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A. Langemeyer

Symphonie Executive Comittee

F. Pene

Symphonie Executive Comittee

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THE SYMPHONIE SYSTEM AND ITS UTILIZATIONS

A. LANGEMEYER

F. PENE

SYMPHONIE EXECUTIVE COMMITTEE

ABSTRACT

After the successful completion of the SYMPHONIE project development phase, which resulted in the injection into geostationary orbit of two flight models (December 1974 and August 1975), the French-German programme is carrying on in the aim of setting up and performing a great number of different experiments demonstrating the capability of this 4/6 GHz satellite system to comply with all kinds of utilizations.

Based upon the capability and the performances offered by the spacecrafts (three-axis-stabilized) and their telecommunication payload (two repeaters each with 90 MHz bandwidth associated with two spot beam transmitting antennae) together with several earth stations (primary stations, secondary transportable stations) there is an ambitious programme of experiments, the main categories of which are listed below :

- experimental telecommunications programme including the French-German tests and other tests with or by foreign countries (e.g. ISRO-programme) ;
- technological test programme to evaluate the performances of the spacecraft (e.g. three-axis-stabilization subsystem) ;
- demonstrations in the frame of various shows and expositions such as the Paris Air Show in le Bourget and TELECOM 75 in Geneva, and occasional TV transmissions for special events ;
- educational and humanitarian utilizations such as the UN experiment, the educational TV programme in African countries, and teleconferences ;
- preoperational utilizations by France, Germany and by/with foreign countries covering various types of transmissions (TV, telephone, data).

As a conclusion, the present status of the SYMPHONIE utilization programme clearly shows the real need for such an experimental system together with the fact that it strongly contributes to the demonstration of European know-how and technology in the field of space communications systems.

1. INTRODUCTION

In 1967, the Governments of the Federal Republic of Germany and France decided to jointly develop a telecommunication satellite system and to launch two satellites. One year later the French-German industrial consortium CIFAS, in which the French companies Société Nationale Aérospatiale (SNIAS), Thomson-CSF, Société Anonyme de Télécommunication (SAT) and the German companies Messerschmitt-Bölkow-Blohm (MBB), Siemens, AEG-Telefunken participate, was charged with the development and construction of the satellites.

The discontinuance by the ELDO program of the EUROPA II launcher, which had originally been destined to launch the two SYMPHONIE satellites, and the subsequent change to the NASA launcher Thor Delta 2914 led to a delay of only half a year. Thanks to the good cooperation between NASA and its contractors on the one side, and SYMPHONIE on the other side the initial difficult technical problems - such as vibration specifications, transfer orbit parameters and launch site security rules - could be solved.

On December 19, 1974 at 2.39 hrs (GMT) the first flight model was successfully launched, and on August 27, 1975 at 1.42 hrs (GMT) the second flight model. After having been positioned the two satellites entirely fulfilled their telecommunication missions. The only failures to be recorded to-date are the breakdown of the redundant local oscillator. Uncritical disturbances of the telemetry/telecommand system were caused by charging effects which could not yet be fully clarified.

2. DEFINITION AND MAJOR CHARACTERISTICS OF THE SYMPHONIE SYSTEM

The Symphonie System, in operations since the beginning of 1975, consists of :

- a) The space segment with two identical satellites stationed at 11°5' W, the attention is to be drawn essentially to - the three axis stabilized spacecraft by a semi-active system allowing actually the orbit control within $\pm 0^{\circ}25$ E/W and N/S (2 corrections per year) and an attitude control within $\pm 0^{\circ}3$ (1 to 2 corrections per week)
 - the telecommunications payload consisting of two identical wide-band repeaters

(90 MHz) associated with two transmission antennae providing two dedicated earth receiving areas with an EIRP better than 29 dBW (edge).

b) The ground segment based upon two primary stations (so called standard) located in Raisting (W-G) and Pleumeur Bodou (P) offering identical performances such as a $G/T = 31.5 \text{ dB/}^\circ\text{K}$ (with a dish diameter of 16 m), uncooled parametric preamplifiers and 3 kW transmitter.

