# ECS – the European Communication Satellite system

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**Summary** The evolution of the European Communication Satellite system (ECS) is traced from feasibility studies in 1970 to the development and launch in 1978 of the Orbital Test Satellite (OTS), by the European Space Agency, to prove the new satellite and radio transmission technology being used on ECS. This was followed by the establishment of 'Interim EUTELSAT' in 1979 as the organization to operate ECS.

The satellite, which operates at 11/14GHz, covers all the capitals in Europe via three spot beam antennas, supplemented by a 'Eurobeam' regional coverage antenna which extends the range to cover all of Europe and the Mediterranean basin.

Telephony channels are transmitted digitally using time division multiple access (t.d.m.a) with digital speech interpolation (d.s.i) to optimize satellite capacity. Television transmission is by analogue f.m over the Eurobeam antenna to North African as well as European capitals.

System implications of t.d.m.a operation are discussed and the EUTELSAT policy for Special Services (ESS) or 'Satellite Business Systems' is discussed.

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He joined the Space Communication Division of the Marconi Company in 1966 and has been continually engaged in system engineering aspects of civil and military satellite systems. Currently he is Satellite Communications Manager in the Marketing Department of Space and Microwave Division.

## Introduction

The successful launch of the Orbital Testing Satellite (OTS) in May 1978 was a major step towards establishing a regional European communication satellite system.

The concept of a European regional satellite system – one which would provide telephony and television trunk facilities overlaying existing terrestrial networks – was first studied by the Conference of European Post and Telegraph Administrations (CEPT) and the European Broadcasting Union (EBU) around 1970. This led to the definition of a European Communication Satellite System (ECS) and a supporting satellite research and development programme by the European Space Agency (ESA).

The CEPT exists for discussion on matters of common interest among the post and telecommunications (PTT) administrations, but it has no executive powers to operate a regional satellite system. Likewise, ESA as a research and development organization is unable to fund and operate a regional satellite system. This administrative problem has been overcome by the creation by the CEPT of a new organization called EUTELSAT.

As a corporate entity on behalf of its member nations, EUTELSAT will finance and operate European regional satellite systems, somewhat on the same lines as Intelsat. The member nations are responsible for providing their own terminal earth stations, and EBU will lease transponders for television distribution. The headquarters of EUTELSAT is in Paris.

## OTS test programme

ESA launched an Orbital Testing Satellite (OTS) in 1978 to prove new spacecraft and communications technology to be used for ECS. This includes digital transmission with dual polar operation in the 11/14GHz frequency bands, about which very little information was then available. Digital transmission was chosen to optimize satellite channel capacity and to harmonize with digital terrestrial trunks planned in Europe for the 80s.

Operation at 11/14GHz overcomes frequency congestion and system coordination problems which precluded establishing a European regional satellite system in the 4/6GHz bands. Dual polarization enables re-use of frequencies in the same coverage area with separation of signals by orthogonal linear polarization, effectively doubling satellite capacity.

The tests were to confirm the characteristics of digital system performance, to assess climatic effects on propagation at 11/14GHz, to investigate co-channel interference mechanisms, and to confirm the viability of television and associated sound/commentary channel transmission. These tests were conducted from 17m to 19m antenna stations at Goonhilly in the United Kingdom, Bercenay-en-Othe in France, Usingen in Germany and Fucino in Italy.

A separate narrow-band transponder on OTS has been used for long term propagation measurements from some 40 small antennas operated by administrations and universities throughout Europe, and for data transmission experiments to demonstrate the potential value of satellite links from low-cost stations with roof-mounted antennas for business and intercomputer data transmission. One such experiment known as STELLA (Satellite Links Linking Laboratories) using Marconi Communication Systems' small data terminal Type P7001 has been operating between the Rutherford Laboratory, Oxford, and the European High Energy Research Institution at the European Organization for Nuclear Research (CERN) near Geneva since 1979.[1]

## ECS: scope of system

The ECS system has been configured to handle intra-European telephony and the distribution of Eurovision programmes during the 1980s between major stations in each country. It covers the area bounded by Iceland, Scandinavia, Finland, West Germany, Turkey, Portugal and the Atlantic islands.

The satellite system will supplement and provide alternative routeings for the terrestrial cable and microwave network at present interconnecting the traffic centres within this area. By 1986 approximately one third of all intra-European circuits exceeding 800km in length will be routed by satellite.

The system is planned for digital transmission of telephony circuits to harmonize with the terrestrial digital networks planned within Europe in the 1980s. This is based on 120Mbit/s time division multiple access (t.d.m.a) operation over 80MHz bandwidth transponders, in conjunction with digital speech interpolation (d.s.i) which effectively doubles the capacity from 1600 to 3200 channels per transponder.

EBU will distribute Eurovision programmes over a coverage area which is extended to include EBU members in the Mediterranean basin and North Africa. This will utilize two transponders on opposite polarizations using f.m transmission for the video carrier, with a high-quality sound channel in digital form in the line synchronizing pulses. The luminance signal-to-noise ratio should be at least 55dB for 99% of the time.

## Satellite configuration

The ECS satellite is to be launched by the European ARIANE launcher in mid 1982, but the satellite has also been made compatible with other launch vehicles including the Space Shuttle, which gives greater flexibility for future applications of the design. The three-axis stabilized satellite has twelve 80MHz wide transponders, each capable of accommodating a 120Mbit/s t.d.m.a system or two television carriers. The satellite solar array panels have been configured to generate sufficient power for nine of the transponders, with the remaining three switchable to provide redundancy for the life of the satellite.

