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A study on the engineering techniques adopted for microstrip antenna for achieving some specific performance for commercial/personal communication

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ABSTRACT

Microstrip antenna has gained the attention of the researchers for its many salient features. The present day is the age of wireless communication. The potential application of Microstrip Antenna (MSA) for the wireless and personal commutation is the hot topic of interest of the researchers around the globe. The present day demands wide band, miniature antennas with other features. The choice of MSA for communication being old, researchers managed to develop new variants of the antenna to meet the demand of the present-day communication. This paper basically investigates the engineering techniques involving the use of MSA for communication.

Keywords: *Microstrip Antenna (MSA), Polarization, Smart Antenna, Ultra Wide Band (UWB)*

INTRODUCTION

In the last few years there has been dramatically increased in the interest of Wireless Communication, which includes the commercial / personal communication. It is the choice of the users to have a small and light weight handset. Due to the development of VLSI/ULSI techniques the researchers are able to reduce the size and power hungry of the devices to a grater extent. Antenna being the front and back end of the wireless communication system [1] place a vital role with respect to size of the equipment. It is of the desire of the antenna researchers to develop electrically small antenna, light weight, and low profile. Omni-directional radiation pattern with respect to the horizontal plane and satisfying the performance specifications with respect to frequency of operation, good bandwidth & efficiency is also desirable. As the radiation interacts with the biological tissues, it should be low at the same time provide reliable voice/video/data communication.

Microstrip Antenna has drawn attention of the researchers for its many salient features. This paper concentrates the engineering applied in getting the antenna of desired choice. The next section deals with the materials and method under which the present day requirement of antenna and a brief introduction to MSA is given. The section III deals with the results and discussion which gives an insight to the polarization control, bandwidth enhancement, multi band antenna, and miniaturization of MSA. It also gives some concept of smart antenna. The paper concludes with the conclusion in the section IV.

MATERIALS AND METHODS

a. Present day Requirement of Communication Antenna

The wireless communication system in a locality operates at different frequencies in order to avoid the interference from other equipments. The wireless transmission, including the commercial and personal communication point of view, there are now different frequency bands for portable cellular/ non cellular devices. The commonly used frequency band for the conventional 0.9 GHz GSM band for mobile phones and 1.8 GHz DCS band are used for wireless mobile application. Similarly, the Bluetooth wireless technology operates at 2.4 GHz and already applied successfully in different portable devices like mobile phones, laptop, PDAS, etc. The Wireless LAN (WLAN) operates at 5.2 GHz is being applied in some applications.

The antenna requirements for such type of communication system are small size, light weight, omni directional radiation pattern, reasonable gain, acceptable bandwidth.

The present-day antenna engineers must keep an eye on the following technical specifications namely (i) antenna operating frequency (ii) input impedance (VSWR & return Loss) (iii) bandwidth (iv) gain and directivity (v) radiation Pattern (vi) diversity (vii) SAR (Specific Absorption rate) of the antenna.

b. Microstrip Antenna an Overview

The basic structure of a Microstrip Antenna (MSA) [2-7] consists of a thin sheet of low-loss dielectric substrate, which is sandwiched between two metal sides. One side which is completely covered is called the ground plane and the other side of partially metalised also known as the patch and derives the name of the antenna. The common structures of the patch antennas are the circular, rectangular, triangular, etc.

The major advantage of MSA includes (i) reduction of size and weight (ii) easy to handle and inexpensive (iii) possibility of large scale fabrication (iv) topological considerations.

It also suffers from some draw backs like (i) narrow bandwidth (ii) low gain (iii) large ohmic loss (iv) excitation of surface waves (v) radiation from the feed (vi) low polarization purity (vii) low power handling capacity.

