Source: Sound and Vision Summer 1971

T. F. HOWELL, B.Sc, Ph.D

DEVELOPMENTS IN COMMUNICATIONS USING SATELLITES

INTRODUCTION

In justification of the immense sums poured into space research, particularly by the governments of the USA and USSR, the concept of 'technological fallout' from these activities is often employed. While some of the subsequent benefits are of somewhat limited usefulness, the field of long distance communication has received an enormous boost from space research with the advent of communication satellites. From the first experiments in the early 1960's to the present day, there has been a continued rapid progression in the use of satellite-borne repeaters for the transmission of voice, television and data communications. The new technique has not only markedly increased the available channel capacity for international telecommunication links, but has simultaneously brought higher quality and lower cost, with the prospect of even lower costs in the near future.

This article gives a brief description of the historical development of the global network of satellite communication that has been built up over the last five years, and then proceeds to a discussion of the regional communication systems now being proposed. These systems use satellites of higher radiated power than those used hitherto, and to illustrate the typical parameters of regional systems, particular reference is made to the European satellite communication network. This is currently under extensive and detailed study under the auspices of the European Space Research Organisation and the Council of European Post and Telecommunications Authorities. In conclusion, an analysis is given of the prospects of direct-to-home broadcasting via satellite, and of the educational television distribution systems due to be implemented experimentally in the near future.

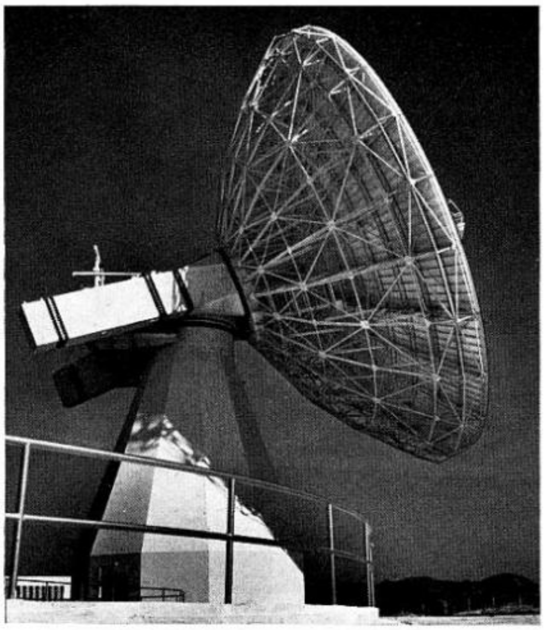

Fig.1 Hong Kong 1 earth station for Intelsat global satellite communications system.

DEVELOPMENT OF THE GLOBAL NETWORK

In order to operate an international network of communications by satellite an international consortium, INTELSAT, was set up in 1964. This body owns the satellites and lays down the technical requirements for the ground stations to be used in the network. The over-all system is managed by the American COMSAT Corporation, which is simultaneously the United States representative on INTELSAT. Holdings in INTELSAT are primarily based on usage of the system; currently the American holding is the largest at just over 53%, the second largest being British holding of 7·3%, the remaining seventy-five members having percentages down to the 0·01% holdings of the Sudan and Iraq. The percentage holdings are likely to change in the near future as a permanent agreement to replace the interim agreement of 1964 is currently under negotiation. It appears likely that the American holding will drop below 50%, the intention being to increase the influence of the smaller countries.

The first satellite to be placed in synchronous orbit by INTELSAT was 'Early Bird'. This was launched in April 1965 and is still in orbit; although it has been switched off it is still available for use as an 'in-orbit' spare if needed.

The global network then developed rapidly through both an INTELSAT 2 and an INTELSAT 3 series of satellites. Since this development has been covered in detail in a previous article in this journal[1] it is not intended to describe the sequence in detail. As a summary of the progression in satellites Table I shows a table of satellite parameters, while figure 1 shows a typical global system ground terminal with an antenna in the diameter range 25–30 m.

