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Circularly polarized Ka-band radiating element unit-cell for SatCom wide-angle electronically steered phased arrays

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Abstract—This paper presents the design and simulations of a circularly polarized cavity-backed patch antenna for a low profile active electronically scanned Ka-band array with a beam-scanning capability over a wide-angle range ($\pm 60^\circ$). The proposed unit-cell devoted to aircraft SatCom applications is derived in two versions for both 18-20 GHz and 28-30 GHz bands. It comprises an upper patch coupled to a dual pin-fed lower patch, both separated by a metal grid spacer. By symmetrically placing the two input feeds, a similar behavior for both polarizations can be achieved, attaining thus a low axial ratio over a wide-angle range.

I. INTRODUCTION

Antennas for connectivity applications are classified into two different categories: mechanical solutions and low profile active electronically scanned array (AESA) solutions. Mechanical solutions are present today on the market but they are bulky and have a strong impact on the aerodynamics of the aircraft. AESA antennas seem to be optimal in terms of connectivity performance, environment, ease of integration and maintenance. However, available solutions on the market for providing fully electronically wide-range 2D scanning remains challenging. With these perspectives, cavity-backed patch antenna is a promising candidate [1], [2], [3]. In [3], an antenna with coupled patches is proposed with a hollow cavity. Wideband large steering angles are obtained thanks to the low permittivity cavity.

In this paper we present the unit-cell design of a new circularly polarized cavity-backed antenna as an antenna element for a low-profile AESA with a beam-scanning capability over a wide-angle range. The proposed design comprises substrates with the upper patches, pin-fed lower patches and a spacer separating these layers. The concept [1] is here extended by using a bottom slotted patch to attain both compactness and bandwidth requirements. Active reflection coefficients simulations of Rx and Tx infinite array with a triangular lattice show low axial ratio even in the $\pm 60^\circ$ directions.

II. UNIT-CELL DESIGN

The proposed unit-cell is shown schematically in Fig. 1, and the assembly of the different layers in Fig. 2. The unit-cell comprises five components: (I) printed circular upper patches at the bottom of a Rogers RT5880 dielectric substrate, (II) an empty spacer, (III) circular lower patches printed on a

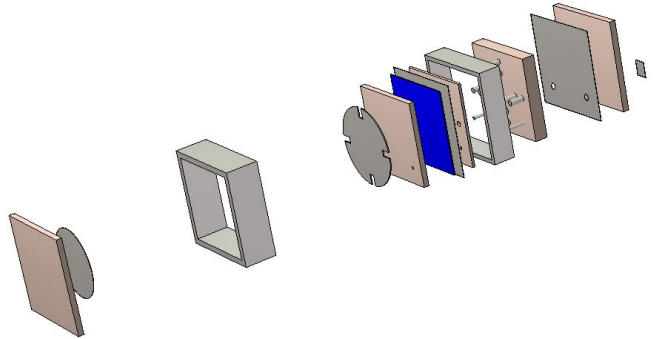


Fig. 1. Ka-band unit-cell design (Tx band).

Rogers RT5880 dielectric substrate, (IV) a RO3003 cavity with feeding and shielding vias, and (V) a microstrip line feeding the pins through a RO3003 substrate. The proposed design includes a symmetry plane to ensure that the reflection coefficients on the two ports remain extremely close which will make it possible to subsequently obtain a good circular polarization. The shielding vias introduced in part (IV) ensure relatively low levels of the coupling coefficient S_{21} over a wide-angle range which is also a prerequisite to form efficiently the circular polarization.

TABLE I
TX UNIT-CELL PARAMETERS

Tx parameters	mm
Periodicity	5.50
Spacer cavity internal edge	5
Spacer cavity depth	1.51
Upper patch diameter	3.16
Lower patch diameter	3.75
Pin diameter	0.2
Microstrip line width	0.6

III. SIMULATION RESULTS

Infinite array simulations are performed with the CST tool using a triangular lattice. A post-simulation processing is then implemented to derive the active reflection coefficients. The simulated [S] matrix and farfields are exploited, at each

TABLE II
RX UNIT-CELL PARAMETERS

Rx parameters	mm
Periodicity	7.5
Spacer cavity internal edge	6.5
Spacer cavity depth	2.18
Upper patch diameter	5.01
Lower patch diameter	5.63
Pin diameter	0.2
Microstrip line width	0.6

