Design of High Performance Radio Frequency Band Pass Filter

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Abstract

In this paper deals the analisis, design and simulation of a small size UWB Band Pass Filter . The Ultra-wideband systems use wireless technology capable of transmitting data over spectrum of frequency bands for short and long distances with very low power and high data rates. At the receiver side there is an requirement to filter out the noises and pass only the desired signal frequency for processing. Hence, a BPF is required for the same. In the present paper the designing of a compact microwave parallel edge coupled line BPF has been discussed and implemented.

The BPF consists of a 4-parallel coupled line pairs designed for a Chebyshev response at a centre frequency of 3.1 GHz with a fractional bandwidth of 10%. The filter has been implemented using Flame retardant4 substrate of dielectric constant 4.4 with thickness of 1.6mm respectively. The physical parameters of the parallel coupled line filter sections have been simulated using the HFSS software to provide the closest values of the band pass filter prototype values. The corresponding Insertion Loss S21 is less than -2.2db& return loss is -12.50db with centre frequency 2.48GHz

1. Introduction

In any communication system the filters play an important role. Filters are generally used to select/reject or combine different frequencies as per requirement of the application. In any communication system the filters play an important role. Filters are generally used to select/reject or combine different frequencies as per requirement of the application. In the USA federal communication (FCC) allocated the frequency band 3.1 to 10.6 GHZ to the ultra wideband communication ISM application. In generally any communication system the filters play on important role and used to pass/attenuate different frequencies as per requirement of the application. The electromagnetic spectrum is limited and has to cover band of frequency need to be used for particular application. Emerging applications such as wireless communications continue to RF microwave filters with more important requirements like performance, weight, size and cost. Due to specifications and requirements RF microwave filters to design a lumped element are realized on various transmission structures, such as microstrip line, coaxial cable, waveguide. A simple way of achieving dual band is to put in cascade narrow band filters having multi resonance frequencies. Moro ever filter results in an increase in the over of the filter. In this study we developed a novel compact multi band pass filter using a new type of transmission line. In our project to introduce new technique to improve the filter performance. The aim is to design band pass filter using multi band application.

2. Metameterial

MTM are artificial materials engineered to have properties that have not yet been found in nature. They are assemblies of multiple individual elements fashioned from conventional materials such as metals or plastics, but the materials are usually constructed into repeating patterns, often with microscopic structures. Metamaterials derive their properties not from the compositional properties of the base materials, but from their exactingly-designed structures. Their precise shape, geometry, size, orientation and arrangement can affect waves of light electromagnetic radiation or sound in a manner not observed in natural materials. These metamaterials achieve desired effects by incorporating structural elements of sub-wavelength sizes, i.e. features that are actually smaller than the wavelength of the waves they affect.

3. Defective Ground Sloted

Defective ground plane structure (DGS) is an etched periodic or non-periodic cascaded configuaration defect in ground of a planar transmission line. (e.g) microstrip, coplanar and conductor backed coplanar waveguide.

4. Basic Theory

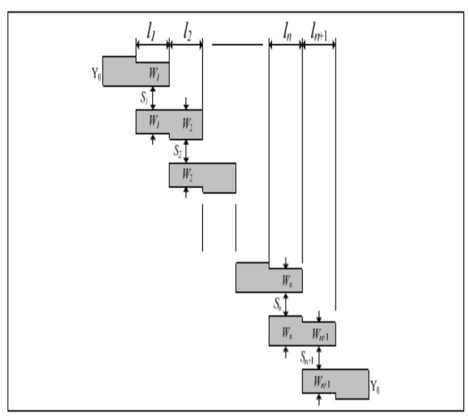

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Fig: 1. General structure of parallel edge coupled strip line band pass filter

A general structure of parallel edge coupled strip line band pass filter that uses half-wavelength line resonators shown in Fig 1.They are positioned in adjacent resonators parallel to each other along half of their length. This parallel arrangement gives relatively large coupling for a given spacing between resonators and thus this filter structure is particularly convenient for constructing filters having a wider bandwidth as compared to the end couple structures the design equations for this type of filter are given by

