Design of a FSS Waveguide Filter at 8.05 GHz

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***Abstract*-A compact FSS (frequency selective surface) filter will be designed in this paper. The length of the filter is reduced by the use of both bandpass and bandstop FSSs. A sample filter at 8.05GHz will be designed using CST Studio as an example. Simulation results show that the FSS filter has a bandwidth of 800MHz and a reflection lower than -20 dB. Tested results from this sample filter agree well with the simulation results. The length of the sample filter is less than half of a directly-coupled waveguide filter with the same specifications.**

***Index Terms*-bandpass, bandstop, FSS, waveguide, filter.**

I. Introduction

Nowadays communication systems demand microwave band-pass filters and multiplexers. The performance of such devices is of paramount importance in the front-end of many radiofrequency systems. Compact filters are a classic topic in communication field.

The mostly commonly used direct-coupled filters are too long, because of the half-wavelength cavities. In 2003, Bario-Garrido et al [1] reported a FSS filter using single-slot bandpass FSS as shown in Fig. 1. The length of the filter is reduced because quarter-wavelength waveguide sections are used to connect resonant FSS irises. A double-slot bandstop FSS, as shown in Fig. 2, has been reported by Sorb [2] and then by Kirilenko and Mospan [3] in 2000. A bandstop FSS can create a transmission zero at certain frequencies. In this paper, we will report a compact filter in which bandstop FSSs are used together bandpass FSSs. Because of the transmission zeros created by the bandstop FSSs, the length of the filter will be further reduced from a FSS filter.

II. Design of the Compact FSS Filter

In order to illustrate the design process, a sample filter will be designed, which has specifications shown in TABLE I. The specifications of the sample TABLE I summarizes the design specifications for the required filter.

In order to design the sample filter, as the first step, we choose the parameters of the bandpass FSS. Throughout this paper, the width and height of the waveguide are chosen as a=28.5 mm, b=12.62 mm and the thickness of all the FSS t=1. The S-parameters of the single-slot bandpass FSS is shown in Fig. 3 together with the slot sizes. From Fig. 3 we can see that the bandpass FSS has a resonant frequency of 8.05GHz.

The second step, the design of bandstop FSS's with stop-bands centered at 7.05 GHz and 8.95 GHz respectively. The S-parameters of the double-slot bandpass FSSs are shown in Fig. 4 and 5, respectively, together with their slot sizes.

TABLE I

DESIGN SPECIFICATONS FOR THE SAMPLE FILTER

Variables	Values	Notes
a	28.5 mm	Width of the input/output ports
b	12.62 mm	Waveguide height
f1	7.7 GHz	Lower limit of the pass-band
f2	8.4 GHz	Upper limit of the pass-band
Ripple	<=0.2 dB	The ripple of the pass-band
Rejection	45 dB	Frequency lower than 7.1GHz and higher than 9GHz
LR	20 dB	Minimum return losses

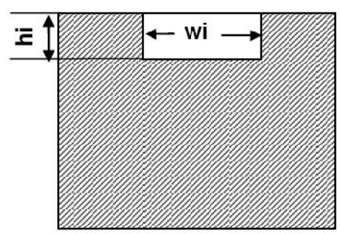

Fig. 1. Structure of a single-slot bandpass FSS

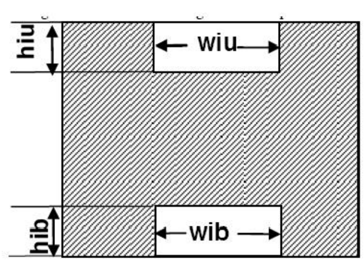

Fig. 2. The structure of a double-slot bandstop FSS

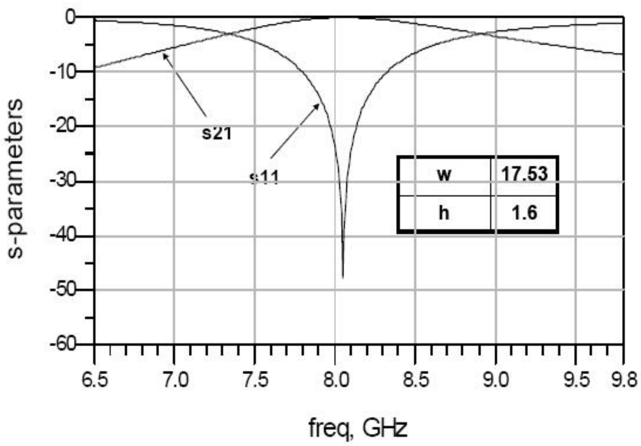

Fig. 3. Simulation results of band-pass FSS to get resonance frequency located at 8.05GHz

