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Design on X Band Frequency Notch Horn Filtenna

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***Abstract*— Satellite Communication is a microwave repeater that consists of a diverse combination of one or more components including transmitter, receiver, amplifier, regenerator, filter on board computer, multiplexer, demultiplexer, antenna, waveguide etc. Satellite communicable applications generally come under categories of HF, VHF, UHF (3-30GHz). In Satellite communication filtering antenna like horn are paid more attention. And in many applications the same band is used for various purposes which lead to interrupt desired frequency. So, we have focused to bring out a particular frequency using a band notch filtenna. A Horn Filtenna with an operating frequency of 8.25 Ghz is investigated, designed and simulated using HFSS (High Frequency Stimulator Software). Filtenna consists of SRR (Split Ring Resonator) etched on a Rogers Duroid RT5880 dielectric substrate which is inserted inside the waveguide at a suitable distance from the throat of the horn. Overall characteristic of resonator frequency of the SRR transmission is highly reduced and a single notched-band is obtained. This result of an experimental study is trying to reach the filtered resonated frequency between 8 Ghz – 12 Ghz in X Band region. The obtained parameters in filtenna are reflection coefficient (return loss) and gain. The proposed solution is economical, light, electrically small easily implementable on already existing radiators and can find applications to wideband communications systems affected by narrowband interfering signals.**

***Index Terms*—Filtenna, Horn Antenna, High Frequency Structured Simulator, Split Ring resonator.**

I. INTRODUCTION

Recently, filtering and radiation performance integrated modules, have been paid more attention. Filters are usually used in the receiver front-end of communication systems to improve the efficiency, performance and increase the signal-to noise ratio (SNR). X band communication systems use a large portion of the electromagnetic spectrum; the performance of the receiver front-end is typically affected by the interfering signals generated by other services operating in a narrower portion of the same operating frequency band. On the other hand, narrowband receiving systems have to differentiate the desired signal from the out-of-band noise. Therefore, depending on the communication system and the relative operating environment, proper filtering components with band notch characteristics should be inserted between the antenna and the receiver front-end, resulting in increased complexity, size, weight and cost of the overall system. One feasible solution to solve the problem is to employ a filtering antenna, or filtenna, which integrates the radiating element and the filter in a single module [1]. In the past few years, several configurations have been proposed to design both microstrip and horn antennas with a filtering behaviour. In particular, for patch antennas a multitude of both band-pass and band stop configurations have been proposed. In this filtennas with band-stop operation, we introduce a novel approach, based on the use of metamaterial- inspired resonators. Metamaterials are materials whose electromagnetic or acoustic properties arise from their internal structure rather than just the matter of which they are composed. Appropriately designed metamaterials can affect waves of electromagnetic radiation or sound in a manner not observed in bulk materials. Those that exhibit a negative index of refraction for particular wavelengths have attracted significant research. These materials are known as negative-index metamaterials and these materials are also known as left handed materials [2]. These metamaterials are used as Split Ring Resonators by properly placing a SRR inside a standard horn antenna, the radiating and matching properties of the overall structure are affected by the strong resonance of the SRR only around its resonant frequency—leading to a band notch—while they are almost unchanged in the rest of the operating frequency band. The dimensions of the SRR can be easily chosen to make the notched-band centred at the frequency of the interfering signal we want to suppress. Moreover, using two or more SRRs, we are able to suppress multiple interfering signals at different frequencies [2]. The above mentioned metamaterial like SRR kind of work was executed in the reference paper.

They have proposed a rectangular split ring resonator in the standard horn by obtaining the band notch characteristics.

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The base paper even described about the dual band notch characteristics. Parameters like reflection co-efficient S(1,1) realized gain and power transmission has been discussed in the base paper [1]. Taking base paper as the reference we focused to obtain a wide band notch in X band region using circular SRR. Circular SRR is placed in the wave guide at particular distance from throat and connected to horn. The structure of the communication is as follows. In Chapter II, We estimated resonance frequency in SRR using Matlab. In Chapter III, we designed SRR in wave guide and implemented in Standard Pyramidal Horn.

