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Dual Band Dielectric Resonator Filter (DBDRF) with Defected Ground Structure (DGS)

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Abstract: In this paper a dual band dielectric resonator with circular defect at the ground plane is proposed. Filter is constructed by placing high-quality factor mode dielectric resonators on the microstripline. This is the integration of microstripine with dielectric resonator and defect at the ground. This is designed without compromising miniaturization and efficiency. It is observed that the integration of dielectric resonator with DGS may be merged to achieve wide band. Two band with 6 GHz low pass filter and 2 GHz band pass filter has been achieved. The filter which is proposed for microwave communication is expected to have better quality factor and higher temperature stability compared to lumped elements-based BPF. The used MBDRF have bandwidth of 6GHz and 2 GHz.

Key words: Dual Band filter · Dielectric Resonator Filter · DGS Filter · High Q Filter

INTRODUCTION

A wireless communication system demands a large number of base-station filters with not only an excellent in-band performance (i.e., low losses), but also a good out-of-band spurious performance. Dielectric-resonator filters are preferable for wireless base stations due to their superior characteristics of a high quality (Q) factor and miniaturization. However, cost reduction remains a key limiting factor for the wide spread use of dielectric-resonator filters in base-station applications. There are increased demands for low-loss dielectric resonator filters that are compact and capable of being manufactured in a large quantity at a reasonable low cost. Dielectric resonator offer high Q values with a relatively high Q/volume ratio in comparison with any other known filter technology. If reconfigurable RF filters are ever employed in wireless base stations and satellite systems, dielectric resonator filters stand to be the optimum solution. High Q dielectric materials with dielectric constants ranging from 20 to 90 are now commercially available from various manufacturers. Dielectric resonators with $\square_r$ =60 are commercially available with a $Q \times f$ product values of 100,000, i.e., an unloaded Q value of about 50,000 can be achieved at 2.0 GHz. As the dielectric constant increases, the achievable unloaded Q typically decreases. For materials with a dielectric constant of 45, the $Q \times f$ value reduces to 44,000. Dielectric resonators can operate at various modes giving the designers with flexibility to select the desire range of frequency that can easily interact with field distribution of that particular mode [1].

Figure 1 show that relative insertion loss and size of typical microwave resonators. The estimated range of unloaded Q values for each resonator is also shown in the given figure. There is a wide range of resonator configurations under each resonator category. The Q value can therefore vary widely for each resonator category. It is well known that a dielectric object with free-space boundaries can resonate in various modes.

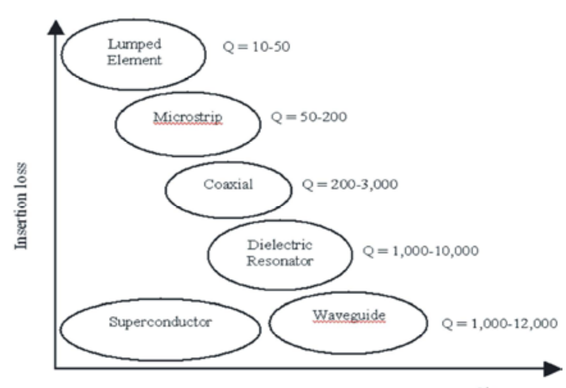

Fig 1: Relative insertion loss and size of various RF resonators.

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If the dielectric constant is high, the electric and magnetic fields of a given resonant mode will be confined in and near the resonator and will attenuate to negligible values within a small distance relative to the free space wavelength. Therefore, radiation loss is minimal and the unloaded Q of the resonator is limited mainly by losses inside the dielectric body. Electric field losses occur as a result of the finite loss tangent (tan δ) of the dielectric material. If all of the electric energy of the resonant mode is stored inside the DR and if no losses occur due to external fields, the unloaded Q will be given by

$$Q_u = 1/_{\tan\delta}$$

For all practical DR, there will always be some external loss due to radiation or dissipation in a surrounding metal shield. These losses tends to reduce, while external stored electric energy tends to increase for on the order of 100 or higher, these effects are small and is a good approximation for the unloaded Q of a DR [2].

For the fundamental-mode resonance, the dimensions of a DR are on the order of one wavelength in the dielectric material. Since where is the wavelength in the dielectric, λ is the wavelength in air and is the relative dielectric constant, the resonator dimensions are small compared to λ if is large. Because the dimensions of an ordinary air-filled waveguide cavity are on the order of λ, a DR can be much smaller than a cavity resonator.

