International Journal of Computer and Information Technology (ISSN: 2279 – 0764)
Volume 02– Issue 05, September 2013

Effect of Loading a Horn Antenna with a Double Square Loop FSS "Filtenna System"

A. Badreldin
Faculty of Information Engineering and technology
German University in Cairo
Cairo, Egypt

A. M. M. A. Allam
Faculty of Information Engineering and technology
German University in Cairo
Cairo, Egypt

Abstract—**This article presents the analysis and investigation of the effect of loading a horn antenna with a double square loop frequency selective surface (FSS) of finite size. It is fabricated on Rogers RT5870 (lossy) of relative permittivity 2.33, thickness 1.575mm and loss tangent 0.0012. This structure is called a filtering antenna (filtenna). Basically it is applied for filtering and minimizing the interference and noise in the desired band. The filtration is carried out using a finite FSS of double square loop of overall dimensions 98x58 mm^2. The structure is simulated using CST MWS and measured using network analyzer. There is a good agreement between the simulated and measured results.**

***Keywords component*—Antenna, filtenna, frequency selective surface (FSS), horn.**

I-INTRODUCTION

MORE attention has recently been paid for sensitive receivers in wireless communication systems. Adding a bandpass RF filter at front-end of a communication system can discriminate the desired signal at operating frequency band from extraneous signals at out-band. In a lot of cases, the noise signals maybe exceptionally strong compared to the desired in-band signals, which would need a stringent performance by the RF filter at front-end. Once the antenna and filter are integrated together, a pre-filtering process is carried out when signal is received by antennas. This integration conducts a compact system and improves its performance according to the applications.

Some researchers realized filter and antenna dual functions. Structural integration antenna and FSS firstly reported in [1] where FSS is used to enhance antenna radiation efficiency for its high impedance characteristic as artificial magnetic conductor. Multilayer FSS combined with open-end waveguide radiators array have been presented in [2]–[4], in which only filtering performance has been analyzed with multimode equivalent network method. Antenna with filtering function by mounting metal post in electromagnetic horn is studied in [5], and microstrip patch antennas in single layer or multilayer substrates are studied in [6] and [7].

This paper presents the filtenna properly constructed by covering FSS at horn aperture having filtering performance for suppressing out-band interference signals.

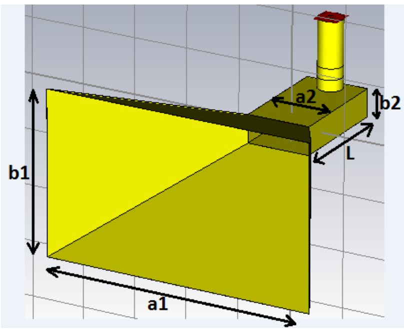
II- DESIGN

A. Horn Antenna and Transition Waveguide

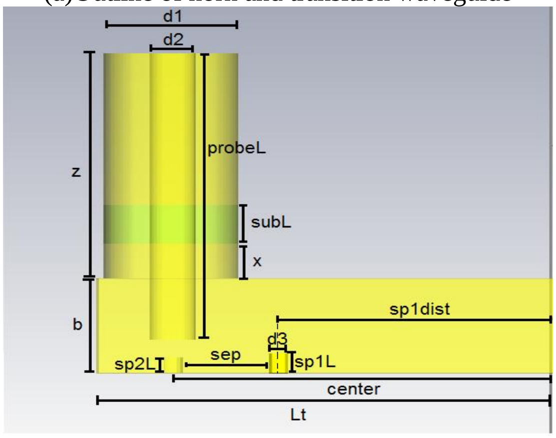
Fig.1 shows the practical pyramidal horn antenna and the transition waveguide operating in the X-band (8GHz-12GHz) whose detailed dimensions are illustrated in Fig.2 and table.1.

