International Telecommunication Union

Booklet No. 14

3rd Symposium on Space and Radiocommunication

Paris, 28 May 1974

30th International Air and Space Show

symposium « space and radiocommunication »

organized by the

international telecommunication union

paris, 28 May 1973

31th international air and space show

INTRODUCTION

As in every other year since 1969, the International Telecommunication Union organized the "Space and Radiocommunication" symposium which took place on Monday, 28 May 1973 in connection with the International Air and Space Show. This third symposium was held under the distinguished patronage of Mr. Hubert Germain, the French Minister of Posts and Telecommunications, who presided over the opening meeting.

The theme for 1973 was "Space radiocommunications after the decisions of the ITU second World Administrative Radio Conference for Space Telecommunications, Geneva, 7 June–17 July 1971".

More than a hundred international specialists attended the lectures which gave rise to sustained discussions under the guidance of the Deputy Secretary-General of the ITU, Mr. Richard E. Butler.

The programme for that day as well as the texts of the lectures are given below.

The fourth "Space and Radiocommunication" symposium will be held in principle in 1975–on Friday, 6 June–in conjunction with the 31st International Air and Space Show at Paris-Le Bourget.

Programme of the third symposium "Space and Radiocommunication", 28 May 1973

OPENING OF THE SYMPOSIUM

Opening address by
Mr. H. GERMAIN
French Minister of Posts and Telecommunications

France is glad to welcome all the participants in this symposium. I am personally very happy to be acting as its Chairman.

In connection with this Show concerned with aeronautics and space, the theme of this symposium "Space and radiocommunication" is a particularly happy choice:

— when thinking of international communications, it is now quite natural to think of space,

— this shows the ground that has been covered since the first operational telecommunication satellite link in 1962,

— at the present time, two satellites routing a total of 3500 circuits connect us with other continents,

— there is now talk of satellites for links within one continent, and even within one country (Canadian, United States, European satellites),

— other satellite uses are coming into being—navigation, radio and television, meteorology,

— all these users have to share two non-extensible common properties: the geostationary orbit and the radio-frequency spectrum,

— hence the necessity of such symposia, with a view to optimum utilization.

Furthermore, I wish to pay a tribute to the oldest intergovernmental organization, which I regard as a model:

– the ITU is over a hundred years old, having been set up here, in Paris, in 1865;
– it is nevertheless more active than ever, since it keeps pace both with ever more rapid advances in technology and with mankind's ever-increasing requirements in communications–thus, the number of telephones has increased tenfold in thirty years and now stands at 300 million;
– the ITU consists of 146 countries, representing all regimes and ideologies. It has been able to rise above political quarrels, remaining faithful to its twofold objective:
  – the development of telecommunications throughout the world, with special reference to international links,
  – extension of co-operation btween countries with regard to all types of telecommunications;

Mr. Hubert Germain, French Minister of Posts and Telecommunications, addresses the participants. On his left, Mr. Serge Dassault, Commissioner-General of the International Air and Space Show. On his right, Mr. Richard E. Butler, Deputy Secretary-General of the International Telecommunication Union, and Mr. Louis-Joseph Libois, Director-General of Telecommunications at the French Ministry of Posts and Telecommunications

— under the distinguished direction and impetus of its present Secretary-General, Mr. Mili, supported by all the senior officials of the General Secretariat and of the Consultative Committees, the ITU must continue its work. It should be noted that the Plenipotentiary Conference, the supreme organ of the Union, is to meet in September of this year.

Our country has associated itself with the two objectives of the ITU:

— we are participating actively in the development of the world telecommunication network, both through such organs as INTELSAT and through more specific action, exemplified by *TAT-VI,* or the future cable between France and the United Kingdom;

— in the area of co-operation, mention should be made of our activities in Mexico, the People's Republic of Poland and Africa.

Telecommunications have a fundamental part to play in bringing all countries closer together and in developing mutual understanding and a sense of belonging to the same community, the community of mankind.

(Original language: French)

Welcoming address delivered by Mr. R.E. BUTLER Deputy Secretary-General of the ITU

Monsieur le ministre,
Monsieur le commissaire général du salon,
Mesdames et messieurs,

I should like to thank you very much, Monsieur le ministre, for your kind words, which emphasize the interest you show in initiatives like these, designed to bring about better understanding, or better "communication", between experts in space telecommunications (designers, developers and users) all of whom have substantial responsibilities to ensure the most effective deployment of this new technology to service mankind.

This third symposium is opening two years after the last World Administrative Radio Conference for Space Telecommunications held in Geneva from 7 June to 17 July 1971.

The second symposium, held just before the Conference, gave participants an opportunity to express their views and wishes concerning the work of the Conference.

That is why we thought it advisable to set as the theme for this symposium "Space and radiocommunication" following the decisions of the ITU World Administrative Radio Conference for Space Telecommunications in 1971.

In 1957, nearly 16 years ago, man entered upon the space age. Vast hopes were placed in the new possibilities that the conquest of space offered to mankind. Already we take for granted space flights; equally the various spin-offs such as the transoceanic and intra-continental telephone, telegraph, data transmission and television relays, the more reliable weather forecasts facilitated by space applications—and not to overlook the direct and indirect benefits to industrial engineering, health and scientific research for example.

If we check the accounts for these past 16 years, we see that a long distance has been covered and that the balance is undeniably favourable.

Naturally the dramatic break-through with these applications could only be arranged with conscientious and realistic international collaboration—indeed regulation—in which the International Telecommunication Union has shown its vitality as an organ providing consultation, co-ordination, planning and regulation for the orderly integration of the new technology into the world telecommunication network.

Even ahead of the United Nations expression of its rightful interest in regard to fundamental political and associated legislative frameworks concerning outer space in the early 1960s, the Union's International Radio Consultative Committee (CCIR) was studying the necessary standardization for the effective and efficient application of space radiocommunications alongside conventional systems—public aviation, maritime, broadcasting, radio astronomy, radio amateurs, etc.—quite apart from the exchanges of scientific and technical data in the consultative process of the Union.

The first World Administrative Radio Conference in 1963 established the first frequency allocations for space radio services, the technical and co-ordination conditions to be observed in the establishment and operation of such services. At that time the accent concerned space applications for communication satellites (telephony, telegraphy and television distribution), space research and satellite aids to meteorology.

Subsequently we have seen a virtual explosion in telecommunication requirements for all services, an ever-increasing demand on the uses of the radio frequency spectrum and a diversity of potential applications for other services which include:

- aviation and maritime (for both traffic and navigational purposes);
- the prospects of direct television reception with its potential dramatic contribution to the removal of illiteracy and to social and educational progress; and
- the further prospect of earth exploration and environmental satellites to improve man's well-being.

The success of the second World Administrative Radio Conference in meeting the demands of various service interests cannot yet be truly measured. Its value is enhanced month by month. The six weeks of intensive work by all the delegations in 1971 following the sustained and collective technical preparations by member nations individually and collectively through the

CCIR have opened up enormous communication possibilities—undreamt of even 15 years ago when the Committee began its orderly study of application and integration of new techniques. For the innovator, the designer and the applications engineer, work can begin on the radio systems of the next decade—with consequent effect not just in space but on mobile and land terminals, providing the necessary interfaces—even a contribution to the Third Development Decade to enable the optimization of investment and further economic progress.

The papers presented to this symposium cover many matters arising from the second Space Conference and I am pleased to have with me today my colleague Mr. A. Berrada, Member of the Union's International Frequency Regulation Board (IFRB), to join in the discussions on the practical consequences of the Conference's decisions, including:

i) the introduction into the Radio Regulations of not only new technical parameters in the use of various systems but also detailed co-ordination procedures to be observed by the planners of satellite services, including through the IFRB, the effective and efficient use of the radio spectrum;

ii) use with equality of rights of radio frequency bands;

iii) no permanent pre-emption of the spectrum (including of orbital positions) for the "first users", who have also a responsibility to take the necessary practical and technical measures to enable others to establish their planned services at a later date;

iv) a new and very specific principle in providing that Members establishing satellite broadcasting services have a responsibility to take all the technical means available to reduce to the maximum extent possible the radiation of signals over countries unless there has been prior agreement;

v) resolutions which foresee further planning conferences and regional agreements for the planning and operation of satellite broadcasting services.

The demands for the expansion of certain fixed and mobile services have already led to the suggestion of an ITU World Conference in regard to planning of certain frequencies to be shared with broadcasting services. Our Administrative Council has decided to recommend to the ITU Plenipotentiary Conference, to be held in September-October of this year, that such a World Planning Conference should be convened in the foreseeable future, possibly between 1978 to 1980—a further example of the Union showing once again its vitality by looking to the long-term future, meeting the demands closer at hand and enabling sound and orderly technical preparations, so essential to the successful outcome of the Regulatory

Conferences because of their significant contribution to the effective application of new technology and the effective use of the huge investments concerned.

These are a few indications of a general character to set the curtain of our third symposium.

Mr. Minister, it is a great honour for me to meet with you again and to participate in the opening of this symposium under your patronage.

I appreciate very much the substantive contribution that France and your Ministry have always made to the history and progress of the ITU–right from its formation, some 108 years ago, not far from here.

I thank you for your continued support.

Thus it is with great pleasure that I call upon Mr. Lombard of CNET to present the first paper.

(Original language: English)

THE INTRODUCTION OF DIGITAL TECHNIQUES IN SATELLITE TELECOMMUNICATION SYSTEMS

by
D. LOMBARD
Telecommunications Engineer
Centre national d'études des télécommunications (CNET)
France

1. Introduction

The first satellite telecommunication systems greatly benefited from the technical experience gained with terrestrial radio-relay systems. They therefore used mainly analogue techniques.

A movement towards digital techniques is at present discernible both in terrestrial transmissions and in satellite telecommunications. Is this another case of the space sector imitating the terrestrial sector, or is it a development prompted by real advantages? We shall try to provide some answer to this question by making a comparative study of analogue and digital satellite telecommunication systems. There is no question here of giving a full account of all these systems, but rather of describing the characteristics of interest for the comparison we have in mind. In doing so, we shall follow the historical order: we shall deal first with analogue and digital frequency-division multiple access systems, and then with multiple access systems by time division. Multiple access systems by analogue frequency division (frequency modulation) are the only ones at present in use in the INTELSAT network; the *SPADE* system, which uses a digital form of frequency-division multiple access (phase-shift modulation), is in the full-scale test stage on an *Intelsat-IV* satellite. Following a number of successful feasibility tests, INTELSAT is drawing up the specification, in preparation for full-scale testing, for a time-division multiple access system.

2. Frequency-division multiple access (FDMA)

2.1 Definitions

Originally, the expression "multiple access" meant the possibility for signals from a number of earth stations to be amplified in the same satellite transponder.

Multiple access is said to be by frequency division when signals of different origin are sent to the satellite on separate frequencies. The origin of a signal can then be identified by its frequency. In other words, in a frequency-division multiple access system, each station emits one or more carriers towards the satellite and all the carriers are amplified simultaneously by one of the satellite's transponders. Such simultaneous amplification of several carriers is only possible because satellite transponders used in multiple access have no signal limiter. This highly non-linear element, which is necessary in radio-relay systems (and even in a non-geostationary satellite) owing to the wide range of levels received, is superfluous in a geostationary satellite because, at the frequencies used (4 and 6 GHz), level fluctuations are slight. We shall see, however (2.2), that the amplifier itself is non-linear and gives rise to intermodulation noise which increases with the number of carriers to be amplified.

To reduce the number of carriers needed to handle the traffic and to simplify the equipment of earth stations, it is found preferable to combine the telephone channels for several links in a single multiplex at the earth station transmitter which modulates a single multiple-destination carrier. This makes it possible to reduce considerably the total number of carriers to be amplified in the satellite's transponders and improves transmission conditions. At the receiving end, there must be a receiver for each carrier containing telephone channels destined for the station; after demodulation, only these channels are maintained. Operation with multiple-destination carriers leads to an asymmetrical structure for the equipments of an earth station, the number of carriers transmitted usually being smaller than the number of carriers received.

2.2 Intermodulation

The primary power on board existing satellites is limited. To obtain the maximum possible radiated power the amplifier unit (travelling-wave tube – TWT) of the satellite transponder is used in the non-linear part of its characteristic. In FDMA, the coexistence of several carriers in a non-linear element results in:

1. A reduction of the available output power as compared with operation with a single carrier;
2. The appearance of parasitic frequency components (intermodulation products) which, as a whole, behave like an additional noise, called intermodulation noise.([1]) This intermodulation noise, due to the non-linearities of the TWT, is accompanied by the noise due to the amplitude-phase conversion of the TWT, which contains components at the same frequencies as the non-linear intermodulation noise.([2])

As the number of carriers reaching a satellite transponder increases, the two phenomena described above produce an appreciable reduction in its capacity. As an example, table I shows the capacity of an *Intelsat-IV* transponder (assumed to be connected to a global coverage transmitting antenna) as a function of the number of FM carriers amplified.([3])

Table I – Capacity of an Intelsat-IV transponder used with a global coverage antenna

number of carriers reaching transponder	*transponder capacity*	*number of channels per carrier*	*frequency band used by carrier (MHz)*
14	336	24	2.5
7	420	60	5
3.5 [1]	456	132	10
1	900	900	36

[1] Three carriers of 132 channels and one of 60 channels.

The data in table I correspond to configurations in which the carriers are assumed to be of the same capacity. In practice, this is not the case: it may thus be advantageous to adopt frequency plans in which the most serious intermodulation products fall outside the useful band of the transponder, so that they will be filtered out in the satellite. This may place certain constraints on the usable frequency plans.

3. The SPADE system* (PCM/PSK/FDMA)** [4, 6]

In INTELSAT's FDMA/FM/FDM system (frequency-division multiple access/frequency modulation (of each carrier)/and frequency-division multiplexing (of telephone channels)) the minimum available size is 12 channels. Since, moreover, the circuits between two correspondents are permanently established, such a system is most suitable for establishing links of high or medium capacity, but is unsuited to the needs of users who require a large number of light-traffic links.

The situation is somewhat similar to that of telephone subscribers invited to lease on a permanent basis as many lines as they have correspondents: the problem would be solved more economically for the small users and for their administrations if they were connected to an automatic exchange. INTELSAT has thought about this problem and now offers the equivalent of an automatic exchange between its participating stations: the SPADE system.

An automatic exchange establishes a connection between the calling and the called party for the duration of a call. In the same way, SPADE establishes on demand a link between two earth stations for the duration of a call: it is an FDMA system with *demand assignment*.

Eight hundred carriers, each phase-modulated by a previously coded channel, are available to participating stations. For each call, a pair of frequencies is assigned to the sations concerned. When the call is completed, the two carriers are returned to the frequency pool for reassignment. In this way a system of mutual aid is established over the 400 available circuits for all the participating stations.

It is the total peak traffic, which is well below the sum of the traffic peaks at each station, that the system is designed to handle. But deterioration due to intermodulation in an FDMA system is aggravated when the number of carriers is increased and SPADE is an FDMA system with 800 carriers. Although it uses digital signals, it would none the less suffer from very high intermodulation noise if it were not equipped with *voice detectors* which interrupt transmission when the channel is inactive during a conversation; for, owing to the simple fact that two people conversing do not usually speak both at the same time, the channel is unoccupied half the time.

---

* SPADE is a mnemonic abbreviation for Single channel per carrier PCM multiple Access Demand-assignment Equipment.

** Pulse code modulation; phase shift keying; frequency-division multiple access.

The complexity of SPADE equipments is due, however, not to the transmission system but to the management of the demand assignment system, as the equipments at a given SPADE station have to:

- decode the telephone signalling received from the international transit exhange;
- converse with the other SPADE stations to select the pair of frequencies to be used for the circuit;
- set up the circuit to the SPADE station of destination;
- transmit the telephone signalling to the transit exchange of destination.

In addition, they have to carry out corresponding operations on receiving any request for a circuit from other stations in the system.

Despite its complexity, SPADE should succeed in proving its viability as it is progressively put into service. It is to be hoped that the fact that it is available will help to encourage the establishment of new earth stations in countries with very scattered traffic.

4. Time-division multiple access (TDMA) (7, 8)

4.1 To avoid the limitations imposed by the simultaneous amplification of several carriers in a travelling-wave tube, the idea is contemplated of amplifying the signals from different stations sequentially by a periodical process. In that case the full power of the tube can be used and one can tune to the same frequency because the satellite receives only one carrier at a time. Such a procedure requires, of course, that the information, i.e., the analogue speech signal, should be put into a form which permits such sequential transmission. For this, pulse code modulation (PCM) is used, in which each telephone channel is sampled at a rate of 8000 samples per second and then coded in the form of 7 or 8 bits. All the outgoing channels from a station are then time-multiplexed to form a frame of $n \times 7$ (or 8) bits.

