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An Extensive Review on a U-slot Microstrip Patch Antenna for Wi-Max Applications

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Abstract - An antenna is an essential element of the wireless system. Antenna is an electrical device which transmits the electromagnetic waves into the space by converting the electric power given at the input into the radio waves and at the receiver side the antenna intercepts these radio waves and converts them back into the electrical power. A microstrip antenna is one who offers low profile and light weight. It is a simple antenna that consists of radiated patch component, dielectric substrate, and ground plane. The radiated patch and ground plane is a thin layer of copper or gold which is a good conductor. Each dielectric substrate has their own dielectric permittivity values. Recent advancement in WiMAX and similar application need the broad bandwidth, small size high gain and efficiency antennas. In This work an extensive literature survey on Microstrip Patch Antenna for Wi-Max Application has been presented.

Keywords- Microstrip Patch Antenna, Wi-MAX Application, U-slot, Antenna Gain, Bandwidth.

I. INTRODUCTION

In modern wireless communication systems, multiband antenna has been playing a very important role for wireless service requirements. Wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) have been widely applied in mobile devices such as hand held computers and intelligent phones. These two techniques have been widely recognized as a viable, cost-effective, and high-speed data connectivity solution, enabling user mobility With the rapid development of the modern wireless communication system, antenna design has turned to focus on wide multiband and small simple structures that can be easy to fabricate. To adapt to the complicated and diverse WLAN and WiMAX environments.

A microstrip patch antenna is consisted of a radiating element of arbitrary shape which is placed on a dielectric substrate. The last is mounted on a ground plane. Fig. 1.1 shows the case of a rectangle microstrip patch antenna.

There is a specific relation between the patch's dimensions and the wavelength in free space: If L is the length of the patch then $0.3333\ \lambda_0 < L < 0.5\lambda_0$ where λ_0 is the free space wavelength [1]. Also it is selected $t \ll \lambda_0$ (t is the patch thickness). The height h of the dielectric substrate takes values: $0.003\lambda_0 \le h \le 0.05\lambda_0$ and the dielectric constant varies between: $2.2 \le \varepsilon_r \le 12$. A patch antenna can take many shapes such as rectangular, triangular, circular, and elliptical as shown in Fig. 1.2.

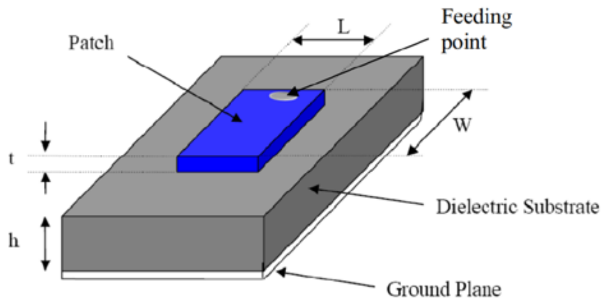

Figure 1.1 Basic Structure of a microstrip patch antenna.

It is known that an antenna performs better if it is characterized by a thick dielectric substrate with low dielectric constant. Under these conditions the antenna has better efficiency and radiation but greater size. In order to reduce the size, materials with higher dielectric constant are used [2]. This leads to less efficiency and narrower bandwidth. So a compromise must be established between the antenna dimensions and operation performance.

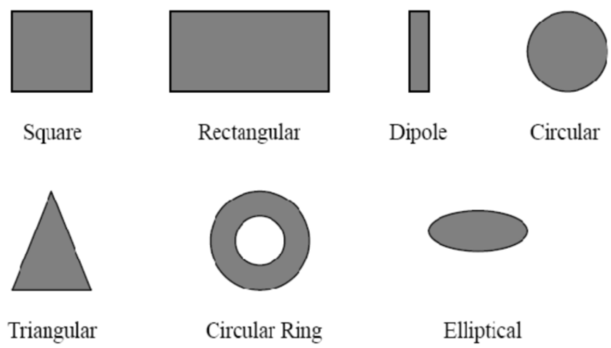

Figure 1.2 Different Shapes of patch elements.

