A REVIEW ON FILTERS

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ABSTRACT

Through this review we intend to present a review on the previous works on filters. With the improvement of microwave filter designs in the last two decades, various types of filters are being used these days. Various types of filter designs are being proposed for good performance. In the paper we have shown the working of multiband filter operating on high gigabytes range.

KEYWORDS: Filter, Metamaterial, Multiband, Microstrip Line.

INTRODUCTION

Filters have been an important part in signal processing not only now but since quite a long time. To eliminate the noise and to get the output response correctly filters are used in laboratories.

To shape the signal spectrum electrical filters are used. Printed filters are used this days but as they have high insertion loss they are not used in application where high power and low loss are needed [1,3]. Metamaterials have gained enough appreciation in microwave engineering. These are double negative resistance materials. Metamaterials in filter application are based on resonant type metamaterial transmission lines. Waveguide method are used for electromagnetic parameter extraction for weakly coupled meta materials [2,19]. Microwave filter designs have improved a lot in last two decades. Filters for space have very challenging requirements to be met under severe environmental condition [4]. Use of superconductors in filters is its small size and low loss. Kinetic inductance and non linearity are the properties used in filters [5]. The substrate integrated waveguide(SIW) has been used owing to it’s advantages of planar structure, low cost, reduced coupling [7]. A contact dual band BPF with CM suppression achieved by using a novel approach with etched slotlines on one broadside of a square SIW cavity [8]. As a key component BPF with good performance and size is highly demanded. The microwave systems usually need band pass filter to handle different frequency band with different bandwidths [10]. Different kinds of filter designs have been proposed like tribandbandpass filter [11], dual-band filter inspired by enz waveguide, band stop filter using coupled line stub loaded shorted SIR for triband application [14], dual band FSS with controllable frequency resonances are some of ideas [18].

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LITERATURE SURVEY

Filters have been designed based on microstrip line. Metamaterials have been used to design these filters. Metamaterials are manmade materials which gain properties from its structure rather than its composition. Often referred to as double negative materials as they have simultaneous negative permittivity. Resonant type metamaterials are used in filters [2]. Filters are used in shaping signals. It reduces noise. Filters are of different types including low pass, high pass, band pass, band stop etc [3]. The last two decades have seen great development in filter designs. Filter for space application are very complex and require many specifications. Improved design techniques. Different filter design techniques used circuit synthesis to achieve this [4]. Superconductors are used in microwave resonators and filters. Due to presence of quasi particle superconductors show finite resistance unless at zero temperature. Kinetic inductance and non linearity properties are exploited for filters. Many new applications of microwave resonators are using low temperature superconductors often coupled with systems already operating at low temperature like quantum information processing systems [5].

