Anti-Stealth X-Band Radar Defense with Palm Tree Antipodal Vivaldi Antenna Applied in Low Signature Strike Aircraft Model

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***Abstract* — This paper presents the application and study of Palm Tree Antipodal Vivaldi Antenna (AVA) in a X-Band radar system for stealth fighter aircraft detect. As the Palm Tree AVA is only genuine directive AVA, allows the generation of high resolution microwave images, even when the target has a low radar signature, dielectric contrast between the target and the medium is between 10% and its surfaces are all faceted with angles around 45 degrees, which diverts direction of return of electromagnetic waves from the radar. The aircraft model used in the analysis stage, is designed with a 1.1 dielectric constant material, and their surfaces mostly distant angularly 45 degrees. The signal processing carried out began with the acquisition of the loss reflection (S_{11}) parameter, where the real component was transformed to the time domain by applying the inverse transform of Fourier following was performed background subtraction step, edge detection and image reconstruction. The final image shows patterns where you can clearly identify the aircraft, as well as the reverberation of ghosts, because the study scenario is relatively small, which does not take into account the attenuation of the medium.**

***Key-Words* — Palm Tree Vivaldi, Radar, Stealth Aircreft.**

I. INTRODUTION

Over many years, the system of Radio Detection and Ranging (Radar) has been considered the most relevant air defense system. Can highlight the use of Russian surface-to-air missiles (SAM) equipped with a targeting radar system (search and destroy) by North Vietnam in the 1950s which led to the slaughter of 190 North American aircraft [1].

In response, the US government funded the development of stealth techniques and 1970s Lockheed Martin presents the F-117 pioneer, Fig. 1, known as “stealth fighter”, although this equipment is better classified as a bomber in contrast the term used fighter [2].

The fire proof of stealth technology, used in the F-117, was during attacks on Iraq strategic and well defended targets during the Gulf War.

On this occasion, it was not accounted for any F-117 lost; on the other hand, 32 aircraft not stealthy were killed by SAMs and antiaircraft artillery (AAA) [2], [3].

Although the number of stealth techniques used in the F-117 makes it a low-signature radar aircraft, does not make you invisible, proof of that is the fact of this aircraft has been shot down in the Balkans, by a Serbian's SAM in 1999 [4].

Of course, for this to happen, some factors contributed, being then: SMA provided with mobility, control of radar emissions system, and camouflage. As the SAM battery was positioned strategically and secretly gave him huge advantage over the F-117 that inadvertently went to meet her, which facilitated the search and destroy algorithm on this occasion [6].

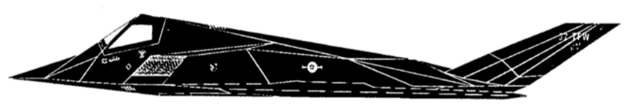

Fig. 1-Side view of the Lockheed Martin F-117 [6].

This stealth technology is the application of a set of techniques to make the difficult aircraft to detect by radar. This promotes the reduction of electromagnetic (EM) signature of the aircraft, and in general, can be categorized in two ways, active and passive. Defined active signature all detectable aircraft electromagnetic emissions. Passive signature is defined as the reflection characteristics of stealth aircraft within the targeted radar electromagnetic signal [7].

Through the correct balance between active and passive signature techniques, it establishes the different designs of stealth aircraft [2].

One of the main features of the concept of stealth aircraft project is to reduce the reflection of radar electromagnetic signal, also called radar cross section (RCS). For this, use absorbing materials and paintings of electromagnetic waves, as well as by modeling the fuselage with angles around 45 degrees, which make the remaining reflected signals, diffuse and directed away from the radar system [8].

Fig. 2 shows a conventional aircraft RCS versus a stealth aircraft. The modeling of the fuselage and the use of EM-absorbent materials contributes to reducing the RCS, especially in systems where the transmitter and receiver are in the same position [9].

To try to increase the RCS stealth aircraft, proposes a study of the use of planar antennas, Ultra-wideband (UWB), and directive called AVA.

Due to the high rate of side lobes level (SLL), which would compromise the quality of the system, in this paper we opted for the use of Palm Tree AVA, considered the most AVA directive, since almost no one has SLL [10].

