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Comparative Study of Microstrip Patch Antenna for Wireless Applications

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Abstract

This paper presents the basic introduction of antenna and comparative study of the Microstrip Patch Antennas which are useful for the wireless application. The extensive literature survey has been carried out in this manuscript on MPA's designed by various researchers on the basis of the antenna performance parameters such as Reflection coefficient and Gain along with their practical usability in the wireless applications. Most of the antennas discussed are simulated on the FDTD and FEM based methodology. For the lucidity, the results based on the performance parameters are delineated in the tabular form.

Keywords: MPA, EBG, Reflection Coefficient, Gain

1. INTRODUCTION

With the advent of time, the ways of the communication have been drastically changed from handwritten letters to emails. Today, we are using modern wireless technology to send or receive the messages or signals, and the backbone of this technology is Antenna. Without proper designing of antenna, the wireless communication system is of no use. In the changing technology era, a compact size, low cost and multifunctional antenna is great in demand. An antenna may be a metallic device which is used to transmit and receive the signals. As per Webster's dictionary," An antenna is a metallic device for transmitting or receiving radio waves." [1]. Antenna is like ear or eye of the electronic circuitry. The evolution of antenna can be credited to Mr. James Clark Maxwell who invented the Maxwell equations in 1873, which are considered as the foundation of antenna theory [2]. J. C. Bose worked on millimeter waves (60GHz), and invented new antenna in the year 1897, and named as Horn Antenna [3]. The revoluation of antenna came into the existence in World War-II when Radar was used to hit the airplanes of enemies. [4].

The continued research was carried out by distinguished researchers to invent the different types of antennas for wireless communication such as Wi-MAX, Point-to-Point high speed communication, WLAN, Wi-Fi, Satellite Communication, Bluetooth , GPS, Mobile/Microwave/Infrared Communication, MANET/VANET, UWB, GPRS etc.[5] -[7]. The different wireless applications require distinct antenna, whereas, a multipurpose antenna is always a prime requirement of the market. Due to less weight, small size, ease of fabrication, low profile, multiband/wideband characteristics, Microstrip Patch Antenna (MPA) and Fractal Antennas are gaining huge popularity.

2. MICROSTRIP PATCH ANTENNA

It came into the existence in the year 1950 but considerable attention was given in the year 1970 [8]. It is composed of four parts like substrate, patch, feeding line and ground plane and, as limned in Fig.1. Patch is situated on the top of the substrate, whereas, ground plane is located on the bottom of the substrate [9]. Patch is designed from the metals like Cu, Ni, Sn(Tin), Al, Au (Gold) etc. Dielectric substrate is made up of materials such as Flame Retardant (FR) 4 epoxy, Teflon, Rogers RT duroid, Arlon, Glass etc. as per the need of design. The most popular and commonly used material is FR4 epoxy [10]. MPA exhibits multiband characteristics but its design will be distinct for different applications like Wi-MAX, WLAN, Wi-Fi, poin-to-point high speed communication, ISM band, Satellite communication etc.[11]-[13]. MPA is available in various types of shapes but most commonly used shapes are rectangular or circular. The equations (1) to (5) are used to calculate the dimensions of rectangular patch, whereas (6) to (8) for circular patch [14]:

$$w = \frac{C}{2fo\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{\frac{1}{2}} \tag{2}$$

$$L_{eff} = \frac{C}{2fo\sqrt{\varepsilon_{reff}}} \tag{3}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \tag{4}$$

$$L = L_{eff} + 2\Delta L \tag{5}$$

Where,

W = Width of patch

L = Actual Length of patch

L_{eff} = Effective length of Patch

ΔL = Extension in actual Length

$$a = F\left\{1 + \frac{2h}{\pi F \varepsilon_r}\left[\ln\left(\frac{\pi F}{2\text{h}}\right) + 1.7726\right]\right\}^{\frac{-1}{2}} \quad (6)$$

$$F = \frac{8.791\ X\ 10^9}{f_r\sqrt{\varepsilon_r}} \quad (7)$$

$$a_e = a\left\{1 + \frac{2h}{\pi a \varepsilon_r}\left[\ln\left(\frac{\pi a}{2\text{h}}\right) + 1.7726\right]\right\}^{\frac{1}{2}} \quad (8)$$

a = Radius of patch

a_e = Effective Radius of patch.

