Sixth Report

by the

International Telecommunication Union

on

Telecommunication and the Peaceful Uses of Outer Space

Printed in Switzerland

GENEVA 1967

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The present document which is submitted for the attention, particularly, of the United Nations Committee on the Peaceful Uses of Outer Space and for the Economic and Social Council, constitutes a progress report on the action by the International Telecommunication Union in the field of outer space since the presentation of its Fifth Report, that is, from May 1966 to April 1967.

1. General

The International Telecommunication Union is making steady progress in its studies regarding telecommunication with respect to the various kinds of peaceful uses of outer space. It should be noted, however, that apart from the international cooperation which is taking place in the I.T.U. at the world-wide level, very important studies are being made and there have been many achievements by a number of countries at the national level and under bilateral or multilateral programmes.

2. Technical studies related to the use of telecommunications in space

2.1 As was explained in greater detail in the I.T.U.'s first report, the technical studies related to the use of telecommunications in space for various purposes are undertaken on a regular basis by two consultative committees of the I.T.U.: one interested in radio techniques - the International Radio Consultative Committee (C.C.I.R.), and the other, interested in telegraph and telephone techniques - the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.).

2.2 The main activity for the C.C.I.R. in 1966 was its XIth Plenary Assembly, which was held in Oslo in the summer of that year. At this meeting the conclusions of C.C.I.R. Study Group IV (Space Systems and Radioastronomy) were approved in Plenary Session.

2.3 The previous report in this series mentioned the results obtained by the Interim Meeting of the Study Group held in Monte Carlo in 1965. The Oslo Plenary Assembly reviewed these results on the basis of 85 new proposals, so that at the present time this Study Group has to its credit 22 Recommendations, 36 Reports and 1 Opinion. A further 26 new items were adopted for study. All these texts, which are listed in the Annex A, are published in Volume IV of the Conclusions of the XIth Plenary Assembly of the C.C.I.R., obtainable from the Publications Division, International Telecommunication Union, Place des Nations, Geneva, Switzerland.

2.4 Their detailed analysis is beyond the scope of the present Report, but the following list of the contents of Volume IV will give a fair impression of the extent of C.C.I.R. Studies on space subjects:

1. General
2. Communication satellites
3. Direct broadcasting by satellites
4. Radionavigation by satellites
5. Meteorological satellites
6. Maintenance telemetering, tracking and telecommand
7. Space research
8. Radioastronomy
9. Radar astronomy

2.5 In the following, salient points are discussed so that the reader may have an idea of the highlights of the Oslo Plenary Assembly in the field of radioastronomy and space telecommunications.

2.6 The problem of sharing frequency bands has been foremost in the mind of the C.C.I.R. since its founding in 1927. It was on the recommendation made by the C.C.I.R. during its Xth Plenary Assembly held in 1963 that the Extraordinary Administrative Conference on Space, held later in that year, was able to revise the frequency allocation table to include space systems and radioastronomy and to adopt administrative measures for the orderly registration of frequencies for these radio services. One subject which is of great importance and which had given rise to long discussions was the maximum allowable power flux density at the surface of the earth produced by communication satellites.

2.7 When satellite communication was first considered, little thought was given to the possibility of using stationary satellites. However, after the success of SYNCOM satellites, this type became of considerable importance in view of the advantages to be expected, especially in the design of earth stations, whose huge antennae would no longer need complicated tracking equipment. However, the plane of a stationary satellite must coincide with that of the equator of the earth, so that unless it is launched at a point on the equator of the earth, auxiliary equipment has to be carried in the satellite to re-orient its orbital plane to that of the earth's equator. The communication satellites of the Molniya series launched by the U.S.S.R., make use of elongated elliptical orbits. Stationary satellites present an interference problem different from other cases, in that being stationary, the interference they might produce, as well as that produced by associated earth stations, would affect fixed areas on the earth's surface and the concept of the limitation of the strength of this interference for a prescribed percentage of time has to be modified. Under these conditions, the orientation of the antenna systems is of considerable importance in considering interference to stations sharing the same frequencies.

2.8 In response to a recommendation of the Extraordinary Administrative Radio Conference on Space, the C.C.I.R. Oslo Plenary Assembly revised the procedure for calculation of the distance within which Administrations planning or using radio relay or satellite systems should consult amongst themselves (commonly known as the coordination distance). In addition to the interference problem connected with stationary satellites mentioned above, it has revised its technical factors to take into account the shielding effect of mountains and obstacles along transmission paths. Thus the C.C.I.R. has developed Recommendation 359-1 and Report 382 for the I.F.R.B. to use as a basis for future work in solving interference problems between communication satellite and terrestrial systems.

2.9 Many factors enter into consideration in designing a multiple access communication satellite system, such as power of the satellite transmitter, earth station receiver characteristics, channel capacity, orbit parameters, method of modulation, multiplexing technique, etc. These have been discussed in new C.C.I.R. Report 213-1. No recommendation, however, has been issued on this subject.

2.10 Problems of antenna radiation, propagation, noise of solar and cosmic origin as well as the effects of rain on radomes, etc. have been studied and Reports on these subjects approved. Recent results obtained by the C.C.I.T.T. on propagation delay, doppler shifts and switching discontinuities are also incorporated.

2.11 While communication satellite systems dominated the scene in the Study Group IV meetings at Oslo, other satellite systems also received attention. The Report on the frequency requirements of meteorological satellites has been revised to include new data as a result of successes of TOS satellites. On space research, emphasis was placed on the re-entry phase of spacecraft returning to Earth. Difficulties in radiocommunication are experienced owing to the plasma sheath surrounding spacecraft due to intense ionization caused by friction between the spacecraft and the atmosphere.

2.12 The basic Recommendation (now No. 314-1) on the protection of frequencies used for radioastronomical measurements was modified and better protection of certain frequency bands, such as the Deuterium and OH-lines, was pressed. In radar astronomy, which makes use of very powerful transmitters, frequency sharing presents very difficult problems which are treated in Report 226-1.

2.13 The problem of the reception of broadcast emissions, including television, from satellites by domestic receivers was given attention in Oslo and Report 215-1 on the subject was prepared in which a large number of technical requirements for such services are defined. However, the means to satisfy many of the technical requirements are not yet evident, so that such a service will require considerable study before it can be realized.

2.14 Since the closing of the XIth Plenary Assembly of the C.C.I.R. several new triumphs had been recorded in space exploits. These include, for instance, the successful completion of the Gemini programme, the launching of the Intelsat II-Pacific and the Molniya-4 communication satellites, and the unprecedented transmission of pictures of the moon's surface by Lunar Orbiter II and Luna-12 space probe. All these, and many others too, would not have been possible without sophisticated radiocommunication. International cooperation is of great importance in this fascinating field, and the C.C.I.R. is very much involved in promoting this cooperation.

2.15 For its part, the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.) is interested in space telecommunication problems in so far as they affect telegraph and telephone techniques. During 1966, various Study Groups of that organ have pursued the following studies:

a) A signalling system (type C) was standardized by the IIIrd Plenary Assembly of the C.C.I.T.T. (Geneva 1964) for an automatic telex service via satellites. Studies are in progress to explore the possibilities of the type A or B signalling systems in operation at present.

b) Study Group XI is actively engaged in the study of a new intercontinental signalling system for the telephone services (C.C.I.T.T. System No. 6). This system is designed to take account of the telephone signalling problems raised by satellite communications.

c) At its meeting in Brussels in December 1965, Special Study Group A undertook the examination of the data transmission problems that arise when space communication media are used. Since error control by the automatic repeat request system may prove difficult owing to the long propagation time, the use of automatic error correction without retransmission is under study.

d) The IIIrd Plenary Assembly adopted a provisional Recommendation on the overall propagation time permissible for an international telephone connection; the limits recommended are of special importance for calls set up via communication satellite systems. Study Group XII met in May 1966 and, after examining the results of tests made in commercial operating conditions, concluded that there was no occasion to amend the recommendation in question for the time being.

e) Study Group XIII, which is responsible in particular for the world routing plan for the automatic telephone service, is primarily concerned with the possible effect of connections via satellites on the operation of this Plan. Study Group XVI is considering what recommendations should be made to enable circuits (and groups of circuits) routed on communication satellite systems to be successfully integrated in the existing world telephone network. In particular, it has already drawn up rules for the application of the world routing plan which will enable the propagation time limits mentioned under d) to be observed.

f) Study Group II, which is concerned with telephone tariffs, has examined the special problems already raised by the use of circuits via satellites. It is interesting to note that, following studies by the C.C.I.T.T. in 1963 and 1964 on the amendment of the rules for the operation of the intercontinental service, the rates for transatlantic calls have recently been reduced. This decision, of great importance to users, was made possible by the marked increase in the number of transatlantic submarine cable circuits and the introduction of satellite circuits.

g) The regional Plan Committees have made an inventory of the possibilities now offered by communication satellites. If the necessary information can be assembled, it should be possible for a definite general programme for the use of satellites in intercontinental communications to be drawn up at the 1967 meeting of the World Plan Committee in Mexico City.

3. International Regulation of Radio Frequency Assignments for Space Communications

3.1 Since the publication of the Fifth Report, the International Frequency Registration Board (I.F.R.B.) of the International Telecommunication Union has continued to apply the relevant provisions of the Radio Regulations annexed to the International Telecommunication Convention, in connection with frequency assignment notices for Space Communications received from Administrations. One hundred and fourteen such notices were received in the year 1966. The notification and registration procedures in question are defined in Article 9 (revised) and 9A of the Radio Regulations which form part of the Final Acts of the Extraordinary Administrative Radio Conference to allocate Frequency Bands for Space Radiocommunications Purposes, Geneva, 1963.

3.2 The I.F.R.B. adopted and is keeping under review, taking into account the conclusions of the XI Plenary Assembly of the C.C.I.R. (Oslo, 1966), the technical standards to be applied for the technical examination of those frequency assignment notices, based on Recommendation No. 1A adopted by the E.A.R.C. Space (Geneva, 1963) with respect to the determination of the distances within which the assignments to stations in the Fixed or Mobile Service are required to be co-ordinated with assignments to Earth stations in the Communication-Satellite Service in those frequency bands allocated to these Services with equal rights. The Regulations providing for the possibility of such co-ordination of the use of frequencies being carried out by the I.F.R.B. having been invoked by two

Administrations during 1965, the I.F.R.B. has continued, during 1966, to give assistance to the Administrations concerned to permit a satisfactory solution of the problems. For one of these Administrations, the co-ordination has already been successfully achieved.

3.3 In 1966, the I.F.R.B. has dealt with frequency assignment notices received from the following Administrations, concerning mainly the establishment or the modification of the following communication-satellite system or experimental programmes:

a) Belgium

European Space Research Organization (E.S.R.O.)

Notifications were received concerning frequencies to be used for telecommand and telemetering by an Earth station situated at Redu in connection with the programme developed under the auspices of the European Space Research Organization (E.S.R.O.).

b) Canada

Space research satellite system

Notifications were received concerning frequencies to be used by Space Research stations aboard satellites Alouette I and II for telecommand, telemetering and tracking and by the associated transmitting and receiving stations at Ottawa, Ont. and Resolute, NWT.

c) United States of America

ESSA Meteorological satellite

Notification was received concerning a frequency to be used by a Meteorological Space station aboard a satellite of the ESSA series for transmission to receiving stations situated throughout the world.

Experimental Communication Satellite System

In addition to the notifications already received concerning this system, notices were received concerning the Earth stations situated at CLARK AFB in the Philippines.

Intelsat programme

In connection with the establishment of a global commercial communication-satellite system which began with the launching of satellite Intelsat I, into orbit, notifications were received concerning frequencies to be used for transmission from and reception by space stations aboard two new satellites HS-303A to be placed in synchronous orbits over the Atlantic and Pacific Oceans respectively.

d) France

Experimental Space Research Earth Stations

Notification was received concerning a frequency to be used by several experimental Space Research Earth stations for tracking of various Space Research crafts.

e) India

Experimental Space Communication system

Notifications were received concerning frequencies for experimental use (transmitting, receiving and tracking) at the Earth station Ahmedabad in communication with satellites of the TELSTAR and A.T.S. series. The assistance of the Board was requested by this Administration in seeking co-ordination with the Administration of Pakistan with respect to stations in the Fixed and Mobile Services.

f) Japan

Experimental Space Communication system

Notifications were received concerning frequencies for experimental use (transmitting and receiving) at the Earth station Ibaraki in communication with a satellite of the Intelsat programma (HS-303A).

g) Pakistan

Experimental Space Communication system

This Administration requested the assistance of the Board in seeking co-ordination with the Administration of India concerning the implementation of Space Communication stations at Sonmiani and Rangamati.

h) United Kingdom of Great Britain and Northern Ireland

Intelsat programme

Notifications were received concerning an Earth station situated in Ascension Island participating in this programme.

i) Sweden

Experimental Space Research programme

Notifications were received concerning frequencies to be used for telemetering by an Experimental Space Research Earth station situated at Kiruna and by the related space station SPARMO.

j) Union of Soviet Socialist Republics

Notifications were received concerning frequencies to be used by four Meteorological Space stations for transmission of meteorological data and by the associated receiving Earth stations Khaborovsk, Novosibirsk and Moskva.

