Updating the Multiband Reconfigurable Synthetic Aperture Radar Antenna

QORTEK

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PROJECT OVERVIEW

- Synthesis of three distinct technologies:
  - tunable dielectrics
  - quadrant steering architecture
  - microprocessor tuning/pattern control
- Produces frequency and pattern agile multiband-capable microwave antennas on thin, flexible substrates

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A Fresh Approach

- Microstrip Patch derived
- Electrostatically Tunable and Steerable
- Lightweight, Flexible
- Low Cost
- Scalable, L-Band through Ka Band
- Durable in Harsh Environments
- Repeatable in Performance

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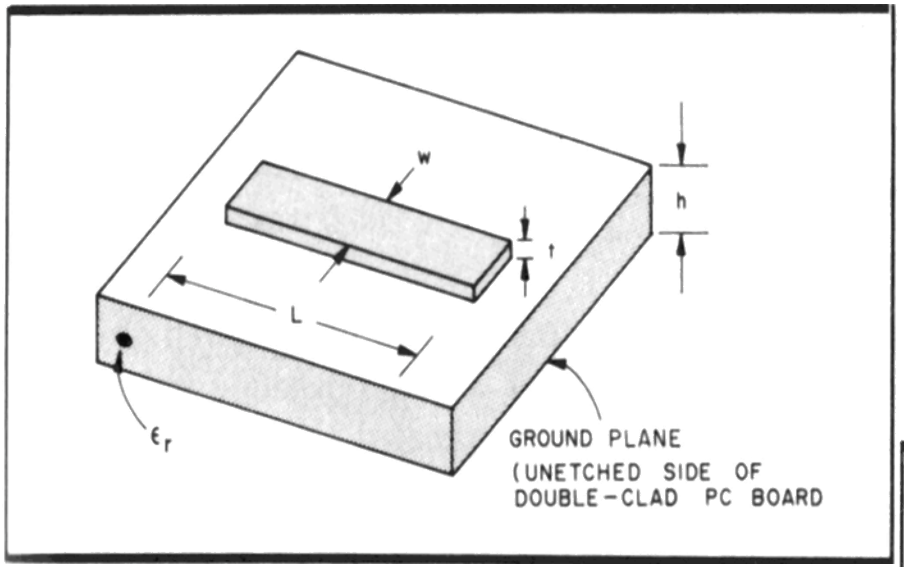
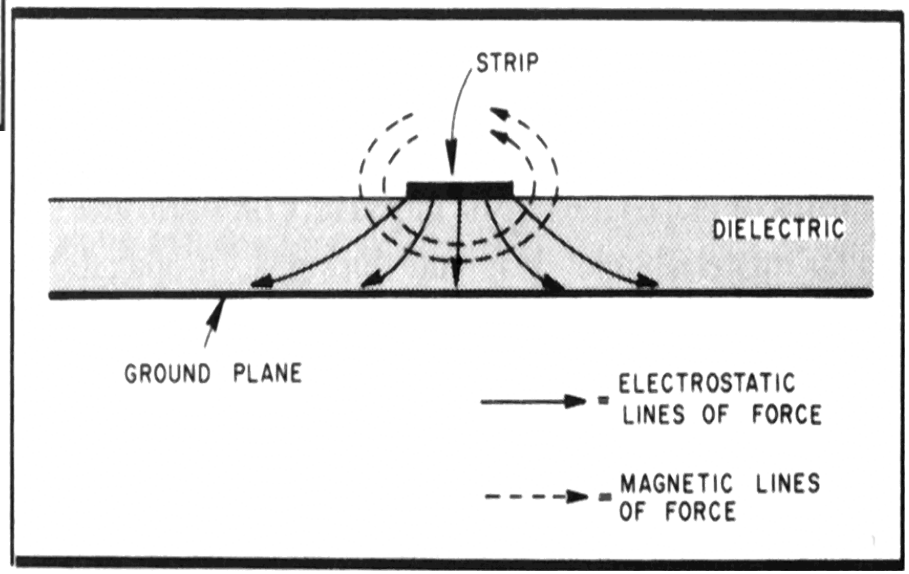
Microstrip Basics