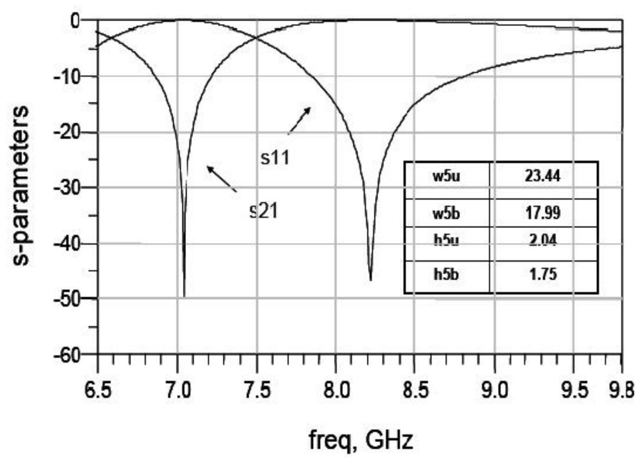

Fig. 4. Simulation results of band-stop FSS to get attenuation pole located at 7.1GHz

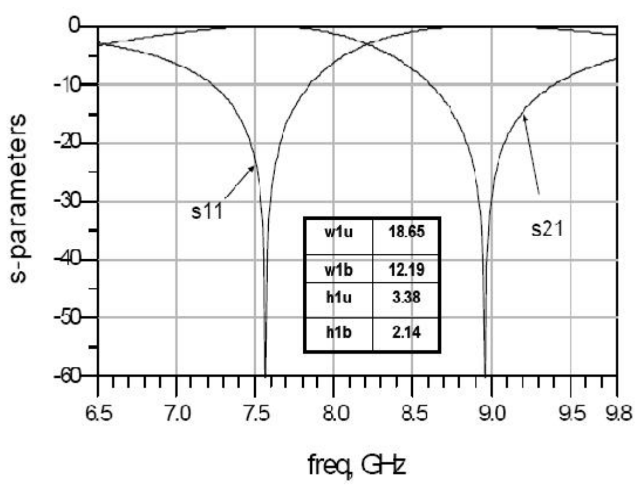

Fig. 5. Simulation results of band-stop FSS to get attenuation pole located at 9.0GHz

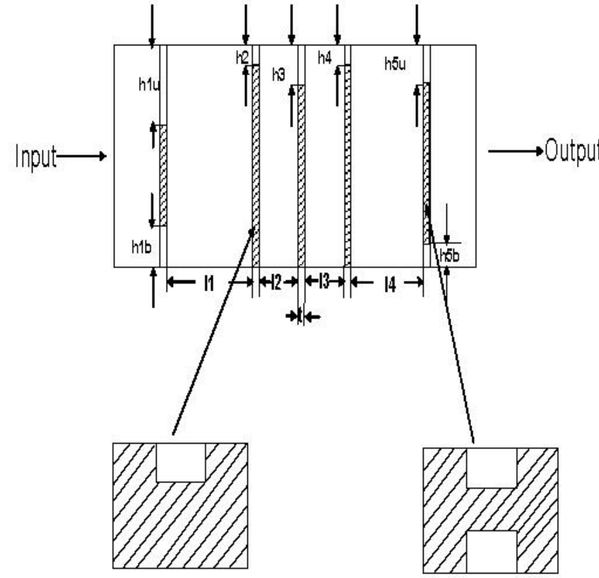

Fig. 6. Configuration drawing of a sample FSS waveguide filter

As the third step in the filter design, 3 bandpass single –slot FSSs and two bandstop double-slot FSSs are connected in series as shown in Fig. 6, with the double-slot FSS at left and right side, respectively. As the initial parameters, the lengths of the waveguide connecting neighboring FSSs are all assumed quarter-wavelength, 12.3 mm at 8.05 GHz. The initial parameters of the sample filter are given out in TABLE II by the column denoted as "Initial". Using such parameters, the S-parameters of the sample filter are simulated and shown in Fig. 7. It can be seen that the frequencies of the transmission zeros and the passband are a little off from the design specifications because of the interaction between the FSSs.

For the sample filter, the center frequency f_0 is 8.05 GHz. And according to the analysis given in the last subsection, we can obtain the initial parameters shown in TABLE II as 'Initial'. Using the above data and software tool CST Microwave Studio, we can get the results as Fig. 7.

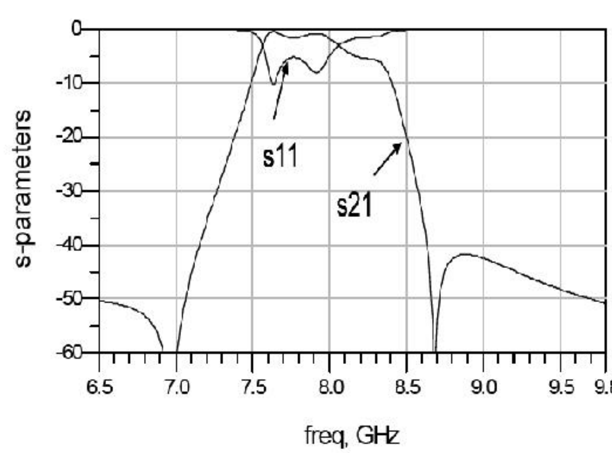

Fig. 7. Configuration drawing of a sample FSS waveguide filter

Optimization function from CST Microwave Studio is then used to obtain the final configuration parameters which are given in TABLE II by the column denoted by “Optimized”. The S-parameters of the optimized filter are shown in Fig. 8.

