Microstrip Circuit Design Using Defected Ground

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Abstract- 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. The proposed periodic defected ground structure (DGS) provides the excellent cut-off and stopband frequency characteristics and also improved slow wave behaviour in the pass band. In order to show the improved effective inductance, different configuration of DGS layouts were simulated by I3ED. DGS layouts that are investigated include symmetrically periodic, asymmetrically periodic, uniform unit cells, non-uniform cells based, etc. In this thesis, new DGS shape, CSSRR unit, has been investigated and utilized for periodic LPF design. CSSRR unit has interesting filtering characteristics, such as very high attenuation rate, couple of the dimension-dependent finite attenuation poles, and low level of passband ripples. Cascading CSSRR units with different dimensions have been utilized to design high standard Low Pass Filter (LPF) with cut off frequency (fc) of 1.80 GHz through simple and straightforward filter design procedure. The designed LPF exhibits attenuation rate of 300 dB/GHz, and less than 0.30 dB passband ripples. Moreover, it has a wide 20-dB isolation band up to four times and half fc with more than 30 dB attenuation for most of the stopband. To our knowledge, the overall performance of the LPF is the best among the published results till now, especially for the achieved attenuation rate. Slow-wave factors for the different shapes DGS like Dumbbell and Complementary square split ring resonator as defected ground structure are calculated and are compared, the most improved slow wave factor is obtained in the case of Complementary square split ring resonator. This configuration is thoroughly investigated and developed.

Keywords: Microstrip circuit design, LPF, DGS, effective inductive

I. INTRODUCTION

Planar transmission lines are broadband, low cost and provide compact dimensions and light weight. The most popular microstrip line includes a conductor trace on one side of a substrate and a single ground plane on the other side. Usually, a designer of microstrip circuits focuses on the analysis, synthesis, and calculation of the microstrip circuit (conductor trace), including configuration, dimensions, and structure of the microstrip conductor, while the ground side remains a complete metallization structure. However, the ground plane structure can be modified to improve electrical performance and reduce size of a microstrip circuit. In recent years, there have been several new designs of microstrip circuits with defected ground structure (DGS), etc. Microstrip lines with DGS have much higher impedance and an increased slow-wave factor as compared to conventional transmission lines. The DGS is attractive as it enables unwanted frequency rejection and circuit size reduction. The DGS is a new type of microstrip design that exhibits well-defined stop bands and pass bands in the transmission characteristics, and as such it finds many applications in microwave printed circuits: filters [1-9], dividers [8], amplifiers [4, 7, 14, 2], oscillators [20], switches [15], directional couplers [36-41], antennas [17], etc.

The DGS is realized by etching a “defective” pattern in the ground plane, which disturbs the shield current distribution. This disturbance can change the characteristics of a transmission line, such as equivalent capacitance or inductance, to obtain the slowwave effect and the band stop (“notch”) property. The DGS applied to a microstrip line creates a resonance in the circuit, with the resonant frequency controllable by changing the shape and the size of the slot.

The equivalent circuit of the DGS can be represented by a parallel LC resonant circuit in series with the microstrip line. The transverse slot in the DGS increases the effective capacitance, while the U-shaped slots attached to the transverse slot increase the effective inductance of the microstrip line. This combination of DGS elements and microstrip lines yields sharp resonances at microwave requencies which can be controlled by changing shape and size of the DGS circuitry. The shape and size of the DGS slot controls both the fundamental resonant frequency and higher order resonances. The size of the p.c. board area is also considered. To fulfil the different requirements, a variety of DGS shapes have evolved over time, including dumbbell, periodic, fractal, circular, spiral, L-, and H-shaped structures.

