

Compact, Low-profile, Low-mass, UHF, Folded Shorted Dipole Antenna Array with Dual Circular Polarization

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Abstract—This article focuses on the design and simulation of a dual circularly polarized antenna centered in 400 MHz comprised of an array of four folded-shortened dipoles using sequential rotation over a ground plane. By altering the relative phase difference between the feedings of each element, both circular polarization senses are achieved for the same frequency. This antenna offers a comparable performance to other similar designs, like folded-shortened patches, while minimizing size and weight.

I. INTRODUCTION

Novel designs for small, compact, low-profile and low-mass antennas are always a topic of great interest for mobile, on-board and on-spacecraft communications applications. The need to reduce the standard size of the typical dipole increases when dealing with UHF frequencies, especially in applications where size and weight minimization are key [1]. This is the case of the New Space paradigm for small satellites, where the size and weight of the systems incur directly into the cost of the mission [2].

Following the folded-shortened patches design proposed in [3] and [4], a novel narrow-band antenna solution centered in 400 MHz is presented by folding and shorting an array of four dipoles over themselves, minimizing the size of a standard dipole array and reducing the weight of the previously proposed folded-shortened patches solution.

By modifying the input phase difference between the array elements, dual circular polarization, left-hand circular polarization (LHCP) and right hand circular polarization (RHCP), are achieved. In order to improve the axial ratio and increase the isolation between the RHCP and LHCP modes [5], a sequential rotation of the array elements is performed. In order to test high power capabilities, useful for long distance or space communications, where propagation losses are orders of magnitude larger, a multipactor analysis is performed.

In this paper, no feeding network circuitry is presented, so ideal feeding of each element, in amplitude and phase, is assumed in all cases. The simulations are performed in CST and Spark3D.

II. DESIGN

The dipole element can be seen in Fig. 1 and is formed by the alternating folding of each arm of a dipole on top of each other. Only the lower arm is fed, while the other one is simply shorted to the ground plane below. Feeding is done by

a 50 Ohm coaxial cable though the middle of the arm. Hollow poly-lactic acid (PLA) columns are designed in order to aid the overall mechanical stability of the system and prevent the arms of the dipole from misaligning. Holes are drilled so each arm can pass through. For simulations, PLA is considered to have a permittivity of 2.4.

To form the array in Fig. 1, four elements are sequentially rotated to face inwards. Table I indicates the necessary relative phase difference in order to achieve dual circular polarization.

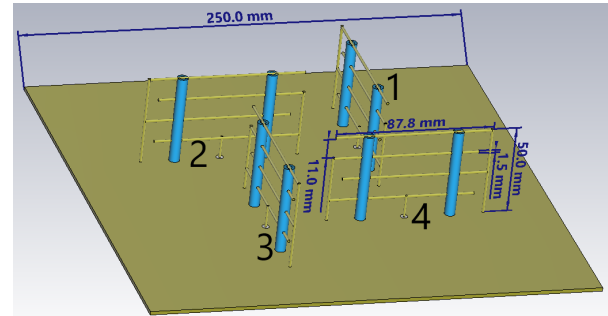


Fig. 1. Array over a conducting ground plane. Element numbering is illustrated in order to aid in the understanding of Table I. In blue, hollow PLA columns. This 4 element array has a dimension of $\lambda/4$, and an estimated weight, if made with aluminum and PLA, of 350g.

TABLE I
PHASE DIFFERENCES TO ACHIEVE CIRCULAR POLARIZATION.

Polarization	Port 1	Port 2	Port 3	Port 4
LHCP	0°	90°	180°	270°
RHCP	0°	-90°	-180°	-270°

III. SIMULATION RESULTS

A. S-parameters

The passive s-parameters of each port, and therefore each element of the antenna, are equal since the array is symmetrical. The -10 dB bandwidth of each element is around 8 MHz and centered at 405 MHz. Due to the non negligible magnitudes of transmission coefficients in Fig 2, the active s-parameters of the array suffer a frequency shift. In this case, the passive s-parameters were purposefully shifted to 405 MHz in order to have the active s-parameters centered at 400 MHz, like Fig. 3 shows. The active s-parameters are equal for both LHCP and RHCP feedings.