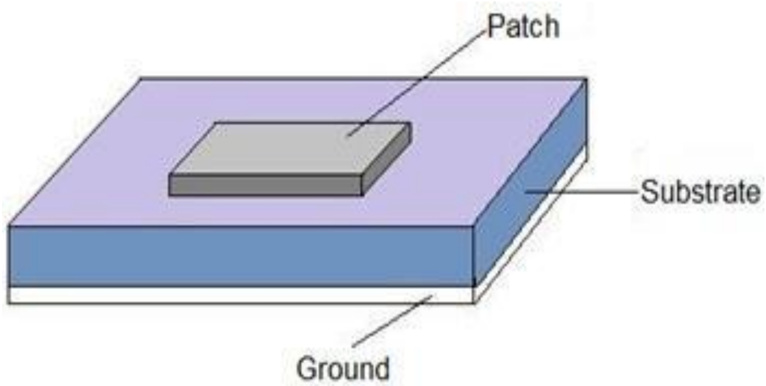

Fig. 1: Microstrip Patch Antenna

For efficient working of MPA, patch length must be taken in the range ($0.3333\lambda_0 < L < 0.5\lambda_0$), breadth must be $\leq \lambda_0$, height of the substrate should be ($0.03\ \lambda_0 \leq h \leq 0.05\ \lambda_0$) and dielectric constant must be chosen between 2.9 to 12 [15]. Patch can be excited by probe feed, as it gets excited, the beneath of it will get positive charge, whereas, ground plane will get negative charge. By reason of this positive and negative charge, the force of attraction will get set between underneath of patch and ground plane which will further lead to the fringing effect between ground plane and patch edges [16]. MPA which depicts good radiations, larger bandwidth and better efficiency is said to be optimal, size may get increased but trade off should be there between the parameters and dimensions of the antenna [17].

3. RESEARCH MOTIVATION

In present era, wireless communication has multiplied enormous popularity, we are so dependent upon these electronic gadgets as we can not live without these gadgets particularly which are related to the wireless technology. Wireless applications which are more widely used are Cellular Phones based on GSM and CDMA, Radar, Satellite, RFID, GPS, Wi-Fi, Wi-MAX, WLAN etc. [[18]. Aforementioned applications are meaningless without proper setup of antennas. So, antenna is the most prominent part of communication due to which various renowned researchers have done the research in this field and resulted to a small size, less cost, low profile, multiband/wideband optimized antenna. The conventional antennas are incapable to fulfill these requirements, only the microstrip patch and fractal antenna is able to satisfy these aforesaid needs without compromising the performance parameters.

4. LITERATURE SURVEY

Wide research has been made by the researchers to improve the performance parameters of a MPA in the previous years. This paper primarily deals with the research motivation and comparative study of the MPA based on its performance parameters. The research carried out by researchers in this field is listed as:

Zavosh and Aberle [19], this paper presents MPA with cavity-backed geometry, multiple dielectric layers and features shorting posts. These unique attributes are elucidated to design proposed antennas which exhibits desirable characteristics of MPA.

A. Foroozesh et al. [20], this paper describes MPA with high impedance EBG substrate. While designing, firstly the bandgap of the EBG structure is determined. further, patch antennas with EBG ground plane is designed to operate within and outside the bandgaps. It has been perceived that wide bandwidths almost 25% achieved with the deviation of EBG parameters which may lead to improve the gain of antenna.

T. A. Denidni et. al. [21], authors report the performance of a Circular MPA improved by using cylindrical EBG substrate. The MPA is integrated with a cylindrical EBG substrate and coaxial probe is used to increase the gain of the proposed antenna. The cylindrical EBG structure is a combination of number of periodic structures with distinct periods. One structure comprises of metallic rings and the other is consist of grounding vias, by employing this, antenna is fabricated and results are measured, and noticed that the experimental results like return loss and radiation patterns of antenna embellishes proper impedance matching with enhancedgain.

R. Azaro et al. [22], This letter demonstrates the design of a Monopole quad-band antenna using Hilbert geometry. The dimensions of the proposed antenna is being optimized by using the PSO technique and reported that almost 39% length is reduced. The discussed antenna is simulated and fabricated. The experimental and numerical data like VSWR and gain are discussed in this letter, and predicted as good agreement with each other.

