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Satellite Technology: Today And Tomorrow

By

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SATELLITE TECHNOLOGY : THE COMMUNICATIONS EQUALISER

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SATELLITE TECHNOLOGY - TODAY AND TOMORROW

K.P. GALLIGAN
1. INTRODUCTION

When examining the future prospects for satellite technology due account must be taken of three important determinants:

- the ultimate application for such technologies;
- the (geographical) context in which such developments are taking place;
- the history of development activities either on a geographical or organisation basis.

Any unilateral discussion of this first determinant is almost certain to fail, depending as it does on a host of perceptions of local requirements and ultimately the forging of administrative compromises and perhaps political bonds.

Instead this paper will present a number of applications for technologies, in the European context, with some background as to reasons for choosing such technology approaches. The treatment will be at the level of the organisation of communication systems.

2. EUROPEAN TELECOMMUNICATION INFRASTRUCTURE

An atlas shows that Europe is, in a geographical sense, highly integrated, countries share land borders with each other and most of the major islands are separated from the continent by a shallow sea.

From the standpoint of telecommunications also Europe is highly integrated, with a mesh of cable and microwave trunk links serving a large (and costly) local network system.
Satellites are also a part of the European communications scene, because they represent an alternative routing to terrestrial networks, because over long distances they provide circuits at superior quality and lower cost, and because satellites can provide a range of services that are difficult to provide using conventional terrestrial networks.

This latter point relates in particular to the ability to set up connections anywhere in the satellite coverage rather quickly, using portable stations, such connections providing a large range of services including video.

Clearly, when fibre optic trunk and switching systems have proliferated to the extent that a large proportion (say 90%) of telecommunications users have a fibre wideband facility on their premises then the role of satellites must diminish.

Such a situation will not however exist in Europe for at least two decades and in the interim satellite technology must develop to keep pace with the demands made for telecommunication facilities.

It may be that by then prior use of satellites as part of an integrated terrestrial/satellite telecommunications network will lead to the demand for a continuation of satellite facilities, perhaps for certain key applications and so satellite use in the fixed network will remain, perhaps at a constant level.

Mobile radio networks are by their nature local and so have tended to develop on this basis in Europe. Pressure due to lack of suitable frequencies and a desire to incorporate mobile users in the pre-existing terrestrial network, as well as a desire to add value to that network, have led to the development of cellular radio networks. These cellular systems have, except it must be said for the Nordic system, developed along local (national) lines. Inevitably the technical standards set and the pace of developments for these systems is different for different European countries.
Clearly satellites can play a unifying role in this situation. In a first approach, and given the limitations, of current and near future space segments, a Pan-European data only service could be provided. With technology enhancements on board satellites, it would be possible to envisage high data rate services including toll quality voice being made available to mobiles as early as the middle of the next decade.

Whilst in general, it is true to say that European infrastructure in quite well integrated, it should be remembered that European population densities range from about 250 per square kilometer for the Netherlands, to densities of perhaps two orders less than this in the extremities of some of the countries on the perifying of Europe. Whilst it may be reasonable to expect lower population densities in Northern Norway, there are also small, but significant areas in countries such as France or Spain where a similar situation applies. Thus a whole range of strategies must be available to system planners in Europe to accommodate to such lack of uniformity; satellite telecommunication must be one of these strategies.

3. TECHNOLOGY PAST AND PRESENT

Development of appropriate techniques and technologies to European Telecommunication satellite system started in the early 1970's. From the point of view of the platform, it was decided that since European satellites would probably continue to be wedded to expendable launchers, the greatest flexibility for meeting a range of prime power requirements would be through a 3-axis stabilised platform with deployable solar panels.

Given this background the prospect of the 4/6 GHz frequency bands becoming harder to operate in the dense microwave link environment of central Europe, and the perception that both point to point trunk telephony links and trunk television would be the first customers for satellite technology, the Orbital Test Satellite (OTS) programme was conceived.
Many of the basic subsystems from these early days were incorporated in later satellites. Thus for instance both the European communications satellites (ECS) and the Maritime satellites (MARECS) use a bus, solar array and indeed power and attitude control systems not unlike these of OTS. Again, the 11/14 GHz TWTAs/receivers are similar on OTS/ECS (as indeed are some TWTAs for 11 GHz used by Intelsat). In addition various European national systems will use growth versions of the basic OTS/ECS design.

Again, whilst the basic satellite design is different, Olympus which is a full Ariane class platform is also 3-axis stabilised with payloads for the new frequency bands of 20/30 GHz and the new technique of satellite broadcasting. The developments involved will however depend on heavily on techniques and procedures perfected in previous programmes.

It will be of interest to trace the development of large platforms in the years to come, because one thesis that is advanced here is that organisations involved in technology developments, such as ESA, are to a large extent captives the past, perhaps because new radical or unfamiliar schemes tend not to be trusted by decision makers.

