CHAPTER- 1

Introduction

Dielectric resonators (DRs) are very popular in satellite and wireless communication systems. Low volume, high quality factor and low loss are the main driving force for using DRs in microwave filters, antennas, voltage controlled oscillator and multiplexer. Dielectric resonators were not significantly utilized in commercial applications after their early analysis by Cohn [1] in the 1960s because they were not readily available commercially. In the late eighties, when more advanced ceramic materials having good dielectric attributes, low-loss performance and other important characteristics were investigated, dielectric resonators gained popularity. Various materials, shapes, size, and modes of operation were implemented.

Most of the filters reported in literature use dielectric resonator with cavities. For satellite and cellular base station where low loss and high quality factor (Q) is the prime motive, they are the best choice. They are a good solution for implementing high performance filters for these applications, but the cavity itself is bulky. Hence, miniaturization of dielectric resonator filter is difficult and still under investigation. However, due to their superior characteristics of a high Q and low loss, dielectric resonator filters are the most popular among all known types of filters. Miniaturization is a key parameter in wireless communication applications, and there is a need to replace cavity DR filters with planar DR filters. Dielectric resonator loaded microstrip filter is capable of achieving a tradeoff between miniaturization and quality factor. In this thesis, our approach is to investigate various types (Band-pass, Low-Pass, Band-stop, etc) of
dielectric resonator loaded microstrip filters whose dimensions are smaller. But they have a lower loaded quality factor. The key features of dielectric resonator loaded microstrip filters are low loss, high quality factor (as compared to microstrip line filters), small size and high temperature stability.

1.1 Motivation

High performance with size reduction and low cost is the prime goal of new technologies. Filters play an important role in communication devices by providing frequency selectivity. Till now, various technologies for filter design have been investigated by many researchers. The scope of advancement always exists in the technologies for betterment. Only a limited number of research-articles on DR loaded microstrip filter have been published. Filters with DRs coupled to microstrip line have rarely been reported by researchers in this new area. Multiband filters also have advantages over single band filter. The Defected Ground Structure (DGS) and Electromagnetic Band Gap (EBG) filters are popular planar structure filters due to their very compact size. The motivation behind this thesis is to find out solutions for designing multiband, small size, low loss, high quality factor and low-cost planar filters for satellite and wireless communication systems.

1.2 Problem under Investigation

The filter is vital for all communication devices. With the advancement of technology, the size of the device is shrinking every day. However, the device functionality is improving tremendously. Therefore, every component of the device needs
miniaturization. Hence, the frequency selective networks must also meet the new age requirements. Many researchers have contributed to the design and development of filter design technologies. But it is always a challenge to design a filter with advanced features and a small size. In this thesis following problems are addressed:

(a) Size reduction techniques in microstrip filters.
(b) Discontinuities in the microstrip line.
(c) Design and simulation of various types of Defected Ground Structure filters.
(d) Characteristics of high quality factor dielectric resonators.
(e) Design, simulation and testing of dielectric resonator filters.
(f) Design, simulation and testing of dielectric resonator filters with Defected Ground Structure.

1.3 High Frequency Structure Simulator (HFSS)

In this work, the High Frequency Structure Simulator (HFSS) software is used for simulations. HFSS is a three dimensional (3-D) structure simulator based on Finite Element Method (FEM). To calculate the full 3-D electromagnetic field inside the structure, it divides the entire structure into thousands of smaller regions and represents the field in each sub-region with a local function. It converts the geometric model into a large number of tetrahedrals, where a single tetrahedron is a four-sided pyramid. This collection of tetrahedrals is referred to as the finite element mesh. Inside each tetrahedron, the value of vector field quantities (H-field or E-field) is interpolated from the vertices. It stores the components of the field that are tangential to the three edges of the tetrahedron at each vertex. It also stores the component of the vector field at the
midpoint of selected edges that is tangential to a face and normal to the edge. The field inside each tetrahedron is interpolated from these nodal values. By representing field quantities, the system can transform Maxwell’s equations into matrix equations that are solved using traditional numerical methods.

1.4 Thesis Organization

This thesis focuses on Design and Simulation of Multiband Compact Dielectric Resonator Filters on novel Defected Ground Structures.

Chapter-2 begins with introduction to various filters which includes filter responses and filter technologies. Various types of filter technologies (lumped element, distributed element, Defected Ground Structure, waveguide, coupled line resonators and dielectric resonator) are discussed in detail along with their layouts.

