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Compact Size Low-Pass Filter Using Array of DGS with High-Low Microstrip Line

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***Abstract*— In this contribution, a microstrip low-pass filter with a wide stop-band is intended to build with a pass band till 7.1 GHz at -3 dB cutoff frequency. This novel design consist of array of triangular shaped Defect ground structure (DGS) with rectangular defected (or distorted) microstrip structure (DMS). The dimensions of proposed compact filter are about 13×13 mm^2 and have very high sharpness factor (0.94). A traditional triangular DGS structure is also analyzed in order to show the worthiness of proposed design. This proposed filter application can be found in anti-aliasing , acoustic barriers, blurring of images and virtually in any test and measurement systems.**

***Keywords*-Low-Pass Filter, DGS,DMS.**

I.INTRODUCTION

Filters play an important role in most RF and Microwave applications. Currently, the electromagnetic spectrum is limited, and the applications are restricted to occupy just a portion of frequency range without affecting the equipment working out of band and also, without being affected by adjacent devices. A microwave filter is a two port network used to control the frequency response at a certain point in a microwave system by providing transmission at frequencies within the pass band of the filter and attenuation in stop band of the filter [1]. In modern wireless communication systems, compact size and high performance filters are commonly required to reduce the cost and enhance system performances. Recently, the defected ground structure (DGS) for microstrip lines [2-6] has become one of the most interesting areas of research owing to their extensive applicability in microwave circuits. A DGS is an intentionally designed defect on a ground plane that creates additional effective inductance and capacitance. This technique can be used to design microstrip lines with desired characteristics, such as higher impedance, band rejection and slow-wave characteristics, which reduces the footprint of the microstrip structure. Hence DGS structures are used in RF/microwave components (filters, dividers, amplifiers and high-speed digital designs) and direct application of such frequency selective characteristics is found in microwave filters. Many passive and active microwave circuits have been developed by using DGS or PBG (Photonic band-gap) patterns to suppress harmonics and realize the compact size [7-9]. Also, the lumped-element filter design generally works well at low frequencies, but two problems arise at microwave frequencies. First, lumped elements such as inductors and capacitors are generally available only for limited range of values and are difficult to implement at microwave frequencies, and hence must be approximated with distributed components. In addition, distance between filter components is not negligible [10].

Defected (or distorted) microstrip structure (DMS) used here is having extra width (rectangular shaped) rather than traditional etching and its dimensions are tuned for desire results. This provide extra path to the surface current reflected through DGS which in turns result into reduction in insertion loss. Central position of the DMS provide equal extra path to the both side of the DGS. The extra width of DMS will also improve the power handling capacity of circuit.

II.DESIGN AND SIMULATION

Various shapes of DGS has been discussed [11-16]. The triangular DGS elements have been shown to have the sharpest responses among several DGS shapes. In order to design an array, we start with conventional single triangular DGS structure and then proceeds towards array of the same. The proposed design is shown in "Fig.1" and corresponding simulated result is shown in "Fig.2"

A. Equations

Sharpness factor = fcl/f0 (1)

Band width BW = fcu-fcl (2)

Quality factor Q = f0/BW (3)

Capacitance C = pF (4)

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Inductance L = (5)

Where fcl, and fcu is the -3dB lower and upper cut off frequency respectively. fo is resonant frequency.

B. *Design Specification of single triangular DGS and its frequency response*

Length of Ground = 13mm
Width of Ground = 13mm
Width of strip = 2.4mm
Area of triangular shaped DGS = 13.1
FR4 Dielectric thickness = 0.8 and ϵr =2.2
Conductor thickness = 0.035mm
Calculated values of various parameters using frequency response curve are as follows.
fcl= 5.2GHz , fcu=12.5GHz, f0 = 7.5 GHz,
Q= 1.07, Stop B.W=7GHz, Sharpness factor = 0.69

