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A COMPREHENSIVE SURVEY ON MICROSTRIP ANTENNAS

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Abstract: Microstrip antennas have found their place in the research areas over the past few decades. The main reason for the popularity of these types of antennas is their small size and ease of fabrication. The size of these antennas depends on the frequency of operation. Therefore, as the frequency of operation increases the size of these antennas decreases significantly. This paper summarises the different types of microstrip antennas, the feeding techniques that can be used to feed the radiating element with the input electrical signal, and the various miniaturization techniques that can be implemented to make these antennas more compact.

***Index Terms* - Antennas, Microstrip, miniaturization, patch antenna, feeding mechanisms, microstrip antenna types.**

I. INTRODUCTION

An antenna system is a transducer that converts electrical energy into electromagnetic energy. This energy travels through space and can be received by similar antennas which converts this electromagnetic energy back into electrical energy. The IEEE definition of an antenna is “The part of a transmitting or receiving system that is designed to radiate or receive EM waves” [1]. Antennas can be used to direct the radiated power in any direction as required by the designer by adjusting its parameters. This will allow the designing engineer to enhance the antenna gain in the required directions and suppress the gain in all the other directions[2].

Antennas can be broadly classified into two broad categories depending on their usage. The first classification antennas are designed for the transfer of data wirelessly from one place to another and are called as communication antennas. The second classification of the antenna is the EMC antennas or Electromagnetic Compatibility (EMC) checking antenna. These antennas as test antennas for checking the antenna parameters for a full functionality measurement. Among the communication antennas, there are two types of antennas namely the Microstrip antennas and the conventional antennas. The microstrip antennas are small in size and are having a planar structure[3]. These antennas are usually preferred for high-frequency applications. Conventional antennas are three-dimensional antennas that can be used in low frequency and high-frequency applications. Conventional antennas were the first type of antennas that were implemented for communication purposes. The first most commonly used conventional antenna is the dipole antenna. There are many antennas that are derived from the conventional dipole antenna like the Yagi Uda antenna.

The main factors under consideration while designing an antenna are Frequency bandwidth, Input Impedance, Reflection Coefficient, Voltage Standing Wave ratio (VSWR), Far-Field Region, Antenna Polarization, Effective Aperture, Radiation Pattern, Directivity, Efficiency, Gain, Half Power Beam Width (HPBW). These factors should be designed according to the application for which the antenna is designed.

This paper focuses on the microstrip antennas and the different types of antennas that are evolved from the basic microstrip antenna. In section 2, there is a brief review of the Microstrip antennas. In the following section, the different feed techniques that can be used to give input to the antenna are discussed. In section 4 the different miniaturization techniques are discussed. The paper is then concluded in section 5 with a brief on the promising areas that can be used for further development in this area.

II. MICROSTRIP ANTENNA

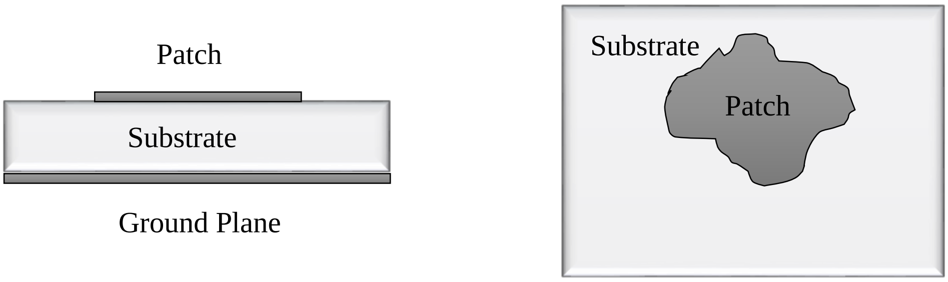
The advent of PCB fabrication made available a new era in antenna technology in the late ’70s which the development of microstrip antennas. Microstrip Antennas are low-profile antennas fabricated using the photolithographic process. This makes these antennas to be easy to fabricate, have low weight, and low cost. These can be easily integrated into microwave integrated circuits (MIC) and parameters can be varied to obtain the desired radiation features. Their disadvantage includes narrow bandwidth[4], poor polarization, limited power capacity and, tolerance problem. Microstrip antennas can be broadly classified as:

- Microstrip Patch Antennas - MPA
- Microstrip Dipoles - MD
- Microstrip Slot Antennas - MSA
- Microstrip Travelling Wave Antennas - MTWA

In a microstrip patch antenna, the main elements are a metallic radiating patch, a thin dielectric substrate, and a metallic ground plane. The basic structure is shown in the figure 2.1.

