# Payloads Development for European Land Mobile Satellites: A Technical and Economical Assessment

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## ABSTRACT

In the frame of the European Space Agency activities, Selenia Spazio has defined two payloads for Mobile Communication, one for pre-operational use (European Land Mobile System, EMS) and one for promoting the development of technologies for future mobile communication systems (L-band Land Mobile Payload, LLM).

The paper provides a summary description of the two payloads, their main performances and, in conclusion, an economical assessment for the potential mobile communication market in Europe.

## 1. INTRODUCTION

The land mobile satellite communication market is expected to grow considerably in Europe during the next decade. Several initiatives are taking place trying to meet the user needs offering a number of services which range from the simplest radiolocalization and messaging to more sophisticated data and voice channels.

The European Space Agency (ESA) has been widely active in promoting the technology for Land Mobile Communications since many years and its PRODAT low data rate terminal is currently conducting field trials using the MARECS satellite.

The next step is the deployment of an European Land Mobile System (EMS) oriented for closed users groups (i.e. trucks) and allowing data and voice communications with an initial capacity of 300 to 500 channels. The technical and economical viability of the EMS project has been amply assessed by several studies performed by different organizations. The payload can be embarked as an additional passenger of the ITALSAT F2 or EUTELSAT II communication satellites by the end of 1992.

These opportunities would allow to start the mobile service by early 1993 in response to the urgent users needs and exploit a lucrative market segment which predicts up to one million of users which can be economically served via satellite by 1995 throughout the european territory.

According to this scenario there exists an amply justification for the deployment of an operational system for a fully developed service with a 2000 channels dedicated satellite.

Therefore ESA has planned to fly an experimental payload on board the Technological Satellite Mission (ARTEMIS) by 1993 for which Selenia Spazio has been selected as Prime Contractor.

This is to develop and qualify all critical elements which will be required for a future high capacity operational mission. The main characteristics of the L-band Land Mobile Payload (LLM), which is presently in the phase B, i.e. design definition, are the use of multiple beams and of an efficient technique for the utilization of spacecraft resources through flexible adaptation to traffic demand.

This paper outlines the importance of the Land Mobile Services in Europe where a number of different systems and operators are making plans for the near future. The two payloads which have been recently defined (EMS, LLM for ARTEMIS) will be described underlying the major technical issues. In particular the design philosophy and the necessary technologies is discussed taking into account recent developments in the areas of antennas, beam forming networks and power amplifiers. Also an economical assessment in terms of potential revenues for the mobile services is given under different hypothesis of traffic capacity.

## 2. THE EMS MISSION AND ITS PAYLOAD

### 2.1 Mission and Payload Requirements

The European Mobile System (E.M.S.) will provide two ways voice and data communications between Fixed Earth Stations (FES) and land mobiles located anywhere in Europe and, possibly, North Africa. Links between satellite and mobiles will be at L-band. Feederlink to/from FES will be at Ku-band.

Table 2.1 excerpts the main EMS payload characteristics.

The definition of a first generation L-band payload addressed properly the technological drivers. Many ESA contracts are infact underway, across the european industry, spurring advanced technologies development and test.

In line with this approach, Selenia Spazio performed several studies for ESA [1], [2], [3] aiming to define a payload architecture making optimum use of the on going development in Europe.

### 2.2 The Payload Architecture

Fig. 2.1 shows the payload block diagram: it consists of two antennas and a multichannel transparent forward and return repeater.

A forward channellized repeater links the FES to the land mobiles. On the other side, a return channellized repeater links, the mobile terminals to the FES.

The 2.5 x 1.5 $m^2$ reflector antenna provides an elliptical beam at L-band covering Europe and North Africa (Fig. 2.2). The elliptical reflector is fed by a cluster of four self-diplexed patches radiating in left hand circular polarization at the transmit and receive bands. The feederlink coverage is provided by an indipendent Ku-band antenna of the Dragone type [4], chosen on the grounds of its inherently good crosspolar performance.

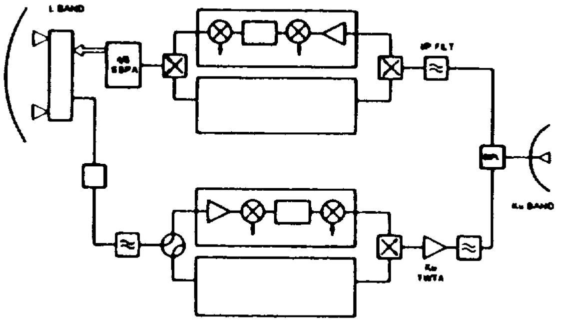

Fig. 2.1 EMS Payload Block Diagram

In the receive side, a passive combiner sums the four signals received by the four antenna patches before LNA amplification. In the transmit side, four power amplifier modules are directly connected to the four patch elements. A single high power beam is synthesized by the four RF signals.

