Design Parameters and Shape Analysis of Microstrip Patch Antenna (A Review)

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Abstract—In This work, the different Antenna designs are highlighted. Nowadays, the most commonly used Microstrip Patch Antenna having different design parameters which can be suitably employed for various applications is elaborated. The work focused on various methodologies and antenna operations for the future Trends.

Keywords-*Antenna; Design Methodology, Microstrip Patch Antenna; MPA Components*

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I. *INTRODUCTION TO ANTENNAS*

It is almost impossible to imagine a world without wireless communication. In order to establish communication, a device called "Antenna" plays a major role. An antenna is important part of a system to establish wireless communication, which converts the electrical signal into electromagnetic waves (free space) efficiently with minimum losses and vice versa.

The basic components of communication system are transmitter and receiver. An antenna provides a means for radiating or receiving radio waves. A guided wave traveling along a transmission line, which flares out as shown in figure 1.1, will radiate the energy as free space wave. The guided wave is a plane wave while the free space wave is a spherically expanding wave.

II. TYPES OF ANTENNAS

There are various types of antennas used for wireless applications such as wire antennas, aperture antennas, reflector antennas, lens antennas, microstrip antennas and array antennas. The commonly used antennas are:

- Wire Antennas
- Aperture Antennas
- Reflector Antennas
- Lens Antenna
- Microstrip Patch Antenna

III. ANTENNA PARAMETERS

The performance of an antenna is described by various necessary parameters. The parameters may be inter-related, it is not even necessary to specify all the parameters. An antenna is chosen to operate for a particular application according to its physical and electrical characteristics. Further, the antenna must perform in a required mode for the particular applications.

A. Radiation Pattern

A radiation pattern is a graphical representation of the radiation(far-field) properties of an antenna.To state the radiation pattern with respect to field intensity and polarization, three patterns are required [2]. The far-field radiation is a function of the spatial co-ordinates which is specified by the elevation angle (θ) and the azimuth angle (φ)of antenna as shown in figure 1. The radiation pattern can be plotted in rectangular/ Cartesian or polar coordinates systems.

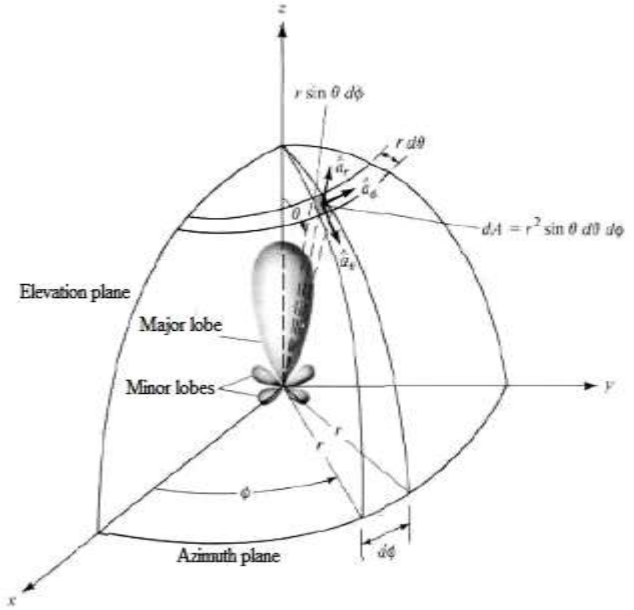


Figure 1: Coordinate systems for antenna analysis [2]

B. Directivity

The directivity is a measure of the maximum intensity of radiation in a particular direction. The ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged in overall directions [2].

$$D = \frac{U}{U_o} = \frac{4\pi U}{P_{rad}}$$

C. Gain

The gain is closely related to the directivity. The absolute gain is given as "the ratio of the radiation intensity (in a given direction) to the radiation intensity that would be obtained, if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted divided by 4π" [2]. The gain can be expressed as:

$$\text{Gain} = 4\pi\frac{\text{radiation intensity}}{\text{total input power accepted}} = 4\pi\frac{U(\theta,\emptyset)}{P_{in}}$$

D. Antenna Efficiency

This parameter takes into account losses at input terminals and within the structure. That losses arises due to:

a. Reflections due to mismatch of transmission line and antenna
b. Conduction and dielectric losses.