$$Z_0 = \sqrt{L/C}$$

$$v = \frac{1}{\sqrt{LC}}$$



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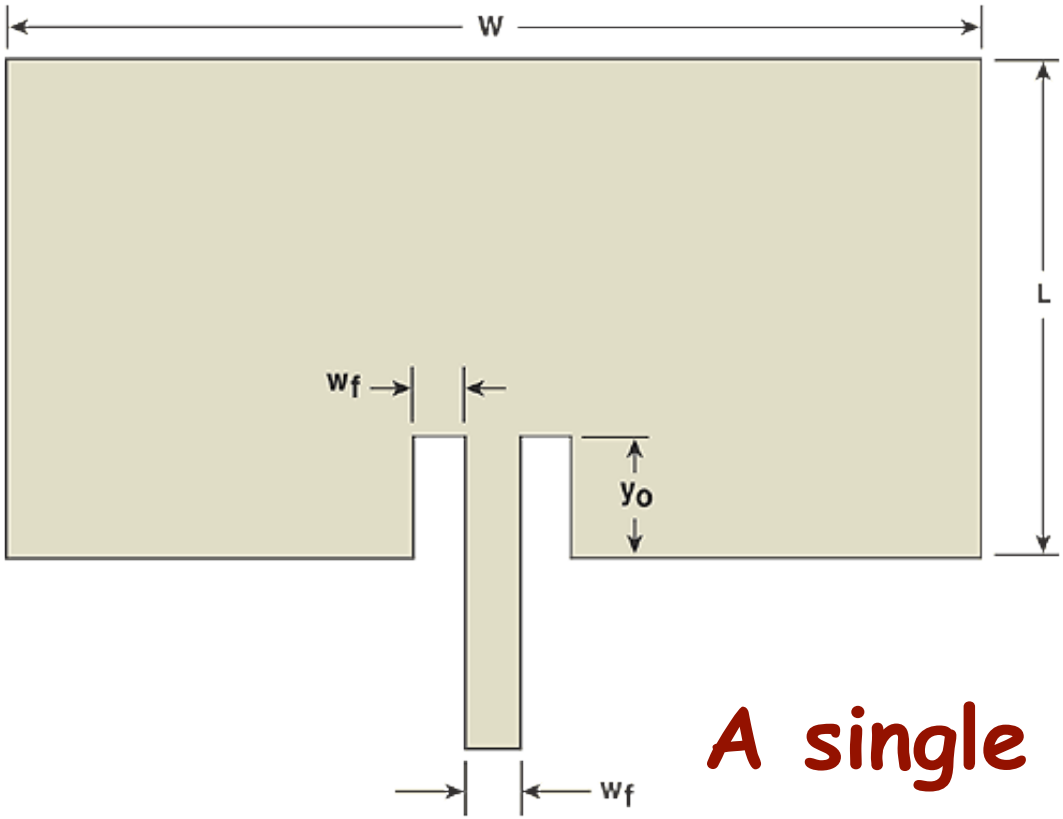
Patch Antenna Basics



A single Patch Element behaves essentially like a Reflector-Backed Dipole

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Patch Antenna Tradeoffs

Advantages:

- Inexpensive
- Low Profile
- Good Pattern
- Easy to Match

Disadvantages:

- Narrow-Band
- Not easily tunable
- Dielectric Losses
- Physically Large

However…

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Design Concept (1)

Microstrip or Dielectric Patch Resonance

$$f_o \simeq c / [2L (\varepsilon_r^{1/2})]$$

where f_o = resonant frequency in Hz

c = the speed of light = $3 * 10^8$ m/s

L = the physical length (in meters) of the patch element

and ε_r = the permittivity or dielectric constant of the substrate, relative to free space.

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Design Concept (2)

$$f_o \simeq c / [2L (\varepsilon_r^{1/2})]$$

Thus, the operating frequency of a patch antenna element varies inversely with the square root of the relative permittivity of its dielectric material.

(Vary ε_r and f_o varies!)

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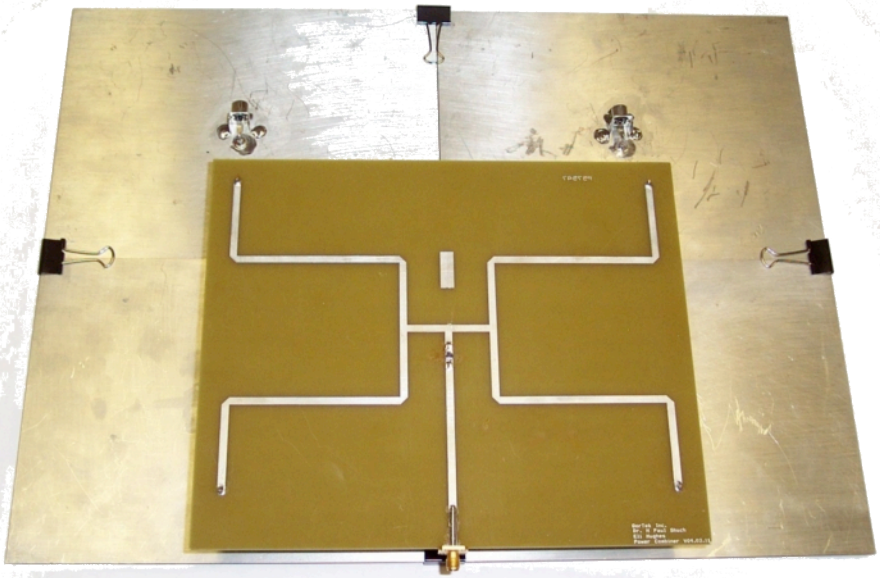
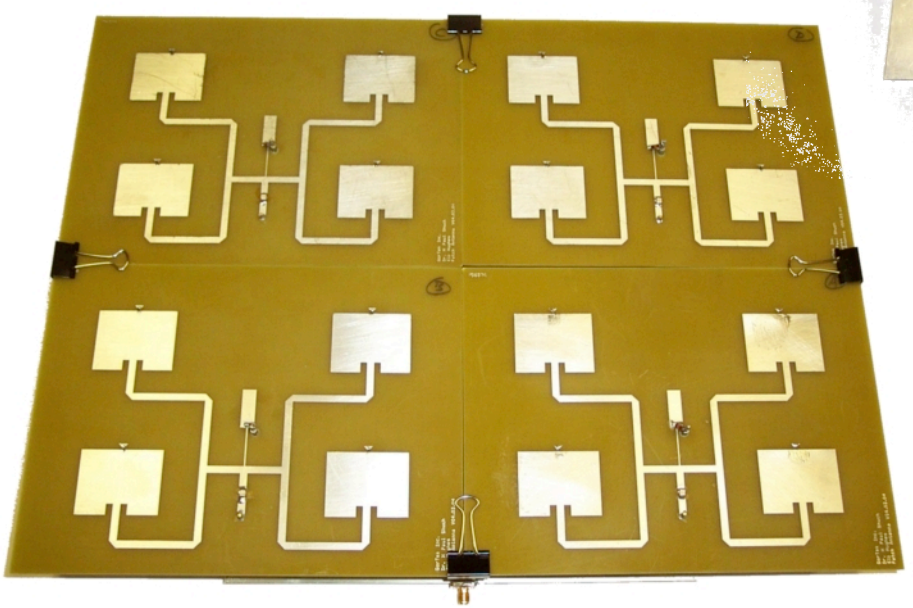
This Time Last Year:





