Study of Radiation with Microstrip Patch antenna

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Abstract: *In this present paper we studied about radiation with microstrip patch antenna.In the early days of mobile communications, the case, being made of metal, was simply treated as a ground plane, because radiation currents flow on it as well as on the antenna element. Conventional antenna design uses image technique to provide the infinite ground plane. This theory is not possible while designing electrically small ground plane antennas. In the case of a whip type antenna, the ground plane can be treated as the other half of the dipole to the antenna. The characteristics of small antennas mounted on the handheld devices are get affected by the antenna position on the terminal chases and the dimensions of the chases due to the existence of radiating surface currents on the terminal ground plane induced by the antenna element.*

Keywords: **Antenna, Metal Strip Grating, Fabry-Perot Cavity, Microstripline.**

1. Introduction

In advanced wireless systems the antenna provides synthesized radiation characteristics depending up on the requirement of the communication equipment. In order to meet the particular requirement, it must take various forms. Wire antennas, reflector antennas, lens antennas, traveling wave antennas, frequency independent antennas, horn antennas and conformal antennas are used for different applications [1]. In addition antennas are also used in array configurations to improve the overall radiation characteristics.Soon after II word war, antenna technology witnessed drastic improvement in its impedance bandwidth as great as 40:1 or more. These wideband antennas had the geometries specified by angles instead of linear dimensions and they are referred to as frequency independent antennas [2]. The major applications of these wideband antennas include TV reception, point to point communication, and feed for reflectors. Patch antenna is invented almost twenty years later[3], which find many applications with much ease of fabrication compared to the earlier designs. The major attractions of these designs were easy integration with active components and various antenna characteristics such as gain, electronic control of radiation pattern etc. Major advances in millimeter wave antennas have been made in recent years including integrated antennas where active and passive circuits are combined with the radiating elements in one compact unit.

In conjunction with such recent trends in mobile communications as personalization, mobile terminals have advanced to be not only smaller, but also instrumental for acquiring various voice and non-voice information, without regard to time and place. In view of the progress of small mobile terminals, the design of antennas is acquiring great importance. The antennas are required to be small, and yet to have prescribed characteristics and performance, such as wide bandwidth, operation in dual or triple frequency bands, diversity, and so forth. In addition, further advanced design is required for improving the antenna's performance in recent, small mobile systems.The ground plane is the return path for the current in the system and its role in wireless communication devices is very much important. Therefore the design of an antenna with suitable ground plane is very much important.In the case of large antennas, the challenges in design are mainly to realize ultra-low side lobes, reduce EMI, achieve superior EMC characteristics etc. The modeling of the large antennas to predict its performance is another difficult task. Currently, commercial softwares are quite limited in their ability to handle the structures which require a problem description with a very large number of meshes because of their complexity, multiscale characteristics and homogeneous nature.

2.Planar Antenna Technologies

The demand for broadband antennas that are capable of supporting high data speeds and multiband operations of modern wireless communication systems have significantly increased. Commonly these systems need low-cost solutions with desired performance in terms of impedance bandwidth, polarization and gain. Planar antennas are playing important roles in various wireless communication applications owing to unique merits such as small volume or low profile, low manufacturing cost, and easy integration into planar circuits [4, 5]. The planar antennas can be usually be categorized in terms of radiation performance into microstrip patch antenna, Suspended Plate Antenna (SPA), planar inverted–L/F antenna and planar monopole/dipole antenna [6]. Generally the changes in such antenna design are from the specific requirements of applications. The microstrip patch antenna in its basic forms has a low profile, which is conductive to conformal design, but suffers narrow impedancebandwidth on order of 1 percent. In contrast, the planar monopoles usually have a high profile above a ground plane but enjoy broad bandwidth. Considering the antenna profile, impedance,and radiation performance, the SPAs are good option for fixed base stations in wireless communication systems, and planar monopole/dipoles for mobile wireless terminals.

3. Microstrip Antenna

A microstrip or patch antenna is a low profile antenna that has a number of advantages over other antennas. It is lightweight, inexpensive, and easy to integrate with accompanying electronics. While the antenna can be 3-D in structure. It can be wrapped around an object. The elements are usually flat; hence their other name. Therefore, the antenna is also called planar antennas. It may be noted that a planar antenna is not always a patch antenna. The patch antenna may be presented in its basic form. There is a flat plate over a ground plane. It is similar to a PC board. The center conductor of a coax serves as the feed probe to couple electromagnetic energy in the patch or it may serve to take energy out from the patch. The electric field distribution of a rectangular patch excited in its fundamental mode may be indicated as given in the figure no 1.

