INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

BLUE BOOK

VOLUME VI – FASCICLE VI.5

DIGITAL LOCAL, TRANSIT, COMBINED AND INTERNATIONAL EXCHANGES IN INTEGRATED DIGITAL NETWORKS AND MIXED ANALOGUE-DIGITAL NETWORKS

SUPPLEMENTS

RECOMMENDATIONS Q.500-Q.554

IXTH PLENARY ASSEMBLY
MELBOURNE, 14-25 NOVEMBER 1988

Geneva 1989

INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

BLUE BOOK

VOLUME VI – FASCICLE VI.5

DIGITAL LOCAL, TRANSIT, COMBINED AND INTERNATIONAL EXCHANGES IN INTEGRATED DIGITAL NETWORKS AND MIXED ANALOGUE-DIGITAL NETWORKS

SUPPLEMENTS

RECOMMENDATIONS Q.500-Q.554

IXTH PLENARY ASSEMBLY
MELBOURNE, 14-25 NOVEMBER 1988

Geneva 1989

ISBN 92-61-03491-8

CONTENTS OF THE CCITT BOOK
APPLICABLE AFTER THE NINTH PLENARY ASSEMBLY (1988)

BLUE BOOK

Volume I

FASCICLE I.1 – Minutes and reports of the Plenary Assembly.

List of Study Groups and Questions under study.

FASCICLE I.2 – Opinions and Resolutions.

Recommendations on the organization and working procedures of CCITT (Series A).

FASCICLE I.3 – Terms and definitions. Abbreviations and acronyms. Recommendations on means of expression (Series B) and General telecommunications statistics (Series C).

FASCICLE I.4 – Index of Blue Book.

Volume II

FASCICLE II.1 – General tariff principles – Charging and accounting in international telecommunications services. Series D Recommendations (Study Group III).

FASCICLE II.2 – Telephone network and ISDN – Operation, numbering, routing and mobile service. Recommendations E.100-E.333 (Study Group II).

FASCICLE II.3 – Telephone network and ISDN – Quality of service, network management and traffic engineering. Recommendations E.401-E.880 (Study Group II).

FASCICLE II.4 – Telegraph and mobile services – Operations and quality of service. Recommendations F.1-F.140 (Study Group I).

FASCICLE II.5 – Telematic, data transmission and teleconference services – Operations and quality of service. Recommendations F.160-F.353, F.600, F.601, F.710-F.730 (Study Group I).

FASCICLE II.6 – Message handling and directory services – Operations and definition of service. Recommendations F.400-F.422, F.500 (Study Group I).

Volume III

FASCICLE III.1 – General characteristics of international telephone connections and circuits. Recommendations G.100-G.181 (Study Groups XII and XV).

FASCICLE III.2 – International analogue carrier systems. Recommendations G.211-G.544 (Study Group XV).

FASCICLE III.3 – Transmission media – Characteristics. Recommendations G.601-G.654 (Study Group XV).

FASCICLE III.4 – General aspects of digital transmission systems; terminal equipments. Recommendations G.700-G.795 (Study Groups XV and XVIII).

FASCICLE III.5 – Digital networks, digital sections and digital line systems. Recommendations G.801-G.961 (Study Groups XV and XVIII).

FASCICLE III.6 – Line transmission of non-telephone signals. Transmission of sound-programme and television signals. Series H and J Recommendations (Study Group XV).

FASCICLE III.7 – Integrated Services Digital Network (ISDN) – General structure and service capabilities. Recommendations I.110-I.257 (Study Group XVIII).

FASCICLE III.8 – Integrated Services Digital Network (ISDN) – Overall network aspects and functions, ISDN user-network interfaces. Recommendations I.310-I.470 (Study Group XVIII).

FASCICLE III.9 – Integrated Services Digital Network (ISDN) – Internetwork interfaces and maintenance principles. Recommendations I.500-I.605 (Study Group XVIII).

Volume IV

FASCICLE IV.1 – General maintenance principles: maintenance of international transmission systems and telephone circuits. Recommendations M.10-M.782 (Study Group IV).

FASCICLE IV.2 – Maintenance of international telegraph, phototelegraph and leased circuits. Maintenance of the international public telephone network. Maintenance of maritime satellite and data transmission systems. Recommendations M.800-M.1375 (Study Group IV).

FASCICLE IV.3 – Maintenance of international sound-programme and television transmission circuits. Series N Recommendations (Study Group IV).

FASCICLE IV.4 – Specifications for measuring equipment. Series O Recommendations (Study Group IV).

Volume V – Telephone transmission quality. Series P Recommendations (Study Group XII).

Volume VI

FASCICLE VI.1 – General Recommendations on telephone switching and signalling. Functions and information flows for services in the ISDN. Supplements. Recommendations Q.1-Q.118 *bis* (Study Group XI).

FASCICLE VI.2 – Specifications of Signalling Systems Nos. 4 and 5. Recommendations Q.120-Q.180 (Study Group XI).

FASCICLE VI.3 – Specifications of Signalling System No. 6. Recommendations Q.251-Q.300 (Study Group XI).

FASCICLE VI.4 – Specifications of Signalling Systems R1 and R2. Recommendations Q.310-Q.490 (Study Group XI).

FASCICLE VI.5 – Digital local, transit, combined and international exchanges in integrated digital networks and mixed analogue-digital networks. Supplements. Recommendations Q.500-Q.554 (Study Group XI).

FASCICLE VI.6 – Interworking of signalling systems. Recommendations Q.601-Q.699 (Study Group XI).

FASCICLE VI.7 – Specifications of Signalling System No. 7. Recommendations. Q.700-Q.716 (Study Group XI).

FASCICLE VI.8 – Specifications of Signalling System No. 7. Recommendations Q.721-Q.766 (Study Group XI).

FASCICLE VI.9 – Specifications of Signalling System No. 7. Recommendations Q.771-Q.795 (Study Group XI).

FASCICLE VI.10 – Digital subscriber signalling system No. 1 (DSS 1), data link layer. Recommendations Q.920-Q.921 (Study Group XI).

FASCICLE VI.11 – Digital subscriber signalling system No. 1 (DSS 1), network layer, user-network management. Recommendations Q.930-Q.940 (Study Group XI).

FASCICLE VI.12 – Public land mobile network. Interworking with ISDN and PSTN. Recommendations Q.1000-Q.1032 (Study Group XI).

FASCICLE VI.13 – Public land mobile network. Mobile application part and interfaces. Recommendations Q.1051-Q.1063 (Study Group XI).

FASCICLE VI.14 – Interworking with satellite mobile systems. Recommendations Q.1100-Q.1152 (Study Group XI).

Volume VII

FASCICLE VII.1 – Telegraph transmission. Series R Recommendations. Telegraph services terminal equipment. Series S Recommendations (Study Group IX).

FASCICLE VII.2 – Telegraph switching. Series U Recommendations (Study Group IX).

FASCICLE VII.3 – Terminal equipment and protocols for telematic services. Recommendations T.0-T.63 (Study Group VIII).

FASCICLE VII.4 – Conformance testing procedures for the Teletex Recommendations. Recommendation T.64 (Study Group VIII).

FASCICLE VII.5 – Terminal equipment and protocols for telematic services. Recommendations T.65-T.101, T.150-T.390 (Study Group VIII).

FASCICLE VII.6 – Terminal equipment and protocols for telematic services. Recommendations T.400-T.418 (Study Group VIII).

FASCICLE VII.7 – Terminal equipment and protocols for telematic services. Recommendations T.431-T.564 (Study Group VIII).

Volume VIII

FASCICLE VIII.1 – Data communication over the telephone network. Series V Recommendations (Study Group XVII).

FASCICLE VIII.2 – Data communication networks: services and facilities, interfaces. Recommendations X.1-X.32 (Study Group VII).

FASCICLE VIII.3 – Data communication networks: transmission, signalling and switching, network aspects, maintenance and administrative arrangements. Recommendations X.40-X.181 (Study Group VII).

FASCICLE VIII.4 – Data communication networks: Open Systems Interconnection (OSI) – Model and notation, service definition. Recommendations X.200-X.219 (Study Group VII).

FASCICLE VIII.5 – Data communication networks: Open Systems Interconnection (OSI) – Protocol specifications, conformance testing. Recommendations X.220-X.290 (Study Group VII).

FASCICLE VIII.6 – Data communication networks: interworking between networks, mobile data transmission systems, internetwork management. Recommendations X.300-X.370 (Study Group VII).

FASCICLE VIII.7 – Data communication networks: message handling systems. Recommendations X.400-X.420 (Study Group VII).

FASCICLE VIII.8 – Data communication networks: directory. Recommendations X.500-X.521 (Study Group VII).

Volume IX – Protection against interference. Series K Recommendations (Study Group V). Construction, installation and protection of cable and other elements of outside plant. Series L Recommendations (Study Group VI).

Volume X

FASCICLE X.1 – Functional Specification and Description Language (SDL). Criteria for using Formal Description Techniques (FDTs). Recommendation Z.100 and Annexes A, B, C and E, Recommendation Z.110 (Study Group X).

FASCICLE X.2 – Annex D to Recommendation Z.100: SDL user guidelines (Study Group X).

FASCICLE X.3 – Annex F.1 to Recommendation Z.100: SDL formal definition. Introduction (Study Group X).

FASCICLE X.4 – Annex F.2 to Recommendation Z.100: SDL formal definition. Static semantics (Study Group X).

FASCICLE X.5 – Annex F.3 to Recommendation Z.100: SDL formal definition. Dynamic semantics (Study Group X).

FASCICLE X.6 – CCITT High Level Language (CHILL). Recommendation Z.200 (Study Group X).

FASCICLE X.7 – Man-Machine Language (MML). Recommendations Z.301-Z.341 (Study Group X).

CONTENTS OF FASCICLE VI.5 OF THE BLUE BOOK

Part I – Recommendations Q.500 to Q.554

Digital local, combined, transit and international exchanges in integrated digital networks and mixed analogue-digital networks

Rec. No.			Page

Rec. No. Page

Part II – Supplements to the Q.500 series of Recommendations

PRELIMINARY NOTES

1 The Questions entrusted to each Study Group for the Study Period 1989-1992 can be found in Contribution No. 1 to that Study Group.

2 In this Fascicle, the expression “Administration” is used for shortness to indicate both a telecommunication Administration and a recognized private operating agency.

3 The strict observance of the specifications for standardized international signalling and switching equipment is of the utmost importance in the manufacture and operation of the equipment. Hence these specifications are obligatory except where it is explicitly stipulated to the contrary.

The values given in Fascicles VI.1 to VI.14 are imperative and must be met under normal service conditions.

PART I

Recommendations Q.500 to Q.554

DIGITAL LOCAL, COMBINED, TRANSIT AND INTERNATIONAL EXCHANGES IN INTEGRATED DIGITAL NETWORKS AND MIXED ANALOGUE-DIGITAL NETWORKS

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

SECTION 1

INTRODUCTION AND FIELD OF APPLICATION

Recommendation Q.500

DIGITAL LOCAL, COMBINED, TRANSIT AND INTERNATIONAL EXCHANGES INTRODUCTION AND FIELD OF APPLICATION

1 Introduction

This series of Recommendations Q.500-554 applies to digital local, combined[1], transit and international exchanges for telephony in Integrated Digital Networks (IDNs) and mixed analogue/digital networks, and also to local, combined, transit and international exchanges in an Integrated Services Digital Network (ISDN).

The series of Recommendations comprises:

Q.500 Introduction and field of application

Q.511 Exchange interfaces towards other exchanges

Q.512 Exchange interfaces for subscriber access

Q.513 Exchange interfaces for operations, administration and maintenance

Q.521 Exchange functions

Q.522 Digital exchange connections, signalling and ancillary functions

Q.541 Design objectives – General

Q.542 Design objectives – Operations and Maintenance

Q.543 Performance design objectives

Q.544 Exchange measurements

Q.551 Transmission characteristics of digital exchanges

Q.552 Transmission characteristics at 2-wire analogue interfaces

Q.553 Transmission characteristics at 4-wire analogue interfaces

Q.554 Transmission characteristics at digital interfaces.

Considerations have been primarily on exchanges utilizing, at least in part, time division switching techniques. However, these Recommendations are implementation independent, and other system implementations using alternative techniques (e.g., space division switching) may be possible, which would meet the requirements of these Recommendations.

[1] A "combined" digital exchange is one which includes both local exchange and transit exchange functions (see definition 1005 in Recommendation Q.9).

2 Field of application

These Recommendations are intended to be applied as indicated below.

2.1 *Application and evolution to the ISDN*

The selection of features, functions and interfaces to be provided in a digital local, combined, transit or international exchange in a particular network application will be determined by the administration concerned. Reference to a function in these Recommendations, including their diagrams, does not imply that it will necessarily be provided in every exchange type or configuration. Similarly, it is possible that some functions may be provided which are not mentioned.

2.2 *Relationship of design performance requirements to operational performance requirements*

Performance requirements as defined in this series of Recommendations should be considered as design objectives for systems under the conditions stated in the Recommendations. These conditions are defined by such parameters as average circuit occupancy, busy hour call attempts, etc. They should be distinguished from the operational performance requirements which administrations establish for exchanges operating in their particular environment.

Further clarification of this point can be obtained in Recommendation G.102.

3 The Q.500-Series of Recommendations

3.1 *Exchange interfaces (Recommendations Q.511, Q.512 and Q.513)*

The interface functions defined are those necessary for interworking with digital and analogue transmission systems on both circuits to other exchanges and on subscriber lines, and with telecommunications management networks.

3.1.1 *Characteristics of exchange interfaces towards other exchanges (Recommendation Q.511)*

This Recommendation describes the exchange interfaces used to provide transmission facilities towards other exchanges. It applies to digital local, combined, transit and international exchanges for telephony in integrated digital networks (IDN) and mixed (analogue/digital) networks, and also to local, combined, transit and international exchanges in an integrated services digital network (ISDN).

3.1.2 *Characteristics of exchange interfaces for subscriber access (Recommendation Q.512)*

The Recommendation describes the subscriber side interface characteristics. It applies to digital local and combined exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks, and also to local and combined exchanges in an integrated digital network (ISDN).

3.1.3 *Exchange interfaces for operations, administration and maintenance (Recommendation Q.513)*

The interfaces defined are those necessary for transmission of messages associated with operations, administration and maintenance of the exchange.

These interfaces include OAM interfaces between the exchange and the following: OAM systems, mediation devices, user workstations, and other network elements.

3.1.4 *Interfaces to non-voice handling facilities*

The need for the Recommendation of interfaces between digital transit, local and combined exchanges and non-voice handling facilities remains for further study. (An example of such a non-voice facility is a packet switched data node.) Attention is drawn to Recommendation X.300 which describes the general principles for interworking between public data networks and also to the I.400/I.500-Series Recommendations for interworking between ISDN and other dedicated networks.

3.2 *Exchange functions (Recommendation Q.521)*

This Recommendation covers the definition of the principal exchange functions to support services and includes a description of an exchange functional model.

3.3 *Exchange connections, signalling and ancillary functions (Recommendation Q.522)*

This Recommendation covers the following functions:

a) *Connections through an exchange*

This section includes the switch block(s), the characteristics associated with connections through exchanges and a set of diagrams showing typical types of connection.

A connection through an exchange may include one or more stages of time and/or space division switching, providing a path for transmission through the exchange.

b) *Signalling*

Signalling includes reception of call-related and other information, interaction with the call control function and transfer of information to subscribers and network(s) as required.

Signalling may involve common channel and/or channel associated signalling.

c) *Control and call handling*

Control and call handling includes initiation, supervision and termination of most actions in the exchange.

Commands are initiated and information passed/received to/from the other functions within the exchange.

Control functions may be contained in one block or distributed throughout the exchange.

d) *Ancillaries*

Examples of such functions are:

- recorded announcements;
- tone generation;
- conferencing facilities.

Their location is dependent on the function itself and the exchange configuration.

3.4 *Exchange design objectives (Recommendations Q.541, Q.542, Q.543 and Q.544)*

3.4.1 *General design objectives (Recommendation Q.541)*

This includes the general design objective principles, availability and hardware design objectives as well as the design objectives associated with the operation of an exchange in an Integrated Digital Network. The latter encompasses timing and synchronization design objectives.

Timing comprises the generation and distribution of timing signals and includes timing of outgoing signals. It enables those parts of the exchange which form the switched path of a connection to operate synchronously. Synchronization will depend on the national synchronization plan and exchange timing arrangements.

Exchanges will usually extract synchronizing information from one or more incoming bit streams or a separate synchronization network and use this to adjust the timing signals generated in the distribution within the exchange.

3.4.2 *Operations and maintenance design objectives (Recommendation Q.542)*

This covers the operations and maintenance design objectives including network management controls, alarm handling and subscriber line maintenance and testing.

3.4.3 *Performance design objectives (Recommendation Q.543)*

Exchange performance design objectives are defined for guiding system design and for comparing the capabilities of different systems. (Recommendations relating to provisioning and operational performance of exchanges in the network are covered in the E.500-E.543 Series.)

3.4.4 *Exchange measurements (Recommendation Q.544)*

Measurements that may be used for planning, operation, maintenance and network management of exchanges and their associated networks are described. The measurement data consists primarily of event counts and traffic intensity levels experienced by the various traffic handling elements of the exchange.

3.5 *Transmission characteristics (Recommendations Q.551 to Q.554)*

3.5.1 *Transmission characteristics of digital exchanges (Recommendation Q.551)*

This includes the general definitions associated with Recommendations Q.551 to Q.554, and transmission parameters from a total exchange perspective such as absolute group delay and the transfer function for jitter and wander. These Recommendations define, for any connection which may be set up by a local, combined, transit or international exchange, the necessary levels of transmission performance to conform with overall objectives for the complete user-to-user connections in which the exchange may be involved.

3.5.2 *Transmission characteristics at 2-wire interfaces (Recommendation Q.552), 4-wire interfaces (Recommendation Q.553) and digital interfaces (Recommendation Q.554)*

These cover the detailed transmission characteristics of the various types of interface that may be provided on a digital exchange.

SECTION 2

EXCHANGE INTERFACES, FUNCTIONS AND CONNECTIONS

Recommendation Q.511

EXCHANGE INTERFACES TOWARDS OTHER EXCHANGES

1 General

This Recommendation applies to digital local, combined, transit and international exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks, and also to local, combined, transit and international exchanges in an Integrated Services Digital Network (ISDN).

The field of application of this Recommendation is more fully defined in Recommendation Q.500.

2 Scope of Recommendation

This Recommendation is not intended to define any systems or equipment in or connected to, a digital exchange via these interfaces. Therefore only the characteristics of the interfaces are described.

The exchange interfaces described in this Recommendation are used to connect these exchanges to transmission facilities towards other exchanges.

All interfaces that have been studied in detail are described, and illustrated in Figure 1/Q.511 but it is not intended to specify every interface. Other interfaces are for further study (e.g., those for broadband facilities).

3 Characteristics of digital interfaces towards other exchanges

3.1 *Interface A*

3.1.1 *General*

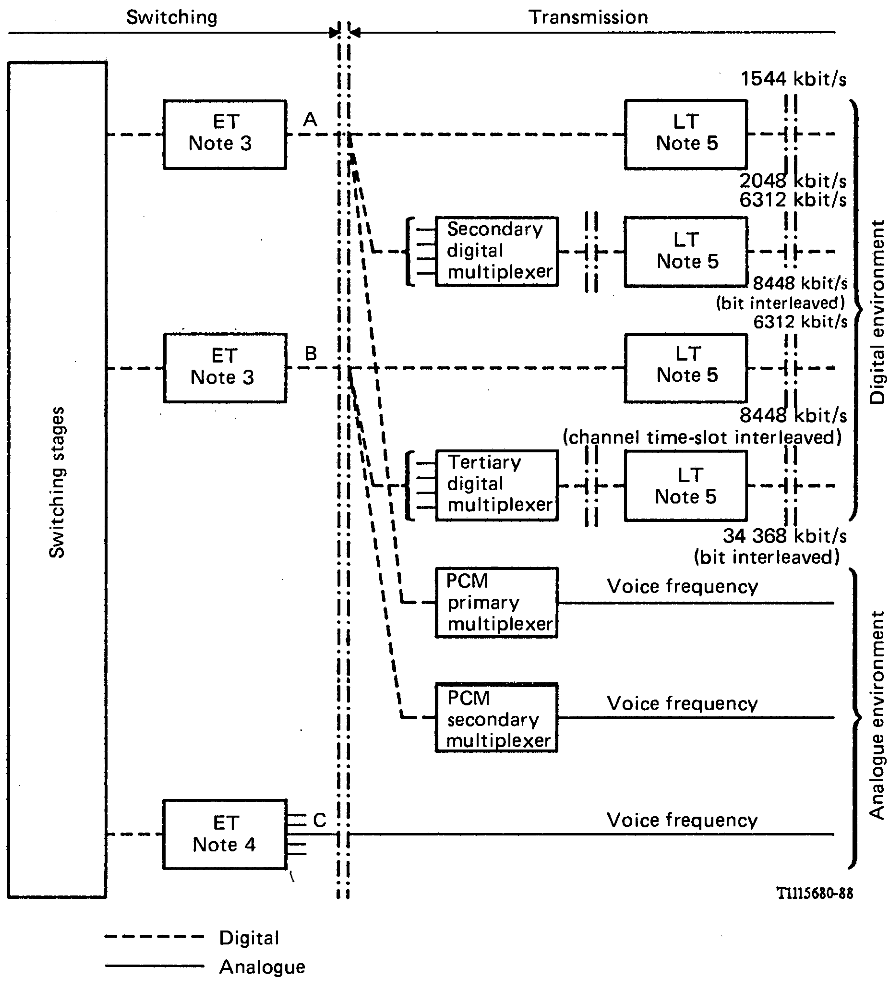
Interface A is a digital interface to allow interconnection at the first level of a digital transmission hierarchy towards other exchanges.

3.1.2 *Electrical characteristics*

The electrical characteristics of interface A are described in Recommendation G.703.

The frame structure at interface A should be identical to that of the first order multiplexes described in Recommendations G.704 and G.705.

Timing in the transmitting direction will be derived within the digital exchange.



Note 1 — The G and Q Series CCITT Recommendations applicable to each interface are detailed in the text.

Note 2 — Other configurations, such as series connection of secondary, tertiary or higher order muldex, may be used.

Note 3 — Examples of functions of Exchange Termination (ET) – interfaces A & B:
- Signalling insertion and extraction
- Code conversion
- Frame alignment
- Alarms and fault indication.

Note 4 — Examples of functions of Exchange Termination (ET) – interface C:
- A/D conversion
- Signalling insertion and extraction
- Multiplexing
- 2-wire/4-wire conversion.

Note 5 — Examples of functions of Line Termination (LT):
- Power feed
- Fault location
- Regeneration
- Code conversion.

Note 6 — Not all interfaces will necessarily exist in every implementation.

FIGURE 1/Q.511

Interfaces towards other exchanges

3.1.3 *Channel types, channel allocation and signalling*:

- number of channel timeslots per frame: 32/24, numbered 0-31/1-24;
- additional channel timeslots may be utilized for common channel signalling when more signalling capacity is required between exchanges. For 2048 kbit/s systems, they should be selected from the channel timeslots allocated in PCM multiplexes for data purposes according to Recommendation G.735. When no such channel timeslots are allocated or available, additional channel timeslots may be selected from channel timeslots allocated for voice channels.

For 2048 kbit/s systems:

- channel timeslot 16 is primarily intended for signalling but should be switchable. On systems between exchanges (not involving PCM primary muldex) when channel 16 is not assigned to carry signalling it may be allocated to speech or other srvices;
- channel timeslot 0 is used for frame alignment, alarm indication, network synchronization and other purposes;
- although no specific application is at present foreseen for switching timeslot 0, it is recommended that the possibility of read and write access to this timeslot should be retained as a safeguard for future requirements. Such access would allow processing of some or all of the information contained in this timeslot, in particular those bits reserved for national and international use. The need to switch channel timeslot 0 as a normal channel, without special access, requires further study. In any case the incoming frame alignment signal will not be passed through the exchange to an outgoing system.

3.1.4 *Functional characteristics*

The use of the Cyclic Redundancy Check (CRC) procedures described in Recommendation G.704 is recommended for interfaces which carry ISDN traffic and optional for other applications. The frame alignment, CRC multiframe alignment and CRC monitoring functions are in accordance with Recommendation G.706.

3.2 *Interface B*

3.2.1 *General*

Interface B is a digital interface to allow interconnection at the second level of a digital transmission hierarchy towards other exchanges.

3.2.2 *Electrical characteristics*

The electrical characteristics of interface B are described in Recommendation G.703.

The frame structure at interface B should be identical to that of the second order multiplexes described in Recommendations G.704 and G.705.

Timing in the transmitting direction will be derived within the digital exchange.

3.2.3 *Channel types, channel allocation and signalling*:

- number of channels: 132/98 numbered 0-131/1-98.

For 8448 kbit/s systems:

- where signalling capacity is required between exchanges, timeslots 67, 68, 69 and 70 can be utilized for signalling in this order of descending priority. Those channels not used for signalling can be used for speech or other purposes. If a channel timeslot is reserved for service purposes within the switch, it shall be channel timeslot 1;
- it is left for mutual agreement whether or not channel timeslot 1 will carry traffic;

– 128 of the channel timeslots may carry traffic through the exchange.

For 6312 kbit/s systems:

– the multiplex structure contains 5 bits and 98 channel timeslots, numbered 1-98, each of 64 kbit/s, of which 96 may carry traffic through the exchange;
– five bits per frame are assigned for a frame alignment signal and for other signals. Timeslots 97 and 98 are assigned to signalling between exchanges.

3.2.4 *Functional characteristics*

The use of the Cyclic Redundancy Check (CRC) procedures described in Recommendation G.704, is recommended for interfaces which carry ISDN traffic and optional for other applications. The frame alignment, CRC multiframe alignment and CRC monitoring functions are in accordance with Recommendation G.706.

4 Characteristics of analogue interfaces towards other exchanges

4.1 *Interface C*

4.1.1 *General*

Interface C is a 2-wire or a 4-wire analogue interface, used where direct interconnection analogue facilities is required. This implies that a PCM codec, associated with this interface, is incorporated in the digital exchange. The equipment on the exchange side of interface C may include a muldex within the exchange termination functions. Differences in circuit configurations with respect to transmission parameters are likely to result in the need to specify a number of different C interfaces, depending on the application environment. This is likely to reduce the flexibility in interconnection possibilities. These C interfaces are specified in Recommendation Q.551. The transmission characteristics of 2-wire interface C2 are described in Recommendation Q.552 and of 4-wire interface C1 in Recommendation Q.553.

4.1.2 *Channel types, channel allocation and signalling*

The signalling characteristics of interface C vary considerably from country to country, and therefore it is not intended that this interface should be the subject of CCITT Recommendations beyond those aspects covered in Recommendations Q.552 and Q.553.

Recommendation Q.512

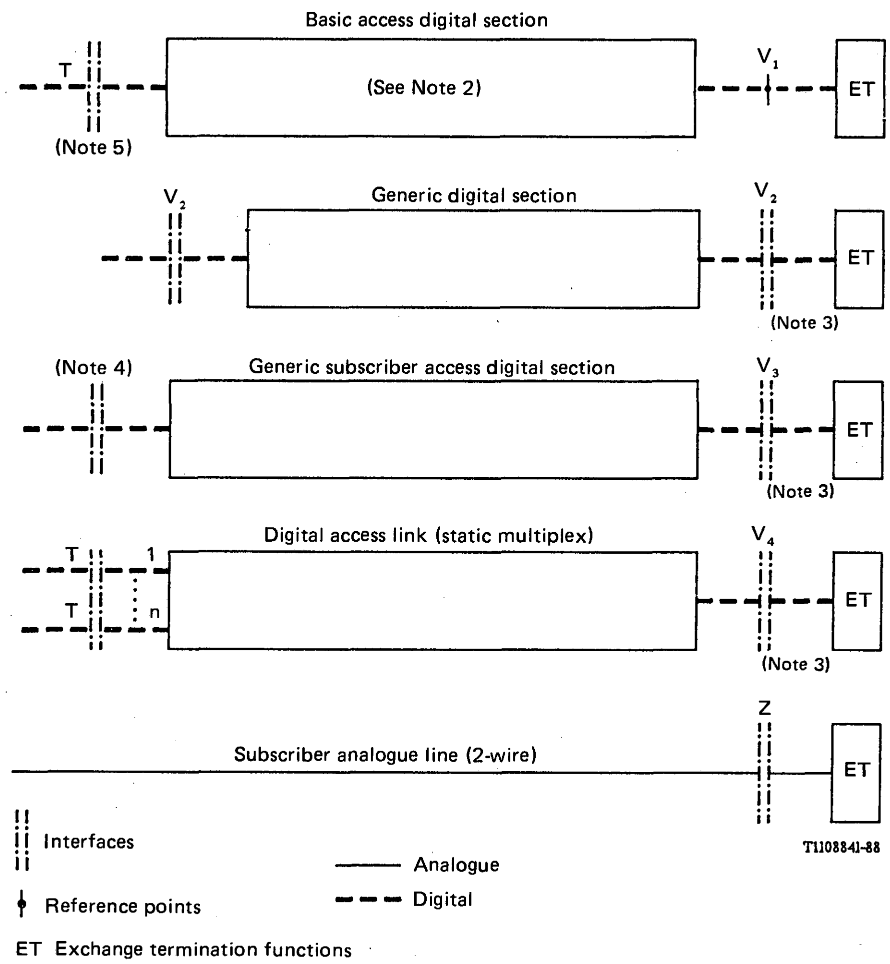
EXCHANGE INTERFACES FOR SUBSCRIBER ACCESS

1 General

This Recommendation applies to digital local and combined exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks, and also to local and combined exchanges in Integrated Services Digital Networks (ISDN). The field of application of this Recommendation is more fully defined in Recommendation Q.500.

2 Scope of Recommendation

Exchange interfaces for subscriber access that have been considered are described, and illustrated in Figure 1/Q.512 and Table 1/Q.512, but it is not intended to specify every interface. Other interfaces are for further study (e.g., those for dynamic multiplexed basic rate access, broadband access, etc.).



Note 1 — Not all interfaces will necessarily exist in every implementation.

Note 2 — The characteristics of a digital transmission system on metallic local lines for ISDN basic rate access which may form part of the basic access digital section are defined in Recommendation G.961.

Note 3 — The differences among V_2, V_3 and V_4 are essentially multiplexing and signalling requirements. The transmission requirements are substantially identical (e.g. Recommendations G.703, G.704 and G.705).

Note 4 — User-network interface. In the case of ISDN primary rate access this is at the T reference point.

Note 5 — Interface T is defined in Recommendation I.411.

Note 6 — Interface V_5 as defined in the Red Book is now being considered as a particular application of the V_2 or V_3 interface. Interface V_4 is now considered for ISDN applications only.

FIGURE 1/Q.512

Illustration of possible access configurations

TABLE 1/Q.512

Interface references

Access type	Interface/reference points	Paragraph	Related physical Recs.	Related OAM Recs.	Application to connect
Basic access digital section	V_1	3.2	(Note 1)	G.960 (Note 1) I.603	ISDN basic access (2B + D)
Generic digital section	V_2	3.3	G.703 G.704 G.705	None	Digital network equipment, supporting any combination of access types
Generic subscriber access (Note 2) digital section	V_3	3.4		G.706 I.604 (Note 3)	Digital subscriber equipment
Digital access link (Static multiplex)	V_4	3.5		G.706 I.605	A multiple of ISDN basic accesses
Generic analogue subscriber access	Z	4.1	None (Note 4)	None	Analogue subscriber lines

Note 1 – Recommendation G.961 specifies the characteristics of a digital transmission system on metallic local lines which may form part of the basic access digital selection.

Note 2 – In the case of ISDN access this is the primary rate access digital section.

Note 3 – Only in the case of ISDN application, G.706 and I.604 are recommended.

Note 4 – Characteristics other than those defined in Recommendations Q.551 to Q.554 are not subject of CCITT Recommendation.

This Recommendation is not intended to define any transmission system, network or subscriber equipment in or connected to, a digital exchange via these interfaces. Therefore only the characteristics of the interfaces are described.

Digital exchange interfaces for subscriber access are defined at the V reference point which is the boundary between the ET and the digital access section or link. These interfaces are designated interface V and are defined to allow flexibility of implementation for different exchange and transmission equipment realizations. However, a physical interface will not be specified for all subscriber access types identified (see Figure 1/Q.512).

In this Recommendation, a digital section is defined as the whole of the means of digital transmission of a digital signal of specified rate between two consecutive reference points. A digital link comprises one or more digital sections and may include either a multiplexer or concentrator, but not switching.

3 Characteristics of digital exchange interfaces for subscriber access

3.1 *General*

As an objective, the characteristics of digital interfaces on the subscriber side of the exchange should be aligned with the characteristics of ISDN user/network access structures (Recommendation I.411).

However in many countries, digital access arrangements not structured according to ISDN principles are used, e.g., to ensure compatibility with existing networks and services and it is expected that these arrangements will continue to be used for several years. Only certain characteristics of these arrangements are the subject of CCITT Recommendations.

3.2 *Interface V_1*

3.2.1 *General*

Interface V_1 may be used at the V_1 reference point to connect to an ISDN basic access digital section for the provision of a single basic access. The characteristics of the basic access digital section are defined in Recommendation G.960 and the characteristics and parameters of a digital transmission system which may form part of the digital section for the ISDN basic rate access are given in Recommendation G.961.

3.2.2 *Functional characteristics*

The functional description is illustrated in Figure 2/Q.512 and the following functional requirements are defined:

1) *(2B + D) channels*

   To provide the bidirectional transmission capability for two B channels and one 16 kbit/s D channel as described in Recommendation I.412.

2) *Bit timing*

   To provide bit (signal element) timing to enable the digital section to recover information from the aggregate bit stream.

3) *Frame timing*

   To provide frame timing to enable digital section and ET to recover the time division multiplexed channels.

4) *CV_1 channel*

   The CV_1 channel provides, for each direction of transmission, the capability to transfer management functions required for the digital section as specified in Recommendations G.960 and I.603. The CV_1 channel may carry one or more functional links. These functions include activation from network side, activation from network side, activation request from a digital section, deactivation from ET side, operation and maintenance signals.

5) *Power feed*

   This function provides for remote power feeding for the digital section and possibly terminal equipment. This function is optional.

3.2.3 *Electrical characteristics*

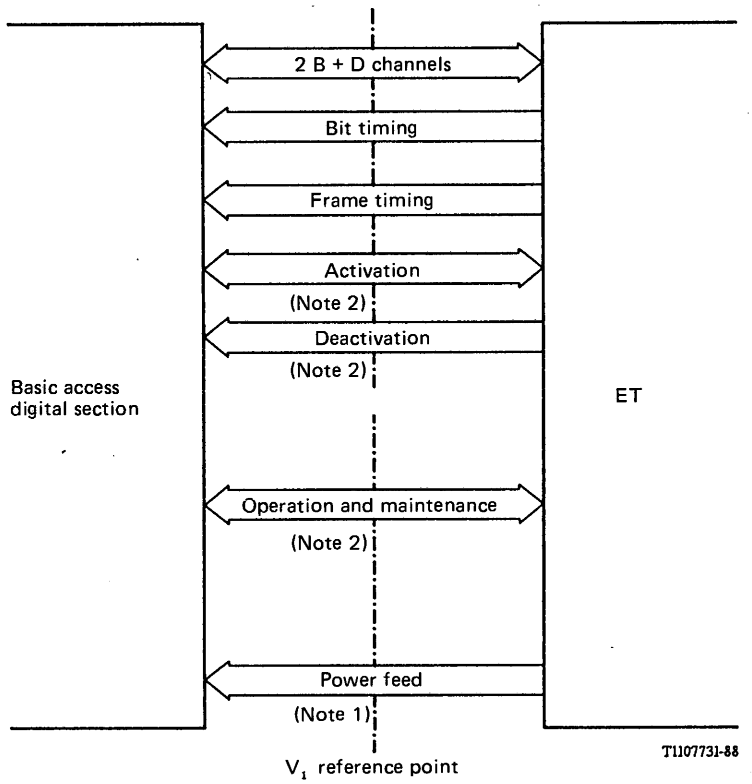
The electrical characteristics of interface V_1 are not subject to CCITT Recommendations.

3.2.4 *Channel types, channel allocation and signalling*

The channel types associated with interface V_1 include two B channels and one D channel as defined at the user network interface in Recommendation I.412. In addition, the CV_1 channel is required to support the operational and maintenance functions.

The channel allocation is not subject to CCITT Recommendations.

The D channel signalling procedures are defined in the Q.920 and Q.930-Series Recommendations.



Note 1 – The provision of power feed function is optional.

Note 2 – These functions are conveyed by the CV_1 channel.

FIGURE 2/Q.512

Functions at interface V_1

3.3 *Interface V_2*

3.3.1 *General*

Interface V_2 is a generic digital interface used to connect remote or local digital network equipment via a first or second order digital section. This network equipment may support any combination of analogue, digital and ISDN subscriber access. The characteristics of this interface may not be structured according to the ISDN principles.

3.3.2 *Functional characteristics*

The functional characteristics depend on the specific application of the V_2 interface. These are not generally subject to CCITT Recommendations.

3.3.3 *Electrical characteristics*

The electrical characteristics of interface V_2 are described in Recommendation G.703.

The basic frame structure at interface V_2 should be identical to that of the first or second order rate multiplexes described in Recommendations G.704 and G.705.

3.3.4 *Channel types, channel allocation and signalling*

The channel types, channel allocation and signalling depends on the specific application of the V_2 interface. These are not generally subject to CCITT Recommendations.

3.4 *Interface V_3*

3.4.1 *General*

Interface V_3 is a digital interface used to connect digital subscriber equipment (e.g., PABX) via a generic digital subscriber section. The characteristics of this interface may not be structured according to the ISDN principles. In this case, only the electrical characteristics defined in § 3.4.2 are recommended. However, in the case of ISDN where interface V_3 is used to connect a primary rate access digital section for the provision of a single primary rate access, all of the following characteristics apply.

3.4.2 *Functional characteristics*

The use of the Cyclic Redundancy Check (CRC) procedures described in Recommendations G.704 and G.706 is recommended. The information on the status of the CRC processing shall be passed across the V_3 interface. The maintenance procedures are defined in Recommendation I.604.

3.4.3 *Electrical characteristics*

The electrical characteristics of interface V_3 are described in Recommendation G.703.

The frame structure at interface V_3 should be identical to that described in Recommendations G.704 and G.705.

3.4.4 *Channel types, channel allocation and signalling*

The channel types and allocation associated with interface V_3 are 30 B + 1 D at 2048 kbit/s or 23 B + 1 D at 1544 kbit/s as described in Recommendation I.431.

The channel allocation should also consider that:

a) when the signalling for the B channels in one primary rate structure is carried by the D channel in another primary rate structure, the channel timeslot normally used for signalling may be used to provide an additional B channel;

b) at interface V_3 the designated number of B channels is always present within the multiplexed channel structure, but one or more of the B channels may not be used in any given application.

The D channel signalling procedures are defined in the Q.920 and Q.930-Series Recommendations.

3.5 *Interface V_4*

3.5.1 *General*

Interface V_4 is a digital interface used to connect a digital access link which includes a static multiplexer supporting several basic access digital sections. The local digital multiplexer application is considered to be a subset of the remote digital multiplexer application.

3.5.2 *Functional characteristics*

The functional description is illustrated in Figure 3/Q.512 and the following functional requirements are defined:

- $m \times (2\text{ B} + \text{D} + \text{CV}_1)$: to provide the bidirectional transmission capability for the B, and D, CV_1 channels from each basic rate access section.
- Timing: to provide the necessary timing information for bit transmission, frame synchronization and subscriber line synchronization.
- Operations and maintenance: to provide the transmission capability to carry the operation and maintenance signals of the digital link and the basic access muldex as defined in I.605.

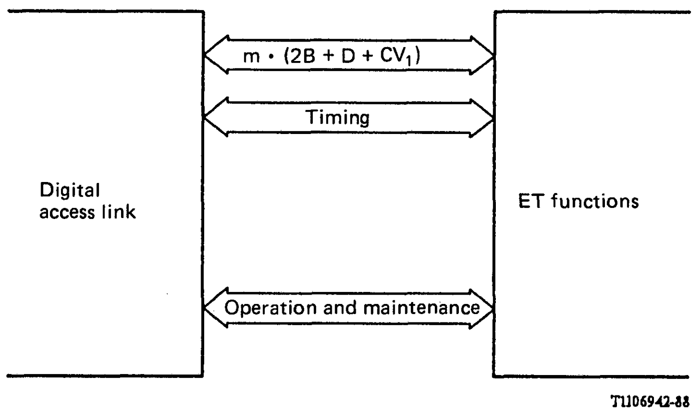


FIGURE 3/Q.512

Functional description of V_4 interface

The use of the Cyclic Redundancy Check (CRC) procedures described in Recommendations G.704 and G.706 are recommended. The information on the status of the CRC processing shall be passed across the V_4 interface.

3.5.3 *Electrical characteristics*

The electrical characteristics of interface V_4 are described in Recommendation G.703.

The basic frame structure at interface V_4 should be identical to that of the first order multiplexes described in Recommendations G.704 and G.705.

3.5.4 *Channel types, channel allocation and signalling*

3.5.4.1 *General*

The V_4 interface is composed of a number of individual ISDN basic rate access digital sections, as described in § 3.2.

The channel allocation at interface V_4 is defined within a first order structure using a static multiplexing principle as follows:

3.5.4.2 *Static multiplexed at 2048 kbit/s*

3.5.4.2.1 *Channel allocation*

In this case 12 basic access channels are multiplexed in a static manner using fixed allocation of the channels. Figure 4/Q.512 illustrates the channel allocation for 2048 kbit/s, where 24 channel timeslots are used by B1 and B2 channels and 6 channel timeslots are used by the D and CV_1 channels of the 12 basic accesses.

The CV_1 and D channels of two basic accesses are multiplexed into one channel timeslot. Five contiguous channel timeslots are occupied by two basic accesses each consisting of B1 + B2 + D + CV_1 channels.

Channel timeslot 0 is used for frame alignment including the application of CRC4 according to Recommendation G.704. Additionally, the alarm handling facilities of channel timeslot 0 are used for maintenance of the primary link as described in Recommendation I.605.

According to the channel allocation shown in Figure 4/Q.512, the CV_1 channels are located in timeslots 5, 10, 15, 21, 26 and 31. These represent 8 bits, namely two bits for each of the D and CV_1 channels of two basic accesses.

Channel timeslot No.	Contents
0	Frame alignment signal/Remote service alarm indication. (See Recommendation G.704)
1	B1,1
2	B2,1
3	B1,2
4	B2,2
5	D1, $CV_1$1, D2, $CV_1$2
6	B1,5
7	B2,5
8	B1,6
9	B2,6
10	D5, $CV_1$5, D6, $CV_1$6
11	B1,9
12	B2,9
13	B1,10
14	B2,10
15	D9, $CV_1$9, D10, $CV_1$10
16	Not used
17	B1,3
18	B2,3
19	B1,4
20	B2,4
21	D3, $CV_1$3, D4, $CV_1$4
22	B1,7
23	B2,7
24	B1,8
25	B2,8
26	D7, $CV_1$7, D8, $CV_1$8
27	B1,11
28	B2,11
29	B1,12
30	B2,12
31	D11, $CV_1$11, D12, $CV_1$12

B1,i B1 channel of basic access i

B2,i B2 channel of basic access i

Di D channel of basic access i

CV_1i Control CV_1 channel of basic access i

FIGURE 4/Q.512

Channel allocation at the V_4 interface for 2048 kbit/s

3.5.4.2.2 *CV_1 channel structure*

To facilitate separate treatment of bundles of two basic accesses, represented by five 64 kbit/s channels, multi-frame alignment should be performed individually for each bundle. The relevant overhead information should be contained in the CV_1 channels. CV_1 channel structure is for further study.

The D channel signalling procedures are defined in the Q.920 and Q.930-Series Recommendations.

3.5.4.3 *Static multiplexed 1544 kbit/s*

For further study.

4 Characteristics of analogue exchange interface for subscriber access

4.1 *Interface Z*

Interface Z is a generic analogue interface defined at the exchange side of an analogue subscriber line used to connect subscriber equipment (e.g., single telephone set or PABX).

It is recognized that the characteristics of analogue interfaces (generally designated Z interface) vary considerably from country to country and therefore it is not intended that those interfaces be the subject of CCITT Recommendations beyond those aspects covered in Recommendations Q.551/552.

5 Combined digital and analogue interface for subscriber access

In the evolution towards an ISDN, user network accesses may exist which have a combination of both analogue and digital interfaces.

This type of interface is not presently considered to be a matter for CCITT Recommendations.

Recommendation Q.513

EXCHANGE INTERFACES FOR OPERATIONS, ADMINISTRATION AND MAINTENANCE

1 General

This Recommendation applies to digital local, combined, transit and international exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks, and also to local, combined, transit and international exchanges in an Integrated Services Digital Network (ISDN).

The field of application of this Recommendation is more fully defined in Recommendation Q.500.

This Recommendation is not intended to define any systems or equipment in or connected to, a digital exchange via these interfaces. Therefore only the interfaces characteristics are described.

In the text of this Recommendation, references are made to operation, administration and maintenance (OAM) equipment which comprises either or both of the following:

a) operations systems (OS) which support personnel responsible for exchange OAM. Note that the word exchange includes both signalling and switching equipment;

b) human-machine terminals which provide access to exchanges or operations systems.

2 General characteristics of the interfaces to OAM equipment

2.1 Interfaces are provided for the transfer of information between exchanges and locations where OAM functions are performed. Items a) and b) below illustrate examples of information that may cross the interface and which may need to be catered for. (The choice of information that crosses the interface is a matter for each Administration/RPOA.)

a) The information transferred from the exchange to OAM equipment may include customer usage and charging data, exchange system status indication, system resource utilization data, system performance measurements, alarms and messages alerting operating personnel to the current state of the exchange and other data.

b) The information transferred to the exchange from the OAM equipment may include commands for system initializations and configuration control, data to effect changes in system operation, commands to initiate, terminate, or otherwise modify the services provided to customers, requests for status information and other commands.

2.2 An exchange may have access to one or more OAM equipment.

2.3 Access may be provided using separate data links, multiplexed data links, or one or more data networks to each OAM equipment.

2.4 The exchange shall not become unavailable due to the failure or malfunction of OAM equipment, or the failure of links between the exchange and OAM equipment.

2.5 The choice between single and multiple physical links at the exchange, and the configuration of the OAM equipment is a national matter, not subject to CCITT Recommendations.

3 Functional characteristics of the interface to OAM equipment

3.1 The exchange should not depend for its basic operation on the correct functioning of the OAM equipment.

3.2 The interface should provide basic initialization, error detection and automatic recovery procedures for the data link.

3.3 The interface should support data transport mechanisms that may be employed by the exchange and the OAM equipment to assure the reliable transfer of particular information (e.g., charging data).

3.4 The interface should support the setting of priorities by the exchange or OAM equipment for the use of the transmission medium (data links).

3.5 The interface should support priority transfer of urgent messages.

4 Exchange OAM interfaces

Exchange OAM interfaces are shown in Figure 1/Q.513.

There are two general classes of OAM interfaces:

a) human-machine interfaces;

b) interfaces to OAM OSs and workstations.

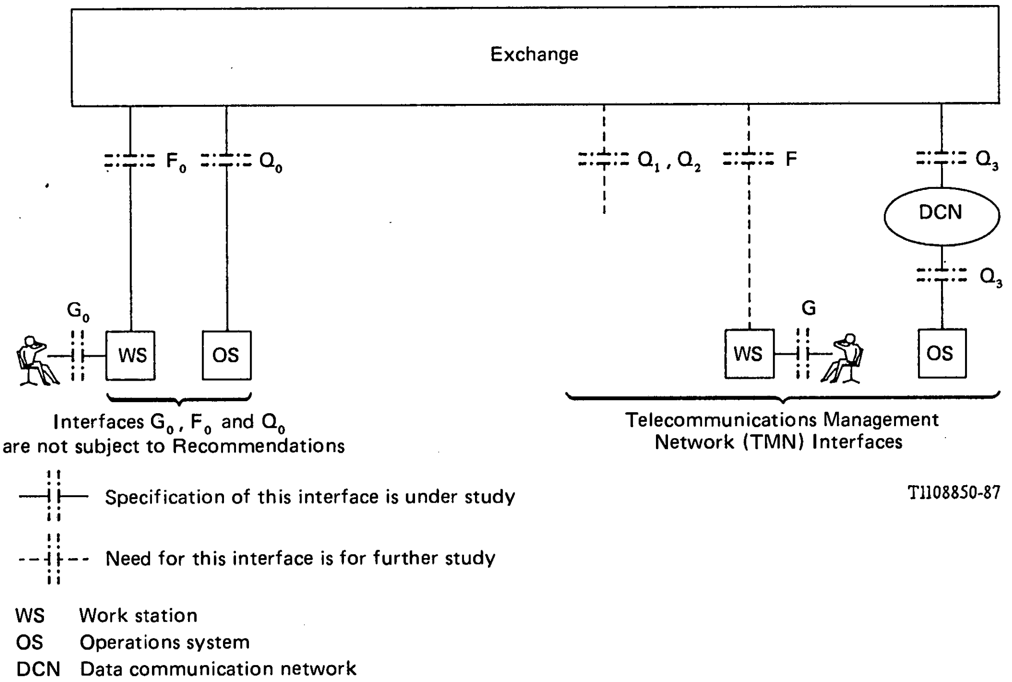
The interfaces for local and remote human-machine functions should conform to the MML Z.300-Series of Recommendations.

It is planned to provide Recommendations which specify interfaces between exchanges and operations systems and between exchanges and workstations. Such specifications will be based on the concept of the Telecommunications Management Network (TMN). The principles and architecture of the TMN are defined in Recommendation M.30.

4.1 *TMN interfaces*

4.1.1 *Q_3 interface*

Interface Q_3 connects exchanges to OSs via the Data Communication Network (DCN).



Note – An exchange is an example of a Network Element (NE) as defined in Recommendation M.30.

FIGURE 1/Q.513

Interfaces associated with operations, administration and maintenance in a digital, transit, local or combined exchange

The interface shall be capable of supporting the following two broad categories of information to be communicated:

a) transactions: low data volumes to be transported, e.g., exchange alarm messages;

b) bulk data transfers: large data volumes to be transported, e.g., billing data.

The characterization of these information types is for further study.

The protocols used across the Q_3 interface will be based on the OSI model and will use OSI protocols specified by CCITT where possible. To allow for alternative DCNs, alternative lower layer protocol sets may be used, depending on the specific situation. Several protocol sets for layers 1, 2 and 3 have been used for similar data communications networks. Examples include:

a) X.25

b) Signalling System No. 7 MTP/SCCP

c) Q.921/Q.931.

Their use in TMN applications is for further study.

It is recommended that each set of TMN application functions with similar protocol needs be supported with unique protocol selections for layers 4 through 7 as defined by the OSI Reference Model (Recommendation X.200). The nulling of service options of individual layers above layer 3 and even entire layers above layer 3 may be necessary where justifiable.

4.1.2 *Q_2 interface*

Interface Q_2 may be used to connect exchanges to Mediation Devices (MDs) or to Network Elements (NEs) which contain a mediation function.

The need for the Q_2 interface on an exchange is for further study.

4.1.3 *Q_1 interface*

Interface Q_1 may be used to connect exchanges to NEs which support only the Network Element Function and no mediation function.

The need for the Q_1 interface on an exchange is for further study.

4.1.4 *F interface*

Interface F connects exchanges to workstations. The definition of functions and protocols is for further study.

4.1.5 *G interface*

Interface G is the human-machine interface for OAM functions, providing output displays and text (e.g., CRT, printer, light panel) and input capabilities (e.g., keyboard).

This interface is specified in the Z.300-Series of Recommendations which may be enhanced in the future.

4.2 *Other OAM interfaces*

These interfaces are intended to represent existing OAM interfaces during the period of transition to TMN. They are not subject to CCITT Recommendations.

4.2.1 *Q_0 interface*

Interface Q_0 connects exchanges to OSs, MDs and NEs using protocols and functions other than those defined in TMN Recommendations.