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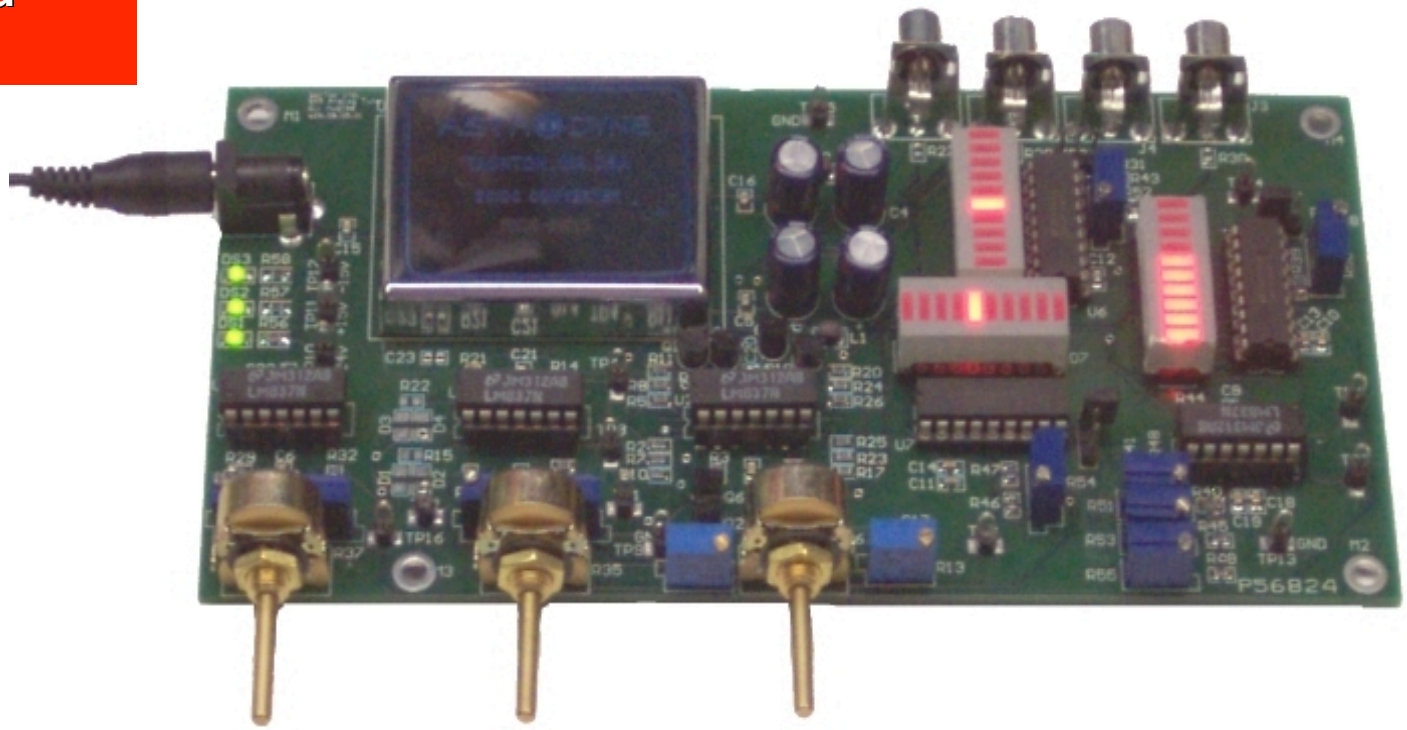
Analog Test Fixture

