Development of Simple Affordable Beamformers for Army Platforms

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Abstract
In this paper we describe some Rotman Lens development software developed for the Army Research Lab by Remcom Corp under a Phase II SBIR. After software simulation, the Rotman Lens was fabricated and measured with impressive results.

Keywords
Rotman Lens

1. Introduction

Affordable Electronic Scanning Arrays (ESAs) have long been a desirable technology for Army requirements such as Satellite on the Move (SOTM) and Communications on the Move (COTM). One way to fabricate an electronically scanned array is to use Commercial off the Shelf (COTS) phase shifters. For COTM C-band systems, these shifters tend to have insertion losses on the order of 3 or 4 dB and they require a shifter for each element of the array – increasing the complexity (and cost) of the design. For SOTM (generally at X, Ku, or Ka bands) the insertion losses become higher.

Building on its historical work with Rotman Lenses [1] – [3], the Army Research Lab awarded an SBIR to REMCOM Inc. to develop software that would allow rapid designs of Microstrip and Stripline Rotman lenses, Figure 1. By the nature of the design, a Microstrip Rotman lens is an inherently simple structure that achieves electronic scanning while avoiding such problems as beam squint. The cost of a Rotman lens implemented on microwave material is primarily driven by the cost of the material itself and the price of photo etching. This results in an affordable ESA that avoids the complexities of individual phase shifters for each element of the array with insertion losses comparable to the discrete phase shifters.

The array ports (shown in red) are connected to the radiating elements. Since the Rotman is realized on planar microwave material, an obvious radiator is a patch antenna array. Such elements can be integrated onto the substrate producing a simple and affordable ESA. Scanning is achieved by selecting an appropriate beam port (shown in gray) – requiring a low loss switch matrix. A number of excellent COTS switches have become available that are ideal for this ESA. One good example (useful for both COTM and SOTM) is an ALGaAs SP8T PIN Diode Switch available from M/A-COM. This switch operates from 50 MHz to 40 GHz with a maximum insertion loss 2 dB and a switching speed of 20 ns. As such, it is ideally suited for both COTM and SOTM applications.

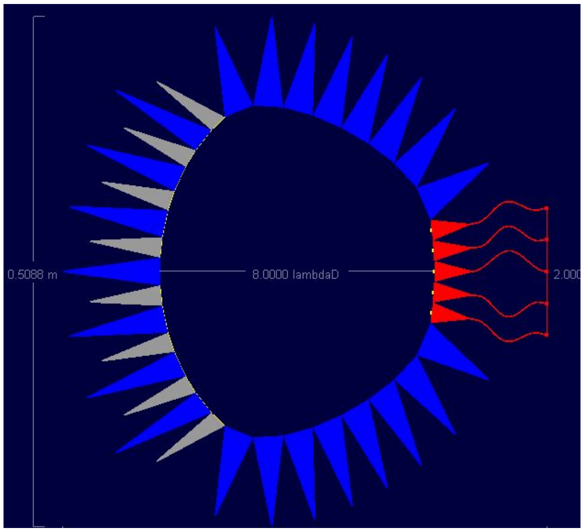

Figure 1 - A Microstrip Rotman Lensdeveloped with REMCOM software.

2. Development and Measurement of the Lens

Our design objectives were to develop a simple Rotman beamformer fabricated for operation at 4.6 GHz to support terrestrial communications. Specifications required +/- 60 Degrees in azimuth scanning and no scanning in elevation. The REMCOM Rotman Lens Design (RLD) software was used as the software design tool. This initial prototype was fabricated using a router to realize a first cut design. The Rotman was then attached to an array of patch antennas and the patterns measures, Figure 2. We found surprisingly good performance in comparison with theory. Photographs of the front and back of the prototype are presented in Figure 3. Simple patch antennas are used for the radiating elements.