4.2.2 *F_0 interface*

Interface F_0 connects exchanges to workstations, using function and protocols not specified in TMN Recommendations.

4.2.3 *G_0 interface*

Interface G_0 is a human-machine interface not subject to CCITT Recommendations.

4.3 *ISDN access interfaces*

The exchange requirements for interworking between the exchange ISDN access sub-system including the V interfaces and the exchange TMN sub-system are for futher study.

4.4 *Signalling System No. 7 network interface*

The exchange requirements for interworking between the exchange Signalling System No. 7 sub-systems and the exchange TMN sub-system are for further study.

Recommendation Q.521

EXCHANGE FUNCTIONS

1 General

This Recommendation applies to digital local, combined, transit and international exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks and also to local, combined, transit and international exchanges in an Integrated Services Digital Network (ISDN).

The field of application of this Recommendation is more fully defined in Recommendation Q.500.

Some text may only apply to a certain type (types) of exchange, e.g. digital transit, local or combined. Where this occurs, the application is defined in the text. Not all the recommended functions will necessarily be provided in every exchange.

2 Exchange functions – Introduction and framework

2.1 *General*

The purpose of this Recommendation is to specifically address those functions required to support basic and supplementary services in performing this test, this Recommendation takes account of the principles set down in Recommendation I.310 and draws a clear distinction between services and the exchange capabilities required to support them.

It should be noted that the list of functions identified in this Recommendation is not necessarily extensive.

2.2 *Exchange model*

The functions described in this and associated Recommendations can be considered within the framework of an exchange functional model. Such a model is shown in Figure 1/Q.521. This divides the exchange into three functional areas as follows:

a) control functions – Those functions required to control services and connections, e.g. signalling, routing and connection/resources handling functions;

b) connection functions – Those functions directly related to the connection path through an exchange, i.e. switching and transmission mechanism (including ET);

c) operation and maintenance functions – Those functions of an operational, management and maintenance nature which are not employed for call establishment and supervisory purposes, e.g. test functions.

The exchange functional model shown in Figure 1/Q.521 is appropriate to exchanges operating in an IDN and also those operating in an IDN which is evolving towards an ISDN. In terms of this Recommendation, most of the functions fall within the control functions area.

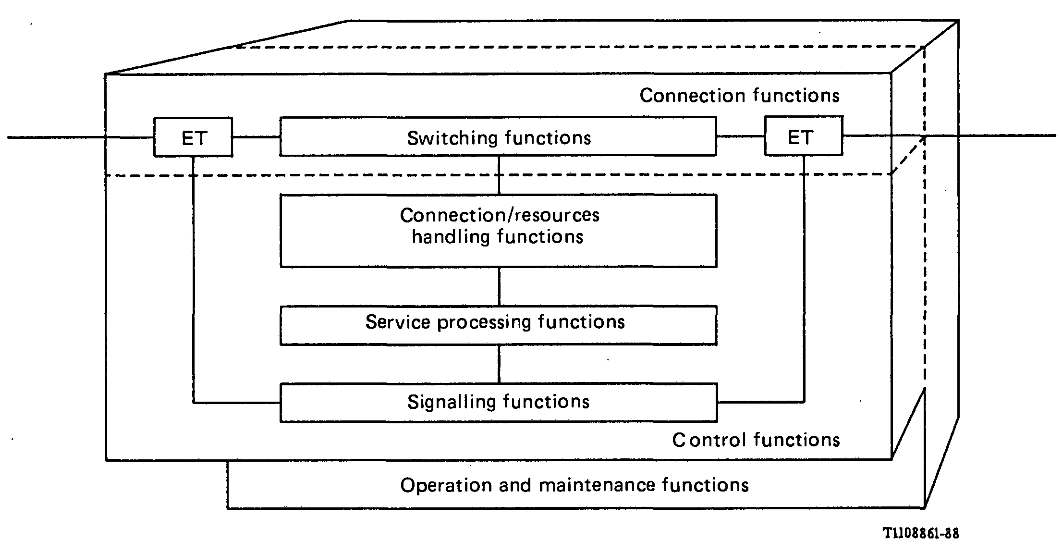


FIGURE 1/Q.521

Exchange functional model

Connection functions are primarily covered in Recommendation Q.522. These address the basic switch characteristics of different connection types. OAM functions are primarily covered in Recommendation Q.542.

3 Utilization of exchange functions for services

3.1 *General*

Exchange functions are used and reused in various stages of call processing. Some may be combined with others to create features used in providing supplementary services. The specific functions used in a given context will be determined by the requested service.

Within the framework of the model shown in Figure 1/Q.521 the utilization of functions arising from a service request, can be considered in the following way:

a) on receipt of a service request (via the Signalling Functions) the Service Processing Functions are used to identify the appropriate connection type(s);

b) the appropriate type of connection is established by use of the Connection/Resources Handling Functions;

c) Supplementary Services which involve additional functions and information flows beyond those required for bearer services, are provided under the control of logic residing in the Service Processing Function. This logic is designed to provide specific services. Corresponding service/feature capabilities must also reside in the Signalling and Connection/Resources Handling Functions.

In addition to services provided by use of logic/data residing in the exchange, some services may be provided under the control of logic located at separate specialized nodes (Service Control Points). Also, data required or process certain service requests may be kept in a remote data base accessed by use of the Signalling Function.

4 General functions required for operation of an exchange in the IDN, ISDN or mixed analogue/digital environment

4.1 *Timing and synchronization*

4.1.1 Exchange timing – Ability to distribute timing within the exchange so that it will maintain synchronism on 64 kbit/s channel timeslots in a connection through the exchange.

4.1.2 Synchronization – Ability to operate in the IDN or ISDN in synchronism with other digital entities and provide timing signals to other network entities as required.

4.1.3 Interval timing – Ability to measure time between events as required in call processing and/or in signalling.

4.1.4 Time-of-day clock – Ability to determine time of day.

Note – The level of accuracy is for further study.

4.2. *Signalling*

4.2.1 *User-access signalling functions*

4.2.1.1 Ability to receive and interpret decadic or Dual Tone Multi-Frequency (DTMF) signalling from user terminals.

4.2.1.2 Ability to support user-access signalling layers 1 and 2 in accordance with Recommendations I.430, Q.921 (I.441).

4.2.1.3 Ability to communicate with user terminals using layer 3 signalling in accordance with Recommendation Q.931 (I.451).

4.2.2 *Network signalling functions*

4.2.2.1 Ability to use and support CCITT signalling systems included in Recommendation Q.7, particularly CCITT Signalling System No. 7.

4.2.2.2 Ability to communicate with other network entities using the CCITT Signalling System No. 7, Q.700-Series of Recommendations User Parts.

Recommendation Q.522

DIGITAL EXCHANGE CONNECTIONS, SIGNALLING AND ANCILLARY FUNCTIONS

1 General

This Recommendation applies to digital local, combined, transit and international exchanges for telephony in Integrated Digital Networks (IDN) and also to local, combined, transit, and international exchanges in an Integrated Services Digital Network (ISDN). The field of application of this Recommendation is more fully defined in Recommendation Q.500.

2 Connections through an exchange

2.1 *General*

The characteristics of the connections detailed in this section refer to an established connection when it is made available to the users.

An exchange must be able to provide originating, terminating and internal exchange connections between input and output interfaces for telephony and other services as required. It may also provide transit connections:

- A connection (if any) between an incoming and an outgoing circuit at interfaces to other exchanges/networks is called a transit connection.
- A connection between channel(s) of a calling subscriber line at an interface for subscriber access and an outgoing circuit at an interface to other exchange/networks is called an originating connection.
- A connection between an incoming circuit at an interface to other exchange/networks and channel(s) of a called subscriber line at an interface for subscriber access is called a terminating connection.
- A connection between channels of two subscriber lines at interfaces for subscriber access is called an internal connection.

An exchange must be able to provide bidirectional connections between input and output interfaces for telephony and other services as required.

Also unidirectional connections may be required.

2.2 *Basic exchange connections*

2.2.1 *General*

The requirements in this section primarily apply to digital local or combined exchanges. Applicability to digital transit or international exchanges requires further study.

Four types of exchange connection have been identified to show the basic forms of connection and their associated information flows that a digital local or combined exchange may be required to handle in an ISDN. They have been based on originating/terminating connections established via interfaces for subscriber access as described in Recommendation Q.512 to/from locations external to the exchange. Calls may be set up in either direction, i.e., subscriber to network or network to subscriber.

These diagrams are functional and not intended to represent any particular implementation. They illustrate the options which may be available for handling a given information type or service within a digital local or combined exchange. Although this approach leads to some duplication between the individual diagrams when considered from the connection point of view, the approach is a logical basis for the further consideration of the more detailed issues arising from the impact of the ISDN on a digital local or combined exchange.

It is not intended to imply that every digital local or combined exchange should necessarily have the capability to handle all these types of connection.

Other types of connection and variants of these basic exchange connections may be feasible in an ISDN and are the subject of further study.

The signalling and control aspects of these connections are covered in §§ 3 and 5 of this Recommendation.

2.2.2 *Explanatory information on the exchange connection diagrams*

The functions associated with the groupings shown on the types I-IV exchanges connection diagrams are covered in § 3.

Key

————————	information other than separate signalling
– – – – – – – –	separate signalling(s)

Information flows

– p_1: packet data information different from customer-originated packetized data;
– s_1, s_2, s_4, s_5: signalling information different from the signalling associated with customer terminals;
– packet switching interworking functions may be provided at other exchanges in an ISDN or at the point of access to a separate packet switched network.

2.2.3 *Type 1 exchange connection* (Figure 1/Q.522)

This connection is sued to transport telephony and associated voice services.

This connection is characterized by (see Table 2/I.340, A 4, A 5, A 7 and A 8):

– *Information transfer attributes*

mode:	circuit
rate:	64 kbit/s
capability:	speech – 3.1 kHz audio
establishment:	switched – semi-permanent
symmetry:	bidirectional – symmetric
configuration:	point-to-point uniform
structure:	8 kHz integrity

– *Access attributes* (Table 1/Q.522)

TABLE 1/Q.522

Access attributes	User access	Network access
Access channel and rate		
Information	B/64	Digital circuit with access to analogue/digital switched network
Signalling	D/16-64	Digital circuit (s_1)
Access protocol [a]		
Layer 1	For further study	Q.702, others
Layer 2	I.441	Q.703, others
Layer 3	I.451	Q.704, Q.714, Q.764, others

[a] Only for switched services.

– *Other attributes*

For further study.

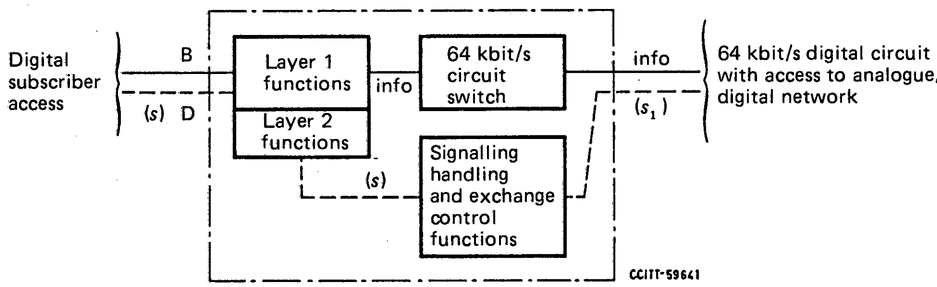


FIGURE 1/Q.522

Type I exchange connection

2.2.4 *Type II exchange connection* (Figure 2/Q.522)

This connection is used to transport circuit switched services such as data, telephony, multiple subrate information streams multiplexed into 64 kbit/s by the user, transparent access to a PSPDN (see § 5.2.2).

This connection is characterized by:

– *Information transfer attributes* (see Table 2/I.340, A 1 and A 2)

mode:	circuit
rate:	64 kbit/s
capability:	unrestricted digital information
establishment:	switched – semi-permanent
symmetry:	bidirectional – symmetric
configuration:	point-to-point uniform
structure:	8 kHz integrity

– *Access attributes* (Table 2/Q.522)

TABLE 2/Q.522

Access attributes	User access	Network access
Access channel and rate		
Information	B/64	Digital circuit with access to analogue/digital switched network
Signalling	D/16-64	Digital circuit (s_1)
Access protocol	See type I (For signalling only) [a)]	See type I (For signalling access to digital switched network) [a)]

[a)] Further study is required for information transfer protocol or access to PSPDN.

– *Other attributes*

For further study.

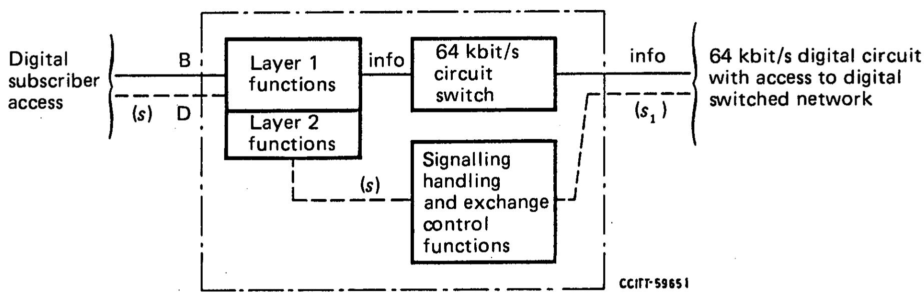


FIGURE 2/Q.522

Type II exchange connection

2.2.5 *Type III exchange connection* (Figure 3/Q.522)

This is a connection used to transport packetized data information between an information channel on a digital subscriber access and a 64 kbit/s digital circuit which has an access to:

a) a remote ISDN Packet Handling Functional Grouping;

b) a remote ISDN Packet Switching Interworking Functional Grouping;

c) a public packet network (see § 5.2.3).

This connection is characterized by:

– *Information transfer attributes* (see Table 3/Q.522)

(see Table 2/I.340, A 10 and A 11)

TABLE 3/Q.522

Access attributes	Option a)	Options b) and c)
Mode	Circuit	Packet
Rate	64 kbit/s (further study)	64 kbit/s (further study)
Capability	Unrestricted digital information	Unrestricted digital information
Establishment	Switched – semi-permanent	Switched – semi-permanent
Symmetry	Bidirectional symmetric	Bidirectional symmetric
Configuration	Point-to-point	Point-to-point
Structure	8 kHz	Service data unit integrity

– *Access attributes* (Table 4/Q.522)

TABLE 4/Q.522

Access attributes	User access	Network access
Access channel and rate		
Information		
Options a), b), c)	B/Further study	64 kbit/s digital circuit [a]
Signalling a), b), c)	D/16-64	64 kbit/s digital circuit [a]
Access protocol		
Options a), b)	For further study	For further study
Option c)	For further study	X.75 - X.25

[a] Information and signalling may be carried by the same circuit (in-band signalling).

– *Other attributes*

For further study.

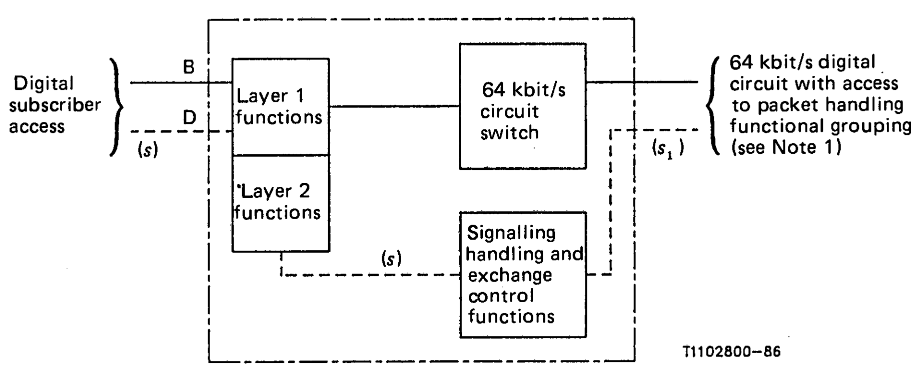


FIGURE 3a/Q.522

Type III exchange connection option a)

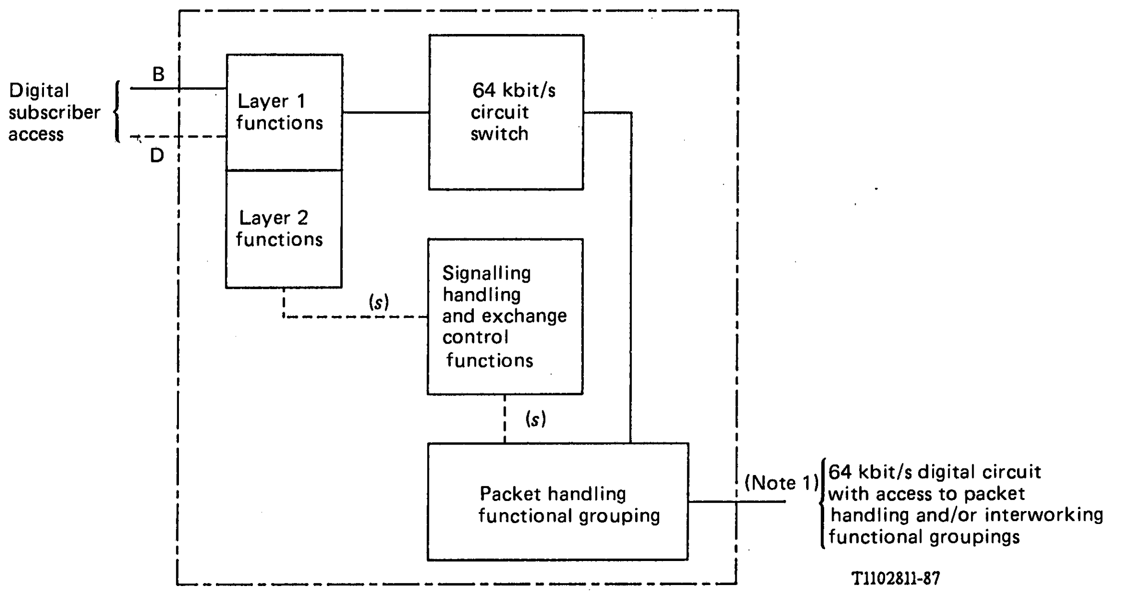
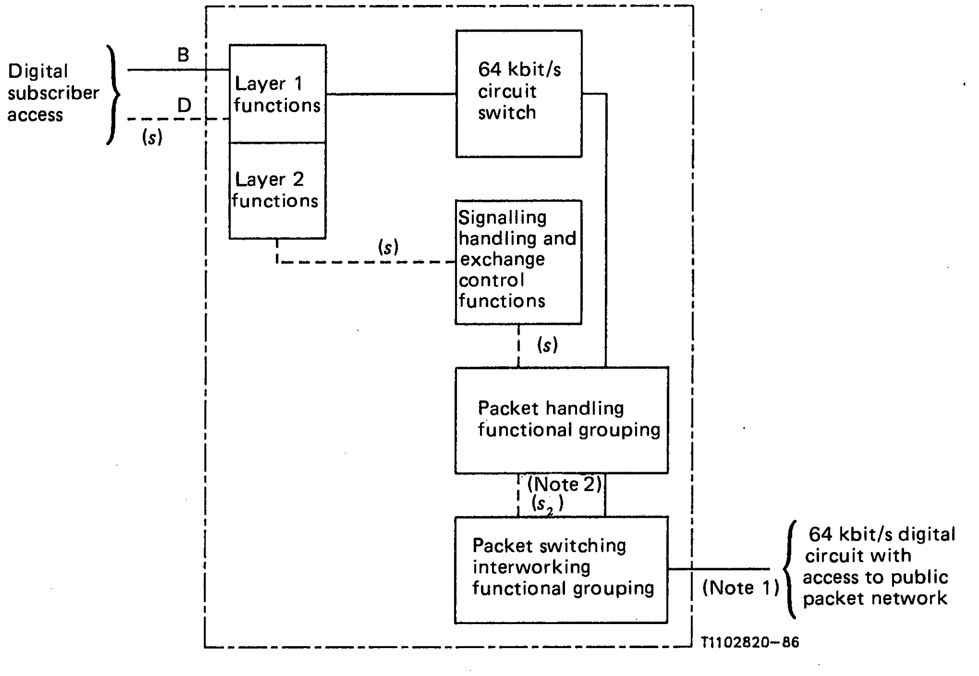


FIGURE 3b/Q.522

Type III exchange connection option b)



Note 1 — These links may pass through the 64 kbit/s circuit switch. This requires further study.

Note 2 — s_2, optional.

FIGURE 3c/Q.522

Type III exchange connections option c)

2.2.6 *Type IV exchange connection* (Figure 4/Q.522)

This connection is used to transport message type data, for example packetized data messages or teleaction information messages (see § 5.2.4).

It consists of a message/packet type connection via a D channel on a digital subscriber access to an access port to either:

a) a remote ISDN Interworking Functional Grouping; or

b) a public packet network.

This connection is characterized by:

– *Information transfer attributes*
(see Table 2/I.340).
See type III, options b) and c).

– *Access attributes* (Table 5/Q.522).

TABLE 5/Q.522

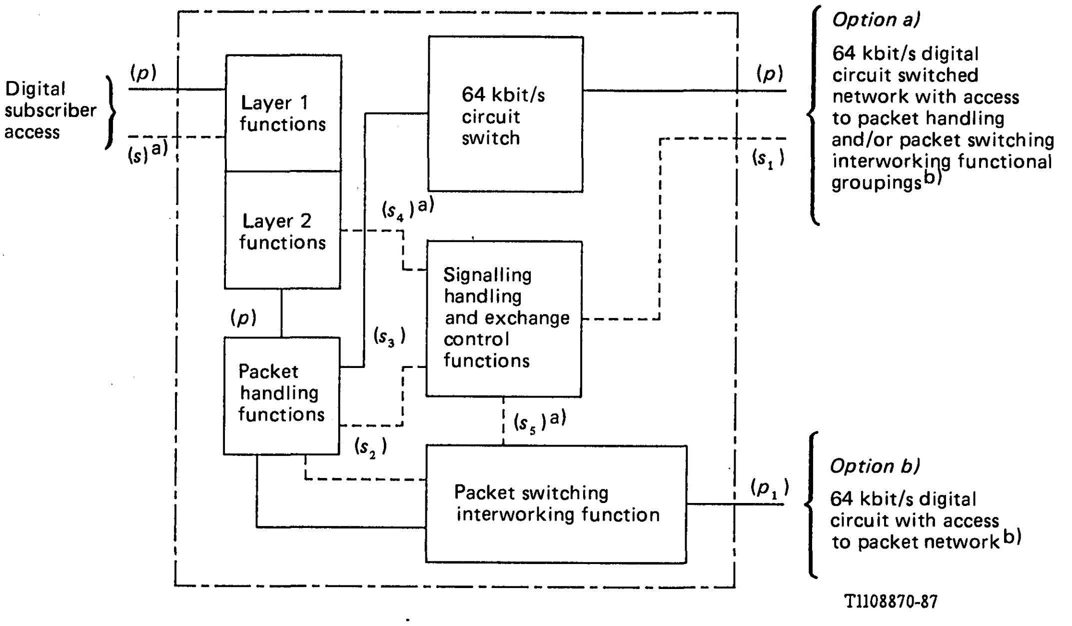
Access attributes	User access	Network access
Access channel and rate		
Information and signalling		
Options a) and b)	D/For further study [a]	64 kbit/s digital circuit [b]
Access protocol		
Option a)	For further study	For further study
Option a)	For further study	X.75 - X.25

[a] Signalling in-band or out-band.

[b] Signalling in-band or out-band for option a), or in-band for option b).

– *Other attributes*

For further study.



a) s, s_4 and s_5 are only applicable when all signalling required is not contained in the p information.

b) Signalling in-band or out-band for option a), or in-band for option b).

FIGURE 4/Q.522

Type IV exchange connection

2.3 *Functions associated with attributes shown in § 2.2*

The following information is to clarify which functions may be associated with the attributes shown on the types I-IV exchange connection diagrams described in § 2.2.

2.3.1 *Layer 1 functions* (see Note in § 2.3.4)

This functional grouping includes:

– digital line/exchange termination interface functions.

2.3.2 *Layer 2 functions* (see Note in § 2.3.4)

This functional grouping includes:

– layer 2 D-channel protocol handling (LAP D)

2.3.3 *64 kbit/s circuit switching functions*

This functional grouping includes:

– 64 kbit/s switching stage(s).

2.3.4 *Signalling handling and exchange control functions*

This functional grouping may include:

- layer 3 D-channel protocol for signalling (see Note);
- functions related to circuit switched connection control;
- signalling functions for common channel signalling;
- signalling interfaces with "packet handling function";
- functions related to packet switched connections;
- signalling interface with "packet switching interworking function".

Note – The term "layer" refers to Open Systems Interconnection as applied to CCITT signalling systems as defined by Recommendations X.200 and I.112.

2.3.5 *Packet switching interworking functions*

This functional grouping may include:

- signalling interface with "packet handling function" and "signalling handling and exchange control function" allowing call packets to be routed to/from the appropriate subscriber terminals;
- routing functions;
- functions such as compatibility checking;
- protocol conversion;
- numbering interworking;
- control function (see Note in § 2.3.6).

2.3.6 *Packets handling function*

This functional grouping may include:

- layer 3 D-channel protocol for packet calls;
- packet level multiplexing for outgoing calls;
- packet level demultiplexing for incoming calls;
- signalling interface with the "signalling handling function" and subscriber terminals via layer 1 and 2 functional block;
- control functions for packet switched connections (see Note);
- some or all the functions associated with packet switching (e.g., internal packet calls).

Note – Clarification of control function would need further study.

In the case where the packet switching interworking function is not present in the local exchange, the local exchange contains the minimum functions necessary to enable it to communicate with the packet switching interworking function. The protocols to carry out this minimum function require further study.

2.4 *Bit rate of a connection through an exchange*

2.4.1 *Basic bit rate for circuit switched connections*

The exchange should be able to make circuit switched connections between channel timeslots with the basic bit rate of 64 kbit/s. The channel timeslots to be connected are contained in primary or higher order frame structures appearing at the digital interfaces of the exchange or derived from analogue channels appearing at the analogue interfaces, or from individual digital interfaces for subscriber access.

Switching at rates other than 64 kbit/s is for further study.

2.4.2 *Basic bit rate for message/packet switched connections Type IV*

The bit rate of a message/packet connection Type IV will depend on a number of factors including the bit rate of the subscriber terminal equipment, the bit rate of the D channel and the bit rate capacity of the connection to the appropriate network.

2.5 *Services offered at bit rates less than 64 kbit/s*

Services requiring less than 64 kbit/s for a connection should be switched as 64 kbit/s connections.

2.6 *Services offered at bit rates greater than 64 kbit/s*

2.6.1 *General*

Services requiring more than 64 kbit/s for a connection are through-connected as a multiple of 64 kbit/s connections. They are called multi-slot connections.

The exchange may be required to establish the following types of multi-slot connections (see Recommendation I.340):

- 2 × 64 kbit/s connections;
- 6 × 64 kbit/s connections to provide a H_0 channel;
- 24 × 64 kbit/s connections to provide a H_{11} channel;
- 30 × 64 kbit/s connections to provide a H_{12} channel.

It should be noted that an n × 64 kbit/s connection can seriously affect the blocking probability of an exchange and the network, particularly if all n timeslots are routed in a defined order in the same multiplex. The ability to handle multi-slot traffic will be influenced by the traffic loading of the exchange at any instant and the number of circuits available on the required route.

2.6.2 *2 × 64 kbit/s connections*

This connection type is characterized by the following attributes (see Recommendation I.340).

The attributes are for further study.

A 2 × 64 kbit/s connection is established in response to signalling information received on the subscriber line or on an inter-exchange link.

The exchange should maintain restricted differential time delay between the two timeslots involved in the connection. The precise definition of "restricted differential time delay" is still to be formulated, but the intention is to ensure that the time delay between the individual slots forming a 2 × 64 kbit/s connection is not excessive, for example as could occur if the two channels were routed out of the exchange on diverse physical routings.

The exchange aspects of meeting this requirement require further study, but will include the need for the exchange to be capable of recognizing the signalling information on incoming inter-exchange circuits/subscriber accesses which indicates that there is an association between two incoming 64 kbit/s channels and to ensure that the two channels are handled by the exchange in a uniform manner.

2.6.3 *Switching of 6 × 64 kbit/s connections (H_0 channel)*

The 64 kbit/s timeslots which form an H_0 channel are transmitted over the same primary multiplex system within the same frame. This is valid for both the subscriber line and the inter-exchange links.

The requirement for 6 × 64 kbit/s connections can be satisfied by establishing 6 separate 64 kbit/s semi-permanent connections, each of which would be set up to preserve the sequence with the other slots forming the 6 × 64 kbit/s connection.

2.6.4 *Switching of 24 or 30 × 64 kbit/s connection (H_1 channels)*

This is for further study.

2.7 *Mode of establishment*

2.7.1 *Circuit switched connections, Type I, Type II and Type III option a)*

Circuit switched connections are set up at any time on demand in response to signalling information received from subscribers, other exchanges or other networks.

2.7.2 *Packet switched connections, Type III options b) and c)*

For further study.

2.7.3 *Message/packet switched connections, Type IV*

These connections are set up on demand subject to any D channel priority/flow control restrictions that may be applicable.

2.7.4 *Semi-permanent connections*

The exchange should have the capability of establishing semi-permanent connections which pass through the exchange switching network.

Other features of semi-permanent connections, e.g. grade of service, the need for an out-slot signalling channel associated with the connection, etc. are for further study.

2.8 *Bit sequence independence*

See Recommendation Q.554.

2.9 *Bit integrity*

See Recommendation Q.554.

2.10 *Octet sequence integrity*

See Recommendation Q.9.

2.11 *8 kHz (structure) integrity*

See Recommendation I.140.

2.12 *Bit patterns generated by the exchange in idle channel timeslots*

At interfaces A and B, the following patterns are recommended for the idle condition, where the left-most digit is the polarity digit.

01111111 for 1544 kbit/s systems

01010100 for 2048 and 8448 kbit/s systems.

At other interfaces the bit pattern generated in idle channel timeslots is for further study.

The patterns should not be used as an indication of the idle or barred conditions of a channel since this information should be derived from the control or signalling functions.

Note – These patterns are slightly different from the quiet code produced by external test equipment and used as an auxiliary signal for noise and crosstalk measurements on digital exchanges (see Recommendations Q.551, § 1.2.3.1, Q.552, §§ 2, 2.2.3, 3.1.4 and Q.553, §§ 2.1.1.2, 3.1.4).

2.13 *Error performance*

See Recommendation Q.554.

2.14 *In-call rearrangement*

In-call rearrangement is the rearrangement by the exchange of the established connections across the switchblock in a more efficient manner.

When it is provided, it is essential that the requirements for error performance, Quality of Service, etc. be met (see Recommendation Q.543).

2.15 *Transmission performance characteristics*

See Recommendations Q.551 to Q.554.

3 Signalling and D-channel handling

3.1 *General*

The exchange should be capable of interworking with other exchanges using signalling systems indicated in Recommendation Q.7, and for local or combined exchanges with user equipment on digital access lines (e.g., terminals and PABXs) using the signalling procedures in Recommendations I.430, I.431, and Q.920 (I.440), Q.930 (I.450)-Series of Recommendations.

For a local or combined exchange interworking with user terminals or analogue subscriber access lines should be accomplished using nationally recommended signalling procedures.

64 kbit/s signalling channels entering the exchange via a multiplex structure may be connected through the exchange as semi-permanent channels.

3.2 *Signalling associated with exchange connections Types I-IV*

This section applies to local or combined exchanges only.

3.2.1 *General*

Details of the exchange connections Types I-IV are given in § 5.

For internal and originating connections, the call set up signalling information will be received from the subscriber.

For terminating and transit connections, the call set up signalling information will be received from the appropriate network or separate signalling network.

Note – Receipt of call set up signalling information may be affected by the involvement of supplementary services.

3.2.2 *Basic connections including Type I exchange connection*

The exchange should carry out the functions defined in the following signalling systems.

3.2.2.1 *On the subscribers side*:

a) analogue line signalling systems as defined nationally; and
b) the defined digital subscriber access signalling system(s) if digital subscriber accesses are provided (see Recommendations I.430 and Q.920, Q.930-Series of Recommendations).

3.2.2.2 *On the network side*

One or more of the signalling systems are defined in Recommendation Q.7.

3.2.3 *Type II exchange connection*

The exchange should carry out the functions defined in the following signalling systems.

3.2.3.1 *On the subscriber side*

The defined digital subscriber access signalling system(s) (see Recommendations I.430 and Q.920, Q.930-Series of Recommendations).

3.2.3.2 *On the network side*

One or more of the signalling systems defined in Recommendation Q.7.

Note – Further study is required for information transfer protocol or access to PSPDN.

3.2.4 *Type III exchange connection*

3.2.4.1 *On the subscriber side*

For further study.

3.2.4.2 *On the network side*

The signalling associated with the messages/packets may be:

a) contained in the individual message/packets; or

b) transported separately, in accordance with one or more of the signalling systems defined in Recommendation Q.7.

A local exchange which supports such services must contain a function that is capable of either interpreting them and routing them appropriately, or of sending them directly to an appropriate interworking function.

3.2.5 *Type IV exchange connection*

On the subscriber side:

The signalling associated with the messages/packets may be:

a) contained in the individual message/packet, or

b) transported separately as s-information (see Recommendations I.430 and Q.920, and Q.930-Series of Recommendations).

On the trunk side:

The signalling associated with the messages/packets may be:

a) contained in the individual message/packet (p_l); or

b) transported separately (s_l information), in accordance with one or more of the signalling systems defined in Recommendation Q.7.

A local exchange which supports such services must contain a function that is capable of either interpreting them and routing appropriately, or of sending them directly to an appropriate interworking function.

3.3 *Digital subscriber access – D channel and protocol handling layers 1, 2 and 3*

The following text refers to handling the D-channel protocol on the exchange side of the interfaces U and V_1.

The functions associated with handling the D-channel protocol are defined in the parts of Recommendations I.430, Q.920 and Q.930-Series of Recommendations relating to call establishment for subscribers connected to the U or V_1 interfaces. Exchange functions for D-channel signalling procedures for users connected via a primary rate multiple access are also given in I.431, Q.920 and Q.930-Series of Recommendations.

3.4 *User-to-user signalling*

The exchange may receive signals from the user (e.g., from a PABX) for transport across the network. It must be capable of receiving this information, verifying its acceptability, and if the service is permitted to the requesting user, send it via the inter-exchange signalling or other network to the distant exchange. Similarly the exchange may receive information from the signalling network for transmission to the subscriber. This capability may not be provided on all types of connection.

Where user-to-user signalling involves network inter-exchange facilities, it may be necessary for the originating local exchange to process this signalling information before sending it to the network, to ensure that it is compatible with signalling, charging and flow control requirements of the originating exchange and network.

4 Ancillary functions

4.1 *Connection of ancillary equipment*

Ancillary equipment may be connected in the following way:

i) Serially. This may require more than one connection through the exchange. Examples of serially connected equipment include:
   - echo control devices,
   - encoding law converters,
   - manual board access equipment (for operator controlled traffic).

ii) As terminal connected equipment usually requiring one connection through the exchange. Examples of such equipment include:
   - recorded announcements,
   - manual board terminations,
   - speech codecs,
   - data terminal facilities,
   - test equipment (such as a test call sender),
   - tone generators,
   - signalling receivers.

The interface between the exchange and the items of equipment listed above may be left to the national designers. However, the use of internationally standardized interfaces is preferred.

Note – In some cases it may be necessary to establish more than one connection to one timeslot at the same time.

4.2 *Digitally generated tones and frequencies*

When tones and frequencies are digitally generated the following minimum requirements apply on a provisional basis.

4.2.1 *Service tones*

Digitally generated tones should meet the recommended limits specified in Recommendation Q.35 when decoded.

4.2.2 *Signalling frequencies*

Digitally generated signalling frequencies should be such that they can be detected after decoding by any analogue receivers designed to CCITT Recommendations.

4.3 *Echo control devices*

The exchange should be able to be equipped with echo control devices (echo suppressors/echo cancellers conforming to Recommendations G.164 and G.165 respectively). When required the exchange should be able to control such devices to meet the requirements of Recommendation Q.115. The means of control by the exchange is for further study.

(*Note* – It is recognized that there is a need for an internationally agreed method of disabling and enabling echo control devices for the purposes of making end-to-end circuit transmission maintenance measurements, e.g. as recommended in Recommendation V.25.)

5 Control functions associated with call handling

5.1 *Basic control functions*

The requirements for the basic control functions are implicit in the requirements recommended for the other functions of the exchange. However recommendation of a number of new requirements for the control functions associated with the handling of digital subscriber lines and the use of a digital local exchange within an ISDN, may be necessary.

The exchange should provide the capability to avoid fraudulent use of the connection. Such capabilities may be based on the use of digital pads or an asymmetrical through-connect procedure.

An originating local exchange should be capable of supporting either symmetric or asymmetric through-connect procedures. The choice of procedure may be determined on the basis of service.

Terminating and transit exchange need only support symmetric through-connect procedure.

This subject is for further study.

5.2 *Exchange connections Types I-IV, general control aspects*

5.2.1 *Type I*

These connections will be set up between the accesses associated with network addresses specified in response to the signalling information received. Voice-associated facilities, e.g. tones, should be provided where appropriate and telephony supplementary services may be invoked if provided.

5.2.2 *Type II*

Such connections will be set up between the accesses associated with network addresses specified in response to the signalling messages received. Compatibility checking may be provided before the connection is completely established (see § 2.3.1). Voice associated facilities (e.g. tones, pads) will be disabled in order to provide a transparent digital path, (the means of doing this is for further study). Data supplementary services may be invoked if provided.

5.2.3 *Type III*

Such connections will be set up between the accesses associated with network addresses specified in response to the signalling messages received. Compatibility checking may be provided before the connection is completely established (see § 2.3.1). Voice associated facilities (e.g. tones, pads) will be disabled in order to provide a transparent digital path (the means of doing this is for further study). Data supplementary services may be invoked if provided.

For option a) in the switched access case, originating calls will be set up over the B channel towards the 64 kbit/s digital circuit using the ISDN signalling procedures prior to starting X.25 layer 2 and layer 3 functions. The corresponding service requested in the Q.931 SET-UP message is ISDN packet mode bearer service. For calls originated by the network, the same consideration applies (see Recommendations X.31 and I.462).

The distant packet handling must be selected by the called address in the D-channel protocol when the terminal sets up the circuit switched connection.

Packet data communications, when using a switched B channel, will be established by separating the establishment phase of the B channel (carried out by the exchange) and the control phase of the virtual circuit using the X.25 link layer and packet layer protocol (carried out in the distant packet handling function).

For options b) and c) the same considerations as above apply except that the control phase of the virtual circuit is performed within the exchange.

5.2.4 *Type IV*

These connections will be of the message/packet type (e.g., virtual circuit). The "p-information handling function" and "packet switching interworking function" shown in Figure 4/Q.521 will implement procedures for control of the logical links on the D channel (e.g., flow control, error control) (see also § 3.2.5). Voice associated facilities (e.g., tones, pads) will be disabled in order to provide a transparent digital path.

The D channel provides a semi-permanent physical connection which enables the user terminal to access a packet handling function by establishing a link layer connection (with a specific SAPI) to that function which can then be used to support packet communications according to X.25 layer 3 procedures. The X.25 packet layer will use the acknowledged information service provided by LAP D (see Recommendation Q.920). X.25 layer 3 procedures are transferred transparently over the D Channel link.

A single or multiple LAP D link must support the multiplexing of logical channels at layer 3.

5.3 *Control functions associated with calls over a digital subscriber access via Interfaces U and V_1*

5.3.1 *Control of circuit switched calls Types I, II and III*

In response to s-information carried on the D channel and network signalling messages, the exchange must have the following capabilities.

a) *Setting up a call*

The exchange must receive address information (overlap sending or en bloc), establish the desired path (digital only or mixed) and send further (e.g., Signalling System No. 7) signalling, if necessary (e.g., address, calling line identity, service indicator) into the network.

The call set up procedure may include steps to verify compatibility based on the record in the exchange of the services permitted for the subscriber. The degree of compatibility checking provided by the exchange requires further study.

b) *During a call*

In addition to the basic functions of maintaining a call record, supervising the call, charging for the call, etc., the exchange must be able to handle in-call service/facility requests. These include for example transfer of a call to another terminal or conferencing.

If it is required that a terminal be moved from one location to another on the same access during a call, the exchange must be able to hold the call while the transfer is made and to re-establish communication on request by the user (including carrying out any compatibility checks). The exchange may limit the time allowed for moving a terminal. In addition, the user must send a signal to the exchange indicating that terminal movement is about to take place. Signalling procedures for terminal movement are given in Recommendation Q.931.

c) *Clearing a call*

The exchange will need to initiate call clearing on receipt of a clear request signal from the terminal or network.

d) *Without a call path*

The exchange may be required to handle signalling information without establishment of a call path (subscriber-network transactions).

5.3.2 *Control of message/packet calls over the D channel, Type IV*

Any messages carrying p-information on the D channel must be handled by the exchange in accordance with the applicable Recommendation for services (e.g., Recommendation X.25) requested by the user. It is not necessary that every digital local or combined exchange in an ISDN should be able to to carry out all the possible functions associated with handling this information. It is possible for example that the exchange may route such traffic to another node which has the appropriate handling facilities.

6 **Control functions associated with maintenance and automatic supervision**

See Recommendation Q.542.

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

SECTION 3

DESIGN OBJECTIVES AND MEASUREMENTS

Recommendation Q.541

DIGITAL EXCHANGE DESIGN OBJECTIVES – GENERAL

1 General

This Recommendation applies to digital local, combined, transit and international exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks, and also to local, combined, transit and international exchanges in an Integrated Services Digital Network (ISDN). The field of application of this Recommendation is more fully defined in Recommendation Q.500. Some objectives only apply to a certain type (or types) of exchange. Where this occurs, the application is defined in the text. Where no such qualification is made, the objective applies to all exchange applications.

2 General design objectives

The exchange and/or any associated operations and maintenance systems/centers shall have the capabilities needed to allow the exchange to be operated and administered efficiently while providing service in accordance with an Administration's performance requirements.

2.1 *Exchange modifications and growth*

The exchange should be capable of having hardware and/or software added or changes made without causing a significant impact on service (see §§ 4.4, 4.10.2 – Planned outages).

2.2 *Service provisioning and records*

There should be efficient means of establishing service, testing, discontinuing service and maintaining accurate records for:

- subscriber lines and services,
- interexchange circuits.

2.3 *Translations and routing information*

There should be efficient means of establishing, testing and changing call processing information, such as translation and routing information.

2.4 *Resource utilization*

There should be efficient means of measuring performance and traffic flows and to arrange equipment configurations as required to insure efficient use of system resources and to provide a good grade of service to all subscribers (e.g., load balancing).

2.5 *Physical design objectives*

The exchange shall have a good physical design that provides:

- adequate space for maintenance activities,
- conformance with environmental requirements,
- uniform equipment identification (conforming with the Administration's requirements),
- a limited number of uniform power up/down procedures for all component parts of the exchange.

3 Integrated Digital Network design objectives

3.1 *Exchange timing distribution*

The timing distribution system of an exchange will be derived from a highly reliable exchange clock system. The distribution of timing within the exchange must be designed so that the exchange will maintain synchronism on 64 kbit/s channel timeslots in a connection through the exchange.

3.2 *Network synchronization*

Within a synchronized IDN/ISDN, different methods of providing timing between exchanges may be used. An exchange should be able to be synchronized:

a) by an incoming digital signal at an interface A (or B, if provided) as defined in Recommendation Q.511; this applies only to signals derived from a Primary Reference Source, as defined in Recommendation G.811;

b) directly by a Primary Reference Source, using an interface complying with Recommendation G.811;

c) optionally, by an analogue signal at one of the frequencies listed in Recommendation G.811.

Plesiochronous operation should also be possible.

The clock of the local, combined or transit exchange shall be responsible for maintaining the synchronization in the part of the network associated with that exchange.

The timing performance of the clocks in local, combined or transit exchanges should comply with Recommendation G.811. The timing performance of clocks at subscriber premises, at digital PABXs, in digital concentrators, at muldexes, etc., require further study.

Synchronized national networks may be provided with exchange clocks not having the frequency accuracy required for international interworking. However, when these synchronized networks within national boundaries are required to interwork internationally as part of the international IDN/ISDN, it will be necessary to provide means to operate these national networks to the internationally recommended value of frequency accuracy in Recommendation G.811.

3.3 *Slip*

The design objective controlled slip rate within a synchronized region (see Note) controlled by the exchange should be zero provided that input jitter and wander remain within the limits given in Recommendation G.823 and G.824.

The design objective controlled slip rate at a digital exchange in plesiochronous operation (or operating to another synchronized region) shall be not more than one slip in 70 days in any 64 kbit/s channel, provided that input jitter and wander remain within the limits given in Recommendations G.823 and G.824.

The operational performance requirements for the rate of octet slips on an international connection or corresponding bearer channel are covered in Recommendation G.822.

The occurrence of a controlled slip should not cause loss of frame alignment.

Note – A synchronized region is defined as a geographic entity normally synchronized to a single source and operating plesiochronously with other synchronized regions. It may be a continent, country, part of a country or countries.

3.4 *Relative Time Interval Error (TIE) at the exchange output*

Relative Time Interval Error (TIE) at the exchange output is defined as the difference in time delay of a given timing signal when compared to a reference timing signal for a given measurement period (see Recommendation G.811).

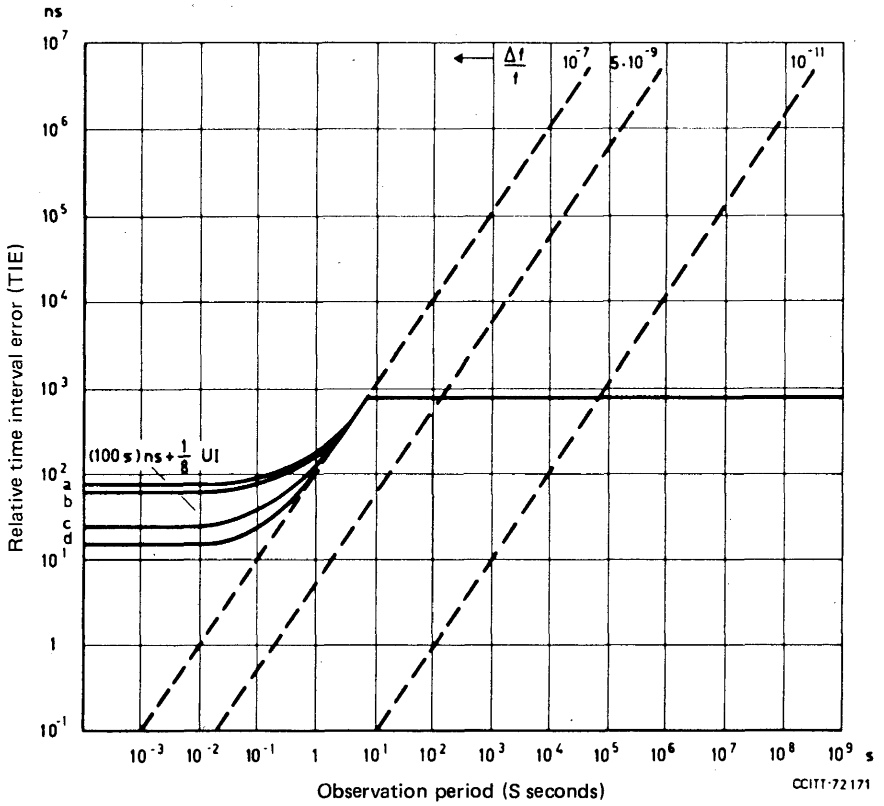
3.4.1 *Interface V_1*

Relative Time Interval Error (TIE) at the exchange output at the interface to the basic access digital section requires further study.

3.4.2 *Interfaces A, B, V_2, V_3 and V_4*

The relative TIE at the output of the digital interfaces A, B, V_2, V_3 and V_4 over the period S seconds should not exceed the following limits:

1) (100 S) ns + 1/8 UI for S < 10.
2) 1000 ns for S ⩾ 10 (see Figure 4/Q.541).



a : 1544 kbit/s
b : 2048 kbit/s
c : 6312 kbit/s
d : 8448 kbit/s

FIGURE 1/Q.541

Limits of relative peak-to-peak TIE at the exchange output interfaces A, B and V_3

In the case of synchronous operation the limits are specified on the assumption of an ideal incoming synchronizing signal (no jitter, no wander and no frequency deviation) on the line delivering the timing information. In the case of asynchronous operation the limits are specified assuming no frequency deviation of the exchange clock, (this is equivalent to taking the output of the exchange clock as the reference timing signal for the relative TIE measurements).

It is recognized that the approach of using relative TIE to specify the performance of an exchange in the case of synchronous operation in some implementations (e.g., when mutual synchronization methods are used) requires further study.

Any internal operation or rearrangement within the synchronization and timing unit or any other cause should not result in a phase discontinuity greater than 1/8 of a Unit Interval (UI) on the outgoing digital signal from the exchange.

The limits given in Figure 4/Q.541 may be exceeded in cases of infrequent internal testing or rearrangement operations within the exchange. In such cases, the following conditions should be met:

The Relative Time Interval Error (TIE) over any period up to 2^{11} unit intervals should not exceed 1/8 of a UI. For periods greater than 2^{11} UI, the phase variation for each interval of 2^{11} UI should not exceed 1/8 UI up to a maximum total Relative TIE defined in Recommendation G.811 for long time periods.

3.5 *Synchronization requirements when interworking with a digital satellite system*

On a provisional basis the following should apply:

The transfer from the timing of the terrestrial digital network to the timing of the satellite system, if required (plesiochronous operation), will not be performed by the digital exchange. The earth station will be equipped with buffer memories of suitable size to compensate for the time delay variations due to shifts of the satellite from its ideal position (and due to any other phenomena with similar effects) and to meet the slip performance requirements established in CCITT Recommendation G.822.

4 Availability design objectives

4.1 *General*

Availability is one aspect of the overall quality of service of an exchange.

Availability objectives are important factors to be considered in the design of a switching system and may also be used by administrations to judge the performance of a system design and to compare the performance of different system designs.

Availability may be determined by collecting and evaluating data from exchanges in operation in accordance with draft Recommendation E.450. Data collection may be facilitated by the use of the Telecommunications Management Network (TMN).

Availability may be expressed as the ratio of the accumulated time during which the exchange (or part of it) is capable of proper operation to a time period of statistically significant duration called the mission time.

$$\text{Availability (A)} = \frac{\text{accumulated up-time}}{\text{mission time}} = \frac{\text{accumulated up-time}}{\text{accumulated up-time} + \text{accumulated down-time}}$$

Sometimes it is more convenient to use the term unavailability (instead of availability) which is defined as:

$$\text{Unavailability (U)} = 1 - \text{A}.$$

The terms used in this section, when they already exist, are in accordance with CCITT Recommendation G.106.

4.2 *Causes of unavailability*

This Recommendation deals with availability as observed from the exchange termination point of view. Both planned and unplanned outages need to be considered, and both types need to be minimized. Unplanned outages reflect on the inherent reliability of the exchange and are therefore considered separately from planned outages in this Recommendation.

Unplanned unavailability counts all failures that cause unavailability. Thus hardware failure, software malfunctions and unintentional outages resulting from craftperson activity are to be counted.

4.3 *Intrinsic and operational unavailability*

Intrinsic unavailability is the unavailability of an exchange (or part of it) due to exchange (or unit) failure itself, excluding the logistic delay time (e.g. travel times, unavailability of spare units, etc.) and planned outages.

Operational unavailability is the unavailability of an exchange (or part of it) due to exchange (or unit) failure itself, including the logistic delay time (e.g. travel times, unavailability of spare units, etc.).

4.4 *Planned outages*

Planned outages are those intentionally induced to facilitate exchange growth or hardware and/or software modifications. The impact of these activities on service depends on their duration, the time of day they are introduced and on the particular system design.

4.5 *Total and partial unavailability*

Exchange unavailability may be either total or partial. Total unavailability affects all terminations, and consequently, all traffic that is offered during the outage is equally affected. A partial outage has an effect only on some terminations.