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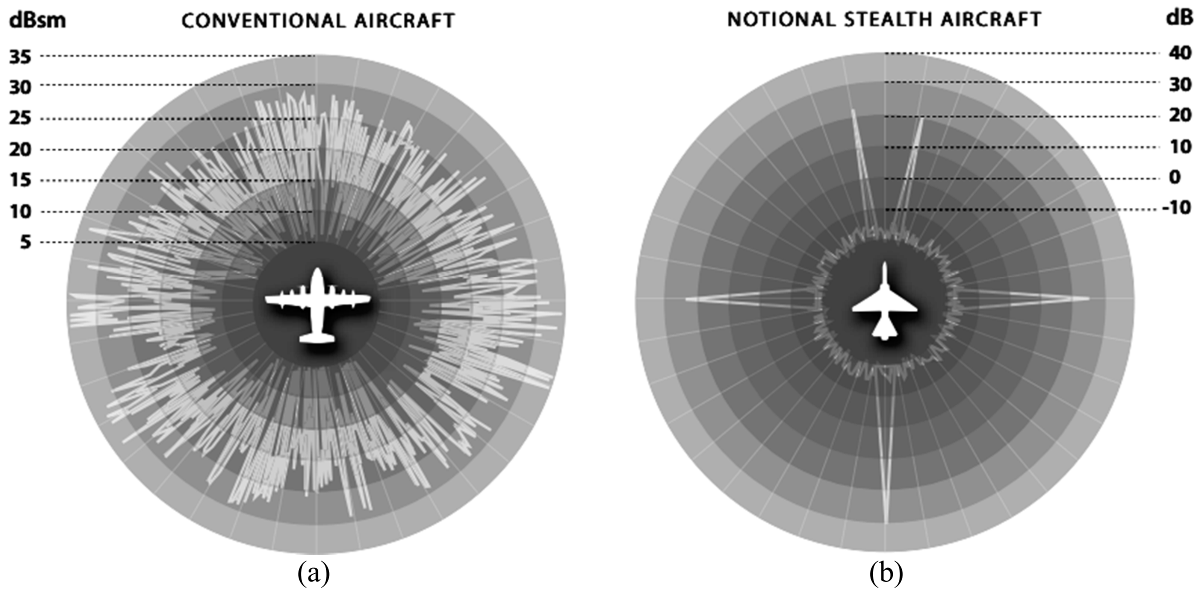

Fig. 2 – Illustration of (a) Conventional and (b) Stealth Aircraft Radar Cross Section Signature [2].

This paper is organized as follows: Section II presents the antenna design and the test environment, Section III presents the numerical analysis and results. Finally, Section IV presents conclusions.

II. Antenna Design and Test Environment

Fig. 3(a) presents a conventional AVA, and Fig. 3(b) presents the used Palm Tree AVA (ESE-AVA). This antenna technology decrease the surface current on the antenna edges, consequently decreasing the SLL, and increasing the ML gain [10].

This technology do not change the antenna dimensions, when comparing conventional AVA and Palm Tree AVA, which corresponds to dimensions of 36.3 x 59.81 mm², with 0.64 mm substrate thickness.

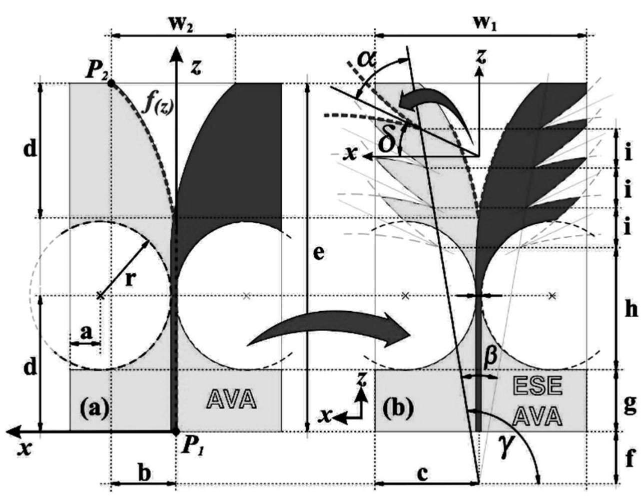

Fig. 3. Design and antenna parameters in xz-plane: (a) conventional AVA. (b) Palm Tree AVA [10].