4 A EUROPEAN APPROACH TO TECHNOLOGY DEVELOPMENTS

Technology developments conducted by ESA are as they are elsewhere, firmly keyed to perceptions of user needs a decade or so in advance. At the risk of oversimplifications, these needs can be stated as:

- pressure on spectrum available for satellite applications such that techniques for frequency re-use in existing bands must be explored and the use of new frequency bands must be explored;
- a requirement for flexibility during the lifetime of satellite systems;
- a requirement to accommodate to an increasingly diverse service environment and in particular a range of video and data oriented business services;
- trends towards smaller user stations.
In order to give these requirements some direction, technological work is channeled into two major missions, or streams of activity.

In the first theme, the wideband mission, are grouped all missions which are demanding in terms of bandwidth or communications rate.

This mission has been sized on the basis of possible needs arising from a future video communication network over Europe in the 90's. The image processing techniques will allow the digital transmission of a 625 line image at a bit rate of 8.5 Mbps (roughly equivalent to an RF bandwidth of about 7.5 MHz for each channel).

The initial approach was to consider a Direct to Users service, with a large number of small, therefore cheap, earth stations. Initial studies seem to indicate that this approach penalizes too much the space segment and leads to an overall system which is not cost effective. Emphasis is therefore to be put on medium size stations with local connections through the established Integrated Services Digital Network (ISDN). The distribution of would-be "video customers" indicates that the trunk connection (as originally foreseen) will also be required.

A preliminary assessment of the potential interest of a cost effective satellite integrated with a terrestrial network, leads to a capacity between 1000 and 2000 videochannels. Such conclusions confirm the need to implement the 20/30 GHz RF band and the necessity to resort to multiple beams in order to re-use the frequency so that the total required bandwidth can be transmitted within the 2.5 GHz allowed.

In the frame of the initial studies, an overall optimisation of the space and the terrestrial segments has been performed, leading to typical payload configurations. The optimal number of beams necessary to provide complete European coverage is in the range 40 to 50. A TDMA access in the uplink is somewhat superior to a SCPC scheme and, in order to save mass and DC consumption, beam hopping techniques would be advantageous. Another important output from these studies is the important role that coding should play to adapt the bit error rate to the user's requirements. Subsystem characteristics will be detailed through payload configuration studies and it is intended that specifications will be developed for payload model.
Concerning the satellite antenna, link budget calculations show that, a coverage gain of 42 to 46 dB will be required, with low sidelobes in view of the frequency reuse requirements.

Beam generation techniques with several constituent beams seem to be a necessary approach when frequency must be reused. Beam scanning offers also a great potential. It is thus anticipated that complex feed array and feed network will have to be implemented, in spite of the heavy penalty they put on the mass budget. Reflector size will be in the order of 4m or less, with a high accuracy. Some emphasis will have therefore to be put on mass saving techniques.

In general, the activities on antennas encompass:

a) Elaboration of trade-offs
b) Antenna electrical design including software support
c) RF sensing
d) Reflectors technology:
   - electrical and mechanical design
   - manufacturing and testing of the engineering model
e) Feed array:
   - design and manufacturing of breadboards and engineering models
f) Feed network:
   - design and manufacturing of breadboards and engineering models
g) Analysis and implementation of test methods suitable for the full antenna testing.

Concerning the RF front end, preliminary analyses, based on various antenna concepts, indicate that RF power levels should be considered in the range 20 to 50W. Travelling Wave Tubes seem more than adequate, although they are heavier than Solid State Amplifiers (1 to 1.2 kg for the tube, 1.5 to 1.8 kg for the EPC) and there is very little prospect for a substantial mass reduction.
An extremely dense packaging behind the antenna feed network will be necessary, leading thus to challenging requirements on the mechanical and thermal aspects. Equally important is the need for high primary DC power and its impact on solar arrays (cells, structure and mechanism), batteries and DC power distribution subsystem.

Other system concepts (scanning for example), seem to be attractive and will also be investigated.

In general, the activities to be covered in the "RF front-end" subsystem can be summarised as follows:

a) Development of a low noise broadband front-end FET amplifier
b) Development of 20 GHz tube amplifiers with their high voltage converters
c) Development of 20 GHz Monolithic Microwave Amplifiers
d) Development of RF filters and multiplexers including dielectric resonator technology and temperature compensation techniques.

Of particular importance is on-board processing, which provides the necessary flexibility in the beam interconnectivity. The concepts being considered at present include: A conventional Time-Space-Time switching approach with ECL. A TDM bus (Time switching) and switching at bit (instead of burst) level implementing a VLSI technology. All concepts lead to reasonable mass and DC consumption figures, so that it is anticipated that most of the problems might lay with the control software.

