Antenna-Filter-Antenna based Frequency Selective Surfaces for Quasi-Optical Applications in Q-Band

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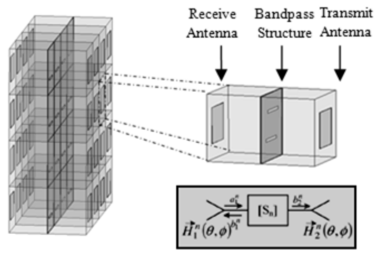
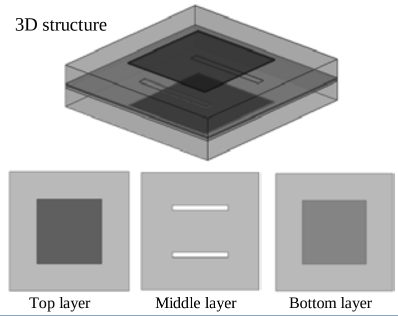
Abstract: A 3-layer antenna-filter-antenna (AFA) elementary cell is proposed for frequency selective surfaces (FSS) in quasi-optical applications, where wideband and low loss characteristics are crucial. The elementary cell is composed of a CPW resonator sandwiched between patch antennas. Finite element method is used for the design and verification of the proposed AFA elementary cell while a free space Gaussian optics measurement system is utilized for S-parameter characterization. The measurement results show a 27.6 % 3-dB (18.5 % 10-dB) bandwidth and a maximum in-band insertion loss of <0.2 dB for 40.5 GHz.

Introduction: Antenna-Filter-Antenna (AFA) element is composed of a receive antenna, a non radiating resonant structure, and a transmit antenna operating between the input and output radiation ports. These elements can be structured in non-uniform arrays to realize Transmit-array antennas (TA) or alternatively structured in uniform arrays to realize frequency selective surfaces (FSS). The FSS can be viewed as filters with radiatives ports, which are generally realized using planar periodic structures. Depending on the geometry, a single-layer FSS can represent a band-pass or band-stop response around its resonant frequency.

In general, these elements are formed as three layer metallic structures: two resonant type planar antennas in the top and bottom layers, and one or more planar transmission line or slot resonators in the middle layer. Using AFA elements in the transmit-arrays results in a band-pass transfer function, whose band-pass characteristics are desirable for radar, satellite, and power combining applications.



AFA element based on patch antennas and slot

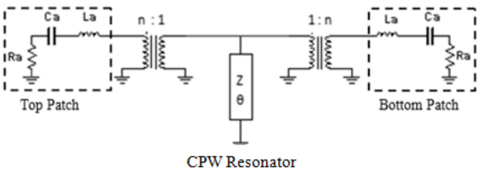


AFA Design: The elementary cell consists of a single ground plane, two substrate layers (Rogers RT/duroid 5880, $\varepsilon_r = 2.2$, $\tan\delta = 0.0009$, thickness 315µm) and two patch antennas coupled by a CPW line (2 slots) in the ground plane. This cell can be used in uniform array for FSS applications (Q-Band), and can also be used in non-uniform array for TA applications (e.g. Satellites communications).

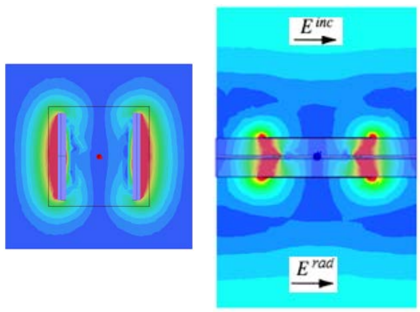
The patch and cell sizes equal 1.95×1.95 mm² and 3.6×3.6 mm² ($\lambda_0/2\times\lambda_0/2$), respectively. The size of the linear line slot in the ground plane is designed for a good matching for 42 GHz which corresponds to wavelength in the substrate λ_g. The line slot size equal 1.7×0.16 mm².

This elementary cell is a single polarization design. An incident wave with the appropriate polarization is received by the first patch antenna in the input side, passes through the CPW resonator, and reradiates from the second patch antenna with the same polarization.

AFA Characterization: The elementary cell was designed with Ansys-HFSS electromagnetic simulation software using Floquet ports and periodic boundary conditions.



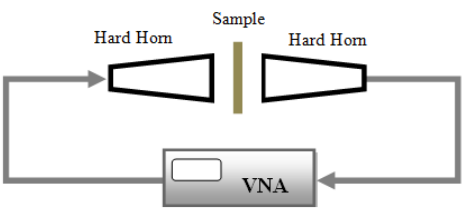
Circuit model of the AFA element



The elementary cell has been characterized by using the **Gaussian quasi-optical measurement systems**.

This measurement setup consists of two hard horn antennas, forming two parallel TEM ports that are separated by an air gap, and a vector analyzer.

The sample under test is placed in the middle of two ports. Due to their high directivity, the hard-horns are expected to generate a good approximation of the plane wave in the near-field, as is required for the FSS/TA measurements. As the sample can be freely reoriented in the air gap, the quasi-guided system proves convenient for performing measurements at arbitrary angles of the incidence. However, the oblique incidence measurement generally requires larger samples and a wider air gap.



Gaussian quasi-optical measurement systems

These results reflect a very good agreement between simulations and experiments.

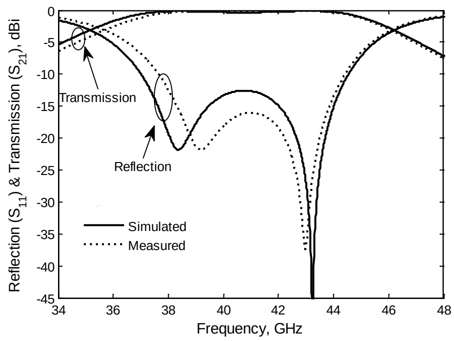
The measurement results show a 27.6 % 3-dB bandwidth for 40.5 GHz (18.5 % 10-dB).

The maximum in-band insertion loss for this design is <0.2 dB.

MATCHING PERFORMANCE OF THE ELEMENTARY CELL AT 42 GHZ

Distance between the slots (W of the CPW line) mm	-3 dB bandwidth %	In-band insertion loss dB
2×0.65	30.9	0.8
2×0.70	28.6	0.6
2×0.72	**27.6**	**0.2**
2×0.75	25.9	0.17
2×0.80	23.2	0.1

S-parameters of the AFA element
Measurements versus Simulation



Conclusion: High-efficiency wideband antenna-filter-antenna element has been designed using patch antennas and CPW resonator. A uniform array of these elements features a low loss and sharp roll-off frequency response, which makes it an excellent candidate for filtering application in quasi-optical amplifier arrays and grid mixers.

Detuned versions of the proposed element can also be used to form lens-arrays or other types of beam-formers. Two other cells are currently under investigation by the authors to design novel reconfigurable discrete lens antennas for high-speed wireless communication.