II. ANTENNA PROPERTIES

The performance of the antenna is determined by several factors. Properties of those factors are as follows:

a. Input Impedance

Generally, input impedance is important to determine maximum power transfer between transmission line and the antenna. This transfer only happen when input impedance of antenna and input impedance of the transmission line matches. If they do not match, reflected wave will be generated at the antenna terminal and travel back towards the energy source. This reflection of energy results causes a reduction in the overall system efficiency. Gain

The gain of an antenna is essentially a measure of the antenna's overall efficiency. If an antenna is 100% efficient, it would have a gain equal to its directivity. There are many factors that affect and reduce at the overall efficiency of an antenna. Some of the most significant factors that impact antenna gain include impedance matching, network losses, material losses and random losses. By considering all factors, it would appear that the antenna must overcome a lot of adversity in order to achieve acceptable gain performance.

b. Radiation Pattern

The radiation patterns of an antenna provide the information that describes how the antenna directs the energy it radiates. All antennas if 100% efficient, will radiate the same total energy for equal input power regardless of the pattern shape. Radiation patterns are generally presented on a relative power dB scale.

c. Directivity

Directivity, D is important parameter that shows the ability of the antenna focusing radiated energy. Directivity is the ratio of maximum radiated to radiate reference antenna. Reference antenna usually is an isotropic radiator where the radiated energy is same in all direction and has directivity of 1. Directivity is defined as the following equation:

$$D = \frac{F_{max}}{F_0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

d. Polarization

The polarization of an antenna describes the orientation and sense of the radiated wave's electric field vector. There are three types of basic polarization:

- Linear polarization
- Elliptical polarization
- Circular polarization

Generally most antennas radiate with linear or circular polarization. Antennas with linear polarization radiate at the same plane with the direction of the wave propagate. For circular polarization the antenna radiate in circular form.

e. Bandwidth

The term bandwidth simply defines the frequency range over which an antenna meets a certain set of specification performance criteria. The important issue to consider regarding bandwidth is the performance tradeoffs between all of its performance properties described above. There are two methods for computing an antenna bandwidth.

An antenna is considered broadband if $f_H / f_L \geq 2$.

Narrowband by percentage %

$$BW_p = \frac{f_h - f_l}{f_0} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Broadband by ratio

$$BW_b = \frac{f_h}{f_l} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where f_0= Operating frequency

fh = Higher cut-off frequency

f_l = Lower cut-off frequency

III. RELATED WORK

SR. NO.	TITLE	AUTHORS	YEAR	APPROACH
1	A U-slot microstrip patch antenna for Wi-max applications	S. Sahithi, S. A. Kumar and T. Shanmuganantham,	2017	A U-slot microstrip patch antenna to yield better bandwidth performance is presented for WiMAX applications
2	Dual-band microstrip patch antenna design with inverted-E slot and U-slot,	P. S. Kumar and B. C. Mohan,	2016	A new configuration of dual-band microstrip patch antenna for S-band (2GHz-4GHz) and C-band (4GHz-8GHz) applications
3	U-slot cut shorted square	A. A. Deshmukh, M.	2016	bandwidth of shorted square

	microstrip antenna,	Gala and S. R. Agrawal		microstrip antenna has been increased
4	Performance analysis of Reconfigurable U- slot Fractal Antenna for Wireless applications,	Y. A. Nafde,	2016	Reconfigurable U-slot Fractal Koch curve Micro strip Reconfigurable antenna is designed.
5	Analysis and design of dual-feed circularly polarized U-slot microstrip antennas,	Xihong Ye, Mang He, Yun Hao, Yali Wang and Guan Wang,	2015	simple formulations to estimate the resonant frequencies of the dual feed antenna are derived
6	Broadband U-slot cut microstrip reflectarray antenna with microstrip antenna feed	A. A. Deshmukh, K. Lele, A. A. Desai, S. A. Shaikh, S. Agrawal and K. P. Ray,	2015	U-slot cut rectangular microstrip reflectarray antenna with a U-slot cut rectangular microstrip antenna as a feed is reported
7	Analysis of Broadband Variations of U-slot cut Rectangular Microstrip Antennas,	A. Deshmukh and K. P. Ray,	2015	an extensive study for the broadband behavior for U-slot, half U-slot and double U-slot cut rectangular MSAs (RMSAs) is presented
8	A triple-band microstrip fed monopole antenna using defected ground structure for WLAN and Wi-MAX applications	S. Oudayacoumar, T. Karthikeyan and V. Hariprasad	2014	A compact triple-band monopole antenna with dimension 30 × 40× 1.6 mm^3 fed by a 50 Ω microstrip line is proposed

