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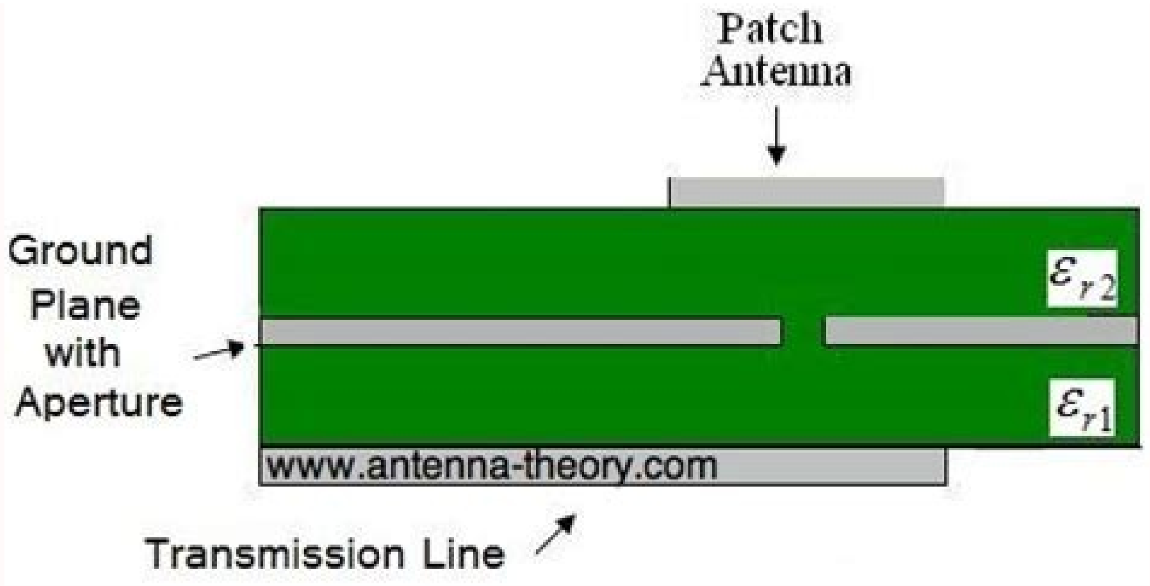

