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Low Profile Microwave Band Pass Filter

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Abstract—Bandpass Filter is an indispensable part of the wireless communication system. This paper proposes an efficient DGS based microstrip bandpass filter for WiMAX application. Here, initially a chebyshev type of bandpass filter is designed and then the losses occurred in the pass band gain is reduced by introducing DGS which will result in miniaturization of the BPF filter. Several simulations and comparison on various DGS based designs have been demonstrated to validate the proposed design. The proposed bandpass filter is fabricated on a FR4 substrate and the measured results also validate the proposed design. The simulation of the proposed DGS based Bandpass filter design is demonstrated for the passband frequency between 5 GHz and 7 GHz. The simulation results agree with the theoretical ones.

Keyword - Wireless communication, parallel line coupled filter, Defected Ground Structure, Low profile.

I. INTRODUCTION

The innovations in telecommunication technology along with the ever increasing market demands and governmental regulations drive the invention and development of new applications in wireless communication. In order to provide improved transmission capacity, the plan of action would be to open certain frequency regions for new applications or systems. WiMAX (Worldwide interoperability Microwave Access) which is reckoned as a key application for solving many actual problems today is an example. A bandpass filter is a crucial component found in the transmitter or receiver. While designing a bandpass filter the question that we face include, how the filter characteristics in the transition regions must look like, maximal loss/attenuation in the pass band region and the minimal attenuation in the stop/reject regions [1]. In the process to fulfill these specifications there are many methods taken in realization of the filters, for example, to achieve minimal transmission loss (insertion loss) the choice of waveguide technology for the filter is preferred. The application of waveguide filters is restrained in huge amount because of the efforts needed to fabricate it. The Microstrip filter based on printed circuit board (PCB) on the other hand provides the advantages of cheap and easy mass production with the demerits of wider transition region and higher insertion losses. In this work we would like to present a way to realize, design and fabricate bandpass filter at the frequency 6 GHz with parallel-coupled microstrips since as shown in [2] the parallel coupled outperforms an end coupled BPF , and [3] which uses the composite resonators and stepped impedance resonators for filter realization. The most common approach to a BPF is a butterworth type filter which provides maximally flat response in the pass band region but it suffers from a slow roll of rate in the transition region. Such a filter is not suitable for application requiring sharp cutoff. The practical filters specification allows higher than zero dB loss in passband region. By introducing ripples in the pass band, steeper roll off rate can be achieved and is known as chebyshev response. The Chebyshev approach thereby exhibits some ripples in the pass region, but illustrates steeper roll-off near cutoff frequency.

Lately, there has been an increase in study of the microstrip line with various periodic structures including photonic band gap (PBG) and defected ground structure (DGS) [3]-[9]. Each periodic structure has its own merits and properties. DGS, which is realized by etching few defects on the ground plane under the microstrip line, is also a kind of periodic structures [4]. Most of PBG applications are limited for providing deep and wide stop band performance for circuits [1]-[2]. The PBG structures are difficult to model for microwave or millimeter wave frequencies. Meanwhile, DGS has prominent advantage in extension its applicability to other microwave circuits such as filters, dividers, couplers, amplifiers, and so on [3]-[9], is relatively easy to design and implement. It adds an extra degree of freedom in microwave circuit design and opens the door to a wide range of application [10].

II. DEFECTED GROUND STRUCTURE

DGS is an intentionally etched defect in ground plane of a transmission line. It can be a periodic or a non-periodic configuration depending on the requirement. It disturbs the distribution of shield current in the ground plane. This disturbance will alter characteristics of a transmission line such as line inductance as well as capacitance. In other words, any defect etched in the ground plane of the microstrip trans- mission line can lead to increasing effective inductance and capacitance [4]. Various DGS geometries such as rectangular, circular, square, dumbbell, spiral, L-shaped, U-shaped and V-shaped, concentric ring, hexagonal, cross shaped, hairpin DGS, arrow head slot, inter digital DGS etc. are available [11]. Many of the DGSs besides dumbbell type leads to complex equivalent structures, hence rectangular dumbbell shape DGS are preferred in many microstrip circuits. It consist of two an x b rectangular defected areas and g x w gaps as shown in Fig. 1. The LC equivalent circuit of the DGS and one- pole Butterworth prototype of the LPF are given in Fig.

