A Single RF Channel Smart Antenna Receiver Array with Digital Beamforming

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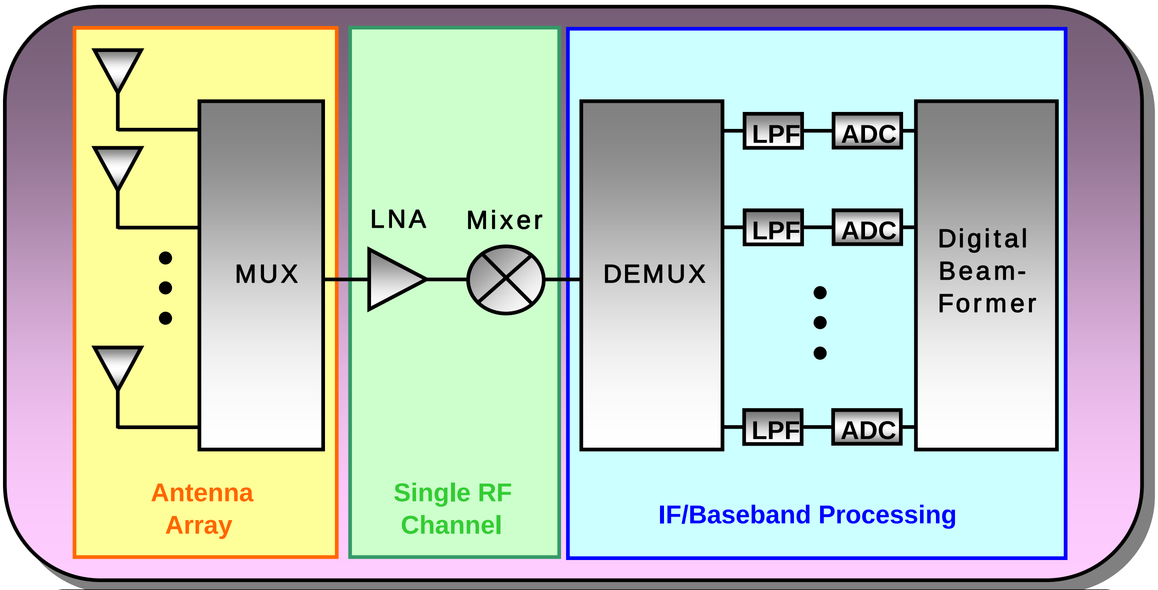
Single RF Channel Smart Antenna System



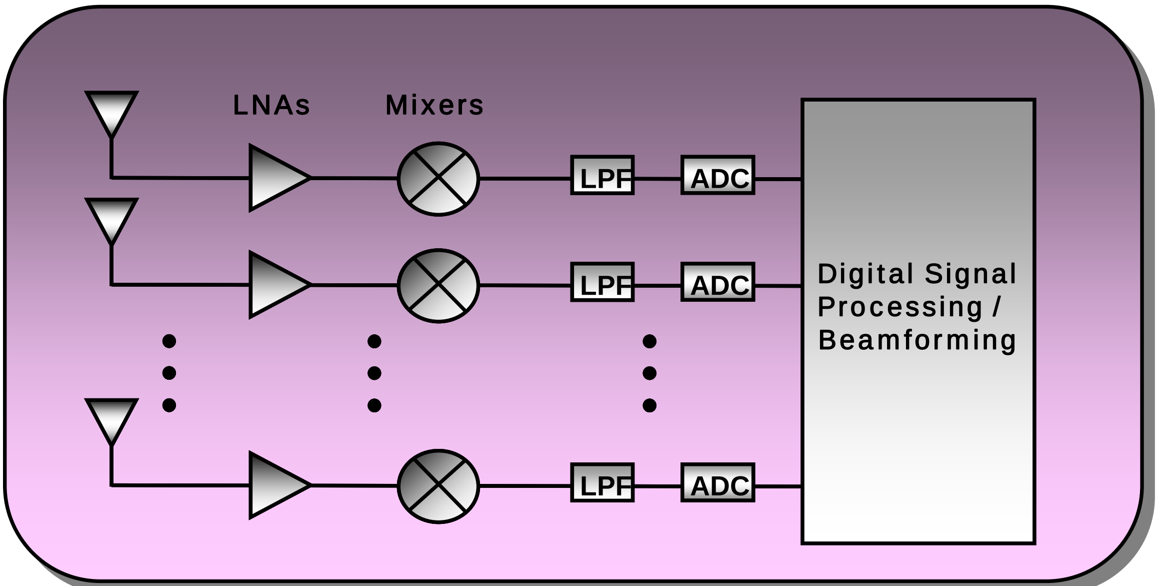
- MUX reduces N-channels (LNAs, Mixers) to 1
- Flexibility in IF/baseband processing – analog or digital DEMUX
- Digital Beamforming in MATLAB environment

