A Novel Leaky-Wave Retrodirective Reflector Using Short/Matched Terminations

Christophe Caloz, Sungjoon Lim and Tatsuo Itoh
Electrical Engineering Department, University of California, Los Angeles, CA 90095, caloz@ee.ucla.edu

I. Introduction

Retrodirective reflectors were originally invented in the form of arrays, such as the Van Atta array, using symmetrical feeds with electrical length differences in harmonic ratios [1], and the more elaborate phase-conjugation array, using heterodyne mixing with LO frequency twice that of the incoming RF frequency [2].

We propose here a novel type of retrodirective reflector based on leaky-wave structures and more particularly on left-handed (LH) or composite right/left-handed (CRLH) structures [3]-[5]. The idea is to generate retrodirectivity from the reflection of the incoming signal by a simple short termination and achieve full-space operation by the use of the CRLH backfire-to-endfire antenna presented in [4]. The concept of this novel reflector is explained in details, and a 2D implementation of it is described and demonstrated experimentally.

II. Principle of the Short/Matched Leaky-Wave Retrodirective Reflector

The principle of the proposed short/matched leaky-wave retrodirective reflector is illustrated in Fig. 1. An incident signal of frequency ω excites a leaky-wave antenna under the angle $\theta = \arcsin\left(\beta_{inc} c_0 / \omega\right)$, where β_{inc} is the tangential component of the wave. If $\theta > 0$ (Fig. 1a), the induced power travels along the structure in the same direction as β_{inc} (toward the left), gets reflected from the short termination at the end of the line with the propagation constant $\beta_{ref} = -\beta_{inc}$ and same frequency, and is therefore radiated retrodirectively toward the source under the same angle $\theta > 0$. The termination matched to the line (Z_0) prevents any reflection of the incoming signal, which would result in a parasitic reflected beam on the other side of the normal.

The retrodirective behavior described so far is limited to the halfspace $\theta > 0$ with conventional antennas, characterized by $\beta > 0$ in all their frequency-scanning range. By using a structure such as the LH or more exactly CRLH structure explained and demonstrated in [4]-[5], however, backfire-to-endfire operation is available. Thus, the positive-angles range illustrated in Fig. 1a can be scanned by operating the antenna in its RH range (higher frequencies) while the negative-angles can be scanned by operating the antenna in its LH range (lower frequencies), where the wave propagates in the direction opposite to power because of the fact that $\beta < 0$; at the transition between the LH and RH ranges, $\beta = 0$ and the reflector is active in broadside ($\theta = 0$).

A more elaborate variant of the reflector would include the use of heterodyne mixing to reflect the signal to any arbitrary angle by varying the LO frequency of the mixer [6]. At the expense of additional circuit complexity, it may also be possible to sweep the frequency range of the structure to detect and automatically tune the device to the direction of the incoming signal.

III. Design of a 2D Retrodirective Surface

Although the *single-element* retrodirective structure of Fig. 1 represents a valid principle, it is desirable in practice to increase its RCS to obtain an efficient reflector. One way to do this is to arrange side-to-side a large number of elements, as shown in the realized prototype of Fig. 2. Each element is of the type of the CRLH leaky-wave antenna of [4], which consists of the periodic repetition of a series interdigital capacitor and shunt shorted stub inductor. The resulting 2D structure is expected to exhibit somewhat different frequency characteristics than those of the isolated element (antenna) because of the interactions between adjacent elements.

IV. Experimental Results

This section presents mono-static (Rx and Tx antennas collocated) transmission (S_{21}) measurements of the RCS of the planar structure shown in Fig. 2. Because the incoming and outgoing signals have the same frequency, time-gating (network analyzer) was used to eliminate the undesired mutual coupling between the Rx and Tx horn antennas and isolate the reflected signal of interest.

Fig. 3 shows the measurement results for different frequencies. It can be seen that the RCS curves exhibit a maximum moving progressively from backfire to endfire as frequency is increased. This demonstrate the retrodirective frequency-scanning predicted from Sec. 2 both in the LH-negative ($\theta < 0$) and RH-positive ($\theta > 0$) half-spaces. The reflection angles are in good agreement with predictions from the single element radiation patterns [6].

Specular reflection is $\theta = 0$ important at most frequencies. It may be reduced by etching appropriate slots in the ground plane, or its effect maybe removed by differencing with the RCS of a simple ground plane of same size.

V. Conclusion

A novel concept of shorted/matched leaky-wave structure retrodirective reflector was introduced and demonstrated experimentally in a 2D planar-surface configuration. This reflector is capable of frequency-scanned retrodirectivity in the full-space from backfire to endfire and can be straightforwardly extended to heterodyne-mixed devices with arbitrary reflection angle.