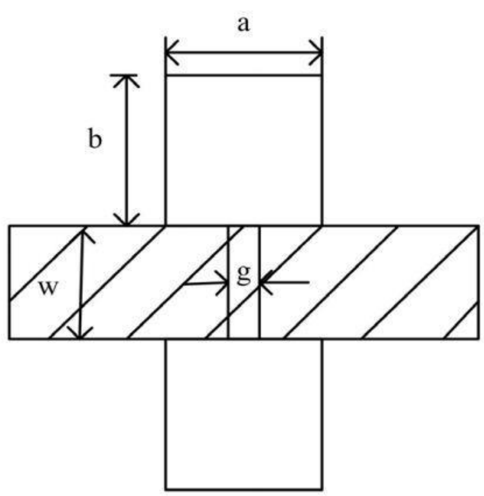


Fig. 1. Dumbbell Shape DGS [10]

The rectangular parts of dumbbell DGS increase route length of current and hence the effective inductance. The slot part accrues charge and increases the effective capacitance of the microstrip line. Two rectangular defected areas and one connecting slot correspond to the equivalently added inductance (L) and capacitance (C), respectively. The effective series inductance increases, as the etched area of the unit lattice is increased resulting in a lower cut-off frequency. The effective capacitance decreases, when the etched gap distance increases moving up the attenuation pole location to higher frequency [10].

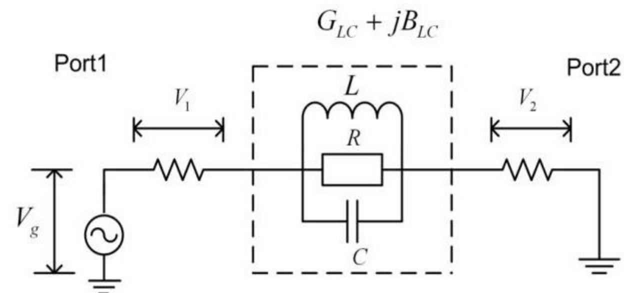


Fig. 2. Equivalent Circuit for unint DGS [10]

III. PROPOSED DGS BASED BANDPASS FILTER

Defected Ground Structure when used on traditional mi- crowave circuits shows improvement in the performance of the circuit often resulting in a smaller size circuit for similar performance. In this paper a Band Pass Filter is realized with DGS to extract improved characteristics. The proposed DGS based bandpass filter may be used for wireless communi- cation applications. This section gives a way to design and fabricate DGS based type bandpass filter for the application such as WiMAX for the frequency range from 5 GHz to 7 GHz with parallel-coupled micro strips which employs the composite resonators and stepped impedance resonators for filter realization. The schematic of the chebyshev type of bandpass filter is shown in Fig. 3. The schematic also shows all the specifications of the filter design this schematic structure of BPF is exported into its layout as shown in Fig. 4 and simulated. A Chebyshev type of filter is designed first and later dumbbell shape DGSs are introduced in this bandpass filter as a proposed design to reduce the ripples in pass band region. Thus, a maximal flat characteristic in the pass region can be achieved so as to reduce the loss in the pass band. The parametric analysis done by introducing a dumbbell shape DGS in it as shown in Fig. 5. Furthermore the number of dumbbell shape DGSs is increased to get the maximal flat characteristic in pass band. The schematic of this proposed filter is as shown in Fig. 6 the bandpass filter given in Fig. 4, is simulated on Agilent's ADS2011.05. The simulation result of the filter is shown in Fig. 7. The proposed DGS based bandpass filter with two dumbbell shape DGS shown in Fig. 5 is simulated for the frequency range from 4 GHz to 8 GHz and the simulation results are as shown in Fig. 8. The proposed bandpass filter with increase in DGSs displayed in Fig. 6. Is simulated and the simulation result is displayed in the Fig 7.
From the result demonstrated in Fig. 9, it shows that the characteristic is maximally flat in pass band. Also the 10 dB bandwidth of the filter have increased when compared with the Fig. 7. As the flat characteristic has been derived by inserting DGS in Chebyshev type of bandpass structure,

the size of the structure will be small compared to that of Butterworth type of bandpass structure.

The proposed Band Pass Filter is fabricated on a FR-4 dielectric substrate material. FR-4 dielectric is used because of its low cost, good performance and easy availability in the market. Fig. 10 show photographs of the fabricated Bandpass filters with Multiple DGS sections and the measured results are shown in Fig. 11 and compared with simulation results in the Table I.

