

Design of Defected Ground Low pass Microstrip Filters with Enhanced Performance Characteristics

Dr. Dheeraj Bhardwaj

*Assistant Professor, Department of Physics,
BIT-Mesra- Jaipur Campus, Jaipur, India.*

Srishti Saraswat

*Bachelor of Engineering-ECE, Department of Electronics & Communication Engineering,
BIT-Mesra- Jaipur Campus, Jaipur, India*

Gitansh Gulati

*Project Engineer, Naltech
National Aerospace Laboratories, Bangalore, India.*

Komal Sharma

*Reader, Department of Physics,
Swami Keshvanand Institute of Technology, Jaipur , India*

Abstract- Advancements in the field of RF/Microwave have triggered the designers to improve each and every component involved in microwave modern communication systems such as Low Noise Amplifier, Multiplier, Mixer, microwave filters, IF filters, antennas, power amplifier etc. In this paper we propose the design of microstrip lowpass filter using stepped-impedance (L-C ladder type) technique with the introduction of basic concept of defected ground structure (DGS) to achieve reduced size circuits. The designed prototype filter exhibits passband from frequency ranges, 0.1GHz-1.76 GHz which has been fabricated on 24.80 mm (L) X 16mm (W) FR4 substrate with 1.6mm thickness. The introduction of semi circular dumbbell shaped defected ground structure cell offers significant improvement of stopband attenuation and size reduction as can be seen. This lowpass filter can be used in wide variety of modern communication applications such as mobile broadcasting VHF band(174 MHz-240 MHz) and L band(1452 MHz-1492 MHz)GPS L1 band(1575 MHz) and L2 band(1227.6 MHz).

Keywords – DEFECTED GROUND STRUCTURE (DGS), STEPPED IMPEDANCE, LC LADDER, LOW PASS FILTER

I. INTRODUCTION

In the last few years, enormous development in wireless communications systems has created the need for new microwave components with stringent specifications. Technological developments have created more demanding requirements that impose new challenges on design, optimization and realization of these components. In case of microwave filters, more challenging parameters such as selectivity, suppression (out-of band), bandwidth, phase linearity and compactness have been researched upon. In this paper, the concept of defected ground structure to enhance the performance characteristics have been taken into account by the authors.

Artificial periodic structures exhibiting an unusual property of preventing EM waves from propagating over a certain range of frequencies and allowing EM waves to propagate through them over different range of frequencies have been termed as electromagnetic band gap structures (EBG). For a printed microwave circuit and transmission

line, another degree of freedom is offered by implementing EBG structures on the ground plane which depending on shape and dimensions can control the excitation and propagation of electromagnetic waves through the substrate layer. The work reported in this paper mainly focuses on improving the insertion loss, return loss and accomplishing sharp roll of characteristics with higher out of band rejection.

II. STEPPED IMPEDANCE L-C LADDER TYPE LOW PASS FILTER DESIGN

This configuration uses a cascaded structure of alternating high and low impedance transmission lines. Due to their size much shorter than the associated guided-wavelength, they are known as semi-lumped elements. The higher impedance lines act as series inductor and low impedance lines act as shunt capacitors as shown in figure 1.

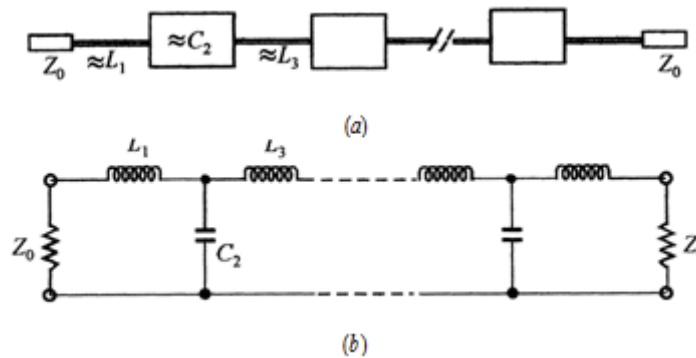


Figure 1. (a) General structure of the stepped-impedance lowpass microstrip filters. (b) L-C ladder type of lowpass filters to be approximated.

In this section a microstrip lowpass filter has been designed based on the specification listed in Table 1 and design equations. Further, same filter design has been carried out using defected ground structure.