The maximum power level, through the transmit chain, does not exceed that of each power module. This considerably reduces multipaction and passive intermodulation problems.

This is an important factor since, in the EMS mission, the frequency plan is such that the 7th order intermodulation products fall in the receive band. This and the very high EIRP require an unprecedented overall strategy for PIMP avoidance and control.

PIMP sources are all passive components interested to the flow of high power density RF multicarrier signal such as:

- transmit filters and/or diplexers
- passive RF circuitry
- antenna feeds
- reflectors
- RF cables

A distributed power amplifier concept will help in reducing the PIMP generation. Besides, the inherent transmit to receive isolation of self-diplexed patch elements (yet unproven in terms of PIMP generation and

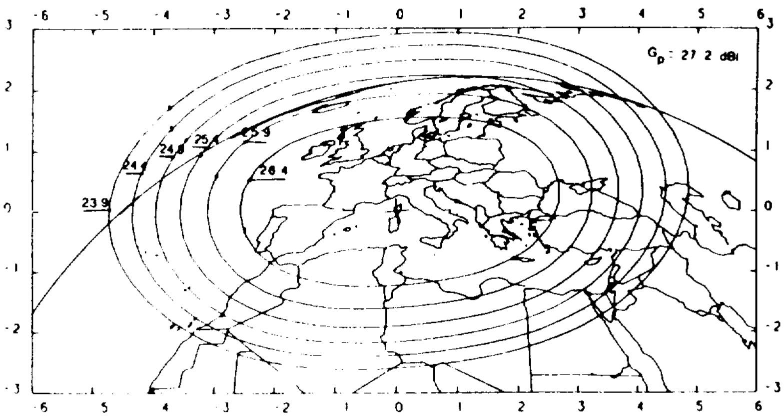

Fig. 2.2 EMS Antenna Isolevel Gain Curves

multipacting behaviour) is expected to be a determining factor for the feasibility of such advanced high power mobile systems.

Solid state L-band power amplifiers have been assessed, compared to TWTAs in terms of mass, efficiency, reliability, and finally chosen for the EMS transponder. At present, two L-band SSPA concepts are under developments in Europe: the DEBS, by MSS, and the PAMELA, by MBB. Both types have efficiencies of about 30%, at a C/I of about 18 dB under multicarrier operation (10 tone test), and low mass.

The forward and return channellized sections serve to multiplex and demultiplex the non-adjacent frequency slots available for the land mobile services. The forward repeater frequency plan shown in Fig. 2.3, consists of three non contiguous bands about 4 MHz wide.

The use of SAW filters will provide the necessary selectivity. A 120 MHz intermediate frequency is used.

Frequency coordination, with existing Ku-band Satellite Systems, requires, however, a more flexible return repeater multiplexing scheme. We slice each of the three non-adjacent frequency slots of Fig. 2.3 into three virtual channels (Fig. 2.4). The assignement of the return link channels may cope with any future spectrum utilization restraint. Nevertheless, fixed bandwidth filter multiplexers have a poor bandwidth utilization efficiency, due to the guardbands required in proximity of crossovers.

The AME company studied, under ESA contracts, a potentially attractive solution to this problem: the Bandwidth Switchable Saw Filter, or BSSF [5]. The device consists of a bank of phase matched SAW filters and a switchable combining network, with controlled phases. It is, thus, possible to combine any filter subset achieving a variable bandwidth filter. The outstanding advantage of the concept consists in the elimination of the guardbands at filters crossover, when using contiguous filters.