In setting up a time-division multiple access system, one first of all defines the recurrent time-slot which separates two successive transmissions from a station. It seems logical, to simplify the system, to take for this interval an integral multiple of the time-slot between two successive samplings, or $n \times 125$ µs. This recurrent interval is then divided into as many unit intervals as there are stations using the satellite. Each station, during the unit interval allotted to it, transmits at high speed the data burst corresponding to a frame (or as many frames as the recurrent time-slot will contain). As in the case of frequency-division multiple access, it receives all the bursts relayed

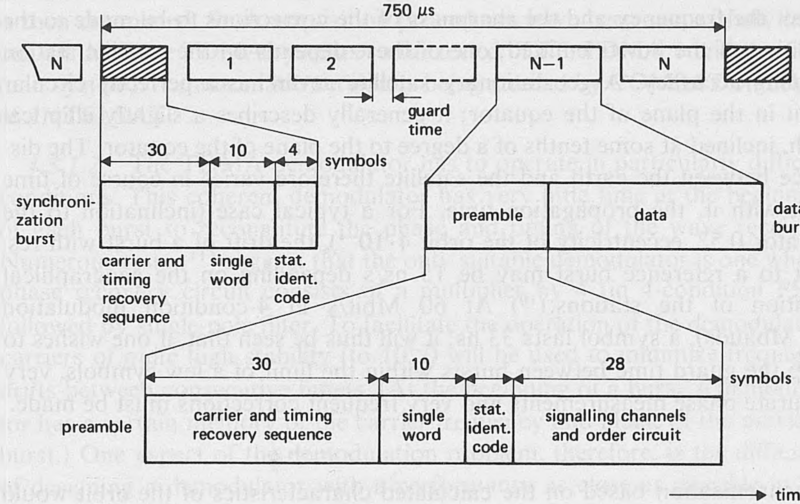


Figure 1 – Frame and bursts format in TDMA system

by the satellite and extracts from them the channels addressed to it. Two- or four-condition phase shift keying is used because it constitutes the best power-passband compromise for the transmission of digital data.

For defining the time-slots allotted to each station, there must be a time base synchronized on a signal (synchronization burst) emitted by a reference station.

4.2 Figure 1 shows a typical configuration of a TDMA frame. It will be noted that the bursts emitted by the different stations are separated by guard times long enough to avoid overlapping due to the inevitable inaccuracies of synchronization.

4.3 Comparison of FDMA and TDMA systems

4.3.1 From the standpoint of transmission alone, TDMA systems have a decisive advantage over FDMA systems: in TDMA, a single signal passes through the satellite's TWT, there is therefore no diminution of output power or intermodulation noise. The satellite TWT can therefore be used up to saturation point.

What are the drawbacks that go with this advantage?

4.3.1.1 Very exact synchronization has to be maintained between the bursts emitted by the various stations. The following orders of magnitude give an idea of the difficulty of achieving such synchronization: two factors affect the frequency and the sharpness of the corrections to be made to the position of the bursts emitted; one of these depends on the satellite station keeping accuracy. A geostationary satellite never has a perfectly circular orbit in the plane of the equator; it generally describes a slightly elliptical path, inclined at some tenths of a degree to the plane of the equator. The distance between the earth and the satellite therefore varies in course of time and, with it, the propagation time. For a typical case (inclination to the equator 0.5°, eccentricity of the orbit $4 \cdot 10^{-4}$), the drift of a burst with respect to a reference burst may be 15 ns/s depending on the geographical position of the stations.[10] At 60 Mbit/s in 4-condition modulation (30 Mbauds), a symbol lasts 33 ns; it will thus be seen that, if one wishes to keep the guard time between bursts within the limit of a few symbols, very accurate phase measurements and very frequent corrections must be made.

Synchronization based on the calculated characteristics of the orbit would be far too inaccurate. A station must therefore constantly measure the position of its own burst in relation to the reference burst after retransmission by the satellite and correct the drift every 300 ms (more frequent corrections would cause instability in the synchronization loop owing to the time-lag between the correction and the measurement of the result produced by it). The second factor is linked to the stability of the digital clocks of the TDMA terminal; if a stability of the order of 10^{-9} is selected for these clocks, the drift due to clock instability becomes negligible in comparison with that due to the Doppler effect. In the present state-of-the-art, such stability can be attained without undue difficulty.

We have just referred to the question of permanent synchronization; the acquisition of such synchronization requires the design of additional equipments. Before starting to transmit, a station (other than the reference station) does not know at what instant in the frame its burst is going to reach the satellite. If it transmitted at full power, its burst might overlap and interfere with a burst already in place; it must therefore start by sending a low-level auxiliary signal to find out the phase of its local frame clock in relation to that of the reference station; this low-level signal (20 dB below the nominal level of the carrier) will not interfere appreciably with the emissions of other stations already in operation because digital modulation is fairly insensitive to interfering signals (especially if they are not on the same frequency as the carrier). Once the phase is known, the entering station will introduce its low-level signal in the middle of the time-slot allotted to it and will then transmit its burst at the nominal level. Acquisition is then completed. Such acquisition procedures have been successfully tried out on the three TDMA systems so far tested (TTT, TDMA 1 and the German system). An automatic version is being studied by COMSAT on behalf of INTELSAT.

4.3.1.2 The TDMA demodulator has to operate in particularly difficult conditions. This coherent demodulator has very little time at the beginning of each burst to reconstitute the phase and timing of the wave received. Numerous tests ([11]) suggest that the only suitable demodulator is one whose phase recovery circuit consists of a multiplier by 4 (in 4-condition PSK) followed by single-pole filter. To facilitate the operation of the demodulator, carriers of quite high stability (to 10^{-7}) will be used to minimize frequency drifts between consecutive bursts. (At the beginning of a burst, a demodulator has a certain memory of the carrier frequency and phase of the previous burst.) One aspect of the demodulation problem, therefore, is the difficulty of designing a demodulator with a performance as close as possible to the theoretical ideal. In passing it may be noted that, in digital modulation, a loss of performance of 1 dB reduces the capacity of a transponder by 1 dB (25%) in the channels. Another aspect is the loss of capacity imposed by the absolute need for a preamble at the beginning of a burst; these preambles are a dead loss as far as the actual transmission of information is concerned, and the greater the number of preambles per unit of time, the greater is the loss. Hence the idea of making the duration of a TDMA frame a multiple of 125 μs. The octets at transmission and reception have then to be memorized so that they can be recovered at the normal channel sampling rate. INTELSAT has worked out an economical compromise involving a TDMA frame of 750 μs = 6 × 125 μs (a value particularly well suited to operation in PSK 4 and then in PSK 8).

4.3.1.3 As a result of these various reductions of capacity, which have to be accepted in a TDMA system as opposed to the transmission of a continuous carrier at saturation level, *Intelsat-IV* (global coverage) transponders have an average capacity of 900 telephone channels each.

4.4 To return to the question of the load factor in digital transmission, we will now talk about call concentration systems.

It may be pointed out that the gain in capacity with a TDMA system as compared with a SPADE system is not very great: 900 as against 800 channels. Why is this?

The answer to this question has already been given in connection with the SPADE system: in digital modulation, the carrier load is the same whether the channel is active or not. TDMA systems therefore carry partially loaded digital frames. By a system similar to that of the SPADE voice detection system, the capacity of a TDMA system can be doubled. For some years past, TASI systems have been in use on submarine cables; they use the inactive times during conversations to interpolate other calls on the same bearer circuit. The gain thus obtained is of the order of two. A TASI-type system can be used with TDMA; the use of digital techniques facilitates the operation of such a system, for example, the voice detection function can be multiplexed.([12])

Without going into details, it will be noted that call concentration systems do not require any processing of the telephone signalling; they are "transparent". There are no interface problems with transit exchanges.

With a TDMA system and a call concentration system (CELTIC), the capacity of the *Intelsat-IV* transponder is doubled and is of the order of 1800 channels. We see, therefore, that when the TDMA concept is used with its natural complement, call concentration, it affords a substantial gain as compared with similar systems.

5. Further developments

More elaborate techniques are already being thought out to increase the efficiency of the systems.

It is contemplated using TDMA in narrow coverage zones with satellites of the same structure as *Intelsat-IV*. There is an obvious power gain from avoiding radiation to unwanted areas; but synchronization of the TDMA is then difficult because certain stations can no longer receive their burst retransmitted by the satellite.([10]) When several satellite transponders use a TDMA system, it is proposed to use a single transmission/reception chain in earth stations which will be switched from one frequency to the other as the bursts come in. This is only possible with common synchronization of all the TDMA systems (([12]) meeting G).

For the next generation of satellites, the possibility of switching on board the satellite is being studied. Practical applications of this idea have already been made (([12]) meeting G).

6. Conclusion

The above survey shows that a wide range of systems suited for specific purposes is available at the present time.

The main characteristics of the systems described above have been summarized in table II. We see how promising the digital systems are; but they will have to be developed with great care if operators are not to yearn for the "good old days" of analogue systems.

(Original language: French)

Table II – Telecommunication systems usable with satellites of the Intelsat-IV generation

multiple access	*frequency division (FDMA)*			*time division (TDMA)*	
system	FDMA/FM	SPADE	SPADE	TDMA	TDMA/CELTIC
modulation	analogue	digital	digital	digital	digital
number of carriers per transponder	about a dozen	800	800	1	1
demand assignment	no	yes	no	no	no
voice detection	no	yes	yes	no	yes
capacity of Intelsat-IV transponder (channels)	400	800	800	900	1800
stage of development	in operation	being introduced in the INTELSAT system	will be tried on *Symphonie*	specifications completed; being developed	
volume of traffic per link for which suited	considerable	low		medium	

Bibliography

(1) Lombard D.: "Intermodulation due à la non-linéarité d'un tube à ondes progressives: programme de calcul et applications" – *Etude CNET 896 EST/EFT*

(2) Chitre N.K.M.: "Intelsat-IV communications system simulation" – IEEE International Conference on Communications, Montreal, June 1971

(3) Puente J.G., Schmidt W.G., Werth A.M.: "Multiple-access techniques for commercial satellites" – Proceedings of the IEEE, Vol. **59**, No. *2* (February 1971)

(4) Werth A.M.: "SPADE: a PCM FDMA demand assignment system for satellite communications" – IEEE International Conference on Communications, paper *70-CP-423-COM,* pages 46-22 to 46-32

(5) McClure R.B.: "Analysis of intermodulation distortion in a FDMA satellite communications system with a bandwidth constraint" – IEEE 70 International Conference on Communications, San Francisco, 8-10 June 1970

(6) Payet G., Monnot M.: "Le système SPADE" – *Echo des Recherches* (April 1971)

(7) Schmidt W.G. *et al.*: "MAT-1: INTELSAT's experimental 700 channel TDMA/DA system" Proceedings 1969 INTELSAT/IEE International Conference on Digital Satellite Communication, pages 428-440

(8) Nosaka K.: "TTT system-50 mbit/s PCM-TDMA system with time-preassignment and TASI features" – Proceedings 1969 INTELSAT IEE International Conference on Digital Satellite Communication, pages 83-94

(9) Lombard D.: "Codage et modulation d'une information numérique en transmission radioélectrique" – *Onde électrique* (September 1971)

(10) Lombard D.: "Accès multiple à répartition dans le temps et couverture par pinceaux" – Text 22E of ref. (11)

(11) Proceedings of "Space and Communication" Symposium, Paris, April 1971

(12) Proceedings of Symposium on "Digital Satellite Telecommunications", Paris, November 1972

SATELLITE BROADCASTING IN THE CONTEXT OF COMMUNICATION PLANNING

by
E. Lloyd SOMMERLAD
Chief, Division of Communication Research and Planning
United Nations Educational, Scientific and Cultural Organization (UNESCO)

In the course of an address at Columbia University last year, the Secretary-General of the United Nations, Mr. Kurt Waldheim, made this statement on the future of communication in the cause of peace:

> " Failure to assert the primacy of policy over technology is an alarming and increasingly dangerous phenomenon of the modern world. All too often, those responsible for the future development of technology are insufficiently aware of the far-reaching political, economic and social implications of their choices. This danger is present also in the area of communication. Unless that danger is removed, future developments in the fields of communication may well produce consequences which were neither foreseen nor desired from a more comprehensive national and international perspective. Often such consequences can only be modified later at considerable cost, if at all."

Perhaps it is not very appropriate to emphasize this aspect of development strategy in the atmosphere of Le Bourget Air Show, surrounded as we are by the wonders of modern science. But it explains in part why UNESCO concerns itself with the problems of satellites and other technologies which have produced what some people call the communication revolution, but which others would prefer to see form part of a well-planned communication evolution.

Arising from its constitutional mandate to promote the free flow of ideas by word and image, UNESCO's programme has naturally evolved to concern itself with problems of utilization of communication technologies. While, on the one hand, UNESCO has encouraged the development of all the media of communication, on the other it reflects the concern of all nations about the quality of information and the content of the messages diffused to ever greater audiences as a result of technical advances. Through its organizational structure, UNESCO has established close links with large numbers of non-governmental organizations, including many in the communications field, and has helped to draw them into the international community. Consequently, in technical conferences UNESCO frequently finds itself in the role of spokesman for "user" interests and for organizations who have the responsibility of providing media services to the public.

Technology and utilization, naturally, should go hand in hand, and national policies should aim at full exploitation of technology in a socially acceptable way. The dilemma faced by many countries today is that the communication revolution has found them unprepared politically, legally, organizationally and economically for application of the technical possibilities. Hence, the growing emphasis on research, policy formulation and strategic and operational planning in the whole field of communication.

We in UNESCO who are concerned with developing the Organization's programme in this area use the word "communication" in a wide sense. It includes the information media in their various forms (newspapers; books, radio, television, cinema), the carriers of the message (telecommunications, print, film, records, tape, video-tape) as well as other forms of social communication such as theatre and direct inter-personal contact.

All countries, developed and developing, are involved today in far-reaching debates on issues which not only affect the nature and role of their communication systems but the very shape of society itself. Even in those countries where communication policies have traditionally been implicit rather than explicitly formulated, there is a growing recognition of the need for consistent policies and plans serving society and the individual, and covering a nation's diverse communication activities as a whole.

It is in this context that the potentialities of communication satellites to help attain national goals should be examined.

The problem may be approached in two ways. The first is to start with the technology and examine ways in which it might be applied or adopted to the problems of development—the establishment of communication networks, the extension of broadcasting facilities, the improvement of the education system. The second is to start with an anlysis of a country's communication needs, a statement of objectives, a listing of available resources, an examination and costing of various system alternatives, an evaluation of satellite uses in the overall communication plan. Then, if space technology is relevant, precise goals to be attained should be defined so that an appropriate system configuration and satellite design may be developed.

Both approaches are valid in certain circumstances. The very existence of a new technology acts as a spur to innovators to experiment with its application in areas of their professional interest. The use of radio and later television for educational purposes are cases in point.

Space communication is no exception. Few recent technical discoveries have so excited the interest of educators, for example, as the possibility offered by broadcasting satellites to transmit television programmes directly to schools in remote and poorly served areas. The satellite is acting as a catalyst to prompt a critical review of traditional educational structures, curricula and methods, as well as to stimulate studies and experiments in its application to school and adult educational problems.

During the first decade of the space age, UNESCO's programme in the space communication field has to a large extent concentrated on promoting the use of satellites for the free flow of information, the spread of education and greater cultural exchange. This programme helped build an awareness of the potential of space communication to solve some of the problems of the developing world. At the request of a number of countries, UNESCO and ITU made preliminary surveys of possible satellite applications for education and development, and it is interesting to note that the first two such studies, in India and Brazil, have been followed by detailed investigations and the elaboration of plans for domestic satellite systems.

Perhaps in 1973 an awareness of the exciting possibilities of satellite broadcasting has been sufficiently established, and there may no longer be a need to promote the idea of applying the new technology for purposes of information and education. So remarkable has been the scientific progress that the technology, although still developing, may be taken for granted by the planning strategist who is certainly looking ahead five to ten years in preparing a national development plan.

Consequently, it may now be appropriate in most cases to adopt the second of the two approaches I mentioned earlier and, starting from an examination of total communication needs, develop a long-term integrated plan, which will take full account of the particular characteristics of satellites, along with other alternatives and advanced technologies such as video cassettes, cable television distribution, computer-based instruction, facsimile newspapers and so on.

Strategic planning of communication takes place under certain constraints, most of which are national, but some key issues must be influenced by the need to conform to internationally formulated norms and standards. Some governments also are vitally concerned about the flow of information to and from other countries which may have political, cultural and social effects which cannot be disregarded.

Communication planning, therefore, must take account of international obligations in such fields as copyright, imports and exports, postal and telegraphic services and radio frequency utilization, as well as broad national policy issues relating to freedom of communication and the free flow or restriction of news and information materials both inwards and outwards.

This brings us to the theme of this symposium–space and radiocommunications–following the decisions of the second ITU World Administrative Conference for Space Telecommunications (WARC-ST, Geneva 1971). The resolutions and recommendations of that conference were of the highest significance for authorities responsible for policy formulation and the planning of development of communication media.

The Conference allocated, for the first time, frequency bands for the broadcasting satellite service and laid down a number of technical conditions applying to their use. This permitted the transmission of television programmes directly from satellite to community receivers, and in the long term when technically feasible to individual receivers.

One of the problems which developing countries in particular faced at the WARC-ST was that they could not know precisely what their requirements for satellite broadcasting frequencies might be during, say, the forthcoming ten years. Some had expressed concern that the more technologically advanced countries might pre-empt the available spectrum space and orbital positions, if a principle of "first come, first served" should apply. To give more time to evaluate needs and develop possible plans for using satellites for broadcasting, proposals were made for procedures which would ensure co-ordinated frequency planning in all regions of the world, and which would take into account future needs as well as present demands for broadcasting satellite frequencies.

Hence the importance of the resolution, adopted by the Conference, recognizing that all countries have equal rights in the use of frequencies and the geostationary orbit, agreeing that the registration with the ITU of satellite frequencies should not provide permanent priority for their use, and deciding that stations in the broadcasting satellite service should be established and operated in accordance with agreements and associated plans adopted by world or regional administrative conferences.

Decisions have not yet been taken as to when such planning conferences should take place, but it is understood that they may commence in the next three or four years.

As a result of these decisions, therefore, the opportunity exists, before binding decisions are taken, for all countries to undertake the necessary research and planning to determine whether or not they may need satellite broadcasting facilities in the foreseeable future. While it is recognized that television via satellite has enormous potential for extending information and education services to rural audiences, thus contributing to development, it is also acknowledged that satellite systems will only be economical if they serve a very large and dispersed population. Comparatively few countries are large enough or have sufficient resources to contemplate establishing an exclusive satellite system for domestic use. Most of such countries already have the possibility under study. But other countries, though seeing no likelihood of launching their own satellite, may have the opportunity in the future of participating in a system shared with their neighbours.

