Development of a Flexible Electrically-Scanned Array Using a Rotman Lens

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Abstract

Electrically scanned arrays that lend themselves to conformal integration with Army platforms (while remaining affordable) are of special interest to Army applications. For these reasons, Rotman Lens beamformers are of particular interest and have been a topic of active Army investigation [1-2]. Building on the cited earlier work, switches for an electrically scanned array (ESA) were integrated into the beamforming array design. The switch integration issues and measured results are discussed here.

1. Introduction

Our on-going effort is to develop a fully integrated Rotman Lens in the C-band suitable for +/- 60^o azimuth scanning while remaining amenable for conformal platform integration. As indicated in [1, 2], REMCOM's Rotman Lens Design (RLD) software was used to design the beamformer. Initially, the antenna array and beamformer were developed separately, Figure 1 (left.) The next step in the integration process (shown in Figure 1 center) was to create an integrated version of the Rotman Lens and patch antenna array design with all the beam ports moved to the bottom of the structure [2]. Electronic scanning requires the integration of switches into the design as shown in Figure 1 (right) and this is the topic of this paper.

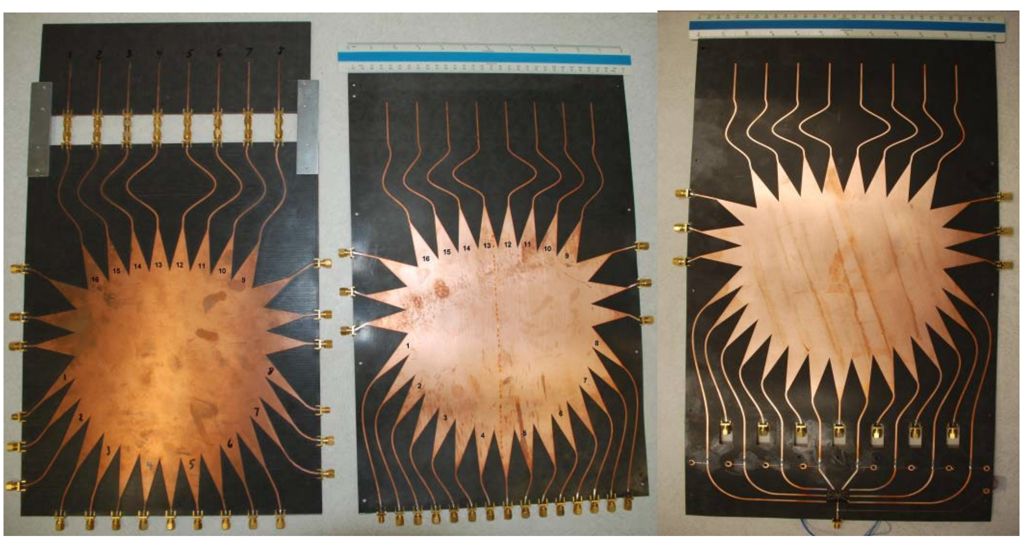

Figure 1 – Transition from modular Rotman & antennas (left) to fully integrated ESA Rotman antenna array (right).

2. Integration of the Switch

A diagram and photo of the switch are presented in Figure 2. We selected M/A-COM's (94mil X 51mil) MA4AGSW8-1 SP8T for this design because of its low insertion loss (2 dB max) and speed of operation (typically, 20 nS.) Narrow microstrip transmission lines were needed to reach the small pads of the switch. The narrow microstrip transmission line requirement dictated that the dielectric material surrounding the switch be very thin. This was accomplished by placing dielectric material (2 mils in thickness) measuring 0.9" X 0.6" around the switch, as seen in Figure 2 (right) – note a small rectangular area of dielectric at the center was removed to accommodate the switch placement. The dielectric material was CuFlon (a product of Polyflon Corp.) We used conductive epoxy to bond the CuFlon to a 1.1” X 0.8” copper ground plane. Next, the switch was conductively bonded to the same ground plane in the rectangular donut hole of CuFlon. Conductive epoxy was used to hold the wire bonds from the Cu transmission lines on the CuFlon substrate to the gold pads on the MA4AGSW8-1. Afterwards, this 1.1” X 0.8” module was soldered underneath the Rotman Lens antenna array design to establish ground plane continuity. The final step in the fabrication process connected the thicker transmission lines of the Rotman lens to the thin lines on the 2 mil thick dielectric using wire bonds and conductive epoxy, Figure 2.

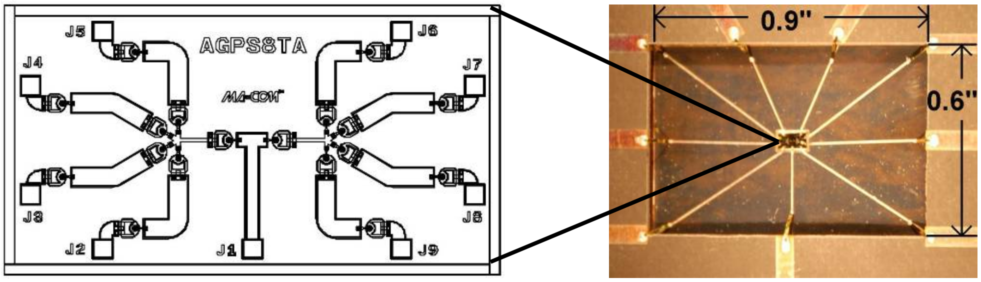

Figure 2 –MA4AGSW8-1 SP8T (left) & it surrounded by CuFlon measuring 0.9” X 0.6” X 0.002” (right).