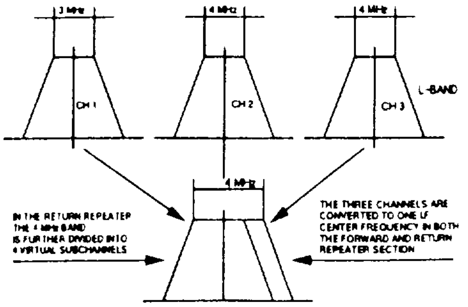

Fig. 2.3 EMS Forward Repeater Frequency Plan

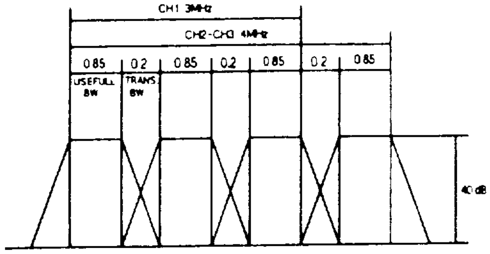

Fig. 2.4 EMS Return Repeater Frequency Plan

Table 2.1 EMS Payload Characteristics

| | |
|---|---|
| - Coverage | Global European |
| - L Band EIRP | 44.5 dBW |
| - L Band G/T | - 1.2 dB/K° |
| - Forward Useful Bandwidth | 11 MHz total in three channels 4, 4. and 3 MHz wide |
| - Return Useful Bandwidth | 9.35 MHz, in 11 channels 0.85 MHz wide each. May implement a BSSF combiner |
| - Ku-Band EIRP | 34.9 dBW |
| - Ku-Band G/T | -1.4 dB/K° |
| - Payload mass including Ku-Band Feederlink | 60 Kg. |
| - Payload DC Power including Ku-Band Feederlink | 400 W |

## 3. THE L-BAND LAND MOBILE PAYLOAD

### 3.1 Mission Requirements

The L-band Land Mobile Payload must provide the same kind of service of EMS Payload, but with different coverage and EIRP requirements.

A spot beam coverage over Europe will be provided at high EIRP (+ 51 dBW) and G/T (+ 2.5 dB/K°) levels.

### 3.1.1 LLM Payload Main Characteristics

The main performances of the LLM Payload are summarized in Table 3.1.

Europe will be covered both by a global coverage and by 6 spot beams as depicted in Fig. 3.1 and 3.2.

A steerable beam is available that can be moved over the positions shown in Fig. 3.3

The same frequency can be reused between spot beam no. 1 and 6 and between spot 3 and 5.

The LLM channel G (4 MHz wide) is permanently connected to the Euroglobal beam, whereas each 1 MHz slot in the L1 and L2 frequency bands can be connected to each spot beam of the L-band coverage.

The LLM Payload is able to perform as EMS back-up system.

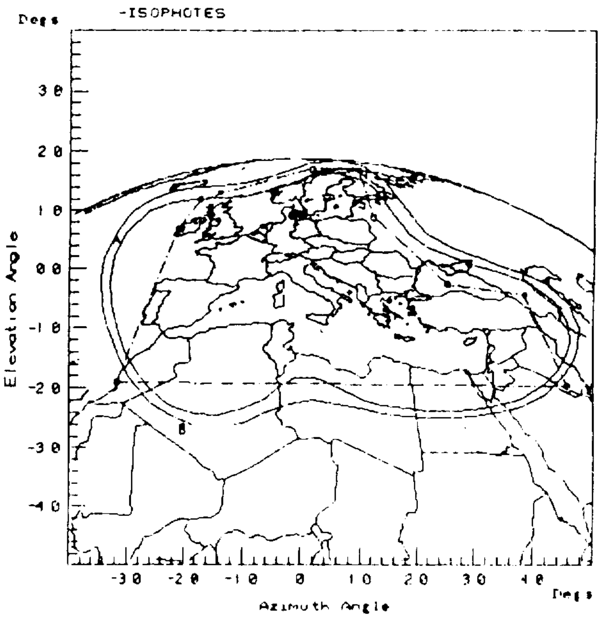

Fig. 3.1 LLM Payload Gain Contours (Euroglobal Coverage)

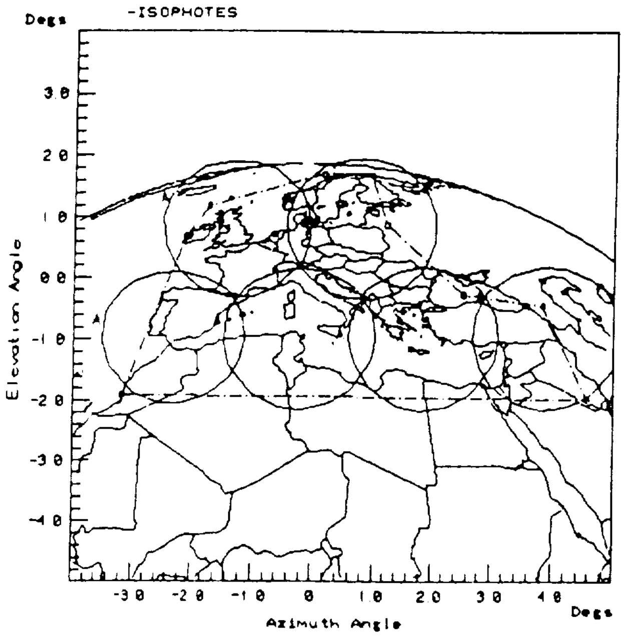

Fig. 3.2 LLM Payload Gain Contours (Beam Coverage)

