# An anti-aliasing filter at S-band microwave frequency using ADS

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**Abstract—The aliasing signal interferes with the actual signal and resembles more-like the original intermediate signal. This is called image frequency. To eliminate this image frequency a filter is to be designed in the RF(Radio Front) stage. At S-band microwave frequency (2 GHz to 4 GHz), the lumped components cannot be used due to distributed effects. Also, for the compactness of the filter, the distributed components are being used in microwave frequencies. Hence the coupled stage of microstrip filter with good frequency response is adopted in this paper.**

**The filter design is carried out by using a simulation software namely, ADS(Advanced Design System). Only the coupled stages of a microstrip filter cannot reduce the aliasing effect, hence extra strict requests are made on the insert loss and standing wave ratio of the received signal in a satellite receiver. This filter is designed at the center frequency of 2.491 GHz. Only on optimization, the filter achieves minimum aliasing interference at the desired center frequency. This is done by the GOALs and OPTIM controller embedded with ADS.**

**Keywords:** image frequency, insertion loss, reflection ratio, microstrip filter.

## I. INTRODUCTION

Satellites receivers at microwave frequencies are being used for a large number of purposes. A satellite receiver without adequate filtering at its input is able to pick up signals at two different frequencies simultaneously; the desired frequency and the image frequency. Hence there is a need for the installation of the preselect filter at the RF stage before mixing. At high frequencies (GHz or higher) the wavelength is so short that only distributed elements are possible to practically realize, while at low frequencies lumped elements are used due to the fact that distributed elements become too large[2].Also, for the compactness of the system, distributed elements are preferred. The existing systems focuses on the Chebyshev type of band pass filter to overcome this problem because this filter provides desired roll-off in the stop band. But the existing system requires more than seven stages to attain the attenuation of around 66 dB. This is evident from the plot of attenuation verses normalized frequency in fig.2, which demands more number of stages for the same attenuation in the alias signal frequency. These problems can be eliminated with the proposed system where, the microstrip filter is used which posses small-size, light weight and high frequency response[3]. This proposed system filter design is made feasible through the simulation software called ADS by AgilentCorporation. This software can make a thorough analysis on high frequency circuit design till realization with high accuracy.This is dealt with the rest of the sections in this paper.

The section II discusses about the design flow of microstrip filter in detail. The design is done through the calculation of the microstrip filter parameters using the LineCalc tool in ADS.The schematic design of the microstrip filter is simulated and the frequency response curve is obtainedbefore optimization. Then the optimization of the filter is carried out using the OPTIM controller with ADS in section III.The optimized values are obtained after which the results are discussed in section IV.

## II. FILTER DESIGN

*A. The filter design steps:*

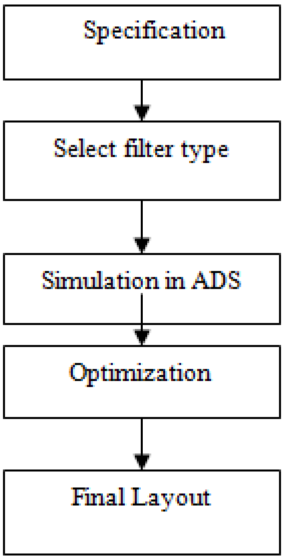


Fig.1 Filter design steps

The project aims in the design of the filter type which can produce the maximum attenuation at the center frequency of 2.491 GHz. This band pass filter selects the band of lower and upper cut-off frequencies as 2.441 GHz and 2.541 GHz respectively. The higher attenuation reduces the energy of the alias interference at this particular frequency. The length of each stage is considered to be $\frac{\lambda}{4}$($\lambda$ is the length of the S band signal), so the goal is to find the width, length and coupling gap of the microstrip filter.Generally for high frequency design the substrate used is FR4, because of its excellent chemical and fire resistant which can withstand high temperature.

