CHAPTER I

INTRODUCTION TO THE RESEARCH PROBLEM

1.1 Introduction

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X-band microstrip transmission line and adaptable radial stub resonator on magneto-dielectric substrate
1.1 INTRODUCTION

New developments and technologies, in recent times, have led to unprecedented strides in wireless communications which in turn generated demands for newer and more efficient technologies. As a result, devices and techniques with improve characteristics such as compactness; light weight is being continuously developed to meet contemporary performance specifications for microwave integrated circuit (MIC) applications. These applications include voice, video, data, remote sensing, defence applications, navigation, medical diagnostics and treatment, industrial applications, security; the list is endless [1-8]. The performance utilization of the MIC is decided by the extrinsic geometries and intrinsic interaction of electromagnetic waves with its substrate materials. Engineering the functional materials for high speed and high frequency operation is a challenge primarily due to the fact that customizing materials to fit into a desired performance range is not predictable. Hence it requires intuition and considerable in-flight into the effects of intended change in composition and processing to obtain the desired performance characteristics.

The material properties, primarily permeability and permittivity greatly influence the choice of microwave materials [9-11]. Permeability dispersions of magnetic material are complicated and interplay between the domain wall displacement, magnetization rotation and gyromagnetic spin rotation due to the effective anisotropic field [12]. Metallic magnetic materials are not used at microwave frequencies as the penetration depth in metals at microwave frequencies is only a few microns and microwave magnetic field do not initiate any response [13]. Low conductivity magnetic materials like ferrites interact throughout the volume with microwaves and the magnetic spectrum of the material shows ferromagnetic resonance at these frequencies [14].
External tuning of MIC devices on magnetic substrates aid in removal of spurious frequencies; achieving broad banding while gyromagnetic absorption works out as band-stop filters or switches [15, 16]. The magnetic material in its bulk form with large coercivity, exchange bias and high saturation magnetization, requires a high magnitude of external dc magnetic field to bring up some appreciable change in tuning [17].

Nano structured ferrites are reported to have very low saturation magnetization and hence a small external dc magnetic field is sufficient to change its gyrotropic properties [18 - 20]. Polymers with magnetic nanocomposites are also very promising for microwave applications due to their potential for miniaturization, tunability and the realization of low-loss magneto-dielectric materials [21-23]. Magneto-dielectric materials have shown considerable improvements in the bandwidth and/or size reduction of microwave devices [24 - 25].

Tunability can be achieved with a good degree of sensitivity even in low absolute field intensity with small field variation. This gives rise to interesting application possibilities of magneto-dielectric composites such as in high Q switching, tunable output multiplexers, switched tracking preselector mixers, frequency hopped receivers, Doppler radars etc. [26, 27].

1.2 THE RESEARCH DIRECTION

The research is essentially directed towards:

- Development of flexible magneto-dielectric composite materials having the desirable microwave permittivity, permeability and minimization of losses to obtain low external field tunability and fast switching in MICs.

- Investigation of auxiliary but necessary properties for microwave device applications including homogeneity, thermal, magnetic and environmental inertness.
• Investigation of the electromagnetic wave propagation characteristics of microstrip line on the magneto-dielectric material under influence of external magnetic field perturbations.

• Development of an effective model for field distributions within the microstrip line on the developed magneto dielectric composite substrates based on the three-dimensional Finite-Difference Time-Domain (3D FDTD) method.

• Exploring the application possibilities of the developed material for other planar devices.

1.3 THEESIS STRUCTURE AND OUTLINE

This thesis structurally consists of eight parts and two appendices. Nano sized nickel substituted cobalt ferrite as reinforcers in low density polyethylene matrix are developed as possible magneto-dielectric substrate material. The preparation technique of nano ferrites and composites is illustrated in Chapter II. The chapter also includes the microstructural studies like XRD, TEM, SEM micrographs to estimate shape, size, distribution and ascertaining of structure.

Other essential property studies like thermal stability, compactness and water passiveness are included in Chapter III. B-H loop and saturation magnetization of the developed magneto-dielectric materials are also included in this chapter.

Chapter IV includes studies on complex permittivity and complex permeability at microwave frequencies. A technique is developed for broad band measurements of these parameters and a detail treatment of the approach is presented.

Background theory on the 3D FDTD technique is dealt in Chapter V. The theory has been modified for anisotropic permeability tensor which
updates in space grid and time stepping. The tensor in turn modifies the H field followed by updating of E field in the usual leap frog manner.

Chapter VI describes the study of EM wave propagation at X-band through the magneto-dielectric material. For this, a microstrip line is developed on the said substrate, and transmission response with varying magnetic field and orientations are studied and analysed. Coupled mode theory is used to study the coupling between the TEM and magnetostatic modes. A full wave 3D FDTD simulation is carried out to obtain insertion loss by taking Fourier transforms of the E field transient values and comparing with that obtained experimentally.

A single port circular resonator with radial stubs to resonate at different frequencies in the X-band is designed and fabricated on the magneto-dielectric material developed. Studies on the performance characteristics on this device application of the material are detailed in Chapter VII.

Chapter VIII summarizes the suitability of the developed magneto-dielectric material as substrates for planar devices for MICs. The limitations and future direction of work that can be incorporated are also highlighted.

Appendix - A gives the detail equations for PML boundary conditions as applied in the modelling. 3D FDTD code is developed in C language. The E, H and permeability tensor updating code modules employed are given in Appendix B.
References


