COMMUNICATION SATELLITE PAYLOADS: A REVIEW
OF PAST, PRESENT AND FUTURE ESA DEVELOPMENTS

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Summary

The successful launch of OTS in 1978 has demonstrated in orbit the capability of European Industry to produce a number of microwaver "firsts" in the 14/11 GHz band. Some of these "firsts" e.g. parametric amplifier, downconverter and TWTA's are or will be re-used in other satellites. Such equipment was the outcome of a preparatory programme started in the early '70 and intended to foster development of space hardware for the Ku band.

The purpose of this paper is to survey the present developments and the future plans for the microwave payloads of communication satellites sponsored by the European Space Agency. These payloads will be reviewed separately for the various applications namely Mobile, Fixed and Broadcast communications.

In each case the basic programme and the payload concept will be shortly described. The development of the key elements of each payload will be illustrated showing the technical solution adopted and the results achieved. A comparison with other solutions or programmes will be outlined.

Finally the future developments foreseen in the Medium Term Plan of the Agency will be examined: two specific examples will be discussed a 30/20 GHz Domestic Satellite Payload using on board regeneration and the payload of L-SAT a newly proposed experimental satellite.

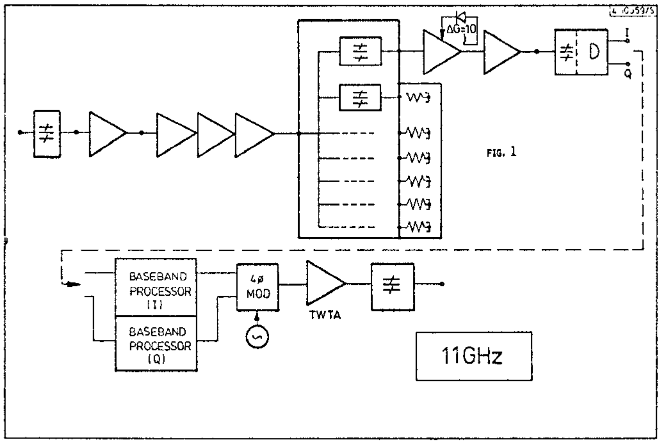
Fixed Services

European hardware has been developed in the 14/11 GHz band for the OTS satellite, presently operating in orbit, and will be used unchanged in the operational ECS (European Communication Satellite).
These developments have been fully documented.[1,2]
Developments have also been done in the 30/20 GHz frequency band, to assess hardware performance.[3]
A 30/20 GHz repeater has been integrated and tested with digital signals at 60 and 180 Mb/S.[4]
The front-end of the repeater: a mixer down-converter and a low-noise X-band amplifier, cover the full 2500 MHz range with 10 dB noise figure, the mixer can also be tuned for lower conversion loss over narrower bandwidths, see table 1.

Instantaneous Bandwidth GHz	Maximum conversion loss dB	Maximum input VSWR
2.0	5.5	2.4
1.5	5.0	2.2
1.0	4.8	1.8
0.5	4.5	1.3
0.25	4.2	1.3

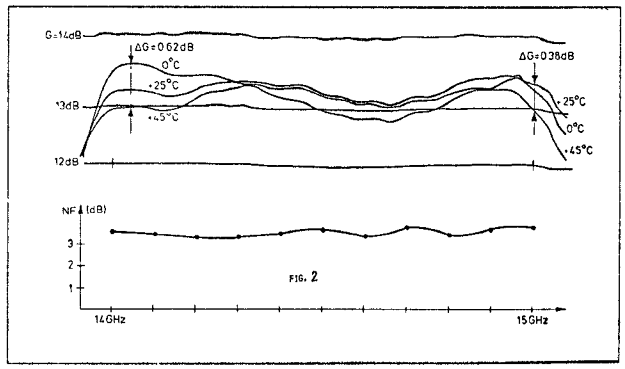
Table 1 Conversion loss and input VSWR vs. instantaneous bandwidth for the 30/11 GHz mixer.