S. Sahithi, S. A. Kumar and T. Shanmuganantham,[1] A U-slot microstrip patch antenna to yield better bandwidth performance is presented for WiMAX applications. It comprises of a symmetric U-slot w.r.t rectangular patch. The working principle, and design procedure are extensively described in this research work. The results are shows that the u slot antenna provides a band from 3.5GHz to 3.7GHz which is capable to achieve minimum voltage with good bandwidth and radiation properties. Finally a microstrip antenna operating at resonant frequency 3.6GHz is designed.

P. S. Kumar and B. C. Mohan,[2] The intention of this work is to present a new configuration of dual-band microstrip patch antenna for S-band (2GHz-4GHz) and C-band (4GHz-8GHz) applications. The dual-band antenna has become a fascinating technology due to its large capacity of data and high-speed data rate. In this work, a rectangular microstrip antenna with inverted E-slot and U-slots is proposed which offers an improved gain with dual-band operation. The antenna performance parameters at 3 GHz are the reflection coefficient (dB), VSWR, gain and radiation efficiency are found to be 17.74 dB, 1.29, 2.49 dBi and 49.45% respectively. At 4.6 GHz the reflection coefficient (dB), VSWR, gain and radiation efficiency are found to be 15.68 dB, 1.39, 3.68 dBi and 56.52% respectively. The designed antenna performance is compared with the existing dual-band designs available in the literature. An improvement with respect gain in both operating frequencies is demonstrated.

A. A. Deshmukh, M. Gala and S. R. Agrawal,[3] By cutting U-slot, bandwidth of shorted square microstrip antenna has been increased. Here, detailed analysis which explain the effects of U-slot to achieve wide band response in shorted square patch is presented. U-slot yields tuning of TM3/4,0 mode frequency with respect to shorted patch $TM_{1/4,0}$ mode, thereby it gives 27% of bandwidth in 2.4 GHz range. Slot also modifies current distribution at second order mode to give broadside radiation pattern over the bandwidth. An insight into the functioning of widely reported U-slot cut shorted square patch antennas in terms of patch resonant modes is provided here. This study will serve as a tutorial to re-design similar antennas at any given frequency.

Y. A. Nafde [4] Rapid growth in the High density networks and advancements in the antenna technology have led to the antenna design with smaller size, lighter weight, lower cost, reconfigurable , multi band & wide band nature. However, all these advances also come with increased complexity. The lower insertion loss , excellent isolation & linearity of the RF MEMS switches serves to replace the semiconductor PIN diode and other RF switches in the reconfigurable antenna design. In this inverstigation Reconfigurable U-slot Fractal Koch curve Micro strip Reconfigurable antenna is designed. The testing of Antenna is performed in 1 to 6 GHz frequency range. The measured & simulated results are demonstrating the Multi Band and Wide band Characteristics which is the major requirement of High density Wireless network. The design considerations of the RFMEMS switch suitable for reconfigurable Micro strip patch antennas are also discussed in this exploration.

Xihong Ye, Mang He, Yun Hao, Yali Wang and Guan Wang,[5] The dual feed circularly polarized (CP) U-slot microstrip antenna (MSA) has recently been proposed to provide more than 20% bandwidth that VSWR ≤ 1.5 and AR ≤ 3 dB overlapped, even with very small size. However, the working principles of the antenna and the design rules for it have not been yet presented. In this work, simple formulations to estimate the resonant frequencies of the dual feed antenna are derived, and an iterative design procedure to determine the initial geometric sizes of the antenna is also given. Compared to the final dimensions of the antenna obtained by numerical simulations, the accuracy of the proposed approximate computer-aided-design (CAD) formulas is within 5.3%.