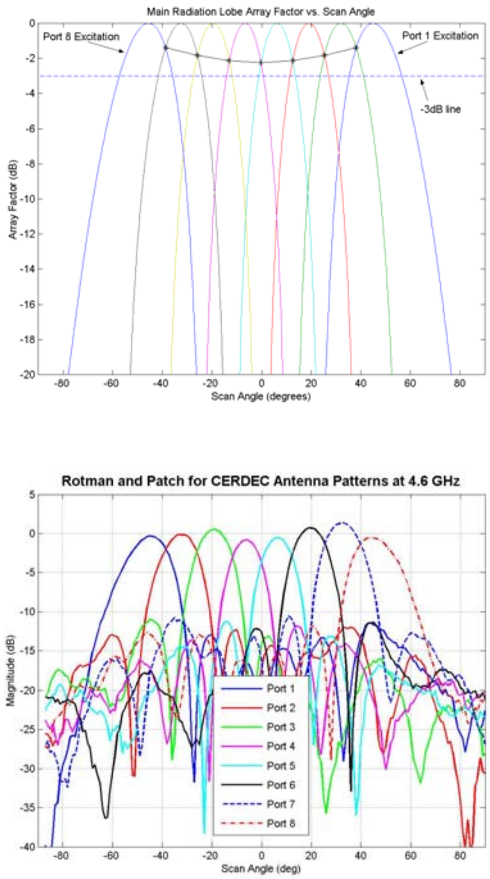

Figure 2 – Comparison of measured and theoretical Radiation patterns for the Terrestrial Link Rotman Lens.

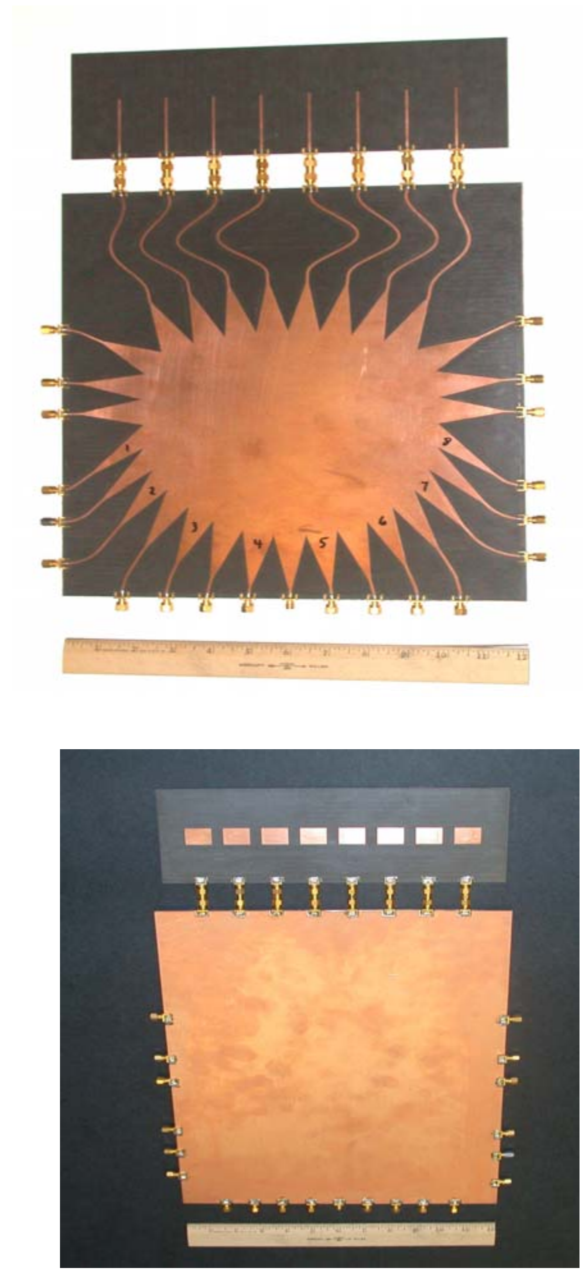

Figure 3 - Prototype of Rotman lens for Terrestrial communications with patch array.

As seen in the measured data presented in Figure 2, the REMCOM RLD, based solely on Geometric Optics, gave measured results very consistent with the theoretical predictions. A slight loss of power is noted for the two beams oriented toward broadside – which we attribute to side reflections from the lens attenuating the beam. The RLD software is for obtaining a first cut model of the lens. It is understood that the model will then be exported and optimized using REMCOM's XFDTD software. The measured system gain of the beamformer and the antenna array was 6 dBi which includes an insertion loss of 10 db for the Rotman lens and the connectors.

This Rotman lens was extensively measured on a network analyzer over a frequency range of 4.0 to 5.0 GHz. As the targeted frequency of operation was 4.6 GHz, we now present measured data for input ports 1 to 8 (seen on Figure 3), showing the progressive phase shift needed to form the beam at various scan angles at the output ports, Figures 4 to 7. Note the good measured linearity – even at the most pronounced scan angle of Figure 7.