The shape of the patch is arbitrary and is normally chosen based on the requirement. These antennas are fed using feeding techniques. There are four types of feed networks they are: Using a microstrip line, using a coaxial probe, proximity feed and aperture coupled feed. This is detailed in the next section.

The main advantages of microstrip patch antennas include their low profile, rugged nature, ease of fabrication, ease of connectivity with MIC, which can be easily designed for different polarizations and multiband operations[5]. The main disadvantages include the narrow bandwidth, low power handling capacity and, large Ohmic loss [6].



(a) (b)

Figure 2.1: Basic Patch (a) Side View (b) Top View

The most common type of Microstrip Patch Antenna used is the rectangular patch antenna. In this type of antenna, the patch is having the shape of a rectangle whose length and breadth can be calculated according to the equation.

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (2.1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2} \quad (2.2)$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.3\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (2.3)$$

$$L = L_{eff} - 2\Delta L \quad (2.4)$$

The pattern thus created is fabricated on a substrate with one side having the patch and the other side having the ground plane.

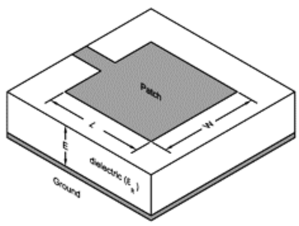


Figure 2.2 Microstrip Patch Antenna

The other feasible shapes for the patch are triangular, circular, and ring-type patches. Of these, the circular patch has found its way into the research areas than the other two types of the patch.

The next type of microstrip antennae is the microstrip dipole antennae. Dipole antennas are the simplest type of antennas that are used. It consists of a wire of half-wavelength length. In the case of a microstrip dipole, the antenna is fabricated on a substrate. The design remains the same. That is the element of the dipole will be half wavelength long [3][7].

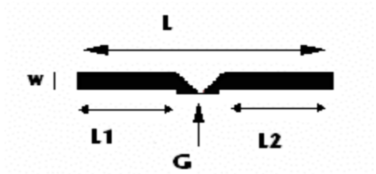


Figure 2.3 Microstrip Slot Antenna

Here L=lambda/2.

The next type of microstrip antennas is the microstrip slot antennas. Slot antennas are openings created in a microstrip line of particular width so that it can transmit electromagnetic energy. The slot antenna works based on the principle that an air or vacuum, slot surrounded by a conductor that is excited with an electric field radiates electromagnetic radiation. The slots antennas find its application in wireless communication, satellite communication, etc. as it is inexpensive has low weight and size is considered small compared to the conventional one[8].

The microstrip slot antennas consist of a slot of length lambda/2 which is placed inside a conductive plate. The excitation of the antenna is given at the center. The gain of these antennas can be improved by using a substrate that has high permittivity. The width of the slot can be calculated using the following equations [4].

$$W = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (2.5)$$

The length of the slot can be calculated by using the following equations.

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-1/2} \quad (2.6)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.3\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (2.7)$$

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0\mu_0}} - 2\Delta L \quad (2.8)$$

ε_{reff} = effective dielectric constant of the substrate
ε_r= dielectric constant of the substrate
h=height of the substrate material
W= width of the slot
ΔL = Extended increment length of the slot (L) can be determined from the following expression
L = Length of the slot
f_r = resonant frequency
W= width of the slot
ε_o=permittivity of free space,
μ_o= permeability of free space,
The structure of a microstrip slot antenna is shown in figure

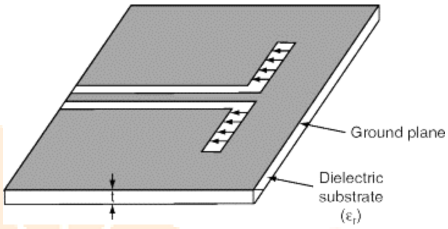


Figure 2.4 Microstrip Travelling Wave Antenna

The next type of microstrip antennas is the traveling wave antennas. This antenna utilized the traveling wave as the main radiation mechanism. These are also known as standing wave antennas or resonant antennas. These antennas are characterized by their current which flows only in one direction. A traveling wave antenna can be created by fabricating a transmission line terminated by a matched load. The length of the transmission line is taken in terms of several wavelengths. There are two types of traveling wave antennas. The first one is the surface wave antenna where the radiation occurs from discontinuities within the structure. These are also called slow-wave structures. The second type of traveling wave antenna is the leaky-wave antenna (LWA). These are also called fast wave structures. Yagi-Uda Antenna is an example of traveling wave antenna.

