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The Need for Narrow Beamwidth in Ridged Horn Antennas for UAV-Based In-situ Measurements of Radars and Communication Systems

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***Abstract*— In this paper, a lens-integrated wideband ridged horn antenna is presented for UAV based in-situ characterization of radars and communication systems. The proposed customized antenna operates from 2 GHz to 12 GHz covering the commonly used radar bands for weather and defense applications. Compared to the narrowband and bulky horn antenna, the proposed lens-integrated ridged horn antenna is wideband, low weight, and compact in size that make it suitable for UAV based measurements. Using a single wideband probe for outdoor in-situ measurements gets rid of installing and re-calibration of multiple probes for meteorology measurements. The main limitation of the commercially available ridged horn antenna is, it suffers from wider H-plane beamwidth performance at low frequencies. The proposed lens integration technique reduces the beamwidth in the H-plane by 67% (for instance at 3 GHz), that also helps in achieving near-symmetry in the patterns.**

***Index Terms*—Antenna, UAV, UAS, calibration, meteorology, phased array radars, outdoor measurements,**

I. Introduction

Antenna test ranges have been used for the characterization of antenna arrays used in radars and communications systems. However, these test ranges both indoor and outdoor, usually have a controlled environment for antenna testing and do not include the effects of the larger system, RF front-end, ground, pedestal and radome, etc, on the performance of antenna arrays. Moreover, environmental factors such as rain, snow, ice, temperature, and pollution can also adversely affect the performance of antenna arrays in terms of gain, side-lobe levels, polarization, and main beam direction. To cater these problems, in-situ characterization of the antenna arrays is usually desired especially in the case of weather radars, to have a reliable measured data considering a real operational environment [1], [2].

Several techniques were used in the past for in-situ characterization such as using tethered balloons [3], or helicopters [4], [5]. However, these techniques are hard to implement and are costly. With a recent surge in Unmanned Aerial Vehicles (UAVs), cheap and precise in-situ measurements and characterization of radars and other systems can be done using a variety of off-the-shelf UAV based flight solutions. Several works can be found in literature using UAVs for antenna characterization [6]–[14].

In [13] and [14], the authors have used different types of probes with a UAV platform and studied the effects of scattering from the UAV system on the performance of the probe antenna. It has been concluded that using a dipole antenna integrated onto a UAV platform gives worst results in terms of degradation of the co-polarization as well as increase in the cross-polarization levels. This is due to the fact that the dipole antenna has an almost omnidirectional pattern which strongly interferes with the UAV platform and hence the scattering degrades the radiation performance. On the other hand using a horn antenna shows very good RF performance as it induces very less current on the UAV system and hence minimum scattering is observed. This is due to the comparatively narrow beamwidth of the horn antenna, minimum back-lobe radiation and also due to its flaring structure.

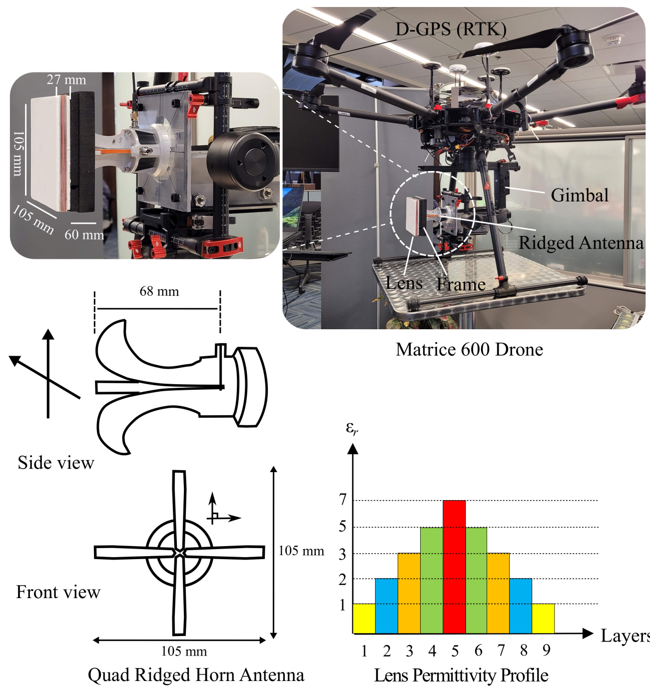

Fig. 1: Illustration of the drone model carrying the ridged horn antenna with the proposed lens prototype.