3.4 Through the I.F.R.B. Weekly Circular, all Administrations were regularly informed of the detailed frequency assignment notices received by the Board as well as of the notification of the proposed establishment of communication-satellite systems.

4. Activities under technical cooperation programmes

4.1 During 1966, there were increased activities in the field of outer space under technical cooperation programmes.

4.2 A seminar on "Communication Satellite Earth Station Technology" was held by the United States in Washington D.C. from 10 to 22 May, 1966. It was largely attended. A number of papers were presented by leading authorities on the subject and on the various aspects of the development in earth station technology. The lectures were followed with interesting discussions between the participants. There were also visits to installations and an exhibition was organized to demonstrate the developments.

4.3 The Special Fund project for the establishment of an experimental research and training station on satellite communications at Ahmedabad was going ahead in its implementation. Significant progress was made during the year. The buildings were under construction and the delivery of equipment commenced from the first week of December. The station is expected to be in operation for training purposes from July next year.

4.4 Increased interest in satellite communications was manifested by several countries. An expert was sent to Ceylon to give advice on the feasibility of having an earth station for satellite communications. Israel had requested three fellowships to study satellite communication techniques.

5. <u>Information supplied by governments</u>

Since the preceding report of the I.T.U., a number of Administrations have sent to the I.T.U. Headquarters, detailed technical information on the progress they have made in studying and applying space techniques to the future development of telecommunications and the knowledge of outer space and its use for peaceful purposes. A brief summary of this information is given in Annex 2.

<u>Annexes</u>: 2

A N N E X 1

STUDY GROUP IV

(Space systems and radioastronomy)

Terms of reference:

To study technical question regarding systems of telecommunication with and between locations in space and radioastronomy

Chairman : Professor I. RANZI (Italy)

Vice-Chairman : Mr. W. KLEIN (Switzerland)

1. QUESTIONS, STUDY PROGRAMMES, OPINIONS AND RESOLUTIONS

Opinion 3 — Data on traffic loading and routing for use in developing communication-satellite system facilities

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Question 2/IV — Technical characteristics of communication-satellite systems (235(IV))

Study Programme 2A/IV — Feasibility of frequency sharing between communication-satellite systems and terrestrial radio services (235F(IV))

Study Programme 2B/IV — Frequency sharing between communication-satellite systems and terrestrial radio services - Wanted-to-unwanted signal ratios (235G(IV))

Study Programme 2C/IV — Communication-satellite systems - Feasibility of frequency sharing among communication-satellite systems (235C(IV))

Study Programme 2D/IV — Study of preferred modulation characteristics for communication-satellite systems (235D(IV))

Study Programme 2E/IV Factors affecting freedom of access in communication-satellite systems (235H(IV))

Study Programme 2F/IV Energy dispersal in communication-satellite systems (IV/1052)

Question 3/IV Sharing of radio-frequency bands by links between earth stations and spacecraft (236(IV))

Study Programme 3A/IV Space research and maintenance telemetering, tracking and telecommand systems - Possibilities of sharing and protection criteria (IV/1032)

Question 4/IV Technical characteristics of links between earth stations and spacecraft (237(IV))

Question 5/IV Active communication-satellite systems for frequency-division multiplex telephony - Transmission characteristics of audio channels (238(IV))

Question 6/IV Effects of plasma on communications with spacecraft (239(IV))

Study Programme 6A/IV Frequency bands for re-entry communications (239A(IV))

Question 7/IV Time delay, echoes and switching discontinuities in communication-satellite systems (240(IV))

Question 8/IV Technical characteristics of radionavigation-satellite systems (242(IV))

Question 9/IV Radiocommunication for meteorological-satellite systems (243(IV))

Study Programme 9A/IV Radiocommunication aspects of meteorological-satellite systems (243A(IV))

Question 10/IV Radioastronomy (244(IV))

Question 11/IV Radar astronomy (245(IV))

Question 12/IV Feasibility of direct sound and television broadcasting from satellites (IV/1053)

Question 13/IV Contributions to the noise temperature of an earth-station receiving antenna (284(IV))

Question 14/IV	Propagation factors affecting sharing of the radio-frequency spectrum and coordination between space and terrestrial radio-relay systems (IV/1035)
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Question 16/IV	Shielding effects due to the ionosphere (IV/1043)
Question 17/IV	Shielding effects due to the moon (IV/1044)

2. RECOMMENDATIONS (Vol. IV, Section L)

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L.2 - Communication satellites

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Recommendation 354	Active communication-satellite systems for monochrome television - Video bandwidth and permissible noise in the hypothetical reference circuit
Recommendation 355-1	Frequency sharing between active communication-satellite systems and terrestrial radio services in the same frequency bands (IV/1042)
Recommendation 356-1	Communication-satellite systems and line-of-sight radio-relay systems sharing the same frequency bands - Maximum allowable values of interference in a telephone channel of a communication-satellite system (IV/1029)

Recommendation 357-1	Communication-satellite systems and line-of-sight radio-relay systems sharing the same frequency bands - Maximum allowable values of interference in a telephone channel of a radio-relay system (IV/1030)
Recommendation 358-1	Communication-satellite systems and line-of-sight radio-relay systems sharing the same frequency bands - Maximum allowable values of power flux density at the surface of the earth produced by communication satellites (IV/1034)
Recommendation 359-1	Communication-satellite systems and terrestrial radio systems sharing the same frequency bands Determination of the coordination distance (IV/1041)
Recommendation 360-1	Communication-satellite systems and line-of-sight radio-relay systems sharing the same frequency bands - Criteria for selection of preferred reference frequencies for communication-satellite systems (IV/1014)
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L.3 - Direct broadcasting from satellites

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L.5 - Meteorological satellites

Recommendation 362	Frequencies technically suitable for meteorological satellites

L.6 - Maintenance telemetering, tracking and telecommand

Recommendation 363	Preferred frequency bands for use in maintenance telemetering, tracking and telecommand of developmental and operational satellites

L.7 - Space research

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Recommendation 366-1	Telecommunication links for manned research spacecraft (IV/1038)
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L.8 - Radioastronomy

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L.9 - Radar astronomy

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3. REPORTS (Vol. IV, Section L)

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Report 205-1	Factors affecting the selection of frequencies for telecommunications with and between spacecraft (IV/1051)

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Report 208-1	Active communication-satellite systems for frequency-division multiplex telephony and monochrome television - Form of the basic hypothetical reference circuit and allowable noise standards; video bandwidth and sound channel for television (IV/1006)
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Report 212-1	Active communication-satellite systems for frequency-division multiplex telephony and monochrome television - Use of pre-emphasis in frequency modulation systems (IV/1011)
Report 213-1	Factors affecting multiple access in communication-satellite systems (IV/1056)
Report 214-1	Communication-satellite systems - The effects of Doppler frequency-shifts and switching discontinuities (IV/1021)
Report 382	Determination of coordination distance (IV/1022)
Report 383	Communication-satellite systems - The effects of transmission delay (IV/1023)

Report 384	Frequency sharing between communication-satellite systems and terrestrial radio-relay systems - Energy dispersal in communication-satellite systems with frequency-modulation of the radio-frequency carrier (IV/1004)
Report 385	Feasibility of frequency sharing between communication-satellite systems and terrestrial radio services - Site selection criteria for earth stations in the communication-satellite service (IV/1019)
Report 386	Feasibility of frequency sharing between communication-satellite systems and terrestrial radio services - Maximum power in any 4 kHz band which may need to be radiated in the horizontal plane by active communication-satellite earth stations (IV/1026)
Report 387	Power flux density at the surface of the earth from communication-satellites (IV/1045)
Report 388	Techniques of calculating interference noise in communication-satellite receivers and in terrestrial receivers of radio relay systems (IV/1028)
Report 389	Estimating interference probabilities between space systems and terrestrial radio relay services - Propagation considerations (IV/1027)
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Report 391	Radiation diagrams of antennae at communication-satellite earth stations, for use in interference studies (IV/1010)
Report 392	Performance of earth station receiving antennae - Effects of rain on radomes and of solar and cosmic noise (IV/1024)
Report 393	Exposures of the antennae of radio-relay systems to emissions from communication-satellites (IV/1054)

L.3 - Direct broadcasting from satellites

Report 215-1	Feasibility of direct sound and television broadcasting from satellites (IV/1020)

L.4 - Radionavigation by satellites

Report 216-1	Use of satellites for terrestrial radionavigation (IV/1015)
Report 394	Feasibility of frequency sharing between the radionavigation-satellite service and terrestrial services (IV/1018)

L.5 - Meteorological satellites

Report 395	Radiocommunications for meteorological satellite systems (IV/1047)

L.6 - Maintenance telemetering, tracking and telecommand

Report 396	Maintenance telemetering, tracking and telecommand for developmental and operational satellites - Frequency sharing between earth-satellite telemetering or telecommand links and terrestrial services (IV/1017)

L.7 - Space research

Report 218	Technical characteristics of telecommunication links between earth stations and spacecraft for research purposes
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L.8 - Radioastronomy

Report 223-1	Line frequencies or bands, of interest to radioastronomy and related sciences, in the 30 to 300 GHz range arising from natural phenomena (IV/1007)
Report 224-1	Radioastronomy - Characteristics and factors affecting frequency sharing with other services (IV/1002)
Report 397	The OH-lines in radioastronomy (IV/1005)

L.9 - Radar astronomy

Report 226-1	Factors affecting the possibility of frequency sharing between radar astronomy and other services (IV/1003)

A N N E X 2

TO THE SIXTH REPORT BY THE INTERNATIONAL TELECOMMUNICATION UNION ON TELECOMMUNICATIONS AND THE PEACEFUL USES OF OUTER SPACE

Information supplied by the following countries : Page

AUSTRALIA (COMMONWEALTH OF)

During 1966, Australia continued to participate with other Administrations in the activities of the Interim Communication Satellite Committee which is establishing a global communication satellite system.

In this direction construction of an earth station with a 42' antenna was completed at Carnarvon in Western Australia and on 25 November 1966, television signals were received for the first time, direct from the United Kingdom. This station is now being used to provide services between Australia and North America, Hawaii, Japan and the Far East via the second Pacific Ocean satellite, INTELSAT II.

Construction of a second earth station with an 85' antenna, was commenced during the year at Moree in northern New South Wales. The station, which is expected to be completed by the end of 1967, will have a capacity of several hundred telephone channels and could provide an international real-time television link if required.

In addition tentative plans were formulated for a third earth station to be established on the west coast to serve the proposed Indian Ocean satellite, INTELSAT III.

During the year, representatives of the Australian Administration actively participated in various experiments conducted by N.A.S.A. at their Applications Technology Station at Cooby Creek near Toowoomba, Queensland. The experiments - designed to establish the best techniques for communications, navigation, meteorology and spacecraft control - were analyzed and evaluated by a team of specially trained experts.

Planning commenced during the year for Australia's first international T.V. relay on a commercial basis to be beamed via a satellite. The broadcast will be made direct from the International Exposition at Montreal in Canada.

In the field of meteorology, Australia has one ground Automatic Picture Transmission station in operation at Werribee, Victoria, and others are planned for Perth, Western Australia; Darwin, Northern Territory and Brisbane, Queensland. Ultimately these will be automatically operated. The equipment used, or to be used, includes I.C.A. receivers at 10 dB Yagi antennae.

Although at present satellites have only been utilized in international communications, Australia continues to review the situation and given continuation of the present rates of progress in technology and their related impact on cost, their application to the internal telecommunications system appears feasible in the near future.

CANADA

Earth Stations

Mill Village, Nova Scotia

When construction of the Mill Village Earth Station started it was planned as an experimental station to participate in experiments with communication satellites launched by the National Aeronautics and Space Administration and the station has been used to perform experiments in time division multiplex voice transmission with a station in the United States through the Early Bird satellite. However, now that construction is complete the station is being operated by the Canadian Overseas Telecommunication Corporation for commercial purposes in conjunction with the Early Bird satellite pending construction of a commercial communication satellite ground station. Upon completion of the commercial station, approximately July, 1968, it is expected that the Mill Village Station will return to its originally intended role and participate in future experiments in satellite communications.

