Microstrip Antenna

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Abstract: This article presents an overview of the microstrip patch antenna and its design techniques. Basically a microstrip patch antenna comprises of a trace of copper or any other metal of any geometry on one side of a standard printed circuit board substrate with other side grounded. The antenna is fed using various feeding techniques like coaxial, strip line, aperture coupling or proximity coupling techniques. The working principle and the radiation mechanism have also been described. The microstrip patch antenna is widely used military, industrial and commercial sectors.

I. Introduction

Microstrip Antenna was initially proposed by G.A. Deschamps in year 1953 but came in to existence in 1970's when Robert E. Munson and some of his fellow researchers developed it using a low loss substrate. Also known as Patch Antenna. These Antennas are mainly used at microwave frequency (above 1 GHz).

II. Basic Structure

The basic design of the antenna consists of Patch (Radiating Element), Substrate& Ground Plane. The typical range for dielectric constant of the substrate being used is $2.2 \le \varepsilon_r \le 12$these antennas are simple to design, easy to modify according to needs, inexpensive, lightweight .One the negative sides these antennas have low bandwidth and low power.

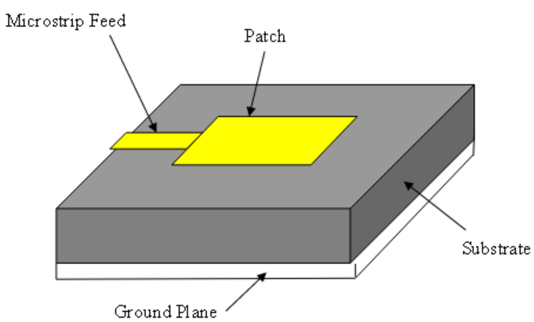

Fig.1 *The Basic Structure of Mricrostrip Antenna*

III. Working Principle

To analyse the radiation from a patch let us take an example of a rectangular patch considering it to be a two-dimensional planar structure. By definition a rectangular patch is defined by its length and width. The width of a patch is comparable to the wavelength and thickness of the substrate is kept very much smaller than wavelength. The fundamental TM_{10} mode can be attained by keeping the length slightly less than λ/2, where λ is wavelength in the dielectric medium (equal to $\lambda_0/\sqrt{\varepsilon}$, where ε is effective dielectric constant and λ_0 is the free space wavelength). The effective dielectric constant is kept slightly less than the dielectric constant of the substrate so that the fields not entirely get confined to the substrate but also fringe and spread in the air. This is shown in the Fig 2.

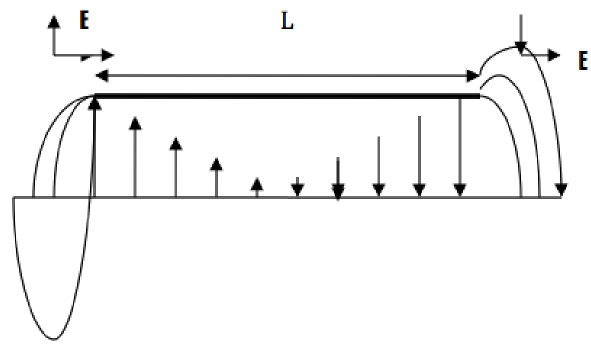

Fig. 2 *E-Field*

In TM_{10} mode, along the length, fields along the length are 180 degree out of phase with each other and cancel out. There is novariation is observed along the width of the patch Consider fig 3. If the field along the width is resolved into components, the vertical components would cancel out and horizontal components add up resulting in a broadside pattern as shown in fig 4. Hence, the width edges are termed as radiating edges and length edges as non-radiating edges.

