Bans Width Enhancement of Filtenna using DGS

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***Abstract*: Current article, *a microstrip filtenna with DGS (Defected Ground Structure) is used to implement a LP (Low Pass) filter is designed using a substrate of FR-4 epoxy as the dielectric material. This filtenna consists of a double N-shaped DGS as well as a double closed X-shaped DGS, to improve the performance in terms of wider operational bands, good selectivity and cut-off frequency. The 3dB cut-off frequency of this filtenna is at 2.3672 GHz. To validate the simulated results, are compared with fabricated and measured results. The proposed filtenna has better gain result compared to a conventional antenna in terms of showing better rejection and out-of-band gain which subsequently reduces the interference with the adjacent frequency bands.*

***Index Terms*: Microstrip antenna, DGS, Low Pass Filter, Filtenna.**

I. INTRODUCTION

Since the early days of wireless communications, the cognitive radio systems have played major role in the development of more sophisticated communication systems such as Satellite communications, in military and civil applications, radar applications, and mobile phone systems. Filters are extensively used in the receiving equipment of almost all communications systems both wired and wireless.
The combination of a radiating element (antenna) into filter to form single module is called filtenna. In [1], compact filtenna with wide band width when compared with its counter parasitic monopole antenna is proposed. It has been explained how two separately designed models, one being a monopole antenna and the other one a band-pass filter operating their respective modes were later combined to obtain an improved impedance bandwidth filter by manipulating the mutual coupling [1].
Compact reconfigurable filtennas were developed which has good band-pass characteristics as well as continuously tuneable narrow-band states which are intended to be used in CR applications [2]. Also, it is further modified to be characterised as a dual-band CP horn filtenna which works at two frequencies and two orthogonal polarisations [3]. In [4], compact planar mono-pole filtenna based on capacitively loaded loop (CLL) resonators is proposed.
Cognitive radio (CR) systems with reconfigurable filtennas were studied in comparison with, the Software Defined Ratio (SDR). Both the CR systems where implemented using MIMO setting [5]. A Reconfigurable polarizer was designed which achieves both linear as well as (CP) circular polarizations, which includes both LHCP and RHCP. Two PIN diodes were used to implement RF switches, and this configuration gives the required symmetry and good axial Ratio by using two off-centered slots [6].
A broadband duplex filtenna which uses an integrated method, and which is based on a metallic cavity structure (3D) was designed. Here two different broadband filtennas were used. These filtennas have separate bands of operation and that they share the same metallic resonator which is cavity-backed. The integration of a duplexer along with an antenna is used for the microstrip structure and LTCC (Low Temperature Co-Fired Ceramics) technology. The aim of the design of this filter is to obtain low loss factor and high power, which is achieved by using a metallic cavity [7]. In another researcher's design rejection of second and third harmonic rejection CPW-feeding mechanisms were used. Two different topologies one which separately blocks the second and third harmonics using a lightly coupled CMRC (Compact Microstrip Resonator Cell) and a U-shaped slot, while the other topology used strongly-coupled CMRCs are used [8],[9-12].

This paper proposes a LP (Low Pass) filter with a DGS in two different configurations, one being N-shaped and the other one is closed X-shaped ground structures. The cut-off frequency for this filtenna is designed to be 1.98 GHz.

II. LOW-PASS FILTENNA DESIGN

The proposed filtenna is designed, studied and simulated using Ansys HFSS (High Frequency Structural Stimulator) software. The Stepped impedance resonators (SIR) and the uniform impedance stubs (UIS) are used to design conventional low-pass filter with the capability to generate transmission zeros at resonant frequencies. A filter has a wider stop frequency; in this more elements are added to increase physical size of the filter. A basic filter can act as a primary resonator. A series resonator normally consists of a high impedance stub along with a low impedance patch. An Inductor and a capacitor are combined in symmetric with a transmission line (TL) of high impedance. Where dimensions of the filter are *a*=3.6, *b*=3.6, *c*=1.5, *d*=0.2, *e*=6.4, *h*=4 and *g*=0.2 (all the units are in mm). The main transmission line with high impedance is of the length *e* and can be represented as Z_{L1}.The impedance of series resonators are Z_{L2} and Z_{C1} respectively. *c* is the width of the microstrip line is 1. 5mm. FR-4 of stature 0.8 mm.
The equivalent circuit which is the LC circuit also called as primary resonator is depicted in figure 1(b). The values of L and C values are given as L'_1=4.4nH, L'_2=3.2nH and C'_1=0.9pF.

