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A Review of Defected Ground Structure for Microstrip Antennas

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Abstract - ***In antenna theory and design, Microstrip antennas have been one of the most innovative topics and are increasingly finding application in government and commercial applications, such as mobile radio and wireless communications, microwave communication and millimeter wave communication. Also Microwave components such as filters, couplers, antennas etc. The microstrip technology is used in high performance aircraft, spacecraft, satellite and missiles where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints. Therefore we need compact and high performance microwave components. Defected ground structures (DGS) have been developed to improve characteristics of many microwave devices.This paper focuses on a tutorial overview of defected ground structure (DGS) and the recent developments in distributed circuit design that offers improved performance in many filter and antenna applications.***

Key Words: *Defected Ground Structure, Microstrip Antennas.*

1. INTRODUCTION

The microstrip technology consists of a microstrip transmission line made of conducting material on one side of a dielectric substrate which has a ground plane on the other side. Presently, there have been some new technologies such as Low-temperature co-fire ceramic technology (LTCC), Low-temperature co-fire ferrite (LTCF) and some new structures such as Photonic band gap (PBG), DGS, Substrate integrate wave-guide (SIW) and so on to enhance the whole quality of system. From these techniques defected ground structure (DGS) and As per Yang F and Ramat Sammi, the Electromagnetic band gap (EBG) structures generally known as the photonic band gap structures (PBG) [1] are two different type of generic structures used for the design of the compact and high performance microwave components.

As per YABLONOVITCH, E. , Wave propagation in periodic structures has been studied in applied physics for a long time [2]. In 1987, Yablonovitch and John proposed PBG [3, 4] which implodes and utilizes metallic ground plane, and breaks traditional microwave circuit confined design to surface components and distributions of the medium circuit plane. PBG is a periodic structure which provides rejection of certain frequency band and slow wave effect. Guida, G., A. de Lustrac, and A. Priou have state that interest of PBG in microwave and millimeter wave has been increased [5]. However, it is difficult to use a PBG structure for the design of the microwave or millimeter-wave components due to the difficulties of modeling. Another difficulty in using the PBG circuit is caused by the radiation from the periodic etched defects. Also a steep and wideband filter design by a PBG requires higher size of the circuit due to an array configuration of PBG cells. Fine-tuning of the stopband is also difficult. There are so many design parameters that effect on the band gap property, such as the number of lattice, lattice shapes, lattice spacing and relative volume fraction. DGS is an etched periodic or non-periodic cascaded configuration defect in ground of a planar transmission line (e.g., microstrip, coplanar and conductor backed coplanar wave guide).

2. DEFECTED GROUND STRUCTURE

DGS can be classified as shown in figeure1 below. Defected ground structure or DGS, enhances the performance of the system by intentionally modifying the ground plane metal of microstrip (or stripline, or coplanar waveguide) circuit. DGS is realized by etching off a simple shape in the ground plane which is called as “defect”. Various shapes and dimensions of the defect, disturbs the shielded current distribution in the ground plane, which results in a controlled excitation and propagation of the electromagnetic waves through the substrate layer. This disturbance will also change characteristics of a transmission line such as line capacitance and inductance. In a word, any defect etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance. The shape of the defect may be changed from the simple shape to the complicated shape for the better performance. Depending on configuration and shape of defect the

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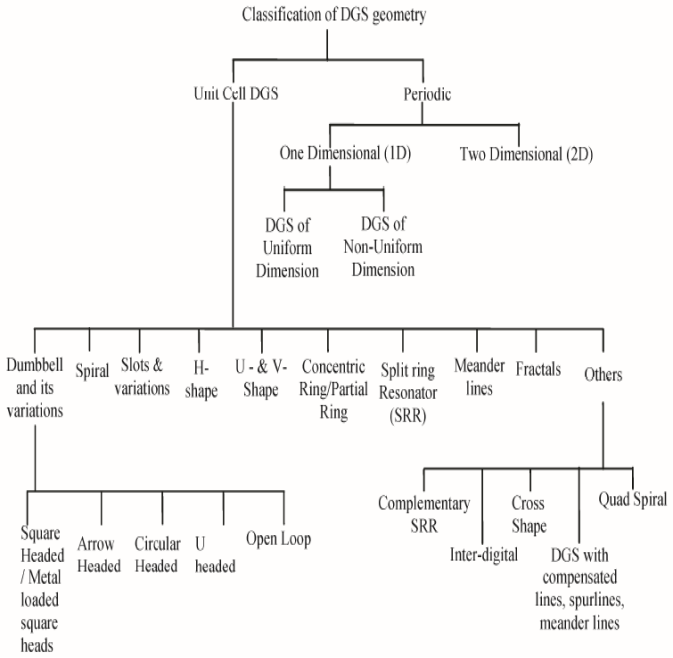