The most practical configuration of the DR is usually a cylindrical disk whose length H is less than it's diameter D. With this shape, the lowest-frequency resonant mode is the mode, which has a circular electric field distribution. A drawback of the DR is that the resonant frequencies of the modes are close to each other. To make the DR practical for most applications, one of the goals of the resonator design is to separate the resonant frequency of the operating mode as far as possible from those of other modes. The DR aspect ratio (thickness/diameter) can also exercise some effect on tuning and Q, but a choice of H/D = 0.4 is recommended for both optimum Q and minimum interference of spurious modes for mode operation [3].

Introducing a hole at the centre of the DR, i.e., ring resonator, can improve the separation between the mode (fundamental mode) and higher-order modes [4]. The spurious characteristics are improved as a function of ring diameter. This property can be used to improve the spurious performance for dielectric loaded filters. The dielectric constant of a material is a parameter that reflects the capability of a material to confine a microwave. The higher this parameter means better in term of microwave signals confinement in the substrate. There is an inversely proportional between size and dielectric constant. A high dielectric constant is required to reduce circuit size of a device.

The main difference lies in the fact that the wavelength in dielectric materials is divided by the square root of the dielectric constant in a function of,

Where is the free space wavelength at the resonant frequency. Moreover, unlike resonant cavities, the reactive power stored during resonance is not strictly confined inside the resonator. The leakage fields from the resonator can be used for coupling or adjusting the frequency. The wavelength inside the DR, guided wavelength is also inversely proportional to the square root of the dielectric [5] The resonant frequency and radiation Q-factor can be varied even dielectric constant of the materials are fixed due to the dielectric resonators able to offer flexible dimensions. Dielectric resonators are being increasingly employed in a variety of microwave components and subsystems such as filters and oscillators. One of the most desirable resonator properties is simple tenability over a reasonably wide frequency b and [6]. The usual approach is to provide some means of perturbing the fields surrounding the resonator, such as a tuning screw placed at a location of strong electric field or a tuning plunger that essentially varies the enclosure's dimensions. Unfortunately, these approaches have two major limitations. First, they provide very narrow tenability ranges (if the unloaded Q's are to be maintained at a high value), because the fields are usually concentrated within the dielectric material due to its high relative permittivity and the effect of perturbing the weak external fields on the resonant frequency of the structure is very small. Second, if the tenability range is increased, the proximity of the conductors to the resonator causes severe degradation to the unloaded Q. In wireless LAN such as IEEE 802.1 communication systems, small size and high performance filters are needed to reduce the cost and improve the system performance. They can be designed in many different ways and by using different materials. Ceramic material with a high quality factor ($Q\times f$) value (□10000) and a high permittivity provides a means to create small resonator structures such as coaxial structures that could be coupled to form comb-line bandpass filters [9]. However, further miniaturization becomes more difficult for this filter. Planar filters with using high permittivity ceramic substrate provide good miniaturization ability. Therefore, there has been much research conducted on planar filters and their components. Since microstrip resonators are the basic components of a planar filter design, it is necessary to select proper resonator types used in a filter design [7]. The rectangular ring resonator can provide better performance such as narrow bandwidth in pass band and lower insertion loss when compare with other ones. A conventional rectangular ring microstrip resonator is too large to be used in the modern communication system.

MATERIALS AND METHODS

The size, location and shape of the dielectric affect the impedance matching of a microwave circuit. In this project three dielectric resonators were excited with a simple microstrip line in order to obtain the optimum coupling effect. A match combination of dielectric resonators and microwave circuit capable to generate an additional coupling effect that can be merged together to produce a wideband device as well as increasing the transmitting power and reduce the insertion loss. Holes are created at the ground plane which provides defected ground structure (DGS) so that it can reduce the harmonics and volume too. This combination proficiently produces a low design profile. There is an inversely proportional between size and dielectric constant. A high dielectric constant is required to reduce circuit size of a device. A significant miniaturization can be achieved, thus high-quality filters can be realized. The DRs used in this filter are cylindrical stair in shape,

Geometry of resonators are shown in the figure 2, which are in stair cylindrical in shape. Total length of microsripline is 35mm; the centre position of first resonator is 10mm, second resonator at 17.5mm and third resonator at 30.2mm from left port respectively. Dielectric constant of resonator is 60. The unloaded Q is 3500. The seven holes are created at the ground plane which is 1mm in diameter.