A. A. Deshmukh, K. Lele, A. A. Desai, S. A. Shaikh, S. Agrawal and K. P. Ray,[6] Broadband U-slot cut rectangular microstrip reflectarray antenna with a U-slot cut rectangular microstrip antenna as a feed is proposed. The 1 × 3, 3 × 1, plus-shaped and 3 × 3 patch arrays have been studied. A parametric study for varying distances between fed patch and the array and for varying U-slot dimensions in reflect array patches is presented. An optimum gain of nearly 11 dBi with bandwidth of around 1100 MHz is obtained in 3 × 3 reflect array configuration.

A. Deshmukh and K. P. Ray,[7] A very popularly used technique to realize broadband and compact microstrip antenna (MSA) is by cutting a slot at an appropriate position inside the patch. More frequently, U-slot and its variation, a half U-slot, have been used to increase the bandwidth (BW). In most of the available literature on U-slot cut antennas, a detailed explanation for broadband response due to U-slot has not been reported. In this work, an extensive study for the broadband behavior for U-slot, half U-slot and double U-slot cut rectangular MSAs (RMSAs) is presented. The U-slot configurations with different aspect ratios (i.e., length-to-width ratio) for patch and slot dimensions have been studied. In U-slot and half U-slot cut patches, it has been observed that slot does not introduce any additional mode, but it modifies the fundamental and higher order mode resonance frequencies of the patch to yield broadband response. The slot also modifies surface current distribution at higher order mode to yield broadside radiation pattern characteristics over the complete BW, without any variations in the directions of principle planes. Further, in double U-slot cut RMSA, the second U-slot optimizes the impedance and frequency at modified higher order TM21 mode and, along with modified TM01 and TM20 modes, yields increase in the BW. This investigation will give an insight into the functioning of U-slot cut antennas.

S. Oudayacoumar, T. Karthikeyan and V. Hariprasad,[8] A compact triple-band monopole antenna with dimension 30 × 40× 1.6 mm3 fed by a 50 Ω microstrip line is proposed in this work. The signaling plane consists of a microstrip feed line and a radiating element. The radiating element contains two branches and two stubs. The branches of the radiating element are used to make the circuit to radiate at 2.3 GHz and 3.9 GHz. The stubs help in making the circuit to radiate at 5.3 GHz. Thus the proposed antenna is capable of radiating triple band of frequencies which meets the specifications of WLAN 2.4/5.3 GHz and Wi-MAX 3.9 GHz. The VSWR values are 1.2, 1.9 and 1.1 at 2.3 GHz, 3.9 GHz and 5.3 GHz respectively. The simulated return loss values at the desired frequencies are -19 dB at 2.3 GHz, -25 dB at 3.9 GHz and -38 dB at 5.3 GHz. The ground plane is designed with a defected ground structure with two inverted L shaped strips that helps to enhance the bandwidth of the system. The bandwidth of the proposed triple band antenna are (2.2 - 2.4) GHz, (3.7 - 3.92) GHz and (5.2 - 5.4) GHz. The radiation pattern of the proposed antenna is bi-directional in H-plane and unidirectional in E-plane which is suitable for WLAN and Wi-MAX applications.

IV. PROBLEM IDENTIFICATION

Different types of application requires antenna with different parameters. Like for cellular mobile communication a circular polarized antenna is requires with high gain and for satellite communication in downlink a high directive antenna is required. The selection and the performance of an antenna is characterize on the basis of some parameters these are Bandwidth, Polarization, radiation, Pattern, Efficiency, Gain. In modern wireless communication systems and increasing of other wireless applications, wider bandwidth, multiband and low profile antennas are in great demand for both commercial and military applications. This has initiated antenna research in various directions; one of them is using fractal shaped antenna elements. Traditionally, each antenna operates at a single or dual frequency bands, where different antenna is needed for different applications. This will cause a limited space and place problem.

V. CONCLUSION

The goal of this inverstigation is to study how the performance of the antenna depends on various parameters of microstrip patch antenna. A microstrip antenna generally consists of a dielectric substrate sandwiched between a radiating patch on the top and a ground plane on the other side. The patch is mainly made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are highly compatible for embedded antennas in handheld wireless devices such as pagers, cellular phones etc... The telemetry and communication antennas on missiles need to be thin and conformal and are often in the form of Microstrip patch antennas. Another area where they have been used successfully is in Satellite communication. Various parameters and application of microstrip patch antenna and recent work on the field has been reported in this brief.

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