To measure complex reflection coefficient of a load six port reflectometers are used by measuring only the power magnitudes at defined points. The early SPRs used five hybrid waveguide couplers and this configuration has formed a basis for many designs. An alternate approach makes use of multiple probes along a transmission line where the probes are relatively weakly coupled to the main line. The use 10-dB, 6-dB and 3-dB couplers with tunable phase shifter is reported. The detectors are arranged with coupled probes along a main line, and the probe couplers are designed for loose coupling and low isolation on a lossy substrate to get desired magnitudes and good phase separation of Q-point. The proposed design is shown to offer a good compromise between size, cost, dynamicrange, bandwidth, and error [6]. The substrate integrated waveguide (SIW) in half mode with its advantages replace SIW with 50% size reduction. In wireless configuration reconfigurable circuits are in constant demand. By matching impedance a reconfigurable circuit is designed which can perform as single pole double throw switch or power divider that can be used to design amplifier or antenna [7]. Balanced circuits are more useful in daily life as they provide immunity to noise. Balanced dual band pass filter have been developed using SIRs, SIWs. In practical dual band response is obtained by creating stop band inside wide virtual stop band. The improved CM suppression is achieved by using a novel approach with etched slot lines on one broadside of a square SIW cavity [8]. Nowadays the microwave devices are manufactured using 3D printing and additive techniques. The most common additive technique consists of the fused deposition modelling and feature allows low cost implementation of microwave elements [9]. Dual band-pass filter has gained attention in modern wireless communication system [10]. Band-pass filter is also in high demand because of compact circuit size. By decreasing the bandwidth size is reduced, which results in in-band performance and narrow bandwidth. Band-pass filter is required for handling different frequency bands with different bandwidths in a microwave system [11]. Demand for narrowband RF/ microwave band-pass filter with high selectivity and low insertion loss has increased in an extraordinary rate and they can achieve the same selectivity with fewer resonators and insertion loss is low [12]. Quasi-elliptic filters are proposed to improve the selectivity. A typical filter has a fractional bandwidth of 14% at 2.45GHz and a minimum measured insertion loss of 2.22dB. This filter employs cross coupling resulting in compact topology which is very important for
communication system [13]. Bandpass filter reduces unwanted spectra that is located within a wide passband signal. For architecture enlargement of BSF, the use of multimode resonator for designing is obtained from multiband BPF counterpart [14]. Suppressing electromagnetic voice is increasingly important in wireless communication. Extension of single band tuning, includes use of different size resonators, compromising compactness [15]. Radar and radio navigation system requires compact microwave filters for operation. The stopband characteristics are improved by introduction of transmission zeros (TZ) [16]. Due to the advancement in wireless communication filters with high selectivity and low insertion loss is preferred. For this quasi-elliptic filter designs have been proposed. And adjusting the position of various TZ (transmission zeroes) leads to higher selectivity. By means of directly applying an elliptical bandpass in microstrip, the insertion loss of the filter can be very less (<0.8dB) [17]. Printed filter circuits plays a very important role in microwave filter design due to the fast advancement of technology as it has low cost, repeatability, high accuracy and due to its very compact sizes which can be achieved by selecting high dielectric constant substrate. These are designed using microstrip or striplines. It can be easily integrated with other active circuits that’s why they are fabricated on the same substrate with transistors, amplifiers, oscillators [18]. A third -order dual-band filter is designed which can operate within a range of 10-15GHz. The design consist of two rectangular cavities connected with a ultra-thin waveguide channel. By changing the dimensions of the filter the centre frequency of both pass bands, their bandwidth and TZ can be changed according to the user needs [19]. We can see how a simple synchronously tuned dual-mode resonator (STDR) is used to achieve a frequency-agile band pass filter (FA-BPF) which will have a predefined bandwidth location, BW variation and stop band characteristics. We can see how by adjusting the varactor loading position used in the STDR we can change the two resonant frequencies separation of the resonator and how the TZ (transmission zeroes) location can be predefined by the dimensions. The measurements results of the FA-BPF shows high selectivity, wide frequency tuning range with simple design or control procedure[20].

Designing an arbitrary tri-band Wilkinson power divider to operate at desired frequencies to create targeted tri-band response. Slow-wave structure has been adopted to miniature the conventional divider’s arm for compact designing. The fabricated circuit shows low insertion loss while offering a good isolation better than 15 dB in the three bands of operation and these bands can be easily extended to more bands by adding QWOS depending on the required number of bands [21]. A wideband bandpass filter who bandwidth (BW) can be reconfigured is designed based on a parallel-coupled line structure and cross-shaped resonator with open stubs. As tuning elements p-i-n diodes are used. The prototype of the design of this filter gives results which shows many tuning states possible than other filters and has a wider bandwidth [22]. Here various filter design implementations are shown based on microstrip technology with the implementation of metamaterials. Showing the properties of various types of resonators that behave as left handed materials and also discussing about it. SRRs, CSRRs and other structures and their implications in filter design[23].

**WORKING PRINCIPLE**

Designing a filter takes a lot of steps to successfully get our desired effective output. Listed below are the steps we should keep in mind while designing high order high frequency filters:
1. A specific frequency response,
2. A specific phase shift or group delay,
3. A specific impulse response,
4. Causality,
5. Stability,
6. Locality (finite time outputs),
7. Low computational complexity,
8. Implementation in particular hardware or software.