III. Feeding Techniques in a Microstrip Antenna

Feeding techniques means the method by which electrical signal is fed into the antenna. For a microstrip antenna the feeding techniques are as follows

- Coaxial Probe Feed.
- Microstrip Line Feed.
- Aperture Coupled Feed.
- Proximity Coupled Feed

The coaxial feeding technique is the most popular method. A coaxial cable consist of an inner conductor and an outer conductor. The radiating patch is connected to the inner conductor of the coaxial probe. The out conductor is connected to the ground plane. Coaxial feed as mostly preferred due to their ease in fabrication, easy impedance matching and low spurious noise. But they provide with narrow bandwidth and difficult to use when the substrate thickness is large [9].

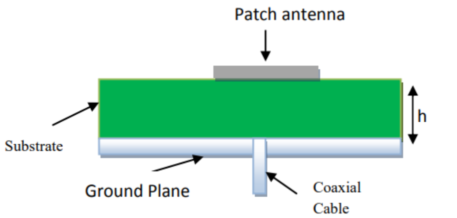


Figure 3.1: Coaxial Feed of Microstrip Antenna[9]

The Microstrip Line feed is the easiest method of feeding a radiating patch. These are fabricated as conducting strips that are attached to the patch. This type of feed is easy to model as it can provide perfect matching of the feed with the patch by controlling the inset position. But these type of feed is also not suitable when the substrate is thick these type of feed network introduces spurious noise in the system [9].

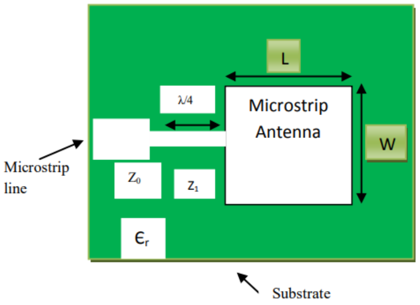


Figure 3.2 Microstrip Line Feed[9]

In Aperture coupled feed, there are two substrates which is separated by a ground plane. The patch is situated on the top substrate and the feed microstrip line is situated on the bottom side of the bottom substrate. The feed line is connected to the radiate patch through a slot on the ground plane sandwiched between these two substrates. The top dielectric is usually selected to have low dielectric constant and the bottom dielectric have high dielectric constant.

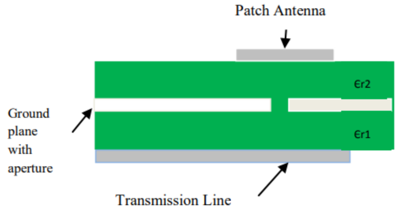


Figure 3.3 Aperture coupled Feed[9]

The proximity type of feed offers the highest bandwidth. But his type of feed mechanism is difficult to fabricate as the substrates needs to be perfectly aligned. The impedance matching between the feed line and the radiating patch is obtained by considering the length of the feeding stub and the length to width ratio of the radiating patch.

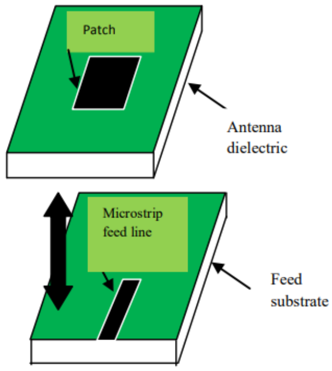


Figure 3.4 Proximity Feed[9]

These are the different types of feeding methods that can be implemented in an antenna. The selection of the type of feed system purely depends on the application. All types of microstrip antennas have the feasibility to have all these mechanisms but the choice of feed mechanism is performed based on the application. That is if in an application, the size of the antenna is very important and the other parameters can be compromised then the feed system that should be chosen should be the microstrip line feed or the coaxial line feed. If in another case the bandwidth of the application cannot be compromised then the feed network for the antenna should be chosen as the proximity feed as proximity feed brings out the possibility of the utilization of the whole bandwidth that the antenna design can offer.