Conventionalmicrostrip antenna consists of a pair of parallel conducting layers separating a dielectric medium, referred as the substrate [7, 8]. In this configuration, the upper conducting layer or patch is the source of radiation where electromagnetic energy fringes off the edges of the patch and into the substrate. This patch is fed with a microstrip transmission line. The lower conducting layer acts as a perfectly reflecting ground plane, bouncing energy back through the substrate and into free space. Physically, the patch is a thin conductor that is an appreciable fraction of a wavelength in extent, parallel to a ground plane and a small fraction of a wavelength above the ground plane. The patch will radiate effectively if the length of the patch is typically about a half guide-wavelength in size. In most practical applications, patch antennas are rectangular or circular in shape; however, in general, any geometry is possible. The large antenna quality factor, Q, of the microstrip antenna leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. So the thickness of the substrate is of considerable importance when designing microstrip antennas. The most desirable substrates for antenna performance are the ones that are thick with a low dielectric constant.

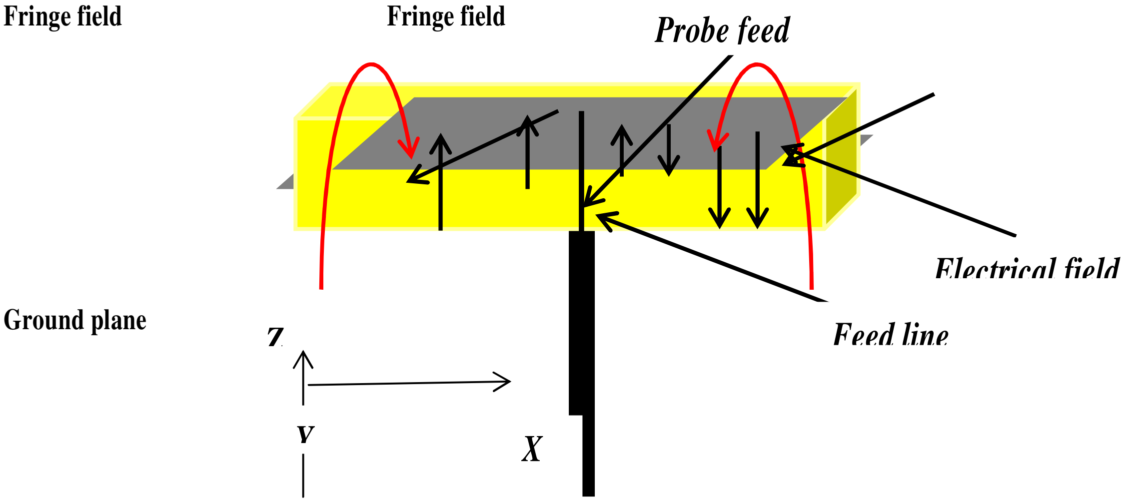

Figure no 1: Microstrip Patch Radiator.

This results in an antenna with a large bandwidth and high efficiency due to the loosely bounded fringing fields that originate from the patch and propagate into the substrate. However, this comes at the expense of a large volume antenna and an increased probability of surface wave formation. On the other hand, thin substrates with high dielectric constant reduce the overall size of the antenna and are compatible with MMIC devices, since the fringing fields are tightly bound to the substrate. With thin substrates, coupling and electromagnetic interference (EMI) issues are less prone.

However, because of the relatively higher loss tangents (dissipation factors), they are less efficient and has relatively smaller bandwidth. Therefore, there is a fundamental tradeoff that must be evaluated in the initial stages of the microstrip antenna design, to obtain loosely bound fields to radiate into the free space, while keeping the fields tightly bound for the feeding circuitry. In this research work the main focus has been given on explaining the general properties of patch antennas by using the simple rectangular probe fed patch. It would cover the topics including: Principles of operation, impedance matching, radiation pattern and related aspects, Bandwidth and efficiency.

