Application of S-band resonant cavity filters for 4G rejection at TTC Ground Stations

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Abstract

S-band ground station is providing Telemetry Tele-Command TTC support to the remote sensing satellites 24x7 and in the recent years due to the 4G mobile signals from the base-station towers the satellite signal encounters a strong interference. Due to this interference ground station receive systems don't work properly resultant as a poor carrier to noise ration C/N0, poor energy per bit to the noise density EB/No at the receiver and observed receiver unlock and data break during different satellite passes. This paper presents the application of low loss combline coaxial cavity bandpass filter for 4G signal rejection at TTC ground station. The filter is a 5th order Chebyshev tunable using tuning and coupling screws. The center frequency F0, lower cut-off frequency FC1 and upper cut-off frequency FC2 of the filter is set to 2225MHz, 2169MHz and 2280 MHz respectively. The filter is having an insertion loss of 1.0dB, ±0.5dB of passband ripple and 40dB rejection at F0 ± 55 MHz

Keywords- TTC, LEO, 4G, Bandpass filter, combline, coaxial resonator, cavity filter, S-band, OFDMA.

1. Introduction

A ground station or an earth station is a terrestrial radio station used to communicate with spacecraft by sending and receiving radio waves [1]. An S-band ground station can transmit and receive radio frequency in the range of 2GHz to 4GHz (Transmit 2025-2120MHz) and receive (2200-2300MHz).
These ground stations and specially used for providing satellite telemetry, tele-command and ranging operations to the remote sensing satellites which are revolving in Low Earth Orbit LEO round the clock. Launch vehicle telemetry and S-band payload data dumping from different satellites are other important operations which are also supported from the above ground stations.

Due to the latest advancements in the field of telecommunications, 4G services are available across the world, which also uses the S-band spectrum for their operations. In the urban areas there are many 4G towers transmitting OFDMA signal continuously in S-band, which are located very near by the earth station antennas. As the earth station antennas are directional and having a very high antenna gain (approximate 45dBi) and a wide S-band LNA (2.2GHz to 2.3GHz) having 100MHz 3dB bandwidth but not having a very sharp cut-off frequency at 2300MHz. At most of the locations 4G spectrum starts from 2301MHz or 2305MHz which are very close to 2300MHz and the ground station antenna receives the 4G signal, amplifies it and further it comes to the baseband. It is also observed that the 4G signals are much stronger than the satellite signal irrespective of antenna Azimuth angle. However, 4G signal maximizes at particular antenna azimuth and elevation angles.

Due to the above 4G signals the noise floor at RF and IF level varies from 20dB to 30dB and creates a very strong interference for the desired satellite signal.

Due to the strong interferences the baseband systems do not work properly and resultant in a poor C/N0 at IF level, poor EB/No at receiver and observed receiver unlock and data break during different satellite passes.

Resonant cavity based bandpass filters are widely known for their high selectivity and low insertion loss. Such filters are used in advanced communication systems to filter out the desired signal frequency and reject the unwanted signals. Microwave resonant cavity-based filters are preferred in comparison with the distributed filters. Specially this kind of filters are used in radar and satellite transceivers where high selectivity, narrowband and high-power handling are required.

This paper presents the application of a resonant cavity based bandpass filter, which is a 5th order Chebyshev tunable filter and can be tuned using tuning and coupling screws. The filter has two SMA connectors for connecting input and output signals. The filter is completely covered with metal cover to provide dust protection. It has tuning and coupling screws for adjusting center and cutoff frequencies and shaping proper filter response.

Figure-1 shows the filter cavity and resonator in 2D model with SMA input/output interface. Figure-2 shows the top cover with tuning (thick) and coupling (thin) screws which are adjusted for a proper filter response. Figure 3 and 4 shows the internal view and complete filter respectively.

