Design and implementation of microwave digital filters

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ABSTRACT

In this paper to design and implement the digital filters at microwave frequencies Microwave is term form electromagnetic waves above 10^3 mega hertz to 300 gigahertz of frequency and used for obtaining the small antennas and low power transmitter. For design of filter used the micro strip line The micro strip is two port networks; it used controls the frequency responses. The lumped elements can be used as components in the design of micro strip line for High pass, Low pass and Band pass filter and also get the filter micro strip layout for each corresponding filter. The simulation results shown in the An soft HFSS software With cut off frequency and insertion loss of the filters. The hardware structure of micro strip in filters are designed on the copper plate and the etching process should be done for micro strip line and the simulation results should be shown on the vector network analyzer with the cut off frequency and insertion loss.

Keywords

Micro strip line, , lumped elements, microwave filters, s parameters , Network analyzer.

1. INTRODUCTION

In signal processing, the filter function is to remove unwanted parts of the signal, such as random noise, or to extract useful parts of the signal, such as the components that are lying within certain frequency range. In digital filter it performs the mathematical operations to reduce the certain aspects of the signal. A digital filter can be either Finite impulse response (FIR) type or Infinite Impulse response (IIR) type. For real time applications IIR filters are preferred.

Main purpose filter are taken up frequencies in the selected operated range In these filter three types of the filter response are there the chebyshev, butter worth, Bessel filter and elliptical filter response. In chebyshev filter it has approximate ideal response of any filter for specified order and ripple, Butterworth filter has maximum flat response, Bessel filter has maximum phase delay, and elliptical filter has the steepest cut off frequency at specified order and ripples. For better response of the filter have taken chybeshev and elliptical filter and it easy to calculate values .There four main types for filter we knows as the Low pass filter, High pass filter, Band pass filter, Band stop filter. Each filter rejects and accepts the Frequency at different levels. The Low pass filter allows frequency at with in cut-off frequency. High pass filter allows higher frequencies than cut off frequency, Band pass filter allows frequency with the pass band and Band stop filter will reject frequencies for certain band.

Microwave engineering is the study and design of microwave circuits, components, and systems. Fundamental principles are applied to analysis, design and measurement techniques in this field. Microwave is term form electromagnetic waves above 10^3 mega hertz to 300 gigahertz of frequency and used for obtaining the small antennas and low power transmitter. The filters used in the microwave system like radars, measurements and satellite communications. Microwave devices will include some kind of filtering on the signals transmitted or received. Such filters are commonly used as building blocks for duplexers and diplexers to combine or separate multiple frequency bands.

2. Microwave filters

Microwave filters represent a class of electronic filter, designed to operate on signal in the Mega hertz to giga hertz frequency The most microwave filters are made up of one or more coupled resonant and any technology used to make resonant is also used make the filters in these microwave filter. The simplest filter structure in microwave filters are the lumped elements gives good compact but low performance and it has the both lower and higher frequency ranges.

Lumped-Element LC filters have both an upper and lower frequency range. As the frequency gets very low, into the low kHz to Hz range the size of the inductors becomes prohibitively large. Very low frequency filters are often designed with crystals we reduce this problems. As the frequency gets higher, into the 600 MHz and higher range, the inductors becomes too small. The filters are Low pass filter, High pass filter, Band pass filter. Depends up on the lumped elements values we can construct filter in microwave filters.

2.1 Low pass Filters

A low pass filter that passes the frequency below the cut off frequency The exact frequency response of the filter depends on the filter design. The design of the low pass filter at micro frequencies ranges we should calculated the lumped elements values to construct the low pass filter .The figure shows below lumped elements of the low pass filter.

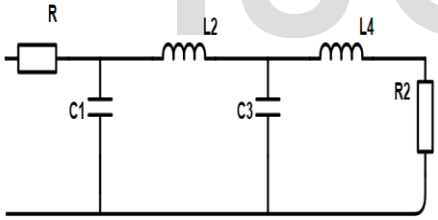

Fig.1.Lumped elements structure of low pass filter

Where

L = inductance
C = capacitance
R = Reactance

2.2 High pass filter

A high-pass filter is an electronic filter that passes signal with the frequency higher than a certain cut-off frequency and attenuates signal with the frequencies lower than the cut-off frequency. The filter design in microwave using the lumped elements we can design filter by rejecting the low frequencies by using the lumped elements .The figure shows below lumped elements of the high pass filter.