Manually controls E-Field and H-Field steering and frequency



Controls 16-patch test array

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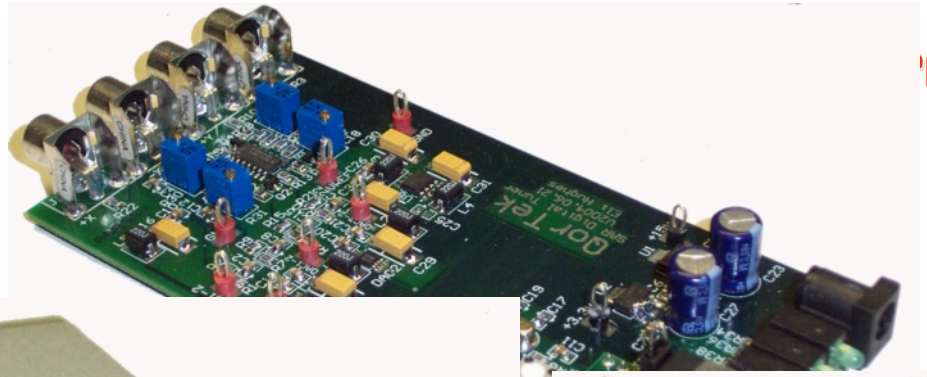
New This Year:

ray Controller



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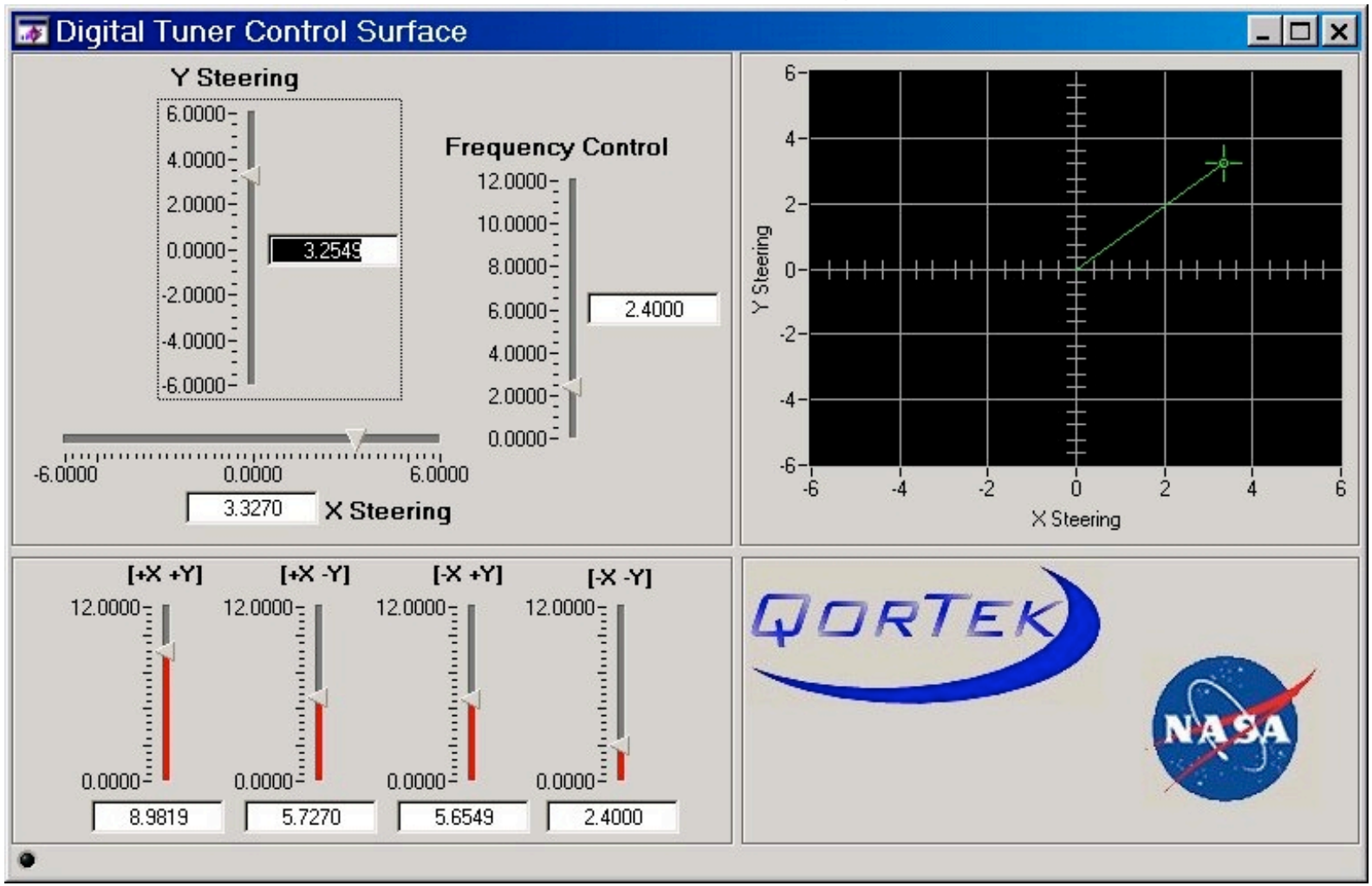
New This Year:

Graphical User Interface



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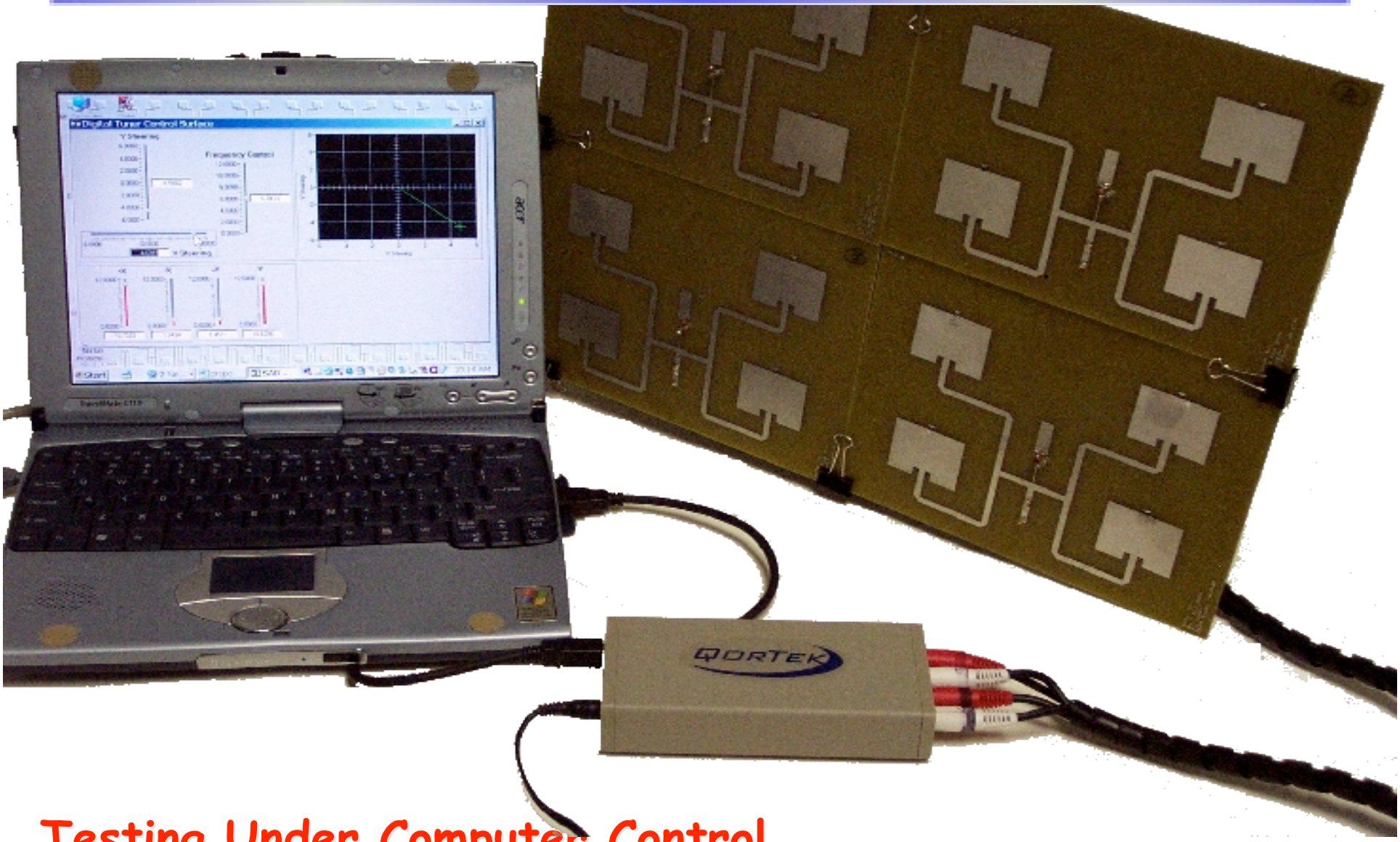
New This Year:



Testing Under Computer Control

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Initial Test Results:

16 patch varactor-tuned array on FR4 circuit board

Center Frequency	=	2.4 GHz		
Bandwidth	=	60 MHz	=	2.5 %
Loaded Q	=	40		
Pre-bias	=	1 VDC		
Tuning Range	~	300 MHz	=	12.6 %

		e-field	h-field	
Beamwidth	~	15	10	deg.
Steering Range	~	20	13	deg.