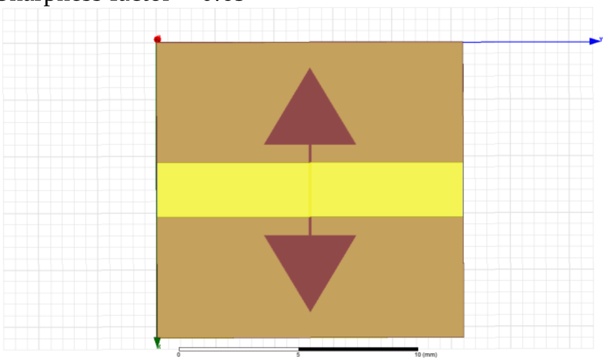

Fig 1. Single triangular DGS without DMS

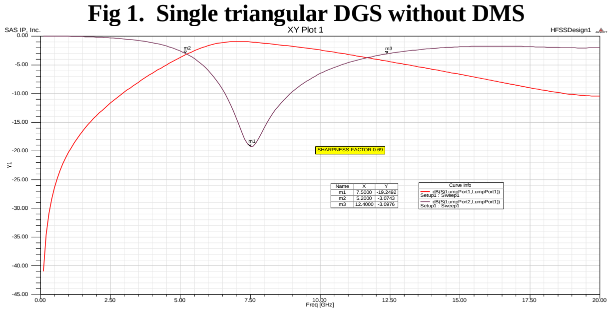

Fig 2. Frequency response of traditional LPF having triangular DGS

C. Low pass filter using DGS array with DMS (proposed LPF)

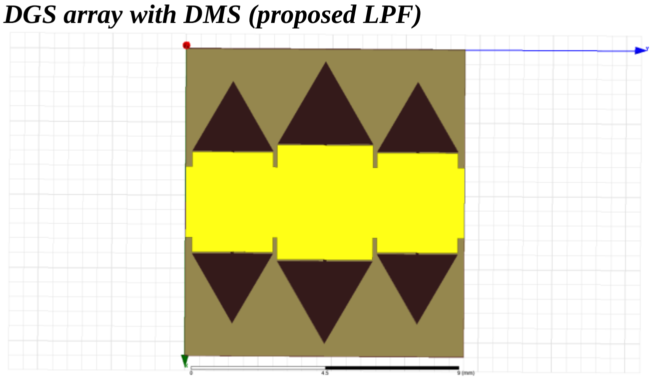

Fig 3. Proposed array of three triangular DGS with DMS

This DGS array consist of three triangular DGS. By using so many iterations [17], the resonant frequency shifted to 7.5GHZ and also reduces the size of the DGS [18]. Thus by using etching geometry and size reduction techniques [19], we get the final design of DGS array. The design is shown in "Fig.3" and corresponding simulated result is shown in "Fig.4".

D. Design Specification of proposed LPF and its frequency response

Length of Ground = 13mm
Width of Ground = 13mm

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Width of strip =2.4mm
Area of centre triangle DGS = 7.7
Are of Left and right triangle DGS =6.5
FR4 Dielectric thickness =0.8 and ϵr =2.2
Conductor thickness =0.035mm
Calculated values of various parameters using frequency response curve are as follows.
fcl=7.1GHz , fcu=19.9GHz, f0 = 7.5 GHz,
Q= 0.58, Stop B.W= 12.8GHz, Sharpness factor = 0.94, C=1.93pF, L=0.233nH

