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DEFECTED MICROSTRIP STRUCTURE BASED BANDPASS FILTER

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ABSTRACT

A defected microstrip structure (DMS) unit is proposed in this paper to perform bandpass filter. A G-shaped DMS act as a serious LC resonance circuit for certain frequency and suppress the spurious signals thus acting as a lowpass filter. This defect creates resonance characteristics in the frequency response. This kind of structures are constructed by removing different shapes of patterns etched from the top conductor of microstrip Compared with conventional T-shaped DMS, the proposed G-shaped DMS exhibits lower resonant frequency and wider stopband. Microstrip gap is a common discontinuity in planar structures. Circuit modeling of gap capacitances convert the microstrip line to a highpass transmission line. Cascading of this microstrip gap with the G-shaped DMS results a bandpass filter. The use of DMS allows an increase in slow wave factor (SWF) in the transmission lines in which they are introduced. This phenomenon reduces the size of microstrip filter. A 3D full wave simulations using IE3D show operation for the frequency range 6.5GHz to 7.5GHz. The insertion loss, return loss characteristics of the proposed filter is presented and ensure the validity of the filter. The frequency range is suitable for satellite communication.

Keyword : Microstrip filter, Bandpass filter, Defected micro strip structure.

1. INTRODUCTION

The communication systems commonly employ filters in microwave and millimeter wave transceivers as channel separators. There is an increasing demand for low cost, light weight and compact size filters. Thus, planar filters utilizing printed circuit technology seems very suitable. Bandpass filters are one of the most usable structures in microwave engineering. Bandpass filters have found numerous applications in approximately all aspects of microwave engineering and communication technology.

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) which disturbs the shield current distribution in the ground plane cause of the defect in the ground. This disturbance will 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. EM simulation is certainly accurate for the circuit itself, but with uncertainty of radiation effects, the construction and careful evaluation of a prototype is strongly recommended. An experienced designer may be able to create a simplified model of the enclosure for more accurate simulation, but measurement remains essential for verification. A lesser disadvantage is that DGS structures increase the area of the circuit. Slot on the strip that is called defected microstrip structure (DMS) makes a defect on the circuit which can be used in designing filters.

This defect creates resonance characteristics in the frequency response. This kind of structures are constructed by removing different shapes of patterns etched from the top conductor of microstrip and can be used a low pass filter. The DMS is advantageous in high frequency and millimeter wave applications. However, DGS introduces wave leakage through the ground plane, which brings difficulties with encapsulation.

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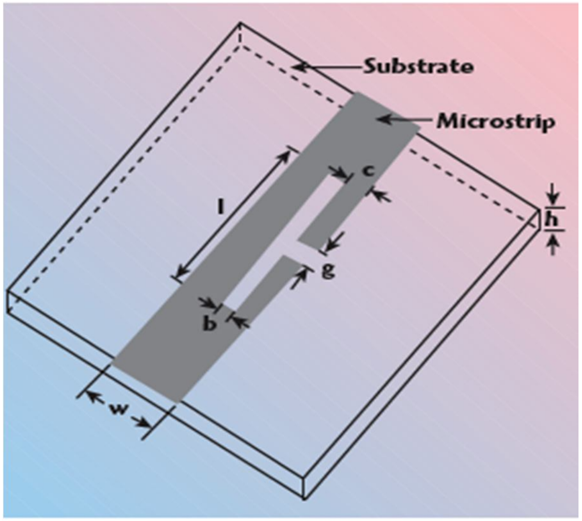

Figure.1. Defected microstrip structure

The novel defected microstrip structure (DMS), which consists of a rectangular slot of length l and width b etched in the middle of the center conductor and a small slot of width g perpendicular and in the center of the main slot, is shown in Figure 1.

The width of the microstrip line is then W = b + 2c. Similarly to DGS, the DMS increases the electric length of microstrip and disturbs the current distribution. The effective capacitance and inductance of the microstrip line increase. Accordingly, a microstrip with a unit DMS has a stop-band and slow-wave characteristics. Novel compact microwave components can be designed by using these characteristics. A G-shaped DMS is presented which performs a serious LC resonance property in certain frequency and suppress the spurious signals thus acting as a lowpass filter. The microstrip gap adds capacitor to the transmission line. Since series capacitors at two port network shows highpass filters, the transmission line converts to filter that do not pass low frequencies. The idea of bandpass filter was developed by cascading the microstrip gap to G-shaped DMS.