The station uses a Cassegrain antenna consisting of a 26 meter paraboloid illuminated by a 2.6 meter hyperboloid, housed in a 36.6 meter inflated radome.

The receiving equipment receives simultaneously any two RF channels in the band 4040 to 4200 Mc/s. One can be used, if desired, to monitor the station's own transmissions. The receiving system consists of a liquid-helium-cooled parametric amplifier followed by an uncooled low-noise tunnel-diode amplifier. These are common to both received channels. The tunnel diode amplifier drives the two conventional demodulators via separate IF amplifiers of 50 c/s to 4.0 Mc/s with audio sub-carriers at either 4.5, 6.0 or 7.5 Mc/s. The audio bandwidth at these sub-carriers is 30 kc/s. Video pre-emphasis is per C.C.I.R. Recommendation 405.

The voice circuit capacity is 1200 channels for phase modulation and 300 or 600 channels for FM. Channelling plans followed are C.C.I.T.T. M.G. 1, 2, 3, 4 for PM and C.C.I.T.T. Study Group 1, 2, 3, 4, 5 for 300 channels FM. Test tone deviations are 0.25 radian peak (PM) and up to 1.0 Mc/s r.m.s. (FM).

The transmitting system has two power amplifiers and two exciters, one for SSB with the telephony, the other for FM with telephony or television, each consisting of a modulator and an up-convertor. The FM transmitting system can deliver 10 kW over the 6 Gc/s band. Specified frequency stabilities for SSB and FM are 1 part per hundred million and 10 parts per million respectively. The general signal characteristics of the transmitting system are similar to those of the receiving system.

The station has a general purpose computor which can generate tapes for programme tracking. Auto-tracking using error signals generated by a monopulse system is also provided. Servo-drives are electromechanical. Maximum velocities are 3 degrees per second in azimuth and 1.5 in elevation. Maximum accelerations are .03 degrees per second per second azimuth and 0.06 in elevation.

The location of the antenna at the station is 44° 11' 18" N and 64° 40' 11" W. A bore-sight tower 117 metres high, approximately 11 km away, is available for antenna patern determination and for studies of emission characteristics.

Bouchette, Quebec

The construction of a communications earth station is planned near Bouchette, Quebec or approximately fifty miles north of Ottawa.

The construction of this station will provide the experience necessary for the design and development of practical and economical earth stations for operation in the Canadian far north.

When the necessary operating experience has been gained, a satellite communications system, providing telecommunications service to several remote northern communities now served by HF radio, will be established.

Domestic satellite communications study

The Canadian Department of Transport has awarded the Northern Electric Company a contract for a major study of the potential use of satellite communications systems for domestic purposes in Canada.

The study will include a review of future communications requirements for all purposes within Canada, the volume and type of communications which can best be provided by use of satellites, including a review of systems and techniques possible and most likely to be applicable. It will cover inter-relation and inter-connection with ground communications now provided by telephone, telegraph or microwave links, and will include all aspects of communications: telephone, telegraph, private systems, radio and television. It will take into consideration not only the requirements in the densely populated or southern parts of Canada, but the requirements of northern regions as well.

The Research and Development Laboratories of the Northern Electric Company have already started on the contract. Hughes Aircraft Company, United States, who are manufacturers of the first commercial communications satellites now in regular use for the International Telecommunications Satellite Consortium (INTELSAT) will assist as a subcontractor on certain portions of the study.

The study is expected to be completed in the first half of 1967 and will provide the necessary technical and factual data required to assist the Government in reaching the major policy decisions which are necessary to ensure the best availability and use of satellite communications for domestic purposes in Canada.

Propagation studies

Because it is believed that additional frequencies for satellite communications will be necessary and will probably have to be found above 8 Gc/s Canada embarked in 1964 on a programme to determine, experimentally, the effects of the troposphere, and particularly rainfall, on the propagation of frequencies between 8 Gc/s and 16 Gc/s. For the last two summers the attenuation and rainfall rate along a terrestrial path at 8Gc/s and 15 Gc/s have been measured. The data for 1965 has been analyzed and results will be published in the I.E.E.E. Transactions on Antennas and Propagation.

To simulate more closely an earth-space path, similar attenuation measurements using aircraft borne beacons as signal sources will be made in the summer of 1967.

An experimental satellite communications ground terminal has been established at the Shirley Bay site near Ottawa. The antenna has a diameter of 30 feet and is of sufficient accuracy to give substantially full gain at 16 Gc/s and to give a gain about 3 db below theoretical at 35 Gc/s.

Upper atmosphere research

Alouette I, launched in September, 1962, continues to operate and supplies several hours of useful ionospheric data each day.

Alouette II, launched on 28 November 1965, has completed its first very successful year in orbit with all systems operating perfectly.

About two hundred scientific papers based on Alouette data have been published to date by scientists all over the world. Some of the highlights of the scientific results obtained by Canadian scientists are summarized below :

i) Several important plasma effects were first observed by the Alouette satellites. (Ionized gases, such as the ionosphere, are often called "plasmas" to indicate their peculiar properties.) One of these, the observation of plasma resonances at harmonics of the gyro-frequency, has permitted a direct check of existing theories of the strength of the earth's magnetic field at great heights.

ii) One of the other new plasma effects has been called a "remote resonance", because the resonance effect occurs at a considerable distance from the satellite. This resonance is now being investigated in the laboratory and has stimulated research into the nature of plasmas.

iii) However, the most immediately useful of these plasma effects is the observation of a band of very low frequency (VLF) radio noise. From these observations, a great deal has been deduced about the composition and temperature of the upper atmosphere. For example, atomic oxygen is the most abundant ion at 1000 km over the polar regions, whereas hydrogen is the predominant ion near the equator. Also, the temperature of the plasma is about 1300°C near the equator but reaches 4000°C in the polar region, at this 1000 km height.

iv) Guidance of high frequency (HF) radio waves by the earth's magnetic field has been dramatically demonstrated by some of the Alouette records. These show that the radio waves may follow the magnetic field lines for some 10,000 kilometers, reversing direction at high latitudes in the northern and southern hemispheres, and making as many as 4 "hops" across the equator.

v) Knowledge and understanding of the structure of the high ionosphere has been greatly increased from analysis of Alouette data. The complexity of the structure is such that the analysis is far from complete, but the gross structure is now reasonably well established.

At heights of 2000-3000 kilometers, the ionization over the equatorial regions is often as much as one hundred times as dense as the polar ionization. The boundary between these high- and low-ionization density regions is relatively sudden, and at heights below 1000 km this boundary appears as a very sharp deficiency in ionization along a line of constant magnetic latitude. The exact location of this ionization "trough" depends on events that take place on the sun. At night, the trough is frequently at latitudes near Ottawa.

vi) A new technique for the measurement of exceedingly low electron densities has been discovered. This technique makes use of the beat frequency between two plasma resonances excited by the sounder transmitter, and has accurately measured the lowest electron densities that have occurred at Alouette heights, about 8 electrons per cm^3. This Alouette technique is now being used to calibrate measurements made by other experimenters at these low electron densities.

vii) The radio noise experiments on Alouette made the first comprehensive measurements of extra-terrestrial (i.e., "cosmic") radio noise levels for frequencies below five megacycles/sec. Such measurements cannot be made on the ground, due to the blanketing effect of the ionosphere. The noise levels measured in Alouette differed by almost an order of magnitude from the isolated values that had been previously measured. Also, this experiment was the first to measure at these frequencies bursts of radio wave energy that originate on the sun. From this data, it has been possible to make the first deductions of properties of the solar corona at distances of 5-20 solar radii from the sun.

viii) The radio noise experiments have also provided new and significant data on radio noise levels generated terrestrially; i.e., noise originating in the ionosphere. The mechanisms whereby this noise - which may be very intense between 200 kilocycles and 1 megacycle/sec - is generated are now being studied and are expected to improve knowledge of energetic processes in plasmas. Four distinctive bands of noise, corresponding to four different plasma generation processes, have been identified.

ix) Two new types of radio "whistlers", called the proton whistler and the helium whistler, were first identified on Alouette VLF records. (Proton whistlers have since been seen by other satellites, but the Alouette helium whistler data are still unique.) These new types of whistler provide quantitative data on the density and temperature of ionized hydrogen and helium in the upper atmosphere. In addition, they provide a valuable check of certain theories that cannot be readily demonstrated in laboratory work. For instance, the Alouette results are pertinent to theories that have been applied in the design of thermonuclear plasma devices.

DENMARK, NORWAY, SWEDEN

In 1966 our main activity in the field of space radiocommunications has taken place at our common experimental earth receiving station south of Gothenburg in Sweden.

In the beginning of the year a series of experiments was carried out in collaboration with Japan. Wide band signals, transmitted by the Kashima earth station and relayed by the communication satellite Relay II, were received successfully. The experiments were concluded with colour television transmissions using the NTSC 525 lines standard.

Experiments with narrow band transmissions have been carried out in collaboration with the Federal Republic of Germany. The signals were transmitted by an earth station at Raisting and received via Relay II.

The measurements of atmospheric noise temperature, reported last year, have been continued and a common report on the results obtained was submitted by our three Administrations to the XIth Plenary Assembly of the C.C.I.R.

The interference effect of terrestial radio relay systems into an earth receiving station are under study and a number of measurements in this respect has been carried out.

The technology of an earth station has continued to be studied. Among various subjects that have been analysed may be mentioned the antenna scanning system.

Our activity at the experimental earth receiving station will be terminated in the course of 1967.

UNITED STATES OF AMERICA

United States space research programmes employ radio frequencies for commercial and experimental means of data transmission as well as for determining propagation characteristics of earth-space paths. Use of space research bands below 10 Gc/s is approaching optimum utilization; the use of the higher frequency bands, 15.25 and 31.5 Gc/s, is in the planning stage. The bulk of research is accomplished within bands specified in the international Radio Regulations. However, because certain major projects require phase-coherent frequencies or are intended to ultimately serve other radio services, some research activities are conducted "out of band". As spacecraft employ minimum operable power and prior notification is made, the potential for interference to other services is minimized.

The first of the Application Technology Satellite (ATS) series was successfully launched and placed in synchronous orbit over the Pacific Ocean. This satellite employs parts of the frequency bands 132-136, 137-138, 3700-4200, and 5925-6425 Mc/s. One of the experiments being conducted by this satellite is an aircraft to satellite to ground station link using standard VHF equipment. The experiment utilizes a group of five watt VHF transmitters on the satellite, each driving a dipole antenna. As the satellite spins, the antenna is electronically despun so as to form a beam pointed constantly earthward. At any instant, the effective power output is 30 watts into an earth-pointing antenna of 8.5 db gain, providing for an effective radiated power of over 200 watts. This satellite communications programme was discussed at the I.C.A.O. Communications/Operations Divisional Meeting held at Montreal, Canada, October 4 - November 8, 1966, which led to four specific recommendations summarized as follows :

1) The United States makes available to I.C.A.O. the technical data resulting from the ATS-B and C tests, and that this data be evaluated by I.C.A.O.

2) Various I.C.A.O. States should explore the technical suitability of both the bands 118-136 and 1540-1660 Mc/s for the aircraft-satellite links.

3) States should participate in any trials of satellite systems in an operational environment which may be conducted subsequent to the ATS series of tests.

4) I.C.A.O. should give consideration to a number of basic factors in establishment of future system parameters, among them the detailed operational functions; essential system characteristics; radio frequencies; methods of financing; and others.

Other experiments in the Application Technology Satellite series include the transmission of high quality cloud pictures, weather maps and nephanalysis (cloud analysis) over great distances.

The United States meteorological satellite programme (Tiros, Tiros Operational Satellite (TOS), and Nimbus) has provided hundreds of thousands of cloud cover pictures and a great deal of infrared data that have contributed greatly to our better understanding of the atmosphere, in better forecasts and in surface storm detection. The Environmental Science Services Administration (ESSA) series of satellites are the United States' operational meteorological satellites, while the Nimbus series are research and developmental type satellites.

The band 136-138 Mc/s is used in the Meteorological Satellite Service for the spacecraft beacons and for telemetering. Presently, the band is used heavily with 77 transmitters in orbit, each using bandwidths of 30 kc/s to 100 kc/s. The satellite beacon transmissions are continuous and are used to track the satellite from earth stations. The telemetering transmissions containing data on the status of the spacecraft systems are sent on command from the two Command and Data Acquisition stations used in the programme. One station is located at Wallops Island, Virginia, and the other near Fairbanks, Alaska.

