CHAPTER - I

CHAPTER I
INTRODUCTION

The work reported in this thesis involves the study of ferrite loading on electromagnetically coupled microstrip patch antenna. Ferrite loading means placing ferrite on patch antenna that is using ferrite as overlay. In this chapter therefore details about both microstrip patch antenna and ferrite are given along with brief introduction to the antenna.

An antenna is a structure that transforms guided electromagnetic wave into free space electromagnetic waves and vice a versa. An antenna is a reciprocal device that is its directional pattern as receiving antenna is identical to its directional pattern when the same is used as a transmitting antenna (provided it does not employ unilateral and non linear devices such as some ferrites).

Antennas are characterized by following parameters.

a) Directive gain,
b) Power gain,
c) Directional pattern,
d) Beam width,
e) Band width,
f) Polarization,
g) Impedance,
h) Aperture.

Types of antennas are

a. Yagi-Uda antenna,
b. Reflector antenna
c. Horn antenna
d. Helical antenna
e. Log periodic antenna
f. Phased array antenna
g. Microstrip antenna.

1.1 Microstrip antenna.

Although antenna engineering has a history of over 60 years, the microstrip antenna forms one of the most innovative areas of antenna. Deshamp [1] was the first to report microstrip radiators. This type of antenna could find applications [2, 3] only after 20 years from its first report.

Microstrip antennas are increasingly finding applications in microwave communication system. They are used in various systems such as radar, satellite communication, missiles, space vehicles and various defence equipments because of thin profile, low weight, planer configuration and easy integratibility with other circuits.

The simplest configuration of microstrip antenna is a metallic radiator on a dielectric substrate as a support, with ground plane on the other side. The metal used is normally gold, copper or silver. Ideally the dielectric constant of the substrate should be low ($\varepsilon_r = 2.5$), so as enhance the fringing fields, which account for radiation. The higher limit for value of ε_r is 13. Various types of substrates used are quartz, glass, sapphire and alumina etc. Alumina (Al_2O_3) is most commonly used, because of higher thermal conductivity, strength, and stability and good electrical properties.

Microstrip antennas may be of any geometrical shape and any dimensions. However all the microstrip antennas may be divided into three basic categories.

A) Microstrip patch antennas,
B) Microstrip traveling wave antennas,
C) Microstrip slot antennas.

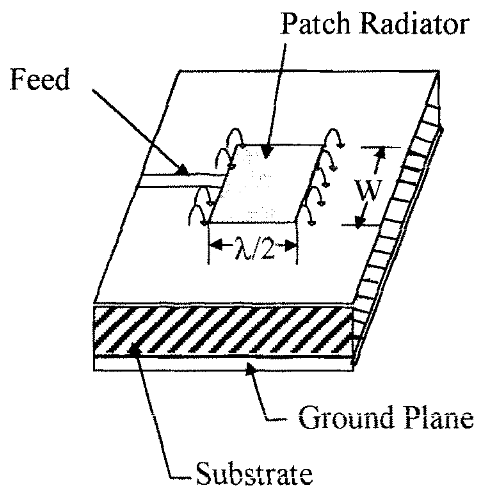
Here we are concerned with microstrip patch antenna, which is discussed in more detail in the following articles.

1.2 Microstrip Patch Antenna

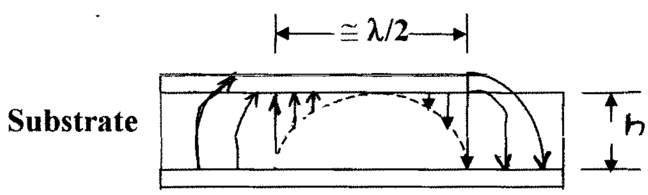
Microstrip Patch Antenna (MPA) consists of a conducting patch of any planer geometry on one side of dielectric substrate backed by a ground plane on the other side. There are virtually an unlimited number of different patch antennas with different geometries. Rectangular element is most commonly used one. It is half wavelength open circuit patch fed by microstrip line or by co-axial probe.

