Dual Band H-Shaped Antenna-Filter-Antenna based Frequency Selective Surface for Q-Band Applications

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Abstract —a multi-layer antenna-filter-antenna (AFA) based frequency selective surface isproposed for Q – band applications, consisting of dual bands. The elementary cell consisting of two micro strip patch antennas and a non-radiating resonant structure in the form of H shape. The design is simulated with the help of ANSYS-HFSS simulation software. The simulated results give two bands (37.9GHz-39.4GHz & 43.7GHz-44.9GHz). The simulation results gives a 22.6% 3-dB (3.88% &2.7% 10-dB for two bands) bandwidth.

IndexTerms—Antenna-filter-antenna, Frequency-selective-surfaces.

Introduction

The main part of the proposed method is Antenna-Filter-Antenna (AFA) elementary cell. It consists of three elements namely a receiving antenna operating at input port, a resonant structure which is not radiating and a transmitting antenna operating output port [1]. For realization of transmit array antennas (TA) [2], the elements of the cell can be configured in non-uniform arrays. In order to realize the frequency selective surfaces (FSS) [3], we can configure the elements of the cell in uniform arrays. Planar periodic structures are used for to realize the FSS. The FSS can be considered as filters with radiative ports. Based on the geometry, a bandpass or band elimination response is obtained by a single layer FSS around its resonance frequency.

The metallic structure consists of three layers. The two patch antennas are presented at bottom and top layers and the middle layer consists of three slot resonators in the form of H-shape. Transfer function of the bandpass filter obtained from transmit array AFA elements. For satellite [4], power combining and radar [5] applications, the characteristics of bandpass filter are more desirable. The heat dissipation and power handling in the structure can be improved by the distributed nature of transmit arrays.

Multi-layer FSS structures [6-7] are used for design of high order filters because the computational complexity dramatically rises. By combining the individually designed FSS layers gives a high order FSS. A thick dielectric slab of thickness (0.2-0.3λ0) is used to stack the each of the FSS layers resonators. Normally the dielectric slab acts as an impedance inverter. All these arrangements will create a multipole filter. This method has multiple problems as given below:

- The very first problem is that the filter topology so obtained is a sequence of resonators and inverters which can be used for a constrained class of filter responses which reduces the design space significantly.
- The second issue is that the simple resonator inverter interpretation is not valid because of the direct near-field coupling present between the layers of FSS in the stack.
- Finally the structure looks bulky and thick hence it is not preferable for more applications.

In this paper we presented our approach to design a dual band Antenna-Filter-Antenna element. The elementary cell is a three-layer structure composed of two patch antennas and co-planar waveguide (CPW) resonators (the coupling slots are in the form of H-shape). The results obtained for this design are simulated results only.

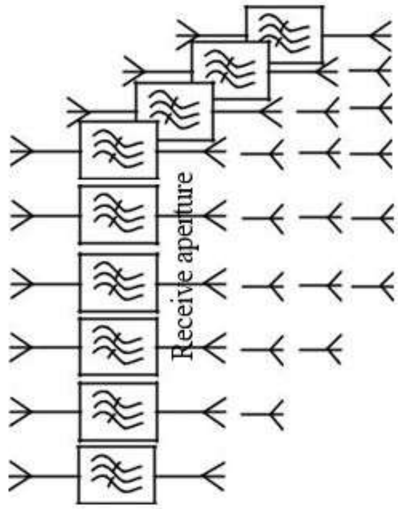

Fig. 1. An array of AFA modules as a bandpass FSS.

AFA Concept

An AFA array schematic representation is shown in figure 1. Basically the components which are presented in AFA elementary cell are two patch antennas(one is for receiving purpose and another one is for transmitting purpose) and a non-radiating resonant structure. The boundary for the transmission bandwidth of AFA modules altered by the frequency characteristics of the antenna. Hence this method helps for synthetization of a wide variety of filtering responses. A pseudo high pass filter is treated as an example for such type of FSS. An open ended waveguide acts as pseudo high pass filter in between its inlet and outlet apertures of an array. The two micro strip patch antenna presented in the AFA elementary cell acts as radiative elements as shown in Figure2. In the middle of the cell a non-radiating resonant structure consisted of three slots which are in the form of H-shape.A collection of co-planar waveguide (CPW) resonators put together gives a resonant structure. In the common ground plane, fabrication of the co-planar waveguide resonators takes place.