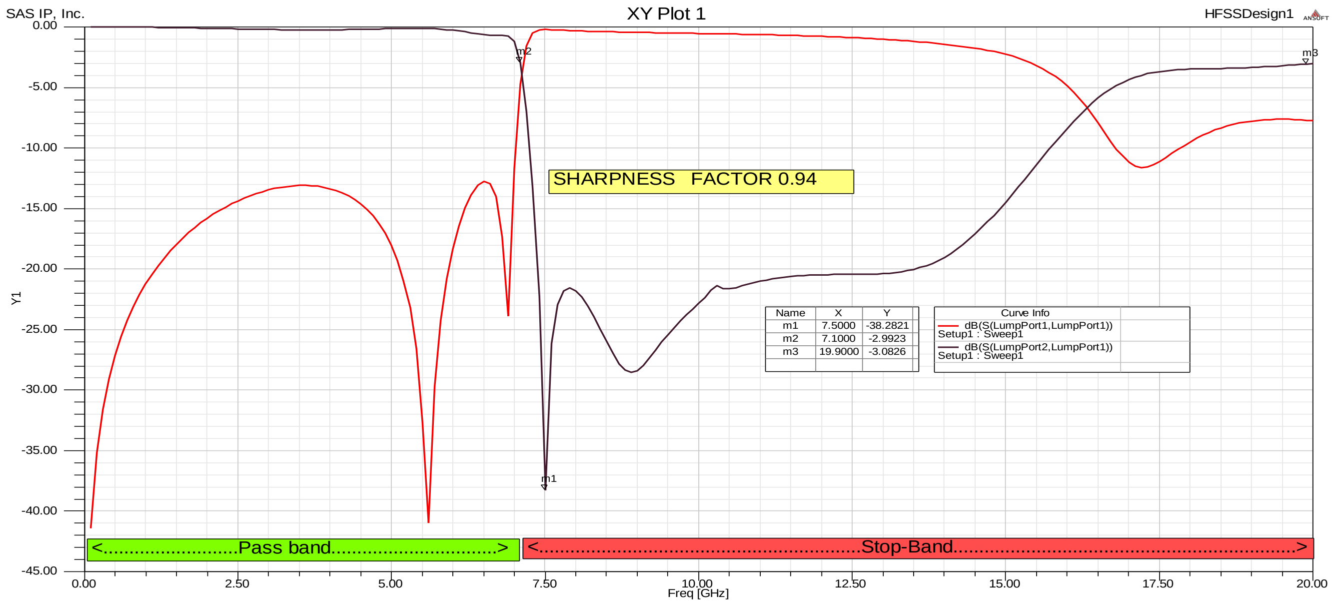

Fig 4. Frequency response of proposed LPF having array of three triangular DGS

E. *Investigation of frequency response and performance*

Thus from the observation of frequency response it is clear that for the same resonant frequency 7.5GHz, the array of DGS has more sharpness factor, wide stop bandwidth and less area of the etched DGS than the conventional single triangular DGS - LPF. For illustration the level of suppression in band-stop region, the VSWR parameter is shown in "Fig.5" As can be seen, the VSWR value is very low till pass band region and sharply increased at resonant frequency and then gradually decreases after that. This shows that even high power harmonics can be completely rejected after the resonant frequency.

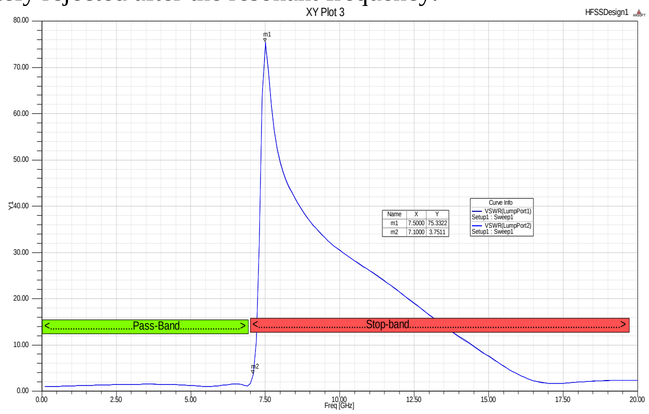

Fig 5. VSWR parameter of proposed LPF

For investigation of the linear distortion of the filter, we plot the group delay in "Fig.6" It is revealed that the delay is almost constant up to the 6.5GHz but there is a sudden abrupt after -3dB cut-off frequency 7.1GHz . This problem is not important because this frequency falls in band stop region of proposed LPF and not affects the signal passing in operating frequency.

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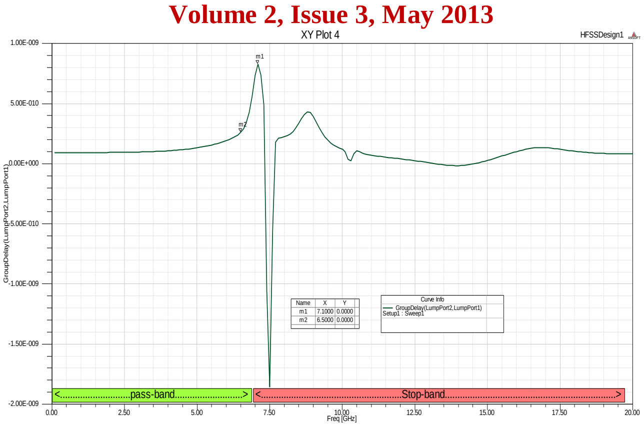

Fig 6: Group delay parameter of proposed LPF.

F. *Ground field analysis*

Field analysis at ground surface shows that it has high electric field intensity along the length of rectangular etching (“Fig.7”) and high magnetic field intensity along the sides of triangular etching (“Fig.8”). Hence it reveals that rectangular etching produces capacitive effect and triangular etching produces inductive effect. The value and combination of produce capacitance and inductance are in such a way that proposed circuit behaves as a low pass filter.