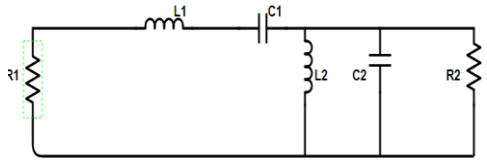

Fig.2.lumped elements structure of high pass filter

2.3 Band pass filter

A band-pass filter is a device that passes frequencies within a certain range and rejects frequencies outside that range. The filter design in microwave we used lumped elements and it combination of the both low pass and high pass filter. The figure shows lumped elements structure of the band pass filter.

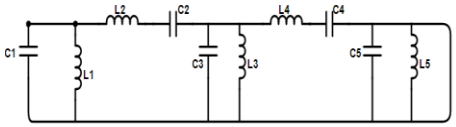

Fig.3. lumped elements structure Band pass filter

In this microwave filter for designing of any filter we need the lumped elements values by using can draw filter structure and the type of filter pro type ,element values order of the filter of the particular filters. We get the values of length and width of the structure in micro strip line.

3. Micro strip line

Micro strip line is a electrical transmission line and used to convey microwave frequency signals. It consist of conducting strip separated from the ground plane by a dielectric layer is known as the substrate. Microwave components like antennas, couplers, filters, etc.. Can be formed micro strip line and it is less expensive. The disadvantage of micro strip is higher losses .The micro strip line has the Low impedance frequency and the high impedance frequency and these should be controlled by characteristic of the micro strip line .The structure of micro strip line is

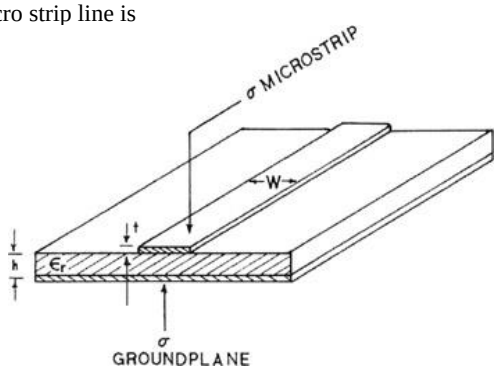

Fig. 4. Structure of micro strip line

Where

W =width of the micro strip
h =height of the substrate
ἐr=permittivity of substrate.

The characteristic of micro strip line Zo is

$$Z_0 \frac{120\pi}{\sqrt{\epsilon_{eff}}[\frac{w}{h}+1.393+\frac{2}{3}]\ln[\frac{w}{h}+1.4141]} \qquad (1)$$

For the different cases exact the characteristic values of micro strip line is

- w>>h ,any ϵ_r for parallel plate transmission line
- w<<h, any $\epsilon_{r=1}$ for wire above the ground plane.
- w<<h, ϵ_r>>1

The dielectric of micro strip line is

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2\sqrt{1+12\frac{h}{w}}} \qquad (2)$$

Micro strip line will have low to high radiation will support 20 to120 ohm impedance. In the micro strip line has high impedance and low impedance frequency and these should calculated by lumped elements of the particular filter. For designing of the micro strip we calculated the lumped values and in this we take two port networks for the lumped elements for this we S parameters.

4. S-parameter

Scattering parameter or S-parameters describe the electrical behaviour of linear electrical networks when undergoing various steady state stimuli by electrical signals. S-parameters do not use open or short circuit conditions to characterize a linear electrical network; instead, matched loads are used. s parameters are used networks operating at the radio frequency or microwave frequency.

The transfer function of a cascaded network can be found by multiplying the chain scattering matrices of the components composing the network. The chain scattering parameters, of a two-port network are defined by assuming the waves and at port1 are dependent variables and the waves and at port2 are independent variables.

Fig.5. Twoport network.

The transfer function of the Two port network in scattering matrix is

$$\begin{bmatrix} a(1) \\ b(1) \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} a(2) \\ b(2) \end{bmatrix} \qquad (3)$$

Where

a (1), b (1) = dependent variables

a (2), b (2) = independent variables

5. Designing of filters in micro strip line

To design the filters in the micro strip line first we have construct the micro strip in filters we calculated the lumped values depending up on the pro type of the particular filters. For designing any filter we need L and C values and should be calculated by using following equations.

$$L_i = \frac{Z_0}{g_0} * \frac{\Omega_c}{2\pi f_c} * g_i \qquad (4)$$

$$C_i = \frac{\Omega_c}{2\pi f_c} * \frac{g_0}{Z_0} * g_i \qquad (5)$$

Form equations above equations can caluclate Land C values.