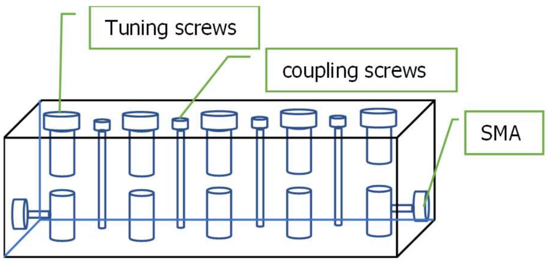


Fig-1 Filter cavity and resonator 2D model

Fig-2 Filter top cover with tuning and coupling screws

Fig-3 Filter top view without top cover

Fig-4 Complete tuned filter

2. Electrical and Mechanical parameters of Cavity Band Pass Filters

Table-1 shows the electrical characteristics of the desired filter obtained after tuning. The filter is tuned as per the frequency usage which is approved by the component authority. The filter is tuned to achieve a rejection of 40dB at F0 ± 55MHz. Table-2 shows the mechanical parameters of the combline filter, which includes physical dimensions of the filter mostly the design parameters.

Electrical characteristics	Value
Pass band center frequency F0	2225 MHz
Bandwidth	110 MHz
Insertion loss	1.0 dB max
Return loss	16 dB min
Rejection at (F0 ± 55) MHz	40 dB min.
Pass band ripple	0.5 dB max
Operating temperature	0–50°C
Input/output connectors	SMA (f)

Tab-1 Electrical characteristics of the combline filter

Symbol	Mechanical Parameters	Value
D	diameter of the cavity	12mm
l	length of the cavity	76mm
h	height of the cavity	24.5mm
L	length of the cylindrical resonator	20mm
d	diameter of cylindrical resonator	5mm
n	number of resonators	5

Tab-2 Mechanical parameters of the combline filter

3. Tuning of Cavity Band Pass Filters

Most of the microwave cavity filters, after assembling, does not meet the specified electrical specifications. The cavity filter used here meet the required specifications after coarse and fine tuning. Tuning the above filter was difficult and little time consuming because of multiple iterations and adjustments. Vector Network Analyzer (VNA) is ideal and most suited for the tuning of cavity filters; however, Spectrum Analyzer is used to tune the above filter as VNA was not available.

In microwave cavity-based band pass filters, the following adjustments are available for tuning:

1. To tune the center frequency of the filter tuning screws for the tuning resonators are adjusted.
2. The bandwidth of the filter is adjusted by the coupling between resonators which is adjusted by coupling screws.

a. Return loss is adjusted by adjustment in filters with probe coupling (adjusting probe diameter, gap between the end resonators and the probe).

4. Frequency response of the Cavity Band Pass Filters

After tuning the filter, it is kept on observation for 24 hours to see the variations if any in the response of the filter. Plot -1 shows the frequency response, gain flatness and rejection at F0±55MHz. Plot-2 shows the 3-dB bandwidth of the filter.

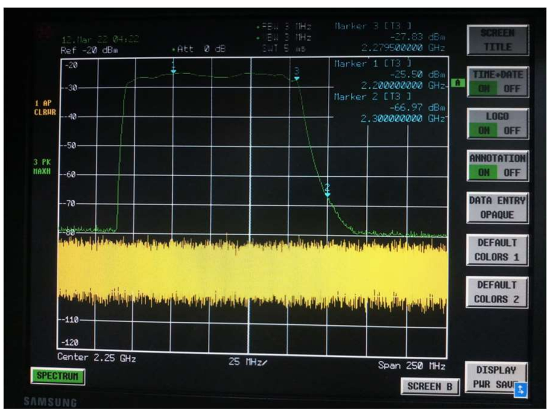
The center frequency F0 is tuned to 2225 MHz, lower cut-off frequency FC1 to 2169 MHz and upper cut-off frequency FC2 is tuned to 2280 MHz, this is because we have been approved to use frequency up to 2280MHz.