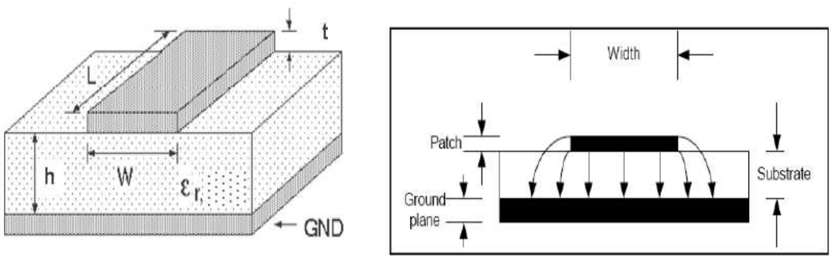

Figure 1: Microstrip Antenna

Some of the lacunas of MSA can be overcome by utilizing the concept of an array. When the discrete radiators are combined to form an array, lead to enhance the characteristics like gain and beam scanning and also the power handling capacity. The elements of the array can be distributed to form linear, planner or volume array. Several ways of feeding can be used to obtain certain characteristics. SISO (Single Input Single Output), MIMO (Multi Input Multi Output) is the common.

The need of present day communication requires a broadband, miniature antenna. The engineering approach to meet the requirements in case of MSA related to its polarization, widening the bandwidth and reducing the size of the antenna is addressed in the subsequent sections.

RESUTLS AND DISCUSSION

a. Polarization Control of Microstrip Antenna

The polarization of MSA is controlled by different techniques some are addressed below.

The common procedure adopted for circular polarization [8-9] using a rectangular microstrip antenna is either by (i) single feed (ii) Dual feed with delay line or 90^o hybrid phase shifter (iii) Synchronous sub array technique.

In the first case, the feed is on the diagonal of a nearly rectangular patch antenna. The two modes are excited with equal amplitude but with a +/- 45^0 phase difference.

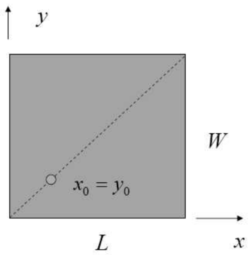

Figure 2(a): Single feed

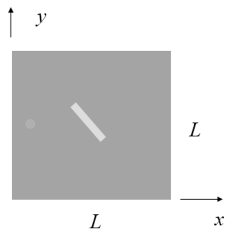

Figure 2(b): Patch with slot

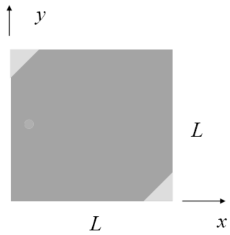

Figure 2(c): Patch with truncated corners

Other variants such as patch with slot or patch with truncated corners can be used, but the diagonal modes are used as degenerate modes.

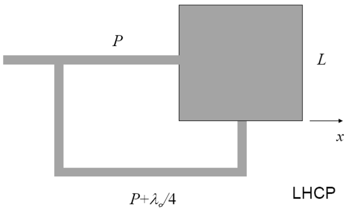

Figure 3(a): Dual feed

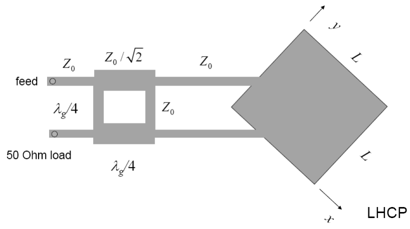

Figure 3(b): Dual feed branch line copular

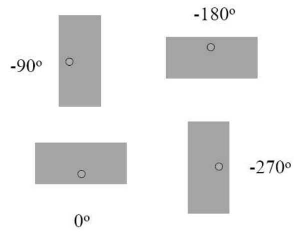

Figure 3(c): Synchronous rotation

In the second case, i.e. the dual feed with delay line or 90^0 phase shifter is used, which are presented in self-explanatory diagrams in figure (2 & 3).

Finally, synchronous sub array technique, the elements are rotated in space and fed with phase shifts. This technique gives a good cross-polarization on account of symmetry and radiation from higher-order modes tends to be reduced.

b. Microstrip Antenna for Wide Band and Multi-Band Communication

There has been an increase in demand of communication bandwidth due to choice of the user for high data rate applications like video-on-demand.

