

RECEPTION OF S-BAND SIGNALS FROM METEOROLOGICAL SATELLITES

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Summary

The Department of Microwave Telecommunication has been dealing with the S-band reception of meteorological satellites for a long time, in collaboration with the Electronic Institute of the Scientific Academy of the GDR. In the course of the research work, an autotrack antenna system, a low-noise RF amplifier and various other circuits have been developed together with the mechanical construction satisfying the environmental requirements of the outdoor location of these units. A number of such receiving systems are operating successfully. The paper reports on the authors' experience gained with the system and discusses their work done so far in connection with further development.

Introduction

Meteorological satellites, according to Figure 1 transmit nowadays mostly in the lower S band. Their modulation can be narrow-band analog (WEFAX) or broad-band digital (HIR). Polarization may be linear or circular [1].

This paper gives a description of a multi-use experimental earth station as a joint development work of the Institute for Electronics (Neustrelitz; under the

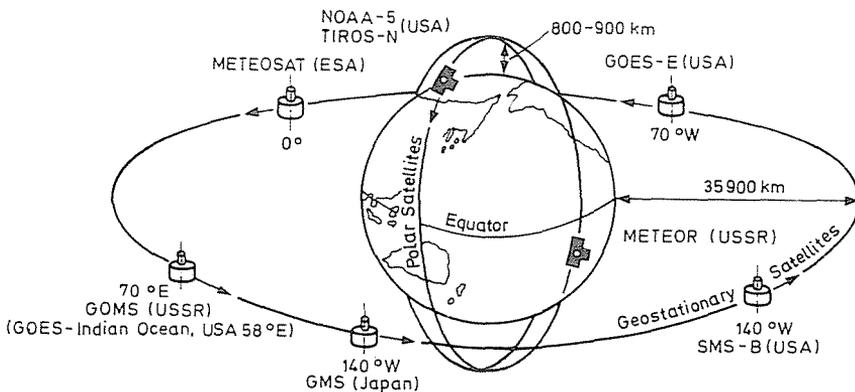


Fig. 1

direction of Dr. H. D. Bettac) of the Academy of Sciences of the GDR (IE) and of the Chair of Microwave Telecommunications of the Technical University Budapest (ChMT) [2]. The cooperation was based on the knowledge of the IE on reception of signals from meteorological satellites in the meter and decimeter bands and on the previous results of the ChMT on low noise reception.

Technical requirements

Reception necessitates the fulfilment of the following maximum requirements:

Input frequency band	1680–1710 MHz
Quality factor of reception (G/T)	12 dB/K ⁰
Polarization	linear, RHC, LHC
AGC dynamic range	50 dB
Tuning speed	350 Hz/sec
Antenna movement: azimuth	360°
elevation	180°

In the realization of the station a further point of view has been the requirement of applying the existing data processing and antenna-control equipment, as well as a distance of max. 200 m between the receiving antenna and the measuring room. This way the requirements have been extended:

Output frequency	137,5 MHz
Output band-width	10–15 MHz
Noise factor of receiver	6 kTo
Attenuation of the cable	20 dB

S-band antenna, mixer unit (Fig. 2)

The antenna used at the station is a paraboloid with a $D=4$ m diameter and $F/D=0,35$ ratio. The angular error signal necessary for automatic tracking of the satellite is produced by an amplitude comparison monopulse system [3].

The primary feed system placed in the focus of the antenna consists of 5 radiators [4]. A central feed placed in the focus serves for receiving the information signal (used at the same time as the reference signal of the monopulse system), while two pairs of feeds placed symmetrically on the antenna axis and shifted perpendicularly to each other give the difference characteristics. This arrangement constitutes a good compromise between high antenna gain and good error signal characteristic. The primary feeds are V-dipoles; the central feed is an interchangeably linear or crossed dipole (in

