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A SATELLITE SYSTEM FOR LAND-MOBILE COMMUNICATIONS IN EUROPE

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ABSTRACT

There exists a great unsatisfied demand for land mobile communications in Europe, particularly in sectors of the business activity such as the road transport industry which covers the entire European continent. This demand could best be satisfied by means of satellite-based private networks providing voice and data communications in a hub configuration. The potential market is estimated to encompass several hundred thousand road vehicles and the transmission capacity required would be several thousand channels. ESA is currently demonstrating the potential of satellite communications for this type of application, using a system called PRODAT. System studies are being performed with the aim of defining the architecture of a regional satellite system for Europe.

INTRODUCTION

Mobile communications is a fast growing market in Europe as it is in North America. Several countries are equipping themselves with cellular networks or are planning to do so in the near future. Most of these systems unfortunately have different characteristics which make them incompatible. Under pressure from the Commission of the European Communities, fourteen governments have recently agreed to adopt the same standard for the next generation of cellular system, the so-called "pan-European" system, that will eventually cover the entire continent. The principal milestones for its implementation are the coverage of major cities and airport areas by 1993 and the main roads connecting these cities by 1995. Thereafter, the network will continue to expand at a rate which is not specified and which will depend on circumstances prevailing in each country. Given the magnitude of the investments required for the infrastructure of this project (estimated at $ 3200 million over the first five years), it can be expected that the coverage in terms of percentage of the total geographical area will still fall short of 100% by the year 2000. In fact, it is likely that the least populated areas of Europe will remain uncovered for a very long time.

Although the future pan-European cellular system no doubt raises very bright prospects and will be welcomed by millions of users (present estimates are 15 million subscribers by 2000), it will not be the universal panacea. In the framework of its prospective studies of new

satellite applications, ESA has identified certain categories of users whose specific needs are too urgent to wait for the new system and moreover would not be satisfied very well by it even if it existed. The purpose of the present paper is to outline the nature of these requirements and to give an overview of the ESA's current and planned activities to meet them.

RESULTS OF MARKET SURVEYS

Private Network Applications

For several years, ESA has been exploring new markets for mobile services by satellite in Europe. Several surveys have been completed and others are still going on. The sector that appears to have the largest and most urgent needs is the road transport industry. There are in Europe several thousand transport companies that might be interested in mobile communications by satellite, for the following reasons : they operate fleets of vehicles of significant size (more than 50) hence they have high operating costs which they try to reduce; and their activities are international i.e. their field of operation includes the whole of Western Europe, and sometimes extends to peripheral areas such as Eastern Europe, the Middle East and North Africa.

These companies fall into three categories :

(i) International haulage companies

This category includes a total of 5000 companies with more than 50 vehicles, 600 of them having more than 100 vehicles. The market survey shows that 2300 of these companies would respond positively to an offer of satellite services.

(ii) Companies that carry their own goods on an international scale

In this category, 300 companies operating more than 100 vehicles were identified as potential subscribers.

(iii) Freight forwarders

This category includes 250 very large companies, including 30 giants that operate thousands of vehicles each. 140 of them were identified as potential subscribers.

In addition to the above categories, the survey identified some 90 companies that would be interested, located in countries outside the coverage of the future pan-European cellular systems (Turkey, North Africa) .

The reasons for the interest of these organisations in satellite-based services are two-fold. On the one hand, they require access to these services everywhere in Europe and not only in those areas that the cellular system will cover; on the other hand, they need these services urgently and, if possible, not later than 1992, which is the year when all internal barriers to trade end services will be removed in the European Community. As far as types of service are concerned, they express the following requirements in order of decreasing priority : voice, message and data transmission, telex and facsimile, radio-location. A clear preference is also expressed for access to these services in the form of closed private networks rather than by

way of connection to a public network. Private networks certainly offer greater flexibility and the costs are more easily controlled.

The results of the survey are summarised in the table below :

	Number of companies interested	Number of vehicles (thousands)	Number of satellite channels
International haulage companies	2300	260	2600
Companies that carry their own goods	300	45	450
Freight forwarders	140	85	850
Companies in peripheral countries	90	10	100
Total	2800	400	4000

The above values correspond to the average of a range which goes from 2500 to 7000 channels depending on the assumed penetration of the service.