In Chapter IV, we extended our design for quardruple SRR in horn with band notch characteristics. Finally, in Section V, we draw the conclusion.

II. Estimation of Resonance Frequency in SRR

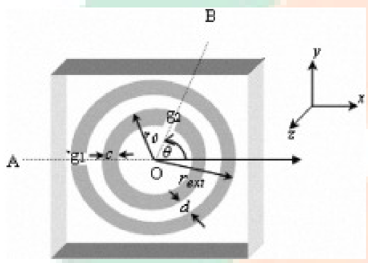

Fig .1. Edge coupled circular split ring with rotated inner rings.

The SRR have splits or gaps *g1* and g2 with identical dimension and lying on the same axis within the inner ring and outer rings as shown in Fig. 1. Two rings if SRR are coupled by a strong distributed capacitance caused by the gap between the rings. When a time harmonic fields is applied such that magnetic fields is along x axis, an electromotive is experienced by the SRR. With quasi static model in mind, the induced current lines will pass from one ring to another ring through the capacitive gaps in the form of displacement current. Therefore, the total current intensity flowing on both the rings remains same for any section of the structure i.e. independent of the angular co-ordinates. The whole device behaves as a LC circuit (Fig. 2).

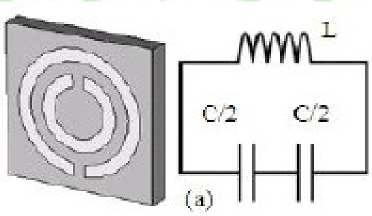

Fig.2. Equivalent circuit for SRR

Therefore, the resonant frequency is given by

Further to obtain the resonant frequency using Matlab, surface capacitance and gap capacitance must be calculated .

The gap capacitance:

$$c^{gap} = \varepsilon_0 \left[\left(\frac{wh}{g} + \frac{2\pi h}{(\ln \frac{2.4h}{w})} \right) \right]$$

The surface capacitance :

$$c_{ur} = \frac{2\varepsilon_0 h}{\pi} \ln \frac{4\pi}{g}$$

Total capacitance :

$$c = c_{ur} + c^{gap}$$

The required resonant frequency is:

$$f_0 = \frac{1}{2\pi\sqrt{L(c_{ur} + c^{gap})}}$$

Using these formulas, we have written code in the matlab and derived the resonant frequency. This model also predicts the shift in the resonance frequency for rotational SRR as per the calculation in matlab resonance frequency is 8.25 GHz.

III. Designing of SRR in Wave Guide And Implemented in Pyramidal Horn.

A. *Overview of proposed structure*

In this paper microwave components exhibiting a self-filtering behavior has been shown and a new family of horn antennas and waveguide components have been proposed by introducing electrically small resonators. This approach has been proposed to simplify the whole structure and add polarization-transforming capabilities [1], [2]. Therefore, these approaches lead to the propagation direction of the electromagnetic field and they can be used only for microwave components exhibiting a band-stop (notch) behavior. First, the single SRR is taken in the waveguide as per the dimensions and measurements achieved from the above estimation of resonance frequency (Fig-3). Later the reflection co–efficient S (1, 1) for single SRR in wave guide is obtained in the x-band region.

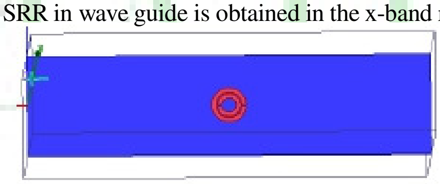

Fig. 3 Design of single SRR in a waveguide

When a single SRR is placed in the waveguide, we obtained the simulated reflection coefficient at the input port shown in fig. 4.

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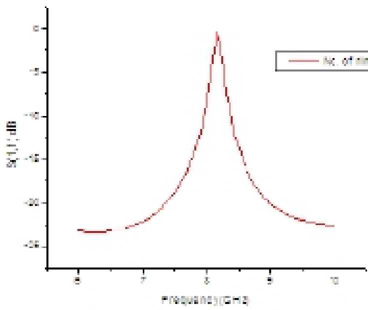

Fig:4 Simulated Reflection Co-efficient for single SRR.

