A Novel Microwave Bandpass Filter for Rf Applications

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***Abstract*— This paper presents a design of a microwave bandpass filter using combination of a simple transmission lines and cylindrical resonator for Radio frequency Application as well as wireless communication system. Four resonators are used at different – different position. Resonator having same material Pec (relative permittivity=1, relative Permeability=1) to be contributed to an wideband bandwidth of the filter. This new approach increase the coupling effects as well as minimizing the insertion loss in the passband. The resonator can increase Q-factor .The resonator offers advantages in increasing the signal transmission performance of RF and Microwave devices. The resonator and microwave circuit capable to generate additional coupling effect that can be merged together to produce a wideband devices as well as increasing the transmitting power and reduce the insertion loss. The new approach contributes more advantages and viable at desired application band, the return loss ,VSWR, ripples ,Q-factor, mismatch loss, reflection coefficient (rho),group delay, E-field, roll-off of the microwave bandpass filter were analyzed. Bandpass filter play a significant role in RF application as well as wireless communication system**

***Keywords*— Microwave bandpass filter, HFSS, Insertion Loss, Ripple, Q factor ,VSWR, Cut-off Frequency, Roll-off.**

I. INTRODUCTION

Bandpass filter is a passive component which is able to select signals inside a specific bandwidth at a certain center frequency and reject signals in another frequency region, especially in frequency regions, which have the potential to interfere the information signals [1]. A bandpass filter must be used in transmitter and receiver to reject undesired signals [2]. In the previous research we have done the designed and simulated the bandpass filter as in [2] using HFSS software. This research, we simulated and fabricated bandpass filter using dielectric resonator and stripline for the radar system and wireless communication at the operating center frequency of 10GHz, bandwidth of 60 MHz. The simulation of bandpass filter in this research using HFSS. Microstrip bandpass filter is one of the most important components in wireless communication systems [3-4].

Unfortunately, without special measures, most of the microstrip BPFs exhibit harmonic responses degrading the system performance. To overcome this problem, various methods have been presented in the past [5-6].

Among the fundamental components of Microwave, bandpass filters are used in many RF/microwave applications and contributes in the overall performance of a communication system. Microwave filters are utilized in broadband wireless applications like satellite and mobile communication systems and WLAN systems. Filters on various materials are available but preferably standard printed patch filter are being used by engineers over higher frequencies, as they can be fabricated easily with low cost. The size is main constrained in front of microstrip filter designers. Numerous researchers have proposed various configurations for reducing filter size and improving filter performance. Some of the filter configurations are using hairpin resonator, ring resonator, step impedance resonator, defected ground structure, and short circuited stub [7]. From the early investigation of ultra-wideband (UWB) technology in 1960s various wireless services grown very fast, and the demand of multi-band microwave communication systems capable of adapting multiple wireless communication platforms have greatly increased. Apart from the various microstrip components the BPFs possessing tunable multi-band characteristics. In the designing of microwave bandpass filters commonly ring resonator are utilized with the benefit of small circuit size and sharp rejection response [8-9].

II. BASIC CONCEPTS

This section describes the basic concepts and theories necessary for the overall design of RF/microwave filters including microstrip lines structures. The transfer function of a two-port filter network is a mathematical description of network response characteristics, namely, a mathematical expression of S21. On many occasions, an amplitude-squared transfer function for a lossless passive filter network is defined as:

$$|S_{21}(jw)|^2 = \frac{1}{1+\varepsilon^2 F_n^2\ (W)} \qquad (1)$$

Where ε is a ripple constant, Fn (ω) represents a filtering or characteristic function, and ω is a frequency variable. For our discussion here, it is convenient to let ω represent a radian frequency variable of a low pass prototype filter that has a cutoff frequency at ω = ωc (rad/s).

For a given transfer function of equation (1), the insertion loss response of the filter can be computed by:

$L_A(\omega)=10\log\frac{1}{|S_{21}(jw)|2}(\text{dB})$ (2)

Since $|S11|^2+|S21|^2=1$ for a lossless, passive two-port network, the return loss response of the filter can be expressed by:

$L_A(\omega)=10\log(1-|S_{21}(jw)|^2)(\text{dB})$ (3)

Q factor

Quality factor or Q factor is a dimensionless parameter that describes how under-damped an oscillator or resonator is, and characterizes a resonator's bandwidth relative to its center frequency. Higher *Q* indicates a lower rate of energy loss relative to the stored energy of the resonator; the oscillations die out more slowly.