Fig -1: Classification of DGS

As per Debatsh Guha and Yahia M.M. Antar The use of various DGS geometries, such as rectangular, circular, square, dumbbell, spiral, L-shaped, concentric ring, U-shaped and V-shaped, hairpin DGS, hexagonal, cross shaped, arrow head slot, interdigital DGS etc has been reported [6]. As per Roy, the dumbbell shaped DGS pattern is easy to design and simple. So in many microwave circuits the dumbbell shaped DGS pattern is mostly used.[7].

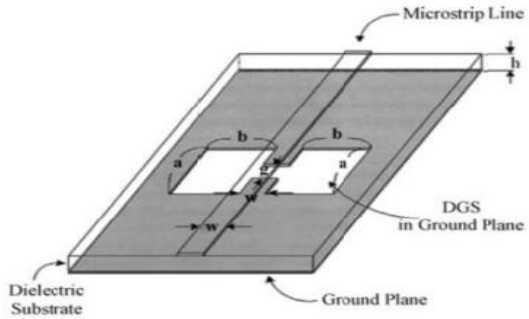

Fig -1: Dumbell Shaped DGS

Figure.2 shows the structure of the Dumbbell shaped DGS etched on the metallic ground plane of a microstrip line [8]. It consists of two rectangular slots of dimension a x b connected by a narrow slot of dimension g x w thereby resembling a dumbbell [9].

2.1 Photonic Band Gap Structure and Defected Ground Structure

The difference between the PBG and DGS is shown in the table (1).

Table -1: PBG vs. DGS

	Photonic Band Gap Structure	Defected Ground Structure
Geometry	Periodic Etched Structure	One or Few EtchedStructure
Microwave Circuit Properties	Similar	Similar
Equivalent Circuit Exaction	Very Difficult	Relatively Simple

The PBG modifies the properties such as characteristic impedance and propagation constant of the microstrip line. Defected Ground Structure (DGS) is an etched lattice shape (slot), which locates on the ground plane. It is motivated by a study of PBG to change guided wave properties. DGS makes one or a few of PGB etched ground elements in the ground plane .The shape of slot is modified from a simple hole to a more complicated shape. The DGS structure may be found in both one-dimensional and two dimensional forms.

2.2 DGS Element Characteristics

The basic element of DGS is a resonant gap or slot in the ground metal, which is placed directly under a transmission line and aligned for efficient coupling to the line. Figure 3 shows several resonant structures that may be used. Each one differs in occupied area, equivalent L-C ratio, coupling coefficient, higher-order responses, and other electrical parameters. A user will select the structure that works best for the particular application.

The equivalent circuit for a DGS is a parallel- tuned circuit in series with the transmission line to which it is coupled

as shown in figure 4.. The input and output impedances are that of the line section, while the equivalent values of L, C and R are determined by the dimensions of the DGS structure and its position relative to the transmission line.