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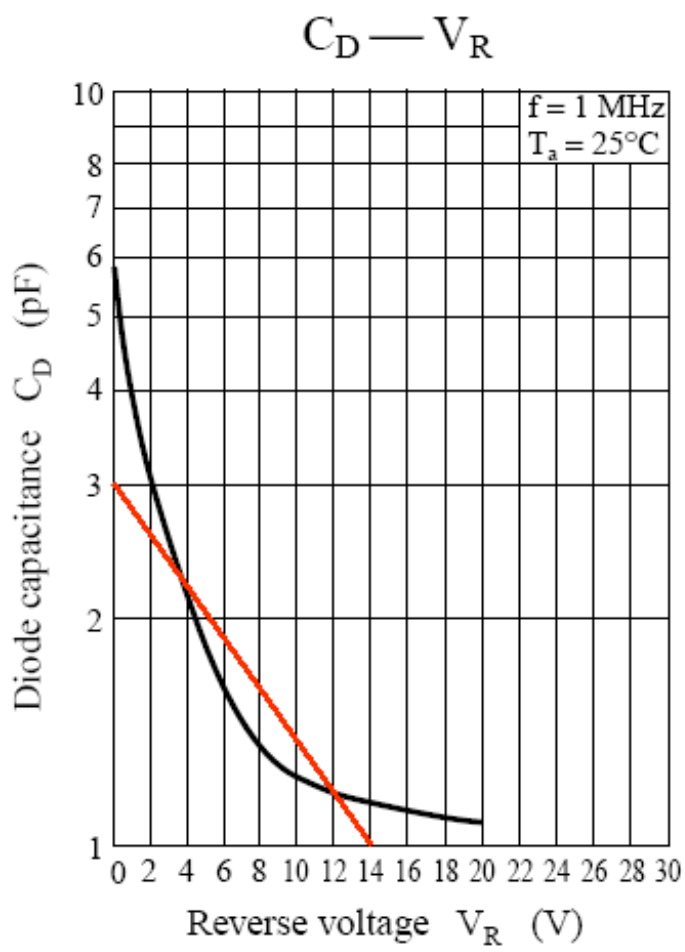
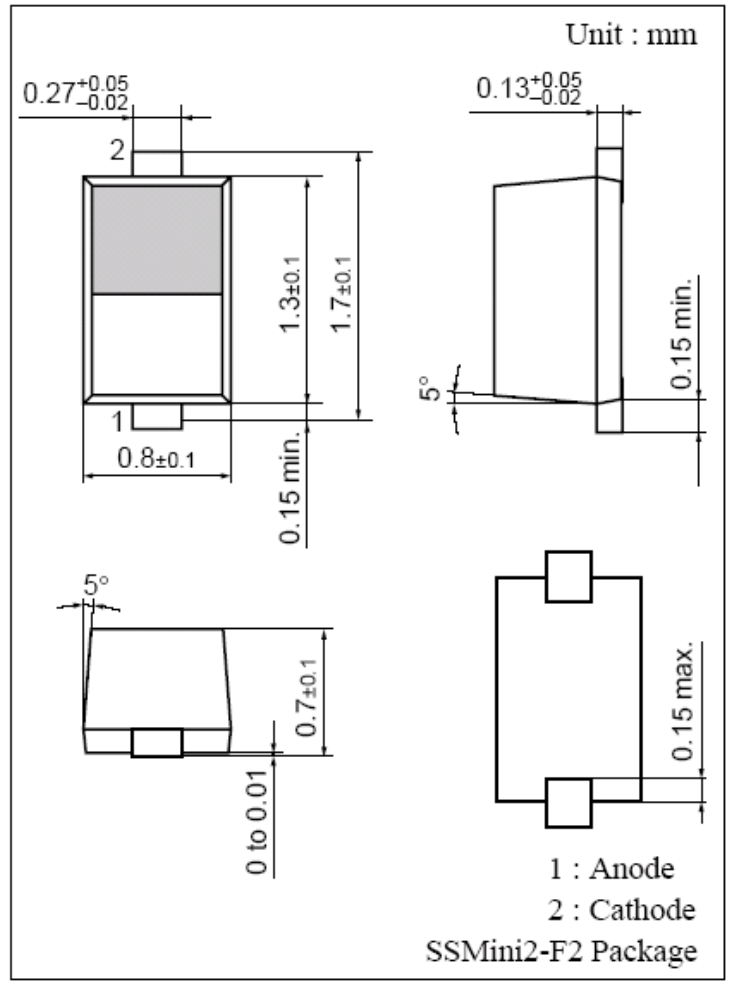
