Proceedings of the 26th IASTED International Conference
MODELLING, IDENTIFICATION, AND CONTROL
February 12–14, 2007, Innsbruck, Austria
ISBN Hardcopy: 978-0-88986-633-1 / CD: 978-0-88986-635-5

DESENSIBILIZATION MEASUREMENT AT A LEO – SATELLITE GROUND STATION

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ABSTRACT
The project "MOST" (Microvariability and Oscillations of Stars) is a Canadian micro satellite space telescope mission. The micro satellite carries a Rumak-Maksutov telescope with an aperture of 15cm. The size of the satellite is 65cm x 65cm x 30cm and the mass is about 65kg. The goals of the mission are to analyze the inner structure of stars, to set a lower limit to the age of the universe and to search for Exoplanets. The project MOST consists of a Low Earth Orbiting (LEO) Satellite and three Ground Stations, one of them in Vienna [1]. The Vienna ground station was set up at the Institute for Astronomy of the University of Vienna in cooperation with the Institute of Communications and Radio-Frequency Engineering of the Vienna University of Technology. The satellite link operates full duplex at the 2GHz band. This paper presents the methodology and the experiment for checking an eventual desensibilization of the receiving system caused by the presence of the permanent uplink signal.

KEY WORDS
Desensibilization, LEO, satellite.

1. Introduction

With the design of the Vienna LEO ground station it is demonstrated that by implementing sophisticated concepts, ground stations for scientific satellites can be built and maintained at affordable cost. The Vienna ground station is implemented within the MOST space observation project, relied on the experience of the Institute for Communications and Radio-Frequency Engineering of the Vienna University of Technology [1]. In course of receiving system evaluation different experiments and measurements are executed. It is known that strong signals near the passband of an LNA (Low Noise Amplifier) can reduce the sensibility of the LNA and consequently the sensibility of the entire receiving system. Due to the full duplex operation the uplink signal is permanent present while receiving data from the satellite. Therefore we had to check the sensibility of the receiving system when the uplink signal is turned on.

2. Vienna LEO Ground Station Concept

The Vienna LEO ground station design concept was based on three objectives: *affordable cost, unattended work* and *safety system.* Usually, satellite ground stations are located in rural areas, in order to minimize the interference by man made noise. Through the station in Vienna it is demonstrated that a ground station can operate reliably also in urban areas at a fraction of the initial costs of commercial stations [2]. The block diagram of the Vienna LEO ground station is presented in Fig. 1.

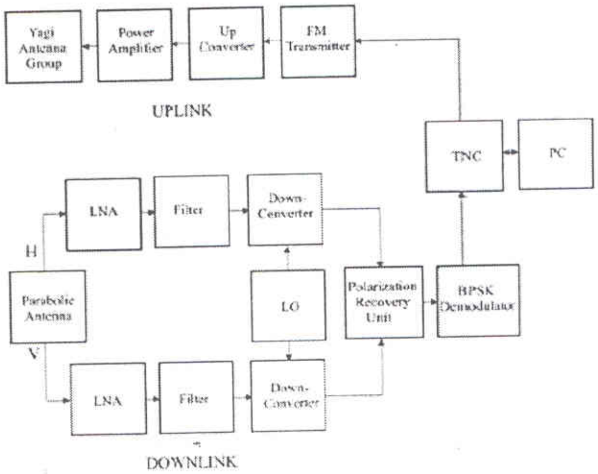

Fig. 1. Block diagram of the Vienna LEO ground station.

The acronyms in the Fig.1 are: BPSK (Binary Phase Shift Keying, FM (Frequency Modulation), LNA (Low Noise Amplifier), LO (Local Oscillator), TNC (Terminal Node Controller) and PC (Personal Computer).

The uplink block is planned to issue commands for operation the satellite's payload, attitude control subsystem and other house keeping functions. The downlink block is responsible for receiving the observation data.

The signal from the satellite will be picked up by means of a parabolic antenna (diameter of 3m), receiving two orthogonal polarization states, horizontal and vertical. The signal will be amplified by LNAs and further by downconverters. To avoid possible blocking of the downconverters due to stray coupling of the uplink transmit signal (full duplex mode) filters are introduced between LNAs and downconverters. The two stage amplification by low noise amplifiers and low noise converters is necessary to guarantee that the signal input to the demodulator will be sufficiently strong. A polarization recovery unit optimally combines the output of the two downconverters choosing the higher output signal. The demodulator recovers the data signal. At the Terminal Node Controller (TNC) the transmit protocol will be removed.

At the uplink the TNC adds the transmit protocol to data commands originated from the PC. The transmitter generates the frequency modulated signal. Conversion to the transmit frequency is done by upconverter. Then, the transmit signal is amplified by a power amplifier and transmitted via a Yagi antenna group.

