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Intermodulation by Uplink Signal at Low Earth Orbiting 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, 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 system 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 ground satellite station in Vienna is installed in urban area with high penetration of GSM 1800 mobile systems. This paper presents the investigations related to the possibility of disturbances by the intermodulation factors generated by uplink signal and GSM 1800 mobile signals.

1. INTRODUCTION

Since, the ground station is located in the urban area where is very high penetration of mobile radio systems, in Vienna city, we expected the presence of intermodulation products near the downlink frequency *(f = 2232 MHz)* caused by GSM 1800 and uplink signal *(f = 2055 MHz)*. To analyze this case, we will firstly clarify the concept of Intermodulation Distortion (IMD).

2. INTERMODULATION DISTORTION (IMD)

Intermodulation distortion can be classified as:

- *Harmonic Products*
- *Intermodulation Products*

2.1. Harmonic products

Harmonic products are single-tone distortion products caused by device nonlinearity. When a non-linear device is stimulated by a signal at frequency f_1, spurious output signals can be generated at the harmonic frequencies $2f_1$, $3f_1$... Nf_1. The order of the harmonic products is given by the frequency multiplier; for example the second harmonic is second order product. These harmonics are presented in Fig. 1. Harmonics are usually measured in dBc, and this means dB below the carrier (fundamental) output signal.

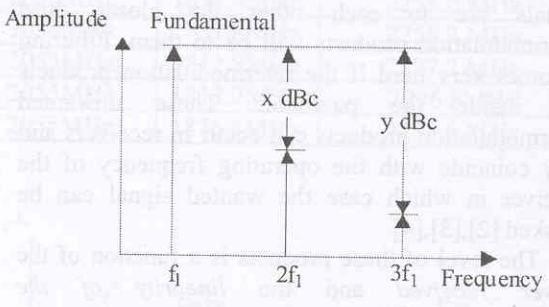

Fig.1. Harmonic distortion.

2.2. Intermodulation products

Intermodulation products are a multi-tone distortion products that result when two or more signals at frequencies f_1, f_2 ...f_n are present at the input of a nonlinear device. The spurious products which are generated due to the non-linearity of a device are related to the original input signals frequencies. Analysis and measurements in practice are most frequently done with two input frequencies (sometimes termed "tones"). The frequencies of the two-tone intermodulation products are:

$$Mf_1 \pm Nf_2 \quad \text{where} \quad M,N = 0,1,2,3,.....$$

The order of the distortion product is given by the sum $M+N$. The second order intermodulation products of two signals at f_1 and f_2 would occur at f_1+f_2, f_2-f_1, $2f_1$ and $2f_2$. The third order intermodulation products of the two signals at f_1 and f_2 would be $3f_1$, $3f_2$, $2f_1+f_2$, $2f_1-f_2$, f_1+2f_2 and f_1-2f_2 [2]. These are presented in Fig. 2.

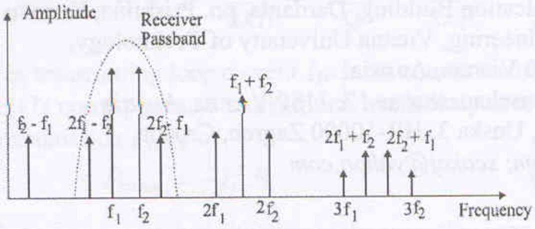

Fig. 2. Second and third order intermodulation products.

Mathematically intermodulation product calculation could result in "negative" frequency, but it is the absolute value of these calculations that is of concern.

Broadband systems may be affected by all non-linear distortion products. Narrowband circuits are only susceptible to those in the passband. Bandpass filtering can be an effective way to eliminate most of the undesired products without affecting in band performance (see Fig. 2). But, third intermodulation products are usually too close to the fundamental signals to be filtered out. The closer the fundamental signals are to each other the closer third intermodulation products will be to them. Filtering becomes very hard if the intermodulation products fall inside the passband. These unwanted intermodulation products can occur in receivers and may coincide with the operating frequency of the receiver in which case the wanted signal can be masked [2],[3],[4].

