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Civil maritime satellite communication systems

The need for MARSAT is already established, and is likely to be satisfied by a global satellite network provided solely for this purpose by 1980. This network could be based on derivatives of either the MARISAT or MAROTS satellites. MARISAT has the advantage of being launched three years before MAROTS, which is itself attractive by being designed by ESRO to meet the requirements agreed by IMCO, including simpler ship terminals.

The MARSAT Management agency should be set up after the 1975 Government Conference on the service. A European shore station must be provided soon to support MAROTS and encourage user interest which should grow rapidly once these first satellites are in use.

Introduction

In common with many other old-established businesses, the commercial shipping industry is discovering that the increased pace of world trade requires the application of modern business practices. The provision of fast error-free communications is essential to any company operating a competitive business in the international field.

Responsible authorities in the P and T Departments of major maritime nations are now able to predict that saturation of the h.f service is likely to occur in the late seventies. This is a service where telegraphy traffic delays can be as much as 36 hours, with 12 hours delay common and 6 hours average; also the quality of radio telephony communication is unsatisfactory in 60 per cent of the calls.[1]

Clearly these standards of communication are not good enough for future ship-to-shore communication as the basic requirements of shipowners will be for an improved speed of communication on a world-wide basis and improved quality of communication allowing reliable direct printing telegraphy, radio telephony and facsimile.

The established and widespread use of the h.f band for long range communications is, however, something that need not be changed overnight, though the adoption of the new system would certainly make possible some impressive improvements. Even so, equipment development towards overcoming the deficiency of the h.f service has been continuing with some success. A recent example is the error-correcting facility[2] (SPECTOR) which permits telex messages to be passed between ships at sea and international telegraph networks. However, it is not disputed that the congestion of the h.f band is increasing and a longer term need for further improvement therefore exists.

Early proposals

It has been recognized since the late sixties, when the success of the INTELSAT system was demonstrating the viability of long-range telecommunications using synchronous satellites that this technique could be readily used by ships and aircraft. At about the same time air traffic control authorities identified a need for more precise navigation, particularly over the North Atlantic, with complementary voice and data communications.

Early work tended to assume that the aeronautical/maritime satellite system would meet the similar requirements of both, and so make the best possible use of an expensive satellite. A number of studies were made by Industry for the US Government and the French started work on a national programme known as DIOSCURES. In the UK more limited effort was applied mainly to particular aspects of a dedicated AEROSAT, although some early workers got their feet wet participating in trials[3] of a v.h.f link between a ship and ATS-3 satellite.

At this time, use of the v.h.f band for the aircraft to satellite link was supported by the airlines but due partly to the expense of the aircraft equipment they were somewhat lukewarm about adopting AEROSAT. Use of higher frequencies would only exaggerate this cost problem though workers on ship equipments had a preference for u.h.f around 400MHz or possibly L-band.

The position around 1971–2 was covered in a Point-to-Point article[4] which illustrated that the thinking on AEROSAT at that time was much further advanced than on the maritime equivalent. In fact, firm recommendations had been made at a meeting in Madrid of the European and US interests for a pre-operational AEROSAT.

Since then the progress on AEROSAT has been checked by the difficulty of obtaining the necessary agreements within the US administration, and between the US and Europe. However in 1973 a new proposal for a dual-frequency (u.h.f and v.h.f) AEROSAT was agreed. This proposal has advanced further than any previous one and at present looks like becoming a reality.

