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High-Gain Tapered Long Slot Array in PCB Technology Integrated with PCB Based Dual-Band LP-to-CP Converter for SatCom Applications

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Abstract—In this communication, we presents a circularly polarized radiating antenna covering the frequency band [17-31 GHz] for K-/Ka-band satellite. The antenna is composed of two parts, a high gain linearly-polarized (LP) antenna and a dual-band linear-to-circular polarization converter (PC). The LP antenna's radiating aperture is an array of long slots, fed by a tapered corporate feed network (CFN) to reduce the sidelobe level in the radiating plane orthogonal to the slots. A pillbox beamformer is used to illuminate the CFN. This beamformer consists of an H-plane horn located in the focal plane of an integrated parabolic reflector. The polarization converter converts linearly polarized waves into circularly-polarized waves at (17–22)GHz and (28.6–30) GHz frequency bands with opposite handedness. The antenna and the polarization converter are fabricated in printed circuit board (PCB) technology. The radiation patterns are shown for the LP antenna. The PC is mounted over the antenna aperture with 10 mm separating air-gap. The reflection coefficient measurements for the antenna with and without the polarization converter are presented for 0-60 degrees scanning angles.

Index Terms—linear-to-circular polarization converter, long slot, pillbox couplers, satellite communication (Satcom).

I. INTRODUCTION

New and advanced satellite communication (SatCom) technologies for high-data-rate wireless ser-

vices are in increasing demand [1]. For such applications, circular polarization (CP) is favoured over linear polarization due to its insensitivity to multipath fading [2].

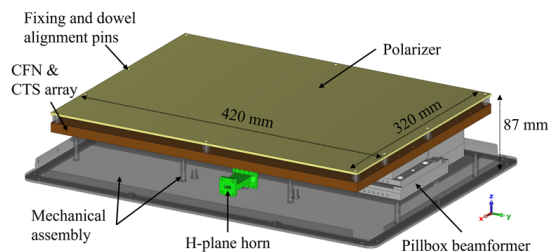


Fig. 1. Perspective view of the antenna with its polarizer and mechanical assembly.

Antennas based on long slot arrays, are broadband radiating architectures suitable for SatCom [3]. However radiation due to long slot arrays is inherently linearly-polarized (LP) [4]. A possible strategy to achieve CP, without significantly changing the antenna structure, consists in cascading a standard LP long slot array and a LP-to-CP converter [5].

On other side, orthogonal polarizations are preferred in these two bands to improve the isolation

between transmitted and received signals. Different research works have been devoted for designing dual-band LP-to-CP converters with opposite handedness for both the downlink and uplink bands [6]-[7]. Most of these studies focused on designing and measuring a stand-alone LP-to-CP with the incident field is assumed to be a plane wave. However in actual SatCom radiating systems, LP-to-CP converter is placed over the radiating aperture, interacting with the near-field of the radiating aperture.

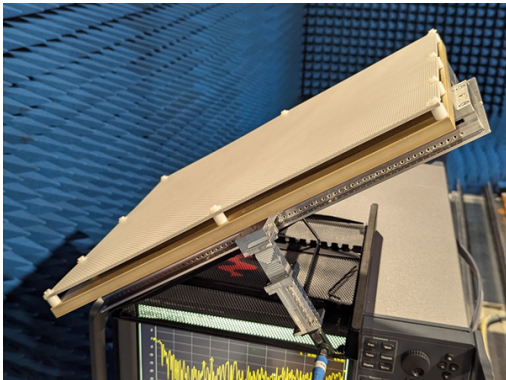


Fig. 2. Measured prototype without radome and mechanical support.

In this study, we consider the integrated antenna system composed of long slot array covered by a LP-to-CP converter. The LP antenna and LP-to-CP converter were previously studied in [8] and [9] respectively. Here we report the radiation pattern of the LP antenna. A measurement setup has been implemented to measure both the reflection coefficients measured at the feeding waveguide and the radiated field. Here the measured reflection coefficients for different scanning angles (0-60 degrees) are reported for the antenna with and without the LP-to-CP polarizer. The measurement process for the radiated field are still in progress and more results will be reported at the conference. This study is organized as follows. In sections II and III, the designs of long slot array based antenna and LP-to-CP converter are summarized respectively. The integrated antenna system, the measurement setup and the measured reflection coefficients are reported in section IV. Conclusions are drawn in section V.