1.3 Radiation Mechanism of MPA

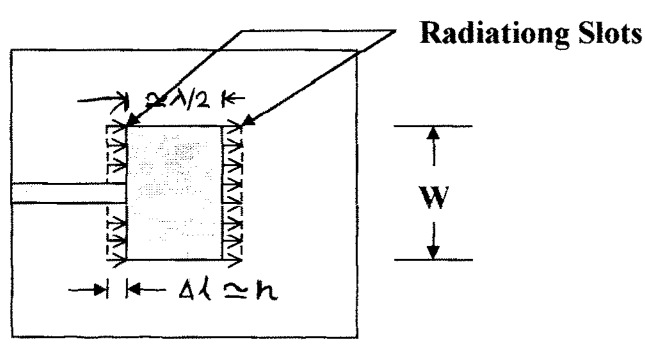
Radiation from microstrip antenna can be understood by considering the simplest case of rectangular microstrip patch placed at a distance of small fraction of wavelength above the ground plane as shown in Figure 1.1(a) [4] Assuming no variation of electric field along the width and the thickness of microstrip structure, the electric field configuration of the radiator is as shown in figure 1.1(b). The fields vary along the patch length, which is about half a wavelength ($\lambda/2$). Radiation may be ascribed mostly to the fringing fields at the open circuited edges of the patch. The fields at the end can be resolved into normal and tangential components with respect to ground plane. The normal components are out of phase because the patch line is $\lambda/2$ long; therefore far fields produced by them cancel in the broad side direction. The tangential components (those parallel to ground plane) are in phase, and the resulting fields combine to give maximum radiated field normal to the surface of the structure, that is the broad side direction. Therefore the patch may be represented by two slots $\lambda/2$ apart as shown in Figure 1.1(c) excited in phase and radiating in the half space above the ground plane. If we consider the variation of fields along the width of the patch, then in this case, the microstrip patch antenna may be represented by four slots surrounding the patch structure. At resonance the patch launches



(a) Rectangular Microstrip Patch Antenna



(b) Side View.



(c)Top View

FIGURE 1.1 : Radiation Mechanism of Microstrip Patch Antenna

electromagnetic wave from feed line to free space by matching the antenna impedance with air characteristics impedance.

1.3.1 Far Field Radiation Pattern

In close proximity of an antenna, the radiation fields exhibit complex characteristics, because reactive components are present in addition to the radiation field. The reactive components vanish and only the radiated field remains in the far field region, when moving far enough away from the antenna. The distance R between the calibrated reference antenna and the antenna under test must satisfy the condition

$R >> 2D^2 / \lambda_0$

D is largest dimension of the antenna and λ_0 is free space wavelength.

The reactive field may be considered to be that region immediately surrounding the antenna and the radiating field is that region beyond the reactive field, in which the radiation pattern dependent upon R.

There are several analysis techniques for the determination of the far field radiation pattern of microstrip antenna element. Two slot model [5], the cavity model [6] and the electric surface current model methods are applicable for calculating the far field radiation pattern of rectangular microstrip antenna elements

The accurate measurement of far field radiation pattern in the E and H plane involves a number of factors such as physical and effective dimensions of the antenna element, its feed point location its operational frequency, and environment in which it is operated (e.g. ground plane). In addition the feeding and construction discontinuities can cause asymmetry in radiation patterns [8]. The three models are briefly discussed below.

1.3.1.1 Two slot model

Generally the fringing fields occur around the four edges (side walls) of the rectangular patch. These fields preferred as source of radiation for antenna, which is vertically polarized. The fields along the patch width edges radiate horizontally polarized power and can't be avoided. Based on this observation, the antenna element can be regarded as an antenna system equivalent to the two-slot model.

1.3.1.2 Cavity model

This model treats the region between two parallel conductor planes, consisting of a patch conductor and ground plane as a cavity bounded by the electric walls and magnetic wall along the periphery of the patch. The fields in the antenna elements are assumed to be those of this cavity.

1.3.1.3 Electric surface current model

The antenna element is replaced by an assumed surface current distribution and the fields are solved taking in to account the presence of the dielectric layer. Calculations take place in the Fourier domain. The far field calculated asymptotically from this solution is used to get radiation pattern of the antenna element.