The microstrip transition line has a length of 23.02 mm and a width of 1 mm with a Rogers RO3206 substrate, and dielectric constant of 6.15, and tangential loss of 0.0027. The radiator of antenna is designed, according to [11], by the exponential curve ***f (z)***, given by (1), (2) and (3) equations with opening rate R=0.105 and the points $P_1(z_1,x_1)$ and $P_2(z_2,x_2)$, shown in Fig. 3.

$$f(z) = c_1 e^{Rz} + c_2 \quad (1)$$

where

$$c_1 = \frac{x_2 - x_1}{e^{Rz_2} - e^{Rz_1}} \quad (2)$$

and

$$c_2 = \frac{x_2 e^{Rz_2} - x_1 e^{Rz_1}}{e^{Rz_2} - e^{Rz_1}} \quad (3)$$

Fig. 4 shows the Palm Tree antenna.

Fig. 4. Fabricated ESE-AVA photograph, top view on the left and bottom view on the right [10].

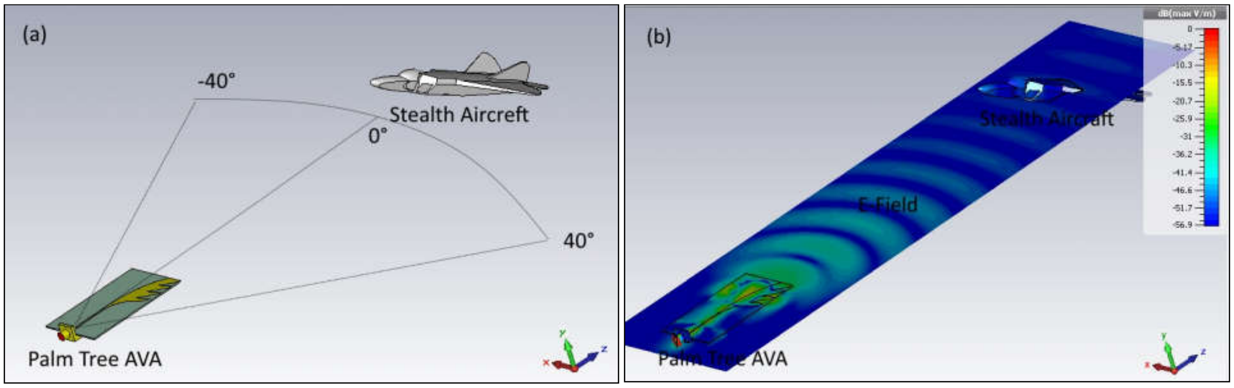

Fig. 5 – Numerical test environment. (a) Positioning of the antenna and the aircraft. (b) Detail of propagation of the E-field to 6 GHz.

Table I presents the antenna dimensional parameters.

TABLE I - PARAMETERS OF THE AVA AND ESE-AVA ARCHITECTURES.

Dimension parameters						Angles	
a	4.03	e	59.81	i	6.87	α	55º
b	11.17	f	5.91	r	13.12	β	20º
c	18.15	g	9.97	w_1	36.30	γ	100º
d	23.02	h	21.59	w_2	21.35	δ	25º

The parameters a, b, c, d, e, g, r, w_1, and w_2 are identical for AVA, RSE-AVA, TSE-AVA and ESE-AVA architectures shown in this letter. Dimensions are given in mm.

Figs. 6(a) and (b) display the radiation patterns for co-polarization at 6 and 8.4 GHz, respectively. There is a good agreement between simulated and measured values, confirming that the ESE reduces SLL and increases the ML gain. At 6 GHz, the ML gain is 3.3 dB higher in ESE-AVA than in AVA. Another interesting aspect is the effect of the squint correction. In the reference-AVA it was 5 degrees, and in the ESE-AVA it is 0 degrees. This suggests that ESE-AVA is suitable for Phased and Timed-array applications [12].

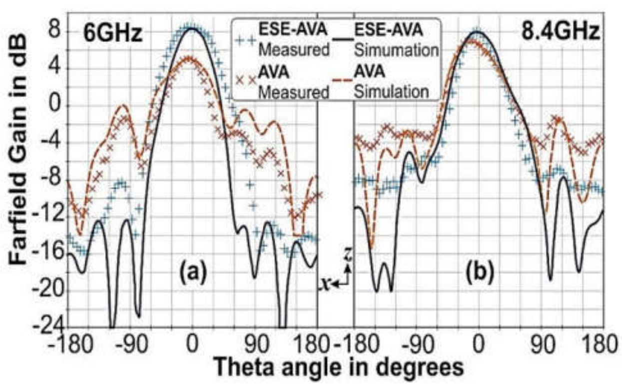

Fig 6 - Measured and simulated radiation pattern at (a) 6 and (b) 8.4GHz of the conventional AVA and Palm Tree (ESE) AVA [10].