The filters are tuned for the desired frequency response using spectrum analyzer and it is installed at the multi-coupler input rather than at the LNA input, so that it should not reduce the receive system G/T.

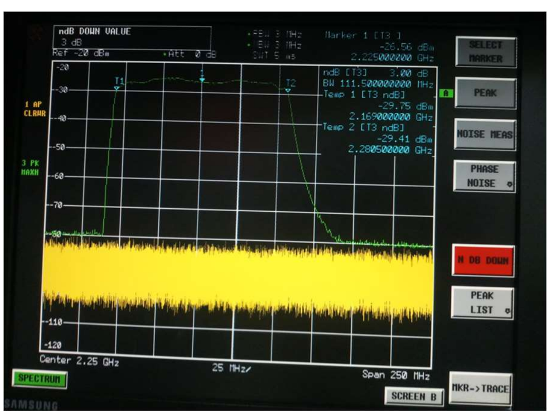
Two filters are installed in downlink chain, one for the RCP sum signal and the other for the LCP sum signal. The filters are provided with SMA connectors for input/output interface. Suitable SMA to N-Type adapters are used to connect the filter in the circuit with minimum losses.

A comparative study is done on the downlink system results to show the advantage of the filters and the location at which it is installed.

Plot-3(a) and Plot-3(b) shows the measured Y-factor plots using sun as a source without filter and with filter respectively. From the plots it can be concluded that there is no degradation in Y-factor due to the insertion of the resonant cavity filter. Hence downlink G/T remains same with the filter.

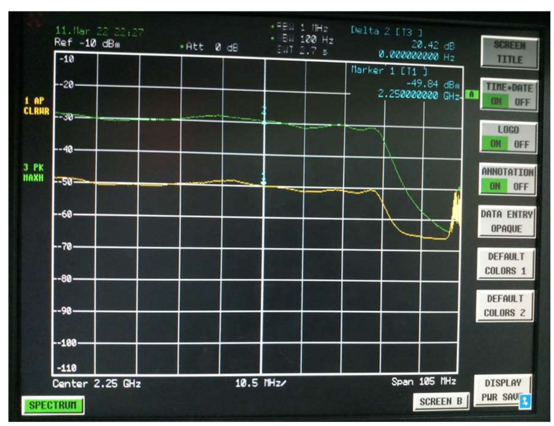


Plot-1 Filter frequency response @ desired frequency



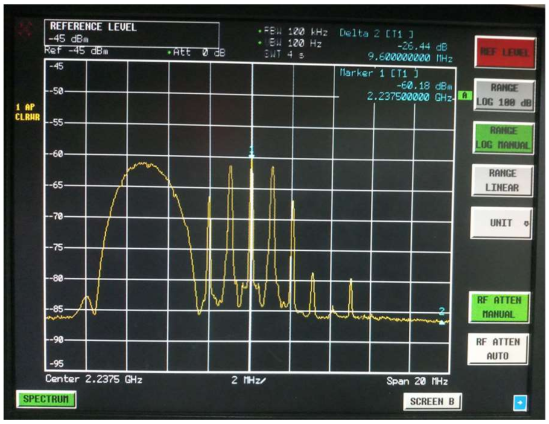
Plot-2 Filter 3dB bandwidth

Plot-3(a) Y-factor plot without filter

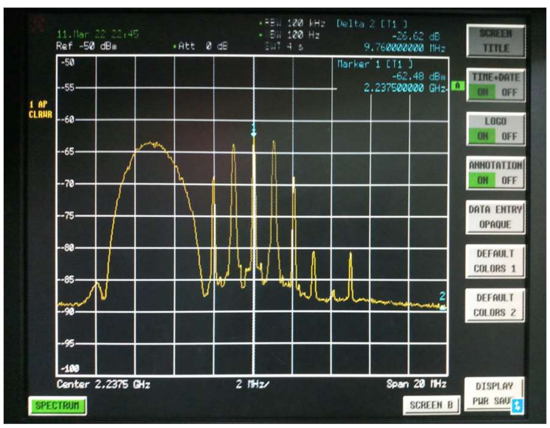


Plot-3(b) Y-factor plot using with filter

Plot-4(a) and Plot-4(b) shows the measured C/N0 plots using GMS as a source without filter and with filter respectively. From the plots it can be concluded that there is no degradation in C/N0 due to the insertion of the resonant cavity filter.