From the point of view of one termination on an exchange (e.g. a subscriber line termination), the numerical value of mean accumulated downtime (and hence the unavailability) for a specified period of time should not depend on the exchange size or its traffic handling capacity. Similarly, from the point of view of a group of terminations of size n, the mean accumulated downtime for a specified period of time, *in case they are simultaneously unavailable*, should not depend on exchange size. However, for two groups of terminals of differing size n and m such that n is greater than m ($n >$ m), the mean accumulated downtime (and hence the unavailability) for n will be less than the mean accumulated downtime (MADT) or the unavailability for m.

Thus:

$$\mathrm{MADT}(n) < \mathrm{MADT}(m) \text{ where } n > m$$

and

$$\mathrm{U}(n) < \mathrm{U}(m)$$

The lower limit of m is one termination, and it can be specified as having a mean value of T minutes per year.

4.6 *Statistical basis*

Any estimation of unavailability is of necessity a statistical quantity, because outages are presumed to occur randomly and they are of random duration. Therefore, availability measurements are significant when made over a statistically significant number of exchanges. It follows then, that a single exchange may exceed the unavailability objectives. Further, to be statistically significant the mission time must be adequate in order to have sufficient collected data. The accuracy of the result is dependent on the amount of collected data.

4.7 *Relevant failure events*

Different types of failure events may occur in an exchange. In order to evaluate the unavailability of an exchange (or part of it) only those events having an adverse effect on the exchange's ability to process calls as required should be taken into account. A failure event which is short in duration and results only in call delay rather than in a call denial can be disregarded.

4.8 *Availability independence*

The design objectives for the unavailability of a single termination or any group of terminations of size n are independent of exchange size or internal structure.

4.9 *Intrinsic downtime and unavailability objectives*

The recommended measure for use in determining *intrinsic unavailability* is mean accumulated intrinsic down time (MAIDT) for individual or groups of terminations, for a given mission time, typically one year.

For one termination:

$$\text{MAIDT}(1) \leqslant 30 \text{ minutes per year.}$$

For an exchange termination group of size n:

$$\text{MAIDT}(n) < \text{MAIDT}(m) \text{ where } n > m.$$

This reflects the consequences (e.g. traffic congestion, social annoyance, etc.), of the simultaneous outage of a large number of terminations.

The above expression is a statement of principle and means that units serving larger group sizes shall have lower MAIDT.

4.10 *Operational unavailability objectives*

4.10.1 *Logistic delay time*

Due to differing national conditions, logistic delay times may vary from country to country and therefore may not be subject to international Recommendation.

Nevertheless, for design guidance, an indication of the Administration's logistic delays is considered desirable to establish overall operational performance objectives. It is left for the operating Administration to determine how it should be accounted for in the determination of operational unavailability.

4.10.2 *Planned outages*

Planned outages are to be minimized to the greatest extent practicable. They should be scheduled so as to have least impact on service practicable.

4.11 *Initial exchange availability performance*

A system rarely meets all long-term design objectives when first placed into service. The objectives contained in this Recommendation may therefore not be fulfilled for a limited period of time after the newly designed switched system has been put into service; this period of time should be minimized to the greatest extent practicable.

5 Hardware reliability design objectives

A bound on the rate of hardware failures is recommended. It includes all types of hardware failures and the failures counted are independent of whether or not there is a resulting service degradation.

An acceptable hardware failure rate for an exchange is a function of the exchange size and the types of terminations.

The following formula can be used to verify that the maximum failure rate does not exceed the Administration's requirements:

$$F_{\max} = \mathrm{C}_0 + \sum_{i=1}^{n} C_i T_i$$

where:

- $F_{\max}$ the maximum acceptable number of hardware failures per unit of time;
- T_i the number of terminations of type i;
- n the number of distinct types of terminations;
- C_0 to be determined taking into account all failures which are independent of exchange size;
- C_i coefficients for terminations of type i, reflecting the number of failures associated with individual terminations of that type. Different hardware used with different types of terminations may result in different values for C_i.

Recommendation Q.542

DIGITAL EXCHANGE DESIGN OBJECTIVES – OPERATIONS AND MAINTENANCE

1 General

This Recommendation applies to digital local, combined, transit and international exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks, and also to local, combined, transit and international exchanges in an Integrated Services Digital Network (ISDN).

The field of application of this Recommendation is more fully defined in Recommendation Q.500. Some objectives only apply to a certain type (or types) of exchange. Where this occurs, the application is defined in the text. Where no such qualification is made, the objective applies to all exchange applications.

2 Maintenance design objectives

The exchange shall be arranged so that normal maintenance activities can be easily performed by maintenance personnel. It should be capable of providing all information necessary for the identification of trouble conditions and the direction of repair activities.

2.1 *Status and other information*

The exchange shall provide information to maintenance personnel so that they can quickly ascertain:

- equipment/system status,
- critical load levels,
- trouble conditions,
- network management controls in effect.

2.2 *Inputs and outputs*

The exchange shall be able to transmit and receive maintenance information and respond to commands from on-site and if appropriate, from remote maintenance centre(s) or systems over the recommended interface(s) (Recommendation Q.513).

In performing operations and maintenance functions, the exchange shall use CCITT MML at its input/output terminals as covered in the Z.300-series of Recommendations.

2.3 *Routine testing*

The exchange shall have facilities for performing or directing routine test activities on its component parts and possibly with interfacing equipment or systems.

2.4 *Trouble localization*

The exchange shall have adequate facilities for diagnosing and locating faults within the exchange.

2.5 *Fault and alarm detection and actions at interfaces A, B, V_2, V_3 and V_4*

The exchange shall interact with transmission systems as required to detect fault and alarms and take appropriate actions.

2.5.1 *Fault detection*

The following fault conditions should be detected:

- failure of local power supply (if practicable);
- loss of incoming signal;

  Note – The detection of this fault condition is required only when the fault does not result in an indication of loss of frame alignment.

- loss of frame alignment (see Recommendations G.706; the loss of frame alignment will also be assumed if no CRC multiframe alignment can be achieved or if the proportion of corrupted CRC checks exceeds a certain value);
- excessive error ratio (without CRC procedure). The criteria for activating and deactivating the indication of the fault condition are given in draft Recommendation G.707. Consequent actions are given in § 2.5.3;
- CRC error reporting, if applicable:
  a) every time a received CRC block is detected errored by the exchange termination:
     - a report will be transmitted to the error monitoring function;
     - the information "one multiframe errored" is transmitted in the outgoing signal at the interface using an E bit (see Recommendation G.704, § 2.3.3.4);
  b) every time that an E bit in the binary state 0 is received, a report will be transmitted to the error monitoring functions.

     (On a provisional basis the considerations related to the E bit may only apply to V interfaces – for further study.)

2.5.2 *Alarm signal detection*

The following alarm indications should be detected:

- Alarm indication (remote alarm) received from the remote end.
- AIS (alarm indication signal). The equivalent binary content of the alarm indication signal (AIS) is a continuous stream of "1"s at 2048 or 8448 kbit/s.

The strategy for detecting the presence of the AIS should be such that the AIS is detectable even in the presence of an error ratio of 1 in 10^3. However, a signal with all bits except the frame alignment bit in the 1 state should not be mistaken as an AIS.

2.5.3 *Consequent actions*

2.5.3.1 *Generation of alarm signals for action within the exchange*

- The service alarm indication should be generated to signify that the service is no longer available (see Table 1/Q.542).
- The prompt maintenance alarm indication should be generated to signify that performance is below acceptable standards and that immediate maintenance attention is required locally (see Table 1/Q.542).

2.5.3.2 *Generation of alarm signals transmitted by the exchange*

- Alarm signals sent in the outgoing direction at the exchange interface. The relevant alarm bits for the remote alarm indication, as recommended in G.704 should be effected as soon as possible (see Table 1/Q.542).
- Alarm signals sent towards the switching function. Alarm indication signal applied in all received time-slots containing speech, data and/or signalling should be applied as soon as possible and not later than 2 ms after the detection of the fault condition (see Table 1/Q.542).

2.5.3.3 *Removal of alarm indications*

When all fault conditions have been cleared and alarm indication signal is no longer received, the alarm indication signal and remote alarm indication should be removed within the same respective time limits as specified in § 2.5.3.4 after the conditions have cleared.

TABLE 1/Q.542

Fault conditions and alarms detected by exchange termination functions and consequent actions (excluding interface V_1)

Fault conditions and alarm signals detected	Consequent actions (see § 2.5.3)			
	Service alarm indication generated	Prompt maintenance alarm indication generated	Alarm indication to remote end generated	AIS towards the switching stages
Failure of power supply	Yes	Yes	Yes, if practicable	Yes, if practicable
Loss of incoming signal	Yes	Yes	Yes	Yes
Loss of frame alignment	Yes	Yes	Yes	Yes
Excessive error ratio	Yes	Yes	Yes	Yes
Alarm indication received from remote end	2048 + 8448 kbit/s: Yes 1544 + 6312 kbit/s: optional	1544 + 6312 kbit/s: Yes		
AIS received	Yes		Yes	Yes

Note – A *Yes* in the table signifies that an action should be taken. An open space in the table signifies that the relevant action should *not* be taken if this condition is the only one present. If more than one fault condition or alarm is simultaneously present, action should be taken if for at least one of the conditions a *Yes* is shown, except in the case of AIS received for which § 2.5.3.4 applies. The use of error performance monitoring in this table is for further study.

2.5.3.4 *Alarm processing*

The following items are required to ensure that equipment is not removed from service due to short breaks in transmission (e.g. due to noise or transient fault) and to ensure that maintenance action does not result where no direct maintenance action is required.

– The persistence of service alarm and of the prompt maintenance alarm indications may be verified for 100 ms before action is taken.

– When the AIS is detected, the prompt maintenance alarm indication, associated with loss of frame alignment and excessive error rate in the frame alignment pattern, should be inhibited.

– When the fault conditions cease, the service alarm and prompt maintenance alarm indications, if given, should be removed. Again, the persistence of this change in condition may be verified for 100 ms before action is taken.

– It is possible that some systems could suffer from frequent transient faults resulting in an unacceptable quality of service. For this reason, if a persistence check is provided, fault rate monitoring should also be provided for each digital transmission system. This monitoring will result in permanent removal from service of digital transmission system which are frequently removed from the service or frequently produce transient alarm conditions. The threshold for removal from service needs study. When this action is taken the service alarm indication and the prompt maintenance alarm indication shall be given.

2.5.4 *Error performance monitoring using CRC*

2.5.4.1 *General*

When the CRC procedure is implemented at the interface, the exchange should monitor the error performance of the interface to report on the performance (see Recommendation G.821).

2.5.4.2 *Error performance parameters*

The exchange should derive the following information from CRC checks in the incoming signal and received E bits:

– degraded minutes (DM),
– severely errored seconds (SES),
– error-free seconds (EFS).

Note 1 – These parameters are defined in Recommendation G.821.

Note 2 – The definition of a value for the suitable time interval during which the parameters should be assessed needs further study.

Note 3 – The choice has to be made between the association of one type of parameter to each direction of transmission and the integration of the two directions in one type of parameter. This needs further study.

Note 4 – The correlation between the results of CRC checks and the parameters quoted above requires further study.

2.5.4.3 *Error performance evaluation*

Each of the performance parameters will be processed separately in order to evaluate the performance of the interface.

The following classification of the interface maintenance conditions has to be made by the exchange (see I.600-series of Recommendations):

– correct functioning interface;
– degraded transmission interface;
– unacceptable transmission interface.

Note 1 – This section may only apply to V interfaces (for study).

Note 2 – The level at which an interface for ISDN access enters the degraded transmission condition may be dependent on the quality of service provided to the customer.

Note 3 – The levels at which an interface enters the degraded or unacceptable transmission conditions are for further study and are outside the scope of this Recommendation.

2.5.4.4 *Consequent actions*

For further study.

2.6 *Fault and alarm signal detection and actions at interface V_1*

The exchange shall interact with transmission systems as required to detect fault and alarm signals and take appropriate actions.

a) Fault detection
b) Alarm detection
c) Consequent actions

} To be specified

2.7 *Fault and alarm signal detection and actions at interface Z*

a) Fault detection
b) Alarm detection
c) Consequent actions

To be specified

2.8 *Fault and alarm signal detection and actions for transmission systems*

Faults and alarms which cannot be directly detected by the exchange termination function but which are detected by transmission equipment (e.g., group pilot failure) should be accepted by the exchange as needed to take appropriate action.

2.9 *Fault and alarm signal detection and actions for channel associated signalling* (2048 and 8448 kbit/s)

2.9.1 *Fault detection*

The exchange signalling function should detect the following fault conditions for each multiplex carrying a 64-kbit/s signalling channel:

– failure of local power supply (if practicable),
– loss of 64 kbit/s incoming signal,

  Note – The detection of this fault condition is required only when the fault does not result in an indication of loss of multiframe alignment.

– loss of multiframe alignment.

The criteria for activating and deactivating the indication of the fault condition are given in Recommendations G.732 and G.744.

2.9.2 *Alarm detection*

The exchange signalling function should detect the alarm indication (remote alarm) received from the remote end.

2.9.3 *Consequent actions*

2.9.3.1 *Generation of alarm signals for action within the exchange*

– The Service Alarm indication should be generated by the exchange signalling function to signify that the service is no longer available (see Table 2/Q.542).
– The prompt maintenance alarm indication should be generated to signify that performance is below acceptable standards and that immediate maintenance attention is required locally (see Table 2/Q.542).

2.9.3.2 *Alarm transmitted by the exchange*

An alarm indication (remote alarm) should be applied in the outgoing direction at the transmission/switching interface as soon as possible (see Table 2/Q.542). The relevant alarm bit for the remote alarm indication is given in Recommendation G.732.

2.9.3.3 *Removal of alarm indication*

When all fault conditions have been cleared and AIS is no longer received, the remote alarm indication should be removed as soon as possible.

2.9.3.4 *Alarm processing*

Same as in § 2.5.3.4.

TABLE 2/Q.542

Fault conditions and alarms detected by the exchange signalling function and consequent actions

Fault conditions and alarms detected)	Consequent actions (see § 2.9.3)		
	Service alarm indication generated	Prompt maintenance alarm indication generated	Alarm indication to remote end generated
Failure of power supply	Yes	Yes	Yes, if practicable
Loss of 64 kbit/s incoming signal	Yes	Yes	Yes
Loss of multiframe alignment	Yes	Yes	Yes
Alarm indication received from remote end	Yes		

Note – A *Yes* in the table signifies that an action should be taken. An open space in the table signifies that the relevant action should *not* be taken if this condition is the only one present. If more than one fault condition or alarm is simultaneously present, action should be taken if for at least one of the conditions a *Yes* is shown.

2.10 *Fault and alarm signal detection and actions for channel associated channel signalling* (1544 kbit/s)

Requires further study.

2.11 *Fault and alarm signal detection and actions for common channel signalling*

Requirements specified in relevant Recommendations apply.

2.12 *Fault and alarm detection and consequent actions – other functions of the exchange*

2.12.1 *Faulty circuits*

The exchange should not switch any new calls to a detected faulty circuit.

The exchange should remove from service all circuits found to be permanently faulty as detailed in §§ 2.5, 2.8, 2.9, 2.10 and 2.11.

2.12.2 *Master clock distribution*

The absence of timing information distributed from a master clock located at the exchange or received from an external master clock shall be recognized and a prompt maintenance alarm shall be given.

Changeover to an alternate timing source shall be operated so as to fulfil the requirements of §§ 2.7.2 and 2.7.3 of Recommendation Q.543.

2.12.3 *Internal timing distribution*

The distribution of timing information to the major elements of the exchange shall be supervised as required. A service alarm shall be given when a failure is detected. A maintenance alarm shall be given if it is appropriate.

Note – Remote elements may have to be taken into consideration.

2.13 *Supervision or testing of interface function*

The exchange shall have the capability of verifying the proper operation of the interface functions, including the fault detection and supervision functions.

Routine tests, statistical tests, manual activities and/or other means may be used to verify proper operation of these functions.

Information shall be given to the far end exchange when new calls cannot be established on the circuits on which routine tests are being initiated. Established calls, including semi-permanent connections, must not be interrupted. During the tests, the generation of alarms at the far end exchange due to the removal of circuits from service should be avoided, if possible.

2.13.1 *ET functions – Interfaces A, B, V_2, V_3 and V_4*

The verification of the proper operation of exchange termination functions can be performed by the means of statistical observations or by testing. Testing may be manual or automatic.

2.13.2 *ET functions – Interfaces C and Z*

i) Failures of codecs (except those covered in ii) below) should be recognized by the exchange using the criteria defined in Recommendation G.732.

ii) Supervision or testing of codecs of one or a small number of channels may be accomplished according to i) above or by inter-office transmission measurement and testing on circuits between exchanges or by statistical measurements.

2.13.3 *ET functions – Interface V_1*

To be specified.

2.14 *Supervision or testing of signalling functions*

In addition to fault detection required in § 2.7, the following applies.

2.14.1 *Channel associated signalling*

The exchange should be able to verify the proper operation of the signalling functions by generating and responding to test calls or by a statistical observation.

2.14.2 *Common channel signalling*

The exchange should be able to verify the proper operation of the signalling functions as required by common channel signalling recommendations.

2.15 *Supervision or testing of exchange connections*

Checking the different portions of the path individually in a digital exchange network helps to ensure the continuity of the connections overall. In this respect the exchange has to verify:

– the continuity across the exchange, as covered in this section;

– the continuity in the transmission links terminating on the exchange as covered in §§ 2.16 and 2.17.

2.15.1 *Continuity across the exchange*

A means should be provided to determine that the operational error performance requirement (i.e., on bit error ratio) is being met. (The design objective for error performance can be found in Recommendation Q.554.)

The exchange should provide adequate provision of the cross office path continuity and verify the transmission performance. (The design objective for transmission performance can be found in Recommendation Q.543.) This will guarantee, in particular, an acceptable transmission quality to its connections.

2.15.2 *Verification depending on the type of connection*

The verifications to be performed by the exchange should depend also on the type of connection. In particular:

- for 64 kbit/s switched connections, the transmission performance requirements of Q.543 may be considered to be sufficient in order to guarantee the cross office path continuity;
- semi-permanent connections may require special supervision procedures which need further study;
- supervision of n × 64 kbit/s requires further study for both switched and semi-permanent connections.

2.16 *Supervision or testing of digital link performance*

The exchange shall have the capability of monitoring digital link performance to detect when bit error ratio and loss of framing thresholds exceed operational objectives. The exchange will then take subsequent action to give appropriate trouble indications or alarms and perform other appropriate actions, such as removing circuits from service.

2.17 *Supervision or testing of analogue link performance*

2.17.1 *Interexchange circuit continuity check*

The exchange should be capable of performing circuit continuity checks in accordance with appropriate signalling system recommendations. Circuits failing circuit continuity checks should be removed from service and repair procedures initiated as required.

2.17.2 *Interexchange transmission measurement and testing on circuits between exchanges*

The exchange may also be equipped within itself or give access to external equipment to perform other transmission tests on circuits. Faulty circuits should be removed from service and repair procedures initiated as required.

3 Subscriber line maintenance and testing design objectives

3.1 *Analogue subscriber lines*

For further study.

3.2 *Digital subscriber lines*

For further study.

4 Operations design objectives

4.1 *General*

The exchange and/or any associated Operations and Maintenance Systems/Centres shall have the capabilities necessary to permit it to be operated, administered, and maintained efficiently while providing service in accordance with an Administration's performance requirements.

The Telecommunications Management Network (TMN) architecture, as described in Recommendation M.30, considers the exchange to be a Network Element (NE) which can interact with Operations Systems (OS) within a TMN. Operations systems may be used at the discretion of Administrations to improve operating efficiencies and service by centralizing and mechanizing operations, administrative and maintenance functions. The number and variety of operations systems will depend on the operating practices of the Administration.

The decision to implement TMN principles rests with the Administration.

4.2 *Operations features*

4.2.1 *Service provisioning and records*

There should be efficient means of establishing service, testing, discontinuing service and maintaining accurate records for:

- subscriber lines and services (in local exchanges);
- interexchange circuits.

4.2.2 *Translation and routing information*

There should be efficient means of establishing, testing and changing call processing information, such as translation and routing information.

4.2.3 *Resource utilization*

There should be efficient means of measuring performance and traffic flows and to arrange equipment configurations as required to insure efficient use of system resources and to provide a good grade of service to all subscribers (e.g., load balancing).

4.2.4 *Exchange observation and measurements*

The exchange should provide means for making observations and measurements on Quality of Service and network performance, to satisfy, for example, Grade of Service objectives as covered in Recommendation E.500, or for provisioning purposes. Details of measurements for digital exchanges are given in Recommendation Q.544.

4.3 *Exchange functions related to the TMN*

Detailed descriptions, definitions, and classifications of TMN functions to which the exchange will contribute is for further study.

A partial list of TMN functions is given below. A more complete list is given in Recommendation M.30.

Exchanges may have requirements for Operations, Administration and Maintenance functions which are not related to TMN. This is for further study.

4.3.1 *Functions potentially related to TMN*

- Subscriber administration;
- tariff and charging administration;
- routing administration;
- network management;
- maintenance of subscriber lines;
- maintenance of circuits between exchanges;
- exchange maintenance;
- signalling network maintenance;

- administration of hardware configuration;
- administration of software configuration;
- external alarms and indications;
- O&M staff procedures;
- traffic measurements;
- quality of service and network performance observation.

4.3.2 *Information flows*

Generally, information flows will consist of requests/demands to the exchange and responses from the exchange. There will also be autonomous information flows from the exchange (e.g. alarms, programmed response, etc.). Refer to Recommendation Q.513 for information on interfaces to the TMN.

This subject is for further study.

5 Network management design objectives

5.1 *General*

Network management is the function of supervising the performance of a network and taking action to control the flow of traffic, when necessary, to promote the maximum utilization of network capacity.

These functions have application in exchanges within the IDN, and may or may not have application in national networks during the transition period to IDN.

The implementation of network management features and functions in national networks and in specific exchanges will be at the option of Administrations. Likewise the choice of which controls and features to use will be the option of each Administration.

5.1.1 *Network management objectives*

Information on network management objectives can be obtained from Recommendation E.410, and from the CCITT "Handbook on Service Quality, Network Maintenance and Management", ITU, Geneva 1984.

5.1.2 *The application of network management in exchanges*

In addition to the normal engineering and economic factors, the decision whether or not to provide network management capabilities in a digital exchange will be based on the following considerations:

- the size of the exchange, the size of circuit groups it serves and the network architecture;
- the role and importance of the exchange in its own network, or as an access exchange interfacing other exchanges and networks (e.g., international or other exchange networks);
- the requirement for the exchange to interact for network management purposes with other exchanges and/or network management centres;
- the features necessary to provide essential services in emergency situations, where other means are not available;
- alternative approaches such as providing redundancy and special routing methods;
- the need for managing network resources effectively when overload conditions occur in its own or interworking networks.

Other factors to be considered are:

- the network management organization, its equipment and selected functions;
- the possible interactions of both the circuit switched and signalling networks when network management actions are applied under various traffic conditions or network configurations;
- the potential impact of network management functions on the engineering design and administration of the network and the exchange;
- the evolution towards IDN and interworking of SPC with non-SPC exchanges in the interim period;

- the proportion of automatic and manual features to be implemented and the rate of introduction of various network management features;
- the reduction of exchange processing capacity due to the additional load imposed by network management (if appropriate);
- possible additional holding time of equipment in some switching and signalling systems where open numbering is used, if and when certain network management controls are applied.

5.2 *Network management elements*

The basic elements of a network management system to be provided by an exchange or by network management centres are:

- collection of information about network status and performance;
- processing of information for network management decisions;
- delivery to exchanges of network status information and/or commands for control activities;
- activation/deactivation of controls resulting from decisions made in the exchange or a network management centre;
- feedback of status in response to control actions.

Descriptions of the functions required in the exchanges to support these elements are given in §§ 5.3 and 5.4.

5.3 *Information provided by an exchange for network management purposes*

5.3.1 *General*

The term "information" is used here as meaning all messages, signals or data in any form, used or provided by the exchange or by a network management centre.

5.3.2 *Sources of information*

The information provided by an exchange for network management will be based on the status, availability and performance and configuration of:

- circuit groups;
- exchange processes;
- common channel signalling link sets;
- other exchanges with direct links to this exchange;
- destination exchanges.

Status information is generated by comparing the current value of load indicators with appropriate threshold values and/or detecting abnormal conditions. Such type of information assumes discrete values and it can be used, without other processing, to activate traffic control routines.

This information should be sent spontaneously in a real-time basis to other exchanges or to a network management centre.

Performance information is obtained by means of traffic measurements and can be used for centralized processing or for network supervision in a network management centre. Such type of information can be sent in a near-real-time basis.

Configuration information is used for a network management data base at exchange level. This information could include:

- threshold values actually used,
- list of supervised circuit groups,
- list of supervised signalling circuits,
- list of supervised processors,
- list of supervised destination codes,
- list of primary and alternate routes for specified destinations.

Details of network measurements are given in Recommendation Q.544.

5.3.3 *Processing of network management information in an exchange*

Information collected at an exchange for network management purposes may or may not require some form of sorting and assembly (processing) before being used for network management.

Where processing is required, this may be done by the exchange processor, or by a data processing system serving one or more exchanges, or by a network management centre.

5.3.4 *Transmittal of information*

Network management information may be sent on a scheduled near-real-time basis when triggered by abnormal situations (e.g., overload conditions, alarms, etc.): alternatively, information may be sent on demand, i.e., in response to an external request. Table 3/Q.542 shows the correspondence between sources of information and their transmission mode.

TABLE 3/Q.542

Source of information \ Data transmission mode	Real-time	On demand	Scheduled
Status information	X	X	
Performance and availability information		X	X
Configuration information		X	

The destinations of network management information may be:

- within the originating exchange,
- to distant exchanges,
- to a network management centre.

Information may be carried by the TMN over a dedicated telemetry or data facility, over a common channel signalling network, or over other telephony network facilities as appropriate.

For each mode of transmittal the appropriate interface and protocol requirements, where covered by CCITT Recommendations, should be satisfied.

5.3.5 *Presentation of information*

Indications of network management controls in effect in an exchange shall be presented on visual indicators and/or printing-type or video display terminals for purposes of advising on-site personnel.

Similar displays and/or indicators may also be provided in a co-located and/or distant network management centre.

5.4 *Exchange controls for network management*

5.4.1 *General*

Network management controls provide the means to alter the flow of traffic in the network, in support of network objectives. Most network management controls are applied by, or in the exchange; however, certain actions may be taken external to the exchange. Recommendation E.412 provides specific information on network management controls and gives guidance on their application. Additional information is provided in the CCITT "Handbook on Service Quality, Network Management and Maintenance".

5.4.2 *Activation and deactivation of controls*

Controls in an exchange can be activated, or deactivated, by input from a network management operations system or by direct input from an exchange man-machine interface terminal. In addition, some controls can be activated automatically either by external or internal stimulus, or by a threshold being crossed.

When automatic control operation is provided, means for human override should also be provided.

Controls will usually be activated or deactivated in steps (stages) that are intended to avoid surge effects in the network that could be caused by too much control being added or removed too quickly.

A low level threshold may be required to remove controls as appropriate, when traffic conditions have been stabilized.

5.4.3 *Traffic to be controlled*

Exchanges should be capable of applying a range of network management controls (see Recommendation E.412).

The operational parameters of a control can be defined by a set of traffic attributes. As shown in Figure 1/Q.542, these parameters include distinctions based on the origin of traffic, for example, customer-dialed, operator-dialed, transit or other classification as may be specified by the Administration. These can be further defined by type of service, particularly by ISDN.

Additional attributes can be specified, for example, incoming/outgoing circuit group class, or hard-to-reach status of destinations can be used. Further distinctions can be based on the outgoing traffic type, for example, direct-routed, alternate-routed or transit.

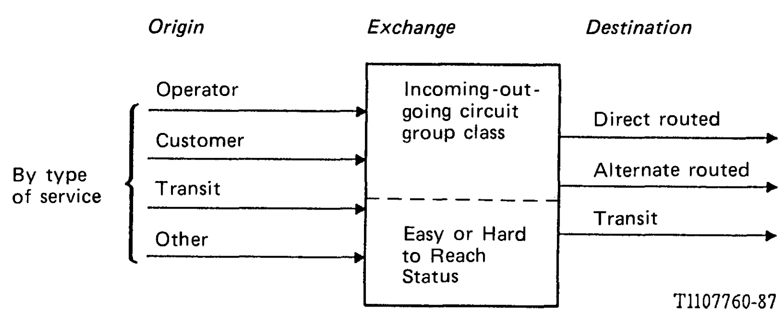


FIGURE 1/Q.542

Traffic attributes affecting network management controls

5.4.4 *Network management controls*

The following is a list of typical network management controls to be considered for implementation in a given exchange.

It is desirable that these controls be activated to affect a variable percentage of traffic (for example, 25%, 50%, 75% or 100%). Alternatively the number of call attempts routed in a particular period may be controlled (for example 1 calls per minute). It may also be desirable to apply controls on a destination code basis.

These controls are normally activated/deactivated manually from a man-machine interface in the exchange, or from an operations system. The automatic operation of these controls and the need for new controls is for further study.

It is preferable that these controls be provided in international transit exchanges and large transit exchanges in national applications. However, the decision whether or not to provide these controls in local and combined local/transit exchanges is at the discretion of the Administration.

5.4.4.1 *Code blocking control*

This control bars or restricts routing to a specific destination code. Code blocking can be done on a country code, an area code, an exchange identifying code and, in some cases, on an individual line number.

5.4.4.2 *Cancellation of alternative routing*

There are two types of cancellation of alternative routing control. One version prevents traffic from overflowing from the controlled route (Alternate Routed From – ARF). The other version prevents overflow traffic from all sources from having access to the controlled route (Alternate Routed To – ART). When cancellation of alternative routing is to be provided, both types are recommended.

5.4.4.3 *Call gapping*

This control sets an upper limit on the number of call attempts allowed to be routed towards the specified destination in a particular period of time (for example, one call per minute).

5.4.4.4 *Restriction of direct routing*

This control limits the amount of direct routed traffic accessing a route.

5.4.4.5 *Skip route*

This control allows traffic to bypass a specific route and advance instead to the next route in its normal routing pattern.

5.4.4.6 *Temporary alternative routing*

This control redirects traffic from congested routes to routes not normally available which have idle capacity at the time. This can be done for subscriber, and/or operator-originated traffic.

5.4.4.7 *Circuit directionalization*

This control changes both-way operated circuits to one-way operated circuits.

5.4.4.8 *Circuit turndown/busying*

This control removes one-way and/or both-way operated circuits from service.

5.4.4.9 *Recorded announcements*

These are announcements which give special instructions to operators and subscribers, such as to defer their call to a later time.

5.5 *Automatic controls for network management*

5.5.1 *General*

This section provides descriptions of some automatic traffic control methods that can be provided in digital exchanges for network management purposes.

Automatic, and/or dynamic network management controls represent a significant improvement over static manual controls. These controls, which are pre-assigned, can respond automatically to conditions internally detected by the exchange, or to status signals from other exchanges and can be promptly removed when no longer required.

The following are a basic set of automatic methods for use in the telephone network:

– Automatic Congestion Control system (ACC);
– Selective Circuit Reservation control (SCR);
– Hard-to-Reach process (HTR);
– Temporary Trunk Blocking (TTB).

The above list of methods is not exhaustive, but will provide a framework for more advanced controls which may be required in the ISDN.

In the following four sections the typical operation of each control is described, and guidance on the application of the controls is given in § 5.5.6.

5.5.2 *Automatic Congestion Control system*

The Automatic Congestion Control (ACC) system allows a congested exchange to send a congestion indicator in a backward direction to the preceding exchange. The exchange receiving the congestion indication should respond by reducing the amount of traffic offered to the congested exchange.

The preferred method of conveying the congestion indication is via the relevant common channel signalling system.

a) *Detection and transmission of congestion status*

An exchange should establish a critical operating system benchmark, e.g., the time required to perform a complete basic cycle of operations. The exchange should continously monitor this benchmark and, when continued levels of nominal performance are not achieved, a state of congestion is declared. Thresholds should be established so that two levels of congestion can be identified, with congestion level 2 (C2) indicating a more severe performance degradation than congestion level 1 (C1). When either level of congestion is detected, the exchange should have the capability to

1) code an ACC indication in the appropriate signalling messages, and

2) notify its network management support system of its current congestion status.

The system can offer benefit, however, by recognizing a single level of congestion. Where this situation exists, it should be regarded as congestion level 2.

b) *ACC control operation*

Exchanges receiving an ACC indication from an affected exchange or network operations centre should have the capability to institute the appropriate ACC controls and to notify its network management support system of the receipt of an ACC indication.

An exchange receiving an ACC indicator from a congested exchange should activate the assigned ACC controls and start a timer. (The provisional value of the timer is five seconds and is for further study.) Subsequent received ACC indicators restart the timer, when the timer expires, the ACC controls in the exchange are removed. One or more different response categories should be available from which to choose.

To avoid the incorrect application of controls, it is important that an exchange receiving an ACC indication should not re-transmit that indication to a preceding exchange.

c) *ACC response*

An exchange should have the capability of assigning an ACC response category to individual circuit groups. There should be several categories available from which to choose. Each category would specify how much traffic should be controlled in response to each of the received ACC indicators. The categories should be structured so as to present a wide range of response options to received ACC indicators.

The control options for further processing of calls denied access to the circuit group may be SKIP or CANCEL. The SKIP response allows a call to alternate route to the next circuit group in the routing pattern (if any) while the CANCEL response blocks the call.

Note – ACC response categories can be set locally in the exchange or by input from a network management center.

Table 4/Q.542 is an example of the flexibility that could be achieved in a control's response to an exchange that is experiencing congestion.

In this example, different control actions would be taken based upon the distinction between Alternate Routed To (ART) and Direct Routed (DR) traffic types. In the future, other distinctions between traffic could be identified that would expand the number of traffic types in Table 4/Q.542. These additional traffic types could be assigned different control percentages (or excluded from ACC control, as in the case of priority calls), to give them different treatment during periods of congestion. An example would be to control hard-to-reach traffic as indicated in § 5.5.4.

Methods used to achieve the percentages are implementation specific. Additional response categories could also be added to Table 4/Q.542 to give greater flexibility and more response options to the ACC control.

TABLE 4/Q.542

An example of 2-congestion level ACC percentage control response table

Congestion level	Traffic type	Response category		
		A	B	C
CL1	ART DR	0 0	0 0	100 0
CL2	ART DR	100 0	100 75	100 75

5.5.3 *Selective Circuit Reservation control*

The Selective Circuit Reservation (SCR) Network Management control enables a digital exchange to automatically give preference to a specific type (or types) of traffic over others (e.g., direct routed calls over alternate routed calls) when circuit congestion is present or imminent. A digital exchange should provide either the single threshold of multi-threshold version of the countrol, with the latter being preferred due to its greater selectivity.

5.5.3.1 *General characteristics*

A Selective Circuit Reservation control may be defined, for a given circuit group, by the following parameters:

- a reservation threshold(s), and
- a control response.

The reservation threshold defines how many circuits should be reserved for those traffic types to be given preferred access to the circuit group. The control response defines which traffic types should be given a lesser preference in accessing the circuit group, the quantity of each type of traffic to control, and how those calls denied access to the circuit group should be handled. Examples of possible traffic types are Direct Routed (DR), Alternate Routed To (ART), Hard-To-Reach (HTR), and various combinations thereof. The quantity of each type of traffic to be controlled when the threshold is exceeded may be represented by a percentage of the total traffic of that type. The control action options for further processing of calls denied access to the circuit group may be SKIP or CANCEL.

When the number of idle circuits in the given circuit group is less than or equal to the reservation threshold the exchange would, for that call, check the specified control response to determine if the call should be controlled. The SKIP response allows a call to alternate route to the next circuit group in the routing pattern (if any) while the CANCEL response blocks the call.

These parameters should be able to set locally in the exchange or by input from a network management centre. In addition, the network manager should have the capability to enable and disable the control, and to enable the control but place it in a state where the control does not activate (e.g., by setting the reservation threshold to zero).

5.5.3.2 *Single-threshold Selective Circuit Reservation control*

In this version of the control, only a single reservation threshold would be available for the specified circuit group.

Table 5/Q.542 is an example of the flexibility that could be achieved in the control's response to circuit group congestion. Consider, for example, a case in which a network manager assigns response category "B", a reservation threshold of 5 circuits (RT1 = 5), and a control action of SKIP to a circuit group. Then, when the control is enabled, every time the number of idle circuits in the circuit group is less than or equal to five, the exchange SKIPs 50 percent of the alternate routed traffic attempting to access the circuit group. Direct routed traffic has full access to the circuit group because the quantity of direct routed traffic to be controlled is zero percent. Note that the reservation threshold (in this example RT1 = 5) is the same for any of the response categories (A, B and C) that can be assigned to a circuit group. One or more response categories should be available from which to choose.

In the future, other distinctions between traffic could be identified that would expand the number of traffic types in Table 5/Q.542. An example would be to control Hard-To-Reach traffic, as indicated in § 5.5.4, or to give preference to priority calls.

TABLE 5/Q.542

An example of a single threshold selective circuit reservation percentage control response table

Circuit group reservation threshold	Traffic type	Response category assigned to circuit group		
		A	B	C
RT1	ART	25	50	100
	DR	0	0	25

5.5.3.3 *Multi-threshold Selective Circuit Reservation control*

The multi-threshold control would support two reservation thresholds for the specified circuit group. The purpose of multiple reservation thresholds would be to allow a gradual increase in the severity of the control response as the number of idle circuits in the circuit group decreased. The only restriction on the reservation thresholds would be that a reservation threshold associated with a more stringent control must always be less than or equal to the reservation threshold of any less stringent control, in terms of the number of reserved circuits [RT2 $\leqslant$ RT1 in Table 6/Q.542].

Table 6/Q.542 is an example of the flexibility that could be achieved in the control's response to circuit group congestion with two reservation threshold control. In the future, other distinctions between traffic could be identified that would expand the number of traffic types in Table 6/Q.542, or to give preference to priority calls.

TABLE 6/Q.542

An example of a two threshold selective circuit reservation percentage control response table with HTR capability

Circuit group reservation threshold	Traffic type	Response category assigned to circuit group				
		A	B	C	D	E
RT1	ART-HTR DR-HTR ART-ETR DR-ETR	50 0 0 0	75 0 25 0	100 0 50 0	100 0 75 0	100 0 100 0
RT2	ART-HTR DR-HTR ART-ETR DR-ETR	100 0 50 0	100 25 50 0	100 50 75 25	100 75 100 50	100 100 100 75

5.5.4 *Hard-to-reach (HTR) process*

The Hard-to-Reach process for network management allows exchanges to automatically make more efficient use of network resources during periods of network congestion.

Part of the improved performance of automatic controls can be derived from the ability to distinguish between destinations that are easy-to-reach (ETR) and destinations that are hard-to-reach (HTR), i.e., destinations with a low answer bid ratio, and applying heavier controls to HTR destinations. This distinction can be based on:

i) internal performance measurements within the exchange/Network Management Operations System (OS) (for example, low Answer Bid Ratio (ABR) to a destination);

ii) similar information gathered by other exchanges;

iii) historical observations of network performance by network managers.

The network manager should have the ability to set the threshold for HTR determination and to assign manually a destination code as HTR.

5.5.4.1 *Simplified HTR process components*

To provide the fundamental elements of a simplified HTR process, the following capabilities must exist:

a) HTR administration,

b) HTR determination,

c) manually controlling calls as if hard-to-reach.

Items a) and b) may be entirely provided by the exchange or by a Network Management (OS) in cooperation with the exchange(s). Item c) can only be provided in the exchange.

a) *HTR administration*

Network managers will administer the HTR process to optimize the information obtained about current network performance. In order to properly administer the HTR system, network managers need four capabilities. These capabilities are listed below.

1) *Codes to be observed*

An exchange should automatically collect ABR data for some destination areas, e.g., countries, area codes, etc. In addition, network managers should have the capability to designate/change destinations an exchange should monitor in greater detail. An exchange should accept at least three network management designated sets of digits that identify a specific destination area and automatically begin surveillance of the specified destination areas. The specific number of digits to be analyzed is left to the discretion of the administration and may be exchange dependent.

2) *Administration of HTR thresholds*

There should be a set of thresholds used to monitor destination areas and another set for use when monitoring destinations in greater detail. Network managers should be able to specify/change the values of "B" and "T" for the pre-established threshold sets and the HTR hysteresis modifiers (see b, sub-section 3), below).

3) *Administration of HTR determination exclusion*

A network manager should have the capability to exclude destination codes from being determined as HTR. This should prevent these destination codes from automatically being calculated as HTR and prevent these destination codes from being automatically placed on the "HTR Control" list. A network manager should also have the ability to restore destination codes to the fully automatic HTR determination function.

4) *Administrative review of HTR list*

Network managers should have the capability to view the contents of the "HTR Control" list, either via a terminal at the exchange or remotely through a Network Management OS. The list should indicate which destination codes have been manually designated as HTR (see c) below). In addition, network managers should have access to a list of those destination codes which have been manually excluded from automatic HTR determination.

b) *HTR determination*

The capability should exist to determine automatically which destination codes are HTR. This is based on three capabilities.

1) *Code measurements*

The HTR/ETR status of a destination is based on analyzing the data for groupings of routing digits. An exchange should take measurements based on a sufficient number of routing digits to identify a destination. The exchange should take those measurements necessary to calculate the ABR for each such destination.

2) *HTR calculations*

Periodically, the ABR for these destination codes under surveillance should be calculated. A recommended time interval is every 5 minutes.

3) *Determining destination code HTR/ETR status*

For each destination code, the capacity should be provided to compare the number of bids and the calculated ABR to a set of pre-established thresholds. There should be a set of thresholds applicable to determining HTR destination areas and another set for destinations being monitored in greater detail.

A set of pre-established threshold consists of:

- B: Bids; the number of calls received by an exchange for a given destination code. This count includes calls that are successfully forwarded to the succeeding exchange as well as calls that fail within the current exchange.
- T: ETR threshold; the threshold above which a destination code's ABR should be considered ETR.

A destination code would be considered HTR if, based on the 5-minute calculations, the measured number of bids to the code is greater than or equal to threshold "B" and the ABR is less than or equal to threshold "T".

A destination code that is determined to be HTR should be placed on a "HTR Control" list in the exchange.

To avoid having destination codes oscillate on and off the "HTR Control" list, hysteresis modifiers should be applied to determine when destination codes should be removed from the "HTR Control" list. In succeeding 5-minute periods, these hysteresis modifiers should be applied to both values "B" and "T" when it is time to recalculate the HTR/ETR status of the destination code.

At the beginning of each 5-minute period, the "HTR Control" list should be reviewed. If a destination code that was calculated to be HTR is determined to be no longer than HTR, then it should be removed from the "HTR Control" list.

c) *Manually controlling calls as if HTR*

A network manager should have the capability of specifying any destination code as HTR so as to cause automatic network management control actions to take place within the exchange as indicated in § 5.5.4.2 below. The manually specified destination code(s) may go on the "HTR Control" list. They should not, however, be subject to the 5-minute review and removal procedure described above. They should be removed upon request of a network manager. To this end, a network manager should have the capability of ending this stimulus to identifying a destination code as HTR.

Whenever a network manager adjusts the HTR status of a destination code, that manual action should take precedence over any automatic actions for that destination code.

5.5.4.2 *Controlling calls based on HTR status*

When a call to a destination code that is on the "HTR Control" list is being routed and a manual or automatic network management control is encountered during the processing of the call, the control should take into account the fact that the destination code is HTR. If a destination code is on the "HTR Control" list, then the call should be considered HTR for all outgoing circuit groups.

As an example of an automatic network management control incorporating HTR, the Automatic Congestion Control (ACC) Response Percentage Table (Table 4/Q.542) could be expanded to apply more stringent controls to HTR traffic, as shown in Table 7/Q.542. A similar application of the Selective Circuit Reservation Control is possible (see § 5.5.3).

TABLE 7/Q.542

Example of automatic congestion control response percentages with HTR

Congestion level	Traffic type	Response category				
		A	B	C	D	E
CL1	ART-HTR	0	0	100	100	100
	DR-HTR	0	0	0	100	100
	ART-ETR	0	0	0	0	0
	DR-ETR	0	0	0	0	0
CL2	ART-HTR	100	100	100	100	100
	DR-HTR	0	100	100	100	100
	ART-ETR	0	0	0	100	100
	DR-ETR	0	0	0	0	75

5.5.5 *Temporary Trunk Blocking*

Temporary Trunk Blocking (TTB) is an alternative method of exchange congestion control for application in national networks.

When an exchange is in a low level overload condition, a Temporary Trunk Blocking signal may be sent to a preceding exchange to indicate that the release or re-occupation of a trunk should be delayed for a short (e.g., 100 s) period of time. This may permit an overall level of up to the maximum possible load in the overloaded exchange without need to generate ACC signals. The preferred method of conveying the TTB signal is via the relevant common channel signalling system.

The exchange receiving the Temporary Trunk Blocking signal will delay the release or the re-occupation of the concerned trunk for a short time. This time should be made changeable by operating personnel command.

The duration of trunk blocking is limited by a timer in the exchange receiving the Temporary Trunk Blocking signal. Therefore, an unlimited blocking of the trunk is avoided.

5.5.6 *Application*

5.5.6.1 *ACC*

Generally, where an Administration has introduced or is planning to introduce network management controls, it is considered appropriate for digital transit and large digital combined local/transit exchanges to be provided with full ACC capabilities. Digital local and smaller combined local/transit exchanges should only be provided with ACC receive and control capabilities.

5.5.6.2 *SCR*

It is considered appropriate for digital transit and large digital combined local/transit exchanges to be provided with a two-threshold Selective Circuit Reservation Network Management Control. Network Management of digital local and smaller combined local/transit exchanges could benefit from having available, ideally, the two threshold or the single threshold Selective Circuit Reservation Network Management Control. The decision whether or not to provide this control in these exchanges is left to the discretion of the various Administrations.

5.5.6.3 *HTR*

It is considered appropriate for digital transit and large digital combined local/transit exchanges (optionally in conjunction with a Network Management OS) to be provided with full HTR capabilities. Digital local and smaller combined local/transit exchanges should only be provided with the manual HTR and HTR controlling (based on HTR status) capabilities, i.e., those capabilities found in §§ 5.5.4.1 subsection c, and 5.4.4.2 of this Recommendation. It is also recommended that control modifications, based on HTR status, be added to both the ACC and Selective Circuit Reservation capabilities.

5.5.6.4 *TTB*

It is considered appropriate for TTB to be provided in digital transit and large digital combined local/transit exchanges in national applications. It may be particularly useful in exchanges that may not be provided with ACC capabilities, such as local exchanges.

5.6 *Order of application of controls*

The order in which various network management controls shall be applied in an exchange is for further study.

Recommendation Q.543

DIGITAL EXCHANGE PERFORMANCE DESIGN OBJECTIVES

1 General

This Recommendation applies to digital local, combined, transit and international exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks, and also to local, combined, transit and international exchanges in an Integrated Services Digital Network (ISDN).

The field of application of this Recommendation is more fully defined in Recommendation Q.500. As to the application in an ISDN, transit connections and exchange connections types I, II, III and IV as defined in Recommendation Q.522 are covered (Notes 1 and 2). Other types of connection and variants of these connections may be feasible in ISDN and will be the subject of further study.

These performance design objectives are applicable to all exchange implementations at all points in the growth cycle up to the maximum size. These reference loads and performance objectives may be used by manufacturers in designing digital switching systems and by Administrations in evaluating a specific exchange design or for comparing different exchange designs for potential use in the Administration's intended implementation.

These recommended performance design objectives relate to the technical capabilities of exchange design. They are intended to assure that exchanges operating in their intended implementation will be capable of supporting the network grades of service recommended in the E.500-series of Recommendations and will offer a level of performance consistent with the overall network performance objectives given in the I-series of Recommendations. The recommended parameters are *design objectives* which should not be construed to be grade of service or operating requirements. In actual operation, exchanges will be engineered to provide adequate grades of service as economically as possible and the *performance requirements* (delays, blocking, etc.) of the exchange in operation will *differ from* the recommended values for these performance *design objectives.*

2 Performance design objectives

2.1 *Reference loads*

The given reference loads are traffic load conditions under which the performance design objectives stated in §§ 2.2 to 2.7 are to be met. In order to have a comprehensive characterization of exchange reference loads, supplementary services and other types of services must be taken into account. Administrations may specify hypothetical models for use in computing exchange loading. These models should characterize the sets of traffic parameters and services that are considered to be typical in the intended application of the exchange, and should include the traffic mix (originating-internal, originating-outgoing, incoming-terminating, transit, abandoned, busy non-answer, etc.), the mix of service classes (residential, business, PABX, coin, etc.), the types and volume of supplementary services (call waiting, call forwarding, etc.) and any other pertinent characteristics. Using the above information, it should be possible to "engineer" the exchange to produce the model. It should also be possible to determine the maximum size of the exchange by the computations discussed in § 2.1.4.

Reference load A is intended to represent the normal upper mean level of activity which Administrations would wish to provide for on customer lines and inter-exchange activities. Reference load B is intended to represent an increased level beyond normal planned activity levels. (Recommendations E.500 and E.520 recommended that the normal provisioning of international circuits in automatic and semi-automatic operation be based on a particular loss probability during the mean busy hour and the average traffic estimated for the "five busiest days" as set down in Recommendation E.500.)

Note 1 – For the time being, the following definitions and corresponding values are only applicable to 64 kbit/s circuit switched connections, i.e., including transit connections and connection types I, II and III option a). Other rates and transfer modes require further study.

Note 2 – The applicability of this document to connections originating or terminating on PABXs is for further study.

2.1.1 *Reference load on incoming interexchange circuits*

a) *Reference load A*

– 0.7 erlangs average occupancy on all incoming circuits

$$\text{Call attempts/h} = \frac{0.7 \times \text{number of incoming circuits}}{\text{Average holding time in hours}}$$

Note – Ineffective call attempts must be included in reference call attempts.

b) *Reference load B*

– 0.8 erlangs average occupancy on all incoming circuits

with 1.2 times the call attempts/h for reference load A.

2.1.2 *Reference load on subscriber lines (originating traffic)*

Characteristics of traffic offered to local exchanges vary widely depending upon factors such as the proportions of residence and business lines that are served. The following Table 1/Q.543 provides reference load characteristics for lines typical of four possible local exchange applications. Also provided are representative ISDN cases which are discussed below. Administrations may elect to use other models and/or loads that are more suitable for their intended application.

In the following text, ISDN lines will be referred to as digital lines and non-ISDN lines as analogue lines.

2.1.2.1 *Reference load A*

TABLE 1/Q.543

Subscriber line traffic model

a) *Non-ISDN subscriber lines with or without supplementary services*

Exchange type	Average traffic intensity	Average BHCA
W	0.03 E	1.2
X	0.06 E	2.4
Y	0.10 E	4
Z	0.17 E	6.8

b) *ISDN digital subscriber access 2B + D*

The following ISDN models and traffic parameters are provisional and may be revised in subsequent study periods.

Line type	Average traffic intensity per B channel	Average BHCA per B channel	Average packets per second per D channel
Y′	0.05 E	2	0.05 (signalling) + Data packets [a]
Y″	0.10 E	4	0.1 (signalling) + Data packets [a]
Y‴	0.55 E	2	0.05 (signalling) + Data packets [a]

BHCA Busy hour call attempts.

[a] Data packet rates are for further study. These include teleaction and packet services data.

Even though only limited ISDN traffic data is available, the specification of the corresponding reference loads remains an important factor in exchange evaluation. For the case of digital subscriber lines in Table 1/Q.543 b), access is assumed to utilize the Basic Access with 2B + D channels. The B channels are available for circuit-switched calls, while the D channel is used to carry signalling information or may be used to carry teleaction data and packet switched data. It is assumed that digital lines typically carry traffic comparable with the heavy-traffic analogue lines designated as case Y in Table 1/Q.543 a). Three cases representing likely ISDN applications are included in the table.

Case Y′ traffic per pair of B channels comparable to 1 Case Y line.