Overall efficiency is given as [2]:

$$e_o = e_r\, e_e\, ed$$

E. Beam Efficiency

Beam efficiency is another parameter that is frequently used to find the quality of transmitting and receiving antennas. The beam efficiency (BE) is defined as [2]:

$$\text{Beam Efficiency} = \frac{\text{power transmitted (received)within cone angle }(\theta)}{\text{power transmitted (receivied)by the antenna}}$$

F. Bandwidth

The bandwidth of an antenna is defined as "the range of frequencies within which the performance of the antenna, with respect to some characteristics, conforms to a specified standard" [2]. The bandwidth can be considered to be the range of frequencies, on either side of a center frequency (usually the resonance frequency for a dipole), where the antenna characteristics (such as input impedance, pattern, polarization, side lobe level, gain, beam direction, beamwidth, radiation efficiency) are within an acceptable value of those at the center frequency. For narrow band antennas, the bandwidth is expressed as a percentage of the frequency difference (upper minus lower) over the center frequency [2].

$$\text{Bandwidth in percentage } (\%) = \frac{f_2 - f_1}{f_c} \times 100\%$$

G. Return Loss

This parameter indicates the amount of power that is reflected back to the load and is not radiated by antenna. A simple return loss plot is shown in figure 2.

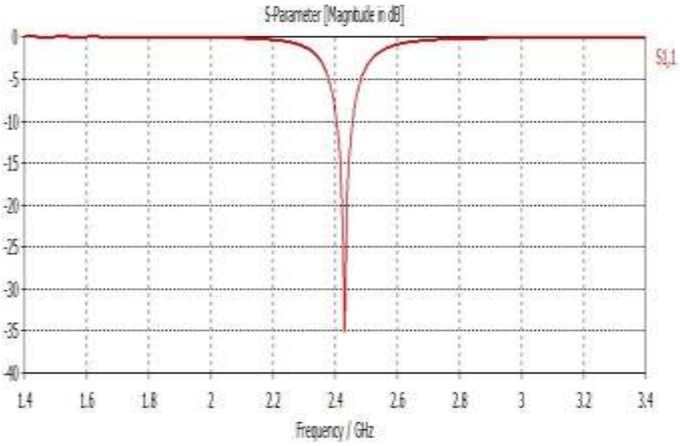


Figure2: Return Loss Plot

It indicates how well the antenna and input port is matched. For optimum working such the return loss plot shows a dip at the operating frequency(fr) and should have a minimum -10dB value at this frequency [2].

H. Beamwidth/Half Power Beam Width (HPBW)

The HPBW is defined as "a plane containing the direction of the maxima of a beam, the angle between the two directions in which the radiation intensity is one-half of the maximum value of the beam." The beamwidth of an antenna is determined from its 2D radiation pattern. The beamwidth of the antenna is also known as figure of merit, and it often used as a tradeoff between the bandwidth and the side lobe level. As the bandwidth decreases, the side lobe increases and vice versa [2]. It is the angular separation of the half-power points of the radiated pattern. The beamwidth plot is shown in figure3.

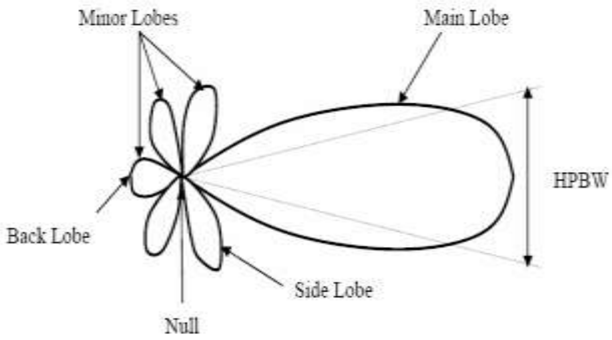


Figure 3: HPBW Radiation Plot

IV. MICROSTRIP PATCH ANTENNA

A. Introduction to MPA

The microstrip antennas became very popular in the 1970s primarily for space borne applications. They are low profile antennas with small size, light weight, inexpensive, high performance, ease of installation and aerodynamic profile are constraints that are being used in aircraft, spacecraft, satellite communication and missile applications [2]. The basic structure of microstrip patch antenna given in figure 4.

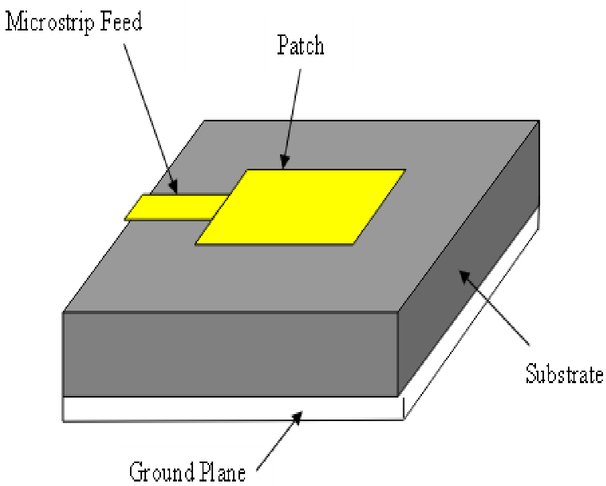


Figure. 4: Basic structure of Microstrip patch antenna [2]

