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Microstrip Patch Antennas for Uwb Applications: A Review

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Abstract : *The need for development of microstrip patch antennas for ultra-wideband (UWB) communications has been very well recognized.UWB antennas are mainly used for wearable MIMO sytems,weather mesurements and also UWB radar applications. Patch antenna can be a good choice for handheld devices in UWB applications.There was a great success in finding a suitable structure for mobile applications.This paper is a review of various methods that enhance the bandwidth and gain of microstrip patch antennas that specifically used for UWB applications. For instance, the UWB utilizes the frequency band of 3.1-10.6 GHz. Conventionally microstrip antennas operating at narrow band width. Broadening the antenna bandwidth is achieved by using the U-slot technique.The performance of the antenna related with its parameters. The variation of antenna performance depends on variation of location of microstrip feed (L) and the partial ground plane size (G).Length of the antenna is another factor that determines directivity and gain. Use of graded substrate also enhances the directivity and band width.Microstrip antenns are used in satellite communication, military purposes, GPS, mobile, missile systems and many more applications.Simulated and measured results are also used to validate the usefulness of the antenna structure for UWB applications.*
Keywords: *Microstrip antenna, MIMO,U-slot, Ultra-wide band,GPS*

I. Introduction

In 2002, the Federal Communications Commission (FCC) allocated the spectrum from 3.1 to 10.6 GHz for unlicensed ultra-wideband (UWB) measurements and communication applications.The microstrip UWB antennas have attracted much attention owing to their advantages such as simple structure, low profile, high data rate, easy integration with monolithic microwave integrated circuits (MMICs), and ease of fabrication. Thus, the UWB antenna has become the most promising solution for future short-range high-data wireless communication applications, UWB for short-range (10 m), peer-to-peer ultra-fast communications, It is used in satellite communication, military purposes, GPS, mobile, missile systems and many more application.These are relatively inexpensive to manufacture and design because of the simple 2-dimensional physical geometry.This has instigated researchers to dwell deep in the design of UWB antennas. Various shapes of monopole antennas, such as a beveled rectangular patch and a circular printed monopole with steps [11], and various shapes of slot antennas, such as inverted cone slot and tapered slot with tuning patch , have been reported for a compact UWB antenna.

For a good wireless communication system, antenna is one of the most critical components.A good design of the antenna can relax system requirements and improve overall system performance.A micostrip patch antenna has the advantages of low cost, light weight, and low profile planner configuration. However, they suffer from the disadvantage of low operating bandwidth [1-2].Bandwidth improves as the substrate thickness is increased, or the dielectric constant is reduced, but these trends are limited by an inductive impedance offset that increases with thickness. A logical approach, therefore, is to use a thick substrate or replacing the substrate by air or thick foam, the dielectric constants are usually in the range of ($2.2 \leq \varepsilon r \leq 12$) [3-4]. The use of transmission line method to analyze the rectangular micro strip antenna. RMPA operating of resonance frequency (2.4GHz) for TM10 mode, with the coaxial probe feed used the antenna is matched by choosing the proper feed position [6].RMPA is characterized by its length L, width W and thickness h,
It is of a very thin thickness h ($h << \lambda_o$, usually $0.003 \lambda_o \leq h \leq 0.05 \lambda_o$) where λ_o is free space wavelength above a ground plane [7].
For rectangular patch, the length L of the element is usually

$$\lambda_o / 3 < L < \lambda_o / 2.$$

Much intensive research has been done in recent years to develop bandwidth enhancement techniques. These techniques include the utilization of thick substrates with low dielectric constant, and slotted patch [2]. In general the use of electronically thick substrate only result in limited success because a large inductance is introduce by the increased length of the probe feed, resulting few percentage of bandwidth at resonant frequency. Hence instead of using probe feed, inset feed is used in the design antennas with thicker substrate. Now with the loading some specific slot in the radiating patch of microstrip antennas, compact or reduced size microstrip antennas can be obtained. The loading the slots in the radiating patch can cause meandering of the excited patch surface current paths and result in lowering of the antenna's fundamental resonant frequency, which corresponds to the reduced antenna size for such an antenna, compared to conventional microstrip antenna at same operating frequency. Recently, Ultra-Wide Band (UWB) is attracting both academic and industrial attention due to its ability to exchange the data in high speed and low power density. These characteristics make it one of the promising technologies for short range applications such as centric-body systems which distribute the antennas on human body.

Broadening the antenna bandwidth is achieved by using the U-slot technique.The effect of the U-slot inclusion on the performance of a patch antenna operating at the TM $_{02}$ mode is studied across the entire achieved bandwidth. The antenna analysis is carried out with the aid of full wave simulation, and an antenna prototype is fabricated and measured for validation.