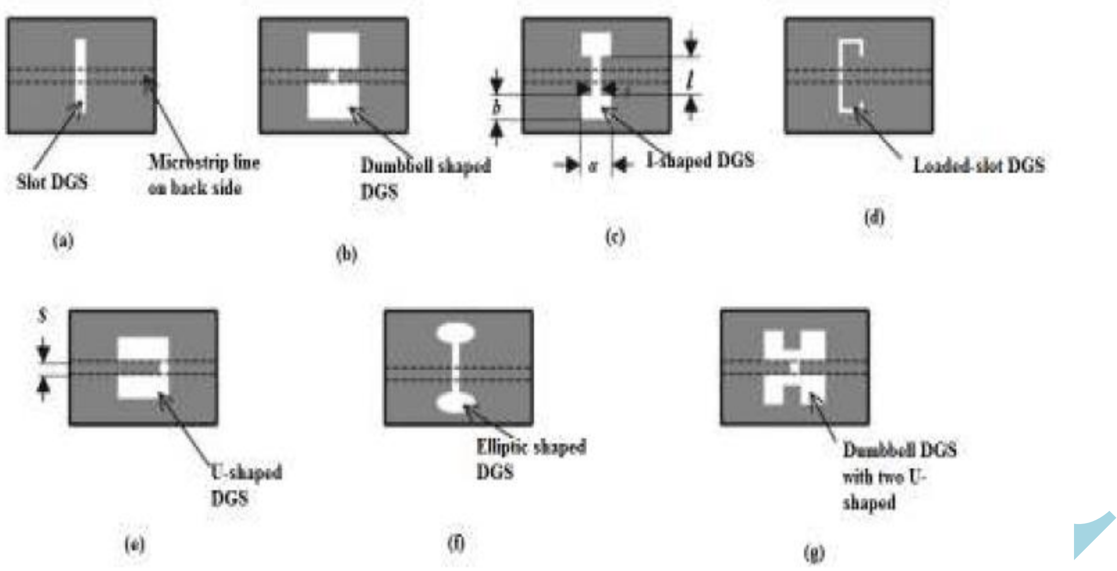

Figure 1.1 Various DGS structure

Figure 1.1 shows several resonant structures that may be used. The basic element of DGS is a resonant gap or slot in the ground surface (Figure 1.1(a)), placed directly under the transmission line and aligned for efficient coupling to the line. The dumbbell- shaped DGS (Figure 1.1(b) includes two wide defected areas connected by a narrow slot. The conventional dumbbell-shaped DGS has been modified into an Ishaped DGS, as shown in Figure 1.1(c).The frequency control of the I-shaped DGS is accomplished by adjusting the length of the transverse slot and the dimensions a and b. The stopband characteristic of the DGS in Figure 1.1(c) depends on l, which is the distance between two rectangular lattices. In the U-shaped structure of Figure 1.1(e), the loaded Q-factor increases as distance s decreases.
Elliptic DGS cells are also obtained by etching a slot that connects two elliptic DGS shapes in a microstrip ground plane (Figure 1.1(f) [12]. Figure 1g represents the DGS unit composed of two U-shaped slots connected by a transverse slot. This DGS section can provide cut-off frequency and attenuation pole without any periodicity, unlike other DGS

II. BASIC STRUCTURE AND TRANSMISSION CHARACTERISTICS

The dumbbell DGS are composed of two a × b rectangular defected areas, g ×w gaps and a narrow connecting slot wide etched areas in backside metallic ground plane as shown in Figure of stopband, slow-wave effect and high impedance. DGS has more advantages PBG as follows: (1) the structures because only a few DGS elements have the periodic structure like the stop dumbbell DGS unit can be matched to the response. For the DGS unit, DGS pattern is simply fabricated and its equivalent circuit is easily extracted. (3) DGS needs less circuit sizes for only a unit or a few periodic structures showing slow easily to be designed and implemented and has higher precision with regular defect structures. Therefore, it is very extensive to extend its practical application to microwave circuits. DGS has more competition than PBG in the micro with high requirement of dimension under certain craftwork conditions.

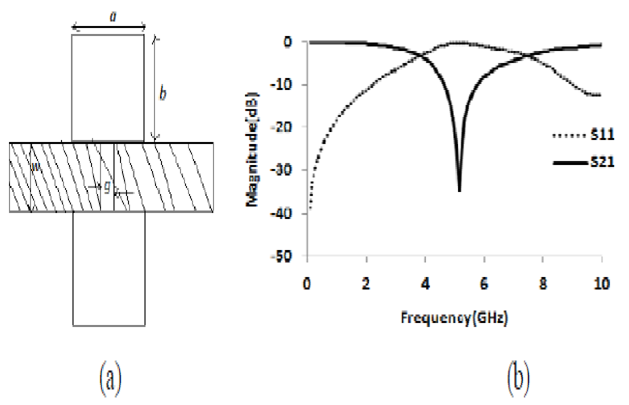

Figure 1.2 (a) DGS structure (b) Simulated DGS UNIT

There have been two research aspects for adequately utilizing the performance of DGS: DGS unit and periodic DGS. A variety of etched in the microstrip line ground plane have been 1.3, it is shown that a variety arrowhead-slot and "H" DGSs so as to improve the c open-loop with a slot in middle section, open The new DGS unit could control the two transmission and easily control the frequency of the 1.2(a). This is the first DGS. DGSs have the characteristics circuit area becomes relatively small without periodic similar typical properties as the stop-band characteristic. (2) The simulated S-parameters for one-pole Butterworth-type low slow-wave effect. Compared with PBG, DGS is more (b) S-parameters for dumbbell DGS unit

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.