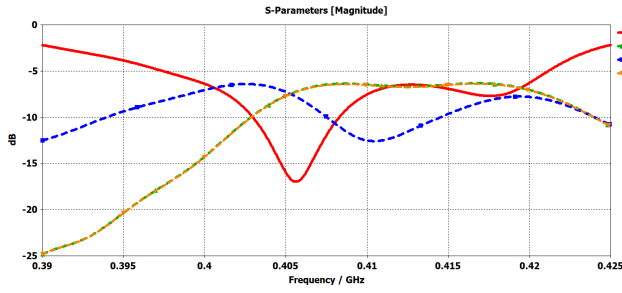


Fig. 2. Passive S-parameters of each of the elements in the array.

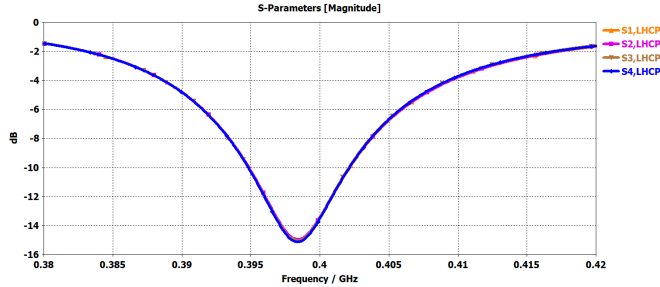


Fig. 3. Active S-parameters of the array.

B. Radiation

By applying the different element feeds shown in Table I, the two different circular polarizations are achieved. The size of the conducting plane in which the array rests helps reduce backwards radiation, but due to the current small size seen in Fig. 1, this radiation will not be negligible.

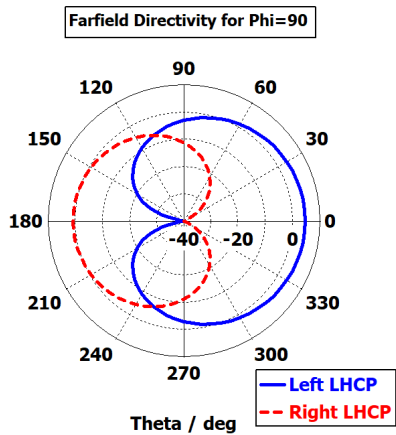


Fig. 4. LHCP directivity for $\Phi=90$ cut. Dashed line represents the crosspolar RHCP directivity. When the RHCP feeds are provided, the results are analogous.

For LHCP, in Fig. 4, broadside directivity is observed to be around 5 dB with a beamwidth at 3 dB of around 60 degrees. Polar and crosspolar levels, LHCP and RHCP respectively, are correctly isolated. This results in an excellent axial ration

level as shown in Fig. 5. RHCP is analogous, with the same radiation pattern, axial ratio and directivity.

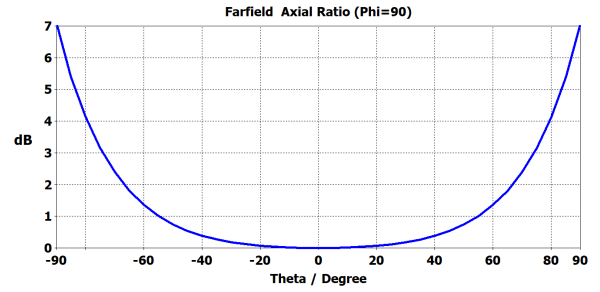


Fig. 5. S-parameters of each of the folded shorted dipole elements in the array shown in Fig. 1.

C. Multipactor Analysis

When analyzing the model without PLA columns, the breaking power for when electron multipactor effect grows exponentially is 60 kW for the whole system, like Fig. 6 shows, implying a 15 kW power limit for each element. This results in a 25dB safety margin over a typical 50W feed.

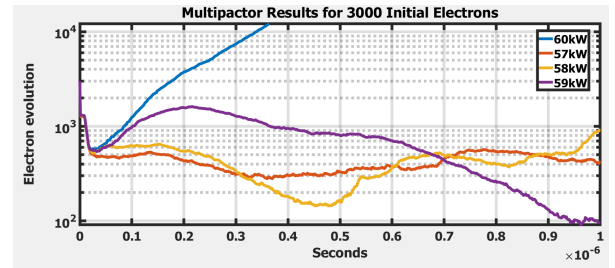


Fig. 6. Multipactor analysis performed on Spark3D software.

IV. CONCLUSION

A compact, low-profile, low-mass, UHF antenna array centered in 400MHz was designed and simulated. Through the use of sequential rotation and phase differences between element feedings, dual circular polarization was achieved with 5 dB broadside directivity and less than 2 dB of axial ratio in a width of 120 degrees.

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