As mentioned earlier, surveys are also conducted in other sectors of activity such as inland waterway transport, railways, and environment control by government agencies. None of these sectors seems to have the same massive requirements as the road transport industry although, taken together, they might amount to a substantial market.

Public Network Applications

To many potential users in the categories described above, the pan-European cellular network would not be an attractive proposition because of its insufficient coverage and the fact that it would not offer the same flexibility and cost control possibilities as a private mobile radio (PMR) service by satellite. There is however a significant fraction of that population (5%) that would be interested in having access to both the cellular and a satellite-based PMR service.

The integration of a satellite system with the terrestrial cellular system also has a number of advantages, the most obvious one being that it would offer quasi-complete European coverage right from the outset, therefore adding another attractive feature to a system already designed to meet the needs of the international traveller.

In the case of a satellite used as part of the public network, the problem for the system designer is of a quite different nature. The services to be provided by satellite must be of the same quality as those of the associated terrestrial network. Furthermore, space and terrestrial links have to be interfaced in such a way that the complete network is perfectly transparent, to the point that users remain unaware of the type of channel used at a particular time to relay their communications. There are also problems of a less technical nature such as charging, harmonisation of tariffs and, last but not least, finding an adequate amount of frequency spectrum. Assuming that all these problems can be resolved in due time, it seems likely that in the long term a sizeable market will develop for public mobile communications by satellite, as a complement to the terrestrial cellular service.

OUTLINE OF ESA PROGRAMMES

ESA's activities in mobile communications by satellite are aimed at offering the following services, listed in order of increasing sophistication :

(a) unidirectional wide-area paging
(b) bidirectional low-rate data transmission for the following applications :
  - message delivery and telex communications
  - data collection
  - packet-voice message transmission
  - radio-location
(c) voice/medium-rate data transmission for private network applications
(d) voice/data transmission for public network applications in an integrated space/terrestrial system

The PRODAT System

The PRODAT system is a two-way data transmission system that has been developed to test the first two layers of the services mentioned above and to evaluate user reactions under operational conditions. In its design, emphasis has been placed on achieving the best performance at the lowest cost with terminals small enough to be installed easily on land vehicles, small boats and light aircraft [1].

An extensive campaign of propagation measurements, carried out at the outset of the programme, showed clearly that the land mobile environment presents a much tougher challenge to the system designer than either the maritime or the aeronautical. Indeed in the land-mobile case, shadowing by buildings, bridges, trees and all kinds of obstructions causes deep fades in the radio link or even interrupts it completely. A self-adaptive scheme has therefore been developed to take maximum advantage of the favourable time periods without being disturbed by momentary signal interruptions.

The services provided by the PRODAT system are :

(a) Sending of messages from fixed user to mobile user and vice-versa, and from mobile to mobile users
(b) Sending of messages to multiple mobile users (broadcast)
(c) Request/reply function
(d) Periodic polling of mobiles
(e) Paging.

These services are implemented through the combined operation of the mobile satellite network and the terrestrial access networks, i.e. the telex and Packet-Switched Public Data networks. The interaction between these takes place in a store-and-forward mode in the Network Management Centre, which acts as the hub of the mobile network. This centre is located at ESA's Villafranca station in Spain, which controls the MARECS satellite over the Atlantic Ocean.

The forward link characteristics are as follows :

- Multiplexing mode : TDM
- Signalling rate : 1500 baud
- Data rate per channel : 47 bit/s
- Total number of channels : 23

The data rate on the return link can be set to around 200 bit/s using a signalling rate of 300 baud.

The preliminary system tests have been completed successfully. Although the system thresholds have not yet been accurately determined, results show qualitatively that the challenging design objectives of the mobile link have been met, thanks to the technical options selected. Messages can be exchanged in a heavily perturbed propagation environment in minimum time and with no errors.