### 3.2 LLM Payload Block Diagram Description

The LLM Payload L-band Section is based on a large reflector, offset antenna with the following characteristics:

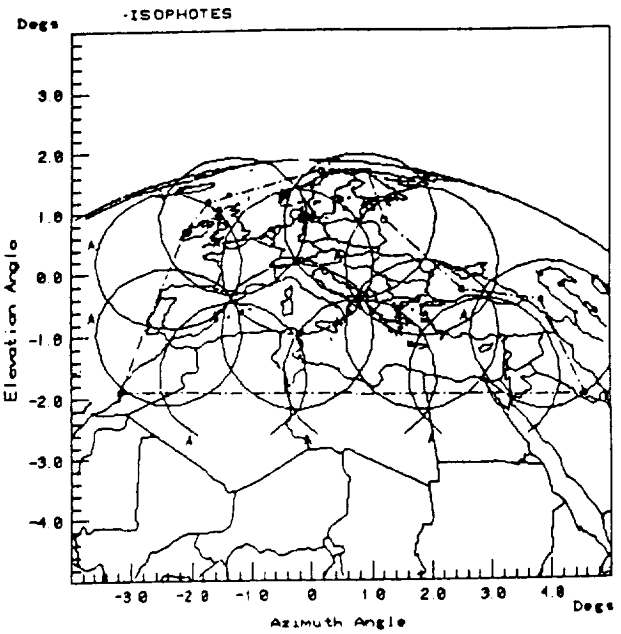

Fig. 3.3 LLM Payload Gain Contours (Steerable Beam)

| | |
|---|---|
| - Projected Aperture | 5 m |
| - F/D ratio | 0.625 |
| - Focal Length | 3.125 m |
| - Clearance | 0.71 m |

The reflector is implemented by an inflatable structure manufactured by Contraves.

The L-band Feed Array is composed by 12 radiating elements, that are LH circular polarized except three of them that can provide both senses of circular polarization.

The Euroglobal Beam is generated by combining the signals from all of the twelve radiating elements, whereas the spot beams are synthesized by the signals from selected triplets of feed elements.

The correct phase distributions for the beams are generated in the Forward and Return Beam Forming Matrix.

The L-band High Power Section is formed by 12 dual-redundant SSPA's, of 10 W of output power each.
The Power Amplifiers are arranged as 3 Multi port Amplifiers of order 4 x 4. This particular configuration has been defined by ESTEC and is patented as "Multimatrix Antenna".

One of its most important feature is that it allows to share the available RF power among the various beams in whichever ratio according to the traffic demand.

In the Return Link, each line from the Feed Array to the BFM is equipped with a dual-redundant LNA.

There are two IF Processors, one in the Forward and one in the Return Link.

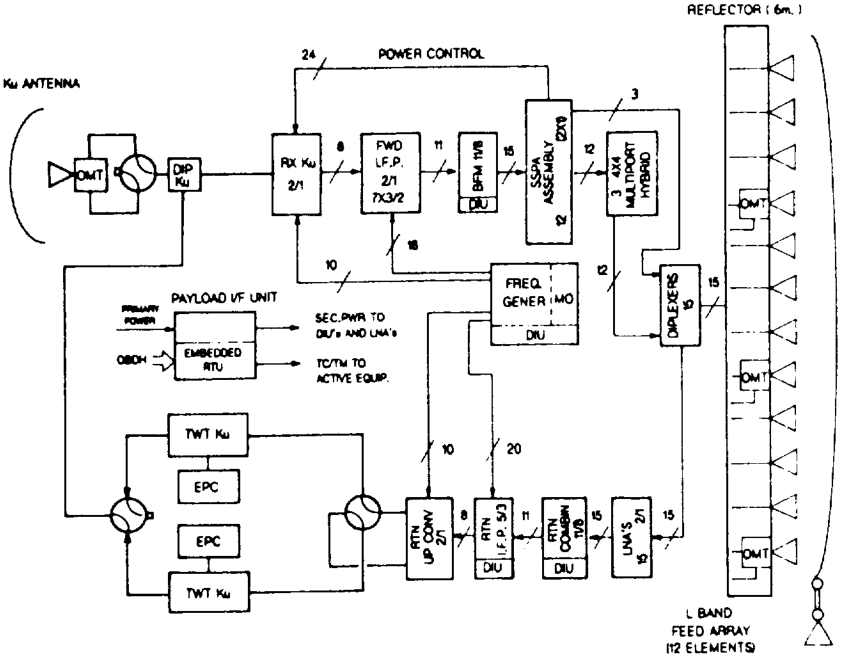

Fig. 3.4 LLM Payload Block Diagram

They perform channel filtering by using SAW filters and provide channel-to-beam switching function.