The frequency response over the bandwidth of a channel (40 or 120 MHz wide) is flat within 0.5 dB and 3 ns; the E/No degradation through the saturated repeater with respect to the back-to-back Modem loop is 0.9 dB at 10^{-4} and this compares well with the results obtained through the 14/11 GHz repeater.[5] Further work in this area is ongoing with the development of a 30GHz parametric amplifier. More recently the development of a regenerative repeater has been started. This repeater is being developed for purpose of evaluation and testing: will operate at 14/11 GHz and is specified for passing 120 Mb/s digital signals. The block diagramme is given in fig. 1.



Block diagramme of Evaluation Model of Reg. Repeater.

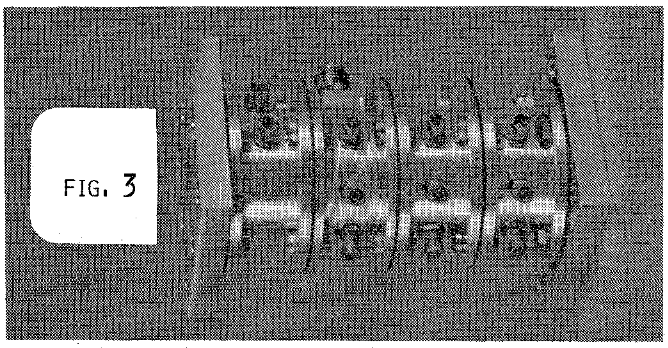
The front-end receiver is a cascade of FET amplifier stages: the results obtained on the low noise stages are shown in fig.2.



Gain and NF for 14 GHz low-noise pre-amplifier.

The demodulation is achieved via a differentially coherent demodulator implemented directly at 14 GHz: the stable delay line (16,6 ns) has been obtained using a line on $BaTi_4O_9$ further compensated by a short line on alumina. The phase variation over the temperature range 10 to 40°C is ± 2,5 degrees. The shaping filter in front of the demodulator has also the function of channel filter: its implementation in a very compact form has required a special design.[6] The filter is shown in fig. 3
The modulator, presently under completion, has been implemented with dual gate FET, directly at 11 GHz. The baseband switching matrix is still in a preliminary phase of development: its completion is planned, in a 16x16 size for mid '81. In conclusion all the elements

of a 14/11 GHz regenerative repeater are being completed and extensive evaluation is planned for late in the year at unit level. The integration of the whole repeater requires still a multistage FET front-end and a baseband processor: both activities are already contracted.

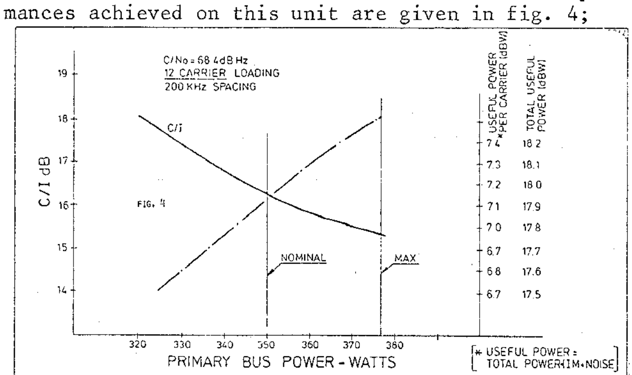


Pre-demodulation filter for the Reg. Repeater.

Mobile Service

The microwave hardware for this application has been developed along two different system concepts: the MARECS (Maritime European Communications Satellite) and the MAM (Multibeam Array Model).