DC bias lines were created to control the MA4AGSW8-1, as illustrated in Figure 3. DC blocking capacitors ensured isolation of the control voltages to the switch. The DC biasing was automated by a control unit off the board. Also shows in Figure 3 are dummy beam ports that were not needed for scanning and that were terminated with 50 Ohm terminations.

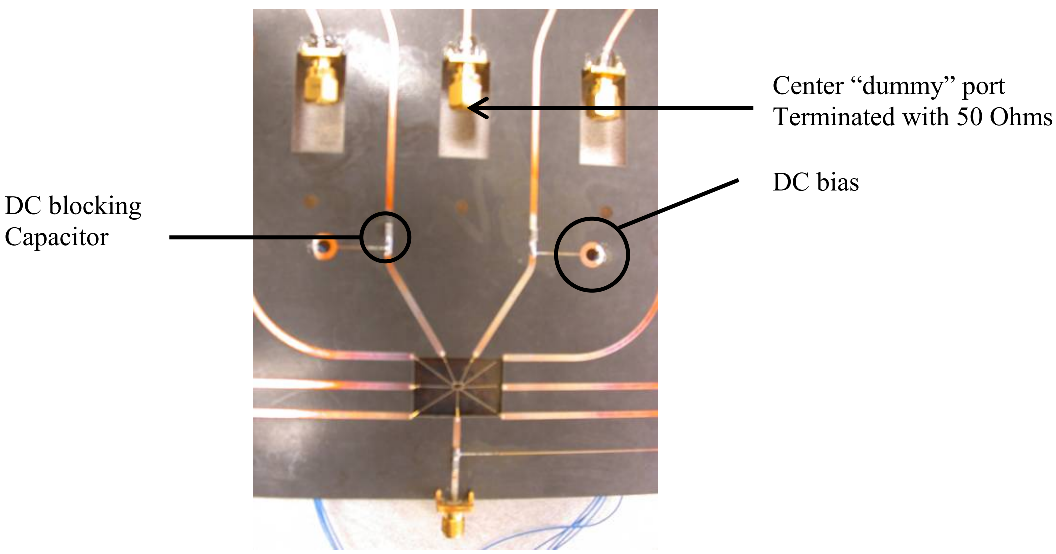

Figure 3 – DC bias line connected to transmission linking the MA4AGSW8-1 & Rotman Lens.

3. Measured Results

Measurements of the design provided performance consistent with RLD’s Geometric Optics theoretical predictions presented in Figure 4. The Rotman Lenses were measured on a network analyzer and in an anechoic chamber with radiation plots presented in Figure 5. The scan angles are consistent for all three designs, but the latest design has diminished amplitudes for some beams which we believe are due to transitions mismatches from the Rotman Lens substrate to the CuFlon or from the CuFlon to the switch itself (or both.) This problem is now under investigation with our simulation models.

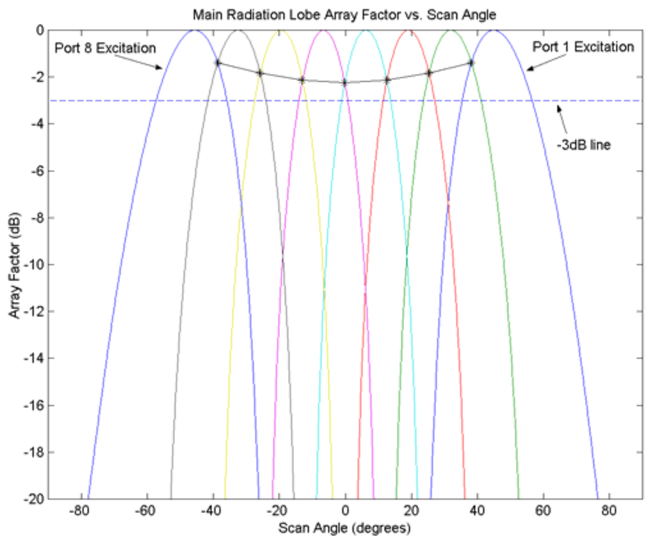

Figure 4 – RLD's Main Radiation Lobe Array Factor vs. Scan Angle.