The ECS frequency plan is as shown in figure 1, using the full 500MHz allocated to up links between 14GHz and 14·5GHz, and two 250MHz bands for the down link from 10·95GHz to 11·20GHz and from 11·45GHz to 11·7GHz. There will also be an 'add-on' specialized-services payload comprising two 12/14GHz transponders (or repeater chains) with the down path centred on 12·54GHz on the second and subsequent satellite launches, for business systems.

A similar frequency plan, apart from the specialized services transponder and with single polarization, has been adopted by Intelsat in the Intelsat V series of satellites.

It should be noted that the next generation of satellites in the latter half of the 80s will exploit the wider 1GHz frequency band from 10·7GHz to 11·7GHz following the agreement at the World Administrative Radio Conference (WARC-79) in Geneva in 1979 to revise the Radio Regulations of the International Telecommunications Union.

The satellite has a combination of regional coverage, or Eurobeam, and spot beam antennas. The Eurobeam antennas will be used for reception of all up-path carriers at the satellite, and for down-path transmission of television and special service carriers. In order to provide sufficient flux density at the ground for the high-capacity t.d.m.a carriers, it is necessary to confine down-path transmissions to 3·7° beamwidth spot beams. EUTELSAT requirements are met with three spot beams, known as Spot East, Spot West and Spot Atlantic, with small overlapping areas between them as shown in figure 2.

The satellite has switching arrangements between its transponders and the spot beam antennas to provide a measure of flexibility and redundancy facilities.

Operating a transmission time-sharing t.d.m.a system via three spot beams introduces a signal distribution problem. This is overcome by 'fre-