The frequency 136.95 Mc/s is used on the Nimbus satellites for the Automatic Picture Transmission System (APT). This system, during the daylight portion of the orbit, takes a picture and then automatically transmits it in a slow scan format compatible with facsimile type recording devices. The APT system was designed to provide up-to-the-minute cloud cover information to meteorological stations equipped with relatively inexpensive receiving and recording equipment. About 150 such stations are now in existence throughout the world. An experimental night time APT system is also on Nimbus II using the same frequency. The frequency 137.50 Mc/s is used by the ESSA 2 satellite for its APT system.

The frequency 235.0 Mc/s is used in the Tiros and TOS satellite programmes for the transmission of wideband data (video) from the satellites on command from the Command and Data Acquisition stations. The improved TOS will use the 1690-1700 Mc/s band for this transmission. The first of these series of satellites, which replaces the present TOS series, is expected to be launched in 1968.

The band 1700-1710 Mc/s is used by the Nimbus meteorological satellite for the transmission of data on command from a Command and Data Acquisition station.

The frequencies 148.25 Mc/s ± 15 kc/s and 154.2 Mc/s ± 15 kc/s as well as others in this spectrum area, are used extensively for telecommand.

There is increased interest in the application of satellite communications for ground vehicles, aircraft and ships. The terminals for these applications must be simple, small and light weight. The use of frequencies in the VHF/UHF bands appears to offer some advantages, in that simple non-steerable omni-directional antennas may be employed. The satellite LES-3 was launched on 21 December 1965 into an elliptical orbit having an apogee of approximately 17,000 n.m. and perigee of approximately 100 n.m. The satellite radiates a 25 watt signal, about 200 kc/s in bandwidth, at a wavelength of about one meter. Measurements have been made of the received signal of multipath and doppler frequency-smear propagation effects as observed by aircraft flying over various types of terrain. Preliminary results of this work may be summarized as follows : The received signal consists mainly of the primary direct signal from the satellite plus a secondary earth return with a multipath delay as predicted from the theoretical "flat-sea" curves for satellite elevation angles of about 7° and below (degrees above visible horizon). For higher elevation angles, the mechanism of reflection is apparently quite complicated.

In addition to the above UHF measurements, some work has been done in the same frequency region in determining typical noise power contributions by the galaxy, the earth, and lightning, all as seen by an aircraft. Some early results are roughly tabulated below :

	Noise source	Effect
1)	Galactic (over a hemisphere)	$<150°K$
2)	Earth (rural)	250-300°K
3)	Ocean	160°K
4)	City (effective power density on the earth)	2.7×10^{-18} watts/m^2/c/s
5)	Lightning (radiated energy)	10^{-5}-10^{-6} joules/c/s

The first three items are in general agreement with values that may be derived from data found in standard texts, although no airborne measurements of this kind have been published in the past.

However, the power density measurements made on a number of cities on the eastern U.S. seaboard are quite interesting. They indicated that in general the effective power density along the ground did not vary from city to city, implying that the power radiated was proportional to the area of the city. New York City was an exception, having a power density of about 5 db higher than other cities. More important, these density levels were generally 14 db lower than published noise density levels which had been derived from ground measurements. Night measurements indicated levels 3 to 7 db lower than those made during the day. Airborne measurements were also made on lightning strokes at various distances. The experiment showed that storms within a 100 mile radius are clearly detectable, while a storm at 50 miles range increases the nominal steady state background noise about 3 db. At close range (less than 15 miles), typical mean temperature increases during the discharge pulse ranged from 1000 to 5000°K, with peaks greater than 10,000°K.

Wide band (300-500 kc/s) telemetering of environmental data from observatory type satellites is accomplished in the space bands 400.05-401.0 Mc/s and 401.0-402.0 Mc/s. Meteorological satellites (Nimbus, Tiros, TOS, and ESSA); Ionosphere monitor satellites (ISIS); Orbiting Astronomical Observatory satellites, (OAO); and Orbiting Geophysical Observatory satellites, (OGO), use these bands. Rigidly scheduled interrogation and read-out of these satellites have prevented satellite-to-satellite interference.

The following bands are used in support of the U.S. Manned Space Programme : 1427-1429 Mc/s, 1525-1535 Mc/s, 1535-1540 Mc/s, 2100-2120 Mc/s and 2200-2300 Mc/s. In addition the bands 2110-2120 and 2290-2300 Mc/s are used in the Deep Space Research programmes.

In the coming Manned Space Projects of the Apollo series, a system of telecommunications utilizes the 2300 Mc/s spectrum area in which voice, video, telemetering, tracking and ranging functions are all multiplexed in a single up and single down frequency "closed loop" system. Where the manned spacecraft has a separate lunar landing vehicle, as in the Apollo projects, a second pair of up and down frequencies will be used. To conserve power and bandwidth, slow-scan T.V. will be employed.

Additional tests and experiments have been conducted using the Syncom II and III satellites in synchronous orbit. As part of the tests, the U.S. has been using these satellites for passing operational type traffic since 1 July 1966 with considerable success. Syncom II is still located over the Indian Ocean where it will remain near the triaxial point, estimated to be approximately 77° E longitude. Syncom III is located at approximately 161° E longitude and is drifting westward at about .005° per day. It is planned to keep the satellite near 162° E if there is sufficient gas remaining in the control system. Syncom II still has a remaining useful life of up to two years while Syncom III has a remaining useful life of approximately five years.

Meteorological video data from the Nimbus satellites are transmitted in the band 1700-1710 Mc/s. In addition, the Orbiting Geophysical Observatory Satellites and the Geodetic Research Satellites use the band for transmitting very accurate tracking information (Range and Range-Rate System).

Seven experimental communications satellites, operating within the two exclusive 50 MHz bands (7250-7300 Mc/s and 7975 to 8025 Mc/s), were placed into near-synchronous equatorial orbits on 16 June 1966. These satellites have different drift rates to provide a dispersion within the orbit. Up to eight additional satellites will be placed into the same type orbit by a launch early in 1967.

The successful launch of these satellites has permitted activation for test purpose of the initial U.S. Government Communications Satellite System. A description of and information relating to this system were published in I.F.R.B. Circular No. 659 of 6 July 1965. The initial system is being tested utilizing various earth stations, including locations in the Eastern and Western United States, Hawaii, and the Philippines. Additional planned terminals are currently in various stages of co-ordination and construction.

To date no harmful interference has been experienced either to or from the test operations of the system. A number of frequency assignments to line-of-sight radio relay stations have been changed within the United States in the process of co-ordination of the earth stations involved.

Concurrently with the launch of the first seven satellites of the initial U.S. Government Communications Satellite System on 16 June 1966, a two axis gravity gradient experiment was placed into a near-synchronous (18,200 nautical mile) circular equatorial orbit to evaluate the potential of passive antenna stabilization and orientation techniques. During this experiment, stabilization was achieved within the predicted time and the technique was successfully demonstrated. Early in 1967, a second experimental gravity gradient satellite with controlled damping will be retested. Also in 1967, an experiment is planned employing an electronically despun antenna to provide antenna stabilization and orientation. Further effort is continuing on the follow-on programmes for a more advanced communication satellite capability.

One current rain propagation study programme can be separated into two areas of investigation : 1) the study of the dependence of propagation effects on the microstructure of rain and 2) the study of the dependence of these effects on the macrostructure of rain. The microstructure programme consists of measuring and calculating the dependences of the electromagnetic scattering properties on the per-unit volume characteristics of rain. The macrostructure programme consists of a study of the organization of the per-unit volume parameters in rainstorms that occur in the New England area.

The microstructure investigation has centered on computing the per-unit volume scattering parameters for measured and modeled raindrop distributions. Computations were made for nearly four hundred measured raindrop size distributions. The results of these computations show that the scattering parameters can vary widely as a function of the common raindrop parameters used such as rain rate.

The macroscale study has centered on making passive measurements of storm structure at 8.0 Gc/s and comparing with attenuation and expected antenna temperature calculated from simultaneous weather radar measurements. The weather radar data are further analyzed to derive attenuation statistics for a variety of possible propagation paths through the storm. To date three sets of measurements have been made. The results show that the sky temperature measurements fall within the maximum and minimum predicted values. This experiment is being continued with emphasis on narrowing the maximum and minimum predicted value limits.

The U.S. is conducting some research in the band 8400-8500 Mc/s on advanced high gain antennas and space propagation in this spectrum area. This band is considered favourable for lunar-distance wideband transmissions, such as television.

Satellites in the Advanced Technology Satellite (ATS) programme will investigate the equipment and propagation problems of various bands above 10 Gc/s.

There have been no reports of interference to terrestrial stations from space stations utilizing frequencies in shared bands. There have, however, been problems of interference between space stations in the crowded space research bands, but major difficulties have been avoided by on-off control and through scheduling of transmissions.

Command and Data Acquisition stations have caused no interference to other terrestrial services, primarily because of their locations, and no significant harmful interference has been reported to the reception of transmissions from the meteorological satellites.

Satellites carrying millimeter wave equipment have been authorized and money allocated for their construction. None have yet been launched. Investigations of radio propagation phenomena are underway while equipment is being developed and the techniques of using it are tested. A study group has been formed to determine the most suitable frequency bands for space-earth links in spectrum areas above 10 Gc/s.

During the past year the National Aeronautics and Space Administration's (NASA) 210 foot (64 meter) diameter antenna at Goldstone, California, became operational. With the aid of a maser preamplifier, it has successfully received signals from Mariner IV at a distance of 316,000,000 kilometers (over two solar units). The Mariner IV space probe first photographed Mars in 1965 and has continued to transmit data concerning its environment back to earth. It has travelled beyond the reception capabilities of 85 foot (26 meter) antennas. Use of the NASA 210 foot antenna made it possible to extract telemetry data of sufficient quality to permit analysis two and a half months after the Mars encounter. This provided an unexpected report on the environment of deep space and on Mariner's own successful operating performance.

Experimental communications between Andover, Maine, and the Canadian earth station at Mill Village were conducted during the summer months with the objective of developing a system of multiple access. In particular, a type of pulse modulation was tried in which each station was assigned a particular time slot and each earth station switched "on" and "off" at a pre-determined rate. This system has an inherent capacity of 72 channels. With a guard space of 160nano-seconds between accessing bursts, there was no degradiation of performance.

There seems to be a trend away from radome protection for antennas used in space communications because of the high losses encountered during rain and snow storms (occasionally 9 db loss). Consideration is being given to the use of special steel in the construction of antennas and then equipping them with electrical heaters to avoid the accumulation of snow.

Additional space radiocommunication effort has been directed toward the determination of basic data required for estimating the likelihood of compatible operation between space communication systems and other radio services. This effort included work on the protection of synchronous orbits, easing the power flux density limitations, and site shielding with emphasis on procedures for predicting interference probabilities at space research stations. Basic work in the improvement of tropospheric propagation predictions and in the estimation of the likelihood of radio duct formation was supplemented by a special effort in two areas : (1) estimation of propagation of unwanted signals by thunderstorms, and (2) the development of idealized antenna patterns for use in interference studies. The specific problem of compatible operation of satellite communication systems with conventional air-ground systems was considered.

In the estimation of unwanted signals by thunderstorms, bistatic radar was used to measure radio scattering cross sections of thunderstorms in Northeastern Colorada. The radio reflectivity of individual thunderstorms was measured as a function of azimuth and elevation at 4.85 and 9.1 Gc/s. Results of the experiment confirm that thunderstorms will scatter much larger signals than exist over normal tropospheric scatter paths. The 76 largest Colorado thunderstorms measured in June and July 1964 have median scattering volumes 13 kilometers high and 34 kilometers in diamater. At

9.1 Gc/s and a height of 3 kilometers the median radio scattering cross section per cubic meter of storm was observed to be 3.10^{-7} square meters. The maximum cross section was about 10^{-4} square meters. Based on these reflectivities, the forward scatter transmission loss between randomly oriented antennas spaced 100 kilometers apart with a path through a randomly oriented median thunderstorm is 191 decibels. The standard deviation of 17 decibels produces normally distributed transmission losses that are less than 157 decibels for 2 percent of the thunderstorms. Similar data at 4.85 Gc/s confirm that scattering is proportional to frequency to the forth power.

Conventional weather radar data are examined to determine their correlation with the bistatic measurement results. Data were sufficient to develop a statistical model of the scattering properties of Colorada thunderstorms. Comparisons with weather radar data show the conventional weather statistics are suitable for predicting forward scattering cross sections, provided certain empirical corrections are included. For example, comparisons with simultaneous 3.2 cm weather radar reflectivity data show weather radar data to be a good estimator of maximum forward scattering intensity when increased by 6 decibels.