System Features

- ✓ Reduction in costly RF hardware
- ✓ Space reduction
- ✓ Reduction in power dissipation
- ✓ Maintains complete functionality

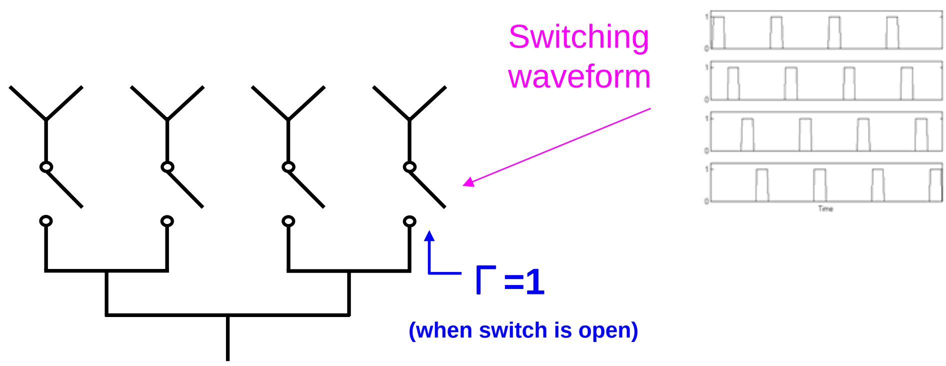
as with typical smart antenna arrays

Traditional DBF Smart Antenna System



- ➢N-channel array requires N individual receiver chains
- ➢Each channel must be well matched and calibrated

System Principles



- ➢SMILE (**S**patial **M**ult**I**plexing of **L**ocal **E**lements) scheme
  - ✓ Sequential switching samples signal at each element
  - ✓ Sampling rate greater than Nyquist rate
  - ✓ Parallel feed network retains all signal information
  - ✓ Sampling frequency limits signal modulation bandwidth

System Principles

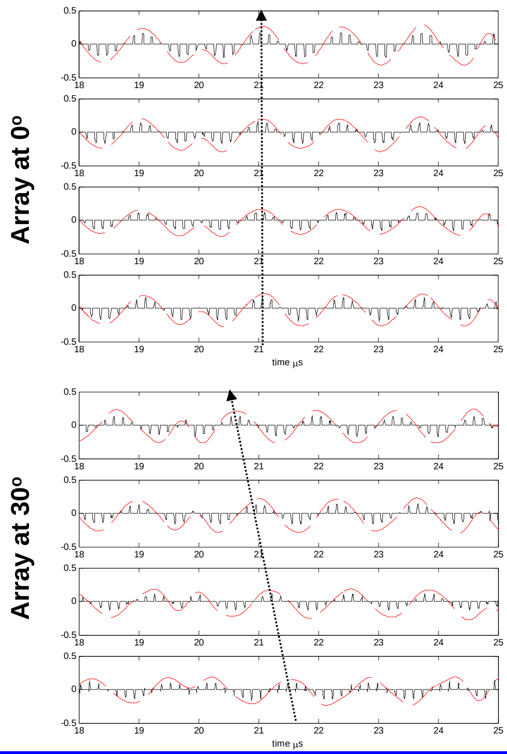
Sampling Frequency:

$$f_s \geq B \times N$$

LPF Cutoff Frequency:

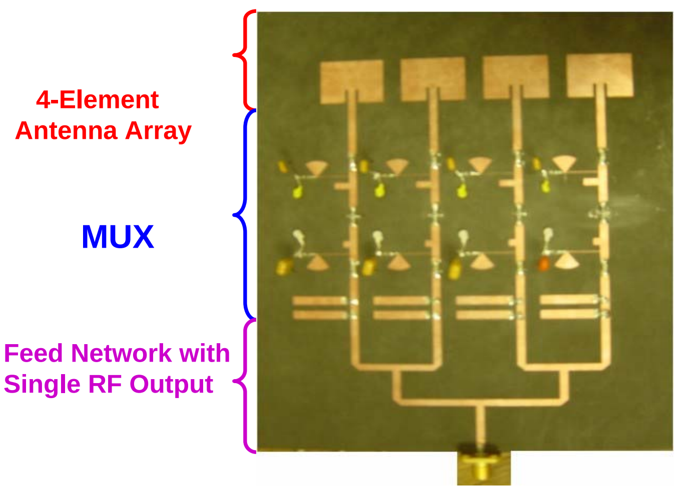
$$\frac{B}{2} < f_{lpf} < f_s - \frac{B}{2}$$

System Principles



- ➢ Baseband data recovery
  - ✓ Non-conventional feed network properly retains phase information
  - ✓ Allows use of advanced beamforming and DOA algorithms

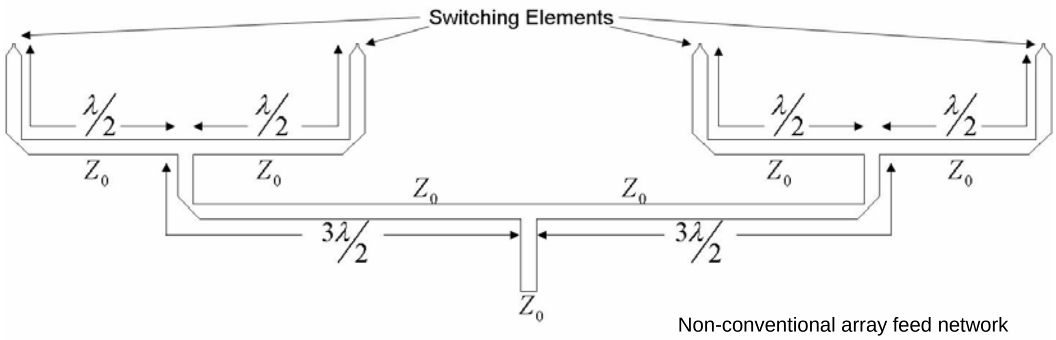
4-Element Prototype Hardware



LNA MUX with patch antenna element at 5.8 GHz

- ➢ LNA MUX
  - ✓ NEC32485C Pseudomorphic HJ FET (LNAs) as switching element
  - ✓ Low-noise switching improves overall noise figure compared with passive switch
  - ✓ No current required to drive switching

Non-conventional Feed Network



Non-conventional array feed network

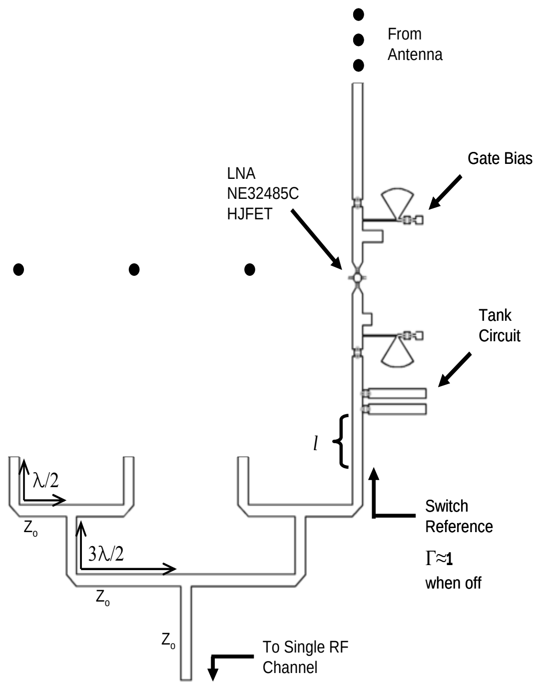
➢Always Matched Feed Network

- ✓ Only one active channel at each instant
- ✓ All lines at T-junction matched to Zo
- ✓ No loss compared with 6 dB loss of Wilkinson dividers