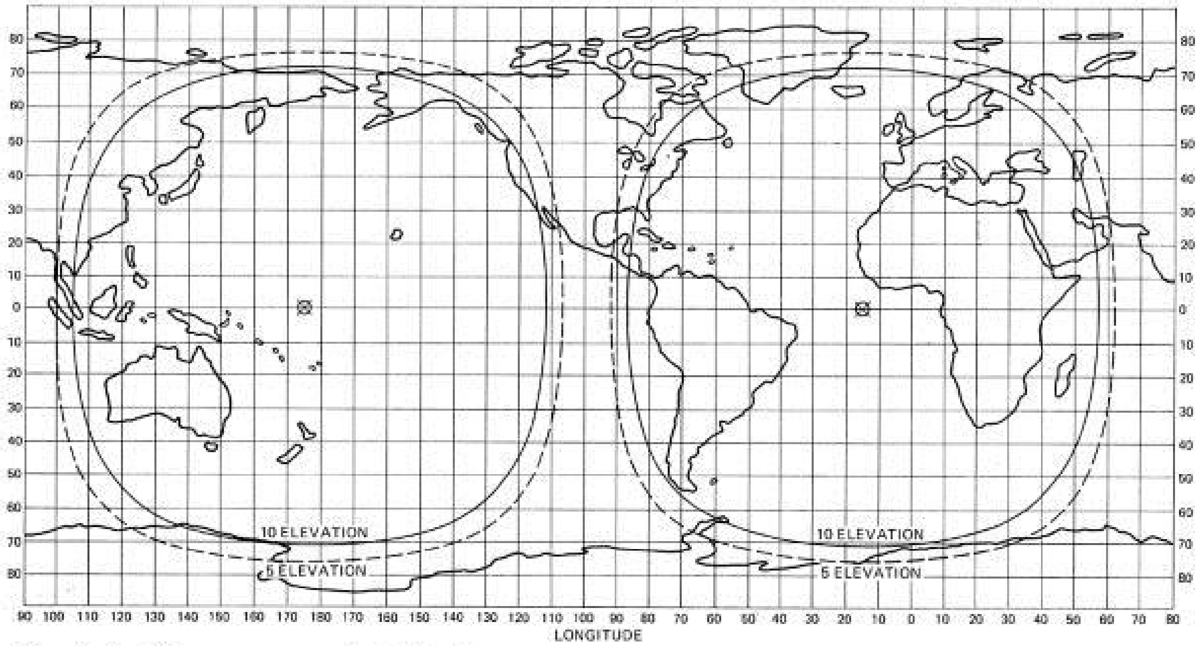

Figure 1. Satellite coverage areas for MARISAT (15°W–175°E) and MAROTS (12·5°W)

Established programmes

A major step forward was the WARC-ST Conference (Geneva 1971) at which international agreement was reached on the allocation of commercially suitable frequency bands exclusively for maritime use in the L-band. Since this conference, activity has greatly increased on the maritime satellite communications system now commonly referred to as MARSAT.

Since early 1972 ESRO has sponsored a coordinated series of studies in Europe into the many aspects of MARSAT, and Marconi have participated in this programme to a significant extent on ship terminal and overall system aspects. The ESRO studies have led on to the MAROTS programme which will culminate in 1977 with the launch of the first all-civil maritime satellite, using a new 3-axis stabilized spacecraft. The MAROTS system is based on the recommendations of IMCO which, as part of the United Nations, is the primary regulatory body for the shipping community and is analogous to ICAO for aviation.

Operating independently, COMSAT announced early in 1973 the similarly named MARISAT programme, sometimes known as GAPSATCOM. This is aimed at providing the US Navy with its own system based on synchronous satellites and covering the period 1974–79, the spacecraft being of the proven type as used for INTELSAT IV. On behalf of INTELSAT, COMSAT are also studying the feasibility of incorporating a MARSAT transponder in the INTELSAT V satellite, building on the experience which will have been gained with MARISAT.

Contribution by IMCO

Through its 'Panel of Experts on Maritime Satellites', IMCO are becoming increasingly involved in the system implementation and operational planning of MARSAT. Thus, when IMCO reached agreement during 1973 on the basic technical characteristics of a first-phase global MARSAT, this represented the nearest approach thus far to a joint democratic decision by all leading maritime powers.

The major points[5] agreed by IMCO were that the prime requirement is for a public correspondence service and that global coverage should be achieved as soon as possible. The system should be based on satellites having a 7-year design life and be launched by a Thor-Delta booster. A broadband transponder using a global coverage antenna was recommended and, based on traffic statistics, IMCO said that the satellite must have a minimum capacity equivalent to 20 telephone channels. Adequate voice quality is to be ensured by providing a link carrier-to-noise density of 53dBHz for at least 99 per cent of the time. It was judged that the ship terminal figure of merit (G/T) should be around −10dB/K thus leading to an antenna gain of 17dB and a transmitter power of about 20 watts. Looking ahead, the access control system was to be capable of development into a fully automatic facility including through-dialling. This preliminary work by IMCO is continuing and its recommendations will be reviewed at The Meeting of Governments early in 1975.

Contrasts between MAROTS and MARISAT

Although MAROTS is intended to follow the recommendations of IMCO as far as possible, only one satellite is initially funded providing coverage of the Atlantic Ocean and the Western part of the Indian Ocean including the Persian Gulf, as illustrated in figure 1. In this diagram the coverage of the Atlantic region is approximately the same for MARISAT and MAROTS since they are separated longitudinally by only 2½ degrees.