The reason for building a LEO station in Vienna is to increase the coverage and number of measurements per observed object and practically increase the download capability, because, the Vienna LEO ground station allows communication with the MOST satellite when it is not visible from Canada. Fig. 2 shows the visibility of the MOST satellite from Vienna, Toronto and Vancouver.

Fig. 2. Visibility of the MOST satellite from Vienna, Toronto and Vancouver (Canada) [3].

The parameters of the equipment which is used in the Vienna LEO ground station are presented in Table 1 and Table 2 respectively for uplink and downlink. The equipment is chosen to be affordable related to the project university budget.

Table 1. Uplink parameters.

Transmit frequency	2055MHz	
Transmit power	50W	17dBW
Antenna gain		25dBi
Loss (cables)		2.5dB

Table 2. Downlink parameters.

Receiving frequency	2232MHz	
Antenna gain		34.9dBi
Feed line loss		0.4dB
LNA noise figure		0.65dB
LNA gain		41dB
Loss (cables and filter.) Lc		4dB
LNC noise figure		0.8dB
LNC gain		32dB
Data rate		38.4Kbit/s
Receiver bandwidth	76800Hz	48.9dBHz
Required S/N for 10E-5C BPSK		4.9dB

The Vienna LEO ground station achieved its first communication with the MOST microsatellite on 30th September 2003 and it is still operational [1].

3. LNA at Vienna Ground Station

In Fig. 1, the first stage of a satellite receiving system is presented.

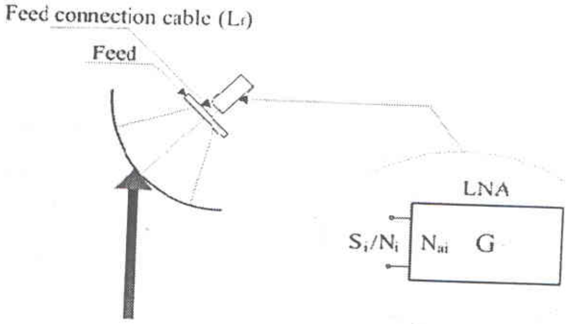

Fig. 3. The first stage of a satellite receiving system.

A LNA is used as front end equipment of a receiving satellite system, since the sensibility depends on the first stage of the receive chain. Before the desensibilization experiment is presented the concept of the noise figure is shown.

The *noise figure* is a parameter that expresses the noisiness of two-port networks or devices (such as an amplifier). The noise figure F is the ratio of the *signal-tonoise ration (S/N)* at the input of a network or device to the *S/N* at the output of the network or device [4]. It is defined as:

$$F = \frac{\left(\frac{S}{N}\right)_{in}}{\left(\frac{S}{N}\right)_{out}} = \frac{\frac{S_i}{N_i}}{\frac{GS_i}{G(N_i = N_{ai})}} \qquad (1)$$

where S_i is signal power at the amplifier input port, N_i is noise power at the preamplifier input port, N_{ai} is amplifier's noise referred to the input port and G is amplifier's gain. Eqn.1 can be reduced to:

$$F = \frac{N_i + N_{ai}}{N_i} = 1 + \frac{N_{ai}}{N_i} \tag{2}$$

An ideal amplifier with no internal noise $(N_{ai} = 0)$ has noise figure *F=1* or *F(dB)=0dB*. For the noise figure concept a reference value N_i must be defined. In 1944 Friis, suggested the noise figure to be defined for a noise source at a reference temperature of $T_0 = 290\ K$ [4]-[6].

The low noise amplifier used at Vienna ground station is manufactured by Kuhne Company. Technical data about the low noise amplifier are presented in Table 3 [2].

Table 3. Low noise amplifier technical data.

Model	KU 222 LNA
Operating frequency	2232 MHz
Gain	41dB
Noise figure	0.65 dB
Supply voltage	9V to 20V DC

The amplification of the low noise amplifier was tested for uplink and downlink frequencies. Fig. 4 shows the results of the measurements of the low noise amplifier.

From Fig. 4 it can be seen that the low noise amplifier is not so highly selective. There is only a moderate attenuation for the uplink signal. This is the reason to check the receiving system on possible desensibilization.