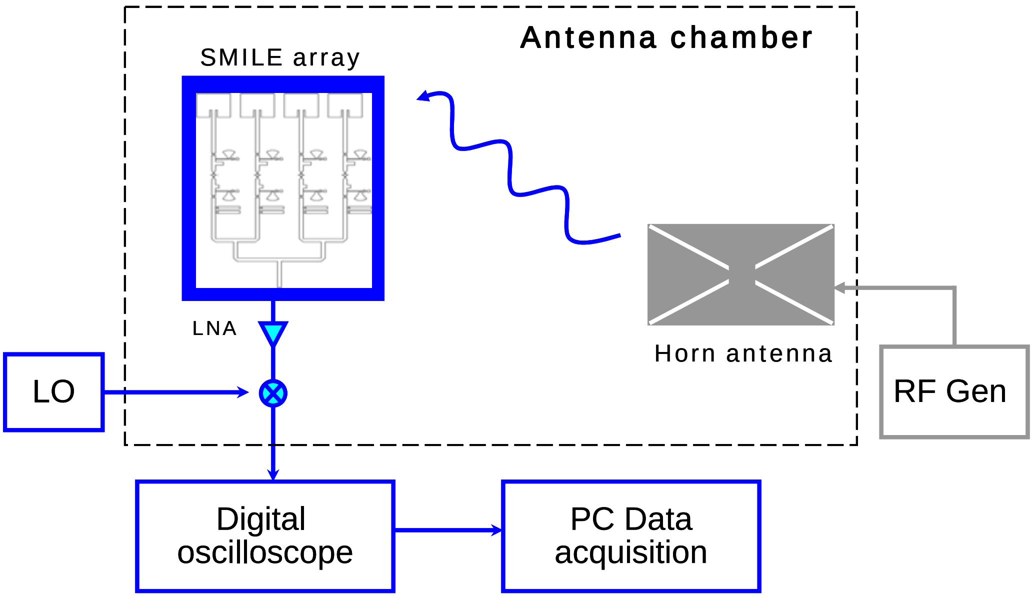
Circuit Schematic

➢Multiplexing Hardware Circuit

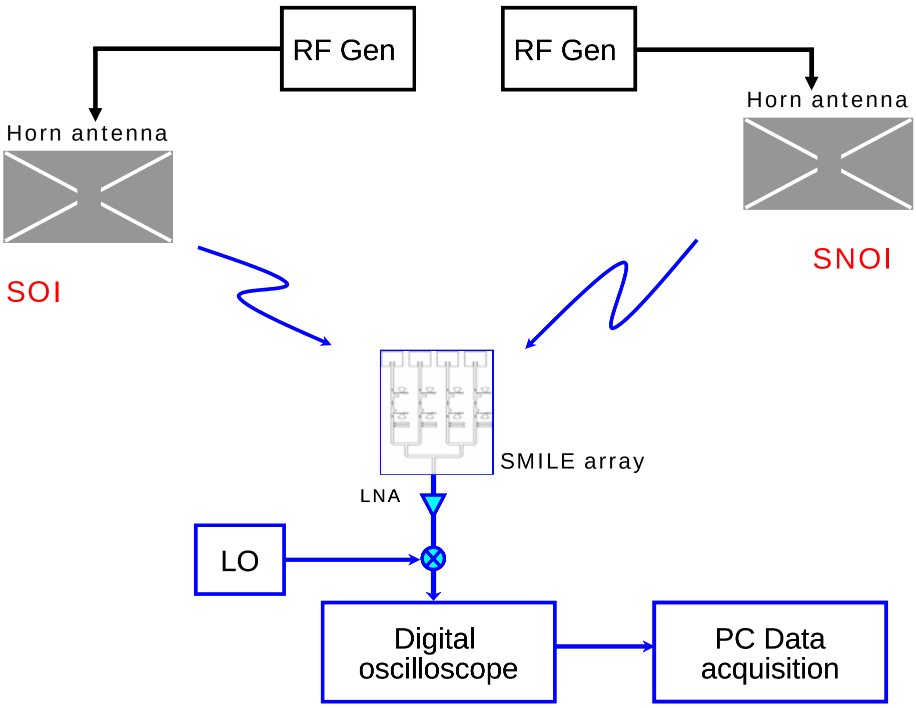
- ✓ Tank circuit adds isolation sacrificed with non-conventional feed network
- ✓ Switch reference must be precisely matched to feed network