As regards coverage, the MARISAT programme with satellites over both the Atlantic and Pacific Oceans has a clear advantage over MAROTS. Examination of figure 1 shows that effectively 80 per cent or 90 per cent coverage of the world's oceans is provided. Although initially deployed to meet the needs of the US Navy, MARISAT will be superseded for military use in 1976/82 with the launch of the more advanced satellite FLEETSATCOM. This will release MARISAT to provide 8 channels for use by civil merchant shipping, see figure 2.

For the start of full capacity operations both MAROTS and MARISAT are planned to be available around late 1977 and a comparison of the most basic characteristics of the two satellites is made in the following table.

	MARISAT	MAROTS
First Satellite Launch	Early 1975	1977
Satellite coverage	80/90%	approx 45%
Satellite type	Spin-Stab	3 Axis Stab
Capacity per Satellite (Equivalent voice chns)	2-CH Start 8-CH End	14-CH
Ship G/T	-4dB/K	-10dB/K
Ship Antenna Gain	23dB	18dB
EIRP (minimum)	36dBW	31dBW

Apart from coverage, the most important point is timescale and the practicability of each programme meeting its stated targets. In each case, success of supporting programmes is critical; if FLEETSATCOM is late, full use of MARISAT by the maritime community will be put back. On the other hand, MAROTS depends on successful development of the ECSS/OTS platform which has many elements common to both the OTS and MAROTS programmes.

MARISAT has been conceived as a revenue-producing commercial venture, whereas MAROTS has only experimental or pre-operational status as a condition for the availability of the US launcher, but when the MARSAT management agency is formed it may choose an operational system based on a MAROTS satellite since its design closely matches the IMCO requirements.

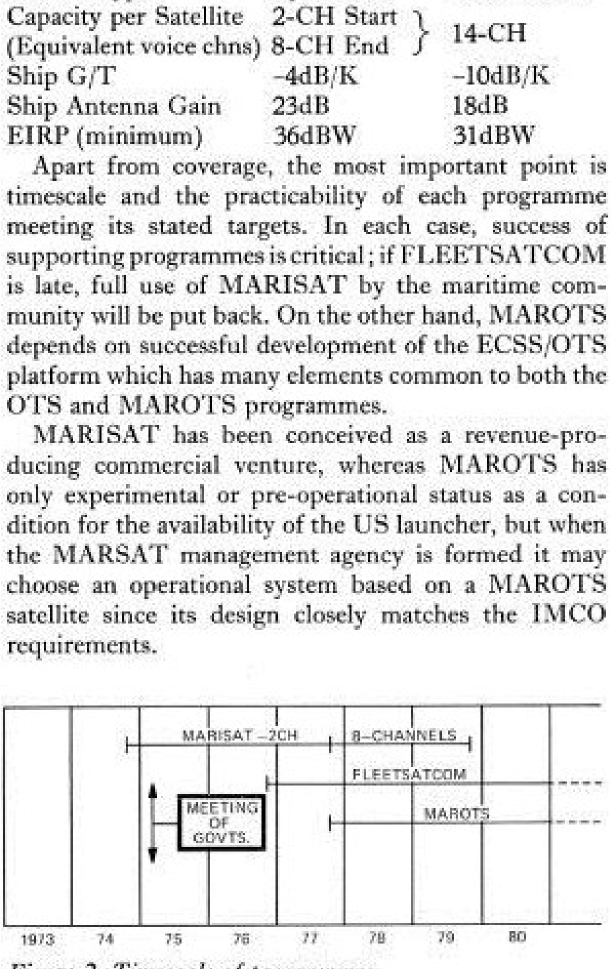

Figure 2. Timescale of programmes

Effect of system design of ship terminal performance requirements

MARISAT features a spin-stabilized satellite of the established type used by INTELSAT IV and launched with a Thor-Delta 2914. The mass constraint on the maritime transponder is increased by the mass of the u.h.f transponder for US Navy use, the result being a system limited to a capacity of 8 channels and requiring a ship terminal G/T of -4dB/K and EIRP of 36dBW.

MAROTS is a 3-axis stabilized satellite which is also to be launched by a 2914. The satellite EIRP is higher than for MARISAT and although the capacity specified by ESRO is greater, useful reductions in ship G/T to -10dB/K and EIRP to around 31dBW are possible. The implications of this relaxation are discussed later.