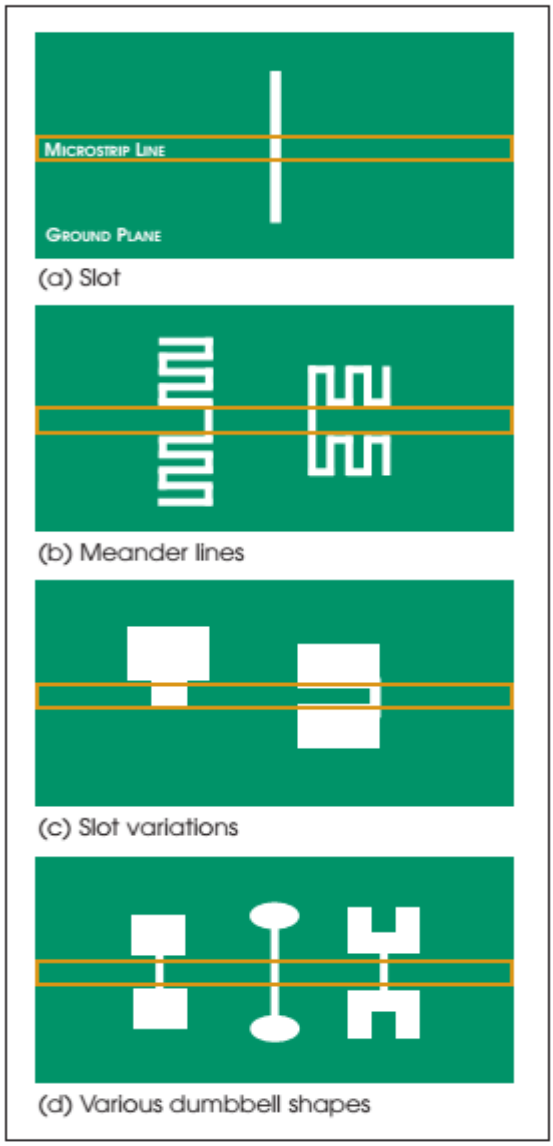

Fig -3: Common configurations for DGS resonant circuits

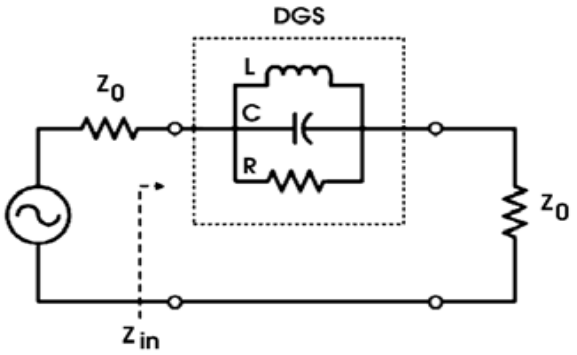

Fig -4: Equivalent circuit of a DGS element

As per Oskouei, H.D., Forooraghi, K. and Hakkak, M, there are two main characteristics of Defected Ground Structure, which are slow wave propagation in Pass band & Band Stop Characteristics in microwave circuits [10].Slow wave Propagation in Pass Band: DGS circuit just like a circuit which consist capacitance and inductance as given in the Fig. 2. The defect in ground plane increases the inductance ,this increase in inductance will produce the high effective dielectric constant. This is called as slow wave property. Due to this DGS has the longer electrical length than the standard Microstrip line, for the same physical length. The desired resonance frequency can be achieved by varying the various dimensions of the defect.

Band Stop Characteristics: The band gap effect can be explained by the equivalent circuit of proposed DGS. The series inductance due to the DGS section increases the reactance of a microstrip with the increasing of the frequency. Thus, the rejection of the certain frequency range can be started. The parallel capacitance with the series inductance provides the attenuation pole location, which is the resonance frequency of the parallel LC resonator. As the operating frequency increases, the reactance of the capacitance decreases.

The microstrip line should have the impedance around 100– 130 ohms. By using the defected ground structure in the ground plane the effective inductance will increase and at the same time the capacitance will be decrease and finally the impedance of the transmission line increases and becomes more than 200 ohms. This high impedance of the DGS is used in the digital systems.

3. APPLICATIONS OF DEFECTED GROUND STRUCTURE

For microstrip antenna design DGS have various applications namely antenna size reduction, cross polarization reduction, mutual coupling reduction in antenna arrays, harmonic suppression etc.