Ultra Wide Band (UWB) technology [1] now a day plays a vital role in wireless communication due to its some salient features, like the licensee free and high bandwidth. It primarily depends on the transmitting pulses of widths in order of nano seconds instead of modulating the signals and hence broadening its spectrum, and it operates below the noise level. This technology has the potential advantages like (i) immunity to jamming (ii) combat fading due to multi-path effects (iii) penetration capability due to the presence of low frequency component (iv) low power consumption, hence enhances battery life and (v) finally it is secure. This technology has found its application in different fields of wireless communication like wireless sensor network (WSN) which is useful in tracking, medical, remote-sensing applications.

This UWB technology suffers challenges like radiation pattern stability and polarization purity in the entire band of operation.

In case of MSA [2-3], it is an establish fact that the substrate thickness (h) is directly proportional to the bandwidth. This height (h) is extended to infinity by eliminating the ground plane, the bandwidth becomes very wide. Resonate frequency of a rectangular patch antenna is a function of patch length, width and height. When the antenna is printed on a very thin substrate, it excites higher-order modes if they are close to each other the overall bandwidth is ultra-wideband.

Improving Bandwidth

Some of the techniques that have been successfully developed by researchers are illustrated here.

Improving Bandwidth [10-13] using Probe Compensation is depicted in fig (4).

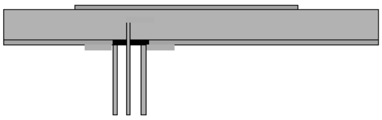

Figure 4(a): L-shaped probe

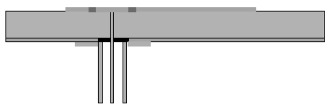

Figure 4(b): capacitive "top hat" on probe

Improving bandwidth using Strip Slot Foam Inverted Patch (SSFIP) a version of the ACP is presented in fig 5(a). This technique enhances the bandwidths greater than 25%. The increase is accounted due to the thick foam substrate and a dual-tuned resonance (patch and slot).

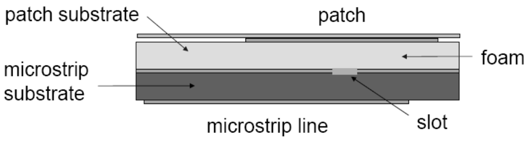

Figure 5(a): SSFIP

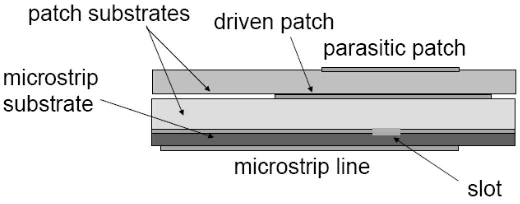

Figure 5(b): Stacked Patches

Improving bandwidth using Stacked Patches is depicted in fig 5(b). Here, the bandwidth increase is due to thick low-permittivity antenna substrates and dual or triple-tuned resonance. It has been noticed that bandwidths of 25% have been achieved using a probe feed and 100% have been achieved using an ACP feed.

Improving Bandwidth utilizing Parasitic Patches

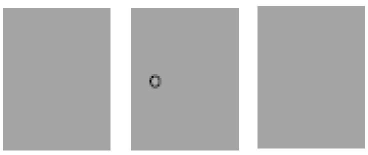
Fig 6(a): REGCOMA

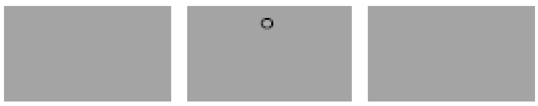
Fig 6(b): NEGCOMA

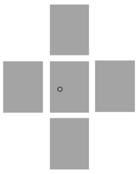
Fig 6(c): FEGCOMA

The bandwidth improvement factor for the three configuration of parasitic patches depicted in figure 6(a, b, c) is given below.