In addition to these two firm programmes, COMSAT have carried out some MARSAT studies for INTELSAT, the full results of which have yet to be published. A comparison was made between a dedicated satellite launched by a Thor-Delta and an INTELSAT V with a minority provision for a MARSAT transponder.

The mass constraints imposed by the launcher would produce a dedicated system similar to MAROTS if the channel capacities assumed were similar. However, the greater optimism in the United States regarding the establishment and growth of MARSAT might be reflected in a design system capacity even greater than the 20 channels (telephony equivalent) recommended by IMCO. The effect of this would be to force the ship terminal requirements up to the level demanded by MARISAT. There is a danger that the resulting sophistication of the ship terminal might slow growth on which the system design was based, with serious economic consequences.

ESRO are well aware of this danger as it has been stated specifically that the MAROTS system design shall minimize the cost and complexity of the ship terminal.

Ship Terminal design

ANTENNA

Next to be considered is the kind of ship terminal that results from the performance requirements imposed by the system design. The antenna is the major component of the terminal, and its design is influenced by the choice of receiver front end. Development of low-noise L-band transistors and amplifiers has produced units having noise figures typically better than 3dB. Thus, the advantage to be gained from the slightly lower noise parametric amplifier is small considering the extra cost.

Assuming such a transistor LNA, the ship G/T requirements for MARISAT and MAROTS lead to antenna peak gains of 23dB and 18dB respectively. These gains imply beamwidths of 10° and 18°, and limitation of the gain degradation from inaccurate pointing leads to allowable system errors of between 3° and 6°. This order of accuracy demands stabilization

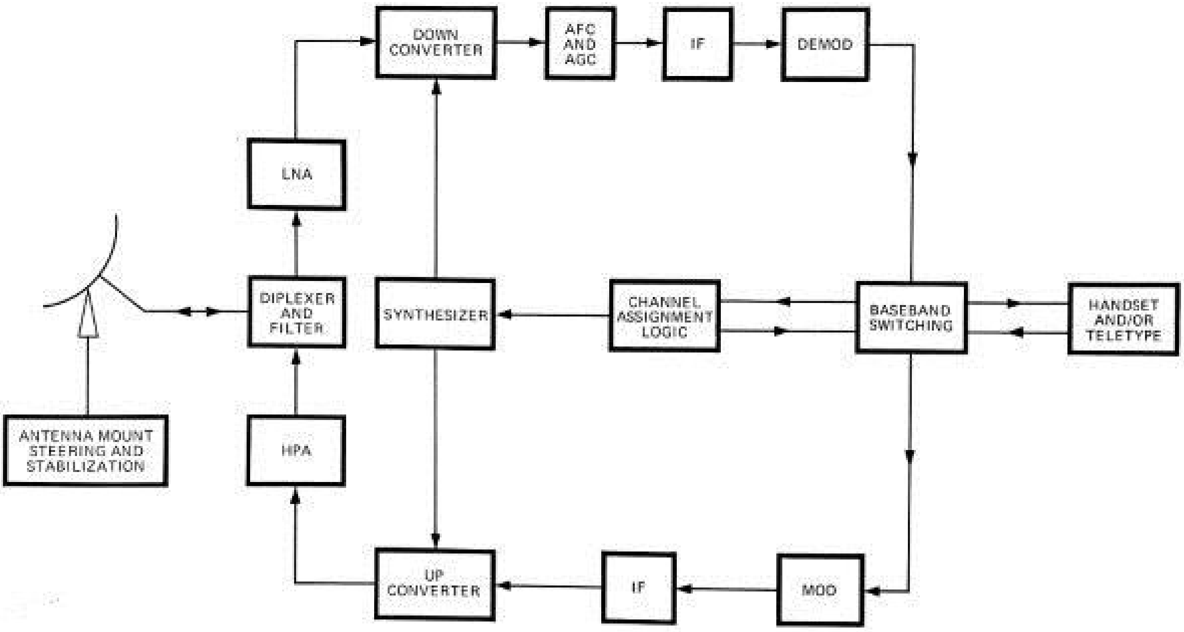

Figure 3. Ship terminal block diagram

against ship roll and pitch, as well as automatic steering from ships' compass information to compensate for heading changes.

