# 20/30 GHZ FRONT-END FOR THE TMS-7 RECEIVING STATION OF THE OLYMPUS SATELLITE

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## SUMMARY

In this paper we present the 20/30 GHz front-end of the TMS-7 station to perform the measurement of the flux density of one or more signal carriers received from the OLYMPUS satellite. The front-end is composed of two receiving channels and a pilot generator. Local oscillators follow the frequency drifts of the satellite signals using a complex phase-locking system.

## 1. INTRODUCTION

Olympus is a large satellite platform, developed under the auspices of ESA (European Space Agency) and designed to meet the payload requirements of future space telecommunications systems |1|. OLYMPUS-1 will acommodate four payloads. One of them is a 20/30 GHz Communications Payload for point to point and multipoint teleconference and other experimental applications. In order to perform in orbit test, ESA has scheduled several test and measurement stations (TMS). The TMS-7 front-end described here, has been integrated in the full station by the Spanish Company INISEL as the main contractor of the project.

## 2. SYSTEM DESCRIPTION

The system is composed of two receiving channels, at 30 and 20 GHz, and a 30 GHz pilot generator (Figure 1). The low EIRP of beacons at 20 and 30 GHz (24 dBW), and requirements in amplitude measurement accuracy (around 0.7 dB at 20 and 30 GHz), impose high signal to noise ratios (around 40 dB at 30 GHz and 30 dB at 20 GHz). For a receiver factor G/T of 20 dB/K at 30 GHz and 11 dB/K at 20 GHz, the postdetection bandwidth must be around 10 Hz to achieve the expected performances. Both channels perform one frequency down-conversion, where each local oscillator is obtained by phase-locking multiplication of a low frequency signal with high spectral purity.

In order to keep the signal within the narrow band limits imposed by filtering, a synchronous detection and a frequency tracking of the satellite signal must be made. Local oscillators must follow the frequency drifts of the satellite signals. This is accomplished by a complex phase-locking system; each frequency multiplier contains several phase-locked loop (PLL) levels.

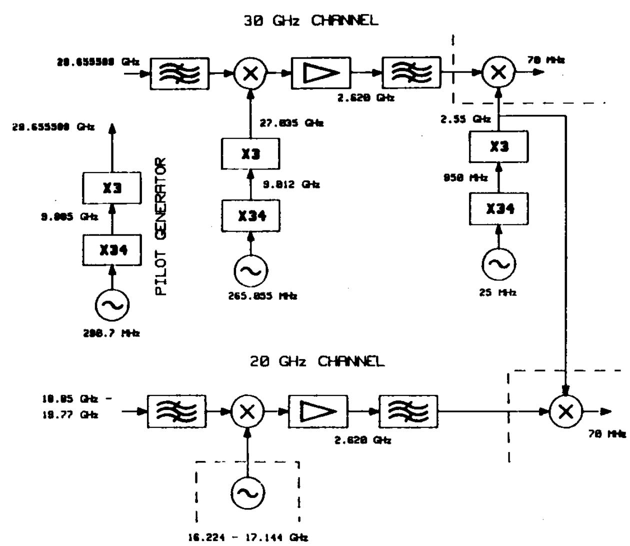


Fig. 1.- Block diagram of the front-end channels and pilot generator

The input frequency bands are: a single fixed carrier at 29.655 GHz and a selectable signal between 18.85 and 19.77 GHz. The last one is emitted by the satellite with a switched orthogonal polarization. For calibrating purposes of the 30 GHz channel, a pilot generator simulating the incoming signal from the satellite is included.

The receivers are composed of a large number of microwave, RF and low frequency circuits: waveguide filters, millimeter wave and RF mixers, low-noise IF amplifiers, solid state oscillators (Gunn, MESFET and bipolar), phase detectors (analogue and digital), harmonic mixers, frequency dividers and IF filters. All these subsystems have been specially designed, built and tested for this application by the authors.

### 3. CHANNEL RECEIVER AT 20 GHZ.

Given the desired dynamic range in the 20 GHz reception, direct mixing has been used. Local oscillator frequency range is 16.224 to 17.144 GHz. IF is fixed at 2.62 GHz. The frequency converter is a single balanced mixer in microstrip lines. The balanced structure is a 3 dB quadrature hybrid, with an additional quarter wavelenght line in one of the hybrid arms, Figure 2. One beam-lead T-mount Schottky diode is placed at the end of two hybrid arms. A transition between rectangular waveguide and microstrip, by a ridge waveguide transformer, is used in the RF signal port. Coaxial SMA connectors are located in LO and IF ports.