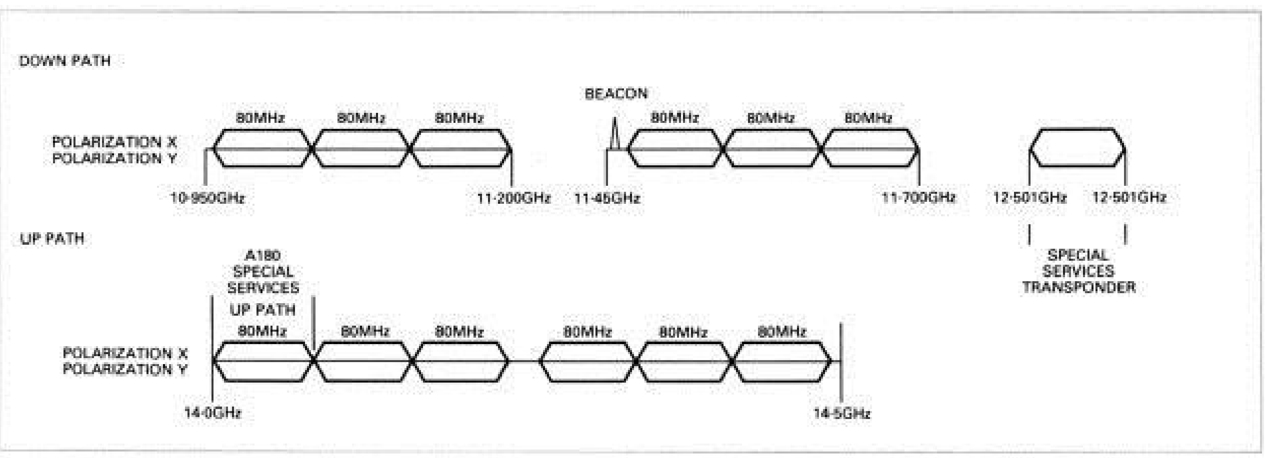



*Fig. 1. ECS frequency plan*

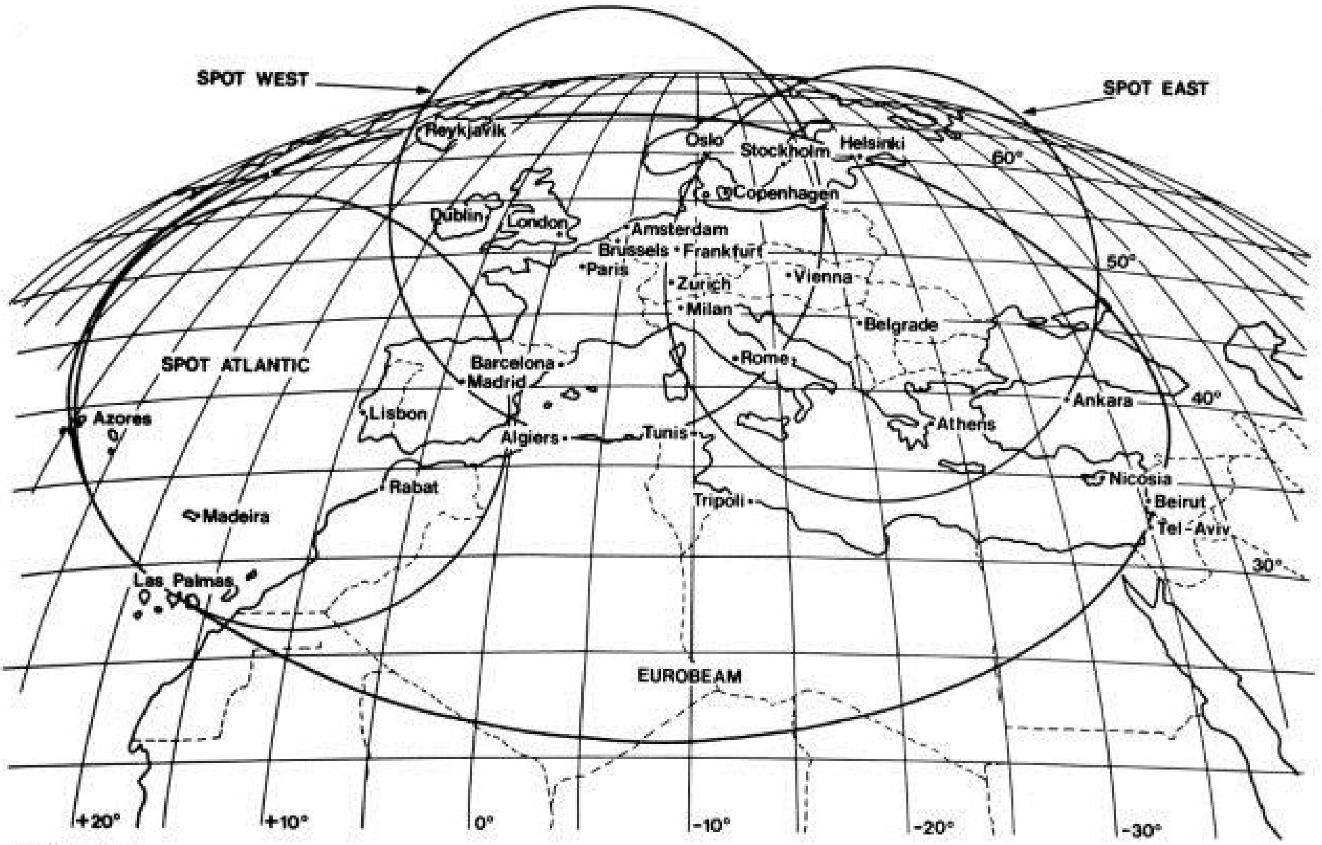



*Fig. 2. ECS coverage area*

quency hopping', whereby successive bursts from a station are transmitted on different frequencies (say f1, f2 and f3) within the t.d.m.a frame time of 2ms (figure 3). These carriers f1, f2 and f3 are translated in the satellite for retransmission via transponders associated with spot beam antennas covering the required destinations. More than one transponder on each polarization may be connected to a single spot beam according to the traffic pattern. The pattern of operating t.d.m.a over spot beams is the basis of the next generation of satellite systems now being planned. It is of interest to note that high-speed switching technology is now approaching the high degree of reliability that permits its use for switching traffic streams within the t.d.m.a time frame on board the satellite as an alternative to frequency hopping. Satellite-switched t.d.m.a (s.s/t.d.m.a) is planned for the next generation European and Intelsat satellites in 1987/90 period.

## ECS earth station arrangement

The satellite system has been optimized for t.d.m.a transmission between large stations with antennas from 17·5m to 19m diameter, uncooled parametric amplifiers, and a maximum transmitter power of 2kW which is the limit of power available with air-cooled tubes at 14GHz.

### Receive chain

The antenna size and state of technology establishes a nominal earth station gain-to-noise temperature (G/T) of

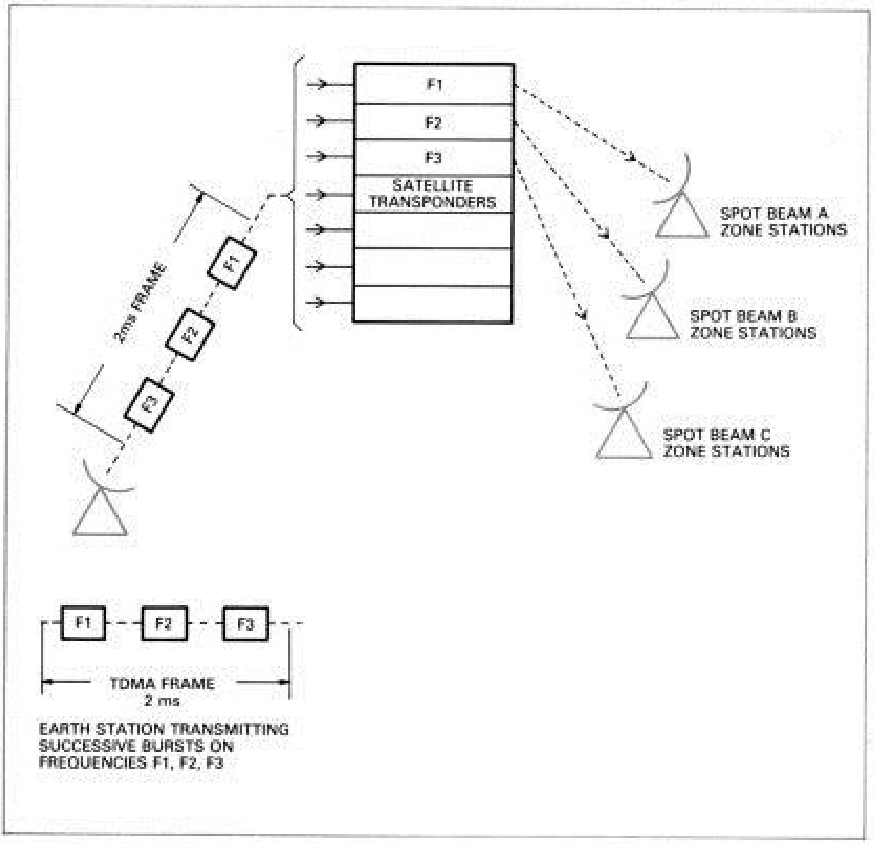



*Fig. 3. Frequency hopping*

39dB/K and a maximum estimated isotropic radiated power (e.i.r.p) capability of about 89dBW.

Receiving system G/T is related to the carrier-to-noise (c/n) needed to meet the CCIR digital transmission performance of a bit error rate of 1 part in $10^6$ for 90% of the time. However, since the effects of weather on propagation at 11GHz is greater than at 4GHz, a new procedure taking into account the probable increase in attenuation at each station according to local climatic conditions is involved.

