Implementation of AESA Technology for High-Target Dynamic Telemetry Ground Antennas

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A. Lohou, A. Robert, B. Lesur, G. Kipfer
SAFRAN DATA SYSTEMS
La Teste de Buch, France
anael.lohou@safrangroup.com

P.-M. Bastie
SAFRAN DATA SYSTEMS Inc
Norcross, GA 30071, USA
pm.bastie@safrandatasystemsus.com

ABSTRACT

This paper describes the implementation of AESA technology for telemetry ground antennas. Telemetry ground antennas play a key role in the functioning of telemetry systems, by receiving the data transmitted by the system and sending it to a ground station for analysis and processing. The use of AESA technology allows for more precise targeting and tracking, making them ideal for high target dynamic applications.

The design proposed is a 1-axis electronically steerable antenna, which would be used for elevation while the azimuth axis would be mechanically driven. This proposed design would result in a 1 m² antenna that is specifically intended for short to medium range telemetry and is able to handle high target dynamics. The paper presents results about the first prototype that was manufactured and tested. The focus of the document then shifts to the development of a complete prototype that will be used for evaluation and testing in order to further refine and improve the design.

INTRODUCTION

Nowadays, needs for ground telemetry are covered by reflector antennas for high gain applications, or by small passive panels for smaller gain applications. Safran Data Systems offers a wide variety of products ranging from small-size panel to large reflector antennas (1.8 m to 9.3 m diameter) in L, S and C bands for these applications [1]. In order to complete its product range, and to propose innovative solutions, Safran Data Systems carries out an R&D effort on electronically steerable solutions for these applications. Indeed, these promising technologies would allow to offer new possibilities such as faster tracking and a low-gain mode for targets in a close perimeter. There is also a reduction of mechanics for the hybrid steering antenna and a complete removal of mechanics for the fully electronically steered antenna, with other functions, such as multi-beam capacity.

This publication fits into this context of development of a 1-D electronically steerable antenna in S-band. The scope of the article is the implementation and experimental characterization of a 16x8 elements electronically steered antenna array which will allow to validate the working principle and performance with integrated active electronics.

In the next part, the architecture of the antenna will be presented. Then, the design and modelling of the 16x8 active array will be explained. Experimental results will be showed in anechoic chamber. Finally, an approach to tracking will conclude the article.

ARCHITECTURE

Test range telemetry applications require complete coverage of a hemisphere with optimal performance when the elevation is low. The use of flat electronically steered antennas is prohibited due to the decrease in performance at low elevation angles. The chosen solution involves pointing the antenna towards the test zone. As a result, only an azimuthal sector is accessible, and therefore, the panel needs to be mounted on a mechanical positioner that enables continuous azimuthal rotation. The antenna is positioned at a 45° angle from the horizon and placed on a rotating axis (see Figure 1). By electronically steering within a range of +/-45° in elevation and combining it with the 360° mechanical rotation, the entire hemisphere can be covered with reasonable loss in performance at low elevation and zenith angles.For this first hybrid steering product, specifications set by Safran Data Systems are the following:

- S-band: [2.2-2.4] GHz
- RHCP/LHCP simultaneously
- Gain: [25-27] dBic // G/T: [3.5-5] dB/K
- Elevation electronic steering: +/-45°
- Az & El tracking ability

To meet the specifications, the antenna needs to have a size of approximately 1m². By using single-axis electronic steering, it becomes possible to increase the inter-element spacing horizontally, resulting in a rectangular array with a form factor of 1:3, consisting of 16x8 elements. However, manufacturing constraints prevent the fabrication of such a large object in one piece. As a solution, the panel is divided into four separate tiles, each containing 8x4 elements. This division into four quadrants also enables the implementation of azimuth and elevation tracking functions [2].

The restriction of electronic steering to a single axis simplifies the design of the individual components and beamforming networks. The phase shift can be applied to the array's lines after combining the polarization of each line. These lines are subsequently combined to form the radiation pattern of the entire array. By utilizing phase shifters, beam steering can be achieved, and the axial ratio can be dynamically minimized.