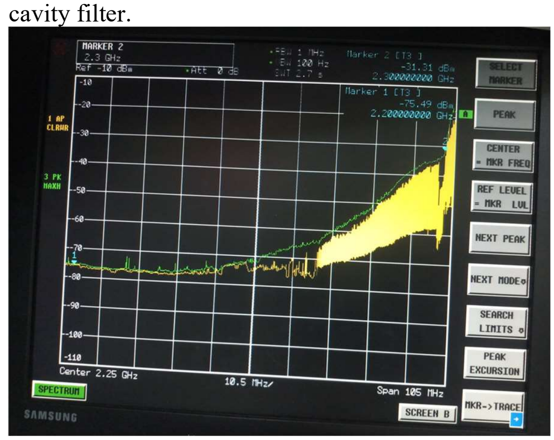


Plot-4(a) C/N0 plot using GMS without filter

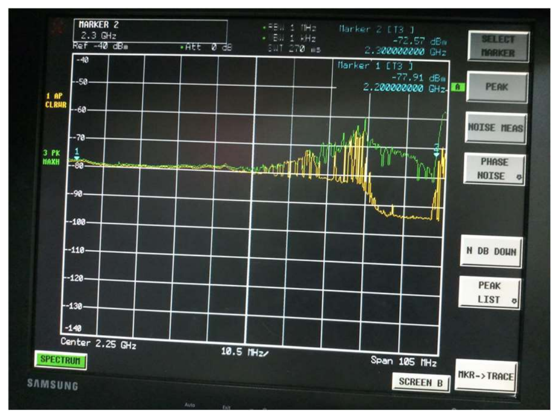


Plot-4(b) C/N0 plot using GMS with filter

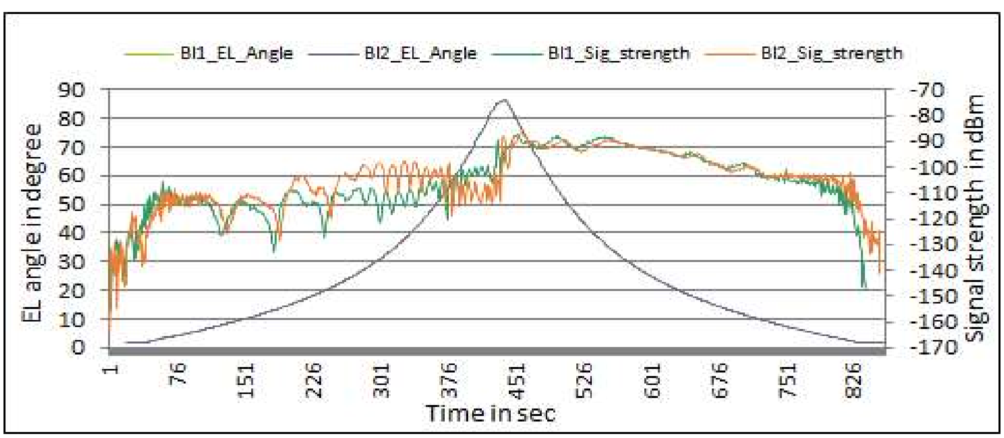
Plot-5(a) and Plot-5(b) shows the downlink RF spectrum plot during antenna AZ and EL looks at 4G tower without filter and with filter respectively. From the plots again it can be concluded that maximum interferences at the end of the frequency band is almost rejected by the use of resonant cavity filter.