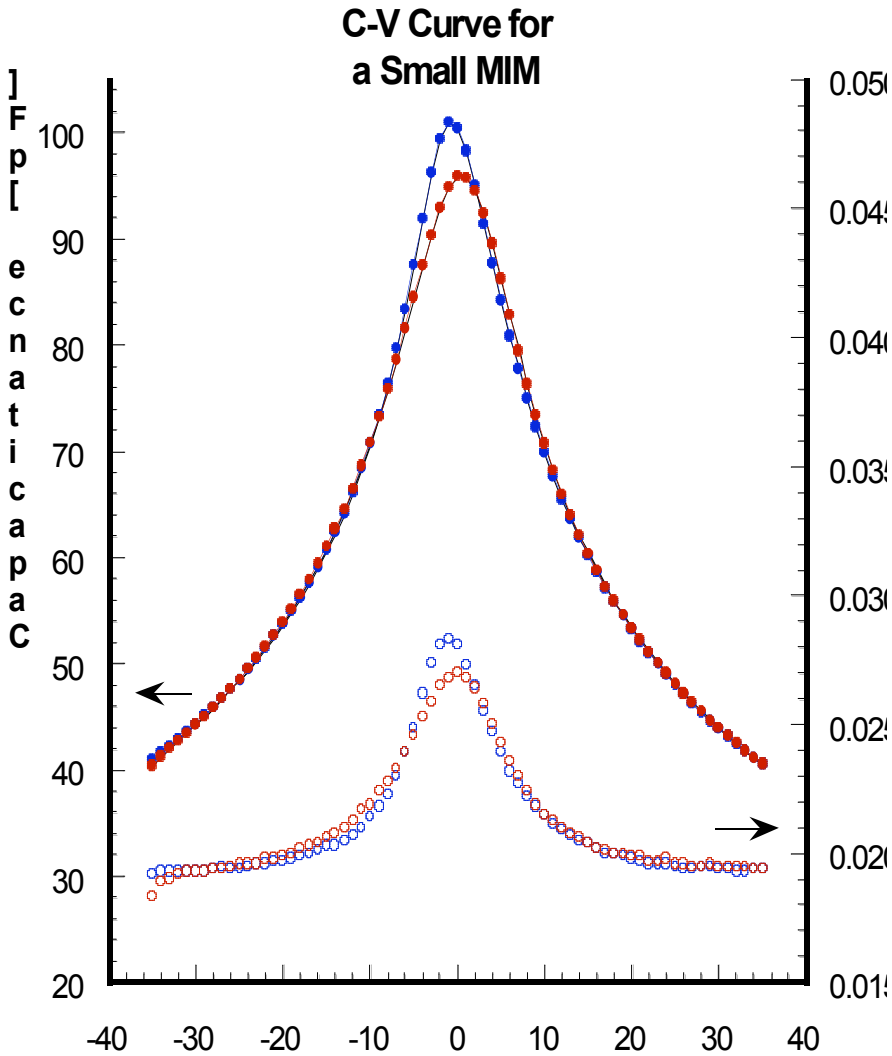
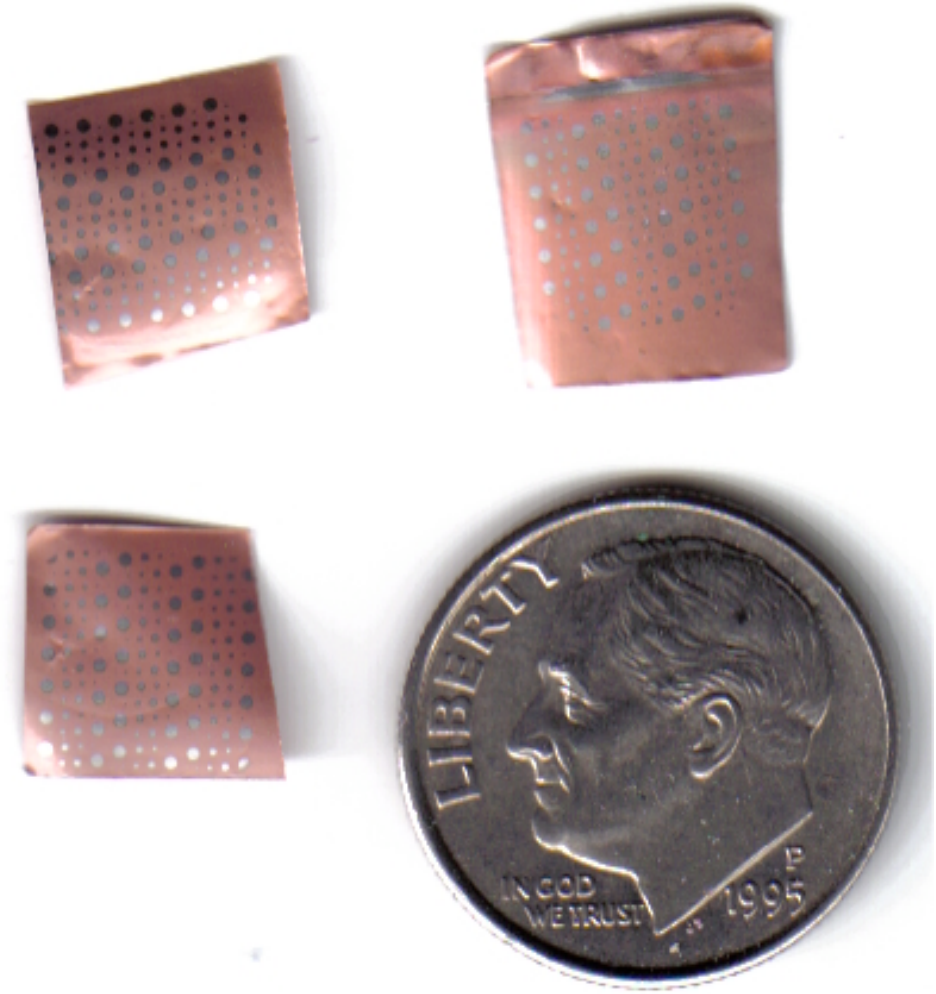
Still Using Varactors