The electric field is zero at the center of the patch, maximum (positive) at one side, and minimum (negative) on the opposite side. It should be mentioned that the minimum and Maximum continuously change side according to the instantaneous phase of the applied signal. The electric field does not stop abruptly at the patch's periphery as in a cavity; rather, the fields extend the outer periphery to some degree. These field extensions are known as fringing fields and cause the patch to radiate. Some popular analytic modeling techniques for patch antennas are based on this leaky cavity concept. Therefore, the fundamental mode of a rectangular patch is often denoted using cavity theory as the TM10 mode. Since this notation frequently causes confusion, we will briefly explain it. TM stands for transversal magnetic field distribution. This means that only three field components are considered instead of six. The field components of interest are the electric field in the z direction and the magnetic field components in x and y direction using a Cartesian coordinate system, where the x and y axes are parallel with the ground plane and the z-axis is perpendicular. In general, the modes are designated as TMnmz. The z value is mostly omitted since the electric field variation is considered negligible in the z-axis. Hence TMnm remains with n and m the field variations in x and y direction. The field variation in the y direction (impedance width direction) is negligible; thus m is 0. And the field has one minimum-to-maximum variation in the x direction (resonance length direction); thus n is 1 in the case of the fundamental. Hence the notation TM10. Dimensions The resonant length determines the resonant frequency and is about$\lambda/2$ for a rectangular patch excited in its fundamental mode. The patch is, in fact, electrically a bit larger than its physical dimensions due to the fringing fields. The deviation between electrical and physical size is mainly dependent on the PC board thickness and dielectric constant. A better approximation for the resonant length is:

$$L \approx 0.49\ \lambda_d = 0.49\ \frac{\lambda_0}{\sqrt{\varepsilon_r}}\ . \tag{1}$$

This formula includes a first order correction for the edge extension due to the fringing fields, with:

L = resonant length

λ_d = wavelength in PC board

λ_0 = wavelength in free space

εr = dielectric constant of the PC board material her parameters that will influence the resonant frequency:

Ground plane size Metal (copper) thickness Patch (impedance) width impedance Matching Looking at the current (magnetic field) and voltage (electrical field) variation along the patch, the current is maximal at the center and minimal near the left and right edges, while the electrical field is zero in the center and maximal near the left and minimal near the right edges. The figures below clarify these quantities.

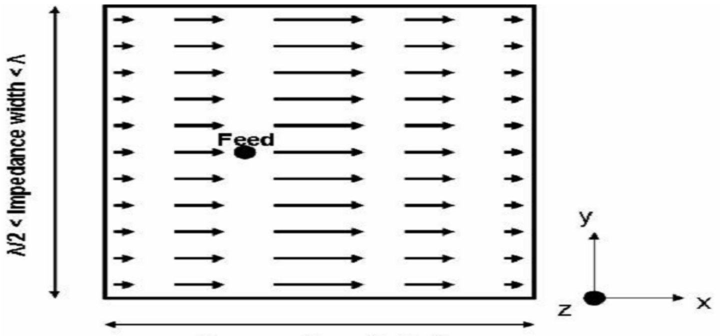

Figure no 2.Resonant length = ± λ/2The current distribution on the patch surface.

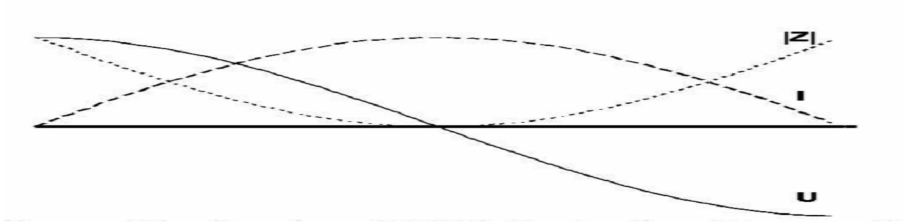

Figure no 3.Voltage U, Current I and Impedance Z distribution along the patch resonant length

From the magnitude of the current and the voltage, we can conclude the impedance is minimum (theoretically zero) in the middle of the patch and maximum (typically around 200, but depending on the Q of the leaky cavity) near the edges. Put differently, there is a point where the impedance is 50 somewhere along the "resonant length" (x) axis of the element. Fundamental Specifications of Patch Antennas Radiation Pattern. The patch's radiation at the fringing fields results in a certain far field radiation pattern. This radiation pattern shows that the antenna radiates more power in a certain direction than another direction. The antenna is said to have certain directivity. This is commonly expressed in dB. An estimation of the expected directivity of a patch can be derived with ease. The fringing fields at the radiating edges can be viewed as two radiating slots placed above a ground plane. Assuming all radiation occurs in one half of the hemisphere, this results in 3 dB directivity. This case is often described as a perfect front-to-back ratio; all radiation towards the front and no radiation towards the back. This front-to-back ratio is highly dependent on ground plane size and shape in practical cases. Another 3 dB can be added since there are 2 slots. The slots are typically taken to have a length equal to the impedance width (length according to the y-axis) of the patch and a width equal to the substrate height. Such a slot typically has a gain of about 2 to 3 dB results in a total gain of 8 to 9 dB.

