A Palm Tree Vivaldi Antenna with Metal Director for Improved Radiation Pattern

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***Abstract*— This paper presents a Substrate Lens (SL) and Metal Director (MD) on a Palm Tree Antipodal Vivaldi Antenna (Lily AVA), with improvements on either the gain and squint features compared to the conventional Palm Tree AVA design. Besides these improvements, it can be seen that there was a reduction of side and back lobe levels and extension of the low-end bandwidth limitation, when compared to a Palm Tree AVA, this because radiated fields are collimated in the end-fire direction, caused by the SL and MD.**

***Index Terms*—Ultra-wideband, Antipodal Vivaldi Antenna (AVA), Substrate Lens (SL), Metal Director (MD).**

I. Introduction

The Vivaldi Antenna, originally separated with a coplanar shape [1] and after with an antipodal shape [2] (Antipodal Vivaldi Antenna, AVA), has been the target of intense research due to its favorable features for many applications, such as medical imaging systems [3], radar systems [4,5], through-wall detection [6] and others. Those applications require an ultra-wideband (UWB) antenna, compact, easy to manufacture, with small dimensions, and with a high gain, and able to be integrated directly in the circuit board [7-11].

In order to reduce the Side Lobe Level (SLL) and squint and improve the directivity characteristics of the antenna, the Palm Tree AVA- design with an Exponential Slot Edge (ESE) has been recently [12] proposed. Aiming to further improve those characteristics of directivity, here we propose the addition of a substrate lens with also a metal director in the Palm Tree AVA. Taking the frequency of 8 GHz as example, with the original AVA reduced the squint from 5 to 0 degrees and resulted in a main lobe gain increase of the original 7.9 to 8.8 dB.

II. Antenna Design

Fig. 1(a) illustrates the design of an original Palm Tree AVA, while Fig. 1(b) presents the proposed Lily AVA, showing the SL and the MD or Anther, Fig. 1(c), by remembering their biological namesake. This new design tries to decrease the original AVA SLL, as well as the Palm Tree AVA, by inhibiting the surface currents in the edges of the antenna, while simultaneously increasing the ML gain.

The antenna has total dimensions of 23 mm width by 60 mm in length, with a thickness of 0.64 mm on a Rogers RO3206 substrate with dielectric constant of 6.15 and tangential loss of 0.0027. Its feeding is performed by a microstrip line transition with width of 1 mm, in order match the 50Ω SMA Multicomp connector. The main exponential slot radiator (MESR), and the all ESE are designed according to Ref. [11].

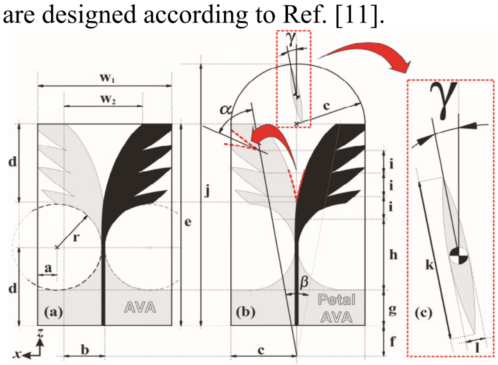

Fig. 1. Antenna parameters in xz plane: (a) reference Palm Tree AVA. (b) proposed Lily AVA. (c) Metal Director (Anther) in detail. r = 13.12mm.

Fig. 2 shows the picture of the fabricated antennas.

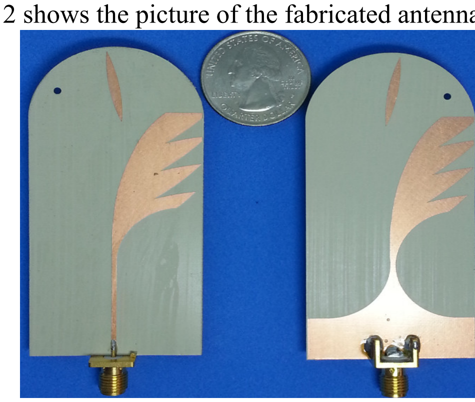

Fig. 2. Fabricated Lily AVA – top and bottom sides.

The remaining dimensional parameters are displayed in Table I. According to Ref. [12], the ESEs are added on the side of the antenna, in order to mitigate the edge surface currents, simultaneously decreasing the lower limit of the bandwidth and increasing the gain of the ML.

TABLE I
Final parameters of the AVA and SL-Palm Tree AVA architectures.