The resonant frequency is given by [8]:

$$f_o = \frac{34}{\sqrt[r]{\varepsilon_r}}\left(\frac{r}{H}+3.45\right)$$

Where r is radius and H is the height and is the dielectric constant of dielectric resonator. The dimensions of the DR specify its fundamental mode. Among all these modes the mode is the most interesting one because it is usually the dominant mode and it is simple to excite. The electric field is confined inside the resonator and is parallel to the

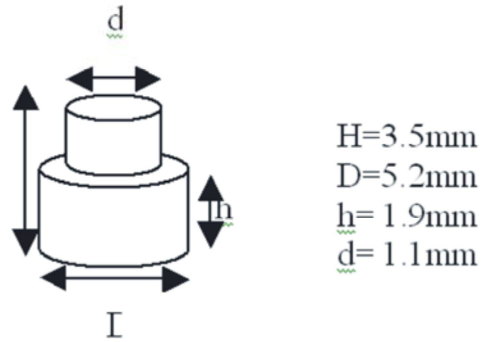

Fig 2: Geometry of dielectric resonator

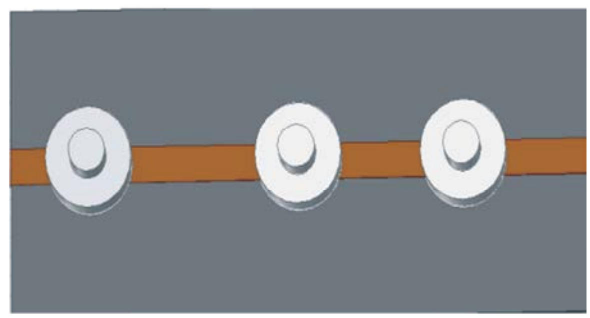

Fig 3: Top view of dielectric resonator filter

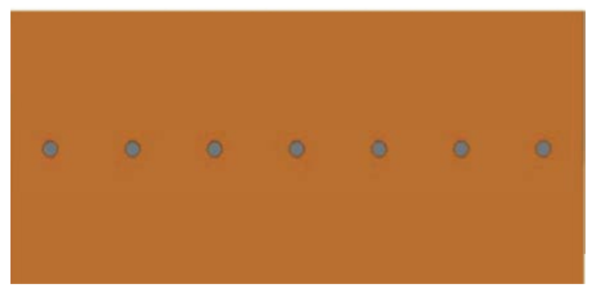

Fig 4: Bottom view of dielectric resonator filter

boundaries but the magnetic field is perpendicular to the boundaries. Hence, in this mode the DR can be modeled as a magnetic moment vector aligning with the axis of the cylindrical resonator. To achieve mode the height of the DR must be in between 35% to 65% of the diameter. The lowest mode of the DR is set close to the lower end of the desired operating band as the starting point. Since dielectric permittivity values are fixed, the parameters diameter and height of DR used to determine the overall operating band of the filter. The placing between the resonators on the microstripline used to tune the operating band and/or to achieve good impedance matching within a desired band. Following this method, a DR filter has been designed and optimized using HFSS simulator. Figure 3 and figure 4 shows the top and bottom view of filter.

RESULTS AND DISCUSSION

Wideband devices can be designed using two or more DRs. All DRs are operating in a same principle. Each DR will resonate for a same mode but with different frequency such that the combination response is an additional result from the single response which able to increase the overall bandwidth. For example if DR1 has a normalized resonant frequency of and bandwidth of *BW1*, while DR2 has a normalized resonant frequency of and bandwidth of *BW2*, then the combination response could has a bandwidth *BW* that is larger than the sum of *BW1* + *BW2*, if and are properly chosen. If the Qf actors of the two resonators are approximately the same ( ) and if the return loss of thecombined response is equal to or better than 10 dB over the bandwidth *BW*, then the required values for the resonant frequencies of the individual DRs can be approximately equal to [9]:

$$f_1 \approx \left(1-\frac{5}{6Q_0}\right)f_0,\quad f_2 \approx \left(1+\frac{5}{6Q_0}\right)f_0$$

Assuming the bandwidths of the two DRs are also similar (BW, then the combined bandwidth is approximately *BW* = by ignoring any mutual interaction as well as any loadingeffects of the feed, that could either increase or decrease the bandwidth response. When we vary the dimension of various parameter of Dielectric Resonator (DR) for optimization we realize that the resonance frequency of filter depends on the physical dimensions of the DR. Using the tuning and optimization functions of 3-D simulator, a double band DR filter was obtained. The relationship between unloaded Quality factor, loaded Q and external Q is given by the relation.

$$\frac{1}{Q_L} = \frac{1}{Q_e} + \frac{1}{Q}$$

Where Q_L is loaded Quality factor and Q_e is external Quality factor.