The G/T for ECS and Intelsat stations is therefore specified in terms of a basic value required for system operation under clear sky conditions, with an adjustment for the predicted 'excess attenuation' (i.e the amount by which the clear sky value is exceeded) plus the related increase in earth station system noise at the operational elevation angle for the appropriate percentage of time. The basic value of G/T for ECS is specified as 39dB/K for 90% of the time.

For a typical site in the United Kingdom the 'excess attenuation' for 10% of the time would be 0·6dB, and the related increase in earth station noise by 38°K from 250°K to 288°K constitutes a further 0·6dB. The required G/T for which the station has to be engineered in this case would be 39dB/K–(0·6+0·6)dB, i.e 40·2dB/K.

A typical 19m antenna is shown in figure 4. This was installed for British Telecom at Goonhilly in 1979 for OTS trials and is currently being converted into an operational Intelsat Type C station.

For ECS working, a similar antenna to be erected will be fitted with 750MHz bandwidth 150°K uncooled parametric amplifiers configured in a '1 for 2' redundancy arrangement as shown in the block schematic, figure 6. These parametric amplifiers have an instantaneous bandwidth of 750MHz to cover the receiver band from 10·950GHz to 11·700GHz. A separate receiver is connected to each polarization and the arrangement of down-converters varies according to the traffic pattern of the station. The typical schematic shows two main-path receive chains, 'one for one' redundant, on each polarization, plus non-duplicated receivers on each polarization for television reception.

T.D.M.A carriers occupy an 80MHz transponder. The down-converters have a first i.f stage at

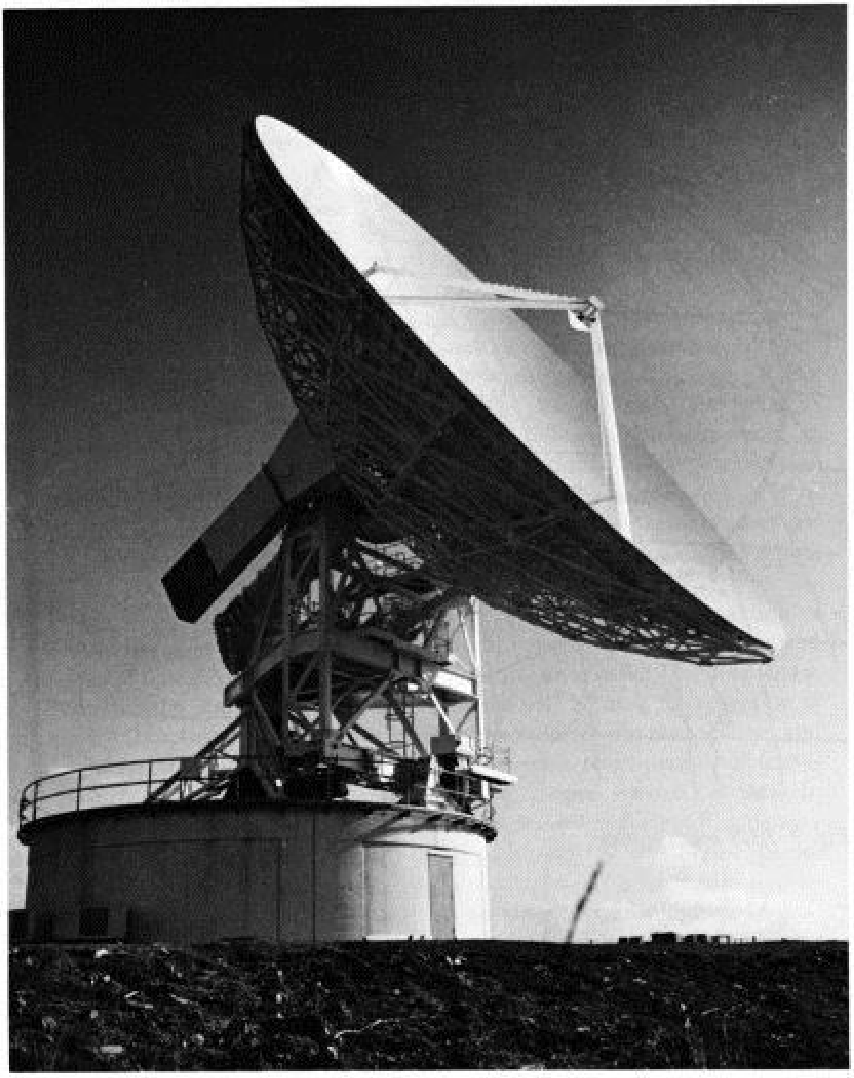


*Fig. 4. 19m antenna at Goonhilly*

1·2GHz with a bandwidth of 80MHz and output interface at 140MHz to a cross-site cable and the 120Mbit/s phase shift key (p.s.k) demodulators.

The 140MHz i.f signal is passed to the p.s.k demodulator via an i.f frequency-hopping switch. In a simple two-carrier case this would switch between polarization (or receive frequencies) under control of the t.d.m.a common equipment according to the t.d.m.a hopping plan. The hopping-switch matrix also controls redundancy switching at two levels, firstly as between redundant ground control equipment (g.c.e) paths and secondly as between redundant p.s.k. demodulators. The frequency-hopping switches are very quick acting to permit switching between bursts, with a minimum interburst separation time of 16 symbols at a transmission rate of 60·416Mbaud (i.e 260ns). The two-receive-carrier situation is depicted as a 'typical' case. In practice the receive configuration depends upon the location of the station and the traffic distribution pattern (for instance the British Telecom ECS station at Madley is planned for three receive carriers).

