A Compact Printed Van Atta Array with Zero-Phase CRLH Transmission Lines

Benjamin D. Braaten*, Sajid Asif, Saeed Khan, Jared Hansen and Daniel L. Ewert
Electrical and Computer Engineering Department
North Dakota State University
Fargo, ND 58108-6050, USA
Email: benbraaten@ieee.org

***Abstract*—A key component in the design of a printed Van Array is the requirement of the transmission line (TL) interconnects between the elements to be a factor of the operating wavelength. This results in interconnects that introduce a 2π phase shift. Traditionally, meander-lines have been used to design these interconnects; however, one drawback is the large space required for the layout. In this paper, a more compact Van Atta array that uses zero-phase composite right/left-handed TLs instead of meander-lines is presented. The result is a Van Array array that is 34.0% smaller at the operating frequency of 2.43 GHz. For validation, simulations are compared to measurements of several prototypes.**

***Index Terms*—Van Atta array and CRLH Transmission Lines**

I. INTRODUCTION

Electromagnetic reflectors, such as a Van Atta array [1], have been used to improve the performance of navigation systems [2] and wireless power harvesting [3]. The authors of these papers have shown that a printed Van Atta array can be used to create a surface that reflects an incoming electromagnetic wave in a direction back towards the source and that wireless power harvesting from various directions can be greatly improved.

The operation of a 1X4 Van Atta array is shown in Fig. 1(a). There are four elements interconnected with transmission lines that are a factor of the operating wavelength long. When the wavefront of the incident wave arrives at antenna element 1, denoted as A_1, a voltage is induced on the port, denoted as V_1^+. This voltage then propagates down the interconnect and drives element A_4 and is denoted as V_4^+. If the interconnect is a factor of the operating wavelength, the voltage arrives at A_4 with the same phase induced at A_1 or the phase of $V_1^+ = V_4^+$. Then, the field radiated by A_4 has the same phase as the field arriving at A_1. A similar interaction is occurring between elements A_2 and A_3. The overall result is a field radiated from the array back in the direction of the incident wave. Historically, these interconnects were designed with printed meander-lines and the length of each line was chosen such that L = Nλ (N = 1, 2, ...). This ensured that the phase of the voltages on both ends of the meander-lines were the same. However, one drawback of a meander-line interconnect network is the layout space required. Therefore, the objective of this paper is to present the more compact Van Atta array design in Fig. 1(b) that uses composite right/left-handed transmission lines (CRLH-TLs) [4] to reduce the overall layout size. The layout of the CRLH-TLs were chosen such that the zero-phase frequency and the operating frequency of the patches were the same, then, the CRLH-TLs had a similar phase behavior to the meander-lines with L = Nλ.

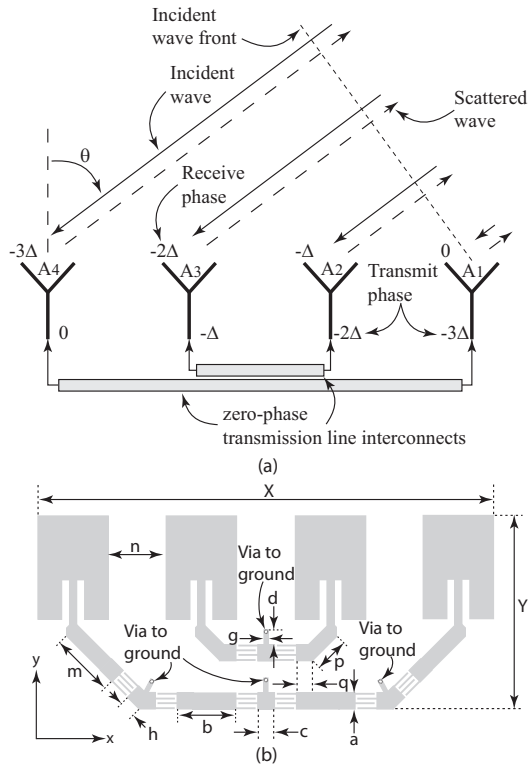

Fig. 1. (a) Illustration of the scattering from a 1X4 Van Atta array and (b) drawing of the proposed compact Van Atta array with zero-phase CRLH interconnects (a = 2.9 mm, b = 16.1 mm, c = 2.48 mm, d = 2.86 mm, g = 1.33 mm, h = 4.33 mm, m = 9.2 mm, n = 10.0 mm, p = 4.2 mm, q = 3.48 mm, X = 110.1 mm and Y = 44.3 mm).