1.4 Feeding techniques

There are mainly two techniques for feeding the microstrip antenna.

I) Contacting feeding techniques.
   a) Direct feeding by stripline
   b) Probe feeding

II) Non-contacting feeding technique.
   a) Aperture or slot coupling.
   b) Electromagnetic coupling.

1.4.1 Contacting feeding technique.

In direct feeding microstrip line is directly connected to the pattern. It is a very simple technique. This type of excitation is coplanar, which allows feed network and other circuitry to be fabricated on the same substrate as the antenna element.

1.4.1.1 Microstrip line

Microstrip line is planar transmission line available for miniaturization of microwave circuits. It was first introduced in 1952 [10]. Microstrip structure consists of thin plate of low loss insulating material (the substrate) covered with metal completely on one side (the ground plane) and partially on the other where the circuit patterns are printed. The microstrip structure is shown in Figure 1.2

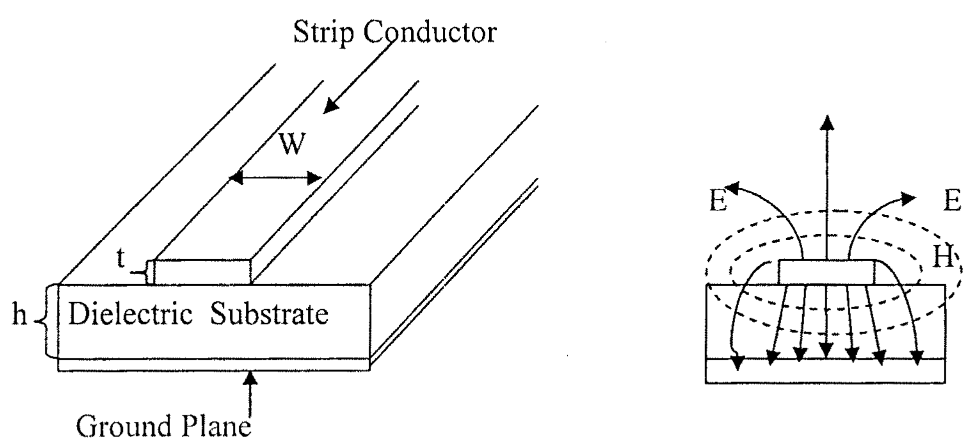


FIGURE 1.2 : Schematic diagram of microstrip line with its field lines

Although microstrip has very simple geometric structure, the electromagnetic fields involved are actually complex. The electromagnetic boundary conditions are actually complex. The electromagnetic boundary conditions infer the presence of longitudinal component at dielectric air interface that indicates microstrip can't support the TEM mode. It is characterized by its complex mode of propagation called quasi TEM mode. The microstrip is a slow wave dispersive structure. Hence the propagation constant varies nonlinearly with frequency [11]

MIC using microstrip can be designed for frequencies ranging from few GHz up to many tens of GHz. But at higher frequencies, particularly millimeter wavelength ranges losses increases greatly, higher order modes become considerable problem and fabrication tolerances become exceedingly difficult to achieve. The frequency limit for extensive use of microstrip is probably around 60 GHz [14]. The structure is popular due to its planar geometry suitable for bounding and used as interconnect. The most important dimensional parameters are the microstrip width (w), height of the substrate (h) and the relative permittivity of the substrate (ε_r). The thickness t of the substrate should be greater than skin depth.

In probe feeding, holes have to be drilled in the substrate and coaxial probe is connected to the patch in a perpendicular plane. This model is destructive. In both above mentioned feeding methods the feed points are not easily varied, particularly for adjustment of impedance matching. These two feeding methods are very similar in operation and offer essentially one degree of freedom (for a fixed patch size and substrate) in the design of antenna element, through the positioning of the feed point to adjust the input impedance level [12]

Such direct contacting feeding methods have advantage of simplicity, but also configurations suffer from the bandwidth / feed radiation trade off; where an increase in substrate thickness for the purpose of increasing bandwidth leads to an increase in spurious feed radiation, increased surface wave power and possibly increased feed inductance. For practical purposes such antennas are limited bandwidth to about 2% to 5%.

