EXPERIMENTAL SATELLITE PHASE 3D BEFORE LAUNCH

Miroslav KASAL, Jiří ŠEBESTA
Institute of Radioelectronics
Technical University of Brno
Purkyňova 118, 612 00 Brno
Czech Republic

Abstract

To build a satellite can be a dream for many engineers. We are happy that we can participate in the AMSAT PHASE 3D project. Our responsibility is very high because one of our on-board receivers is the main one for the command link and will never be switched off. The project is also a very good opportunity for our students to meet satellite technology.

Keywords

satellite, satellite communication

1. Introduction

The satellite has been developed by the international corporation AMSAT that is a non-profit organisation. Its aims are to build experimental satellites with a very wide access for scientific and educational purposes. There is only one limitation for users - national amateur radio licence. On the other hand, the amateurs bands (with space segments) are allocated world wide and allow relatively simple administration before satellite launch. During the past thirty years AMSAT launched more than 30 satellites on different orbits.

In the order of AMSAT satellites, the last one developed is the international spacecraft PHASE 3D (P3D). The satellite structure is a hexagonal cylinder that is 2240 mm across the corners and 675 mm high. The spacecraft mass is about 600 kg and its getting to the final orbit will require a substantial propulsion by a 400 N hypergolic motor. For a fine orbit correction, the small ammonia plasma thruster (0,1 N) has been developed at the University of Stuttgart. The spacecraft will be three axis stabilised by means of three momentum wheels with a magnetic bearing developed at the Universities in Marburg and Darmstadt. Only the manoeuvring satellite will be stabilised by rotation around the short axis. Besides optical sensors, the sophisticated GPS system that has been supplied by NASA will be applied for the attitude control of the spacecraft. Besides the main payload - linear multiband transponder, the satellite will carry two colour cameras developed by JAMSAT (Japan), digital communication system called RUDAK (Germany, USA) and RF monitor experiment (Hungary). The total cost of the project is about 5 mil. US$ that is about 10 times less compared with a similar commercial satellite. More than 13 countries contribute to this project.

2. Matrix linear transponder

The P3D satellite will carry a linear transponder. The uplinks are in V, U, L, S and C bands and the downlinks in V, U, S, X, and Ka (24 GHz) bands. The transponder receiver and transmitter will be switched by means of the IF matrix for the selected crossband operational mode. Tables 1 and 2 contain the proposed parameters for the uplink and downlink [1].

In the frame of the agreement on co-operation with the Central Laboratory of Electronics Philipps University of Marburg and AMSAT-DL, two on-board receivers of the P3D satellite have been developed for the linear transponder and the command link on the L-band. The first with the central frequency 1268.450 MHz and the second with the central frequency 1269.375 MHz. The bandwidth of the analog passband is about 250 kHz. Because high-gain (SBF circularly polarised) and omni antennas will be applied, two LNAs directly connected to the antennas are used for achieving a low noise temperature [2]. The LNA's output signals are coming into the power divider through the PIN diode switch. Divided signals are coming into double conversion receiver modules. Besides the analog (linear) passband, a next 250 kHz passband for digital modes is reserved. Each receiver has three signal outputs - IF matrix, CMD unit and RUDAK unit as well as two telemetry outputs - AGC and TEMP, fig. 1, 2, 3.

Tab. 1. P3D transponder parameters for the uplink

Band	MHz	146	435	1268	2400	5600
T_N	K	1000	500	300	300	300
P_{RX}(23dB)	dBW	-142	-145	-147	-147	-147
G_{AS}	dBic	10	14	20	20	20
L_0	dB	170	179	188	194	200
EIRP	dBWic	18	20	21	27	33

- T_N is total equivalent noise temperature of the transponder receiver,
- P_{RX}(23dB) is signal level of single user at the transponder input for ratio C/N = 23 dB and bandwidth of single channel 3 kHz,
- G_{AS} is satellite antenna gain,
- L_0 are propagation losses (at apogee),
- EIRP is corresponded equivalent isotropic radiated power of user station. In all causes the RHCP will be applied.