A second stream of activity concerns narrow bandwidths and low communication rates, a 'narrow band' mission. Like the wideband missions, the narrowband mission is hypothetical and its objectives are long-term oriented in the sense that they are concerned with the payload technology necessary for the mid90's. This technology will cover the lower part of the RF spectrum, i.e. the L-band, and the digital signal processing at rather low bit-rates. Additionally the use of the UHF bands for mobiles will be re-assessed.
In this context, the satellite payload should be able to handle a large number of narrowband digital signals carrying either data at (up to) 2.4 kb/s for a typical teletype application and or coded voice at 9.6 kb/s as could be obtained from hybrid vocoders. These services would be provided to mobile users, either aircraft, ship or terrestrial vehicles, equipped with cheap terminals. In particular, the RF performance would be rather modest, for example antenna gain of about 0 to 5 dB and RF power in the range 10 to 50W. In short the satellite can be defined by two main characteristics:

(i) The necessity to generate high gain spot beams with a good control of the sidelobes providing either global coverage (for aeronautical and maritime purpose) or domestic (for a terrestrial application).

(ii) The signals must be processed, on board, in order to achieve the required flexibility in channel to beam allocation.

These two aspects have already been covered in the past in the Multibeam Array Model (MAM) programme. The generation of contiguous spot beam has been demonstrated using phased array technology. Some solutions have been implemented for the channel to beam allocation, which proved satisfactory for a technological purpose but the lack of known mission requirements prevented testing the efficiency of these solutions at overall level. Some other aspects have also been addressed such as: active thermal control, mechanical design of the array element (short backfire) and, electrical (decentralised power supply). An Electrical Demonstration Model has been built and extensively tested, both in the transmit and receive modes, first in ESTEC and now at the Royal Aircraft Establishment in the United Kingdom.

The narrowband mission is a step beyond MAM. The traffic is assumed to be at the limit that can be supported by the RF spectrum available, at L-band, for these services. The antenna gain will be higher (30-35 dB instead of 24 dB for MAM) and the on board processing more sophisticated.
The Narrowband mission studies will cover the following general areas:

- conceptual system designs,
- survey of devices and sub-systems,
- transmission performance study,
- survey of communication techniques for traffic management and routing,
- introduction of new services and techniques,
- repeater configuration,
- definition of demonstration equipment.

Additionally work is progressing in the area of large antennas (8-10 m), the impact of payload technologies appropriate to this mission and there is also an activity regarding low orbit satellites for navigation and distress applications.

The traffic expansion and the introduction of new services, will place increased requirements on the limited orbit and implemented spectrum resources and on individual satellite power, mass and antenna farms. As already in the Intelsat system and planned for ECS, use of multiple satellites in the same or different orbital slots is an economic approach which uses to the best advantage the available launcher capability, while furthermore providing a high system reconfigurability for growth and life extension by replacement.

Interconnection between the different satellites is, however, essential for minimising the number and cost of ground stations, and the synchronisation and mutual tracking of the satellites should also be provided for a most effective system operation.

The study of these requirements and in particular the development of the inter-satellite links by laser or millimeter waves will be an important element to be included in the preparation of the technology infrastructure for space communications in the 1990s. As a matter of fact the development of several relevant technology elements has already been initiated in the context of other themes. For example:

- 20/30 GHz antenna subsystem,
- 20/30 GHz RF front-ends,
- Inter-satellite laser range finder,
- antenna pointing mechanisms
Further development work is also planned for cluster synchronisation and attitude and orbit control.

Not unnaturally, work is also being continued with the aim of providing appropriate technologies, largely based on the evolution of existing techniques aimed at a second generation European fixed service satellite. Examples of such work are:

- development of a contoured beam antenna;
- investigation of field effect devices as a TWT replacement;
- development of higher power TWTAs;
- production of filters and multiplexers for high power with low losses.

5. CONCLUSION

Clearly, the activity described above, representing as they do approximately 25% of the average funding of technology, are only a small part of ESAs activity. Covering as it does a broad range of scientific, applications (e.g. Earth Resources) and space transportation applications, there is a need for the remaining 75%. However many technologies for example attitude control of structures will be common to a number of the application areas.

It probably takes ten years for a technology to become mature enough to be incorporated in an operational system so the Agencies time horizons are necessarily far away. It is however important to try and see over these horizons and so we also are interested in the perspectives for the year 2000 and beyond. Clearly the examination of the state of the art so far away must be speculative, it is nevertheless useful in establishing today's technological development environment.

The techniques available in 2000 will be numerous. In general however we can foresee that a greater autonomy will be conferred on the satellite, both to maintain the orbit and to provide the communications function, whilst spacecraft will become mechanically more complex.

It is too early to foresee the impact of developments such as the space station on communication satellites in particular, aside from the probable need for a European data relay capability. Ariane will however continue development so the constraints and benefits provided by expandable launchers will flow through the technology development activity.