Multifunctional Huygens Dipole Antennas

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***Abstract*—Two electrically small, multifunctional Huygens dipole antennas that operate in the L-band are reviewed briefly. In both designs, two pairs of magnetic and electric near-field resonant parasitic (NFRP) elements are combined. Egyptian axe dipoles (EADs) generate the electric dipoles; capacitively loaded loops (CLLs) generate the magnetic dipoles. These NFPR elements are excited with coax-fed driven dipole elements. Both systems are low profile and radiate cardioid patterns pointed in the broadside direction. One Huygens antenna is a dual linearly polarized (dual-LP) system. The other one produces parallel, LP fields at two operating frequencies (dual-band LP).**

***Index Terms*—Dual band, dual polarization, broadside radiation, electrically small antennas, Huygens dipole antennas, near-field resonant parasitic elements.**

I. INTRODUCTION (*Heading 1*)

With emerging fifth generation (5G) wireless systems, the need for compact multifunctional antennas has burgeoned. For many practical applications, dual-polarized antennas are well-known to have significant advantages over their single-polarized counterparts. Similarly, dual-band antennas provide two channels of operation from the same device. Thus, both systems reduce the total number of units in a mobile platform and, hence, its overall cost, weight, and footprint while still maintaining, if not increasing, its capabilities and qualities.

In this paper, two recently realized [1], [2] electrically small, low-profile, Huygens dipole antennas are reviewed. One is dual-LP system. The other is a dual-band one. Both are based on advanced combinations of magnetic, capacitively loaded loop (CLL), and electric, Egyptian axe dipole (EAD), near-field resonant parasitic (NFRP) elements and driven, yet smaller dipole elements fed coaxially. Both radiate broadside-directed cardioid patterns. Prototypes of both were fabricated and tested. As will be demonstrated in our presentation, the measured and simulated results are in good agreement, validating their designs.

II. HUYGENS DIPOLE ANTENNA CONCEPTS

The Huygens dipole antenna concept is illustrated in Fig. 1 [3]. It is based on the near-field resonant parasitic (NFRP) antenna paradigm [4]. An Egyptian axe dipole (EAD) NFRP antenna consists of a coaxially-fed dipole that drives its EAD element into resonance. The currents on it are responsible for the radiated fields. Thus, this electric-based NFRP antenna radiates a linearly polarized (LP) field parallel to the central section of its EAD element. Similarly, the capacitively loaded loop (CLL) NFRP system mimics a magnetic dipole antenna. The coaxially-fed dipole drives loop currents in its CLL elements yielding a magnetic dipole orthogonal to them. By seamlessly combining these electric and magnetic NFRP elements, an electric and magnetic pair of orthogonally-oriented NFRP elements can be excited in-phase by a single driven dipole. A Huygens system is realized that radiates a cardioid pattern broadside to the plane parallel to the electric and magnetic dipoles.

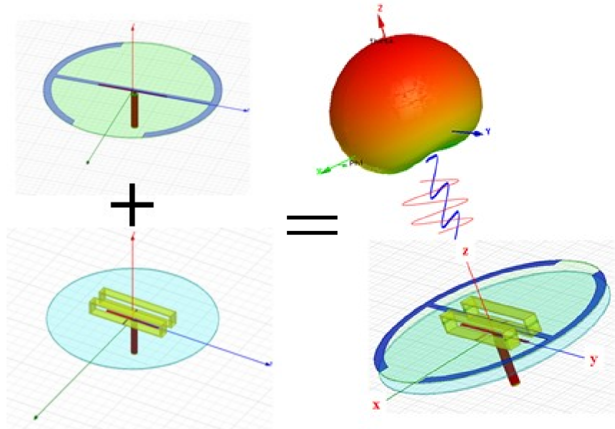

Fig. 1 Huygens dipole antenna evolved from a seamless combination of EAD- and CLL-based ESAs. It radiates a broadside-directed cardioid pattern.

III. DUAL-LP HUYGENS ANTENNA

Dual-LP antennas achieve polarization diversity. They facilitate a wireless communication system with improved anti-multipath performance in the same frequency band. The dual-LP Huygens dipole ESA reported in [1] has a low profile, wide beamwidths, and high FTBR values for both LP states. Moreover, it exhibits high isolation between its two ports. It is a five substrate layer design and is composed of two pairs of orthogonal CLL and EAD NFRP elements. It is shown in Fig. 2.

Both pairs are driven by a corresponding set of orthogonally-oriented dipole strips excited from two ports.

Whichever port is active, the LP fields generated by the antenna correspond to the active driven element direction. There is large isolation from the inactive port direction. A prototype dual-LP Huygens dipole ESA was fabricated, assembled and tested. Good agreement between the simulated and measured performance characteristics verified the effectiveness of the reported design [1].