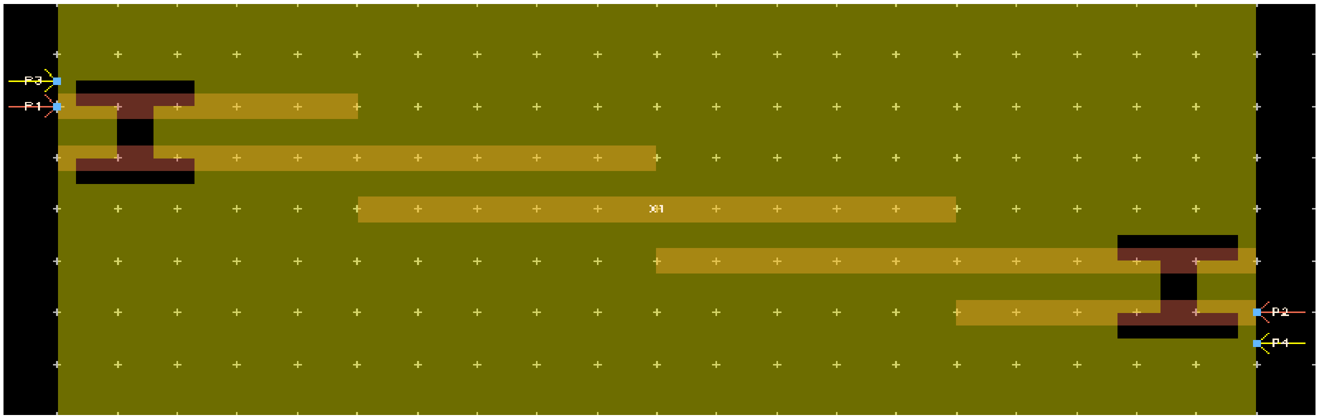


Fig. 5. BPF with DGS at feed point

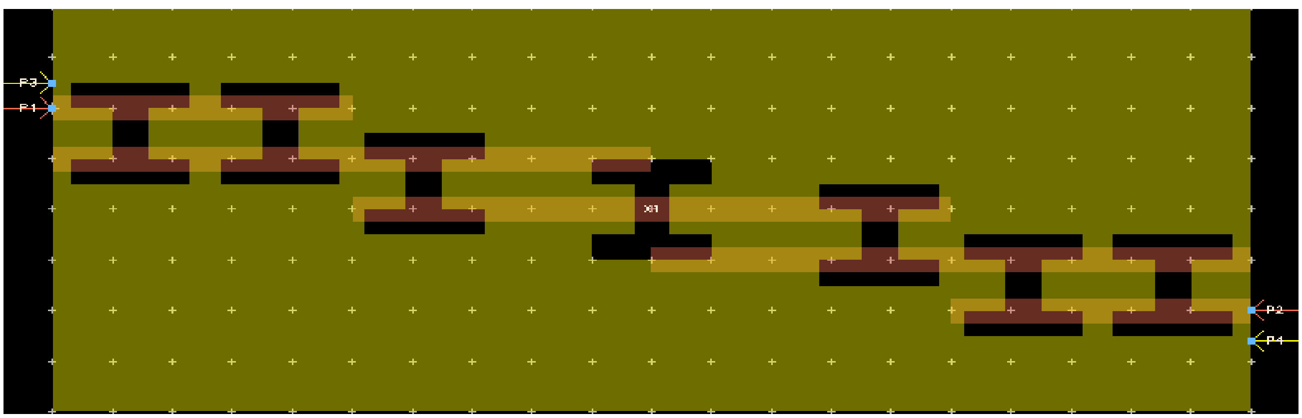
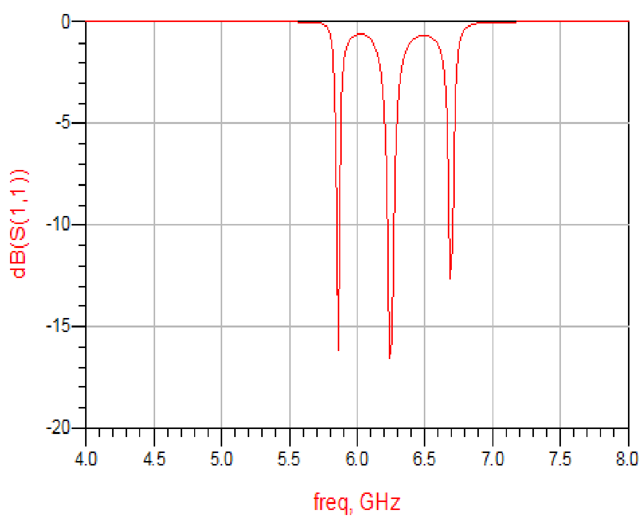