Earth curvature produces changes in satellite apparent position in the sky but the extent is usually sufficiently small for daily adjustment of antenna pointing angle to be adequate. The case for the provision of autotrack is therefore debatable, especially for a first-generation or pre-operational system featuring cheap, simple and easily maintained ship terminals.

However, the requirement for antenna stabilization is unfortunate as this conflicts with the aim of simplicity. In the case of MARISAT, the requirement for a 3° error will only be met with a conventionally stabilized antenna steered by servomotors and gyroscopic sensors. The gyros may be supplanted by more attractive alternatives but such components are only available at present from a very few suppliers in the USA.

A most interesting challenge to the antenna designer is provided by the lower gain MAROTS antenna which only requires stabilization to around 6° and this relaxation should allow the introduction of much simpler methods of stabilization. Possibilities range from the use of cheaper motion sensors to pendulous mounting of the complete antenna. To date, some of the theoretical studies of pendulous mounting have been discouraging, but the British Post Office[8] have taken the idea further with some interesting sea trials on a test rig.

At present there is no complete agreement as to the type of array to be used on the ship terminal. Offset-fed parabolas, quad-helical and short-backfire arrays have all been seriously proposed, but no complete practical evaluation has been made. However, irrespective of the array, mount or stabilization details, the antenna will probably be enclosed by a radome about 5 feet (1·52m) both in height and diameter. To provide all-round coverage, masthead mounting is also likely in the long-term, since the cost of this particular part of the terminal would tend to preclude duplicate antennas in lower positions.

Electronics

The overall functional diagram is shown in figure 3. It is necessary to co-locate the transistorized low-noise amplifier with the antenna to maximize receive sensitivity and it should be possible to mount the transmit power amplifier in a similar position to minimize output feeder losses and the rating of the amplifier. The disadvantage of this arrangement is that maintenance of the equipment would be made difficult as the antenna will be relatively inaccessible. Solar heating of the radome interior will also produce elevated temperatures which may significantly aggravate the cooling problem, since forced ventilation of the radome is clearly to be avoided.

The required 25 watts of r.f transmitter power can be readily produced by a solid-state amplifier unit which is well suited to the equipment design aims of compactness and simplicity. Higher powers are available which would enable the feeder losses to be compensated for if locating the transmitter in the radio cabin is preferred.

It has also been suggested that the frequency conversion should be carried out adjacent to the antenna with the relatively long connections to the radio cabin at i.f. No doubt in the future one of the major differences between equipment designs is likely to be the extent to which equipment is mounted near the antenna or in the radio cabin.

However it appears that at least the modems, i.f stages, power supplies and operational controls will be housed in a single radio cabin unit. With the use of microstrip and integrated circuits, this unit might be around 15 inches high (381mm) and of standard width and depth.

Regarding modems, the preferred modulation method is not yet universally agreed. The two most likely alternatives are companded f.m and variable slope delta modulation with differentially-coded 2-phase p.s.k. Digital modulation methods have advantages in ease of integration of telephony, telex and facsimile services and possibly greater immunity to interference, while companded f.m is claimed to give better link quality[7]. However, it is anticipated that MARISAT and MAROTS will be used to obtain practical experience of both types of modulation, making an early decision unnecessary.

In the early phases, the operational controls of the equipment will be limited to facilities for pointing the antenna towards the satellite and possibly push button selection of transmit/receive frequency. Even automatic tuning on receipt of channel assignment information from the shore would introduce little complication.

Assignment of the few available channels between hundreds or thousands of ships is beyond the scope of this article but the chosen method will be affected by the system organization and institutional arrangements which are uncertain. Most studies have suggested that assignment on demand using a randomly-accessed control or calling channel is likely.

Provision of shore stations by European administrations

The provision of satellites by agencies such as COMSAT, INTELSAT and ESRO has been covered whilst the ship terminals will no doubt be manufactured by a number of industrial companies and sold or leased to a great number of ship owners or operators. A third element is essential to the working of the complete system and this element is the shore station or earth terminal. The USA are already installing shore stations on their Atlantic and Pacific coasts to work with MARISAT.

At the time of writing no official announcement has been made by any European administration to the effect that it will provide similar facilities on this side of the Atlantic. Although the Atlantic region contains about half the world's shipping, plans by many ship owners to use the service are discouraged so long as there is no guaranteed access to the satellite via a European shore station.