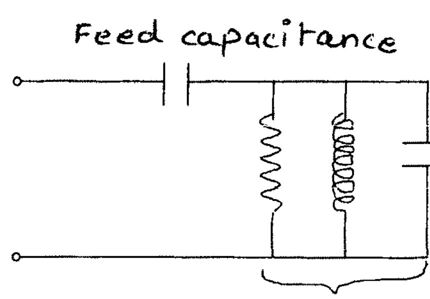
Coaxial probes can be used to feed patch elements through the ground plane from a parallel feed substrate, but in any array having thousands of elements such a large number of solder joints make the fabrication difficult and lower reliability (especially important consideration for space applications)

Finally although probe and microstrip line feeds primarily excite the dominant mode of patch element, the inherent asymmetry of these feeds generates some higher order modes, which produce cross-polarized radiation.

1.4.2 Non-contacting feeding technique

Proximity coupling (often referred as electromagnetic coupling) uses a two-layer substrate with a microstrip line on lower substrate, terminating in an open stub (end) below the patch, which is printed on upper substrate.

Electromagnetic coupling has the advantage of allowing the patch to exist on a relatively thick substrate, for improved bandwidth, while the feedline sees an effectively thinner substrate, which reduces spurious radiation and coupling. Fabrication is bit more difficult because of requirement for reasonably accurate alignment between substrates but soldering is eliminated. EMC patch has at least two degrees of freedom, the length of the feeding and the patch width to line width ratio. This coupling is capacitive in nature. The equivalent circuit has a capacitor in series with the parallel RLC resonator, which represents the patch.



RLC Resonant patch

This can be used to impedance match the antenna, as well as aiding in the tuning of the element for improved bandwidth. Bandwidth of 13 % has been achieved in this manner [16]. Since this work is on EMC antenna the advantages of this antenna are elaborated

1.4.2.1 Advantages of EMC

1) Feed line is closer to the ground plane, to reduce the radiation from various transmission line discontinuities [17-19].

2) The patch ground plane spacing can be increased to obtain greater bandwidth [19].

3) Match of patch to the feed line is simple and is achieved by selecting an appropriate line patch overlap [19, 20]. Flexibility and adjustment of the patch above the feed line to find the best match points.

4) The absence of physical connection between resonator and feed line facilitates the fabrication of antenna [19]. It does not disturb the antenna geometry (independent ness)

5) Two or three resonance frequencies can be operated at the same time in a single patch [21]

6) Two different thickness layers (SP and SF) with the same Substrates of different thicknesses with the same ε_r and of different ε_r can easily be used and calculated [21, 22].

7) Shift of f_r, variety of bandwidths and maximum gain possible for single patch to find with VSWR < 2.

8) End field feeding and side field feeding by open ended microstrip line is adjustable [21, 22]

9) A single pattern for E and H plane [21, 22], inclined pattern for E plane [22], and symmetric lobe pattern at single frequency is adjustable with angle variation.

10) Design procedure, manufacturing, and cost are compatible with other methods.

1.4.2.2 Aperture coupled or slot coupled feeding technique.

This configuration uses two parallel substrates separated by a ground plane. A microstrip line on the bottom substrate is coupled through a small aperture (typically a narrow rectangular slot) in the ground plane to a microstrip patch on the top substrate. This arrangement allows a thin high dielectric substrate for the antenna element, thus allowing independent optimization of both the feed and radiation functions This geometry has at least four degrees of freedom; the slot size, its position, the feed substrate parameter and the feed line width. The other advantages and disadvantages of this type of feeding technique have been discussed in detail by Pozar [23].

1.5 Review of methods of improvement of the properties of microstrip antenna.

Research on microstrip antenna was carried out to improve input impedance and resonance frequency calculations, to improve bandwidth, directivity, and gain and to improve flexibility. There are several ways to achieve this. Since this work deals with EMC antenna with ferrite as an overlay, the review of work done regarding these aspects are elaborated in the proceeding articles.