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi}{2}\frac{FBW}{g_0 g_1}}$$

$$\frac{J_{J,J+1}}{Y_0} = \frac{\pi FBW}{2}\frac{1}{\sqrt{g_J g_{J+1}}} \quad j = 1 \text{ to } n-1$$

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi FBW}{2 g_n g_{n+1}}}$$

Where n is a number of filter order, and g0,g1,….gn are the element of a ladder-type low pass prototype with a normalized cut off Ωc = 1, and FBW is the fractional bandwidth of band pass filter. are the characteristic admittances of J-inverters and is the characteristic admittance of the terminating lines. The reason for this is because the both types of filter can have the same low pass network representation. However, the implementation will be different. To realize the J-inverters obtained above, the even- and odd-mode characteristic impedances of the coupled strip line resonators are determined by

$$(Z_{0e})_{J,J+1} = \frac{1}{Y_0}\left[1 + \frac{J_{J,J+1}}{Y_0} + \left(\frac{J_{J,J+1}}{Y_0}\right)^2\right]$$

$$(Z_{0o})_{J,J+1} = \frac{1}{Y_0}\left[1 - \frac{J_{J,J+1}}{Y_0} + \left(\frac{J_{J,J+1}}{Y_0}\right)^2\right]$$

5. Designing Methodology

A Parallel-Coupled, Half-Wavelength Resonators Filters To design the band-pass filter with 3rd order Coupled Line configuration following specification are considered a center frequency of 2.48 GHz, bandwidth of 10% and equal ripple in the pass-band of 0.5dB. FR4 substrate of dielectric constant 4.2 with thickness of 1.58 mm and 3.38 mm is used respectively. According to D.M Pozar [2] the coefficients for equal ripple in the pass-band of 0.5dB third order Chebyshev filter are = 1.0000, = 1.5963, = 1.0967, = 1.5963, = 1.0000. These values are for low-pass prototype design with source and load impedance equal to unity. A ladder circuit that begins with a series element is chosen, g1and g3 are inductors and g2 is a capacitor

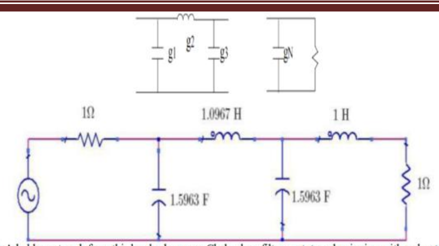

Fig. 2: A ladder network for a third order low pass Chebyshev filter prototype beginning with a shunt element.

To calculate the admittance inverter using equation (1) (2) & (3)

1. Determining the admittance inverter constants for 1st line pair:

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi}{2}\frac{FBW}{g_0 g_1}} = \sqrt{\frac{\pi}{2 \times 1.0000 \times 1.5963}\,0.1} = 0.3137$$

2. Determining *the admittance inverter constants for 2nd line pair:*

$$\frac{J_{1,2}}{Y_0} = \frac{\pi FBW}{2}\frac{1}{\sqrt{g_1 g_2}} = \frac{\pi \times 0.1}{2}\frac{1}{\sqrt{1.5963 \times 1.0967}} = 0.1187$$

3. Determining the admittance inverter constants for 3rd line pair*:*

$$\frac{J_{2,3}}{Y_0} = \frac{\pi FBW}{2}\frac{1}{\sqrt{g_2 g_3}} = \frac{\pi \times 0.1}{2}\frac{1}{\sqrt{1.0967 \times 1.59637}} = 0.1187$$

4. *Determining the admittance inverter constants for 4th pair:*

$$\frac{J_{2,3}}{Y_0} = \frac{\pi FBW}{2}\frac{1}{\sqrt{g_2 g_3}} = \frac{\pi \times 0.1}{2}\frac{1}{\sqrt{1.0967 \times 1.59637}} = 0.1187$$