2. DMS CHARACTERICTICS

Defected Microstrip structures (DMS) have two main characteristics slow wave propagation in Pass band & Band Stop Characteristics in microwave circuits

A. Slow wave Propagation in Pass Band

The DMS is considered as an equivalent circuit consisting of capacitance and inductance. The equivalent inductive part increases due to the defect and produces equivalently the high effective dielectric constant, that is, slow wave property due to this fact the DGS line has the longer electrical length than the standard Microstrip line, for the same physical length. By varying the various dimensions of the defect the desired resonance frequency can be achieved.

B.Band Stop Characteristics

This equivalent circuit of the Proposed DMS unit can explain the band gap effect. 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.

3. SIZE REDUCTION USING DMS

DMS presents a greater slowwave effect, since it has more discontinuities, providing a longer trajectory to the electromagnetic wave. Simultaneously, DMS also performs a greater stop-band bandwidth compared to spurline, both having the same dimensions. The use of DMS allows an increase in the slowwave factor (SWF) in transmission lines in which they are introduced. This phenomenon can be used to reduce the size of passive planar circuits like microstrip line lengths, coupling lines and microstrip antennas, among other microstrip structures.

4. SLOW WAVE FACTOR IN MICROSTRIP LINE WITH DEFECTS

The SWF is the relationship between the wave number in free space, k_0, and the propagation constant, β, of the transmission line. For loss less microstrip line, the SWF is determined by :

$$SWF=\sqrt{\varepsilon_e} \tag{1}$$

Where ε_e is the effective permittivity of the material, and the propagation constant is determined by:

$$\beta = \sqrt{\varepsilon_e} k_0 \tag{2}$$

Where k_0 is the wave number in free space .The SWF of a microstrip line is raised when a discontinuity is introduced in the path of the electromagnetic wave, increasing the impedance of the line.

5. METHOD TO REDUCE DIMENSION OF MICROSTRIP CIRCUITS

To find the dimensions of the structure, it is necessary to know the electrical length introduced in a microstrip line when a DMS unit-cell (or several unit-cells) are employed. Every circuit based on transmission lines presents an electrical length, and for microstrip lines the electricallength is given by:

$$\theta = \beta l = \sqrt{\varepsilon_e} k_0 l \tag{3}$$

On the other hand, these lines show a resonant frequency, f_r by themselves. In many cases, lines can be seen as resonators, and in this case, for simplicity, a $\lambda_g/4$ line resonator is considered, where λ_g is the wavelength in the material, either in an open- or short-circuited configuration. In the case of microstrip lines, f_r is given by

$$f_r = \frac{V_0}{4l\sqrt{\varepsilon_0}} \tag{4}$$

where l = physical length of the line; V_0 = speed of light in free space. For each line, the respective resonant frequency must be found and, at that frequency, the wave number in free space, k_0, is obtained.

The next step is to propose a unitcell dimension (or a pattern of unit cells). The structure can be either a DGS or DMS [5], and this is introduced in the microstrip line and for such a configuration, the electrical length, θ, at fr is obtained by EM simulation. From these results, the SWF is:

$$\text{SWF} = \theta\left(\frac{\pi}{180}\right) k_0 l \tag{5}$$

After introducing the unit-cell in the microstrip line, the substrate employed in the implementation presents an apparent effective dielectric constant ε_{eff}, which is larger than the real effective dielectric constant ε_{ref}.

This apparent permittivity provides the tool to explain how the dimensions of microstrip circuits can be reduced, which means that for a higher dielectric constant the wavelength is shorter as well as the microstrip circuits, both being a function of this parameter. Since the original microstrip lines have an electrical length and introducing a DMS unit-cell into the structure increases it, a new dimension must be found to keep the electrical length equal to that of the non-defected lines [9]. The new length that gives the original electrical length for the microstrip line with DMS unit-cell is obtained by employing new technique.