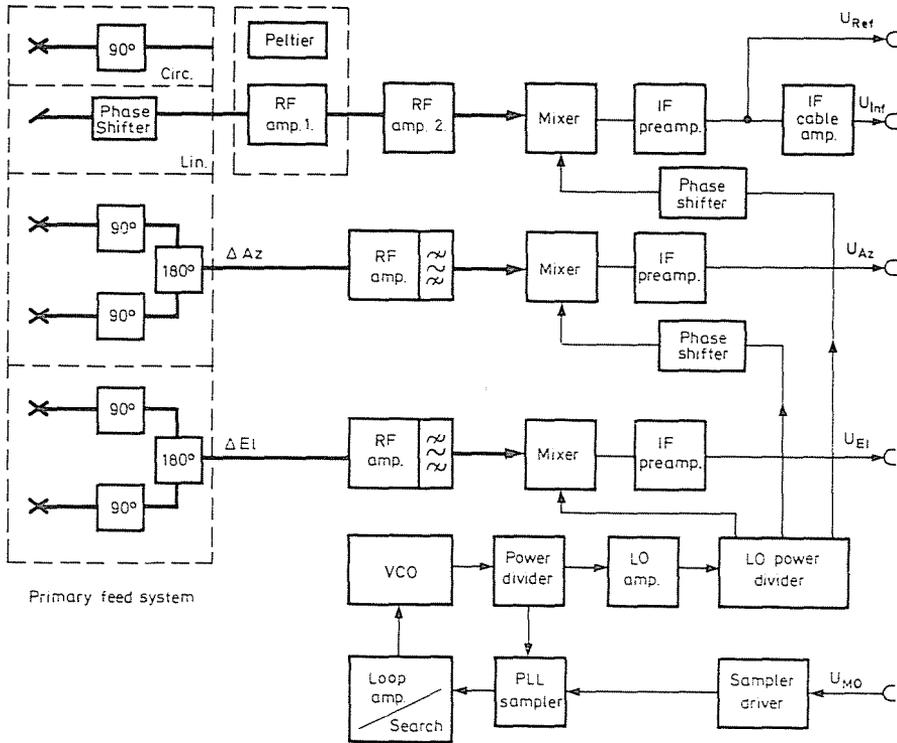


Fig. 2

accordance with the polarization of the signal to be received), the difference feeds are crossed dipoles of fixed position. The dipoles are located over a reflector plate having a diameter: $d=0,4$ m, and are protected from weather effects by a radom releasable by bayonet locking.

The information and difference antenna direction diagrams are shown in Fig. 3 [5].

For receiving circularly polarized signals, the two outputs of the crossed dipoles are summed at the corresponding output of a 90° hybrid. The azimuth and elevation error signals are obtained in the 180° hybrid by subtracting the signals of the primary feeds in the given plane.

The information signal and the two difference signals pass to the output through an RF amplifier, a mixer and an IF preamplifier. The RF amplifier of the information channel is a cascaded low-noise parametric-transistor amplifier circuit (also a low-noise transistor amplifier has been designed and used instead of the parametric one), the difference channels have singlestage transistor amplifiers. The first stage of the RF amplifier of the information channel is thermally stabilized by a Peltier element preventing thus the noise factor increase with the ambient temperature.

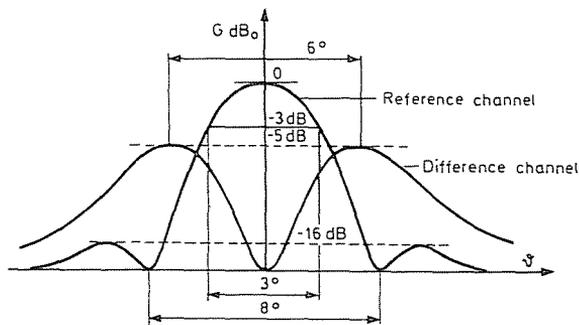


Fig. 3

The mixers of the three channels are of identical design: they are 2-diode circuits formed by combining strip- and slotlines. The mixers are pumped by the signal of a common local oscillator, through separating attenuators and phase shifters.

To minimize the cable losses, the circuits mentioned above are placed in a so-called Container I mounted on the reflector plate holding the primary feeds. The output signals of this Container (IF signals in the 137 MHz-band), the input signal of the local oscillator and the supply voltages are led by cables running in the tubes supporting the Container to the further units located on the counterweight at the rear side of the antenna.

The effect of the elements of the information channel upon the input noise-temperature is given by (1):

$$\begin{aligned}
 T_{\text{in}} &= L \cdot 293 \left(F_1 + \sum_{i=2}^{\infty} \frac{F_i - 1}{\prod_{j=1}^i G_j} \right) = \\
 &= T_{R1} + T'_{R2} + T'_{M+IF} + T_{\text{cable+rec.}} \\
 T_{\text{in}} &= 140,3 + 7,7 + 2,6 + 0,7 = 150,7 \text{ } ^\circ\text{K} \quad (1)
 \end{aligned}$$

Equation (1) justified the insertion of the IF cable-drive amplifier.

