A Review Analysis on Microstrip Patch Antenna

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Abstract

This article presents the general overview of various antennas and a detailed study of Microstrip Antenna (MPA). The MPA designing equations and basic structure is explained in this manuscript. The properties of the materials required for MPA is summarized in table form. Some practical antenna structures are also explained here in order to analyze the overall view of MPAs after explanation of most common patch structure shapes. At last, the properties of Co-axial, Proximity Coupling, Aperture Coupling and stripline feeding are also introduce in terms of ease of fabrication, impedance, modelling, bandwidth etc.

Keywords: Microstrip, Patch, Resonator, FR4

1 Introduction

In wireless communication, since from its inception, Antenna plays an integral part. From large broadband Antenna to tiny mobile transceiver antennas play considerable role for effective communication. The different selection and designing parameters for antenna were invented in recent times by keeping in view of application-based requirement. Therefore, the antenna with various shapes and sizes exists. Since with the utilization of wide band and Ultra-wide band spectrums in multiple application-based devices, the main challenge was to introduce antennas with larger bandwidths because of lesser availability of frequency spectrum below 6 GHz and requirement of continues high speed connectivity [1-3]. In fact, with extensive growth in utilization of 4G spectrum based mobile networks, which introduced multiband applications, the design requires miniature but less complex circuits with wideband and ultra-wideband based spectrum operations and it can be suitable for multiple mobile applications in one go. There are many efforts in process to identify and design the different geometrical designs that satisfied the requirements of users [4-5]. The design, shape and complexity of antenna also decides the future shape and size of modern wireless system design. As different standards are adopted by different countries for Ultra-wide Band spectrum range, broadly come in range of 3.1-10.6GHz [6-7]. The various geometrical structured antennas [8-9] were designed for suited application, the basic mechanisms of reception and transmission were introduced. These were **Dipole Antenna** or **Whip Antenna** consists of small wires of metal or rods of metal, here, ohmic losses are considered to be zero for VLF range [8]. With zero ohmic losses, the maximum power will be transmitted for efficient transmission and receptions. **Monopole Antennas [5]** were derived from combination of dipole antennas with half of total dipole antennas that are required for successful operation. The monopole antenna has a field only for the upper part and no radiation from underneath of ground plane whereas in dipole antenna, radiation can be performed from both parts. **Loop Antenna**[3] consists of single turned wire shaped conductor forming loop for applications up to 3 GHz. It is also known as folded dipole antenna due to its loop formation. The shape of loop antenna can be derived by its utilization in the circuitry like circle, square etc. **Slot Antenna** [3] can be designed by extracting small region designated as slot from the radiating metal ground plane. Slot was used for excitation by applied voltage across it.

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Another form of antenna exists is **Microstrip Antenna [10-11]** that is now used for modern systems. It consists of integrated circuitry technology that allows high accuracy and with different indefinite designed shapes results in better output as compare to traditional ones. Some other common geometries are **Horn antenna** is well-known for waveguide feeding at input slot. **Yegi-Uda** was commercialized as T.V. antenna and **Spiral Plate Antenna** is also recognized as frequency independent antenna leading to applicable for larger bandwidths. Total ground based radiant structures were developed to enhance the design to overcome the electromagnetic field effect developed by the antenna during communication with contact of user's body. Mathematical simulations with consideration of human models results in development of specially designed connectors, transition lines as well as suitable feeding lines and the complete setup of trans-receiver is termed as **Wearable Antenna [7]**. The combination of macro cells-based structure termed as macro units which are having continues and non-continues sub-wavelength properties were introduced and termed as **Metamaterial Antennas** [9]. These are realization of distinct materials which have no existence in nature. Some of the structures are introduced such as SRR (Split Ring Resonators) and Complementary SRR, AMC (Artificial Magnetic Conductors) with an aim of improving the quality of service which includes exceptional radiation properties, having high gain, capable of handling the pulse and efficiency provided by antennas. 3D profile based **DRAs** (Dielectric Resonance Antenna) were introduced in 1990s and preferred for most of applications like Radio and Satellite links development and where very high performance is required. The considerable fact of DRAs includes effect for surface waves losses and metal losses due to the use of dielectric materials having very less permittivity and having broad-band signal acceptance because of its special structures which results in considerable performance in both linear as well as circular polarization.