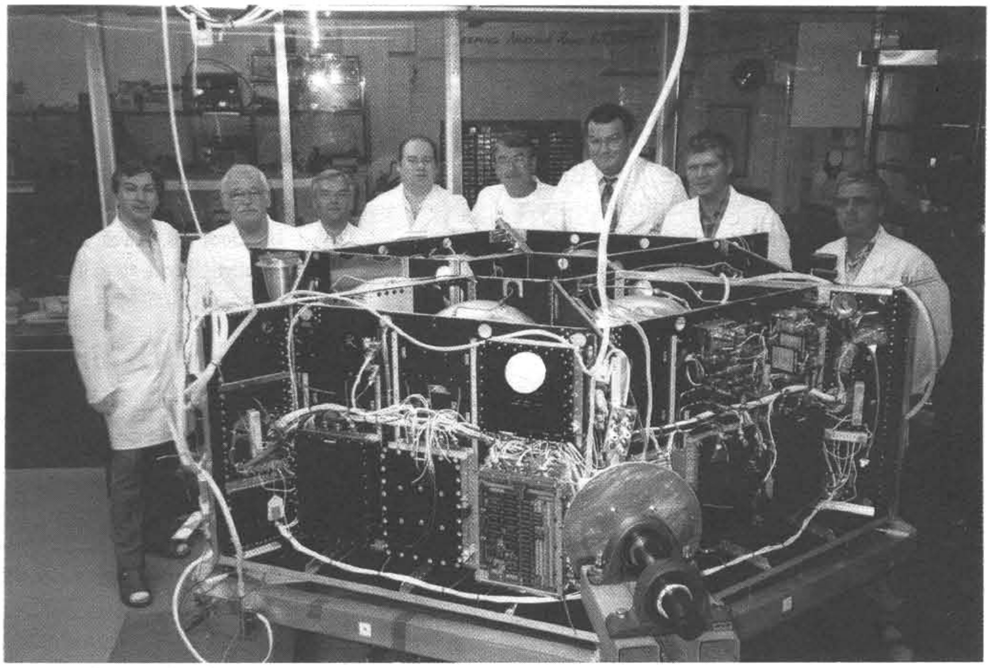

Fig. 2. European team at the P3D satellite body in Orlando AMSAT facility. The signed module (white circle) is the L-band receiver for the command link.