Case Y″ traffic per pair of B channels comparable to 2 Case Y lines.

Case Y‴ traffic per pair of B channels comparable 1 Case Y line plus some very high traffic (e.g., circuit switched data traffic at 1 erlang).

Each of these digital lines also carries the associated ISDN signalling and data services on the D channel. For the circuit switched calling rates specified in Table 1/Q.543 b), ISDN signalling is expected to contribute less than 0.05 packet per second per digital subscriber line. The packet rates for D channel ISDN data services can be much larger than this; however, these are left for further study.

2.1.2.2 *Reference load B*

Reference load B is defined as a traffic increase over reference load A of:

+25% in erlangs, with +35% in BHCA.

Reference load B levels for D channel activity are for further study.

2.1.3 *Impact of supplementary services*

If the reference model exchange assumes that significant use is made of supplementary services, the performance of the exchange can be strongly affected, especially in exchange designs where processor capacity can become a limiting item. The performance delays recommended in §§ 2.3 and 2.4 can be significantly lengthened at a given call load under such circumstances. The Administration or Operating Agency defining the reference model should estimate the fractions of calls which use various supplementary services so that an average processor impact relative to a basic telephone call can be calculated (e.g., possibly by a methodology similar to that of Annex A to this Recommendation).

2.1.4 *Exchange capacity*

In order to evaluate and compare exchange designs, an Administration will usually want to know the maximum possible size of the exchange for the intended implementation. While several factors may limit exchange capacity, processing capacity will frequently be the limiting factor. The maximum possible number of lines and circuits served by an exchange, *while meeting performance objectives*, will depend on the mix, volumes and types of traffic and the services expected in the particular implementation.

Two methods of determining exchange processing capacity are provided in the annexes to this Recommendation:

- Annex A provides an example of methodology for computing processing capacity of an exchange using information provided by the manufacturer and estimates of traffic mix and load provided by the Administration.
- Annex B provides an example of methodology for estimating the capacity of an exchange by making projections from measurements made on a functioning exchange in the laboratory or in the field. The test exchange must be representative of mix and load of traffic and services expected at maximum size.

2.1.5 *Reference loads on other accesses and interfaces*

At this time, other applications, such as n × 64 kbit/s on the Primary Rate Interface, are left for further study.

2.2 inadequately handled call attempts

2.2.1 *Definition*

Inadequately handled call attempts are attempts which are blocked (as defined in the E.600-series of Recommendations) or are excessively delayed within the exchange. "Excessive delays" are those that are greater than three times the "0.95 probability of not exceeding" values recommended in the tables in §§ 2.3 and 2.4. (See Note.)

For originating and transit calls, this inadequately handled call attempt parameter applies only when there is at least one appropriate outlet available.

Note – Provisionally, call request delay is not included in this parameter. Further study is required.

2.2.2 *Probability of inadequately handled call attempts occurring*

The values in Table 2/Q.543 are recommended.

TABLE 2/Q.543

Type of connection	Reference load A	Reference load B
Internal	10^{-2}	4×10^{-2}
Originating	5×10^{-3}	3×10^{-2}
Terminating	5×10^{-3}	3×10^{-2}
Transit	10^{-3}	10^{-2}

2.3 *Delay probability – non-ISDN or mixed (ISDN – non-ISDN) environment*

The non-ISDN environment is composed of analogue subscriber lines and/or circuits that use either channel associated or common channel signalling.

The ISDN environment is composed of digital (ISDN) subscriber lines and/or circuits that use common channel signalling.

This section defines delay parameters related to non-ISDN environment and mixed (ISDN – non-ISDN) environment.

When a delay parameter in this section is also applicable to the pure ISDN environment, a reference to the appropriate part of § 2.4 (delay probability – ISDN environment) is provided.

In the following delay parameters, it is understood that delay timing begins when the signal is "recognizable", that is, after the completion of signal verification, where applicable. It does not include line-dependent delays for the recognition of induced voltage conditions or line transients.

The term "mean value" is understood to be the expected value in the probabilistic sense.

Where several messages are received at the exchange from a digital subscriber line signalling system (e.g., several alert messages are received from a multi-user configuration), the message that is accepted for call handling is the one considered in determining the start of a given delay interval.

Where common channel signalling (including inter-exchange and subscriber line signalling) is involved, the terms "received from" and "passed to" the signalling system are used. For CCITT Signalling System No. 7, this is designated as the instant the information is exchanged between the signalling data link (layer 1) and the signalling link functions (layer 2). For digital subscriber line signalling, this is designated as the instant the information is exchanged by means of primitives between the data link layer (layer 2) and the network layer (layer 3). Thus, the time intervals exclude the above layer 1 (CCITT Signalling System No. 7), and layer 2 (D channel) times. They do, however, include queuing delays that occur in the absence of disturbances but not any queuing delays that occur in the absence of disturbances but not any queuing delays caused by re-transmission.

2.3.1 **incoming response delay – transit and terminating incoming traffic connections**

Incoming response delay is a characteristic that is applicable where channel associated signalling is used. It is defined as the interval from the instant an incoming circuit seizure signal is recognizable until a proceed-to-send signal is sent backwards by the exchange.

The values in Table 3/Q.543 are recommended.

TABLE 3/Q.543

	Reference load A	Reference load B
Mean value	≤ 300 ms	≤ 400 ms
0.95 probability of not exceeding	400 ms	600 ms

2.3.2 **local exchange call request delay – originating outgoing and internal traffic connections**

2.3.2.1 For ANALOGUE SUBSCRIBER LINES, call request delay is defined as the interval from the instant when the off-hook condition is recognizable at the subscriber line interface of the exchange until the exchange begins to apply dial tone to the line. The call request delay interval is assumed to correspond to the period at the beginning of a call attempt during which the exchange is unable to receive any call address information from the subscriber.

The values in Table 4/Q.543 are recommended.

TABLE 4/Q.543

	Reference load A	Reference load B
Mean value	≤ 400 ms	≤ 800 ms
0.95 probability of not exceeding	600 ms	1000 ms

Note – The above values are understood to apply when a continuous tone, i.e., without a cadence, is used and do not include delays caused by functions such as line tests, which may be used in national networks.

2.3.2.2 For DIGITAL SUBSCRIBER LINES using overlap sending, call request delay is defined as the interval from the instant at which the SETUP message has been received from the subscriber signalling system until the SETUP ACKNOWLEDGE message is pased back to the subscriber signalling system.

Note – In this case this parameter is equivalent to the user signalling acknowledgement delay (see § 2.4.1).

The values in Table 5/Q.543 are recommended.

TABLE 5/Q.543

	Reference load A	Reference load B
Mean value	$\leq$ 400 ms	$\leq$ 800 ms
0.95 probability of not exceeding	600 ms	1000 ms

2.3.2.3 For DIGITAL SUBSCRIBER LINES using en-bloc sending, call request delay is defined as the interval from the instant at which the SETUP message is received from the subscriber signalling system until the call proceeding message is passed back to the subscriber signalling system.

The values in Table 6/Q.543 are recommended.

TABLE 6/Q.543

	Reference load A	Reference load B
Mean value	$\leq$ 600 ms	$\leq$ 900 ms
0.95 probability of not exceeding	800 ms	1200 ms

2.3.3 **exchange call set-up delay – transit and originating outgoing traffic connections**

Exchange call set-up delay is defined as the interval from the instant that the information is required for outgoing circuit selection is available for processing in the exchange, or the signalling information required for call set-up is received from the signalling system, until the instant when the seizing signal has been sent to the subsequent exchange or the corresponding signalling information is passed to the signalling system.

2.3.3.1 *Exchange call set-up delay for transit connections*

2.3.3.1.1 For transit traffic connections that involve circuits that use channel associated signalling or a mix of channel associated and common channel signalling, the values in Table 7/Q.543 are recommended.

TABLE 7/Q.543

	Reference load A	Reference load B
Mean value	≤ 250 ms	≤ 400 ms
0.95 probability of not exceeding	300 ms	600 ms

2.3.3.1.2 For transit traffic connections between circuits that use CCITT Signalling System No. 7 signalling exclusively, the requirements of the appropriate signalling system Recommendation should apply, e.g. CCITT Recommendations Q.725 and Q.766 for T_{cu} value (case of a processing intensive message).

2.3.3.2 *Exchange call set-up delay for originating outgoing traffic connections*

2.3.3.2.1 For outgoing traffic connections originating from ANALOGUE SUBSCRIBER LINES, the values in Table 8/Q.543 are recommended.

TABLE 8/Q.543

	Reference load A	Reference load B
Mean value	≤ 300 ms	≤ 500 ms
0.95 probability of not exceeding	400 ms	800 ms

2.3.3.2.2 For outgoing traffic connections originating from DIGITAL SUBSCRIBER LINES using overlap sending, the time interval starts when the INFORMATION message received contains a "sending complete indication" or when the address information necessary for call set-up is complete.

The values in Table 9/Q.543 are recommended.

TABLE 9/Q.543

	Reference load A	Reference load B
Mean value	≤ 400 ms	≤ 600 ms
0.95 probability of not exceeding	600 ms	1000 ms

2.3.3.2.3 For outgoing traffic connections originating from DIGITAL SUBSCRIBER LINES using en-bloc sending, the time interval starts when the SETUP message has been received from the digital subscriber signalling system.

The values in Table 10/Q.543 are recommended.

TABLE 10/Q.543

	Reference load A	Reference load B
Mean value	≤ 600 ms	≤ 800 ms
0.95 probability of not exceeding	800 ms	1200 ms

2.3.4 **through-connection delay**

Through-connection delay is defined as the interval from the instant at which the information required for setting up a through-connection is available for processing in an exchange, or the signalling information required for setting up a through-connection is received from the signalling system, to the instant at which the appropriate transmission path is available for carrying traffic between the incoming and outgoing exchange terminations.

The exchange through-connection delay does not include an inter-office continuity check, if provided, but does include a cross-office check if one occurs during the defined interval.

When the through-connection is established during call set-up, *the recommended values for exchange call set-up delay apply*. When the through-connection in an exchange is not established during the exchange call set-up interval, the through-connection delay may then contribute to the network call set-up delay.

2.3.4.1 *For transit and originating outgoing traffic connections*

The values in Table 11/Q.543 are recommended.

TABLE 11/Q.543

	Reference load A		Reference load B	
	Without ancillary equipment	With ancillary equipment	Without ancillary equipment	With ancillary equipment
Mean value	$\leqslant$ 250 ms	$\leqslant$ 350 ms	$\leqslant$ 400 ms	$\leqslant$ 500 ms
0.95% probability of not exceeding	300 ms	500 ms	600 ms	800 ms

The requirements for multi-slot connections require further study.

2.3.4.2 *For internal and terminating traffic connections*

For connections terminating on ANALOGUE SUBSCRIBER LINES, the through-connection delay is the interval from the instant at which the called subscriber off-hook condition (answer) is recognizable at the subscriber line interface of the exchange until the through-connection is established and available for the carrying traffic or a consequent signal is sent backwards by the exchange.

The maximum values applying to this parameter are included with those for incoming call indication sending delay in § 2.3.5.

For connections terminating on DIGITAL SUBSCRIBER LINES, the through-connection delay is the interval from the instant at which the CONNECT message is received from the signalling system until the through-connection is established and available for carrying traffic as those indicated by passing to the respective signalling systems of the ANSWER and CONNECT ACKNOWLEDGE messages.

The values in Table 12/Q.543 are recommended.

TABLE 12/Q.543

	Reference load A	Reference load B
Mean value	$\leqslant$ 250 ms	$\leqslant$ 400 ms
0.95 probability of not exceeding	300 ms	600 ms

2.3.5 **incoming call indication sending delay – (for terminating and internal traffic connections)**

2.3.5.1 For calls terminating on ANALOGUE SUBSCRIBER LINES, the incoming call indication sending delay is defined as the interval from the instant when the last digit of the called number is available for processing in the exchange until the instant that ringing signal is applied by the exchange to the called subscriber line.

It is recommended that the sum of the values for ringing signal sending delay and through-connection delay for internal and teminating traffic connection should not exceed the values in Table 13/Q.543. In addition, it is recommended that the value of the incoming call indication sending delay should not exceed 90% of these values nor the though-connection delay exceed 35% of these values.

TABLE 13/Q.543

	Reference load A	Reference load B
Mean value	$\leq$ 650 ms	$\leq$ 1000 ms
0.95 probability of not exceeding	900 ms	1600 ms

Note – The above values assume that "immediate" ringing is applied and do not include delays caused by functions such as line tests, which may be used in national networks.

2.3.5.2 For calls terminating on DIGITAL SUBSCRIBER LINES, the incoming call indication sending delay is defined as the interval from the instant at which the necessary signalling information is received from the signalling system to the instant at which the SETUP message is passed to the signalling system of the called digital subscriber line.

In the case of overlap sending in the incoming signalling system, the values in Table 14/Q.543 are recommended.

TABLE 14/Q.543

	Reference load A	Reference load B
Mean value	$\leq$ 400 ms	$\leq$ 600 ms
0.95 probability of not exceeding	600 ms	1000 ms

In the case of en-bloc sending in the incoming signalling system, the values in Table 15/Q.543 are recommended.

TABLE 15/Q.543

	Reference load A	Reference load B
Mean value	⩽ 600 ms	⩽ 800 ms
0.95 probability of not exceeding	800 ms	1200 ms

2.3.6 *Alerting sending delay – terminating and internal traffic connections*

2.3.6.1 **alerting sending delay for terminating traffic**

2.3.6.1.1 For calls terminating on ANALOGUE SUBSCRIBER LINES, alerting sending delay is defined as the interval from the instant when the last digit is available for processing in the exchange until the ringing tone is sent backwards toward the calling user.

The values in Table 13/Q.543 are recommended.

2.3.6.1.2 For calls termining on DIGITAL SUBSCRIBER LINES, the alerting sending delay is defined as the interval from the instant that an ALERTING message is received from the digital subscriber line signalling system to the instant at which an ADDRESS COMPLETE message is passed to the interexchange signalling system or ringing tone is sent backward toward the calling user.

The values in Table 16/Q.543 are recommended.

TABLE 16/Q.543

	Reference load A	Reference load B
Mean value	⩽ 200 ms	⩽ 350 ms
0.95 probability of not exceeding	400 ms	700 ms

2.3.6.2 **alerting sending delay for internal traffic**

2.3.6.2.1 For calls terminating on ANALOGUE SUBSCRIBER LINES, alerting sending delay is defined as the interval from the instant that the signalling information is available for processing in the exchange until ringing tone is applied to an ANALOGUE calling subscriber line or an ALERTING message is sent to a DIGITAL calling subscriber line signalling system.

For calls from ANALOGUE SUBSCRIBER LINES to ANALOGUE SUBSCRIBER LINES, the values in Table 13/Q.543 are recommended.

For calls from DIGITAL SUBSCRIBER LINES to ANALOGUE SUBSCRIBER LINES, the values in Table 17/Q.543 are recommended.

TABLE 17/Q.543

	Reference load A	Reference load B
Mean value	⩽ 300 ms	⩽ 500 ms
0.95 probability of not exceeding	500 ms	800 ms

2.3.6.2.2 For internal calls terminating on DIGITAL SUBSCRIBER LINES originating from ANALOGUE SUBSCRIBER LINES, alerting sending delay is defined as the interval from the instant that an alerting message is received from the signalling system of the called subscriber's line until ringing tone is applied to the calling subscriber line.

The values in Table 13/Q.543 are recommended.

Alerting sending delay on internal calls between DIGITAL SUBSCRIBER LINES are covered by Table 28/Q.543.

2.3.7 **ringing tripping delay – internal and terminating traffic connections**

Ringing tripping delay is a characteristic that is applicable for calls terminating on ANALOGUE SUBSCRIBER LINES only. It is defined as the interval from the instant that the called subscriber off-hook condition is reconizable at the subscriber line interface until the ringing signal at the same interface is suppressed.

The values in Table 18/Q.543 are recommended.

TABLE 18/Q.543

	Reference load A	Reference load B
Mean value	⩽ 100 ms	⩽ 150 ms
0.95 probability of not exceeding	150 ms	200 ms

2.3.8 **exchange call release delay**

Exchange call release delay is the interval from the instant at which the last information required for releasing a connection is available for processing in the exchange to the instant that the switching network through-connection in the exchange is no longer available for carrying traffic and the disconnection signal is sent to the subsequent exchange, if applicable. This interval does not include the time taken to detect the release signal, which might become significant during certain failure conditions, e.g., transmission system failures.

2.3.8.1 For transit traffic connections involving circuits using channel associated signalling or a mix of channel associated and common channel signalling, the values in Table 19/Q.543 are recommended.

TABLE 19/Q.543

	Reference load A	Reference load B
Mean value	⩽ 250 ms	⩽ 400 ms
0.95 probability of not exceeding	300 ms	700 ms

For transit traffic connections involving circuits using CCITT Signalling System No. 7 signalling exclusively, the values in Table 35/Q.543 are recommended.

2.3.8.7 For originating, terminating and internal traffic connections, the values in Table 20/Q.543 are recommended.

TABLE 20/Q.543

	Reference load A	Reference load B
Mean value	⩽ 250 ms	⩽ 400 ms
0.95 probability of not exceeding	300 ms	700 ms

2.3.9 **exchange signalling transfer delay – other than answer signal**

Exchange signalling transfer delay is the time taken by the exchange to transfer a signal, no other exchange action being required. It is defined as the interval from the instant that the incoming signal is recognizable, or the signalling information is received from the signalling system, until the instant when the corresponding outgoing signal has been transmitted, or the appropriate signalling information is passed to the signalling system.

2.3.9.1 For transit traffic connections involving circuits using channel associated signalling or a mix of channel associated and common channel signalling, the values in Table 21/Q.543 are recommended.

TABLE 21/Q.543

	Reference load A	Reference load B
Mean value	≤ 100 ms	≤ 150 ms
0.95 probability of not exceeding	150 ms	300 ms

For transit traffic connections between circuits that use CCITT Signalling System No. 7 signalling exclusively, the requirements of the appropriate signalling system Recommendations should apply, e.g., CCITT Recommendations Q.725/Q.726 for T_{cu} value (case of a simple message).

2.3.9.2 Exchange signalling transfer delay for originating, terminating and internal traffic involving a mix of ANALOGUE and DIGITAL SUBSCRIBER LINES is left for further study. Exchange signal transfer delay between DIGITAL SUBSCRIBER signalling systems or between DIGITAL SUBSCRIBER LINE signalling systems and CCITT Signalling System No. 7 is covered in § 2.4.2.

2.3.10 **answer sending delay**

Answer sending delay is defined as the interval from the instant that the answer indication is received at the exchange to the instant that the answer indication is passed on by the exchange toward the calling user. The objective of this parameter is to minimize the possible interruption of the transmission path for any significant interval during the initial response by the called user.

2.3.10.1 For transit traffic involving circuits that use channel associated signalling or a mix of channel associated and common channel signalling, the values in Table 22/Q.543 are recommended.

TABLE 22/Q.543

	Reference load A	Reference load B
Mean value	≤ 100 ms	≤ 150 ms
0.95 probability of not exceeding	150 ms	300 ms

More stringent values are recommended where in-band line signalling may be encountered in the national part of a built-up connection. The recommended values are given in Table 23/Q.543.

TABLE 23/Q.543

	Reference load A	Reference load B
Mean value	≤ 50 ms	≤ 90 ms
0.95 probability of not exceeding	100 ms	180 ms

For transit traffic connections involving circuits that use CCITT Signalling System No. 7 exclusively, the requirements of the appropriate signalling system Recommendations should apply, e.g., CCITT Recommendations Q.725 and Q.766 for T_{cu} value (case of a simple message).

2.3.10.2 For connections in a terminating exchange, exchange answer sending delay is defined as the interval from the instant that the off-hook condition is recognizable at the ANALOGUE SUBSCRIBER LINE interface on an incoming call or a CONNECT message is received from a DIGITAL SUBSCRIBER LINE signalling system until the instant that an answer indication is sent back toward the calling user.

The values in Table 24/Q.543 are recommended.

TABLE 24/Q.543

	Reference load A	Reference load B
Mean value	≤ 250 ms	≤ 350 ms
0.95 probability of not exceeding	300 ms	700 ms

2.3.10.3 For connections in an originating exchange, exchange answer sending delay is defined as the interval from the instant that the answer indication is received from the outgoing circuit signalling system or in the case of an internal call, from the called subscriber's line, until the instant that the answer indication is sent to the calling user. In the case of a call originated from a DIGITAL SUBSCRIBER LINE, the answer indication is a CONNECT message that is sent to the DIGITAL SUBSCRIBER LINE signalling system. If an ANALOGUE SUBSCRIBER LINE originated the call, the answer indication may not be sent.

The values in Table 25/Q.543 are recommended.

TABLE 25/Q.543

	Reference load A	Reference load B
Mean value	≤ 250 ms	≤ 400 ms
0.95 probability of not exceeding	300 ms	700 ms

For ISDN operation involving DIGITAL SUBSCRIBER LINES and CCITT Signalling System No. 7 exclusively, the values in Table 28/Q.543 are recommended.

2.3.11 **timing for start of charging (circuit switched calls)**

When required, timing for charging at the exchange where this function is performed, shall begin after receipt of an ANSWER indication from a connecting exchange or the called user. The start of timing for charging should occur within the intervals recommended in Table 26/Q.543.

TABLE 26/Q.543

	Reference load A	Reference load B
Mean value	≤ 100 ms	≤ 175 ms
0.95 probability of not exceeding	200 ms	350 ms

2.4 *Delay probability – ISDN environment*

The following notes apply to the delay parameters included in this section:

1) The term "mean value" is understood as the expected value in the probabilistic sense.

2) Where several messages are received at the exchange from a digital subscriber line signalling system (e.g. several alert messages are received from a multi-user configuration), the message that is accepted for call handling is the one considered in determining the start of a given delay interval.

3) The terms "received from" and "passed to" the signalling system are used. For CCITT Signalling System No. 7 this is designated as the instant the information is exchanged between the signalling data link (layer 1) and the signalling link functions (layer 2). For digital subscriber line signalling, this is designated as the instant the information is exchanged by means of primitives between the data link layer (layer 2) and the network layer (layer 3). Thus, the time intervals exclude the above layer 1 (CCITT Signalling System No. 7) and layer 2 (D channel) times. They do, however, include queuing delays that occur in the absence of disturbances but not any queuing delays caused be re-transmission.

2.4.1 user signalling acknowledgement delay

User signalling acknowledgement delay is the interval from the instant a user signalling message has been received from the subscriber line signalling system until a message acknowledging the receipt of that message is passed back from the exchange to the user line signalling system. Examples of such messages are SETUP ACKNOWLEDGEMENT TO SETUP, CONNECT ACKNOWLEDGEMENT to CONNECT and RELEASE ACKNOWLEDGEMENT to RELEASE.

The values in Table 27/Q.543 are recommended.

TABLE 27/Q.543

	Reference load A	Reference load B
Mean value	⩽ 400 ms	⩽ 800 ms
0.95 probability of not exceeding	600 ms	1000 ms

2.4.2 signalling transfer delay

The exchange signalling transfer delay is the time taken for the exchange to transfer a message from one signalling system to another with minimal or no other exchange actions required. The interval is measured from the instant that a message is received from a signalling system until the moment the corresponding message is passed to another signalling system. Examples of messages are ALERT to ADDRESS COMPLETE, ADDRESS COMPLETE to ADDRESS COMPLETE, CONNECT to ANSWER, RELEASE to DISCONNECT, etc.

The values in Table 28/Q.543 are recommended for originating and terminating connections.

TABLE 28/Q.543

	Reference load A	Reference load B
Mean value	⩽ 200 ms	⩽ 350 ms
0.95 probability of not exceeding	400 ms	700 ms

For transit connections, the requirements of the appropriate signalling system Recommendation should apply, e.g. CCITT Recommendations Q.725 and Q.766 for T_{cu} value (case of a simple message).

Note – User-to-user signalling may imply additional functions in the exchanges, e.g. charging, flow control, etc. The requirements for user-to-user signalling transfer delay and the impact of user-to-user signalling on exchange performance is for further study.

2.4.3 **call set up delay**

Call set up delay is defined as the interval from the instant when the signalling information required for outgoing circuit selection is received from the incoming signalling system until the instant when the corresponding signalling information is passed to the outgoing signalling system.

2.4.3.1 For originating 64 kbit/s circuit switched connections (types I, II and III option a).

i) If overlap sending is used, the interval starts when the information message received contains a "sending complete" indication or the address information for call set up is complete.

ii) If en-bloc sending is used, the time interval starts when the SETUP message has been received from the user signalling system.

For call attempts using overlap sending, the values in Table 29/Q.543 are recommended.

TABLE 29/Q.543

	Reference load A	Reference load B
Mean value	≤ 400 ms	≤ 600 ms
0.95 probability of not exceeding	600 ms	1000 ms

For call attempts using en-bloc sending, the values in Table 30/Q.543 are recommended.

TABLE 30/Q.543

	Reference load A	Reference load B
Mean value	≤ 600 ms	≤ 800 ms
0.95 probability of not exceeding	800 ms	1200 ms

2.4.3.2 For originating supplementary service call attempts:

for further study.

2.4.3.3 For transit 64 kbit/s circuit switched connections between circuits that use CCITT Signalling System No. 7, the requirements of CCITT Recommendations Q.725 and Q.766 should apply for T_{cu} value (case of a processing intensive message).

2.4.4 **through connection delay**

2.4.4.1 For originating outgoing and transit traffic 64 kbit/s switched circuit connections, through connection delay is defined as the interval from the instant that the signalling information required for setting up a connection through the exchange is received from the incoming signalling system to the instant that the transmission path is available for carrying traffic between the incoming and outgoing terminations on the exchange.

Usually, both directions of transmission will be switched through at the same time. However, at an originating exchange, on certain calls, there may be a requirement to effect switch through in two stages, one direction at a time. In this case, different signalling messages will initiate the two stages of switch through and the recommended delay applies to each stage of switch through.

The values in Table 31/Q.543 are recommended.

TABLE 31/Q.543

	Reference load A		Reference load B	
	Without ancillary function	With ancillary function	Without ancillary function	With ancillary function
Mean value	$\leqslant$ 250 ms	$\leqslant$ 350 ms	$\leqslant$ 400 ms	$\leqslant$ 500 ms
0.95 probability of not exceeding	300 ms	500 ms	600 ms	800 ms

2.4.4.2 For internal and terminating traffic 64 kbit/s switched circuit connections the through connection delay is defined as the interval from the instant that the CONNECT message is received from the called line signalling system until the through connection is established and available for carrying traffic and the ANSWER and CONNECT ACKNOWLEDGEMENT messages have been passed to the appropriate signalling systems.

The values in Table 32/Q.543 are recommended.

TABLE 32/Q.543

	Reference load A	Reference load B
Mean value	$\leqslant$ 250 ms	$\leqslant$ 400 ms
0.95 probability of not exceeding	300 ms	600 ms

2.4.5 **incoming call indication sending delay – (for terminating and internal traffic connections)**

The incoming call indication sending delay is defined as the interval from the instant at which the necessary signalling information is received from the signalling system to the instant at which the SETUP message is passed to the signalling system of the called subscriber line.

In the case of overlap sending in the incoming signalling system, the values in Table 33/Q.543 are recommended.

TABLE 33/Q.543

	Reference load A	Reference load B
Mean value	⩽ 400 ms	⩽ 600 ms
0.95 probability of not exceeding	600 ms	1000 ms

In the case of en-bloc sending in the incoming signalling system, the values in Table 34/Q.543 are recommended.

TABLE 34/Q.543

	Reference load A	Reference load B
Mean value	⩽ 600 ms	⩽ 800 ms
0.95 probability of not exceeding	800 ms	1200 ms

2.4.6 **connection release delay**

Connection release delay is defined as the interval from the instant when DISCONNECT or RELEASE message is received from a signalling system until the instant when the connection is no longer available for use on the call (and is available for use on another call) and a corresponding RELEASE or DISCONNECT message is passed to the other signalling system involved in the connection.

The values in Table 35/Q.543 are recommended.

TABLE 35/Q.543

	Reference load A	Reference load B
Mean value	⩽ 250 ms	⩽ 400 ms
0.95 probability of not exceeding	300 ms	700 ms

2.4.7 *Call clearing delay*

Disconnect and call clearing will usually be performed at the same time. However, on certain calls it may be necessary for an exchange to retain call references after disconnect has occurred, until a clearing message is received. The exchange may then discard the call reference information. The corresponding RELEASE message must be passed on to other involved signalling systems in the interval allowed for signalling transfer delay (see § 2.4.2).

2.4.8 *Timing for start of charging* (circuit switched calls)

When required, timing for charging at the exchange where this function is performed, shall begin after receipt of an ANSWER indication from a connecting exchange or the called user. The start of timing for charging should occur within the intervals recommended in Table 36/Q.543.

TABLE 36/Q.543

	Reference load A	Reference load B
Mean value	$\leqslant$ 100 ms	$\leqslant$ 175 ms
0.95 probability of not exceeding	200 ms	350 ms

2.5 *Call processing performance objectives*

2.5.1 *64 kbit/s switched connections*

2.5.1.1 *Premature release*

The probability that an exchange malfunction will result in the premature release of an established connection in any one minute interval should be:

$$P \leqslant 2 \times 10^{-5}$$

2.5.1.2 *Release failure*

The probability that an exchange malfunction will prevent the required release of a connection should be:

$$P \leqslant 2 \times 10^{-5}$$

2.5.1.3 *Incorrect charging or accounting*

The probability of a call attempt receiving incorrect charging or accounting treatment due to an exchange malfunction should be:

$$P \leqslant 10^{-4}$$

2.5.1.4 *Misrouting*

The probability of a call attempt misrouted following receipt by the exchange of a valid address should be:

$$P \leqslant 10^{-4}$$

2.5.1.5 *No tone*

The probability of a call attempt encountering no tone following receipt of a valid address by the exchange should be:

$$P \leqslant 10^{-4}$$

2.5.1.6 *Other failures*

The probability of the exchange causing a call failure for any other reason not identified specifically above should be:

$$P \leqslant 10^{-4}$$

2.5.2 *64 kbit/s semi-permanent connections*

This requires further study taking into consideration:

– need to recognize an interruption;
– probability of an interruption;
– requirements for re-establishment of interrupted connection;
– any other unique requirements.

2.5.3 *n × 64 kbit/s switched connections*

To be recommended if/when specific services are defined.

2.5.4 *n × 64 kbit/s semi-permanent connections*

To be recommended if/when specific services are defined.

2.6 *Transmission performance*

2.6.1 *64 kbit/s switched connections*

The probability of a connection being established with an unacceptable transmission quality across the exchange should be:

$$P(\text{Unacceptable transmission}) \leqslant 10^{-5}$$

The transmission quality across the exchange is said to be unacceptable when the bit error ratio is above the alarm condition.

Note – The alarm condition has yet to be defined.

2.6.2 *64 kbit/s semi-permanent connections*

To be recommended.

2.6.3 *n × 64 kbit/s switched connections*

To be recommended, if/when specific services are defined.

2.6.4 *n × 64 kbit/s semi-permanent connections*

To be recommended if/when specific services are defined.

2.7 *Slip rate*

2.7.1 *Normal conditions*

The slip rate under normal conditions is covered in Recommendation Q.541.

2.7.2 *Temporary loss of timing control*

The case of temporary loss of timing control corresponds to the "holdover operation" defined and recommended in Recommendation G.812. The allowable slip rate will correspond to the maximum relative TIE also recommended therein.

2.7.3 *Abnormal conditions at the exchange input*

The slip rate in case of abnormal conditions (wide phase diviations, etc.) at the exchange input is the subject of further study taking into account the requirements of Recommendation G.823.

3 **Exchange performance during overload conditions**

This section applies to digital exchanges operating during periods when the number of call attempts presented to the exchange exceeds its call processing capacity for a significant period of time, excluding momentary peaks. Under these conditions the exchange is said to be operating in an overload condition.

This Recommendation identifies requirements for exchange performance during overload and for overload mechanisms in the exchange. Network management functions to be supported by an exchange are defined in Recommendation Q.542, § 5.

3.1 *Explanation of terms used in definition of overload parameters*

- **load**: the total number of call attempts presented to an exchange during a given interval of time (i.e. offered load)
- **overload**: that part of the total load offered to an exchange, in excess of the engineered traffic processing capacity of the exchange. Overload is usually expressed as a percentage of engineered capacity.
- **throughput**: the number of call attempts processed successfully by an exchange per unit time.
- **engineered capacity**: the mean offered load at which the exchange just meets all grade of service requirements used by the Administration to engineer the exchange.

3.2 *Call processing performance during overload*

An exchange must continue to process a specified load even when the offered call attempts exceed its available call processing capacity. The number of call attempts handled during an overload condition should not be significantly lower than the engineered capacity of the exchange for a specified Grade Of Service (GOS), as noted in § 3.7.

Two basic requirements for exchange performance during overload are:

- to maintain adequate exchange throughput in sustained overload
- to react sufficiently quickly to load peaks and the sudden onset of overload.

As the offered load increases beyond the engineered attempt capacity of the exchange, the throughput or the carried attempt load may exhibit a behaviour shown by curve A in Figure 1/Q.543, i.e. processor throughput may be reduced drastically if the offered load increases well beyond the engineered load. Curve B in Figure 1/Q.543 represents the maximum throughput, where the throughput remains at the nominal design level under overload. Appropriate overload protection mechanisms should be included in the overall exchange design so that the throughput performance of the processor under overload resembles the curve C in Figure 1/Q.543.

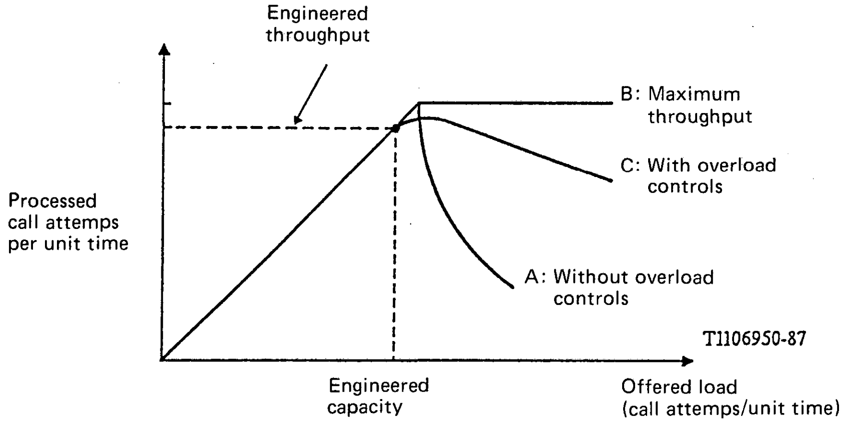


FIGURE 1/Q.543

Throughput characteristics

3.3 *Engineered exchange capacity*

Exchange engineered capacity is the maximum load that the exchange can handle while operating in a "normal" mode (i.e. performing all required operating and administrative functions) while meeting performance requirements specified in § 2 or those specified by the Administration. It is not necessarily the point of maximum throughput (see Figure 1/Q.543).

Overload controls, when applied, may have a significant effect on exchange capacity. Overload throughput performance should be specified relative to the engineered capacity of the exchange when overload controls are operating.

3.4 *Overload control strategy*

An effective overload control strategy will prevent the rapid decrease in processed call attempts with increasing overload (see Curve A in Figure 1/Q.543); the relatively gradual decrease with overload controls enabled (Curve C in Figure 1/Q.543) is due to the increasing processing overhead in exercising the overload controls.

Overload is defined as the level of call attempts offered to the exchange in excess of the exchange engineered capacity. For example, when the exchange is offered call attempts at a rate of 10% greater than the engineered capacity, the exchange is said to have 10% overload.

The exchange throughput at an overload of Y% above the engineered capacity load should be at least X% of the throughput at engineered capacity. This concept is shown in Figure 2/Q.543 which shows the region of unacceptable throughput performance. Any throughput curve which remains above the X% level until reaching the point of Y% overload is acceptable. The recommended values are Y = 50% and X = 90%. Beyond Y% overload the exchange should continue to process calls in an acceptable manner.

As long as the level of overload does not exceed Y% above the exchange engineered capacity, then the exchange throughput should be no less than X% of engineered capacity, as depicted in Figure 2/X.543.

Measurements that can provide data as the basis for calculation of X and Y, are identified in § 3.8.

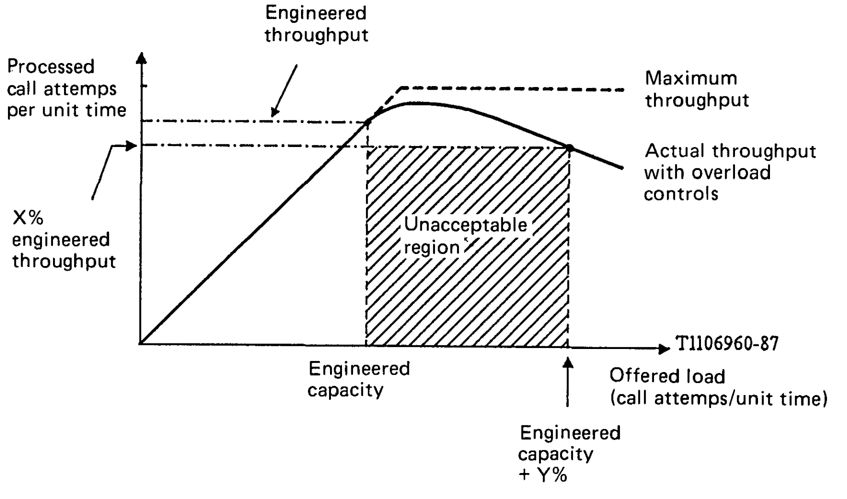


FIGURE 2/Q.543

Throughput performance with overload control actived

3.5 *Detection of overload*

The exchange should incorporate suitable means for detecting overload conditions.

The onset of an overload state should be recognized by the exchange processing logic which in turn will invoke strategies to avoid a severe degradation in throughput load. During overload, both severe delays and processing delays will increase and will normally exceed the performance objectives given for Reference load B.

Overload indications may, for example, be provided by: a continuous measurement of the occupancy of the resources used for call handling over short periods (e.g. a few seconds); monitoring the queue lengths for the various call handling processes, etc. Overload control activation indications should be given to the administration staff.

3.6 *Overload protection*

The internal overload control methods used in an exchange are dependant on the particular technical arrangement of the switching system, and are not subject to CCITT Recommendations. Overload controls used in conjunction with adjacent exchanges are discussed under "Network management design objectives" in Recommendation Q.542, § 5.

In order to reduce the load on the exchange caused by calls that cannot be processed during overload, it may be necessary to discourage further attempts by customers during this situation. Methods used to achieve this reduction should not significantly increase the load on exchange processors, as for example, routing calls to recorded announcements.

Overload controls, once applied, should be removed as quickly as possible when the degree of overload reduces, consistent with the need to avoid oscillatory behaviour which might prolong the period of degraded service.

As a guideline to providing service during overload conditions, the following general principles are applicable:

- give preference to the processing of terminating calls,
- give preference to priority class lines, calls to priority destinations based on digit analysis and incoming calls with priority indications in, for example, the Initial Address Message of a call using CCITT Signalling System No. 7, if an essential service protection capability has been invoked,

- defer some or all activities non-essential to handling offered traffic; examples are some administration and maintenance processes in the exchange. (Nevertheless the man-machine communications essential for priority operational tasks should always be preserved. In particular, network management terminals and functions associated with interfaces to network management support systems should be afforded high priority, since network management actions can play an important role in reducing exchange overloads),
- maintain normal charging and supervisory functions, and established connections until the receipt of the appropriate release signal,
- assign priorities to specific exchange measurements, such that low priority measurements cease at a predetermined level of congestion. Higher priority measurements may be ceased at a higher level of congestion, or may be run continuously, depending on their importance to the call handling functions,
- give preference to calls already being processed, before accepting new calls.

3.7 *Grade of service during overload*

In general the overall grade of service seen by the subscribers will deteriorate when the exchange experiences severe overload conditions and the overload protection mechanisms have been invoked. This may be due to the fact that the overload protection procedures may require that the exchange not accept all the call attempts offered.

Accepted calls may or may not receive a grade of service equal to that received by calls at Reference load B of § 2. In terms of the exchange overload performance, it is sufficient that calls be accepted in such a way that throughput is maximized.

3.8 *Performance monitoring during overload control activation*

The operational measurements in the exchange should be sufficient to determine the number of call attempts accepted by the exchange, and the number that are successfully being completed, from the exchange point-of-view. Separate measurements should be available to count the number of attempts rejected by the exchange during overload, so that the total load can be estimated.

An accepted call attempt is defined to be a call attempt which is accepted for processing by the exchange. This does not necessarily mean that an accepted call attempt will complete or receive an acceptable grade of service.

The call completion rate can vary statistically with time, according to the specific call attempt acceptance process invoked by the overload controls. Therefore the call completion rate estimated from the operational measurements needs to be taken over a sufficiently long period of time to verify conformance to the X% throughput requirement.

ANNEX A

(to Recommendation Q.543)

An example of methodology for computing the call processing capacity of a Digital Exchange, taking into account ISDN services, including packet data handling

A.1 *General*

Exchanges will generally be required to handle many types of calls as they provide basic telephony service, supplementary telephony service, ISDN bearer service and ISDN supplementary services. A variety of signalling types will be used on subscriber lines and for handling calls over interexchange circuits. Performance objectives have been recommended and are applicable over the full range of exchange sizes and loads up to the limit of exchange "engineered" capabity at its maximum size for the mix of call types handled and signalling types used in the exchange. Different mixes of call types and signalling types require different amounts of processing capacity. Thus the maximum number of subscriber lines that can be served and the number of calls that can be handled will be different for each mix on the same switching system. This ANNEX serves as an example of a methodology that makes it possible to compute the processing capacity of an exchange for any particular mix of call types and signalling expected to be encountered in its implementation. Of course, other possible limiting factors such as allowable hardware configuration, memory capacity, etc., must also be taken into account when determining the capacity of the exchange.

The method of calculating call processing capacity illustrated herein is for a particular multi-processor exchange design shown in Figure A-1/Q.543. However, the principles used can be applied to any processor controlled exchange design for any mix of services, traffic and signalling handled by the exchange. This method requires that manufacturers provide information and data about their exchange designs in terms that Administrations can use in the formulae derived below and that Administrations make measurements and/or estimates to forecast the expected traffic volumes and mix of services, call types and signalling.

It is important to examine the exchange architecture and to understand how calls are processed in order to recognize potential limiting elements. For example, ISDN calls involving packet switching will have two separate elements to be considered, call set up and packet handling. Packet call set up can be dealt with in the same manner as circuit switched call setup by considering these types of call attempts in and with the circuit switched call attempt originations and dispositions. However, subsequent packet handling requires continuing processing capacity, occasionally for long periods of time, may be handled by processors other than those involved in call setup and thus, must be dealt with separately.

Figure A-1/Q.543 of this ANNEX shows a block diagram of an exchange design with several processors, which is used as an example in this ANNEX.

a) The Interface Unit 1 through n provide interfaces to user lines, interexchange circuits, signalling terminals and any other interfaces to entities outside the exchange. A certain amount of call processing (e.g. handling signalling to or from lines or interexchange circuits, digit analysis, etc.) can be performed by processors in these interface units. In this example, each Interface Unit also contains its own packet handler (shown as PH). The Interface Units communicate with a Central Processing Unit over high capacity inter-processor lines.

b) The Central Processing Unit directs call processing by the exchange. It receives information about call attempts from the Interface Units, determines how they should be handled and routed and directs their disposition by the appropriate Interface Units. In connection with packet switching calls, it is assumed that the Central Processing Unit is involved only in call set up and call release and that ongoing packet handling requires no significant amount of CPU processing capacity. The CPU also performs other call related and administrative tasks, such as maintaining charging information, and performs other administrative and operations functions for the exchange.

To determine the capacity of this design it is necessary to know how many Interface Units can be connected to an exchange. Then it is necessary to compute the call processing capacity of the Central Processing Unit and the capacity of the Interface Units to determine which is the limiting factor. In some designs, other elements, such as a utility processor or the switching network, can limit the size of the exchange. Thus, it is necessary to understand the exchange design and then to make appropriate computations involving the limiting elements to determine the processing capacity of the exchange for the traffic mix envisioned.

A.2 *Definitions*

A.2.1 **capacity unit**

The processing capacity required in an exchange (or processing unit) to process a call attempt consisting of the originating portion plus the terminating (or disposition) portion.

A.2.2 **half unit**

The processing capacity required to process either the originating or terminating (disposition) portion of a call attempt handled by an exchange or a processing unit, e.g. an Interface Unit in the exchange design shown.

A.2.3 **originating type**

A type of call attempt entering the exchange (e.g. a telephone call from a line class-marked for basic telephone service, or one from a line marked for supplementary services, or basic ISDN services, *or* ISDN supplementary services, or a call entering the exchange on an incoming interexchange circuit, etc.).

A.2.4 **terminating (disposition) type**

A type of call attempt leaving or disposed of by the exchange (e.g. a call attempt terminating to a line class marked for basic telephone service, or one to a line with supplementary or ISDN services assigned, or to an outgoing interexchange circuit, etc.).

A.2.5 **reference capacity unit**

The processing capacity required for processing an arbitrarily selected pair of half units, one an originating type attempt and one a terminating (disposition) type attempt, usually a pair that is expected to be involved in a significant portion of the traffic load in the exchange. The reference capacity unit uses a standard against which capacity units for other types of attempts are compared. (It is suggested that an originating outgoing "local" telephone call attempt from a basic telephone line and disposed of by routing it to an interexchange circuit using CCITT Signalling System No. 7 as the reference capacity unit.)

A.2.6 **reference capacity half-unit**

The processing capacity required in an interface unit to process an arbitrarily selected half-unit, either an originating or a terminating (disposition) type (usually one that is involved in a significant portion of traffic that interface units handle, e.g. an originating telephone call attempt from a basic telephone line). The reference capacity half-unit is used as the standard against which half-units of other types of attempts are compared. When separate calculations for different interface units are necessary, which occurs when different mixes of line classes and traffic are served by the different interface units, the same reference capacity half-unit should be used for all calculations.

A.2.7 **central processor unit (CPU) reference capacity unit**

The processing capacity required in the CPU to process the portions of attempts associated with one reference capacity unit. The reference capacity unit is assigned unit value. Thus, if F is the fraction of one reference capacity unit for processing the originating portion and F' is the fraction of one reference capacity unit required for processing the terminating (disposition) portion, the sum is unity ($F + F' = 1$).

A.2.8 **interface unit (IU) reference capacity unit**

The amount of processing capacity required in the IU in the exchange design shown, to properly handle one reference capacity half-unit.

A.2.9 **weighting factor**

The ratio of the relative amount of processing capacity required to handle either portion, originating or terminating (disposition), of any *attempt* type, to the capacity required in that processor to perform the same functions for reference capacity unit, (originating and terminating (disposition) portions). For example, if a complete reference capacity unit requires 1000 processor cycles in the CPU and the originating portion of a call attempt entering the exchange requires 430 cycles in the CPU, the weighting factor (CPU) for that originating attempt type would be 0.43.

Similarly, in the interface unit, a weighting factor is the ratio of the amount of IU processing capacity required to handle a particular half-unit to the amount of IU processing capacity required to handle a reference capacity half-unit. Thus if an IU requires 600 cycles to handle a reference capacity half-unit and another type of call entering the exchange via the IU requires 725 IU processor cycles, the weighting factor (IU) for that half-unit attempt type would be 1.21.

Weighting factors for all originating and terminating (disposition) types of capacity units and half-units, are required for each processing unit in the exchange in order to make capacity computations. These weighting factors must be furnished by the manufacturer.

A.2.10 **reference unit (and half-unit) processing capacity (RUPC)**

Is capacity information that should be furnished by the manufacturer. RUPC is the total number of reference capacity units (and half-units) that can be performed by a processor (or processing unit) in one hour in an exchange while meeting performance criteria specified by the Administration and at the same time performing all the operations and administrative tasks required for normal operation of the exchange. Thus, RUPC is the processing capacity available for call handling. It is the total installed capacity diminished by an amount required for overhead, administrative tasks, etc. In addition to accounting for the overhead of administrative tasks, it may also be desirable to "reserve" a certain percentage of capacity for program growth additions that would be needed in a maximum size exchange for adding new features in the future. To be able to make a realistic comparison of different systems, it is necessary that the Administration learn from the manufacturers, the non-call handling functions that are accounted for and the percent of capacity that is being reserved for growth.

A.3 *Processing capacity computation (for a central processing unit)*

Capacity information and weighting factors are furnished by the manufacturer.

Let F_i = weighting factor for originating type i

F'_j = weighting factor for terminating (disposition) type j.

Traffic mix on the CPU is specified by the Administration.

Let P_i = fraction of call attempts expected to be originating type i

P'_j = fraction of call attempts expected to be terminating (disposition) type j.

where

$$\sum_{i=1}^{n} P_i = 1.0$$

and

$$\sum_{j=1}^{m} P'_j = 1.0$$

If, R = the call attempt rate expressed in terms of busy hour call attempts, then the amount of processing capacity required for originating type work units associated with the i-th call attempt type traffic is:

$$P_i F_i R_i$$

Similarly, the processing capacity required for disposition work associated with the j-th call type traffic is:

$$P'_j F'_j R$$

In order to satisfy the performance design objectives in Recommendation Q.543, the reference unit processing capacity (RUPC) must be equal to or greater than the total originating type work plus the total terminating (disposition) type work:

$$RUPC\,(CPU) \geqslant \left[\sum_{i=1}^{n} P_i\, F_i + \sum_{j=1}^{m} P'_j\, F'_j \right] R$$

From which:

$$R\ (\text{maximum}) = \frac{RUPC\,(CPU)}{\sum_{i=1}^{n} P_i\, F_i + \sum_{j=1}^{m} P'_j\, F'_j}$$

A.4 *Processing capacity computation (for an interface unit)*

Capacity information and weighting factors are furnished by the manufacturer.

Let H_i = weighting factor for half-unit type i.

Traffic mix on the interface unit is specified by the Administration.

Let P_i = fraction of attempts to be half-unit type i.

where

$$\sum_{i=1}^{n} P_i = 1.0$$

If, R = the attempt rate in terms of busy hour half-units, the processing capacity required for i-th type half-units is:

$$P_i H_i R$$

In order to satisfy performance criteria, the reference unit call processing capacity (RUPC) must be equal to or greater than the total processing load:

$$RUPC\,(IU) \geqslant \left[\sum_{i=1}^{n} P_i\, H_i \right] R$$

From which:

$$R\,(\text{maximum}) = \frac{RUPC\,(IU)}{\sum_{i=1}^{n} P_i\, H_i}$$

A.5 *Examples of processing capacity computations*

A.5.1 *For a central processing unit*

Inputs

Information furnished by manufacturer:

- RUPC = 100,000 central processor reference capacity units per hour
- Weighting factors (see Table A-1/Q.543).

TABLE A-1/Q.543

Termination type	Originating portion (F)	Termination (disposition) portion (F′)
Basic analogue access line	0.60	0.40
Analogue access line with supplementary services	0.72	0.48
ISDN access line	0.72	0.56
Interexchange circuit (IXC)	0.50	0.40

Information furnished by the Administration.

Expected traffic mix (see Table A-2/Q.543).

TABLE A-2/Q.543

Originating call type	From – termination type	Traffic mix (fraction of total)
Telephone	Basic analogue access line	0.28
Telephone	Analogue acess line with supplementary services	0.32
64 kbit/s switched	ISND access line	0.05
Packet switched (setup)	ISDN access line	0.02
Incoming-circuit switched	Interexchange circuit (IXC)	0.33
	Total	1.00
Terminating call type	**To – termination type**	**Traffic mix (fraction of total)**
Telephone	Basic analogue access line	0.26
Telephone	Analogue access line with supplementary services	0.30
64 kbit/s switched	ISDN access line	0.05
Packet switched (setup)	ISDN access line	0.02
Outgoing-circuit switched	Interexchange circuit (IXC)	0.37
	Total	1.00

Computation (see Table A-3/Q.543).