Radiating Edges Gap Coupled Microstrip Antennas (REGCOMA): 3
Non-Radiating Edges Gap Coupled Microstrip Antennas (NEGCOMA): 3
Four-Edges Gap Coupled Microstrip Antennas (FEGCOMA): 5

Improving Bandwidth using Direct-Coupled Patches

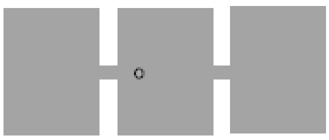
Figure 7 (a): REDCOMA

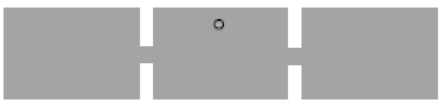
Figure 7 (b): NEDCOMA

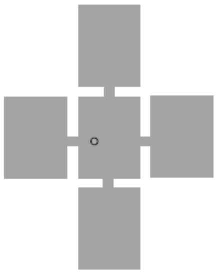
Figure 7 (c): FEDCOMA

The bandwidth improvement factor for the three configuration of direct coupled patches depicted in figure 7(a, b, c) is given below.

Radiating Edges Direct Coupled Microstrip Antennas (REDCOMA): 5.0
Non-Radiating Edges Direct Coupled Microstrip Antennas (NEDCOMA): 5.0
Four-Edge Direct Coupled Microstrip Antennas (FEDCOMA): 7.0

Improving Bandwidth using U-shaped slot

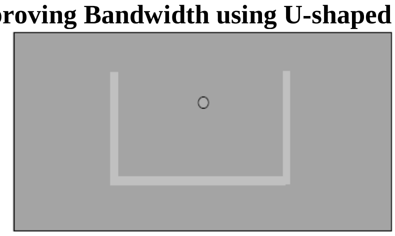
Figure 8 (a): U-shaped slot

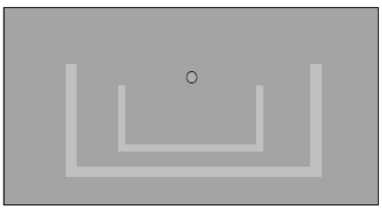
Figure 8(b): Double U-Slot

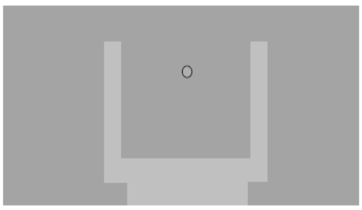
Figure 8(c): E-Patch

The introduction of a U-shaped slot can give a significant bandwidth (10%-40%).This is partly due to a double resonance effect. In case of Double U-Slot a 44% bandwidth were achieved. The E-Patch a modification of the U-slot patch, a bandwidth of 34% was achieved (40% using a capacitive "washer" to compensate for the probe inductance).

Multi-Band Antennas
A multi-band antenna is often more desirable than a broad-band antenna, if multiple narrow-band channels are to be covered.

General Principle
Introduce multiple resonance paths into the antenna. The same technique can be used to increase bandwidth via multiple resonances, if the resonances are closely spaced. Multi-Band Antennas as examples are depicted in fig 9(a, b).

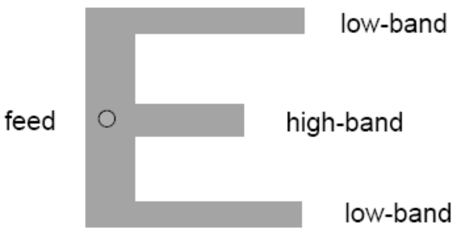

Figure 9(a): Dual-Band E patch

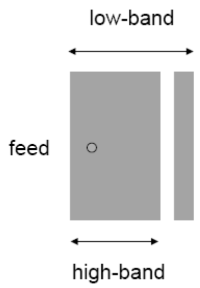

Figure 9(b): Dual-Band Patch with Parasitic Strip

c. Miniaturization of Microstrip Antenna
The conventional MSA is narrow band in nature. Therefore, some approaches are investigated for multi-band antenna with reduced size. The main objective of antenna designers for wireless communication application is to have a compact antenna while reserving the characteristics of multi-band, light weight, low cost, robustness, diversity, packaging capabilities and ability for MEMs integration for smart antenna system.

The techniques that are commonly adopted for the antenna size reduction [14-17] includes the dielectric loading to reduce the electrical size, top hat loading and use of shorting pins or plates. Dielectric loading usually leads to bandwidth reduction and cost increase, therefore it is not a wise approach.