The ITU has already circulated a questionnaire to its Members seeking to elicit information, particularly from developing countries, about likely future requirements for satellite television. UNESCO has followed up this initiative, through its own channels, offering in co-operation with the ITU to provide advisory services to Member States to assess their needs for satellite broadcasting frequencies.

As indicated earlier in this paper, these needs should be seen in the context of overall communication planning, and particularly of television development—whether terrestrial or via satellite and whether on a national or a regional basis. Before a national decision can be made as to whether a satellite frequency assignment will be required, it is necessary to define what television services will be provided; what will be the nature and design of the system—is it to be used for education, if so at what levels and how frequently; is it to be a centralized or decentralized service; how many simultaneous programmes are required; is the whole population to be served; can a system of common regional programming be arranged with other countries; what are the costs and available resources and the desired phasing of television expansion?

The answers to these questions require a comprehensive survey, based on research, taking into account national policy decisions and leading to a communication development plan with wide implications. Certainly the satellite option, as part of the solution, should not be lightly discarded, bearing in mind the possibility of participating in a regional system.

It is obvious, however, that if States are to be ready in a few year's time to say "yes" or "no" to the assignment of satellite frequencies, there is no time to lose before putting in train the major planning exercise which must precede far-reaching decisions on future communication development.

Other decisions of the WARC-ST imposed international constraints on communication system development and touched on some sensitive policy questions relating to the future of satellite broadcasting. The Conference revised Article 7 of the Radio Regulations by adding the following section:

> "In devising the characteristics of a space station in the broadcasting-satellite service, all technical means available shall be used to reduce, to the maximum extent practicable, the radiation over the territory of other countries unless an agreement has been previously reached with such countries."

Furthermore, when allocating the band 2 500-2 690 MHz to the broadcasting satellite service, the Conference imposed the condition that the use of the band was limited to domestic and regional systems for community reception and subject to agreement with the administrations concerned.

The ITU, not being concerned under its Convention with the *content* of transmitted messages, established these restrictions on technical grounds. Nevertheless the decisions reflected the concern of many countries, expressed elsewhere, that in the absence of international agreement they might be exposed to satellite broadcasts of foreign origin that were objectionable on either political or cultural grounds.

It was to meet this foreseen situation that the General Conference of UNESCO, as long ago as 1968, asked the Director General to formulate a declaration of guiding principles on the use of satellite broadcasting for the free flow of information, the spread of education and greater cultural exchange. After lengthy consultations the text of the declaration was approved by the UNESCO General Conference last year. The declaration is not a binding legal instrument, but is an ethical statement, backed by the international community, for guidance in the development and use of space broadcasting. Among the principles enunciated is one which confirms the technical decision of the WARC-ST that States should reach prior agreement on direct satellite broadcasting to the population of countries other than the country of origin of the transmission.

The United Nations is also engaged in a study of this same problem and the General Assembly last December called upon its Outer Space Committee to undertake the elaboration of principles governing the use by States of artificial earth satellites for direct television broadcasting with a view to concluding an international agreement. Both the UNESCO declaration and the WARC-ST decisions may be regarded as contributing to the evolution of internationally accepted standards in the peaceful use of outer space.

The Administrative Conference of 1971 marked a large step forward in establishing a regulatory framework fot the development of space broadcasting. It now remains for its potentialities to be examined in the context of comprehensive and integrated communication planning and for the technology to be exploited in conformity with national policies and goals.

(Original language: English)

THE DECISIONS OF THE WORLD ADMINISTRATIVE RADIO CONFERENCE FOR SPACE TELECOMMUNICATIONS, 1971 AND ESRO's PROGRAMMES

by
G. F. BLOCK
Engineer, Technical and Industrial Policy Division
European Space Research Organisation (ESRO)

Introduction

"What impact does the outcome of the World Administrative Radio Conference for Space Telecommunications (WARC-ST) held in Geneva in June-July 1971, have on ESRO's programmes, in both the scientific and applications fields? Do the results of the WARC-ST solve all previous problem areas and lay a sound base for the Organisation's future work in space technology?" These questions come to mind when reviewing the Final Acts of the WARC-ST, 1971, which are the official record of six weeks' work by several hundred delegates and specialists.

Europe is not always a simple area for spacecraft designers and operators. The high density of communication links in the terrestrial services established long ago does not leave much room for additional users, and so Region 1 could be called the Cinderella of all regions, as concerns space service frequency allocation. However, ESRO being a European Organisation has to live with the facts and try to please its customers as best it can.

ESRO undertook to review the Final Acts in relation to its present programmes, and would now like to report on some of its findings. Obviously, some ESRO programmes are in a more advanced stage of definition than others so that not all areas could be covered in the same detail. Moreover, this report is meant to be a review of the results of WARC-ST and not necessarily a proposal for ways to improve the situation it created.

Space research satellites

Frequency allocations of interest to the space research service in the light of present technology are found in three bands of the spectrum: VHF, UHF (S-band) and SHF (X-band). Allocation of higher frequencies would at present demand that new technologies be developed.

It is important to note that for space research one usually likes to work with a single antenna for up-link and down-link—provided both are in the same general band—in order to simplify the spacecraft design. Thus the ratio of the up-link to the down-link (or vice versa) should be around 1.1, which means that the antenna bandwidth would be of the order of 10%. The separation between the two links in this case is sufficiently large to avoid the need for excessively complex diplexers in order to control cross-coupling in the on-board RF system. This ratio is thus a liveable compromise. If the ratio were to be increased to 1.2 or 1.3 (resulting in an antenna bandwidth of 20-30%) constraints on efficient antenna design would become very severe and in some cases sharing of one antenna between the two links might even become impossible.

■ VHF

The classical VHF telemetry band, 136-138 MHz, has remained unchanged and even though it is densely occupied will continue to serve space research and particularly its low-orbiting satellites. For the associated telecommand frequencies, however, the WARC-ST departed from the originally allocated two discrete frequencies (148.2 and 154.5 MHz) and allocated the band 148-149.9 MHz. Welcome as this increase in available bandwidth is, it inevitably leads to considerable co-ordination problems. The 148-150 MHz band is densely occupied by fixed and mobile services, and the space research service—having footnote status—has to co-ordinate with these.

In a ground station network comprising quite a number of stations in different countries and regions this means that the network authority would have to try to obtain clearance for one or several frequencies from a considerable number of different PTT authorities. This could be quite a complicated business, and it may be that the only way of solving the problem will be by an iterative process in which frequencies are identified that can be agreed to by all parties involved. ESRO has so far not yet initiated any action on these lines but will have to do so in the near future for the transfer orbit operations of its *Geos* satellite, to be launched in 1976.

■ UHF

A particular situation exists for the S-band frequencies. The Region 1 representatives to the WARC-ST did not agree to the Region 2 proposal to make available 100 MHz (2 200-2 300 MHz) for the down-link and 95 MHz (2 025-2 120 MHz) for the up-link, the reason for this refusal being the fact that Europe is extremely densely covered by microwave radio-relay links handling an important percentage of the national telecommunications traffic. Region 1 has to live with 10 MHz bandwidth in each direction (2 290-2 300 MHz for the down-link and 2 110-2 120 MHz for the up-link, except for Spain which agreed to the Region 2 allocation for the up-link, see footnote 356AB). The two 10 MHz bands available in Region 1, however, are the classical frequency bands used by NASA's "deep space network" (DSN) which is equipped only for these bands. NASA would naturally be very reluctant to assign frequencies in the DSN bands to spacecraft other than their deep space probes, for fear of harmful interference to the latter.

This situation has recently caused considerable problems to ESRO, which has decided to participate–with the establishment of a ground station in Europe–in the NASA IUE (international UV explorer) project. ESRO was compelled to plan a second ground facility for geostationary satellites, the first one being located about 30 km from ESOC, ESRO's Space Operations Centre in Darmstadt. Fortunately the Spanish Government was prepared, exceptionally, to grant ESRO protection outside Region 1 allocations on a site close to Madrid for the IUE telemetry down-link.

IUE is only a first case; others could arise in the future. The difference in available bandwidth and the existence of the DSN will, for instance, call for very close co-operation with NASA when assigning a telemetry frequency to ESRO's *Geos* project which, being a European project controlled from a European station, will have to use Region 1 bands. Furthermore, even in these bands ESRO is experiencing extreme reluctance on the part of some PTT authorities to assign frequencies to the space research service.

■ SHF

For the time being, ESRO is not considering the assignment of frequencies in the X-band. It must, however, be recognized that the two bands (7 145-7 235 MHz up-link and 8 400-8 500 MHz down-link) are so widely separated that an antenna bandwidth of about 20% becomes necessary, resulting in design problems. Furthermore, standard range and range-rate tracking equipment defined for the VHF and UHF bands, where the ratio of up- and down-link frequencies in the transponder can be expressed by 240/221, cannot be used. The same problems of heavy occupation of the bands by microwave radio relays in Europe appear to arise as in the case of the UHF bands.

Meteorological satellites

For its *Meteosat* programme ESRO will use the bands 1 680-1 700 MHz for the down-link and 2 096-2 120 MHz for the up-link. The same general bands are used by NASA/NOAA for their *SMS/Geos* project. The next higher bands—7 450-7 550 MHz for the down-link and 8 175-8 215 MHz for the up-link—might be considered for later generation spacecraft with increased bandwidth requirements. Other allocations exist only beyond 20 GHz.

When deciding on the *Meteosat* frequency bands, ESRO had to recognize shortcomings inherent in the UHF allocations. The two bands for up-link and down-link are separated by 450 MHz, which imposes a significant demand on the on-board antenna design.

Another severe limitation originates from Footnote 354A; it allocates to fixed and mobile services in some Eastern European and African countries of Region 1 the only portion of the band, namely 1 690-1 700 MHz, which would otherwise be allocated exclusively to meteorological services and thus could well be used for data dissemination to meteorological users. This Footnote, together with the application of Regulations 470NE, NF and NG limits, for Region 1 and particularly for Europe, the power flux density on the ground to -154 dBW/m^2 in any 4 kHz. This limitation has a budgetary impact on the design of data users' stations operated by meteorological or other interested services. Instead of being able to work with small receiving antenna diameters and simple receiver/preamplifier systems, users are now forced into procuring more expensive ground equipment.

The restriction in available up-link bandwidth in the 2 096-2 120 MHz band as imposed by Footnote 356AC, in comparison to Footnote 356AB for Regions 2 and 3 and Spain, leads not only to the considerable antenna bandwidth already mentioned, but also to a difficult sharing situation with the space research service in Region 1, particularly with the deep space network of NASA.

Finally, it should be noted that the ratio of up- and down-link frequency bands, which is about 1.3, precludes the use of standardized range and range-rate tracking equipment developed for space research satellites.

To sum up, it can be stated that the frequency allocations to the meteorological satellite service are not fully satisfactory in Region 1. The technical difficulties can obviously be overcome, but only at some financial cost.

Earth exploration satellites

ESRO's earth observations or earth resources satellite programme is still at a very early stage, but as part of the programme definition ESRO is conducting research into the active sensor field, such as side-looking radars, etc.

The Special Joint Meeting (SJM) of the CCIR, February 1971, held in preparation of the WARC-ST, considered the question of active sensors and concluded that the spectral region selected for these devices would, in principle, be the microwave-window between 3 cm and 1 m (300 MHz-10 GHz). However, the SJM felt that insufficient information was available at that time for a proposal to be submitted to the WARC-ST, which subsequently decided not to allocate frequencies for active sensors. This situation is felt by ESRO to be unsatisfactory. As side-looking radars may prove to be very promising sensors for earth exploration, an attempt should be made to change it in the future.

Nor is the frequency allocation for space-to-earth links in Region 1 considered capable of satisfying earth exploration missions, which require extremely wide bandwidths. No primary allocation is available below 21.2-22 GHz, and this is a band which is still difficult to handle with present technology. The two other bands, 1 525-1 535 MHz (which is regarded as too narrow) and 8 025-8 400 MHz have secondary status only. Considering the high occupation of the lower X-band by (primary) fixed and mobile services it appears very unlikely that this band can be used without suffering harmful interference. This means that earth exploration missions in Region 1 would have to rely on the availability of 20 GHz equipment for spacecraft in the future.

The only up-link which is explicitly allocated to the earth exploration satellite service in Region 1 is the band 2 096-2 120 MHz (Footnote 356AC). The whole of this band is shared with the meteorological satellite service, and the portion 2 110-2 120 MHz is additionally shared with the space research service.

The situation for the earth exploration service in Region 1 is not at present very satisfactory and a future ITU conference should try to correct it so as to ensure that the earth exploration satellite service in this Region does not suffer from severe disadvantages.

Communications satellites

In the field of communications satellites ESRO is not entirely free to select the frequency bands to be used for this service. Already in 1970 the European Space Authorities had decided to operate the first European communications satellite in the 11 GHz band for the down-link and in the 14 GHz band for the up-link. This decision sought to avoid interference in Europe between the ground stations operating in the 6 GHz bands and the existing microwave links, and to allow these stations to be located near traffic centres. This decision was also aimed at giving industry the possibility of developing 12 GHz technologies to meet long-range traffic forecasts.

The present considerations are consequently limited mainly to the situation, following the WARC-ST, in the 11 and 14 GHz bands.

Initial proposals to the WARC-ST by different delegations had been to allocate in both directions, earth–space and space–earth, a continuous band of 1 GHz, which was regarded as being satisfactory from the point of view of actual telecommunications needs. In the course of its deliberations, however, the WARC-ST did not go along with the initial proposals. It allocated only a continuous band of 0.5 GHz for the up-link (14-14.5 GHz), and the down-link even suffered a split into two 250 MHz bands covering the ranges 10.95-11.2 and 11.45-11.7 GHz. Additionally, the band 12.5-12.75 GHz was authorized for both directions (earth–space and space–earth), without power flux density limitation except in the case of those countries listed in Footnote 405BD.

In particular, the splitting of the down-link band has a considerable impact on the design of ESRO's communications satellites, the first of which is *OTS* (Orbital Test Satellite). The bandwidth of 2 × 250 MHz leads to non-optimum spectrum utilization with the TDMA techniques planned for *OTS*.

OTS will have two antenna beams: the so-called *Eurobeam* (illuminating Europe and the Mediterranean basin) with a repeater bandwidth of 40 MHz for transmission of 60 Mbit/s and the spotbeam with 120 MHz for transmission of 180 Mbit/s. The factor 3 between the two transmissions is caused by a difference of 3 (or 5 dB) in the gain of the two antennae, assuming equal power flux density. Thus, only two spotbeam repeaters can be accommodated in each of the 250 MHz bands. Apart from this waste of bandwidth, the splitting of the band causes additional problems on board the satellite, e.g. with the repeater local oscillators.

In order to increase the spectrum utilization efficiency ESRO plans to experiment with *OTS* techniques involving frequency re-use by orthogonal polarization. Each carrier frequency is transmitted simultaneously, once in linear vertical and once in linear horizontal polarization, with the two polarizations carrying different information.

It is evident that the shortage of bandwidth and the splitting of the band has imposed some constraints in the layout of the satellite.

Broadcasting satellite

The particular problems which arise from the frequency allocations of the WARC-ST have to be separated into those associated with the down-link—where the broadcasting satellite service bands are applicable—and those associated with the up-link, where the fixed satellite service bands will be used. Only one of the bands allocated for the down-link can at present be envisaged for use: 11.7-12.5 GHz, i.e. an 800 MHz bandwidth. The four other bands available suffer considerable drawbacks: both the 620-790 MHz band and 2.5-2.69 GHz band are shared service bands with power flux density limitations imposed, apart from their bandwidth being insufficient for the type of service foreseen at European level. The two other bands, at 41-43 and 84-86 GHz, are presently out of the question and will remain so for some time, since the corresponding technology is not yet available in respect of either the satellite or the individual ground receiver equipment.

Only the band 11.7-12.5 GHz will therefore be considered here. This band is shared with the terrestrial fixed, mobile and broadcasting services. However, Footnote 405BA restricts the use of these services by ruling that they shall not cause harmful interference to the broadcasting satellite service, i.e. no power flux density limit is imposed on the broadcasting satellite service. The application of this footnote could result in serious network planning difficulties for the restricted services since the broadcasting satellite service will make sharing difficult because of its high power levels, relatively large bandwidth and the great number of channels to be radiated.

The situation for the broadcasting satellite service down-link can thus only be regarded as satisfactory once the PTT authorities of the participating countries are prepared to grant this service the protection Footnote 405BA calls for.

Whereas the down-link allocation provides for 800 MHz bandwidth there is no up-link with an equivalent bandwidth available below 27.5 GHz. ESRO is studying the implications of using the different possible up-link frequency bands. The 14.0-14.5 GHz band is shared with radionavigation (14-14.3 GHz), radionavigation satellite (14.3-14.4 GHz) and fixed and mobile (14.4-14.5 GHz). Furthermore, this being a band of the fixed satellite service, it is very likely that communications satellites will also file their claims.

A severe problem is created by the limited bandwidth available when trying to relate the down-link channels to the 11-14 GHz up-link bandwidth. One way to overcome this shortage would be to use digital modulation or narrow band FM in the up-link or to plan on several satellites and practise frequency re-use by orbital separation. These solutions, however, might raise technological problems on board the satellite or would have the considerable disadvantage of "polluting" the geostationary orbit, particularly in orbital positions already in heavy demand by other geostationary satellite services. Another way might be the use of the 30 GHz band.

Aeronautical satellites

Aeronautical satellites for the evaluation of communication and surveillance techniques as planned jointly by ESRO, the United States and Canada, require two different classes of links: the satellite–ground links and the satellite–aeronautical links.