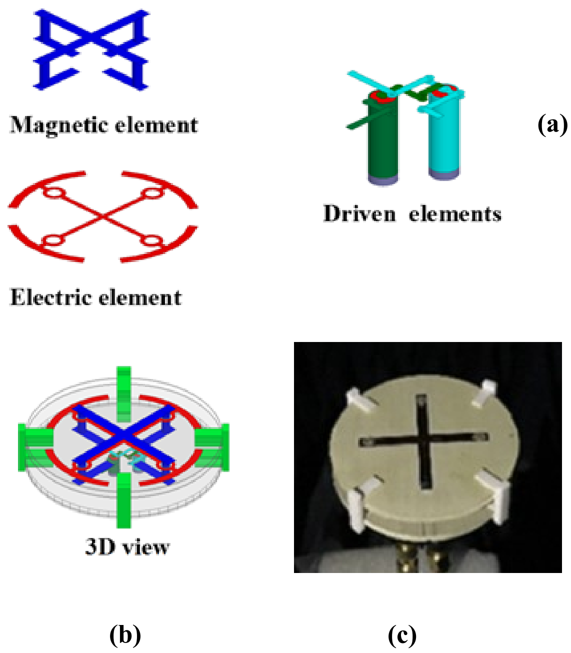

Fig. 2. Geometry of the dual-LP Huygens dipole ESA. (a) 3D views of the components of the antenna. (b) 3D isometric view of the entire structure. (c) 3D view of the fabricated prototype.

The measured prototype is also shown in Fig. 2. At $f_0 = c/\lambda_0 = 1.515$ GHz the L-band prototype is electrically small (ka = 0.904) and low profile (0.0483 λ_0). More than 25 dB isolation between its two ports was demonstrated over its -10-dB fractional impedance bandwidth. When port 1 (port 2) is excited, the peak realized gain is 2.03 dBi (2.15 dBi) strictly along the broadside direction with a 12.4 dB (12.1 dB) front-to-back-ration (FTBR). This dual-LP Huygens dipole ESA is anticipated to be a good candidate for future wireless applications needing a high performance, multifunctional, compact, narrow-band antenna system.

IV. Dual-Band Huygens Antenna

On the other hand, dual-band antennas can potentially operate at two different frequencies through a single port and with either parallel or orthogonal LP behavior depending on the actual application requirements. Both types were demonstrated in [2] for L-band operation.

The dual-band, electrically small, low profile, broadside radiating, Huygens dipole antennas with parallel LP behavior is shown in Fig. 3. It has its two pairs of electric and magnetic NFRP elements oriented in a parallel configuration. This dual-band NFRP ESA yields LP fields along the same direction at 1.206 GHz (x-LP) and 1.504 GHz (x-LP), i.e., the two pairs of NFRP elements are both linearly polarized along the x-axis.

The coupling between its adjacent radiators was significantly reduced by introducing a rectangular metallic strip halfway between these two NFRP elements. This strip acts as an additional parasitic element. Its presence facilitates a strict broadside radiation behavior at the higher frequency.

The optimized design was also fabricated and tested. The measured results demonstrate that it too is electrically small (ka = 0.99) and low profile (0.032 λ_{LF}), λ_{LF} being the free space wavelength at the lower frequency. Its measured peak realized gain at the lower (higher) frequency was 2.66 (2.33) dBi. Its -10-dB fractional impedance bandwidth was 0.66% (0.86%). Its FTBR value was 13.1 (14.6) dB. Its radiation efficiency value was 62.8% (61.3%). These measured results confirmed the design's simulated performance characteristics.

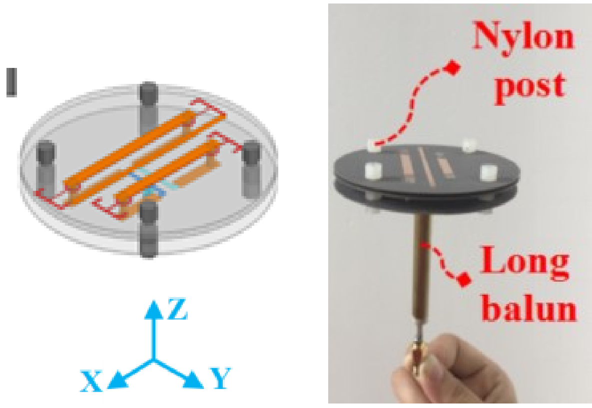

Fig. 3. Geometry of the dual-band, parallel LP ESA. (a) 3-D view. (b) Side view. Upper and lower surfaces of (c) Layer_1, (d) Layer_2, and (e) Layer_3. Fig. 2 Fabricated prototype of the dual-band, parallel LP, Huygens dipole ESA.

An electrically small dual-band Huygens system that produced two orthogonal LP fields was also realized [2]. Additional parasitic elements were again introduced to mitigate the mutual coupling effects between the pairs of NFRP elements. These results will also be described in our presentation.

V. Conclusion

In this paper, two multifunctional Huygens dipole ESAs were reviewed briefly. The dual-LP system radiated orthogonal LP fields at the same frequency. The dual-band LP system radiated parallel LP fields at two different frequencies. Both radiated broadside-directed cardioid patterns. Both of these antennas were fabricated and tested.

The measured results were in good agreement with their simulated values. They demonstrated that they both are electrically small in size and low profile in height. They were shown to radiate efficiently in the broadside radiation with high FTBR values at their operating frequencies. Their compactness and multifunctional features are attractive for many existing and aspirational narrowband wireless applications in the emerging 5G wireless environment.

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