Fig. 6. BPF with dumbbell shape DGS



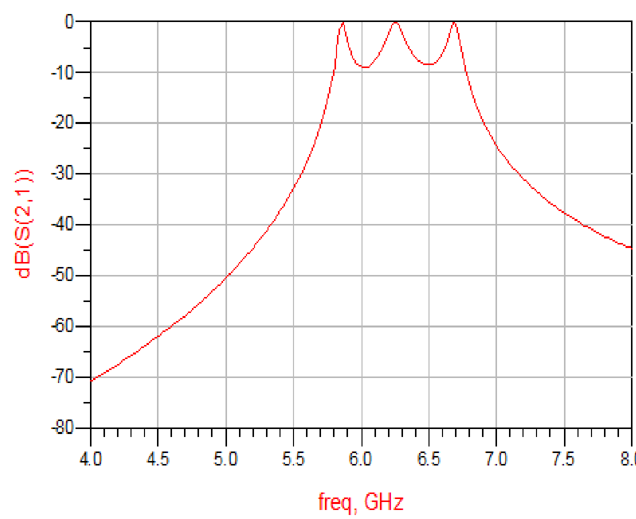


Fig. 7. $S11$ and $S21$ simulation results for designed BPF shown in Fig. 4.

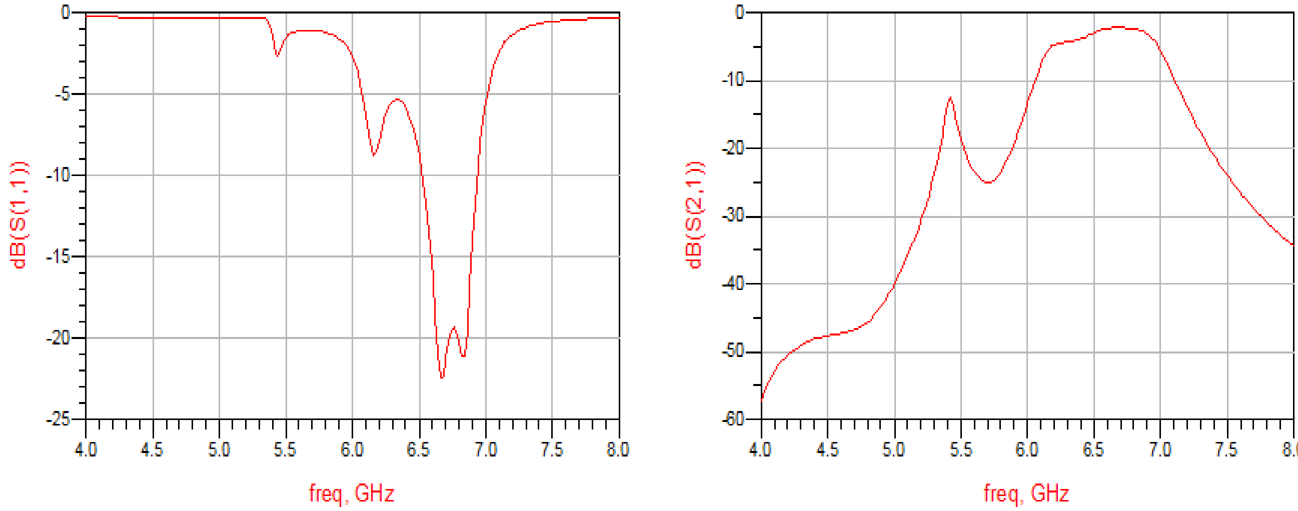


Fig. 8. $S11$ and $S21$ simulation results for designed BPF shown in Fig. 5.