The field trials that are currently in progress involve ten prototype mobile terminals installed on trucks of transport companies in France, the Netherlands and the Fed. Rep. of Germany. At a later stage, the scope of the trials will be extended to include the transmission of voice messages, digitally encoded at 800 bit/s and radiolocation by coupling a navigation receiver to the PRODAT terminal.

The European Mobile Services (EMS) System

For the next step forward in the provision of land mobile services in Europe, ESA is developing a concept aimed mainly at offering voice/data channels in the form of private networks for users such as the road transport industry. This concept, called "EMS" could form the basis of an operational regional system.

The purpose of EMS is to provide, in the first instance, the following mobile services in Europe :

- Low-data-rate services for mobile terminals of the PRODAT type ($G/T = -24$ dBK^{-1})
- Business services (voice/data) for mobile terminals of a more advanced type ($G/T = -12$ dBK^{-1})

The EMS system is based on the use of a satellite payload dedicated primarily to the Land Mobile Satellite Service in Europe. This payload would be of a modest size (75 kg, 200 W), i.e. similar to the SMS payload belonging to EUTELSAT. The overall characteristics of the system are described below.

An orbital position will be selected between 10 and 20° East to provide a mobile service with the highest elevation angle in Europe. The coverage of EMS is a single elliptical beam illuminating Europe. The gain at edge of coverage is 26 dB minimum, and the EIRP at 1.5 GHz is at least 43 dBW. The transmission capacity available is :

- 10 TDM carriers (24 dBW each) for PRODAT-type terminals
- 500 business channels (19 dBW each with voice activation) for enhanced terminals

The polarisation is LHCP (axial ratio ≤ 1.5 dB).

The frequency bands used in the satellite-to-mobile direction are as follows :

1530 to 1533 MHz : business services
1540 to 1544 MHz : low-data-rate services
1555 to 1559 MHz : business services

Frequencies in the up and down directions are paired with a fixed difference of 101.5 MHz.

Feeder links operate in the same 14/12 GHz bands as SMS and IBS.

Business services are intended to meet the specific requirements of enterprises and organisations which need a Private Mobile Radio (PMR) service at European scale. They would therefore be provided in the framework of closed networks in much the same way as is done by EUTELSAT with SMS. The fixed stations would operate at 14/12 GHz and would be small enough to be installed at the user's premises.

As far as the data services are concerned, the network is composed of sub-networks, each of which is roughly equivalent to the PRODAT demonstration network described above. Each participating country operates its own sub-network(s) through its earth station(s) (hub stations), where gateways to the corresponding national networks are installed. The feeder links to the satellite are at 14/12 GHz. The various sub-networks share a common satellite transponder, which provides the required geographical coverage for all mobiles.

FURTHER DEVELOPMENTS

To achieve the remaining objectives and to provide full quality telephony services by satellite as well as interconnectivity with the terrestrial public network, further advances are necessary both in satellite and in mobile terminal technology.

As far as space technology is concerned, the efforts currently concentrate on two key items, namely high-gain multibeam antennas and onboard processing. A companion paper reports on the latest achievements in multibeam antennas [2]. Work has started on onboard processing and on terminals more advanced than those used in PRODAT.

One remaining problem is the allocation of more frequency spectrum to the Land Mobile Satellite Service (LMSS), since the EMS system described previously would occupy all the spectrum available at 1.5/1.6 GHz in Europe.

In the long term, the problems encountered in trying to share frequencies between the LMSS and other radio services may be alleviated by the introduction of a new generation of satellites that would be placed in highly inclined and eccentric orbits of the Molnyia (12 hour) or Tundra (24 hour) type. Such satellites would spend a significant fraction of their orbital period in a region of space near the zenith of Europe and would provide quasi-vertical up and down links. This would have the advantage of minimising the shadowing problems that cannot be avoided with geostationary satellites. It would also facilitate the sharing of already used frequency bands.

CONCLUSIONS

The needs for Europe-wide land mobile services are already manifesting themselves. There are plans to deploy a new pan-European radio cellular network, but its implementation will take many years. In the short term a satellite system would go a long way towards meeting the most urgent needs. In the longer terms, having a satellite integrated into the cellular network would have many advantages.

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