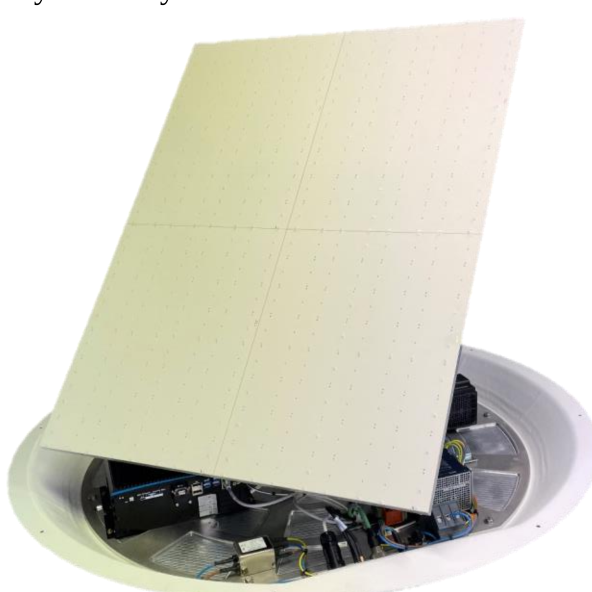


Figure 1 View of the antenna orientated at 45° on its azimuthal positioner without protection radome.

This compact ground station weighs weighs less than 40 kg. Its lightness enables easy deployment on any operational situation. An inertial navigation system can be added to the system if the ground station were placed on a moving vehicle.

DESIGN AND MEASUREMENT OF THE 16X8 ACTIVE ARRAY

Therefore, the 16x8 panel consists of 4 8x4 panels. Each line of 4 radiating elements is amplified and phase-shifted switch specific command. Then, a beamforming network is added to combine different signals provided by different radiating elements.

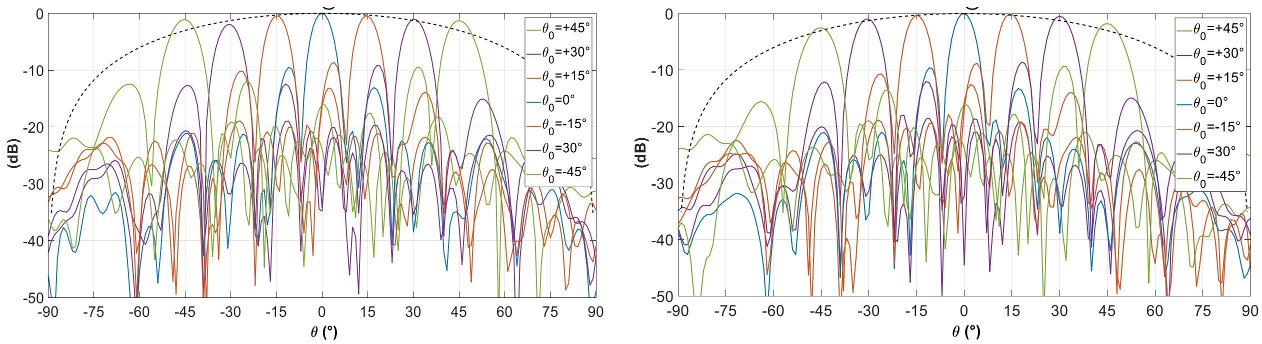
Concerning the active circuits, a LNA (Gain: 22 dB; NF: 0.5 dB) and a phase shifter (4 bits; loss: 4 dB) were chosen because their performance match the G/T specification of our system. Note that the 1 dB compression point at the output of the LNAs (17 dBm) located just downstream of the radiating elements increases the station's resilience to external interferences.

The radiating element is a printed antenna placed into a cavity with an upper superstrate. The excitation is made by coupling stripline feeding lines through a slotted ground plane. This kind of unit-cell is used for its compactness and its performance in an array environment [3,4,5,6,7]. The use of a metallic cavity allows to widen the bandwidth and to mechanically hold the upper (superstrate) and lower (multilayer) PCBs.

All presented results below are in an anechoic chamber. Figure 2 shows the antenna placed on its positioner prior to the measurement. The control of phase gradients is done directly with a servo control unit.

Figure 2 16x8 panel inside the anechoic chamber.