N. Singh et al. [23], this paper takes the research on compact sized corner triangular patch antenna with truncated corners. Antenna is designed for Wi-MAX bands (2.5 GHz – 2.55GHz) and (3.4 GHz to 3.7 GHz). Proposed antenna reveals $S_{11} \leq -10$ dB and minimum refelction coefficient has been attained at two distinct resonant frequencies i.e; 2.53GHz and 3.5GHz at -29.3dB and -18dB respectively.

C. Singh et. al [24] , this paper explains the MPA with rectangular slots. Bandwidth of proposed antenna has been enhanced by etching the slots from the patch**.** The designed antenna illustrates the three distinct resonant frequencies, reflection coefficient $\leq -10dB$, VSWR$\leq$ 2 and peak gain 7 dBi. The axial ratio reported is $\leq$ 3dB which also anticipates that the designed antenna exhibits circular polarization, and is useful for the C-band applications.

T. Chang et. al. [25], This paper anticipates the research on MPA using radome which is used to enhance the boresight gain, flat-gain bandwidth and reflection coefficient bandwidth. The radome consists of couple of parallel strips in pair, incised on the bottom of the material. The spacing between each strip is kept to tune the -10 dB reflection coefficient- bandwidth.

J. W. Jayasinghe et al. [26], this manuscript explains the multi-frequency compact sized broadband patch antenna. Proposed antenna is useful for the WLAN applications. Discussed antenna comprises of patch, and shorting pin is notched on a substrate and is suspended in air 5 mm above the ground plane. Genetic algorithm is used to optimize the dimensions of patch, a feed point and positions of shorting pin. Antenna contemplates -10 dB fractional impedance bandwidth of 12.6%.

K. Gangwar et al. [27] , this paper clarifies design of rectangular MPA with Metamaterial structure at 2.54 GHz. The performance parameters such as bandwidth, gain and reflection coefficient have been enriched using Metamaterial structure.

M. K. Khandewal et al. [28], This paper projects the design of Dual band MPA with microstrip line feed. Proposed antenna reveals the dual bands and 8.1dB gain with good radiation characteristics which can be used for WLAN and Wi-MAX. Designed antenna also shows omnidirectional radiation pattern. Almost 40% miniaturization has been reported in this manuscript by cutting the four corners of the rectangular defect and replacing these corners by defected square ring

J. P. Jacobs [29], this paper explains the modeling of the antenna with Gaussian Process Regression (GPR) methodology. In this manuscript, Two types of antennas are discussed and their shapes are U-slot patch and center square slot. The results lucidly reveals that GPR is better approach in juxtaposition to neural networks.

M. R. I. Faruque et al. [30], this paper investigates the MPA design for cellular applications. Design comprises of slots and FR4 epoxy dielectric substrate fed by a line feed along with partial ground plane. The SAR value of the proposed antenna is evaluated at distinct frequency bands, and noticed that antenna shows impedance bandwidth of 230.4 MHz and 522.24 MHz. Aforementioned bandwidth is useful in GSM 900 MHz and 1900 MHz.

R. K. Pandey et al. [31], the major focus of this manuscript to propose a wideband compact sized slotted MPA with enhanced bandwidth using coaxially fed. The designed antenna reports increased -10 dB impedance bandwidths i.e; 500 MHz, 400 MHz and 550 MHz. Proposed antenna is useful for WLAN and WiMAX applications. Slots and slits are also employed in the structure to enhance the bandwidths.