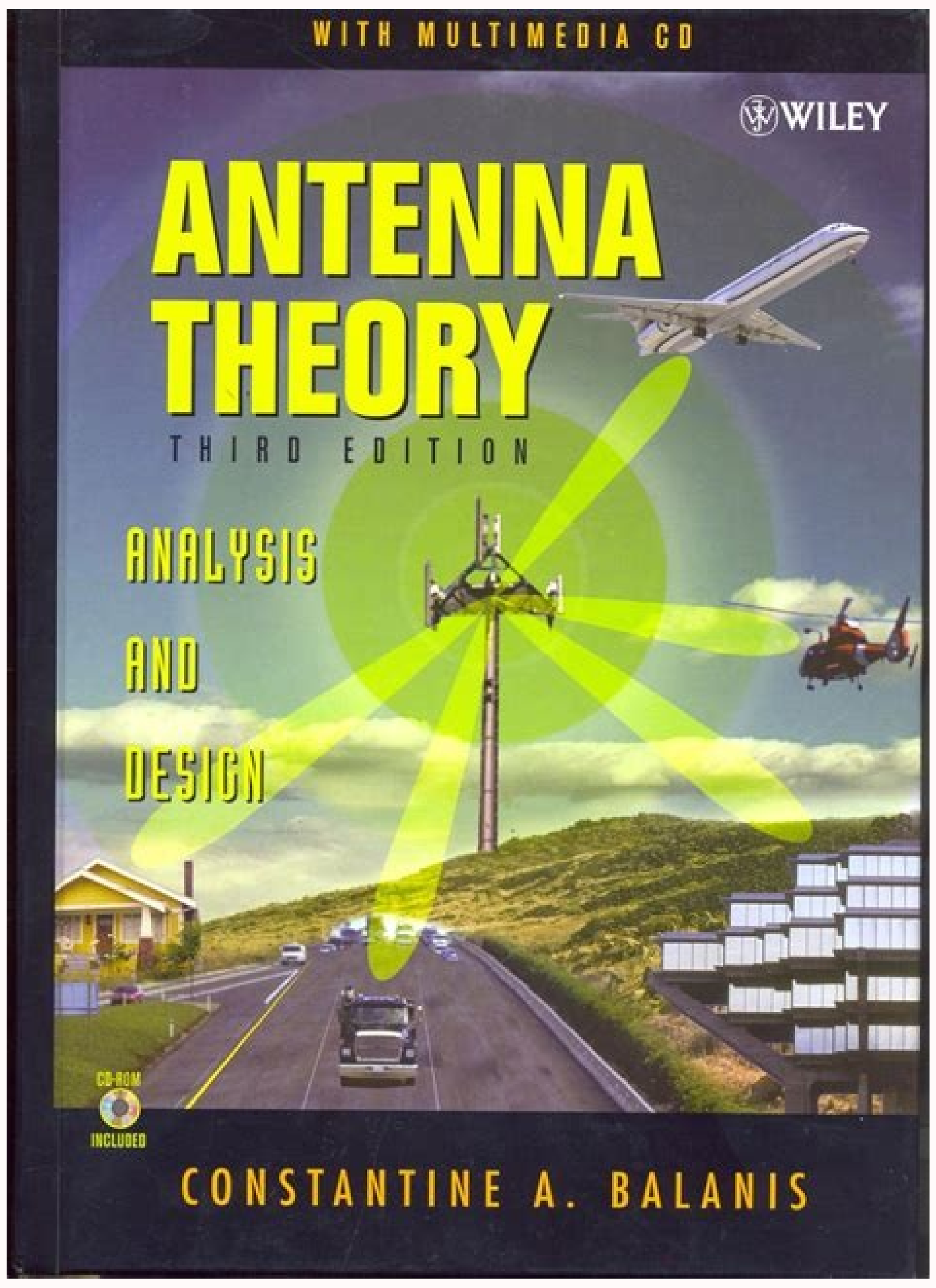

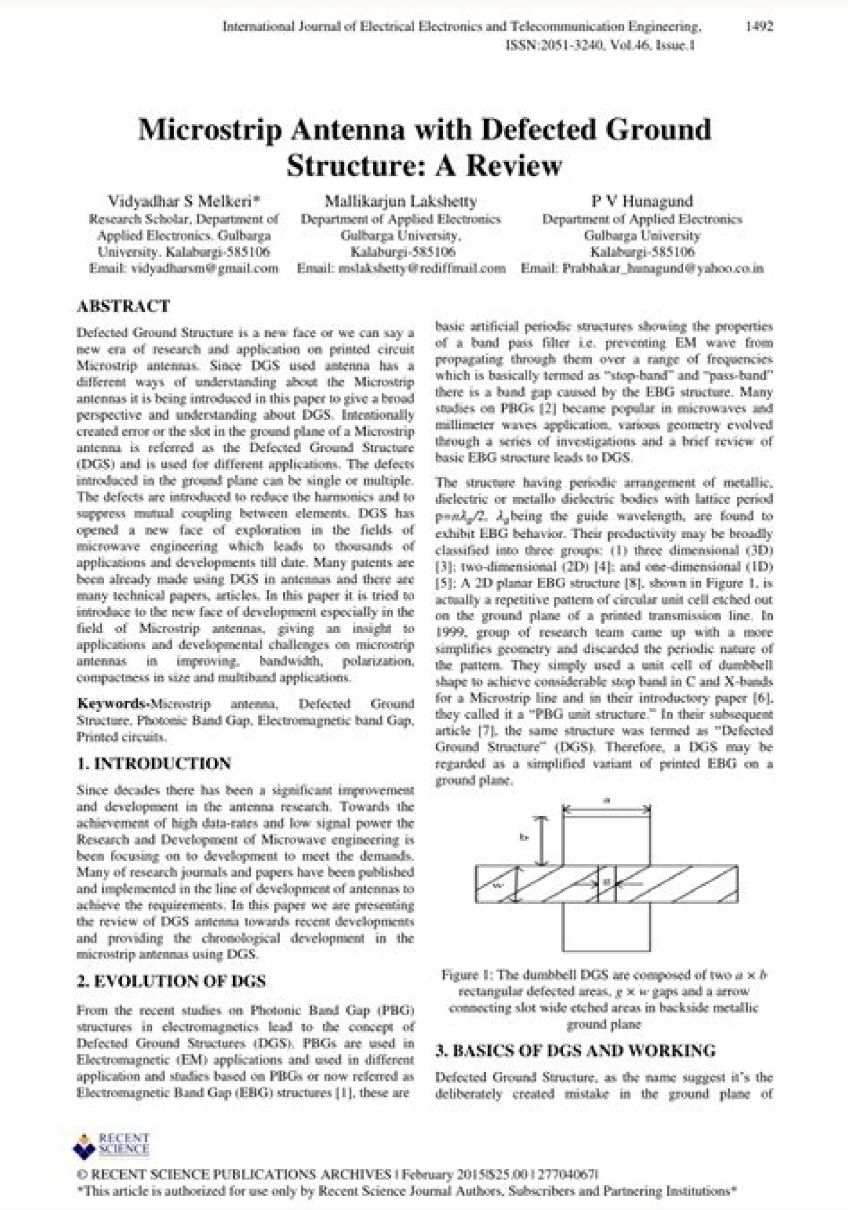
International Journal of Electrical Electronics and Telecommunication Engineering, 1492
ISSN:2051-3240, Vol.46, Issue.1