When two SRR is employed in the waveguide, we obtained the simulated reflection coefficient at the input port shown in fig. 5.

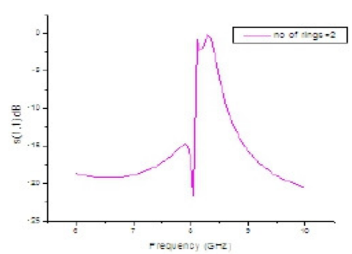

Fig :5 Simulated Reflection Co-efficient for two SRR.

Similarly, we have added six consecutive SRRs reflection coefficient is analyzed and shown in Fig-6. We have obtained a wide band of filter notch in X-band region.

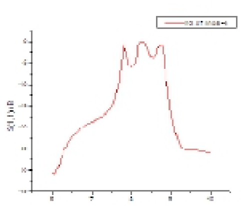

Fig:6 Simulated Reflection Co-efficient for 6 SRRs

Finally in the end of chapter II, we implemented single SRR in the Standard Horn (Fig. 7) at distance from the throat of 25 dB. Simulated reflection co-efficient is shown in Fig. 8.

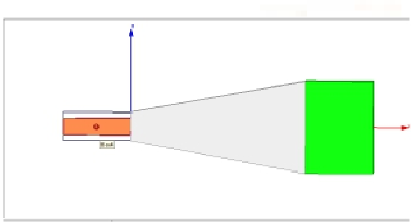

Fig:7 Design of single SRR in a waveguide conneted with Standard horn

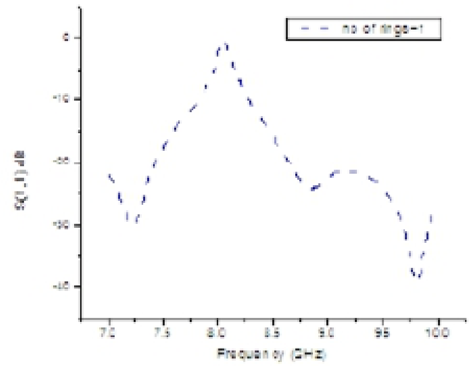

Fig. 8 Simulated Reflection Co-efficient for single SRR with horn.

We measured and simulated realized gain in the main beam direction of the proposed horn antenna with single SRR is shown in Fig. 9.

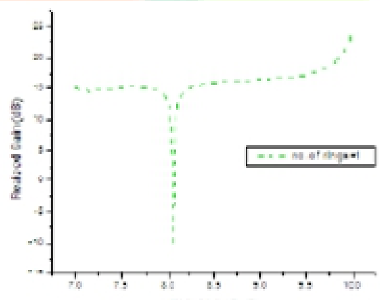

Fig. 9 Simulated realized gain in single SRR with Horn

B. Measurement of Horn Filtenna

In order to design a horn filtenna with band-stop characteristic, we need to design a proper resonant inclusion that stores/dissipates energy at a given operating frequency, leading to a band-notch in a narrow frequency range. For this purpose, we have chosen the circular SRR that is an electrically small resonator typically used to design negative permeability metamaterials [2] or metamaterial-inspired components [2]. Due to the SRR's strong magnetic resonance, significantly affects the antenna matching properties only around its resonant frequency, while at the other frequencies it weakly interacts with the electromagnetic field inside the horn, without affecting the radiating and matching properties of the overall system. The entire structure and perspective view are shown in Fig.10.

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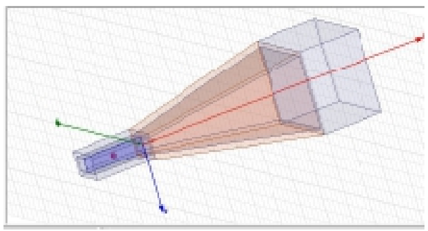

Fig:10 Structure of Horn Filtenna

It consists of a WR-90 waveguide (whose operating frequency range is 8.25 –12 GHz), a regular standard model (640) pyramidal horn and the proposed filtering module. The latter consists of a circular SRR etched on one side of a Rogers Duroid RT5880 tangent loss of 0.0009, and dielectric substrate with a thickness of20mil.