Where

L_i = inductance
C_i = capictance
Z_0 = characterstic impedence
Ω_c = desired frqeuency
f_c = cutoff frequency
g_0, g_i = element values of the particular filter

Now protype elements values of the particular filter we find the lumped elements values and lumped model filter for any filters in microwave filters are

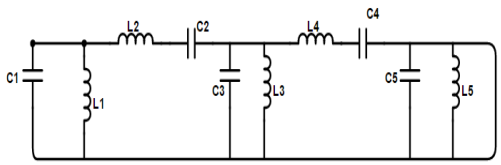

Fig.6. lumped model filter.

To design the microstrip line for that we need the Length and wdith of the microstrip line using the lumped element

values for that particular filter we can find the dimesions of the microstrip line.

$$L = \frac{Z_o L_i}{Z_h} \quad (6)$$

$$W = \frac{Z_h c_i}{Z_o} \quad (7)$$

Form above equations find out the Width and Length of the microstrip line and mesurements should taken in mm or Mile to construct the microstrip line.

Where

L = Length of th microstrip
W = Width of the microstrip
L_i = inductance value
c_i = capictance value
Z_h= thickness of the substrate.
Z_0= charactestric impedence.

By using all these equation we can find out lumped elementsn values of filter and microstrip.

6. Proposed structure of microstrip line

The design of microstrip in filter frist we have to know the values of the lumped elements to construct the filter and then we design microstrip line due dimesions of the Width and height of the strip line. In this here we design three types of the filter are Lowpass ,Highpass,Bandpass filter and values are calculated for these filter are using equations 1 and 2 and for microstrip line we use equations 3 and 4 for Width and height of the miocrostrip.
In the microstrip line charactestics impedance varies between 20 to 120$\boldsymbol{\Omega}$. In these we are appliying sparameters to show the simulation results in sparameters.Now we construct the microstrip line in filters and simulation results re shown in HFSS software.
In these for filter response we have taken has chyebhesve filter because it esay and it has quick respones and the order of the filter is taken has the n=3 and the characterstic impedance of the microstrip line is $Z_0 = 50\ \boldsymbol{\Omega}$. The design specifiction of microstrip line is

Table1 .Design specification of the microstrip line.

Chebyshev specfications		Dielectric substrate specifctions		
Filter order N=3	Equal ripple Rp=0.5	Relative permativity $\epsilon_r = 4.4$	Substrate Thickness h=1.6mm	Characterstic impedance Z_o=50

By using the these design specifictaion values we can construct the microstrip line with filter and we use chebyshev response with order n=3 .The design and simulation results are shown in High frequency selective simulator(HFSS) and results are shown in the S parameter.

The design of Three filters in microstrip line using HFSS software is shown below.

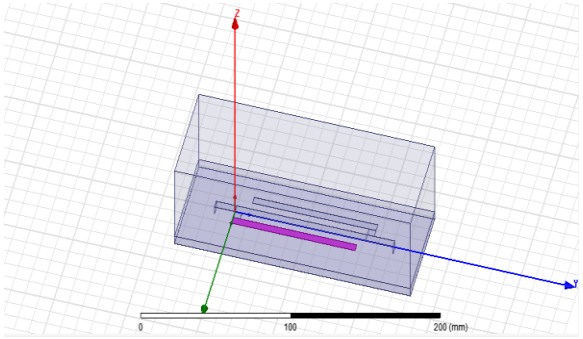

Fig.7. Designed structure of microstrip filter in HFSS

The above figure 8 is the Structure of the microstrip line in for threefiltersaretheHighPass,Lowpass,Bandpass filter with the above prposed values designed the microstrip line with these three filter layout structure and the simulation results are shown in the sparamters.

7. Simulation Results

The simulaton results of microstrip line filter in HFSS for Low pass, High pass ,Bandpass filtes with the cut off frquency and insertion loss are. The below figures shown as the simulation results of the filters and the outputs of these filters are shown in the sparameter so the cureves are respersented to indicate as dB(S(1,1)),dB(S(2,1)) these gives information of the curves and by using these curves observe the insertion loss and cutoff frequency of the particular filter . The graph respernation is HFSS on X axis taken as frequency in giga hertzs and on y axis taken as sparametersthat is dB(S(1,1)),dB(S(2,1)).