The experimental programme was augmented by studies of possible interference between earth stations of a communication-satellite system and stations of terrestrial line-of-sight radio relay systems caused by scattering from continuous rain. A model was developed to calculate transmission loss for various propagation paths and rainfall rates.

In the development of idealized antenna patterns for use in interference studies, antenna patterns to represent earth station antennas of communication satellite systems were derived from available published data. The patterns include an analytic expression describing the main beam and first side lobe. Higher order side lobes are specified in terms of smoothed mean power levels of these side lobes.

An analysis of frequency sharing problems associated with the simultaneous operation of a satellite air traffic control system and conventional VHF aeronautical mobile service facilities was inaugurated. Laboratory tests have been designed to determine the wanted to unwanted signal ratios required for satisfactory service from different potential system configurations.

In conclusion, it will be noted that detailed technical particulars on U.S. operational communication satellite systems have not been included in this report. Such information already has been provided to the Chairman of the I.F.R.B. in the form of frequency notifications and descriptive material pursuant to Resolution 1A of the Final Acts of the Extraordinary Administrative Radio Conference to Allocate Frequency Bands for Space Radiocommunication Purposes (Geneva, 1963).

FRANCE

1. Telecommunications by satellites

Participation by the station PLEUMEUR-BODOU in the operation of the satellite Intelsat 1 (Early Bird) in cooperation with the stations at GOONHILLY (United Kingdom) and RAISTING (F.R. of Germany) and in liaison with the American stations at ANDOVER (United States) and MILL VILLAGE (Canada).

Television transmission tests at PLEUMEUR-BODOU 1 by means of the MOLNYA satellites, in liaison with the station at CHELKOVO (U.S.S.R.) in May 1966 (in colour, SECAM system, from PARIS to MOSCOW), June 1966 (black and white, from MOSCOW to PARIS), July 1966 (black and white, from LONDON to MOSCOW), November and December 1966 (black and white, from PARIS to MOSCOW).

Study and first construction stage of the station PLEUMEUR-BODOU 2 intended to operate with the Atlantic Intelsat 3 satellite at the end of 1968.

Study of an experimental stationary telecommunication satellite for French and European requirements in telephony and distribution of sound and vision broadcasting (SAROS project).

2. Space tracking

a) Operation of two "Diane" tracking stations from PRETORIA (Union of South Africa) and HAMMAGUIR (Algeria). Tracking of the French satellites FR 1 (1965-101 A) and DIAPASON (1966-13 A) and some foreign satellites: BEACON B or EXPLORER 22 (1964-64 A) BEACON C or EXPLORER 27 (1965-32 A) GEOS A or EXPLORER 29 (1965-89 A) and ERS 16 (1966-51 C).

At the beginning of 1967, the French satellites DIADEME 1 (1967-11 A) and DIADEME 2 (1967-14 A) were added to this list.

b) Tracking experiments with coherent light pulses (laser) at the observatory at St-Michel (Basses-Alpes, France) on satellites BEACON B or EXPLORER 22 (1964-64 A) BEACON C or EXPLORER 27 (1965-32 A) GEOS A or EXPLORER 29 (1965-89 A).

These experiments were continued in 1967 on the French satellites DIADEME 1 (1967-11 A) and DIADEME 2 (1967-14 A) equipped with laser reflectors with the station at St-Michel and two other stations situated at STEPHANION (Greece) and COLOMB-BECHAR (Algeria).

3. Telemetering and Telecommand

Operation of the stations at IRIS de BRETIGNY (Essonne, France) HAMMAGUIR (Algeria), OUAGADOUGOU (Upper Volta), BRAZZAVILLE (Congo) and PRETORIA (South Africa). Transfer of the station at BEYROUTH (Lebanon) to STEPHANION (Greece).

Telecommand and telemetering of the French satellites FR 1 (1965-101 A) DIAPASON (1966-13 A) and telemetering of certain foreign satellies : ALOUETTE 1 (1962 beta alpha 1) ALOUETTE 2 (1965-) and EXPLORER 30 or IQSY-solar radiation (1965-93 A).

At the beginning of 1967, the French satellites DIADEME 1 (1967-11 A) and DIADEME 2 (1967-14 A) were added to this list.

4. Space Research

a) Scientific operation during the whole of 1966 of satellite FR 1 (1965 -101 A), intended for the study of the propagation of very low frequency waves through the main part of the ionosphere. The experiments took advantage of the standard frequency and time signal transmitters FUB at SAINTE-ASSISE (Essonne, France) on 16.8 kc/s and NBA at BALBOA (Panama) on 24 kHz. The maintenance parameters and the slowly variable scientific data are transmitted on 136,800 Mc/s (power 0.35 W); the very low frequency signals, after conversion to 80 c/s, are transmitted with phase conservation on a telemetering equipment with a wider band (FM/PM, power 1 W).

Systematic scientific operation was temporarily abandoned at the end of 1966, but the satellite FR 1 is still operating satisfactorily and can be used from time to time.

Design and initial operation of a laboratory for the semi-automatic analysis of signals received from the satellite FR 1 by means of two sets of telemetering.

b) First stage in the construction of satellite D2, which is planned to be launched in 1969 and which is intended for the study of the distribution of hydrogen in the upper atmosphere by means of measurements of ultra-violet rays emitted by the sun, absorbed and re-emitted by the atmosphere.

5. Space Research on satellite radio navigation and satellite geodesics

Reception of signals emitted by the satellite DIAPASON (1966-13 A) on 150 and 400 Mc/s, measurement of the Doppler effect and use of the results for geodesic purposes. The measurements are made in three stations situated :

- at NICE (Alpes-Maritimes, France) transferred to St-Michel (Basses-Alpes, France),
- at BEYROUTH (Lebanon) transferred to STEPHANION (Greece),
- at COLOMB-BECHAR (Algeria).

This programme was supplemented at the beginning of 1967 by emissions from the satellites DIADEME 1 (1967-11 A) and DIADEME 2 (1967-14 A).

6. Space Research on satellite meteorology

First stage in the construction of the satellite EOLE, intended for locating balloons with ceiling in the atmosphere and for the re-transmission of data obtained from these balloons. Special study of the system of interrogating and locating balloons, operating in the bands 460-470 Mc/s (balloon to satellite) and 401-402 MHz (satellite to balloon). This satellite is to be launched in 1969 by an American Scout (FR2 cooperation programme).

INDIA (REPUBLIC OF)

1. Experimental satellite communications earth station

The work on the establishment of the experimental communication earth station at Ahmedabad progressed during the year, as scheduled. The technical and operational buildings will be ready towards the end of January, 1967. The main equipment will arrive in India by April, 1967, and the station is expected to become operational by the middle of next year.

The Department of Atomic Energy has sanctioned fellowships of the value of Rs. 1000/- per month for each foreign engineer with post-graduate qualifications and of Rs. 800.00 per month for each foreign technician who will participate in the training courses which will be organized at the station. The International Telecommunication Union acting as the executing agency for this project has been requested to convey this offer to those countries who will be asked to nominate candidates for the training courses to be conducted at the station.

The station is also expected to participate in the test plan to be conducted by the National Aeronautics and Space Administration of the United States, involving a new series of satellites designated 'Applications Technology Satellites.'

2. Commercial satellite communication earth station

India is a member of the International Communications Satellite Consortium owning the space segment, with a capital participation of 0.5%.

The Indian earth station will be located at Arvi (Longitude 73-57' E Latitude 19-09'N) about 50 miles north of Poona in Maharashtra State. The station is expected to be operational by 1968.

ITALY

I. FUCINO EARTH STATION FOR SATELLITE COMMUNICATIONS 1966 - 1967 DEVELOPMENT PROGRAMME

Introduction

In view of the forthcoming implementation of the Intelsat system of satellites and in order to make the station adequate to the increasing traffic needs, a new plant consisting of a large antenna, transmitting, receiving, steering and control systems is under development in the same site, the new antenna being installed about 300 metres apart from the first one. The new plant is expected to be completed within June 1966.

A brief illustration of the new installation is given hereunder.

Antenna

After an accurate survey of the rainfall and wind speed data for the site, the possible use of a radome has been discarded also for the new antenna. With a view to reducing the tracking errors due to wind, a special structure, the "wind spoiler", will be mounted around the edge of the reflector to counterbalance the effect of the wind.

The antenna is being supplied by Philco W.D.L. of Palo Alto, California, U.S.A., with a large participation of Italian industries.

The main characteristics of the antenna are as follows : I

Type of illumination	Cassegrain
Diameter of the paraboloid	27,4 m
Diameter of the sub-reflector	2,74 m
Focus/diameter ratio	0,33
Mounting	Az-El
Primary feed	five horn feed; the centre conical horn carrying the received and the transmitted signals, the outer horns determining the direction of the arriving wave.
Steering capability	-2° -95° Elevation ± 360° Azimuth
Gain at 6 Gc/s	62,5 db
Gain at 4 Gc/s	59,6 db
Beamwidth at 6 Gc/s (at 3 db)	0,135°
Beamwidth at 4 Gc/s (at 3 db)	0,17°
Maximum surface errors at 6° elevation for a 50 Km/h wind:	1 mm/rms
corresponding gain loss at 6 Gc/s 4 Gc/s	0,15 db 0,03 db
antenna noise temperature	20°K at 90° elevation 50°K at 5° elevation
Survival wind speed when in stowed position:	190 Km/h
Idem with one inch layer of ice:	95 Km/h
Servosystem	electrical
Storage rooms:	- one room on the azimuthal platform; - one room behind the paraboloid.

Receiving equipment

The following are the main characteristics resulting from the specifications :

- two low noise amplifiers for full equipment duplication will be installed behind the paraboloid;
- the receiver noise temperature will not exceed 15 degrees Kelvin;
- the R.F. bandwidth at 1 db of the low-noise preamplifier will be 500 Mc/s (3700 - 4200 Mc/s), thus covering the full Intelsat III bandwidth;
- the interconnection between the antenna plant and the main building will be made at a first intermediate frequency of 750 Mc/s, which allows the conveying of the entire 500 Mc/s bandwidth to the main equipment building through a low loss rigid coaxial cable. Also the interconnection sub-system will be fully redundant;
- after filtering, the various sub-carriers will be individually frequency converted to 70 Mc/s, amplified and demodulated;
- threshold extension and conventional demodulators for at least five carriers will be provided, the use of plug-in filters permitting optimum demodulation of carriers modulated by various numbers of channels;

Transmitting equipments

The following are the main characteristics according to the specifications :

- Two 2 KW transmitters will be provided for full redundancy. Tuning bandwidth will be 5925 - 6425 Mc/s;
- transmitters, exciters, power supply sub-systems, dummy loads and control panels will be installed in the storage room which is available on the azimuth platform of the antenna;
- the interconnection between the control building and the transmitting equipment will be probably performed at 70 Mc/s by the laying of various coaxial cables each of them carrying one sub-carrier;

- alternatively the interconnection between the control building and the transmitting equipment will be made at 750 Mc/s, two separate interconnection sub-systems having to be foreseen for full duplication;

- modulators, and 70/750 Mc/s converters if necessary, will be installed in the control building.

Power supply

Energy will be normally supplied by a new 20 kW/1000 kW public power line. The incoming voltage will be stepped down to 6 KV in an open-air transformer station; at this voltage energy will be distributed within the station. The voltage will be further stepped down to 380/220/125V in two secondary switching cabins annexed to the two antenna plants.

A 780 KVA/6 KV diesel generator with automatic start equipment will be installed. The unit can start and be on the line within ten seconds from the public power failure.

"No-break" power supply unit, will be only provided for those equipments for which no power interruption is permissible. Two 154 KVA/380 V units will be initially installed to work in parallel at half-load conditions.

Buildings

A new building, the central control building, will be erected close to the existing one, to house the intermediate frequency and the baseband section of the communication equipment, together with tracking, measurement and control equipment. Taking into account the building housing the diesel generator, the secondary cabin for the 6000/380 V transformation annexed to the new antenna, the enlargement of the existing offices, storehouse and workshop buildings, and the room available in the new antenna blockhouse, the total covered area will be about 2400 square meters.

II. TECHNICAL DESCRIPTION, PERFORMANCE AND RELIABILITY DATA ON THE LOW-NOISE RF AMPLIFIER OF FUCINO EARTH STATION

1. Introduction

The first low noise RF amplifier installed at the Fucino earth station during late 1962 in view of the participation in Telstar and Relay experimental programmes, was designed and manufactured by Marelli-Lenkurt laboratory of Milan, Italy. It was a parametric amplifier realized by two similar stages in series, the first cooled at liquid nitrogenum boiling temperature (77 degrees Kelvin) and the second at ambient temperature. The noise temperature of the low noise receiver alone was about 100°K and the instantaneous bandwidth 25 Mc/s at 3 db points.