$$L_C = \frac{V_0}{4f_r(\text{SWF})} \tag{6}$$

6. MICROSTRIP GAP

A microstrip line can generally be assumed as transmission line. transmission lines are low pass filters that their cutoff frequencies are much higher than our common frequencies. This cutoff frequency is limited by higher order modes. The microstrip gap adds capacitor to transmission line structure. Since series capacitors at two port network shows high pass filters, the transmission line converts to filter that do not pass low frequencies. Cut off frequency depends on gap distance. Using a simple analysis, modeling gap with first order RC high pass filter, the cut off frequency will be

$$f_c = \frac{1}{2\pi RC} \tag{7}$$

$$\text{Where } C = \frac{\varepsilon_0\varepsilon_r A}{d} = \varepsilon_0\varepsilon_r\frac{wt}{d}$$

ε_r-relative permittivity
w-microstrip line width
t-microstrip thickness

Therefore increasing gap distance(d) lead to increase in cut off frequency and vice versa.

7. G-SHAPED DMS

G-shaped DMS consists of one circular ring and one connecting slot in the microstrip line, which seems like the letter G. Compared with the conventional DMS, the proposed G-shaped DMS exhibits lower resonant frequency and wider stopband. The desired frequency response can be obtained by changing the G-cell dimensions and gap space at the beginning of structure. Figure 2 shows the G-shaped DMS.

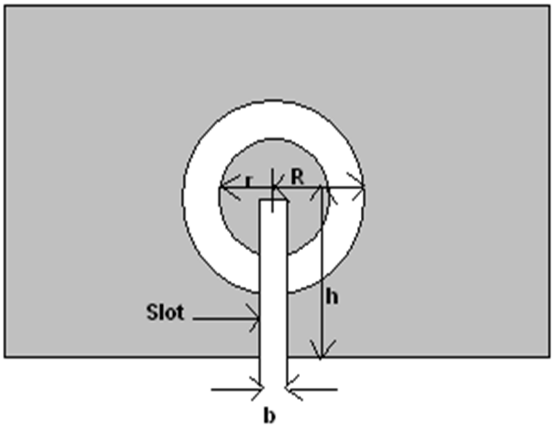

Figure.2. G-shaped DMS

Equivalent circuit of the proposed G-shaped DMS is shown in Figure 3 which is equivalent to a first order lowpass Butterworth prototype.

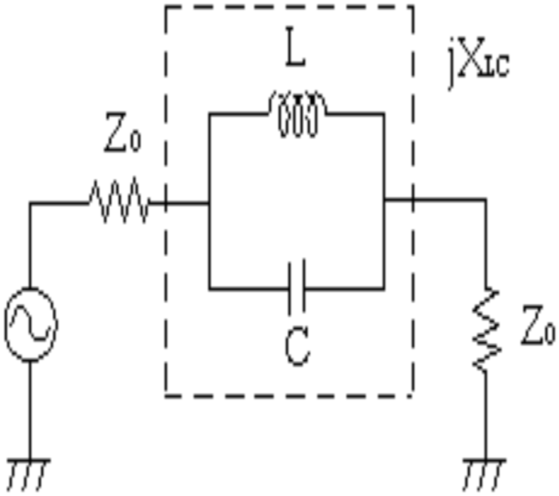

Figure.3.Equivalent circuit of the proposed G-shaped DMS

8. PROPOSED STRUCTURE AND ITS EQUIVALENT CIRCUIT

The idea of band pass filter was developed by cascading a high pass filter(microstrip gap) to low pass filter(G-shaped DMS). The proposed DMS is shown in figure 4.

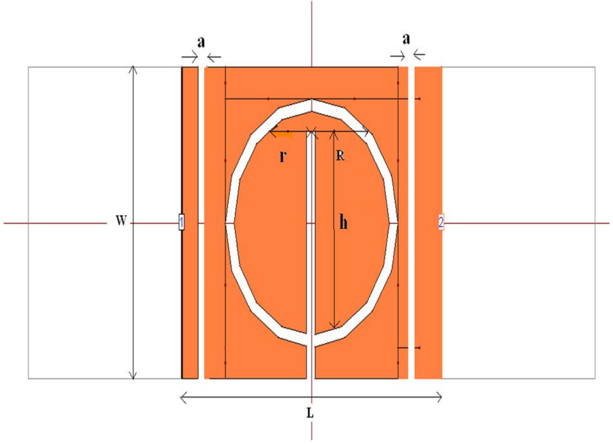

Figure.4.Proposed structure

The physical parameters of proposed structure is shown in table.1

PHYSICAL PARAMETERS	
Relative permittivity ‘ε_r’	2.2
Thickness of substrate ‘t’	0.8mm
Width of microstrip ‘W’	5mm
Length of the microstrip ‘L’	6mm
Inner radius of G-shaped DMS ‘r’	1.9mm
Outer radius of G-shaped DMS ‘R’	2mm
Height of the vertical slot ‘h’	4mm
Area of microstrip gaps ‘a’	0.05mm

Table.1.Physical parameters of proposed structure

Equivalent circuit of proposed bandpass filter is shown in figure 5.

