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Using Gaussian Optics Measurement System to Characterize A New Wideband Low-Loss Antenna-Slot-Antenna

Hamza KAOUACH, *Member, IEEE*
ECE Department
CEL, Umm al-Qura University (UQU)
Makkah, KSA
hamza.kaouach@gmail.com

Amar KABASHI, *Member, IEEE*
ECE Department
CEL, Umm al-Qura University (UQU)
Makkah, KSA
amarkabashi@hotmail.com

Abstract—A new type of unit cell featuring wideband low loss characteristics is proposed for transmit-arrays (TA) and frequency selective surfaces (FSS) in Quasi-Optical applications. The TA is realized as a non-uniform array of antenna-resonator-antenna (ARA) elements and the FSS is realized as a uniform array of ARA elements. Each ARA element is a three layer structure consisting of two patch antennas and a slot resonator. The ARA elementary cell is designed and verified using finite element method simulation. A free space Gaussian optics measurement system (GOMS) is utilized to characterize the elementary cell. The measurement results show a 20.7% -3dB (12.2% -10dB) bandwidth and a maximum in-band insertion loss of <0.2 dB for 42 GHz.

I. INTRODUCTION

Antenna-Resonator-Antenna (ARA) elements is composed of a receive antenna, a non-radiating resonant structure, and a transmit antenna operating between the input and output radiation ports [1]. These elements can be used for the Transmit-Array antennas (TA) [2], or to form Frequency-Selective-Surface (FSS) [3].

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 resonators in the middle layer. Microstrip antennas and coplanar waveguide (CPW) resonator have been mostly used for the antenna-resonator-antenna elements to form either TAs [2] by non-uniform array or FSS by uniform arrays. Using ARA elements in the transmit-arrays results in a band-pass transfer function, whose band-pass characteristics are desirable for radar, satellite [4], and power combining applications [5], where the distributed nature of the transmit-arrays can improve the power-handling and heat dissipation in the structure.

In terms of wave optics, a convex lens can be described as a device that transforms a diverging input spherical wave into a plane wave at the output, or an input plane wave into a converging spherical wave at the output [6]. In a transmit-array, the wave transformation is achieved by modifying the received phase distribution through the phase-delay of the ARA elements. In an array with optimal cell size, the input-output phase-delay in each cell is a function of the frequency,

and can be written in terms of the S-parameters of the ARA cell as follows:

$$\Phi_m(\omega) = -\angle S_{21}^m(\omega) \quad (1)$$

An accurate measurement technique is vital to the assessment of the design method. In particular, the ability to accurately measure both transmission and reflection coefficients is critical in identifying the design errors and fabrication imperfections.

Usually, the transmit-array and frequency selective surface unit elements are measured either by shining a large sample with a plane wave in the anechoic chamber [4], or by replacing a small sample in a waveguide and measuring the S-parameters [7]. The first method obviously requires a large sample, and normally does not provide a way to measure the reflection. The waveguide technique can measure the reflection, but it has two disadvantages. First, the cross-sectional dimensions of a standard waveguide are not generally integer multiples of the FSS grid period. Second, as full metallic waveguide cannot carry a TEM mode, it cannot be used to measure the sample at normal or arbitrary angles of incidence. An alternative approach is to use a free space measurement setup that simulates the guided system. This method will be detailed in section III.

This paper highlights our approach to the Antenna-Resonator-Antenna element design, as a three-layer structure consisting of two patch antennas and a slot resonator, and further discusses effective measurement methods that can be used to characterize it. Especially, we introduce a method to extract the focusing S-parameters of the ARA based on the Gaussian optics measurement system. The focus will be on FSS applications.

II. CONCLUSION

High-efficiency wideband antenna-resonator-antenna elements has been designed using patch antennas and slot resonators. A uniform array of these elements features low-loss and wideband, which makes it an excellent candidate for frequency selective surfaces and filtering applications in quasi-

optical amplifier arrays. Detuned versions of the proposed element can also be used to form other types of beam-formers. This ARA element has been adequately characterized in non-anechoic environments by using the Gaussian optics measurement system. The experimental results show good agreement with the simulation in terms of impedance matching and insertion loss. Two other cells are currently under investigation by the authors to design novel reconfigurable discrete lens antennas for high-speed wireless communication.

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