In chapter-3, we discuss the discontinuities in microstrip line. This chapter mainly focuses on characteristics of Defected Ground Structures (DGS) including their design, simulation and comparison of different shapes and sizes of etching geometry at the ground plane of microstrip line. The first section introduces the basic theory of Defected Ground Structures. DGS filters and formulations related to changes in impedance, phase constant, phase velocity etc have been discussed thereafter. In the next section, size reduction techniques in microstrip line, slow wave factor and resonant frequency changes achieved by changing the dimensions of Defected Ground Structures have been described. This chapter also includes the design and simulation of different shaped Defected Ground Structures and their performance analysis. For the same resonating frequency any type of DGS cell can be designed. The resonant frequency depends on the shape and size of DGS cell. The comparison of the transmission
coefficient of square, circular, triangular, hexagonal and hexagonal with transmetal dumb-bell shaped DGS at 4GHz resonating frequency has been made. A comparison of extracted equivalent-circuit parameters, upper cut-off frequency \( f_{cu} \), Lower cut-off frequency \( f_{cl} \), Quality factor (Q) and sharpness factor of the band stop resonators with all types of DGS cell has been discussed. Next, in this chapter a triangular DGS band stop filter with small patch has been reported. Also, a low-pass filter using arrow head dumb-bell shaped DGS has been designed and simulated. Simulated electric-field and magnetic-field variations of the filters is also analyzed.

**Chapter-4** describes the characterization of dielectric resonators. In this chapter, various parameters of dielectric resonators have been explained. This includes resonance, loaded quality-factor, unloaded quality-factor, coupling, coupling coefficient and different resonating modes. Coupling between the microstrip line and dielectric resonators and between the resonators themselves and their equivalent circuits has been discussed.

**Chapter-5** includes design and simulation of Dielectric Resonator Filters. In this chapter four different novel dielectric resonator filters have been designed and simulated. Firstly, a \( \text{TE}_{01\delta} \) mode low-pass and band-pass dielectric resonator filter has been investigated. Here two dielectric resonators loaded on a \( z \)-shaped microstrip line has been designed. This filter is fabricated on Rogers RO 4232 and tested on a network analyzer. Simulated and measured results are compared and found to be very close to each other. The second filter is a multiband dielectric resonator filter. In this filter four dielectric resonators are placed over the microstrip line at equal distances. This filter resonates at 9.4GHz and 12.55GHz with a bandwidth of 2GHz and 1.8GHz respectively. The third filter is a single dielectric resonator loaded on L-shaped microstrip line low-pass filter.
This filter is designed and simulated on the FR-4 epoxy substrate. Again the measured results are compared with the simulated predictions and found to be in true agreement with each other. The fourth filter is a band-pass filter resonating at 10.8GHz. It is designed and simulated with three dielectric resonators loaded to FR-4 epoxy microstrip line.

**Chapter-6** deals with Dielectric Resonator (DR) filters with discontinuities in microstrip line. In this chapter, the integration of DR loaded microstrip filter and filter with Defected Ground Structures (DGS) and/or Defected Microstrip Structure (DMS) has been investigated. In the first type of filter, a stair-case dielectric resonator with dielectric constant 60 is loaded on a microstrip line and a circular defect is etched out at the ground plane. This is a dual-band low-pass and band-pass filter. The second is a band-pass filter operating at 3.5 GHz. This filter is loaded with a dielectric resonator having dielectric constant 68. Comparisons of simulated and measured results of transmission-coefficient and reflection-coefficient have been performed. The next type of filter is a Dielectric Resonator (DR) band-pass filter with DGS and DMS. Here, a Z-shaped microstrip line with a defect at the strip and ground plane has been investigated. The fourth type is a dielectric resonator band-stop filter using ring type DGS. Single DR is placed between two open stubs. This resonator is placed on the substrate of microstrip line in the vicinity of stubs and the strip. Four circular ring type equidistance defects are created on the ground plane. The last filter is a dual band dielectric resonator filter with defect on microstrip. Here again, a Z-shaped microstrip line with cut out on the strip line just below the resonator has been used. This is also a dual-band filter operating at 6.82GHz and 8.02GHz with 980MHz and 400MHz bandwidth respectively. For all filter investigated,
step by step procedures have been shown. Measured results and simulated results have been compared.

In Chapter 7, result discussion, conclusion and further scope of work are presented