B. Microstrip Patch Antenna Specifications

Microstrip patch antenna consist of following basic components:

- Ground Plane
- Substrate plane
- Patch

- Microstrip feed

V. DIFFERENT PATCH SHAPES

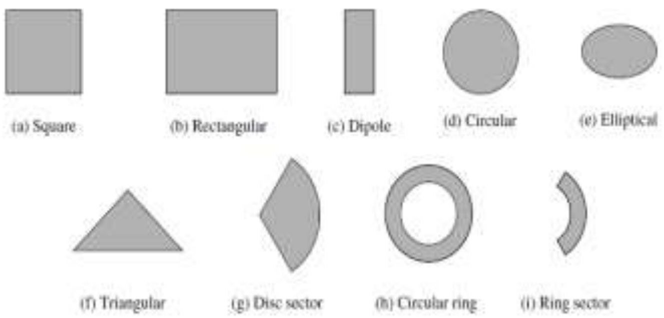


Figure 5: Different shapes of patch mostly used in microstrip patch antenna [2]

The patch is made of conducting material such as copper or gold of any possible shape. The radiating patch and feed is usually photo etched on substrate. The common shapes of patch are generally square, circular, rectangular, triangular and elliptical or some other as shown in figure 5 [2]. Usually square, rectangular, circular and dipole are used, because they are easy to fabricate and analyze [2].

A. Basic Rectangular Patch Antenna Structure

The microstrip patch antennas consist of a patch of metal such as copper that is on top of a grounded dielectric substrate having some thickness h, with relative permittivity (εr) and relative permeability (μr) as shown is figure 6.

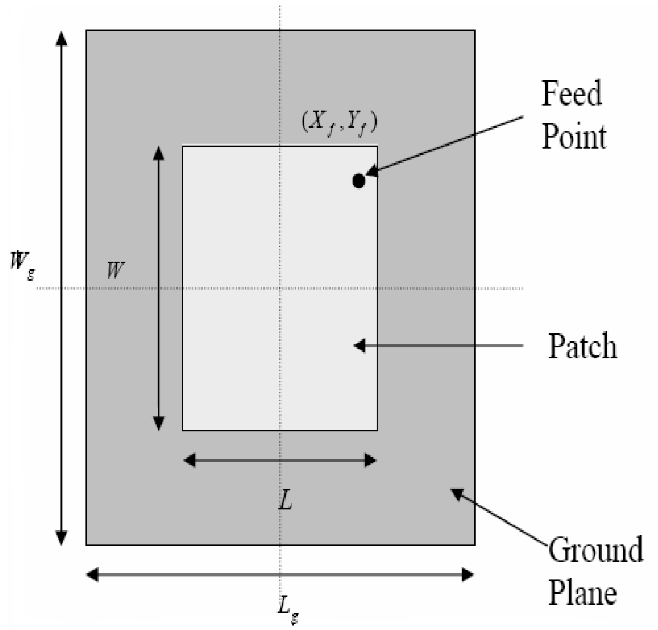


Figure 6: Basic structure of rectangular patch

B. Defected Ground Structure (DGS)

A notable ground structure named defected ground structure (DGS) has recently been investigated and found to be a simple and effective method to reduce the antenna size as well as excite additional resonance modes [15]. In this the reduced shape of ground plane is usually adopted to improve the bandwidth of antenna. The ground plane is cut out to shape as reduced ground antenna structure. The defected ground structure is shown as in figure 7, where the width of the substrate is represented as Ws and the width of the reduced ground structure is Wg.

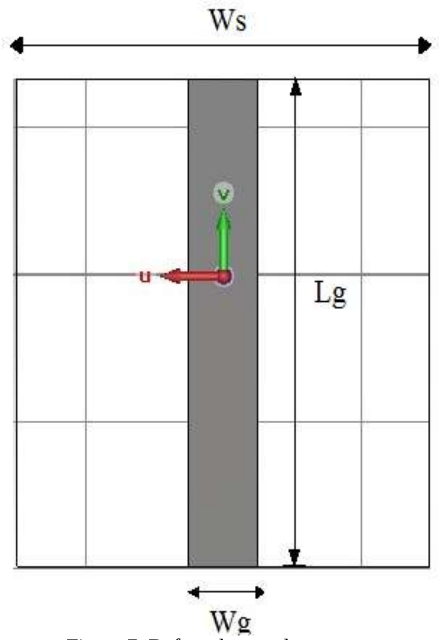


Figure 7: Defected ground structure

VI. METHODS OF MICROSTRIP PATCH ANTENNA ANALYSIS

There are various methods of analysis for microstrip antennas. The most popular models are transmission line, cavity and full wave. The transmission line is easiest amongst all, provide good physical insight but less accurate with difficult coupling. The cavity model is more accurate with good physical insight. The full wave is extremely accurate and complex [2].