Coupling depends upon the mode of the resonator to be excited and amount of coupling required. For fundamental mode of cylindrical dielectric resonator's magnetic coupling is optimum solution as there is enough magnetic fields coming out of the resonator radially. Dielectric resonator size and distance between resonators define the internal coupling for resonators. Transmission loss and insertion loss is shown in the figure 5 with two pass band (low pass and band pass).

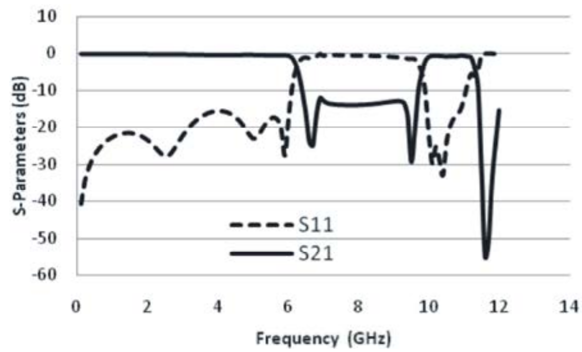

Fig 5: Frequency response of Dielectric Resonator filter

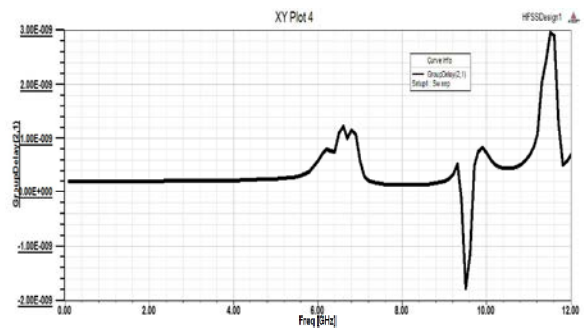

Fig 6: Group delay response of filter

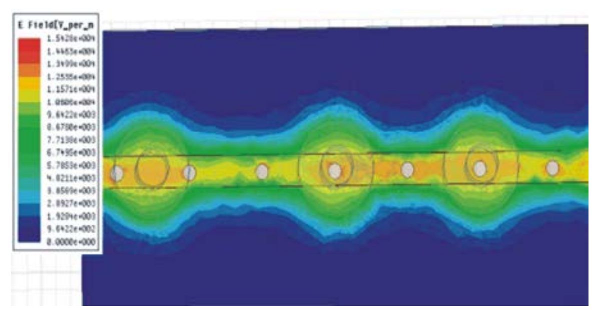

Fig 7: E-field variations

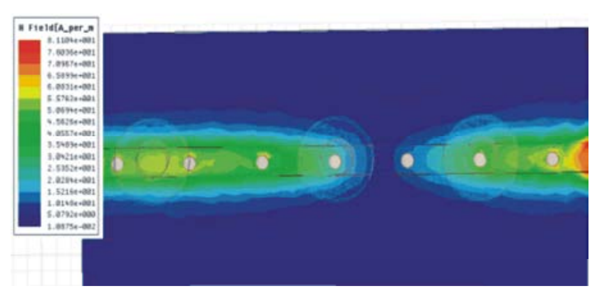

Fig 8: H-field variations

Table 1:

Result Parameters			
Return Loss	-25dB at 6.5GHz	-30dB at 9.5GHz	-14dB at 8 GHz
Transmission Loss	-0.3dB at 6GHz	-0.15dB at 9.5 GHz	-0.35 dB at 8 GHz
Group Delay	~0ns uniformly flat from 6 to 8 GHz		
Band Width (3dB)	(9.7-6.2)= 3.5GHz =44%		

A very minor group delay response shown in the figure 6. Figure 7 and 8 shows the E-field and H-field distribution.

Here we observe dual band dielectric resonant filter with resonant frequency 6 GHz (Lowpass), 10.75 GHz (band pass) with stop band of 3.3GHz. The pass band of band pass filter is 2 GHz.

CONCLUSION

The application of mode DRs for microwave filters around 6 Ghz and 10 Ghz has been investigated. The choice of the DR is discussed in detail. Finally, a mode DR filter with inductive direct coupling is simulated. The developed dual-band dielectric-resonator filters are compact in size while offering a much higher in comparison with microstrip dual-band filters. DGS reduce the harmonics as well as overall size of the filter. Here we successfully design a very compact size of dual band dielectric resonator filter for wireless application.

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