The level of these products is a function of the *power received* and the *linearity of the receiver/preamplifier.*

3. INTERMODULATION PRODUCTS AT VIENNA GROUND SATELITE STATION

In case of Vienna satellite ground station the uplink signal at f_t = 2055 MHz is permanently present. Also signals of GSM 1800MHz are present. This situation is presented in the Fig. 3. The non-linearity is present at the preamplifier used at the downlink of the Vienna ground station. By the non-linearity of the preamplifier, the intermodulation products will be generated from the uplink signal at frequency f_t on one hand and GSM signals at frequencies f_{GSM} on the other. Only third intermodulation products will be considered.

In order to make correct analysis, from Internet (http://www.rtr.at) it is provided the GSM frequency plan related to GSM 1800 providers in Austria. These data are presented in Table 1.

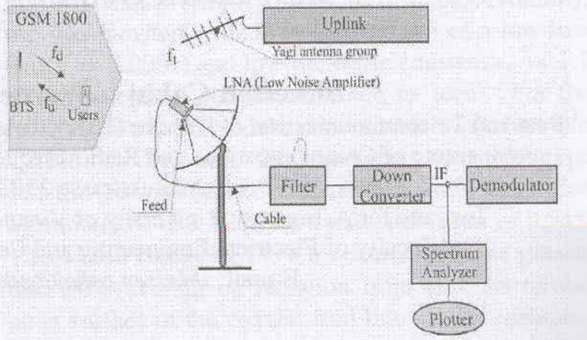

Fig. 3. GSM 1800 signals presence and uplink signal at Vienna ground station.

Table 1. Frequency table of GSM 1800 providers operating in Austria.

Channel	f_u	f_d	*Provider*
512	1710.2MHz	1805.2MHz	TMA
521	1712.0MHz	1807.0MHz	TMA
523	1712.4MHz	1807.4MHz	Mobilkom
573	1722.4MHz	1817.4MHz	Mobilkom
575	1722.8MHz	1817.8MHz	Free
584	1724.6MHz	1819.6MHz	Free
586	1725.0MHz	1820.0MHz	Telering
617	1731.2MHz	1826.2MHz	Telering
619	1731.6MHz	1828.8MHz	Mobilkom
630	1733.8MHz	1828.8MHz	Mobilkom
632	1734.2MHz	1829.2MHz	One
659	1739.6MHz	1834.6MHz	One
661	1740.0MHz	1835.0MHz	TMA
666	1741.0MHz	1836.0MHz	TMA
668	1741.4MHz	1836.4MHz	Mobilkom
673	1742.4MHz	1837.4MHz	Mobilkom
675	1742.8MHz	1837.8MHz	TMA
680	1743.8MHz	1838.8MHz	TMA
682	1744.2MHz	1839.2MHz	Telering
699	1747.6MHz	1842.6MHz	Telering
701	1748.0MHz	1843.0MHz	TMA
712	1750.2MHz	1845.2MHz	TMA
714	1750.6MHz	1845.6MHz	Telering
736	1755.0MHz	1850.0MHz	Telering
738	1755.0MHz	1850.4MHz	Mobilkom
743	1756.4MHz	1851.4MHz	Mobilkom
745	1756.8MHz	1851.8MHz	TMA
750	1717.8MHz	1812.8MHz	TMA
752	1718.2MHz	1813.2MHz	One
868	1781.4MHz	1876.4MHz	One

In the Table.1. f_u is the GSM uplink signal frequency (the frequency of the signal from users toward BTSs (Base Transmission Station)) and f_d is the GSM downlink signal frequency (the frequency of the signal from BTSs toward users) of the GSM1800 network (see Fig. 3).