Microstrip Antenna with Defected Ground Structure: A Review

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ABSTRACT

Defected Ground Structure is a new face or we can say a new era of research and application on printed circuit Microstrip antennas. Since DGS used antenna has a different ways of understanding about the Microstrip antennas it is being introduced in this paper to give a broad perspective and understanding about DGS. Intentionally created error or the slot in the ground plane of a Microstrip antenna is referred as the Defected Ground Structure (DGS) and is used for different applications. The defects introduced in the ground plane can be single or multiple. The defects are introduced to reduce the harmonics and to suppress mutual coupling between elements. DGS has opened a new face of exploration in the fields of microwave engineering which leads to thousands of applications and developments till date. Many patents are been already made using DGS in antennas and there are many technical papers, articles. In this paper it is tried to introduce to the new face of development especially in the field of Microstrip antennas, giving an insight to applications and developmental challenges on microstrip antennas in improving, bandwidth, polarization, compactness in size and multiband applications.

Keywords-Microstrip antenna, Defected Ground Structure, Photonic Band Gap, Electromagnetic band Gap, Printed circuits.

1. INTRODUCTION

Since decades there has been a significant improvement and development in the antenna research. Towards the achievement of high data-rates and low signal power the Research and Development of Microwave engineering is been focusing on to development to meet the demands. Many of research journals and papers have been published and implemented in the line of development of antennas to achieve the requirements. In this paper we are presenting the review of DGS antenna towards recent developments and providing the chronological development in the microstrip antennas using DGS.

2. EVOLUTION OF DGS

From the recent studies on Photonic Band Gap (PBG) structures in electromagnetics lead to the concept of Defected Ground Structures (DGS). PBGs are used in Electromagnetic (EM) applications and used in different application and studies based on PBGs or now referred as Electromagnetic Band Gap (EBG) structures [1], these are basic artificial periodic structures showing the properties of a band pass filter i.e. preventing EM wave from propagating through them over a range of frequencies which is basically termed as "stop-band" and "pass-band" there is a band gap caused by the EBG structure. Many studies on PBGs [2] became popular in microwaves and millimeter waves application, various geometry evolved through a series of investigations and a brief review of basic EBG structure leads to DGS.

The structure having periodic arrangement of metallic, dielectric or metallo dielectric bodies with lattice period $p=n\lambda_g/2$, λ_g being the guide wavelength, are found to exhibit EBG behavior. Their productivity may be broadly classified into three groups: (1) three dimensional (3D) [3]; two-dimensional (2D) [4]; and one-dimensional (1D) [5]; A 2D planar EBG structure [8], shown in Figure 1, is actually a repetitive pattern of circular unit cell etched out on the ground plane of a printed transmission line. In 1999, group of research team came up with a more simplifies geometry and discarded the periodic nature of the pattern. They simply used a unit cell of dumbbell shape to achieve considerable stop band in C and X-bands for a Microstrip line and in their introductory paper [6], they called it a "PBG unit structure." In their subsequent article [7], the same structure was termed as "Defected Ground Structure" (DGS). Therefore, a DGS may be regarded as a simplified variant of printed EBG on a ground plane.