(a)Horn

(b)Transition waveguide
Fig.1: Pyramidal horn and transition waveguide



(a)Outline of horn and transition waveguide



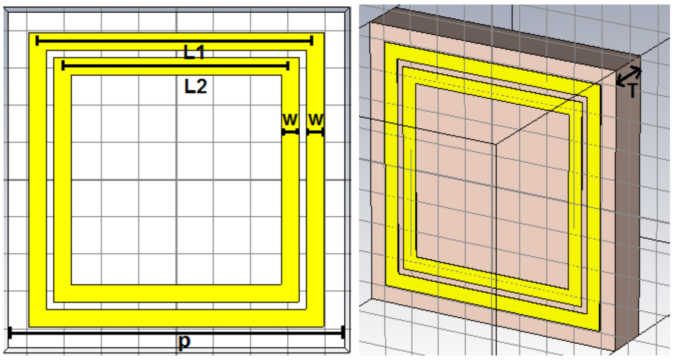
(b)Vertical cut of transition waveguide
Fig.2: Structures of horn antenna and transition waveguide with detailed dimensions

Table.1
Horn and transition waveguide dimensions

Parameter	Dim. in mm
a1	98
b1	58
a2	23
b2	10
L	41
d1	9
d2	3
Z	24.5
probeL	31
subL	4
b	10
x	4
sp1L	2
sp2L	1.5
d3	1.2
sep	7.2
center	27
Lt	32
Sp1dist	19.8

B. Frequency Selective Surface

A unit cell of the infinite structure of double square loop FSS is depicted in Fig.3. The square loop arms' dimensions are tuned to have a narrow transmitting band for filtration. Table.2 illustrates the dimensions of the unit cell where p is the repetition period of the cell, ε_r is the relative permittivity of the substrate and T is the substrate thickness.



(a)Front view (b) Prospective view
Fig.3: Unit cell of double square loop FSS

Table.2
FSS unit cell dimensions

Parameter	Dim. in mm
L1	7.44
L2	6.1
W	0.47
P	9
ε_r	2.33
T	1.575

A finite FSS structure shown in Fig.4 is designed, having the same size of the horn aperture to load the horn antenna.

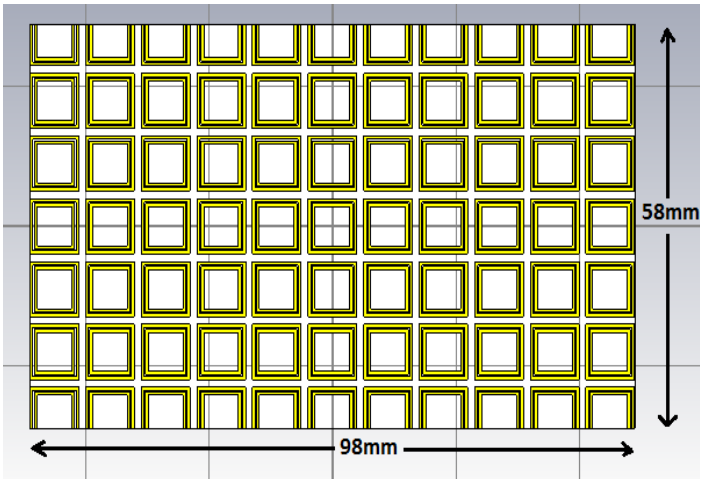


Fig.4: Finite double square loop FSS

Integration of the fabricated finite FSS of double square loop elements with the pyramidal horn is shown in Fig.5.

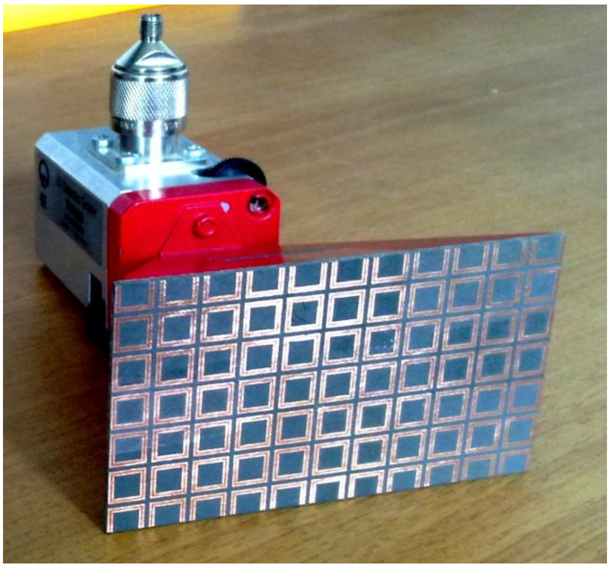
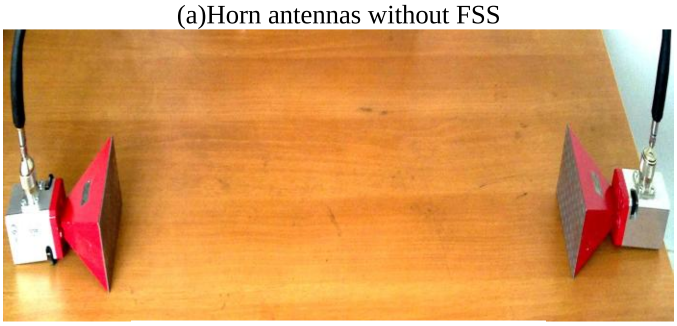