Based on ITU-R F.382-6 (1.7 GHz - 2.1 GHz) frequency band for mobile systems at 1710 MHz – 1785 MHz is for the uplink and at 1805 MHz – 1880 MHz is for the downlink. The difference between the upper edge of the band and the last frequency within a band is called *Guard Band* (GB).
The guard band for uplink GB_u is:

$$GB_u = 1785\text{ MHz} - 1781.4\text{ MHz} = 3{,}6\text{ MHz} \quad (1)$$

and the guard band for downlink GB_d is:

$$GB_d = 1880\text{ MHz} - 1876.4\text{ MHz} = 3{,}6\text{ MHz} \quad (2)$$

Signals present at the frontend of the preamplifier of the receiving system at the Vienna ground station are presented in the Fig. 4.

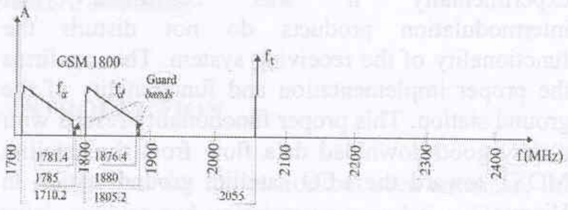

Fig. 4. Signals present at frontend of preamplifier (LNA) of the downlink.

Intermodulation products generated by signals at frequencies f_t and f_u fall too far on the frequency domain from the receiver's downlink frequency f_r, therefore they will not be treated. Third order intermodulation products generated by frequencies ft and fd are $2f_t \pm f_d$ and $2f_d \pm f_t$. Products $2f_t - f_d$ are worth further analysis, because only they fall in the frequency domain near the receiver's frequency f_r. These intermodulation products which appear at the preamplifier's (LNA) output (respectively at the filters input) in frequency domain (RF) are presented in Fig. 5.

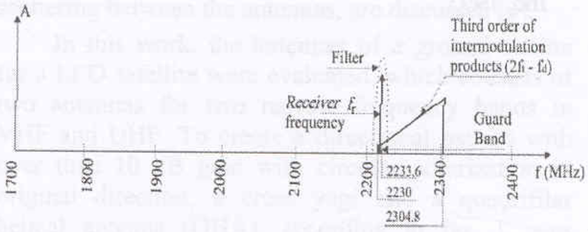

Fig. 5. Third order of intermodulation products.

The frequencies of these signals are presented in Table. 2.These signals now will be faced with filter before going into the downconverter (see Fig. 3). The situation behind the filter and in front of the downconverter is presented in the Fig. 6.

Table 2. Third order intermodulation products.

f_t	f_d	$2f_t - f_d$
2055MHz	1805.2MHz	2304.8 MHz
2055MHz	1807.0MHz	2293.0MHz
2055MHz	1807.4MHz	2292.6 MHz
2055MHz	1817.4MHz	2282.6 MHz
2055MHz	1817.8MHz	2292.2 MHz
2055MHz	1819.6MHz	2290.4 MHz
2055MHz	1820.0MHz	2290.0 MHz
2055MHz	1826.2MHz	2283.8 MHz
2055MHz	1828.8MHz	2283.4 MHz
2055MHz	1828.8MHz	2281.2 MHz
2055MHz	1829.2MHz	2280.8 MHz
2055MHz	1834.6MHz	2275.4 MHz
2055MHz	1835.0MHz	2275.0MHz
2055MHz	1836.0MHz	2274.0 MHz
2055MHz	1836.4MHz	2273.6 MHz
2055MHz	1837.4MHz	2272.6MHz
2055MHz	1837.8MHz	2272.2 MHz
2055MHz	1838.8MHz	2271.2 MHz
2055MHz	1839.2MHz	2270.8MHz
2055MHz	1842.6MHz	2267.4MHz
2055MHz	1843.0MHz	2267.0 MHz
2055MHz	1845.2MHz	2264.8 MHz
2055MHz	1845.6MHz	2264.4MHz
2055MHz	1850.0MHz	2260.0 MHz
2055MHz	1850.4MHz	2259.6 MHz
2055MHz	1851.4MHz	2258.6 MHz
2055MHz	1851.8MHz	2258.2 MHz
2055MHz	1812.8MHz	2297.2 MHz
2055MHz	1813.2MHz	2296.8MHz
2055MHz	1876.4MHz	2233.6 MHz

