Reviewing Design Challenges of Microstrip Circuit Design

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Abstract- Defected Ground Structure technology makes intentionally designed defects in the ground plane, which creates beneficial inductive and capacitive effects on the designed structure. These additional networks can be used to introduce higher impedance, band rejection, and slow-wave characteristics to otherwise standard microstrip lines. The resulting microstrip structure can be significantly reduced in size and has superior frequency characteristics in some applications compared to the conventional design. This paper provides A novel defected ground unit lattice is investigated in order to improve the effective inductance and capacitance of planar microwave filter circuits. Increasing the effective inductance makes it easy to control the cut-off frequency characteristics. We have also compared the methods in a table on the basis of their merits and demerits.

Keywords: Microstrip circuit design, approaches, effective inductive

I. INTRODUCTION

Microwave components such as filters, couplers, antennas etc., in the microstrip technology, are used in high performance aircraft, spacecraft, satellite and missiles where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints. Presently there are many other government and commercial applications, such as mobile radio and wireless communications, microwave communication and millimetre wave communication. There have been some new technologies such as Low-temperature co-fire ceramic technology (LTCC), Lowtemperature co-fire ferrite (LTCF) and some new structures such as Photonic band gap (PBG), DGS, Substrate integrates wave-guide (SIW) and so on to enhance the whole quality of system. In 1987, Yablonovitch and John proposed PBG which implodes and utilizes metallic ground plane, and breaks traditional microwave circuit confined design to surface components and distributions of the medium circuit plane.

Consequently, there has been an increasing interest in microwave and millimetrewave applications of PBG. Similarly, there is another new ground plane aperture (GPA) technique which simply incorporates the microstrip line with a centred slot at the ground plane, and the use of GPA has attractive applications in 3 dB edge coupler for tight coupling and band pass filters for spurious band suppression and enhanced coupling.

PBG is a periodic structure which has been known as providing rejection of certain frequency band. However, it is difficult to use a PBG structure for the design of the microwave or millimetre-wave components due to the difficulties of modelling. 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. Another problem is caused by the radiation from the periodic etched defects. Furthermore, with the introduction of a GPA below the strip, the line properties could be changed significantly as the characteristic impedance varies with the width of the GPA.

Usually the GPA is considered as the basis of equivalent J-inverter circuit theory and its filtering behaviour has been characterized by a closed form equation. As a technique to improve circuit performance, there are more investigations on the applications than the essence of GPA. In order to alleviate these problems Park et al. [1] Proposed DGS which is designed by connecting two squares PBG cells with a thin slot? DGS which bases on GPA focuses not only on its application but also on its own characteristics. DGS adds an extra degree of freedom in microwave circuit design and opens the door to a wide range of application. In the following years, a great lot of novel DGSs were proposed and they had become one of the most interesting areas of research owing to their extensive applicability in microwave circuits [1-41]. The parameters of equivalent circuits' models of DGSs were also researched and utilized to design planar circuit easily. Many passive and active microwave and millimetre devices have been developed to suppress the harmonics and realize the compact physical dimensions of circuits for the design flow of circuits with DGS comparatively simple[10-16].

In its most basic form, 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 [15]. There are two different type of generic structures used for the design of the compact and high performance microwave components, named as defected ground structure (DGS) and the Electromagnetic band gap (EBG) structures generally known as the photonic band gap structures (PBG) [1]. These structures have been attractive to obtain the function of unwanted frequency rejection and circuit size reduction.DGS cells have inherently resonant property; many of them have applied to filter circuits. However, it is difficult to use a PBG structure (periodic structure) for the design of the microwave or millimetre wave components due to the difficulties of the modeling. Another difficulty in using the PBG circuit is caused by the radiation from the periodic etched defects.

Recently a defected ground structure (DGS) have been introduced, DGS is realized by etching off a simple shape in the ground plane, depending on the shape and dimensions of the defect, the shielded current distribution in the ground plane is disturbed, resulting a controlled excitation and propagation of the electromagnetic waves through the substrate layer. The shape of the defect may be changed from the simple shape to the complicated shape for the better performance.

II. PHOTONIC BAND GAP STRUCTURE

The photonic band gap structure is a periodic structure etched in the ground plane. The difference between the PBG and DGS is shown in the TABLE-1. The PBG modifies the properties of the microstrip line such as characteristic impedance and propagation constant. 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.