The commonly adopted procedure for reducing the size of the microstrip antenna can be (A) High dielectric material, slow wave (B) Shorting panes, Walls, pins etc, (C) Patching etching: slits, slots, notches etc (D) Multilayered: fold, bend, stack etc. Lets define parameters α refers to the geometrical size reduction w.r.to conventional resonant size, β be the impedance bandwidth enhancement ratio and, γ is the term connected with radiation pattern symmetry versus cross polarization. A comparison of the techniques adopted for size reduction is as follows.

A: α= 70 %, β=2%, γ= High; B: α= 50 %, β=5%, γ= low, C: α= 50 %, β=7%, γ= Medium, D: α= 60 %, β=10%, γ= High.

The Effect of PIFA Parameter on its Characteristics:
The height, width controls the bandwidth, impedance matching respectively. The length of the antenna is responsible for determining the resonant frequency and the inductance of the antenna increases as the length increases. The width of the strip effects on the anti-resonance and increase the bandwidth. Similarly, the feed position from the short strip also affects the resonance frequency and bandwidth of the antenna.

Miniaturization Methods
The general miniaturization methods adopted are High Permittivity, Quarter-Wave Patch, PIFA, Capacitive Loading, Slots, and Meandering.

It is to be noted that miniaturization usually comes at a price of reduced bandwidth. The general rule is maximize obtainable bandwidth is proportional to the volume of the patch (based on the Chu limit.)

Figure 10(a): Miniaturization: High Permittivity

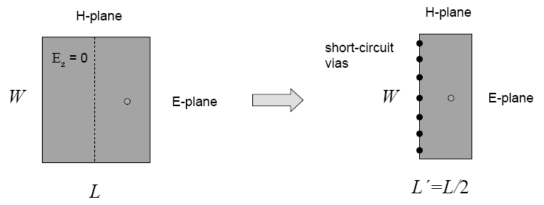

Figure 10(b): Miniaturization: Quarter-Wave Patch

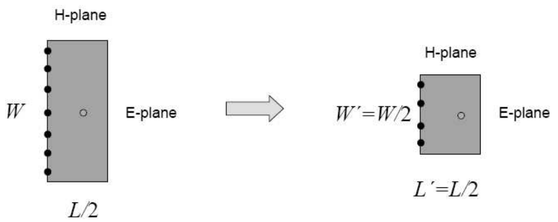

Figure 10(c): Smaller Quarter-Wave Patch

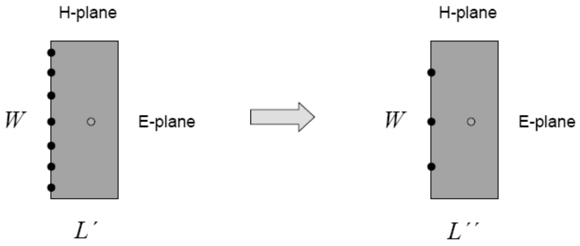

Figure 10(d) : Quarter-Wave Patch with Fewer Vias

In Fig (10 a) it has about one-fourth the bandwidth of the regular patch. It is inspired by the concept bandwidth is inversely proportional to the permittivity. Similarly fig (10 b) has about one-half the bandwidth of the regular patch.

$$Q = \omega_0 \frac{U_s}{P_r} \qquad \left. \begin{array}{l} U_s \rightarrow U_s / 2 \\ P_r \rightarrow P_r / 4 \end{array} \right\} \Longrightarrow Q \rightarrow 2Q$$

(1)

In fig (10 c) about one-fourth the bandwidth of the regular patch is achieved. It is inspired by the concept bandwidth is proportional to the patch width.

In fig (10d) $L'' < L'$ fewer vias actually gives more miniaturization. It is to be noted that the edge has larger inductive impedance.

