PREFACE

In wireless communication and radar systems, antenna is the only interfacing device attached to both the transmitter as well as the receiver. Wideband systems can provide high data rates, voice biometrics, multi-lingual communication, multiple communication channels, controlled data traffic and good range resolution due to availability of wide frequency spectrum. Thus, large impedance bandwidth is required for efficient wireless communication and radar systems. Dielectric resonator antenna (DRA) is one of the best options to achieve wide impedance bandwidth. An American physicist, R.D. Richtmyer theoretically predicted that a dielectric piece of suitable shape can function as a microwave resonator and he coined the term "dielectric resonator (DR)" in 1939. In the early 1980s, Stuart A. Long gave an introductory experimental investigation on the resonant cylindrical dielectric cavity antenna.

Now-a-days, DRAs are drawing great attention for radar and wireless communication due to their attractive advantages, such as large bandwidth, ease of excitation, high radiation efficiency, low phase noise, flexible feed arrangement, ease of integration with other active or passive microwave integrated circuit components, easily controlled characteristics and wide range of material dielectric constants. DRAs can be excited by different feeding techniques including coaxial or probe, microstrip line, slot coupling technique, coplanar waveguide and dielectric image guide. The conventional shapes of DRA: rectangular, cylindrical, hemispherical, and ring provide a typical bandwidth of around 10%, which may not be adequate for wideband applications. Bandwidth enhancement of a DRA, especially with a low profile design is a demanding task for the researchers. Different approaches are used to enhance the bandwidth of DRAs. Multi-element stacking is one of the approaches to enhance the bandwidth but overall antenna

volume is increased in this approach. Another approach includes the merging of a hybrid radiating mode with the DRA mode. Such merger of modes occurs in dielectric resonator on patch configuration and coplanar waveguide inductive slot embedded as a hybrid radiator along with the DRA. Although to achieve wideband impedance match, some special feeding mechanisms viz. L-shaped probe feed in cylindrical DRA and tall microstrip transmission line (TML) are used. Several DRA geometries, such as H-shaped, T-shaped, dumb-bell shaped DRAs, were analyzed for wideband applications. Material selection for the DRA also plays an important role in deciding the final antenna performance. For the DRA performance to be effective, both the aspects i.e. DRA design and the DRA material selection need to be essentially considered. It is possible to get good DRA performance using proper material with simple design instead of going for complex design with improper material selection.

The present state-of-the-art on dielectric resonator antennas (DRAs) using dielectric ceramic draw great attention of researcher working in the area of DRAs. The thesis would help these researchers in their endeavor to address the issues related to ceramic material design of DRAs. The thesis is broadly comprises of eight chapters.

Chapter 1 contains compact description about different types of dielectric resonator antennas (DRAs), excitation techniques, modes of excitation, radiation mechanism, bandwidth and gain enhancement techniques as well as reconfigurable DRAs. It gives brief idea about the parameters of ceramic dielectric materials affecting the performance of the DRAs as well as recent development in DRAs. It also deals with the discussion about the role of dielectric materials used for DRAs, mechanism of interaction of microwave with ceramic dielectric, parameters that effect the dielectric constant of ceramic materials used for DRAs. For future investigations, such studies will be useful for understanding the effect on the microwave device performance on the end user side.

Also, emphasis is placed on the low cost production and eco-friendly materials, which can be recycled further, keeping in view the environmental protection aspect. This review might provide a systematic guideline to researchers for design and development of novel DRAs.

Chapter 2 describes the objectives of the present investigation in detail. In the present investigation, it is aimed to synthesize and characterize Barium – Strontium Titanate (BST) (50Ba:50Sr) which was sintered using a few low melting glasses as sintering additives. Further, filleted rectangular DRA (F-RDRA) and cylindrical DRA (CDRA) are designed and fabricated using these materials and their input and radiation characteristics are studied through simulation and experimentation in X-/Ku- band(s).

Chapter 3 describes the experimental procedure used for the synthesis and characterization of materials, and for the design and fabrication of different DRAs. The solid state synthesis route has been used for the BST ceramic preparation. Two different glasses i.e. PBBS and BB glasses were prepared by melting in the glass melting furnace at 1323K and 1123K temperatures. After that the glass added BST ceramic was prepared using liquid phase sintering.

For the design and simulation study of DRAs, Ansys HFSS simulation software was used. The two different DRAs have been proposed i.e. F-RDRA and composite feed CDRA. The optimization of DRA dimensions have been done through parametric study in HFSS. The fabrication and measurement of proposed DRAs are also described in this chapter.

Chapter 4 describes the synthesis of novel $60PbO–20B_2O_3–5BaO–15SiO_2$ (PBBS) glass, which has been utilized as the sintering aid for $Ba_{0.5}Sr_{0.5}TiO_3$ (BST) ceramic. The effects of different amount of PBBS glass additions on the sintering temperature, phase, microstructural and dielectric properties of BST ceramic have been investigated

comprehensively. With 3-10 wt% of glass addition to the BST ceramic, the sintering temperature of BST significantly reduces by > 300K. BST with 10 wt% PBBS glass (BST-10P) shows the highest density with lowest sintering temperature as compared with all other compositions. XRD analysis has revealed that addition of PBBS glass has no effect on the crystal structure of BST. analysis of dielectric property has revealed that transition temperature increases with increase in glass concentration up to 5 wt% and then it starts decreasing by further increase of the glass concentration (>5 wt%). Transition temperature also shifts towards higher temperature side on increasing the frequency. Average dielectric constant values of glass added BST samples lie in the range 13.8 - 27.0 and thus these materials can be potentially useful for the design of microwave dielectric resonator antennas. The synthesized ceramic reduces the manufacturing cost and can be potentially useful for the miniaturized devices or components in the radio frequency/ microwave range.