The EVEN and ODD impedances of line pairs was determined by following equation (4) & (5)

1) *For 1st line pairs:*

$$(Z_{0e})_{0,1} = \frac{1}{1/50}\left[1 + 0.3137 + (0.3137)^2\right] = 70.6047$$

$$(Z_{0e})_{0,1} = \frac{1}{1/50}\left[1 - 0.3137 + (0.3137)^2\right] = 39.2355$$

2) *For 2nd line pairs:*

$$(Z_{0e})_{1,2} = \frac{1}{1/50}\left[1 + 0.1187 + (0.1187)^2\right] = 56.6407$$

$$(Z_{0o})_{1,2} = \frac{1}{1/50}\left[1 - 0.1187 + (0.1187)^2\right] = 44.7688$$

3) *For 3rd line pairs:*

$$(Z_{0e})_{2,3} = \frac{1}{1/50}\left[1 + 0.1187 + (0.1187)^2\right] = 56.6407$$

$$(Z_{0o})_{2,3} = \frac{1}{1/50}\left[1 - 0.1187 + (0.1187)^2\right] = 44.7688$$

4) *For 4th line pairs:*

$$(Z_{0e})_{3,4} = \frac{1}{1/50}\left[1 + 0.3137 + (0.3137)^2\right] = 70.6047$$

$$(Z_{0o})_{3,4} = \frac{1}{1/50}\left[1 - 0.3137 + (0.3137)^2\right] = 39.2355$$

Using (4) and (5) design equations yield the design parameters, half of which listed in Table I because of symmetry of the filter, where the even- and odd-mode impedances are calculated for Y=1/Z and Z=50 ohms.

TABLE I: DESIGN PARAMETERS

J	J_{J+1}/Y_0	$(Z_{oe})_{j,j+1}(\Omega)$	$(Z_{oo})_{j,j+1}(\Omega)$
0	0.3137	70.6047	39.2355
1	0.1187	56.6407	44.7688
2	0.1187	56.6407	44.7688
3	0.3137	70.6047	39.2355

The next step of the filter design is to find the dimensions of coupled edge-strip lines that exhibit the desired even - and odd-mode impedances. Firstly, determine equivalent single edge-strip shape ratios (w/d) s. Then it can relate coupled line ratios to single line ratios. For a single edge-strip line,

$$Z_{ose} = \frac{(Z_{oe})_{j,j+1}}{2}$$

$$Z_{ose} = \frac{(Z_{oe})_{j,j+1}}{2}$$

1) *For 1st line pairs & 4th line pairs:*

$$Z_{ose} = \frac{70.6047}{2} = 35.30235$$

$$Z_{oso} = \frac{39.2355}{2} = 19.61775$$

2) *For 2nd line pairs & 3rd line pairs:*

$$Z_{ose} = \frac{56.6407}{2} = 28.32035$$

$$Z_{oso} = \frac{44.7688}{2} = 22.3844$$

Thus the required resonator of 1st line pairs & 4th line pairs:

$$l = \frac{0.068153}{4} = 0.01704$$

For find out value of 2ndline pairs & 3rdline pairs:

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{re}}} = \frac{300}{2.48\sqrt{3.2342}} mm = 0.067264$$

Thus the required resonator of2nd line pairs & 3rd line pairs:

$$l = \frac{0.067264}{4} = 0.01682$$

Using the design equations for coupled edge-strip lines given (7) and (8), the width and spacing for each pair of quarter wavelength coupled sections are found, and listed in Table II

TABLE II: WIDTH AND THE QUATER WAVELENGTH

J	W_J/h	S_J/h	ε_{re}	$\vartheta(mm)$
1	1.6106	0.0288	3.1504	0.01704
2	2.2368	0.2728	3.2342	0.01682
3	2.2368	0.2728	3.2342	0.01682
4	1.6106	0.0288	3.1504	0.01704