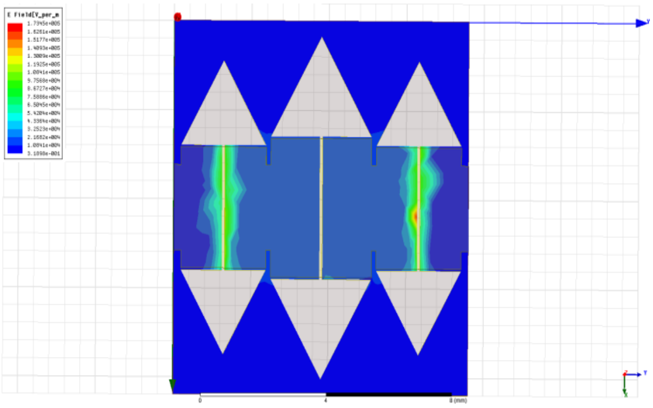

Fig7. Electric field at ground surface

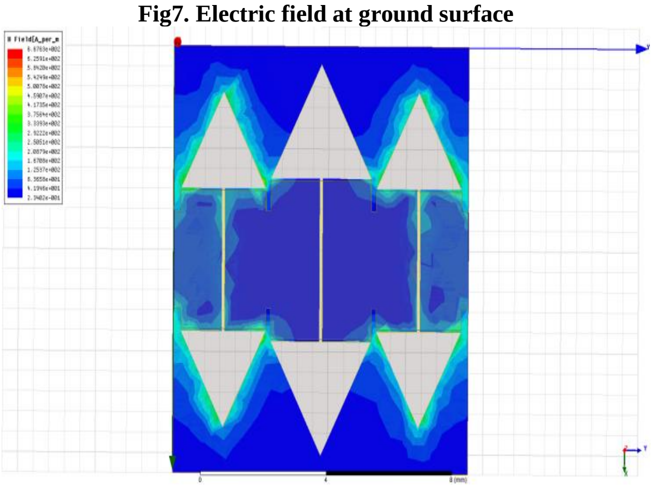

Fig 8. Magnetic field at ground surface

G. *Equivalent circuit of proposed LPF*

With the help of frequency response curve and using “(4)” and “(5)” we can calculate equivalent circuit of proposed LPF. The equivalent circuit is shown in “Fig-9” and corresponding frequency response is shown in “Fig-10”. The obtained result has same resonant frequency response of proposed LPF.

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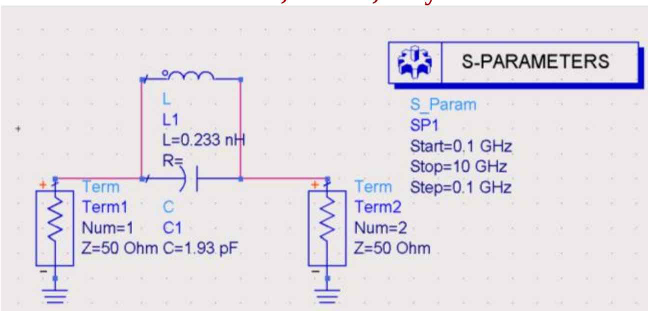

Fig 9:-. Equivalent circuit of L & C(Calculated from frequency response curve)

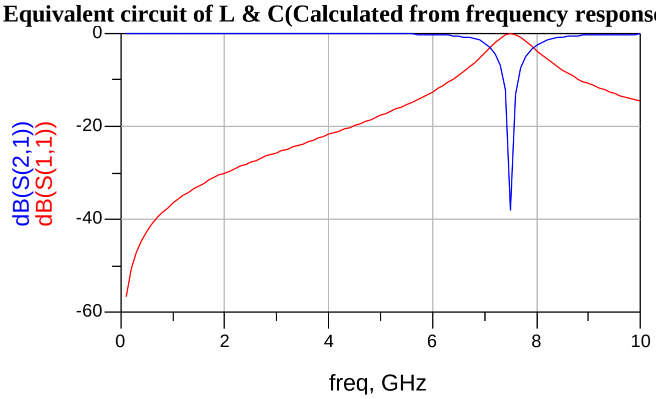

Fig 10: Regenerated frequency response curve from calculated value of L & C

Thus from the above observation it is clear that the array of DGS has more sharp cutoff frequency, wide stop bandwidth as well as compact size.

III.CONCLUSION

In this paper, we have investigated array of triangular DGS pattern for microstrip low pass filter. An equivalent lumped *L-C* network has been presented to model the introduced DGS unit. By using parametric relationships, the values of lumped *L-C* elements for the DGS unit have also been extracted. The proposed array of DGS LPF design is much better than the same conventional type of DGS LPF because it has better frequency response and much better sharpness factor. Also, unlike conventional low pass filter it does not have any undesired harmonics due to presence of high low impedance microstrip line. It is expected that the broadened width of microstrip line would provide an improved high power-handling capability.

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