### Transmit path

The transmit sub-system is configured around 600–750W 14GHz travelling-wave tube (t.w.t) amplifiers for t.d.m.a carriers and 2kW 14GHz klystron amplifiers for television video carriers.

In the typical station depicted schematically in figure 6, provision is made for three t.d.m.a carriers (each with duplicated g.c.e operating on three carrier frequencies). Outputs of the up-converters are fed to working and standby t.w.t amplifiers on each polarization. The t.w.t amplifiers cover an instantaneous bandwidth of 500MHz (14·0GHz to 14·5GHz) and are thus capable of amplifying carriers on any transponder frequency. The amplifiers are shown in a '1 for 2' redundancy arrangement. As in the case of the receive chain, there is a 140MHz equalized path cross-site cable between the p.s.k modulators and up-converters routed via i.f frequency-hopping control switches. The hopping switches control routeing of the 140MHz output from 120 Mbit/s p.s.k modulators to up-converters tuned to the appropriate channel frequency and connected to the correct polarization as required by the t.d.ma traffic burst pattern; these switches also control selection between working and redundant p.s.k modulators and the chains of up-converters.

Television carriers have a 70MHz cross-site cable and are amplified by non-redundant 2kW air-cooled klystron amplifiers, one for each polarization. The klystron outputs are connected by 7·5dB couplers into the transmit waveguide runs to combine the television and t.d.m.a carriers into the antenna feedhorn.

The typical station arrangement has been shown with only three t.d.m.a telephony carriers for simplicity but in the case of the British Telecoms UK station provisioning is planned for four-carrier operation at the outset, with capability of expansion to eight carriers. The equipment layout of the Goonhilly OTS station in figure 5 is representative of a small station installation.

## T.D.M.A baseband interfaces

In a station equipped with Marconi 120Mbit/s 4 p.s.k modems, the baseband interface to the t.d.m.a common equipment is over two 60·416Mbaud paths, and the p.s.k modem interface to the earth station r.f equipment is at 140MHz.

The schematic diagram shows an interface between the redundant t.d.m.a common equipment and the digital speech interpolation/terrestrial interface modules (d.s.i/t.i.m). The details of this interface vary between suppliers according to the extent of features concentrated in the common equipment or built into the d.s.i/t.i.m.

In essence each d.s.i/t.i.m accepts up to ten 30-channel A–law-encoded pulse code modulation (p.c.m) groups at 2·048Mbit/s each. It should be noted that the maximum channel utilization capability of d.s.i is 240 circuits (eight primary multiplex inputs), but designs will normally permit termination of up to ten primary multiplex inputs (300 channels) to cater for a proportion of non-allocated channels within some of the connected groups.

The d.s.i increases the capacity of the t.d.m.a transmission system by interleaving of 'speech spurts' from different terrestrial channels on the same satellite channel. That is, terrestrial channels are connected through the satellite only whilst active speech is detected on them, and are disconnected from the satellite path during periods with no active speech. The d.s.i gain can be as high as 2:1 so that 240 terrestrial circuits would occupy the equivalent of 120 satellite circuits. The system gets quite complex as there has to be a 'mapping pattern' of control signals between all connected terminals, and the design has to minimize 'clipping' due to switching on and off when speech is detected. Similarly the integrity of overall end-to-end signalling channels has to be preserved on channels whilst subjected to interpolation. For the EUTELSAT system it has been agreed that CCITT Type R2 signalling will be used on all circuits and special signalling memory provisions are incorporated (R2 signalling employs a forward/backward calling or supervisory signal transmitted over Slot 16 on a 30-channel p.c.m system group, with high-speed multifrequency in-band 'called number' or decadic dialling information).

Provision has to be made for transmission of data over 'non-interpolated' channels which are not subject to interruption according to the presence of speech. For these channels the digital non-interpolated (d.n.i)/t.i.m is used.

The d.s.i system operates with a 2ms frame synchronized to the t.d.m.a frame, and one t.d.m.a terminal may comprise one or more d.s.i terminals, connected with appropriate redundancy (the most secure arrangement is of course '1 for 1' redundancy of d.s.i). One d.s.i sub-burst per t.d.m.a frame is generated by each d.s.i module. Individual modules may be arranged either for multi-destination or single-destination operation. Terrestrial channels are preassigned to their destinations.

## Business systems

In December 1980 the Interim EUTELSAT Council made a compromise policy decision on establishing satellite business services in Europe by means of:

a) Provision of an add-on specialized-services payload on ECS satellites comprising two 12/14GHz repeater chains (or transponders) covering Europe, including the capitals of Turkey, Finland and Portugal. These transponders will be used to provide data services by frequency division multiple access (f.dm.a). The system is becoming known as the European Specialized Services System (ESS);

b) Agreement with French PTT to use part of the French National Telecom 1 satellite for t.d.m.a services in Europe.