TABLE A-3/Q.543

Termination type	Originating portion	Terminating portion
Basic analogue access line	0.28 × 0.60 = 0.168	0.26 × 0.40 = 0.104
Analogue access line with supplementary services	0.32 × 0.72 = 0.230	0.30 × 0.48 = 0.144
ISDN access line – circuit switched	0.05 × 0.72 = 0.036	0.05 × 0.56 = 0.028
ISDN access line – packet switched	0.02 × 0.72 = 0.014	0.02 × 0.56 = 0.011
Interexchange circuit (IXC)	0.33 × 0.50 = 0.165	0.37 × 0.40 = 0.148
Total	0.613	0.435

Maximum call attempt rate for the central processor for the specified mix of traffic:

$$R \text{ maximum} = \frac{100{,}000}{0.613 + 0.435} = 95{,}420 \text{ call attempts per hour}$$

At this point in the computation, it would be wise to examine the exchange design to verify that hardware configuration, memory capacity, or any other possible limitations do not prevent reaching this computed capacity.

A.5.2 *Example of a processing capacity computation for an interface unit* (see Table A-4/Q.543)

Weighting factors are furnished by the manufacturer.

Traffic mix is estimated by the Administration.

TABLE A-4/Q.543

	Call type	Weighting factor		Traffic mix (fraction of total)	
From:					
Basic analogue access line	Telephone (reference call)	1.00	×	0.14	= 0.140
	False start/abandon	1.16	×	0.005	= 0.006
Analogue access line	Telephone	1.15	×	0.10	= 0.115
	False start/abandon	1.20	×	0.005	= 0.006
	Supplementary service No. 1	1.52	×	0.05	= 0.076
	Supplementary service No. 2	1.31	×	0.01	= 0.013
	Supplementary service No. n	1.++	×		
ISDN access line	64 kbit/switched	1.20	×	0.025	= 0.030
	Packet call setup	1.15	×	0.01	= 0.012
	Supplementary service No. 1	1.44	×	0	
	Supplementary service No. 2	1.20	×	0.01	= 0.012
	Supplementary service No. n	1.++	×		
IXC – CCITT No. 5	Incoming	1.30	×	0.07	= 0.091
IXC – CCITT No. 7	Incoming	0.90	×	0.08	= 0.072
To:					
Basic analogue line	Telephone	0.65	×	0.13	= 0.085
Analogue line	Telephone	0.75	×	0.12	= 0.090
	Supplementary service No. 4	0.80	×	0.035	= 0.028
ISDN	64 kbit/switched	0.75	×	0.02	= 0.015
	Packet call setup	0.75	×	0.01	= 0.008
	Supplementary service No. 5	0.80	×	0.01	= 0.008
IXC – CCITT No. 5	Outgoing	1.62	×	0.08	= 0.130
IXC – CCITT No. 7	Outgoing	0.83	×	0.10	= 0.083
				Total	1.020

Information from the manufacturer.

Reference capacity for an interface unit = 15,000 reference capacity half-units per hour.

Computation:

$$R \text{ maximum} = \frac{15{,}000}{1.020} = 14{,}705 \text{ half-units per hour or } 7{,}352 \text{ call attempts per hour}$$

If the traffic load is distributed in the above proportions across all interface unit the number of interface units required to fully load the central processing unit would be 13 [95,420 divided by 7,352]. In this case it would probably be wise to plan on a maximum of 14 interface units in order to reserve some processing capacity for future program growth. At this point in the computation, it would be wise to examine the exchange design to verify that hardware configuration, memory or any other possible limitations do not prevent reaching this computed capacity.

The above capacity computation methodology can also be used to study the effects of different traffic mixes on interface units.

A.6 *Packet handling*

A.6.1 *Definitions*

A.6.1.1 **packet**

The unit of information exchanged between processors at layer 3.

A.6.1.2 **user packet**

A packet of information exchanged between the originating and terminating users in a packet switched connection. The length of packets may vary, depending on the protocol used. The number of user packets transferred between the originating and terminating users measures the amount of information transferred. The fundamental measure of packet switching capacity is expressed as the number of some agreed standard length user packets per second.

A.6.1.3 **acknowledgement packet**

Packet switching protocols have various strategies to ensure the reliable transmission of packets between users. These strategies involve sending packets not containing user data to verify the successful transmission of users packets. Such packets are called acknowledgement packets. The acknowledgement strategy depends on the packet switching protocol being used.

A.6.1.4 **reference packet type**

An arbitrarily selected user packet type, usually one of a protocol that is expected to be involved in a significant portion of the packet traffic an exchange might handle.

A.6.1.5 **reference packet work unit**

The amount of processor capacity required to handle one packet of the reference packet type together with its "share" of capacity required to handle associated acknowledgement packets. The reference packet work unit is assigned unit value.

A.6.1.6 **weighting factor**

The ratio of the amount of processing capacity required to handle any type of packet [including its "share" of associated acknowledgement packets] to the amount of processing required to handle one reference packet [including its "share" of associated acknowledgement packets]. For example, if a complete reference packet requires 1000 processor cycles and a complete X.25 message packet requires 1200 cycles, the weighting factor for that packet type would be 1.2. The weighting factors must be furnished by the manufacturer for each packet type handled by the exchange.

A.6.1.7 **reference packet processing capacity (RPPC)**

The total number of reference type user packets that can be handled by the processor in one second while meeting the specified performance criteria. This number should be furnished by the manufacturer. It is important to note that RPPC derives from that processing capacity reserved for packet handling and generally is the installed capacity diminished by an amount required for overhead, administrative tasks, etc.

A.6.2 *Packet calls*

Packet calls consist of two parts: packet call set-up [and disconnect] and ongoing packet exchanging [packet handling stage].

A.6.2.1 Packet call set-up can be dealt with in the same manner as that described previously for circuit switched call set-up. Appropriate weighting factors for the various types of packet call set-up and estimates of packet type calls in the traffic mix are used for computing the capacity of the processor involved. [See § A.5. Packet call set-up was included in the example of call attempt processing capacity computations]. Just as with circuit switched services, there may be packet calls with different processing requirements and therefore it will be necessary to treat the different type packet calls individually in the computation.

A.6.2.2 After packet call set-up, each packet exchanged between users during the call requires processing at the originating and terminating exchanges. The total amount of processing work required during a packet switched call is a function of the number of packets exchanged throughout the call. If a processor is dedicated to handling packets, the processing capacity is usually expressed in terms of number of user packets of a standard length handled per second. To account for the packet processing capacity that will be needed in an exchange during a busy hour, data on the average number [and type] of packets per call must be forecast. Note that for very long duration calls, e.g. permanent virtual circuits, only packets offered during the busy hour need to be considered. Also, packets from long duration calls originated prior to but extending into the busy hour, must be included.

In the exchange architecture shown in Figure A-1/Q.543, it is assumed that each interface unit has a separate packet handling processor (shown as PH) within the unit. This processor interacts with digital line or digital circuit units to handle the protocols involved in packet switching. Once a packet call has been set-up, there is no further demand for processing work on the interface unit processor nor the central processing unit processor until call disconnect. Thus, the only potential capacity limitation due to packet handling in the exchange will be that imposed by the processing capacity of the packet handling processor in the interface unit. [For systems that use the same processor for call set-up *and* packet handling, see § A.7.]

A.6.2.3 *Processing capacity computation for a packet handling processor*

Weighting factors are furnished by the manufacturer. Let G_k be the weighting factor for handling a user packet of type k [including the handling of an appropriate "share" of associated acknowledgement packets].

The data traffic mix (fractions of total) and volumes is forecast by the Administration.

Let Q_k be the fraction of user packets of type k. Note that:

$$\sum_{k=1}^{n} Q_k = 1$$

If R_p = user packet arrival rate, then the amount of processing capacity required for work associated with user packet traffic of the k-th type is:

$$Q_k \, G_k \, R_p$$

In order to satisfy performance criteria the reference packet processing capacity (RPPC) must be equal to or greater than the total packet handling work. Thus:

$$RPPC \geqslant R_p \left[\sum_{k=1}^{n} Q_k \, G_k \right]$$

From which the maximum packet processing capacity R_p max is:

$$R_p \text{ max} = \frac{\text{RPPC}}{\sum_{k=1}^{n} Q_k G_k} \text{ packets per second.}$$

A.6.2.4 *Example of a packet processing computation for an interface unit packet processor*

Information furnished by the manufacturer:

a) RPPC = 10000 reference packet work units per second

b) Weighting factors (G):

- X.25 type data = 1.00 (reference type)
- X.75 type data = 0.70

Estimated data traffic mix (furnished by the Administration):

Type	Traffic portion (Q)
X.25	0.52
X.75	0.48

Computation

Packet type	Processing factor
X.25 data	1.00 × 0.52 = 0.520
X.75 data	0.70 × 0.48 = 0.336
	Total 0.856

Maximum processing capacity for the above data traffic mix:

$$R_p \text{ max} = \frac{1000}{0.856} = 1168 \text{ packets per second}$$

If the estimated data packet arrival rate (R_p) does not exceed the above number, then packet handling capacity in the interface unit will not limit the number of digital lines or circuits that generate data packets terminated on the unit. If it does exceed the above number, the digital lines and circuits generating the packet traffic will have to be spread over more interface units.

A.7 *Capacity computation for exchange architectures other than that assumed in Figure A-1/Q.543*

If the same processor is used for both call set-up (circuit switched calls and packet calls) and for handling data packet traffic, the capacity of the processor must be allocated between the two functions. This can be done by computing the capacity of the processor for each function separately [with zero capacity used for the other function] and then allotting capacity between the two functions as required. Thus, if a processor has a maximum call processing capacity of 100,000 calls per hour *or* 1,000 packets per second, for every 100 packets per second of packet handling capacity required, the call processing capacity will be reduced by 10,000 calls.

A.8 *Conclusion*

The methodology shown here illustrates a possible approach for determining the limiting factors in an exchange design and for computing its processing capacity. It is most important that the exchange architecture be understood, that capacity limiting elements be identified and that the proper computations be made to determine the true capacity of the exchange. These procedures can be used in engineering and loading the exchange most effectively. Trade-offs can be made between the use of capacity for various purposes. For example, in Figure A-1/Q.543, a signalling terminal is shown connected to an interface unit. In that IU, the available processing capacity will be reduced by the amount of work required by the interface unit to support that terminal. The remainder of the processing capacity can be allocated effectively by using information generated in the call processing computation methodology.

It is also very important that the capacity of an exchange should not be calculated using the entire capacity for call processing. It should be made using the processing capacity available under "normal" operating conditions with the exchange performing all the operations and administrative functions expected of it during the busy hour.

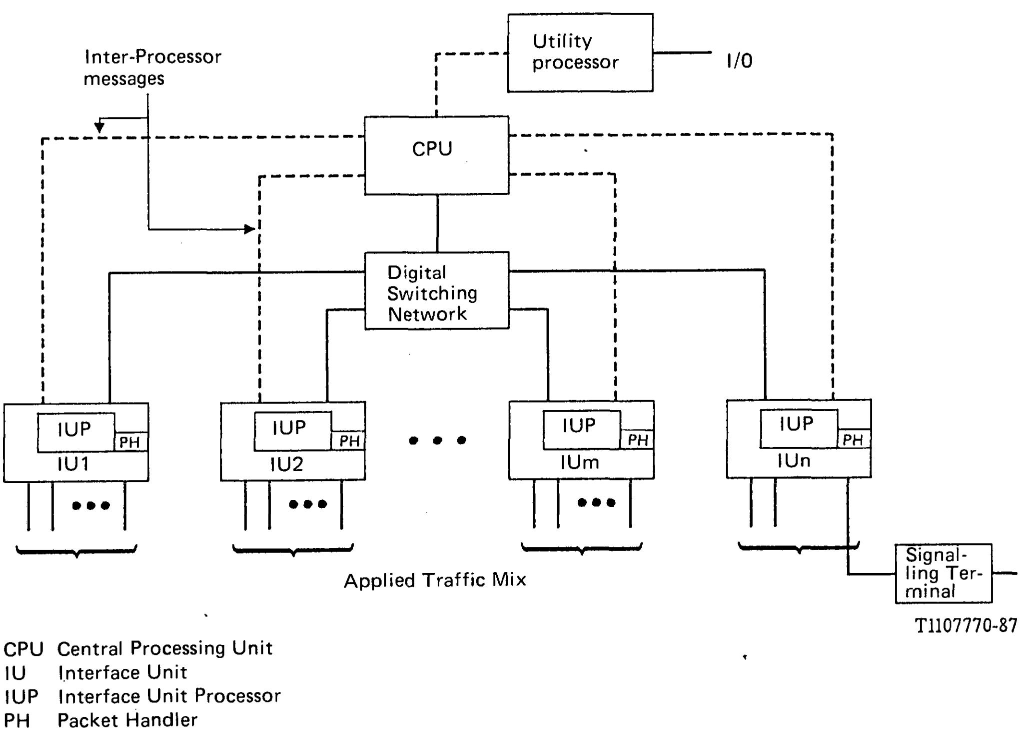


FIGURE A-1/Q.543

Example of an exchange design with several processors

ANNEX B

(to Recommendation Q.543)

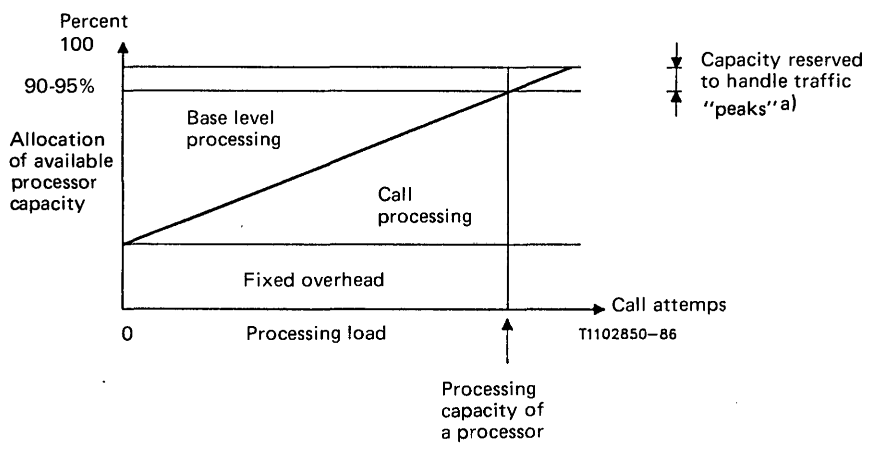
An example of a methodology for measuring exchange capacity

B.1 *General*

The capacity of an exchange used for call processing can be measured in a laboratory or in the field and projections can be made to predict the maximum processing capacity of the exchange design for the configuration and load characteristics involved in the measurements. This Annex serves as an example of a methodology that makes it possible to measure the processing capacity of an exchange for the configuration and load characteristics involved in the measurement.

B.2 *Theory behind the measurement method*

The call handling capacity of *a processor* can be expressed in terms of the maximum number of calls (or call attempts) which can be processed in a fixed interval of time while meeting all service criteria. In normal conditions, the work functions performed by a switching system processor can be divided into three categories (one fixed level and two variable) as shown in Figure B-1/Q.543.



a) The amount of reserved capacity depends on system architecture and hierarchical position of the processor.

FIGURE B-1/Q.543

Allocation of processing capacity

At normal loads, a linear relationship is usually observed between offered load and processor utilization. However, at heavy loads, some system components may become overloaded and this can be reflected in non-linearity in the processor utilization versus load characteristic.

In the case of a single processor controlled system, Figure B-1/Q.543 represents the processing capacity of the exchange. In a multi-processor system, the capacity is distributed among processors and the exchange capacity is related to the system configuration and the exchange processing capacity is a function of the processors involved in call handling functions.

As shown in Figure B-1/Q.543, the processing capacity of a processor is divided between three elements:

1) fixed overhead related to mandatory tasks (e.g. task scheduling and scanning);

2) call processing work (including traffic-related overhead tasks);

3) deferrable (base-level) tasks (e.g. routine maintenance).

The tasks which a processor executes are assigned to three levels of priorities, base, medium and high-level tasks (see Figure B-2/Q.543 a) and Figure B-2/Q.543 b)).

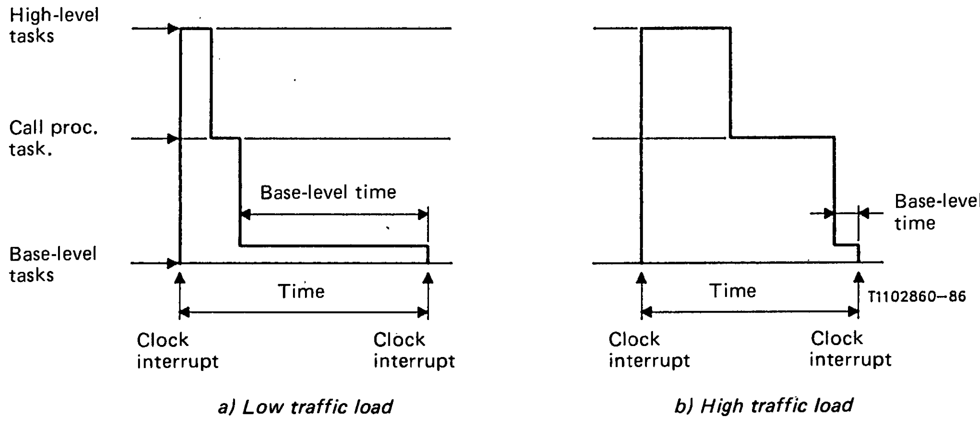


FIGURE B-2/Q.543

Allocation of processor time to tasks

As the traffic load (call attempts) increases call processing work expands and the processing of deferrable tasks decreases.

Measurement of the percentage of time spent by the processor performing base-level tasks gives an indication of the percent or processing capacity required for a particular load on the processor.

As shown in Figure B-2/Q.543 a), at low traffic load, the percentage of time used to perform base-level tasks is relatively high. In Figure B-2/Q.543 b), at high traffic load, the percentage of time at base-level is relatively low. Thus the measurement of percentage of time used to perform base-level tasks can be used to determine call processing capacity.

B.3 *Capacity measurement methodology for exchanges*

Measurements can be performed on exchanges in laboratories or in the field to measure capacity usage for various load levels and then to project the data to estimate the call processing capacity of a processor.

The collection of data will depend on facilities available to perform the required measurements. The exchange may be designed to provide indications of time spent performing base-level tasks or it may be necessary to access the bus system of a processor in order to measure this time. Equipment will be needed to create loads, or loads in a working exchange must be measured in order to establish load points. Various level loads for the various types of calls (or services) should be observed in order to establish a basis for projecting the load line to determine the maximum processing capacity for the mix of traffic services assumed or measured. In projecting call capacity care must be taken not to extrapolate beyond the linear region of the processor utilization versus offered call attempts relationship.

Where multi-processors are involved, the exchange configuration, the distribution of traffic types and processing capacity of each processor must be examined to determine the limiting factors that controls the exchange capacity (as discussed in Annex A. An example of methodology for computing the call processing capacity of a digital exchange, taking into account ISDN services, including packet data handling).

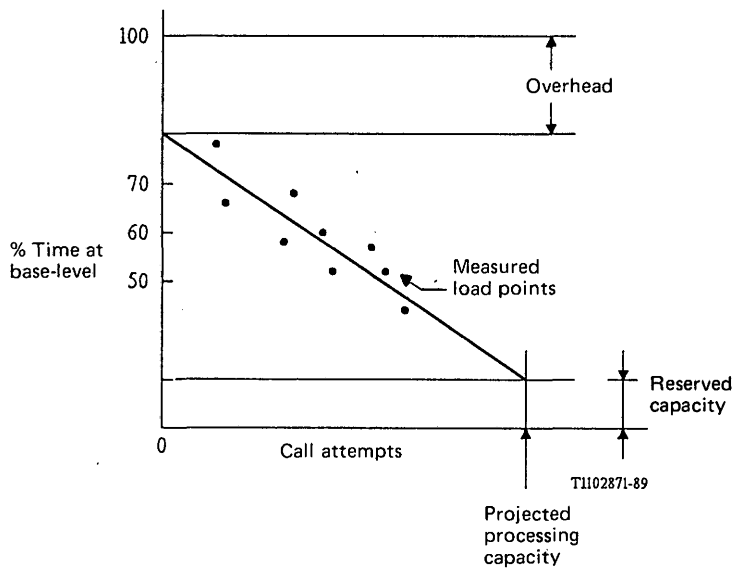


FIGURE B-3/Q.543

Measurement of processing capacity

Recommendation Q.544

DIGITAL EXCHANGE MEASUREMENTS

1 General

This Recommendation applies to digital local, combined, transit and international exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks, and also to local, combined, transit and international exchanges in an Integrated Digital Networks (ISDN). The field of application of this Recommendation is more fully defined in Recommendation Q.500. Some measurements only apply to a certain type (or types) of exchange. Where this occurs, the application is defined in the text. Where no such qualification is made, the measurement applies to all exchange applications.

This Recommendation includes traffic and performance measurements that are necessary for provisioning and operating exchanges so as to satisfy grade of service objectives covered in the E.500 series of Recommendations. These measurements are typically performed during specified periods and intervals after which the results are sent to designated local and/or remote exchange terminals or operation and maintenance centres (OMC) or any other appropriate data handling centre. In some cases, data may be utilized in its original form whereas in other cases data may need to be processed to determine when pre-set thresholds are exceeded and/or to recognize an abnormal condition when it occurs. In this Recommendation, no particular system design requirement is implied. Different designs may have more or less data accumulated and processed within the exchange or by an external system.

Different types and sizes of exchanges may require different sets of measurements. Also, different Administrations may have different requirements for measurements depending on policies, procedures or national network considerations. An Administration may thus find it desirable in some applications to measure items that are not covered by this Recommendation whereas in other applications some measurements may not be desired.

Exchange measurements are required for both national and international service. Requirements for international service take into consideration the following CCITT Recommendations:

- Recommendations E.401 to E.427: International telephone network management and checking of service quality;
- Recommendations E.230 to E.277: Operational provisions relating to charging and accounting in the international telephone service.

The aspects of traffic engineering are given in Recommendations E.500 to E.543. Recommendations on traffic meaurements for SPC exchanges are provided by Recommendations E.502, E.503 and E.504.

Additional measurements in an exchange, not specified in this Recommendation, are required, e.g. for:

- Transmission performance (Recommendations Q.551, Q.552, Q.553 and Q.554).
- Digital access signalling (Recommendations Q.920 to Q.931). This is for further study.
- Packet mode (Recommendations X.25 and X.75). This is for further study.
- Signalling System No. 7 (e.g. those measurements specified in Recommendation Q.791 for the message transfer part require further study to determine their applicability to this Recommendation).

Note – For the terms and definitions of teletraffic used in this Recommendation, see Recommendation E.600.

2 Measurement processes

2.1 *General*

The activities involved in exchange measurements can be split in four processes as represented by Figure 1/Q.544.

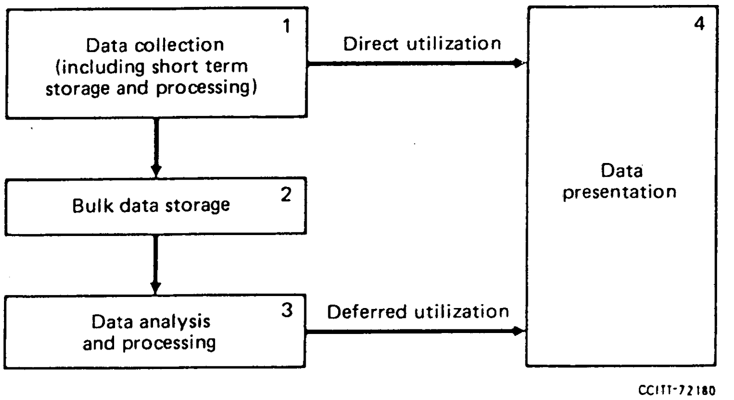


FIGURE 1/Q.544
Measurement processes

On choice of each individual national Administration, the above four processes can be fully or partially integrated into the exchanges.

It is nevertheless recommended that:

a) *data collection* be fully integrated into the exchange for all types of data;

b) *data presentation* be integrated into the exchange and/or at the O&M centre at least for the measurements required by O&M personnel.

Presentation of data required for planning and administration activities could be performed at the O&M personnel premises or in other locations which could be more centralized and generally takes place at a deferred time.

2.2 *Data collection*

Three different activities of data collection can be identified:

- event registration;
- traffic registration (traffic intensity and/or volume of traffic);
- call records registration.

The data generated by event registration and traffic registration are suitable for direct utilization (immediate presentation).

Call records can only be utilized after off-line analysis. Processing of call records can generate any type of data, including the event registration and traffic registration.

2.3 *Bulk data storage, analysis and processing*

Data storage for collected data can be required for accumulation of a massive data base suitable for subsequent analysis and processing.

These data can be held in the exchange for processing at the exchange location or transferred to administrative and engineering centres.

2.4 *Data presentation*

It is the function through which the collected data are becoming readable. Features related to the data presentation are:

a) location of presentation;

b) time frame of presentation. It is dependent on the nature of the data and their utilization. The activities of maintenance and network management require immediate presentation;

c) physical support of the displayed data and relevant format. These aspects are mainly related to the type of data and are to be left to individual implementations.

3 Types of measurement data

Measurement data primarily consists of counts of various events and the traffic intensity on various resources. For certain measurement data, sampling, or time averaging techniques may provide an acceptably accurate result. In some cases, externally generated test calls may provide the most practical method of obtaining the data. In other cases, call records, such as detailed charging records, may be used.

3.1 *Event counts*

Events, for example incoming seizures, call attempts encountering busy, and call attempts to specified destination codes should be countable. Some event counts may be accumulated over the whole exchange whereas others may be accumulated only over a subset such as an inter-exchange circuit group. In some cases, event counts may be accumulated several ways.

3.2 *Traffic intensity*

Traffic intensity on a pool of resources is the traffic volume divided by the duration of observation. It is thus equal to the average number of busy resources. As in the case of event counts, traffic intensity data may be for the whole exchange or for various subsets.

3.3 *Call records*

Call records contain data used by the exchange for the setting up of calls. The data may include the identity and classification of the originating line or incoming circuit, the dialled number, the call routing and disposition, and possibly the time of occurrence of certain events during the entire call period.

Call records can be generated and outputted by the exchange to allow the establishment of a data base suitable for off-line processing to determine traffic values and characteristics. Output of the call records associated with a statistical sample of total calls may be sufficient for this purpose.

4 Measurement administration

Exchanges should provide capabilities for operating personnel to establish measurement schedules and direct the output routing of measurement results. The methods of establishing measurement schedules should be designed to minimize the introduction of errors when defining relevant parameters. It should be possible to have a number of measurements simultaneously active with different schedules and output routings. A single measurement should be capable of having more than one measurement schedule and/or output routing simultaneously. The number of measurement types running concurrently may be limited to conserve exchange storage and processing resources. Criteria for measurement and recording of traffic may be found in Recommendation E.500 and other related E-Series Recommendations.

4.1 *Scheduling*

4.1.1 *Recording periods*

A recording period is the time interval during which a measurement is performed. Measurements can be activated either on-demand or according to a time schedule.

Different measurement periods may be schedulable for different days of the week. For example, a measurement may be scheduled for 0900 to 1800 on Monday through Friday and 0900 to 1200 on Saturday. The measurements for an entire week may be programmed and the weekly cycle may be repeated until a new command will stop it.

4.1.2 *Result accumulation periods*

A recording period contains one or more result accumulation periods. The beginning and ending of the recording period must correspond to the beginning and ending of result accumulation periods.

The measurement result outputs are to be made available at the end of each result accumulation period and shall refer to that period.

More than one result accumulation period may be required for an individual measurement.

4.2 *Data output criteria*

4.2.1 *On schedule*

Measurement data output typically occurs shortly after the end of each result accumulation period specified by the measurement schedule. Alternatively, the exchange may store the data in its memory for limited periods, e.g. in the event of contention for output resources.

4.2.2 *On demand*

(For further study.)

4.2.3 *On exception*

The exchange should be able to provide measurement data when specified criteria are met, for example, when the rate of incoming call attempts exceeds a particular value.

4.3 *Data output routing*

4.3.1 *To a local or remote terminal*

Measurement data should be able to be routed for printing or display on designated terminals which are either directly connected to the exchange or remotely connected via dedicated or switched circuits.

4.3.2 *To an external processing centre*

Measurement data should be routable to external locations such as OMC that provide data collection and analysis functions for multiple exchanges.

4.3.3 *To local storage media*

An Administration may require exchanges to store measurement data in bulk memories such as magnetic tapes for later processing and analysis. This could be an alternative to sending the data to an OMC.

4.4 *Priorities*

High priority should be assigned to certain measurements that are essential, e.g. those associated with collection and output of data used for overload detection, network management and accounting. These should not be discontinued during periods of exchange processing congestion (see Recommendation Q.543, § 3.8). Measurements that have been suspended should be resumed in an order that is reverse to the order in which they were suspended.

When recovery procedures are invoked, records associated with call accounting and billing should be retained.

5 Application of measurements

5.1 *Planning and engineering*

Measurement data is essential for planning efficient telecommunication networks that meet specified grade-of-service standards. Analysis of data accumulated over a period of time provides information needed to forecast future demand and to plan and engineer extensions to the network.

5.2 *Operation and maintenance*

Operation and maintenance functions are supported by the following types of measurement data:

i) performance data pertaining to call handling irregularities and delays;

ii) availability data for the exchange, its subsystems, and its connecting subscriber lines and inter-exchange circuits;

iii) load on various components of the exchange.

The above data may be used to evaluate exchange and network performance and to plan rearrangements to improve the service provided by the existing network equipment.

5.3 *Network management*

Data for network management includes certain traffic and performance measurements and status indications. These are used to detect abnormalities in the network and to automatically enable, or allow manual operation of, network management controls. In some cases, the data must be analyzed to determine whether specified thresholds are being exceeded. Since the effectiveness of network management actions depends upon their responsiveness to changing conditions in the network as a whole, it may be appropriate to perform this analysis by a data processing system serving one or more exchanges and display the results at a network management centre. Network management functions are covered in Recommendations E.410 through E.414 and Q.542.

5.4 *Accounting in international service*

Accounting in international service needs to be mutually agreed between Administrations; Recommendations E.230 to E.277 apply.

5.5 *Subdivision of revenue*

Subdivision of revenue is a matter of agreement between RPOAs of the same country. Requirements in this area are a national matter.

5.6 *Tariff and marketing studies*

The studies are intended to identify subscriber needs and trends. Requirements in this area are a national matter.

6 **Call events definition**

This section is applicable to 64 kbit/s circuit switched call attempts. Application to other types of calls or Supplementary Services is for further study.

6.1 *General*

Every call attempt coming from a subscriber line or interexchange circuit moves across a branch of the possible status of call events reference diagram shown in Figure 2/Q.544.

6.2 *Call events detailed description*

6.2.1 *Seizure from a subscriber line or incoming circuit*

This is the starting point for an incoming/outgoing call attempt.

6.2.2 *Valid address*

The incoming/originating seizure is successfully accepted by the exchange.

6.2.3 *Not routed call attempt*

A call attempt that is not routed through the exchange, perhaps due to an exchange condition or to receipt of an address that is incomplete or invalid.

6.2.3.1 *False start*

An incoming seizure signal that has been recognized without being followed by digit reception.

6.2.3.2 *Incomplete dialling (time out, abandon)*

An incoming seizure that has been received but the number of received digits is not sufficient to perform call routing.

6.2.3.3 *Invalid address*

An attempt where the received digits do not correspond to an existing or allowed destination. The call is then given interception treatment (tone or announcements or operators).

6.2.3.4 *Call not routed due to the exchange*

A call attempt where the system cannot perform call routing due to internal reasons (congestion):

1) Blocking through the switching network

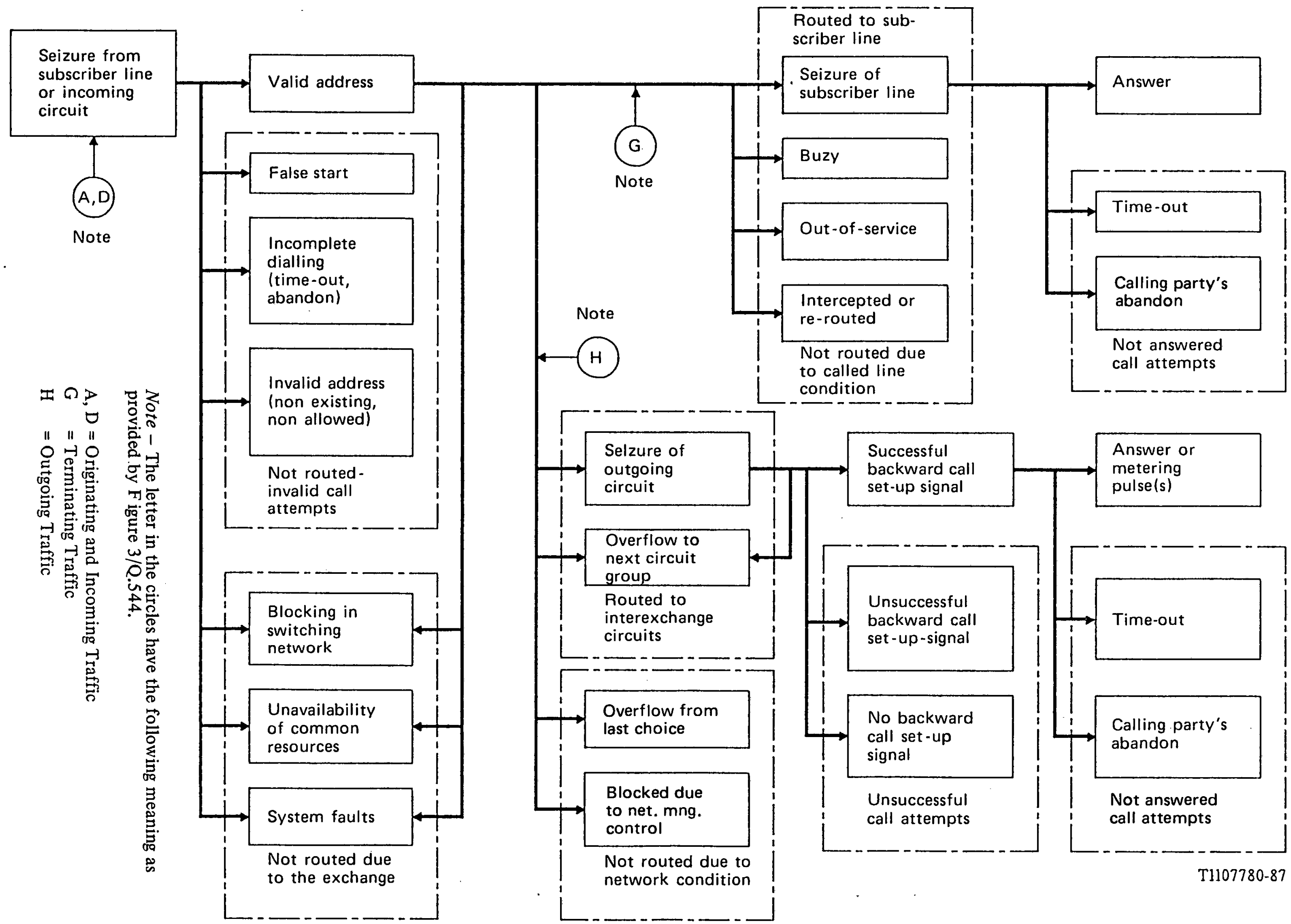
   Although there is an outgoing circuit/subscriber line available for the required destination, the connection cannot be realized through the switching network, and no further routing choices are available.

2) Unavailability of common resources

   Unavailability of service circuits or other common resources (e.g. memory areas)

3) System faults

   Presence of some internal fault in the exchange.



Note – The letter in the circles have the following meaning as provided by Figure 3/Q.544.

A, D = Originating and Incoming Traffic
G = Terminating Traffic
H = Outgoing Traffic

FIGURE 2/Q.544

Call events reference diagram

6.2.4 *Calls routed to interexchange circuits*

These calls are successfully routed to an outgoing circuit available for the required destination or routed to another circuit group for overflow reasons. When making overall exchange measurements, these calls can be counted all together.

6.2.4.1 *Seizure of outgoing circuit*

These are calls that are routed to a specific circuit. They have to be separately counted when making measurements on the outgoing circuit group.

6.2.4.2 *Overflow to next circuit group*

These are calls that cannot be routed on a specific circuit group but are routed to a subsequent routing-choice circuit group. They have to be counted separately when making measurements on the outgoing circuit group. Measurement of the subsequent events associated with these calls are only associated with circuit group on which the calls are routed.

6.2.5 *Calls not routed due to network conditions*

6.2.5.1 *Calls in overflow from the last routing choice (all circuits busy)*

These are calls on which the system cannot perform routing due to the unavailability of outgoing circuits towards the required destination.

6.2.5.2 *Calls blocked by network management controls*

These are call attempts that are suppressed by the exchange as a consequence of the application of network controls.

6.2.6 *Successful backward call set-up signal*

These are calls for which a backward signal is received, indicating the conclusion of call routing at a remote exchange, but not answered. The set of signals typically includes:

– end of selection
– address complete
– subscriber line free

6.2.7 *Unsuccessful call attempts*

6.2.7.1 *Receiving an unsuccessful backward call set-up signal*

This occurs when a backward signal is received indicating the impossibility of setting up the call.

These backward signals typically are:

– congestion signals
– subscriber line busy signals
– signals defined as part of the UBM (Unsuccessful Backward set-up information Message) group of messages in CCITT Signalling System No.7 (see Recommendation Q.723).

6.2.7.2 *Not receiving a backward call set-up signal*

These are calls that are abandoned or forced-out before reception of any backward call set-up signal. They include:

– calls abandoned by the calling party
– calls forced out by the expiration of timers.

Note that within these categories of calls there are several types of call disposition that cannot be distinguished by the exchange since they may be characterized by tones, announcements or the lack thereof, for instance:

– ring-back tone
– busy tone
– congestion tone
– announcements
– no tones or announcements
– incompletely dialled calls

6.2.8 *Calls routed to subscriber line*

These are call attempts that are successfully routed to a subscriber line.

6.2.9 *Calls not routed due to called line conditions*

These are unsuccessful call attempts which do not reach answer status due to the particular condition of the called subscriber line:

– busy
– out-of-service
– rerouted call
– no free outlet
– etc.

6.2.10 *Answered calls*

These are calls that reach the "answered" status. Depending on the signalling protocol answered status can be reached in one of the following ways:

– reception of an answer signal
– reception of a metering pulse
– immediate answer status on seizure (of the subscriber line/outgoing interexchange circuit).

The following events are *not* included in this class of calls:

– reception of Re-answer signal
– answer from an intercepting device (automatic or manual) due to call diversion at the transit exchange.

6.2.11 *Not answered call attempts*

These are calls on which an answer signal is not received after a successful backward signal has been received, or after the seizure of the called subscriber line. These include:

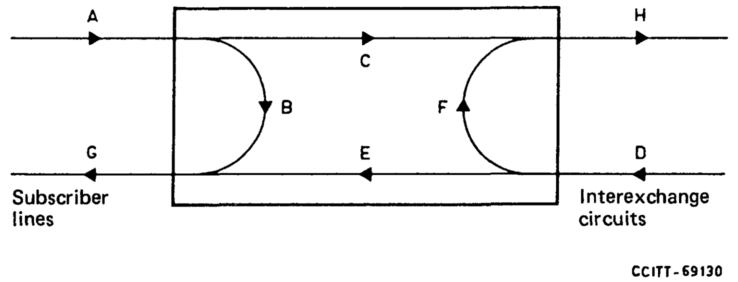
– calls forced-out by the expiration of timers
– calls abandoned by the calling party after listening to ring-back tone.

7 Traffic measurements

This section is applicable to 64 kbit/s circuit switched traffic. "Application to other types of traffic or supplementary services is for further study."

7.1 *General*

Traffic in an exchange can be categorized as shown in Figure 3/Q.544. All measurements listed in this section can be obtained by recording and analyzing events that can be experienced by calls.



A Originating traffic
B Internal traffic
C Originating outgoing traffic
D Incoming traffic
E Incoming terminating traffic
F Transit traffic
G Terminating traffic
H Outgoing traffic

FIGURE 3/Q.544

Exchange traffic categories

It is not intended that every exchange should be required to make all the different measurements in this Recommendation. Due to the application of various signalling methods and differing switching system designs, some variation of the measurements might be appropriate in a specific exchange. For example, an Administration may require more detailed counts of events to permit a meaningful call failure analysis on a specific exchange. Furthermore, the traffic categories to which any measurement relates may vary depending on system design, on system application and measurement utilization.

Measurements may be combined into sets appropriate to a specific type of exchange, for example, local or transit. In particular, Administrations may consider that, by the use of a few measurement sets, it is possible to satisfy the majority of their requirements.

7.2 *Overall measurements*

The following measurements are applicable to the total traffic of an exchange. Due to possible variations in sytem design, the traffic categories to which any measurement relates may vary from that shown in the following text. Figure 3/Q.544 illustrates the exchange traffic categories.

7.2.1 *Originating traffic*

a) Originating call attempts.

b) Invalid call attempts for example:
   - no dialling,
   - incomplete dialling,
   - invalid number dialled.

c) Call attempts not routed due to the exchange, for example, due to:
   - blocking through the switching network,
   - unavailability of common resources,
   - system faults.

d) Internal call attempts.

7.2.2 *Incoming traffic*

a) Incoming seizures.

b) Invalid call attempts for example:
   - incomplete dialling,
   - invalid number dialled.

c) Call attempts not routed due to the exchange, for example, due to:
   - blocking through the switching network,
   - unavailability of common resources,
   - system faults.

d) Transit call attempts.

7.2.3 *Terminating traffic*

a) Call attempts routed to subscriber lines.

b) Call attempts not routed due to line condition.

7.2.4 *Outgoing traffic*

a) Outgoing call attempts routed to an interexchange circuit.

b) Call attempts not routed due to network condition.

c) Unsuccessful call attempts.

7.2.5 *Service utilization*

The exchange should be able to measure the utilization of each type of basic and supplementary service it provides. The mix of services and the corresponding exchange measurements depends upon switching system capabilities and Administration policies.

7.3 *Interexchange circuit groups*

The measurements apply to individual circuit groups. All circuit groups should be measurable. For traffic intensity, it may be desirable to measure all circuit groups simultaneously. Information for estimating the average number of circuits in service during the result accumulation period should be provided in addition to the traffic data for each circuit group.

7.3.1 *Incoming traffic*

Incoming traffic is understood to be:

- the traffic on incoming circuit group,
- the incoming traffic on both-way circuit groups.

The following parameters should be measured:

a) traffic intensity,

b) number of seizures.

7.3.2 *Outgoing traffic*

Outgoing traffic is understood to be:

- the traffic on outgoing circuit groups,
- the outgoing traffic on both-way circuit groups.

The following parameters should be measured:

a) traffic intensity,

b) number of seizures,

c) number of call attempts overflowing from the group,

d) answered call attempts.

7.4 *Subscriber line groups*

These measurements are applicable to groups of subscriber lines that share switching network access paths. The lines served by a particular line concentration unit of a local exchange would be an example of such a group. In systems where traffic levels on such line groups could result in failure to meet grade of service objectives, appropriate measurements for load balancing purposes should be provided.

a) Originating calls
   i) Number of call attempts
   ii) Number of call attempts resulting in an outgoing seizure
   iii) Number of answered calls
   iv) Traffic intensity

b) Terminating calls
   i) Number of call attempts
   ii) Number of answered calls
   iii) Traffic intensity

c) Internal (e.g. intra-concentrator calls)
   i) Number of call attempts
   ii) Number of answered calls
   iii) Traffic intensity

7.5 *Auxiliary units*

Auxiliary units provide functions such as multifrequency signalling, tones, announcements, and access to operators. Grouping of auxiliary units may vary with system implementation characteristics. Groups in this section refer to system independent functional groups. Some systems may allow calls to wait for an auxiliary circuit of one is not immediately available.

The measurements indicated below are intended to provide information for the dimensioning of auxiliary units. They should be provided for each group which may require dimensioning. Measurements may be activated for any specified list of auxiliary units. Information for estimating the average number of units in service during the result accumulation period should be provided in addition to the traffic data for each circuit group:

a) traffic intensity,
b) number of seizures,
c) number of bids not served.

7.6 *Control unit(s)*

These measurements are highly system dependent and therefore no specific recommendations can be made. However, it is essential that systems will have provisions for determining the utilization of control equipment, such as processors, for dimensioning, planning, and grade of service monitoring of the exchange.

7.7 *Call attempt destinations (see also § 9.3)*

These measurements are used to assess the probability of success on calls to various destinations and may be used in deciding on any network management actions considered necessary. The number of destination codes specified for measurement at any one time may be limited. For any specified destination code, the following parameters should be measured:

a) number of call attempts,
b) number of call attempts resulting in an outgoing seizure,
c) number of answered calls.

Intensity measurements for specified destination codes may be required by some Administrations for traffic engineering purposes.

8 Exchange performance and availability measurements

8.1 *Performance measurements*

For monitoring the exchange grade of service, a certain number of parameters should be observed. They may include the measurements given in Recommendation E.543 for delay grade of service monitoring. However, other processing delays (see relevant paragraphs of Recommendation Q.543) may be observed for complete monitoring of the exchange grade of service.

Measuring processing delays on a per call or statistical basis could be burdensome to the exchange. Moreover, some processing delays may not be measurable with an acceptable time accuracy and others may not be easily measured by the exchange itself.

Operating procedures of Administrations will impose constraints on the accuracy of the measurements for grade of service monitoring purposes. When such accuracy requirements allow, it may be possible to measure processing delays on a sample or test call basis. Requirements in this area are therefore a national matter.

8.2 *Availability measurements*

The exchange should record the beginning and ending time of all detected instances during which service is unavailable to one or more exchange terminations. The recorded information should permit the determination of the number and identity of terminations affected if possible.

9 Data for network management

9.1 *General*

Procedures for network management are specified in Recommendations E.410 through E.414. Those procedures make use of data from exchanges to determine overall network performance and, when required, appropriate control actions. Much of the data required for network management is also needed for other operation and maintenance functions. However, effective network management requires control actions to be executed quickly in response to changing network and traffic conditions. Therefore, exchanges that Administrations have designated to provide network management functions must be able to provide traffic and status data to other exchanges and network management centres on a pre-arranged basis or when triggered by a specific event, such as an overload condition. The network management functions provided by any specific exchange will depend upon factors such as its size, position in the network, and Administration policies.

Details of traffic measurement requirements for network management are found in Recommendation E.502. Most of the information required for network management operations can only be generated by the exchanges and consist of two general categories of data:

a) Network status information, for example:
   - busy/idle status of circuit groups
   - individual equipment's availability
   - alarms
   - network management action (controls) in effect

   Status information generally does not require measurements.

b) Network traffic load and performance information, for example:
   - number of bids per route per hour
   - answer/seizure ratio per route per destination.

This type of information requires "real-time" monitoring of network performances via exchange measurements, and it is specifically the subject of this part of the Recommendation. The objects and entities of measurement are given in full details by §§ 9.2, 9.3 and 9.4.

The exchange generated information can be:

- utilized at the source exchange, if network management actions are taken locally,
- transmitted to other exchanges or elements of the TMN (typically to network management centres) for possible network management actions.

It should be noted that exchange internal overload controls are complementary to network management functions, and the information generated by the internal overload monitoring system can also be used for network management functions. Exchange performance under overload conditions is dealt with in Recommendation Q.543, § 3.

9.2 *Management on interworking circuit groups*

9.2.1 *General*

Performance monitoring of interexchange circuit groups for network management purposes should be performed on outgoing traffic. This is where the offered and routed traffic can be seen.

Circuit group monitoring should be organized on the basis of individual interexchange circuit groups. It should be possible to monitor the performance of all circuit groups. However, the number of circuit groups to be monitored simultaneously at an exchange and the length of data accumulation periods will depend on many aspects of the network management implementation and the function of the exchange in the network. For example, a large transit exchange may require performance monitoring on a large percentage of its outgoing circuit groups while a local exchange may only require monitoring on a few groups.

It should be possible to readily activate/deactivate measurements on circuit groups.

9.2.2 *Entities to be measured on interexchange circuit groups*

The following measurements should be made on outgoing interexchange circuit groups for network management purposes:

a) outgoing bids (see Note)
b) outgoing seizures (see Note)
c) overflow bids (see Note)
d) answers received
e) count of calls affected by network management circuit group controls.

Note – Any two of these measurements are necessary. The third can be derived from the other two.

9.2.2.1 *Additional measurements required on international circuit groups at international transit exchanges*

– transit bids (international traffic only)
– incoming seizures (international transit traffic only).

9.2.3 *Calculated network performance parameters*

The entities of measurement in § 9.2.2 can be used to calculate all the network management performance parameters required for network management on the basis of (Draft) Recommendation E.411 as follows:

a) bids per circuit per hour
b) seizures per circuit per hour
c) percentage overflow
d) answer/seizure ratio
e) answer/bid ratio
f) mean holding time per seizure.

Depending on the type of network management implementation the network performance parameters can be calculated at the source exchange, or in other elements of the TMN, consistent with the distribution of the network management functions in the TMN.

9.3 *Measurements on call destinations*

9.3.1 *General*

Depending on the network management implementation and the function of the exchange in the network, the exchange should be able to make traffic measurements to different numbers of destinations indicated on a preliminary basis to be critical destinations. Call destinations can be represented by country codes, area codes, exchange codes or any combination of them.

Measurement by destination is essential for the implementation of the hard-to-reach network management feature. Typically, traffic measurements by destination will be limited to a predetermined set of destination codes (e.g. country or area code). It should be possible to readily expand the scope of the measurements within a focused area when certain thresholds are exceeded.

9.3.2 *Entities to be measured on call destinations*

The following are the entities that should be measurable per destination for network management purposes:

a) outgoing bids;

b) outgoing circuit seizures;

c) answers;

d) counts of calls affected by network management controls by type of control.

9.4 *Measurements on exchange resources*

9.4.1 *General*

The exchange should be able to monitor the level of utilization of its own common resources, like processing capacity, call registers, hardware units such as digit senders and receivers, etc., in order to provide the information on exchange congestion level to the network management function (see Recommendation E.411).

Since the common resource monitoring function is also required for overload protection purposes, the same mechanisms of measurement can be used for both functions, namely, exchange overload protection and network management.

9.4.2 *Objects and entities to be measured on exchange resources*

The objects and entities of exchange resources to be measured depend on the system architecture. The decision concerning which kind of specific objects and entities should be measured is therefore left to individual Administrations or Operating Agencies.

SECTION 4

TRANSMISSION CHARACTERISTICS

Recommendation Q.551

TRANSMISSION CHARACTERISTICS OF DIGITAL EXCHANGES

1 Introduction

1.1 *General*

The field of application of this Recommendation is found in Recommendation Q.500.

Note – A high percentage of international calls will have a digital PABX included in the connection. Therefore, Recommendations Q.551-Q.554 are applicable also for digital PABXs with regard to those specific transmission parameters affecting the transmission quality of an international call, for instance Loudness Ratings, noise, talker's and listener's sidetone, echo and stability. These Recommendations primarily concern digital PABXs connected digitally to the international network. However, Administrations may find some of the specification details useful for digital PABXs connected by analogue means to the international network.

The signals taken into consideration are passed through the following interfaces as described in Recommendations Q.511 and Q.512 and Figures 1/Q.551 and 2/Q.551.

- Interface A is for primary digital signals at 2048 kbit/s or 1544 kbit/s.
- Interface B is for secondary digital signals at 8448 kbit/s or 6312 kbit/s.
- Interface C comprises both 4-wire and 2-wire analogue trunk interfaces. Interfaces C_1 4-wire and C_2 2-wire represent possible applications of interface C in Figure 1/Q.511.

Interface C_1 represents a 4-wire and interface C_2 a 2-wire analogue trunk interface. For practical reasons, C_1 and C_2 are further sub-divided into C_{11}, C_{12}, C_{13}, C_{21} and C_{22}.

C_{11} interfaces channel translating equipment. C_{12} and C_{13} interface 4-wire analogue exchanges; C_{12} via the relay sets, C_{13} directly to the switching stages.