Table - 1 Design considerations

Parameters	Values
Cutoff Frequency (f_c)	2 GHz
Pass Band Ripple	0.1 dB
Source/Load Impedance	50 ohm
Type/Response	Three Pole Chebyshev Prototype

Using the chebyshev lowpass prototype filter values as referenced in (Pozar) and element transformations, we have;

$$L_1 = L_3 = \left(\frac{Z_0}{g_0} \right) \cdot \left(\frac{\Omega_c}{2\pi f_c} \right) \cdot g_1 = 4.106 \times 10^{-9} \text{ H} \tag{1}$$

$$C_2 = \left(\frac{g_2}{Z_0} \right) \cdot \left(\frac{\Omega_c}{2\pi f_c} \right) \cdot g_2 = 1.827 \times 10^{-12} \text{ F} \tag{2}$$

The filter is to be fabricated on a substrate with a relative dielectric constant of 4.3 (FR-4 Lossy) and a thickness of 1.5 mm. Following the above mentioned considerations, the characteristic impedances of the high- and low-impedance lines are chosen as $Z_{0H} = 100 \Omega$ and $Z_{0L} = 24 \Omega$. The relevant design parameters for the microstrip lines are calculated using standard formulae and depicted in Table 2.

Table - 2 Design parameters for microstrip lines for stepped impedance lowpass filter.

Characteristic Impedance (Ω)	Guided Wavelength (mm)	Microstrip Width (mm)
$Z_{0c} = 24$	$\lambda_{gr} = 79.902$	$W_3 = 8.376$
$Z_{0s} = 80$	$\lambda_{gr} = 83.102$	$W_1 = 2.893$
$Z_{0L} = 100$	$\lambda_{gr} = 86.98$	$W_2 = 0.653$

Physical lengths of high and low impedance lines can be calculated as follows:-

$$l_h = \left(\frac{\lambda_{gr}^2}{2\pi}\right) \cdot \arcsin\left(\frac{W_3}{2Z_{0c}}\right) = 7.490 \text{ mm} \quad (3)$$

$$l_s = \left(\frac{\lambda_{gr}^2}{2\pi}\right) \cdot \arcsin(W_2 Z_{0c}) = 7.349 \text{ mm} \quad (4)$$

The results of (3,4) do not take into account series reactance of the low-impedance line and shunt susceptance of the high-impedance lines. To include these effects, the lengths of the high- and low-impedance lines should be adjusted according to equations referenced in (some paper), thus, giving $l_h = 5 \text{ mm}$ & $l_s = 4.80 \text{ mm}$. The designed layout is illustrated in Figure 2 and its performance is carried out using full-wave analysis simulation as depicted in Figure 3.

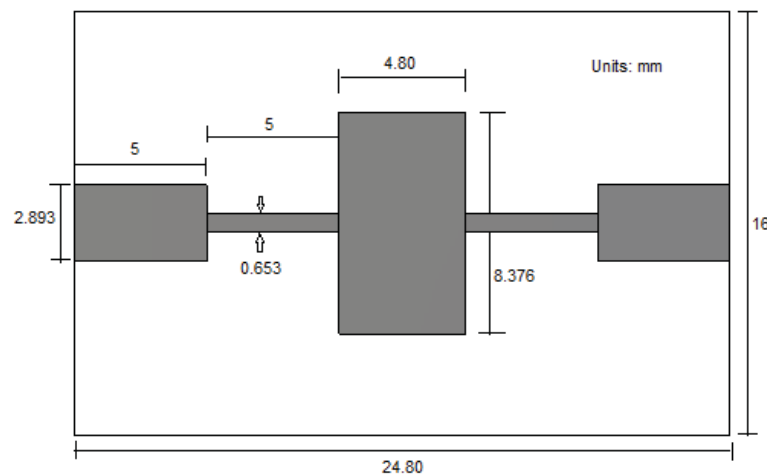


Figure 2. Front view Layout of a three-pole, stepped-impedance microstrip lowpass filter on FR-4 Lossy substrate with height=1.5mm

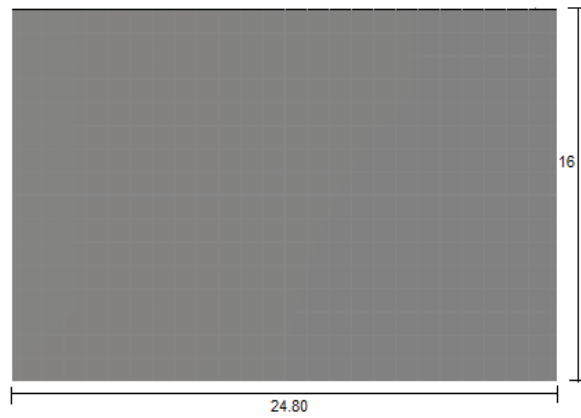


Figure 2. Back view Layout of a three-pole, stepped-impedance microstrip lowpass filter on FR-4 Lossy substrate with height=1.5mm