Figure 1: The dumbbell DGS are composed of two $a \times b$ rectangular defected areas, $g \times w$ gaps and a arrow connecting slot wide etched areas in backside metallic ground plane

3. BASICS OF DGS AND WORKING

Defected Ground Structure, as the name suggest it's the deliberately created mistake in the ground plane of

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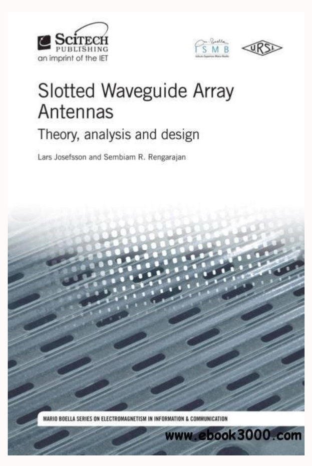

Microstrip slot antenna theory. Microstrip dipole antenna theory. Microstrip antenna theory and design pdf. Microstrip antenna theory and design. Antenna theory and microstrip antennas pdf. Microstrip patch antenna theory pdf. Working principle of microstrip antenna. Microstrip antenna characteristics.

Antennas List Antenna Theory (Home) Introduction to Patch Antennas Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. Consider the microstrip antenna shown in Figure 1, fed by a microstrip transmission line. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper). The patch is of length L, width W, and sitting on top of a substrate (some dielectric circuit board) of thickness h with permittivity . The thickness of the ground plane or of the microstrip is not critically important. Typically the height h is much smaller than the wavelength of operation, but should not be much smaller than 0.025 of a wavelength (1/40th of a wavelength) or the antenna efficiency will be degraded. (a) Top View of Patch Antenna (b) Side View of Microstrip Antenna Figure 1. Geometry of Microstrip (Patch) Antenna. The frequency of operation of the patch antenna of Figure 1 is determined by the length L. The center frequency will be approximately given by: The above equation says that the microstrip antenna should have a length equal to one half of a wavelength within the dielectric (substrate) medium. The width W of the microstrip antenna controls the input impedance. Larger widths also can increase the bandwidth. For a square patch antenna fed in the manner above, the input impedance will be on the order of 300 Ohms. By increasing the width, the impedance can be reduced. However, to decrease the input impedance to 50 Ohms often requires a very wide patch antenna, which takes up a lot of valuable space. The width further controls the radiation pattern. The normalized radiation pattern is approximately given by: In the above, k is the free-space wavenumber, given by . The magnitude of the fields, given by: The fields of the microstrip antenna are plotted in Figure 2 for W=L=0.5. Figure 2. Normalized Radiation Pattern for Microstrip (Patch) Antenna. The directivity of patch antennas is approximately 5-7 dB. The fields are linearly polarized, and in the horizontal direction when viewing the microstrip antenna as in Figure 1a (we'll see why in the next section). Next we'll consider more aspects involved in Patch (Microstrip) antennas. Consider a square patch antenna fed at the end as before in Figure 1a. Assume the substrate is air (or styrofoam, with a permittivity equal to 1), and that L=W=1.5 meters, so that the patch is to resonate at 100 MHz. The height h is taken to be 3 cm. Note that microstrips are usually made for higher frequencies, so that they are much smaller in practice. When matched to a 200 Ohm load, the magnitude of S11 is shown in Figure 3. Figure 3. Magnitude of S11 versus Frequency for Square Patch Antenna. Some noteworthy observations are apparent from Figure 3. First, the bandwidth of the patch antenna is very small. Rectangular patch antennas are notoriously narrowband; the bandwidth of rectangular microstrip antennas are typically 3%. Secondly, the microstrip antenna was designed to operate at 100 MHz, but it is resonant at approximately 96 MHz. This shift is due to fringing fields around the antenna, which makes the patch seem longer. Hence, when designing a patch antenna it is typically trimmed by 2-4% to achieve resonance at the desired frequency. The fringing fields around the antenna can help explain why the microstrip antenna radiates. Consider the side view of a patch antenna, shown in Figure 4. Note that since the current at the end of the patch is zero (open circuit end), the current is maximum at the center of the half-wave patch and (theoretically) zero at the beginning of the patch. This low current value at the feed explains in part why the impedance is high when fed at the end (we'll address this again later). Since the patch antenna can be viewed as an open circuited transmission line, the voltage reflection coefficient will be 1 (see the transmission line tutorial for more information). When this occurs, the voltage and current are out of phase. Hence, at the end of the patch the voltage is at a maximum (say +V volts). At the start of the patch antenna (a half-wavelength away), the voltage must be at minimum (-V Volts). Hence, the fields underneath the patch will resemble that