The low noise RF amplifier presently installed at the Fucino station for the operation with Early Bird was designed and manufactured by laboratories of Società Generale di Telefonia ed Elettronica of Milan, Italy (formerly Marelli-Lenkurt) upon Telespazio technical specifications.

The design of this low noise receiver and its technical performance are much more advanced with respect to the first one and they are reported with some details in the following paragraphs.

The time from the date of the order to the completion of the installation and check-out at the Fucino site was 8.5 months.

2. Technical description

The low noise RF amplifier is realized by two staggered negative-conductance parametric amplifiers in series cooled at about 20 degrees Kelvin, followed by a tunnel-diode amplifier at room temperature. Refrigeration is supplied by a gaseous-helium closed cycle refrigerator manufactured by Arthur D. Little, Inc. (model CRYR-340 L) which can be mounted in any position.

Figure 1 (page 49) shows the block diagram.

The low noise RF amplifier is completely solid-state, including the RF pump generators of the parametric amplifiers. The refrigerator contains both the circulators CL1 and CL2 and the two waveguide cavities each with one varactor PA1 and PA2.

Some difficulties arose in operating the circulators at 20° K but, after further studies and experiments, the problem was solved.

The varactor used (Sylvania D 5147C) are gallium arsenide, diffused junction. The capacity of these varactor at 0 V bias is about 0,5 pF and the cut-off frequency at -6 V bias is higher than 300 Gc/s.

A high degree of stability is achieved by using solid state, frequency and power stabilized RF pump generators. These pump generators are realized with quartz stabilized transistor oscillators followed by several amplification and frequency multipling stages. The power stability is definitively improved with an appropriate automatic control device which keeps the varactor current at a constant value operating a variable attenuator, based on the polarization plane shift phenomenon.

3. Overall low noise RF amplifier performance data

Instantaneous bandwidth (1 db points) *)		250 Mc/s
Instantaneous bandwidth (3 db points)		285 Mc/s
Center frequency		4125 Mc/s
Noise temperature referred at the input flange *)		26 ± 5° K
Total paramp gain *)		24 db
Tunnel diode gain		15 db
Input return loss		> 13 db
Pump frequency		21 ÷ 21,6 Gc/s
Pump maximum output power		100 mW
Saturation input power (1 db gain compression)		> - 65 dbm
Gain stability :	short term	≦ ± 0.2 db /hour
	long term	≦ ± 1 db/day
Phase stability :	short term	≦ ± 3° /hour
	long term	≦ ± 7° /day
Cooling time		about 5 hours

*) The paramp gain can be increased up to 27 db without change of noise temperature but narrowing the bandwidth to about 200 Mc/s (1 db points). In so doing the noise contribution of the tunnel diode amplifier (noise temperature 900°K) referred to the input of the parametric amplifier decreases from 4°K (with 24 db gain of the paramp) to about 2°K.

Figure 2 (page 51) shows the passband characteristics obtained with the parametric amplifier gain adjusted at 24 db.

4. Maintenance and reliability data

The working hours of the RF low noise amplifier and associated refrigerating equipment are more than 7700 with a minimum of down time, mostly for the maintenance operations of the refrigerating system.

During the commercial service hours of Fucino station (more than 1100) only one interruption due to the RF amplifier was experienced: about 2 minutes on 2 October 1965, caused by intermittent piston seizure of the refrigerating unit owing to impurities in the helium (our experience in this field is that, to avoid troubles of this nature, the degree of purity of helium required is at least 99,995% with humidity less than 10 volumes per 10^6). Only one failure in the electronic circuitry was experienced, not during the service hours: breaking of a resister in one of the RF pump generators.

Some other trouble was encountered on the compressor of the refrigerating system: the external copper circulating oil pipe broke three times. We ascribed this breakage to "fatigue stress" (continuous vibrations during operation) and asked the manufacturer to provide for the replacement of the copper pipes with a more suitable material. Presently the pipes are realized with stainless steel and no failure has been experienced till now.

The intervals for preventive maintenance so far adopted are as follows :

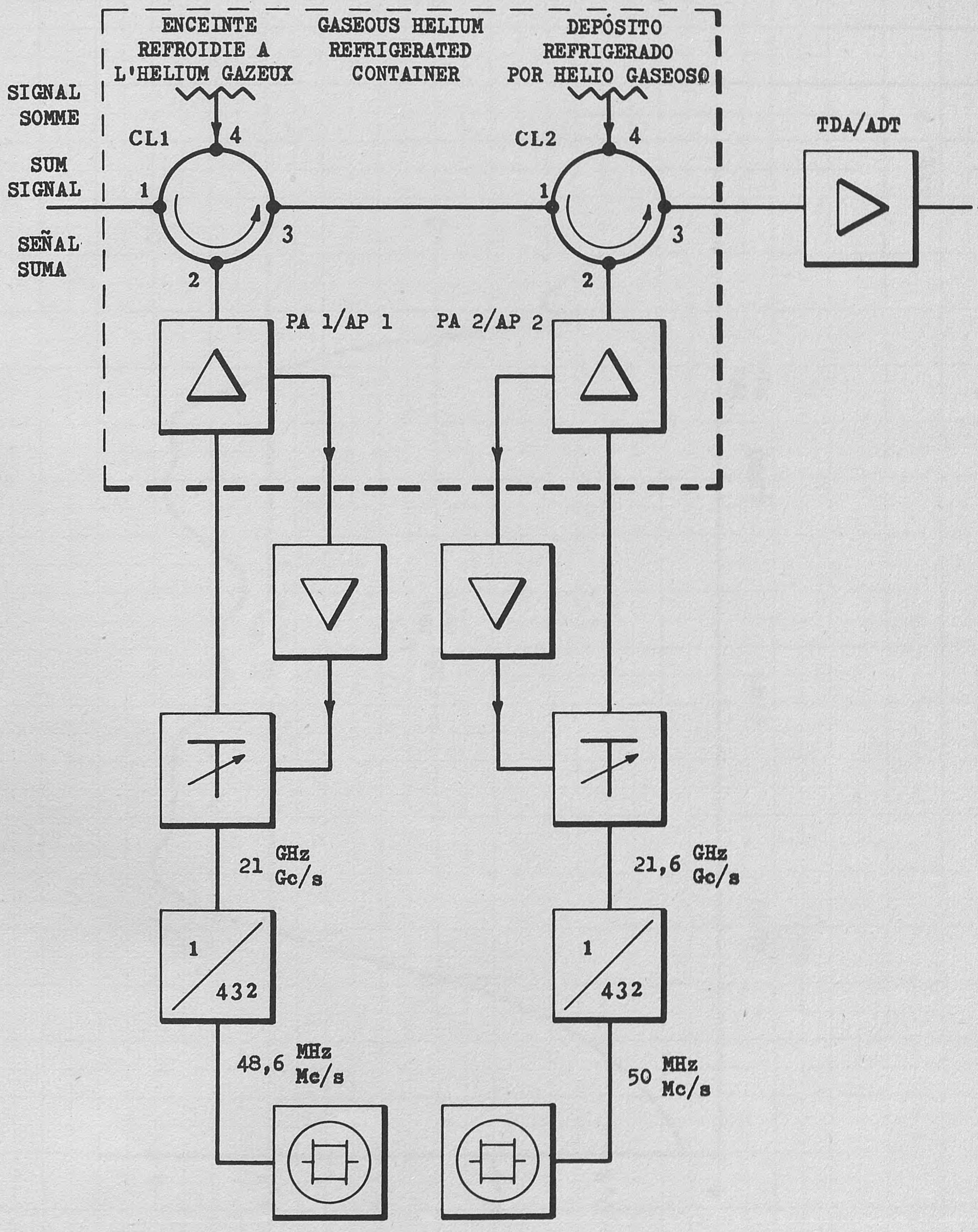
- charcoal trap : 1500 hours
- refrigerator crosshead assembly : 3000 hours
- compressor : 5000 hours

It seems that the crosshead assembly preventive maintenance intervals can be extended to 5000 + 6000 hours without troubles.

5. Future developments

It seems possible to design a parametric amplifier with a noise temperature less than 20°K, using a new type of varactor with a cut-off frequency of about 600 Gc/s and mechanically isolating the RF pump generators from the varactors in order to avoid thermal dispersion along the waveguide. An instantaneous bandwidth of 500 Mc/s should be achieved with three or four paramp stages in series, frequency staggered.

Our specifications for the new low noise RF amplifiers for the Fucino high capacity earth station have been prepared with these goal figures and will be issued for an international bid cycle in the near future.


ENCEINTE
REFROIDIE A
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SIGNAL
SOMME
SUM
SIGNAL
SEÑAL
SUMA
CL1
CL2
TDA/ADT
1
2
3
4
PA 1/AP 1
PA 2/AP 2
21 GHz Gc/s
21,6 GHz Gc/s
1
432
48,6 MHz Mc/s
50 MHz Mc/s

Fig. 1

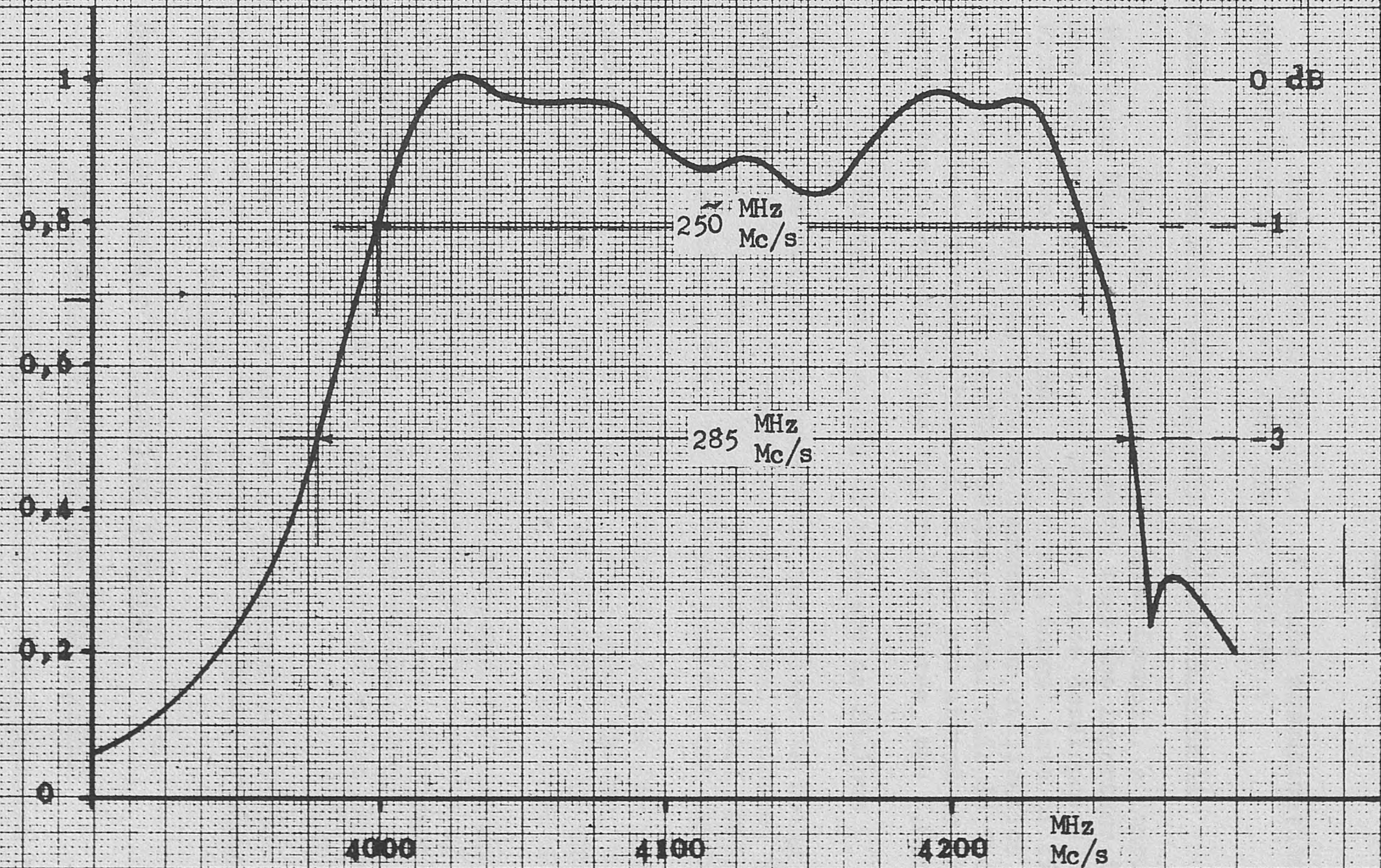
1
0,8
0,6
0,4
0,2
0
0 dB
-1
-3
250 MHz Mc/s
285 MHz Mc/s
4000
4100
4200
MHz Mc/s

Fig. 2

JAPAN

Activities in the field of space communications done in our country during the year 1966 are as follows :

1. Proposal from the National Space Activities Council

The National Space Activities Council, a consultative body to the Prime Minister, in the judgment that the important time had come for decision on Japan's basic policy for space development, proposed to the Prime Minister on 3 August that with a target date of fiscal 1970, artificial satellites would be launched for utilization pending a long-term plan being subject to further deliberations. This is the first time for Japan to have announced herself at home and abroad as the country launching satellites in succession to the United States, the U.S.S.R. and France.