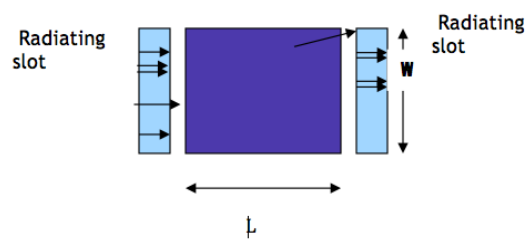

Fig. 3 *Variation of Field Lines*

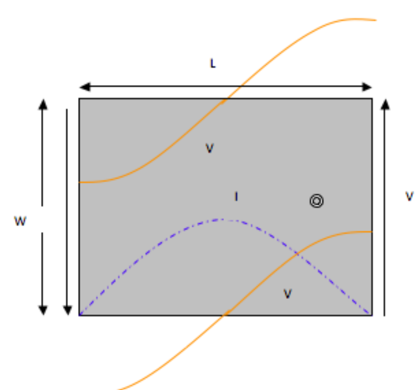

Fig 4 *Field Pattern*

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Now a patch, which operates in TM10 mode, can be visualized and analyzed as a transmission line, as the field lines vary sinusoidally along the length while are uniform along the width. The fringing fields along the edges can be explained and modeled as equivalent capacitance and radiation resistance of the transmission line as shown in fig. 5. Thus, one of the basic methods used in the analysis of patch is by analyzing it as a transmission line.

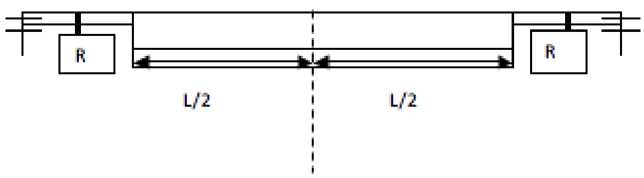

Fig. 5 *Resulting Pattern*

IV. METHODS TO ANALYSE A PATCH

As discussed earlier that a patch antenna can be treated as a two-dimensional planar structure and most of methods for analysis are based on this assumption. The chart below shows the basic methods used to analyze a patch.

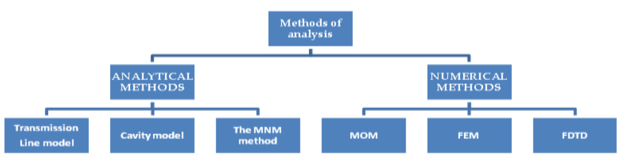

Fig.6 *Methods for Analysis of Patch*

A. Analytical Methods

1. Transmission Line Model-

In the transmission line mode, the patch is viewed as a transmission line resonator with no transverse fields while the radiation mainly occurs due to the fringing fields at the open circuited ends.The effective dielectric constant is kept slightly less than the dielectric constant of the substrate so that the fields not entirely get confined to the substrate but also fringe and spread in the air. Here, two slots that are spaced by the length of the resonator represent the patch. Since the transmission line model does not take care of variation of field in the orthogonal direction to the direction of propagation, all types of configurations cannot be analyzed using this model. However, it is easy to use.

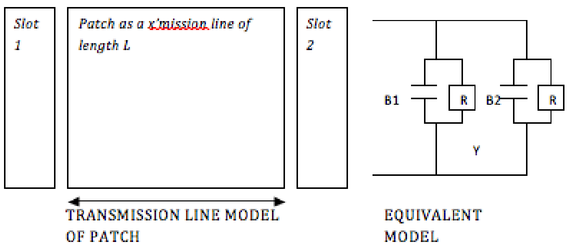

Fig. 7 *Transmission Line &its Equivalent Model*

2. Cavity Model-

Another method to analyse a patch is cavity model where the region between the patch and the ground plane is treated as a cavity, which is surrounded by the electric walls on the top and the bottom surface and the magnetic walls on the periphery. As the substrate used is thin as compared to wavelength inside the dielectric medium, the fields inside the cavity remain uniform along the thickness of the substrate while the equivalent magnetic current around the periphery computes the far fields and the radiation.