Local oscillator [6]

Tuning the receiver is performed by selecting the frequency of the local oscillator. This is based on the signal of a UHF mother oscillator of quartz stability. By means of a sampling PLL loop the voltage-controlled local oscillator (VCO) is adjusted to the 20th harmonic of the mother oscillator. In case the loop is broken the connection will be restored within a tuning period

by a search oscillator, sweeping the frequency of the VCO in the whole tuning range.

The signal of the UHF oscillator can be led by cable from the measuring room to the antenna with permissible loss, making thus possible the remote control of the receiving frequency.

The application of the sampling PLL instead of frequency multiplication resulted in lower phase noise, which is necessary to the demodulation of broad-band digital signals.

The local oscillator, together with the power supply units of the own circuits and of those in Container I as well as with the control electronics (heating, Peltier element), are located in Container II mounted on the counterweight of the antenna.

Monopulse autotrack receiver

The receiver (development of IE) is located in the so-called Container III mounted on the counter-weight of the antenna. Its input signals are the u_R reference signals from the output of the information channel as well as the u_{AZ} and u_{EL} error signals from the outputs of the difference channels. From these signals will be formed in the receiver—after down conversion and compensation for the Doppler shift—the error signals required for controlling the driving motors of the antenna.

The error signal in a given plane on the output of the demodulator of an amplitude comparison monopulse system can be described by

$$u_{\vartheta}(\vartheta) = \operatorname{Re} \frac{U_{\vartheta}(\vartheta) U_R^*(\vartheta)}{U_R(\vartheta)} \quad (2)$$

where ϑ is the angle in the given plane, measured from the antenna axis, U_R is the envelope of the signal coming from the information channel, while $(\)^*$ denotes complex conjugation and Re the real part. If the cross-coupling between primary feeds of the antenna and between the receiving channels is disregarded Equ (2) can be written in the following form:

$$u(\vartheta) = K \cdot \cos \Delta\varphi \cdot \cos \varphi_0 \left[\vartheta - \frac{c}{s_0} \operatorname{tg} \Delta\varphi \cdot \operatorname{tg} \varphi_0 \right] \quad (3)$$

Here $\Delta\varphi$ is the phase difference before the 180° hybrid, including also the possible phase asymmetry of the two primary feeds, φ_0 is the difference between the phase shifts of the reference channel and of the error signal channel of the given plane including also the average of the phase shifts arising in the primary feeds and the hybrids, while the meaning of c and s_0 can be read from Fig. 4.

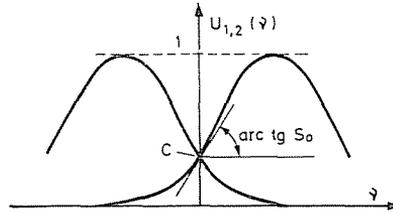


Fig. 4

As can be seen, the phase errors cause tracking errors on the one hand and a decrease of sensitivity on the other. A value of $\Delta\varphi = 15^\circ$ can be realized, and then, based on Fig. 2.

$$\varphi_0 = 45^\circ$$

can be permitted in the case of a tracking error of

$$\vartheta_0 = \frac{c}{s_0} \operatorname{tg} \Delta\varphi \cdot \operatorname{tg} \varphi_0 \left[\vartheta - \frac{c}{s_0} \operatorname{tg} \Delta\varphi \cdot \operatorname{tg} \varphi_0 \right]$$

A further error source is constituted by direct coupling between the primary feeds producing the error signals of perpendicular plane which causes connection between the bi-directional antenna movements, as well as by coupling between the reference and difference receivers, which upsets the sharp minimum of the difference channel. From this point of view the S-band mixer is the most hazardous because of the common supply of the local oscillator, and this stressed the application of a symmetrical mixer.

Structure of the receiving station

The construction of the complete receiving station is shown in Fig. 5. The analog IF signals can be received by telemetry receivers Type APT-137/3 [7] and 137/MB or ZEA-RTT 137 [8], while the photo equipment BAG-1 [9] can be used for demodulation and producing the meteorological picture.

The 700 kHz version of ZEA-RTT 137/M is suitable, as a first step, for receiving the digital signals in the case of METEOSAT and GOMS satellites. The theoretical foundations to this have been given by [10].

After synchronization, the pictorial information is processed on a PRS 4000 computer [11].

The antenna motors can be controlled, in addition to signals coming from the output of the autotrack receiver, also manually or by programmed control. This is provided by the equipment NC 470-A programm controlling the antenna [12].