Fig.5: Filtenna system

To show a comparison between the transmission coefficients of filtenna system and antenna system, two horn antennas were placed facing each other at a distance calculated using the standard farfield formula resulting in 73cm distance as shown if Fig.6(a). Then the finite FSS structures are added to the apertures of both horns to have the filtenna system as shown in Fig.6(b). The transmission coefficients of the two systems are measured by the network analyzer.

(a)Horn antennas without FSS



(b)Horn antennas with FSS "Filtennas"
Fig.6: Facing two horn antennas and two filtennas

III. RESULTS

Fig.7 depicts the return loss of the pyramidal horn without loading the FSS, where the simulated and measured results are imposed in the same figure. The horn antenna is operating in the band (8GHz-12GHz). A good agreement is noticed between the simulated and measured results.

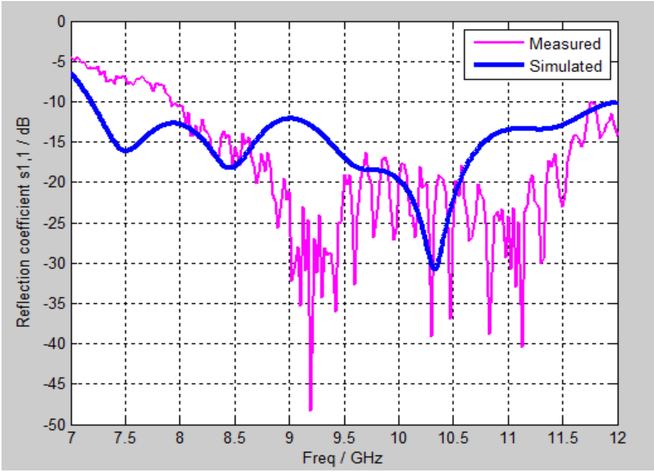


Fig.7: Return loss of the horn antenna

The transmission coefficient of the FSS is simulated for both infinite and finite structures as depicted in Fig.8. One notices the small difference between them which is referred to the edge effect of the finite FSS size. It is clear that the finite FSS conducts a bandpass filtering response by just passing the band (8.3GHz-8.7GHz).

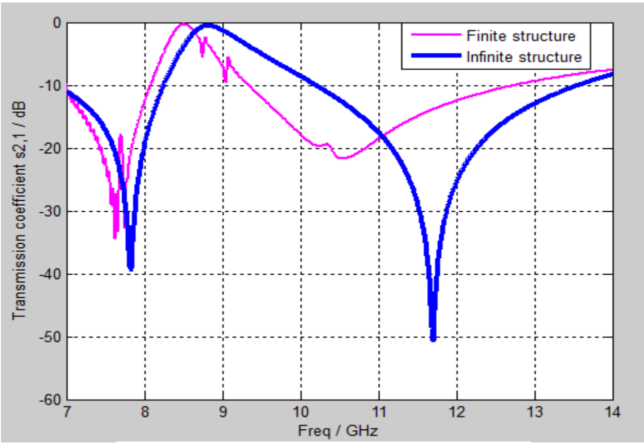


Fig.8: Transmission coefficient of FSS

The simulated and measured return losses of the filtenna are depicted in Fig.9. It is noticed that the transmission bandwidth of the filtenna system is limited to 0.3GHz instead of 4GHz of the horn antenna without the FSS, so that the transmission band is (9.04-9.33GHz). There is also a good agreement between the simulated and measured results.