The contents worthy of note are as follows :

1) The project of scientific satellites is being pushed forward mainly by Institute of Space and Aeronautical Science, University of Tokyo; Satellite No. 1 will be launched in fiscal 1967, and further several scientific satellites will be launched not later than fiscal 1970.

2) The project of experimental satellites for practical use is being pushed forward mainly by National Development Center, the Science and Technology Agency; research and development will be made of rockets and the system necessary for launching with a target date of fiscal 1970.

3) The government agencies concerned will continue, according to their respective duties, in research and development of the system of utilization of satellites for communications, broadcasting, meteorology, navigation, geodesy, ionospheric observations, etc., and will also cooperate in the attainment of the projects by the above two agencies a) and b).

4) The tracking service of artificial satellites is to be centralized so as to be under the sole control of the Space Development Headquarters, the Science and Technology Agency.

2. Research in space communications technique

1) Experiments at the Kashima Earth Station

At the Kashima Earth Station, Radio Research Laboratories, Ministry of Posts and Telecommunications, experiments via satellite Relay II were carried out with Scandinavia and Western Germany from 10 December, 1965, till 1 February, 1966. Experiments were made on one-way wide-band communications with the earth station LSCA (Sweden), Scandinavia, and on two-way narrow-band communication with the earth station LGEB, Western Germany. The goal was mainly for testing transmission in one way TV and two-way telephony.

In the experiment with Scandinavia, movie pictures black-and-white and in colours were transmitted from Kokubunji on the circuit 7 Gc/s. This is the first time that TV in colours has ever been transmitted from Japan to Northern Europe by way of satellite. As the first experiment with Western Germany at the Kashima Earth Station, telephony, high-speed data, facsimile and telegraph transmission were tested by the system of channeling the signals received at Kashima back to Western Germany. The facsimile and telegraph signals were recorded on magnetic tape at Kokubunji on the circuit 13 Gc/s.

It is scheduled that the communications will be tested between Japan and the United States beginning in February, 1967, by the use of ATS (Nos. 1 to 5) to be launched by the National Aeronautics and Space Administrations (NASA). Prior to this experiment, for the purpose of orbit tracking, etc. after ATS No. 1 was launched, the distance to the satellite at the first apogee above Sumatra and its rate of variation were measured with considerable success. Preparations for experiments in PCM communication system developed in Japan, transmission of colour TV signals, etc. in and after February are now being pushed forward.

2) <u>Improvements in the Ibaraki Earth Station</u>

The Ibaraki Earth Station, the Kokusai Denshin Denwa Company, Ltd. (KDD), has on hand a complete set of equipment used for the international TV relay broadcasts delivered first in Japan by satellite Relay II on 23 November 1963. In the past one year this equipment was rearranged for improvement and higher performance so as to be capable of carrying on commercial communications by means of satellite INTELSAT-II system. First, the antenna 20 meters in diameter was enlarged to 22 meters and owing to improvement in performance of the primary projector, the antenna gain increased to 56 to 57 db in the band 4Gc/s and 58 or 59 db in the band 6 Gc/s. As a result, in case of use of MASER mentioned later, the antenna noise temperature (inclusive of the feeding system) came to secure 50° K on 4 Gc/s and at an angle of elevation of 20 degrees. The transmitter and receiver systems were altered into the intermediate frequency transmission system convenient for operation and divided into TV and telephone transmission systems. For reception in low noises, the adoption of MASER has been decided in use of both systems of circulating refrigeration and of pouring of liquid helium.

In addition, the high-sensitivity demodulators have been installed for TV and telephone purposes respectively. The TV voice circuit, telephone for talking between earth stations, and teletype circuits are to be worked through the satellite system, and the equipment required has been installed anew.

Further, the KDD, by the use of facilities mentioned above, commenced the commercial service of TV transmission between Japan and the United States by INTELSAT-II (F1) at the end of 1966.

3) In addition to the above mentioned, researches are in active progress for the sake of space communications, regarding the design of a high-power transmitter in the 6 Gc/s band, various technical problems in the international TV relay broadcasting different in the standard systems, the influence of wind, etc. on the 30 mø antenna drive-control system, reduction in noises and increase in efficiency of a large-sized antenna, a new system of automatic tracking, and so forth.

KENYA, UGANDA, TANZANIA (UNITED REPUBLIC OF)

The East African Posts & Telecommunications Administration in conjunction with the East African External Telecommunications Co. Ltd., who are jointly responsible for the international telecommunications services of Kenya, Uganda and Tanzania (Mainland only) have conducted during 1966 a feasibility study on the provision of a satellite ground station in East Africa. Although the actual site for the installation of the ground station has yet to be decided it has been recommended that the station should be equipped and designed to the following specifications :

1) The ground station will be equipped to work to any equatorial geo-stationary satellite visible from the site down to 5° of the horizon.

2) Facilities will be provided to receive a television carrier by incorporating wide band transmission paths.

3) The ground station will be equipped to transmit one carrier of 36 channels and to receive three separate carriers from three different origins.

PHILIPPINES (REPUBLIC OF THE)

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Prior to the start of the year the Philippine Government have already taken steps to participate in the International Telecommunications Satellite Consortium. Preliminary studies as to the feasibility of establishing and operating a communications satellite earth station were completed and recommendations for membership to INTELSAT and the establishment of an earth station was elevated to the higher echelons of the government for consideration.

This has led to the action of the Philippine Government in indicating its intent of acceding to the Interim Agreement with the request that the International Communications Satellite Committee (ICSC) approve a 0.5% capital investment quota in the financing and ownership of the space segment of global commercial communications satellite system. It has also opened the way for the creation of a Presidential Committee to study ways and means for the establishment, management and control of an earth station.

It was however at the later part of the year when the Philippine Government took major strides towards active participation in the global system by designating the Philippine Communications Satellite Corporation (PHILCOMSAT) a semi-government entity, to represent the government and act as signatory to the Special Agreement. Membership to the consortium took effect on 1 December, 1966. The objective as to the extent of Philippine participation has been clearly defined.

Just as the year ended, technical studies and tests were being conducted for the purpose of selecting the most appropriate location for the Philippine earth station.

It is envisaged that these activities will lead to the establishment of an interim earth station which will be operational by 1 April 1967 and a subsequent establishment of a permanent earth station which will be in operation one year thereafter.

Plans for the permanent earth station call for an ultimate capacity of 240 voice/data channels and a television channel.

Considering the present stage of the art and rapid development of satellite communications, the need for highly skilled personnel has become apparent. In the direction of having qualified personnel to operate and manage an earth station, the government, through its Bureau of Telecommunications, have explored various possibilities of training Filipinos. Representations were made with I.T.U. for possibly developing a course on satellite communications for inclusion in the curriculum of the U.N. Sponsored Telecommunications Training and Research Institute in the Philippines as well as possibly acquiring training grants such as those offered under various technical assistance and cooperation programmes.

FEDERAL REPUBLIC OF GERMANY

1. Communication-satellite service

No major trouble was experienced with respect to the telephone and television transmissions made via the Satellite INTELSAT I and the German earth station at Raisting under the agreements with the European Telecommunication Administrations. The cases of breakdown which occurred at the Raisting earth station amounted only to 0.03 p.c. (relative to the operating time of that earth station).

It is planned to set up, in the course of the next few years, a second antenna system at Raisting for the purposes of the communication-satellite service. Preparatory work to this end has already been started.

2. Aeronautical and maritime satellite service

It is intended to test the use of satellites for the aeronautical and maritime service by means of experimental radio installations on the research ship "Meteor" and on board a Lufthansa aircraft in interaction with the ATS satellites or the future aeronautical satellites.

3. Meteorological-satellite service

Since March 1966 the Central Office of the Meteorological Service at Offenbach has received 6 to 12 picture transmissions per day with its APT-receiving installation (automatic picture transmissions) from the NASA meteorological satellite ESSA 2. By September 1966, 1900 cloud pictures were available.

4. Radio astronomy service

In 1966, the Institute for Radio Astronomy at the University of Bonn took measurements for the observation of the electrical processes on the sun and measurements of the 21-cm line of the interstellar hydrogen. In addition, investigations are being made into the galactic and extra-galactic systems. The respective receiving range is between 1 and 40 Gc/s approximately; as receiving antenna the radio telescope on the Stockert (Eifel) with its 25-m parabolic reflector is used.

It is planned to establish a Max Planck Institute for Radio Astronomy in North Rhine Westphalia. The Institute is to obtain a fully steerable radio telescope with a reflector diameter of 100 m. Beside this antenna two 50-m reflectors of the mobile type are to be installed. The construction is to be made so rigid that surface deformations of the reflector remain below 2 to 3 mm in every position of the reflector. This would allow clear reception including the cm wave range.

5. Space research service

A group of German firms continues the design and construction of the first German research satellite (Project 625 A). As early as in 1965, it had been agreed with NASA to launch the satellite in 1968 by means of a SCOUT rocket. The satellite shall enable measurements to be taken within the earth's radiation belt and measurements of the magnetic field of the earth.

In November 1965, a recoverable high-altitude research rocket was tested by means of gliding experiments; a telemetering apparatus transmitted flight position data over 18 channels on 401.5 Mc/s, which allowed the rocket to be controlled from the ground by means of a radio control transmitter working on a frequency of 450 Mc/s. New flight tests have been planned for 1968, and the rocket is envisaged to be completed in 1970.

It is also intended to associate German stations with the planned world-wide geodesic network of photo-theodolites and Doppler stations with a view to making contributions to the European low-order triangulation network as a result of satellite observations.

In the Federal Republic of Germany, there is nearly a dozen of stations equipped to receive telemetering data from the research satellites. In addition,it is planned to set up a separate research earth station in a side valley of the Raisting basin.

6. Amateur satellite service

A German radio amateur designs, builds and tests, within IARU (International Amateur Radio Union), the satellite "Oscar 5" for amateur radio communications. At present the last tests are carried out on the satellite. Probably at the beginning of 1967, "Oscar 5" will be launched by NASA into an orbit of several 100 kilometres' altitude.

UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

A. Satellite communications

1. 1966 has been a period of intense activity in planning for the deployment in 1968 of the INTELSAT global satellite system. The United Kingdom has contributed by full participation in the work of the Interim Communication Satellite Committee.

2. The provision of a second earth terminal at Goonhilly earth station for operation to an INTELSAT III satellite is in an advanced stage of planning and the terminal should be ready for service by mid-1968. It is intended that the existing earth terminal at Goonhilly should then be withdrawn from service so that it may be modified for operation with a second INTELSAT III satellite. Both earth terminals will then have a working bandwidth of 500 Mc/s, and the development of the necessary wide-band devices including high-efficiency aerial feeds and low-noise parametric amplifiers is in progress.

3. More general studies of various aspects of satellite communication system design are also in progress. Mention is made in particular of investigations of multiple access to satellite transponders using frequency division and time division techniques.

4. The Goonhilly earth station has collaborated with other European earth stations throughout 1966 in providing regular telephone, telegraph and television circuits via the INTELSAT I satellite to U.S.A., and latterly to Canada also. Evidence acquired through this practical experience confirms the satisfactory design and operation of the Goonhilly station and its capability for providing large numbers of telephone circuits to C.C.I.R. standards.

B. Space research relevant to radiocommunications

5. In addition to the work directly concerned with telecommunications satellites, the United Kingdom is carrying out as part of its space research programme a number of experiments which produce information relevant to problems of radiocommunications. The data obtained are in two main fields : firstly, in that of radio-wave propagation by the measurements of the characteristics of the ionosphere and of the external factors influencing them; and secondly, in that of radio noise emissions. The measurements which have been made in the sounding rocket and satellite programmes, and the progress in the preparation of future experiments, are detailed below.

