Abstract: - This paper presents the results of the Computer Aided Design of high-Q dielectric resonators of three different configurations. The resonators were designed and simulated for their electromagnetic performance using HFSS commercial software and the results with respect to the Q-factor were compared.

Key-Words: - Dielectric resonators, periodic structures, Filters, mobile communication, Q-factor.

1. Introduction

It has long been recognised that the use of high permittivity dielectric materials offer large reductions in size and weight compared to conventional waveguide filters. However, only recent advances in material technology have made it possible to combine high Q, good thermal stability and high dielectric constant in materials suitable for use at microwave frequencies. Riding on these technological advances, many researchers have pursued work and as a result new types of dielectric filters [6] such as Image quarter-cut dielectric resonator filters have been introduced. These configurations offer very compact structure yet capabilities to handle much higher power level. The configurations are based on TE011 and HE111 resonant modes of cylindrical dielectric disk symmetrically positioned in a square cross-section cavity.

The electromagnetic field patterns are relatively complex in such partially-loaded cavities. The novel concepts involve taking advantage of the electromagnetic field structure of these resonance modes to create a quasi-multi mode resonance regime within the cavity. This is done by introducing electrically-conducting surfaces within the cavity which intersect the dielectric disk, so splitting the normal resonating modes into several parts. Each of these modes resonates at the same frequency as before, but independently of each other until inter-coupled by some means. The potential advantages of this configuration are substantial savings in size and mass together with the possibility of easy removal of the heat generated within the resonator. However, the main disadvantage with the image resonator is a reduction in Qu-factor as compared with the equivalent full disc resonator. This is because the metallic intersecting walls are in direct contact with surfaces of the dielectric segment and therefore in close proximity with strong electromagnetic fields which are concentrated within the segment. This principle was verified through a CAD for quarter-cur dielectric resonator and three-quarter-cut dielectric resonator band-pass filter for PCN applications [2].

By replacing the inner conductor of the conventional combline resonator by a high $\epsilon_r$ dielectric rod, a new type of resonator is proposed [3] for satellite base-stations which offers high unloaded-Q and the merits of the metallic combline resonator and dielectric loaded resonator. As an experiment, a revised configuration is formed by mounting one or more high-Q dielectric rings onto the cylindrical rod. The physical structure takes the form of slotted penetration of disks mounted on a cylindrical rod, contained within a metallic enclosure.
Using Hewlett-Packard's High Frequency Structure Simulation (HP-HFSS), electromagnetic simulations are done in the lab for all these three structures and the results are compared mainly for the improvements in the Q factor.

2. Resonators

The quarter-cut dielectric resonator is shown in figure 1. The dielectric for the resonator was Alpha-Trans-Tech, Inc., 8300 series with the permittivity = 35.065.

![Figure 1. Quarter-cut DR.](image)

The resonator by replacing the inner conductor of a conventional combline resonator with a dielectric rod is shown in Figure 2. A dielectric cylindrical rod is placed at the centre of metallic box. The excitation is done through the coaxial probes penetrating through the sidewalls of the metallic enclosure.

![Figure 2. Modified dielectric resonator](image)

In the second configuration, the height of the dielectric is reduced but three short dielectric rings are mounted on to the cylindrical rod as shown in the Figure 3.

![Figure 3. Conventional dielectric resonator](image)

3. CAD and Simulation

The design and simulation of the resonators were done using Hewlett-Packard's High Frequency Structural Simulator (HFSS) software. To generate an electromagnetic field solution from which S-parameters can be computed, HFSS employs the finite element methods, in which divides the problem space is divided into thousands of smaller regions and represented the field in each sub-region (element) with a local function. In HFSS, the geometric model is automatically divided into a large number of tetrahedral, where a single tetrahedron is formed by four equilateral triangles. This collection of tetrahedral is referred to as the finite element mesh. A mesh is the basis from which a simulation begins. Initially, the structure's geometry is decomposed into meshes by iterative adding vertex points (seeding). In the case of adaptive refinement, the initial field solution is progressively refined.

The design was reviewed after each simulation run and the modifications were applied to the physical parameters of the
configuration until required results were achieved.

4. Experimental Results

The quarter-cut dielectric resonator has a ceramic puck of 30 mm diameter by 18mm high mounted in a cavity 192.30 mm square by 51.28 mm high. The resonator was tested for the central frequency 1810 MHz. The figure 4 shows the measured resonant frequency of quarter-cut TE01δ image resonator.

**Figure 4.** Measured resonant frequency

The conventional dielectric resonator as shown in Figure 2, has the dielectric at the centre with 6.35 mm radius and 23.0 mm height. The enclosure was a rectangular square of 44 mm and height 27mm. The coaxial probes for the excitation were of 3.0 mm outer radius and 1.5 mm inner radius with the penetration length of the coaxial probe was 6mm from the inside wall.

The modified dielectric resonator as shown in Figure 3, has the dielectric at the centre with 6.35 mm radius and 21.0 mm height. There were three circular dielectric disks (radius 8.35 mm, height 3.5 mm) mounted on the central rod. The enclosure was a rectangular square of 44 mm and height 27mm. The coaxial probes for the excitation were of 3.0 mm outer radius and 1.5 mm inner radius with the penetration length of the coaxial probe was 6mm from the inside wall. In both cases the dielectric permittivity was 37.5. The measured resonant frequency of the conventional dielectric resonator under the TE01δ mode is shown in Figure 5.

**Figure 5.** Simulated resonant frequency

The simulated resonant frequency of the modified dielectric resonator under the TE01δ mode is shown in Figure 6. The resonant frequency for the resonator 2 was at 2.27 GHz with no insertion loss. The resonant frequency for the conventional dielectric
resonator 1 was at 2.19 GHz with the insertion loss of −12dB. Further experiments were carried out in the conventional dielectric resonator by modifying the dimensions in order to get the central frequency as that of the enhanced resonator.

The simulated resonant frequency of the conventional resonator after the modification was shown in Figure 7. The plot shows the S12 values for the final configuration of Resonator 1 when the resonant frequency 2.276GHz is closest to the reference configuration (Resonator 2) and the insertion loss is 1.5dB. For this configuration, the size of the coaxial probes and the penetration length were reset to the original configuration but their co-ordinates were changed in the z-direction (upwards).

Figure 7. Simulated resonant frequency

5. Conclusion

In this paper, we are investigating dielectric resonators for the filters which can replace combline filters to give equivalent performance at a smaller size. In the case of quarter-cut dielectric, the Qu factor was measured to be 3600. In the case of conventional dielectric resonator as shown in Figure 1, the measured Qu-factor was 2190 with the insertion loss of 12dB. In the case of enhanced dielectric resonator as shown in Figure 3, the Qu factor was 2837 with no insertion loss. At L-band frequencies, dielectric resonators are used as single cavities in combines or as very narrowband notch filters. In each case very high Q values are required and any size reduction must be compared with an equivalent waveguide cavity design.

References