The newest phase of the global satellite communications network opened in January 1971 with the launch into a geostationary position over the Atlantic Ocean of the first INTELSAT 4 satellite. This series of satellites represents an important development in the prospective use of communications satellites for other than international telecommunications links, since in addition to antenna beams 17° wide (giving coverage of the whole area of the Earth visible from the satellite), higher gain 'spot-beams' are also available. These beams are approximately 6° wide (on the first satellite, one is directed at Europe, the other at the east coast of the United States), and since the available transmitter power of the satellite is concentrated into a smaller area, the effective 'radiated power' of the satellites is increased.

This increase in available satellite power may be used in two ways: either smaller and simpler ground terminal equipment may be used to pass a similar traffic capacity as a lower-power satellite/more complex ground terminal system, or else the sophisticated ground terminals may be retained and the higher satellite capacity used to increase the system traffic capability. As may be expected the INTELSAT network has opted for the latter alternative. However, it is the purpose of this article to discuss the first option in which the increased power available from concentrating a satellite's transmissions to a particular geographical region is used to reduce drastically the size and complexity (and correspondingly, the cost) of the ground terminals used with the communications system.

CURRENT REGIONAL AND NATIONAL SYSTEM

The first 'national' satellite communications system was set up by the Soviet Union which inaugurated its 'Orbita' network in 1968. This network carries communication between two main stations at Moscow and Vladivostock to a network of subsidiary terminals. Originally there were some twenty stations in the system, but this number has increased until it is now about thirty. The network is used to transmit telephony, television and facsimile information. The principal simplification used in the Orbita system is the use of 12m antennas rather than the 25–30m antennas of the international network, and of first-stage parametric amplifiers cooled only to liquid nitrogen temperatures (80K) rather than the gaseous helium cryogenics (20K) used for a global system terminal.

The second country to implement its own network seems likely to be Canada which has a similar problem to the Soviet Union in its need for communications between population centres separated by vast expanses of unpopulated country.

The Canadian system is based on a satellite closely similar to the INTELSAT 4 vehicle in its 'spot-beam' mode. The satellite is already being built, and it is hoped to launch it in 1972. It is expected that the necessary ground terminals will be ordered this year.

The crucial advance made by this system is the concept of the 'Television Receive Only' (T.V.R.O) terminal. These ground stations have 9m fixed antennas (with very little or no steering capability), first-stage amplifiers with no cooling, and, as the name implies, no transmit capability. The main purpose of these terminals is to use satellite techniques to permit television distribution to the vast hinterland of Canada. The television programmes will be generated by larger 'main stations', very similar to INTELSAT stations, on the west coast and along the St Lawrence population conurbations. These main stations will also be used for bulk telephony traffic across the country.

In addition to capitalizing on the higher satellite power available, the Canadian system makes use of a second development in satellite technology. Satellites used for communications invariably use the 'geostationary' orbit, at an altitude of approximately 22,000 nautical miles. At this altitude a satellite takes 24 hours to travel round its orbit. This means that since the Earth is simultaneously rotating, the satellite appears stationary relative to the Earth's surface.

Early satellites of this type were liable to excursions of up to 20°, which meant that complex steering systems were needed by ground-based antennas to enable them to track the satellites. Successive improvements in satellite station-keeping have reduced the anticipated magnitudes of the excursions such that the design objective of the Canadian system satellite is to maintain station-

Table 1 *Table of comparative global satellite capability*

Satellite	Equivalent radiated power	Area of earth illuminated	Number of transponders	Transponder bandwidth	Approximate channel capacity
INTELSAT 1	10dBW	8 degrees	2	25MHz	240
INTELSAT 2	16dBW	17 degrees (global coverage)	1	125MHz	240
INTELSAT 3	22dBW	17 degrees	2	230MHz	1200 or 960+TV
INTELSAT 4	22dBW 35dBW	17 degrees (global) 6 degrees (spot)	12	40MHz	6000 or 5000+2 TV