It has been agreed to use for the satellite–ground link the C band, 5.0-5.25 GHz, which is allocated to aeronautical radionavigation. Since the total number of channels foreseen for the *Aerosat* system does not require more than a few megahertz bandwidth, the feasibility of a diplexer with about 5% spacing between up- and down-link frequencies does not pose a very difficult problem, bearing in mind that at these frequencies the satellite design can make use of lightweight waveguide techniques. However, should a second generation system require substantially more channels, this may become a problem area.

As far as L-band frequencies are concerned only one area where problems might arise is worth mentioning: nearly the entire band available for both the aeronautical and the maritime mobile satellites, i.e. the band 1 540-1 560 MHz, must be shared with the terrestrial fixed service in the Federal Republic of Germany and in Austria according to Footnote 352D. This sharing situation will probably not cause any problems in aircraft equipment, as aircraft are presently not planning to use the system over Central Europe. It might however, under unfavourable conditions, mean some disturbances to the satellite receiver equipment, if by chance a terrestrial fixed service transmitter were pointing towards the orbital position of the aeronautical satellite. The signal-to-noise density at the spacecraft receiver input of the signals received from the aircraft must be as low as practicable, in order to keep the aircraft equipment simple and light. Transmissions of terrestrial transmitters pointing in the direction of the satellite would be noticed as additional noise in the band and might lead to some deterioration of the incoming aircraft signal. The extent of the interference is obviously a function of the power and spectral composition of the interfering signal. ESRO feels, however, that if this problem arises it should be possible to solve it by suitable co-ordination with the Federal Republic of Germany and Austrian PTT authorities.

Maritime satellites

As in the case of the aeronautical satellite, two classes of links are also needed for the maritime satellite. The functions of this satellite are mainly communications, distress alerting and search and rescue activities. As a secondary assignment the satellite would also provide radionavigation aids.

The WARC-ST did not allocate any particular bands for the spacecraft—ground links of the maritime satellite; however, it was generally agreed that the maritime mobile satellite service would be granted equal footing with other services in the fixed-satellites frequency allocations. As a result of reviewing these bands, it is believed that the bands 10.95-11.2 GHz for the down-link and 14-14.5 GHz for the up-link would most probably be used, as all other (lower) bands (which make use of available technology) are already densely occupied by other users. The 11-14 GHz bands would, moreover, be compatible with frequency allocation for a world-wide system covering Regions 1, 2 and 3. Ensuring availability in the near future of 11-14 GHz technology for the maritime mobile satellite service does not appear to pose a problem, thanks to the development work undertaken both on national initiatives and, in particular, under ESRO sponsorship within the framework of the European Communication Satellite Programme. Technology for the next higher bands, 17-21 and 27.5-29.5 GHz, has not yet been developed in Europe.

The problem that may arise in the maritime satellite—maritime mobile link in the 1 535-1 660 MHz band is similar to that already outlined for aeronautical satellites. The sharing with fixed services in the Federal Republic of Germany and in Austria may have the same effect on the satellite receiver input as in the aeronautical case. However, a better signal-to-interference ratio can be expected at the satellite receiver input, since the maritime mobile EIRP is much higher than that foreseen for the aeronautical mobile.

The available bandwidth in the L-band for transmissions between maritime satellite and maritime mobile is considered sufficient for the first generation system. However, it is likely that future generation spacecraft will have to meet increased user requirements which it will not be possible to accommodate within the bands presently available.

Inter-satellite links

The failure of the WARC-ST to allocate space-to-space links at any frequency below 54.25 GHz forces the use of experimental frequencies for inter-satellite links. This is acceptable while the space-to-space links remain of an experimental character, but immediately operational use between two satellites is envisaged it ceases to be in line with the Radio Regulations.

The fact that no band below 54.25 GHz is available for this service may thus effectively preclude the operation of space-to-space links for quite a few years to come, as it will undoubtedly take a considerable time to develop the necessary technology.

Conclusions

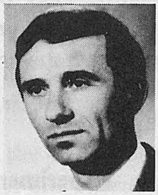
Eight different space services have been reviewed, and in most services it has been found that the situation after "WARC-ST 1971" is liveable, but in quite a few instances life could have been made easier—and cheaper—for the spacecraft designer. It is fully realized that the terrestrial services, which share the bands and may at some time demand a certain priority—on the grounds that modern society needs them (or simply on grounds of their seniority!)—have their own problems. Perhaps there is room, however, in some areas for even closer collaboration between terrestrial and space communications engineers, thus enabling both to understand and appreciate each others' problems and to work jointly towards optimum utilization of the frequency spectrum.

Acknowledgement

The author gratefully acknowledges the help and suggestions he received in the preparation of this paper from colleagues in the ESRO/DPP/Application Satellites Division and in various ESRO/ESTEC Project offices.

(Original language: English)

SPACE RADIOCOMMUNICATIONS IN THE SERVICE OF MAN



by
B. MANUALI
Chief, Programmes Application Division
Centre national d'études spatiales (CNES), France

The space age has opened up vast opportunities for radiocommunications and during the last ten years amazing progress has been made in world radiocommunications thanks to the *Intelsat* and *Molnya* satellites.

This progress has taken place against a background of recurrent political tensions, but it is a remarkable fact that world-wide co-operation between States has nevertheless been established and is functioning effectively, while the vital interests of individual States have been safeguarded.

Looking to the future, it is evident that the need for communications is immense and it seems unthinkable that co-operation among States should not be developed and strengthened. Such co-operation, however, should not be regarded as an end in itself; the only ultimate goal is human well-being and satellites constitute an extremely powerful means for promoting it.

Economic criteria, which are doubtless extremely important for decisions on the manufacture of satellites, cannot be dissociated from human criteria, which must weigh heavily in any decisions taken. It is impossible, for example, to assess the value of educational television by satellite solely on the basis of economic studies when the satellite probably represents the only solution to problems of illiteracy, the abolition of which should be a prime objective of States, especially the most affluent. Similarly, the functions of a maritime satellite system cannot be geared to economic criteria alone when the safety and living conditions of seamen are at stake and the need for protecting the environment–in particular in the event of shipwreck of tankers–must be taken into account.

Lastly, the collection of data and the location of beacons on the earth's surface, either by non-synchronous or by geostationary satellites, should promote the development of new countries and facilitate the study of marine and air pollution which are indispensable for the improvement of the environment.

These three areas of application of satellites are analyzed in greater detail below. They constitute three major branches of the activities of the CNES *(Centre national d'études spatiales)* and every effort will be made to ensure that, whatever the difficulties, the programmes produce quick results.

1. Experiments with educational television by satellite

1.1 World educational needs; the possibilites of television and the advantages of using satellites

In all countries of the world the increase in the numbers receiving education of one kind or another, the breakdown of the school's former monopoly of the teaching function, which is now being superseded by permanent education for people of various age groups, and the critical questioning by the newly-independent peoples of the methods and programmes formerly imposed from outside, have compelled educationists to rethink the very foundations of their activities.

At the same time, whereas the financial cost of education continually rises owing to the increase of the population, the quality of education deteriorates. In most of the developing countries, not only are the schools unable to cope with the flood of illiterates, but only too often the pupils educated by the existing system have great difficulty in finding a place in the economy and society of their countries, despite the latters' desperate need of their brains and their capacity for work.

Traditional methods are powerless to solve the world educational crisis. Drastic innovation is needed.

The very marked trend towards calling on the resources of modern technology, which can be observed in many countries (Brazil, Niger, Ivory Coast, the United States, France, India, Australia, the Andean countries, the Arab States) is bound to spread because it provides an answer to the problems of the mutation in education. Education is in transition from the handicraft to the industrial stage.

Recourse to industrial solutions makes it possible:

- to use teachers more effectively,
- to provide high-quality education,
- to organize an efficient system of refresher and further training courses for teachers,
- to reach a very large audience quickly.

In brief, it makes it possible to provide better teaching for larger numbers *at costs appreciably lower than those of the traditional system.*

This educational revolution is of particular importance for the developing countries which are compelled, on the one hand, to devote a considerable part of their budgets to directly productive investments and, on the other, to train the men who will ensure that the investments bear fruit.

Amongst the means which technology has made available to education, television is destined to play a major role.

The example of *educational television in Niger* shows, over a limited area, the advantages of this type of teaching which is better adapted to the human and geographical conditions. These include the quality of the televised programmes prepared by a highly competent team, the possibility of using, at the outset, less qualified teaching staff and of giving them practically constant training, the powerful motivation that television can provide, and the virtual elimination of school drop-outs.

It should be pointed out that, in this system of educational television, the actual broadcast is only one element, designed to convey a strictly programmed message. The other two components of the system are utilization of the broadcast and the use of active methods. The user's freedom is fully safeguarded.

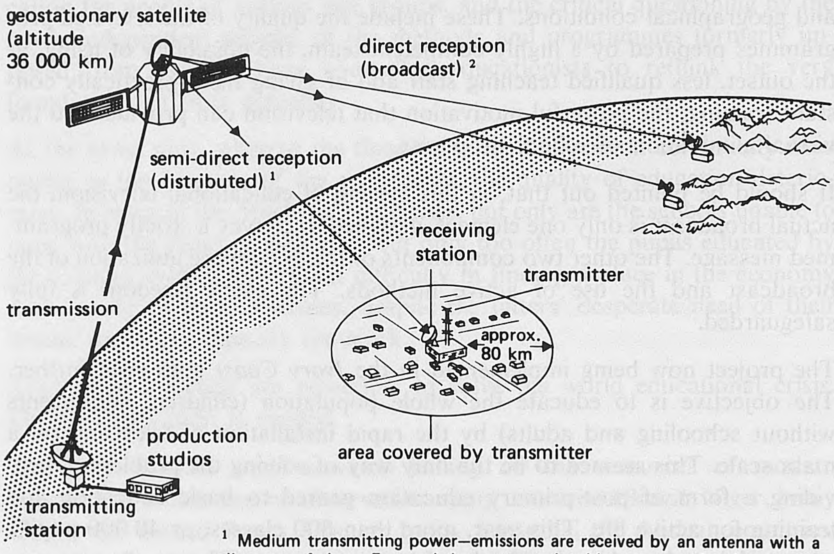
The project now being implemented in the *Ivory Coast* goes even further. The objective is to educate the whole population (children, adolescents without schooling and adults) by the rapid installation of television on a mass scale. This seemed to be the only way of solving the problem of providing a form of post-primary education geared to basic education and training for active life. This year, more than 800 classes, or 40 000 pupils, are receiving the educational television programmes. The results are very encouraging and, by 1977-1980, nearly 700 000 pupils will have received schooling by television.

In many countries, however, the distances between population centres are so great that the transmission network required for such a system is expensive and difficult to build. In such cases it is tempting to *replace the conventional radio-relay network by a satellite* and this has led to a system of an entirely new conception.

Educational television programmes are produced at a centre by teams of educationists and television experts; they are transmitted by a large antenna to a stationary satellite which relays them to receivers in the various schools. If the transmissions are sufficiently powerful to be picked up by the schools, a *direct broadcasting* system can be used; the so-called *distribution* system involves the reception of the satellite emissions by earth stations which relay them to the schools (see figure 1).

Similar ideas have been adopted by the Governments of India and of the United States, which recently decided to conduct an experiment with educational television in 5000 villages in 1975, using the *ATS-F* satellite launched by NASA. Comparable educational projects for South America (the Andean countries and Brazil) are being studied.

The United Nations is anxious to encourage the technical and economic study of systems of this kind, and UNESCO and the ITU have made fea-



[1] Medium transmitting power—emissions are received by an antenna with a diameter of about 5 m and then retransmitted by a conventional transmitter.

[2] High transmitting power—emissions may be received directly with an antenna 1 m in diameter.

Figure 1 — Operating principle

sibility studies of different regional systems while conducting parallel experiments concerning the content and presentation of the televised message.

France and the Federal Republic of Germany, which are preparing to launch the *Symphonie* telecommunication relay satellite in 1974, are planning to use the satellite for a number of educational television experiments designed to familiarize users with space techniques and to give them a clearer idea of the educational and operational problems involved in the use of space systems. It should be possible to meet the requirements formulated either by adapting *Symphonie* for specific missions or by developing more sophisticated satellites.

1.2 "Symphonie" and its possibilities for educational television

a) The "Symphonie" programme provides for

- the construction and launching of a prototype and two flight models of the satellite;
- the construction of two earth stations.

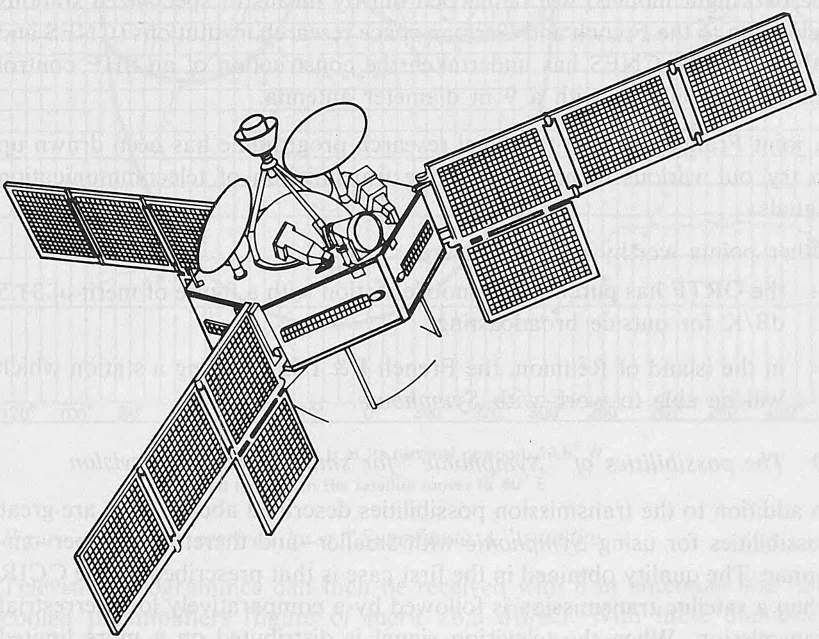


Figure 2 — The "Symphonie" satellite

The *Symphonie* satellites will be geostationary. The two flight models and the prototype will be positioned above the Atlantic Ocean at longitude 11.5° W (see figure 2).

The satellite will be able to receive signals in the 6 GHz band from its whole visibility zone and to re-transmit them by means of two 13 W microwave transponders in the 4 GHz band. Each of the transponders can be connected, at will, with either of the two transmitting antennae whose service areas are Europe and Africa for the one and the western part of America for the other (see figure 3).

The two earth stations of the joint programme are equipped with 15-16 m diameter parabolic antennae, and non-cooled parametric amplifiers (figure of merit 31.5 dB/K). The two stations are being built at Pleumeur-Bodou in France and at Raisting in the Federal Republic of Germany.

The capacity of *one Symphonie*-type transponder in a system equipped with such antennae will be one television channel or 300 telephone circuits.

The operations of launching, positioning and control during the life of the satellites (expected duration: one year for the prototype and five years for the two flight models) will be carried out by means of specialized stations belonging to the French and German space research institutions (CNES and DFVLR). The CNES has undertaken the construction of an SHF control station at Toulouse with a 9 m diameter antenna.

A joint Franco-German technical research programme has been drawn up to try out various techniques for the transmission of telecommunication signals.

Other points worthy of mention are:

- the ORTF has purchased a mobile station with a figure of merit of 31.5 dB/K for outside broadcasting;
- in the island of Réunion, the French P& T is installing a station which will be able to work with *Symphonie*.

b) The possibilities of "Symphonie" for small-antennae television

In addition to the transmission possibilities described above, there are great possibilities for using *Symphonie* with smaller—and therefore cheaper—antennae. The quality obtained in the first case is that prescribed by the CCIR when a satellite transmission is followed by a comparatively long terrestrial transmission. When the television signal is distributed on a more limited scale, reception quality requirements can be reduced.

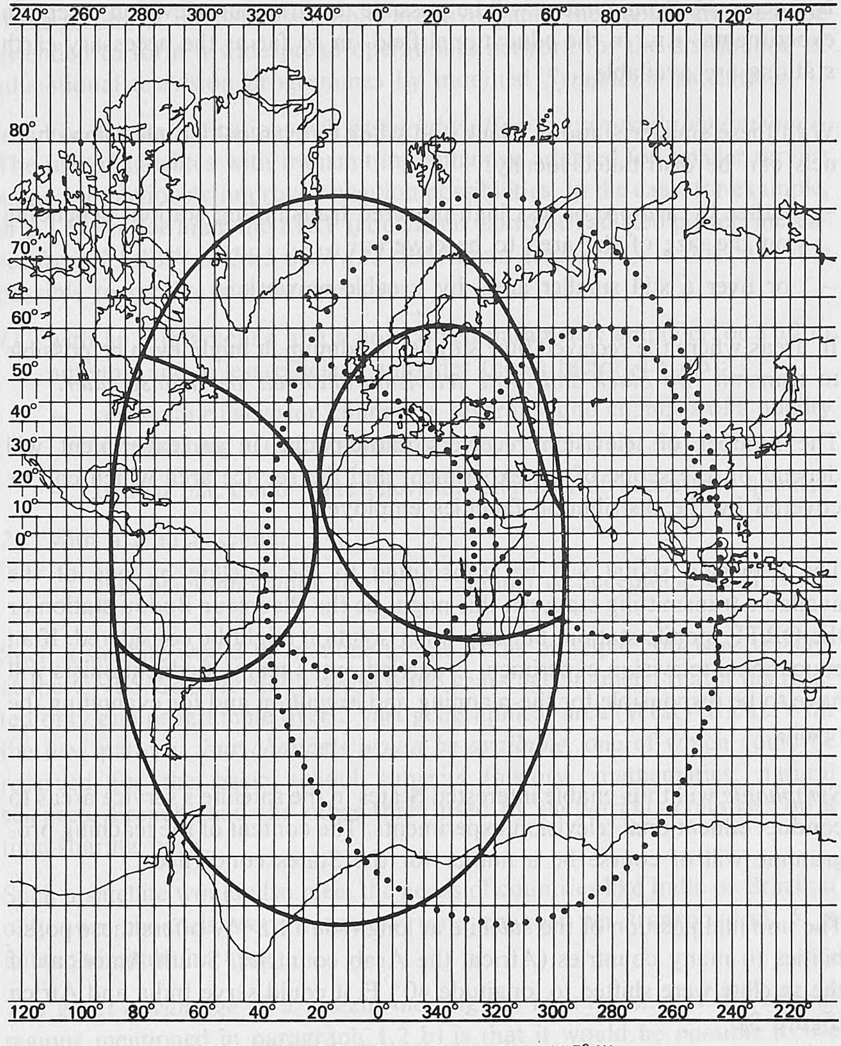


Figure 3 – Areas serviced by a "Symphonie A" satellite

Television programmes can then be received with 8 m antennae and non-cooled preamplifiers (figure of merit 26.5 dB/K). With these diameters, antennae without automatic tracking can be used; they cost about 1.2 million French francs.