Typical measured conversion loss and noise figure are 7.5 dB and 8 dB respectively for this mixer (when measured with the IF amplifier described in Section 5). A LO power of 10 dBm is required for normal operation. The local oscillator is a commercially available frequency agile PLO (Phase Locked Oscillator).

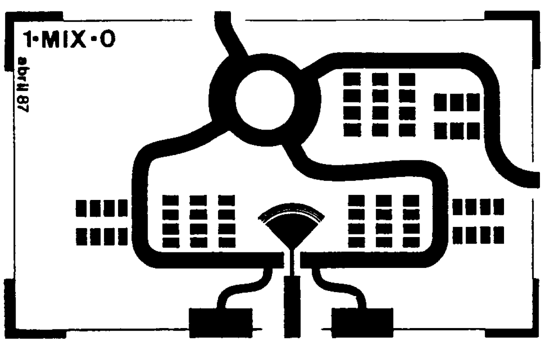


Figure 2.- 20 GHz microstrip mixer lines layout.

### 4. 30 GHZ CHANNEL RECEIVER

A Low Noise Amplifier LNA, not shown in Figure 1, is located at the 30 GHz input to achieve the specified dynamic range. A filter is required at the preamplifier output to reject noise generated at the image frequency. It is a rectangular waveguide filter with E-plane metal inserts. This filter has been designed from a third order Tchebyscheff prototype, and it is composed of three cavities (Figure 3). Passband filter response is shown in Figure 4. Insertion loss at 29.65 GHz is 0,4 dB.

The mixer is a microstrip balanced mixer which is the same as in the 20 GHz mixer. Local oscillator (27.03 GHz) and RF signal (29.65 GHz) ports have rectangular waveguide connections. The transitions between microstrip and waveguide are made with a coaxial probe protruding into the waveguide. A modular structure, shown in Figure 5, allows the mechanical assembly. Measured conversion loss and noise figure have been lower than 8.5 and 9 dB respectively. Local oscillator generation is explained in Section 6.

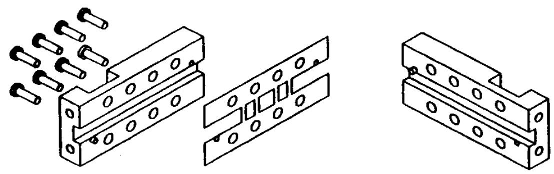

Figure 3.- Exploded view of the E-plane 30 GHz filter

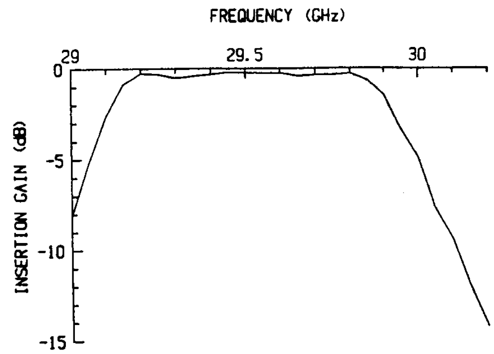


Figure 4.- Insertion loss of the E-plane filter

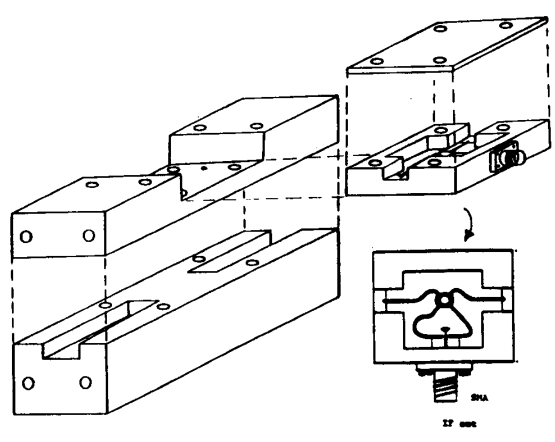

Figure 5.- Exploded view of the modular structure in the 30 GHz mixer

## 5. IF AMPLIFIER AND FILTER

The IF network is composed of a two stages LNA and a bandpass filter, both centered at 2.62 GHz. The amplifier is a made on microstrip lines using Epsilam-10 substrate. The active device is a MESFET (NE75083). Typical performances of the amplifier are:

Gain = 33 dB
Noise Figure = 1.2 dB at 2.62 GHz.

The filter is a compact lumped and semi-lumped element bandpass Tchebyscheff filter designed to achieve a good image frequency rejection (2.48 GHz) while maintaining low IF insertion losses.

