Conception and Realization of Flat FPC Antenna with Different Polarization at Submillimeter Wave Frequencies for 6G Applications

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Invited Paper

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***Abstract*—This article presents the conception and realization of a Flat Fabry Perot Cavity (FPC) antenna with different polarization at sub-millimeter-wave frequencies. The FPC layout is made of metallic layers and its design relies on the laser cutting brass technique to simplify fabrication and low cost. The proposed antennas have a compact size, low fabrication cost, high gain, and wide operating bandwidth. The proposed FPC antennas are suitable for 6G Sub-Terahertz wireless communication systems.**

Keywords—300 GHz; 6G wireless; laser- technology; low-profile, low-cost; metallic layers; sub-Terahertz (THz).

I. Introduction

Sixth-generation (6G) wireless systems are currently an attractive topic in academic and industrial research. To increase the throughput of wireless networks with low latency features, they are now made to run at higher frequencies, frequently in the sub-THz band (0.1–1 THz)[1, 2]. According to IEEE Std. 802.15.3d-2017 [3], the sub-THz frequency range has been allocated for use around 300 GHz (252- 325 GHz) for future wireless communications. Taking the potential of abundant bandwidths compared to the millimeter wave (MMW) band to achieve short-range connectivity with data rates in the vicinity of 1 Tbps. However, many challenges of high-frequency THz communications have to be still addressed. One of the main challenges is molecular absorption and spreading losses are much more noticeable for the THz band compared to lower frequencies. The antenna is a key element for any type of wireless communication system. Antennas working in this sub-THz frequency band [4-9]need to be with high-gain characterization, to overcome these drawbacks, which are big challenges in terms of fabrication processes at higher frequencies.

II. Antenna Structure

In this paper, we first realize a linearly polarized fully metallic FPC antenna design that operates at 300 GHz and is fabricated with laser-cutting brass technology with good accuracy at such high frequency. Circularly polarized (CP) antennas are required for wireless communication systems because of their ability to avoid multipath fading, and mismatch polarization (alignment issue), and enhance the channel capacity. Therefore, developing front-end components with a focus on CP sub-THz antennas is important. We secondly present the FPC antenna with a homogenous and non-homogenous partially reflective surface (PRS) CP-layer. Using laser-cutting metal brass, we present the simplified technology procedure at 300 GHz; with a low-cost fabrication process. This laser-cutting technology works by directly cutting the brass metal layers, without the need for a mask and a metallization process, which ease the fabrication. All brass metal layers are simply stacked by using four plastic screws. This direct-mount procedure is easier than alternative setups of silicon-micromachining which needs a bonding alignment method and is expensive. These antennas find potential applications in future 6G wireless communication systems.

III. Fabrication, Measurement, and Discussion

The prototypes are fabricated using LPKF ProtoLaser U4 laser machine as shown in Fig. 1. The seven brass metal layers (A-G) needed for one antenna assembly, having different thicknesses, have been used to manufacture the proposed 300 GHz FPC antennas are shown in Fig. 2. The metal layers contain holes for the alignment dowel pins and screws, which enable a direct connection to the standard UG-387 waveguide flange without any additional test fixtures or interfaces.

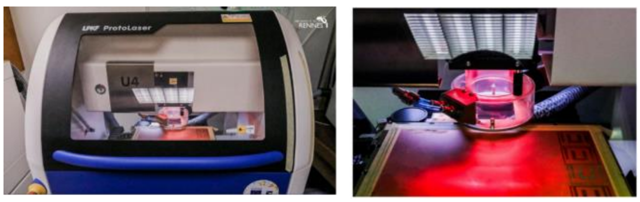


Fig1: LPKF ProtoLaser U4 laser machine

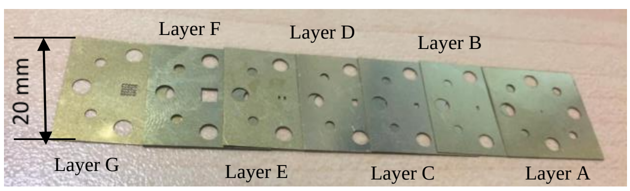
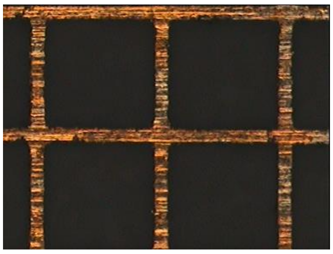


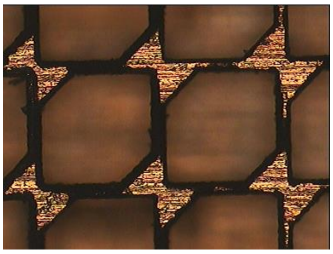
Fig. 2 Photographs of fabricated brass layers for 300 GHz FPC antenna.

Fig. 3 demonstrates microscope images of the proposed different PRS structures. The linearly polarized (LP)-PRS structure is radiating square aperture element as shown in Fig.3(a). The CP-PRS structures are homogenous radiating hexagonal aperture elements and non-homogenous hexagonal and octagonal-shaped radiating apertures as shown in Fig. 3(b), and (c).

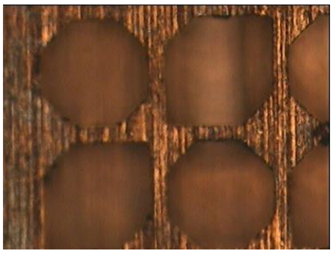
For measurements, the Fabricated prototype must be connected to standard UG-387/U waveguide flange as shown in Fig.4.