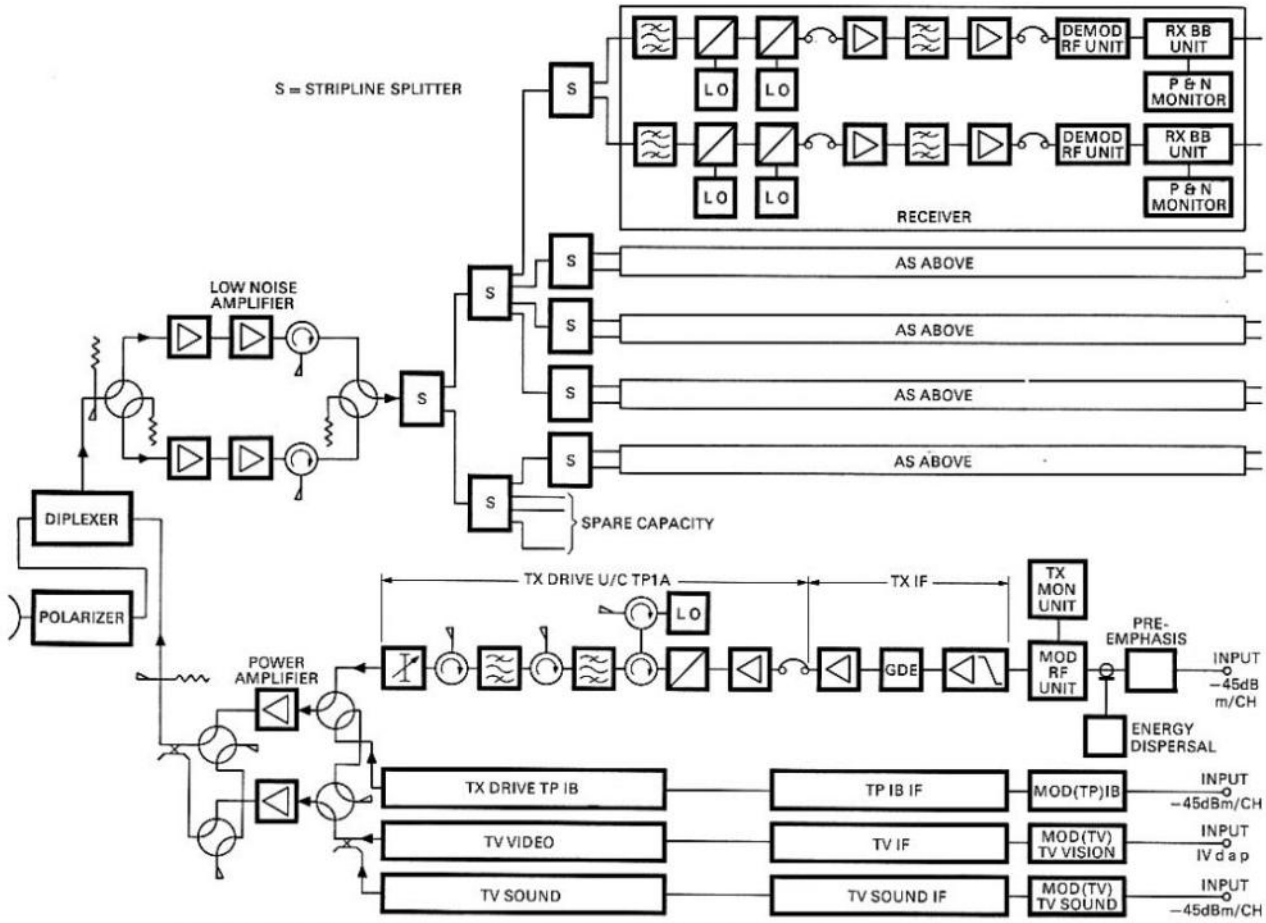

Fig.2 Communications schematic diagram for typical regional ground stations.

keeping to 0·1 °. This in turn means that the steering systems of the ground antennas can be greatly simplified, and should the figure of 0·1 ° be attained, it will be possible to do away with steering equipment altogether and use fixed antennas.