It is important to choose the correct bandwidth for a give type of signal. It is necessary to ensure that it is narrow; otherwise unwanted off-channel signals will pass through the filter. The bandwidth of the filter is 100 MHz, so the low pass normalized frequency of the alias interference is [1]

$$\varphi = \frac{\omega_c}{\omega_U - \omega_L}\left(\frac{\omega}{\omega_c} - \frac{\omega_c}{\omega}\right) = -3.7$$

Where:

$\omega_c$= 2491.75MHz

$\omega_U$= 2541 MHz

$\omega_L$= 2441MHz

$\omega$= 2308.25 MHz

This normalized frequency is plotted against the attenuation which gives the number of stages required for the filter design.

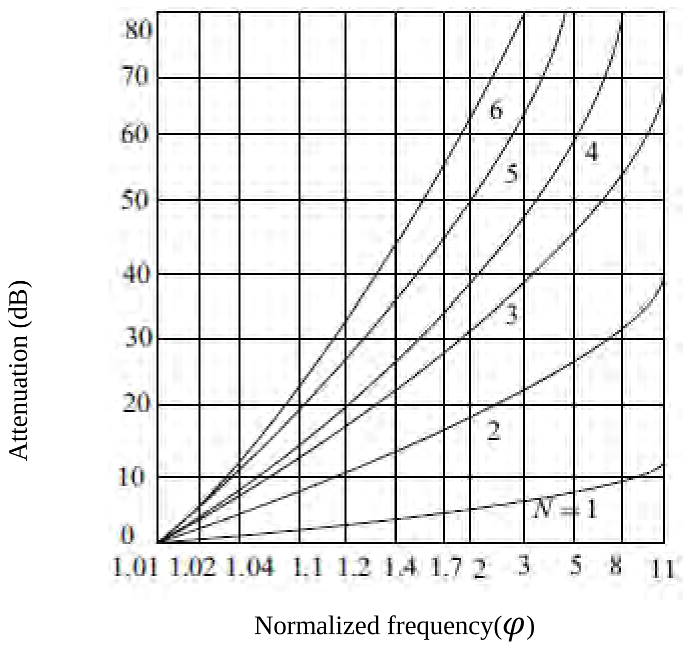


Fig.2 Plot of attenuation Vs normalized frequency

The plot in fig.2 shows that the normalized frequency of 3.7 requires seven stages for the filter to have maximum attenuation.

*B. Design in ADS[1]:*

The circuit design and realization of such a filter is carried out in a simulation software ADS. The LineCalc tool in ADS is used to obtain the parameters such as length, width and coupling gap of microstrip filter[6]. These values are as given in the following Table I.

Table I. Parameters of microstrip filter by LineCalc tool

| WIDTH (mm) | GAP (mm) | LENGTH (mm) |
|---|---|---|
| 1.09099 | 0.977841 | 11.981500 |
| 1.191400 | 3.415800 | 11.813700 |
| 1.191770 | 3.946540 | 11.808200 |
| 1.184040 | 3.087590 | 11.831400 |
| 1.184040 | 3.087590 | 11.831400 |
| 1.191770 | 3.946540 | 11.808200 |
| 1.191400 | 3.415800 | 11.813700 |
| 1.09099 | 0.977841 | 11.981500 |

Here the S-parameter simulation is being carried out for the filter where, S(2,1) indicates the insertion loss and S(1,1) indicates the reflection ratio. Only the coupled stages of microstrip Chebyshev band pass filter is not capable to produce the maximum attenuation at the desired frequency. This can shown evident from the fig.3 that the curve deviates from the center frequency.