$Q=\frac{f_r}{\Delta f}=\frac{\omega_r}{\Delta\omega}$ (4)

Where f_r the resonant frequency is Δf is the half power bandwidth. $\omega_r=2\Pi f_r$ is the angular resonant frequency $\Delta\omega$ is the angular half power bandwidth.

Bandwidth= $\Delta f=f_2-f_1$ (5)

$Q=\frac{f_c}{\Delta f}$ (6)

Q factor can be mathematically expressed as

$Q=\frac{E_{Stored}}{E_{lost\ per\ cycle}}$ (7)

When looking at the bandwidth of RF resonant circuit this translates to

$Q=\frac{F_0}{F_{3dB}}$ (8)

Insertion loss

Insertion loss(IL) is the loss of signal power resulting from the insertion of a device in a transmission line or optical fiber and is usually expressed in decibels (dB).

$\text{IL}=-\text{dB}(S_{21})$ (9)

IL>0 for passive filter

RL(return loss)= $-\text{dB}(S_{11})$ (10)

RL>0 for passive filter

Mismatch Loss

$(ML_{dB})=-10\log_{10}\left[1-\left(\frac{VSWR-1}{VSWR+1}\right)^2\right]$ (11)

In case the two measurement port use the same reference impedance the insertion loss (IL) is defined as

$\text{IL}=-20\log_{10}|S21|\text{dB}$ (12)

$\text{IL}=10\log_{10}\frac{|S21|^2}{1-|S21|^2}\text{dB}$ (13)

Where S_{11} and S_{21} are two of the scattering parameters

Reflection Coefficient rho (dB)

$\text{Rho}=\left(\frac{VSWR-1}{VSWR+1}\right)$ (14)

Ripple

Ripple(dB) = mismatch loss(dB) =

$10*\log[1-(VSWR-1)/(VSWR+1)^2]$ (15)

$\text{VSWR}=\frac{V_{MAX}}{V_{MIN}}$ (16)

Group Delay

Group delay is negative slope of the transmission phase angle with respect to frequency

$\text{Group delay}=-\frac{\Delta\phi}{\Delta\omega}$ (17)

Where ϕ is waveguide and ω is frequency

III. DESIGNING

A. Construction

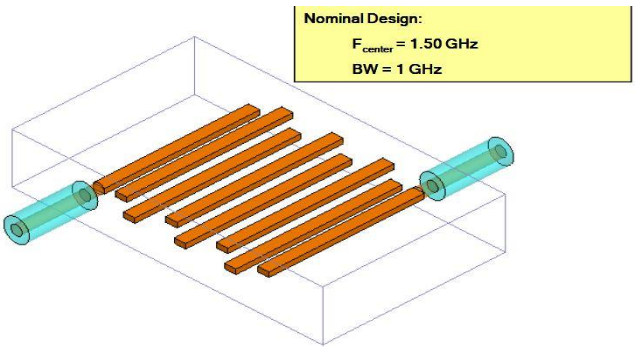

Fig. 1 A Construction details of Microwave Bandpass Filter

B. Principle of operation

Dielectric resonators are pieces of dielectric material inserted into the waveguide. They are usually cylindrical since these can be made without machining but other shapes have been used. They can be made with a hole through the centre which is used to secure them to the waveguide. There is no field at the centre when the TE_{011} circular mode is used so the hole has no adverse effect. The resonators can be mounted coaxial to the waveguide, but usually they are mounted transversally across the width. The latter arrangement allows the resonators to be tuned by inserting a screw through the wall of the waveguide into the centre hole of the resonator.

When dielectric resonators are made from a high permittivity material, they have an important space saving advantage compared to cavity resonators. However, they are much more prone to spurious modes. In high-power applications, metal layers may be built into the resonators to conduct heat away since dielectric materials tend to have low thermal conductivity. The resonators can be coupled together with irises or impedance transformers. Alternatively, they can be placed in a stub-like side-housing and coupled through a small aperture.