1.5.1 Use of ferrite material in the printed antenna system.

There are many possibilities and combinations for using ferrite materials on printed antenna system. Ferrite material can be used as single substrate, in multi-layer substrates configurations with dielectric or as a cover layer for printed antennas [24]. The reason for using ferrite (gyroscopic material) in microstrip structure is that the applied magnetic field changes the permeability and thus electric properties of the material.

Many workers have used ferrite as a substrate. Das and his co-workers [25, 26] have utilized ferromagnetic substrates with high effective permeability in order to reduce the size of printed antennas when operating at low UHF.

Pozar [24] have studied radiation and scattering characteristics of microstrip antennas and arrays printed on ferrite substrate with normal biased field. It has been shown that circular polarization can be obtained from a square microstrip antenna on a magnetized ferrite substrate using only a single fed point. The operating frequency of this antenna can be tuned by adjusting the bias field and sense of polarization can be switched by reversing the polarity of the biased field. Biased ferrite substrate can be used to reduce RCS of microstrip antenna. The results were generated via full wave moment method solutions for isolated elements and cavity model for circular patch antenna.

Pozar et al [27] have studied experimentally the tuning of microstrip antenna on ferrite substrate by varying the direction of bias field [28, 29]. Antenna array of circular patches on ferrite substrate has been studied. Rainville et al [30] fabricated patch antenna on ferrite film instead of ferrite substrate (thick).

Patch antenna on ferrite substrate allow for pattern control, frequency shifting and scattering reduction. Their inherent anisotropy and nonreciprocal properties permit variable frequency tuning [27, 28, and 29] and antenna polarization diversity [31]. External biasing of ferrite substrate also allows for beam steering [32, 33], pattern shape control and radar cross-section control by forcing ferrite into cut off state [34, 35].

1.5.2 Effect of superstrate on microstrip antenna.

The term super-strate and overlay are normally used for bulk overlays, in touch with the microstrip components. Most of the available literature on superstrate / overlay effects on microstrip patch antenna is of the superstrate being a pure dielectric material. There are very few reports on ferrite being used as overlay. The conductive patches of microstrip antenna are often covered by dielectric layer for protective purposes or for other mechanical thermal requirements. The basic properties of MPA with cover layer are discussed by [11].

Bhel et al [36] have reported effect of in touch superstrate on patch for different resonance frequencies and with superstrate of different ε_r, which shows continuous exponential like decrease in f_r up to superstrate of thickness of 2 mm above which it saturates that is frequency shift is very small. They have suggested such method to saturate f_r shift, so that further additional parasites like ice, snow and drops of rain does not affect the microstrip patch antenna parameters (Z_{in}, f_r).

Due to overlay, change in effective dielectric constant and corresponding change in edge effects are considered by S. M. Iyer et al [38]. Radiation and surface waves of a microstrip antenna covered with dielectric have been also studied [39]. For the analysis magnetic current line source model has been used. It has been found that the beam width of the radiation pattern in E plane will initially decrease and then increase upon increasing normalized thickness of the cover.

The superstrate loading effects on the circularly polarized rectangular patch antenna are investigated by Chen et al. [40] Results indicates that when superstrate layer is placed away from the patch, loading effects on the patch are considerably reduced.

Verma et al [13] combined variation technique, with the transmission line model for covered rectangular patch antenna. Shavit [14] and Fan and Lee [41] presented spectral domain analysis that examines the resonance and input impedance characteristics of covered microstrip antennas. Verma and Rostamy [42] proposed modified Wolff models to calculate resonance frequencies of various microstrip structures. Ramahi and Lo [43] applied the method of moments approach to calculate antenna resonant characteristics with superstrate. Afzalzadeh and Karekar [42] have considered the effect of a spaced dielectric superstrate on the microstrip patch antenna. They concluded that the spaced superstrate has negligible effects on the resonant characteristics of antenna as long as the air gap between the patch and the superstrate is at least a free space wavelength. Jenifer Bernhard et al [45] presents a predictive model for the resonant frequencies of rectangular microstrip antennas with spaced superstrates

H. T Hui et al [46] have presented a rigorous analysis method for the multilayered hemi-spherically dielectric loaded slot antenna. Numerical solutions have shown that a higher permittivity dielectric load generally favors a smaller slot size while a narrower bandwidth is resulted. A higher microstrip permittivity has also been shown to reduce the radiation efficiency.