3.1 Microstrip Patch Antenna Size Reductions

For many applications, The designed antenna for particular frequency with the transmission line model is larger and is not compatible. So antenna size reduction becomes necessary. Different techniques such as using the substrate with high dielectric constant , edge shorted patched with shorting plates or shorting walls, use of shorting pin at the suitable position etc. have already been used for the antenna size reduction. As per Arya the etching of a defect in the ground plane is also a unique technique for the antenna size reduction [11, 12]. The Transmission Line model is used to design the main patch for resonant frequency 6.2 GHz. The antenna size 12 mm

15 mm 1.524 mm is better compatible for the different applications. The creation of a Dumbbell shaped DGS in the ground plane of the antenna is used for the size reduction of the antenna for working at the frequency of 5.2 GHz. From the analysis methods the antenna size 14.5 mm 18.0 mm 1.524 mm is
calculated for the frequency 5.2 GHz and is optimized with the IE3D simulator, with the dumbbell defect in the ground plane the antenna size reduced to 12 mm 15 mm 1.524 mm for the same resonance.

3.2 Harmonics reduction

The radiation level of both active and passive devices should be very low at harmonic frequency for active antennas. The feed line losses are reduced by integrating the active device very close to the radiating patch along with the feed line. But due to this these antennas suffer from the harmonic radiation which results in a non linear process. Thus active integrated microstrip antennas has a drawback of harmonic reduction. So, the PBG/DGS structures are used to reduce higher order harmonics in microstrip antennas. As per Sung the DGS antenna strongly eliminates the harmonic resonance [13– 17]. Different DGS units has been used in the harmonic reduction in antennas such as H-shapedDGS, spiral shaped, dumbbell shaped, and tapered DGS.

3.3 Cross polarization reduction

The cross-polarized (XP) radiation is reduced by using a defected ground structure in a microstrip antennas. The DGS patterns are simple and easy to etch on a microstrip substrate. This defect does not affect the dominant mode input impedance and co-polarized radiation patterns of a conventional antenna but this defect reduces the XP radiation field. Sun has examined and verified this concept experimentally for a particular DGS pattern employing a circular patch as the radiator [17].

3.4 Mutual coupling reduction

In an array, the field radiated by one element induces voltages across the terminals of other elements and scatters from the other elements into the far field. Input impedances, radiation patterns, gain, effective receiving area, and other parameters of the array antenna gets affected due to mutual coupling. Therefore it is very important to reduce mutual coupling between the elements of the antenna array. As per Guha the defected ground structure is a unique technique used to reduce mutual coupling of a two-element microstrip antenna array in comparison with other techniques[18].

3.5 Design approach for circular polarization

For the circular polarization of the patch antennas, the DGS is used under the feed lines including feed line
Structures which are edge coupled to the microstrip patch antennas in a single layer substrate. Saleli have state that, the presented designs can easily be extended to other bands satellite and terrestrial systems that require circularly polarized antennas [19]. This type of antenna can be easily integrated with the RFID reader system and also useful for other wireless communication systems, which involve circular polarization.

3.5 Broadband RCS reduction

The surface of an aircraft can have low radar cross section by using some radar- observing materials or other shaping methods. Thus the antenna becomes more important contributor to the overall RCS signature of the same object. . AS per thakur, the shorting pin is used for the RCS reduction at the frequencies outside the desired band [20].

4. DISADVANTAGES OF DGS

A DGS element, it is a slot antenna, which is a highly efficient radiator.That is Defected ground radiates. Although much of the incident energy at the resonant frequency is reflected back down the transmission line, there will be significant radiation. Radiation within enclosed microwave circuits can be difficult to include in simulation. Boundary conditions are usually set to be absorbing (no reflections), which simplifies calculations, but excludes the structures around the circuit being examined.

A lesser disadvantage is that DGS structures increase the area of the circuit. However, the additional area will usually be less than that of alternative solutions for achieving similarly improved performance.

5. CONCLUSIONS

There is a growing and significant development in microstrip antennas using DGS.In this paper the microstrp technology with Defected ground structure is discussed. The etched defect (DGS) in the ground plane plays an important role in the design of compact and high performance microwave circuits. It consists of L-C parallel circuit having a resonant frequency characteristic. It is having band gap property , which is used in the many microwave applications. The given applications in the microstrip antennas with the DGS are in a good performance in the microwave circuits. Further we can

use the DGS for other parameters improvement in the antennas also.

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