C. STEPS OF CONSTRUCTION

A. Microwave Bandpass Filter

(i) Draw>Box
Box position: -1.0,-1.7,-0.3125
- In create box dialog box edit the command and attribute tabs.
- Select the Menu items view> fit all> Active View or Press CTRL+D.

(ii) Create coax outer Diameter
- Select menu item Draw > Cylinder
- Centre position : 1.0,-0.9,0.0
- In create Cylinder dialog edit the command and attribute tabs.
- Click the ok bottons.
- Select the Menu items view> fit all> Active View or Press CTRL+D.

(iii) Define new Default Material
- Select definition window
- Type pec (relative permittivity 1 and relative permeability 1) in the search by name.

(iv) Create coax inner Diameter
- Select the menu item Draw> Cylinder
- Position : 1,-0.9,0.0
- In create Cylinder dialog edit the command and attribute tabs

(v) Create the coax feed probe with copy/paste
- Select the object feedin 1 from the model tree.
- Type CTRL-C/CTRL-V to create copy.
- In model tree , double click on the resulting object feedin 2.
- In the attribute tab change the name of feed probe 1 .
- In the model tree expand the feed probe 1 branch.
- Double click on the command create cylinder
- In the command tab change the height to “ -0.15”.

(vi) Create a first resonator
- Select the menu item Draw> Box
- Position:0.85,-0.9625,-0.03
- In create Box dialog edit the command and Attribute tabs.

(vii) Create a second resonator
- Select the menu item Draw> Box
- Position: -1.0,-0.75,-0.03

(viii) Create a third resonator
- Position:1.0,-0.48,-0.03

(ix) Create a fourth resonator
- Position:-1.0,-0.2,-0.03

(x) Create the wave port
- Graphically select the end face of coax line at X=1.75in

(xi) Create remainder of model with “Duplicate Around Axis”
- Axis :Z
- Angle: 180
- Total no:2

(xii) Boundary display
- Select the menu items HFSS>boundary display

(xiii) Create a setup window
- Solution frequency: 1.5 GHz
- Maximum no. of passes: 15
- Maximum delta S per pass: 0.02

(xiv) Frequency setup type: Linear count
- Start: 0.6 GHz
- Stop: 2.4 GHz
- Count: 513

IV. ANALYSIS OF RESULTS

A. Max.Mag. Delta S Versus Pass Number

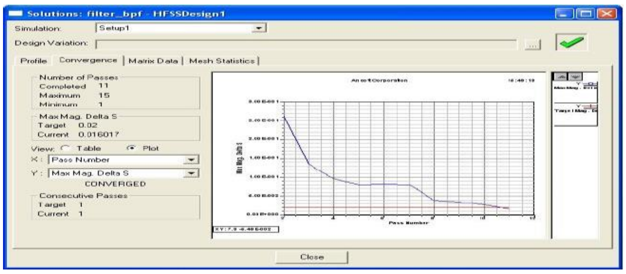

Fig.2 A Max.Mag. Delta S Versus Pass Number of Microwave Bandpass Filter

In above Fig.2 we have achieved no. Of passes: complete 11, maximum: 15, minimum: 1 as well as max mag. Delta S target 0.02, current0.016017.

B. S Parameter versus Frequency

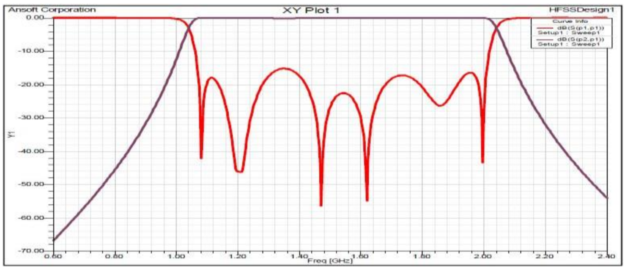

Fig.3 S parameter(dB) versus Frequency of Microwave Bandpass Filter

In Fig.3 we find centre frequency 1.50Ghz , no internal losses occurs in above figure.
In above Fig. F_1=1.10 Ghz and F_2=2.10 Ghz achieved, then obviously bandwidth is 1Ghz (1000Mhz) achieved which is suitable for radio frequency, wireless communication system. We will find wide bandwidth then achieved fast roll-off, which increases selectivity on the adjacent channel. We also achieved high Q-factor. Q-factor of an element relates the losses, this links directly into the bandwidth of resonator with respect to the centre frequency. Higher the Q the lower the rate of energy loss and hence oscillation will reduce more slowly i.e. they will have a low level of damping and they will ring for longer.