Similar type of dielectric superstrate effects for various thicknesses has been reported [47]. The results indicate that for higher substrate thickness the resonance frequency does not shift further, the radiation pattern drastically changes into two or three lobes depending on substrate thickness.

The gain enhancement method relying on substrate – superstrate resonance for more complex microstrip patch antenna has been studied using moment method [48, 49]. According to them the resonance can be tuned by optimizing various thick nesses of substrates superstrates.

The effect of ferrite overlay (d = 3mm) on circular patch is reported by Henderson [35], who found an increase in directivity. When overlay was unmagnetized the side lobe was nearly 5 dB. But on magnetizing the overlay not only HPH reduces to nearly 30^0, but also main lobe scans by 30^0. Thus overlay can be used for scanning the beam without need of switching phase arrays.

1.5.3 Electromagnetically coupled microstrip patch antenna.

The electromagnetically coupled microstrip line excitation (EMCME) of patch antenna was introduced and studied both theoretically and experimentally [19, 50-53]. The EMCME may also be modified by proper choice of substrate material and its thickness to adjust antenna parameters like radiation pattern, impedance bandwidth, VSWR, and resonance frequency.

Studies for all possible variations of feedline, particularly with respect to inset, offset and diagonal feed point variations for EMCME has been done [21,22]. They have reported that when a patch designed for long side feeding, is fed from the short side it gives a two lobe radiation pattern, about 90^{O} apart in E plane and single lobe in the H plane. The amplitude of these two lobes changes systematically and can be adjusted easily by EMC. This is an additional tailoring facility for radiation control. Along with this wide range variable bandwidth can be achieved. Thus broad bandwidth can be obtained by a two layer electromagnetically coupled patch antenna which provides a better compromise between bandwidth and surface wave effects. Two layers are also used [54,55]. This consists of a stack of driver (feeder) patches and parasitic (radiating patches with an air region in between. Experiments using triangular [56] and rectangular [57-59] patches have shown that this antenna can provide an impedance bandwidth of 10 to 20 % with a maximum VSWR of 2:1.

An experimental study on the three layer EMC using circular patches has been investigated. The investigation indicates that the broadband behavior with low cross polarization and better directivity may be realized. The impedance bandwidth may be broadened to as high as 19 % with a proper combination of interspacing of the stacked patches.[60]

The stacked circular microstrip patch antenna for optimal spacing between the patches gives 8 times increase in bandwidth in comparison with a single patch antenna [61]. In the operating bandwidth the antenna gain was between 6.1 and 8.7 dB.

The structure formed by a set of co-axial probes and a single layer patch antenna has been studied theoretically [62]. The analysis is based on the mixed potential integral equation solved by method of moments applied to each conductor. The tuning properties of parasitic load on resonant frequency are stressed. Similar type of theoretical investigation has been done with variation of size and position of a parasitic element [63].

Atsuya Ando et al [64] proposed a novel electromagnetically coupled microstrip antenna with ratable patch for personal Handy phone system units. Dual stub tuning to enhance the bandwidth is also reported [65].

1.6 Fabrication of the microstrip antenna.

Two types of fabrication techniques have evolved for hybrid microwave circuits. Thin film technology and thick film technology. The properties that affect the circuit performance are to be taken into account while choosing materials.

1.6.1 Substrates

Substrates are supporting plates upon which the circuit elements are built. The substrate becomes the medium of propagation of electromagnetic waves. The ideal substrate materials for microwave circuit should have the following characteristics [66].

1) High dielectric constant should be in the range of 8-16.
2) Low dissipation factor or loss tangent.
3) Dielectric constant should remain constant over the frequency and temperature range of interest.
4) High purity and constant thickness.
5) High surface smoothness.
6) High resistivity and dielectric strength.
7) High thermal conductivity.

In addition to general properties of the substrate above discussed, there are other properties, which are specific for thick film technology. Thermal expansion should be matched with the critical element that will be deposited on the substrate. The surface should have proper rough ness. The relative rough surface costs less and aid in ink transfer during the screen-printing operation.