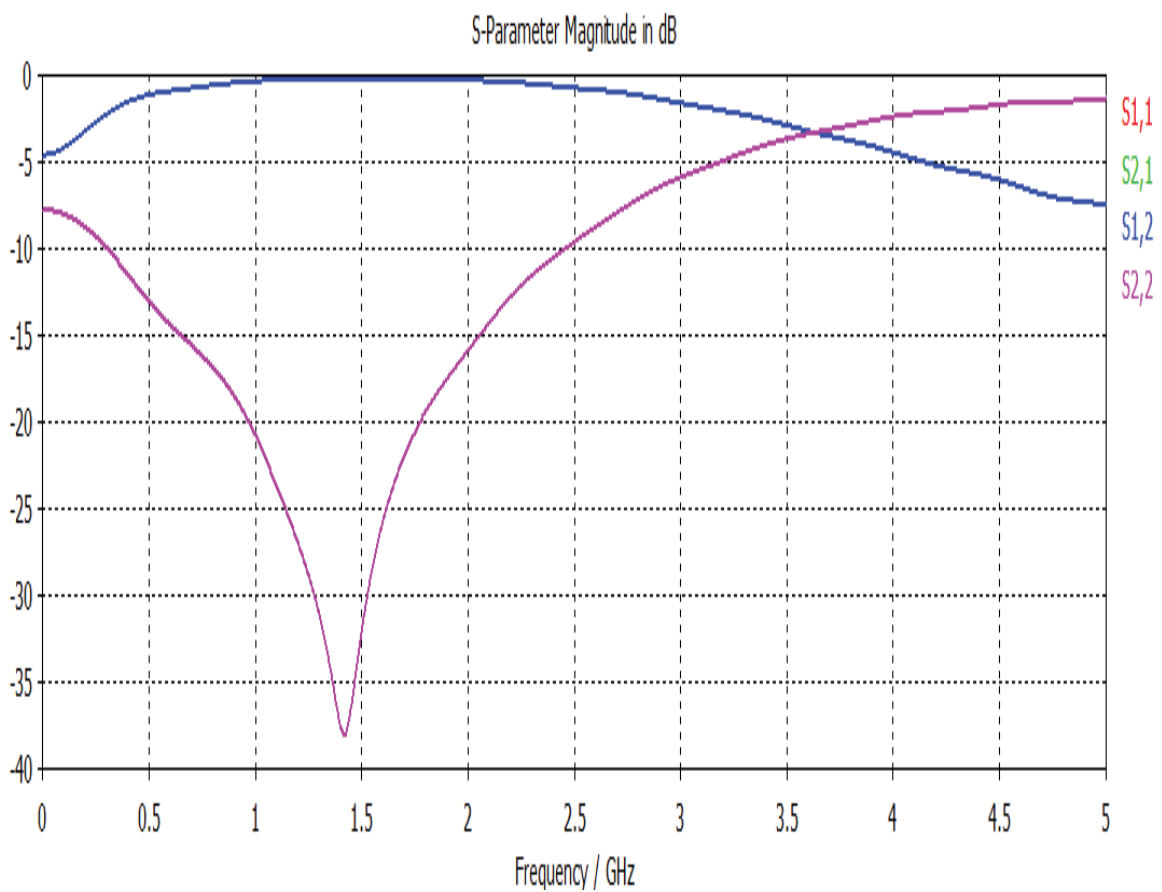


Figure 3. Full-wave EM Simulated performance characteristics.

II. STEPPED IMPEDANCE L-C LADDER TYPE LOW PASS FILTER DESIGN WITH DEFECTED GROUND STRUCTURE

In this paper a new compact filter design is proposed with better pass band characteristics along with improved stop band rejection as well as high attenuation in the stop band. The proposed compact filter design constitutes a semi circular dumbbell shaped unit cell structure in the ground plane. A DGS unit cell structure can be characterized by an LC equivalent circuit.

The semi circular dumbbell shaped DGS is inserted along the centre of the ground plane. A resonating frequency is achieved by a combination of inductance and capacitance to attain the perfect impedance match at that particular frequency. Embedding the structure in the ground has shifted the cutoff frequency towards the higher side due to decrease in the microstrip inductance and characteristic impedance. The effect of the gap is depicted by the shift in the attenuation pole to higher frequency side.

The semicircular dumbbell shaped structure has improved the series effective inductance and effective capacitance. The dumbbell shaped structure has suppressed the higher order harmonics of 2GHz and provide an improved maximally flat lowpass response.