Table 1: Comparative analysis of various MPA based on Performance parameters

Ref.	Antenna Size (mm* mm)	Operating Frequency (GHz)	Reflection Coefficient (dB)	Gain (dB)	Wireless Applications
[35]	80 x 80 x 1.59	6.25 – 7.7GHz	-44.77	10.32	C, X and Ku band
[36]	180 * 180	2.6	-20	2.9	S band
[37]	41 * 14	0.9, 1.8 and 5.3	-20, -25 and -29	0.44, 0.63 and 0.71	WLAN and Cellular Bands
[17]	40*50	2.53 and 3.5	-29.3 and -18	----	Wi-Max (2.5-2.55/3.4-3.7GHz)
[24]	----	6.47, 6.87 and 7.84	-20, -22 and -30	7	Airbone and Ground based applications in C-band
[38]	45*70	0.69, 1.88 and 2.5	-16.23, -22.27 and -19.68	-----	GSM, , PCS, Cellular phone system, UMTS, WLAN, Wi-Fi, Bluetooth, DCS
[39]	8*4	5.48	-30	---	WLAN
[40]	80*80	2.29	-29.5	7.29	Satellite Communication
[41]	46.4*46.4	2.45 and 5.1	-20 and -16.5	6 and 7.2	WLAN and WiMAX
[42]	20*7	2.45 and 5.95	-20.5 and -19	2.5 and 3.2	Bluetooth and WLAN
[43]	20*7	`2.9	-11	----	WLAN
[44]	22*24	3.2-36, 4.4-4.8, and 5.1-5.6	-20.3	2.6	WLAN and WiMAX
[45]	20.2*20.2	9.31	-46.14	----	X-Band applications
[46]	100*40	2.27-17.98	-23	----	Bluetooth, UWB and Satellite
[47]	30*32.4	1.6-10.4	-28	1.51	UWB
[48]	112*28	2.46 and 3.58	-31.29 and -10.26	----	Bluetooth and GSM
[49]	24.5*16.8	14.25	-35	----	Air-to-ground applications
[50]	40*60	3.19	-52.61	9.13	Compact size wireless communication
[51]	51.16*39.86	1.42 and 2.65	-18.6 and -26.9	1.95 and 3.34	S-band
[52]	48*50	4.4, 6.2 and 8.5	-19.4, -14.6 and -18.5	5.3, 5.03 and 5.27	WLAN, WiMax and RADAR
[53]	52*49	.87, 1.25, 1.6, 1.83 and 2.37	-10.88, -11.25, -11.7, -23.13 and -15.56	-----	S-band
[54]	37*32	3.6 and 6.1	-13 and -33	3.8 and 2.1	S and C-band

Y. P. Saputra et al. [32] , this paper demonstrates the design of MPA with slots. Proposed antenna can be utilized for altering polarization of X-band. The alternation of polarization is done without changing the feed line and parameters of other polarization technique. The size of the proposed antenna is 20.2 × 20.2 mm^2, whereas, dimensions of the slot which is used to alter the polarization is 0.65 × 5.1 mm^2.

X. Liu et al. [33], this paper investigates the design of triple-band MPA. Proposed antenna depicts three unique resonant frequency bands i.e; 0.9GHz, 1.8GHz and 2.4GHz.

S. Mishra et al. [34], this paper explores the design of MPA with T and U shaped slots truncated along rectangular corners. The designed antenna operates at 3.105 GHz, and useful for the S- band applications. The main focus of this manuscript is to improve the reflection coefficient by aking changes in the slots inserted on the patch.

Ankita et al. [13], this paper focus on the design of Microstrip Antenna with stacked patches along with wide ground slot. Stacked patches and slots are used to improve the antenna performance parameters. The discussed antenna displays six unique resonant frequencies with maximum gain 5.11 dB, and used for wireless communications such as Wi-MAX, Bluetooth, Wibro, DCS, Satellite and C-band.

It can be anticipated from the aforementioned literature study and Table 1 on the basis performance parameters comparative analysis that different antennas are designed for distinct applications, even one antenna can be used for the multifunctional tasks. The prominent antenna performance factors are gain, reflection coefficient and impedance matching. In the discussed papers, it has been worth noticed that small size antenna which can depict multiband or wideband characteristics is preferred by the researchers on the cost of performance parameters.

5. CONCLUSION AND FUTURE SCOPE

The numerous types of MPA's have been discussed based on Antennas' performance parameters in this paper. The main focus of this review is to realize the antenna performance based on its parameters. The extensive literature survey has been done on MPA and understood that different techniques like employing slit or slot, EBG structure can help to depict the multiband characteristics. MPA is compact in size and single MPA is useful for distinct wireless applications but researcher should not decrease the size of antenna on the cost of its performance parameters, as each Parameter has its own significance for the effective practical use of antenna. Antennas are the eye and ear of the wireless communication systems, and without proper antenna designing, signals can not be transmitted or received effectively. Antennas discussed in this manuscript are useful for wireless applications like GSM, GPRS, WLAN, WiMAX, Satellite, Point-to-point high speed communication etc.

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