The first concept provides 34 dBW of EIRP at 1535/1560 MHz in the shore-to-ship link via a global beam with 17,5 dB at edge of earth coverage, and a 60W transistor amplifier. The development of all equipments has passed the stage of qualification. The main problem in the payload has been the design of the high power L-band transistor amplifier capable of high efficiency reliable operation in multicarrier. The performances achieved on this unit are given in fig. 4;

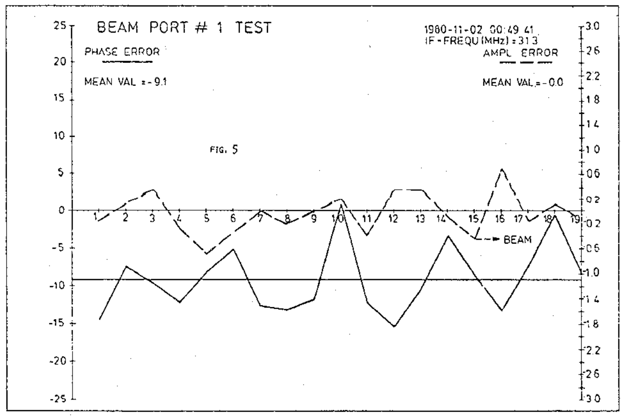


Power and C/I for MARECS Transmitter (Qual. Model)

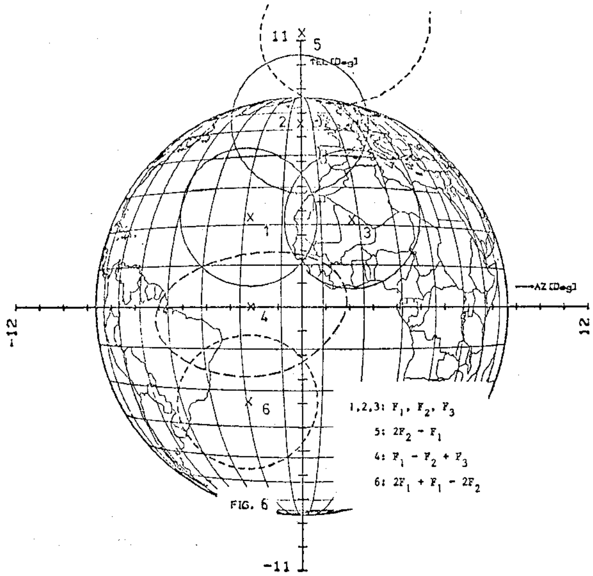
considerable effort has been spent on the implementation of linearisation techniques, to the qualification programme of the transistor and to the characterisation of amplifier non-linearities in multicarrier, [7,8].

The second concepts provides 45 dBW of EIRP via an 18 beam array antenna and 18 transistor amplifiers each having an output of 9W. The development to date has concentrated in the transmit section and has reached Engineering Model stage. The performance evaluation of this section has been carried out with advanced testing methods, [9]. The main question in the design of an array payload, is in the level of phase and amplitude matching between the 18 amplifying chains: such matching must be obtained at unit level and then completed during the alignment. The calibration of phase and amplitude errors were under desk calculator control, a typical plot is given in fig. 5; similarly the measurement of output power and intermodulation products on each o/p port was also done with semi-automatic procedure.

It is to be noted that the difference between the performance of a global beam concept and an array concept is not only in the achievable EIRP, higher in case of an array for the same DC power, but also in terms of intermodulation level. Indeed, see fig. 6, for the same principle through with the various channels are phased in a given beam, their intermodulation products are phased in different directions. This advantage disappears of course in case all beams are equally loaded.



Calibration errors, ampl. and phase for MAM transmitter.



Off-setting of intermod. beams w.r.t. signal beams.

The performances of the TPA's used in the MAM transmit section are given in table 2.

Transistor Power Amplifier for L-band array

Bandwidth (at 0.3 dB)	23 MHz
Gain	53 MHz ± 0.2 dB
Phase tracking	<5°
Output power	9W (rms)
C/I with 3 carriers	>23 dB
Efficiency	>28%
Mass	<600 gr.

Transistor: class AB common emitter configuration; two Mullard six cells devices are paralleled in the final stage.

Future activities in the Mobile Service application, apart from the MARECS launch planned for December 80, are the integration into the array of the receiving section, i.e. 18 diplexers and 18 receivers plus additional work in the IF processing part.