The Palm Tree AVA was positioned 160 mm away from the aircraft, and has the freedom of rotation on the y-axis of 40 to -40 degrees, as shown in Fig. 5(a). The modeled aircraft has faceted surfaces in order to avoid right angles. The model print surface with a dielectric contrast medium only 10%, ie, εr = 1.1.

In Fig. 5(b) is illustrated the x-z plane with the graphical representation of the EM simulation of the E-field in the direction of the z-axis, in 6 GHz.

III. NUMERICAL RESULTS

The simulation was performed in the environment CST Microwave Studio 5.5 on a frequency range 8.5 GHz. 81 simulations were performed between -40 to 40 degrees of antenna rotation, making a step angle of only 1 degree per simulation.

Each simulation, the Return Loss parameter (S_{11}) in the frequency domain was stored.

The signal processing, illustrated in the Fig. 7, adopted for the image generation of microwave consists the following steps: Also in CST environment, the real component of the S_{11} parameter is converted to the time domain by using inverse Fourier transform. In SCILAB mathematical environment, was applied to the following signal processing algorithms: background removal, module, and envelope.

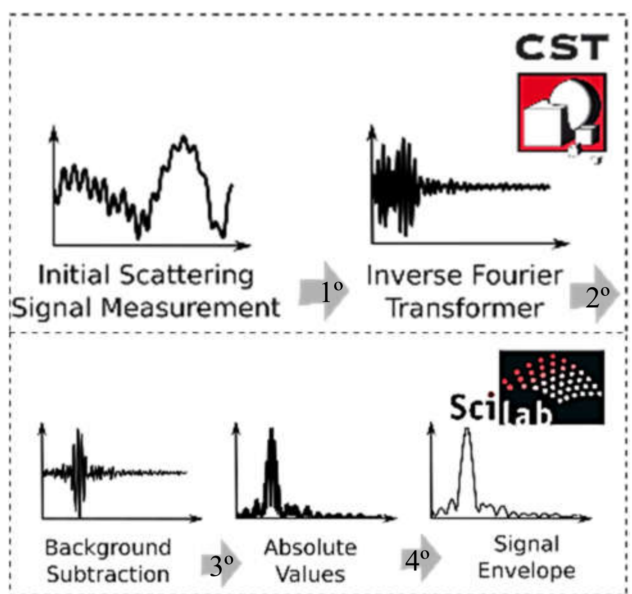

Fig. 7 - Illustration of signal processing steps.

The stored S parameters data, with x from 0 to 360mm, was converted to the time domain, through the Inverse Fourier Transform (IFT), and after this, is performed the background subtraction and the application of the absolute function for obtaining the signal module. Finally, the envelope algorithm is applied, and after this, the signal processing was generate a 2D image microwave image was built, as shown in Fig 8.

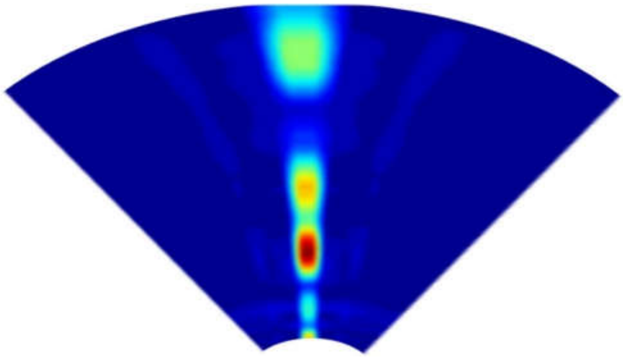

Fig. 8 – Obtained microwave image after the signal processing.

Note that the center is a region with the highest amplitude (dark region) caused by signal reflection. It is also possible to observe the reverberation signal in the form of multiple echoes, these are caused by multiple reflections of the transmitted pulse, between the antenna and the aircraft [13].

IV. CONCLUSIONS

Stealth aircraft are military equipment of great importance, as they allow entering in monitored airspace, with less chance of being detected. This work presents the study of a detection system of stealth aircraft by the use of Palm Tree AVA. Since this antenna has UWB, operates at X-Band, has directivity, and high gain characteristics, it was possible to generate the microwave image of the scanned airspace. From the microwave image generated, it was possible to detect the signature of stealth aircraft.

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