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High Aperture Efficiency Plastic Lens Antenna for Scanning Lens Phased Array at 180 GHz

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***Abstract*—In this contribution, we present a plastic resonant leaky-wave lens antenna with high aperture efficiency (>80%) over a 1:2 bandwidth centered at 180 GHz. This antenna can be integrated in a scanning lens phased array architecture for next-generation wireless and sensing applications that require high-directivity steerable beams. The high aperture efficiency is achieved thanks to the combination of annular corrugations in the ground plane with a leaky-wave resonant cavity. A WR-5 (140-220 GHz) prototype is manufactured and measured in terms of reflection coefficient, radiation patterns, directivity, losses, cross-polarization and scan performance, showing excellent agreement with simulations.**

I. INTRODUCTION

NEXT-GENERATION communication and sensing systems above 100 GHz require high-directivity antennas, to overcome the free-space path loss, with dynamic beam steering capabilities [1]. Recently, a scanning lens phased array architecture has been demonstrated with silicon micromachined lenses to achieve high directivity and hybrid electro-mechanical scanning up to ± 25 degrees with only a few active elements for space applications [2].

The scanning lens phased array architecture consists of a sparse array of lenses with a diameter $D_l \gg \lambda_0$. Beam scanning of the complete array is achieved by electronic steering the array factor (AF), i.e., phase shifting each lens feed, and simultaneously steering the element pattern by displacing the lens mechanically via a piezo-motor. In [2], it was shown that the grating lobes that arise due to the sparsity of the array are suppressed if the lens array elements have a high aperture efficiency.

In this conference abstract, we present a novel leaky-wave (LW) lens antenna with high aperture efficiency (>80%) over a wide bandwidth of 1:2 (two WR waveguide bands) that is suitable for integration in a scanning lens phased array at 180 GHz. This antenna uses a low permittivity plastic lens instead of silicon as in [2] which in the lower submillimeter-wave band provides low losses and avoids the use of anti-reflection coating, making it ideal for low-cost applications. Furthermore, the fabrication complexity of this leaky-wave lens antenna is reduced by using annular corrugations in the ground plane of the antenna instead of a doube-slot iris as in [3].

II. LW CORRUGATED ANTENNA ARRAY

The array element, shown in Fig 1, consists of an elliptical lens and a leaky-wave waveguide feed similar to [3], where the nearly-degenerate TM_1 and TE_1 LW modes are excited to achieve highly-efficient lens illumination. In [3], the spurious TM_0 mode was suppressed using a double-slot iris which is the most complicated part to manufacture due to the small size and thin membrane. In the proposed antenna, instead, we suppress the TM_0 LW mode by using periodic annular corrugations in the ground plane in combination with a circular waveguide feed. Compared to the double-slot iris, these corrugations can easily be manufactured using standard milling techniques, enhance the bandwidth to 1:2 and lead to a lower cross-polarization.

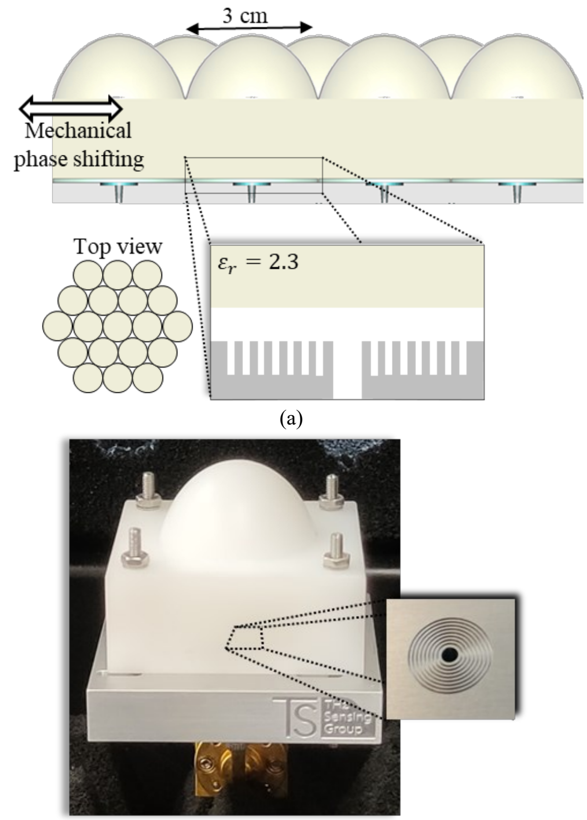
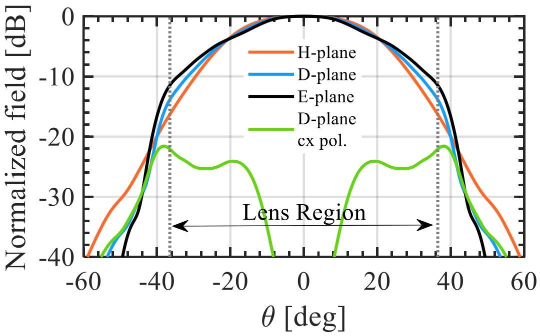


Fig. 1. (a) The proposed scanning lens phased array with a cross section of the stratification, (b) the fabricated lens antenna with inset of the corrugations.