Chapter 5 deals with the design and development of filleted rectangular dielectric resonator antenna using 3wt% PBBS glass added BST (BST-3P) as a resonating segment for antenna. It BST-3P material average dielectric constant of 15, which is used for the design of proposed antenna under investigation in this chapter. The simulation studies of single segment rectangular DRA (SS-RDRA), double segment rectangular DRA (DS-RDRA) and filleted rectangular DRA (F-RDRA) were carried out using Ansys HFSS software at microwave frequencies and simulation results for input and / or radiation characteristics are compared. The proposed filleted RDRA (F-RDRA) was fabricated and measurements on it were performed. The simulation results for input and radiation characteristics of the proposed F-RDRA are compared with respective experimental results as well as with the respective results for conventional dual segment RDRA (DS-RDRA) and those reported in literature. The proposed F-RDRA provides widest

bandwidth with reasonable gain among all the RDRAs studied and those reported in literature. The proposed F-RDRA provides broadside radiation pattern with reasonably good realized gain over its operating frequency range. The proposed antennas can find potential application as primary feed for parabolic reflector in radar and satellite communication.

Chapter 6 describes the study the effects of B_2O_3-Bi_2O_3 glass additive on phase, microstructure, sintering temperature and dielectric behavior of $Ba_{0.5}Sr_{0.5}TiO_3$ ceramic. The BB glass has been utilized as the sintering aid for BST ceramic preparation. Composition BST-5B shows the highest density at sintering temperature of 1223 K as compared with all other compositions. XRD analysis has revealed that addition of BB glass has no effect on the crystal structure of BST. Analysis of dielectric property has revealed that transition temperature increases with increase in glass concentration up to 5 wt% and then it starts decreasing by further increase of the glass concentration (>5 wt%). Dielectric constant of all glass added BST samples have been observed over the frequency range 8.5 - 12 GHz at room temperature with the highest value for BST-5B. Dielectric constant of glass added BST samples lie in the range 17 – 43.2 and thus these samples can be potentially useful for the design of microwave dielectric resonator antennas. The synthesized ceramic reduces the manufacturing cost and can be potentially useful for design of miniaturized devices or components in the RF/microwave range.

Chapter 7 presents the design and development of cylindrical dielectric resonator antenna using 3 wt% BB glass added BST (BST-3B) excited by novel composite feed. BST-3B ceramic has been used as dielectric resonator in the proposed single segment cylindrical DRA (SS-CDRA). A new simple composite feeding technique consisting of a probe

connected to XOR-shaped patch (PXP feed) has been proposed to obtain the monopole like radiation pattern from SS-CDRA. The simulation and experimental studies on the proposed antenna were performed in microwave frequency range and results obtained for the antenna characteristics have been compared. Simulation study on the antenna was carried out using Ansys HFSS software. The simulated and measured -10 dB reflection coefficient bandwidths for the proposed antenna have been determined to be 40.77 % (7.44 - 11.25 GHz) and 52.08 % (7.03 - 11.98 GHz), respectively. The near E-field distributions show the generation of distorted $TM_{01\delta}$ mode in the proposed CDRA. The proposed antenna has provided monopole like radiation patterns. The simulation and the experimental results of the proposed antenna have been found to be nearly in agreement with some deviation in the results especially for reflection coefficient-frequency characteristics which may be due to fabrication and measurement errors. The proposed antenna has also been found to provide the widest bandwidth when compared with other antennas producing monopole like radiation pattern reported in literature. The proposed CDRA may find potential application as an element in antenna array in radar and satellite communication. The benefits of the proposed antenna is in its simple design and simple feed layout for obtaining monopole like radiation characteristics. The composite feed employed here can be exploited for excitation of different DRAs using wide range of available dielectric materials, which can provide much flexibility to cover wide range of frequencies.

Chapter 8 presents the summarized conclusion of the present investigations made in the thesis on dielectric materials and dielectric resonator antenna. A table for comparison of properties of BST ceramic, PBBS and BB glass added BST ceramics are also given in this chapter. In the present study, emphasis has been given on lowering the sintering temperature of BST ceramic by liquid phase sintering. Two different types of low melting

temperature glasses (PBBS and BB) were prepared and added to the calcined powder of BST ceramic described in chapters 4 and 6, respectively. The results have shown that a small PBBS glass addition (BST-10P) lowers the sintering temperature by 375K giving good relative density of 90.2 %. Significant effect of PBBS glass has been observed on the microstructure of BST ceramic. Dielectric constant is almost stable with temperature and frequency for the PBBS glass added ceramic compositions.

A microstrip-fed aperture-coupled single segment RDRA (SS-RDRA), dual segment RDRA (DS-RDRA) and filleted RDRA (F-RDRA) have been investigated through simulation and/or experimentally (chapter 5). The -10 dB reflection coefficient-frequency plots for the three DRA configuration reveals that the maximum bandwidth is obtained for the filleted-RDRA configuration. The proposed F-RDRA provides widest bandwidth with reasonable gain among all the RDRAs studied and those reported in literature. Another antenna, CDRA with novel composite feed is described in Chapter 7. A table for comparison of antenna characteristics of these two proposed antenna configuration is given in this chapter. The scope of future work is also described in brief.