SOFTWARE USED:

We can design filters using various softwares namely 5Spice, MATLAB, 13D, High Frequency Spectrum Simulator (HFSS) and many other softwares. HFSS is the best suited for designing filters because of the following reasons:

1. HFSS is the better at extracting s-parameters and other fields.
2. Distributing Frequency points makes it faster by 10-20%.
3. An soft pioneered the use of the Finite Element Method (FEM) for Electro-Magnetic simulation by Implementing technologies in order to get a more desired accurate solutions.
4. HFSS is mainly advantageous because of library files or method included in the software which allows us to get the total 3-D blueprint of the filter design enabling us to enter minute details in the software specially for those having complex shapes and curves.
5. It also enables us to work with high frequency components.
6. HFSS is full-wave 3D this means that it can solve all Maxwell’s Equations.

STEPS INVOLVED IN DESIGNING THE FILTER

The filter is designed by using the coupling resonator model, that is considered to be in symmetrical geometry. We design the coupled line filters using two microstrip parallel end lines at least within subsection from the length of the microstrip line. It equals to the 1/4 or 1/8 of a wavelength. The coupled line of the filter has designed using four tapes parallel. They are assigned as a perfect conductor. The microwave filter is designed on (10×10×0.5 mm3) LaAlO3 substrate, which assigned as a dielectric material with a high dielectric constant of 23.5. Other specifications used in the software are given below.

<table>
<thead>
<tr>
<th>No</th>
<th>The Designed Part</th>
<th>Assigned Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Air body</td>
<td>Vacuum</td>
</tr>
<tr>
<td>2.</td>
<td>Feed1(Coax outer diameter)</td>
<td>Vacuum</td>
</tr>
<tr>
<td>3.</td>
<td>FeedPin1(coax inner diameter)</td>
<td>Perfect conductor</td>
</tr>
<tr>
<td>4.</td>
<td>Resonators</td>
<td>Perfect conductor</td>
</tr>
</tbody>
</table>

The first part (i.e. Air Body) is the enclosure body which contains the filter system while the rest parts, it will have the duplicate state as illustrated before. The center of x-y coordinates is assigned at the top center of the substrate.

The frequency setup was linear and the start and stop frequency are given as:

- Start frequency - 8.0 GHz
- Stop frequency - 12.0 GHz
- Step Size - 0.001
Table 2. Designed part dimensions of filter

<table>
<thead>
<tr>
<th>Designed Part</th>
<th>Dimension (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed 1 (Coax outer Diameter)</td>
<td>0.8 (in radius)</td>
<td>2.0</td>
</tr>
<tr>
<td>Feedpin 1 (Coax inner Diameter)</td>
<td>0.2 (in radius)</td>
<td>2.0</td>
</tr>
<tr>
<td>L1 Resonator</td>
<td>8.0*9.0 in mm²</td>
<td>0.15</td>
</tr>
<tr>
<td>L2 Resonator</td>
<td>7.2*9.0 in mm²</td>
<td>0.15</td>
</tr>
<tr>
<td>substrate</td>
<td>1.6*1.6 in mm²</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Microstrips are being used as they can operate at microwave frequencies and they are much lighter, smaller and compact. Troubleshooting is easier. They are less expensive than traditional waveguides. Excitation of other undesired modes is minimized. The microstrip patches of various shapes like rectangular, square, triangular, etc. are easily etched. Multiple frequency bands (dual, triple) can be supported Fabrication is easier and thus mass manufacturing can be done. They are robust when mounted on rigid surfaces of the device.

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The parameters of the capacitor are capacitance ($C_C$) and resistance ($R_C$) between nodes 1 and 0. The parallel resonant frequency of the unloaded resonator (Figure 1) is

$$ f_0 = \frac{1}{2\pi \sqrt{L_C(C_C + C_{L2})/(C_C + C_{L1} + C_{L2}) + C_{IC}}} $$

**HARDWARE IMPLEMENTATIONS USING COUPLED RESONATORS**

The resonators have been designed using double-sided microstrips. This resonator consists of three elements: a spiral inductor and a parallel-plate capacitor.