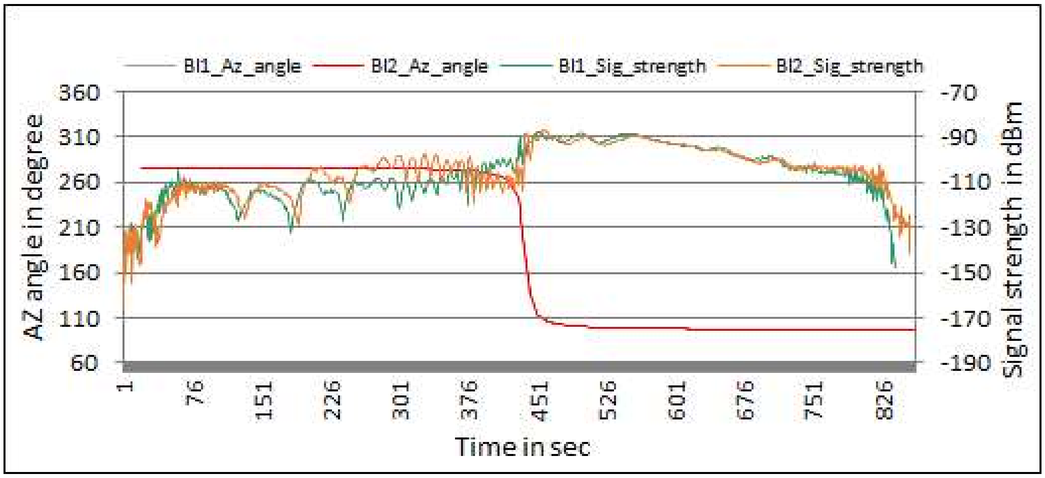
Plot-5(a) Downlink RF spectrum plot during antenna AZ and EL looks @ 4G tower without filter



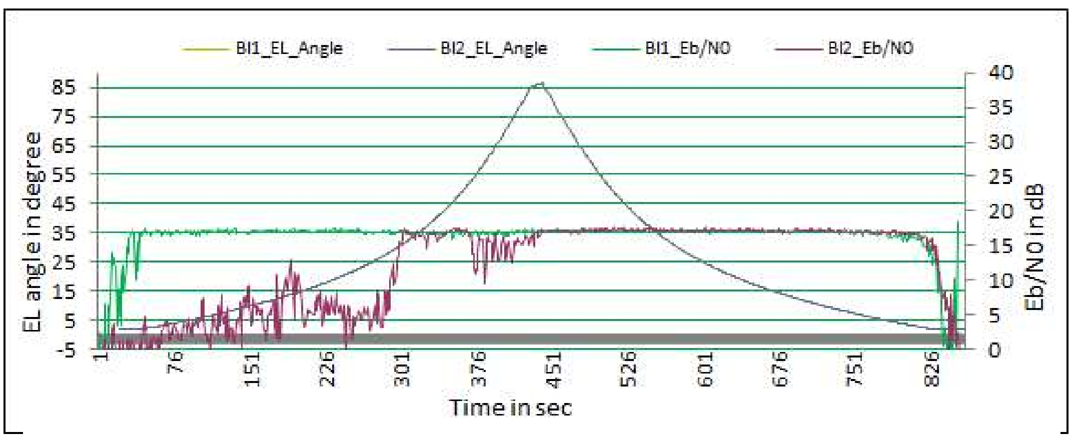
Plot-5(b) Downlink RF spectrum plot during antenna AZ and EL looks @ 4G tower with filter