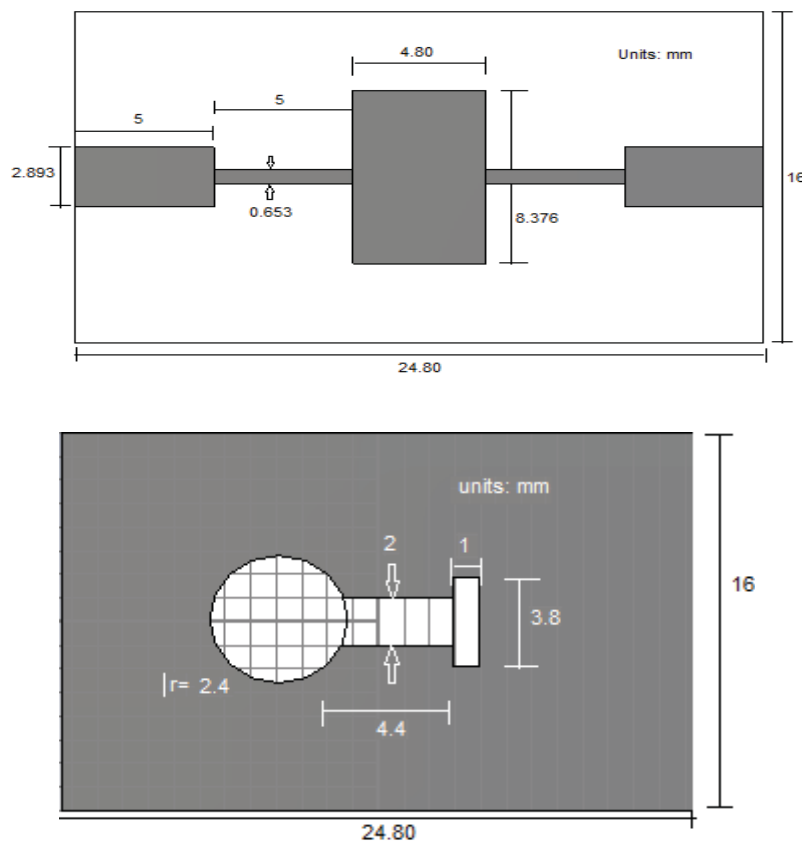


Figure 4. Layout of a three-pole, stepped-impedance microstrip low pass filter with semi-circular dumbbell shaped DGS on FR-4 Lossy with height=1.6mm (a) Front view (b) Back view

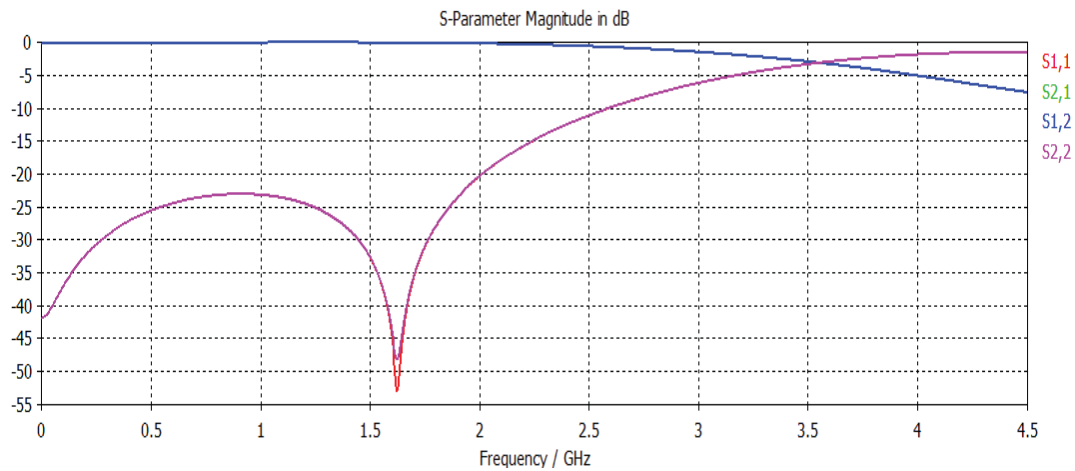


Figure 5. Fullwave EM Simulated performance characteristics.

IV. CONCLUSION

The conventional semi lumped low pass filter design exhibits a pass band from 0 -1.76GHz on a substrate of dielectric constant 4.4 and height 1.5 mm. The introduction of defected ground structure to the conventional LC ladder type low pass filter has altered the ground plane current distribution further leading to change in the inductance and capacitance which in turn alter the filter characteristics . On introduction of a semi circular dumbbell shaped unit cell slot on the ground plane effective improvement of stop band attenuation has been achieved and the pass band 0- 2.1 GHz is maximally flat.

The basic problem lies in the accurate circuit modeling of the filter with DGS which can be overcome to a great extent by considering each and every discontinuity encountered in the design to have been formulated separately (such as in Quasi-Static modeling) but the various losses introduced are not taken into account. Moreover, this design realization gives you the most well-defined desired outcome but some modifications are necessary to optimize the design to improve the skirt selectivity, insertion losses and stopband attenuation characteristics.

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