Hopefully, all the administrations of leading maritime powers are now considering providing such stations but their reticence regarding plans may be due to the uncertainty about the status of the systems discussed in this article. In order to ensure the timely availability of equipment and the acceptance of the service within the next few years, investment planning by both the ship terminal equipment industry and the shipping companies is now obviously required and will be vital to rapid growth and economic viability. This would be possible if even one administration, announced its intention to establish a shore station by a given date.

Conclusion

Many interesting developments will undoubtedly occur in the next few years. MARISAT will be launched and a pilot service with a single voice channel and 22 telex channels will commence.

At the end of May, ATS 6 was launched successfully and will use its solar power to run a long comprehensive series of programmed experiments for a number of purposes. Included in the satellite equipments will be an L-band transponder and a high-gain antenna providing a high EIRP similar to MAROTS. This capability will be used by ESRO and others during the limited period that has been allocated to the testing of ships and aircraft terminal equipment and the L-band link to the satellite itself.

The IMCO 'panel of experts' on maritime satellites will prepare and present their report on the proposed service to an International Conference early in 1975. This report consists of recommendations on how the service might be set up and administered, its economic viability and technical characteristics. It is to be hoped that the Conference will approve the early formation of a MARSAT management agency who will advance the service to a reality within a few years.

Three years from now in 1977, MAROTS is scheduled to be launched and MARISAT should have made its full 8 channels available for civil use. However, in the intervening period of 1975–77 it is hoped that installation of MARSAT ship terminals will be included in the design of many new ships so that traffic and operational experience can be rapidly built up when the satellites become available. A number of shore stations should also be built in this period and their links with the existing terrestrial network proven.

It is the belief of many who have studied this subject that first-hand operational experience of the speed and quality of the satellite service will rapidly lead to a conviction that it is vital to the advancement of day-today maritime operations.

References

[1]W. Mateer: 'Shipowners Requirements for a Marine satellite communications service', *I.E.E Conference on Satellite Systems for Mobile Communication and Surveillance*', March 1973 (p. 108).

[2]*Financial Times*, 5th June '73: 'Links ships to Networks'.

[3]British Post Office, et al.: 'United Kingdom Maritime Satellite Communication Tests Aug–Dec 1970', *Post Office Publication PG277*. Sept. 1971.

[4]G. L. Grisdale: 'Communications with Ships and Aircraft through satellites', *Point-to-Point Communication*, Vol. 16 No. 2 (May 1972).

[5]*IMCO papers MARSAT II/WP7* (May 1973) *and III/WP8* (September 1973): 'Technical Parameters of a First-Phase Maritime Satellite System'.

[6]R. J. Kirby: 'A simple stabilized antenna platform for Maritime Satellite Communications', *I.E.E Conference on Satellite Systems for Mobile Communication and Surveillance*', March 1973 (p. 135).

[7]D. G. Pope: 'Modulation and Speech Processing Techniques for a Maritime Satellite Service', ibid. (p. 56).

Glossary

AEROSAT	Generic term for an aeronautical satellite system.
ATS3 AND ATS-6	Two of a series of Applications Technology Satellites sponsored by the US National Aeronautics and Space Administration (NASA).
C/N.	Ratio of carrier power-to-noise power per Hz of bandwidth in dB.
COMSAT	US company called Communications Satellite Corporation.
DIOSCURES	French project for a global coverage Aeronautical/Maritime satellite system.
ECSS/OTS	European Communication Satellite System, a trunk telecommunication satellite network planned by ESRO for Europe in the 1980's, to be preceded by the launch of a pre-operational orbital test satellite (OTS) in Jan 1977.
EIRP	Equivalent isotropic radiated power.
ESRO	European Space Research Organization, replaced by the European Space Agency (ESA) in July 1974.
FLEETSATCOM	A second-generation military communications satellite sponsored by the US Navy.
GAPSATCOM	See MARISAT.
G/T	Receive figure of merit, a ratio of gain to noise temperature.
IMCO	Intergovernmental Maritime Consultative Organization.
INTELSAT	International Telecommunications Satellite organization.
INTELSAT IV	Satellite type used in the existing global-coverage trunk telecommunications satellite network sponsored by INTELSAT.
INTELSAT V	Satellite type planned to be complementary to INTELSAT IV and possibly replacing it.
MARISAT	Satellite(s) or satellite system sponsored by COMSAT for US Navy and civil maritime use.
MAROTS	Satellite sponsored by ESRO for civil maritime use.
MARSAT	Generic term for a global coverage maritime satellite communications system.
WARC-ST	World Administrative Radio Conference on Satellite Telecommunications.