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Study of Microstrip Patch Antenna Using Planar Antenna Technologies

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ABSTRACT

In this present paper we studied about study of microstrip patch antenna using planar antenna technologies. 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. Generally, the changes in such antenna design are from the specific requirements of applications.

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

I. INTRODUCTION

In this work we aim at showing that, when an electric dipole parallel to the strips is used as an excitation, azimuthally omnidirectional pencil beams pointing at broadside or nearly omnidirectional conical beams scanned off broadside can be produced with excellent polarization properties. For the usual FPC structures nearly omnidirectional pencil beams at broadside can be produced, but the degree of Omni directionality degrades rapidly as the beam is scanned away from broadside to become a conical beam.

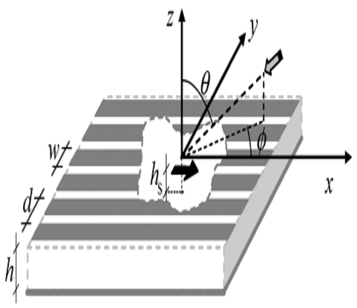

Fig. 1. Metal strip grating above a ground plane

Metal strip grating above the ground plane is excited by a horizontal electric dipole, with the relevant physical and geometric parameters; also shown is a uniform plane wave incident from the direction, used in the calculation of the far field radiated by the dipole based on reciprocity. This was among the first leaky-wave antennas, proposed by Honey in the 1950s [1-5]. It is similar in geometry, but very different in operating principle, from periodic leaky wave antennas that also use MSGs but radiate from the space harmonic [6, 7]. We would like to stress that the leaky wave excited in this structure radiates through the fundamental spatial harmonic of the periodic structure. the structure is thus in the category of a quasi-uniform leaky-wave antenna, which is physically periodic but acts as a uniform structure. We recall that there is another class of leaky-wave antennas based on using a guiding structure with periodic perturbations spaced on the order of a wavelength apart, radiating from the space harmonic. These are referred to as periodic leaky-wave antennas.

The model is based on the use of a transverse equivalent network (TEN) to represent the fields in the FPC structure. This is useful to derive and explain the peculiar features of the analyzed structure. For periodic leaky-wave antennas that radiate from a higher-order space harmonic [8-10] the period is not small relative to a wavelength and such a homogenization is not possible.

II. 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 [9]. 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 [10]. 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 impedance bandwidth 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. A verity of techniques has long been developed to further enhance the broadband performance of the SPAs and planar monopoles. Due to the merits of acceptable performance, low profile and in particular low manufacturing cost, the SPAs and planar monopoles have widely been applied in high-speed wireless communication systems.

III. 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.

Conventional microstrip antenna consists of a pair of parallel conducting layers separating a dielectric medium, referred as the substrate [11]. 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. 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.

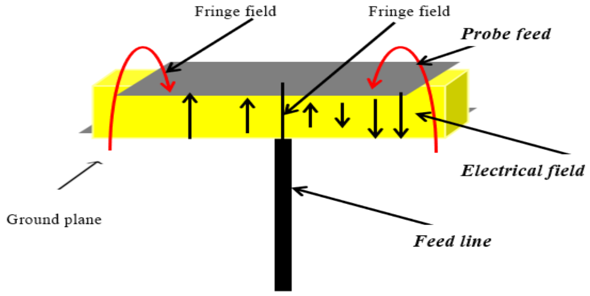

Fig. 2. Microstrip patch radiator

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 λ/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:

$$L \approx 0.49\ \lambda_d = 0.49\ \frac{\lambda_0}{\sqrt{\varepsilon_r}}. \qquad \text{------------------------1}$$

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

ε_r = 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.

IV. CONCLUSIONS

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.

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