Generally Alumina (96-99.5 % Al_2O_3) is used for thin and thick film MIC. It is most widely used because the electrical characteristics and the reliability in microwave region are excellent and cost is reasonable. [67]. Alumina is quite good as far as all the general requirements of thick film technology are concerned. The majority of the commercially available thick film inks are developed to give optimum properties when fired on alumina substrates.

1.6.2 Thin film technique.

The most commonly used technique for the metallisation of MICs is the thin film technology. Following processes come under the thin film process.

1) Vacuum deposition.
2) D.C. sputter.
3) Vacuum deposition followed by electroplating.
4) D.C. sputter followed by electroplating.
5) Electro less deposition followed by electroplating.

In the present work, thick film technology is considered.

1.6.3 Thick film technique.

Thick film technique is that field of microelectronics wherein specially formulated pastes are screen printed and fired onto a ceramic substrate in a definite pattern. Thick films are distinguished from thin films by their method of fabrication, not by their thickness [67]. Thickness of thick film element is typically 3 to 30 μm. Multiple printings are often used to produce the desired thickness and combinations of conductors, resistors and dielectrics.

The technology is based on the formation of patterns through the use of woven cloth "screen" and viscous pastes. The main component of the printing equipment is the screen, which usually consists of woven mesh of stainless steel, nylon or silk mounted under tension on a metal frame. The stencil is formed on the screen. The process is explained in detail in the next chapter. The finished screen has open mesh holes only over the circuit pattern area. The appropriate paste is then placed on one side of the printing screen. The screen is suspended about 0.5 mm above the substrate and scraper blade, called a squeegee, traverses the screen under pressure, bring in contact with substrate and at the same time driving paste through the open mesh of the screen. The natural elasticity of the screen peels it off the substrate and the paste, having wet the substrate and then left in position. The scraping steps can be either carried out by hands or by machine. The whole process is known as "screen printing process".

As already mentioned, this thesis involves use of ferrite as an overlay. Therefore some details about the ferrite are also given in the following articles.

1.7 Ferrite

Ferrites constitute a very important class of material having large potential applications in the field of computers, electronics, and microwave devices. The microwave applications of ferrite had their foundation in the early work on the Faraday Effect. Using this effect significant contribution has been made in the development of microwave devices.

Ferrites are ferromagnetic oxide materials, containing iron oxide as their main component. It consists of magnetic ions arranged in a manner, which produces spontaneous magnetization while maintaining good dielectric properties.

The general formula for simple ferrite is MFe_2O_4. M is a divalent metal ion. When divalent metal ions or trivalent iron ions are replaced by other magnetic or nonmagnetic ions, the resulting ferrites are called substituted ferrites.

The ferrite materials for microwave device application should have high resistivity, low dielectric loss, and low resonance line width, moderate saturation magnetization, high Curie temperature etc. To achieve this substituted ferrites or mixed ferrites were developed.

Basically there are three simple microwave ferrites, Magnesium ferrite, Nickel ferrite, and lithium ferrites. In designing ferrite for particular application, the substitution of particular ion is required to obtain desired value for a specific parameter.

Magnesium ferrites are particularly appropriate for microwave applications because of its relatively low dielectric and magnetic losses [68]. The magnesium ferrites require small quantity of Mn^{+2} ions to suppress the formation of Fe^{+2}, which is detrimental to dielectric properties. To reduce magnetization Al^{+3} ions are used to substitute for Fe^{+3} ions, because Al^{+3} mainly go into the B sites. The family magnesium ferrite is noted for its high stress insensitive remanance ratios with reasonably small coercive forces [69]. If Zn is substituted it predominantly enters the tetrahedral sites in the ferrite systems [70]. Its additions are effective in lowering the anisotropy, decreases the resonance line width. Besides these Zn promote densification and grain growth. These three factors all contribute to decrease of Hc.

Mossbaur study of Al^{+3} additives in Mg-Mn ferrite is done by M. Singh et al [71, 72]. The effect of substitution of nonmagnetic Al^{+3} ions on electrical and magnetic properties of Mg-Mn ferrites have been reported, which proved its applicability at high frequency. The high D.C. resistivity thereby lowering the dielectric losses and low value of saturation magnetization are desired characteristics of aluminum substituted Mg-Mn ferrite used to prepare microwave devices operating in L, S and C bands.