With the development of Planer and Printed antennas (i.e. 2D & 3D), with the aim of supporting the integration requirements of hand held wireless systems and since size remains always a main constraint the printed antennas are maximum utilized for the development of wireless systems. Most commonly utilized is microstrip antenna which due to its small size, low profile and having low cost has been preferred. In this study we discuss the effect of different feeding and design techniques for microstrip antennas [12].

2 Microstrip Patch Antennas (MPAs)

In early ages of its inception i.e. from 1950s when it was invented to 1970s and early 1980s, it was dominated by rapid and continues growth of integration and communication combination concepts and because of simpler size and low cost general design kept it always out of race for the modern communication design considerations because of low fractional bandwidths i.e. almost 7% to 10% and therefore these are assumed as not or very less compatible for advance wireless system designs [13-15]. Therefore, in order to overcome certain issues, continues research for almost 15-20 years yields in different geometry shapes which effects in improving feeding, various radiation and efficiency parameters of MPAs were introduced. Figure 1 illustrates the MPA consist of a radiating patch on one side of a insulating substrate fed by microstrip feed line and ground plane on backside of it. Gold or Copper can be used as a patch due to its conducting properties. Photoetching process is used to integrate feed line and patch on the surface [16]. Because of easy fabrication process also, microstrip antenna is preferred and is replacing most traditional antennas but it experiences certain disadvantages like low fraction bandwidth, less gain etc.

Material Used for Dielectric Substrate – Initial design consideration revolves around the selection of Dielectric Substrate material. Bakelite, FR4, RO4003, Taconic and RT Duriod are some common materials with all are having constant height i.e. 1.6 mm [16]. Some basic parameters are shown below in table 1.

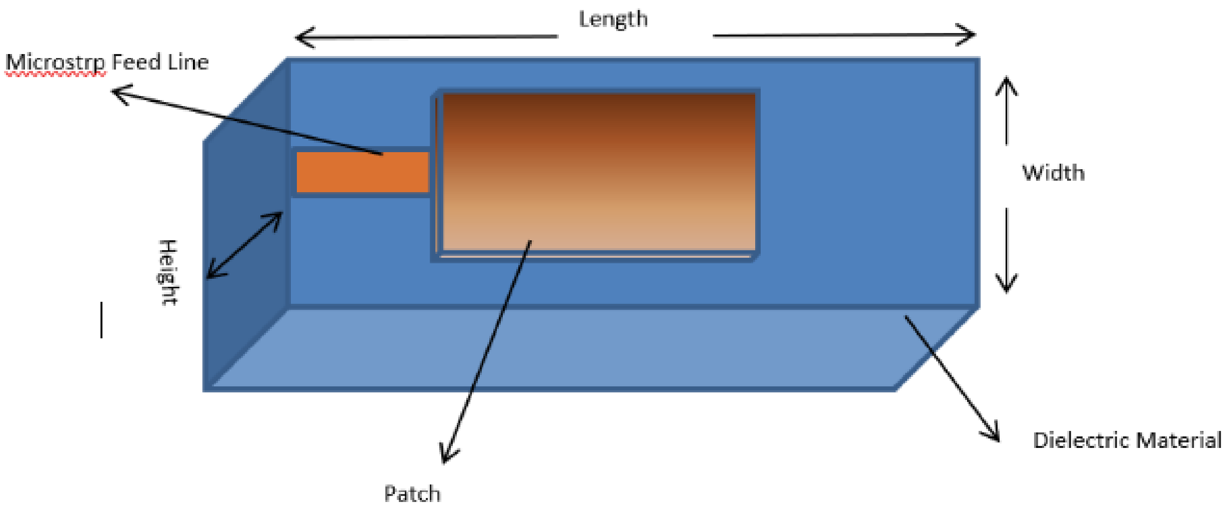


Figure 1 :- Microstrip Patch Antenna

Table 1 :- Properties of Different materials used for Substrates [16]

