Cavity-Backed Dual-Sinuous Antenna Modeling

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***Abstract*—Recently, for Radio Frequency (RF) signal identification on air vehicles, it has become critical to not only be able to detect the direction and angle of arrival of signals, but to also properly identify the polarization of such signals. For decades, cavity-backed dual-spiral antennas were heavily used for this purpose. However, that required the placement of both right-hand and left-hand elements to perform this function. Due to limited space and other issues, an alternative type of broadband antenna had to be identified. The Cavity-Backed Dual-Sinuous (CBDS) antenna makes an excellent replacement for this function. With its elements rotated 45° about its center, each element exhibits slant linear performance. Such an antenna, paired with proper connections and detection hardware, allows the detector to determine the polarization of arriving RF signals. A CBDS antenna was developed in the WIPL-D CEM code. Its RHCP and LHCP performance was studied over a broad range of frequencies. Results did prove that CBDS antennas have excellent broadband performance and polarization extraction.**

Keywords—Angle of arrival, cavity-backed, dual-sinuous, dual-spiral, polarization, RF signal, WIPL-D.

I. Introduction

Sinuous type antennas are very attractive for many applications due to their broadband performance, polarization agility and miniaturized size. A sinuous antenna belongs to the log-periodic antenna family. However, its arms (made up of arcs and bends) are etched on PC-boards, which miniaturizes their size. Two sinuous asymmetric arms form a very broadband log-periodic dipole. The smallest and largest arcs and bends dictate its highest and lowest frequencies of operation, respectively. The number of arcs and bends allows the designer to better control a sinuous antenna's Radiation Pattern (RP) at intermediate frequencies.

A crisscrossed four-arm sinuous antenna [1] is one of the more commonly used versions of the antenna. The four arms form a cross-dipole antenna. Similar spiral antennas, sinuous antennas radiate in both directions, normal to the plane of the antenna. However, in most uses, the RP needs to be directed to one side only. Due to its broadband performance, one cannot place a ground plane at ¼-wavelength from one side of the antenna that will achieve the required performance at all operating frequencies. Therefore, a square or circular cylindrical conductive cavity, filled with absorbing materials, is customarily used to eliminate or significantly reduce the unwanted radiation. In this effort, a circular cylinder cavity, whose interior is laced with thin layers of magnetically loaded absorbing materials, is considered. Sources for such absorbing materials are Laird's Emerson Cuming and PPG Aerospace's Cuming Microwave Corporation.

II. Modeling Effort Details

A. Cavity-Backed Dual-Sinuous Antenna Design

The sinuous antenna described in this effort is capable of three-octave frequency coverage 2-18 GHz). The number of arcs/bends per arm was set to nine. Due to the lack of antenna software (such as Antenna Magus) to generate the arm models, an alternate approach was used. A web-search identified [2] as a source for sinuous arm design. Following the design procedures in [2], a MATLAB script was used to generate a single sinuous line with nine arcs/bends. The dense number of points forming one bound of the sinuous line were then imported into a CAD tool, where a Non-Unifrom Rational B-Spline (NURB) line containing those points was generated. The other bound, required to form the metalized arms, was created by copying the first sinuous line and rotating it to fit a sample physical antenna's footprint.

The two created nurb lines were then connected to form nurb surfaces representing a single sinuous arm's metallization. The sinuous arm was then copied three times, using a 90° rotational copying command, to form the antenna's four arms. Once that was completed, the four arms were rotated by 45° to form two slant linear sinuous dipoles. This model was then meshed in CAD and the mesh was exported into WIPL-D [3]. The feed region, all with feed wires were added in WIPL-D. The cylindrical cavity, including all absorbing materials, was then created using WIPL-D's Canonical Shape generators, to produce the WIPL-D model shown in Fig. 1.

Due to the frequency dependent nature of the absorbing materials used, a relatively new feature in WIPL-D was utilized. This feature allows for the frequency dependent

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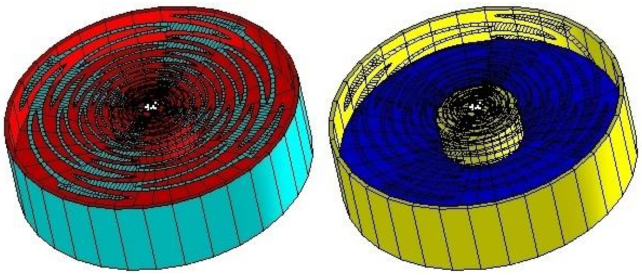
absorbing materials characteristics to be read directly from files, for each frequency of interest. If an exact frequency match is not available in the materials' table, WIPL-D interpolates the available data to produce an approximate set of absorbing materials' electrical properties to use for that frequency.