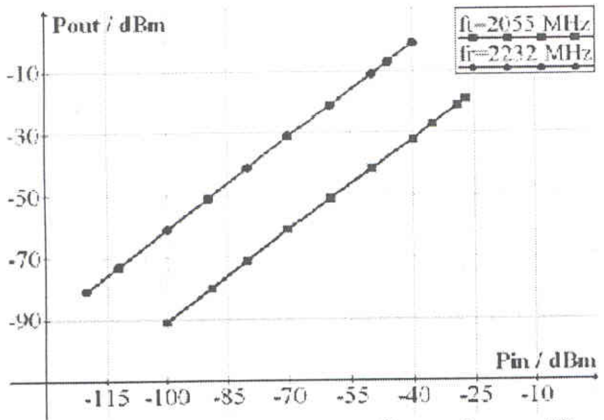

Fig. 4. Performance measurement of low noise amplifier.

4. Desensibilization Measurement

Strong signals near the passband of the LNA can reduce the sensibility and consequently the sensibility of the entire receiving system. Therefore a measurement to check if the sensibility of the receiving system in the presence of the 50W uplink signal is reduced is performed. The experiment set up is presented in Fig. 5.

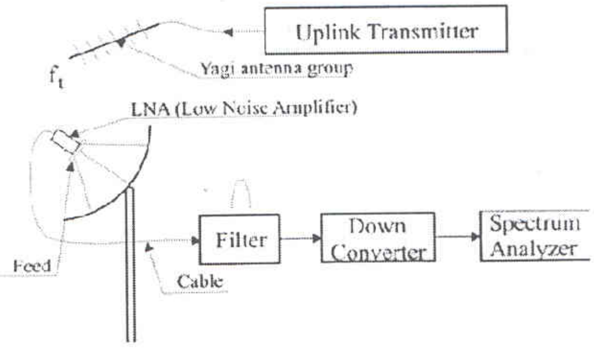

Fig. 5. Desensibilization measurement set up.

In Fig. 5 the spectrum analyzer is used as power meter. The *ft is* the uplink signal frequency. The desensibilization effect is measured at the output of the downconverter. As receive signal the Sun noise is used [7]. For LEO satellites, the ground station must track the satellite during its short flyover period of about 5-15 minutes. A ground satellite station antenna must follow the satellite very fast with high pointing accuracy of 0.5°. Mismatch in pointing will lead to a decrease of the desired signal strength. This mismatch in the antenna's pointing had to be considered also during our experiment. The measurement results at the output of the demodulator are presented in Fig. 6.

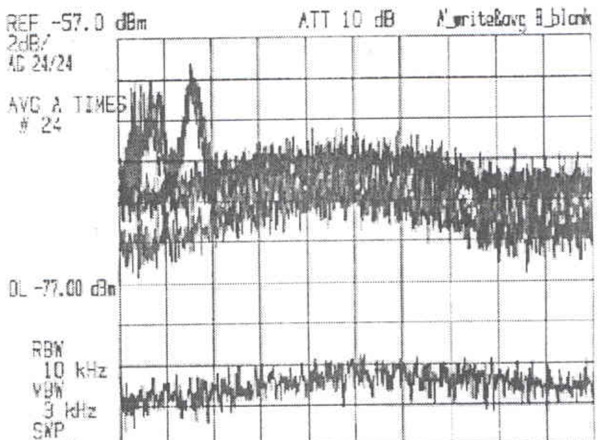

Fig. 6. Desensibilization measurement result by uplink signal at Vienna ground station.

At the first phase of the experiment the uplink transmitter is turned off. In the Fig. 6 the bottom signal (blue color) represents the received noise power density when antenna is pointing to the cold sky. Then the antenna is pointing to the Sun. As already mentioned, there is a residual pointing error of the antenna. So, the highest and the lowest Sun noise power output level at the downconverter's output of several pointing attempts are recorded as two green color traces (for black – white version of the picture these are two traces little bit more lighter). The difference of around 2 dB between the green traces represents the measurement uncertainly including pointing error and instruments accuracy.

In order to test the influence of the uplink signal on the sensibility of the downlink receiving system, the uplink transmitter is turned on. In this case the downconverter's output is the red colored trace (for black – white version of the picture this is the darker trace with two picks).

On the left upper corner in the Fig. 6 the red trace has two peaks and then continually falls within the two green traces. These peaks represent generated intermodulation products which is confirmed that do not fall in the receiver's passband and do not disturb the receiving system [8]. Since, the red trace is in between the two green traces, we can conclude that the sensibility of the receiving system is not reduced by the uplink signal presence. In case of desensibilization the red trace had to be under the lower green trace. Our experiment confirmed that the receiving system at the Vienna LEO ground station is not desensibilized by the permanent present uplink signal.

5. Conclusion

By planning and implementing satellite ground stations the performance analysis of the satellite receiving system is very important. One of such a performance test was the measurement if desensibilization of the receiving system exists due to the permanent present uplink signal. In case of the Vienna LEO ground station the experiment has shown that the uplink signal does not lead to a desensibilization of the receive chain. This ensures a proper work of the ground station. Further an easy executable measurement to check if desensibilization is present was shown.