By means of *Symphonie* it will be possible to carry out television reception experiments–e.g., in the educational field–in so far as the necessary earth stations are available.

With these smaller stations, black-and-white or even colour television channels can be distributed locally:

- either by a more or less high-powered transmitting station, depending on the size of the area to be covered;
- or over a still smaller area, by a cable network.

In areas where the received flux is quasi-maximum, it might even be possible to transmit *two black-and-white television channels per transponder.*

The number of television receivers participating in an experiment will depend on the scope of the experiment and the service area which can be covered by the distribution facilities employed.

The television signal will be transmitted to the satellite by one of the available transmitting stations; this might be the Pleumeur-Bodou station or the ORTF mobile station, but any other solution might be considered. If an educational television experiment is carried out, a team of educationists will have to be responsible for the planning and execution and for evaluating the results.

Symphonie will thus enable interested States in the satellite's service areas to conduct educational television experiments. The content of the teaching programme will of course be a matter for the States concerned.

The nominal position of the satellite at longitude 11.5° W offers these possibilities to many countries (Africa, the Arab countries, South America). If the satellite were shifted to longitude 40° E, it could serve India and Africa (figure 3).

Experiments can begin in October 1974; all the results required could probably be obtained in an experimental period of two years.

1.3 The modified "Symphonie" satellites and their possibilities

After the initial demonstrations described here, an operational system can be expected to develop between 1976 and 1980.

If the results of the demonstrations are favourable, they could gradually be extended to form a widespread operational network for the distribution of educational television programmes by modified *Symphonie* satellites.

a) The first modifications will *essentially affect the transmitting antennae.* The use of satellites with transmitting antennae adapted for smaller service areas will obviously improve reception possibilities. In the case, for example, of a 3.5° service area, the EIRP (equivalent isotropic radiated power) increases from 29 dBW to 34.5 dBW (33 dBW in an area of 6°). In this case, it is possible to receive via *each* receiver:

1) with an 8 m antenna and a non-cooled parametric amplifier, or a 12 m antenna and a less efficient amplifier (noise factor 4.5 dB):

- one colour television channel + several sound channels of a quality approaching CCIR standards,
- or *two* black-and-white television channels of acceptable quality;

2) with a 5 m antenna:

- one black-and-white television channel of acceptable quality.

Such a satellite would be immune to one of the principal criticisms levelled at the CNES/*Socrate* study made some years ago: namely, that it distributed only one programme over a vast geographical area (West Africa). With the new pattern, *four channels would be available,* one of which could be reserved for the basic school subjects (history, mathematics, natural sciences, French) and the other three used by the various countries on a time-sharing basis.

Such a satellite would also meet the needs of countries like India or Brazil; if only two channels were necessary (one channel per transponder), 5 m antennae could be used.

The *great advantage* of a system meeting the requirements of the various regions mentioned in paragraph 1.2 b) is that it would be possible to use *identical satellites* and a common stand-by satellite and even to arrange for mutual backup in orbit.

In this way, whereas *one* regional system would require the building of *three satellites and two launchings,* the equivalent figures for two parallel regional systems could be *four and three* respectively, which would mean *a saving of about 30%.* The possibilities for the at least partially joint use of the ground installations would imply a further reduction of cost.

b) *Symphonie* satellites can also be modified in respect of the *frequency bands used*; the 2.5-2.69 GHz band allocated by the WARC-ST to community broadcasting seems to be more convenient in the tropical and equatorial countries (though the problem of co-ordination remains a difficult one).

A study carried out by the CIFAS Group of a space telecommunication and educational television system for Brazil concluded that it would be possible to install two 4-6 GHz transponders (of smaller power: 8 W instead of 13 W) and one 2.5-6 GHz transponder; an educational television channel on 2.5 GHz could then be received by 8 m antennae. If only one 4-6 GHz transponder was used, two 2.5-6 GHz transponders could be installed.

1.4 Satellites after 1980

Later, in the 1980s the satellites derived from *Symphonie* will be replaced by bigger satellites (350 to 500 kg) on the basis of the studies carried out for the European telecommunication satellite.

One possibility would be for a European satellite to take over part of the work of the *Symphonie* satellites; this would therefore be a mixed—4-6 GHz (or 2.5-6 GHz) and 11-14 GHz—satellite. The cost of putting the transponder in orbit would be much reduced in the case of a 500 kg satellite, thus reducing the cost of the space segment.

A second possibility would be to go over to *direct broadcasting* during the 1980s. A broadcasting satellite, while continuing to serve the areas already equipped with distribution facilities, would be able to reach areas of scattered population which could not be covered by other means. It is precisely the inhabitants of such areas which, by reason of their isolation, have the greatest need for contacts with the outside world.

A rough calculation based on the service area and costs assumed in the *Socrate* study shows that the investment cost of a terrestrial system would be 50% higher and that, in ten years, an equivalent sum would be spent on operations, whereas the operating costs of a space system are negligible.

Space systems therefore offer very promising possibilities. It is important that governments should realize this fact and should at least explore them with the aid of the experimental *Symphonie* satellites.

The use of these satellites for the educational and humanitarian purposes outlined above will certainly receive every encouragement from the States which developed the programme.

2. Use of satellites by shipping

A ship at sea must be able to find its position and to communicate with land. At the present time navigational aids and communications are still almost exclusively provided by conventional terrestrial methods. It was, however, apparent from the first artificial satellite launchings that space techniques could be used to great advantage in these fields. During the past ten years the basic techniques have been developed and applied in the military sphere. There is no doubt that in the years to come space techniques will play their part in the civilian sector and in the near future, thanks to satellites, shipping will enjoy improved services or even services which do not exist at present.

Maritime telecommunications will be the first to benefit from a satellite service. At present coast stations and ships communicate by radio, the medium frequencies being used for intermediate distances (about 500 km) and high frequencies for long-distance communications.

Generally speaking, this service does not give satisfaction, particularly in the case of long-distance links:

1) owing to defects in propagation it is very difficult to link certain widely separated areas and generally speaking the quality of the link is very fluctuating (and often bad);

2) the setting up of communications is not automatic and has to be done by the radio officer who is on watch for 8 hours per day;

3) the frequency ranges used are becoming more and more congested and it will not be long before saturation point is reached.

In all, the setting up of a call may take several hours (a period of 12 hours is not uncommon in the "coast station–ship" direction) and then the quality may be bad, so there is undeniably a need for faster and more reliable telecommunications. A stationary satellite situated above an ocean would provide an ideal relay for signals exchanged between land and ships.

Satellites have the following advantages:

- telecommunications are more distinct and are of unvarying quality;
- access time is minimal (of the order of a few minutes);
- operations are automatic so it is unnecessary to have radio operators on board;
- there is greater secrecy than with ordinary communications.

A maritime communication-satellite system should make it possible to provide a ship's crew with telephone and telex equipment and even a computer terminal, i.e. a service comparable to that provided for office staff on *terra firma.*

For latitudes below 70°, a system of three geostationary satellites would cover all the oceans. It is planned to introduce such a service by satellite under the aegis of an international organization to be set up for that purpose by 1978. Experimental systems may be available before that date.

Very accurate *radiolocation* of ships is also possible with a satellite system. With systems consisting of one geostationary satellite per ocean and a constellation of three or four synchronous satellites inclined over the equator, a position can be located anywhere on the ocean between 70° N and 70° S to within a distance of less than 100 m.

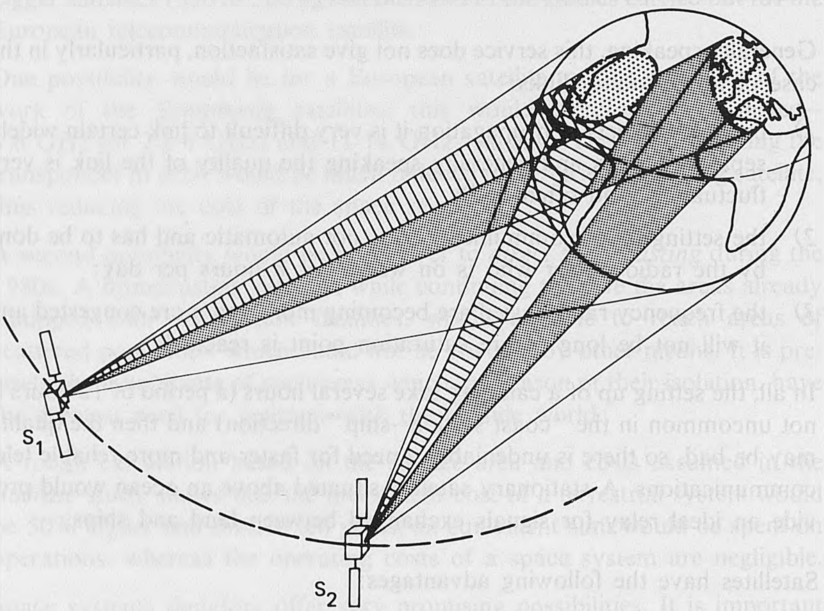


Figure 4 — Radiolocation using two geostationary satellites.

A narrow beam illuminates areas with high traffic density requiring surveillance or monitoring (North American seabord, Western Europe). An antenna with global coverage ensures radiocommunications and radiolocation over the entire ocean

A system *with only two geostationary satellites* (see figure 4) ensures an accuracy of the same order for medium and high latitudes and their performance is limited only in areas around the equator. On the whole, satellites can be used to provide a radiolocation system which is much superior to the conventional systems. Moreover, a combined radiolocation and telecommunication service, which is very simple to achieve with a satellite system, can considerably enhance the safety of a ship at sea by:

1) notably improving the accuracy of traditional navigational methods;

2) in certain areas, providing a system of surveillance or even control of maritime traffic from the land;

3) considerably increasing the efficiency and speed of rescues at sea.

2.1 Navigation

Navigation involves taking constant decisions on the best and shortest route for a ship to take to her destination, avoiding the various hazards she might encounter:

- fixed hazards: shoals, wrecks ...,
- moving hazards: other ships,
- bad weather areas.

There are various ways in which the crew can obtain information which, *after analysis on board*, can be used to determine what course to take.

With an integrated radiolocation and telecommunication system, satellites can provide information which is superior both in quantity and quality.

■ In particular, an *anti-collision system* can become much more efficient.

■ Very accurate location in coastal areas *prevents ships from running aground* in the shallows.

■ Finally, the receipt of meteorological information means that the ships *can avoid bad weather areas,* which cause delay and sometimes damage to the vessel and the cargo.

Using these methods, the basic principles governing navigation are retained: the crew itself decides which course to follow; the satellite has merely increased the efficiency of the aids to navigation.

2.2 Surveillance

Satellites, with their scope for combining radiolocation and telecommunication operations, can bring about a complete change of attitude with respect to the piloting of ships.

A land station can have at its disposal a considerable amount of information concerning the ships in a given area (position, course, speed, etc.). It will also possess general information about the area (state of shipping routes: position of wrecks, shoals, weather conditions, etc.).

Knowing at any given time the situation in the area as a whole, the earth station can provide *surveillance* over that area, following the movements of the different ships and intervening if a difficult situation arises.

To some extent the surveillance scheme on land is a form of *support* for the crew on the bridge of the ship. With such organization a good number of the accidents due to human error in navigating can be avoided. This type of surveillance could be carried out in very dense traffic areas or in sectors where the important sea lanes pass near coasts.

A *traffic control* system could be introduced in certain areas considered to be particularly critical (narrow straits with heavy traffic such as the Channel). The control station would co-ordinate the movements of the various ships and thus increase safety at sea.

Industry in France has made a study of this subject, using the concrete example of the Channel. It has shown that technically such control is possible.

For the Channel a system of parallel lanes with a set speed was suggested. The ships would follow the axis of the lane at a fixed and steady speed. When they deviated from the axis and went beyond a certain threshold, or if the distance between a vessel and a ship forward or aft of it in the same lane were no longer correct, the control centre would transmit a signal.

In the Dover Strait, with a two-way traffic of 250 boats in 24 hours, with two lanes each way having a width of *2 nautical miles* each (which is entirely possible: see figure 5), a 10-minute interval between locations and ships keeping reasonably well on course (85% probability of being less than 0.25 nautical miles from the axis of the lane), the number of collisions could be reduced to *one every eight years* if all the boats were equipped. On an average one intervention per boat would be necessary by the control station for a Channel passage (figure 5).

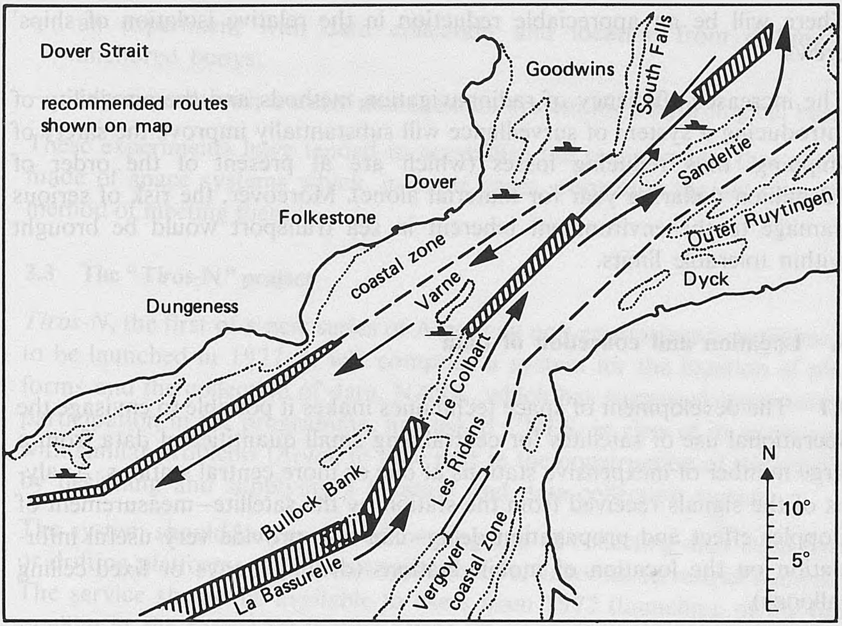


Figure 5

Two channels, each 2 nautical miles wide, can be established in both directions on the recommended routes

2.3 Search and rescue

For maritime safety purposes, the advantages of a system combining automatic and accurate radiolocation with reliable telecommunications are obvious. At the present time, search operations in the event of an accident often take several hours owing to the lack of an accurate location system. Co-ordination of rescue facilities is managed as well as possible under the circumstances. Reliable telecommunications combined with radiodetermination would provide almost immediate information on disasters and where they had occurred.

To sum up, satellites will enable the maritime telecommunication services to bring their quality and efficiency up to the level regarded nowadays as normal for the land service. It will be possible to link vessels at sea with the general land network, thus facilitating the more rational management of merchant shipping (an American study has shown that for a typical United States fleet of 300 vessels, savings of the order of 17 million dollars could be made if management were improved by efficient communications).

There will be an appreciable reduction in the relative isolation of ships' crews.

The increased efficiency of radionavigation methods and the possibility of introducing a system of surveillance will substantially improve the safety of shipping, thus reducing losses (which are at present of the order of 50 million dollars a year for material alone). Moreover, the risk of serious damage to the environment inherent in sea transport would be brought within tolerable limits.

3. Location and collection of data

3.1 The development of space techniques makes it possible to envisage the operational use of satellites for centralizing small quantities of data from a large number of inexpensive stations at one or more central stations. Analysis of the signals received from the station by the satellite—measurement of Doppler effect and propagation delay—can also provide very useful information on the location of mobile stations (drifting buoys or fixed-ceiling balloons).

The satellites now being studied or developed by CNES for these purposes derive more or less directly from the findings of the *Eole* satellite launched by a *Scout* rocket in August 1971. This technique can be used in various projects: a sub-system for the location and collection of data installed in the low-orbit, global-coverage American meteorological satellite, *Tiros-N*, an experimental geodesic satellite launched by *Diamant*, the *Dialogue* satellite which is to pave the way for the operational precise-location satellite *Geole*, and a data-collection system associated with the European geostationary satellite *Meteosat*.

3.2 The "Eole" programme

The CNES data-collection and location programme began with the *Eole* meteorological experiment and is being continued through the so-called complementary *Eole* experiments. These include:

- the transmission of commercial messages from merchant ships and the simultaneous location of the vessels to facilitate centralized management of the fleet;
- the transmission of meteorological messages from ships selected by the French Meteorological Service;

— an experiment with data collection and location from drifting or anchored buoys;
— experiments with a water management system for a hydrological basin.