Each of them has a section dedicated to the EMS mode.

The frequency band of the Feeder Link of this Payload is at Ku-band, but the frequency allocation is not yet been defined. The Ku-band antenna is a 42 cm. onset parabola that can provide signals both in vertical and horizontal polarization.

The actual sense of polarization can be selected by ground command to cope with coordination requirement with other systems.

The received signals are LN amplified and down-converted by the Ku-band Receiver and then provided to the Forward IF Processor.

On the other side, the signals from the Return IF Processor are up-converted in the Return Upconverter.

The RF power at Ku-band is provided by a TWTA of 20W linear power that works at 6 dB back-off to cope with the linearity requirement.

## 4. ECONOMICAL ASSESSMENT

The growth projections for mobile communications in Europe predict a potential market of 12 million users by 1995. At least an 8% of these can be served economically via satellite. To satisfy this demand the EMS payload should be available in orbit by 1993 providing some 400 channels.

The ITALSAT F2, scheduled for launch in the same time frame, is a convenient opportunity to embark the EMS payload because of the minimum impact on ITS primary telecommunication mission [1].

In this respect the estimated cost of the space segment for the EMS mission is in the order of 10 to 13 million dollars per year while the potential revenue could be up to three times higher. The operator can take advantage of this opportunity considering also the possibility to have in orbit the LLM payload whose equivalent capacity could be leased for operational purposes. Financial risks should be agreed on the basis of the effective traffic carried out while preserving the technological content of the EMS and LLM missions which represent the forerunner of a dedicated commercial system.

## CONCLUSIONS

Selenia Spazio has defined two payloads for Mobile Communications. The EMS Payload is a relatively "simple" payload in order to provide a pre-operational mobile communication service over Europe with limited risks within the required time frame (1993). The LLM Payload, through the experimentation of beam coverage at very high EIRP levels, intends to provide a field for development and testing of advanced technologies such as very large antennas, Beam Forming Matrices and Multiport Amplifiers that will be useful for future mobile communication payloads.

Both the systems have been demonstrated to be able to provide an adequate financial revenue.

Table 3.1 LLM Payload Performance Summary

| | | |
|---|---|---|
| EIRP | L-band Euroglobal | +45.9 dBW |
| | L-band Spot Beam | +51.4 dBW |
| | Ku-band Euroglobal | +38.3 dBW |
| G/T | L-band Euroglobal | + 4.9 dB/K° |
| | L-band Spot Beam | - 1.2 dB/K° |
| | Ku-band Euroglobal | - 1.5 dB/K° |
| Coverage | See Fig. 3.1 and 3.2 | |
| Linearity | L-band C/I > 16.1 dB | |
| (10 tone test) | Ku-band C/I > 21.1 dB | |
| P/L mass | 140 kg. | |
| P/L Power Cons. | 611 W | |

## REFERENCES

1. Selenia Spazio Final Report: "Study of Technological Boundaries for the EMS Payload accomodation on Italsat F2" ESA Contract 8070/88 April 1989

2. G. Perrotta, F. Rispoli: "Characteristics of first generation L-band Payloads for land mobile applications in Europe" 19th European Microwave Conference London Sept. 1988

3. ESA contract 8332/89: "Investigation into a Combined Italsat/PSDE SAT2 Mission" ongoing at Selenia Spazio.

4. A. Saitto, D. Patel, G. Doro, B. Trombetta: "High Efficiency Satellite Antenna" Electronic Letters; April 1983, Vol. 19

5. Andreassen, Viddal: "Bandwidth Switchable SAW Filters (BSSF) on Quartz" Ultrasonic Symposium Proceedings, 1988

6. Selenia Spazio Document: "L-band Land Mobile Payload Detailed Definition and Interface Description", RPT/SAT/0181/SES, March 1990

7. S. Egami and M. Kawai, "An Adaptive Multiple Beam System Concept" IEEE Journal vol. SAC-5, no. 4, May 1987