Referring to the above literature we have taken up the preparation of $Mg_{0.4}Mn_{0.5}Zn_{0.1}Al_{0.8}Fe_{1.2}O_4$ ferrite for studying its effect on X band microstrip patch antenna.

1.8 Preparation techniques of ferrites

For preparation of homogeneous, fine particles and high purity ferrites, a number of methods have been developed. These methods can be broadly classified as follows.

Methods of preparation

Ceramic method

Chemical methods

Precursor methods

1) **Hydroxide**
2) **Carbonate**
3) **Oxalate**
4) **Hydrazine carbonate**

Wet chemical methods

1) **Spray reaction**
2) **Freeze drying**
3) **Co precipitation**
4) **Hydrothermal oxidation**

1.8.1 Ceramic method

This is most widely accepted commercial method for the preparation of ferrite powders. In this process, wet milling mixes the metal oxides in proportion required for the end product intimately together. The mixture is dried, presintered, pressed to desired shape and finally sintered at very high temperature to obtain end product.

1.8.2 Precursor method

This method involves preparing a precursor, a solid solution containing both metal ions M^{+2} and Fe^{+3} in the desired ratio and decomposing the precursor to yield the end product that is ferrite.

1.8.3 Wet chemical method

In this method ferrite is prepared from solution of water-soluble salts of corresponding metals. Compared with ceramic method main advantages of both the chemical methods of synthesis are, it requires comparatively low temperature, low sintering period. Final product produced by these methods has fine grain size and materials are strain free.

All the methods have their own specific advantages and disadvantages. In this work we followed wet chemical method for synthesis, which requires low temperature and final product has fine grain size. This particular method has been explained in more details in the following artical.

1.8.3.1 Hydrothermal oxidation.

This process achieves preparation of ferrites directly from solution. The alkaline solution is added to a stiochemetric solution of metallic salts with iron in the divalent state. This results in suspension of mixture of hydroxides. The suspension is kept at temperature between 60^{O} C and 90^{O} C. When air is bubbled uniform ally into this suspension, it promotes the oxidation reaction, converting the precipitate in ferrite. Takada and Kiyama [73] have prepared Mn-Zn ferrite by this method. Same ferrite was prepared by Darko Makovec et al [75]. R.G. Kulkarni et al [76] compared the magnetic properties of $MgFe_2O_4$ prepared by wet chemical method by means of Mossbaur spectroscopy, susceptibility and magnetization measurements. They found that high temperature annealing of $MgFe_2O_4$ prepared by wet chemical method gives the properties close to that obtained with usual ceramic method, thus concluded that the magnetic properties depend upon the particular method of preparation.

1.9 Aim of the work

Microstrip antenna being in planar form has the advantage of lightweight, low cost, low volume, printability, conformability and compatibility with microwave integrated circuits. The electromagnetically coupled antenna offers further flexibility of feed position. The flexibility aspect of EMC antennas have not been fully explored even experimentally.

The work in this thesis aims towards a cost effective EMC antenna. Thick film metallization has been used for fabricating the radiating patch and feedline structure. To the author's knowledge EMC patch antenna using Ag thick film has been studied for the first time. The effects of changes in the feedline positions like long side feed (LSF), short side feed (SSF) and diagonally feed (DF) on the % power efficiency, radiation pattern and polar pattern has been studied in details.

Most of the reported work on using ferrites with antennas is when ferrites are used as substrate. If ferrites are used as overlay, changes in the characteristics of the antenna can be achieved as obtained from this work. The effect of ferrite loading on EMC patch antenna has also been studied for the first time.

All the designing and fabrication of the EMC antenna was done in the laboratory itself. The formulation of ferrite by co-precipitation method was also done in the laboratory.

Chapter II contains the experimental aspects of the work. The results in the form of graphs and table are given chapter III. This chapter focuses on the microwave measurements of the microstrip antenna with and without ferrite loading. The results of chapter III are discussed in chapter IV along with conclusions of the work.