Broadcast Service

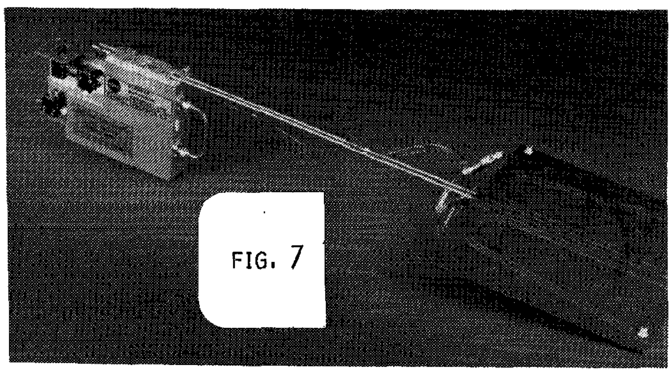
The developments in this area have concentrated up to now in the feasibility of satellite front-end capable of wide-band and low noise figure in the 18 GHz uplink recently allocated to this service.

The front-end solutions being evaluated are: a degenerate parametric amplifier and an FET amplifier. The parametric amplifier breadboard has been completed and its performance extensively tested over frequency, temperature and pump level. Some results are given in table 3.

Performance data of 18 GHz degenerative paramp

Operating bandwidth	18.3 / 18.7 GHz
nominal gain	12 dB
gain variation over -5 to +45°C	0.9 dB pk to pk
gain variation over 400 MHz	0.5 dB
gain variation over any 27 MHz	0.15 dB
noise figure (w/o filter)	4.7 dB max
linearity: 2 i/p carriers each -40 dBm	40 dB down

The FET amplifier work is under completion: noise figure of the first two stages is 5.2 at band center and gain is 10.5 dB $\pm$ 0.25 over 19.4 to 20.2 GHz. The improvements on noise figure attainable by cooling an FET at low temperature has been widely reported: such concept has been assessed recently[10] using a technique suitable for use in space, i.e. cooling by heat-pipe. A heat-pipe constitute a simple and light weight means of conducting the heat away from the front-end device to an external radiator. The set up used in the test is shown in fig. 7; the results have confirmed the predicted improvement.



Heat-pipe cooling of X-band FET amplifier.

Advanced 30/20 GHz Communications

In the frame of the Advanced Supporting Technology Programme a system study has been completed for the definition of a high capacity 30/20 GHz communication system intended to handle the telephone traffic over Italy in the year 2000. The key outcome of the study is as follows: very narrow beams (0.25°), i.e. very high antenna gain, is necessary to ensure the link because of the deep fades due to heavy rain; up to 13 beams, and 17 channels, are necessary to provide the coverage and the capacity of this future system. The interconnection between beams is foreseen at baseband and regenerative repeaters would be required. The system would make use of a single station per spot beam thus both up and down link can operate in a continuous mode: the concept can be defined as SS-TDMD single access and Multiple Destination.

To date only a first phase of the system definition has been completed and it is quite clear that such ambitious programme will require extensive investigation and pre-development to assess the hardware feasibility in all respects. Such development programme exist and will be carried out over the '80-'82 period.

Fig. 8 gives the coverage with the location of the spots and the frequency plan. The frequency plan assigning the channel to the respective city has been arrived at after careful assessment of the interferences due to the co-channel and adjacent channel level. The sidelobe template used is given in fig. 9 and a computer programme calculates the contribution, in each channel, of all other channels taking into account their position in the frequency, their allocation, the sidelobe template and the TWTA spectrum spreading.

L-SAT Communication Payload

The programme is now in the definition phase. The communication payload in its present shape includes

(i) a TV-broadcast payload with two channels and two beams.

(ii) a data transmission payload with four channels and five beams

(iii) a 30/20 GHz experimental payload with three channels.

(iv) a propagation package with beacons at 30 and 20 GHz.

Conclusions

European industries are presently working on a variety of new challenging subjects. Some of these new developments are intended for evaluation of new technlogies and techniques; others have been started off for more immmediate applications. The European Space Agency wishes good success to all of them.

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