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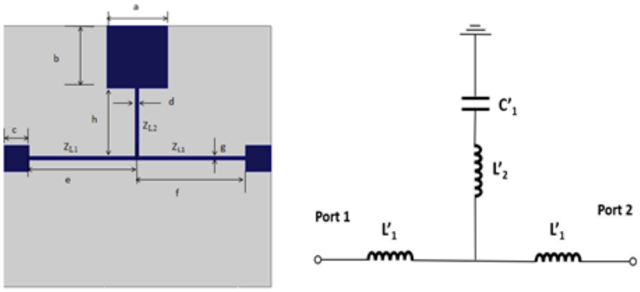

(a) (b)

Fig. 1 Basic diagram of a resonator (a) the structure (b) equivalent circuit

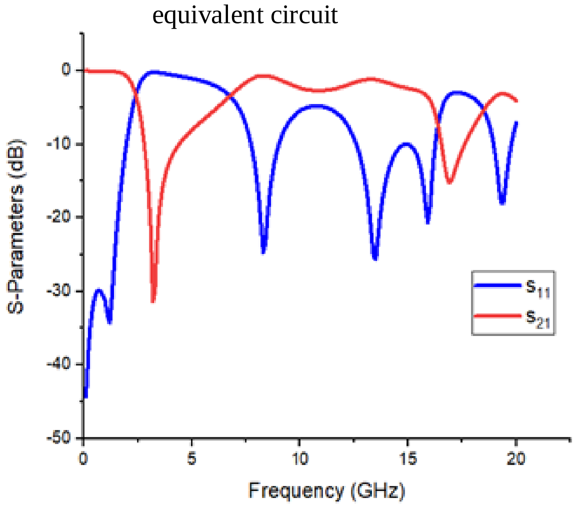

Fig. 2 Reflection coefficient (in dB) plotted against the Frequency (in GHz)

Basically, the ABCD parameters of the symmetrical two port for T-network (1) as shown in the figure 1(a)

$$A = D = 1 + \frac{Z_{L1}}{Z_{L2} + Z_{C1}} \tag{1}$$

$$B = 2(Z_{L1}) + \frac{Z^2_{L1}}{Z_{L2} + Z_{C1}} \tag{2}$$

$$C = \frac{1}{Z_{L2} + Z_{C1}} \tag{3}$$

For substituting the impedance of the inductors and capacitors

$$A = D = 1 + \frac{\omega^2 L'_1 C'_1}{\omega^2 L'_2 C'_1 - 1} \tag{4}$$

$$B = \frac{2j\omega L'_1 - 2j\omega^3 L'_1 L'_2 C'_1 - j\omega^3 (L'_1)^2 C'_1}{1 - \omega^2 L'_2 C'_1} \tag{5}$$

$$C = \frac{j\omega C'_1}{1 - \omega^2 L'_2 C'_1} \tag{6}$$

S-parameters for the primary resonator (1) are

$$S_{11} = \frac{A + B/Z_0 - CZ_0 - D}{A + B/Z_0 + CZ_0 + D} \tag{7}$$

$$S_{21} = \frac{2}{A + B/Z_0 + CZ_0 + D} \tag{8}$$

we get the transmission characteristics and reflection characteristics are controlled by the varying the values of L'_1, L'_2 and C'_1.

From these we can write $|s_{21}|=0$, for a single finite frequency attenuation pole may occurs at f_p

$$f_p = \frac{1}{2\pi\sqrt{L'_2 C'_1}} \tag{9}$$

f_p 3.2 GHz is calculated from resonant frequency.

From the figure (2) it has been observed that the frequency response which is simulated for the EM as well as the LC circuits of the primary resonator.

Both the EM as well as the LC circuits has good results. The cut-off frequency for this microstrip structure is to 1.2 GHz. For this circuit single transmission zero occurred at 2.40 GHz.

$$X_{LC} = \frac{1}{\omega_0 C_H \left(\frac{\omega_0}{\omega} - \frac{\omega}{\omega_0}\right)} \tag{10}$$

ω_0 -angular frequency response

X_L -series inductance of Butterworth filter

$$X_L = \omega L = \frac{\omega}{\omega_c}(Z_0 g_1) \tag{11}$$

$$\frac{1}{\omega_0 C_H \left(\frac{\omega_0}{\omega_C} - \frac{\omega_C}{\omega_0}\right)} = Z_0 g_1 \tag{12}$$

g_1 -proto type element

$$C_H = \frac{\omega_c}{Z_0 g_1 (\omega^2_0 - \omega^2_c)} \tag{13}$$

C_H-capacitance

L_H-inductances

$$L_H = \frac{1}{4\pi^2 f_0^2 C_H} \tag{14}$$

This design uses an extended version the basic resonator so as to make it a microstrip low-pass filter making use of SIR and UIS. From the figure 4 the cut-off frequency is at 1.75GHz and the frequency at 20dB suppression-level at 2.55 GHz. Basically, the design consists of two low-impedance stubs which are uniformly shaped and three resonators of stepped-impedance.