A typical horn antenna is bulky and thus not recommended for UAV based measurements. Moreover, it is also

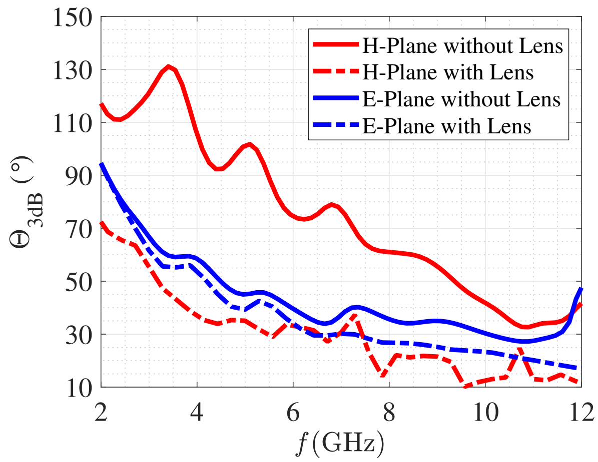

Fig. 2: Simulated 3dB beamwidth comparison in the principle planes of the proposed ridged horn antenna with and without the proposed lens structure.

narrowband, which makes the measurements difficult, time consuming, and costly by removing and installing various probes for each band of operation. However, ridged horn antennas are famous for their reduced size, low weight, and wideband operation and can be found suitable for UAV based in-situ measurements. However, these antennas suffer from wider beamwidth at low frequencies especially in the H-plane. Radiation pattern of the probe with a wider beamwidth strongly interferes with the UAV platform and thus adversely affects the gain and cross-polarization performance.

Reducing the beamwidth of a horn antenna at low frequencies without increasing the aperture size, is challenging. In this work, an effort has been made to integrate a multi-layer lens structure having a Luneburg-like permittivity profile, with a ridged horn antenna. By using the proposed lens structure, a reduction in the 3dB beamwidth of around 67% is obtained at 3 GHz in the H-plane.

II. Geometry and Simulations Setup

Fig. 1 shows the proposed quad-ridged horn antenna with a multi-layer lens structure integrated onto a commercially available Matrice-600 drone. Permittivity profile and geometry model of the antenna are also shown. The proposed lens is compact in size ($27 \times 105 \times 105$ mm^3) and can be easily fabricated by stacking up the materials with the desired permittivity or can be artificially designed using the technique discussed in [15].

III. Results and Discussion

Fig. 2 shows the simulated 3dB beamwidth comparison of the ridged horn antenna with/without the proposed lens structure. The frequency of operation is 2-12 GHz. Unlike the traditional lens-integrated horn antennas that improves the performance and reduces the distortion only in the narrowband, the proposed multi-layer lens significantly improves the radiation performance in the entire band of operation. It can be seen that without the lens, the 3dB beamwidth specifically in the H-plane is very wide at low frequencies. By integrating the proposed lens structure, the beamwidth is reduced by almost 67% at 3 GHz and the patterns in the E and H-planes are now nearly symmetric which is desired for dual-polarized antenna measurements.

IV. Conclusion

A wideband quad-ridged horn antenna integrated with a lens structure is proposed for UAV based in-situ characterization of radars and communications systems. The wideband performance of the ridged horn antenna eliminates the need for using multiple probes and re-calibration of the system. The limitation of wider beamwidth and non-symmetric radiation patterns of the ridged horn antenna at low frequencies, can be overcome by using the proposed lens structure.

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