A. Transmission line model:

The transmission-line model is the simplest of the three techniques, but it is the least accurate. The microstrip antenna is designed as two radiating slots that are separated by a distance Leff. The microstrip is essentially a non-homogeneous line of two dielectrics, typically the substrate and air, shown in figure 8 (a) and (b) [2].

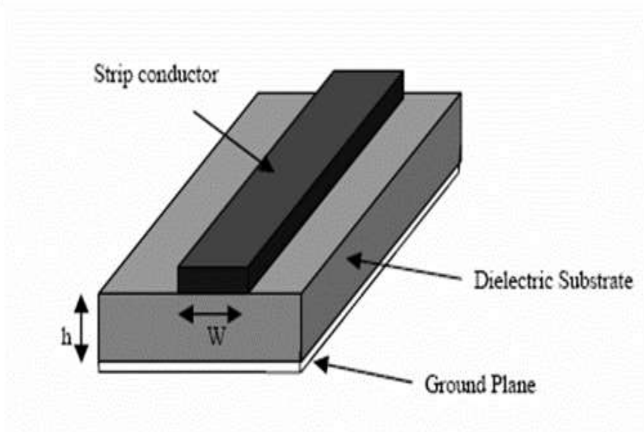
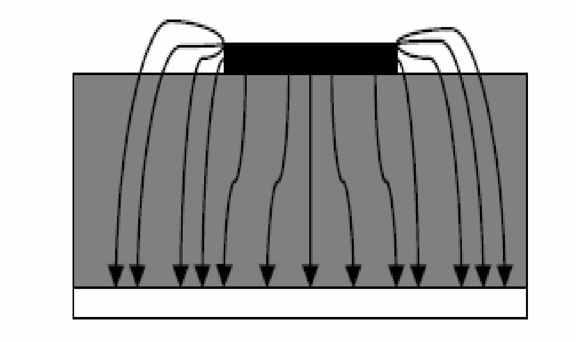


Figure 8: (a) Microstrip line [2]



(b) Electric field lines [2]

B. *Cavity Model*

The transmission line model has some inherent disadvantages. Specifically, it is useful for rectangular patch design and it ignores field variations along the radiating edges.

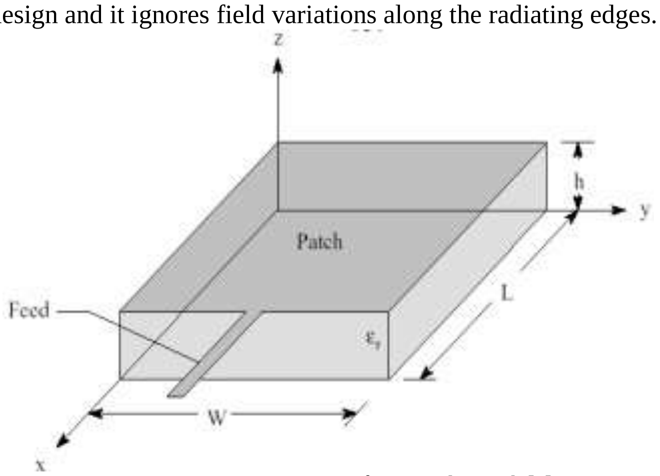


Figure 9: Geometry structure of rectangular patch [2]

C. *Full Wave Numerical Method*

In full wave analysis or Method of Moments, the surface currents are used to model the microstrip patch and the volume polarization currents are used to model the fields in the dielectric.

VII. Merits of Microstrip Patch Antenna

The various advantages of microstrip patch antennas are listed below:

- Light in weight and low volume.
- Low profile planar configuration.
- Low fabrication cost, hence can be manufactured in large quantities and easily.
- Support both, linear as well as circular polarization.
- MPA can be easily integrated with microwave integrated circuits (MICs).
- Capable of dual and triple or multiband frequency operations.
- Mechanically robust when mounted on rigid surfaces

VIII. Demerits of Microstrip Patch Antenna

The various disadvantages of microstrip patch antena are listed below:

- Narrow bandwidth (improving)
- Low efficiency
- Low Gain
- Extraneous radiation from feeds and junctions
- Poor end fire radiator except tapered slot antennas
- Low power handling capacity.
- Surface wave excitation.

IX. Applications

- Micro-strip antennas are used in medical applications
- Used in GPS (Global Positioning System)
- Used in radar applications
- Used in mobile satellite communications, remote sensing.

CONCLUSION

In wireless communication, an antenna is essential component which helps to radiate energy. The antenna should have sufficiently large bandwidth to cover the application frequency range and the return loss should be below minimum of -10dB magnitude. There should be proper impedance matching of transmitter with antenna and antenna with free space to ensure maximum power transfer and vice versa.

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