PREFACE

Dielectric Resonators (DR) are ceramic pieces that can act as frequency determining components at microwave frequencies. DRs should have high dielectric constant \( (\varepsilon_r) \) in the range 20 to 100 for better miniaturization, high Q factor \( (Q > 2000) \) for better frequency selectivity and nearly zero temperature coefficient of resonant frequency \( (\tau_f) \) for frequency stability with temperature. In addition to the above characteristics, their low cost of production and excellent integrability to microwave integrated circuits (MICs) make them indispensable components in microwave oscillators, filters, duplexer used in cellular phones and in dielectric resonator antennas. Dielectric resonators increasingly replace the conventional resonators such as metallic cavities or micro strip circuits. Though several temperature-stable DRs are available at present, investigation is still going on to find new materials having better dielectric resonator properties. In this work we investigate the microwave dielectric properties of (1) \( A_3B_4O_{15} \) \((A = Ba, Sr, Mg, Ca, Zn; B = Nb, Ta) \) ceramics, their solid solutions and mixtures (2) \( MO-La_2O_3-TiO_2 \) \((M = Ba, Sr, Ca) \) ceramics which mainly consists of \( \text{AnB}_n \_O_{3n} \) \((n = 5, 6, \text{or} 8) \) type cation deficient hexagonal perovskites and (3) a novel method of achieving temperature compensation by stacking positive and negative \( \tau_f \) resonators. Dielectric resonator properties were studied in terms of phases, crystal structure, crystal symmetry, polarisability of ions, lattice parameters and characterization techniques such as XRD and SEM are employed.

Chapter 1 is a general introduction about material, scientific and technological aspects of DRs. Three important parameters, \( \varepsilon_r \), \( Q \) and \( \tau_f \), used for the DR
characterization are described. The relationship of the above parameters with the fundamental material characteristics is discussed. Different modes are excited when a DR is excited with suitable microwave spectrum of frequencies. A description of analytical determination of frequencies and construction of mode charts used for sample design and mode identification are also discussed.

Chapter 2 presents the methods used for the preparation of ceramics and the various techniques used for the microwave characterization of dielectric properties. The ceramic samples were prepared through the solid-state ceramic route. The dielectric constant of the ceramics at microwave frequencies are measured using the end shorted dielectric post resonator. The quality factors are determined by a transmission mode cavity. The temperature coefficient of resonant frequency (\(\tau_f\)) is measured by heating the end shorted dielectric post resonator set up in the temperature range 20 to 75°C and by noting the variation of the resonant frequency with temperature. The crystal structure of the samples is analysed using powder X-ray diffraction pattern and surface morphology and grain size is observed using Scanning Electron Microscopy.

Chapter 3 describes the investigation of microwave dielectric properties of \(A_2B_4O_{15}\) (\(A = Ba, Sr, Mg, Ca, Zn; B = Nb, Ta\)) ceramics. The ceramics show dielectric constant in the range 11 to 51. The hexagonal perovskites show higher dielectric constants than the orthorhombic phases \(Mg_5Nb_4O_{15}\) and \(Mg_5Ta_4O_{15}\). The FIR and submillimeter techniques are used to study the above compounds. The basic theory of the techniques is discussed. An indirect estimation of the lower limit of dielectric loss and upper limit of dielectric constant at microwave frequencies can be obtained by the extrapolation of real part and imaginary part of the dielectric function down to
microwaves from data obtained through far infra-red spectroscopy. The solid solution phase of the type \( \text{Ba}_{5-x}\text{Sr}_x\text{Ta}_4\text{O}_{15} \), \( \text{Sr}_3\text{Nb}_x\text{Ta}_{4-x}\text{O}_{15} \), \( \text{Ba}_5\text{Nb}_x\text{Ta}_{4-x}\text{O}_{15} \) are prepared and microwave dielectric properties are characterized. The \( \text{Sr}_3\text{Nb}_x\text{Ta}_{4-x}\text{O}_{15} \) phases show abnormal dielectric properties where a decrease in dielectric constant is observed for the intermediate compounds when compared to the end members. This is attributed to the possible structural changes and is evident from analysis of X-ray diffraction data. The \( \text{Ba}_3\text{Nb}_x\text{Ta}_{4-x}\text{O}_{15} \) show linear behaviour for solid solution and intermediate dielectric properties of the end members are obtained. In section of the chapter \( x\text{Zn}_3\text{Nb}_2\text{O}_8-(1-x)\text{Zn}\text{Nb}_2\text{O}_6 \) mixture phases are discussed. The results are interpreted based on the method of mixtures. The mixture phases show good sinterability and higher quality factors than the end members. The substitution of Zn at Mg site in \( \text{Mg}_5\text{Nb}_4\text{O}_{15} \) also gave mixture phases and the compositions \( x\text{ZnO}-(5-x)\text{MgO}-2\text{Nb}_2\text{O}_5 \) showed high quality factors (\( Q \times f \) up to 89000 GHz) with \( \varepsilon_r \) in the range 11 to 22. The mixture phases showed intermediate dielectric properties of the end compounds.

Chapter 4 describes the microwave dielectric properties of \( \text{MO-La}_2\text{O}_3-\text{TiO}_2 \) (\( \text{M} = \text{Ba}, \text{Sr}, \text{Ca} \)) ceramics. All the ceramics, except \( \text{CaLa}_4\text{Ti}_3\text{O}_{17} \) and \( \text{CaLa}_8\text{Ti}_9\text{O}_{31} \), which are orthorhombic structured, belong to the cation deficient hexagonal perovskites belonging to the \( \text{A}_n\text{B}_{n-1}\text{O}_{3n} \) (\( n=5, 6 \)) type compounds. The ceramics show high dielectric constant in the range 41 to 54 with high quality factors and small temperature coefficients of resonant frequencies. The applicability of Claussius - Mossotti equation to these ceramics is discussed. These ceramics are suitable for low frequency applications requiring narrow bandwidth and low insertion loss. The orthorhombic phases show comparatively higher dielectric constants than the hexagonal phases.
Chapter 5 describes a novel method of achieving temperature compensation by stacking positive and negative $\tau_f$ resonators. The stack acts as a single resonator. The $\tau_f$ of the resultant stack depends on the volume fraction of the positive $\tau_f$ and negative $\tau_f$ DR materials. The $\tau_f$ can be tuned to zero or to a desired value by adjusting the volume fraction of the positive and negative $\tau_f$ materials. The dielectric constant and quality factor also change depending on the volume fraction of the two different DR materials. The experiment is performed with varying volume fraction of $\text{Ba}_3\text{Nb}_4\text{O}_{15}$ as the positive $\tau_f$ DR and $\text{Sr(Y}_{1/2}\text{Nb}_{1/2})\text{O}_3$ and $\text{SbO}_2\text{O}_5$ as the negative $\tau_f$ DR materials. The DR material in the bottom of the stack has greater influence on the $\tau_f$ of the resultant stacked resonator.

Chapter 6 gives a summery and conclusion of the present investigation and also discusses the scope for further work in this field.