Material → / Parameter ↓	Bakelite	FR4	RO4003	Taconic	RT Duriod
Dielectric Constant	4.8	4.4	3.4	3.2	2.2
Water Absorption	0.4%-1.4%	<0.25%	0.06%	<0.02%	0.02%
Tensile Strength	60 MPa	<310 MPa	141 MPa	----	450 MPa
Loss Tangent	0.030	0.013	0.002	0.002	0.0004
Breakdown Voltage	20-28 kv	55 kv	----	----	>60 kv
Density	1810 kg/m³	1850 kg/m³	1790 kg/m³	----	2200 kg/m³

Effect of Various Geometries in performance of MPA: - As discussed above basic rectangular shaped antenna suffers with three main setbacks i.e. narrow bandwidth, small gain and bulky size. The very easier way to increase the bandwidth of antenna is to increase in thickness of substrate but it leads to increase in surface waves and radion power then decreased which reduces efficiency [1]. There are other different methods applied like by using arrays and multi layered structure to increase the effective parameters which are over stacked layers which reduces the size but the fabrication process will then become challenge [17]. So, to overcome these challenges different alterations were made and antenna with different geometry shapes is purposed.

There is long list of articles and books purposing different shapes and modification in basic geometry shapes which leads to better results like larger bandwidth with high fractional bandwidth is discussed. The basic and common geometry architectures which are used initially are as shown below in Figure 2. There are considerably changes occur when the design is switched over from basic rectangular shape to some other modified shapes like when the patch is designed in hexadecimal shape, radiation efficiency is achieved by 95% as compared to basic shape which is having lesser efficiency and also return loss will become notably low [18-20].

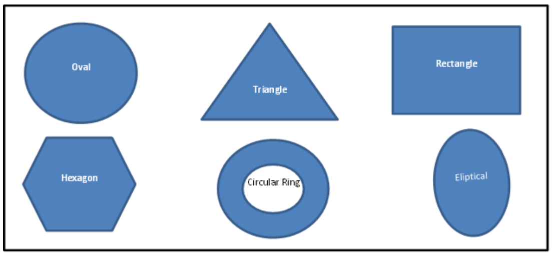
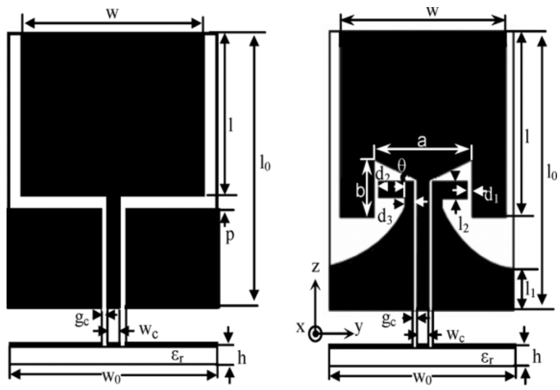


Figure 2 :- Basic Geometry Shapes

It is also observed that when semi elliptical antenna is proposed as shown in Figure 3, broad impedance matching is noted ie. From 2.5 to 15 GHz. It was also noted that by changing the angles or change in position of slots vary the band rejection performance [21-22]. There are some innovative novel designs as shown in Figure 4 were also introduced like T-Stub and U slot MPA having reduced patch size with lesser return loss which indicates larger bandwidth and also higher impedance bandwidth. There is 164% bandwidth enhancement is observed by an M-Shaped notch and a tapered exponentially at the bottom [23]. So, there are many parameters in shaping process also like tapering the ground, shaping the notch and impedance characteristics which improves the high cutoff frequency rises accordingly. It is also observed that return loss is decreased. Bandwidth is enhanced to 136% in the range of 2.1 to 11.1 GHz band by designing a pair of parasitic patches [24] as shown in Figure 5 which observes the excitation of resonance which is helpful in improved impedance matching.