C. S_{21} And S_{11} Parameter For Studied Of Microwave Bandpass Filter

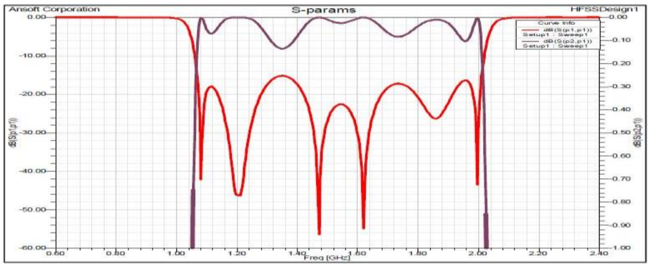

Fig.4 S_{11}(dB) and S_{21}(dB) Parameter Studied For Microwave Bandpass Filter

In Fig.4 ripple=0.1dB achieved. Return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line. Return loss is related to both standing wave ratio (SWR) and reflection coefficient (Γ).
Here in above Fig. We achieved return loss (dB) =15dB.

D. Voltage Standing Wave Ratio(VSWR) At Port 1

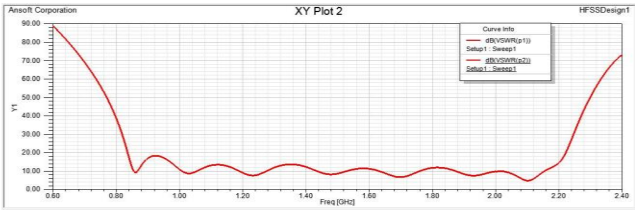

Fig.5 VSWR At Port 1 For Microwave Bandpass Filter

In above Fig.5 we will see that the VSWR is achieved 1.43:1 at port2. SWR is used as a measure of impedance matching of a load to the characteristic impedance of a transmission line carrying radio frequency (RF) signals.
A transmission line that is properly terminated, that is, terminated with the same impedance as that of the characteristic impedance of the transmission line, will have no reflections and therefore no mismatch loss. Mismatch loss represents the amount of power wasted in the system. It can also be thought of as the amount of power gained if the system was perfectly matched. Impedance matching is an important part of RF system design; however, in practice there will likely be some degree of mismatch loss.
Mismatch loss is calculated from reflection coefficient rho.

E. Voltage Standing Wave Ratio (VSWR) At Port 2

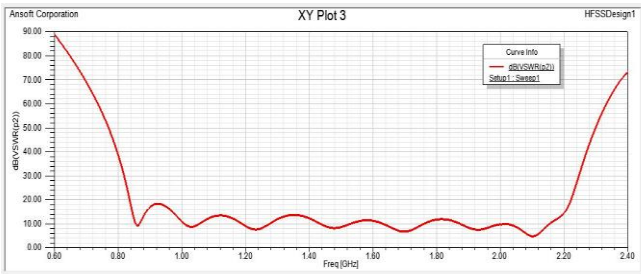

Fig.6 VSWR At Port 2 For Microwave Bandpass Filter

In above Fig.6 we will see that the VSWR is achieved 1.43:1 at port1. SWR is used as a measure of impedance matching of a load to the characteristic impedance of a transmission line carrying radio frequency (RF) signals. we achieved little loss is due to mismatch losses and is order of 0.176 dB. System components such as filters, attenuators, splitters, and combiners will generate some amount of mismatch loss. The resultant mismatch loss is not only due to the mismatches from the individual components, but also from how the reflections from each component combine with each other.