Single Source Testbed Setup

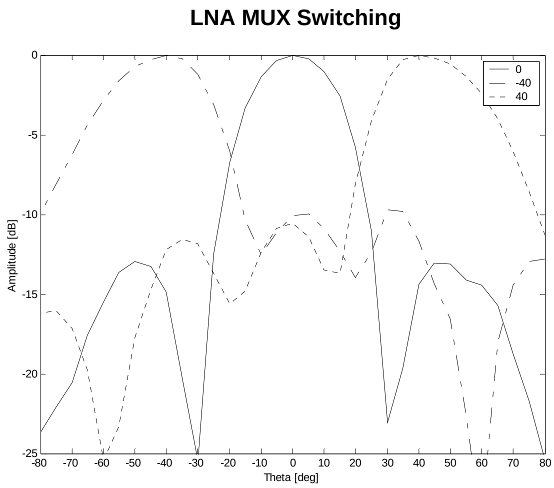


Two Source Testbed Setup



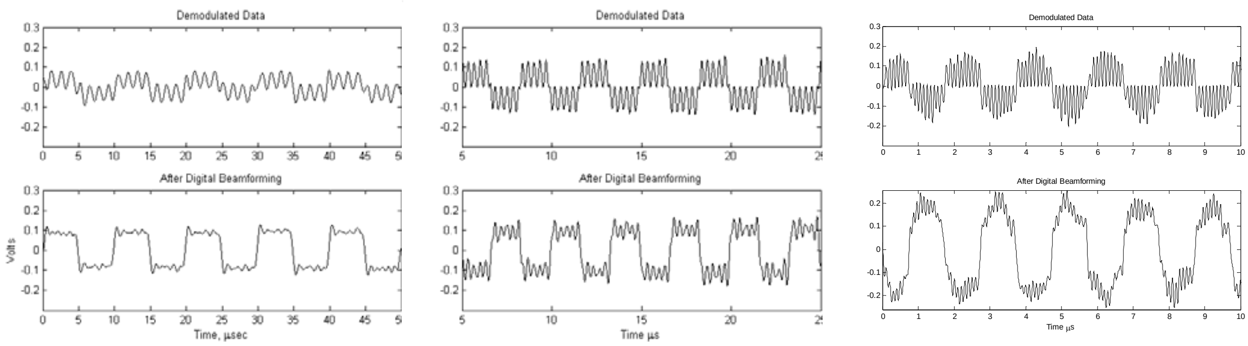
Beamforming Performance

Synthesized Beam Patterns



- ➢ Digital Beamforming
  - ✓ Synthesized beamforming accomplished in DSP
- ➢ FET Switching Benefits
  - ✓ Fast switching with FET increases possible data rate
  - ✓ Broader Symmetric Scan Range
  - ✓ Lower sidelobes