II. Antenna Operation Principle And Design

2.1 Introduction

Indoor wireless links have intrinsic characteristics that affect the system performance, such as the multipath effect that causes signal fading, and interference effect from adjacent cells that degrades the bit error rate. From the physical layer perspective, one solution to combat these impairments is the use of directional antennas rather than the traditional omnidirectional ones [1]. They have the ability to confine the power in certain directions instead of scattering the power everywhere. They have the ability to confine the power in certain directions instead of scattering the power everywhere. As a result of less power loss toward unwanted directions, the multipath and interference effects are reduced. Directional antennas can be single or dual/multi-beam. Dual/multi-beam antennas are antennas that have more than one directive beam from a single aperture. These antennas are useful for indoor wireless systems which require coverage of multiple areas [2], as they reduce the required number of antennas and are found to improve the link quality [3], resulting in easier network deployment. Microstrip antennas have been widely used in many modern communication systems, because of its robustness, planar profile, and low cost.

2.2 Operation Principle

To design a rectangular patch antenna operating at theTM_{02} mode that gives dual radiation beams, the patch length L should be λ_d, instead of $\lambda_d/2$ for the fundamental mode, where λ_d is the wavelength in the dielectric substrate. According to the cavity model of the patch antenna, the current on the patch's surface, has two maxima atTM_{02} mode. Therefore, for a U-slot to work effectively, It is obvious that the presence of two maxima on the patch indicates a λ_d resonator at the TM $_{02}$ mode.It should be mentioned that optimization and parametric study are needed for the U-slot parameters to acquire a wide bandwidth.

2.3 Parametric Study

The parameters that have critical influence on the antenna performance are chosen for parametric study. These parameters are: L, W, L_S, b. Parameters L and L_S are responsible for the patch and U-slot electric lengths, whereas w changes the patch impedance[9]. Lastly, b tells how the U-slot intercepts the current maxima on the patch's surface. To study their effects on the antenna performance, parametric study is carried out on the parameters mentioned above, using the full wave simulator Ansoft HFSS [10]. It is observed that L and L_S control the lower and higher resonant frequencies of the antenna, respectively, as expected. With the proper selection of L and L_S , an overlap between both resonances occurred leading to a wide impedance bandwidth. On the other hand, a small variation of the antenna width W does not show significant effect on the bandwidth.
It should be pointed out that wider variation W of is not suggested, because it might excite the horizontal higher order TM_{02} mode. The parameter that represents the position of the U-slot on the rectangular patch, controls the separation between the two resonances which consequently affects the achieved impedance bandwidth.For the U-slot antenna investigated experimentally gives an idea about the band width enhancement techniques.The U-slot effect for broadening the antenna bandwidth is obvious. According to the measured results, the U-slot technique increases the impedance bandwidth for more than two times. The difference between the simulated and measured results is due to the defects in the prototype during fabrication.

TABLE 1Impedance Bandwidth Of the U-Slot Microstrip Antenna

BW	HFSS	Measured
Without U-slot	5.5-5.72(4%)	(5.3%) 5.54-5.822
With U-slot	5.17-5.81(12%)	(11.3%) 5.18-5.8

III. Relationship Between Bandwidth And Feeding Methods

3.1 Introduction

Modern communication systems demand for low cost and low profile antennas. Microstrip patch antenna is one of the candidate antennas meeting those requirements due to its conformal nature and capability to integrate with the rest of the printed circuitry.Feeding mechanism plays an important role in the design of microstrip patch antennas. Proper impedance matching of a microstrip patch antenna to the feed line is paramount for efficient radiation.

3.2 Bandwidth And Feeding Methods

There are two common contacting microstrip feeding schemes: probe and edge feeding techniques. In the former method, the inner conductor of a coaxial cable penetrates through the substrate and is soldered to the radiating patch while the outer conductor is connected to the ground plane. Matching in this technique is achieved by placing the probe at an appropriate longitudinal position. In the edge feeding method, a conducting strip is connected directly to the edge of the radiating patch.Impedance matching in this technique, however, is a challenge since the edge impedance is very high varying between 1500-2500. However, it decreases as the feed point approaches the center of the patch. A variation to this scheme is the inset feeding where an inset notch is cut in the patch to enhance matching. Matching is achieved by controlling the longitudinal length of the notch thus controlling input impedance level. Appropriate positioning of a coaxial probe and determining the appropriate notch length in the probe and inset –fed antennas respectively, is not easy. The main challenge therefore facing the designers of microstrip antennas is how to exactly position these feed lines for matched microstrip antenna systems.