F. *Group Delay at S_{21}*

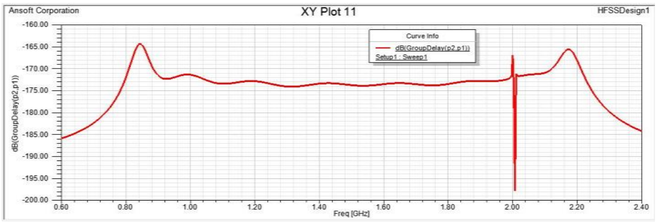

Fig.7 Group Delay at S_{21} For Microwave Bandpass Filter

In Fig.7 we will see that we achieved flat group delay over passband, which helps in reducing signal distortion. The group delay of a filter is a function of many things besides the types of filter. Group delay increases as the order of a filter is increased. The group delay is getting longer as the band width decreases. The group delay is a function of frequency.

G. *E- Field For All Object Of Microwave Bandpass Filter*

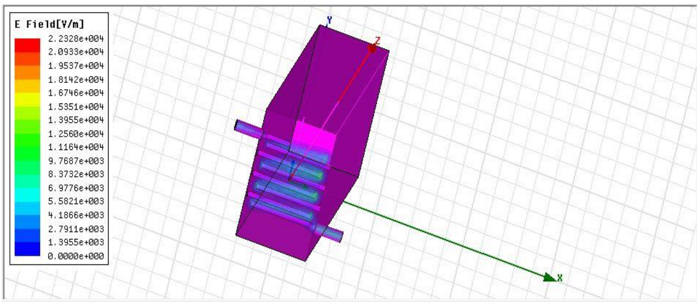

Fig.8 E-Field For All Object Of Microwave Bandpass Filter

In above Fig.8 E-Field For All Object Of Microwave Bandpass Filter is achieved. The filtration efficiency of the microwave bandpass filter increased with increasing EF strength.

H. *Animation of Microwave Bandpass Filter*

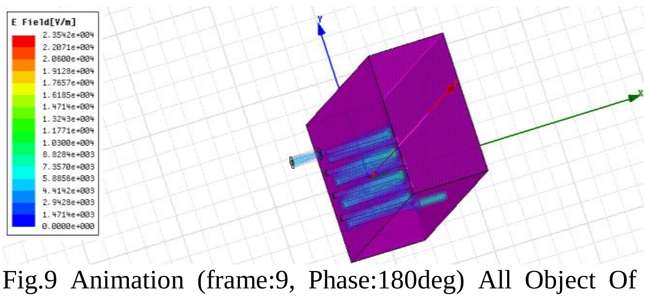

Fig.9 Animation (frame:9, Phase:180deg) All Object Of Microwave Bandpass Filter

In above Fig.9 we will see that Animation model of microwave bandpass filter for all object of filter achieved at frame :9, phase:180 deg.

I. *Mess Plot for all Objects of Microwave Bandpass Filter*

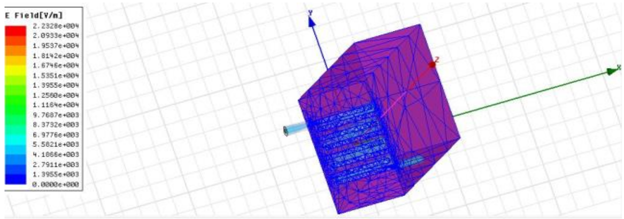

Fig.10 Mesh Plot (frame:9, Phase:180deg) All Object Of Microwave Bandpass Filter

In above Fig.10 we will see that Mesh Plot of microwave bandpass filter for all object of filter achieved at frame :9, phase:180 deg.

V. CONCLUSION

From section IV. Analysis of results we say that we achieved centre frequency 1.50Ghz,bandwidth 1000Mhz,fast roll-off, ripple=0.1dB,return loss=15dB, VSWR=1.43:1(at both port such as port1and port2),little loss is due to mismatch losses of order of 0.176dB,Filtering efficiency of microwave bandpass filter increased with increasing electric field strength. Very small ripple at passband insertion loss, good VSWR, flat group delay, fast roll-off, good matching and low loss in passband. High Q-factor having strong resonance as well as high frequency stability. High Q indicates a lower rate of energy loss relative to stored energy of the resonators. Then we say that the Microwave bandpass filter is applicable for RF application as well as wireless communication system.

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