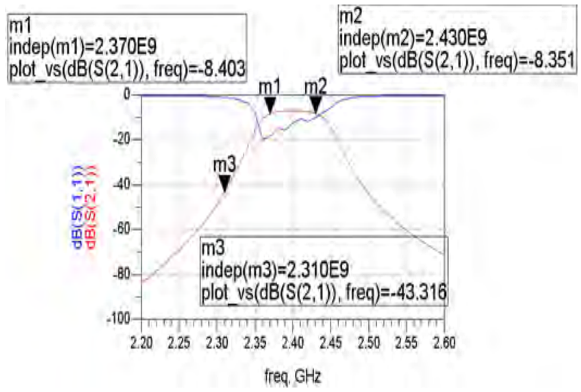


Fig.3 Filter response before optimization

## III. OPTIMIZATION OF THE FILTER

In order to reach the specified requests the OPTIM controller embedded with ADS is used by setting the predetermined GOALs. In this project three GOALs are specified. The Optim Goal1 is set the S(2,1) parameter and also the $\boldsymbol{\omega}_{\mathbf{L}}$ and $\boldsymbol{\omega}_{\mathbf{U}}$ between which the insertion loss is expected to be minimum. To reduce the high insertion loss[4], filterswith an enhanced coupling structure were proposed. In this project we couple the stages of the microstrip filter by inserting MCLIN and MLIN components, which induce some losses in the filter circuit. This produces the insertion loss to be -4.440 dB at 2.500 GHz, which is the desired center frequency.

The Optim Goal2 is also set the S(2,1) parameter and the alias signal frequency. In order to reduce its energy the maximum field is set to -60 dB. By which we obtain the attenuation in the alias signal attenuation as -66.414 dB. The Optim Goal3 is set the S(1,1)and the maximum field is set to -14 dB in the frequency range of 2.441 GHz and 2.541 GHz. By simulation we were able to obtain it as -15.733 dB, which is only slightly greater than the desired value.

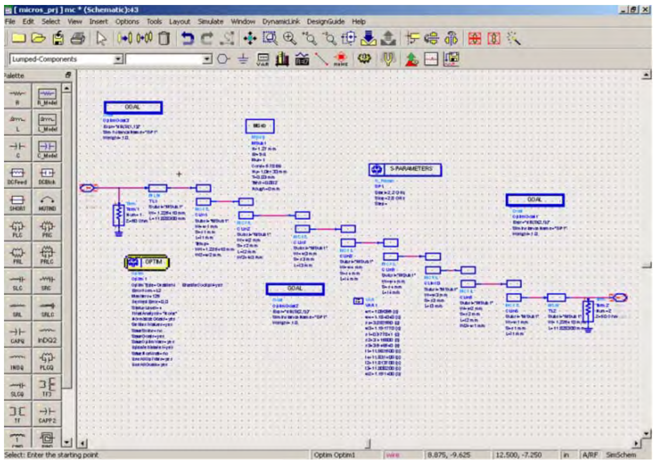

Fig.4 Schematic design of the microstrip filter in ADS

The cockpit optimization is done in ADS with the number iterations as 125 to produce the optimum values for the filter.The VAR components are being used to set the tunable parameters such as length, width and coupling gap of the microstrip filter[5].This tuning of the parameters is shown in the fig.5.

In this design, the filter is symmetrical geometrically, because the obtained values for the first four stages repeats itself for the next four. Indeed only four group different values are need to be determined during optimization also. These can be set as (w1,s1,l1), (w2,s2,l2), (w3,s3,l3) and (w4,s4,l4) in the schematic. The optimization is done only when the EF(error function) approaches zero. The GOALs are defined as a function of the OPTIM controller, hence called optim goal.