Design in [1], the dimensions of the circular SRR are properly chosen to obtain a resonant frequency from (8-8.5) GHz. In particular, the split rings capacitive gaps have a width of 0.5 mm, radius of 0.925; thickness of the ring is 0.035mm while all the other dimensions are reported in Fig-1. Please note that the dielectric substrate has been properly placed in order to facilitate the placement of the filter inside the waveguide. Later by simulating the design consisting of single SRR and horn, we analyzed the realized gain and return loss. The measurement of the standard 640 model horn is shown in Fig. 11.

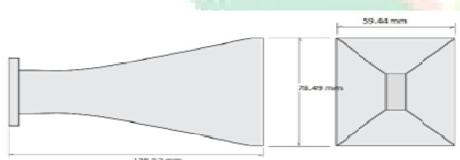

Fig:11 Measurement of standard 640 model horn

C. Simulation Results

The design of the proposed antenna has been carried out by using the high frequency structured simulator [HFSS] [3]. Considering the field distribution of the fundamental mode travelling through the waveguide and the horn, we expect that the frequency position of the notched-band depends mainly on the circular SRR dimensions and the relative permittivity of the dielectric substrate where the resonator is printed on. On the other hand, we expect that the distance between the center of the resonator and the throat of the horn till the wave guide influences the magnitude of the reflection/ transmission. In fact, when the number of SRR is increased then there is a wide band in the band stop characteristics. These expectations are confirmed by the graphs reported in Fig-6. The frequency variation of the reflection coefficient amplitude at the input port for consecutive increase in number of SRR is shown in the Fig-6. Therefore, in order to make a wise design, we have chosen the distance, which guarantees a strong mismatch in the notched-band and a good impedance matching in the rest of the frequency band. In this way, as reported in Fig. 9. The performance of the horn with and without the filtering module is similar over the whole frequency range, except for the notched part. The expected filtering behavior of the proposed structure is also confirmed by the values of the broadside gain shown in Fig.11. As expected, in fact, the realized gain is very low within a narrow frequency band around 8.25 GHz, due to the strong excitation of the SRR. An interfering signal falling in the same frequency range, thus, would not affect the performance of the receiver. On the contrary, in the rest of the frequency band, the radiating properties of the proposed structure are almost identical to the ones of the regular horn. In Fig- , we also show the realized gain patterns at three sample frequencies. These results confirm that, at 8.25 GHz, the field is not simply deviated from the broadside direction, but is, indeed, not radiated by the antenna.

IV. EXTENDED DESIGN FOR QUADRUPLE SRR IN HORN WITH BAND NOTCH CHARACTERISTICS

As shown in the previous chapter, by properly designing and positioning a single circular SRR inside a horn antenna, we can obtain a filtenna with a stop-band characteristic. However, many wideband communication systems require more than one stop-band. In order to obtain a horn filtenna with a quadruple-band behavior, we have etched four SRRs with slightly different dimensions on the same Rogers Duroid RT5880substrate (Fig-12) in order to have four independent resonant frequencies at 8 GHz and 12 GHz. The main geometrical dimensions of the structure are reported in Fig-14. The simulated results of the matching (i.e., magnitude of the reflection coefficient at the input port) and radiating (i.e., broadside realized gain) properties of the quadruple-band structure, reported in Fig-13-14 respectively, confirm the expectations