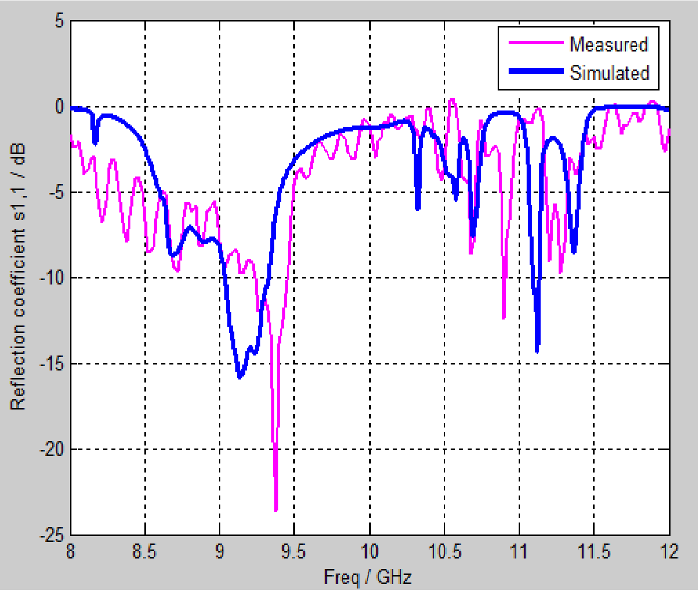


Fig.9: Return loss of the filtenna

Fig.10 illustrates the measured transmission coefficient of the horn antenna versus that of the filtenna using the network analyzer. It is noticed that the transmission bandwidth in the case of the filtenna is limited to 0.3GHz which clarifies the filtration.

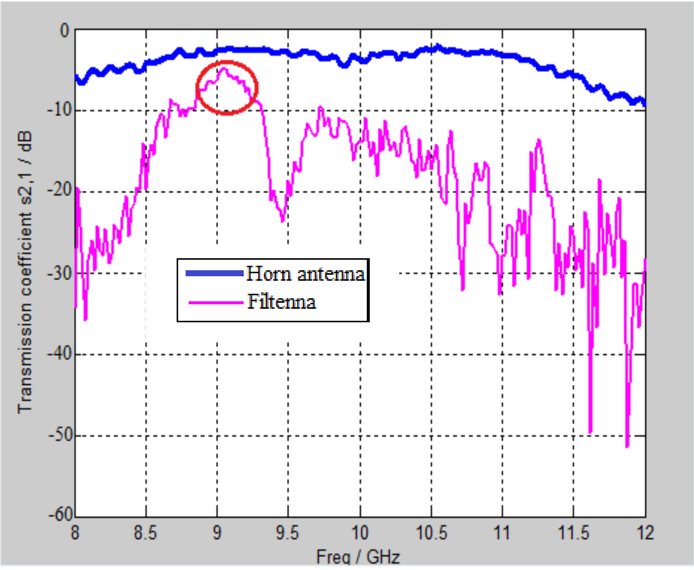


Fig.10: Measured transmission coefficient of horn antenna vs. that of filtenna

Fig.11 shows a comparison between the directivities of the horn antenna without the FSS and the filtenna system. Adding the FSS to the horn gives lower directivity at the passband by a figure of 3.6dB and that is due to the filtenna's wider beamwidth response.

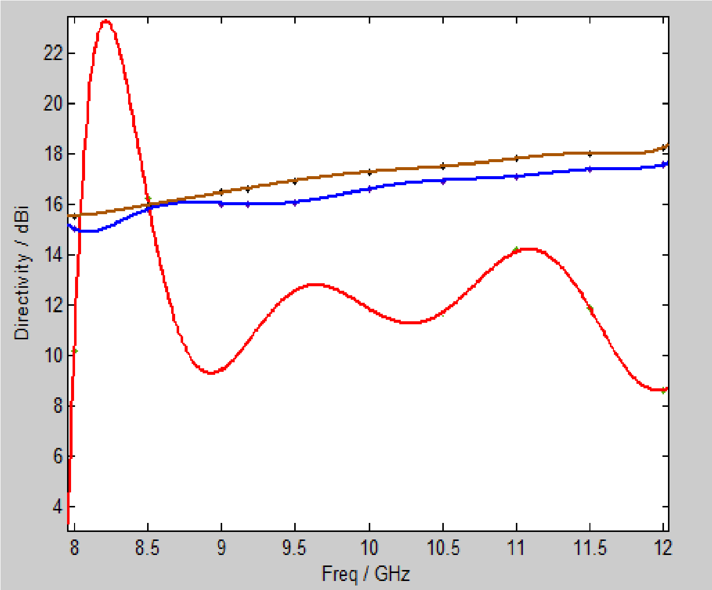


Fig.11: Directivity of horn antenna and filtenna

Simualted directivity of filtenna using CST
Simulated directivity of horn antenna using CST
Calculated directivity of horn antenna using basic formulas

There is no effective change in the efficiency after loading the FSS where it is above 90% in the passband in both cases as shown in Fig.13.