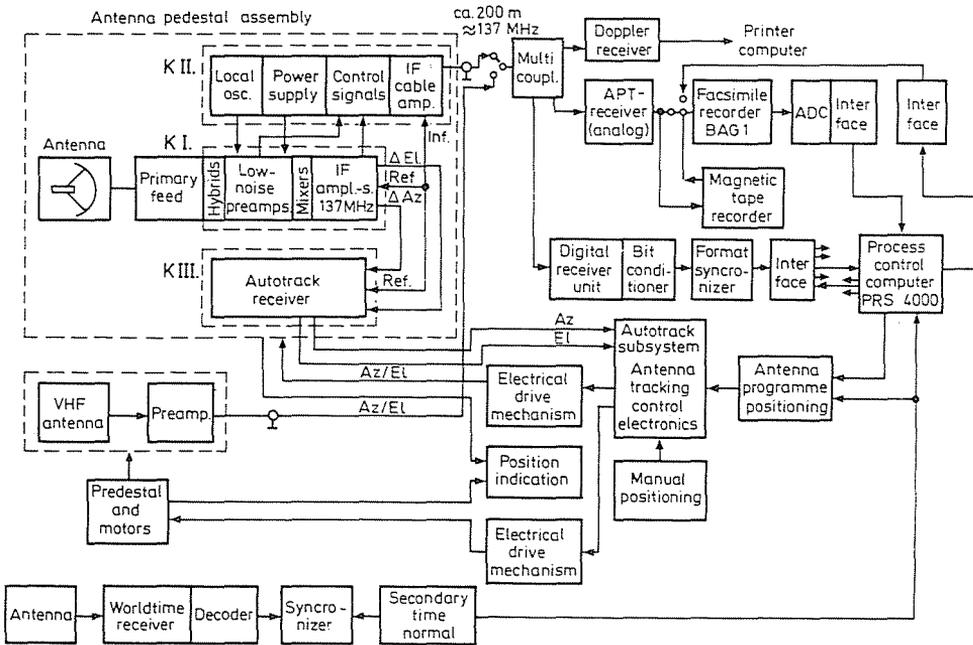


Fig. 5

The exact time synchron is ensured by a time signal receiver synchronizing secondary time standards.

The system is completed by the earlier antenna system serving to receive signals in the meter-band.

The main technical data of the receiving station discussed are contained in Table 1.

Acknowledgments

It is my pleasant duty to list here the participants fulfilling their tasks from theoretical computations to the last measurements on the erected antennas at different sites in the GDR:

Béla Szekeres (antenna), dr. György Galambos and Gábor Reizik (RF units of down converter and local oscillator), Ferenc Völgyi (low-noise parametric amplifier), dr. László Jachimovits (RF signal combining circuits) dr. Éva Gödör (RADOM), dr. István Gálfi (control electronics, power supply) and last but not least László Wittine and Gerhard Hecker from the Institute for Heat- and Systemtechnics (mechanical and thermal design).

Table 1

Antenna

Type	Paraboloid, $\varnothing 4$ m. $F/D=0,35$
Primary feed	5 element, amplitude comp. monopulse
Polarization	linear, RHC, LHC
Frequency band	1670—1720 MHz
Gain	> 34,5 dB
3 dB beamwidth	< 3,5 degrees
First sidelobe	< -16 dB
VSWR	< 1,4
Tracking range	> 5 degrees
Cross coupling AZ/EL	< -20 dB

Antenna-controll:

Drive	electromotor, revolution-controlled
Operation	autotrack, program-contr. by hand
Rotation	azimuth > 540 degrees elevation > 180 degrees
Position error	< 0,2 degrees

Converter

Type	3 channel: INF/REF, Δ_{Az} , Δ_{El}
Input frequency band	1680—1710 MHz
Output frequency (1st IF)	137,5 MHz
Output bandwidth	INF \approx 16 MHz $\Delta \approx$ 12 MHz
Gain (RF—IF)	INF \approx 45 dB $\Delta \approx$ 38 dB
Cross coupling	INF/ Δ < -40 dB Δ/Δ < -50 dB
Input VSWR	INF Paramp < 1,4 Trans. < 2 Δ < 2,5
Output VSWR	< 1,4

Complete system

Input noise temperature	INF < 150 K° Δ < 500 K°
Quality factor G/T	> 11,5 dB/K°
Second IF	10,7 MHz
AGC range	> 50 dB
AFC range	\pm 80 kHz
Remote tuning	Converter/Receiver max. 200 meters

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