Table 1: Difference between photonic structure and defected structure

	Photonic band gap structure	Defected ground structure
Geometry	Periodic etched structure	One or few etched structure
Microwave circuit properties	similar	similar
Equivalent circuit extraction	Very difficult	Relative simple

III. MOTIVATION

Photonic Band Gap (PBG) is a periodic structure which has been known as providing rejection of certain frequency band. However, it is difficult to use a PBG structure for the design of the microwave or millimetre-wave components due to the difficulties of modelling. 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. Another problem is caused by the radiation from the periodic etched defects. DGS alleviate these problems by connecting two PBG cells with a thin slot which causes, (1) The circuit area becomes relatively small without periodic structures because only a few DGS elements have the similar typical properties as the periodic structure like the stop-band characteristic. (2) DGS needs less circuit sizes for only a unit or a few periodic structures showing slow-wave effect. Due to these significant advantages, it gives the huge motivation to do the thesis in this topic.

IV. OBJECTIVE

Recently, there has been much interest in various kinds of defected ground structures (DGS), realized by etching a defected pattern on the ground plane.

Different shapes of DGS structures, such as rectangular, square, circular, dumbbell, spiral, L-shaped etc and combined structures have been published in the literature. In this thesis work detailed investigation of a number of DGS profiles for microwave filter application are reported, a few circuits are designed and developed.

V. DESIGN CHALLENGES

There are typically no circuit models available for DGS structures in commercially available design tools. Therefore, the design and modelling of DGS structures require full-wave EM simulations. Since, with DGS structures, design perturbations are incorporated into the ground plane, the designs are no longer ideal, and designers must include the details of the ground plane defects in the EM simulations.

VI. LITRETURE REVIEW

In 2008 L. H. Weng et al. [1] focuses on a tutorial overview of defected ground structure (DGS). The basic conceptions and transmission characteristics of DGS are introduced and the equivalent circuit models of varieties of DGS units are also presented. Finally, the main applications of DGS in microwave technology field are summarized and the evolution trend of DGS is given.

In 1987, Yablonovitch and John proposed PBG which implodes and utilizes metallic ground plane, and breaks traditional microwave circuit confined design to surface components and distributions of the medium circuit plane. Consequently, there has been an increasing interest in microwave and millimetre-wave applications of PBG. Similarly, there is another new ground plane aperture (GPA) technique which simply incorporates the microstrip line with a cantered slot at the ground plane, and the use of GPA has attractive applications in 3 dB edge coupler for tight coupling and band pass filters for spurious band suppression and enhanced coupling.

In 2000 C.S. Kim et al. [2] proposed a new one-dimensional (1-D) defected ground unit lattice in order to improve the effective inductance. Increasing the effective inductance makes it easy to control the cut-off frequency characteristics. The proposed periodic defected ground structure (DGS) provides the excellent cut-off and stopband characteristics. In order to show the improved the effective inductance, three DGS circuits were fabricated with identical periodic and different dimensions. Measurements on the fabricated DGS circuits show that the cut-off and stopband centre frequency characteristics depend on the physical dimension of the proposed DGS unit lattice.

In 2007 W. H. Liu et al. [3] provides a simple approach to determine slow-wave factors. Furthermore, a comparison of the dispersion characteristics between DGS unit and periodic DGS is clarified. Also, the slow-wave and fast-wave behaviours of defected ground structures (DGS) unit are investigated and explained by an LC resonator.

In 2004 Liu et al. [4] proposed a novel one-dimensional (1-D) periodic defected ground structure (DGS) for microstrip line. Different from the periodic DGS with uniform square-patterned defects, the improved periodic DGS has a compensated microstrip line and the dimensions of the square defects are non-uniform and varied proportionally to the relative amplitudes distribution of the exponential function n e1/(n denotes the positive integer). A uniform periodic DGS circuit and two improved periodic DGS circuits are designed, fabricated, and measured. Measurements show that the latter exhibit more excellent performances by suppressing ripples and enlarging stopband bandwidth.

In 2001 D. Ahn et al. [5] proposed a new defected ground structure (DGS) for the microstrip line. The proposed DGS unit structure can provide the band gap characteristic in some frequency bands with only one or more unit lattices. The equivalent circuit for the proposed defected ground unit structure is derived by means of three-dimensional field analysis methods. The equivalent-circuit parameters are extracted by using a simple circuit analysis method. By employing the extracted parameters and circuit analysis theory, the band gap effect for the provided defected ground unit structure can be explained. By using the derived and extracted equivalent circuit and parameter, the low-pass filters are designed and implemented. The experimental results show excellent agreements with theoretical results and the validity of the modelling method for the proposed defected ground unit structure.