Details of the operational arrangements of services to be offered had not been resolved by EUTELSAT as of mid-1981, and the way ahead was still not clear. The following comments on the two approaches summarize the

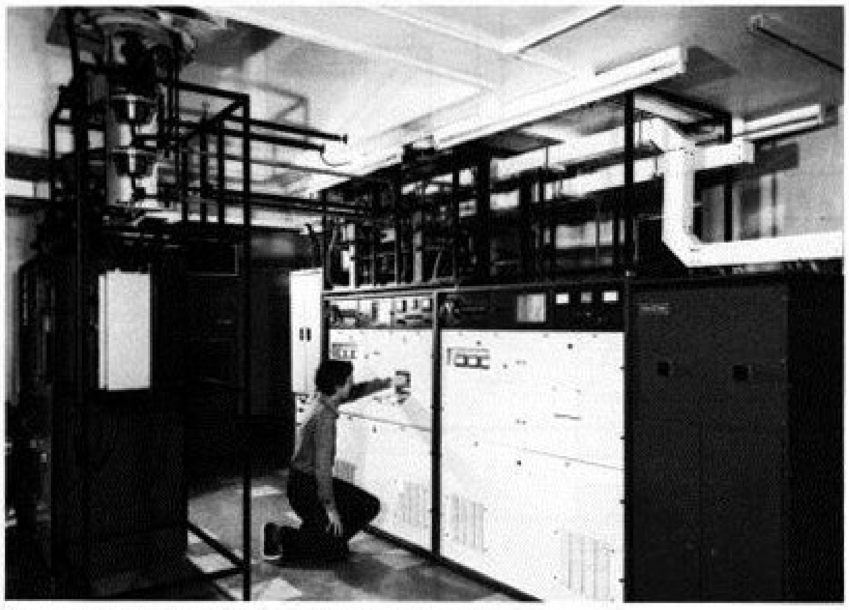


*Fig. 5. OTS Station Layout showing transmitters*

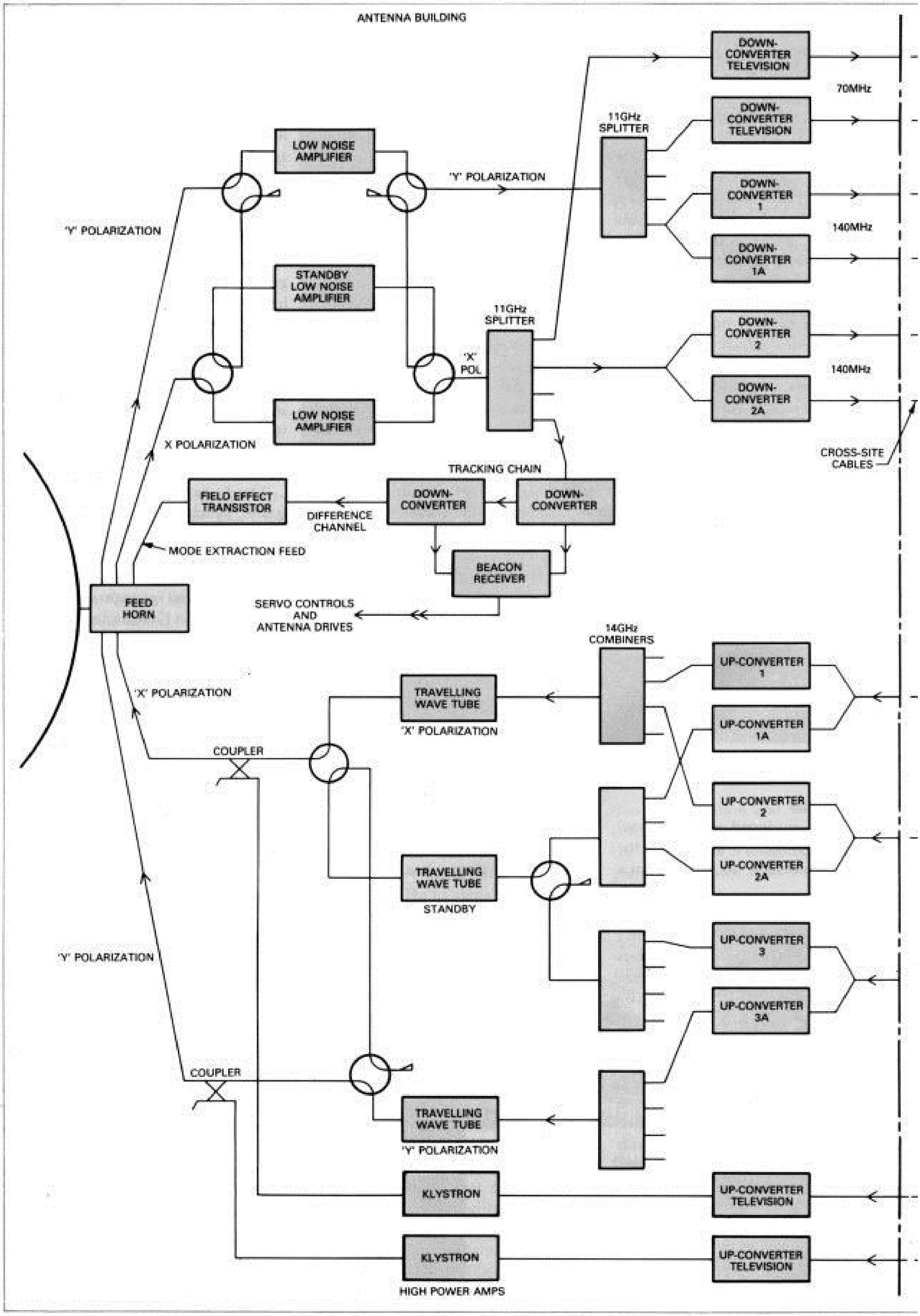
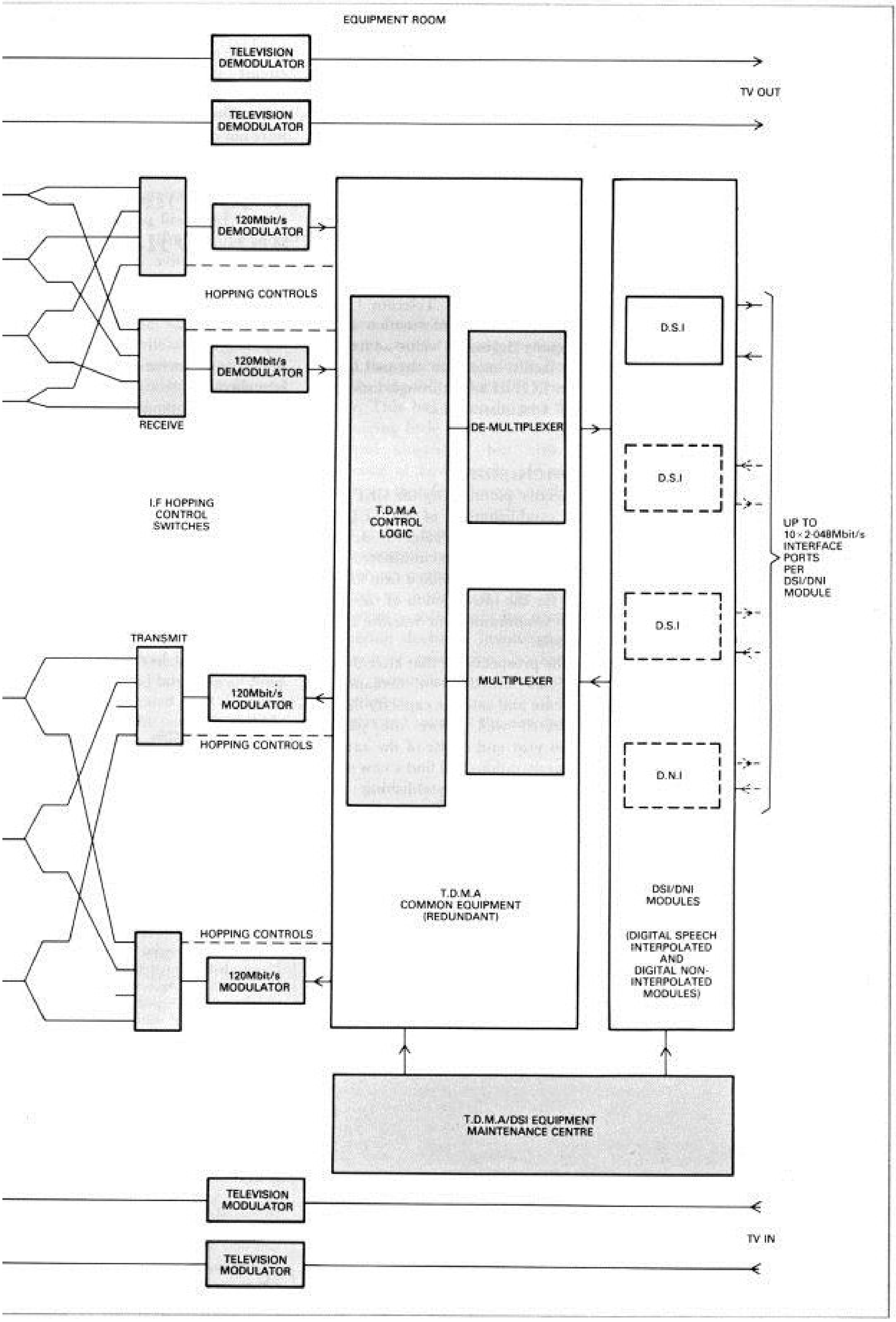