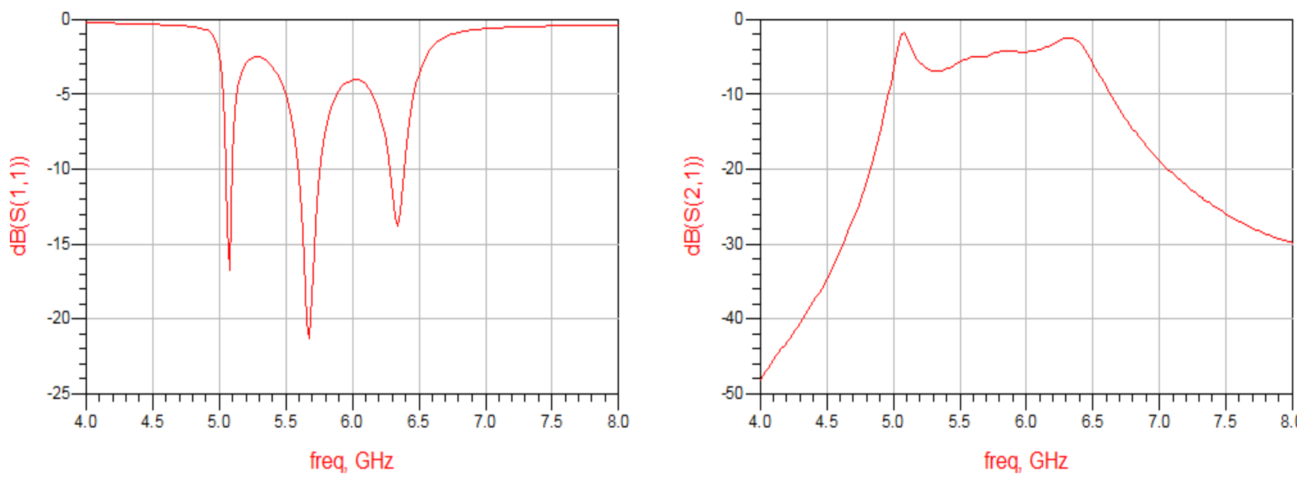


Fig. 9. $S11$ and $S21$ simulation results for designed BPF shown in Fig. 6.