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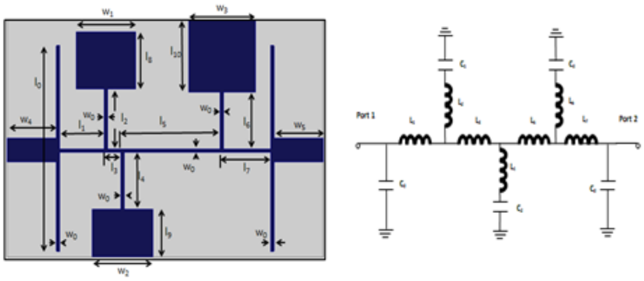
A wider stop band of up to the 9 GHz at 20 dB suppression level is obtained as depicted in figure 4. There are Resonator-A, Resonator-B and Resonator-C. It can be loaded on high impedance main transmission line. In uniformly shaped low impedance stubs have the modelled as a capacitor; it will have length l_0 and width w_0. In the design of an antenna, the dimensions are l_1=2.7, l_2=3.8, l_3=0.8, l_4=3.6, l_5=6.85, l_6=3.6, l_7=3.05, l_8=3.6, l_9=3.0, l_{10}=4.55, w_0=0.2, w_1=3.6, w_2=3.7, w_3=4.05 (all are in mm).

The physical dimensions of this filter are 19.2 mm x 15 mm. From the figure 3(a) the cut-off frequency is 1.75GHz, and at 20dB suppression-level the frequency is 2.55 GHz. Also, the bandwidth of the stop band with a suppression-level of 20dB is between 2.2GHz and 9.5GHz.

We can improve the performance of the low pass filter without increasing the physical size (shapes) of the design. It has future like simplicity, wide and deeper stop band characteristics. DGS is used to design the filter. It has same filter as SIR-UIS with the two symmetrical N-shaped slots is printed on ground surface.



(a) (b)

Fig .3 Basic Low-Pass filter (a) the structure (b)LC circuit of LPF design

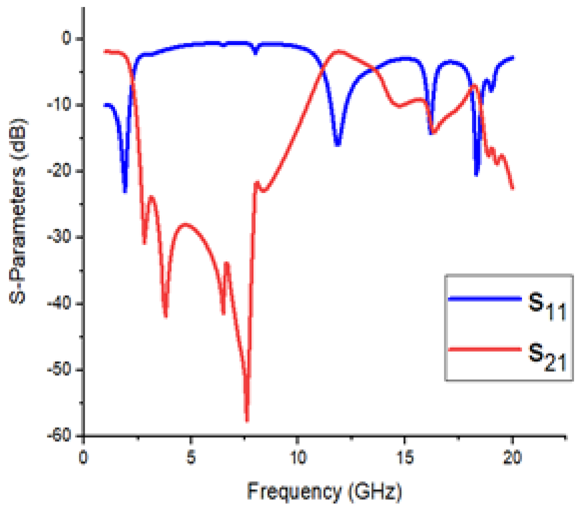


Fig.4 Reflection coefficient (in dB) plotted against the Frequency (in GHz)

III. CHARACTERISTICS OF DOUBLE N-SHAPED DGS

The filtenna consists of two N shaped on DGS is printed on ground surface function as low pass filter structures. In this, N-two shaped units are separated by spacing s=4 mm. The dimensions of the DGS are as shown in figure *a*=6, *b*=3.6, *c*=0.45, and d=1 (all are in mm). By using this we can improve the stop band, bandwidth of the filter is etched to the ground plane with out increase the physical shape (size) of the filter. The N-shape DGS characteristics are used to allow good selectivity and the stopband bandwidth is 20GHz at the 18-suppression level. From the figure 5 the simulated at 3 dB the cutoff frequency of the filter is 1.78 GHz is and wide stop band width is 2.5GHz to 20GHz with the level of the rejection 18 dB .