TABLE II
CONFIGURATION PARAMETERS OF THE SAMPLE FILTERS BEFORE AND AFTER OPTIMIZATION

Variables	Initial (mm)	Optimized (mm)	description
a	28.5	28.5	Width of waveguide
b	12.62	12.62	Height of waveguide
t	1	1	Thickness of irises
w1u	18.65	17.13	Width of upper slot of the band-stop iris
w1b	12.19	11.54	Width of bottom slot of the band-stop iris
w2	17.53	18.83	Width of slot of band-pass iris
w3	21.99	17.79	Width of slot of band-pass iris
w4	17.53	18.83	Width of slot of band-pass iris
w5u	23.44	23.44	Width of upper slot of the band-stop iris
w5b	17.99	18	Width of bottom slot of the band-stop iris
h1u	3.38	4.36	Height of upper slot of the band-stop iris
h1b	2.14	1.87	Height of bottom slot of the band-stop iris
h2	1.60	1.57	Height of slot of band-pass iris
h3	1.18	1	Height of slot of band-pass iris
h4	1.60	1.57	Height of slot of band-pass iris
h5u	2.04	2.04	Height of upper slot of the band-stop iris
h5b	1.75	1.76	Height of bottom slot of the band-stop iris
l1	12.3	15.48	Length of waveguide between irises
l2	12.3	6.35	Length of waveguide between irises
l3	12.3	6.35	Length of waveguide between irises
l4	12.3	13.95	Length of waveguide between irises

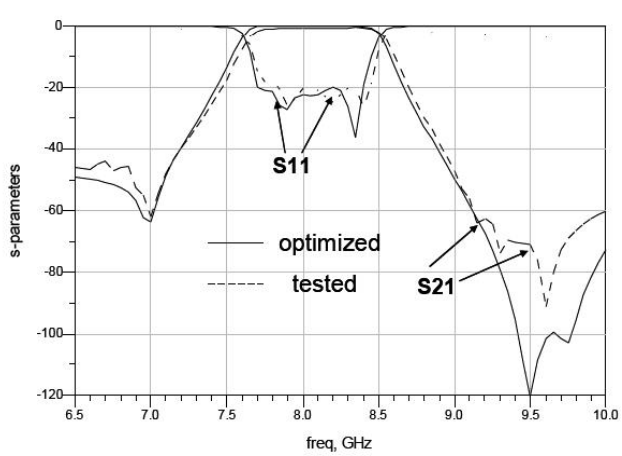

Fig. 8. Simulation S-parameters (dotted lines) and tested S-parameters (solid lines) from a sample FSS waveguide filter

III. Tested Results

Fig. 9 shows the sample filter fabricated using the optimized configuration parameters shown in TABLE II. The tested results are also shown in Fig. 8 as the solid lines, for comparison with the simulated ones. From Fig. 8 we can see that the test results agree well with the simulation ones. The sample filter has a centre frequency of 8.05 GHz, reflection lower than -18 dB and insertion loss lower than 0.8 dB in a passband of 800 MHz. The stopband rejection is better than 49 dB for frequencies lower than 7.12 GHz and higher than 8.95 GHz, satisfied the design specifications shown in TABLE I.

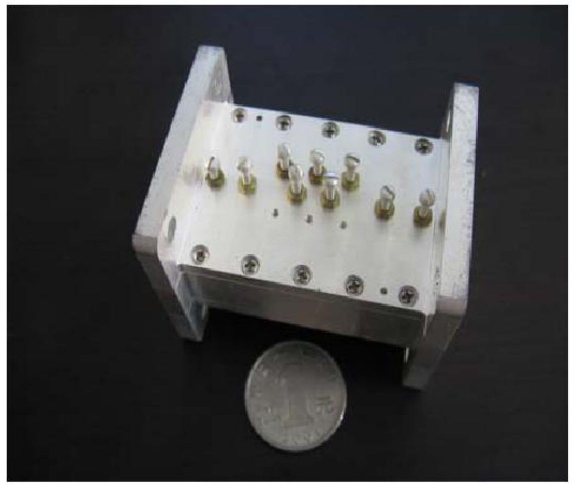

Fig. 9. Photo of the sample compact FSS filter

IV. Conclusion

A compact FSS filter has been designed in this paper. The length of the filter is considerably reduced by the use of both bandpass and bandstop FSSs.

The total length of the sample filter is only 42 mm, plus 10 mm, which are the lengths of two connector flanges. If we use directly-coupled waveguide filter to realize the same specifications, the order would be 5, corresponding to a length of 125 mm. Comparably the length of the sample compact FSS filter is about 1/3 of a directly-coupled waveguide filter.

References

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