*Fig. 6. Schematic diagram of an ECS station*


EQUIPMENT ROOM
TELEVISION DEMODULATOR
TELEVISION DEMODULATOR
TV OUT
120Mbit/s DEMODULATOR
HOPPING CONTROLS
120Mbit/s DEMODULATOR
RECEIVE
I.F HOPPING CONTROL SWITCHES
T.D.M.A CONTROL LOGIC
DE-MULTIPLEXER
MULTIPLEXER
D.S.I
D.S.I
D.S.I
D.N.I
UP TO 10 × 2·048Mbit/s INTERFACE PORTS PER DSI/DNI MODULE
TRANSMIT
120Mbit/s MODULATOR
HOPPING CONTROLS
T.D.M.A COMMON EQUIPMENT (REDUNDANT)
DSI/DNI MODULES
(DIGITAL SPEECH INTERPOLATED AND DIGITAL NON-INTERPOLATED MODULES)
HOPPING CONTROLS
120Mbit/s MODULATOR
T.D.M.A/DSI EQUIPMENT MAINTENANCE CENTRE
TELEVISION MODULATOR
TELEVISION MODULATOR
TV IN

position as seen by the author, and represent a personal opinion only.

The ECS specialized services transponder will give full European coverage, including the capitals of Sweden, Finland and Turkey within the 3dB satellite contour. Both satellites have 20W t.w.t amplifiers, but Telecom 1 with a high-density spot beam will give up to 7dB higher flux density at the beam centre as compared with the ECS regional-coverage antenna. This also means that 12dB contour conditions, where the beam edge falls away rapidly, will be encountered with Telecom 1 in areas like Sweden, Southern Italy and Northern Spain. Larger steerable earth station 6·8m antennas will be required in fringe areas. In the main ECS coverage area antennas up to 4·5m may be required and the more convenient 3m antennas, as used in the pioneering Marconi SPINE, STELLA and UNIVERSE stations using the OTS satellite, will be feasible only for beam centre stations in the Telecom 1 system.

Telecom 1 has a 25Mbit/s t.d.m.a system with automatic demand assignment. It uses complex signalling protocols and is operated under the control of a master station. A modified semi-automatic demand assignment access arrangement will have to be evolved to enable stations equipped to recognized European data interface standards (such as V35 and X21) to be connected to the Telecom 1 System.

