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Circular and Dual-Linear Polarized Continuous Transverse Stub Arrays for SatCom Applications

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Abstract

This paper proposes the summary and the main achievements of Michele Del Mastro's PhD thesis, developed at the Institut d'Electronique et des Technologies du numéRique (IETR), Rennes, France, and discussed on December 14, 2020. This PhD work aims at proposing and exploring potential solutions suitable for the new generation of terminal antennas fulfilling the requirements of modern satellite communications (SatCom). A powerful idea was promoted and made reality: the dual-mode continuous transverse stub (CTS) array. Thanks to this intuition, the CTS arrays may radiate circular polarization without using any add-on external component used for the polarization conversion. Three prototypes have been designed, fabricated and tested in the anechoic chamber, thus showing the potentiality of these antenna modules for the new era of SatCom applications.

1 Introduction

The ever-increasing demand of wideband systems for SatCom links calls for satellite spacecraft deployed in constellations orbiting in low and medium Earth orbits. An advanced generation of ground antenna modules is thus requested to operate in K/Ka-band and fulfilling challenging requirements. Specifically, the antenna must perform high-gain (> 30 dB) and provide circular and/or dual-linear polarized radiation over a large field-of-view.

Among a huge variety of solutions, the CTS arrays stand as a promising solution to fulfil modern SatCom requirements. For the recent years, these antennas have indeed aroused thrilling interest from space agencies such as the French Space Agency (CNES), Toulouse, France, and the European Space Agency (ESA), Noordwijk, The Netherlands, as well as leader companies like Thales Alenia Space (TAS), Toulouse, France. Since 2012, the IETR has investigated these antenna solutions in the framework of two R&D projects with CNES. In addition to giving birth to a corpulent scientific production, this collaboration strengthened the will of drastically redefining the original concept of the CTS array to overcome its weaknesses. Classical CTS arrays, in fact, suffer from being intrinsically linearly-polarized.

The aim of this thesis is to analyze and design a promising candidate as a terminal device: the CTS array providing circular or dual-linear polarization. The CTS arrays consist of open-ended radiating stubs, parallel-fed by a corporate feed network in parallel-plate waveguide (PPW) technology. The underlying idea of the thesis is to exploit enlarged radiating stubs supporting the propagation of the transverse electromagnetic (TEM) and the first transverse electric (TE_1) modes. These two modes exhibit orthogonally-polarized E-fields over the waveguide cross-section. If properly excited, they are thus able to generate a circularly-polarized radiation. Several numerical models have been developed throughout Michele Del Mastro's PhD thesis and employed as *ad-hoc* tools to address the design of three prototypes. The latter have been also tested in the IETR's facilities, showing results of great interest for the scientific community.

2 Main contributions of the PhD thesis

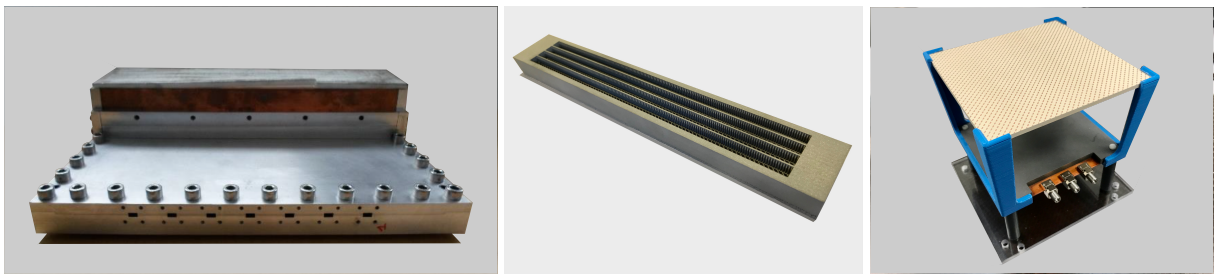
As above-mentioned, the PhD thesis has led to the design and fabrication of three prototypes [see Fig. 1], afterwards tested in the anechoic chamber of IETR.

The prototype shown in Fig. 1(a) represents the first proof-of-concept worldwide of dual-mode CTS array achieving dual-linear polarized radiation. The antenna module consists of corrugated PPWs parallel-fed by a pillbox system through a corporate feed network. The prototype in Fig. 1(a) was realized in collaboration with CNES and awarded the "Best Innovation Award" at the 39th ESA Antenna Workshop, Noordwijk, The

Netherlands, in 2018. The work carried out through this research activity resulted in two IEEE papers [1-2] and two conference contributions.

A numerical code was also developed to allow a complete description of the electromagnetic phenomena and performances of the device. By employing this tool, the time consumption needed for the design of the antenna's radiating section drops down dramatically. A ten-fold reduced computational cost is, indeed, observed with respect to using a commercial software. The numerical method is based on a hybrid mode-matching approach based on Green's functions. To the best of the authors' knowledge, this PhD work applies it to dual-mode CTS arrays for the first time ever. The developed in-house tool eased the antenna design, whose corresponding fabricated prototype is shown in Fig. 1(b). This research activity resulted in two journal papers [3-4] and several contributions in international conferences.

A third prototype was developed in a collaboration involving the University of Michigan, Thales SIX GTS, and IETR. To date, this antenna solution is the subject of a patent and it is in the short list for the "Best Paper Award" at 15th European Conference on Antennas and Propagation (EuCAP 2021). The antenna solution provides a dual-circular polarization between the up-link and the down-link frequency channels of K/Ka-band SatCom applications using a single ultra-low-profile terminal. The array is fully realized using staked-up substrates in printed circuit board technology. Further details about the antenna system can be found in [5].



(a) (b) (c)

Figure 1: Fabricated prototypes in the framework of Michele Del Mastro's PhD thesis. (a) Dual-linear, (b) circular, and (c) dual-circular polarized CTS arrays.

3 Conclusion

Michele Del Mastro's PhD thesis has dealt with the investigation of a promising antenna architecture for the upcoming market of SatCom applications: the dual-mode CTS array. The emphasis was particularly dedicated to exploring a novel antenna concept based on over-moded, open-ended stubs able to ensure the propagation of two orthogonally-oriented modes. If properly excited, these two modes can radiate orthogonal field components. The thesis work resulted in five published journal paper [1-5] and more than nine contributions in international conferences. Furthermore, the concepts developed during the thesis are the backbones of a current action at IETR to create a start-up. The project was selected by CNRS Innovation in the framework of the RISE program aiming in a year time at creating a start-up on terminal antennas for SatCom applications.

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