![Figure 1. Double sided coupled resonator](image)

In this circuit model, the square-spiral inductor is modeled with $\pi$ electric network between nodes 2 and 3, and the element parameters are inductance ($L_L$), resistance ($R_L$), and parasitic capacitances ($C_{L1}$ and $C_{L2}$) with their resistances ($R_{L1}$ and $R_{L2}$). The interspiral capacitance ($C_{IC}$) is capacitance between the turns of the spiral inductor.

The parameters of the cylindrical via-hole are inductance ($L_{via}$) and resistance ($R_{via}$) between nodes 1 and 3.

$$ L = \frac{1.27 \mu_0 N^2}{2} \left( \frac{d_L + d_i}{2} \right) $$

$$ \times \left( \ln \left( \frac{2.07}{\rho} \right) + 0.18\rho + 0.13\rho^2 \right) K_g $$
The resonators are used as the main building block for the band-pass filter design.

CALCULATING PARAMETERS

In order to analyse and design filter characteristics, using the electric-circuit model, we made a relationship between the circuit-element values and the physical dimensions of the 3D filter structure. We then used a closed-form expressions for inductance, capacitance, and resistance.

The capacitance of a rectangular parallel plate structure is calculated considering the effect of fringing field. The effective capacitance can be calculated by:

$$C = \varepsilon_0 \varepsilon_r \frac{d_x d_y}{d_{sub}} \left( 1 + \frac{d_{sub}}{\pi d_x} \left( 1 + \ln \left( \frac{2 \pi d_x}{d_{sub}} \right) \right) \right) \times \left( 1 + \frac{d_{sub}}{\pi d_y} \left( 1 + \ln \left( \frac{2 \pi d_y}{d_{sub}} \right) \right) \right).$$

where $d_x$ and $d_y$ are outer capacitor dimensions (in our case $d_x = d_y = d_i$) and substrate thickness $h_C = d_{sub}$. And $\varepsilon_r = 2.2, \tan\delta = 0.001$, substrate thickness $h_L = h_C = 1.60$ mm, metallization thickness $t = 18 \mu$m.

The equivalent inductance can also be calculated after a relationship between the circuit elements and the physical 3D element dimensions.

Where $N$ denotes the number of inductor turns, $d_i$ is the outer diameter and $d_i$ is the inner diameter of the inductor, $\rho = (d_i - di)/(d_i + di)$ and $K_g$ is the correction factor for the presence of a ground plane. $K_g = 0.57 - 0.145 \ln \left( \frac{w_s}{h_l} \right)$, where $(w_s/h_l) > 0.05$.

ADVANTAGE

1. Electronic filters are used to differentiate the frequency spectrum of EM Wave. It can be high pass filter low pass filter or band pass filter or band stop filter.

2. They are highly sensitive to frequency ranges

3. They amplify the signal partially.

DISADVANTAGE

1. The value of inductor and capacitor depend on the temperature so effective temperature can cause the change in frequency to passed by that filter.

CONCLUSION

This paper reviews the previous works and development of filter techniques in the last decades. The industry demands certain stringent specifications to be met in the application of the filters. The introduction of new technologies and theories have been developed and applied to meet the demands. An independent frequency control tri-band filter is also studied in the paper.

REFERENCES

[1]. Rethabile Khutlang, design and implementation of RF and microwave Filters using Transmission Line, October, 2006, Cape Town.
[5]. Daniel E. Oates, Microwave Resonators and Filters, Lexington, USA.
[7]. Haidong Chen, Wenquan Che, Yue Cao, Wenjie Feng and Kamal Sarabandi,


[12]. Milos Radovanovic and BrankaJokanovic, Dual-Band Filter Inspired by ENZ Waveguide, Vol. 27, No. 6, June 2017.