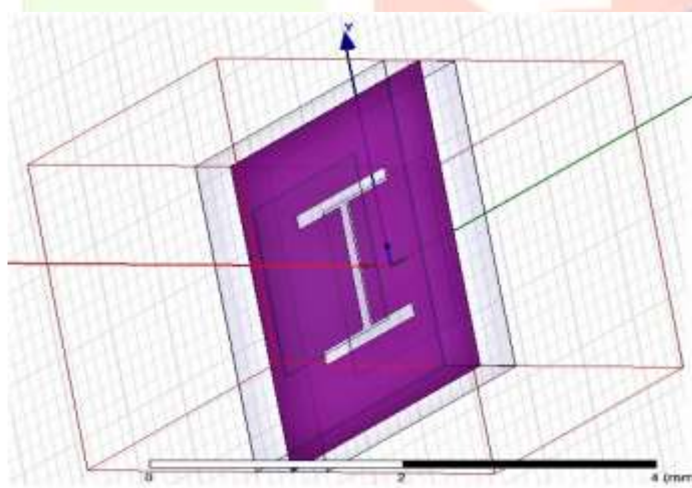

Fig.2.An AFA cell composed of patch antennas and CPW resonator

The coupling slots were used for to establish the coupling between the antennas and the CPW resonators in the CPW layer. The main advantage in the usage of the resonant-type radiative elements are the resonant element by itself can be treated as a fusion of a resonator and a radiative resistance. The two patch antennas contains built-in resonators. The CPW resonant structure combines with these resonators gives bandpass filter. It lowers the CPW resonators count based on the given order of the filter. A simple example [8-12] for this is a two pole bandpass filter is obtained from the two patch antennas coupling through a non-radiating resonant slot.To add more number of resonators in the CPW layer, we simply get the higher order response without incrementing the number of layers [13-16].

AFA Design

In the design of elementary cell Rogers RT/duroid 5880 is used as a substrate material. The relative permeability (εr) for this material is 2.2 and scan angle is tan δ=0.0009. The thickness of the substrate is 315µm. One single ground plane and two substrate layers are presented in the elementary cell. The ground plane having one patch antenna acts as receiving antenna followed by a coplanar waveguide having three slots in the form of H-shape and then followed by one more patch antenna acts as transmitting antenna. Based on the arrangement of the elementary cell, the applications varied. If we want FSS applications then arrange the cell in uniform array fashion and for TA applications, arrange the cell in non-uniform array fashion. In this cell design, the dimensions of patch and cell were 1.95×1.95 mm² and 3.6×3.6 mm² (λ0/2×λ0/2), respectively. The size of the slot was 1.7×0.16 mm². The slot which is perpendicular to the other two slots plays an important role in the S-parameter characterization. It converts the wide band into dual band. For attaining good matching at 38.6GHz&44.4GHz, the slot (which is presented in the ground plane) size which equivalents to wavelength in the substrate λg. Single polarization was implemented in this elementary cell design. The patch antenna which is present at input side receives an incident wave with proper polarization then it travels through the CPW resonator, and finally the second patch antenna reradiates the same polarized wave.

AFA Characterization

ANSYS-HFSS simulation software was used for the design of elementary cell with Floquet port type of excitation and master slave type of boundary condition which gives the response of a filter equivalent to infinite array. The figure 3 shows the simulation results of proposed design. From the simulation results it clear that it gives two bands which are at (37.9GHz-39.4GHz) & (43.7GHz-44.9GHz). We can use thetwo bands simultaneously based on the capability of antenna. Due to thepresence of two bands it can be used for different applications at a time. In the table 1 the comparison between different substrate materials and corresponding bandwidths is shown. From the reference10 the presented structure having two slots which are parallel to each other yields a wide band antenna having 27.6 %3-dB bandwidth. The proposed design having three slots which are in the form of H-shape gives a dual band antenna. The bandwidths corresponding to various substrate materials are shown in the table.

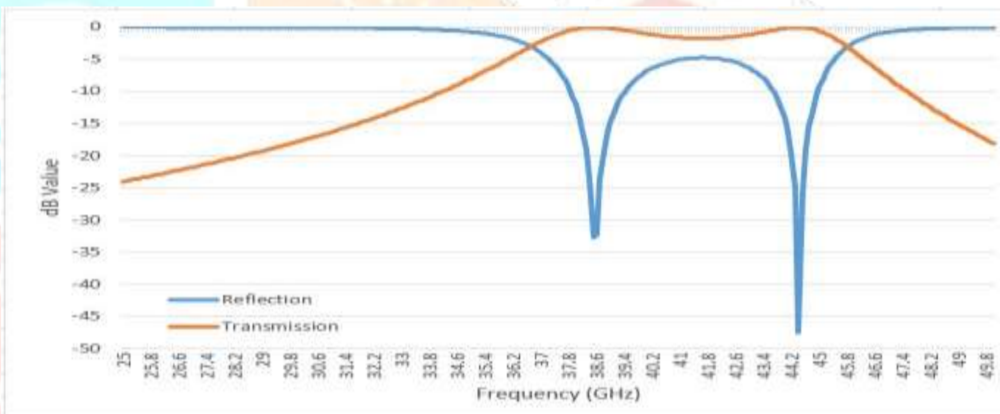

Fig. 3. S-parameters of the AFA element simulation results.

Table 1 Comparison between different substrate materials and corresponding bandwidths

S.NO	Design of AFA	Substrare name(relative Permittivity)	% 3-dB band width	%10-dB band width
1	Reference [10]	Rogers RT/ duroid 5880 (2.2)	27.6	18.5 (wide band)
2	Proposed(H shape)	Rogers RT/ Duroid 5880 (2.2)	22.6	For band1:3.88 For band2:2.7
3	Proposed(H shape)	Fr4 EPOXY(4.4)	23.58	For band1:3.48 For band2:1.04
4	Proposed(H shape)	Bronze(1)	0	0

Conclusion

The dual band antenna-filter -antenna elementary cell has been designed using two patch antennas and resonating structure. Due to the availability of two bands we can operate the devices at two frequencies simultaneously. It can be used as a filter in quasi optical amplifiers because it having sharp roll-off frequency response. Some other applications for this design are grid mixers, beam formers and lens arrays.

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