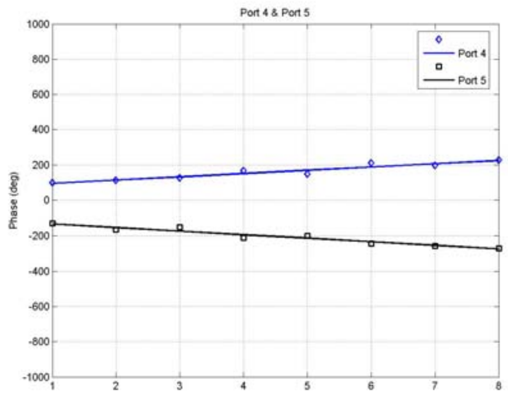

Figure 4 – Progressive phase shift for array ports exciting beam ports 4 and 5.

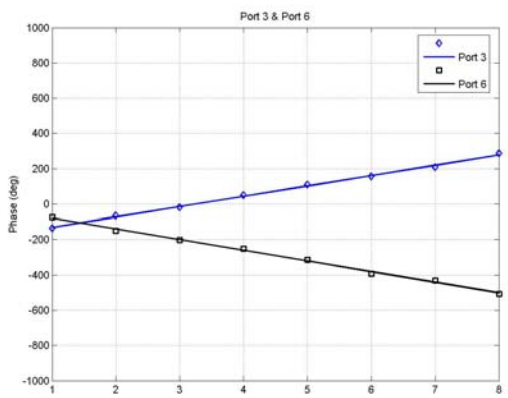

Figure 5 - Progressive phase shift for array ports exciting beam ports 3 and 6.

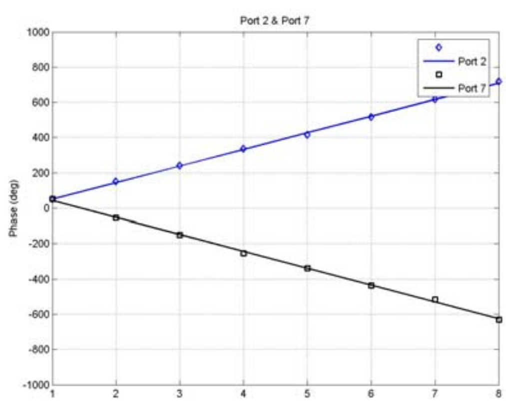

Figure 6 - Progressive phase shift for array ports exciting beam ports 2 and 7.

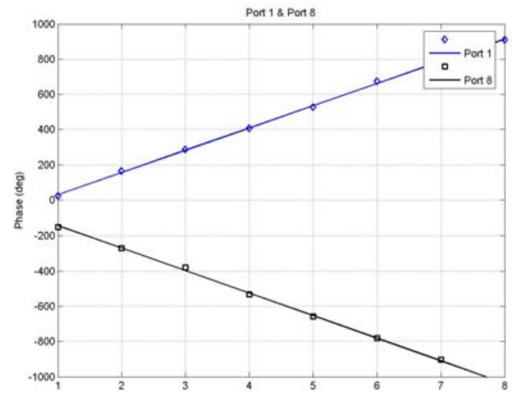

Figure 7 - Progressive phase shift for array ports exciting beam ports 1 and 8.

As a Rotman lens is supposed to be a wideband “true-time delay” beamformer [4], we expect to observer a linear phase shift at each output port as a function of frequency. Such a plot is presented in Figure 8. For this plot, we observe the phase shift measured between beam port #2 and the array port #9. Again we note good linearity - indicating a stable beam position over a wide frequency range. Similar plots are obtained for the matrix of other beam and array ports.

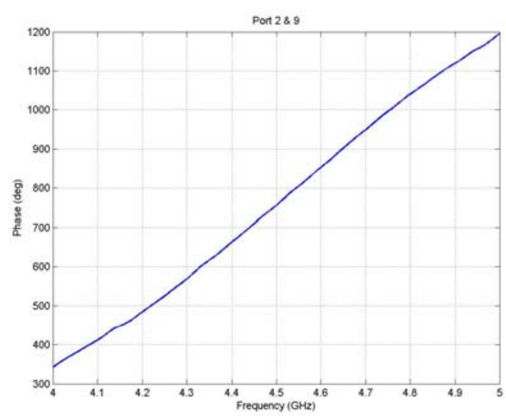

Figure 8 – Measured phase between beam port #2 and the array port #9 versus frequency.

3. Conclusions

We have used newly developed Software by REMCOM to realize an affordable Rotman lens. The software (RLD) is based on Geometric Optics and gives a first cut for the design. We found this to give very satisfactory results without using the more computationally intensive XFDTD code. Measured results validated the simulations. Follow on work will integrate active components (amplifiers) between the lens and the radiating elements as well as a switch array for selection of the input ports.

References

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