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Ka-band antenna panel for wide-angle beam steering

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Abstract— a 256-radiating element array is designed, manufactured and measured to meet wide-angle beamsteering requirements in Ka-band (18.3-20.2 GHz). The originality of the design is mainly based on the use of an Interleaved Parasitic Array Antenna (IPAA) to reach the specifications. This solution aims to stabilize the dispersion of the active reflection coefficient of the array for important beamsteering.

Keywords—phased arrays, antenna.

I. INTRODUCTION

Wide-angle beam scanning capability is more and more required for both civil and military applications. The development around 5G, 6G and Low Earth Orbit (LEO) constellations is an important driver to promote this characteristic. A lot of antenna architectures can be used to this end [1]. Among these solutions, phased arrays remain complex to optimize, due to the density of the elements. Their feeding systems with distributed amplifiers and the need to remove protection circuits between radiating elements and amplifiers, in order to improve the integration of the system, are complex tasks.

In this context, an important challenge is the management of the active reflection coefficients of the array, whatever the scanning angle. Most requirements tend to active reflection coefficients below -10 dB for all steering combinations, over the bandwidth. To obtain this property, the radiating elements should be designed carefully and should integrate some degrees of freedom to perform an optimization without deteriorating other electromagnetic characteristics. The Interleaved Parasitic Array Antenna (IPAA) can be used to reach these objectives [2]. The application in this contribution is dedicated to a Very High Throughput System (VHTS) for SatCom in receiving mode, between 18.3 – 20.2 GHz, in linear polarization. The main challenge is the ability to steer the beam until $\theta_0 = \pm 70^\circ$, whatever the azimuth plane. The second part of this work describe the array structure and the third one gives some RF performances.

II. PROPOSED DESIGN

The radiating element is based on an IPAA design. The readers can refer to [2] for the design methodology. It is made of a three-level design. The radiating cell is based on a circular patch into a cavity with a double roof to enhance the bandwidth and to limit surface waves. The radiating element is then optimized with an XLIM laboratory optimization software (SynTosa) in order to:

- limit the frequency dispersion of the active reflection coefficient;

- enhance the scanning angle of the antenna up to $\pm 70^\circ$ for all azimuth planes, while keeping the active reflection coefficient below -10 dB in the final array.

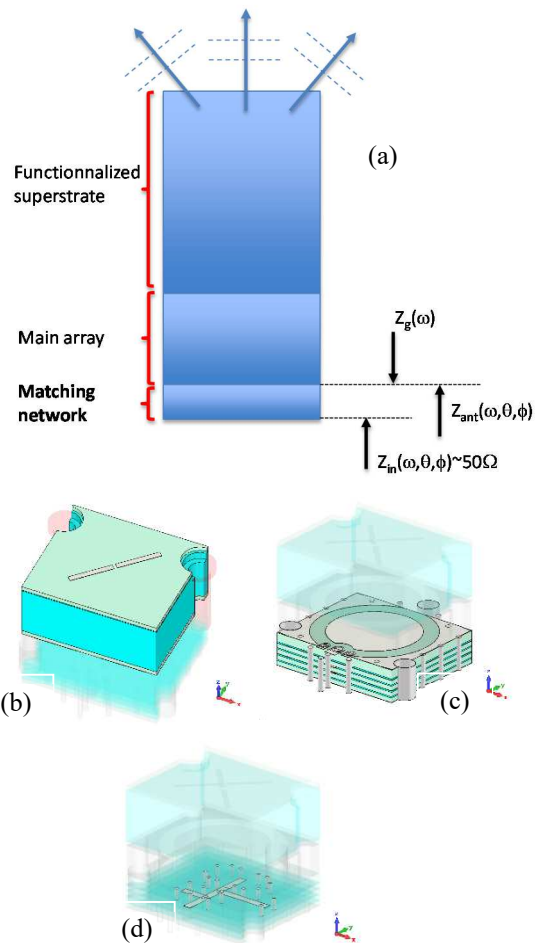


Fig. 1. (a) Stackup principle of the IPAA. CAD views of the designed IPAA in Ka band (b) functionalized superstrate with parasitic dipoles (c) main array cell with double roof circular patch in cavity (d) matching network.

To satisfy the first criterion, the input impedance of the radiating element is scanned to find the lowest frequency dispersion geometry. Then, the second criterion is reached through the third layer (Fig.1(b)), acting as a functionalized superstrate. It is made of a classical RF substrate (Taconic TLY-5) with printed parasitic elements on the top and bottom faces. They act as degrees of freedom to enhance the scanning ranging without the manufacturing complexity of a Wide Angle Impedance Matching layers. At last, the first level is made of a matching network (Fig.1.d) to reach the required 50 ohms for the RFICs.

III. PROPOSED DESIGN

The unit cell of the array has been optimized with a constraint to maintain the active reflection coefficient below -12dB (2 dB margin compared to specifications) between 18.3 and 20.2 GHz until $\theta_0=70^\circ$. At this stage the optimization is led with the classical periodic boundary conditions on the cell with CST MWS. The results are plotted in Fig.2. Then, the cell has been duplicated to create a 16x16 array with a triangular lattice. To predict the performances of the finite-size problem, the method presented in [3] has been used to calculate the finite size scattering matrix and the different active reflection coefficients, depending on the steering direction. As an example, the circle diagram of the center cell is presented for three frequencies in Fig. 3. Even with the finite-size of the panel, the active matching remains below -10 dB over the frequency range until $\theta_0=70^\circ$. It validates the numerical design.