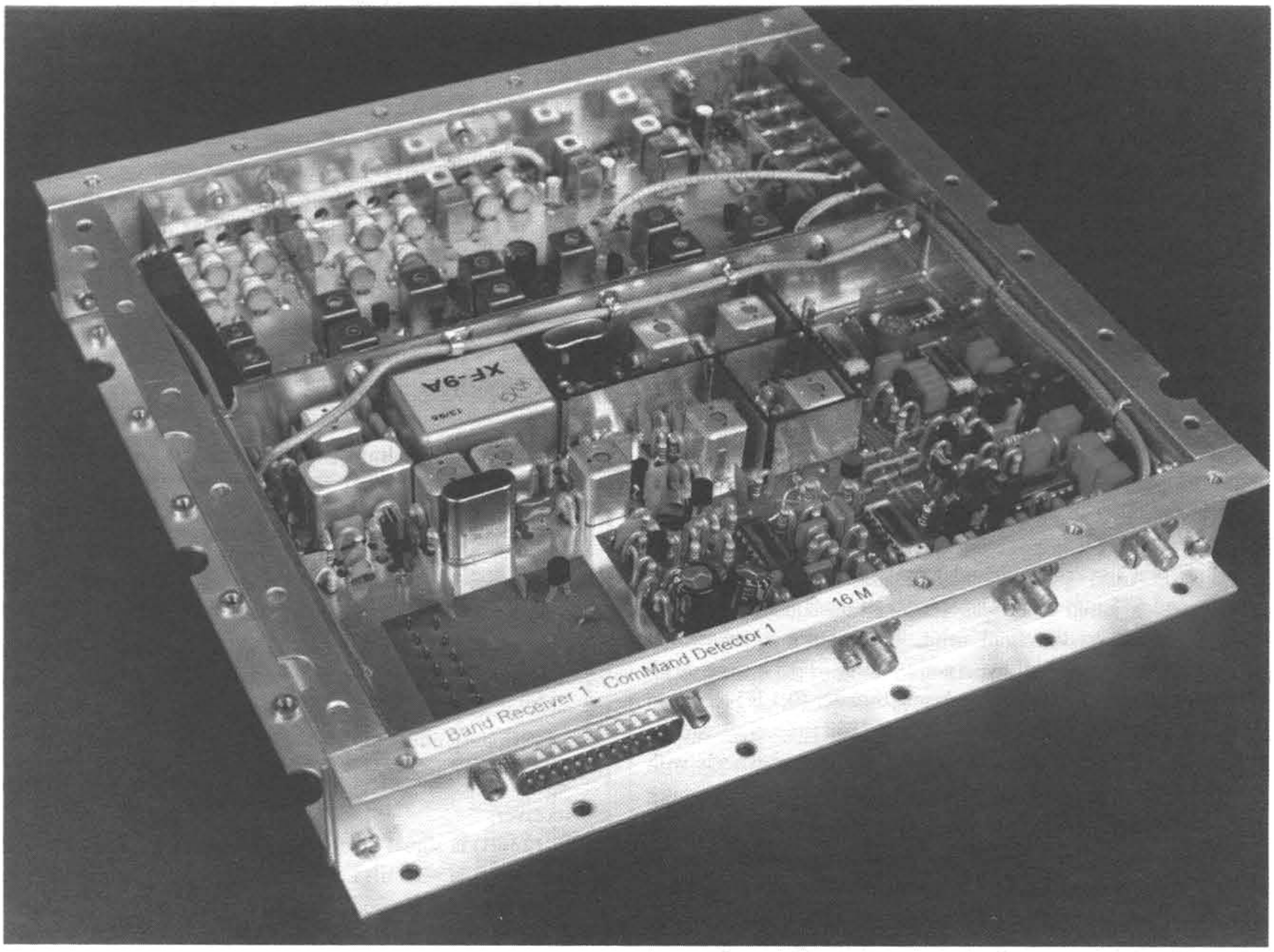

Fig. 3. P3D satellite L-band receiver with command detector

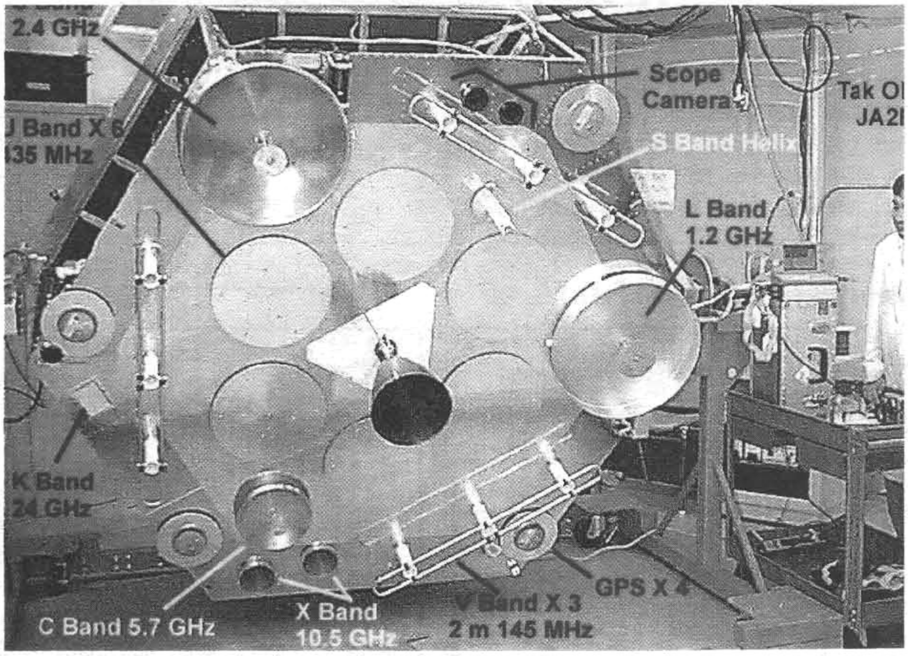

Fig. 4. P3D self portrait which was taken by using an on-board camera and mirror. Antennas are described.