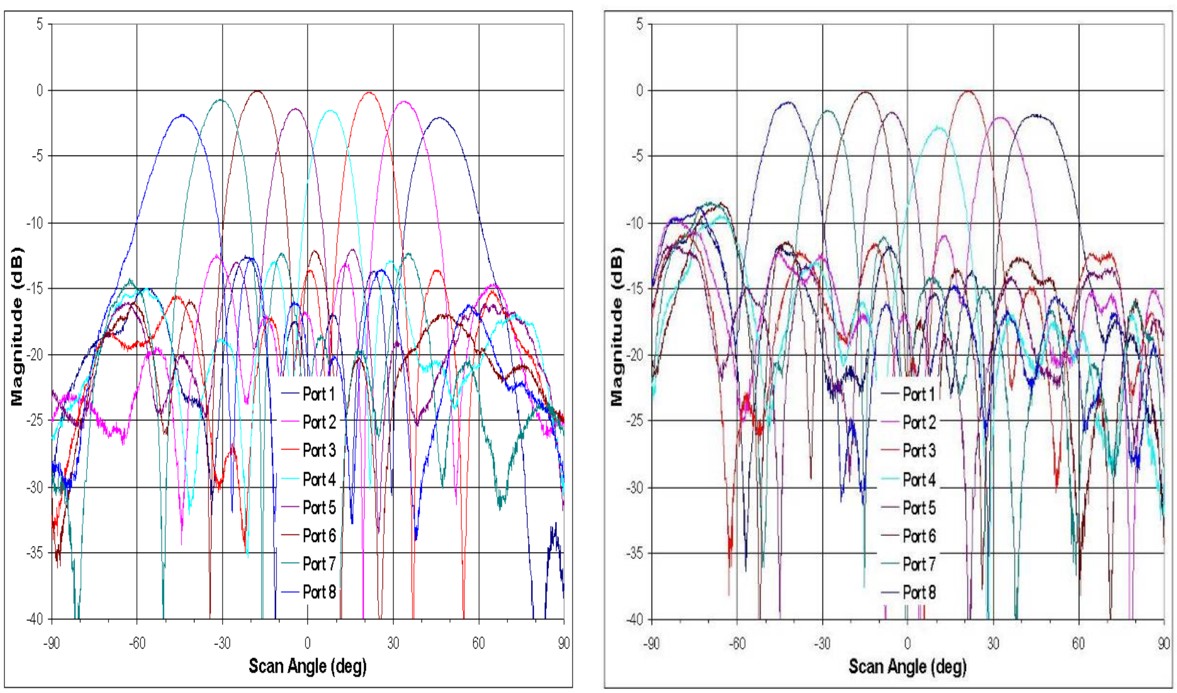

Figure 5 – Comparison of Rotman Lens integrated without switches (left), & integrated with switches (right) Rotman antenna array.

For calculation of system gain (including losses of the Rotman and the switches), our measurements used comparison to a standard gain horn antenna. Note that the array never scans directly to broadside unless the appropriate dummy port is excited. As such, our baseline gain used the dummy port at the center of the beam ports (seen in Figure 3.) The resulting gain was measured to be 8.875 dBi. This measurement includes beamformer and transmission line losses, but does not include the switch losses. The system gains for each beam position were then calculated from the peak power readings of each beam relative to this baseline and are presented in Table 1. Note that these gains now include switch losses.

Table 1 – Measured systems gain for each beam (beamformer and switch losses included.)

Beam	1	2	3	4	5	6	7	8
Gain dBi	8.19	8.00	10.02	7.34	8.41	9.94	8.52	9.15

At first glance, it may seem troubling that some beam positions in Table 1 have gains that exceed the broadside gain of 8.875 dBi – especially since these beam positions will have the switch losses included while the broadside gain does not. However, we note that the beamformer design gain is not maximized to broadside and there was a measured dip of about 2 dB in earlier versions as seen in the plot of Figure 5 on the left. The actual trend of the measured data (comparing the left and right plots of Figure 5) tends to indicate that the included switch losses are on the order of a couple dB (or less) and that the fluctuations seen on the measured patterns in Figure 5 are due to impedance mismatches from the embedded switch. Note some slight positioning errors are also introduced.

One attractive feature of this beamformer/array is the *physical flexibility* that makes it suitable for conformal integration, Figure 6. The Rotman is created on a thin sheet of Duroid (20 Mils) and can tolerate a significant amount of bending (curvature) without adverse effects on performance [2]. Note the structure has a 90 Degree bend to accommodate it placement.

Figure 6 – Flexible Electrically Scanned Rotman lens antenna array on a platform.

3. Conclusion

We have discussed some engineering issues pertaining to integration of a switch into our electronic scanning array. Additionally, we have presented some measured results validating that our system performance is reasonable; although, work remains to ensure good impedance matching between the switch and the Rotman lens. Finally, the nature of the design (using thin sheets of dielectric) is inherently low-cost and lends itself to conformal integration onto Army platforms.

4. References

1. S. Weiss, S. Keller, and C. Ly, "Development of Simple Affordable Beamformers for Army Platforms," Proceedings of GOMACTech–07 Conference, Lake Buena Vista, FL, March 2006.

2. T. K. Anthony "Rotman Lens Development, "Proceedings of 2008 IEEE Ant. & Prop. Conference, San Diego, CA, July 2008.

3. W. Rotman, and R. F. Turner "Wide-Angle Microwave Lens for Line Source Applications," IEEE Trans. on Ant. and Prop., 1963, pp. 623-632.