II. ANTENNA STRUCTURE

Fig. 1 provides a perspective view of the proposed antenna architecture. This antenna consists of several blocks: long slot array of 64 slots, a corporate feeding network (CFN), a quasi-optical beamformer and a polarizer that will be discussed in section III. The whole assembly is fed by an H-plane waveguide and is mounted on a mechanical support allowing the addition of a radome. These systems are discussed in detail in the following sub-sections.

A. Ultra-low profile long slot array

The first block constituting the antenna presented in this paper is a system widely reported in the literature, e.g.[5], [10] and [11]. Its design procedure is available in several references, including [8]. The top parts comprise an ultra-low-profile array with 64 radiating long slots and a CFN both realized in multilayer PCB technology. The stack-up is made of 15 dielectric substrates (ISOLA Astra® MT77 [12]) with bonding films between the substrate layers (Rogers CuClad 6250 [13]). This array operates over a wide bandwidth from 17 GHz to 31 GHz and operates in a linear polarization. The CFN, feeding the tapered long slot array, achieves low Side Lobe Levels (SLL), better than -18 dB in the E-plane. The lower parts of the antenna consists of a pillbox beamformer realized in CNC milling of Aluminium blocks. This quasi-optical system produces a very narrow beam with an half-power beamwidth (HPBW) ranging from 2.8 to 2.3 degrees in the H-plane and 2.2 to 3.5 degrees in the E-plane along the operating frequency band. The beam steering is enabled along the H-plane up to ± 42 degrees, by moving the feeding horn along the focal line of the pillbox coupler's parabolic reflector. The size of the aperture is 420×320 mm ($44.5 \times 33.1 \lambda_0^2$ with λ_0 is the wavelength in vacuum).

B. Radiation patterns

The proposed LP antenna in [8] demonstrates very broadband properties and stability with beam scanning. The normalized measured electric field in the upper half hemisphere are presented in Fig.s 3-6. at frequencies of 19.5 GHz and 29 GHz for two main beam directions (broadside and 42 degrees). At broadside, the power is well collimated, and the pointing directions remain stable across the full

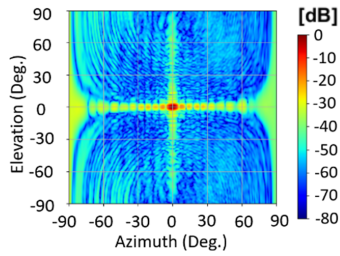


Fig. 3. Measured radiation patterns for co-polarization radiation at 19.5 GHz and at broadside.

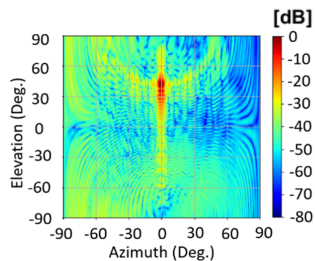


Fig. 4. Measured radiation patterns for co-polarization radiation at 19.5 GHz and at 42 degrees.

frequency band. The side lobe level (SLL) across the E-plane is stable and below -20 dB. In the H-plane, the SLL remains below -24 dB, however they increase with the scanning angle. A stability of radiation is expected up to a 60 degrees scanning angle. Only the co-polarization results of the linear CTS array are shown in this section. The addition of a LP-to-CP polarizer will be discussed in the next section.

III. DUAL-BAND POLARIZER

The overall antenna module is combined with a dual-band, orthogonally polarized LP-to-CP converter proposed in [9]. This system transforms the linear polarization wave radiated by the array into a dual-circular polarized fields. Those two CPs are orthogonal between the uplink frequency band (27.5-31 GHz) and the downlink frequency band (17.3-21.2 GHz) of the K/Ka band satellite communications. Under normal incidence, this polarizer effectively converts LP to LHCP within the 18-22.2 GHz range (approximately 21% fractional bandwidth). Additionally, it achieves LP to RHCP conversion in the 28.7-30.4 GHz range (around 6%). These

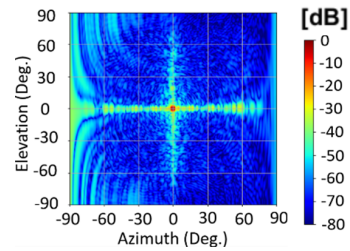


Fig. 5. Measured radiation patterns for co-polarization radiation at 29 GHz and at broadside.