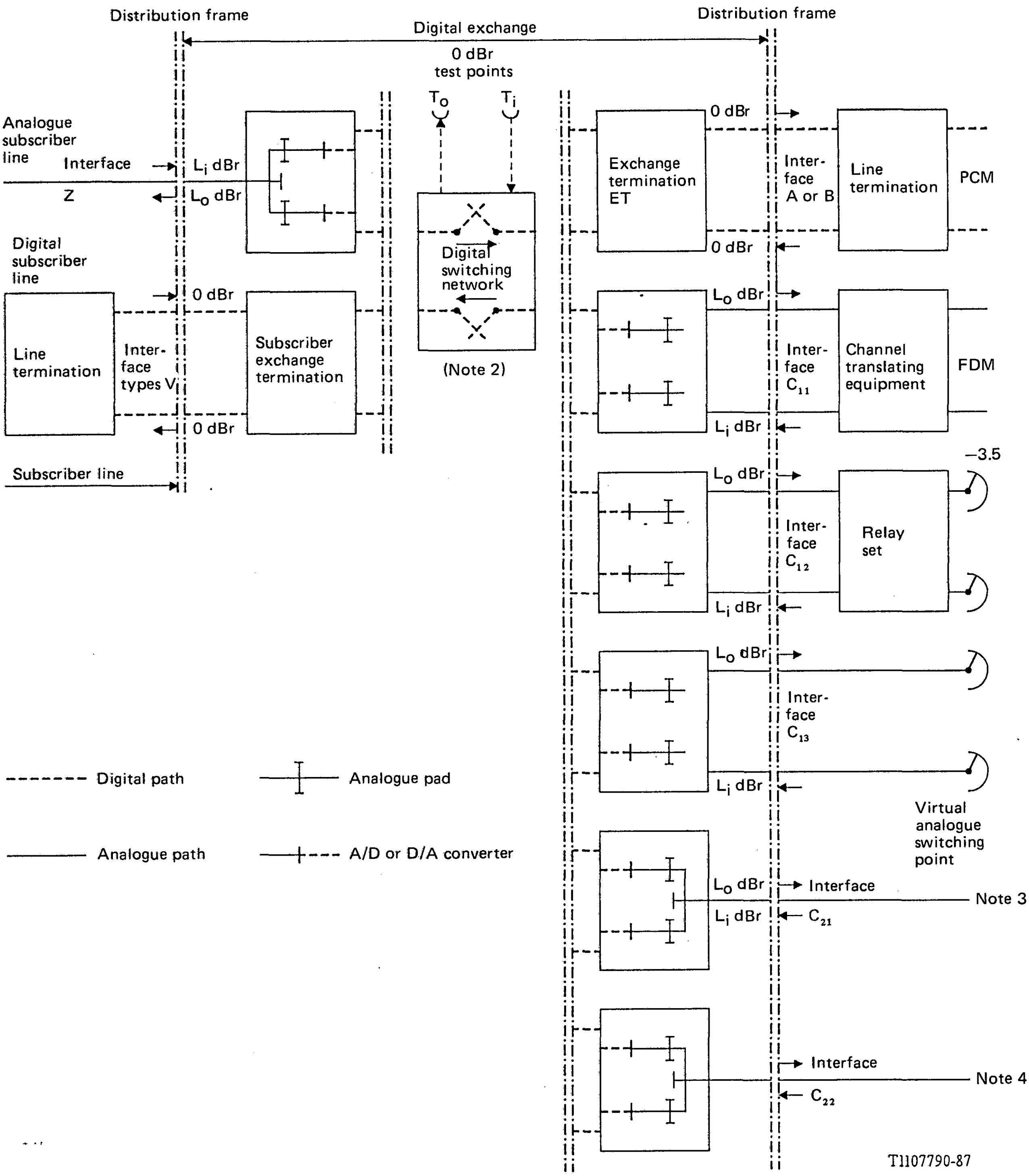
C_{21} is an interface applicable when a 2-wire circuit connects a digital transit exchange with a local exchange, analogue or digital. C_{22} is an interface applicable when a 2-wire circuit connects local exchanges, analogue and/or digital.

See Figures 1/Q.551 and 2/Q.551 for illustration of the principles.

- Interface type V is for digital subscriber line access.
- Interface type Z is for analogue subscriber line access.

Note 1 – Remote analogue exchange concentrators and analogue PABXs may use interface Z for access to a digital exchange.

Note 2 – In the future, differences in circuit configurations with respect to transmission parameters may cause a sub-division of the Z interface.



Note 1 – This figure shows typical examples utilizing the defined interfaces.

Note 2 – Digital loss pads, if required, may be located in the digital switching network or the exchange terminals (see § 1.2.4.1).

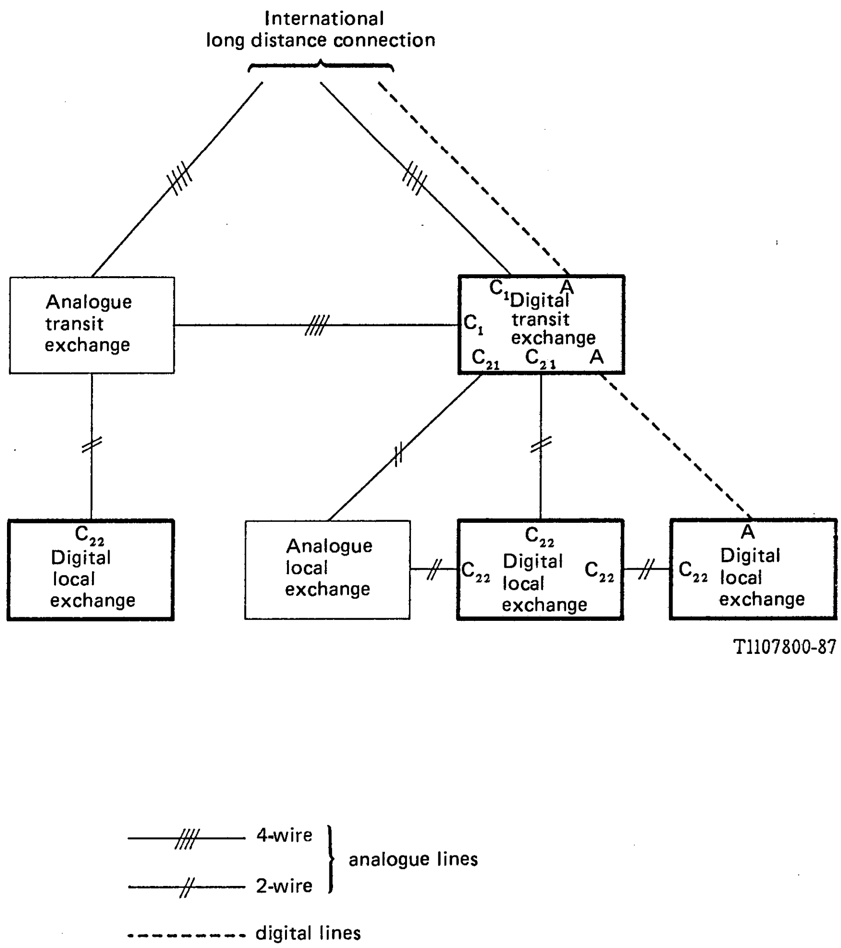
Note 3 – Termination of international long distance switched connections.

Note 4 – Termination of local or 2-wire trunk switched traffic.

Note 5 – The values of L_i and L_o for 2-wire and 4-wire interfaces are, in general, not equal.

FIGURE 1/Q.551

Interfaces, transmission levels and test points at a digital exchange



Note – The trunks between local exchanges carry local traffic only.

FIGURE 2/Q.551

Interfaces in possible network interconnections

Also for ports other than those designated Z, there can exist types whose transmission characteristics have not been defined, even though they may be recognized as being in practical operation. This may be due to CCITT not having considered their international standardization justified, e.g., because of their limited use, or because their function is to coordinate with pre-existing national standards. However, later additions to recommended interfaces are not ruled out (e.g., 4-wire subscriber interface).

Interface types V and Z may appear remote from the exchange through the use of digital transmission facilities. When this occurs, there should be no impact on transmission parameters other than delay. Transmission parameters associated with interface Z include the effects of the equipment provided for interfacing the analogue subscriber line to the digital switching network of the exchange.

Multislot channels are not considered in this Recommendation. This requires further study.

It is necessary to ensure that representative feeding currents are flowing during the measurements of all of these transmission parameters. These feeding currents can contribute to noise, distortion, crosstalk, variation of gain with input level, etc. Therefore, appropriate allowances for this must be made. In some cases, where indicated, the permissible limits quoted include these allowances.

Detailed transmission characteristics for these interfaces are provided in the following Recommendations:

– Recommendation Q.552 for 2-wire analogue interfaces
– Recommendation Q.553 for 4-wire analogue interfaces
– Recommendation Q.554 for digital interfaces.

In the present Recommendations, values given for transmission characteristics relate to the path from an exchange test point to an exchange interface and vice-versa; the overall characteristics for connections involving two interfaces can in most cases be obtained by suitably combining these values (see Recommendation Q.551, § 3).

In the future, other interfaces may be defined.

At this time these Recommendations consider analogue signals which are encoded in accordance with Recommendation G.711. Other coding laws may be defined in the future and these Recommendations will need to take them into account.

The transmission characteristics of voice-frequency (VF) connections through a digital transit exchange should in principle provide performance in accordance with Recommendations G.712, G.713 and, where applicable, Q.45 *bis* (see also Recommendation G.142).

The principles of Recommendation G.142 and the limits of Recommendations G.714 and G.715 have been used as a basis for establishing the transmission characteristics for analogue voice frequency connections specified in §§ 2 and 3 of Recommendations Q.552 and Q.553, respectively. The limit values are not necessarily identical with those specified in the G-Series, since in the case of a connection through the exchange, additional allowances generally have been made for cabling (see § 2). The principles of Recommendations G.714 and G.715 have been used for the analogue/digital test connections referred to in §§ 2 and 3 of Recommendations Q.552 and Q.553, respectively.

The values given are to be considered as either "design" or "performance objectives" according to the explanations of the terms given in Recommendation G.102 (Transmission performance and objectives and recommendations) and the particular context.

The specification clauses in this Recommendation exclude the effects of auxiliary functions such as echo suppression, echo cancellation or transmission to the subscriber of metering impulses, or of non-telephony functions such as telemetering over the subscriber pair.

1.2 *Definitions*

1.2.1 *Exchange test points, exchange input and output and half-connections*

1.2.1.1 **exchange test points**

The exchange test points shown in Figure 1/Q.551 are defined for specification purposes. They may not physically exist in an exchange but may be accessed via the digital switching network. In this case, some or all of the switching network will be included in the path from the exchange interface to the access points.

The transmission parameters affected by this means of access are the absolute group delay and possibly jitter and wander and bit error ratio. For most other parameters, either the exchange test points or the access points are located such that end-to-end performance can be determined by suitably combining performances between each interface and either the exchange test points or the access points.

1.2.1.2 **exchange input and output**

The exchange input and output for a connection through a digital exchange are located at the interfaces identified in § 1.1 and shown in Figures 1/Q.551 and 2/Q.551.

The exact position of each of these points depends on national practice, and it is not necessary for the CCITT to define it.

However, the applicability of recommended values to points arbitrarily located is subject to certain restrictions:

- for analogue interfaces, as referred to in § 2 of this Recommendation (maximum length of exchange cabling between exchange equipment ports and the interface);
- for digital interfaces, as also mentioned in § 2 (maximum loss between exchange interfaces and connected equipment, e.g., digital line or higher order multiplex equipment).

1.2.1.3 *Half-connections*

input connection – A unidirectional path from an interface of a digital exchange to an exchange test point.

output connection – A unidirectional path from an exchange test point to an interface of a digital exchange.

half connection – A bidirectional path comprised of an input connection and an output connection, both having the same exchange interface.

Note 1 – These terms may be qualified by the words analogue or digital, the qualification signifying the property of the exchange interface.

Note 2 – An analogue input (output) (half) connection may be further qualified by the words 2-wire or 4-wire.

Note 3 – Refer to Recommendation Q.9 for additional information.

1.2.2 *Relative levels*

1.2.2.1 *Exchange test points*

The nominal relative level at the input and output exchange test points is assigned the value 0 dBr.

1.2.2.2 *Analogue interfaces*

The nominal relative level at the exchange input point is designated L_i.

The nominal relative level at the exchange output point is designated L_o.

1.2.2.3 *Digital interfaces*

The relative level to be associated with a point in a digital path carrying a digital bit stream generated by a coder lined-up in accordance with the principles of Recommendation G.101 is determined by the value of the digital loss or gain between the output of the coder and the point considered.

If there is no such loss or gain the relative levels at the exchange input and output points (i.e., digital interfaces V, A and B) are by convention said to be 0 dBr. For further information, see Recommendation G.101, § 5.3.2.4.

Note – The digital level may be established using measuring equipment in accordance with Recommendation O.133.

Relative level has no meaning for digital bit streams that are not derived from real or simulated analogue sources.

1.2.3 *Measurement conditions*

1.2.3.1 *Common measurement conditions*

All digital signal processing devices which affect bit integrity of the 64 kbit/s path (e.g., digital loss pads, code converters, digital echo control devices, digital speech interpolation apparatus or all-zero suppressors) must be rendered inoperative when measuring the transmission parameters of this Recommendation. However, if the nominal transmission loss, NL, for speech connections is implemented by a digital loss pad, the loss pad must *not* be inoperative for the output connection when measuring parameters dependent on NL.

Where measuring transmission parameters between 2-wire ports is considered necessary, the opposite direction of transmission must be interrupted in order to avoid disturbing effects due to reflections at hybrids.

In addition, a quiet code, i.e., a PCM signal corresponding to decoder output value 0 (μ-law) or output value 1 (A-law), with the sign bit in a fixed state should be applied to the exchange test point.

Note – These patterns are slightly different from the idle code produced by an exchange (see e.g., Recommendation Q.522, § 2.12).

1.2.3.2 *Reference frequency*

For the reference frequency, Recommendation O.6 applies:

– A reference test frequency of 1020 Hz is recommended for test frequency generating circuits or instruments that provide reference test frequencies. The specified frequency tolerance should be +2 to −7 Hz.

1.2.3.3 *Impedance*

Unless otherwise specified, measurements at analogue interfaces shall be made under nominally matched conditions.

Note – The preferred interpretation of this statement should be that the nominal exchange impedance should be used as the internal impedance of the analogue test generator and the analogue level meter. However, under some circumstances it may be preferable to use a low impedance generator and a high impedance meter which corresponds to an exact matching to the actual exchange impedance. (Losses measured according to the two methods will only differ by a small amount, in the same order of magnitude as the loss of a very short subscriber cable.)

1.2.3.4 *Test levels at analogue interfaces*

At the reference frequency, test levels are defined in terms of the apparent power relative to 1 mW.

Where no value is given, the test level should be −10 dBm0.

At frequencies different from the reference frequency, test levels are defined as having the same voltage as the test level at the reference frequency. Measurements are based on the use of a test generator with a frequency-independent EMF.

The above considerations are primarily concerned with measurements at discrete frequencies. Their impact on the measurement at interfaces with complex impedances of broadband signals (e.g., random or quasi-random noise with defined spectral intensity) and *vice versa* needs further study.

1.2.4 *Transmission loss*

1.2.4.1 *Nominal transmission loss*

A connection through the exchange (see Figure 1/Q.551) is established by connecting in both directions an input located at one interface to an output located at another interface.

The **nominal transmission loss for a connection through an exchange** is equal to the difference of the relative levels at the input and the output.

$$NL = (L_i - L_o) \text{ dB}$$

The **nominal transmission loss between the input at an analogue interface and the exchange test point** is defined as:

$$NL_i = L_i$$

The **nominal transmission loss between the exchange test point and the output of an analogue interface** is defined as:

$$NL_o = -L_o$$

This is equal to the nominal "composite loss" (see definition in Blue Book, Fascicle I.3) at the reference frequency. See also Recommendation G.101, § 5.3 and Supplement No. 1 in Fascicle VI.5 of the CCITT Blue Book.

Note 1 – The nominal transmission loss, NL, may be implemented by an analogue loss pad. It may also be implemented by a digital loss pad. In the latter case, the digital loss pad may be on the incoming side of the digital switching network, or on the outgoing side of the digital switching network or both.

As a general principle, the use of digital loss pads should be avoided because bit integrity is lost for digital services and additional transmission impairments are introduced for analogue services.

However, it is recognized that during the transition stage to a completely digital network, existing national transmission plans may require digital pads to be inserted for speech.

In addition, connections in a future ISDN used for voice can be expected to contain other devices which destroy bit integrity of the 64 kbit/s path (e.g., code converters, digital echo control devices, digital speech interpolation apparatus, or all-zero-suppressors). Provision must be made to render all such devices inoperative when necessary. See Recommendation Q.521, § 4.3.7.

Note 2 – The nominal transmission loss of the exchange may be different in the two directions.

1.2.5 *Attenuation frequency distortion*

The attenuation frequency distortion (loss distortion) is the logarithmic ratio of output voltage at the reference frequency (nominally 1020 Hz), $U(1020\ \text{Hz})$, divided by its value at frequency f, $U(f)$:

$$LD = 20 \log \frac{U(1020\ \text{Hz})}{U(f)}$$

See Recommendation G.101, § 5.3 and Supplement No. 1 in Fascicle VI.5 of the CCITT Blue Book.

1.2.6 *Digital parameters*

1.2.6.1 **bit integrity**

The property of a digital half connection of a digital exchange in which the binary values and the sequence of the bits in an octet at the input of the half connection are reproduced exactly at the output.

Note – Digital processing devices such as A/μ law converters, echo suppressors and digital pads must be disabled to provide bit integrity.

2 **Characteristics of interfaces**

The interfaces taken into account are those of Figures 1/Q.511 and 1/Q.551. For voice-frequency interfaces (C and Z), the electrical parameters refer to the appropriate distribution frame (DF), on the assumption that the length of the cabling between the DF and the actual exchange does not exceed 100 m (exchange cables). In this respect, Recommendation Q.45 *bis* § 3 applies. For corresponding limitations on the location of digital interfaces, see Recommendation G.703.

2.1 *Two-wire analogue interfaces*

Detailed transmission characteristics of 2-wire analogue interfaces are provided in Recommendation Q.552.

2.1.1 *Interface Z*

The interface Z provides for the connection of analogue subscriber lines and will carry signals such as speech, voice-band analogue data and multi-frequency push button signals, etc. In addition, the interface Z must provide for DC feeding the subscriber set and ordinary functions such as DC signalling, ringing, metering, etc., where appropriate.

Other extraordinary (supplementary) functions, as mentioned in § 1.1 above, are not considered as forming part of the exchange but rather of the line, i.e. included on the exchange side. Since the interface Z ordinarily terminates the subscriber line, it is necessary to control the impedance and unbalance about earth. (While this will also be true of equipment providing supplementary functions, its specification is not dealt with here.)

When the Z interface is used as an extension line interface of a digitally connected digital PABX, additional functions may be required to provide special features of the PABX. If the extension line is entirely contained within a building some attributes of the PABX such as longitudinal conversion loss, may no longer need to be specified and others may take special values.

2.1.2 *Interface C_2*

The interface C_2 provides for the connection of 2-wire analogue circuits to other exchanges.

The interface C_{21} provides the termination of outgoing and incoming international long-distance connections and possibly national connections also with the exchange acting as a transit switch (see Figure 2/Q.551).

The interface C_{22} provides for the connection of a 2-wire trunk line. Typical is the interconnection of a Z interface with a C_{22} interface in a local exchange for routings through the existing 2-wire analogue trunk network. A C_{22} interface cannot be part of the international 4-wire chain.

2.2 *Four-wire analogue interfaces*

Detailed transmission characteristics of 4-wire analogue interfaces are provided in Recommendation Q.553.

2.2.1 *Interface C_1*

The interface C_1 provides for the connection of 4-wire analogue circuits to other exchanges.

According to Figure 1/Q.551, the interface C_{11} of a digital exchange is intended for connection to the channel translating equipment of an FDM system.

According to Figure 1/Q.551, the interface C_{12} of a digital exchange is intended for connection to the incoming and outgoing relay set of an analogue 4-wire exchange (see Figure 1/Q.45 *bis*).

According to Figure 1/Q.551, the interface C_{13} of a digital exchange is intended for connection to a 4-wire analogue switching stage (see Figure 1/G.142, case 5.)

2.3 *Digital interfaces*

Detailed transmission characteristics of digital interfaces are provided in Recommendation Q.554.

2.3.1 *Interface A*

The interface A operating at a rate of 1544 kbit/s or 2048 kbit/s provides for the digital connection of circuits to other exchanges.

2.3.2 *Interface B*

The interface B operating at a rate of 6312 kbit/s or 8448 kbit/s provides for the digital connection of circuits to other exchanges.

2.3.3 *V-type interfaces*

V-type interfaces provide for digital subscriber line access.

V-type interfaces allow the connection to the exchange of a digital subscriber line capable of providing digital subscriber side access for ISDN. The different variants, V_2, V_3 etc., are described in Recommendation Q.512 § 3. It will be seen that the differences lie essentially in multiplexing and in the associated signalling facilities, the transmission requirements being substantially identical, i.e., providing 64 kbit/s B channels, with bit integrity assumed unless the transmission plan specifically requires otherwise. See also Recommendation Q.554, § 2.5.

Note – The designation "V_1" is applied to a reference point which is connected to a basic access digital section.

3 Voice frequency parameters of a connection between two interfaces of the same exchange

3.1 *General*

This section of Recommendation Q.551 provides guidance on obtaining the overall characteristics for connections between two interfaces of the same exchange. For overall connections involving one or more digital interfaces, the results may be interpreted by assuming that ideal send and receive sides (see Recommendations G.714 and Q.715) are connected to the digital inputs and outputs, respectively.

In this section, transmission parameters relating to the path from an exchange interface to an exchange test point will be referred to as input parameters. Transmission parameters relating to the path from an exchange test point to an exchange interface will be referred to as output parameters.

3.2 *Transmission loss through the exchange*

The transmission loss through the exchange is equal to the algebraic sum of the input transmission loss and the output transmission loss.

The overall characteristic for the following parameters can be obtained the same way.

- short-term variation of loss with time;
- attenuation/frequency distortion;
- variation of gain with input level.

3.3 *Group delay*

3.3.1 *Absolute group delay*

"Absolute group delay" refers to the minimum group delay measured in the frequency band 500-2800 Hz.

The absolute group delay through an exchange will very much depend on the exchange architecture and the types of connections involved. Table 1/Q.551 gives estimated mean and 0.95 probability of not exceeding values of round trip delay between interfaces exemplified in Figure 3/Q.551. These values may not be applicable to digital PABXs.

The absolute group delay includes delay due to electronic devices such as frame aligners and time stages of the switching matrix but does not include delays due to ancillary functions, such as echo suppression or echo cancellation.

TABLE 1/Q.551

Round trip delay between interfaces as depicted in Figure 3/Q.551

Figure	Mean µs	0.95 probability of not exceeding µs
a)	900	1500
b)	1950	2700
c)	1650	2500
d)	3000	3900
e)	2700	3700
f)	2400	3500

Note 1 – These values for the absolute group delays are applicable under reference load A conditions as defined in Recommendation Q.543.

Note 2 – These values do not include the propagation delay associated with transmission across the link between the main part and any remotely located parts of a digital local exchange.

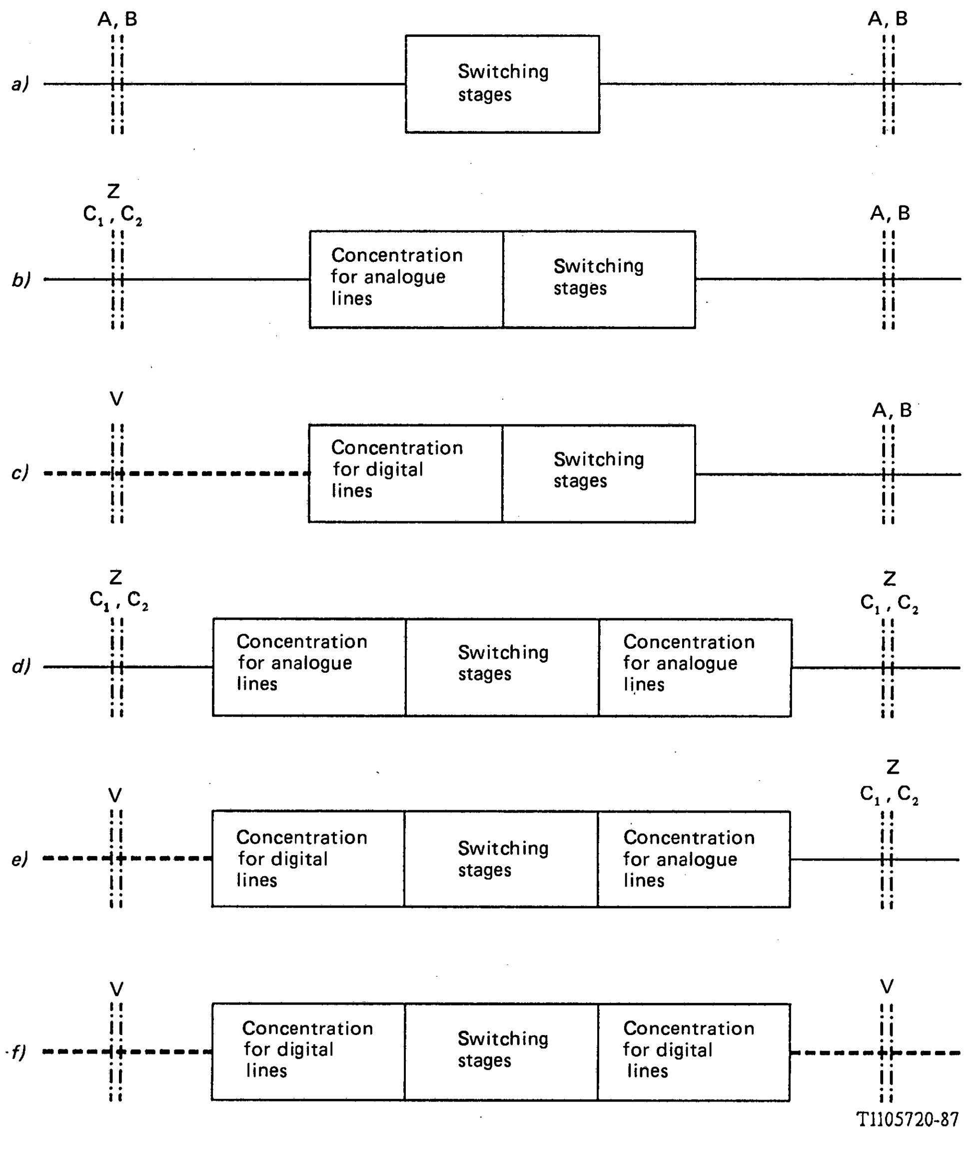


FIGURE 3/Q.551

Exchange configurations as used for estimation of round trip absolute group delay

3.3.2 *Group delay distortion*

The total group delay distortion is equal to the sum of the input and the output group delay distortions.

3.4 *Noise and total distortion*

When evaluating the exchange noise characteristics, it is necessary to consider two components of noise. One of these arises from the PCM translating process, the other from analogue sources e.g., signalling circuits, exchange power supply, line power feeding on both sides of a connection between two interfaces through the same exchange.

The noise arising from the PCM translating process is limited by Recommendation G.712, the noise from analogue sources by Recommendation G.123. This applies to both weighted noise and total distortion. The requirements for weighted noise and total distortion for connections between the same interfaces and through the same exchange are of value for test purposes.

In real connections through the network, usually several connections between different exchanges with different levels and different interfaces apply. This would result in very complex calculations for the overall noise contribution and cannot be handled in a simple way. Consideration of the contribution of noise and total distortion for each individual half connection as specified in Recommendations Q.552 and Q.553 for the case in question should be preferred.

3.4.1 *Weighted noise*

The total psophometric noise power allowed at a Z interface contributed by a whole connection through the exchange Z-Z is approximated by the formula:

$$P_{TN} = P_{AN}\left(1+10^{\frac{L_o - L_i}{10}}\right) + 10^{\frac{90 + L_{IN} + L_o}{10}} \text{ pWp}$$

respective the total noise level

$$L_{TN} = 10 \log \left(\frac{P_{TN}}{1 \text{ pW}}\right) - 90 \text{ dBmp}$$

where

P_{TN}: Total weighted noise power of a whole connection through the local digital exchange Z-Z.

P_{AN}: Weighted noise power caused by analogue functions according to Recommendation G.123, Annex A, i.e., 200 pWp.

L_o: Output relative level at the Z interface.

L_i: Input relative level at the Z interface of the same exchange.

L_{IN}: Weighted noise (idle channel noise) for PCM translating equipment according to Recommendation G.712, i.e., -65 dBm0p

L_{TN}: Total weighted noise level of a whole connection through the local digital exchange Z-Z.

Alternatively the same P_{TN} and L_{TN} can be obtained by adding the relevant values for input and output connections at Z interfaces according to Recommendation Q.552, § 3.3.2.1, observing that the values for L_{INi} and L_{INo} are different from L_{IN}.

However, a small difference in the numerical results occurs due to approximation errors between L_{IN} on the one hand compared with L_{INi} and L_{INo} on the other.

For the C_2 interfaces, similar considerations can be made to obtain the allowed psophometric noise power.

Either calculating the idle channel noise according to Recommendation G.712 (to be maximum -65 dBm0p) together with the analogue noise according to Recommendation G.123 (to be maximum -67 dBm0p) which results in approximately -63 dBm0p. Alternatively, the allowed values for the input and output connections according to Recommendation Q.553, § 3.2.2.1 for equipment with signalling on the speech wires can be combined, giving again approximately -63 dBm0p.

3.4.2 *Total distortion including quantizing distortion*

The method shown below uses the sinusoidal test signal with the reference frequency of 1020 Hz as specified in Recommendation O.132. The ratio of signal-to-total-distortion power for a whole connection through the exchange is given by the formula:

$$\frac{S}{N_T} = L_S + L_o - 10 \log \left(10^{\frac{L_S + L_o - S/N}{10}} + 10^{\frac{L_N}{10}} \right)$$

where

S/N_T: resulting signal-to-total distortion ratio for a whole connection through a digital exchange.

L_S: signal level of the measuring signal in dBm0.

L_o: output relative level of the local exchange in dBr.

S/N: signal-to-total distortion ratio for PCM translating equipment in Recommendation G.712 (whole connection).

L_N: Weighted noise caused by analogue functions according to Recommendation G.123, Annex A, i.e., -67 dBmp.

Note – No band limiting effect on the noise by the encoding process was taken into account to compensate for overall effects. Thus the calculation above is assumed to give the worst case requirements.

This calculation of S/N_T applies to both Z and C_2 interfaces.

Total distortion including quantizing distortion using the noise method as specified in Recommendation O.131 will be the subject of further study.

3.5 *Crosstalk*

Where measurement of the signal to crosstalk ratio between any two complete connections (analogue to analogue) through the exchange is considered necessary, a sine wave test signal at the reference frequency of 1020 Hz and at a level of 0 dBm0 is applied to the analogue 2-wire or 4-wire interface of one connection. An auxiliary low level activation signal, for example a band limited noise signal (see Recommendation O.131) at a level in the range -50 to -60 dBm0 is injected into the input of the connection to be measured. The level produced in any other connection should not exceed -65 dBm0 (value to be further studied).

Care must be taken on the choice of frequency and the filtering characteristics of the selective measuring equipment, in order to avoid that the activating signal and noise affects the accuracy of the crosstalk measurement. This measurement arrangement is shown in Figure 4/Q.551.

Note 1 – The go to return crosstalk of 4-wire connections is covered by Recommendation Q.553 §§ 3.1.4.1.2 and 3.1.4.2.2.

Note 2 – Measurement of NEXT is not required, as it is the same as in a half-connection.

Note 3 – If it is not possible without considerable difficulty to break the return path of the 4-wire loop, reflection should be minimized by making the terminating impedance and the balance impedance equal.

Note 4 – Further study is required to determine whether MORE STRINGENT LIMITS or measurements at additional frequencies should be specified.

3.6 *Discrimination against out-of-band signals applied to the input interface*

The values for these parameters for a complete connection through an exchange are identical to the corresponding values for a half connection. See Recommendation Q.552, § 3.1.6 and Recommendation Q.553, § 3.1.6.

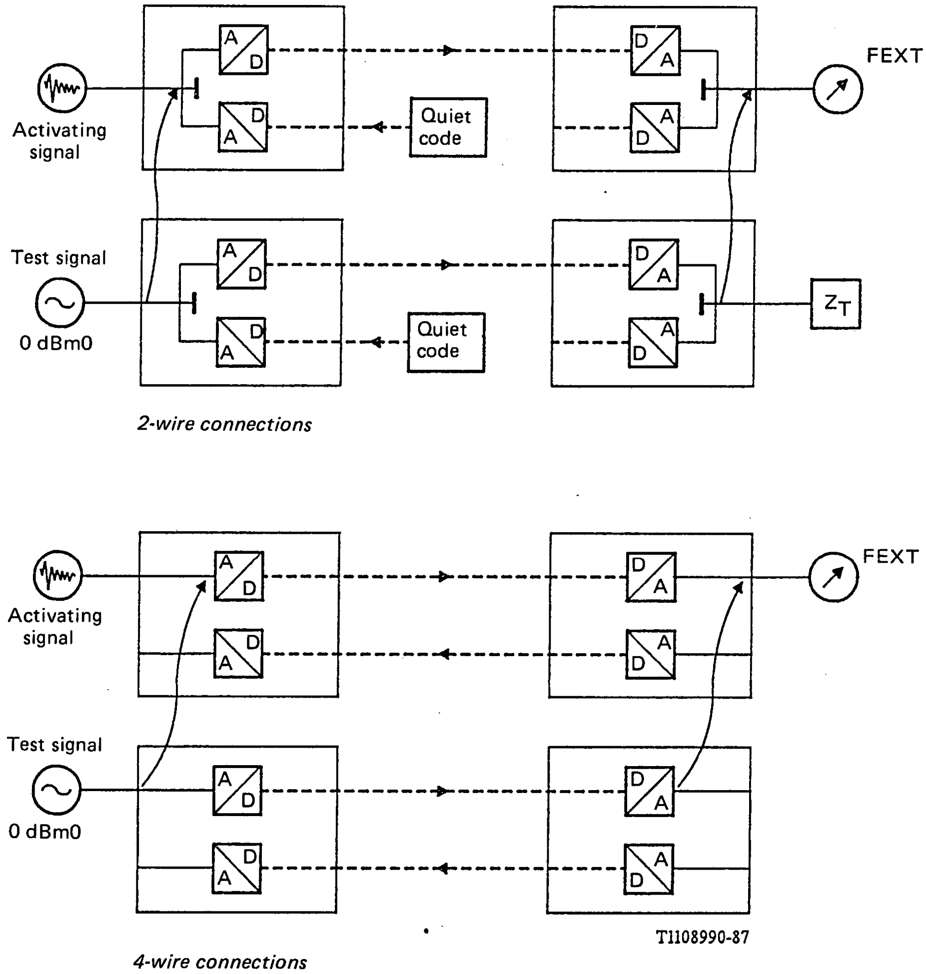


FIGURE 4/Q.551

Measurement of crosstalk between two connections

3.7 *Spurious out-of-band signals received at the output interface*

The values for these parameters for a complete connection through an exchange are identical to the corresponding values for a half connection. See Recommendation Q.552, § 3.1.7 and Recommendation Q.553, § 3.1.7.

3.8 *Echo and stability*

When a complete connection, comprised of a 2-wire analogue half connection and a 4-wire half connection, terminates the international chain, the total stability loss of the national extension is provided by the 2-wire analogue half connection. See Recommendation Q.552, § 3.1.8.

If in a digital exchange (including PABXs), 2-wire half connections (Z or C_2 interfaces) cooperate in such a way that an additional 2-wire – 4-wire – 2-wire is included as part of an international connection, then Recommendation G.122 concerning echo, stability and especially effects of listener echo has to be fulfilled.

The effects of listener echo depend on the maximum total number of loops in a complete connection. Listener echo signals:

– can lead to objectionable "hollowness" in voice communications, and

– can impair the bit error ratio of received voice-band data signals.

4 Exchange transfer function - jitter and wander

The exchange transfer function relates wander at the output of the exchange to wander at the inputs used for synchronization purposes. It is recognized that the approach of using the exchange transfer function to specify the performance of an exchange is not applicable to all implementations (e.g., when mutual synchronization methods are used). The exchange transfer mask is similar to that of a low pass filter with a maximum gain of 0.2 dB, a break point at 0.1 Hz and slope of 6 dB/octave as shown in Figure 5/Q.551.

The higher frequency (jitter) portion of the mask is undefined, but must provide significant attenuation above 100 Hz.

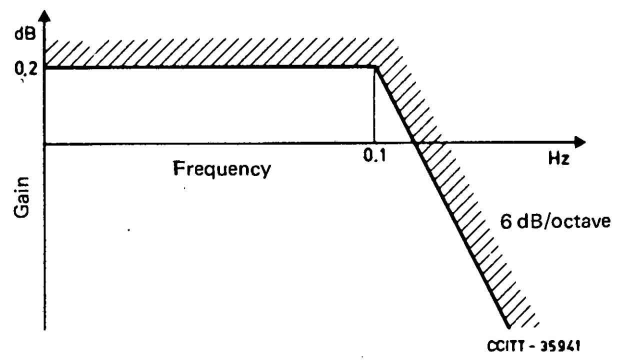


FIGURE 5/Q.551

Exchange transfer function mask

Recommendation Q.552

TRANSMISSION CHARACTERISTICS AT 2-WIRE ANALOGUE INTERFACES OF DIGITAL EXCHANGE

1 General

This Recommendation provides characteristics for:

- 2-wire analogue interfaces (Type C_2 and Z),
- input and output connections with 2-wire analogue interfaces, and
- half-connections with 2-wire analogue interfaces,

in accordance with definitions given in Recommendation Q.551 particularly in Figure 1/Q.551.

The characteristics of the input and output connections of a given interface are not necessarily the same. The characteristics of half-connections are not necessarily identical for different types of interfaces.

This Recommendation is valid for equipment that may terminate an international long-distance connection via 4-wire circuits interconnected by 4-wire exchanges. It also includes, in a separate category, characteristics for interfaces which cannot terminate an international connection and are therefore entirely national in application.

2 Characteristics of interfaces

Note – For measuring 2-wire analogue interface conditions it is necessary to apply a quiet code, i.e. a PCM signal corresponding to decoder output value 0 (μ-law) or output value 1 (A-law), with the sign bit in a fixed state, to the exchange test point T_i, when no test signal is stipulated.

2.1 *Characteristics of interface C_2*

The recommended values of interfaces C_2 are valid for digital exchanges including PABXs with transit functions and routing capabilities for originating and terminating traffic. Depending on the type of traffic to be handled, two different sets of relative levels are required. This suggests subdivision into C_{21} and C_{22} interface specifications. The interface C_{21} provides the termination of outgoing and incoming international long distance connections and possible national connections, with the exchange acting as transit switch. The interface C_{22} provides for the connection of a 2-wire trunk line. A typical example is the interconnection of a Z interface with a C_{22} interface in a local exchange for routing through the 2-wire analogue trunk network. A C_{22} interface cannot be part of the international 4-wire chain (see Figure 2/Q.551).

2.1.1 *Exchange impedance*

2.1.1.1 *Nominal value*

Nominal values of exchange impedance should be defined depending on national conditions. The definition shall include a test network for the exchange impedance. Administrations may want to adopt different test networks corresponding to the cable types used (e.g. unloaded and loaded).

2.1.1.2 *Return loss*

The return loss of the impedance presented by a C_2 interface against the test network for the exchange impedance should comply with the limits given in Figure 1/Q.552.

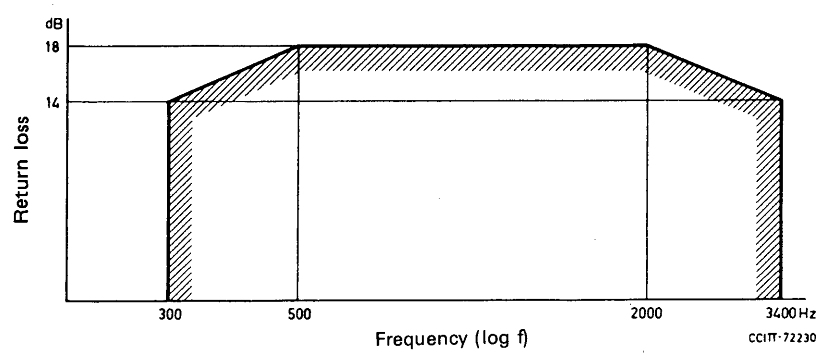


FIGURE 1/Q.552

Minimum value of return loss against the test network for the exchange impedance at a 2-wire interface

2.1.2 *Impedance unbalance about earth*

The longitudinal conversion loss (LCL), defined in Recommendation G.117, § 4.1.3, should exceed the minimum values of Figure 2/Q.552 with the equipment under test in the normal talking state, in accordance with Recommendation K.10.

Note 1 – An Administration may adopt other values and in some cases a wider bandwidth, depending on actual conditions in its telephone network.

Note 2 – A limit may also be required for the transverse conversion loss (TCL), as defined in Recommendation G.117, § 4.1.2, if the exchange termination is not reciprocal with respect to the transverse and longitudinal paths. A suitable limit would be 40 dB to ensure an adequate near-end crosstalk attenuation between interfaces.

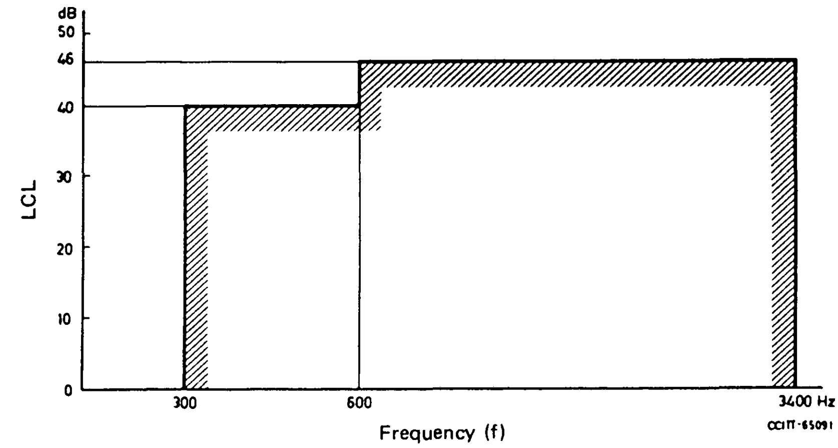


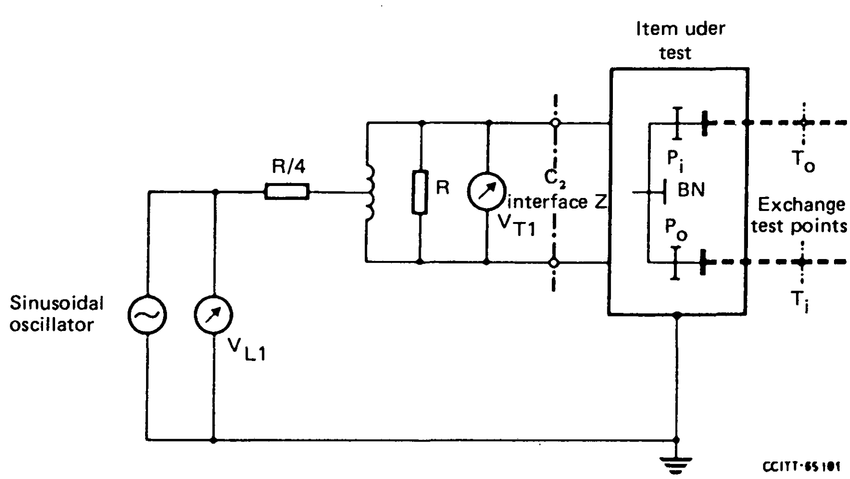
FIGURE 2/Q.552

Minimum values of LCL measured in the arrangement shown in Figure 3/Q.552

Test method

Longitudinal conversion loss should be measured in accordance with the principles given in Recommendation O.121, §§ 2.1 and 3. Figure 3/Q.552 shows an example of the basic measuring arrangement for digital exchanges.

Measurements of the longitudinal and transverse voltages should preferably be done with a frequency-selective level meter.



BN: Balance network

R should be in the range of 600-900 Ω.

Longitudinal convertion loss (LCL) $= 20 \log_{10} \left| \frac{V_{L1}}{V_{T1}} \right|$ dB

Note — Special care must be taken in those applications using active hybrids.

FIGURE 3/Q.552

Arrangement for measuring LCL

2.1.3 *Longitudinal interference threshold level*

Under study.

2.1.4 *Relative levels*

2.1.4.1 *Nominal levels*

2.1.4.1.1 *Interface C_{21}*

C_{21} interfaces should meet the recommended values for Z interfaces in § 2.2.4.1 if no loss compensation comparable to § 2.2.4.3 is provided.

2.1.4.1.2 *Interface C_{22}*

To adjust the transmission loss of a digital transmission section to the values of national transmission planning for local or national traffic, depending on the relative levels given in §§ 2.1.4.1.1 and 2.2.4.1, the following ranges encompass the requirements for C_{22} interfaces of a large number of administrations:

- input level: $L_i = +3.0$ to -7.0 dBr in 0.5 dB steps;
- output level: $L_o = +1.0$ to -8.0 dBr in 0.5 dB steps.

According to Annex E of Recommendation G.121 (column 2 of Table E-1/G.121), the range of transmission loss from 1.0 to 8.0 dB for the digital transmission section encompasses the requirements of a large number of administrations.

In order to compensate loss on long toll or junction lines, an administration may, to satisfy local conditions, choose values of relative levels derived from the basic values as follows:

$$L'_i = L_i + \text{x dB}$$

$$L'_o = L_o - \text{x dB}$$

where x should take a negative value. The value of x is in national competence. Such compensation of loss require careful selection and application of balance networks.

It has been recognized that it is not necessary for a particular design of equipment to be capable of operating over the entire level range.

2.1.4.2 *Tolerances of relative levels*

The difference between the actual relative level and the nominal relative level should lie within the following values:

- input relative level: -0.3 to $+0.7$ dB;
- output relative level: -0.7 to $+0.3$ dB.

These differences may arise, for example, from design tolerances, cabling between analogue ports and the (DF), and adjustment increments.

Note – Level adjustment procedures are given in Recommendation G.715, § 2.1.

2.2 *Characteristics of interface Z*

The recommended values of interface Z are valid for digital local exchanges, PABXs and digital remote units. For PABXs, see Recommendation Q.551, § 2.1.1

2.2.1 *Exchange impedance*

2.2.1.1 *Nominal value*

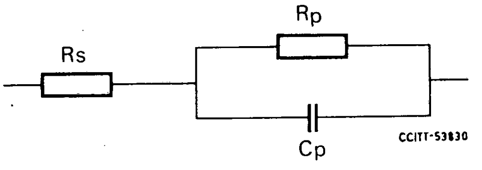
The principal criterion governing the choice of the nominal value of the exchange impedance is to ensure an adequate sidetone performance for telephone sets, particularly those operated on short lines. If this criterion is met, the impedance will also be suitable for subscriber lines fitted with voice band modems.

As a general rule a complex exchange impedance with a capacitive reactance is necessary to achieve satisfactory values of stability, echo and sidetone. For additional information, see Supplement No. 2, Fascicle VI.5 of the CCITT Blue Book and Recommendations G.111 and G.121.

The use of the preferred configuration below will minimize the diversity of types of exchange impedances. At present no unique component values can be recommended. However, to provide guidance for administrations, examples of nominal values chosen by some administrations are given in Table 1/Q.552.

TABLE 1/Q.552

Test networks for exchange impedances being considered



	Rs (ohms)	Rp (ohms)	Cp (farads)
NTT	600	infinity	1 μ
Austria, FRG	220	820	115 n
USA	900	infinity	2.16 μ
BT	300	1000	220 n
New Zealand	370	620	310 n

Note 1 – The test network and the component values represent a configuration that exhibits the required exchange impedance. It need not necessarily correspond to any actual network provided in the exchange interface.

Note 2 – The range of component values reflects the fact that there are substantial differences in the sensitivity and sidetone performance of the various telephone instruments throughout the world. In general, the combination of short lines and sensitive telephone sets might be rather common in the future due to increased use of remote concentration. In order to control sidetone performance, Administrations need to take into account telephone set parameters. Not only should the parameters of existing telephone sets be considered but also the parameters that may be desirable in the future to allow improvement in sidetone performance to be achieved.

Note 3 – It may be necessary to group the subscriber lines of a particular exchange into classes, each requiring a different exchange impedance of the Z interface.

2.2.1.2 *Return loss*

Tolerances are needed for values of exchange impedance. For this purpose the return loss of the impedance presented by a 2-wire port against the test network for the exchange impedance should comply with limits which depend on the particular conditions of the subscriber network considered. These are given in the template of Figure 1/Q.552.

Some administrations may want to specify higher values. Examples of limit values for the return loss, currently accepted by some administrations, are given in Table 2/Q.552 for guidance.

TABLE 2/Q.552

Examples of limit values of return loss against the exchange impedance

FRG	14 dB at 300 Hz, rising (log *f* scale) to 18 dB at 500 Hz remaining at 18 dB to 2000 Hz and then falling (log *f* scale) to 14 dB at 3400 Hz.
NTT	22 dB: 300-3400 Hz.
BT	18 dB: 200-800 Hz; 20 dB: 800-2000 Hz; 24 dB: 2000-4000 Hz.
USA	20 dB: 200-500 Hz; 26 dB: 500-3400 Hz.
Austria	14.5 dB at 300 Hz, rising (log *f* scale) to 18 dB at 500 Hz remaining at 18 dB to 2500 Hz and then falling (log *f* scale) to 14.5 dB at 3400 Hz.

Note – The 12 dB spread in values stems from the difference in telephone set sensitivities.

2.2.2 *Impedance unbalance about earth*

The longitudinal conversion loss (LCL) of the Z interface should meet the values given in § 2.1.2 and Figure 2/Q.552, measured in accordance with the test method given in Figure 3/Q.552.

2.2.3 *Longitudinal interference threshold levels*

The signalling and transmission performance of the Z interface can be degraded when the subscriber line is exposed to an electromagnetic field of sufficiently high intensity. The value of induced interference energy causing performance degradation may be below a level which would cause permanent damage or operate protective devices. Longitudinal interference may come from power or traction lines or radio frequency sources.

Radio frequency interference tests at the Z interface should be in accordance with Recommendations of the K-Series (intended by Study Group V).

Longitudinal interference tests relative to power and traction line sources should be performed according to Figure 4/Q.552.

Interference up to the interference threshold level should not affect signalling and transmission more than the limits stated below. Measurements should be performed using quiet code at the exchange test point T_i.

There are two groups of parameters to be observed while performing the tests:

i) signalling related parameters;

ii) transmission related parameters, i.e. noise parameters.

For group i) the performance of the signalling parameters mentioned in Recommendation Q.543 should be tested in a go – no go procedure under normal operating conditions.

For group ii) two test steps should be performed under normal operating conditions, the first step without and the second one with the longitudinal test generator connected to the coupling network. The additional noise in the second test step should not contribute more than:

$L_{EN} = Y_1$ pWp using sinusoidal longitudinal test signal with X_1 volts rms;

$L_{EN} = Y_2$ pWp using longitudinal EMF test signal with defined harmonic content (e.g., triangular waveform with X_2 volts zero to peak).

The values Y_1 and Y_2 of the noise power must be specified depending on the interface the noise measuring set is connected to, i.e. the analogue interface at the termination T representing subscriber apparatus or the digital interface at the exchange test point T_o. The noise measuring set should be provided with a notch filter to exclude the activating signal at the nominal reference frequency.

The associated noise level limit results from the use of the equations given in §§ 3.3.2.1 and 3.3.3 of this Recommendation.

Note 1 – The values of X_1 and X_2 need further study. (Some administrations reported an X_1 value of 15 volts and an X_2 value of 25 volts.)

Note 2 – The value of the induced noise power L_{EN} needs further study. (Attention is drawn to § 3.1.6.2 of this Recommendation and to § 1 of Recommendation G.123.)