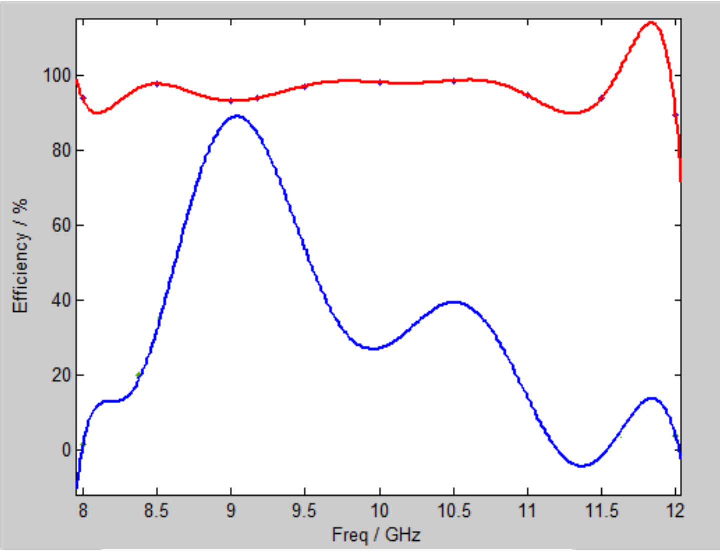


Fig.12: Total efficiency of horn and filtenna

Total efficiency of horn without FSS
Total efficiency of filtenna

III. CONCLUSION

A filtenna system is designed by loading a horn antenna with a double square loop FSS of finite size 98x58 mm^2 for filtration and minimization of interference and noise in the desired band. It is fabricated on Rogers RT5870 (lossy) of relative permittivity 2.33, thickness 1.575mm and loss tangent 0.0012.

The finite structure of the FSS has a narrow band response of 0.4GHz bandwidth operating from 8.3GHz to 8.7GHz. Therefore loading the horn antenna with the FSS limited the operating bandwidth to 0.3GHz instead of 4GHz of the horn antenna without the FSS, so that the transmission band is (9.04-9.33GHz). The filtenna has a lower directivity than the horn antenna by a figure of 3.6dB and that's due to the increase in its beamwidth. The efficiency is almost in the same range of 90% in both cases, antenna and filtenna.

III. REFERENCES

[1] Y. E. Erdemli, K. Sertel, R. A. Gilbert, D. E. Wright, and J. L. Volakis, “Frequency selective surfaces to enhance performance of broad band reconfigurable arrays,” *IEEE Trans. Antennas Propag.*, vol. 50, no. 12, pp. 1716–1724, Dec. 2002.

[2] H. J. Visser and M. Guglielmi, “Filter design of waveguide array antennas,” in *IEEE AP-S Symp. Digest*, vol. 4, pp. 2338–2341, Jul. 1997.

[3] S. Monni, N. L. Juan, A. Neto, and G. Gerini, “Phased array antenna integrated with a frequency selective surface—theory and experiments,” in *Phased Array Systems and Technology, IEEE Int. Symp. Digest*, pp. 458–463, Oct. 2003.

[4] G. Gerini and L. Zappelli, “Multilayer array antennas with integrated frequency selective surfaces conformal to a circular cylindrical surface,” *IEEE Trans. Antennas Propag.*, vol. 53, no. 6, pp. 2020–2030, Jun. 2005.

[5] B. Froppier, Y. Mahe, E. M. Cruz, and S. Toutain, “Integration of a filtering function in an electromagnetic horn,” in *Proc. 33rd European Microwave Conf*, vol. 3, pp. 939–942, Oct. 2003.

[6] A. A. Tamijani, J. Rizk, and G. M. Rebeiz, “Integration of filters and microstrip antennas,” in *IEEE AP-S Symp. Digest*, vol. 2, pp. 874–877, Jun. 2003.

[7] T. L. Nadan, J. P. Coupez, and C. Person, “Optimization and miniaturization of a filter antenna multi-function module using a composite ceramic-foam substrate,” in *IEEE MTT-S Symp. Digest*, vol. 1, pp. 219–222, Jun. 1999.