III. LITRETURE REVIEW

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 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.

In 2009 Karthikeyan et al. [14] presented a paper, compact, wide fractional bandwidth band pass filter using a new open slot split ring resonator (OSSRR) defected ground structure and compact microstrip resonating cell (CMRC). OSSRR is the modified and dual version of the open split ring resonator (OSRR). The band pass filter (BPF) is constructed by cascading low pass and high pass sections designed using CMRCs and OSSRR respectively. The designed BPF has wide fractional bandwidth of 74%, sharp passband to stopband transition and low passband insertion loss of less than 1 dB. The simulated results are well validated by the experimental results.

In 2010 Arya et al. [15] gave the detailed discussion on Defected ground structures (DGS) for the characteristics of many microwave devices. Although the DGS has advantages in the area of the microwave filter design, microwave oscillators, microwave couplers to increase the coupling, microwave amplifiers, etc., it is also used in the microstrip antenna design for different applications such as antenna size reduction, cross polarization reduction, mutual coupling reduction in antenna arrays, harmonic suppression etc., The DGS is motivated by a study of Photonic/Electromagnetic Band gap structures. The etching of one or more PBG element creates defect in the ground plane and used for the same purpose. The DGS is easy to be an equivalent L-C resonator circuit. The value of the inductance and capacitance depends on the area and size of the defect. By varying the various dimensions of the defect, the desired resonance frequency can be achieved. In this paper the effect of DGS, to the different antenna parameter enhancement is studied In 2002 Lim et al. [16] presented a paper, a spiral-shaped defected ground structure for coplanar waveguides (DGSCPW), which can be used as a kind of periodic structure for planar transmission line. The proposed spiral-DGSCPW adopts spiralshaped defects on both ground planes of CPW. Due to the spiral-shaped defects, the equivalent shunt inductance and slow-wave effects increase more rapidly than the standard CPW or CPW lines combined with the conventional PBG. The modelling and analysis to extract the equivalent circuit, increased slow-wave factor, and simulated and measured performances are presented.

IV. A NOVEL 1-D PERIODIC DEFECTED GROUND STRUCTURE FOR PLANAR CIRCUITS

In this thesis, a new lattice shape for the microstrip is proposed as a unit DGS. An etched defect in ground plane disturbs the shield current distribution in the ground plane. This disturbance can change characteristics of a transmission line such as line capacitance and inductance. The proposed DGS consists of narrow and wide etched areas in backside metallic ground plane as shown in Figure 3.1, which gives rise to increasing the effective capacitance and inductance of a transmission line, respectively. Thus, an LC equivalent circuit can represent the proposed unit DGS circuit. The effects of physical dimensions of the proposed DGS on these equivalent circuit parameters are described. It is the purpose of this paper to show a potential forapplying the proposed DGS to practical circuits. To design a circuit with the proposed DGS section, the equivalent circuit and parameters for the DGS section should be extracted. In this paper, the equivalent circuit of the proposed DGS unit section is derived by using the field analysis method. The equivalent-circuit parameters are extracted based on the circuit analysis theory. By employing the extracted parameters and the circuit analysis theory, the band gap effect for the provided DGS section can be explained. Three-pole low-pass filters are designed by using the proposed DGS sections and the equivalent circuit. A DGS section can be performed as a series element of a low-pass filter. The shunt capacitance for low-pass filters will be implemented by employing the open stub. The low-pass filter using the DGS circuit has a number of attractive features, which include the following. 1) The structure is very simple 2) The stopband is very wide and deeper than that of a conventional lowpass filter. 3) The insertion loss is very low. 4) Extremely small element values for implementation of low-pass filter can be realized.

V. RESULT

The proposed structure is shown in Figure 5.1.