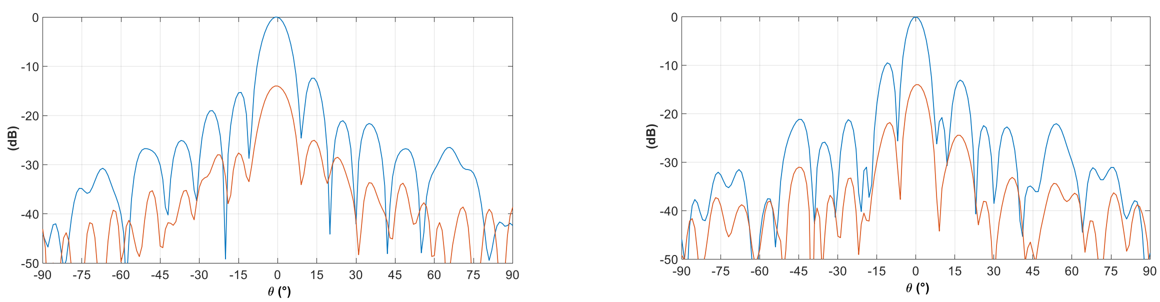
Figure 3 shows the radiation patterns obtained for electronic steering from -45° to +45° in LHCP and in RHCP at 2.25 GHz. The patterns are well formed and the steering directions are respected. The cross-polarization is really low as well. These results allows to validate the different aspects of design and driving of this first prototype.



(a) (b)

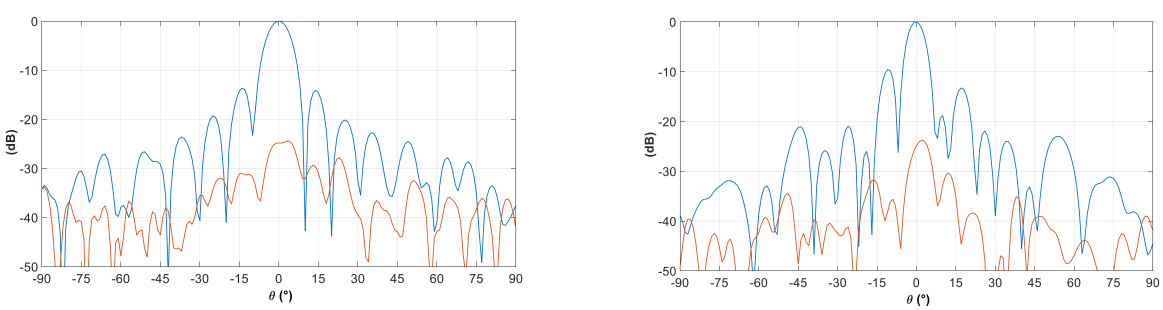
Figure 3 Measured radiation patterns of the panel in LHCP (a) and in RHCP (b) at 2250 MHz.

Figure 4 and 5 show the radiation patterns obtained for 0° in LHCP and in RHCP at 2.25 GHz in co-polarization and cross-polarization. The patterns are well formed and there is no pointing error. We can observe a slight asymmetry between the sidelobes in elevation for each polarization.



(a) (b)

Figure 4 Measured radiation patterns of the panel in Az (a) and in El (b) for LHCP at 2250 MHz, θ_0 = 0°, Co-polar in blue, Cross-pol in orange

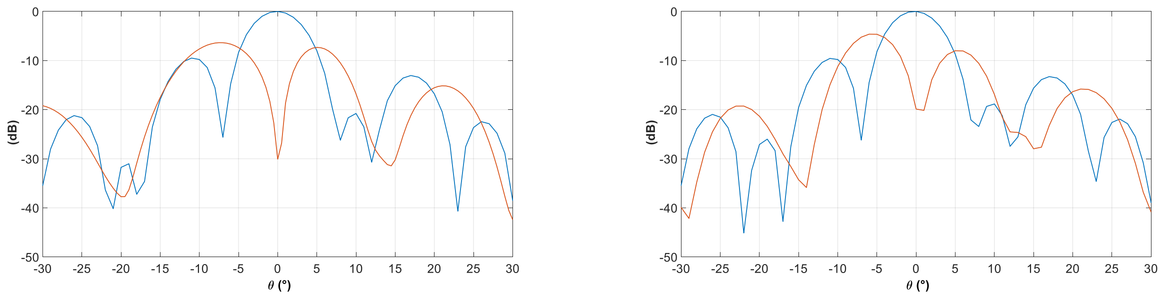


(a) (b)