II. DESIGN OF THE VAN ATTA ARRAY WITH ZERO-PHASE CRLH INTERCONNECTS

The prototype array was designed on a grounded 1.52 mm thick Rogers TMM4 substrate with ε_r = 4.5 and $\tan\delta$ = 0.002 [5]. First, the CRLH-TL interconnects were designed in ADS [6] using an iterative approach and the design guidelines

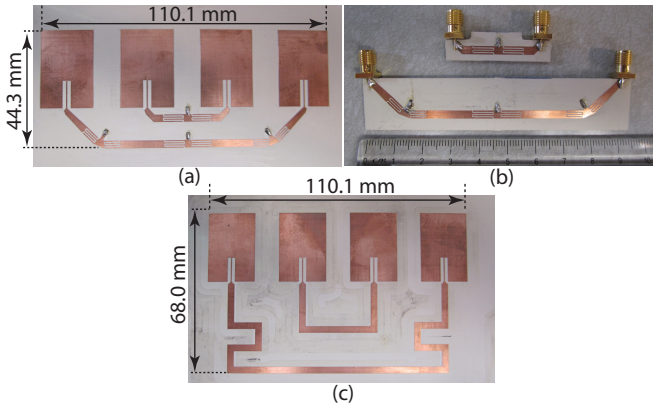

Fig. 2. (a) Photograph of the prototype Van Atta array with the zero-phase CRLH interconnects; (b) photograph of the zero-phase CRLH interconnects for testing and (c) photograph of the prototype Van Atta array with meander-line interconnecting microstrip transmission lines that have an electrical length of Nλ where N = 1, 2, ...

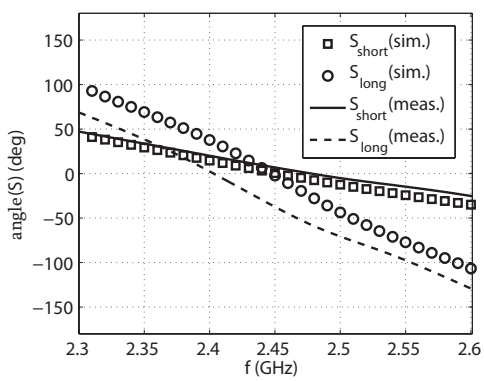

Fig. 3. Measured and simulated angle introduced by the CRLH interconnects.

summarized in [4] for a zero-phase frequency of 2.45 GHz. Then, a microstrip patch with the same operating frequency was designed in ADS and interconnected to form the Van Atta array shown in Fig. 1(b).

III. MEASUREMENT AND SIMULATION RESULTS

A prototype was then manufactured and is shown in Fig. 2(a). Along with the prototype array, the CRLH-TL interconnects were individually manufactured (shown in Fig. 2(b)). This was done to measure the zero-phase frequency. The measured results are compared to simulation results in Fig. 3. The measured zero-phase frequency for the short line was 2.47 GHz and for the long line was 2.4 GHz, which are reasonably close to simulated results. Next, the scattering from the prototype array was measured using two horn antennas in a full anechoic chamber in the x-z plane. One antenna was used to provide an incident field (E_θ) on the array and the other antenna was used to measure the scattered field (E_θ) with respect to angle. The horn providing the incident field

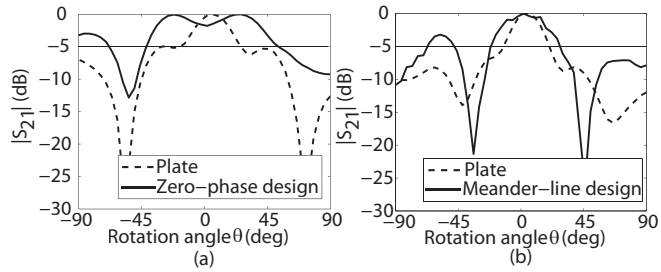

Fig. 4. Normalized scattering from the prototype Van Atta array (a) with the CRLH-TL interconnects and a plate, and (b) with the meander-line interconnects and a plate at 2.43 GHz.

was connected to port 1 of the network analyzer and the horn measuring the scattered field was connected to port 2 of the analyzer. The normalized results (in terms of S-parameters) are shown in Fig. 4(a) for 2.43 Ghz and a -5 dB scattering angle of 94.0° was measured. To illustrate the wider scattering that is characteristic of a Van Atta array, the -5 dB scattering angle from a plate the same size as the ground plane on the Van Atta array is also shown for comparison and was determined to be 40.0°. Much wider scattering from the prototype array is shown.

Next, to show the size reduction of the CRLH-TL interconnect approach, the prototype Van Atta array with the meander-line interconnects shown in Fig. 2(c) was manufactured and tested. The results are shown in Fig. 4(b) for 2.43 Ghz. The -5 dB scattering angle for the array was 49.0° and for the plate was 33.0°. Again, a much wider scattering from the meander-line design was observed. Finally, the overall size of the design with the CRLH-TL interconnects was 34.0% smaller than the design with the meander-lines.

IV. CONCLUSION

A compact printed Van Atta array that uses zero-phase composite right/left-handed transmission line (CRLH-TL) interconnects was presented in this paper. Additionally, a Van Atta array designed with traditional meander-lines was presented and compared to the design with the zero-phase CRLH-TLs. An overall size reduction of 34.0% was successfully shown with measurements at 2.43 GHz.

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