Initially the ESS system will operate through the reserve ECS satellite. The policy of f.d.m.a operation opens up the possibility of introducing a low-cost 64kbit/s single channel per carrier (s.c.p.c) service similar to some recent US domestic systems and also the possibility of operating several small capacity (2Mbit/s) t.d.m.a systems in the same transponder for specialized applications.

It is difficult to see how any commercial business satellite systems can be established in Europe in the short term using ECS or Telecom 1 satellites, unless some information service company devises a 'value-added' service facility based on channel leasing from EUTELSAT through individual PTT administrations.

## Conclusion

Collective planning by the CEPT and the establishment of EUTELSAT, supported by the satellite developments by ESA which culminated in the launch of OTS provide a firm foundation for the introduction of the European Communication Satellite system in 1983.

The prospects are that after the system has settled down, demand will increase and satellite capacity become saturated well before the planned seven year end of life of the satellite. Administrations will find a new degree of flexibility in establishing intra-European circuits which can avoid the long lead time now required to coordinate and implement long-distance circuit provision affecting several administrations.

Satellite business systems which were not even considered by the CEPT in the early stages of planning for ECS have become a reality. The introduction of business systems at the inception of ECS will provide administrations with a timely capability of meeting an explosive demand for high-speed data and information transfer services that is now foreseen in the mid-80s, and additional satellite capacity may well be required before the second generation ECS satellite is launched.

Marconi Communication Systems Limited is well placed for the provision of ECS stations by virtue of developments undertaken for the OTS station at Goonhilly covering the 19m antenna, 14GHz 2kW amplifiers, 11/14GHz up- and down- converters and 120Mbit/s p.s.k modems (figure 6).

The author acknowledges permission to publish this article, and stresses that opinions expressed are personal and do not necessarily represent company or national policies.

## References

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**RÉSUMÉ**

On retrace l'évolution du Système Européan de Communications par Satellite (ECS) à partir des études de faisabilité de 1970 jusqu'au développement et au lancement du Satellite d'essais orbitaux (OTS) effectués par l'Agence spatiale européenne (ESA) en 1978 pour mettre à l'épreuve le nouveau satellite et la technologie de transmission radio utilisée sur l'ECS. Cette opération fut suivie en 1979 par la mise sur pied d''Interim EUTELSAT', organisme chargé de l'exploitation du système ECS.

Le satellite, qui est exploité à 11/14GHz, est en mesure de couvrir toutes les capitales en Europe par l'intermédiaire de trois antennes à faisceau ponctuel complétées par une antenne à couverture régionale 'Eurobeam' qui étend cette portée pour couvrir toute l'Europe ainsi que le Bassin méditerranéen.

Les voies téléphoniques sont transmises numériquement grâce à la technique d'accès multiple par répartition dans le temps (AMRT) avec concentration numérique de la parole (CNP) dans le but d'optimiser la capacité du satellite. La transmission de télévision se fait par voie FM analogique via l'antenne Eurobeam en direction des capitales nord-africaines et européennes.

**RESUMEN**

La evolución del Sistema de Satélites de Comunicaciones Europeo (ECS) se descubre desde la época de los estudios de viabilidad en 1970 al desarrollo y lanzamiento de los Satélites Orbitales de Pruebas verificados por la Agencia Espacial Europea en 1978, para demostrar la nueva tecnología de satélites y radiotransmisión empleada actualmente en el ECS. A esto le siguió el establecimiento del 'Interim EUTELSAT' en 1979 como la organización para operar el ECS.

El satélite, que opera a 11/14GHz, abarca todas las capitales europeas en virtud de tres antenas de haz de punto luminoso aumentadas mediante una antena de cobertura regional 'Eurobeam' que extiende el alcance para cubrir toda Europa y la cuenca del Mediterráneo.

Los canales de telefonía se transmiten digitalmente haciendo uso de acceso múltiple de división de tiempo (t.d.m.a) con interpolación digital de voz (d.s.i) para optimizar la capacidad del satélite. La transmisión de televisión se hace por FM de tipo analógico sobre la antena Eurobeam a las capitales del Africa septentrional, lo mismo que a las capitales europeas.

Se discuten las implicaciones sistemáticas del funcionamiento del t.d.m.a y se explica la política de EUTELSAT para Servicios

**ZUSAMMENFASSUNG**

Die Entwicklung des europäischen Fernmeldesatelliten-Systems (ECS) basiert auf den 1970 ausgeführten Durchführbarkeitsuntersuchungen und geht über die Entwicklung und den Abschuss im Jahre 1978 des Planetenbahn-Testsatelliten (OTS) durch die European Space Agency (Europäischer Raumfahrtdienst) zur Erprobung der für ECS verwendeten neuen Satellit- und Radioübertragungstechnik. Darauf folgte im Jahre 1979 die Gründung von 'Interim EUTELSAT' als Betriebsorganisation für ECS.

Der Satellit deckt alle europäischen Hauptstädte mit seiner Arbeitsfrequenz von 11–14GHz über drei Punktstrahl-Antennen sowie einer regionalen 'Eurobeam'-Bereichsantenne, durch die ganz Europa sowie der Mittelmehrbereich gedeckt wird.

Telefonkanäle werden digital mittels Mehrfachzugriff durch Zeitteilung (time division multiple access – t.d.m.a) mit digitaler Sprachinterpolierung (d.s.i) übertragen, um die Satellitenleistung zu optimieren. TV wird durch Analog-FM über die 'Eurobeam'-Antenne zu nordafrikanischen sowie europäischen Hauptstädten übertragen.

Die sich aus t.d.m.a-Betrieb für das System