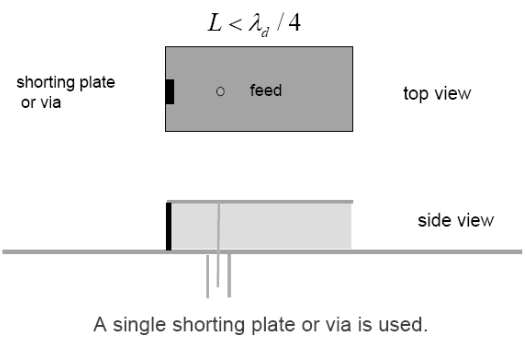

Figure 11(a): Planar Inverted F Antenna (PIFA)

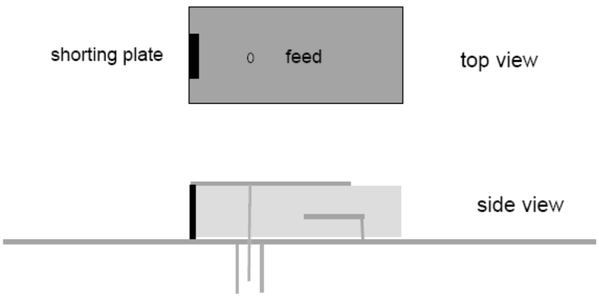

Figure 11(b): PIFA with Capacitive Loading

In case of Planar Inverted F Antenna (PIFA) the antenna can be viewed as a limiting case of the quarter-wave patch, or as an LC resonator. Similarly PIFA with Capacitive Loading, the capacitive loading allows for the length of the PIFA to be reduced.

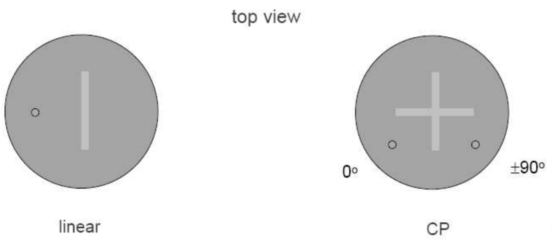

Figure 12(a): Miniaturization utilizing Slotted Patch

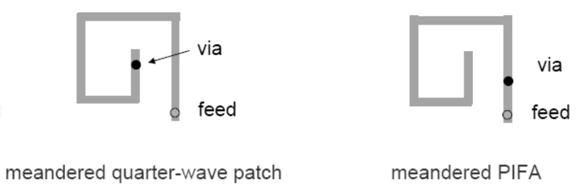

Figure 12(b): Miniaturization utilizing Meandering

In case of slotted patch the slot forces the current to flow through a longer path, increasing the effective dimensions of the patch. Miniaturization utilizing meandering is similar to slotted patch which forces the current to flow through a longer path hence increasing the effective dimensions of the patch.

d. Smart Antenna

A technique that has drawn the antenna researcher to apply in the communication engineering is the reconfigurable antennas. It is same as that of the conventional antennas but here one or more of the characteristics (specifications) can be adjusted or tuned using RF switches / MEMs or variable capacitor/inductor. This technique can be of four types namely (i) frequency reconfigurable enables efficient use of EM spectrum and reduction of interference (ii) polarization diversity leads to increase in the communication capacity (iii) Radiation pattern steering gives fading immunity (iv) any of the combination of the first three. The main advantage of this reconfigurable antenna is avoiding the use of multiple antennas.

Anther dimension of advance antenna system is the concept of smart antenna [18-20]. This type of antenna system automatically change the direction of its radiation pattern or any other characteristics like resonating frequency, polarization direction, antenna gain, antenna bandwidth, etc. in response to its surrounding signal environment. This smart antenna concept can spectacularly improve the performance of wireless systems.

CONCLUSION

There are many salient features of Microstrip antenna and obviously it is the choice of the designers. It is the property of nature that no advantage comes without a disadvantage. It is the work of the researchers to use the advantage and also think about the disadvantage for meeting the requirements. This paper gives insight how to meet the desired technical performance of Microstrip antenna particularly the issues connected to size reduction, bandwidth enhancement, polarization control. Research is all about trying new techniques or improving existing techniques to address problems. There is scope of further research and development in improving the performance of MSA.

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