of Figure 4, which roughly displays the fringing of the fields around the edges. Figure 4. Side view of patch antenna with E-fields shown underneath. It is the fringing fields that are responsible for the radiation. Note that the fringing fields near the surface of the patch antenna are both in the +y direction. Hence, the fringing E-fields on the edge of the microstrip antenna add up in phase and produce the radiation of the microstrip antenna. This paragraph is critical to understanding the patch antenna. The current adds up in phase on the patch antenna as well; however, an equal current but with opposite direction is on the ground plane, which cancels the radiation. This also explains why the microstrip antenna radiates but the microstrip transmission line does not. The microstrip antenna's radiation arises from the fringing fields, which are due to the advantageous voltage distribution; hence the radiation arises due to the voltage and not the current. The patch antenna is therefore a "voltage radiator", as opposed to the wire antennas, which radiate because the currents add up in phase and are therefore "current radiators". As a side note, the smaller is, the more "bowed" the fringing fields become; they extend farther away from the patch. Therefore, using a smaller permittivity for the substrate yields better radiation. In contrast, when making a microstrip transmission line (where no power is to be radiated), a high value of is desired, so that the fields are more tightly contained (less fringing), resulting in less radiation. This is one of the trade-offs in patch antenna design. There have been research papers written were distinct dielectrics (different permittivities) are used under the patch antenna and transmission line sections, to circumvent this issue. Next, we'll look at alternative methods of feeding the microstrip antenna (connecting the antenna to the receiver or transmitter). Next: Feeding Methods for Patch Antennas Top: Introduction to Microstrip Antennas Antennas List Antenna Theory Page This page on microstrip antennas and patch antennas is copyrighted. It can be reproduced without permission from the author as long as the source is referenced. Copyright 2011-2021, antenna-theory.com. Patch antennas, microstrip antennas. Also called an aerial, an antenna is a conductor that can transmit, send and receive signals such as microwave, radio or satellite signals. A high-gain antenna increases signal strength, where a low-gain antenna receives or transmits over a wide angle. A microstrip antenna array for a satellite television receiver. Diagram of the feed structure of a microstrip antenna array. In telecommunication, a microstrip antenna (also known as a printed antenna) usually means an antenna fabricated using photolithographic techniques on a printed circuit board (PCB).[1] It is a kind of internal antenna. They are mostly used at microwave frequencies. An individual microstrip antenna consists of a patch of metal foil of various shapes (a patch antenna) on the surface of a PCB (printed circuit board), with a metal foil ground plane on the other side of the board. Most microstrip antennas consist of multiple patches in a two-dimensional array. The antenna is usually connected to the transmitter or receiver through foil microstrip transmission lines. The radio frequency current is applied (or in receiving antennas the received signal is produced) between the antenna and ground plane. Microstrip antennas have become very popular in recent decades due to their thin planar profile which can be incorporated into the surfaces of consumer products, aircraft and missiles; their ease of fabrication using printed circuit techniques; the ease of integrating the antenna on the same board with the rest of the circuit, and the possibility of adding active devices such as microwave integrated circuits to the antenna itself to make active antennas [2] Patch antenna The most common type of microstrip antenna is commonly known as patch antenna. Antennas using patches as constitutive elements in an array are also possible. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Some patch antennas do not use a dielectric substrate and instead are made of a metal patch mounted above a ground plane using dielectric spacers; the resulting structure is less rugged but has a wider bandwidth. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices. Advantages Microstrip antennas are relatively inexpensive to manufacture and design because of the simple 2-dimensional physical geometry. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency. A single patch antenna provides a maximum directive gain of around 6–9 dBi. It is relatively easy to print an array of patches on a single (large) substrate using lithographic techniques. Patch arrays can provide much higher gains than a single patch at little additional cost; matching and phase adjustment can be performed with printed microstrip feed structures, again in the same operations that form the radiating patches. The ability to create high gain arrays in a low-profile antenna is one reason that patch arrays are common on airplanes and in other military applications. Such an array of patch antennas is an easy way to make a phased array of antennas with dynamic beamforming ability.[3] An advantage inherent to patch antennas is the ability to have polarization diversity. Patch antennas can easily be designed to have vertical, horizontal, right hand circular (RHCP) or left hand circular (LHCP) polarizations,[4] using multiple feed points, or a single feedpoint with asymmetric patch structures.[5] This unique property allows patch antennas to be used in many types of communications links that may have varied requirements. Rectangular patch The most commonly employed microstrip antenna is a rectangular patch which looks like a truncated microstrip transmission line. It is approximately of one-half wavelength long. When air is used as the dielectric substrate, the length of the rectangular microstrip antenna is approximately one-half of a free-space wavelength. As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases. The resonant length of the antenna is slightly shorter because of the extended electric "fringing fields" which increase the electrical length of the antenna slightly. An early model of the microstrip antenna is a section of microstrip transmission line with equivalent loads on either end to represent the radiation loss. Specifications The dielectric loading of a microstrip antenna affects both its radiation pattern and impedance bandwidth. As the dielectric constant of the substrate increases, the antenna bandwidth decreases which increases the Q factor of the antenna and therefore decreases the impedance bandwidth. This relationship did not immediately follow when using the transmission line model of the antenna, but is apparent when using the cavity model which was introduced in 1973 by Itoh and Mittra [6] The radiation from a rectangular microstrip antenna may be understood as a pair of equivalent slots. These slots act as an array and have the highest directivity when the antenna has an air dielectric and decreases when it is replaced by a dielectric substrate with increasing relative permittivity. The half-wave rectangular microstrip antenna has a virtual shorting plane along its center. This may be replaced with a physical shorting plane to create a quarter-wavelength microstrip antenna. This is sometimes called a half-patch. The antenna only has a single radiation edge (equivalent slot) which lowers the directivity/gain of the antenna. The impedance bandwidth is slightly lower than a half-wavelength full patch as the coupling between radiating edges has been eliminated. Other types Another type of patch antenna is the planar inverted-F antenna (PIFA). The PIFA is common in cellular phones (mobile phones) as a built-in structure.[7][8] These antennas are derived from a quarter-wave half-patch antenna. The shorting plane of the half-patch is reduced in length which decreases the resonance frequency.[9] It offers a low profile and also with acceptable SAR properties. This antenna resembles an inverted F, which explains the PIFA name. It is popular as a compact antenna with an omnidirectional pattern.[10] Often PIFA antennas have multiple branches to resonate at the various cellular bands. On some phones, grounded parasitic elements are used to enhance the radiation bandwidth characteristics. The folded inverted conformal antenna (FICA)[11] has some advantages with respect to the PIFA, because it allows better volume reuse. Defected Ground Structure (DGS)-integrated microstrip patch has been popular for multiple purposes. This technique introduces a limited number of small-sized slots, termed as 'defects' on the ground plane beneath the patch, and is potentially capable of improving its far-field as well as near-field properties. This was conceived and introduced in 2005 by Guha[12] to control the cross-polarized radiations without involving any extra component, volume, weight, or cost. The technique is advanced enough to reduce cross-polarized radiations even over the diagonal-planes of a microstrip patch. DGS-technique is equally effective in reducing the mutual coupling in large microstrip arrays and hence mitigating the scan blindness issue of the radar beams.[13][14] The DGS technique is found to be highly attractive in air-borne applications. See also Rectenna References ^ Lee, Kai Fong; Luk, Kwai Man (2017). Microstrip Patch Antennas. World Scientific. pp. 8–12. ISBN 978-981-3208-61-2. ^ Pandey, Anil (2019). Practical Microstrip and Printed Antenna Design. Bostan: Artech House. p. 443. 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