Circularly Polarized Terahertz Leaky-Wave Antenna with Metamaterial Scatterers

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***Abstract*—We propose a leaky-wave antenna to generate circularly polarized highly directional terahertz beam using metamaterial scatters. A microstrip line is loaded with a series of complementary electric-LC and electric-LC resonators to generate respectively E_x and E_y components. The 90^0-phase difference and almost unity amplitude ratio of E_x and E_y are achieved by relative positioning of the resonators on and off the stripline and optimizing the gap size. Moreover, the phase front of the radiated wave can be adjusted to a specific direction by controlling the period of the resonator array. These highly directional planar antennas can be utilized in short-range THz communication, sensing and imaging applications.**

I. INTRODUCTION

Terahertz solid-state emitters and detectors have strong beam divergence due to their subwavelength aperture size. Adopting leaky-wave antennas (LWAs) widely implemented in microwave systems is one of the approaches proposed to overcome the issue [1-3]. A THz LWA comprising periodic electric-LC resonators on stripline has been design for THz beam steering and collimating [1]. The beam radiated by this earlier LWA design was TM polarized due to alignment of the electric dipole of the scatterers with the microstrip axis.

In this abstract, we propose a periodic LWA design for circularly polarized THz beam generation. The circularly polarized directional THz beam is generated by employing periodic complimentary electric-LC (ELC) and ELC resonators respectively on and off the stripline [4]. The beam direction can be engineered by changing the resonators period with respect to the guided wavelength. The proposed antenna is planar, compact, and can be fabricated using photolithographic techniques.

II. DESIGN

The schematic of the LWA antenna is shown in Fig.1 (a). The guiding structure is a gold printed microstrip on a COC substrate (with a refractive index of 1.53 and loss tangent of 0.00064) with similar parameters used in [1]. Identical parameters are chosen for comparison purposes. This microstrip is loaded with metamaterial scatterers. The complimentary ELC resonators loaded on the stripline generate TM-polarized beam (E_x), as they are induced by the longitudinal electric field component of the guided mode. It is essential to have an additional TE-polarized radiation (E_y) with a 90°-phase difference to generate a circularly polarized beam. Thus we loaded the microstrip with ELC resonators along the stripline so that the resonators are excited by the lateral component or the fringing electric field. The resonators are added on both side of the line to keep the structure balanced, and are shifted by half a guided wavelength with relative to each other to compensate the phase difference of electric fields on either side of the line. Additionally, the ELC resonators are shifted with respect to the complimentary ELC resonators to create the 90^0-phase shift leading to a circularly polarized beam.

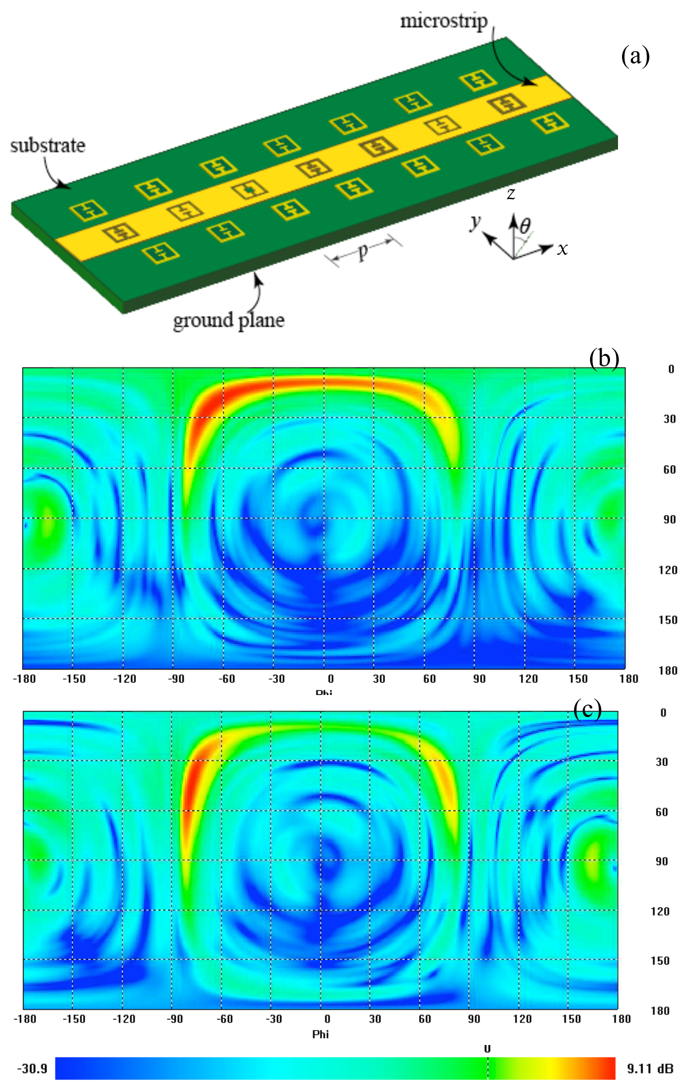

Fig. 1. (a) Schematic of the ELC-loaded microstrip antenna. The far-field realized gain of (b) left- and (c) right-polarization of LWA.

III. RESULTS AND CONCLUSION

We use CST Microwave Studio 2014 to numerically study the structure. The open boundary condition applies to all sides of the simulation volume with sufficient space from the microstrip. Two waveguide ports are implemented to excite and receive the quasi-TEM mode wave propagation on the microstrip. First, TM (CELC on stripline) and TE (ELC off the stripline) polarized LWAs are designed separately to make sure they have similar realized gain, i.e. similar electric field strengths, which is necessary for creating circularly polarized beam. Then both are combined so that there is a 90° phase difference in between the two polarizations. The LWA has 25 triplets ELC/CELC/ELC resonators distributed with 1.2-mm period. The 2D far-field patterns for left- and right-handed circularly polarized (LHCP and RHCP) waves are respectively shown in Fig. 1(b) and 1(c). The realized gains for the LHCP and RHCP are respectively 7.8 dB and 0.83 dB at $\theta=9°$ angle in $\phi=0$ plane at 0.19 THz. Suppression of RHCP beam indicates the proposed configuration in Fig.1 (a) has a dominant LHCP beam at 0.19 THz. The observable beam direction is slightly different from the beam direction determined from the grating equation (11°), which can be attributed to the effect of the resonators on the guided wavelength.

In conclusion we have designed a THz LWA by loading a guiding microstrip line with periodic ELC and complementary ELC resonators. The direction of the beam can be steered passively by alternating the period of resonators and the numerical results are in good agreement with theory. Relative positioning of the resonators on and off the stripline and the resonators gap size determines the phase difference and amplitude ratio between the E_x and E_y components. Fabrication and measurement are in progress. Further details on optimization of the numerical results will be presented.

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