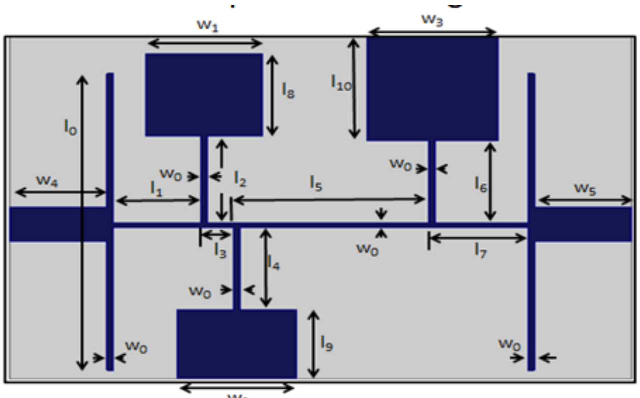


Fig. 5 Basic Low-Pass filter

The lumped elements of filter circuit (LC) is shown in figure 3(i). L_1, L_3, L_5, L_7 these values are representing the inductances and high impedances of transmission line length is l_1, l_3, l_5, $l_{7.}$ These values of L2,L4,L6 are representing the inductances. The C_1, C_2 and C_3 are representing the capacitances and it act as Resonator-1, Resonator-2 and Resonator-3.

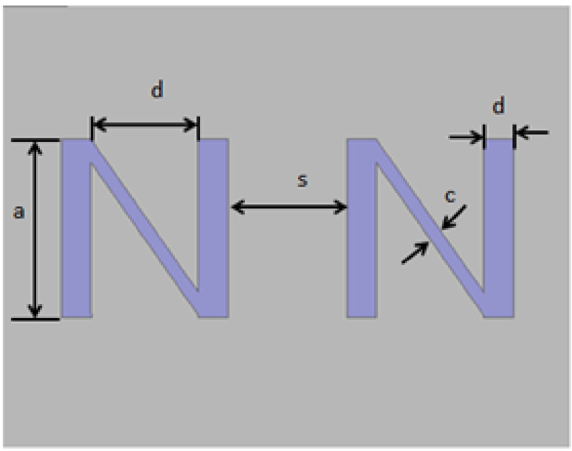


Fig. 6 Double N-shaped DGS

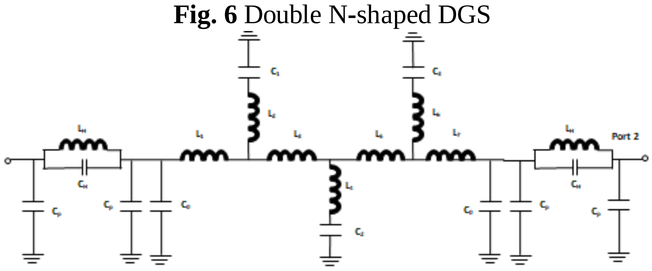


Fig. 7 Equivalent circuit of the structure

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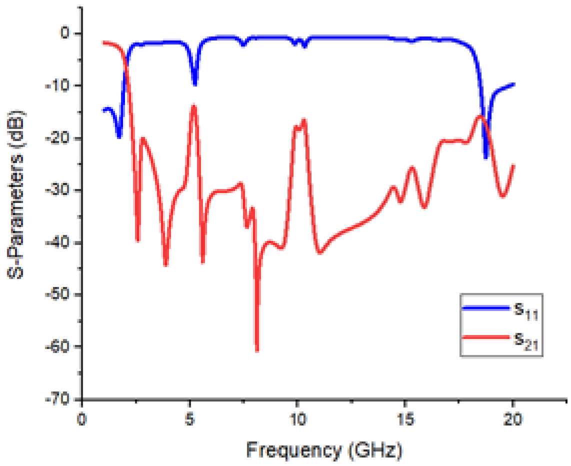

Fig. 8 Reflection coefficient (in dB) plotted against the Frequency (in GHz).

C_0 is the capacitance and it act as uniform impedance stubs. The (Lc) equivalent circuit values are L_1=1.1 nH, L_2=2.6 nH, L_3=0.6 nH, L_4=2.4 nH, L_5=4.1 nH, L_6=3.4 nH, L_7=2.1 nH, L_H=0.8 nH, C_1=0.8 pH, C_2=0.6 pH, C_3=1.1 pH, C_0=0.7 pH, C_H=0.1 pH, C_P=0.2 pH .

IV. CHARACTERISTICS OF DOUBLE X-SHAPED DGS

This filter consists of double closed X-shaped on DGS is printed on ground surface on the low pass filter structures. In this X-two shaped units are separated by spacing S=2mm.The dimensions are of the DGS are shown in figure 10 are a=8, *b*=1.5, *c*=7.6.