In addition, several stations have been developed for the purpose of the utilization plan of Symphonie. Among these stations, we will notice for instance :

- Four 8,8 m diameter receiving stations ($G/T = 26,5 \text{ dB/}^\circ\text{K}$) dedicated to the Educational TV programme in Africa,
- one 5 m diameter T/R station ($G/T = 20 \text{ dB/}^\circ\text{K}$, 250 W transmitter) used to experiment digital telephone technics and visiophonie (teleconference system),
- one 3 m diameter T/R station providing one voice channel + telex (or a fac-simile transmission).

Other stations are under development by the time being (ex : two multipurpose T/R station).

3. TELECOMMUNICATION TEST PROGRAM

3.1. Verification of the telecommunication specifications of the satellite

This verification consists of ten test series :

- 1 - the satellite's EIRP
- 2 - receiving sensitivity of the satellite (G/T)
- 3 - bandpass characteristic of the transponders
- 4 - group delay behavior of the transponders
- 5 - stability of frequency conversion
- 6 - stability of amplification
measuring of nonlinear distortion :
- 7 - level of intermodulation products
- 8 - AM/PM conversion
- 9 - intelligible crosstalk
- 10 - EIRP, level and frequency stability of the beacons

The main purpose of this verification is to prove that the satellite's properties, which had been measured on the ground, did not change while in orbit. These measurements were carried out by the Pleumeur Bodou and Raisting stations which are not special measuring stations but regular operational stations. In some measuring series for example - such as the measuring of the transponder bandpass characteristic - the influences of the ground stations on the measuring results could not be completely eliminated. The observance of the specified values could therefore only be confirmed within the scope of the measuring accuracy.

3.2. Optimization of the transmission parameters

In this test series transmission tests with telephone, telex and data channels in single and multi-carrier operation are carried through. Since the

satellite's transponder is fully controlled, and therefore no longer only operates in the linear range of its characteristic curve, the optimization of the transmission parameters is necessary in order to optimally use bandwidth and satellite power for a given minimum transmission quality. The influence of the number of carriers, their distance from each other and the transmitting power, which determines the distance from the operating point to the saturation point, on the signal-to-noise ratio of the telephone channel was experimentally determined. For flight model 1 these measurements, in multi-carrier operation, resulted in a capacity of 768 channels for the transponder b, and of 624 channels for the transponder d. The different capacity of the two transponders is a result of their different frequency plans. The frequencies of the operation carriers were therefore arranged in such a way that intermodulation products fall together with operation carriers. The cross-talk attenuation was not allowed to fall below 60 dB.

A further test series dealt with the verification of transmissions of television and sound channels with optimized transmission parameters. The transmission of a single TV signal according to specifications could be valued with quality grade 5, i.e. the highest reachable. During further tests one TV channel and two sound channels were transmitted without reciprocal interference. The transmission of two TV channels still reached quality grade 4.

3.3. Newer transmission procedures

After conclusion of the above-mentioned measurements transmission procedures are to be tested with the aid of SYMPHONIE in order to increase the transmission capacity of satellite links.

This year, for example, a French-developed procedure, by which 30 analog channels are to be put together into 6 single channels plus two 12-channel systems or one 24-channel system respectively, is to be tested.

To improve the transmission of TV and sound channels digital procedures for the transmission of TV signals are to be tested. The procedure of putting sound channels and a picture channel into one carrier is to be examined just as well as the integration of sound channels into the sync pulse or by digital coding into the horizontal blanking interval between picture informations. Further tests are to deal with video telephony (picture telephone) and with the transmission of four 15 kHz sound channels concentrated in 24 telephone channel carriers.

For the future it is also planned to use SYMPHONIE for the testing of TDMA procedures. However, the development of the ground equipment has not yet prospered far enough to set up a concrete test program.