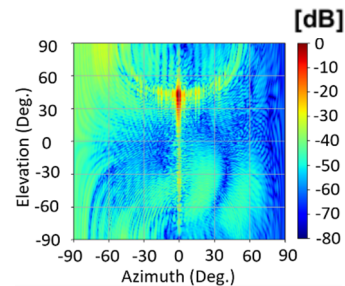


Fig. 6. Measured radiation patterns for co-polarization radiation at 29 GHz and at 42 degrees.

bandwidths are defined by frequency ranges where the axial ratio (AR) is below 3 dB and transmission exceeds -1 dB [9]. The polarizer maintains stable performance under oblique incidence for angles up to ± 45 degrees.

In this paper, a new polarizer with the dimensions of the radiating surface of the long slot array was produced on Rogers RO3003 [13] panels ($\epsilon_r = 3.00$ and $\tan \delta = 0.0010 @ 10 \text{ GHz}$). The spacing between the antenna aperture and the polarizer has been fixed to 10mm. This length represent a trade-off between performances of the polarizer and the compactness of the whole system.

IV. PROTOTYPE AND MEASUREMENTS

The fabricated prototype is shown in Fig. 2 and sizes $420 \times 320 \times 59 \text{ mm}^3$. The measurements were performed without its mechanical support. For this prototype, the fabrication accuracy, particularly of the pillbox, has been improved up to $10 \mu\text{m}$. The metal parts also received a surface treatment (Surtec 650) to improve surface conductivity and reduce surface roughness. The antenna was characterized at IETR, Rennes, France, in one of the anechoic

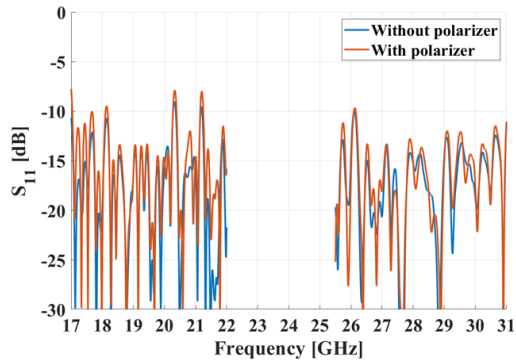


Fig. 7. Measured reflection coefficient at broadside across downlink and uplink frequency bands.

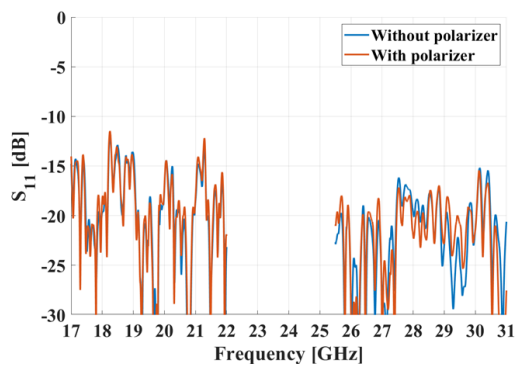


Fig. 8. Measured reflection coefficient at 60-degrees across downlink and uplink frequency bands

chambers of M²ARS platform. The microwave measurement chain includes a vector network analyzer N5244B [14] from Keysight Technologies and coaxial cable to waveguide transitions: WR51 for the lower band and WR28 for the upper band. The reflection coefficients of the antenna were measured for broadside radiation and for different scanning angles from 10 to 60 degrees with a 10-degree step. The scanning angle is easily managed by adjusting the feed horn to specific positions along the focal line of the pillbox coupler's parabolic reflector. Measurement results obtained at broadside and 60 degrees results are presented in Figs 7-8 respectively. The reflection coefficient level remains below -10 dB over the entire high and low frequency band for all scan angles. The highest levels are mainly observed in the broadside position. This behavior at broadside is generally observed for pillbox-powered

systems. As depicted in those measurements, the impact of the polarizer is really low regardless of the scanning angle. This behavior will be confirmed in the radiation pattern measurements that are currently in progress. The study of the radiation patterns will be performed at broadside radiation and at different scanning angles from 10 to 60 degrees. Particular attention will be given to the performance of the polarizer, characterized by the measurement of the axial ratio along the K/Ka-band satellite communications.

V. CONCLUSION

A broadband circularly-polarized integrated antenna system has been presented for SatCom applications at K/Ka-bands. The propose antenna architecture compromises a wide-band linearly-polarized radiating long slot based antenna, cascaded by a dual-band linear-to-circular polarization converter. Both components are fabricated in printed circuit board. This study focused on the measurement of the integrated antenna system with the reflection coefficients are reported and the radiation measurements will be reported during the conference. Radiation pattern measurements will be also provided during the conference.

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