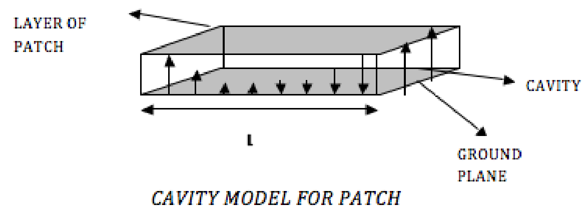

Fig. 8 *Cavity Model*

3. MNM-

This method models the electromagnetic fields underneath and outside the patch separately and the patch is analyzed as a two dimensional planar network with multiple ports around the periphery. By segmentation multiport impedance matrix is obtained and is solved. The far fields and radiation are obtained by the voltage distribution around the periphery. The above-mentioned analytical methods offer simplicity and physical insight however last two utilize corresponding voltage distribution obtain magnetic current distribution around the periphery. These methods work accurately for regular shaped patches but sometimes turn inaccurate when applied to a patch of arbitrarily shaped geometry. For arbitrarily shaped geometries numerical techniques discussed below are suitable.

B. Numerical Methods

1. MOM-The method of moments is one of the most commonly used numerical techniques. Here the surface currents are used to model a patch. An integral equation is formed that is expanded in terms of some basis and testing functions and transformed into a matrix form that can be easily solved by a computer. This method takes into account effect of fringing fields so provides more exact solution.
2. FEM-Finite Element Method is suitable for volumetric configuration. In this method, the region of interest is divided into a number of finite surfaces. These discretized units may be any well-defined geometrical shapes such as triangles, tetrahedral etc. depending whether configuration is planar, 2D or 3D. This method is very handy when the shape of the patch is arbitrary. But its only limitation is that it needs a truncation boundary to be applied, which may result into some inaccuracies.
3. FDTD-Finite Difference Time Domain method conveniently models patch antennas. It utilizes spatial as well as time grid for electric and magnetic fields over which solution is required. The entire domain is divided into small units called cells. The Maxwell's equations in differential form are used in this method. The discrete time variations of the fields are determined at desired

locations. Using line integral of electric fields the voltage across two locations can be obtained. The current is computed by using loop integral of magnetic field.

V. Types of Feeds

A. Direct Feeding-

1. Microstrip Line Feed-The Figure 9 shows the Microstrip Line feed used in the patch antennas. This is the most basic and easy method used in the feed for microstrip patch antennas. The antenna is provided with excitation using the microstrip line.

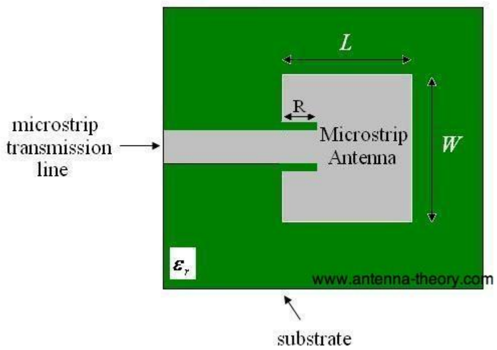

Fig. 9 *Microstrip Transmission Line*

2. Coaxial Feed-The Figure 10 below shows the coaxial feeding method in which the central conductor directly touches the patch and thus provides the excitation to the patch. The outer part of the probe is connected to the ground plane in order to complete the circuit. The input signal is provided using the coaxial coupler.

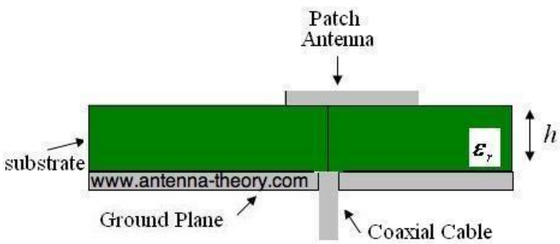

Fig. 10*Coaxial Feed*

B. Indirect Feeding-

These types of feeding are used when there is no actual contact between the patch and the input radiating material. These methods include Aperture Coupled Feed and Proximity coupled Feed.

