High-Power Ultra-Wideband Spiral Antenna Arrays

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Abstract

High-power circularly-polarized (CP) ultra-wideband (UWB) arrays are of great interest for wide range of applications including pulsed through-wall imaging, ground penetrating radar, electronic warfare (EW), and communication systems. The design thereof is; however, quite challenging. The main challenge is the design of the unit cell which needs to be inherently broadband simple CP antenna and can sustain relatively large amount of power. Spirals are frequency-independent antennas that can be designed to have multi-octave consistent input impedance, gain, and circularly-polarized radiation patterns over a wide field of view which make them excellent candidate for wideband CP arrays. However, the major issues of these antennas include efficiency, dispersion, and the complexity of the beamformer; especially when a multi-arm spiral is considered to achieve better frequency-domain performance. In this work, different approaches are adopted to overcome these issues. Specifically, high-power lumped resistors are utilized to terminate the arms of a metal-backed spiral antenna (array's element) and thus improving their performance (i.e. efficiency at high and mid bands) with the lossless metallic backing. The four-arm spiral antenna configuration is considered to ensure a good frequency-domain performance of the good time-domain spiral (i.e. loosely-wrapped spiral). Finally, the four-arm spiral's beamformer complexity is addressed by the development of a dual microstrip feed which acts not only as an integrated balun (infinite Dyson balun), but also as an impedance transformer to match 50Ω to the input impedance of spiral.

In this work, a seven-element hexagonal array based on simply-fed resistively-loaded four-arm slot spiral elements is proposed and analyzed. The hexagonal array configuration is chosen after detailed theoretical studies. Experiments and full-wave modeling are used to verify the performance quality of the proposed array. High power measurements are also conducted and the high power handling capability is demonstrated. The benefits of using the ferrite to improve the low-end gain, impedance match, quality of radiation patterns, and axial ratio of the metal-backed spiral antenna array are discussed. In addition to good frequency-domain characteristics, the time-domain performance is also characterized and the ability of this array to radiate short time-domain pulses is demonstrated. The developed arrays have VSWR < 2.3:1, broadside axial ratio <1.2dB, gain 5-17dBi, excellent pattern symmetry, power handling up to 500 W, side lobe level (SLL) < -10 dB, and fidelity factor > 93% over up to two-octave bandwidth.