In 2002 Lim et al. [6] presents a new technique to reduce the size of microwave amplifiers using defected ground structure (DGS). The DGS on the ground plane of microstrip line provides additional effective inductive component, which enables a microstrip line with very high impedance to be realized and shows a slow-wave characteristics. The resultant electrical length of the microstrip line with DGS is longer than that of the conventional microstrip line for the same physical length. Therefore, the microstrip line with DGS can be shortened in order to maintain the same electrical length, matching, and performances of the basic (original) amplifier. In order to show that this idea is valid, two amplifiers, of which one is designed using conventional microstrip line and the other is reduced using DGS, are fabricated, measured, and compared. The measured performances of the reduced amplifier with DGS are quite similar to the ones of the basic amplifier, even though the series microstrip lines with DGS are much smaller than those of the basic amplifier by 53.8% and 55.6% at input and output matching networks, respectively.

In 2002 Kim et al. [7] proposed the microstrip and coplanar waveguide
transmission lines combined by a vertically periodic defected ground structure
(VPDGS). The slow-wave effect, equivalent circuit, and the performances are shown.
As an application example, VPDGS is adopted in the matching networks of an
amplifier for size-reduction. Two series microstrip lines in input and output matching
networks of the amplifier are reduced to 38.5% and 44.4% of the original lengths,
respectively, due to the increased slow-wave effects, while the amplifier performances
are preserved.

In 2005 Liu et al. [8] proposed a meander microstrip line with defected ground
structure. Its radiation loss and slow-wave effect are evaluated. The compact
configuration presents broad stopband and improved slow-wave characteristics. A
good agreement between simulation and measurement verifies the designed circuit.

In 2003 Lim et al. [9] presented a new method to reduce the size of amplifiers and
reject harmonics using spiral-defected ground structure (Spiral-DGS). A microstrip
transmission line having Spiral-DGS provides increased slow–wave factor (SWF) and
excellent rejection characteristics for a specified harmonic frequency band as if it is a
band rejection filter. Due to the increased SWF, the physical lengths of matching
networks are shortened while the original matching and performances are preserved.
The reduced lengths by Spiral-DGS are 39% and 44% of the original lengths in input
and output matching networks, respectively. It is shown that the measured Sparameters
of the reduced amplifier agree well with those of the original amplifier.
The measured second harmonic of the reduced amplifier is much less than that of the
original amplifier by at least 10dB.

In 2007 Parui et al. [10] propose a new defected ground structure (DGS)
consisting of three numbers of circular slots connected by two thin slots underneath a
microstrip line is proposed. Both simulated and measured S-parameter results shows a
very sharp low pass filtering characteristics with one number of poles and one number
of zeroes at finite frequencies. Thus DGS unit is modeled by 3rd order elliptical low
pass filter. Cascading two cells under microstrip line realize a 3-pole low pass filter.
By replacing simple microstrip line by HI-LO line, improved filter performance is
obtained.

In 2008 Lai et al. [10] presented a novel wide band pass filter making use of
complementary split-ring resonator (CSRR) as the basic resonant unit. The resonant
characteristic of CSRR is carefully studied through full wave analysis. The coupling
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of CSRR structure is very strong that can be used to realize wideband filter with small
insertion loss. A filter with center frequency at 3.5 GHz, passband from 3.1 GHz to
3.8 GHz is designed and fabricated. The measured results are in good consistent with
simulated results.

In 2008 Hou et al. [11] presented a novel wide band filter using a split-ring
resonator as a defected ground structure (SRR DGS). A micro-strip band-pass filter

with a transmission zero at right out-of-band are designed using the equivalent-circuit
analysis and curve-fitting method, which is then realized in the actual compact
structure, making use of lumped chip capacitors and T-shaped open-circuit stub to
achieve series and shunt capacitance, respectively. A band-pass filter with a wide
pass-band from 1 GHz to 2.4 GHz is fabricated and measured, and the experimental
results have a good agreement with the simulation results. complementary split ring
resonators with dual mesh-shaped couplings and defected ground structures for wide
pass-band and stop-band BPF design.

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