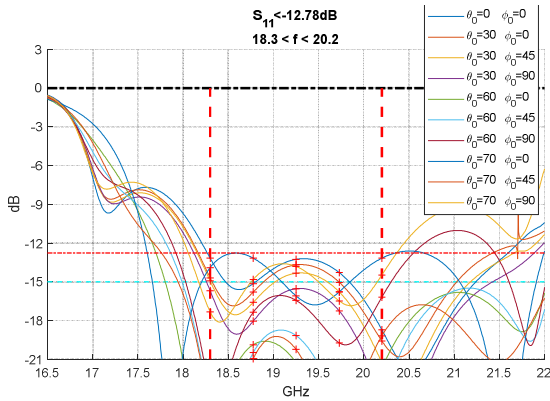


Fig. 2. Simulation of the active reflection coefficient of the optimized cell for beam steering until $\theta_0=70^\circ$

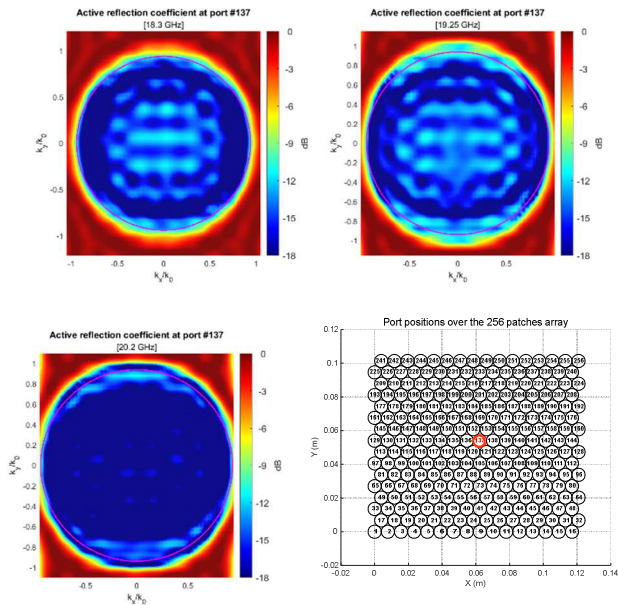


Fig. 3. Active reflection coefficients of the central cell (nr137) of the finite array for 18.3 GHz, 19.25 GHz and 20.2 GHz. The magenta circle represents the direction $\theta_0=70^\circ$. One can notice some ripples due to finite size but no reflection higher than -10 dB appears.

At last, a prototype has been manufactured. To avoid the cost of RFICs integration in Ka band and in the objective of a validation of the test vehicle, we realized several arrays with passive feeding networks, i.e. several prototypes, to validate

critical beamsteering directions. The one corresponding to the most important beamsteering capability $\{\theta_0=70^\circ; \varphi_0=90^\circ\}$ is shown in Fig. 4. The different prototypes have then been manufactured and measured to confirm the simulations. In particular, the realized gain obtained is contained between 25.7 dBi on boresight and 23 dBi at $\theta_0=60^\circ$. In Fig. 5, for the prototype corresponding to $\{\theta_0=70^\circ; \varphi_0=90^\circ\}$, a good agreement is observed while comparing measured and simulated realized gain.

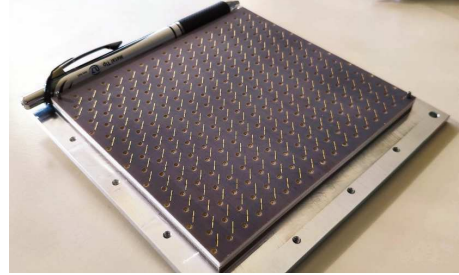


Fig. 4. Photograph of the manufactured 256-element array in Ka-band

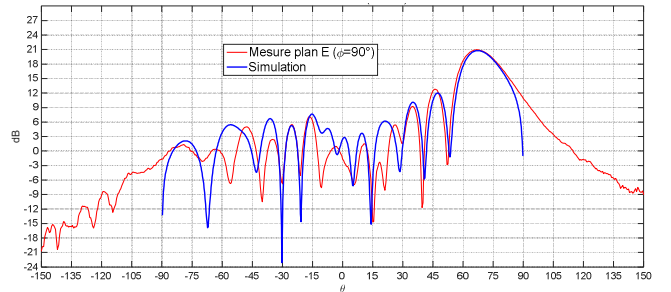


Fig. 5. Realized Gain radiation pattern for the prototype at $\{\theta_0=70^\circ; \varphi_0=90^\circ\}$, at 19.25 GHz. Comparison between simulation in blue and measure, in red

IV. CONCLUSION

The proposed design is suitable to wide-angle beamsteering in Ka-band, with limited degradation of active reflection coefficients thanks to the proposed method. It offers opportunity for the integration of distributed amplifiers with RFICs to minimize the variation of the consumed power and power added efficiency.

ACKNOWLEDGMENT

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