PROSPECTIVE REGIONAL SYSTEMS

Two other localized satellite systems are currently the subject of much study and debate. Firstly, the United States, conscious of earlier developments in a field of space science elsewhere, is energetically pursuing plans for a variety of satellite solutions to its internal communications problems. The main difficulties in starting a US domestic system have proved to be political rather than technical. Firstly, the common carriers operating across America had to be convinced of the usefulness of an internal satellite network in a country already extensively covered by existing high-quality communications links. Secondly, an acceptable compromise had to be reached on the framework of control of any system between the government and any potential operators.

The government, via the Federal Communication Commission, eventually decided that it would consider applications to build and operate domestic satellite systems from any bodies (common carriers, data transmission companies, television companies) who could propose technically and financially viable systems. The status as this article is being written is that the F.C.C is considering applications from a number of organizations, and considering which proposals it is prepared to license.

A variety of possibilities has been put forward, depending on the particular interests, and it is more than possible that several networks will be set up. The common carriers are interested in transcontinental telephony. Other proposals cover bulk broad-band data transmission, while the television companies are interested in a distribution system resembling the Canadian T.V.R.O. network. The timescale of these programmes is obviously vague until F.C.C licences have been issued, but it is unlikely that any system will be in operation before the end of 1973.

The other major system currently under consideration is the use of satellites to provide telephony and television links between the countries of Europe. Proposals for a European Regional Network have been studied for several years now, the original impetus being the possibility of replacing the Eurovision television distribution network by a satellite system carrying television only. However, it was soon realized that the economic viability of such a proposal was very doubtful and, following a commitment by the European Council of Scientific Ministers last July, current work is based on a system that would provide both telephony and television links. It is hoped that a 'pre-operational' satellite could be placed in orbit in the period 1975–78 and that an operational system could be functioning by 1980.

DETAILED PARAMETERS OF THE EUROPEAN SYSTEM

Should it be implemented as currently proposed, the European Regional System is likely to be the most sophisticated satellite communications network in operation this decade. In one major respect, the frequencies used and the advanced techniques anticipated are the result of the existing complex communications network in Europe. Established satellite systems use microwave frequencies, almost invariably employing a ground station to satellite link in the frequency band 5·9 to 6·4GHz, and satellite to ground transmission between 3·7 and 4·2GHz. However, these frequencies are shared with microwave line-of-sight links, and care has to be taken to ensure that no mutual interference occurs. While it is possible to achieve compatibility for the global satellite network, the problem is much more intransigent for a regional system using less directive ground antennas. It has therefore been decided that the European Regional System must use difference frequencies, and it is currently proposed that two bands near 12GHz should be employed. The precise bands have yet to be decided, this should be achieved at the World Administrative Radio Conference to be held in Geneva in July of this year.

The change to a higher frequency brings associated problems. Not only does it mean the development of much new equipment for the satellite and ground stations, but the system parameters are adversely affected. The propagation path between a satellite and a ground station is subject to attenuation from rain, gaseous oxygen and water vapour, etc, these effects being much more serious at 12GHz than at the lower frequencies. This means that a system at the higher frequencies needs more margin than previously used, which in turn requires the use of larger antennas (13–15m) than it was possible to use for other regional satellite networks. In some cases, earth stations operating at low angles of elevation, it may even be necessary to use first stage amplifiers cryogenically cooled to 20K, just as in the INTELSAT Global Network.

The main parameters of ground stations for the European Regional Communications System are given in Table 2, while figure 2 shows a block diagram illustrating the configuration of the stations. The distribution of terminals is expected to cover all the major European countries – and several of the nations bordering the Mediterranean are also expected to join the network. One possible distribution of the terminals is shown in figure 3.