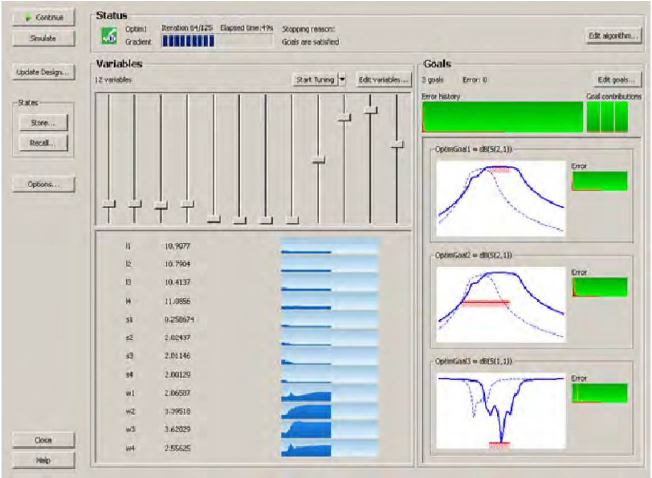


Fig.5 Cockpit optimization to reach specified GOALs

## IV. RESULTS

Hence the GOALs which are specified is evaluated on the cockpit OPTIM controller. The filter offers the desired performance at the center frequency, 2.491 GHz. This is as shown in the fig.6

The actual frequency of concentration has reduced insertion loss, which is less than almost 5dB and the attenuation is being -66.414dB and also the reflect ratio appears to be in much reduced form as -15.733 dB. The GOAL parameters completely define the required specification, which can be inferred from the above graphical representation.

Table II. Optimized values of the microstrip filter

| WIDTH(mm) | GAP(mm) | LENGTH(mm) |
|---|---|---|
| 2.06587 | 0.25867 | 10.9077 |
| 3.39518 | 2.02437 | 10.7904 |
| 3.62029 | 2.01146 | 10.4137 |
| 2.55625 | 2.00129 | 11.0856 |
| 2.55625 | 2.00129 | 11.0856 |
| 3.62029 | 2.01146 | 10.4137 |
| 3.39518 | 2.02437 | 10.7904 |
| 2.06587 | 0.25867 | 10.9077 |

The values that are obtained during optimization are then plotted for results. The plot of amplitude verses frequency curve after optimization shows that, we can get that the center frequency of the filter has been adjusted to 2.491 GHz and the corresponding insertion loss is -4.44 dB, the reflect ratio in pass band is -15.733dB with a -66.414 dB attenuation in the alias frequency, indicating that the requested performance is well satisfied.

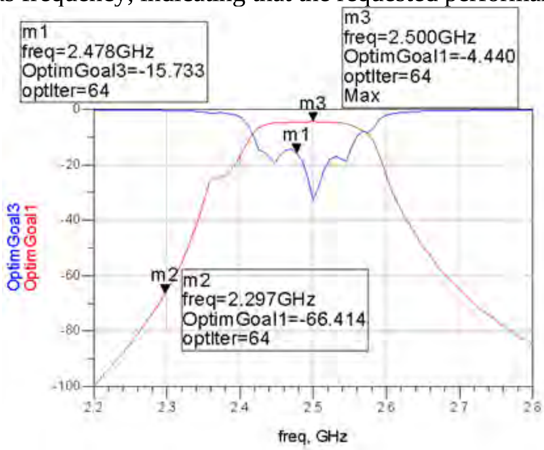


Fig.6 Filter response after optimization

The results confirmed the improvement in the stages and the GOALs of the filter.This confirmation can also be made clear from the comparison between the existing and the proposed system as shown in Table III.

Table III. Comparison between existing system and proposed system

| Parameters | Existing system | Proposed system |
|---|---|---|
| Insertion loss | Around 5 dB | -4.440 dB |
| Reflection Ratio | -23.168 dB | -15.33 dB |
| Attenuation in alias frequency | -46.406 dB | -66.414 dB |
| Length of microstrip filter | 11.4396 | 10.9077 |
| Width of microstrip filter | 1.26839 | 2.06587 |
| Coupling gap of microstrip filter | 0.253797 | 0.25867 |
| EF during optimization | 0.340766 | 0 |
| Number of iterations | 125 | 64 |

## V. CONCLUSION

The results obtained by the proposed design of the coupled microstrip type band pass filter confirmed the enhanced attenuation in the alias signal frequency. This design is made possible by the ADS software and the optimization tool made a remarkable achievement. This project aided by ADS is also feasible in practice.

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