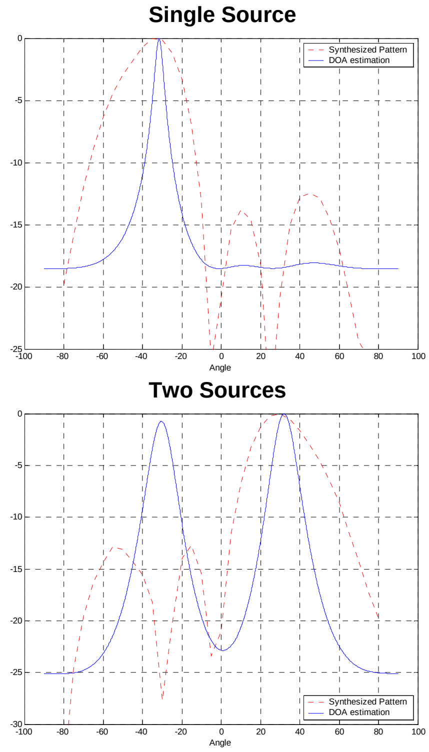
Digital Data Recovery



200 kbps **600 kbps** **1 Mbps**

- ➢ Digital Data
  - ✓ BPSK modulated carrier
  - ✓ Compare demodulation before and after applying DBF
  - ✓ Digital beamforming algorithm coherently sums all channels

DOA Estimation and Synthesized Patterns



➢DOA Estimation

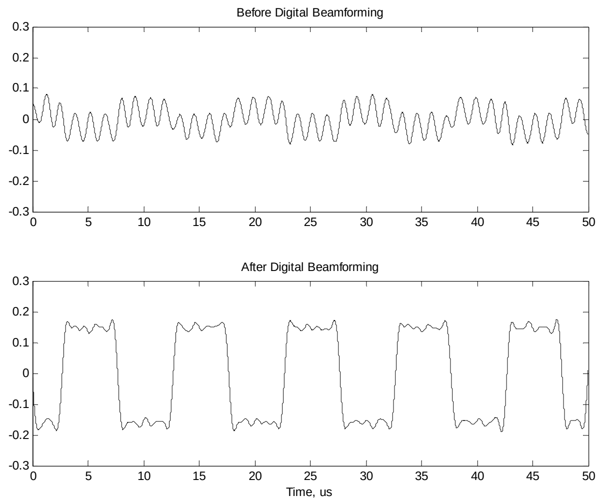
- ✓ Proper recovery of IF channel data allows advanced beamforming algorithms and DOA estimation
- ✓ MUSIC algorithm detects proper direction of signals

➢Synthesized Beamforming

- ✓ Beam formed indirection of source
- ✓ Null formed in direction of unwanted signal

Spatial Filtering

Single Source:

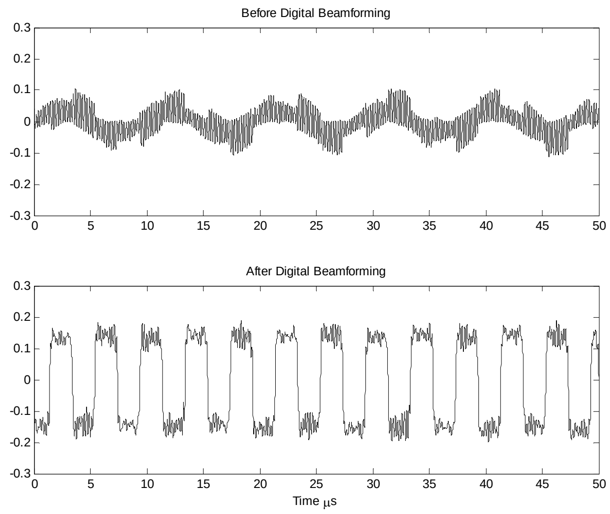


➢Single Source Data Recovery

- ✓ Coherent summation recovers a much clearer pattern
- ✓ Results more evident for angles farther off broadside

Spatial Filtering

Two Sources:



- ➢Two Source Data Recovery
  - ✓ Incoherent demodulation does not resemble a digital pattern
  - ✓Interference ‘nulling’ demonstrates spatial filtering

Conclusion

- ➢Measured 20 MHz switching rate
- ➢DOA Estimation and Beamforming
- ➢Recovered up to 1 Mbps digital data
- ➢Demonstrated full smart antenna functionality

Other Works

- Slot Antenna Based SMILE Array
  - ✓ Compact design
  - ✓ Series fed PIN diode switching
- 2-D Configuration
  - ✓ Increase scanning flexibility for possible radar application