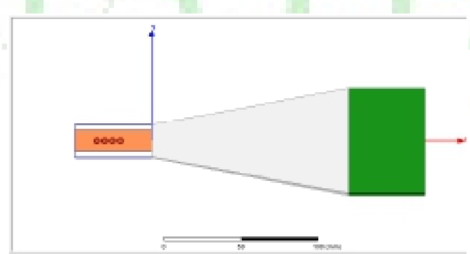

Fig. 12 Design of quadruple SRR in Horn Filtenna

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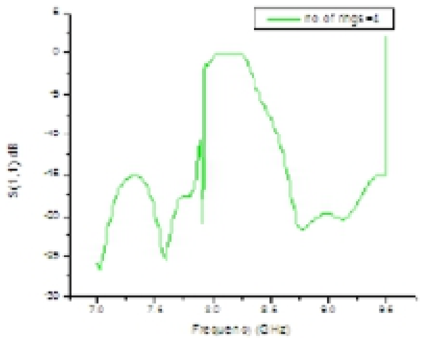

Fig. 13 Simulated Reflection Co-efficient of quadruple SRR in horn filtenna

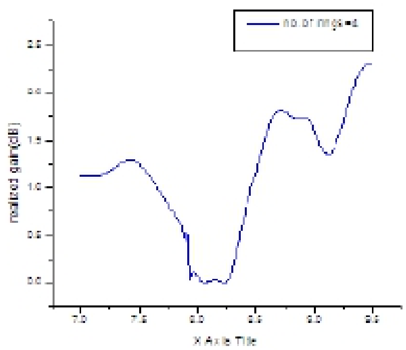

Fig. 14 Simulated realized gain in the main beam direction of the horn filtenna with quadruple-band-stop characteristic

V. CONCLUSION

In this communication, we have presented a novel approach to design horn filtennas with quadruple-band-stop characteristics. First, we estimated resonance frequency in SRR using Matlab and designed SRR in wave guide and implemented in Standard Pyramidal Horn. We have designed a horn filtenna combining a standard horn radiator and a single SRR etched on a dielectric substrate. The SRR has been properly positioned outside the horn in order to obtain good filtering properties inside the stop-band. Later, we extended our design for quardruple SRR in horn with band notch characteristics; avoid affecting radiation in the rest of the frequency band. Then, we have shown that, by using four SRRs, the overall structure can exhibit wide notched-bands.

We remark here that the proposed radiators can be employed in communication platforms, where structural and cost constraints require strong integration of different components. The proposed modules, in fact, allow for a dramatic reduction of the interfering signal power, besides having advantages such as reduced cost, weight, and space occupancy. Finally, the filtering module can be thought of as a simple add-on to be designed and inserted into already operating horn antennas to suppress interference, when needed.

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REFERENCES

[1] Mirko Barbuto, Fabrizio Trotta, Filiberto Bilotti,and Alessandro Toscano," Horn Antennas With Integrated Notch Filters" *0018-926X © 2015 IEEE.*

[2] C.. Saha and J.Y. Siddiqui,"Estimation of the Resonance Frequency of Conventional and Rotational Circular Split Ring Resonators", *978-1-4244-4819-*7/09 ©2009 IEEE

[3] Ricardo Marqués, Jesús Martel, and Francisco Medina, "Comparative Analysis of Edge- and Broadside- Coupled Split Ring Resonators for Metamaterial Design—Theory and Experiments", 2572 IEEE Transactions On Antennas And Propagation, Vol. 51, NO. 10, October 2003 *0018-*926X/03 © 2003 IEEE

[4] Chinmoy Saha and Jawad Y. Siddiqui,"A Comparative Analyis for Split Ring Resonators of Different Geometrical Shapes", *978-1-4577-1099-5/11 ©2011* IEEE

[5] Filiberto Bilotti, Luca Di Palma, Davide Ramaccia, and Alessandro Toscano*,"* Self-Filtering Low-Noise Horn Antenna for Satellite Applications", 354 IEEE Antennas And Wireless Propagation Letters, Vol. 11, 2012 *IEEE 1536-1225 © 2012 IEEE*

[6] Mirko Barbuto, Fabrizio Trotta, Filiberto Bilotti, and Alessandro Toscano," A Combined Bandpass Filter and Polarization Transformer for Horn Antennas", IEEE Antennas And Wireless Propagation Letters, Vol. 12, 2013 1065, IEEE 1536-1225 © 2013 IEEE.