These experiments have tended to crystallize the requirements that can be made of space systems which, in some cases, constitute the only possible method of meeting them.

3.3 The "Tiros-N" project

Tiros-N, the first of a new series of American non-geostationary satellites, is to be launched in 1977. It will comprise a system for the location of platforms and the collection of data. NASA, which has suggested international participation in the programme, has asked CNES, in view of its experience with similar problems (*Eole*), to take part in the construction of the satellite by designing and supplying a location and data-collection system.

The system should be capable of locating and of collecting data from fixed or drifting platforms of different types (buoys, balloons, terrestrial stations). The service should be available to users from 1977 (launching of the first satellite in the series) till at least 1981. To complete this long mission, a series of about four satellites will have to be launched.

The practical utilization of a location and data-collection system is mainly conditioned by the cost of the whole system and more particularly by that of the beacons. It is aimed to achieve the cost reduction on which the success of the operation depends by maximum simplification of the platforms which will just consist of transmitters.

Characteristics and performances

— number of satellites in flight simultaneously	: 1
— orbit	: circular heliosynchronous at 1600 km
— coverage	: world-wide
— transmitted power of stations	: 3 W at 400 MHz

Data collection

— method of collection	: random access
— storage	: static memory + recorder
— messages	: from 4 to 32 parameters at 8 bits (accuracy 0.5%)

– probability of collection	: 98%
– maximum density of stations	: 600 in the satellite's circle of visibility (radius 4000 km) for 32-sensor stations (without location)
– maximum number of stations	: 6000 on same assumptions as above
– frequency of satellite passes	: at least five times per day
– restitution time	: about 3 hours

Location

– principle	: measurements of frequencies received by satellite
– precision of location	: 5 km for fixed and 5 to 8 km for mobile platforms between +55° and –55° of latitude
– maximum density of stations	: 200 in the circle of visibility for stations with location and 4 sensors
– maximum number of stations	: 2000
– location frequency	: twice a day
– restitution time	: 5 to 7 hours
– probability of location	: 95%

3.4 The "Meteosat" project

The *Meteosat* project, proposed by the CNES, is being implemented as part of ESRO's European programme; *Meteosat* will be one of the five geostationary meteorological satellites launched for the 1977 GARP global experiment. The launching is scheduled for the end of 1976.

The main objective of *Meteosat* is the infrared observation of clouds and the distribution of images processed at a central station to secondary receiving stations. It will, in addition, be equipped with a sub-system for the collection of data in real time.

Three types of stations are planned:

— multiple access: the station emits an alarm signal whenever the parameter it is measuring falls outside pre-arranged limits;
— interrogation by a central station;
— programmed access.

This system does not include location.

Characteristics and performance

— number of satellites	: 5 (2 American) (1 Japanese) (1 Soviet) (1 European)
— orbit	: geostationary
— method of operation and data collection	: *1)* multiple access : *2)* interrogation : *3)* programmed access
— respective capacities of three methods	: *1)* 100 stations : *2)* 1000 stations : *3)* 3000 stations
— transmitted power:	
— fixed stations (directive antenna)	: 4 W
— mobile station (non-directive antenna)	: 20 W
— messages	: 28 at 4000 bits
— coverage	: ±60° latitude (see figure 6)

3.5 "Geole"

The survey made by CNES showed that a number of requirements for accurate location are not met by existing systems either because they are insufficiently precise because restitution times are too long, or because they are too complicated to use. For this reason, CNES thought it would be interesting to study a system for meeting these needs: this is the *Geole* system (contraction of *geodesy* and *Eole*) which is based on the same principle as *Eole*. The non-geostationary satellite would have two functions: first, it would measure (by Doppler effect) the distance and radial velocity of the beacons to be located and it would date the measurements by the stable clock on board; second, it would record these data in a memory and retransmit them by telemetry to a network station when this is visible.

The target set for the satellite (location to within 10 m on a single visible pass and to 1 m calculated over a day's measurements) has a number of implications. It means that the path-tracing—to be carried out by a worldwide network established during the first months of the satellite's life (geometrical geodesy mission)—would have to be extremely precise. It also determines the system characteristics: satellite on circular orbit at an altitude of 3500 km (optimum value), inclined at 60° to 70° to the equator; distance measurements accurate to 2 m and radial velocity measurements to 2 mm/s.

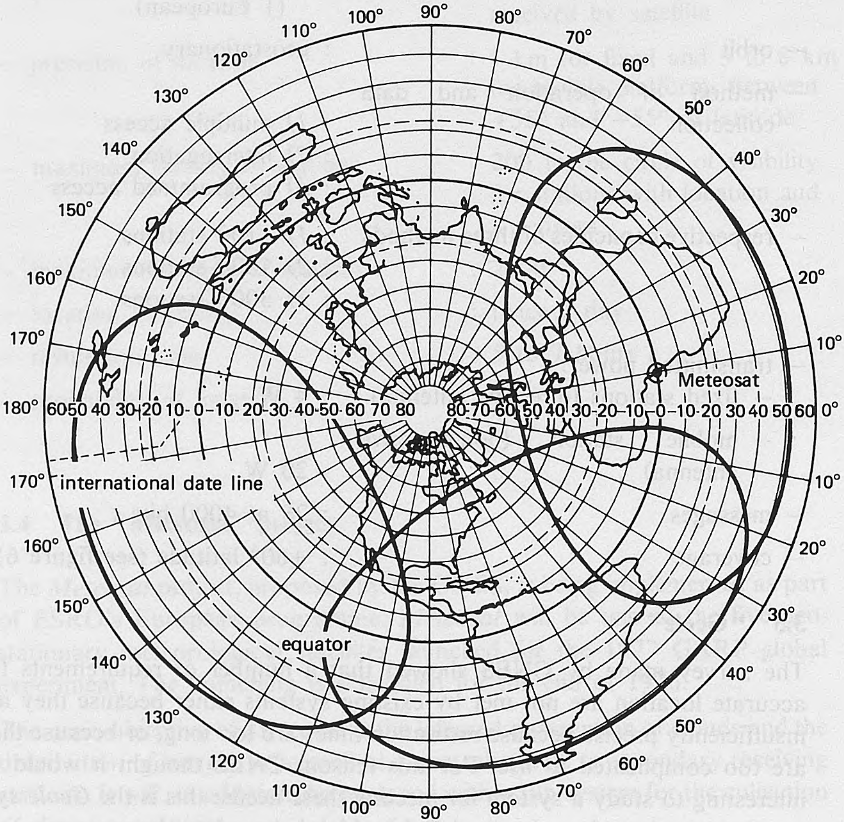


Figure 6 — World-wide observation network of three geostationary satellites

Characteristics and performance

— number of satellites in flight simultaneously	: 1
— coverage	: world-wide
— automatic and transportable stations	
a) measurements during one day	
— restitution times	
— to calculating centre	: 1 hour 30 minutes
— to located station	: 7 hours
— calculating time at station	: 24 hours
— precision	
— stations with directional antennae	: 1 m
— stations without directional antennae	: 5 m
b) measurements during one visible pass	
— restitution time	
— to calculating centre	: 1 hour 30 minutes
— to located station	: 7 hours
— location frequency	: five times a day
— precision	
— stations with directional antennae	: 10 m
— stations without directional antennae	: 50 m

Studies are being made with a view to carrying out the location calculations *on board the satellite*, which would virtually eliminate the restitution time to the located station.

3.6 "Dialogue"

This experimental project is designed to test the Doppler and distance-measuring sub-systems developed for the *Geole* system.

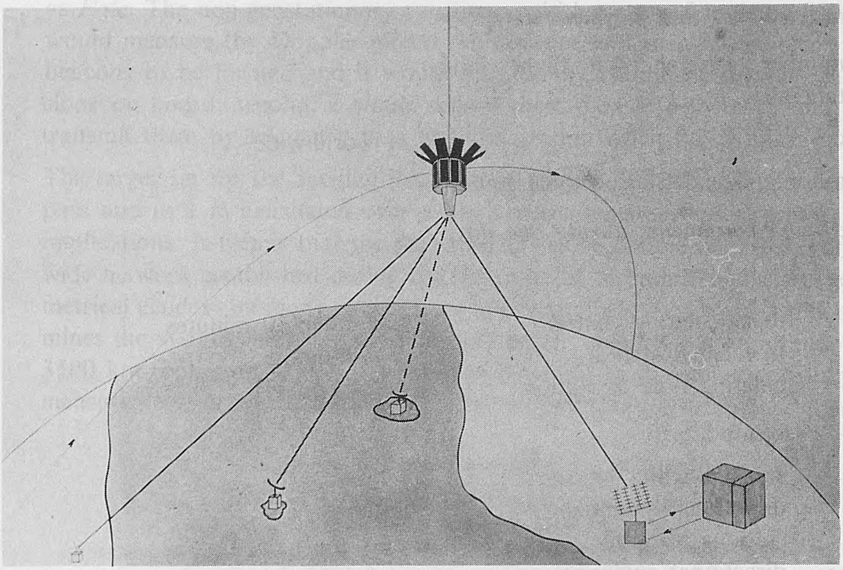


Figure 7

"Geole" location system – Satellite-beacon-satellite measurements of distance and Doppler effect are taken and then stored on board until such time as the satellite passes over a station in the network and a telemeasurement can be made

These tests will cover:

– the general working of the systems,
– distance measurements in comparison with simultaneous laser measurements,
– Doppler measurements by different methods (integration or differential),
– *Geole* processing methods.

In addition, *Dialogue* will help to interest potential users in *Geole* by associating them with the project, which will mark an important stage in the credibility of the system.

The *Dialogue* satellite is to be launched at the end of 1976 by the *Diamant* launcher.

3.7 The advantages of locating and data-collecting satellites

It would be long and tedious to enumerate all the advantages of locating and data-collecting satellites, but some mention must be made of the services they will render to various human communities.

In the first place, the collection of data and the low-precision (5 km) location of buoys and fixed-ceiling balloons and of isolated stations will help to supplement the operational meteorological synoptic measurement network. The buoys and fixed-ceiling balloons can also be used for scientific experiments in oceanography (studies of currents) and in meteorology (study of ocean-atmosphere interaction, of winds, etc.), as well as for studies of marine and atmospheric pollution without which no genuine control of pollution is possible.

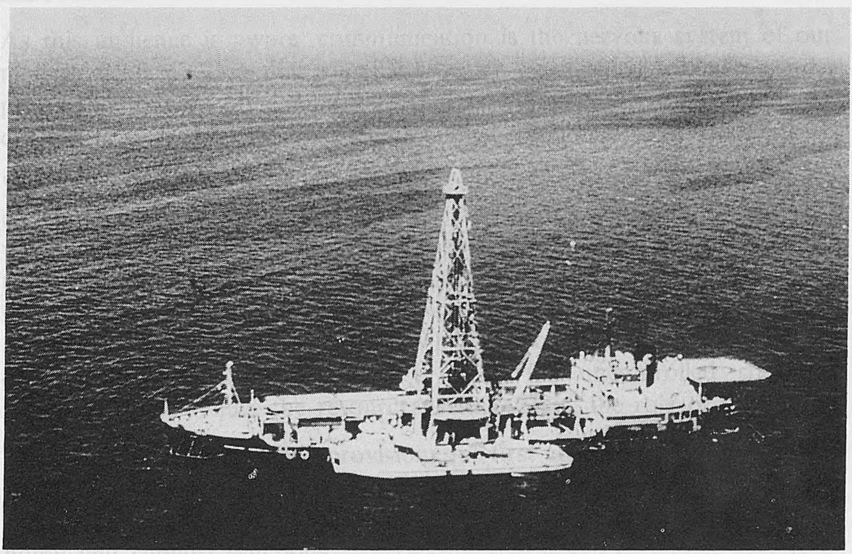


Figure 8

Prospecting for oil – Owing to the very high cost of operating drilling platforms, drilling points at sea have to be pinpointed with the greatest accuracy

Technologically highly sophisticated systems, like *Geole*, will, *inter alia*, help to improve the productivity of petroleum prospecting, geodesic and cartographic teams, because highly accurate locations can be made in record time, whatever the weather conditions. The systems will therefore facilitate and accelerate the development of the new countries while avoiding certain deteriorations (clearing of trees for sighting) which are inevitable with traditional cartographic methods.

(Original language: French)

UNITED STATES EXPERIENCE RESULTING FROM THE WARC-ST (1971)

by
W. DEAN, Jr.
Assistant Director, Frequency Management
Office of Telecommunications Policy
Executive Office of the President
Washington, DC

Introduction

As this audience is aware, communication is the nervous system of our modern society. It is that capability which permits us to flash words, pictures, and data from one place to another with the speed of light; a major catalyst in such areas as international politics, economics, and world peace.

With the advent of satellites sixteen years ago, a new communication capability became available to man. The first Space Conference of the ITU was held in 1963, primarily to provide spectrum resources which would foster the application of space communications. Such actions are necessary at the international level since the spectrum is a limited and highly contested natural resource wherein all of the world's uses of radio must be accommodated. International co-operation is vital, for uncontrolled spectrum pollution would render the resource useless. Thus, the role of the ITU.

The 1963 Conference made provisions for first generation communication satellites, navigation satellites, and meteorological satellites. Some provision was also made for other applications such as space research, radio astronomy and support functions.

The advancement of space technology since 1963 has been truly phenomenal and portends even greater future strides. The 1971 World Administrative Radio Conference for Space Telecommunications (WARC-ST) of the ITU, with over 100 countries and 700 representatives participating, was successful in setting an international course for the expansion of space telecommunications for the next ten to twelve years. Precise engineering criteria were agreed upon at this Conference, providing the foundation for considerably expanded spectrum allocations for space communications. Detailed procedures were also developed, aimed at ensuring the necessary co-ordination among nations in planning for and implementing their terrestrial and space systems. While all attending administrations signed the Final Acts of the Space WARC, it was necessary for the results to be ratified by the cognizant authorities in the respective countries. The United States Senate gave advice and consent to ratification on 13 June 1972, and Presidential signature was appended on 14 July 1972.

Actions taken

Immediately upon completion of the 1971 Conference, the appropriate agencies in the United States—primarily the Federal Communications Commission (FCC) and the Office of Telecommunications Policy—initiated action to bring national regulations into conformity with the Final Acts of the WARC-ST. Such regulations were modified to incorporate the many changes in procedures for the co-ordination and notification of frequency assignments. The National Table of Frequency Allocations was also modified and, as a subsequent action, national allocations to terrestrial services were initiated above 40 GHz, to complement those established for space services as a result of the WARC-ST.

For the remainder of this presentation, I should like to outline some experiences of the United States in the area of space telecommunications since the 1971 WARC-ST; forecast developments in space telecommunications as seen by the United States; and touch on certain problems encountered and conclusions reached to date.

International communication satellites

INTELSAT, with COMSAT as the operating agent, has continued to expand its global operations, and by the close of 1972 four *Intelsat-IV* satellites were in operation. These satellites provide for full coverage of the three major ocean areas with a capacity of 3000 to 9000 voice circuits in each satellite depending upon the type of service, area to be served, and other factors. The space segments were designed to provide service for a seven-year period.

Operations in all areas, i.e., telephony, record, and television, continue to expand. As an example, by the end of 1972 the number of television transmit and receive hours had nearly doubled from that at the close of the previous year. Also, the number of earth stations and participating countries having access to the INTELSAT system increased during 1972 from 52 earth stations in 39 countries to 65 earth stations in 49 countries.

Domestic satellites

In the case of domestic communication satellites, as in many other areas, technical solutions have been easier to arrive at than institutional ones. After several years of considering policy alternatives in the exploitation of satellites for domestic communications, the FCC recently adopted a policy of multiple entry for commercial enterprises. Initially, the Commission had before it eight applications for complete systems, plus several for receive-only earth stations.

Markets to be served in the near time frame include the provision of circuits for long-distance switched message service, leased private lines for voice and/or data, and the transmission of video programmes directly to cable systems. Future uses include distribution of television programmes from network origination points to local television broadcast stations and more advanced, specialized services not now provided by electronic means.

The first construction permits for domestic satellites have been issued and systems could be in operation by early 1974.

Most of the pending applications are based on 12, 24 or 48 transponder spacecraft working with either a few large earth stations (30 m diameter antennae), or with a larger number of smaller earth stations (10 m diameter antennae). Most systems plan to use 4 and 6 GHz, but the newly allocated 12 and 14 GHz bands may be employed as well.

Broadcasting satellites

During the 1971 WARC-ST and in forums of the United Nations during 1972 it was increasingly evident that the possibility of broadcasting satellites is a matter of interest to many countries. The WARC-ST identified two modes of reception in the broadcasting-satellite service, i.e., individual reception and community reception. Concerns expressed thus far are primarily in regard to individual reception or so-called "direct broadcasting" whereby it is envisaged by many that the world's television receivers of today could eventually be receiving programmes via broadcasting satellite. Such a concept appears open to question.

Of major relevance is the fact that, at least in a practical sense, the stipulations of the Radio Regulations serve to preclude "direct broadcasting" in frequency bands now used for sound or television broadcasting.

It is possible that for certain bands, e.g., 620-790 MHz, the future could see the development of relatively low-cost, small-size antennae and low noise-level preamplifiers that would enable direct broadcasting despite existing power flux density limitations. On the other hand, it is highly questionable whether such systems would be technically and economically feasible, particularly in face of the increasing use being made of the bands by terrestrial services.

The new allocation at 12 GHz is the lowest band in which direct broadcasting appears most feasible, there being no limitation on power flux density. However, even with requisite power in a satellite, a direct broadcasting capability could not become a reality at 12 GHz until either a new family of receivers were developed or major augmentation made to existing equipment.