We have investigated the performance of a 3 cm diameter plastic (HDPE) lens antenna in the band 120-240 GHz as an element in a scanning lens phased array. The simulated reflection coefficient is below -10 dB in the entire bandwidth. The patterns radiated by the leaky-wave feed into the semi-infinite plastic medium, shown in Fig. 2 at the central frequency, have been calculated from full-wave simulations. The primary patterns form a directive, symmetric beam around broadside and have a low cross-polarization level, below -20 dB. The lens truncation angle that maximizes the aperture efficiency is $36.5°$, as indicated in Fig. 2. The aperture efficiency that is achieved is shown in Fig. 3a and is above 80% in the bandwidth from 120-240 GHz. This aperture efficiency is higher than the aperture efficiency of the double-slot LW feed [3] over a larger bandwidth.

The simulated radiation pattern of a single lens at 180 GHz is shown in Fig. 3b, which is very directive (34.8 dBi) and symmetric around broadside. A 19-element hexagonal array of these antennas was then considered (Fig. 1a). The grating lobes due to very large periodicity ($18\lambda_0$) are shown in Fig. 3b. The array pattern is also shown in Fig. 3b where very low grating lobe levels are achieved thanks to the high aperture efficiency of the proposed lens antenna.

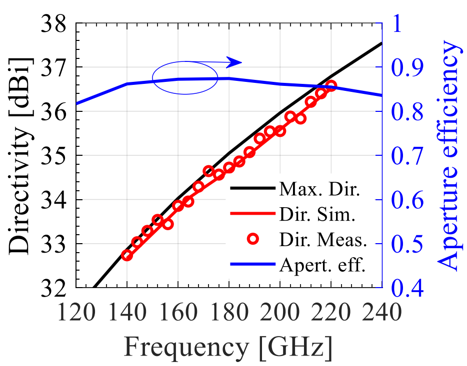


(c)

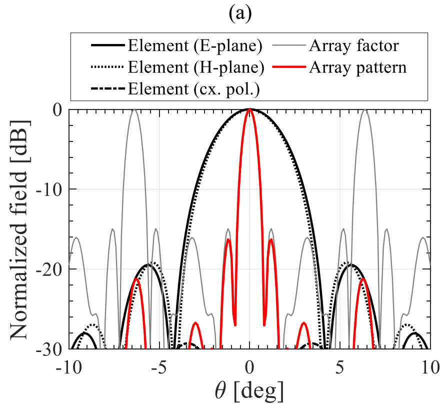
Fig. 2. Patterns radiated into semi-infinite plastic medium by the leaky-wave lens antenna feed at the central frequency.

We have fabricated a WR-5 (140-220 GHz) single antenna prototype to validate the concept. The prototype is shown in Fig. 1b and consists of a 3 cm diameter dielectric lens and an aluminum split block 1 cm thick. The split block contains the annular corrugations and circular waveguide (see inset of Fig. 1b) that transitions to a standard WR-5 waveguide flange at the bottom of the block.

The antenna prototype was measured using a PNA and WR-5 frequency extenders. The measured reflection coefficient is below -15 dB in the WR-5 bandwidth. Next, we measured the near field over a plane 4 cm above the lens surface using a WR-5 waveguide probe. The far-field pattern of the lens was then calculated from this planar measurement, the result being shown in Fig. 4 at 180 GHz. The measured antenna patterns show excellent agreement with simulations. The directivity was calculated from these measurements and is shown as a function of frequency in Fig. 3b. The antenna element achieves very high directivities and good agreement to simulations.



(a)



(b)

Fig. 3. (a) Simulated and measured directivity of the antenna compared to the maximum directivity of a 3 cm circular aperture. The aperture efficiency is also shown and (b) single lens pattern, array factor and resulting array pattern.

III. Conclusions

We have presented a plastic resonant leaky-wave lens antenna with annular corrugations in the ground plane. The corrugated ground plane suppresses the spurious TM0 leaky-wave mode and leads to a lens antenna with high aperture efficiency (>80%) over a 1:2 bandwidth. This antenna can be integrated in a scanning lens phased array architecture for next-generation wireless and sensing applications that require high-directivity steerable beams. We have developed, manufactured and measured a WR-5 (140-220 GHz) prototype. The measured reflection coefficient, radiation patterns, directivity, losses and scan performance are in excellent agreement with simulations over the entire WR-5 bandwidth, which makes this leaky-wave lens antenna suitable for integration into a scanning lens phased array.

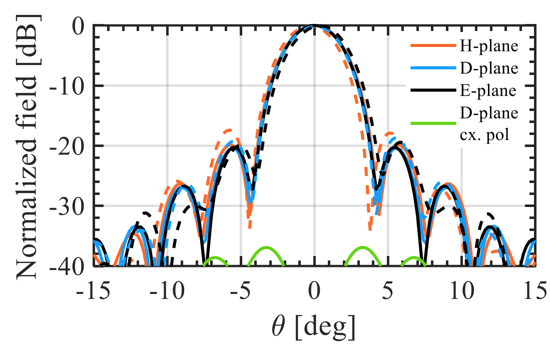


Fig. 4. Measured (dashed) and simulated (solid) radiation patterns of the lens prototype of Fig. 1b at 180 GHz.

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