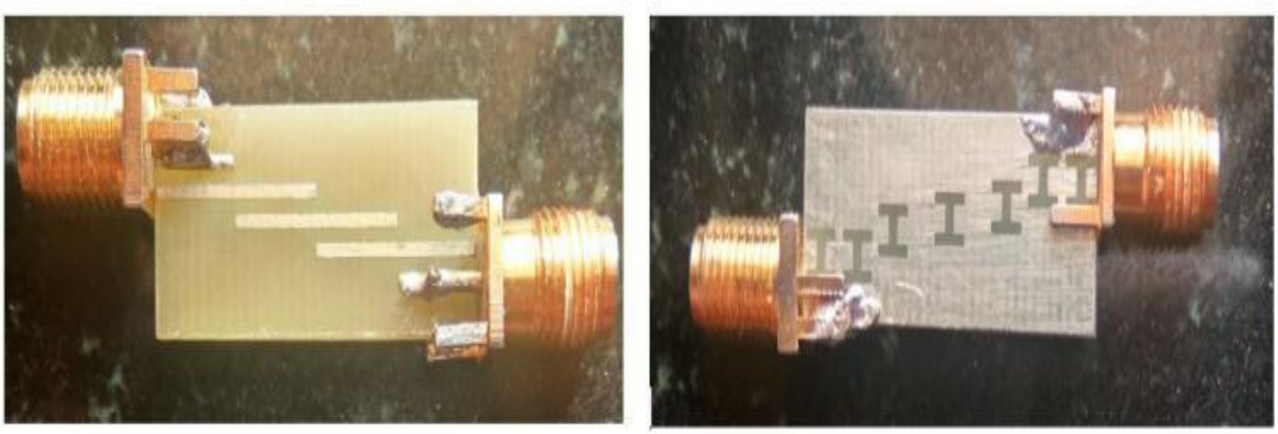


Fig. 10. Top and bottom view of fabricated BPF with DGS

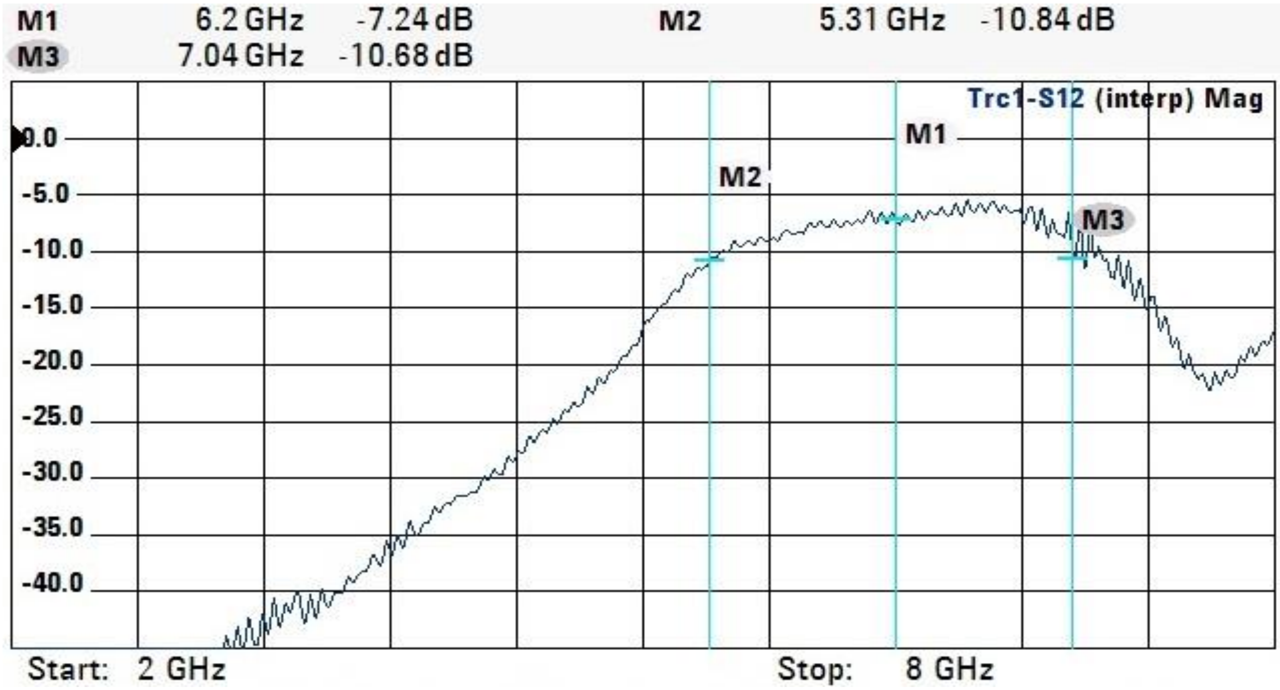


Fig. 11. *S*21 simulation results for fabricated BPF shown in Fig. 10.

TABLE I: COMPARISON OF SCHEMATIC AND PRACTICAL RESULT

Bandpass Filter	Lower Frequency	Upper Frequency	10 dB B/W
Without DGS	5.79 GHz	6.78 GHz	0.99 GHz
DGS at Feed point	6.05 GHz	7.10 GHz	1.05 GHz
Multiple DGS	4.96 GHz	6.64 GHz	1.68 GHz
Fabricated	5.31 GHz	7.04 GHz	1.73 GHz

IV. CONCLUSION

An efficient technique to design a defected ground structure (DGS) based microstrip bandpass filter is proposed. A dumbbell shaped DGS is used to design a microstrip bandpass filter. Due to the use of Chebyshev type of bandpass filter and DGS, the losses occurred in the gain of pass band are reduced and results in the miniaturizing of bandpass filter structure since a higher order filter will be needed if Butterworth design is used to achieve steeper roll off rate. Also, by employing the proposed equivalent circuit of DGS, a harmonic rejection bandpass filter is optimized. Simulation results for an optimized DGS based band pass filter for pass band from 5 GHz to 7 GHz are demonstrated and exhibits a 2 dB improvement in the pass band. The proposed bandpass filter is fabricated on a FR4 substrate to further validate it. The proposed filter design is also able to achieve larger 10 dB bandwidth. Bandpass Filter is an essential part of microwave communication system and an attempt has been made to pro- pose a more efficient bandpass filter. Several simulations and comparisons have been demonstrated to validate the proposed DGS based design.

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