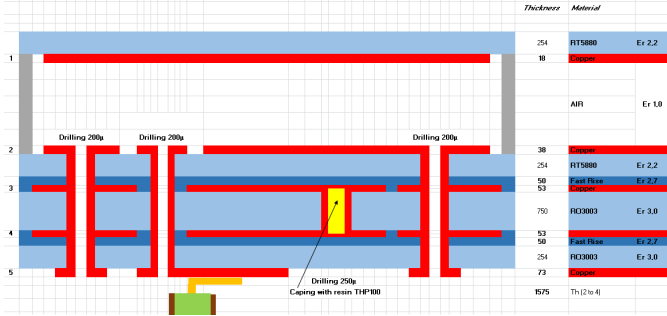


Fig. 2. Assembly of the different layers of the radiating element.

frequency and scanning angle, to reconstruct perfect circular polarization by adding a phase and magnitude difference between the two ports. As the radiating elements will be fed later by RFIC chips, the control of the amplitude and the phase of the signal on each port can be ensured. Simulations in the Rx band (Fig. 3) (18-20 GHz) as well as in the Tx band (Fig. 4) (28-30 GHz) show that the active reflection coefficients remain below -10 dB for pointing directions included in a cone of $\pm 60^\circ$. Moreover, Fig. 5 shows that the reflection coefficients of the two ports are also very close due to the symmetrical design of the unit-cell. It should also be noted that the design has been optimized for a beam steer at $\theta = 50^\circ$, $\phi = 0^\circ$ which explains the poorer matching (but sufficient) at broadside.

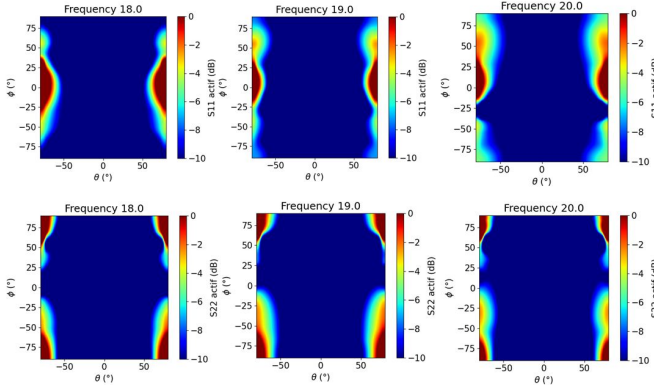


Fig. 3. Active reflection coefficients in Rx band (for an axial ratio of 0 dB).

IV. CONCLUSION

The design and simulations of a circularly polarized cavity-backed patch antenna for a low profile active electronically

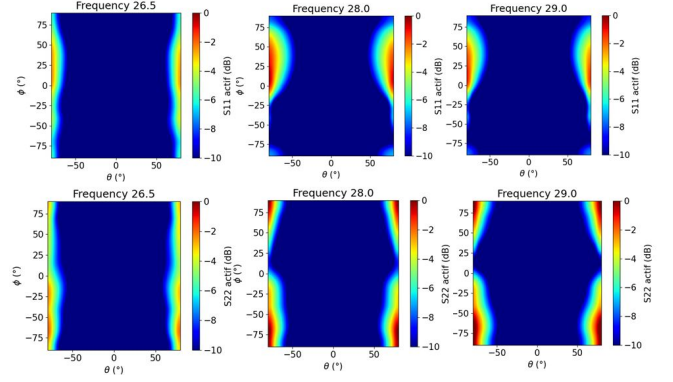


Fig. 4. Active reflection coefficients in Tx band (for an axial ratio of 0 dB).

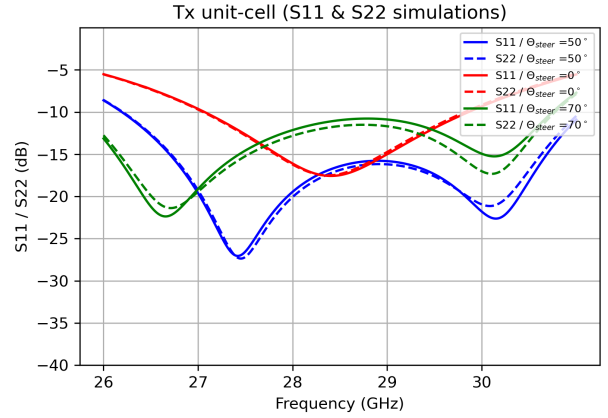


Fig. 5. Tx band S_{11} and S_{22} coefficients in plane $\phi=0$.

scanned Ka-band array with a beam-scanning capability over a wide-angle range ($\pm 60^\circ$) is proposed. The manufacturing of a 64 elements array is in progress in order to carry out experimental validations.

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