Acknowledgements

The authors wish to thank the Aeronautics and Space Agency of the Austrian Research Promotion Agency (FFG) for funding the Austrian contribution to the project "MOST".

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IASTED
A Publication of the International Association
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Proceedings of the 26th IASTED International Conference on

Modelling, Identification, and Control

February 12 – 14, 2007
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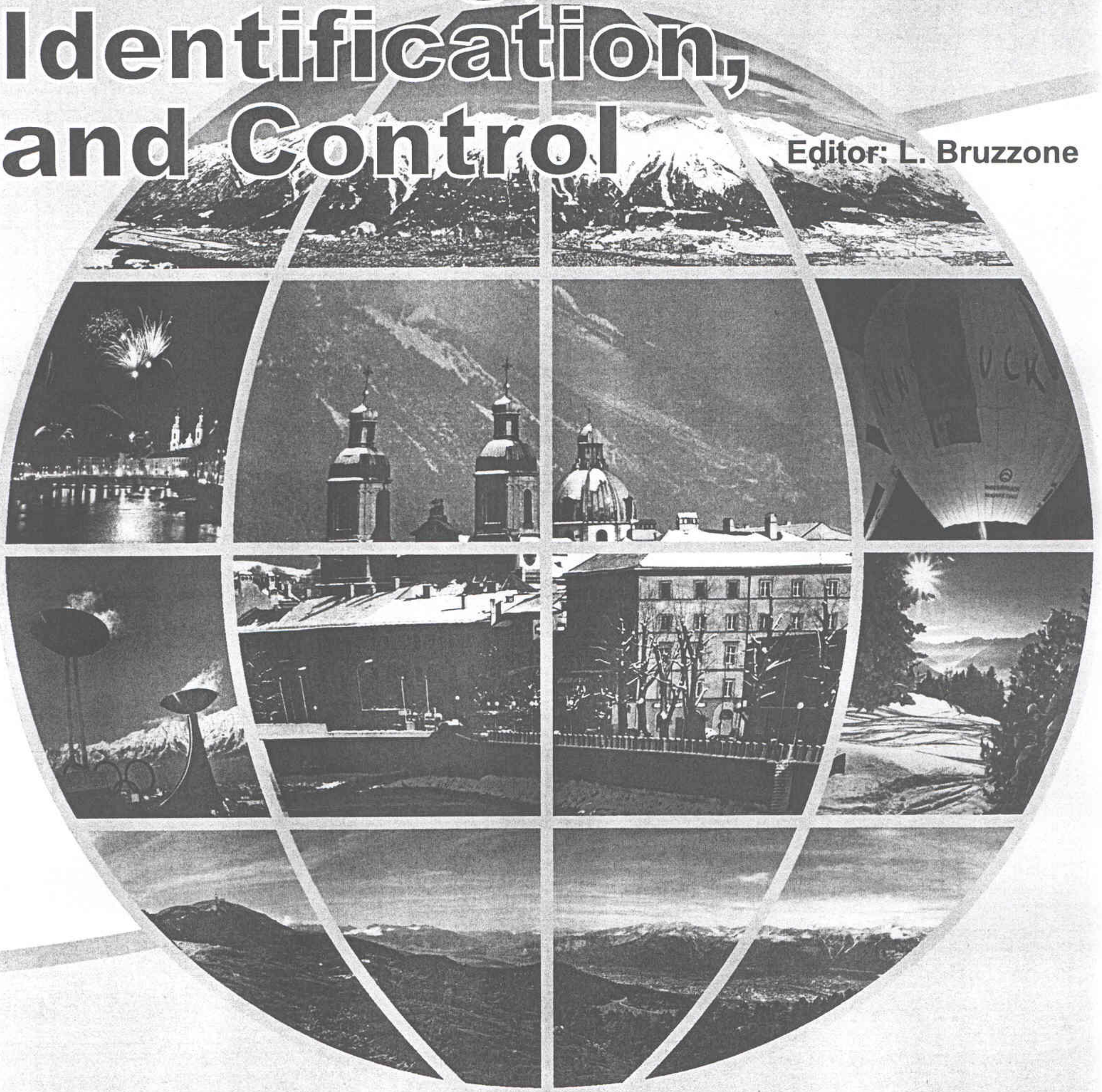
Editor: L. Bruzzone



ISBN: 978-0-88986-633-1

ACTA Press Anaheim | Calgary | Zurich

Proceedings of the 26th IASTED International Conference on **Modelling, Identification, and Control**, held February 12 – 14, 2007, Innsbruck, Austria.

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