Table 2 *Main parameters of ground terminals for European regional system*

Antenna size	13m	15m
Receive frequency	11GHz	11GHz
Antenna efficiency	55%	55%
Antenna gain	61·6dB	62·8dB
First stage receiver noise temperature	250K	50K
Receiver g/t	37·6dB/K	43·3dB/K
Transmit frequency	13GHz	13GHz
Transmitter power	0·5–3kW	0·5–3kW
Elevation angle (min)	25°	10°

The basic premise of the system studies currently under way is that maximum satellite capacity should be achieved. Conversely, in order to contain the satellite design within the limits of present technology, it is necessary to have sophisticated ground stations. Techniques under consideration are the use of Time Division Multiplexing for access through the satellite, rather than the Frequency Division System in use in the INTELSAT System; the use of speech interpolation techniques to maximize the number of telephony channels in a given bandwidth, and even complete re-use of the frequency bands. This can be achieved by simultaneous transmission on the ground station/satellite link on two orthogonal linear polarizations, the isolation between the carriers on identical frequencies being achieved by the cross-polarization rejection of the antennas used on the spacecraft and on the ground.

In order to keep the costs within acceptable limits in the face of this signal processing sophistication, it is envisaged that cost savings may be made by simplifications in other areas. One particular area being investigated is the ground terminal antenna. If it is possible to ensure that a satellite remains closely within its orbital design limits, it is possible to use an antenna that can only be steered to, for example, a 10°×10° area of sky centred on the design satellite position. This means that great savings can be made in the antenna. Figure 4 shows a photograph of a model of an antenna which uses a simple 'multipod' system of links between the backing structure of the main reflector and the supporting structure. This system permits a limited steerability to be achieved using simple and inexpensive screw jack components.

HIGHER-POWER SATELLITES

Satellites of even higher power than those under consideration for regional systems are now being designed. The main application for these is seen as either 'direct-to-home' broadcast systems, in which each house may have its individual antenna for satellite reception, or for educational television distribution.

The application of 'direct-to-home' systems may be seen as occurring in the developed countries. However, the investment involved in existing ground-based television distribution systems is high, and although satellite systems are beginning to look attractive economically, it is as yet unclear whether 'direct-to-home' satellite systems will prove to be the optimal solution. A technique which is presently showing promise is that of 'semi-direct' distribution. In this solution, a satellite (which need only be of the power capability of existing types) would broadcast to terminals using 3–5m antennas. There would be one of these terminals to a town,

Fig.3 Estimate of ground terminals for the first phase of a Eurovision satellite network.

with distribution from the terminal to individual houses by cable. This is, of course, a satellite adaptation of the CATV technique already prevalent in the United States, and growing in popularity elsewhere.

One area in which a ratio of 'one television set to a ground terminal' is likely to be used in practice is in the field of educational television distribution. In this technique, the satellite rebroadcasts programmes from a central studio/transmitting station either to subsidiary central units for subsequent rebroadcast, or else direct to village schoolrooms. Both India and Brazil intend to carry out pilot experiments with an American applications technology satellite to be launched in 1972. As an example of the possible development of these schemes, India is proposing a pilot scheme of three receive and transmit main stations and one receive only main station. These will in turn transmit at v.h.f to 3000 conventional receivers. At the same time, a direct distribution system with 2000 receivers capable of operating from the satellite emission itself is to be set up.

CONCLUSION

While satellite communications in the international area are a well established technique, future developments will take the use of satellites into other fields. The first of these, already underway, is the use of satellites for regional and national communications. Farther ahead there is the prospect of television distribution systems, which may be used either for normal programme distribution or, with particular relevance to underdeveloped countries, the distribution of educational television.

REFERENCE

1 J. M. Brown: Vision Broadcasting—The Role of Satellites; *Sound and Vision broadcasting*, Vol.9, No.3, Winter 1968.

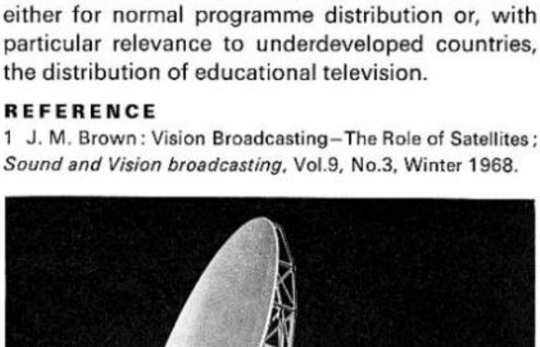

Fig.4 Model of proposed medium size satellite communications antenna for regional system application.