CHAPTER VI

CONCLUSION AND SCOPE OF FUTURE WORK

6.1 Brief Review and Discussion of Results

6.2 Scope for Future Work


6.1 BRIEF REVIEW AND DISCUSSION OF RESULTS

A detailed and systematic study of propagation characteristics of different ferrite loaded layered waveguide systems has been undertaken in the thesis. The waveguide systems were formed by combining ferrite films with films of high transition temperature superconductors, linear and nonlinear dielectric and nonlinear ferroelectrics.

In chapter I, the ferrimagnetic materials and their basic properties and specialities were reviewed. The modern ferrite film fabrication technique, the Liquid phase epitaxy method was outlined and effect of doping on the properties of yttrium iron garnet was discussed. A brief discussion on high frequency integrated circuits was also attempted as it being the field where the structures studied are to be tested and put into practice.

In chapter II, an attempt has been made to examine in detail the electromagnetic wave propagation characteristics of ferrite medium which is an integral part of all structures studied in this thesis. This attempt has begun with the derivation of the permeability tensor, the so called ‘Polder tensor’ of ferrite into which D. Polder tactfully included all the specialities of ferrimagnetic materials. Faraday rotation, birefringence and damping effects, exhibited by ferrimagnetic materials are able to give deep insight into the interaction of electromagnetic wave with ferrimagnetic medium.
and hence they were discussed in detail. Depending on the kind of the structure and kind of its interaction with the propagating electromagnetic wave, different regimes of wave propagation, like spinwaves, magnetostatic waves, magnetostatic surface waves etc. are available and they were discussed. In this era of nanostructure bulk ferrite medium has only little relevance. In all the structures studied in this work, different layers are of thin film form. Detailed discussions of electromagnetic wave propagation in a standalone ferrite film and in a ferrite/dielectric/ferrite hybrid structure were presented in the last part of chapter II. The derivation of dispersion relation corresponding to the surface wave propagation in the structure with tangentially magnetized ferrite film, using Maxwell’s equations and finding its numerical solution is the method of analysis of all the structures presented in this thesis.

In the third Chapter, propagation characteristics of various hybrid structures consisting of ferrite and superconducting films were analyzed in detail. The structures considered are (i) ferrite/superconductor/ferrite, (ii) ferrite/superconductor, (iii) superconductor/ferrite/superconductor and (iv) ferrite/dielectric/superconductor. The advantages of using superconductors along with ferrites were elaborated. The problems and remedies in the coexistence of ferrite and superconductors were also discussed followed by discussions on electrodynamics of superconductors. The modelling of superconductors was done on the basis of ‘two fluid model’.
Each structure has been considered separately and dispersion relation corresponding to the TE wave propagation has been derived using Maxwell’s equations. Numerical solutions of the dispersion relations have been obtained and detailed discussions of the results were presented. All the structures have been found to be nonreciprocal and exhibit the very important property, the magnetic tunability. The dependence of propagation on different structural parameters is also established in each case.

The TM wave propagation in the structures has also been studied. The dispersion relation corresponding to the TM wave propagation in the ferrite/superconducting/ferrite structure has been derived and the results were discussed. It has been found that the TM surface wave propagation in the tangentially magnetized structure is reciprocal and cannot be tuned magnetically. Also, the TM wave propagation is found to be independent of the structural parameters. It hass also been found that the above mentioned points regarding TM wave propagation are applicable to all the remaining structures and hence further derivations of TM wave dispersion relations and discussions upon them were avoided.

In the fourth chapter, wave propagation and power propagation characteristics of layered structures consisting of ferrite and nonlinear dielectrics (any value for the nonlinearity) were analytically studied and useful results were obtained. Derivation of dispersion relations using
Maxwell’s equations and power expressions using Pointing theorem and their programming and computation was the method of approach adopted. Structures with Kerr-like nonlinearity were well studied by others. The importance of the structures studied in this work is that they are structures with general nonlinearity and power propagation in them is tunable and the propagation is nonreciprocal.

In chapter IV, two structures were studied. First structure studied was a three layer structure with a linear ferrite film in between cladding and substrate of general nonlinearity. The dispersion relation has been derived and expressions for power corresponding to different values of nonlinearity were formulated. The wave propagation in this structure was found to be reciprocal but the power propagation was found to be nonreciprocal and tunable. The differences in the nature of power propagation in the structure corresponding to the positive and negative ‘effective permeability regions’ of the ferrite film were also established and discussed.

The second structure studied in chapter IV was a double layer structure formed by a linear ferrite and a cladding of general nonlinearity. The dispersion relation derived was solved and found that the wave propagation in this structure is nonreciprocal as well as magnetically tunable. The power expressions formulated for different nonlinearity values were numerically evaluated and nonreciprocal effect and tunability
of power propagation in the structure have been confirmed. Also, when the
nonlinearity value in the general dispersion relation derived for the
structure II is made equal to two, then it got reduced to the dispersion
relation derived for the ‘Kerr-like’ structure [1]. The power propagation as
well as tunability behavior of structure II were also found to be different in
the positive and negative regions of effective permeability of the ferrite
film used.

The third structure studied consists of a linear ferrimagnetic substrate
and a nonlinear ferroelectric cladding. The permittivity of the ferroelectric
cladding was taken to be depending on the electric field linearly and
quadratically. The dispersion relation has been derived analytically and
numerical results were discussed.

Since surface wave propagation alone is considered, TM wave
propagation in the structures were irrelevant with respect to nonreciprocal
and tunability aspects. Hence the TE wave propagation alone has been
undertaken in the fourth chapter.

In chapter V, A microstrip line and a slot line on magnetized ferrite
substrates have been analyzed using spectral domain approach. Dispersion
has been examined for forward and reverse propagations and it is found
that the propagation is non-reciprocal in both the structures.
6.2 SCOPE FOR FUTURE WORK

The work reported in this thesis can be extended in several directions. The most important of them are detailed below.

1. In the case of multilayers with dielectric films, the problem of propagation in anisotropic dielectric/ferrite structures needs to be investigated. It is sure that the use of anisotropic dielectric will modify dispersion and this information is essential in various applications to various devices.

2. The theoretical investigations and modelling of various devices like phase shifters, isolators, filters etc. is to be done.

3. In the case of structures with nonlinear and dissipative materials, the problem of propagation of nonlinear waves like ‘soliton’ may be investigated.

4. As far as superconducting/ferrite structures are concerned, the mesoscopic effects has not considered yet. This is an important area of future work.

5. Experimental verification of several of these structures as well as various devices can be undertaken.