Test method

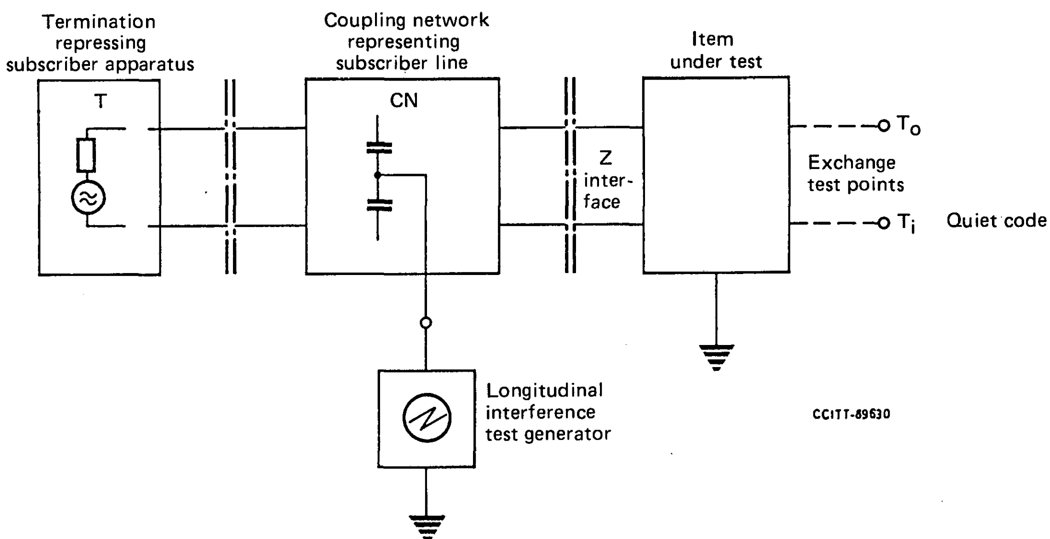


FIGURE 4/Q.552

Arrangement for measuring longitudinal interference threshold level

The longitudinal interference test generator should provide the longitudinal interference EMF with the fundamental frequency of the interference source (as appropriate to national conditions, i.e. 16 2/3 Hz, 50 Hz or 60 Hz) with a sinusoidal waveshape, and additionally with a waveshape having a certain amount of harmonic content [1)], e.g. a triangular waveshape.

The coupling network CN [1)] should represent a typical subscriber line (length, type of cable) exposed to power or traction line interference. The impedance of the coupling path within the network should be primarily capacitive. (One RPOA reported an impedance of $-j$ 1.17 kohm at 60 Hz for each capacitor indicated in Figure 4/Q.552.)

The termination T representing subscriber apparatus should provide for an appropriate loop current and the requested internal impedance of the reference frequency signal generator.

Note 1 – Annex A gives an example of a CN applicable to the measuring arrangement of Figure 4/Q.552, the application of which needs further study.

Note 2 – The measuring arrangement in Figure 4/Q.552 covers the general use of subscriber equipment, as recommended in Recommendation K.4, without low impedance to earth, especially without signalling using earth return. National deviations from this general case need to be considered for each special type of subscriber circuit.

1) The exact definition of the harmonic content and the coupling network is for further study.

2.2.4 *Relative levels*

Operation of the Z interface in the ranges of relative levels given below is recommended when the interface terminates an entirely 4-wire international long-distance connection. Pairs of input and output levels can be chosen for internal, local, or national long-distance traffic in a wider range if these connections can be discriminated from international ones for correct level switching. If digital pads are used, the additional distortion must be considered (see Recommendation G.113, Table 1/G.113).

In assigning the relative levels for international long-distance connections to the interface it should be noted that:

- The limiting of "difference in transmission loss between the two directions of transmission" in Recommendation G.121, § 6.4 must be taken into account. For the national extension this is the value "loss (t-b)-loss(a-t)". (See the text in the cited Recommendation for guidance.) This difference is limited to $\pm$ 4 dB. However, to allow for additional asymmetry of loss in the rest of the national network, only part of this difference can be used by the digital exchange.
- If within the ranges of L_i and L_o given under §§ 2.2.4.1.1 and 2.2.4.1.2, the values are chosen such that $L_i - L_o \geqslant 6$ dB and if adequate balance networks are used (e.g., § 3.1.8 and Figure 11/Q.552), the requirements of Recommendation G.121, § 6 (Incorporation of PCM digital processes in national extensions) as well as for Recommendation G.122 (Stability and echo loss) will be satisfied.

2.2.4.1 *Nominal levels*

2.2.4.1.1 *Input relative level*

According to Annex C to Recommendation G.121 (columns 1, 2 and 3 of Table C-1/G.121), the following range of input relative level for all types of connections (internal, local, national and international) encompasses the requirements of a large number of administrations.

$$L_i = 0 \text{ to } +2.0 \text{ dBr}$$

Note 1 – Recommendation G.101, § 5.3.2.3 indicates that if the minimum nominal send loudness rating (SLR) of the local system under the same conditions is not less than -1.5 dB, then the peak power of the speech will be suitably controlled. It follows that, for instance, the value $L_i = 0$ dBr (lower limit of the range for L_i) is suited to a send loudness rating $\geqslant -1.5$ dB.

Note 2 – The values given above are in conformity with current national practices and with the existing text of Recommendation G.101. However, the latter is itself partly based on a very old investigation (which Study Group XII has been asked to review) of the relationship between loudness ratings and speech levels. This may, in the near future, lead to amending the basis of objectives, so that it may be useful to allow wider design margins.

2.2.4.1.2 *Output relative level*

According to Annex C to Recommendation G.121 (column 3 of Table C-1/G.121), the following range of output relative level for international long-distance connections encompasses the requirements of a large number of administrations.

$$L_o = -5.0 \text{ to } -8.0 \text{ dBr}$$

The chosen value may be used for connections entirely within a national network as well.

If the connection type can always be detected, the nominal output relative levels for local or national connections can take other values in accordance with national transmission planning. According to Annex C to Recommendation G.121 (columns 1 and 2 of Table C-1/G.121) the following range encompasses the requirements of a large number of administrations:

$$L_o = 0 \text{ to } -8.0 \text{ dBr}$$

It has been recognized that it is not necessary for a particular design of equipment to be capable of operating over the entire range.

2.2.4.2 *Tolerances of relative levels*

The difference between the actual relative level and the nominal relative level should lie within the following limits:

- input relative level: -0.3 to $+0.7$ dB,
- output relative level: -0.7 to $+0.3$ dB.

These differences may arise, for example, from design tolerances, cabling (between analogue ports and the DF) and adjustment increments. Short-term variation of loss with time as discussed in § 3.1.1.3 is not included.

Note – Procedures for adjusting relative level are given in Recommendation G.715, § 2.1.

2.2.4.3 *Consideration of short and long subscriber lines*

In order to compensate for the loss of short or long subscriber lines, an administration may choose values of the relative levels derived from the basic values as follows:

$$L'_i = L_i + \text{x dB}$$

$$L'_o = L_o - \text{x dB}$$

The value of x is within national competence (e.g., x = 3 dB for short subscriber lines).

If values of L'_i and L'_o are chosen as indicated, the loss difference with respect to the conditions given in § 2.2.4.1 will be left unchanged.

The use of values of $x < 0$ requires careful selection of balance networks; values of $x < -3$ dB are not recommended.

3 Characteristics of half-connections

For interfaces C_2 this Recommendation is valid for digital local and transit exchanges and for C_{21} interfaces of PABXs connected to the digital local exchange by a digital transmission system.

For interface Z this Recommendation is valid for digital local and combined local/transit exchanges, for PABXs and for digital remote units, each connected to the digital local exchange by a digital transmission system. For further information concerning PABXs, see Recommendation Q.551, § 2.1.1.

Note – In measuring an input connection it is necessary to apply a quiet code, i.e. a PCM signal corresponding to decoder output value 0 (μ-law) or output value 1 (A-law) with the sign bit in a fixed state to the exchange test point T_i. (See Recommendation Q.551, § 1.2.3.1.)

3.1 *Characteristics common to all 2-wire analogue interfaces*

3.1.1 *Transmission loss*

3.1.1.1 *Nominal value*

The nominal transmission loss according to Recommendation Q.551, § 1.2.4.1 is defined in §§ 3.2.1 and 3.3.1 for input and output connections of half-connections with a 2-wire analogue interface.

3.1.1.2 *Tolerances of transmission loss*

The difference between the actual transmission loss and the nominal transmission loss of an input or output connection, according to §§ 2.1.4.2 and 2.2.4.2 should lie within the following range:

$$-0.3 \text{ to } +0.7 \text{ dB}$$

These differences may arise, for example, from design tolerances, cabling (between analogue equipment ports and the DF) and adjustment increments. Short-term variation of loss with time as discussed in § 3.1.1.3 is not included.

3.1.1.3 *Short-term variation of loss with time*

When a sine-wave test signal at the reference frequency of 1020 Hz and at a level of -10 dBm0 is applied to the 2-wire analogue interface of any input connection, or a digitally simulated sine-wave signal of the same characteristic is applied to the exchange test point T_i of any output connection, the level at the corresponding exchange test point T_o and the 2-wire analogue interface respectively should not vary by more than $\pm$ 0.2 dB during any 10-minute interval of typical operation under the steady state condition permitted variations in the power supply voltage and temperature.

3.1.1.4 *Variation of gain with input level*

With a sine-wave test signal at the reference frequency 1020 Hz and at a level between -55 dBm0 and $+3$ dBm0 applied to the 2-wire analogue interface of any input connection, or with a digitally simulated sine-wave signal of the same characteristic applied to the exchange test point T_i of any output connection, the gain variation of that connection, relative to the gain at an input level of -10 dBm0, should lie within the limits given in Figure 5/Q.552.

The measurement should be made with a frequency-selective level meter to reduce the effect of the exchange noise. This requires a sinusoidal test signal.

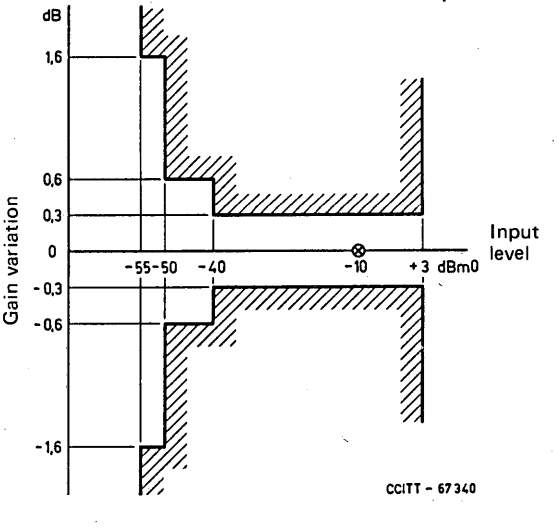


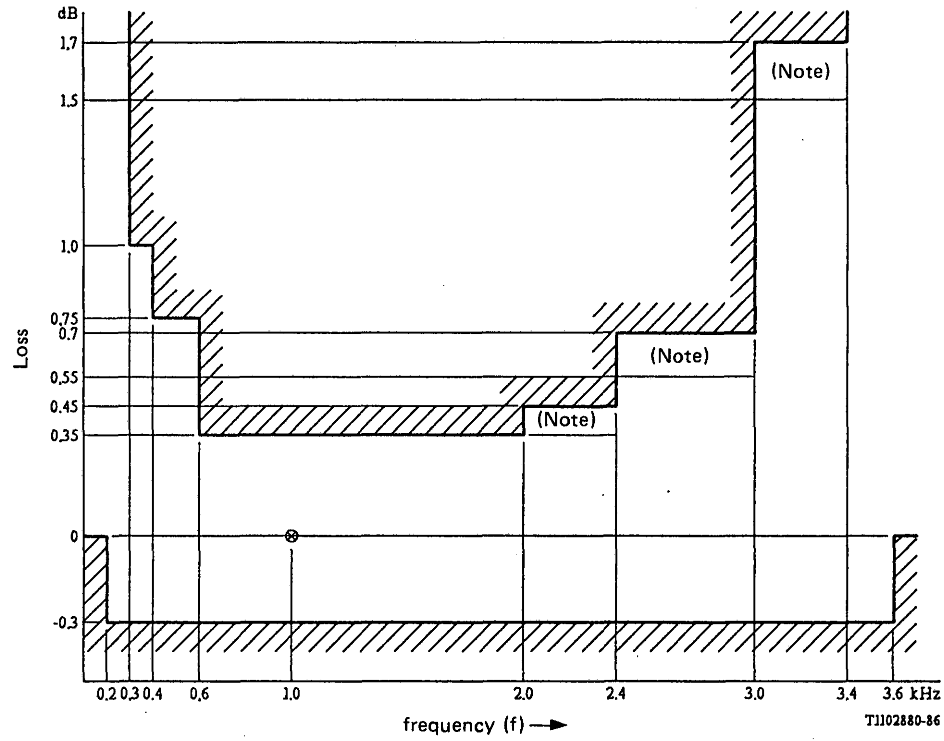
FIGURE 5/Q.552

Variation of gain with input level

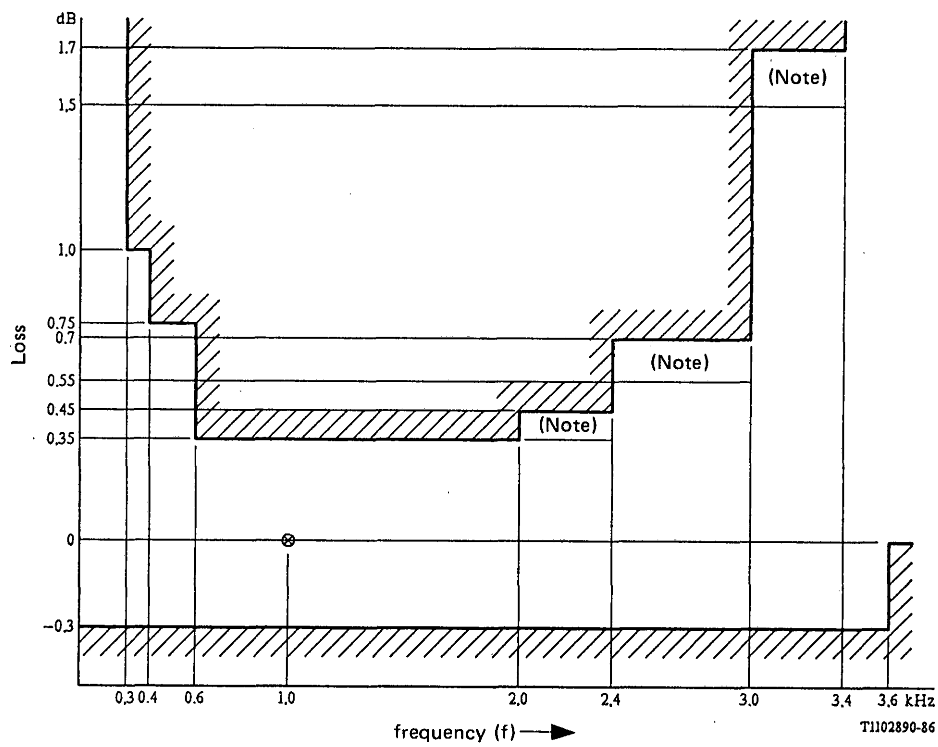
3.1.1.5 *Loss distortion with frequency*

The loss distortion with frequency of any input or output connection according to Recommendation Q.551, § 1.2.5 should lie within the limits shown in the mask of Figure 6/Q.552 a) or 6/Q.552 b) respectively using an input level of -10 dBm0.

Note – The limits of this clause shall not apply to Z half-connections which include equalization for the distortion in the subscriber line.



a) Input connection



b) Output connection

Note – In the marked frequency ranges relaxed limits are shown which apply if the maximum lengths of in-station cabling is used. The more stringent limits shown apply if no such cabling is present.

FIGURE 6/Q.552

Loss distortion with frequency

3.1.2 *Group delay*

"Group delay" is defined in the Yellow Book, Fascicle X.1.

3.1.2.1 *Absolute group delay*

See Recommendation Q.551, § 3.3.1.

3.1.2.2 *Group delay distortion with frequency*

Taking as the reference the minimum group delay, in the frequency range between 500 Hz and 2500 Hz, of the input or output connection, the group delay distortion of that connection should lie within the limits shown in the template of Figure 7/Q.552. Group delay distortion is measured in accordance with Recommendation O.81.

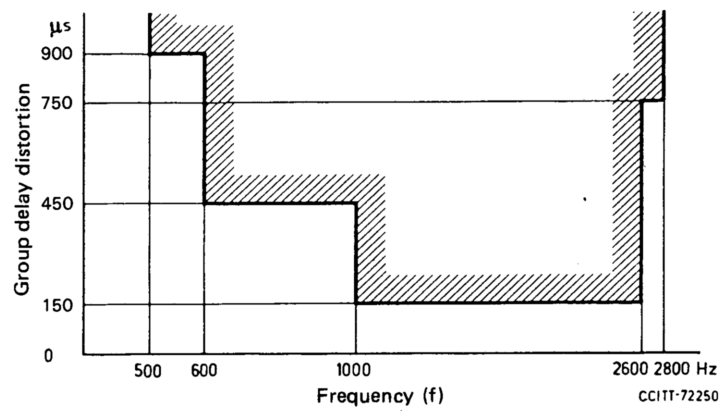


FIGURE 7/Q.552

Group delay distortion limits with frequency

These requirements should be met at an input level of -10 dBm0.

3.1.3 *Single frequency noise*

The level of any single frequency (in particular the sampling frequency and its multiples), measured selectively at the interface of an output connection, should not exceed -50 dBm0.

Note – See Recommendation Q.551, § 1.2.3.1.

3.1.4 *Crosstalk*

For crosstalk measurements, auxiliary signals are injected as indicated in Figures 8/Q.552 and 9/Q.552. These signals are:

- the quiet code (see Recommendation Q.551, § 1.2.3.1);
- a low level activating signal. Suitable activating signals are, for example, a band limited noise signal (see Recommendation O.131), at a level in the range -50 to -60 dBm0 or a sine-wave signal at a level in the range from -33 to -40 dBm0. Care must be taken in the choice of frequency and the filtering characteristics of the measuring apparatus in order that the activating signal does not significantly affect the accuracy of the crosstalk measurement.

3.1.4.1 *Input crosstalk*

A sine-wave test signal at the reference frequency of 1020 Hz and at a level of 0 dBm0, applied to an analogue 2-wire interface, should not produce a level in any other half-connection exceeding -73 dBm0 for near-end crosstalk (NEXT) and -70 dBm0 for far-end crosstalk (FEXT) (see Figure 8/Q.552).

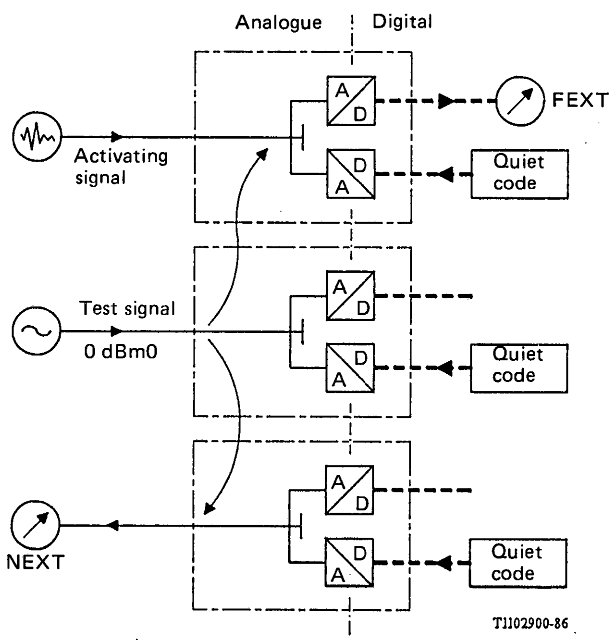


FIGURE 8/Q.552

Measurement with analogue test signal between different equipment

3.1.4.2 *Output crosstalk*

A digitally simulated sine-wave test signal at the reference frequency of 1020 Hz applied at a level of 0 dBm0 to an exchange test point T_i, should not produce a level in any other half connection exceeding −70 dBm0 for near-end crosstalk (NEXT) and −73 dBm0 for far-end crosstalk (FEXT) (see Figure 9/Q.552).

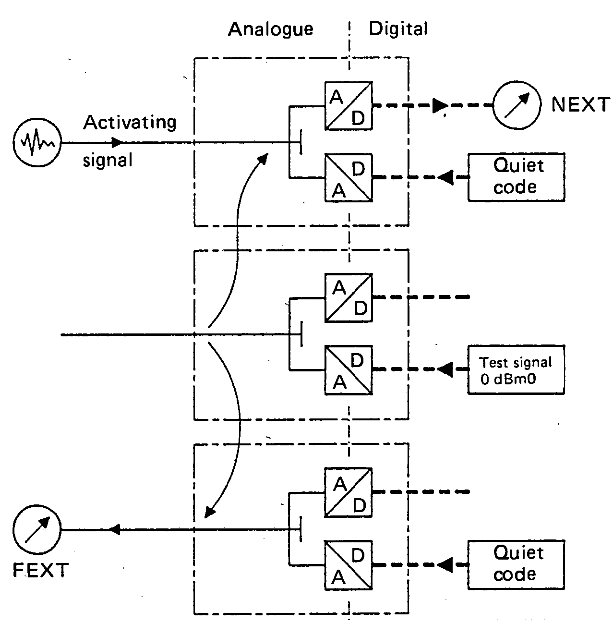


FIGURE 9/Q.552

Measurement with digital test signal between different equipment

3.1.5 *Total distortion including quantizing distortion*

With a sine-wave test signal at the reference frequency of 1020 Hz (see Recommendation O.132) applied to the 2-wire interface of an input connection, or with a digitally simulated sine-wave signal of the same characteristic applied to the exchange test point T_i of an output connection, the signal-to-total-distortion ratio, measured at the corresponding outputs of the half connection with a proper noise weighting (see Table 4/G.223) should lie above the limits given in §§ 3.2.3, Figures 13/Q.552 and 14/Q.552 for interface C_2 and § 3.3.3, Figure 15/Q.552 for interface Z.

Note – The sinusoidal test signal is chosen to obtain results independent of the spectral content of the exchange noise.

3.1.6 *Discrimination against out-of-band signals applied to the input interface*

(Only applicable to input connections.)

3.1.6.1 *Input signals above 4.6 kHz*

With sine-wave signal in the range from 4.6 kHz to 72 kHz applied to the 2-wire interface of an input connection at a level of −25 dBm0, the level of any image frequency produced in the time slot corresponding to the input connection should be at least 25 dB below the level of the test signal. This value may need to be more stringent to meet the overall requirement.

3.1.6.2 *Overall requirement*

Under the most adverse conditions encountered in a national network, the half connection should not contribute more than 100 pW0p of additional noise in the band 10 Hz to 4 kHz at the output of the input connection, as a result of the presence of out-of-band signals at the 2-wire interface of the input connection.

3.1.7 *Spurious out-of-band signals received at the output interface*

(Only applicable to an output connection.)

3.1.7.1 *Level of individual components*

With a digitally simulated sine-wave signal in the frequency range 300-3400 Hz and at a level of 0 dBm0 applied to the exchange test point T_i of a half connection, the level of spurious out-of-band image signals measured selectively at the 2-wire interface of the output connection should be lower than −25 dBm0. This value may need to be more stringent to meet the overall requirement.

3.1.7.2 *Overall requirement*

Spurious out-of-band signals should not give rise to unacceptable interference in equipment connected to the digital exchange. In particular, the intelligible and unintelligible crosstalk in a connected FDM channel should not exceed a level of −65 dBm0 as a consequence of spurious out-of-band signals at the half-connections.

3.1.8 *Echo and stability*

Terminal Balance Return Loss (TBRL) as defined in § 3.1.8.1 is introduced in order to characterize the exchange performance required to comply with the network performance objective of Recommendation G.122 with respect to echo. The TBRL of an equipment port is measured in the talking state as in an established connection through a digital exchange.

The parameter "Stability Loss", as defined in Recommendation G.122, applies to the worst terminating conditions encountered at a 2-wire interface in normal operation.

3.1.8.1 *Terminal Balance Return Loss (TBRL)*

The term TBRL is used to characterize an impedance balancing property of the 2-wire analogue equipment port.

The expression for TBRL is:

$$\mathrm{TBRL} = 20 \log \left| \frac{Z_o + Z_b}{2\, Z_o} \cdot \frac{Z_t + Z_o}{Z_t - Z_b} \right|$$

where

Z_o exchange impedance of a 2-wire equipment port

Z_b impedance of the balance network presented at a 2-wire equipment port

Z_t impedance of the balance test network

Some administrations have found that it is advantageous to choose $Z_o = Z_b$ in order to optimize TBRL. In this case the expression reduced to

$$\mathrm{TBRL} = 20 \log \left| \frac{Z_t + Z_b}{Z_t - Z_b} \right|$$

and the balance test network will be identical to the test network for the exchange impedance.

The balance test network should be representative of the impedance conditions to be expected from a population of terminated lines connected to 2-wire interfaces, as determined by the national transmission planning.

The TBRL is related to the loss a_{io} between the exchange test point T_i and T_o of a half connection as follows:

$$\mathrm{TBRL} = a_{io} - (a_o + a_i)$$

where a_o and a_i are the losses between the exchange test point T_i and the 2-wire port and between the 2-wire equipment port and the exchange test point T_o, respectively.

TBRL can thus be determined by measurement of a_{io} provided the sum ($a_o + a_i$) is known. This can be derived in several ways:

a) a_o and a_i are assigned their nominal values NL_o and NL_i as defined in §§ 3.2.1 and 3.3.1. Then:

$$\mathrm{TBRL} = = a_{io} - (NL_o + NL_i)$$

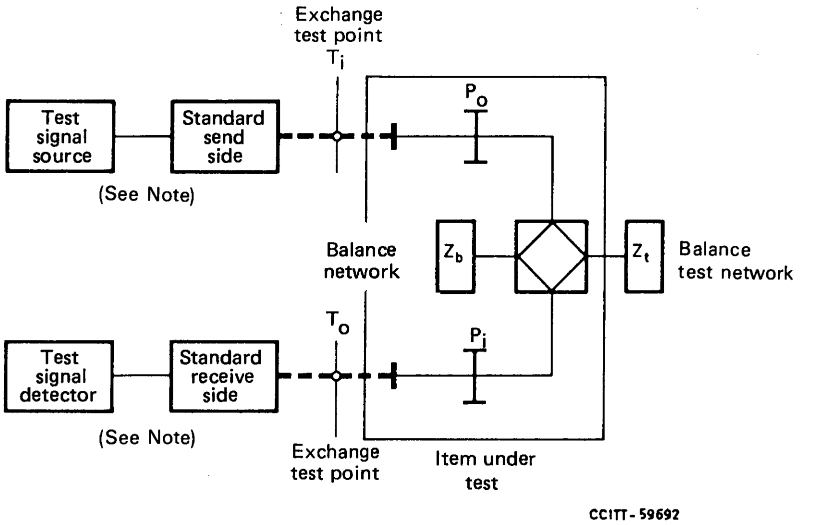
b) a_o is measured with the load matched to the exchange impedance as actual transmission loss AL_o and AL_i (see § 3.1.1.2). Then:

$$\mathrm{TBRL} = a_{io} - (AL_o + AL_i)$$

c) the loss a_{io} is measured with the 2-wire equipment port open- and short-circuited, giving losses a'_{io} y and a''_{io} respectively.

$$\mathrm{TBRL} = a_{io} - \frac{a'_{io} + a''_{io}}{2}$$

Method b) provides the most accurate results.



Note – This equipment may be all digital, with equivalent functions (see Recommendation O.133). The test signal source and the test signal detector may be as shown in Figure A-1/G.122.

FIGURE 10/Q.552

Arrangement for measuring the loss a_{io}

Using the arrangement of Figure 10/Q.552 and sinusoidal test signals, the measured TBRL should exceed the limits shown in Figure 11/Q.552.

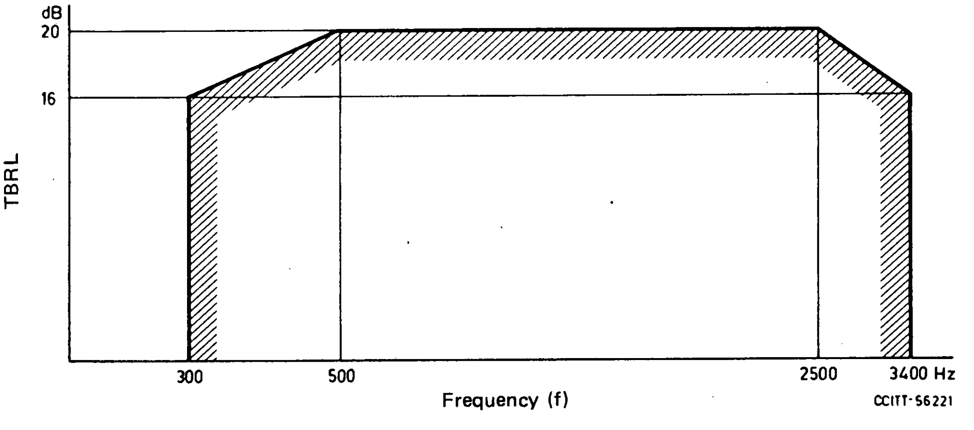
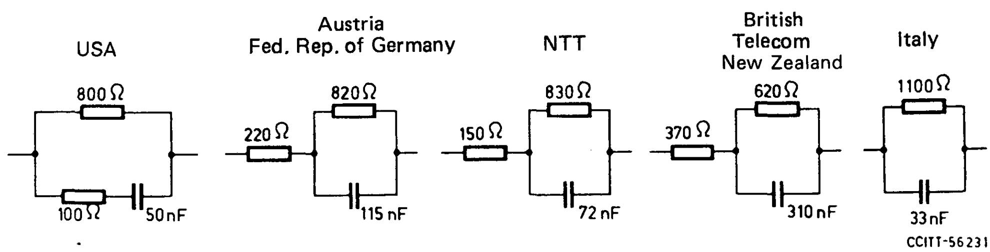


FIGURE 11/Q.552

Limits for TBRL

Figure 12/Q.552 gives examples of balance test networks adopted by some administrations for unloaded subscriber lines. These examples may provide guidance for other administrations in order to minimize the diversity of types of test networks.

Note – Some administrations may need to adopt several balance test networks to cover the various types of unloaded and loaded cables.



Impedance at 1000 Hz: $770\ \Omega\ \angle{-14^\circ}$ $900\ \Omega\ \angle{-23.5^\circ}$ $919\ \Omega\ \angle{-17.3^\circ}$ $693\ \Omega\ \angle{-26^\circ}$ $1072\ \Omega\ \angle{-12.8^\circ}$

FIGURE 12/Q.552

Examples of test networks to be used by some administrations (applicable to unloaded subscriber lines)

3.1.8.2 *Stability loss*

The stability loss should be measured between the exchange test points T_i and T_o of a half-connection (Figure 10/Q.552) by terminating the 2-wire interface with stability test networks representing the "worst terminating condition encountered in normal operation". Some administrations may find that open- and short-circuit terminations are sufficiently representative of worst-case conditions. Other administrations may need to specify, for example, an inductive termination to represent the worst-case condition.

With worst-case terminating conditions on the 2-wire interface of a half-connection, the stability loss T_i to T_o measured as a_{io} should be:

Stability Loss $= a_{io} \geqslant x$;

where x is under study for sinusoidal signals at all frequencies between 200 Hz and 3600 Hz. This frequency band is determined by the filters used in the interface designs.

The need for requirements outside this frequency band is also under study.

Where the digital exchange is connected to the international chain using only 4-wire switching and transmission, the half connection of the digital exchange may provide the total stability loss of the national extension. The value of stability loss (SL) that is required for a 2-wire interface is a matter of national control provided that the requirements of Recommendation G.122 are met. A SL value of 6 dB at all frequencies between 200 Hz and 3600 Hz will ensure that the G.122 requirements are met. However, SL values of between 6 dB and 0 dB will formally comply with the present requirements of G.122 (Red Book 1984) but further study is required to provide guidance in this area. One administration has found that a value of 3 dB is satisfactory in its environment.

Note – It is suggested that the half-connection of a digital PABX, or of a digital remote unit, when connected to the digital local exchange by a digital transmission system, should also meet the requirements of § 3.1.8.

3.2 *Characteristics of interface C_2*

3.2.1 *Nominal value of transmission loss*

According to the relative levels defined in § 2.1.4.1, the nominal transmission losses of input or output connections NL_i and NL_o of a half connection with C_2 interfaces are in the following ranges:

C_{21} interfaces

NL_i = 0 to 2.0 dB for all types of connections

NL_o = 0 to 8.0 dB for international connections
0 to 8.0 dB for local or national connections

C_{22} interfaces

$$\left.\begin{array}{l} NL_i = 3.0 \text{ to } -7.0 \text{ dB} \\ NL_o = 8.0 \text{ to } -1.0 \text{ dB} \end{array}\right\} \text{for all types of connections}$$

It has been recognized that it is not necessary for a particular design of equipment to be capable of operating over the entire range of nominal transmission losses.

If a loss compensation is applied the nominal loss NL_i and NL_o should be corrected by the value of x dB chosen in connection with §§ 2.1.4.1.2 or 2.2.4.3.

3.2.2 *Noise*

3.2.2.1 *Weighted noise*

For the calculation of noise, worst case conditions at the C_2 interface are assumed. The band limiting effect of the encoder on the noise was not taken into account. For a more exact calculation further study is necessary.

3.2.2.1.1 *Output connection*

Two components of noise must be considered. One of these arises from the quiet decoder, the other from analogue sources, such as signalling equipment. The first component is limited by Recommendation G.714, § 10 as receiving equipment noise to −75 dBm0p; the other component by Recommendation G.123, § 3 to −(67+3) dBm0p = −70 dBm0p for one 2-wire analogue interface. This results in the maximum value for the overall weighted noise in the talking state at the C_2 interface of a digital exchange of:

−68.8 dBm0p for equipment with signalling on the speech wires,

−75.0 dBm0p for equipment with signalling on separate wires.

3.2.2.1.2 *Input connection*

Two components of noise must be considered. One of these arises from the encoding process, the other from analogue sources, e.g. signalling equipment. The first component is limited by Recommendation G.714, § 9 as idle channel noise to −66 dBm0p; the other component by Recommendation G.123, § 3 to −(67+3) dBm0p = −70 dBm0p for one 2-wire analogue interface. This results in the maximum value for the overall weighted noise in the talking state at the exchange test point T_o of a digital exchange of:

−64.5 dBm0p for equipment with signalling on the speech wires,

−66.0 dBm0p for equipment with signalling on separate wires.

3.2.2.2 *Unweighted noise*

This noise will be more dependent on the noise on the power supply and on the rejection ratio.

Note – The need for and value of this parameter are both under study. Recommendations Q.45 *bis*, § 2.5.2 and G.123, § 3 must also be considered.

3.2.2.3 *Impulsive noise*

It will be necessary to place limits on impulsive noise arising from sources within the exchange; these limits are under study. Pending the results of this study, Recommendation Q.45 *bis*, § 2.5.3 may give some guidance on the subject of controlling impulsive noise with low frequency content.

Note 1 – The sources of impulsive noise are often associated with signalling functions (or in some cases the power supply) and may produce either transverse or longitudinal voltage at C_2 interfaces.

Note 2 – The disturbances to be considered are those to speech or modem data at audio frequencies, and also those causing bit errors on parallel digital lines carried in the same cable. This latter case, involving impulsive noise with high frequency content, is not presently covered by the measurement procedure of Recommendation Q.45 *bis*.

3.2.3 *Values of total distortion*

The total distortion including quantizing distortion of a half-connection with a C_2 interface is measured in accordance with § 3.1.5.

The signal-to-total-distortion ratio for a half-connection at interface C_2 should lie above the limits shown in Figure 13/Q.552 for equipment with signalling on separate wires, and in Figure 14/Q.552 for equipment with signalling on the speech wires both measured in the talking state.

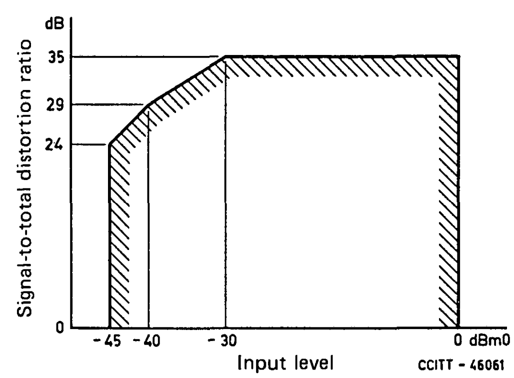


FIGURE 13/Q.552

Limits for signal-to-total distortion ratio as a function of input level; input or output connection with signalling on separate wires

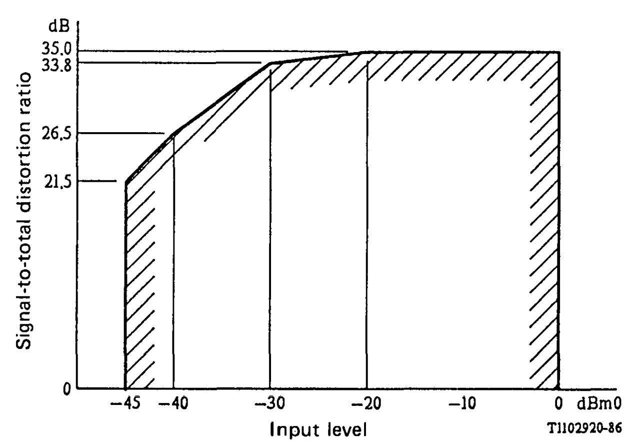


FIGURE 14/Q.552

Limits for signal-to-total distortion ratio as a function of input level; input or output connection with signalling on the speech wires

The values of Figure 14/Q.552 include the limits for the encoding process given in Figure 4/G.714 and the allowance for the noise contributed via signalling circuits from the exchange power supply and other analogue sources (e.g., analogue coupling), which is limited to $-(67+3)$ dBm0p = -70 dBm0p for one C_2 analogue interface by Recommendation G.123, § 3.

3.3 *Characteristics of interface Z*

3.3.1 *Nominal value of transmission loss*

According to the relative levels defined in § 2.2.4.1, the nominal transmission losses of input or output connections NL_i and NL_o of a half-connection with Z interfaces are in the following ranges:

NL_i = 0 to 2.0 dB for all types of connections

NL_o = 5.0 to 8.0 dB for international connections
0 to 8.0 dB for internal, local or national connections.

If a compensation for the loss of short or long subscriber lines is applied, the nominal loss NL_i and NL_o should be corrected by the value of x dB chosen in connection with § 2.2.4.3.

3.3.2 *Noise*

3.3.2.1 *Weighted noise*

For the calculation of noise, worst-case conditions at the Z interface are assumed. The band limiting effect of the encoder on the noise has not been taken into account. For a more exact calculation further study is necessary.

3.3.2.1.1 *Output connection*

Two components of noise must be considered. One of these, e.g. noise arising from the decoding process, is dependent upon the output relative level. The other, e.g. power supply noise from the feeding bridge, is independent of the output relative level. The first component is limited by Recommendation G.714, § 10 as receiving equipment noise to -75 dBm0p; the other component is assumed by Recommendation G.123, Annex A to be 200 pWp (-67 dBmp). This can be caused by the main DC power supply and auxiliary DC-DC converters.

Information about the subject of noise on the DC power supply is given in Supplement No. 13 to the G-Series Recommendations (Orange Book, Volume III-3).

The total psophometric power allowed at a Z interface with a relative output level of L_o dB may be approximated by the formula:

$$P_{TNo} = P_{AN} + 10^{\left(\frac{90 + LINo + L_o}{10}\right)} \text{ pWp}$$

The total noise level is given by:

$$L_{TNo} = 10 \log \left(\frac{P_{TNo}}{1 \text{ pW}}\right) - 90 \text{ dBmp}$$

where

P_{TNo}: total weighted noise power for the output connection of the local digital exchange;

P_{AN}: weighted noise power caused by analogue functions according to Recommendation G.123, Annex A for local exchanges, i.e. 200 pWp;

L_{INo}: receiving equipment noise (weighted) for PCM translating equipment according to Recommendation G.714, § 10, i.e., −75 dBm0p;

L_o: output relative level of a half-channel of a local digital exchange according to § 2.2.4.1.2, e.g., 0 to −8.0 dBr;

L_{TNo}: total weighted noise level for the output connection of the local digital exchange.

For the range of output relative levels according to § 2.2.4.1.2 the resulting total psophometric powers and the total noise levels for the output connection are:

L_o	=	0	−5.0	−6.0	−7.0	−8.0	dBr
P_{TNo}	=	231	210	208	206	205	pWp
L_{TNo}	=	−66.4	−66.8	−66.8	−66.9	−66.9	dBmp

3.3.2.1.2 *Input connection*

Two components of noise must be considered. One of these, e.g. noise arising from the encoding process, is dependent upon the output relative level. The other, e.g. power supply noise from the feeding bridge, must be corrected by the input relative level for calculation at the exchange test point T_o. The first component is limited by Recommendation G.714, § 9 as idle channel noise to −66 dBm0p; the other component is assumed by Recommendation G.123, Annex A to be 200 pWp (−67 dBmp) which results in −67 dBmp − L_i at the exchange test point T_o.

The total psophometric power allowed at the exchange test point T_o with a relative input level of L_i dB may be approximated by the formula:

$$P_{TNi} = P_{AN} \cdot 10^{\frac{-L_i}{10}} + 10^{\left(\frac{90 + L_{INi}}{10}\right)} \text{ pWp}$$

and the total noise level by

$$L_{TNi} = 10 \log \left(\frac{P_{TNi}}{1 \text{ pW}}\right) - 90 \text{ dBm0p}$$

where

P_{TNi}: total weighted noise power for the input connection of the local digital exchange;

P_{AN}: weighted noise power caused by analogue functions according to Recommendation G.123, Annex A for local exchanges, i.e. 200 pWp;

L_{INi}: idle channel noise (weighted) for the input connection of a digital local exchange according to Recommendation G.714, § 9 i.e., −66 dBm0p;

L_i: input relative level of a half-channel of a local digital exchange according to § 2.2.4.1.1, e.g. 0 and +1 dBr;

L_{TNi}: total weighted noise level for the input connection of the local exchange.

For the relative levels according to § 2.2.4.1.1, the resulting psophometric power and the total noise levels for the input connection are:

L_i	=	0	+1.0	+2.0	dBr
P_{TNi}	=	451	410	377	pW0p
L_{TNi}	=	−63.5	−63.9	−64.2	dBm0p

Note – The calculation above is intended to account for the worst case. No band limiting effect of the encoder on the noise was taken into account.

3.3.2.2 *Unweighted noise*

This noise will be more dependent on the noise on the power supply and on the rejection ratio.

Note – The need for and value of this parameter are both under study. Recommendation G.123, § 3 must also be considered.

3.3.2.3 *Impulsive noise*

It will be necessary to place limits on impulsive noise arising from sources within the exchange; these limits are under study.

Note 1 – The sources of impulsive noise are often associated with signalling functions (or in some cases the power supply and the ringing voltage) and may produce either transverse or longitudinal voltages at Z interfaces.

Note 2 – The disturbances to be considered are those to speech or modem data at audio frequencies, and also those causing bit errors on parallel digital subscriber lines carried in the same cable. This latter case, involving impulsive noise with high frequency content, is not presently covered by the measurement procedure of Recommendation Q.45 *bis.*

3.3.3 *Values of total distortion*

The total distortion including quantizing distortion on half connections with Z interfaces is measured in accordance with § 3.1.5.

The signal-to-total distortion ratio required for a half connection may be approximated by the formula:

$$\frac{S}{N_T} = L_s + L_r - 10 \log \left[10^{\left(\frac{L_S + L_r - S/N}{10}\right)} + 10^{\left(\frac{L_N}{10}\right)} \right]$$

where

$\frac{S}{N_T}$ resulting signal-to-total distortion ratio for input or output connections in digital local exchanges;

L_s: signal level of the measuring signal in dBm0;

L_r: for input connections, input relative level L_i in dBr for output connections, output relative level L_o in dBr;

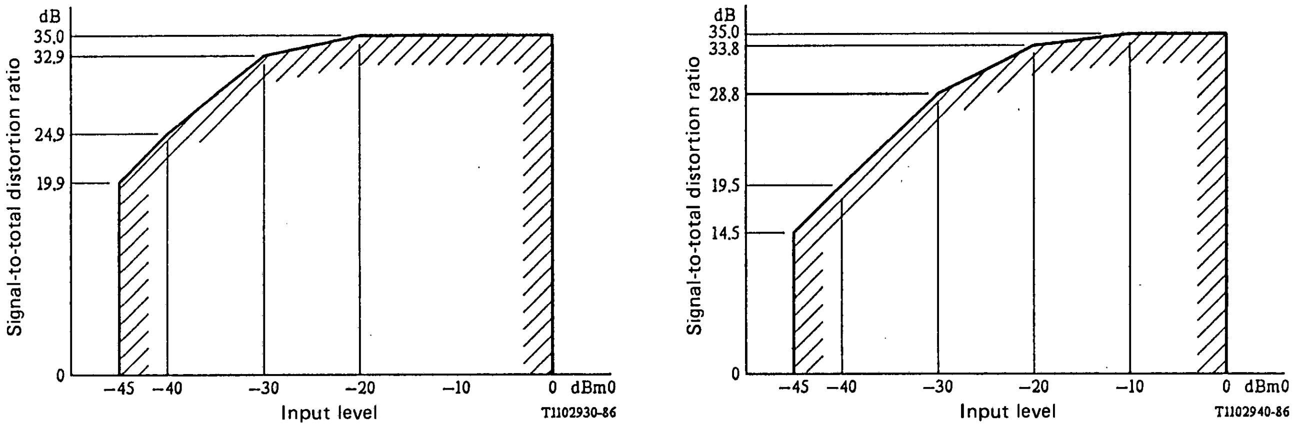
S/N: signal-to-total distortion ratio for PCM translating equipment in Recommendation G.714;

L_N: weighted noise caused by analogue functions according to Recommendation G.123, Annex A for local exchanges, i.e. −67 dBmp at the Z interface.

One resulting template for the signal-to-total distortion ratio of input and output connections in a local exchange is shown in Figure 15/Q.552 a) and b) as an example.

The values of Figure 15/Q.552 include the limits for the coding process given in Figure 5/G.714 and the allowance for the noise contributed via signalling circuits from the exchange power supply and other analogue sources, which is limited to -67 dBmp for a Z interface (with feeding) by Recommendation G.123, Annex A. As an example, the mean relative levels according to § 2.2.4.1 are assumed to be $L_i = 0$ dBr and $L_o = -7$ dBr.

Note – For an input connection the calculation above is assumed to be the worst case. No band limiting effect of the encoder on the noise was taken into account.



a) Input connection: L_i = 0 dBr

b) Output connection: L_o = −7 dBr

FIGURE 15/Q.552

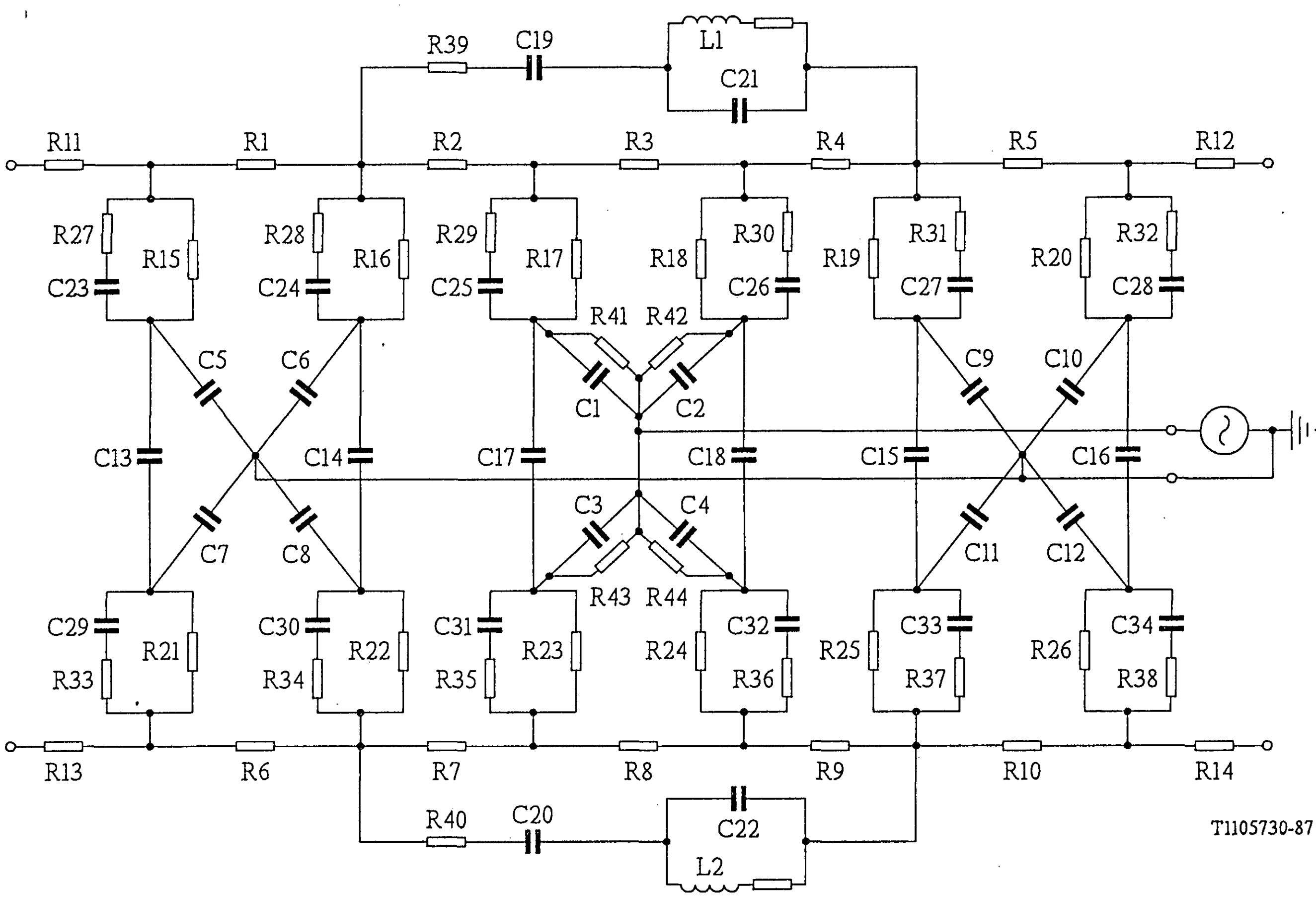
Limits for signal-to-total distortion ratio as a function of input level including analogue noise

ANNEX A

(to Recommendation Q.552)

Example of a longitudinal interference coupling network

The component should be chosen with small absolute tolerances (at least resistors and capacitors with 1% and the inductance with less than 5%) and matched to pairs where relevant to achieve a longitudinal conversion loss better than 60 dB at 1000 Hz. For this LCL measurement a terminating resistance of 600 Ohms symetrically applied to each port should be used.



Note – The component values given in Table A-1/Q.552 are applicable to 4 km of 0.4 mm cable with a mutual capacitance of 47 nF/km and a capacitance to earth of 15 nF/km.

FIGURE A-1/Q.552

An example of a longitudinal interference coupling network (CN)

TABLE A-1/Q.552

Components list

	Quantity	Type
		Metallized resistors
1	10	R1 ... R10: 100 ohm 1%, 1.1 W
2	4	R11 ... R14: 49.9 ohm 1%, 1.1 W
3	12	R15 ... R26: 133 ohm 1%, 0.35 W
4	12	R27 ... R38: 32.4 ohm 1%, 0.35 W
5	2	R39 ... R40: 24.9 ohm 1%, 0.35 W
6	4	R41 ... R44: 200 kohm 1%, 0.35 W
		Styroflex foil capacitors
1	4	C1 ... C4: 15 nF 1%, 160 V
2	8	C5 ... C12: 7.5 nF 1%, 160 V
3	4	C13 ... C16: 28 nF 1%, 160 V
4	2	C17 ... C18: 24.3 nF 1%, 160 V
5	2	C19 ... C20: 20 nF 1%, 160 V
6	2	C21 ... C22: 499 pF 1%, 160 V
7	12	C23 ... C34: 60.4 nF 1%, 63 V
		HF-chokes, ferrite rod
1	2	L1 ... L2: 47 µH 5%, R_o 1.1 ohm

Recommendation Q.553

TRANSMISSION CHARACTERISTICS AT 4-WIRE ANALOGUE INTERFACES OF A DIGITAL EXCHANGE

1 General

This Recommendation provides characteristics for:

– 4-wire analogue interfaces (Type C_{11}, C_{12} and C_{13}),
– input and output connections with 4-wire analogue interfaces, and
– half connections with 4-wire analogue interfaces,

in digital transit and combined local and transit exchanges in accordance with the definitions given in Recommendation Q.551, particularly in Figures 1/Q.551 and 2/Q.551.