1. Aperture Coupled Feed-The Figure 11 below shows the aperture coupled feeding in which there is a small aperture or a slot cut into the ground plane in order to provide patch with radiation using the transmission line

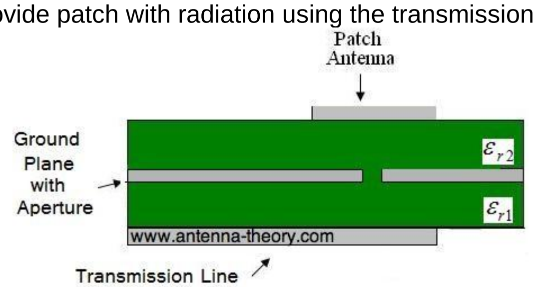

Fig 11 *Aperture Coupled Feed*

VI. Types of Patch Antenna

These antennas can be made of various designs. The basic shapes like circular, rectangular, square, semi-circular etc. form a major section of the research in this field. They can be modified according to the use by adding slots, monopoles, arrays etc. Shown below are examples of some basic types of patch antennas.

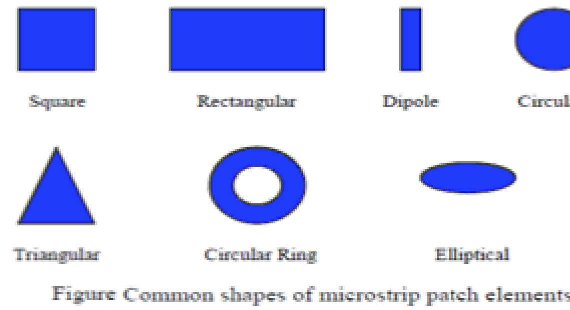

Figure 12 *Common Shapes of Patch*

VII. Why Patch Antenna?

Important question that arises is why should we use patch antenna? Here are some answers to that:

- These antennas are lightweight, small in size and low profile.
- Both liner and circular polarizations can be obtained using them.
- Can be made compact.
- Ease of mass production using the printed circuits makes them a cheaper option to use.
- Major advantage is that they can work in multiband of frequencies.

VIII. Conclusion

This article presents a review on microstrip patch antenna. The design and analysis methods of a patch antenna have been discussed. Different shapes of the patch have been used and discussed according to the applications. Although a lot of work has been done on microstrip antenna, still lot has to be done. With the advancement of microwave and millimeter wave technologies, systems are now going towards miniaturization.

References

[1] David R. Jackson Jeffery T. Williams Donald R. Wilton “Chapter 9: Antennas II Applied Electromagnetics Laboratory” Department of Electrical and Computer Engineering University of Houston.

[2] www.antenna-theory.com

[3] http://www.brainwareknowledgehub.com

[4] George Casu, Cătălin Moraru , Andrei Kovacs “Design and Implementation of Microstrip Patch Antenna Array “

[5] Priya Upadhyay, Vivek Sharma, Richa Sharma, Design of Microstrip Patch Antenna Array for WLAN Application, IJEIT, Volume 2, Issue 1, July 2012.

[6] G. A. Deschamps, " Microstrip Microwave Antennas", presented at Third USAF symposium on Antennas, 1953

[7] C. A. Balanis, "Antenna Theory, Analysis and Design," John Wiley & Sons, New York, 1997

[8] R Garg, P Bhartia, I Bahl, and A. Lttipiboon, Microstrip antenna design handbook, Artech House, 2000.

[9] Sunil Kumar Thakur"DESIGN & ANALYSIS OF MICROSTRIP PATCH ANTENNA USING METAMATERIAL"

[10] Richards, W.F., Microstrip Antennas, Chapter 10 in Antenna Handbook: Theory Applications and Design (Y.T. Lo and S.W. Lee, eds.), Van Nostrand Reinhold Co., New York, 1988.

[11] JR James & P S Hall, "Handbook of Microstrip Antennas", Peter Peregrinus Ltd., 1989.

[12] S. Gupta. "Design of Ultra Wideband Microstrip Antenna", 2006 IEEE Antennas and Propagation Society International Symposium, 2006