Dimension parameters						Angles	
a	4.03	e	59.81	i	6.87	w_2	21.35
b	11.17	f	5.91	j	77.96	α	55º
c	18.15	g	9.97	k	17.42	β	20º
d	23.02	h	21.59	w_1	36.30	γ	10º

III. 3D Numerical and Experimental Results

As mentioned in Ref. [12], the design of the Lily AVA was performed in two stages. In the first stage, the optimization of the antenna characteristics by 3D field solver was performed.

The second stage is associated with laboratory measurements [13], in two antenna prototypes, in order to guarantee the same characteristics with minimal change in the manufacturing process.

Fig. 3 presents the measured and simulated reflection coefficients (S_{11}) of the Palm Tree AVA and Lily AVA. The setup of the acquisition of S parameters is described in [12]. As reported in Refs. [14, 15, 16], the lower limit frequency is reduced with the addition of slot edges, and further with the addition of the SL and MD.

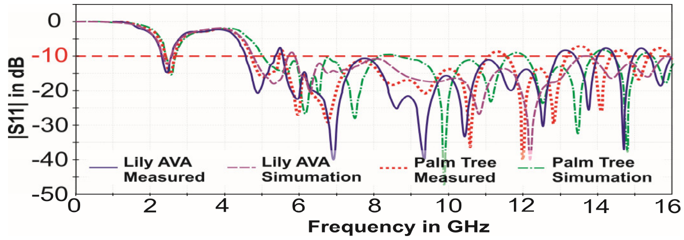

Fig. 3. Measured and simulated S11 of the Palm Tree AVA and Lily AVA..

Another interesting aspect is the gain presented by the SL with ESE techniques at 6 GHz (3.5dB), which remains around 9 dB up to 10 GHz, compared to traditional AVA without the ESE. This gain is kept approximately constant in a wide frequency range, which is not observed in the original AVA without the ESE, only the Palm Tree AVA and Lily AVA. This is an ideal feature for UWB applications, since the a more stable gain helps transmit pulses with less distortion throughout the UWB channel.

The improvement of the Lily AVA, as well as Palm Tree, regarding the characteristic radiation is due, as mentioned by Ref. [12], to the current distribution near the antenna lateral edges, additionally to improvements from the radiated fields collimated in the end-fire direction, an effect which is caused by the SL and MD.

In the original AVA at 10GHz, the surface currents are concentrated in the edges, and in consequence promote the E-fields distribution in lateral directions [12]. This is mitigated by the ESEs. The second constructive aspect, which contributes to the directivity improvement, is the effect of collimating the beam ML, due to the SL and DM presence.

Figs. 4(a) and (b) display the co-polarized radiation patterns at 8 and 10 GHz, respectively. There is a good agreement between simulated and measured values, confirming that the Lily AVA corrects the squint and increases the ML gain. At 8 GHz, the ML gain is almost 1 and 4 dB higher in Lily AVA than in original AVA without ESEs and Palm Tree AVA respectively. The interesting aspect is the effect of the squint correction. In the original AVA, and Palm Tree AVA, it was 5 degrees, and in the Lily AVA it is 0 degrees. This suggests that Lily AVA is suitable for Phased and Timed-array applications [5].

IV. Conclusion

This investigation presents a new design of AVA, called Substrate Lens with Metal Directors at Palm Tree AVA, or simply Lily, by remembering their biological namesake, which, in addition to reducing the surface currents amplitude along the antenna edges, also collimates the main lobe beam using a SL and MD. The application of these two design techniques resulted in a major SLL reduction and a main lobe gain increase, improving the end-fire radiation characteristics of the antenna. The measured results, at a frequency of 8 GHz, indicated that there was a better performance of Lily AVA in contrast to the original AVA and Palm Tree AVA, with a 4.5 and 1 dB gain improvement respectively, and a SLL decrease of -12.5 dB compared to the original AVA. Finally, the new design also led to a squint correction from 5 to 0 degrees. The addition of these of SL with MD in the Palm Tree AVA promoted good improvement in antenna directivity.

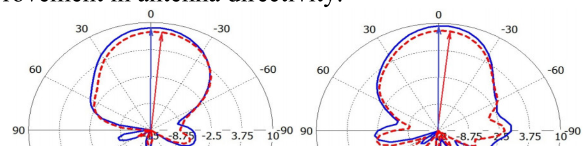

Fig. 4. Radiation pattern at 8 (left) and 10 GHz (right) of the Palm Tree AVA (dashed line) and Lily AVA (solid line).

Acknowledgments

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