IV. Miniaturization Techniques

This session deals with the size reduction techniques that can be implemented. Reduction in size of the antenna is very important nowadays as most of the application prefers to have small devices which are stationary or mobile. The size of an antenna is mainly dependent on the operating frequency as the antenna dimensions are usually expressed in terms of wavelength. So as the frequency increases, the wavelength of the signal decreases, and thereby miniaturization occurs. So the first and foremost method of device miniaturization is to upgrade the device to a higher frequency of operation. When this method is not feasible other methods of miniaturization should be implemented. The various miniaturization techniques researched for antennas are discussed below.

4.1 Corrugation Method

Corrugation is the process of forming uniform ridges all over the surface. Corrugated antennas will not have smooth patches on the substrate. This in effect increases the electrical length of the antenna and thereby reduces the antenna size. These antennas even though they are considered to be planar antennas, cannot be fabricated using simple planar fabrication techniques. They require different fabrication methods to produce the even corrugation to the patches. This miniaturization technique is usually costly and is used only in the cases where cost is not a constraint or the required miniaturization is not achieved using the other methods [8].

4.2 Perturbation Method

In this method, the end of the radiating element is constructed with a strong electric field intensity. This is achieved by introducing a deformity in the radiating element. This affects the resonant frequency of the radiating element. To adjust the antenna to work in the required frequency of operation, the size of the antenna should be varied. If the shift in deformity is made in such a way that the antenna size has to be reduced to achieve the operating frequency then this method will reduce the overall size of the antenna for that particular resonant frequency [8].

4.3 Iris Method

This method uses a combination of the corrugation method and perturbation method. This is based on the fact that the resonant frequency of a radiating structure decreases as the ratio of the width of the intaglio to the embossed portion of the one-directional corrugated structure is reduced. Modifying the electrical length of the radiation element causes a larger change to the magnitude of the embossed portion than it does to the intaglio portion [8].

4.4 Folding Method

In this method, the radiating element of the antenna is folded in such a way that it will be creating a two-directional antenna instead of the conventional one-directional antenna [8]. This method reduced directivity and gain and also is costly for fabrication.

4.5 Slot Cutting

This is the most widely used method for miniaturization of the microstrip antenna. In this method, several slots are made on the original antenna, or the antenna is reshaped to obtain the desired parameters. The introduction of slots on the radiating patch shifts the resonant frequency. It is also found to make a great effect on the bandwidth, polarization, and efficiency of the antenna [9].

4.6 Substrate Material

The main factor under consideration for any substrate is its dielectric constant ‘εr’ which is normally kept between the ranges 2.2 to 12. If the dielectric constant of the material used as a substrate is small, then it will reduce the fringing field in the patch antenna. This miniaturization technique is especially suited for good impedance matching of the antenna. If the substrate is having a greater dielectric constant, then the dimension of the antenna will reduce as per the antenna equations [9].

4.7 Defected Ground Structure

This miniaturization technique offers the advantage of enhanced bandwidth with a compact-sized antenna. In this method, the ground plane which is usually a planar sheet that covers the backside of the whole of the substrate is modified in terms of shape and size. Slots can also be introduced in the ground plane to get improved antenna parameters. The parameters that are improved by this type of structure include bandwidth, polarization, radiation pattern, antenna efficiency, and resonant frequency. Another type of DGS is the Complementary Split Ring Resonator (CSRR) technique. In this method, CSRR is placed under the patch to enhance its bandwidth [9].

4.8 Metamaterials

Metamaterials are artificial composites that inherit their properties from their structure. These materials exhibit some unusual properties like zero permittivity, negative permeability, and permittivity, antennas, and absorbers, etc. The surface waves on the MPAs are also considerably reduced using metamaterials. These materials are usually used as absorbers for microwave signals. These absorbers lead to almost unit absorption resulting in improved bandwidth, insensitive polarization with compact size [9].

V. Conclusion

Microstrip antennas are widely considered for antennae due to their planar structure and their ability to be altered for parameter improvement. This paper presented a survey on the types of microstrip antennas, the feeding techniques that can be implemented for effective coupling of the electrical signal onto the antenna, and the different miniaturization techniques that are already literature in various researches to date. This survey of microstrip antenna will help the researchers in identifying the various paths of research concerning this topic. The researcher will get an idea about the various techniques that have to be considered for selecting a microstrip antenna and how the performance can be varied using these parameters. Metamaterials are becoming popular nowadays as they are overriding the performance characteristics of popular techniques used for parameter improvement like DGS, CSRR, etc.

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