Figure 5 Measured radiation patterns of the panel in Az (a) and in El (b) for RHCP at 2250 MHz. θ_0 = 0°, Co-polar in blue, Cross-pol in orange

TRACKING

The chosen architecture allows for the generation of ∑ and Δ patterns. Indeed, through specific recombination between the different sub-arrays A, B, C, and D, it is possible to obtain Δ_{Az} and Δ_{El}. Figure 6 illustrates the generation of the Δ pattern in relation to the ∑ pattern. It is noticed that the delta patterns are well defined and have a linear slope. Tracking of flying objects is now feasible.

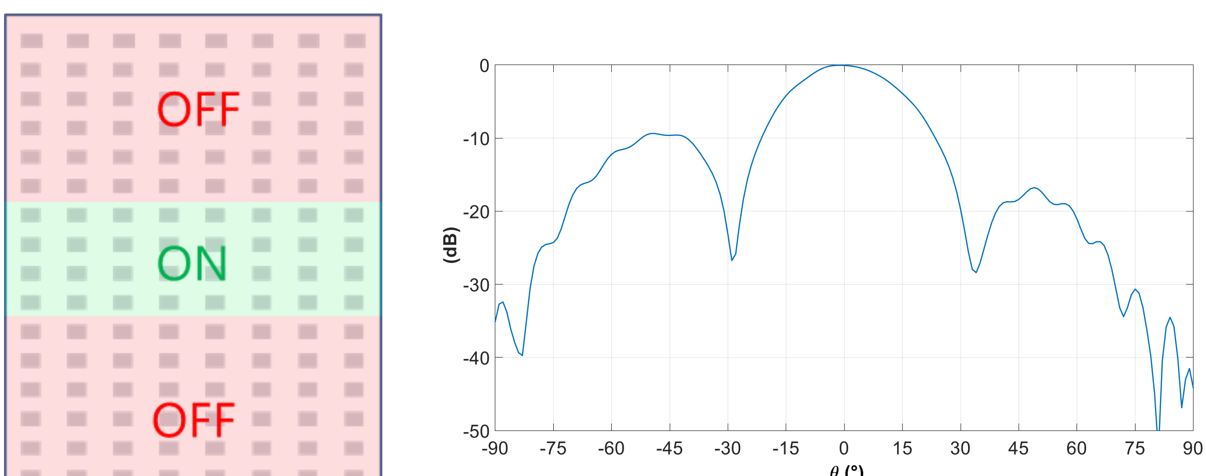


(a) (b)

Figure 6 Measured radiation patterns ∑ (blue) and Δ (orange) of the panel in LHCP (a) and in RHCP (b) at 2250 MHz.

On parabolic antennas, we deliver a option which consists in reducing the LNA gain to avoid saturation when the target is close to the antenna. This function solves the issue of signal saturation, but it does not impact the antenna beamwidth. One would like the beamwidth to increase rather than only acting on the LNA gain.

The AESA concept allows muting some panel lines and thus reduces the overall gain, but also increases the beamwidth in elevation. Of course, the beamwidth will be unsymmetrical, but it will give more flexibility to track or re-point the target at high elevation angles. As illustrated in Figure 7, switching off 12 out of 16 lines could lead to a gain reduction of around 6 dB.



(a) (b)

Figure 7 Example of Gain reduction (a) and its measured radiation pattern with this configuration

CONCLUSIONS

The principle and architecture of a hybrid mechanical/electronic scanning antenna were described. The performance was optimized over the required bandwidth, and the angular spectrum was presented. The RF performance is excellent compared to the size of the antenna. The experimental results validated the operation of the 16x8 panel. Furthermore, results regarding tracking were explained, demonstrating good performance. All these results provide confidence for future work in any location.

ACKNOWLEGMENTS

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