Fig. 5. P3D satellite

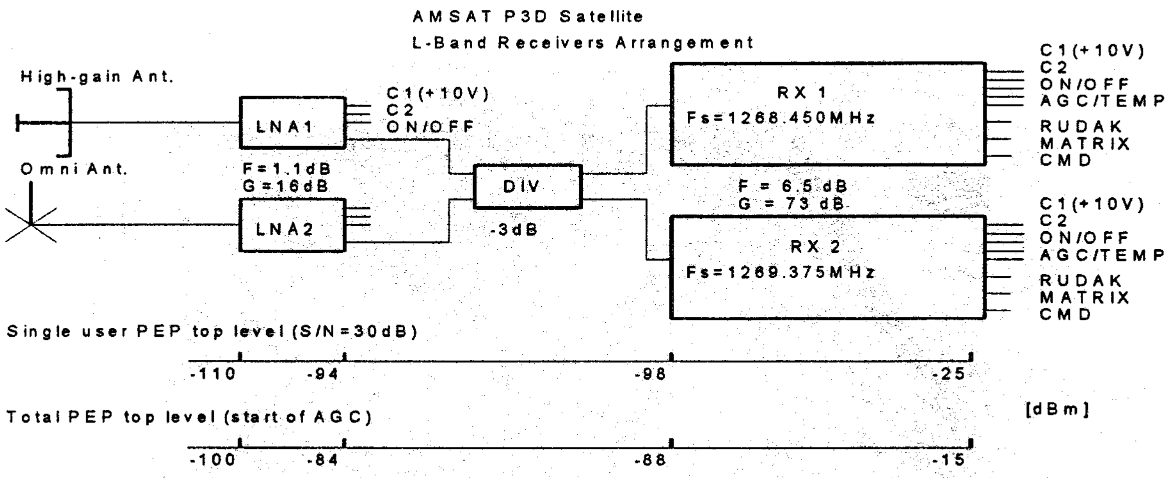

Fig. 1. P3D satellite L-band receivers arrangement

Tab. 2. P3D transponder parameters for the downlink

Band	MHz	146	435	2400	10500
PEP_s	dBWic	34	38	40	35
G_{AZ}	dBic	8	10	20	33
T_z	K	1000	500	300	150
P_N	dBW	-165	-168	-170	-173
P_s(0dBC/N)	dBWic	-3	+1	+4	+1
C_{PEP}/N	dB	26	27	26	24

- PEP_S is peak envelope equivalent isotropic radiated power of the transponder,
- G_{AZ} is antenna gain of the ground station,
- T_Z is equivalent noise temperature of a ground station,
- P_N is ground station receiver noise floor at T_Z and bandwidth 3 kHz,
- P_S(0dB C/N) is transponder EIRP corresponding to single user for C/N = 0 dB,
- C_{PEP}/N is resulting C/N ratio for ground station (the average C/N for SSB signal is about 10 dB lower).

3. Satellite launch and its orbit

The satellite is planned to be launched on one of the ESA new ARIANE 5 boosters from Kourou, French Guyana. If all goes as planned, the satellite will be placed on the 16 hour High Elliptical Orbit with inclination 63 deg. and apogee altitude 47 000 km. The satellite is fully integrated, fig. 5. In October 1998, the Thermal Vacuum tests were made. The whole satellite in vacuum environment was tested at different temperatures in the range from -25 up to +40 °C [3]. At present, the satellite is being prepared for the final Vibration Test in the Orlando AMSAT facility to obtain the certificate 'Ready for Flight'. Fig. 4 shows the satellite self portrait on the gain antennas side, which was taken by using an on-board camera and a mirror.

4. Satellite Laboratory at IREL

In the recent few years, we have equipped well our laboratory for satellite communication at the IREL. We have got a very significant support - grant FR470644 - from the Ministry of Education of the Czech Republic. We are able communicate in the V, U and L bands, and higher bands are under preparation. More than ten student projects were oriented to this field. Students develop special up and down converters, preamplifiers, modems, terminal node controllers as well as useful software. A fully automatic antenna tracking system has been developed and built. Advanced instrumentation and knowledge allow us to work as a secondary command station for P3D after launch.

References

[1] MEINZER, K.: Die Mikrowellenstrecken von P3-D. AMSAT-DL Journal,vol. 21, Nr. 1, pp. 9-11, 1994

[2] KASAL, M.: Real Gain of the Phase 3D On-Board L-Band Antenna. The AMSAT Journal, vol. 20, No. 4, pp. 11-12, 1997

[3] McFADIN, L.: Phase 3D Thermal Vacuum Tests at Orbital Services. The AMSAT Journal, vol. 21, No. 6, pp. 24-27, 1998

About authors...

Miroslav KASAL was born in Litomyšl in 1947. In 1970 he graduated in communication engineering from FEE TU Brno. In 1984 he obtained his PhD degree in metering engineering. He works as a head of Electronics Laboratory at the Institute of Scientific Instruments of the Academy of Science of the Czech Republic in the field of RF spectroscopy. He is Associate Professor at IREL FEI TU Brno. His scientific interests include RF and microwave techniques, satellite communication, signal processing, and scientific instruments.

Jiří ŠEBESTA was born in Brno in 1973. He received the MSc degree in Electrical Engineering of Technical University Brno in 1997. At present, he is the PhD student supervised by Assoc. Prof. Miroslav Kasal at IREL FEI TU Brno. His research interests are signal processing in radio communication systems.