3.4. International cooperation

Besides the experiments described sofar, which were mainly executed by Germany and France, measuring and transmission tests are also to be carried out by other countries. Among other things, the capacity of one transponder was made available to India for such purposes for a period of two years. One of the two flight models will therefore be moved from its actual position at 11,5 degrees West to a position at approximately 50 degrees East.

4. TECHNOLOGICAL TESTS WITH THE SATELLITE

Besides the telecommunication tests, experiments with the space technological subsystem of the satellite are carried out.

4.1. Apogee motor

The liquid apogee motor used for SYMPHONIE represented the first application of liquid propulsion for kick motors by spinning satellites. The exact power had to be determined, and the problem of the spin movement of the liquid-propellant-filled tank had to be observed. The flight measurements brought fully satisfactory results. In comparing transfer and primary orbit the velocity increments reached for PM1/PM2 were measured to be 1473.5/1466.6 m/s; predicted were 1473.0/1465.3 m/s. Thus the deviation amounted to + 0.03/+ 0.09 %.

4.2. Hot gas system

The also newly developed biliquid attitude control system is still to be measured as to its real performance in orbit. Investigations on the minimum realizable thrust impulses led to switching times of 0.016 s. This thrust system is therefore also suited for attitude control, especially for shifting the pitch axis.

4.3. Static infrared horizon sensor

Due to initial procurement difficulties a static infrared horizon sensor for the alignment of the satellite to the earth was also developed in the framework of the project. Measurement results indicated a dispersion of less than ± 0.03 degrees. The winter/summer drift was measured to be 0.28 degrees.

5. DEMONSTRATIONS

The world-wide promotion of the system has been made through active demonstrations in several occasions such as :

- Le Bourget Air-show (Mai 75) where two stations allowed the demonstration of the "visiophonie" system developed by CNET and the educational TV reception,
- Telecom 75 (oct.75) where the multiple capability of SYMPHONIE has been shown thanks to three simultaneous demonstrations : visiophonie, educa-

tional TV and mobile telephone small station ($\phi 3m$),
- DGLR Symposium (nov. 75) : telephone transmission.

In the mean time, SYMPHONIE has also been used to transmit special events such as :

- alive transmission of the launch of Soyouz spacecraft (Apollo-Soyouz mission in Jul. 75),
- visit of the french President in Moscow (oct. 75).

6. EDUCATIONAL AND HUMANITARY UTILIZATIONS

The purpose of such utilizations is to demonstrate the ability of a space telecommunications System to solve various problems in the field of mass education and also to help for in case of disaster relief and/or peace keeping operations.

- For educational experiments, SYMPHONIE has developed four TV reception stations. The first one is now installed and operated in Ivory Coast in order to feed this country with educational TV programmes produced in France and Germany in addition with those produced by Ivoirians. The remaining stations are planned to be installed in the near future in other african countries.
- A small air transportable 3 m station (shown in telecom 75) has been provided to UN for several months in order to experiment the ability and the interest to provide an immediate and direct communication service between HQ in Geneva and New-York and a peace keeping mission located in Middle-East.
- In addition several and various teleconferences will be held through SYMPHONIE for the purpose of Culture, Education, Science... (i.e. cooperation with Canada).

7. PREOPERATIONAL UTILIZATIONS

The intent is to take opportunity of SYMPHONIE to perform experiments complying with all kinds of constraints and requirements of operational service in order to get all actual results which can be used later to size and set up a future real service. Two projects will enter in operation this year :

- the french PTT will use SYMPHONIE to relay the telephone communications between France and La Reunion island (Jul. 76),
- West Germany will transmit, through SYMPHONIE, radioprogrammes to a radiobroadcasting station located in Kigali (Rwanda, Africa).

8. CONCLUSION

When considering the present stage of the SYMPHONIE operations and looking forwards the future utilization plan, there is no doubt in the real need for such an experimental system available, under very limited constraints, to perform any kind of experiments in the field of the space communications.

In addition, the flight proven mission performances of the two SYMPHONIE satellites clearly demonstrate the european know how in the technology of space Communication systems.