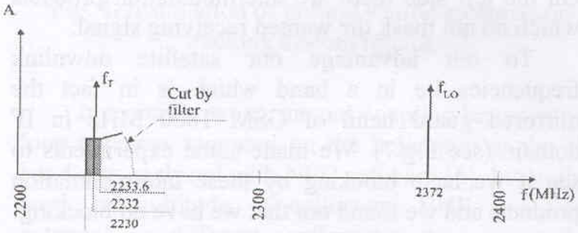

Fig. 6. Signals in front of downconverter.

From the Fig. 6 it is clear that the filter has cut a considerable number of disturbing frequencies.

The local oscillator frequency of the downconverter at the Vienna satellite ground station is f_{LO} = 2372 MHz. Then, if all signals presented in Fig. 6 in RF domain mirror into IF domain with frequency f_{LO}, the spectrum in Fig. 7 follows. From the Fig. 7 is obvious the presence of intermodulation products behind the downconverter and in front of the demodulator.

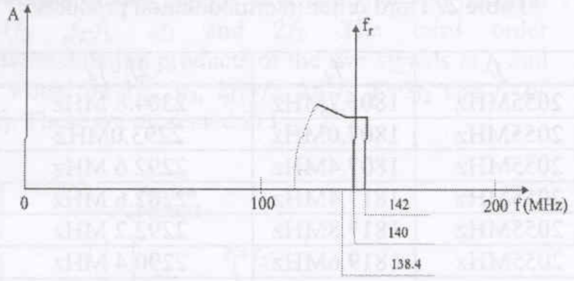

Fig. 7. Downconverter output.

This picture is also obtained by experiment and recorded with a spectrum analyzer, presented in the Fig. 8. The Fig. 8 confirms the calculations.

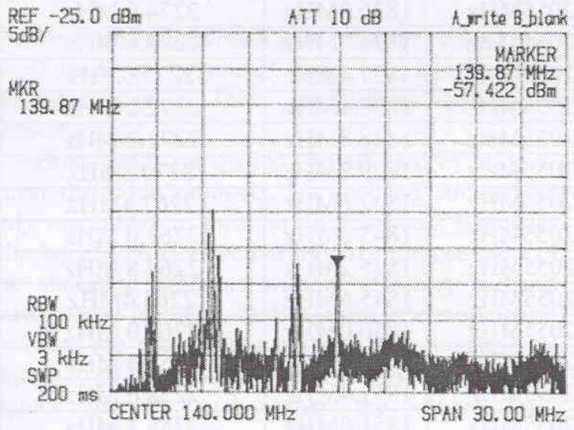

Fig. 8. Presence of intermodulation products.

In the diagram presented in the Fig. 8, in the center is our wanted signal coming from the satellite. On the left side there are intermodulation products which do not mask the wanted receiving signal.

To our advantage our satellite downlink frequencies lie in a band which is in fact the mirrored guard band of GSM 1800 MHz in IF domain (see Fig.7). We made some experiments to see if we have blocking by these intermodulation products and we found out that we have no blocking. This makes possible to have LNAs directly connected to the feed without filter, and therefore the *maximal downlink margin*.

The final conclusion is that the presence of the 50W uplink signal and the GSM 1800 signals do not produce intermodulation products which disturb the performance of the downlink receiving system at the Vienna (LEO) satellite ground station.

4. CONCLUSION

By planning and implementing the satellite ground stations the analysis related to intermodulation products are very important. The satellite ground station in Vienna is built in urban area with high penetration of mobile telephony. At Vienna ground station, both, mathematically and experimentally it was confirmed that intermodulation products do not disturb the functionality of the receiving system. This confirms the proper implementation and functionality of the ground station. This proper functionality results with a very good download data flow from the satellite MOST toward the LEO satellite ground station in Vienna.

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