## 6. LOCAL OSCILLATOR SIGNAL GENERATION

### 6.1 Local oscillator at 27.03 GHz.

The requirements imposed on the receiver obliges to the use of sources with high spectral purity and good long term stability as local oscillators. This goal is achieved using Phase Locked Oscillators (PLO). The subsystem performing the synthesis of the 27.03 GHz oscillator is shown in Figure 6. It is obtained as a x102 multiplication of the reference signal supplied by a commercial low frequency synthesizer (265 MHz). The x102 multiplication is made using three cascaded PLL systems, and decomposing it in two stages: first a x34 multiplication with two PLL's is made, and second, the generated signal is multiplied by 3 in a third PLL.

A 9.01 signal is obtained after the x34 multiplication. This signal feeds a harmonic phase detector, which makes the phase detection between its third harmonic and the 27.03 GHz VCO's coupled signals. The error signal is processed by a loop filter to become the VCO control voltage. As a result, a x3 multiplication is accomplished.

The first phase detection is made at 132.5 MHz with an ECL XOR gate. Frequency dividers by two (at 265 MHz) and by ten (at 1.325 GHz) are commercial integrated circuits. Phase detector at 265 MHz is a commercial RF balanced mixer. The other networks in the x34 multiplier are house made microwave and low frequency circuits.

A key element in the x3 multiplier is the harmonic phase detector. It has been built with a 90 degree microstrip hybrid ring, centered at 9.01 GHz, with one arm a quarter wave-length longer, giving a 180 degree global behaviour at 9.01 and 27.03 GHz at once |2|. The VCO at 27 GHz is a Gunn diode oscillator in a rectangular waveguide cavity. The VCO at 9 GHz is a MESFET oscillator in microstrip lines technology.

### 6.2 Local oscillator at 2.55 GHz.

It is obtained as a x102 multiplication of a 25 MHz reference signal. This multiplication is decomposed in two stages: first a x 34 multiplication is made using a 1.7 GHz VCO and a digital frequency divider (Figure 7). A 850 MHz signal is introduced in a RF balanced mixer working as a harmonic phase detector. Its error signal controls the VCO at 2.55 GHz. Both VCO's are bipolar transistor oscillators in microstrip lines.

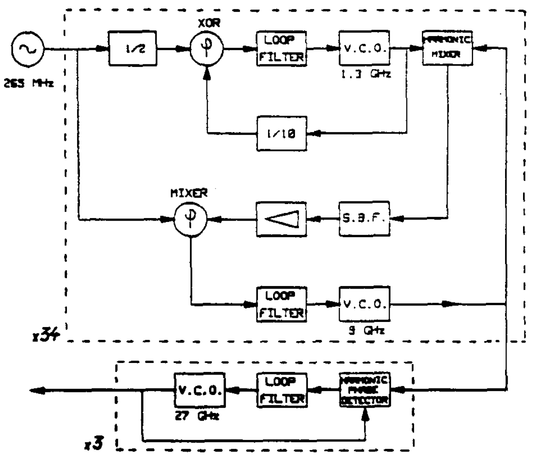


Figure 6.- PLO at 27.03 GHz

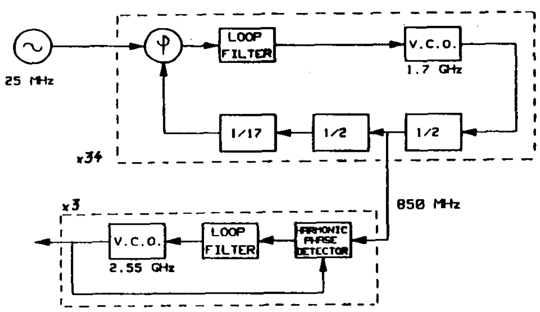


Figure 7. PLO at 2.55 GHz

## 7. PILOT GENERATOR

This subsystem performs the synthesis of a pilot signal of the same frequency as the satellite beacon. Its function is as a test signal in the receiver calibration procedure. The complete block diagram is shown in Figure 8. Signal generation is a x102 multiplication following the same procedure as the 27.03 GHz local oscillator generation (see section 6).

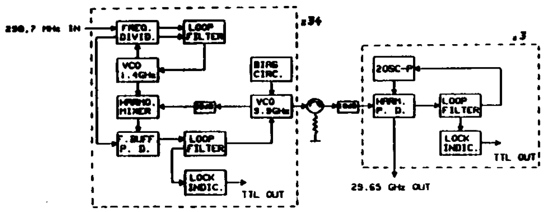


Figure 8.- Pilot generator physical arrangement

## CONCLUSION

The general structure of a 20/30 GHz front end for a receiving station of the OLYMPUS satellite has been described. Requirements in dynamic range have prompted that the most critical part of the design be the local oscillators generation. Several levels of PLO's have been necessary in their implementation.

## ACKNOWLEDGMENT

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