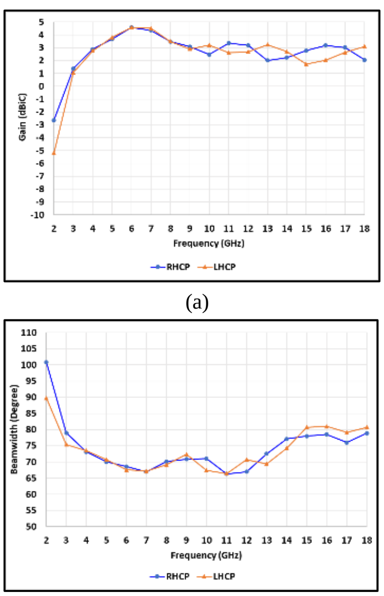


(a) (b)

Fig. 1. CBDS antenna WIPL-D model: (a) full; (b) absorbing materials.

B. Cavity-Backed Dual-Sinuous Antenna Performance

The two slanted dipole elements of the CBDS antenna in Fig. 1 were driven using quadrature phasing to produce RHCP and LHCP RPs. Overlays of the broadband peak gain and beamwidth (BW), over the 2-18 GHz frequency range, for RHCP and LHCP is provided in Figs. 2 (a, b), respectively.



(b)

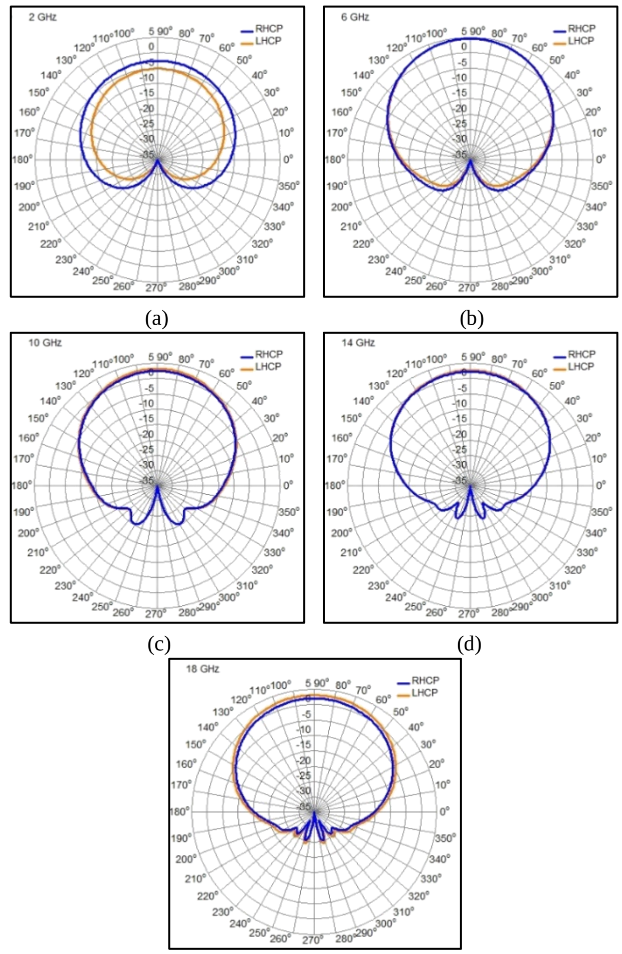
Fig. 2. CBDS antenna broadband RHCP and LHCP overlays: (a) peak gain; (b) beamwidth.

Overlays of RHCP and LHCP principal plane RPs at 2, 6, 10, 14 and 18 GHz are provided in Fig. 3.

III. Analysis of Results

Figs. 2 and 3 provide ample proof that CBDS antennas possess excellent performance, similar to the previously commonly used Cavity-Backed Dual-Spiral antenna, over a three-octave range. This is evident on two fronts: Peak gain exceeds 0 dBiC, except at 2 GHz; BW of 67° to 100°, across the 2-18 GHz range. Such gain and BW performance is critical in quadrant angle-of-arrival determination.

The most significant difference in the RHCP and LHCP RP and BW performance of the CBDS antenna occurs at 2 GHz. Inexplicably, the LHCP peak gain and BW are more than 2 dBiC and 10° lower than those for RHCP, respectively.



(e)

Fig. 3. CBDS antenna RHCP and LHCP overlays: (a) 2 GHz; (b) 6 GHz; (c) 10 GHz; (d) 14 GHz; (e) 18 GHz.

References

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