The below figure shows simulatio results for microstrip line Lowpass filter in HFSS and the results are shown in sparameter with two curves are dB(S(1,1)),dB(S(2,1)) and by these curves the gain of the dB(s(1,1)) is -24dB and cutoff frquency is 14ghz.

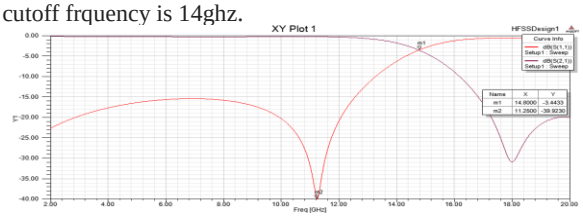

Fig.8. simulation results for Lowpass Microstrip line.

The below figure shows simulatio results for microstrip line high pass filter in HFSS and the results are shown in sparameter with two curves are dB(S(1,1)),dB(S(2,1)) and by these curves the gain of the dB(s(1,1)) is -59dB and cutoff frquency is 5ghz.

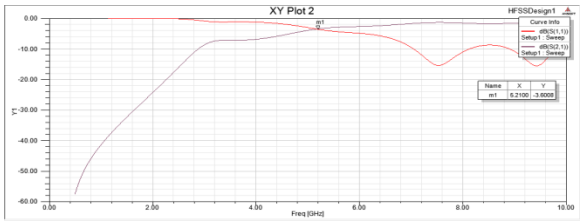

Fig.9. simulation results for highpass microstrip line

The below figure shows simulatio results for microstrip line band pass filter in HFSS and the results are shown in sparameter with two curves are dB(S(1,1)),dB(S(2,1)) and by these curves the gain of the dB(s(1,1)) is -59 dB and cutoff frquency is $f_1 = 17$ghz. and f_2 =10ghz and the cut of frquency of the is 7ghz.

Fig.10.simulation results for Bandpass Microstrip line.

8. Fabrication process to implement a filter

To design a filter in the microstrip in the hardware the same dimesions are taken as the software dimesions of the microstrip line shown in table(1),The materials are used for design the microstrip line are copper plate ,Fr4 erpory(4.4),ferric chloride solution,connectors and Network Anlyazer.To design of the filter in the microstrip line have take the designed structure of filter in Ansoft HFSS software shown in figure6.The filter should be printed on the copper plate and the ground should be coverd with black paper and the printed structure copper plate should kept in the ferric chloride solution for etching process for particular part of strucure of the filters and the reamaing part should vanishied and now the connectors are should be connected to the edges of the filter.The complete structure of microstipe is shown belown and thios should be connected to Network vector anlyazers for the simulation results are shown below.

Table2.design specifications of the microstrip line

Chebyshev specfications		Dielectric substrate specifctions		
Filter order N=3	Equal ripple Rp=0.5	Relative permativity $\in_r = 4.4$	Substrate Thickness h=1.6mm	Characterstic impedance Z_o=50

Form the above table 2 are dimesions of filter in microstrip line we designed the microstrip line in filters and figure is shown below.

Fig.11. Fabrication of microstrip

8.1 Vector Network analyzer

Vector Network analyzer is a instrument used to measure the Network parameters and electrical networks and it is used to mesure the S-parameter because of reflection and transmission of electrical networks and it meaures the high frquency siganlas.Network analyzer areoften used charcterised Twoport network as amplifers and filters with in abritary number of the ports. The basic strucure of network anlayzer is shown below and it is Used inovlve a signal genertors, test set and one or more reciever display and it mesures the Twoport network of Sparameters are $(S_{11},S_{12},S_{21},S_{22})$ it measure the four parameters in network analyzer. The architecture of a network analyzer is shown below.

Fig.12.Basic architecture of the Vector Network analyzer.

The simulation results of the microstrip line filters are seen in the network analyzer to measure sparameter values of the filters response the sparameter are$(S_{11}S_{12}S_{21}S_{22}$)to meaure this parameter values of the particular filters. To mesure values of the sparametr is the design structure of the microstrip connected to one of the probes and another end are connected to the Network analyzer.The figure shows below mesure of the parametr values .