Progress has been made in the development of satellite prime power and EIRP capabilities, but the fact must be borne in mind that direct broadcasting–individual reception–envisages small, relatively inexpensive receiving equipment that an average family could have on and in the home. In the United States view, a direct broadcasting satellite system to serve individuals of the general public is many years and dollars away, economic considerations being a major retarder.

In the light of economic and technical realities, the United States believes that a broadcasting satellite planning conference, as proposed by the 1971 WARC-ST, would be premature if convened before 1980 at the earliest. On what bases would an earlier conference be able objectively to deal with its intended work? When will there be *valid* requirements for incorporation in a plan, rather than "reserving" frequencies and orbital positions for systems that may never come into being? What bandwidth will be the basis for a channelling plan, considering that research is under way on new modulation techniques and ways to compress the spectrum required for a television channel? These and other questions must be assessed objectively in light of the fact that any direct broadcasting satellite system is going to be enormously expensive and will entail virtually a completely new set of equipments from the ground up. In the opinion of the United States, the development of practicable direct broadcasting satellite systems will be a slow process and the co-ordination procedures contained in Resolution No. Spa 2-3 of the 1971 Conference will serve adequately for many years to come.

Amateur satellites

During 1972, *Oscar-6*, the sixth in the series of orbiting satellite carrying amateur radio (*Oscar*), was launched and is presently relaying transmissions from amateurs in Europe, North America, Australia, and other countries of the world. *Oscar-6* was developed and built by amateurs of the United States, Australia, and Germany, and has been designed for one year of service. It will accommodate single-sideband voice, radio teletype, and slow-scan television transmissions. In addition to formal amateur communication, pertinent amateur groups are developing experiments and demonstrations to indicate the potential of amateur satellites for providing communications during periods of special emergencies or natural disasters.

Aeronautical and maritime satellites

Satellites offer a particularly attractive means for meeting world-wide needs of the aeronautical and maritime mobile radio services; communications currently hindered by the shortcoming of high-frequency radio. The technology for such capabilities is currently at hand and specific operational requirements are now being defined. Thought is also being given as to how national and international institutions should be used to guide the applications of this new technology.

Canadian and United States Government officials and representatives of the European Space Research Organisation (ESRO) are developing a programme of international co-operation for the experimental use of satellite capability in support of air traffic control activities in the North Atlantic area, and possibly other areas, during the next several years. ESRO has in progress a review of potential United States commercial partners. Meanwhile, the United States Department of Transportation and the Federal Aviation Administration (FAA) are continuing work with ESRO on an intergovernmental memorandum of understanding which will facilitate a timely and responsive programme definition.

In the maritime area, committees of the Intergovernmental Maritime Consultative Organization (IMCO) have been examining the feasibility of various approaches to the introduction of satellite services, for communications and/or navigation, in support of international maritime activities. The possibility of creating a new international organization for this purpose has been proposed and other options, such as use of the INTELSAT global satellite system, are being discussed. Some administrations are of the view that there is no need for an additional international institution to make possible the near future introduction of maritime satellite services. The United States Government shares this view.

Meteorological satellites

The United States meteorological satellite programme was developed to satisfy three basic goals:

- to provide global atmospheric coverage regularly and reliably, day and night, including direct readout to ground stations within radio range of the satellite;
- to provide continuous viewing of weather systems, and also serve as a relay point between remote sensors and meteorological centres;
- to sound the global atmosphere on a regular basis to provide quantitative measurements needed in numerical prediction models.

Day and night coverage became possible in 1970 following launch of the *Itos* (improved *Tiros* operational satellite), a follow-on to *Tiros* (television infrared observation satellite)–the world's first satellite system developed specifically to satisfy meteorological needs. In 1972, the satellite capability was further expanded with the launch of *Noaa-2*–the first operational environmental satellite to rely entirely on scanning radiometers for imagery in lieu of video systems. With the advent of *Noaa-2,* the first operational environmental satellite capable of sounding the atmosphere on a near-global basis, the third operational goal was satisfied.

The next generation polar-orbiting satellite system will be the *Tiros-N* series of satellites. This series will replace *Itos* in the latter half of the 1970s and will include state-of-the-art advances in spacecraft and launch vehicle technology. The planned on-board sensor complement includes a four-channel high-resolution imagery radiometer; an advanced multi-channel vertical temperature sounder; and communications, processing, and storage instrumentation to provide a location and data collection service for free-floating balloons and ocean buoys. Direct readout or real time imagery will continue to be available.

Environmental satellites

The successful *ATS* (applications technology satellites) satellites form the technological base for the first operational geostationary satellites, to be known as the geostationary operational environmental satellite (*Goes*). The prototype satellite, NASA's synchronous meteorological satellite (*SMS*) is planned for launch in late 1973. The *SMS/Goes* series will permit day and night objective determination of cloud cover and wind fields using film loops and computerized wind-determining techniques. This series of satellites will include a data collection system for gathering data from remote environmental sensor platforms and a direct readout system to selected locations.

The *Goes* data collection system will be available for international participation by environmental services and organizations in programmes of mutual interest. Formal announcement of the data collection programme has been made through the World Meteorological Organization (WMO). A Phase II improved *Goes* system is contemplated for the end of this decade or the early 1980s.

The foregoing total system will consist of satellites of the *Itos/Tiros* variety, orbiting underneath a United States two-satellite geostationary *Goes* system. If other nations were to provide two additional geostationary satellites, the world would then have a truly global meteorological and environmental network.

An earth resources technology satellite (*ERTS*) was also launched in 1972. This polar orbit capability is providing useful data in such areas as agriculture, geology, geography, hydrology, ecology, and oceanography. Results to date are good and co-operative programmes with other countries are being pursued.

Space research

Since the 1971 WARC for space telecommunications, the United States has made use of many of the frequency bands allocated to the space research service. Planned programmes will employ most of the others in the foreseeable future.

For example, since mid-1971 there have been three manned *Apollo* flights to the moon, ten scientific satellites, all still sending useful data, and seven research satellites launched for other countries. Additionally, some 24 other United States and three foreign satellites, all launched prior to the 1971 Space WARC, are also being readout regularly. The normal workload of NASA data readout stations averages about 45 satellites requiring operational support on a regular basis.

Coming events in NASA's space research programme include the *Skylab* workshop with three manned visits planned; the joint United States-USSR *Apollo-Soyuz* test project and the space shuttle *Orbiter,* a manned re-usable vehicle for placing payloads in space and servicing satellites already in orbit. A number of planetary spacecraft are also scheduled, including orbits and landings on Mars, and visits to Mercury, Venus, Jupiter, and Saturn.

Between now and 1976, over a dozen scientific satellites will extend our knowledge of the earth's environment as regards various radiations from space and their sources of origin. The earth's upper atmosphere will be studied, magnetosphere and celestial source radio signals will be investigated and the density of the thermosphere and exosphere measured. Work will be continued in improving communication technology and higher frequencies for earth–space–earth uses will be evaluated. The earth exploration satellite programme will continue, gaining in sophistication and improving the world's weather forecasting and investigating disciplines. A number of special programmes and launches for other nations are also scheduled during the remainder of the 1970s.

Radio astronomy

The United States continues to have strong interest in the field of radio astronomy to explore the universe and its composition.

While being generally gratified with the results of the Space WARC from the standpoint of radio astronomy, some difficulty is being experienced in implementing certain of the footnotes involving the use of bands shared with other radio services, i.e., the determination from a practical standpoint as to how radio astronomy can coexist with other services within footnote limitations. The answers will be greatly dependent upon the specific nature of the other services involved. A similar problem involves the increased use of line-of-sight transmissions by aircraft and space vehicles in frequency bands adjacent to radio astronomy allocations. The advantages of site protection and terrain shielding become ineffective for aircraft and satellite transmissions where interfering signals may be above the horizon for long periods of time.

In the next decade, the sensitivity of radio astronomy receivers will increase, compounding the difficulties of coexistence of radio astronomy with other services in adjacent bands. Design problems are thus raised, calling for the development of more linear components both in transmitters and receivers and greater improvements in filter techniques.

Need for better engineering

As can be gathered from what has been said thus far, the advent of satellite technology has afforded exciting new avenues of adventure and expanded service to man. At the same time, it has also increased the already heavy burden on the radio frequency spectrum, particularly in the ultra high frequency and extremely high frequency regions which are ideally suited for both space and certain terrestrial applications, primarily microwave relay and radiolocation. The results of the 1971 Space WARC attest to the increased spectrum pressures brought about by space telecommunications, wherein the frequency spectrum allocated for space purposes was increased by a factor of 35. Experience to date shows that millions of dollars and many man years are being spent engineering high-powered space system earth station transmitters and companion sensitive receivers into areas already congested with other telecommunications systems.

In the view of the United States, one of the most serious problems encountered in implementing the results of the WARC-ST 1971 is that of ensuring electromagnetic compatibility, i.e., obtaining high levels of confidence, prior to development and procurement, that communication-electronics systems will be able to operate satisfactorily in their intended operational environments without causing or receiving harmful interference.

In dealing with the subject of electromagnetic compatibility, one is faced with several complex parameters—spectrum congestion, the vagaries of radio wave propagation, limitations imposed by the state-of-the-radio-art, and the inadequacies of current engineering practices.

Analysis is the cornerstone to understanding and treating electromagnetic compatibility problems. An analytical capability is needed to provide the means for predicting electromagnetic environments, based on projected uses of equipments and the radio frequency spectrum. Based on United States experience, the attainment of a competent analytical capability should be the catalyst to bring other pertinent needs into perspective. Effective analysis dictates the need for valid data inputs on equipment technical characteristics, accurate environmental data, sound engineering standards, improved measurement techniques and test procedures, better instrumentation, and—as a continuing goal—better spectrum allocation procedures and planning.

Rigorous treatment of electromagnetic compatibility introduces a new era in spectrum management, one requiring a process of extensive education. The problems associated with optimizing the use of the frequency spectrum must be recognized at all levels of radio communications—experiment, design, development, and operational deployment. Unless the experimenter, the builder, and the user understand more fully the capabilities and limitations of systems placed at their disposal, they will neither be able to obtain optimum benefit from electronic capabilities nor to evaluate the adverse effects or benefits which may result from the use of electronics by others.

Within the United States, analysis and improved procedures are being developed and applied prior to each of the stages in the evolution of government radio systems–advanced planning or concept development, experimentation with techniques or equipments, systems development and procurement, and operational deployment. Looking to the future, it is foreseen that this analysis capability for improved spectrum management would be expanded so as to be oriented primarily not only along engineering lines, but also to embrace on a more effective basis such considerations as the impact of economics, possible biological side effects of electromagnetic radiations, and social values. Such a breadth of comprehension dictates that we plan for interdisciplinary capabilities to be brought increasingly to bear in what, heretofore, has been principally an engineering area of endeavour.

The problem of electromagnetic compatibility is not unique to any single administration or to a few selected countries. It is a problem to be recognized and treated by all–individual administrations, neighbouring countries, regions, the ITU and other international organizations concerned with the use of radio, e.g., IMCO, WMO, and ICAO. In short, it is a common need to which all practicable resources should be applied to bring about greater efficiency and savings as regards time, money, and perhaps more importantly, the limited and vital natural resource which we choose to call the radio frequency spectrum.

I appreciate the opportunity to have been able to share with you briefly some of the United States activities since the WARC-ST, to take a look into the future as regards space telecommunications, and to touch on some of the problems encountered and foreseen.

Thank you.

(Original language: English)

SPACE RADIOCOMMUNICATIONS FOLLOWING THE DECISIONS OF THE SECOND WORLD ADMINISTRATIVE RADIO CONFERENCE FOR SPACE TELECOMMUNICATIONS (GENEVA, 1971)

by
P. MAGNE
Directeur technique
Division des faisceaux hertziens
and
B. BLACHIER
Bureau spatial
Division des faisceaux hertziens
Thomson-CSF (France)

I. Introduction

As manufacturers of space and terrestrial radiocommunication equipment, we are very interested in all decisions which might increase the quantity of such equipment and, consequently, our activity in this field.

By drawing up regulations permitting the coexistence of terrestrial and satellite radio systems, the 1971 Geneva Conference opened up for the industry a vast field of new applications, without closing the old ones.

This is what we hope to be able to show in this paper; and for this purpose it is first of all necessary to define space radiocommunications and then to indicate what are the practical consequences for them of the decisions made at Geneva.

II. Space radiocommunications

II.1 Space radiocommunications in general

Every satellite communicates with the ground by radio. Space radiocommunications, therefore, concern all satellites, irrespective of whether they are for telecommunications, broadcasting, radiodetermination, space research, meteorology or radio astronomy.

It is impossible, within the limits of this paper, to describe all the different types of satellite. We shall therefore give particular attention to "fixed service telecommunication satellites". These are also the heaviest consumers of the frequency bands, which they have to share with terrestrial radiocommunications and the other satellite systems.

We shall not deal with the other types of radiocommunications here but they operate with techniques similar to those of fixed telecommunications; we shall occasionally refer to some of their peculiarities.

II.2 The fixed satellite telecommunication service

II.2.1 Basic principles

■ Geostationary orbits

Almost all fixed telecommunication satellites use a geostationary orbit. We may mention, as a matter of interest, the non-geostationary satellites used in the USSR; but such satellites are justified only when communications have to be established with arctic regions.

The accuracy of positioning and attitude of geostationary satellites improves from year to year: for example, the angular definition of the *Intelsat-IV* satellite now being operated for INTELSAT over the Atlantic is better than 0.5° for all earth stations; its altitude varies between 35 739 and 36 230 km.

It is therefore conceivable that all points on the earth within the visibility zone of geostationary satellite could communicate with one another; this is what is called "multiple access".

■ Multiple access

Hitherto, telecommunication satellites have been "transparent", that is to say, all the signals from earth stations are amplified and retransmitted by the satellite without modification. For two stations visible from the same satellite to communicate with each other, all that is necessary is for each station to send a signal to the satellite which relays it on to the other station. When several pairs of stations are communicating with each other simultaneously, the same process is employed, but the signals of all the stations must not interfere with one another. They can, therefore, be separated by using different frequencies; this is known as multiple access by frequency division. It is also possible to separate them in time, with each station sending its signals in turn; this is multiple access by time division.

It is probable that in the near future certain telecommunication satellites will cease to be "transparent" and will carry out some processing of signals on board. To understand the reason for this, we must describe the system in somewhat greater detail, indicating how the two fundamental parameters—the power radiated from the satellite and the frequency band used—tend to limit the telecommunication capacity of satellites.

■ Radiated power and telephone capacity of satellites

At present, and for a long time to come, the power supply on board satellites will be obtained from solar cells. It is evident that the greater the power, the greater the mass of the satellite. The cost of putting a geostationary satellite into orbit is of the order of 20 000 US dollars per kilo. If a system is to be profitable and competitive, the weight, and consequently the power consumed on board the satellite, must be minimized. Now it is the later stages of RF amplification—carried out by travelling wave tubes (TWT)—which account for the bulk of the power consumed on board satellites.

When the purpose of a satellite is to enable earth stations in different parts of the world to communicate with one another, the satellite uses a small slightly directional (17° × 17°) global coverage antenna which can easily be accommodated on board a satellite. On the other hand, the power on board must be considerable, because it is directly proportional to the area illuminated and the number of channels to be transmitted. This power can only be reduced by using large antennae on the ground, because the strength of the signal received on the ground is proportional to the surface area of the antennae. To reduce the cost of antennae on the ground, there is therefore a temptation not to use very high frequencies, because the manufacturing precision of antennae increases with the frequency.

When the purpose of a satellite is to establish communications between points grouped together in one or more definite areas, it is possible to save power on board the satellite by fitting it with directional antennae. The use of high frequencies reduces the dimensions of the satellite antennae and, possibly, the cost of the satellite, if the power on board does not have to be increased.

■ Frequency band used and telephone capacity of satellites

The power per telephone channel to be transmitted from the satellite is a function of the bandwidth available per telephone channel. There is therefore an advantage in using frequencies in which the available bands are widest, i.e., the high frequencies.

a) Frequencies and atmospheric absorption

Atmospheric attenuation increases with the frequency and with the length of the path through the atmosphere. Since the paths through the atmosphere used by satellite systems are short in comparison with those of radio-relay systems, for example, it is reasonable enough to assign high frequencies to them.

At 11 GHz, attenuation may amount to 7 dB for 0.1% of the time in a temperate climate, whereas the attenuation is only 1 dB at 4 GHz. It is therefore important to use to the best advantage the frequency bands in which atmospheric attenuation is low. There is thus a tendency to re-use frequencies.

b) Re-use of frequencies

The capacity of satellite systems depends on the re-use of frequencies. There are three ways of doing this. Several satellites can be spaced at angles in the geostationary orbit. The greater the directivity of the earth stations and the smaller their side lobes, the nearer together the satellites operating in the same frequency band can be placed. This way of re-using frequencies means increasing the number of antennae on the ground or manufacturing a multi-pencil beam type of antenna. Further on we shall see that this possibility is limited. The second way consists in the simultaneous use of two crossed polarizations. The third method consists in producing, on the satellite, directive pencil beams decoupled from one another so that an earth station in the radiation area of one beam is sufficiently decoupled from the radiation of the others. An example is *Intelsat-IV A,* now under construction, which twice re-uses the frequencies in the east and west of the Atlantic. More generally, when a satellite has several directive pencil beams and re-uses the whole band allocated to each of these beams, a switching problem arises on board the satellite, which can be solved, as in the case of multiple access, by frequency or time division.

Everything we have said above about fixed satellite telecommunications can be applied equally to other types of satellite communications.