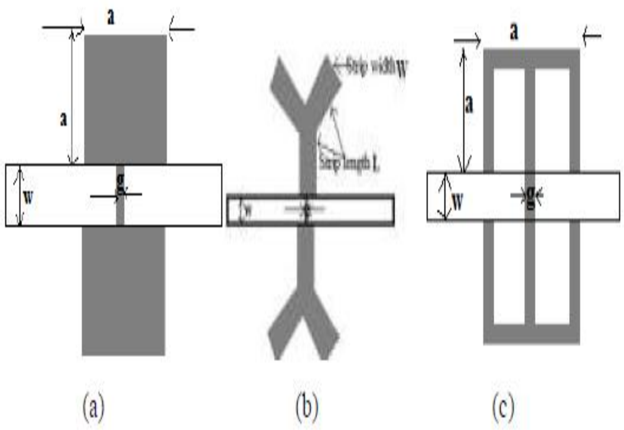

Figure 5.1 (a) square head DGS, (b) Y-shaped DGS, (c) E-shape DGS

Slots are etched on the ground plane of the microstrip line. All slots are of width 'g'. A study has been carried out with the MOM based simulation software, Zealand's IE3D. All required dimensional symbol is shown in Figure 4.5 and their values is given for the same resonance frequency (4.159 GHz). Length of the square head DGS=5mm=a and length for Eshaped DGS=a=3mm, w=1.5mm, g=0.2mm, Strip width of Y-DGS=1.5mm, Length of Y-DGS of each section =3mm and dielectric constant of a substrate for simulation is 10 and substrate thickness is 0.381mm

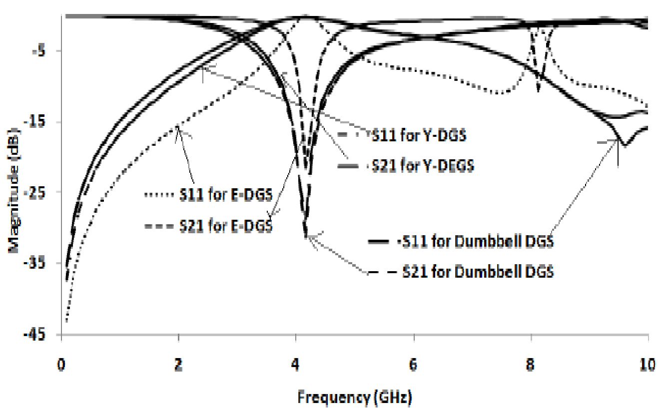

Figure 4.5 (d) simulated result

From the simulated result we see that dumbbell (square head) shaped DGs having the following advantages over the Y-shape and E-shaped DGS:

- Wider rejection band (3.366GHz) at 3-dB cut-off frequency in Square head DGS.
- Lowest 3-dB cut-off frequency (2.971GHz) in Square head DGS.
- Deep rejection band (-31.43dB) in Square head DGS at resonance frequency in square head DGS.
- Occupying the small etched rectangular area for dumbbell shape DGS as compared to Y-shaped DGS for the same resonance frequency (4.159GHz) but takes more occupy rectangular are as compared to E-shaped DGS.

VI. CONCLUSION

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.
The proposed periodic defected ground structure (DGS) provides the excellent cutoff and stopband frequency characteristics and also improved slow wave behaviour in the pass band. In order to show the improved effective inductance, different configuration of DGS layouts were simulated by I3ED. DGS layouts that are investigated include symmetrically periodic, asymmetrically periodic, uniform unit cells, non-uniform cell based, etc. In this thesis, new DGS shape, CSSRR unit, has been investigated and utilized for periodic LPF design. CSSRR unit exhibits interesting filtering properties such as very sharp attenuation rate in addition to two finite attenuation poles in its attenuation band. These characteristics can be controlled with the geometrical dimensions of the unit. Through simple procedure that depends on the performance geometrical dimension relationship high performance LPF has been designed. Its characteristics have been compared with the available published works and proved its superiority from different aspects such low passband ripples, attenuation rate, and wide stopband. Very good agreement has been achieved between simulation results of the designed LPF. Slow-wave factors for the different shapes DGS like Dumbbell and Complementary square split ring resonator as defected ground structure are calculated and are compared, the most improved slow wave factor is obtained in the case of Complementary square split ring resonator. This configuration is thoroughly investigated and developed.

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