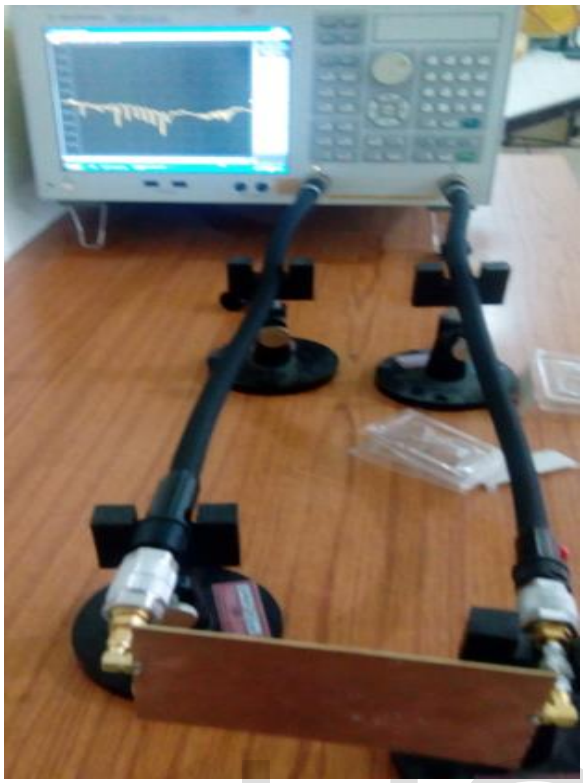

Fig.13. mesurements for sparamters in network analyzer.

9. Simulation results in network analyzers

The simulation results of the filters are shown in Network analyzer with the designed microstrip line and in this shown results in the S parameter and in these on the Yaxis taken as the gain in dB and on the X axis taken as the frquency in giga hertzs. The simulation results of the three filters are shown below in these results are shown in sparameters here we taken as the dBS(1,1) and dBS(1,2) two cureves these siulation results are compared with the HFSS results values the values shown in Netowrk analyzer are shown in the dotted lines in the garaphs .The simulation results for the three filters are shown below.

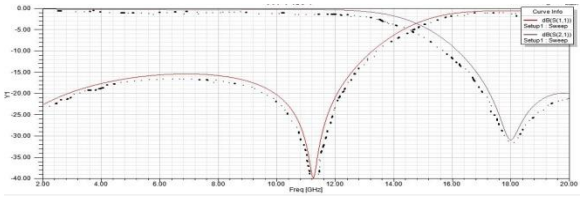

Fig.14. simulation lowpass filter with mesured values

Form above figure the two curves are respersented as the sparamter S(1,1)andS(1,2) and the dotted lines are respersented as the meaured values of lowpass filter with the gain as -24dB and the cut off frquency is 14gigahetrz.

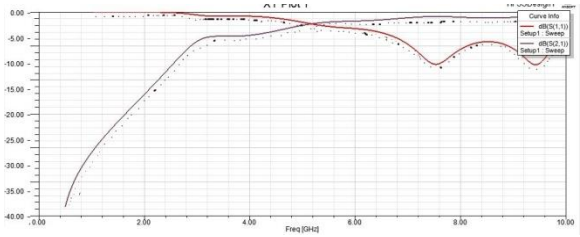

Fig.15. simulation highpass filter with mesured values

Form above figure the two curves are respersented as the sparamter S(1,1)andS(1,2) and the dotted lines are respersented as the meaured values of lhighpass filter with the gain as -39dB and the cut off frquency is 6gigahetrz

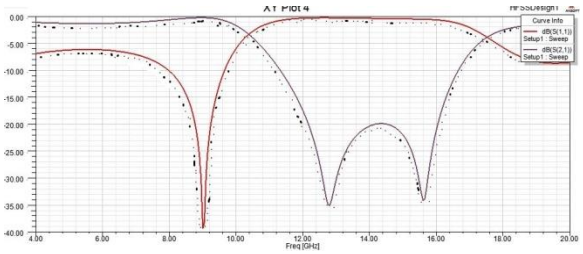

Fig.16. Simulation Bandpass filter with mesured values

Form above figure the two curves are respersented as the sparamter S(1,1)andS(1,2) and the dotted lines are respersented as the meaured values of bandpass filter with the gain as -10dB and the cut off frquency is 7gigahetrz.

These reults of the three filters are Lowpass ,Highpass and Bandpass filter with Lowgain and cuttoff frquency are mesured in software and the haedware architecture and the filter response are seen in the S parameters'.

10. Conclusion

The design and implementation of the digital filters at the microwave frequencies are designed and implemented are done by using two new approach they are HFSS software and hardware and the simulations results are shown for both are in parameters results are shown in S(1,1)and S(1,2) and in the hardware results are seen in network analyzer. By this two new approach we get low gain and cut-off frequencies for the design of the three filters are the Low pass , High pass and Band pass filters and results are in Parameters.

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