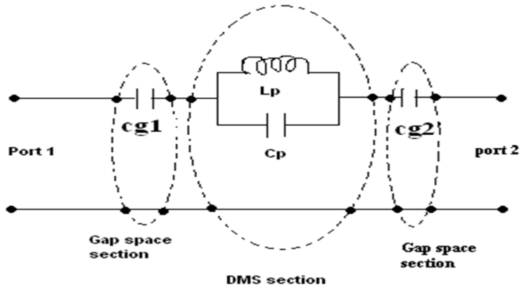

Figure.5.Equivalent circuit of proposed structure

We can obtain equivalent capacitance in pF and inductance in nH of a low pass DMS using,

$$C=\left(\frac{\omega_c}{Z_0 g_1}\right)\left(\frac{1}{\omega_0^{\,2}-\omega_c^{\,2}}\right) \tag{8}$$

$$L=\frac{1}{4\pi^2 f_0^{\,2}} \tag{9}$$

Here, ω_0 and ω_c denote resonant frequency and cut off frequency of the parallel LC resonator. Z_0 is the characteristic impedance and g_1 is the normalized parameter of first Butterworth lowpass protype.

9. CONCLUSION AND FUTURE WORKS

The frequency response of proposed bandpass filter is obtained as in figure 6 and the filter operates in the bandwidth of 1 GHz providing the passband between 6.5 GHz and 7.5 GHz.

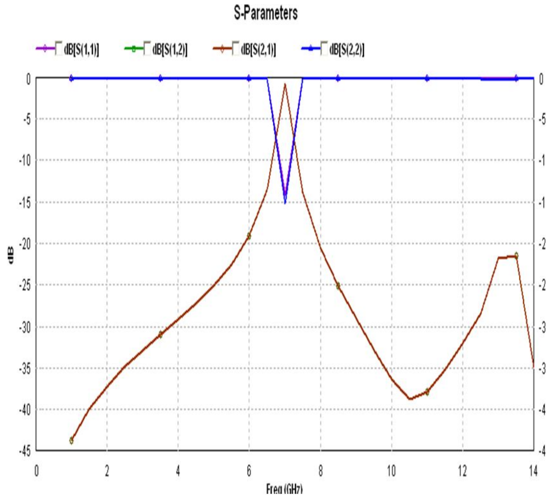

Figure.6 S-parameter of proposed filter

The VSWR of proposed filter is shown in figure7

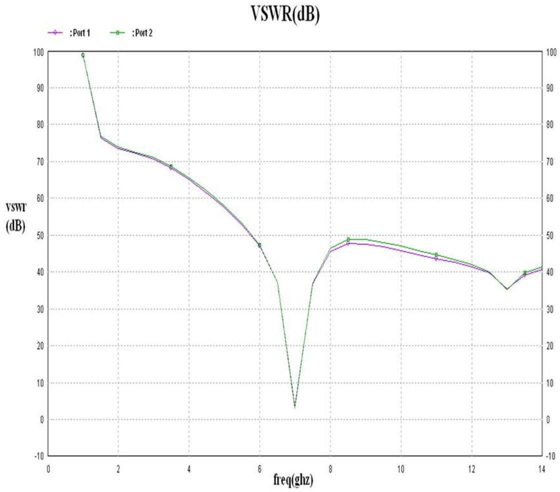

Figure.7 VSWR of proposed filter

The electrical parameters of the proposed structure is shown in Table 6.1

PARAMETERS	VALUES
S11	-15dB
S21	-3dB at 6.5GHz and 7.5GHz
BANDWIDTH	1 GHz

Table.2.Electrical parameters of proposed structure

The proposed filter structure will be fabricated and compare experimental results with the simulated result.

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