**Title:** Optimization of a Constrained-Feed Rotman Lens Beamformer

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**Abstract:**
A previous mathematical analysis has demonstrated the utility of a partially overlapped, constrained-feed network for time-delay control of large linear arrays (R.J. Mailloux, IEEE Trans. 49, February 2001, pp.280-291). In particular, this novel method allows for approximately –30 dB sidelobe suppression over a 20% bandwidth. An array with time-delayed contiguous subarrays with the same separation would have quantization lobes at the –10 dB level; thus, this technique appears to offer significant advantages. We recently developed an experiment to demonstrate this concept. We collected data for the broadside case (array phase shifters set to zero) from –45° to 45° in 0.25° increments and from 9.0 to 11.0 GHz in 0.05 GHz increments (center frequency of 10 GHz). We allowed weighting of both the Rotman lens outputs (constituent beams) and the Butler matrix outputs (subarray patterns). We used a genetic algorithm to optimize these complex weightings. We realized that our data set didn’t represent the best measure of system performance, since there is no beam squinting at broadside; therefore, we performed a limited field of view (LFOV) test. Using this LFOV test, we were able to demonstrate at least –28 dB sidelobes over an angular field of view corresponding to a 20% bandwidth.

**Subject Terms:**
Constrained-feed network, overlapped subarray architecture, phased arrays

**Security Classification:** Unclassified

**Limitation of Abstract:** SAR

**Number of Pages:** 24
Optimization of a Constrained-feed Rotman Lens Beamformer

20 October 2005

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This research was sponsored by DARPA
Outline

• Motivation

• Experiment
  — Experimental Setup
  — Parameter Optimization
  — Results

• Summary/Conclusions/Future Work
Contiguous Subarrays

Phase control

Time delay

\[ f = f_0 \]
\[ N = 12 \]
\[ M = 8 \]

\[ f = 1.1f_0 \]

Section:
- P elements
- N subarrays

-30dB sidelobe levels over 20% bandwidth
- Design experiment to test theory
Experimental Block Diagram

Far-field source $f_0 = 10$ GHz

P = 64

ROTMAN LENS 1 [64 X 8]

ROTMAN LENS 2 [64 X 8]

ROTMAN LENS 3 [64 X 8]
Constituent Beams

![Graph showing normalized amplitude in dB across different U-space values.](image_url)
Experimental Block Diagram

Far-field source \( f_0 = 10 \text{ GHz} \)

\[ \begin{align*}
\text{P} &= 64 \\
\text{ROTMAN LENS 1} &\quad [64 \times 8] \\
\text{ROTMAN LENS 2} &\quad [64 \times 8] \\
\text{ROTMAN LENS 3} &\quad [64 \times 8]
\end{align*} \]
Subarray Patterns

1 & 8

2 & 7

3 & 6

4 & 5
Analysis of a Single Section

P = 64
N = 8

P/N = 8

U-SPACE
Experimental Block Diagram

Far-field source $f_0 = 10$ GHz

$P = 64$

Phase shifter
Power divider
Line stretcher
Load

ROTMAN LENS 1
[64 X 8]

ROTMAN LENS 2
[64 X 8]

ROTMAN LENS 3
[64 X 8]

8 x 8 BUTLER MATRIX

8 x 8 BUTLER MATRIX

8 x 8 BUTLER MATRIX

Weight

Load
Constituent-Beam Weighting

![Graphs showing normalized amplitude in dB vs. U-space for constituent beams 3 & 6, and 4 & 5.](image-url)
Partially Overlapped Sections
Experimental Block Diagram

Far-field source $f_0 = 10$ GHz

P = 64

- Phase shifter
- Power divider
- Line stretcher
- Load
- Complex weight
- Rotman Lens 1 [64 x 8]
- Rotman Lens 2 [64 x 8]
- Rotman Lens 3 [64 x 8]
- 8 x 8 Butler Matrix
- 8 x 8 Butler Matrix
- 8 x 8 Butler Matrix
- Beamformer

Load

Load
System Radiation Pattern (Ideal System)

- **f = 9.0 GHz**
- **f = 10.0 GHz**
- **f = 11.0 GHz**

![Graphs showing radiation patterns at different frequencies](image)
Time Delay vs. LFOV

Time Delay

LFOV
System Optimization

- Optimize weights for constituent beam and subarray ports
- Ideal System
  - Method of Alternating Projections (constituent beams)
  - 40-dB Taylor weighting (subarray ports)
- Experiment
  - Used genetic algorithm to optimize both sets of weights
Results

- **f = 10 GHz**
  - $u_0 = 0$

- **f = 9 GHz**
  - $u_0 = 0.079$

- **f = 11 GHz**
  - $u_0 = -0.064$
Constituent-Beam Weights

IDEAL

EXPERIMENT
Subarray Weights

The graph shows the normalized amplitude of subarray weights as a function of the Rotman lens port. The ideal and experimental results are depicted using dashed and solid lines, respectively. The amplitudes are normalized to values between 0 and 1, with a peak at the central port and a decrease towards the edges.
Subarray Weights (Phase)
Constituent-Beam Weights (Phase)
Rotman Lens Transfer Function: Phase
Conclusions/Future Work

• Partially overlapped constrained-feed network:
  – Solves the quantization lobe problem associated with contiguous subarrays
  – Experiment demonstrated –30-dB sidelobes over a 20% bandwidth
  – Constrained nature allows for array expansion without increasing depth of system

• Future Work
  – Phase shifters at element level
  – Transfer function of entire system