A microstrip patch antenna can be fed either by coaxial probe or by an inset microstrip line. Coaxial probe feeding is some times advantageous for applications like active antennas, while microstrip line feeding is suitable for developing high gain microstrip array antennas. In both these cases, the probe position or the inset length determines the input impedance.

In general by the use of electronically thick substrate only result in limited increase in bandwidth. When we are using the probe feed. because a large inductance is introduce by the increased length of the probe feed, resulting few percentage of bandwidth at resonant frequency. Hence instead of using probe feed, inset feed is used in the design antennas with thicker substrate.

TABLE 2 Effect Of The Dielectric Thickness On Antenna Performance.

Serial No:	DielectricThicknes (h mm)	Patch Specification (mm)	F0 (GHz)	B W (MHz)
1.	4	W=38mm, ▲L=1.8 eff=3.83,L=28.33mm	2.4	155.1
2.	6	W=38mm, ▲L=2.625,eff=3.7 L=28.336mm	2.4	200
3.	8	W=38mm, ▲L=3.415, eff=3.6 L=26.08mm	2.4	150

A small variation in dielectric thickness of the substrate causes significant variation in bandwidth of microstrip antenna.Dielectric thickness at 4mm ,bandwidth is 155MHz.Bandwidth 200MHz at a dielectric thickness of 6mm.At 8 mm ,Bandwidth 150MHz

IV. Significance Of Substrate Material

4.1 Introduction

The substrate material parameters affect the performance of MPA. The intrinsic properties that are considered while selecting the substrate material include: complex permittivity, thermal conductivity, dimensional stability with temperature, humidity and aging Complex permittivity of substrate material plays a critical role in antenna operation. Substrate material with low permittivity may be used to increase the bandwidth of operation, but very low permittivity material increases the dimensions of the MPA, which poses difficulty for use in handheld devices. Increase in permittivity of the substrate material increases the Q of the antenna and hence its impedance bandwidth is reduced. Particulate polymer composites are developed, which are to be utilized as substrate material for microstrip antenna. TiO2 reinforced LDPE composite system shows good thermal stability, light weight and impermeability to humidity so that the composite material has potential to be used as substrate for microstrip antennas in all environmental conditions. Microstrip antenna with rectangular radiating patch is fabricated on composites with different volume fraction (VF) of filler in polymer as substrate. To increase the operational bandwidth of the antenna three layer grading of the composite substrate is done. The bandwidth and S11 parameter performance of the antenna is found to be improved by using graded composite as substrate material. Enhancement of directivity is observed for graded substrate as compared to ungraded substrate**.**

4.2 Measured Parameters Of Microstrip Antenna Designed On Different Substrates.

TABLE 3 Measured Parameters Of Microstrip Antenna Designed On Different Substrates.

Substrate	2%VF of titania in LDPE	3%VF of titania in LDPE	4%VF of titania in LDPE	Graded
Permittivity at 10 GHz	2.23	2.28	2.39	2.27
PatchDimenssion(mm2)	11.4 × 8.3	11.2 × 8.1	10.9 × 7.8	11.2 × 8.1
Resonating Frequency(GHz)	10.06	10.04	10.02	10.1
S11 at the resonating Frequency (dB)	-29	-26.8	-22.4	-38.6
-10dB operational bandwidth (MHz)	6.06 %	5.87 %	5.78 %	6.73 %

V. Conclusion

The thickness of the substrate has significant importance in antenna design.Low permittivity is also improves bandwidth.For substrate thickness (4mm) the first design antenna had a (155.1) MHz bandwidth (6.46 % of central frequency). Whereas when the thickness was used (6mm), the bandwidth increased to be (200) MHz, which gives a percent of bandwidth to the centre frequency of (8.33%) that means the bandwidth improvement approximately (45) MHz. whereas when the thickness was used (h = 8mm) the bandwidth decreased to be 150MHz. Graded composite material developed as substrate for microstrip antenna shows an enhanced S11 parameter and bandwidth as compared to single composition substrate.A U-slot microstrip antenna operating at a higher order mode TM_{02} has 11.3% bandwidth(5.17–5.81 GHz) and exhibit dual radiation beams. The beams are directed around at the center frequency, and both beams' squint is less than 4 within the antenna bandwidth. Realized gain of the forward beam is 7.92 dBi at the center frequency, whereas it is 5.94 dBi for the backward beam. The difference between both beams' maxima is less than 2 dBi across the entire bandwidth. The antenna design using U-slot technique is a desirable candidate for stationary terminals of various indoor wireless communication networks.

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