Splitting the signal in half can be done with a Wilkinson power divider or similar splitter. If a square patch is fed with two feed points as depicted in the figure below, a vertical and a horizontal radiator are created concurrently. By creating the 90° delay in one of the signal lines and connecting each signal to one feeding pin of the patch, a circularly polarized antenna is created.

The co-polar radiation pattern is the radiation pattern of the wanted polarization, and the cross polar radiation pattern is the radiation pattern of the unwanted opposite polarization. Bandwidth Another important parameter of any antenna is the bandwidth it covers. Only impedance bandwidth is specified most of the time. However, it is important to realize that several definitions of bandwidth exist -- impedance bandwidth, directivity bandwidth, polarization bandwidth, and efficiency bandwidth. Directivity and efficiency are often combined as gain bandwidth. Impedance bandwidth/return loss bandwidth This is the frequency range wherein the structure has a usable bandwidth compared to a certain impedance, usually 50.Ohm.

The impedance bandwidth depends on a large number of parameters related to the patch antenna element itself e.g., quality factor) and the type of feed used. The plot below shows the return loss of a patch antenna and indicates the return loss bandwidth at the desired S11/VSWR (S11 wanted/VSWR wanted). The bandwidth is typically limited to a few percent. This is the major disadvantage of basic patch antennas. Several techniques to improve the bandwidth exist, but these are beyond the scope of this article.

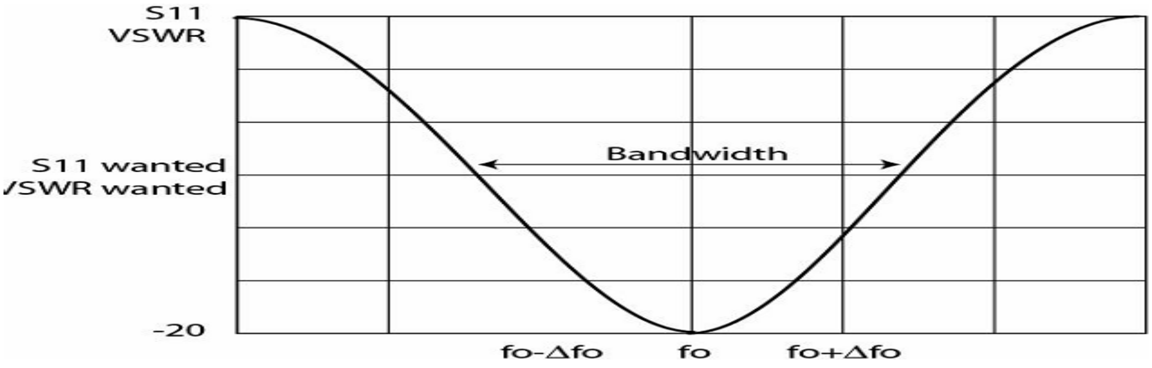

Figure no 4.

4. Conclusions

In this article, the basic properties of linear and circular polarized patch antennas have been covered. We defined a basic set of specifications that allow the user to understand and write a set of requirements for a specific application. Besides the ones covered here, many more design options and different implementations of patch antennas are available. Coverage of these alternatives is beyond the scope of this article, but they should be considered during the specification and development phases of the antenna.

References

[1] Christos G. Christodoulou, Parveen F. Wahid, ―Fundamentals of Antennas: Concepts and Applications,‖ SPIE Press, 2001

[2] Sterling, Christopher and George Shiers (Eds). History of Telecommunications Technology: An Annotated Bibliography (Lanham, MD: Scarecrow, 2000).

[3] V. H. Rumsey, Frequency Independent Antennas, 1957 IRE National Convention Record, Part 1, pp. 114-118.

[4] G. A. Deschamps, Microstrip microwave Antennas, presented at the Third USAF symposium on Antennas, 1953.

[5] Tapan K. Sarkar, History of Wireless, Wiley-IEEE Press, 2006.

[6] Sheng-Bing Chen, Yong-Chang Jiao, Wei Wang, and Fu-Shun Zhang, ―Modified T-Shaped Planar Monopole Antennas for Multiband Operation,‖ IEEE Trans. Antennas and Propagat., vol.54, pp. 3267-3270,2006

[7] Shaoqiu Xiao, Bing-Zhong Wang, Wei Shao, and Yan Zhang, ―BandwidthEnhancing Ultralow-Profile Compact Patch Antenna,‖ IEEE Trans. Antennas and Propagat., vol.53, pp. 3443-3447,2005

[8] Z. N. Chen and M. Y. W. Chia, Broadband Planar Antennas: Design and Applications(New York: John Wiley & sons, Inc. 2006).