Find out value of all dimensions for section 1 and 4, S/h= 0.0288 s=0.046 mm and w/h=1.6106 w=2.54mm for section 2 and 3, S/h=0.2728 s=0.431 mm and w/h=2.2368 w=3.53mm

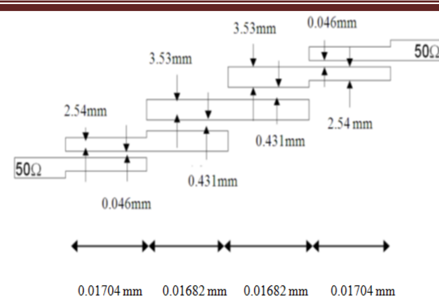

Figure 3: Layout of a three-pole micro strip edge-coupled band-pass filter

6. Geometry on HFSS

In this proposed design the width of the substrate is 3.38 mm and relative permittivity 4.2 and the conductor thickness 1.58 mm, Fig. 4 shows the 3-dimensional view of proposed band pass filter. Proposed design is simulated using HFSS. Fig. 4:

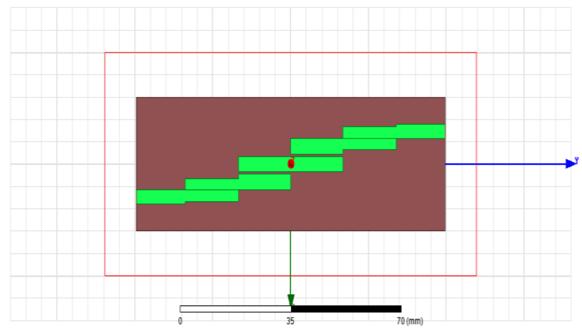

Fig: 4. Layout filter of 3rd order Edge couple Strip line band pass filter on HFSS

Fig.4. indicates that the width, distance & length for section 1 & 4 are w1 = w4 = 2.54 mm, s1=s4=0.046 mm &l1=l4=0.01704mm. And section two and three are w2=w3= 3.53mm, s2=s3=0.431 mm &l2=l3=0.01682mm.

7. Result

A design of wideband band pass filter is designed which is based on a conventional 3rd order parallel Edge coupled-line. The filter is designed and simulated on the HFSS software. The simulation of the final layout provides a response between scattering parameters and the frequency of filter which is shown below.

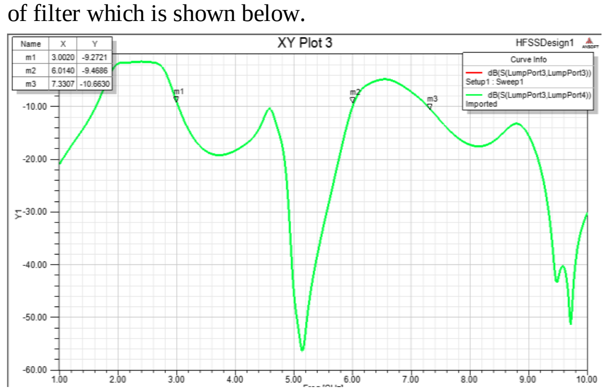

Fig: 5. HFSS plot of S11 and S21 versus frequency with the code giving the centre frequency as 3.75GHz for FR4 substrate for 0.5 dB ripple

This filter is capable to pass a frequency of 2.19GHz to 2.77GHz.The response of filter to be linear with centre frequency 3.75GHz. This filter has S11 response has value of -12.50 dB and the Insertion Loss is S21 less than -2.2dB at centre frequency 2.48GHz.

8. Conclusions

The design of BPF will definitely help the new researchers to understand the methodology and various steps in the process. The half wavelength parallel edge coupled BPF designed with centre frequency 3.75GHz using HFSS software has been presented in this paper. This filter has S11 response at the centre frequency 3.75GHz with a value of -12.50dB and the corresponding Insertion Loss is S21 less than -2.2dB. This filter has 0.58GHz bandwidth at the centre frequency 3.75GHz.

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