The characteristics of the input and output connections of a given interface are not necessarily the same. The characteristics of half connections are not necessarily identical for different types of interfaces.

This Recommendation is intended for switched connections that may be part of an international long-distance connection via 4-wire line circuits interconnected by 4-wire exchanges. Since 4-wire analogue interfaces of digital exchanges may connect with circuits which are used for both international and national traffic, the same values recommended for international connections may also be used for connections entirely within the national network.

2 Characteristics of interfaces

2.1 *Characteristics common to all 4-wire analogue interfaces*

2.1.1 *Exchange impedance*

2.1.1.1 *Nominal value*

The nominal impedance at the 4-wire input and output interfaces should be 600 ohms, balanced.

2.1.1.2 *Return loss*

The return loss, measured against the nominal impedance, should not be less than 20 dB over the frequency range 300 Hz to 3400 Hz.

Note – For output measurement, the exchange test point T_i must be driven by a PCM signal corresponding to the decoder output value number 0 for the μ-law or decoder output value number 1 for the A-law. (See Recommendation Q.551, § 1.2.3.1.)

2.1.2 *Impedance unbalance about earth*

The value for the Longitudinal Conversion Loss (LCL) defined in Recommendation G.117, § 4.1.3, with the circuit under test in the normal talking state, should exceed the minimum values of Figure 1/Q.553, in accordance with Recommendations Q.45 *bis* and K.10.

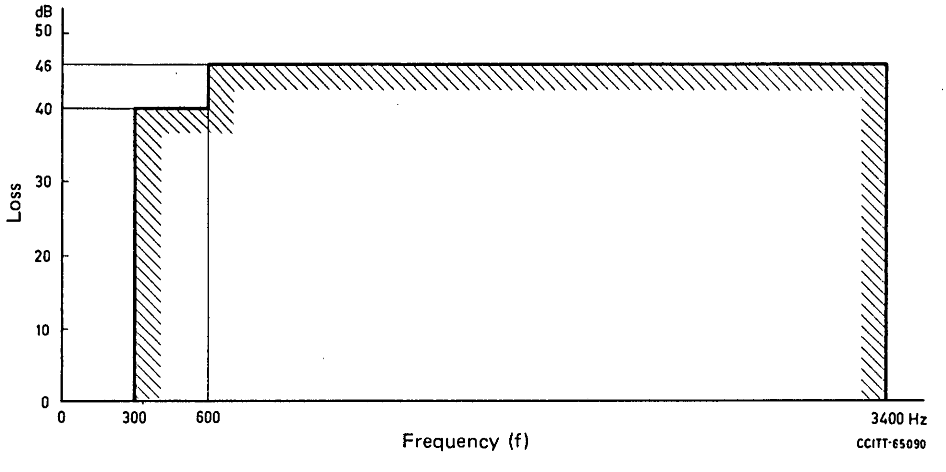


FIGURE 1/Q.553

Minimum values of LCL measured in the arrangement shown in Figure 2/Q.553

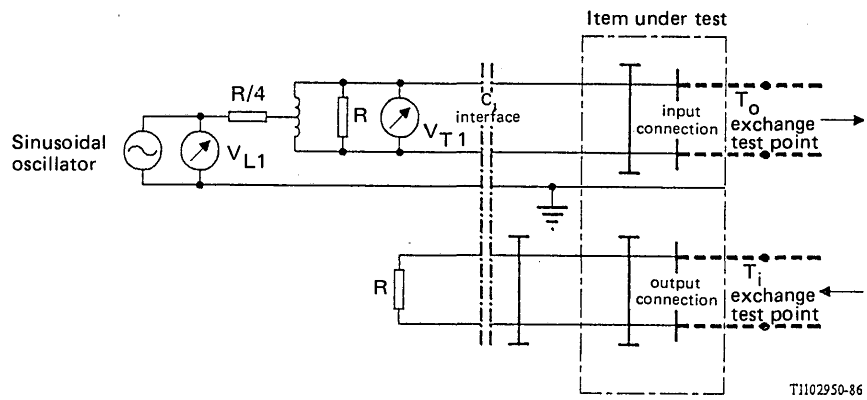
Note 1 – An Administration may adopt other values and in some cases a wider bandwidth, depending upon actual conditions in its telephone network.

Note 2 – A limit may also be required for the Transverse Conversion Loss (TCL) as defined in Recommendation G.117, § 4.1.2, if the exchange termination is not reciprocal with respect to the transverse and longitudinal connections. A suitable limit would be 40 dB to ensure an adequate near-end crosstalk attenuation between interfaces.

Test method

LCL should be measured in accordance with the principles given in Recommendation O.9, §§ 2.1 and 3. Figure 2/Q.553 shows the basic measuring arrangement.

Measurements of the longitudinal and transverse voltages should be performed by means of a frequency-selective level meter.



R = 600 ohms

Note – For output measurement the exchange test point T_i must be driven by a PCM signal corresponding to the decoder output value number 0 for the μ-law or decoder output value number 1 for the A-law. (See Recommendation Q.551, § 1.2.3.1.)

FIGURE 2/Q.553

Arrangement for measuring LCL

2.1.3 *Relative levels*

In assigning the relative levels to the interfaces, the limiting of "difference in transmission loss between the two directions of transmission" in Recommendation G.121, Annex A has been taken into account. For the national extension this is the value "loss (t-b)-loss(a-t)". (See the text in the cited Recommendation for guidance.) This difference is limited to ± 4 dB. However, to allow for additional asymmetry of loss in the rest of the national network, only part of this difference can be used by the digital exchange.

2.1.3.1 *Nominal levels*

The nominal relative levels at the 4-wire analogue input and output interfaces of the digital exchange depend on the type of equipment which is connected to the exchange. (See Figure 1/Q.551.)

In practice it may be necessary to compensate for the loss between the output interfaces of the digital exchange and the input ports of the connected equipment to fulfill transmission plan conditions. The definition of adjustable steps for and the location of this compensation (digital exchange or connected equipment) is within national competence.

Nominal values of relative levels are given in §§ 2.2.1, 2.3.1 and 2.4.1 for the different types of half connections.

2.1.3.2 *Tolerances of relative levels*

The difference between the actual relative level and the nominal relative level should lie within the following ranges:

– input relative level: −0.3 to +0.7 dB;

– output relative level: −0.7 to +0.3 dB.

These differences may arise, for example, from design tolerances, cabling (between analogue equipment ports and the DF) and adjustment increments.

Note – Adjustment of the relative level should be made in accordance with Recommendation G.712, § 15.

2.2 *Characteristics of interface C_{11}*

According to Figure 1/Q.551, the interface C_{11} of a digital exchange is intended to interwork with the channel translating equipment of an FDM system.

2.2.1 *Values of nominal levels*

The nominal values of relative levels at the channel translating equipment are specified in Table 2/G.232 for the two recommended cases. With the pads in the channel translating equipment set to zero, these values are:

	Case 1	Case 2
R S	+4.0 dBr −14.0 dBr	+7.0 dBr −16.0 dBr

The nominal values of relative levels at the digital exchange must be adjusted to compensate for the total loss between the interface of the digital exchange and the channel translating equipment. Therefore:

$$L_i = R - A_R$$
$$L_o = S + A_S$$

where

A_R = total loss in the receive path

A_S = total loss in the send path

2.3 *Characteristics of interface C_{12}*

According to Figure 1/Q.551, the interface C_{12} of a digital exchange is intended to interwork with the incoming and outgoing relay set of an analogue 4-wire exchange. (See Figure 1/Q.45 *bis.*)

2.3.1 *Values of nominal levels*

The nominal values of relative levels at the relay set of an analogue exchange are consistent with Table 2/G.232 for the two recommended cases. These values are:

	Case 1	Case 2
R S	−14.0 dBr +4.0 dBr	−16.0 dBr +7.0 dBr

The nominal values of relative levels at the digital exchange must be adjusted to compensate for the total loss between the interface of the digital exchange and the relay sets of the analogue exchange. Therefore:

$$L_i = R - A_R$$
$$L_o = S + A_S$$

where

A_R = total loss in the receive path

A_S = total loss in the send path

2.4 *Characteristics of interface C_{13}*

According to Figure 1/Q.551 the interface C_{13} of a digital exchange is intended to connect to a 4-wire analogue switching stage. (See Figure 1/G.142, case 5.)

2.4.1 *Values of nominal levels*

The nominal values of relative levels are determined by the relative levels of the analogue 4-wire switching stages in the national transmission plans. For example, if these relative levels are identical with the virtual analogue switching point of −3.5 dBr in both directions of transmission, the nominal input and output levels of a C_{13} interface are:

$$L_i = L_o = -3.5 \text{ dBr}$$

Different levels at the switching stages and transmission loss between interface C_{13} and the switching stages can require adjusting these levels.

3 Characteristics of half connections

3.1 *Characteristics common to all 4-wire analogue interfaces*

3.1.1 *Transmission loss*

3.1.1.1 *Nominal value*

The nominal transmission loss, according to Recommendation Q.551 § 1.2.4.1, is defined for input and output connections of a half connection with 4-wire analogue interface in §§ 3.2.1, 3.3.1 and 3.4.1.

3.1.1.2 *Tolerances of transmission loss*

The difference between the actual transmission loss and the nominal transmission loss of an input or output connection of the same half connection according to § 2.1.3.2 should lie within the following values:

−0.3 to +0.7 dB.

These differences may arise for example, from design tolerances, cabling (between analogue equipment ports and the DF) or adjustment increments.

3.1.1.3 *Short-term variation of loss with time*

When a sine-wave test signal at the reference frequency of 1020 Hz and at a level of −10 dBm0 (if preferred, the value 0 dBm0 may be used) is applied to a 4-wire analogue interface of any input connection, or a digitally simulated sine-wave signal of the same characteristic is applied to the exchange test point T_i of any output connection, the level at the corresponding exchange test point T_o and the 4-wire analogue interface respectively, should not vary by more than ± 0.2 dB during any 10-minute interval of typical operation under the steady state condition permitted variations in the power supply voltage and temperature.

3.1.1.4 *Variation of gain with input level*

With a sine-wave test signal at the reference frequency of 1020 Hz and at a level between −55 dBm0 and +3 dBm0 applied to the 4-wire analogue interface of any input connection, or with a digitally simulated sine-wave signal of the same characteristic applied to the exchange test point T_i of any output connection, the gain variation of that connection, relative to the gain at the input level of −10 dBm0, should lie within the limits given in Figure 3/Q.553.

The measurement should be made with a frequency selective meter to reduce the effect of the exchange noise. This requires a sinusoidal test signal.

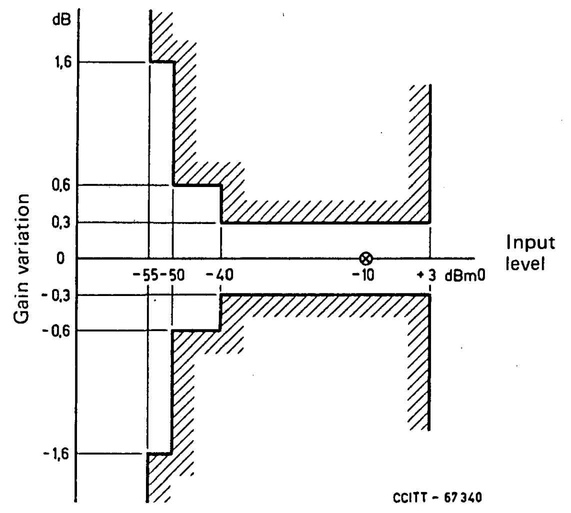


FIGURE 3/Q.553

Variation of gain with input level

3.1.1.5 *Loss distortion with frequency*

According to Recommendation Q.551, § 1.2.5, the loss distortion with frequency of any input or output connection should lie within the limits shown in the mask of Figures 4/Q.553, a) and b), respectively. The preferred input level is −10 dBm0.

3.1.2 *Group delay*

"Group delay" is defined in the Blue Book, Fascicle I.3.

3.1.2.1 *Absolute group delay*

See Recommendation Q.551, § 3.3.1.

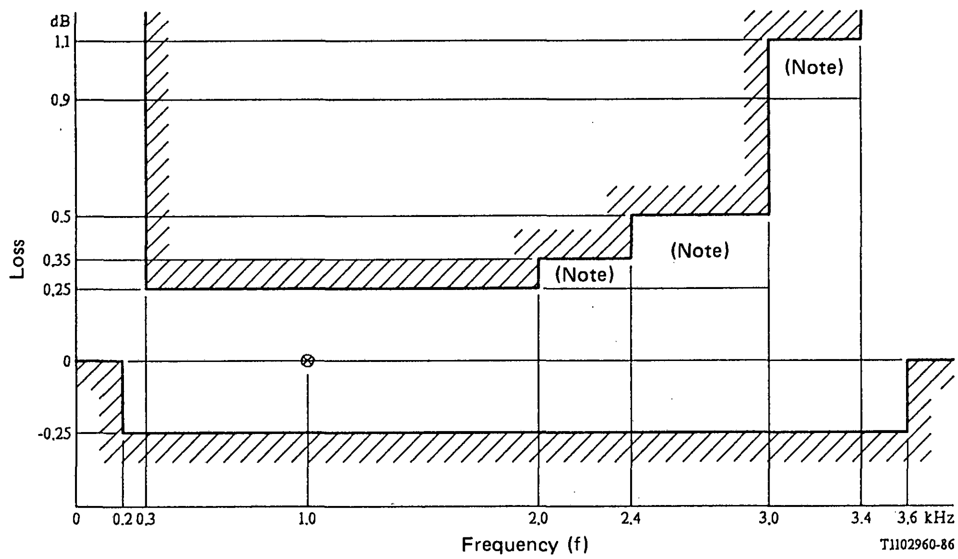
3.1.2.2 *Group delay distortion with frequency*

Taking the minimum group delay, in the frequency range between 500 Hz and 2500 Hz, of the input or output connection as the reference, the group delay distortion of that connection should lie within the limits shown in the template of Figure 5/Q.553. Group delay distortion is measured in accordance with Recommendation O.81.

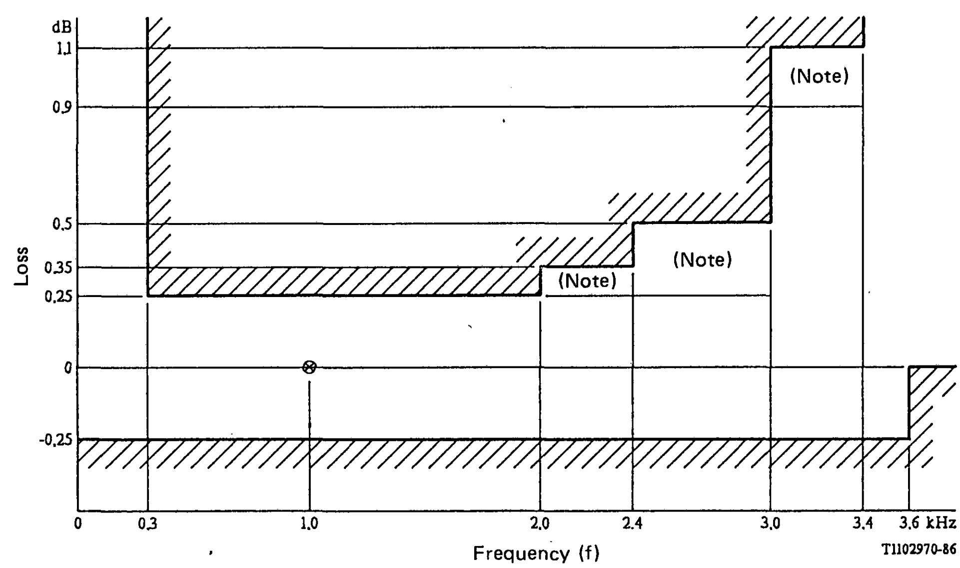
3.1.3 *Noise*

3.1.3.1 *Weighted noise*

Two components of noise must be considered: noise arising from the coding process and noise from the exchange power supply and other analogue sources transmitted through signalling circuits. The first component is limited by Recommendation G.714, §§ 9 and 10 to −66 dBm0p for an input connection; and to −75 dBm0p for an output connection. The other component is limited by Recommendation G.123, § 3 to −(67+3) dBm0p = −70 dBm0p for one 4-wire analogue interface.



a) Input connection



b) Output connection

Note – In the marked frequency ranges relaxed limits are shown which apply if the maximum length of in-station cabling (Recommendation Q.551, § 2) is used. The more stringent limits shown apply if no such cabling is present.

FIGURE 4/Q.553

Loss distortion with frequency

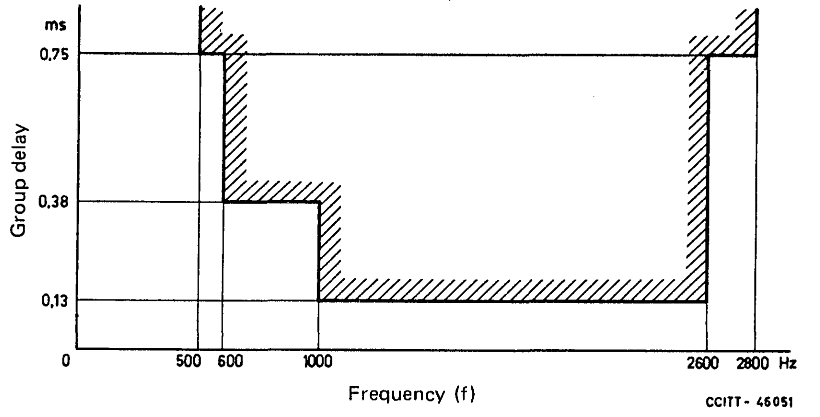


FIGURE 5/Q.553

Group delay distortion limits with frequency

This leads to the following maximum values for the overall weighted noise at the output interfaces of a half connection of a digital exchange:

– Input connection:	–64.5 dBm0p	for equipment with signalling on the speech wires;
	–66.0 dBm0p	for equipment with signalling on separate wires.
– Output connection:	–68.8 dBm0p	for equipment with signalling on the speech wires;
	–75.0 dBm0p	for equipment with signalling on separate wires.

3.1.3.2 *Unweighted noise*

This noise will be more dependent on the noise on the power supply and on the rejection ratio.

Note – The need for and value of this parameter are both under study. Recommendations Q.45*bis*, § 2.5.2 and G.123, § 3 must also be considered.

3.1.3.3 *Impulsive noise*

Limits should be placed on impulsive noise arising from sources within the exchange; these limits are under study. Pending the results of this study, Recommendation Q.45 *bis*, § 2.5.3 may give some guidance on the subject of controlling impulsive noise with low frequency content.

Note 1 – The sources of impulsive noise are often associated with signalling functions (or in some cases the power supply) and may produce either transverse or longitudinal voltage at 4-wire interfaces.

Note 2 – The disturbances to be considered are those to speech or modem data at audio frequencies, and also those causing bit errors on parallel digital lines carried in the same cable. This latter case, involving impulsive noise with high frequency content, is not presently covered by the measurement procedure of Recommendation Q.45 *bis*.

3.1.3.4 *Single frequency noise*

The level of any single frequency (in particular the sampling frequency and its multiples), measured selectively at the interface of an output connection should not exceed –50 dBm0.

Note – See Recommendation Q.551, § 1.2.3.1.

3.1.4 *Crosstalk*

For crosstalk measurements auxiliary signals are injected as indicated in Figures 6 to 9/Q.553. These signals are:

- the quiet code (see Recommendation Q.551, § 1.2.3.1);
- a low level activating signal. Suitable activating signals are, for example, a band limited noise signal (see Recommendation O.131), at a level in the range −50 to −60 dBm0 or a sine-wave signal at a level in the range from −33 to −40 dBm0. Care must be taken in the choice of frequency and the filtering characteristics of the measuring apparatus in order that the activating signal does not significantly affect the accuracy of the crosstalk measurement.

3.1.4.1 *Crosstalk measured with analogue test signal*

3.1.4.1.1 *Far-end and near-end crosstalk*

A sine-wave test signal at the reference frequency of 1020 Hz and at a level of 0 dBm0, applied to an analogue 4-wire input interface, should not produce a level at either output of any other half connection exceeding −73 dBm0 for a near-end crosstalk (NEXT) path and −70 dBm0 for a far-end crosstalk (FEXT) path. These paths are shown in Figure 6/Q.553.

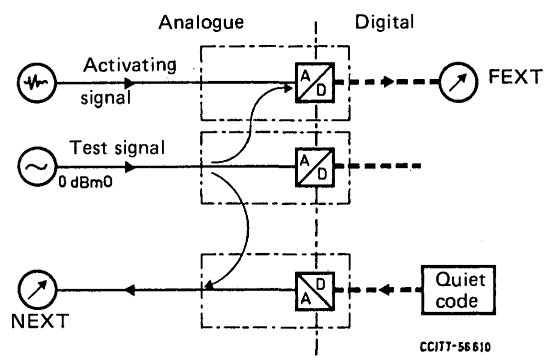


FIGURE 6/Q.553

Measurement with analogue test signal between different input connections of half connections

3.1.4.1.2 *Go-to-return crosstalk*

A sine-wave test signal at any frequency in the range 300-3400 Hz and at a level of 0 dBm0, applied to the 4-wire interface of an input connection, should not produce a level exceeding −66 dBm0 at the analogue output of the same half connection. See Figure 7/Q.553.

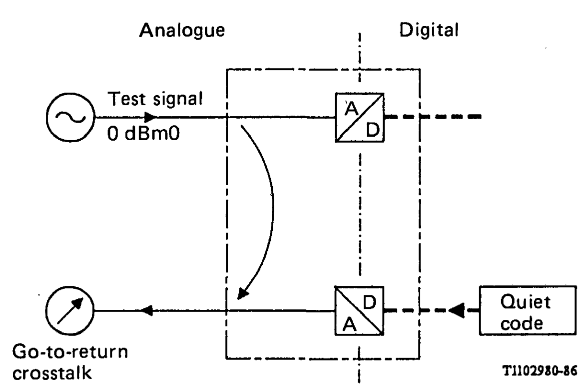


FIGURE 7/Q.553

Measurement with analogue test signals between go and return directions of the same half connection

3.1.4.2 *Crosstalk measured with digital test signal*

3.1.4.2.1 *Far-end and near-end crosstalk*

A digitally simulated sine-wave test signal at the reference frequency of 1020 Hz and at a level of 0 dBm0, applied to an exchange test point T_i, should not produce a level exceeding −70 dBm0 for near-end crosstalk (NEXT) or −73 dBm0 for far-end crosstalk (FEXT), at either output of any other half connection. (See Figure 8/Q.553.)

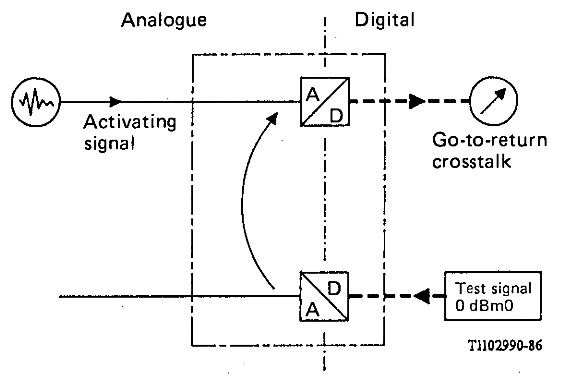


FIGURE 8/Q.553

Measurement with digital test signals between go and return directions of the same half connection

3.1.4.2.2 *Go-to-return crosstalk*

A digitally simulated sine-wave test signal, at any frequency in the range 300-3400 Hz and at a level of 0 dBm0, applied to an exchange test point T_i of an output connection, should not produce a crosstalk level exceeding −66 dBm0 at the exchange test point T_o of the corresponding input connection. See Figure 9/Q.553.

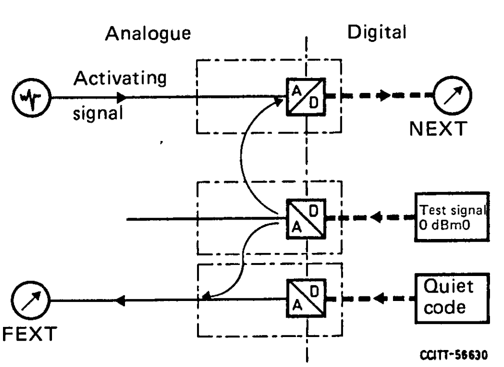


FIGURE 9/Q.553

Measurement with digital test signal between different output connections of half connections

3.1.5 *Total distortion including quantizing distortion*

With a sine-wave test signal at the reference frequency of 1020 Hz (see Recommendation O.132) applied to the 4-wire interface of an input connection, or with a digitally simulated sine-wave signal of the same characteristic applied to the exchange test point T_i of an output connection, the signal-to-total distortion ratio, measured at the respective outputs of the half connection with a proper noise weighting (see Table 4/G.223) should lie above the limits shown in Figure 10/Q.553 for signalling on separate wires and in Figure 11/Q.553 for signalling on the speech wires.

Note – The sinusoidal test signal is chosen to obtain results independent of the spectral content of the exchange noise.

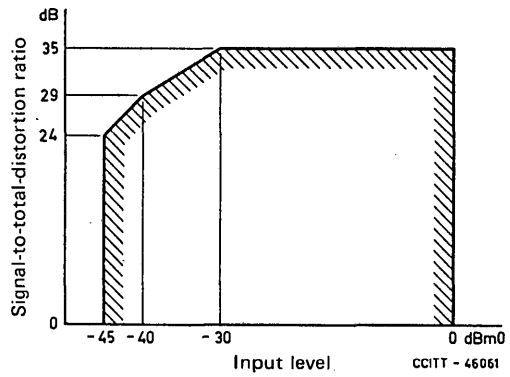


FIGURE 10/Q.553

Limits for signal-to-total-distortion ratio as a function of input level
Input or output connection with signalling on separate wires

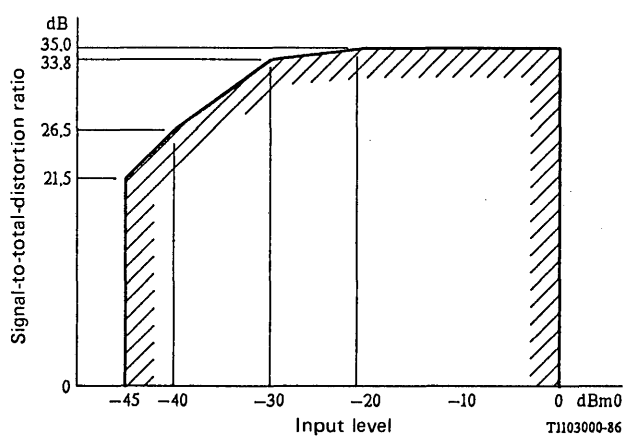


FIGURE 11/Q.553

Limits for signal-to-total-distortion ratio as a function of input level
Input or output connection with signalling on the speech wires

The values of Figure 11/Q.553 include the limits for the coding process given in Figure 5/G.714 and the allowance for the noise contributed via signalling circuits from the exchange power supply and other analogue sources which is limited to $-(67+3)$ dBm0p $=$ -70 dBm0p for one 4-wire analogue interface by Recommendation G.123, § 3.

3.1.6 *Discrimination against out-of-band signals applied to the input interface*

(Applicable only to input connections.)

3.1.6.1 *Input signals above 4.6 kHz*

With any sine-wave signal in the range from 4.6 kHz to 72 kHz applied to the 4-wire interface of a half connection at a level of −25 dBm0, the level of any image frequency produced in the time slot corresponding to the input connection should be at least 25 dB below the level of the test signal. This value may need to be more stringent to meet the overall requirement.

3.1.6.2 *Overall requirement*

Under the most adverse conditions encountered in a national network the half connection should not contribute more than 100 pW0p of additional noise in the band 10 Hz-4 kHz at the output of the input connection, as a result of the presence of out-of-band signals at the input port of the input connection.

3.1.7 *Spurious out-of-band signals received at the output interface*

(Applicable only to an output connection.)

3.1.7.1 *Level of individual components*

With a digitally simulated sine-wave test signal in the frequency range 300-3400 Hz and at a level of 0 dBm0 applied to the exchange test point T_i of a half connection, the level of spurious out-of-band image signals measured selectively at a 4-wire interface of the output connection should be lower than −25 dBm0. This value may need to be more stringent to meet the overall requirement.

3.1.7.2 *Overall requirement*

Spurious out-of-band signals should not give rise to unacceptable interference in the equipment connected to the digital exchange. In particular, the intelligible and unintelligible crosstalk in a connected FDM channel should not exceed a level of −65 dBm0 as a consequence of the spurious out-of-band signals at the half connection.

3.2 *Characteristics for interface C_{11}*

3.2.1 *Nominal value of transmission loss*

According to the relative levels defined in § 2.2.1, the nominal transmission losses of a half connection with a C_{11} interface are:

- Input connection: $R - A_R$
- Output connection: $-S - A_S$

See § 2.2.1 for definitions for R, S, A_R and A_S.

3.3 *Characteristics for interface C_{12}*

3.3.1 *Nominal value of transmission loss*

According to the relative levels defined in § 2.3.1 the nominal transmission losses of a half connection with a C_{12} interface are:

- Input connection: $R - A_R$
- Output connection: $-S - A_S$

See § 2.2.1 for definitions for R, S, A_R and A_S.

3.4 *Characteristics for interface C_{13}*

3.4.1 *Nominal value of transmission loss*

According to the relative levels defined in § 2.4.1 the nominal transmission losses of a half connection with a C_{13} interface are:

- Input connection: −3.5 dB,
- Output connection: 3.5 dB.

Different levels at the switching stages and transmission loss between interface C_{13} and the switching stages can require adjusting these losses.

TRANSMISSION CHARACTERISTICS AT DIGITAL INTERFACES OF A DIGITAL EXCHANGE

1 General

The field of application of this Recommendation is found in Recommendation Q.500.

The signals taken into consideration are passed through the following interfaces as described in Recommendations Q.511 and Q.512 and Figure 1/Q.551.

- Interface A is for primary rate digital signals at 2048 kbit/s or 1544 kbit/s.
- Interface B is for secondary rate digital signals at 8448 kbit/s or 6312 kbit/s.
- Interface types V are for digital subscriber line access.

Interface types V may appear remote from the exchange through the use of digital transmission facilities. When this occurs, there should be no impact on transmission parameters other than delay.

Detailed transmission characteristics of the digital interface ports are given in § 2 of this Recommendation.

§ 3 covers the requirements for transmission characteristics of the half-connections between the digital interfaces and the exchange test points. The half-connection comprises an input connection (the one-way 64 kbit/s path from the interface to the test point) and an output connection (the one-way 64 kbit/s path from the test point to the interface) as defined in Recommendation Q.551. Requirements are given for the input connection and the output connection characteristics and the two are not necessarily identical.

The overall characteristics of a connection through the digital exchange involving two interfaces can be obtained by suitably combining the values for the characteristics of the two half-connections. For example, the overall characteristics of the connection between a Z interface and the A interface are obtained by combining the Z interface half-connection characteristics given in § 3.3 of Recommendation Q.552 with the A interface half-connection requirements given in § 3.1 of this Recommendation.

Where bit integrity is maintained on the digital half-connection and the error performance requirements are met, the digital half-connection will add no impairment to the voice-band performance of a complete connection through the switch (with the exception of delay). For this reason the digital half-connection requirements do not include the conventional voice band parameters.

(The cases where bit integrity is not maintained are for further study.)

The values given are to be considered as either "design" or "performance objectives" according to the explanation of the terms given in Recommendation G.102 (Transmission performance objectives and recommendations) and the particular context. These objectives should be met under the most adverse specified timing and synchronization conditions as given in Recommendation Q.541, § 3.

2 Characteristics of interfaces

This section covers requirements for interfaces A, B, V.

These interfaces must meet the requirements for timing and synchronization given in Recommendation Q.541, § 3.

2.1 *Interface characteristics common to digital interfaces*

The general characteristics of the interfaces A, B, V_2, V_3, V_4 are given in Recommendations G.703, G.704, G.705, G.706, Q.511 and Q.512.

2.2 *Interface characteristics at interface A*

The physical and electrical characteristics of interface A are given in §§ 2 and 6 of Recommendation G.703.

2.2.1 *Jitter and wander tolerance at the exchange input*

Jitter and wander tolerance is the ability of the exchange to accept phase deviations on incoming signals without introducing slips or errors.

The jitter/wander tolerance at input A should comply:

– with Recommendation G.824, § 3.1.1, for the A interface at 1544 kbit/s;

– with Recommendation G.823, § 3.1.1, for the A interface at 2048 kbit/s.

This specification may not be applicable to inputs used solely for synchronization purposes (i.e. for deriving the internal timing of the exchange).

2.3 *Interface characteristics at interface B*

The physical and electrical characteristics of interface B are given in §§ 3 and 7 of Recommendation G.703.

2.3.1 *Jitter and wander tolerance at the exchange input*

Jitter and wander tolerance is the ability of the exchange to accept phase deviations on incoming signals without introducing slips or errors.

The jitter/wander tolerance at input B should comply:

– with Recommendation G.824, § 4.2.2, for the B interface at 6312 kbit/s;

– with Recommendation G.823, § 3.1.1, for the B interface at 8448 kbit/s.

This specification may not be applicable to inputs used solely for synchronization purposes (i.e. for deriving the internal timing of the exchange).

2.4 *Interface characteristics at interface V_1*

The functional characteristics of the basic access digital section between the V_1 and T reference-point are defined in Recommendations Q.512 and I.AA. The characteristics and parameters of a digital transmission system which may form part of the digital section for the ISDN basic rate access are given in Recommendation I.AB.

2.5 *Interface characteristics at other V-type interfaces*

The other V-type interfaces will have transmission characteristics of the A and B interfaces as given in §§ 2.2 and 2.3 above.

3 Characteristics of 64 kbit/s half connections

This section covers the essential digital characteristics of 64 kbit/s half connections. Where these requirements are met, the digital half connection will add no impairment to the voice band performance of a complete connection through the exchange (with the exception of delay). The voice band performance of digital half connections may therefore be interpreted by assuming that ideal send and receive sides (see Recommendation G.714) are connected to the digital inputs and outputs respectively. The digital half connection requirements also ensure that any connection through the exchange using a pair of digital half connections will provide acceptable performance for non-voice 64 kbit/s digital services.

3.1 *Half connection characteristics common to all digital interfaces*

3.1.1 *Error performance*

The design objective long-term mean Bit Error Ratio (BER) for a single pass of a 64 kbit/s connection through an exchange between the digital transmission/switching interfaces should be 1 in 10^9 or better. This corresponds to 99.5% error-free minutes assuming that the occurrence of errors has a Poisson distribution.

3.1.2 *Bit integrity*

Bit integrity will be maintained if called for to support 64 kbit/s non-telephony services.

Note – It is understood that to meet this requirement, digital processing devices such as μ/A law converters, echo suppressors and digital pads must be disabled for non-telephony calls requiring bit integrity. The means of disabling these devices has yet to be determined. (See Recommendation Q.551, § 1.2.6.1.)

3.1.3 *Bit sequence independence*

No limitation should be imposed by the exchange on the number of consecutive binary ones or zeros or any other binary pattern within the 64 kbit/s paths through the exchange.

3.1.4 *Absolute group delay*

The requirements for absolute group delay are given in § 3.3.1 of Recommendation Q.551.

PART II

SUPPLEMENTS TO THE Q.500 SERIES OF RECOMMENDATIONS

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

Supplement No. 1

DEFINITION OF RELATIVE LEVELS, TRANSMISSION LOSS AND ATTENUATION/FREQUENCY DISTORTION FOR DIGITAL EXCHANGES WITH COMPLEX IMPEDANCES AT Z INTERFACES

1 Introduction

During the studies of Study Group XI on transmission characteristics of exchanges it has been recognized that digital local exchanges may require complex impedances at the subscriber line interface (see Recommendation Q.552). These complex impedances result in difficulties with defining relative levels, transmission loss and attenuation/frequency distortion.

This Supplement gives the basis for coherent definitions which are in accordance with the principles outlined by Study Group XII in the G.100 series of Recommendations, Fascicle III.1.

2 Relative levels

There is a clear statement by Study Group XII that relative levels (L) – even at ports of complex impendance – relate to power (in general, apparent power) at a reference frequency of 1000 Hz. Accordingly, at a point of zero relative level (i.e. transmission reference point, cf. Recommendation G.101, item § 5.3.1) and at an impedance Z, the reference power of 1 mW[1] (at 1000 Hz) corresponds to a voltage:

$$U_o = \sqrt{1 \text{ mW} \cdot |Z|} \tag{1}$$

It follows that generally at a point of relative level L the voltage will be

$$U = 10^{L/20} \cdot \sqrt{1 \text{ mW} \cdot |Z|} \tag{2}$$

and that consequently the level L can be expressed as

$$L = 20 \log \frac{U}{\sqrt{1 \text{ mW} \cdot |Z|}} \tag{3}$$

This is the basis for a coherent definition of transmission loss, and subsequently of attenuation/frequency distortion, as derived below.

Note – In the future, measurements should be made at 1020 Hz.

3 nominal transmission loss

In the field of telecommunications, it is a well-established practice to define the nominal transmission loss (NL) between two points as the difference between the relative levels associated with these points. If, for instance, for a "connection through a digital exchange" the relative level at the input is L_i, and at the output, L_o, then the nominal loss is

$$NL = L_i - L_o \tag{4}$$

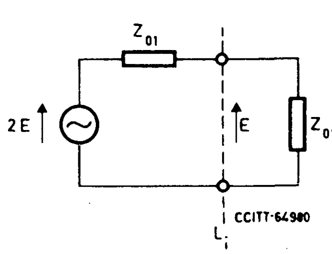


FIGURE 1

Power reference circuit

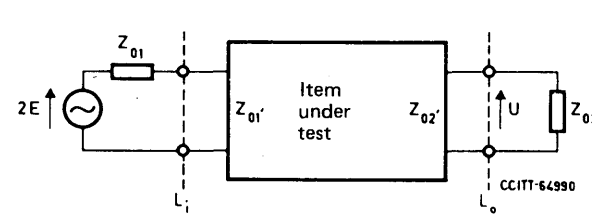


FIGURE 2

Test circuit

[1] Watt is the unit of apparent power as well as of real power.

Taking into account that according to the definition of the power reference circuit (Figure 1), E is frequency-independent, one obtains from equations (3) and (4) the nominal loss.

$$NL = 20 \log \left| \frac{E}{U(1000 \text{ Hz})} \right| + 10 \log \left| \frac{Z_{02} \text{ (1000 Hz)}}{Z_{01} \text{ (1000 Hz)}} \right| \tag{5}$$

It may be noted that equation (5) represents the "composite loss" (ITU definition 05.20) at 1000 Hz. The composite loss is the only measure of attenuation that allows adding of the losses of "half-channels" (i.e. A-D and D-A) regardless of the specific impendances at the input and output ports.

4 attenuation/frequency distortion

"Attenuation distortion" or "loss distortion" is the result of imperfect amplitude/frequency response and is generally specified in addition to the relative levels of a transmission section, from which the nominal transmission loss is derived. The definition of the attenuation/frequency distortion (LD) is well established: it is the difference between the actual response of voltage versus frequency $U(f)$ and the ideal (planned) response of voltage versus frequency $U^*(f)$, referred to the corresponding difference at 1000 Hz:

$$LD = \left[20 \log \left| \frac{E}{U(f)} \right| - 20 \log \left| \frac{E}{U^*(f)} \right| \right] - \left[20 \log \left| \frac{E}{U(1000 \text{ Hz})} \right| - 20 \log \left| \frac{E}{U^*(1000 \text{ Hz})} \right| \right] \tag{6}$$

Equation (6) can be rewritten as follows:

$$LD = 20 \log \left| \frac{U(1000 \text{ Hz})}{U(f)} \right| - 20 \log \left| \frac{U^*(1000 \text{ Hz})}{U^*(f)} \right| \tag{7}$$

For practical reasons the ideal response of voltage versus frequency, $U^*(f)$, is flat. Taking this into account, equation (7) reduces further to

$$LD = 20 \log \left| \frac{U(1000 \text{ Hz})}{U(f)} \right| \tag{8}$$

It should be noted that equation (8) is valid regardless of whether Z_{01} is equal to Z_{02} or not. However, impedance matching at input ($Z_{01}' \approx Z_{01}$) and output ($Z_{02}' \approx Z_{02}$) is assumed. A measurement in accordance with equation (8) is entirely in conformity with existing measuring techniques.

5 Conclusions

Nominal transmission loss and attenuation/frequency distortion are essential loss parameters. Their definitions in Sections 3 and 4 are based on the definition of relative (power) levels at 1000 Hz in accordance with Study Group XII which has stated the following advantages:

1) an illustrative indication of passband performance (especially with regard to band-edge distortion and extraneous ripples);
2) a loss definition in accordance with the relative level definition;
3) the loss values are relevant to singing margin evaluation;
4) the loudness insertion loss will be (almost) equal to the exchange loss;
5) additivity with a fair degree of accuracy;
6) the definition is also suitable for half exchange loss currently envisaged by Study Group XI.

Supplement No. 2

IMPEDANCE STRATEGY FOR TELEPHONE INSTRUMENTS AND DIGITAL LOCAL EXCHANGES IN THE BRITISH TELECOM NETWORK

1 Introduction

When planning the introduction of digital local exchanges it is essential to take into account the subjective performance offered to customers. This will, of course, include provision of overall loudness ratings within an acceptable range of values. Noise, distortion and other impairments also need to be adequately controlled. However, it is also important to consider those parameters largely influenced by the impedances associated with telephone instruments, local lines and exchanges. In particular acceptance values of sidetone and echo/stability losses need to be obtained. These parameters are influenced by the choice of:

i) Input and balance impedances of telephone instruments,

ii) Input and balance impedances of the digital exchange hybrid,

iii) Impedances of the 2-wire local lines.

This contribution outlines the impedance strategy adopted for telephone instruments and digital local exchanges in the British Telecom network. It is shown that there are major advantages in adopting complex impedances both for the exchange hybrid and for new telephone instruments. The contribution includes calculations of sidetone, echo and stability balance return losses based on a sample of 1800 local lines in the British Telecom network.

2 Impedance strategy for a digital local exchange

2.1 In order to adequately control echo and stability losses in the digital network the nominal hybrid balance impedance ZB for lines of up to 10 dB attenuation is based on a 3 element network. This network consists of a resistor in series with a parallel resistor/capacitor combination, i.e.:

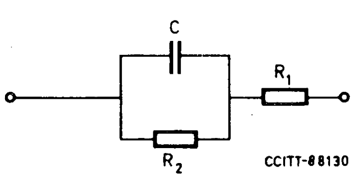


FIGURE 1

Network configuration

With appropriate component values it has been found that this network can give significantly improved echo and stability balance return losses compared with a resistive network.

2.2 The nominal exchange input impedance ZI is also based on a 3 element network of the same form as the balance impedance ZB. This network, with suitable component values, is required to give an acceptable sidetone performance on the lower loss lines. It has been found that a 600 Ω resistive input impedance gives unacceptable sidetone performance on these lower loss lines.

3 Impedance strategy for telephone instruments

It should be noted that the digital local exchange is designed to operate with a low feeding current (≈ 40 mA). The telephone instrument will therefore be operating as though it were connected to a long line on a conventional analogue exchange. In particular, any regulation function will be disabled.

The input impedance of present instruments is, under low current feeding conditions, substantially resistive. It has been found that there is a significant improvement in echo/stability balance return losses at the exchange hybrid if the telephone input impedance is also made complex. The preferred impedance is close to the design value for the exchange balance impedance ZB.

4 Background to calculated results

This section includes the results of calculating STMR values, echo and stability balance return losses for a range of local connections.

Four groups of exchange lines have been used where the groups have mean attenuations of 1 dB, 3 dB, 6 dB and 9 dB. Each group consists of at least 100 samples of local lines in the British Telecom network with attenuations within 1 dB of the mean value for the group.

Two telephone instruments have been used with identical characteristics except for input impedance. One instrument retains a conventional, substantially resistive impedance; the other instrument uses a complex capacitive input impedance. The sidetone balance impedance is, in both cases, designed to match long lengths of 0.5 mm Cu cable.

Two cases for the exchange hybrid impedances are considered. The strategy outlined in Section 2 is used i.e., complex input and balance impedance, and for comparison purposes, a conventional "transmission equipment" hybrid is assumed with nominal 600 Ω input and balance impedances.

Using a computer program, values of echo and stability balance return losses, and sidetone masking rating are calculated for the four exchange line groups with the two telephone instruments and two exchange line hybrids.

5 Results

5.1 *Sidetone values*

For this case the comparison is made between a 600 Ω exchange input impedance and a complex input impedance. (It should be noted that the STMR values have been calculated as in Recommendation P.79 of the Blue Book).

Note – The exchange input impedance has the following approximate values:

$R_1 = 300\ \Omega$, $R_2 = 1000\ \Omega$, $C = 220$ nF (see Figure 1).

The results are summarized in Table 1 below:

TABLE 1

Calculated values of STMR

Exchange termination	Mean value of STMR (dB)			
	Attenuation of local line group (dB)			
	1	3	6	9
600 Ω	2.6	5.2	8.1	12.4
Complex termination	13.9	14.8	12.7	13.0

It is clear from Table 1 that a 600 Ω termination gives far from satisfactory results with shorter local lines which will include at least 50% of local lines in the British Telecom network. Use of a complex input impedance improves these STMR values by approximately 10 dB and the values are closer to the recommended values given in Recommendation G.121.

These results show that a complex input impedance is essential for the case of sensitive telephone instruments directly connected to digital exchange hybrids. The performance with a resistive impedance is in fact worse than the performance on a conventional analogue exchange because of the low feeding current and impedance masking effect of the digital exchange.

5.2 *Echo and stability balance return losses*

As far as impedance is concerned the most important factor is the choice of the balance impedance for the exchange line hybrid as this determines the network echo and stability performance. Initially a comparison is made between a 600 Ω impedance and a complex impedance assuming existing telephone instruments. Having chosen a balance impedance it is then shown that a further improvement can be made by considering the telephone input impedance.

5.2.1 *Exchange balance impedance*

Table 2 below shows the summarized results for mean values of echo balance return loss (calculated according to Recommendation G.122, Volume III.1, of the Blue Book), and stability balance return loss.

Note – The complex balance impedance has approximate values R_1 = 370 Ω, R_2 = 620 Ω, C = 310 nF (see Figure 1).

TABLE 2

Calculated values of mean echo (stability) balance return losses assuming existing telephone input impedance

Exchange balance impedance	Mean value of echo (stability) balance return loss dB			
	Attenuation of local line group dB			
	1	3	6	9
600 Ω	22.5 (13.9)	12.9 (7.5)	9.4 (6.2)	8.3 (6.0)
Complex impedance	10.2 (8.0)	13.8 (9.1)	15.2 (11.2)	17.1 (12.9)

In addition to calculating mean values for the distributions it is important to consider the edges of the distributions. This is especially true for echo and stability performance where it is the worst case values that are likely to cause network difficulties.

Table 3 shows the minimum values of calculated echo and stability balance return losses for the samples of lines considered. The values for stability balance return loss are those given in brackets.

TABLE 3

Calculated values of minimum echo (stability) balance return losses assuming existing telephone input impedance

Exchange balance impedance	*Minimum* value of echo (stability) balance return loss dB			
	Attenuation of local line group dB			
	1	3	6	9
600 Ω	20 (13)	11 (5)	8 (4)	6 (3)
Complex impedance	9 (7)	11 (7)	12 (9)	11 (7)

With the exception of the 1 dB sample of lines it can be seen from Table 2 that the complex impedance results in mean values for the distributions which are higher than the corresponding values using a 600 Ω impedance. The improvement is particularly marked for the higher loss exchange lines. When the minimum values of the distributions are also taken into account (Table 3) there is a clear advantage in using the complex balance impedance. A similar advantage would also be obtained with non-speech devices such as data modems which have an impedance similar to that of the telephone instrument (assuming a low feeding current).

5.2.2 *Telephone input impedance*

Having chosen a suitable complex balance impedance for the exchange hybrid, the options for changing the telephone input impedance can be considered. Tables 4 and 5 present calculated results for the distributions of echo and stability balance return losses at the exchange hybrid, comparing the effect of complex and resistive telephone input impedances.

Note – The input impedance has nominal values R_1 = 370 Ω, R_2 = 620 Ω, C = 310 nF. (See Figure 1.)

TABLE 4

Calculated value of mean echo (stability) balance return losses assuming complex exchange balance impedance

Telephone input impedance	*Mean* value of echo (stability) balance return loss dB			
	Attenuation of local line group dB			
	1	3	6	9
Resistive	10.2 (8.0)	13.8 (9.1)	15.2 (11.2)	17.1 (12.9)
Complex	29.0 (23.6)	21.0 (13.9)	16.9 (12.8)	17.0 (11.8)

TABLE 5

Calculated value of minimum echo (stability) balance return losses assuming complex exchange balance impedance

Telephone input impedance	*Minimum* value of echo (stability) balance return loss dB			
	Attenuation of local line group dB			
	1	3	6	9
Resistive	9 (7)	11 (7)	12 (9)	11 (7)
Complex	24 (18)	15 (11)	13 (10)	10 (7)

The results in Tables 4 and 5 show a significant improvement in echo and stability balance return losses for the lower loss local lines. There is little difference for the higher loss lines as the balance return loss is primarily determined by the cable characteristics. It can be concluded that there is a clear advantage in designing future telephone instruments with a complex input impedance.

6 New telephone instruments in the existing analogue network

In § 5.2.2 the advantages of a complex telephone input impedance have been illustrated when used with digital exchanges. However, there are also advantages if these instruments are used on conventional analogue exchanges.

The sidetone balance impedance of instruments is generally optimised around the capacitive impedance of unloaded cable. If the telephone input impedance is also capacitive then the sidetone performance of instruments on own exchange calls can be improved. The improvement will be most marked when both instruments are on short lines hence the sidetone is largely determined by the input impedance of the other instrument. This situation is widely encountered on analogue PABXs where the majority of extensions are of low loss.

7 Application to other voiceband terminal equipment

The discussions in this paper have concentrated on telephone instruments. However the conclusions concerning telephone input impedance can equally be applied to other voiceband equipment, e.g., data modems. Work in Study Group XII has shown that higher speed modem services require signal to listener echo ratios approaching 25 dB for successful operation. If the data modem adopts a complex input impedance then the improvements in stability balance return losses (and hence signal to listener echo ratio) discussed in § 5.2.2 can be obtained.

8 Summary and conclusions

This paper has considered aspects of an impedance strategy for the local network with the introduction of digital local exchanges and new telephone instruments.

Calculations based on a large sample of local lines in the British Telecom network have shown that:

i) The input impedance of the digital exchange must take into account the sidetone performance of the telephone instruments. To provide acceptable sidetone performance it has been found necessary to provide a complex input impedance which more closely matches the sidetone balance impedance of the telephone instrument.

ii) Adopting a complex exchange balance impedance gives a significant improvement in echo and stability balance return losses. This improvement is considered necessary to provide adequate echo performance in the digital network without requiring extensive use of echo control devices.

iii) A further improvement in echo and stability losses is obtained by using a complex input impedance for new telephone instruments. This impedance also improves the sidetone performance of connections on analogue exchanges.

iv) The conclusions are also relevant to other voiceband apparatus. Signal to listener echo ratios on voiceband data connections can be improved if the modems use a complex input impedance.

ISBN 92-61-03491-8