III. Practical consequences of the decisions of the WARC-ST (Geneva, 1971)

The decisions of the 1971 Geneva WARC-ST fill a 350-page publication. It would be a laborious process to describe and comment on the whole document. We shall therefore, as before, confine ourselves to the decisions relating to fixed satellite telecommunications:

— frequency allocations,
— the technical provisions relating to the limitations on the power and the position of satellites,
— the technical provisions relating to the limitations on the power of earth stations.

III.1 Frequency allocations

III.1.1 11-14 GHz range

The lowest bands newly allocated are:

— the bands 10.95-11.2 and 11.45-11.7 GHz, usually reserved for the space-to-earth link,
— the bands 14-14.5 GHz reserved for the earth-to-space link,
— in Region 2 (America), the band 11.7-12.2 GHz is also allocated to the fixed satellite service (space-to-earth);
— according to the region, the band 12.5-12.75 GHz may be reserved for the up- or down-link.

These new allocations are in addition to the 500 MHz bands available in the 4 and 6 GHz bands; the bands 7.25-7.3 and 7.795-8.025 GHz are reserved for use of the armed forces.

Fixed satellite telecommunications have thus obtained a new 500 MHz band in the 11-14 GHz frequencies, which means that the bands of frequencies below 15 GHz previously allocated to this service have been doubled.

■ Consequences for international satellites

These are the INTELSAT satellites.

Intelsat-IV, positioned above the Atlantic, is approaching saturation. It will shortly be replaced by a more powerful satellite, *Intelsat-IV A*, which will enable traffic to be increased by about 70%. Allowing for an annual increase of 15%, the capacity of this satellite will be saturated in its turn in about four years from now. Saturation may come even sooner if the satellite is used by the domestic services inside countries; but it may also come later than expected. When it does come, *Intelsat-IV A* will be replaced by

Intelsat-V, which will again permit improved re-use of frequencies and delay by a few years saturation in the 4-6 GHz band. Sooner or later it will be necessary to use the band 11-14 GHz.

■ Consequences for domestic satellites

It may be wondered whether the 11-14 GHz range is not better for domestic uses than the 4-6 GHz range. The answer is not simple and largely depends on the existing pattern of terrestrial networks in each of these two bands.

● For a country with hardly any terrestrial radio-relay systems either in the 4-6 GHz or in the 11-14 GHz range, the most economic solution for satellite links is unquestionably the use of the 4-6 GHz range.

● For a country with a dense network of 4-6 GHz terrestrial links and where the 11-14 GHz bands are little used, it is probable that the 11-14 GHz range will provide a good solution for satellite links provided that the establishment of the earth stations does not interfere with the future development of the terrestrial services.

● In a country in which the 4-6 and the 11-14 GHz ranges are both used for terrestrial links, it is difficult to decide on the best solution because the choice will largely depend on the climate; with heavy precipitation, attenuation may be serious in the 11-14 GHz range.

● One way of combating this type of atmospheric absorption is to install a diversity reception system. This means having alternative earth stations so that the probability of serious atmospheric attenuation occurring at the two earth stations at once is very low. In certain climatic regions, where the probability of heavy precipitation is low, 11-14 GHz systems can still dispense with diversity; this probably applies to Europe and to many other countries, but not perhaps to certain areas of the United States. We now understand the interest of Europeans in this frequency band.

III.1.2 17-30 GHz range

Going up the frequency spectrum we find:

— from 17.7 to 21.2 GHz, or a bandwidth of 3.5 GHz,
— from 27.5 to 31 GHz, or a bandwidth of 3.5 GHz.

Of these 3.5 GHz bands, 1.5 GHz of bandwidth is reserved exclusively for the fixed satellite services.

At these frequencies, it will very likely be necessary to use an earth station diversity reception system. The width of the band, and hence the capacity of the systems, is large enough here for diversity reception by means of earth stations not to present undue economic problems. There is a considerable future for systems using these bands, especially in heavy traffic countries, provided they are able to generate high enough power flux densities at the earth's surface to be compatible with the reduced surface area of earth station antennae. Since the cost per kilo of geostationary satellites only diminishes as time goes on, the 17-30 GHz bands will undoubtedly become econominal in the near future and will be used especially for domestic links in countries with high traffic density.

III.1.3 Bands above 30 GHz

Still further up the frequency spectrum, we find the 40-41 and 50-51 GHz bands which are not of great interest.

Lastly, there are the bands 92-95, 102-105 and 140-142 GHz, ranges which the Geneva Conference perhaps reserved for our children, but which we shall probably use ourselves.

To avoid any charge of sectarianism, we may add that the bands 2.5-2.55 and 11.7-12.5 GHz have been allocated to the broadcasting satellite service on a shared basis, and the bands 41-43 and 84-86 GHz on an exclusive basis.

III.2 Technical provisions relating to the limitations on the power of earth stations and satellites

It is important to see how terrestrial and space telecommunication systems can coexist.

In satellite systems, the distance between a geostationary satellite and an earth station is of the order of 36 000 km, so that a considerable transmitter power—of the order of 1 W per channel—has to be used by earth stations. This is because it is impossible to install low-temperature receivers in satellites. Much lower transmitter powers, on the other hand, are used by modern radio-relay systems linking points about 50 km apart and the power per channel, or spectral density, is only about one-thousandth part (30 dB) of that of earth stations. It follows that if earth stations are not to cause interference to terrestrial systems, the power emitted by the former must be strictly controlled, which amounts to saying that the radiation of antennae on the ground must be clearly specified in all directions.

On the other hand, high quality parametric amplifiers are used for reception at earth stations which are 100 times more sensitive than conventional radio-relay receivers. It is therefore important for all unwanted emissions on the ground to be effectively decoupled from antennae receiving satellite signals, which would impose severe limitations on the characteristics of earth station receiving antennae, in so far as these considerations are not outweighed by the antenna temperature requirements. If terrestrial and space systems are to coexist in the same frequency band without having to be situated too far apart, it is essential for the earth stations to be equipped with high quality antennae.

While this condition is more or less sufficient in itself at frequencies in which atmospheric absorption is low, it is very far from being sufficient at frequencies liable to atmospheric absorption and scatter due to precipitation. To prevent such dispersed energy from causing interference to neighbouring radio-relay systems, the main lobes of earth station antennae must not intersect those of radio-relay antennae in regions of the atmosphere where precipitation may occur.

It is for this reason that the WARC-ST stipulated that the equivalent isotropically radiated power transmitted in any direction towards the horizon by an earth station in any 4 kHz band in the frequency bands between 1 and 15 GHz shall not exceed +40 dBW, which is 15 dB lower than the value laid down in previous recommendations. This specification also applies in the reserved band 27.5-29.5 GHz.

The values recommended for the power flux density at the earth's surface produced by emissions from satellites are very low: -152 dBW/m^2 in any 4 kHz band between 0° and 5° above the horizon, and -142 dBW/m^2 in any 4 kHz band between 25° and 90° above the horizon at 4 GHz,

an additional 2 dB is accepted between 8 and 11.7 GHz,
an additional 27 dB is accepted between 17.7 and 22 GHz.

III.3 Position of satellites

The angular position of satellites in geostationary orbit must be determined to within 1°. This enables a large number of satellites to be used in this orbit and increases the possibilities of re-use of frequencies. These possibilities are similarly increased by accurary in the pointing of antennae (10% of the lobe width at 3 dB).

IV. Conclusions

The allocation of new frequency bands and the provisions limiting powers in these new bands, the position and attitude of satellites, are unquestionably favourable to the development of satellite radiocommunications and, in particular, fixed satellite telecommunications, the future of which is directly linked to the widths of the available bands since they limit the capacity of such systems.

With existing techniques, the new frequency bands allocated are probably more expensive to operate than bands lower in the frequency spectrum. But as the demand for radiocommunications grows and the cost per kilo of geostationary satellites diminishes, these bands will be more and more extensively used.

In our view, the decisions of the Geneva WARC-ST have safeguarded the future of space radiocommunications without inhibiting the growth of terrestrial radiocommunications. In any event, these two types of radiocommunications are more complementary than competitive.

(Original language: French)

Closing speech by
Mr. R. E. BUTLER
Deputy Secretary-General of the ITU

Ladies and Gentlemen,

Now that this symposium is drawing to a close I have been asked to sum up, by way of conclusion, the main ideas that have emerged.

First of all, I should like to thank His Excellency, Mr. Hubert Germain, the French Minister of Posts and Telecommunications, who kindly acted as the patron of this third symposium. We appreciate this continuing interest in the ITU and telecommunication collaboration, supported in a very practical way by his Ministry and the French telecommunication organizations and industry.

Mr. Lombard, telecommunications engineer at the French National Centre for Telecommunication Studies (CNET), gave us in his paper clear perceptions of the trend (already well apparent in the terrestrial sector) towards the use of digital techniques and their potential cost effectiveness in space telecommunications. It is certain that the implementation of such techniques in transmission and switching systems will bring many practical advantages to national and international telecommunications, where there are pressing needs to achieve effective and economic technical solutions in matching demands for services. The Consultative Committees (CCIR and CCITT) of the ITU have already embarked on studies for the evolution of relevant co-ordinated international standards.

Mr. Sommerlad, Chief of the Division of Communication Research and Planning at UNESCO, informed us of the interests of his organization in satellite broadcasting in the context of planning of radiocommunications, stressing the problems which could arise from an uncritical application of technology without regard to the political, economic and social consequences. He indicated two possible approaches for the achievement of national objectives in the matter of mass communication by means of satellites:

— the study of the potentialities of the systems and their adaptation to the country's needs; or

— the analysis of national requirements, followed by an evaluation within that context of the possibility of using satellites.

Certainly, the prospective advantages from the use of satellites as relay points in outer space have added new dimensions to the formulation of policy—not only in planning and investment. For precisely this reason governments, acting through the ITU, convened the second World Administrative Radio Conference for Space Telecommunications in March 1971, from which time communities have benefited directly from the agreements affecting public telecommunications (telephone, telegraph and television relays) and indirectly from space research. The governments had realized the expected demand for new services and likelihood of new applications, for example in the maritime, aeronautical, educational and television sectors. New agreements to permit the orderly planning, development and sharing of the radio spectrum between diverse services, including all the terrestrial services, had become necessary. The new legal frameworks, dealing with co-ordinating responsibilities and obligations in regard to planning and the establishment and use of services, signify outstanding achievement in international collaboration and international law. Long-term regulation for development has been a hallmark of the Conference decisions.

Mr. Block, engineer of the Technical and Industrial Policy Division at ESRO, outlined the scientific and practical implications of the Conference for ESRO, reviewing in turn the space research, meteorological satellite, aeronautical mobile satellite, maritime mobile satellite, and inter-satellite services. Whilst outlining the positive aspects of the measures taken at the Conference, he expressed regret that the Conference had not been able to meet certain requirements of special interest to his research organization. This is a very interesting point of view. It demonstrates how useful gatherings such as this can be in bringing about a mutual understanding of the positions of the various users' interests. As was explained by one of the participants, in the preparation of national inputs for such conferences, competing views and interests have to be weighed and reconciled. I personally cannot underline too strongly the importance of the expression of each user's interest at a national level at a very early stage—well in advance of such conferences.

Mr. Manuali, Chief of the Application Programmes Division of the French National Centre for Space Studies (CNES), painted a most interesting and long-term picture of the efforts made by France, through the medium of the CNES, to place radiocommunication at the service of mankind. Particular reference was made to the spheres of educational television as applied, for example, to the struggle against illiteracy, to maritime satellites, data gathering and the tracking of buoys. He has given us concrete examples of the progress made by France in those spheres. He has certainly given us a good insight into future development.

Mr. W. Dean, Jr., Assistant Director for Frequency Management, Office of Telecommunications Policy, Executive Office of the President, gave an account of the experiments conducted by the United States of America since the 1971 World Conference. He indicated the measures taken immediately thereafter by the Federal Communications Commission and Mr. Dean's office with the objective of bringing United States national regulations into line with the Final Acts of the Conference.

I will not repeat the various specific examples Mr. Dean was kind enough to give us. He has made a timely appeal for bold policies of technical application of new philosophies in the evaluation and planning of the frequency spectrum. Briefly, the problem is that, before designing and producing equipment, one must see, as he said, that "the odds are on our side" and that the electromagnetic telecommunication systems will operate correctly in the media in which they are to be used without suffering, or causing, harmful interference. Then, too, he touched an issue of increasing interest, the development of economic and other analytical criteria to assist the achievement of the most effective and economic use of the spectrum, i.e. to assist spectrum management in the widest practical connection. As I indicated for the ITU, in response to questions, the success of such new and challenging concepts at the international level requires progress in the application or understanding of these concepts at the national level. In any event, we will see the time when spectrum use will demand that certain services, which at present share the spectrum, be transferred to guided transmission systems, vacating the radio spectrum for services which require much greater flexibility in transmission or diffusion.

Finally, the representatives of *Thomson-CSF* (France), Mr. Magne and Mr. Blachier of that company's Radio-Relay Systems Division, explained the practical consequences for industry of the decisions of the WARC-ST of Geneva, 1971. They commented on the various long-term frequency allocations citing, for instance, "the bands 92-95 GHz, 102-105 GHz and 140-142 GHz which the Geneva Conference reserved perhaps for our children but which we shall probably use ourselves! ...".

I believe that one of the substantial, and frequently not fully understood roles of the ITU, in its long-term planning for the future, is the utilization of the results of studies at a given level—in this case especially the CCIR—to achieve enough international agreement to protect the future. This agreement provides guide-lines for the expanded use of the spectrum as demands for radiocommunications grow further. These decisions will have considerable benefit to providers of services and for general and industrial research and development programmes. The special design characteristics for the mobile stations on board aircraft and ships can now be defined by the interested industries and authorities.

Generally speaking, the opinion which emerges from this symposium, with regard to the provisions adopted at the 1971 Conference, is a very favourable one. Inevitably, a few pessimistic spots remain and we have had an example of one individual service interest which favoured different allocations. The survey we have made will certainly have the merit of clarifying a good many points. Thanks to the authoritative opinions of our speakers, we are all better informed. Some of the provocative and challenging comments will, I am sure, stimulate a much wider appreciation and understanding of the necessity for continued improvements in preparation for future conferences of this type.

(Original language: English)

Finally, the representatives of Thomson-CSF (France), Mr. Magot and Mr. Blackler of that company's Radio-Relay Systems Division, explained the practical consequences for industry of the decisions of the WARC-ST of Geneva, 1971. They commented on the various long-term frequency allocations citing, for instance, "the bands 92-95 GHz, 102-105 GHz and 140-142 GHz which the Geneva Conference reserved perhaps for our children but which we shall probably use ourselves".

I believe that one of the substantial, and frequently not fully understood, roles of the ITU, in its long-term planning for the future, is the utilization of the results of studies at a given level – in this case especially the CCIR – to achieve enough international agreement to protect the future. This agreement provides guidelines for the expanded use of the spectrum as demands for radiocommunications grow further. These decisions will have considerable benefit to providers of services and for present and industrial research and development programmes. The special design characteristics for the mobile stations on board aircraft and ships can now be defined by the interested industries and authorities.

Generally speaking, the opinion which emerges from this Symposium, with regard to the provisions adopted at the 1971 Conference, is a very favourable one. Inevitably, a few pessimistic spots remain and we have had an example of one individual service interest which favoured different allocations. The survey we have made will certainly have the merit of clarifying a good many points. Thanks to the authoritative opinions of our speakers, we are all better informed. Some of the provocative and challenging comments will, I am sure, stimulate a much wider appreciation and understanding of the necessity for continued improvements in preparation for future conferences of this type.

(Original language: English)

Other publications on the ITU:

Book – From semaphore to satellite (1965) [illegible]

Booklet No. 1 – 1865-1965, a hundred years of international cooperation (1967)

Booklet No. 2 – ITU and space radiocommunication (1968)

Booklet No. 3 – Eighth Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1969)

Booklet No. 4 – Symposium "Space and Radiocommunication" [illegible]

Booklet No. 5 – World Telecommunication Day [illegible]

Booklet No. 6 – Ninth Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1970)

Booklet No. 7 – World Telecommunication Day [illegible]

Booklet No. 8 – Tenth Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1971)

Booklet No. 9 – Speeches made at the inaugural ceremony of the World Administrative Radio Conference for Space Telecommunications on 7 June 1971 (1971)

Booklet No. 10 – Eleventh Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1972)

Booklet No. 11 – Twelfth Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1973)

Booklet No. 12 – Inauguration of the ITU tower (1973)

Booklet No. 13 – PANAFTEL – The pan-African telecommunication network (1974)

Published by the International Telecommunication Union, Geneva [illegible]

Other publications on the ITU:

Book	–	From semaphore to satellite, 1793-1965 (1965)
Booklet No. 1	–	1865-1965, a hundred years of international co-operation (1967)
Booklet No. 2	–	ITU and space radiocommunication (1968)
Booklet No. 3	–	Eighth Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1969)
Booklet No. 4	–	Symposium "Space and Radiocommunication", Paris (1969)
Booklet No. 5	–	World Telecommunication Day – 17 May 1969 (1969)
Booklet No. 6	–	Ninth Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1970)
Booklet No. 7	–	World Telecommunication Day – 17 May 1970 (1971)
Booklet No. 8	–	Tenth Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1971)
Booklet No. 9	–	Speeches made at the inaugural meeting of the second World Administrative Radio Conference for Space Telecommunications on 7 June 1971 (1971)
Booklet No. 10	–	Eleventh Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1972)
Booklet No. 11	–	Twelfth Report by the International Telecommunication Union on telecommunication and the peaceful uses of outer space (1973)
Booklet No. 12	–	Inauguration of the ITU tower (1973)
Booklet No. 13	–	PANAFTEL – The pan-African telecommunication network (1974)

Published by the International Telecommunication Union, Geneva 1974

54973

ARCHIVES

Price: 4 Sw. fr.   Printed in Switzerland