(a)



(b)



(c)

Fig 3. Microscope images of different PRS structures: (a) LP-PRS structures, (b) homogenous CP-PRS structure, and (c) non-homogenous CP-PRS structure.

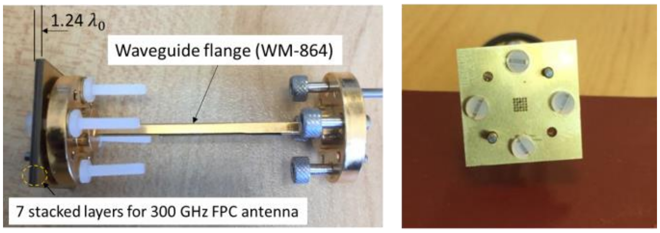
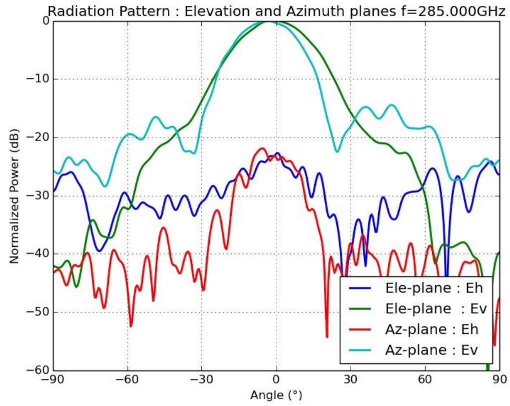


Fig. 4: Photographs of manufactured FPC at 300 GHz (a) fabricated prototype connected to standard UG-387/U waveguide flange and (b) top view.

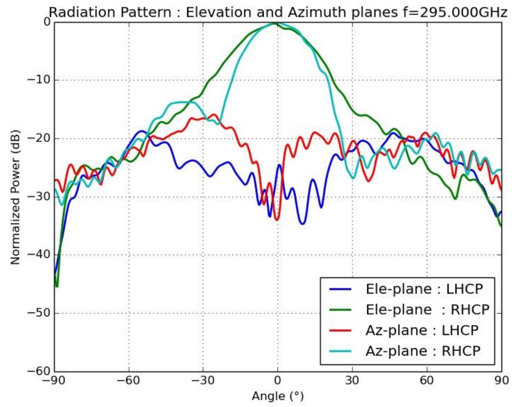
The far-field radiation patterns are measured in a compact antenna test range (CATR) chamber at IETR at different frequencies, for the two principal elevation (Ele.) and azimuth (Az.) planes. The FPC antennas exhibit a directive beam in the broad-side direction.

First, the LP-FPC antenna has a measured bandwidth of 22 GHz. The maximum measured gain observed is 17.7 dBi at 289 GHz. The measured radiation pattern shows a highly directive pattern with a cross-polarization level below − 25 dB over the whole band in all cut planes as shown in Fig. 5(a). Second, the homogenous CP-FPC antenna structure achieves a measured peak RHCP gain of 16.5 dBic at 292 GHz, and the measured radiation pattern at 295 GHz is shown in Fig.5 (b). The antenna achieves a measured impedance bandwidth of 281- 305 GHz for a reflection coefficient of less than -10 dB. The axial ratio (AR) bandwidth AR ⩽ 3 dB is 5.12 GHz.

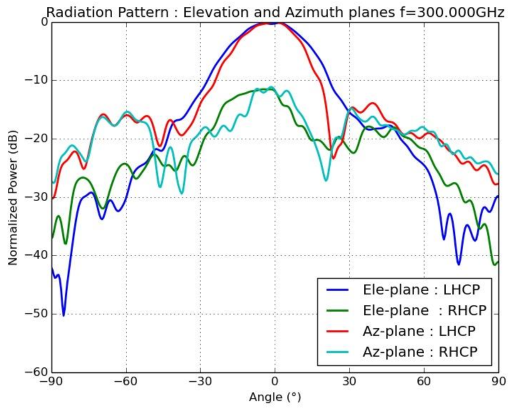
The non-homogenous CP FPC's radiation pattern measured at 300 GHz is shown in Fig.5 (c). Since the physical dimensions are so small at higher frequencies (i.e., 300 GHz), even a little change in one of the dimensions can significantly alter the radiation properties. The measured findings show some azimuth plane deviation. It would be appropriate, nonetheless, for the manufacture of such inexpensive prototypes.



(a)



(b)



(c)

Fig. 5: Measured radiation patterns of the FPC antennas (a) LP-PRS structure (b) homogenous CP-PRS structure and (c) non-homogenous CP-PRS structure.

The experimental results confirm a good agreement between the simulation and the measurements. The proposed antennas have a compact size, low fabrication cost, high gain, and wide operating bandwidth. The total height of the antennas is 1.24 λ_0, with a size of 2.6 $\lambda_0 \times$ 2.6 λ_0.

IV. CONCLUSION

Compact, low profile high gain antennas have been designed and fabricated at 300 GHz. The polarization is based on the different PRS structures, combined with an innovative and effective solution for the 6G wireless communication, based on an FPC-based antenna. The proposed antennas offer a good trade-off between the performance and fabrication simplicity and thus of interest for practical applications, including next generation wireless communication systems

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