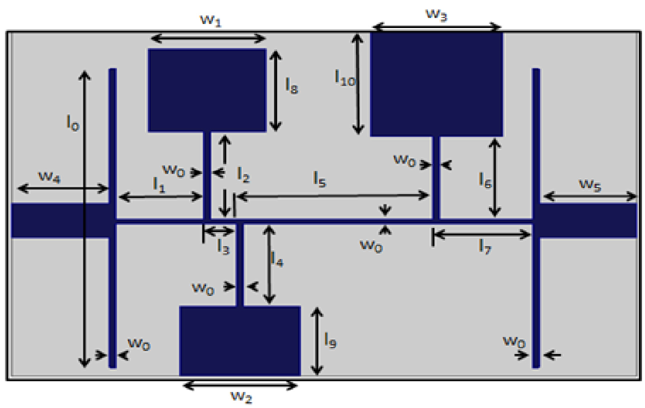

Fig.9 Basic Low-Pass filter the structure

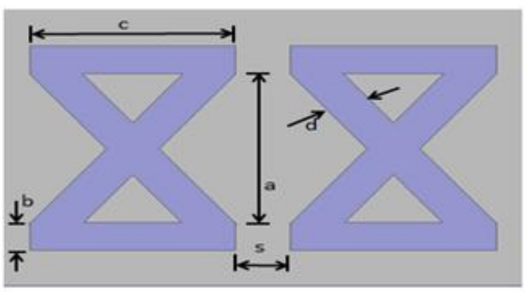

Fig.10 Double closed-shaped DGS

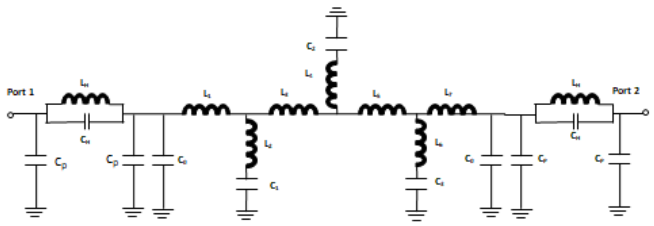

Fig.11 Equivalent circuit of the structure

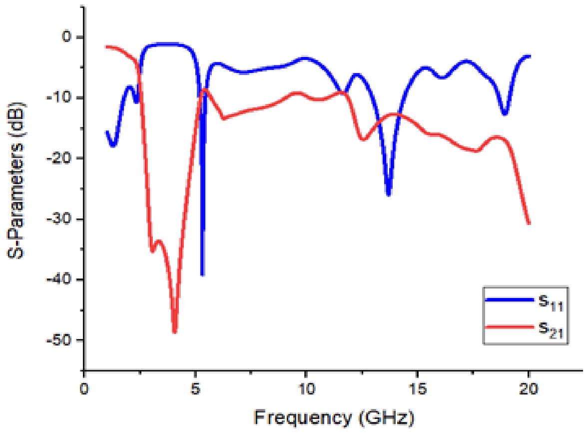

Fig. 12 S-Parameters with DGS structure.

To improve the characteristics of filter we are used different types of shapes. In this we are used two N-shapes to etch the ground plane and the coupling between DGS resonators are increases. In this design the substrate is made up of FR4 epoxy for all structures. To improve the characteristics of filters, two-N shaped and closed two X-shaped filters, are printed on the ground surface and the coupling between the DGS resonator is increased. From these filters, it can be improving the characteristics of a pass band and band stop is without increasing filter physical size.

The filter's equivalent circuit is presented in figure 11. L_1, L_3, L_5, L_7 these values are representing the inductances and high impedances of transmission line length is l_1, l_3, l_5, l_7. These values of L2, L4, L6 are representing the inductances. The C_1, C_2 and C_3 are representing the capacitances and it act as Resonator-1, Resonator-2 and Resonator-3. C_0 is the capacitance and it act as uniform impedance stubs. The (Lc) equivalent circuit values are L_1=1.1 nH, L_2=2.6 nH, L_3=0.6 nH, L_4=2.4 nH, L_5=4.1 nH, L_6=3.4 nH, L_7=2.1 nH, L_H=0.8 nH, C_1=0.8 pH, C_2=0.6 pH, C_3=1.1 pH, C_0=0.7 pH, C_H=0.1 pH, C_P=0.2 pH.

IV CONCLUSION

Compact and cost effective filtenna using DGS is proposed and characterized. The principle, working characteristics of DGS also discussed. The microstrip antenna is used for different specifications (applications) of DGS such as double N-shaped and double closed X-shaped configurations. Current design consists of a low-pass filter with efficient rejection and out-of-band gain characteristics is achieved. This structure reduces interference with tunable frequency bands.

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The measured results of the prototype match closely with the simulated results.

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