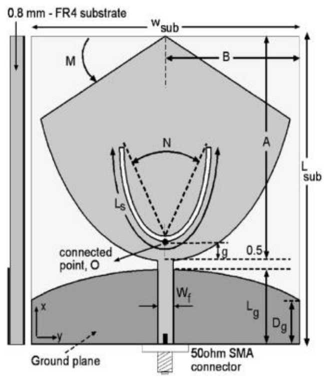


Figure 3:- Semi elliptical Shape[22] Figure 4 :- M shaped notch Printed Antenna[2]

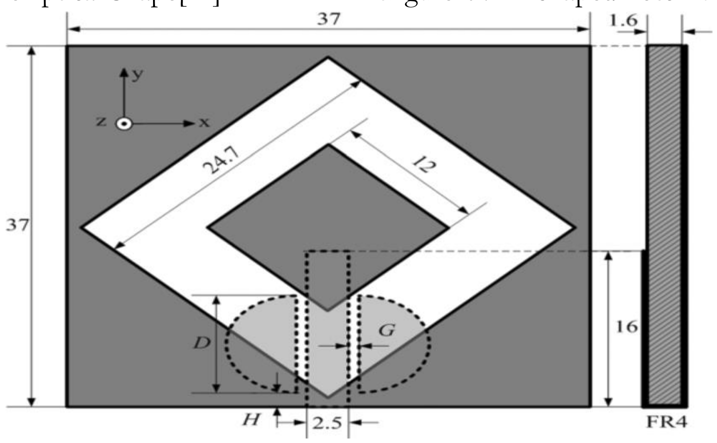


Figure 5 :- Parasitic Paired Printed Slot Antenna[5]

Parameters for Antenna Design :- Since it is discussed earlier that the design and fabrication of single layered MPA is very easy then also there are many parameters which we have to take care off. In general, FR4 material is used for substrate due to its supportive properties. The height and width of the patch have to be formulated. Dielectric Constant, Substrate Height and resonant frequency pattern is also need to be calculated and assumed for efficient design of antenna [9][25]. The different equations which are required for calculation of various parameters are written below,

$$W= \frac{c}{2fr}\sqrt{(\frac{2}{\varepsilon r+1})} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where 'W' is width and 'c' is speed of light. The dielectric constant for various materials used for substrate is given above in Table 1.

For the calculation of Length of Microstrip Patch, ε_{eff} and L_{eff} i.e. is effective dielectric constant and effective Length respectively which is as below,

$$\varepsilon_{eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\ [1 + 12\frac{h}{w}]^{-0.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$L_{eff} = \frac{c}{2fc\sqrt{\varepsilon eff}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\Delta L \text{ (length extension)} = 0.412h\frac{(\varepsilon eff+0.3)(\frac{W}{h}+0.264)}{(\varepsilon eff-0.258)(\frac{W}{h}+0.8)} \ldots\ldots\ldots (4)$$

Now actual length can be calculated as , $L = L_{eff} - 2\Delta L$ …. (5)

Where, h is thickness of substrate, ΔL is change in length due to fringing effect[13].By using above formulations from equations (1) to (5), Length and Height can be calculated for different frequency bands.

Fig. 6. MPA FEEDING

Once the design is finalized, the next step is to access the feeding method and feeding slot design by assuming all the electromagnetic wave signals which can be transmitted. There are many different feeding techniques such as proximity coupling, Strip-line feeding, aperture coupling and Coaxial feed lines are notably used in various structures [26-27]. Connectors are used with feed lines through with the signal is transferred. In Figure 6 different feeding methods are designed and the constructive difference is clear enough between these four.