6. In the national rocket programme, measurements of ionospheric electron and ion parameters have been made with the aid of probes and by wave propagation methods. Seven successful launchings have been made in this field.

7. The third co-operative UK/US satellite, UK 3, now being completed for launching in March-April 1967, contains experiments to measure the ion density and temperature in the ionosphere, the emission of radio noise from terrestrial and galactic sources, and the intensity variation and spectrum of VLF radiation. The prototype model of the flight equipment is now complete.

8. During the year, further United Kingdom experiments have been launched in ESRO rockets with the aim of measuring characteristics of the ionosphere (such as electron temperature by means of probes), and for studying the various solar radiations which also have a bearing on the ionosphere. The United Kingdom had also participated in the series of ESRO rocket launchings from Greece, associated with the solar eclipse of 20 May, 1966 and directed at obtaining further information on the formation of the ionosphere.

9. A 25-metre steerable aerial, capable of following satellites, has recently been completed at Chilbolton, Hampshire, for use by the United Kingdom Radio and Space Research Station. The programme of work will include investigation of propagation problems relevant to satellite communications, particularly the possibilities of interference to and by other radio services.

UNION OF SOVIET SOCIALIST REPUBLICS

A long-distance radio link via the artificial earth satellite Molnya I was brought into service on 23 April 1965. When this satellite link was planned, the problem arose of obtaining radio visibility for the satellite with the whole of the territory of the Soviet Union. As the Soviet Union is in the northern hemisphere, the problem could be solved only by choosing a very long elliptic orbit with its apogee above the northern hemisphere.

The communication satellite Molnya I follows this orbit with an apogee of about 40,000 km above the northern hemisphere and a perigee of about 500 km above the southern hemisphere. The orbit has an angle of inclination to the equator of 65^{0}. The period of revolution of the artificial satellite round the earth lasts 12 hours.

The communication satellite completes two revolutions in 24 hours. During the first revolution, communications are provided during 8 to 10 hours between any point in the Soviet Union and various countries in Europe and Asia. During the second revolution, apart from communications within the Soviet Union, it is possible to set up links between the European part of the U.S.S.R. and places in Central and North America.

An extensive network of earth stations will be built in the Soviet Union as part of a long-term plan for satellite communications. It is essential to increase the power radiated by the satellites as much as possible in order to make the equipment of these stations simple and cheap.

The retransmitter of the communications satellite Molnya I works in the 800 to 1000 Mc/s range. Transmitter power is 40 watts, which is obtained by using powerful travelling wave tubes. In addition, a directional parabolic antenna with circular polarization and a gain of about 18 db was fitted to the satellite. The directivity diagram of the antenna was chosen with an aperture of 22^{0} so that when the satellite was near to its apogee it covered the whole territory of the Soviet Union and other countries situated in the northern hemisphere.

The satellite antenna requires a device to orient it towards the Earth.

There is a special orienting system on Molnya I, which directs the solar array towards the sun and the antennae towards the Earth, and a stabilizing system for the three axes.

The satellite's attitude is Earth-controlled as soon as it becomes optically visible from one of the Earth stations.

A telecommand/telemetry unit is used to direct the satellite and obtain telemetry data concerning the equipment on board. This unit switches on the satellite's orienting device, switches the basic receiver-transmitter unit on and off, switches over to the stand-by equipment, and ensures changeover from duplex to simplex working.

This unit also ensures the transmission to Earth via telecommand-telemetry radio lines of the basic characteristics of the retransmitter and of other systems in the satellite. The possibility of correcting the satellite's orbit from Earth has also been provided. Correction of the satellite's orbit may be necessary to ensure a more convenient and longer period of radio visibility between the various points of the communications system.

For the first stage in the application of the Molnya I satellite, a line was set up between Moscow and Vladivostok, and the two Earth stations required were built and equipped. The anntennae of the Earth stations have circular polarization, a gain of about 40 db and a radiation pattern width of about 1° at half power. The ground control and automatic tracking devices ensure a high degree of accuracy in the automatic tracking of the satellite by the antenna as the former proceeds along its orbit.

A multi-resonant klystron is used in the Earth station FM transmitter to provide powerful amplification; the klystron gives a continuous output power of 10 kW with a transmission bandwidth of the order of 12 Mc/s. Frequency deviation for television transmission corresponds to the full peak-to-peak value of the television signal, i.e. ± 4 Mc/s and can be increased to ± 6 Mc/s.

For telephony, the r.m.s. frequency deviation, corresponding to the measurement level in one telephone channel, is 200 kc/s.

A non-cooled dual parametric amplifier with a noise temperature of 150°K is connected to the input of the Earth station receiver. The full noise temperature of the receiver together with the antenna and the wave-guide section is about 230°. The transmission bandwidth of the receiver is 12 Mc/s.

A device to lower the threshold level is used for duplex working when multi-channel telephone connections are to be set up. This device, known as the "tracking oscillator", has been invented and registered in the U.S.S.R. and patented in France. It differs by the use of double-loop frequency feedback, by the absence of a modulator and demodulator, and provides a larger gain when the threshold level is lowered than the usual frequency feedback system.

Molnya I offers the possibility of relaying black-and-white or colour television signals, or of providing multi-channel telephone connection with the possibility of secondary multiplexing of the telephone channels with VF telegraph, phototelegraph or other types of information signal.

Supervisory telephone channels are also provided to enable the staff in charge of the Earth stations to communicate with each other.

The television sound signals are line-transmitted simultaneously with the picture signals via one communication channel by time division of the signals. After the line synchronized pulse has been transmitted, at the time of the blanking pulse, one or several pulses carrying the sound signals are sent. The sound is sent by pulse length modulation or by PCM.

This method of transmitting the sound signals for television differs from the usual methods applied on radio relay links in that the communication channel bandwidth does not need to be widened. It is particularly suitable for satellite links, in which it is undesirable to widen the frequency band of the earth stations (which receive relatively weak signals from the satellites) since the noise level would be increased.

Continuous control of the basic quality characteristics of the communication channels during transmission is provided for links via Molnya I. During multi-channel operation, the level diagram (overall circuit attenuation) and noise power are controlled. For this purpose, control signals are transmitted at frequencies above and below the edges of the band occupied by the telephone channels. The levels of these signals are changed at the transmitting and receiving stations, and this permits of continuous control of the level diagram. Noise coinciding with the frequency band and situated close to the control signals is separated by filters at the receiving stations, detected and measured.

In this way it is possible to assess the noise level in the lower and upper telephone channels during actual operation.

To check the communication line, it is fed with white noise simulating the multi-channel signal. The white-noise generator is included in the earth station. Thermal and non-linear noise occurring when the line is fed with white noise is measured in the same control channels.

For the transmission of television signals, two lines at the beginning of each field are used to transmit the test signals recommended by the C.C.I.R. and the bursts of sine-wave oscillations of various frequencies. These test signals are introduced into the video channel at the transmitting station and extracted at the video channel output in the receiving station.

In this way, the basic characteristics of the video channel are controlled continuously during transmission of the television signals : transmission level, frequency characteristic, transfer characteristics, non-linear distortion.

To control the separate elements of the circuit and to check the earth station equipment before operation, the transmitters and receivers of the Earth stations are fitted with control devices. The control device of the transmitter consists of a wideband receiver connected to transmitter output via a directional coupler and attenuator. The test signals are separated at the output of this receiver, enabling the working quality of the transmitter to be controlled continuously during multi-channel and television operation.

The receiver's control device consists of a low-power wideband transmitter. It can be connected to the receiver input before operation. The basic characteristics of the receiver are controlled by feeding the same test signals to the transmitter modulator.

The whole receive-transmit equipment network of the Earth station can be checked before operation starts. For this check, the control devices of the transmitter and receiver are connected together to form a signal retransmitter.

A complete control of the working quality of the link via the satellite retransmitter is effected at each earth station. Two receivers are installed in each Earth station : one of them (the working receiver) is tuned to the frequency of the corresponding station, i.e. to the frequency of the signal received from the other station via the satellite relay, while the other (the control receiver) is tuned to the frequency of the signal received from its own station via the satellite relay. In this way it is possible to assess the performance of the whole link by the quality of the signals received by the control receiver, and also to judge the quality of the signals in the other station of the link.

A working test of the link set up via Molnya I showed that the control system adopted provides good and convenient control over the whole link and over separate sections of it.

A television programme has been transmitted regularly over the Moscow-Vladivostok circuit via Molnya I since April 1965, which also provides a commercial multi-channel telephone and telegraph link. Television programmes from Moscow and from various cities in the Soviet Union and abroad, via Moscow, were shown in Vladivostok in 1966.

Telephone and telegraph channels via the Molnya I link between Moscow and Vladivostok have been extended to the wide network of the European and Far Eastern parts of the Soviet Union.

Under an arrangement concluded in 1965 and 1966 between the Governments of the Soviet Union and France, it was decided to carry out joint scientific research on colour television systems and to cooperate in the study and exploitation of outer space for peaceful purposes.

Under this arrangement, the artificial Earth satellite Molnya I was used to set up an experimental international line between Moscow and Paris, for research and for the transmission of experimental colour television signals between Moscow and Paris.

These tests confirmed that it was possible to obtain good-quality colour television pictures with the SECAM system via Molnya I. The results of these tests were published in the contribution by the Administrations of the Soviet Union and France to the XIth Plenary Assembly of the C.C.I.R. (Oslo, 1966).

In addition, this same link was used for the exchange of black-and-white television between the U.S.S.R. and France during the visits of Charles de Gaulle, President of the French Republic, to the Soviet Union, and of Comrade A.N. Kosygin, Chairman of the Council of Ministers of the U.S.S.R., to France.

In June 1966, pictures of the Earth were taken and transmitted by Molnya I. For this experiment, special television cameras were fitted in the satellite and directed towards the Earth. The T.V. camera signals were passed to the communications transmitter of the relay set on board the satellite. The camera possesses a rotary device and interchangeable lenses controlled from Earth.

This was the first time that pictures of the Earth had been received from a high-moving satellite. The regular reception of pictures of the Earth from artificial satellites could be extremely important to meteorological services.

Multi-station access systems and the organization of communication systems carrying only a few channels have been designed and studied in the Soviet Union with an eye to the further development of satellite communication systems.

Basic research was carred out and plans completed in 1966 for economic Earth stations of a simpler type to receive circular information from the central station via Molnya I.

Television programmes, sound broadcasts, newspaper texts, etc. can be transmitted in circular fashion from the centre. It is possible for the centre to set up sufficiently protracted connections with the whole area of the Soviet Union via the high-orbiting satellite Molnya I. There is no doubt about the economic advantages of such a system and it is particularly suitable for the remote areas of the country. Such a system is all the more profitable the higher the current density beamed by the satellite, and a satellite of the Molnya I type fulfils this condition. If the satellite transmitter has a high energy potential, the signals can be received on Earth by small antennae. The system that has been studied and installed in the Soviet Union comprises a large network of Earth receiving stations to receive the Central Television programme via Molnya I.

The stations of this system are equipped with antennae having a mirror diameter of 12 metres and a low level of inherent noise (about 40° K).

The tracking antennae follow the satellite with the aid of an automatic programming device. The programme can be corrected according to the magnitude of the received signal.

An input waveguide filter and a parametric amplifier cooled by liquid nitrogen are installed at the input of the station receiving equipment.

The noise temperature of the whole receiving unit with the antenna is of the order of 140° K.

The receiving equipment includes a noise-suppressor demodulator of the FM signals, which improves the threshold properties of the receiver. A synchronous phase detector with frequency feedback is used as the demodulator. It reduces the threshold level by 2.5 - 3 db, which is the equivalent of improving the output signal/noise ratio in this case by 7 - 9 db. In addition, the synchronous phase detector provides additional noise suppression in the neighbouring channels and very effective suppression of pulse interference.

At present a network of receiving earth stations is being built and the requisite equipment designed. Reception of central television programmes will be arranged in the first place. Then the role of the receiving stations will be extended to include the reception of other types of circular information (sound broadcasting, newspaper texts) and the stations will subsequently be included in the duplex network with multi-station access.

A wide network of economic receiving stations will be built and brought into service on the occasion of the 50th Anniversary of the Great October Revolution in the U.S.S.R. This will enable Central Television programmes to be transmitted to outlying regions and areas of the Soviet Union.

A meeting of experts from the socialist countries was held in Moscow from 5 to 13 April 1967 to discuss cooperation in research into, and utilization of outer space for peaceful purposes. The participants in the meeting (representatives of the eight socialist countries) considered it expedient - in the interests of the further development of economic, commercial, and other relations between the socialist countries - to set up an international system of communication satellites for the transmission of all types of information. This system may be joined by any country which desires to be included in it.