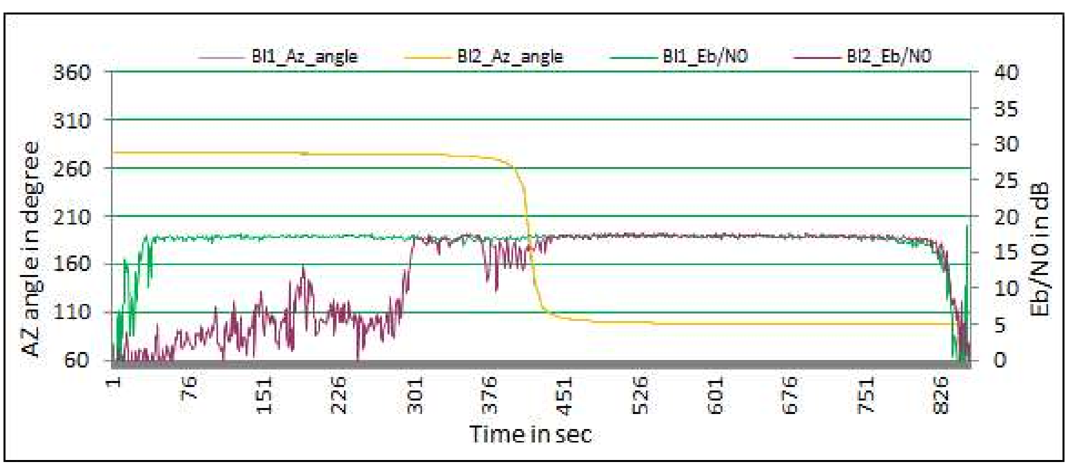
Plot-6(a) Downlink received signal strength at LNA input at different antenna EL angle



Plot-6(b) Downlink received signal strength at LNA input at different antenna AZ angle



Plot-7(a) Downlink received signal EB/No at different antenna EL angle



Plot-7(b) Downlink received signal EB/No at different antenna AZ angle

5. Evaluation of Ground station performances with and without filters

Different satellite passes were tracked to see the down-link performance of the stations, particularly when the 4G signal towers are coming in between the trajectories. Simultaneously same satellite pass is tracked from two co-located ground stations, to observe the impact of 4G signal on the satellite downlink signal and observations are recorded. IRS is tracked to evaluate the performances, especially received signal strength at LNA input and EB/No at the baseband receivers.

The 4G signal strengths for both antenna are very high from azimuth 230 to 270 degrees, maximum at 265degree and EL up to 21degree.

Plot-6(a) & 6(b) shows downlink received signal strength at LNA input at different antenna EL & AZ angle respectively.

We can see from the plot that the signal strengths are very week and fluctuating till azimuth angle near 270degree and elevation angle up to 25degree because of the 4G tower signal, there after it is very strong and steady as expected.

Plot-7(a) & 7(b) shows downlink receive signal EB/No at different antenna EL & AZ angle respectively. Green trace shows EB/No of 1st station which is connected through the filter, whereas brown trace shows EB/No of 2nd station which is not connected through filter. It can be clearly observed that, EB/No without filter is very week and fluctuating till azimuth angle 270degree and elevation angle up to 25degree because of the 4G tower signal.

It is observed that the impact of 4G tower signals is very high for those satellite downlink signals which are close to 2300 Mhz. Launch vehicle 4th carrier is also close to 2300 MHz, hence the impact observed is very high without filter. Similarly, A2 S-band payload is severely affected due to the 4G tower signals.

6. Results and conclusions

All the problems discussed above for IRS downlink signals, launch vehicle signals and S-band payload data signals are absolute normal when we use the above filters, even when the trajectory comes in the direction of 4G mobile towers. Various satellite passes are tracked to prove the above results, which is very satisfactory.

In addition to that it is also recommended that to install this filter at the multi-coupler input rather than at the LNA input. If we use the filter at the LNA input, then there will be a reduction of receive system G/T of around 2 dB/k. The degradation of the G/T can be saved by installing the filter at the multi-coupler input. Further it is also recommended to install the same filter to all the ISRO/ISTRAC ground stations for avoiding interference from 4G signals.

There are many advantages of the filter like tunable, light weight, less insertion loss and very less design time and fabrication cost.

7. References

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