Acknowledgement

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References

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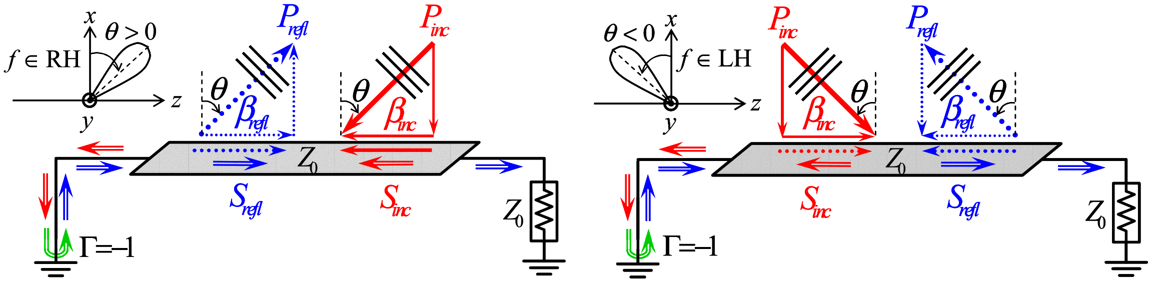

(a) (b)

Figure 1 Principle of shorted/matched retrodirective reflector using a CRLH leaky-wave antenna. The β and S symbols with corresponding arrows represent the propagation constant and Poynting vectors along the CRLH line, respectively. (a) $f \in$ RH range (forward operation). (b) $f \in$ LH range (backward operation).

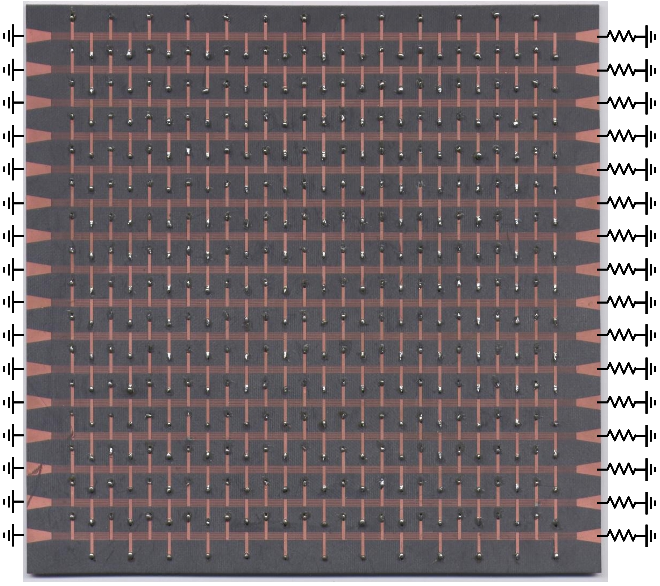

Figure 2 Picture of the 2D-LW reflector prototype, consisting of an array of CRLH structures, terminated at one end by a short circuit and at the other end by a matched *50-Ω* chip resistor. The substrate is the 5880-RT/Duroid with $\varepsilon_r=2.2$ and *h=62 mils*. Each CRLH structure contains 26 unit-cells constituted of two interdigital capacitors (*C=2pF @ 3GHz*) at each side of a shorted stub inductor (*L=5.75nH @ 3GHz*), and the complete reflectors includes 16 CRLH lines.

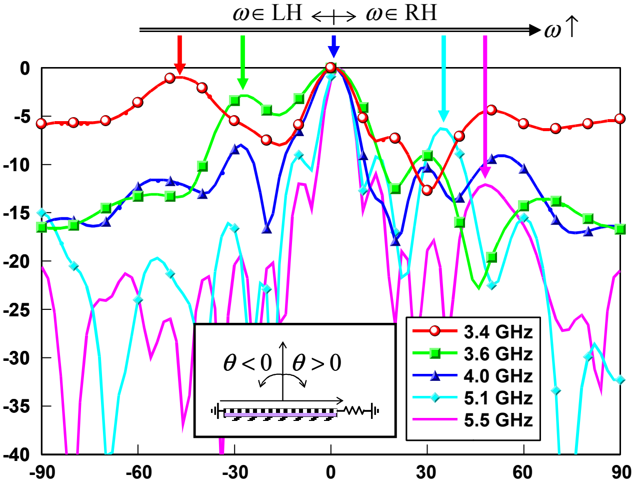

Figure 3 Monostatic measurement of the reflector at different scanning frequencies (polarization $\vec{E}$ || lines)