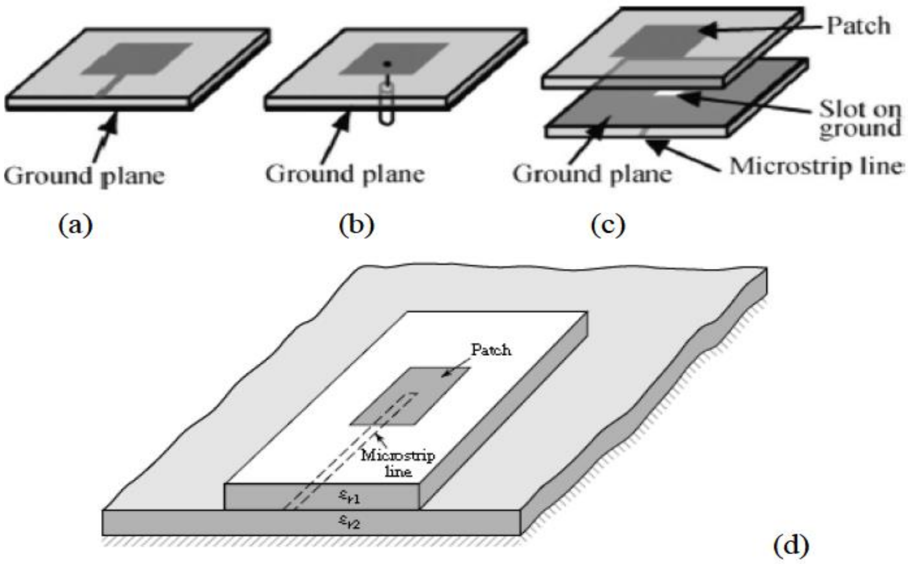


Figure 6 :- MPA Feeding Methods[6]

The coaxial method a)Stripline b) Coaxial c) Aperture d) Proximity includes coaxial connector which is soldered with patch at impedance location of 50 ohms. this method is difficult to design and having very low spurious radiation. The bandwidth is also very low as compare to proximity coupling. In aperture coupling method there are two substrates, upper substrate is used for radiating patch and on lower patch microstrip feed line is modeled. Also, the value of dielectric constant is very high for low substrate and very low for upper substrate [28]. Also, the value of dielectric constant is very high for low substrate and very low for upper substrate [28-29]. There is ground plane in between the two substrates which helps in to reduce the interference due to spurious based radiations. An effective pattern is hence obtained with purity of polarization is developed. All the other parameters are at optimized state for efficient performance in this case. Because of built in asymmetries and cross polarization effects occurs in strip-line and coaxial methods, aperture coupling and proximity coupling is preferred [18][30]. The comparison for different feeding methods is explained below in table 2.

Table 2 :- Comparison of Feeding Techniques[8]

Parameter	Feeding Methods			
	Coaxial	Proximity Coupling	Aperture Coupling	Stripline
Fabrication	Easy	Difficult	Difficult	Easy
Impedance Matching	Simple	Difficult	Difficult	Simple
Spurious Radiation	Low	Low	Low	High
Modelling	Difficult	Simple	Simple	Simple
bandwidth	Narrow	High 13%	Narrow	Narrow < 5%

3 Conclusion

In this review article the design consideration of MPA is discussed. There are different metals are used and based on the intense study of different articles it is concluded that FR4 is preferred over other materials for substrate and copper and gold is used as the patch and feedline material. It is also concluded that simple basic patch structure rectangular in shape fabricated on FR4 material is cost effective as compared to other substrates. The bandwidth of an FR4 based antennas can easily be extended to 180% by modifying the basic shapes mentioned in Figures 3-5. It is concluded that with advancement in technology the shapes and structures are not only changed even these are becoming compact in shape like Microstrip antennas.

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