Awaiting Unobtanium!





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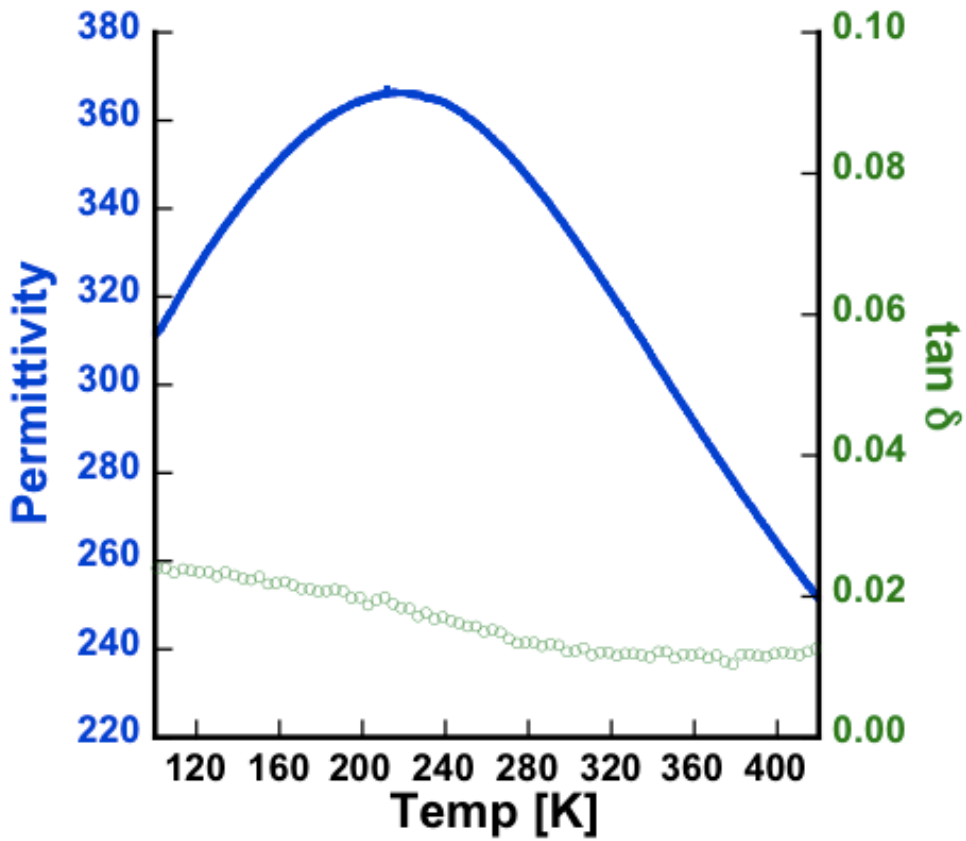
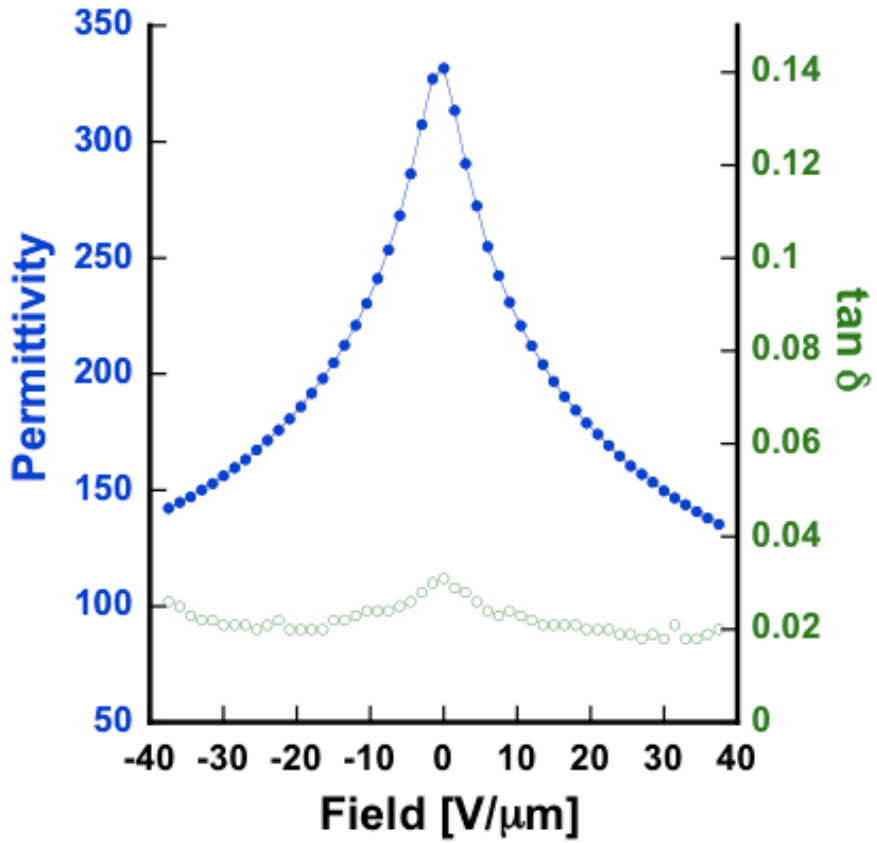
Thermal Stability





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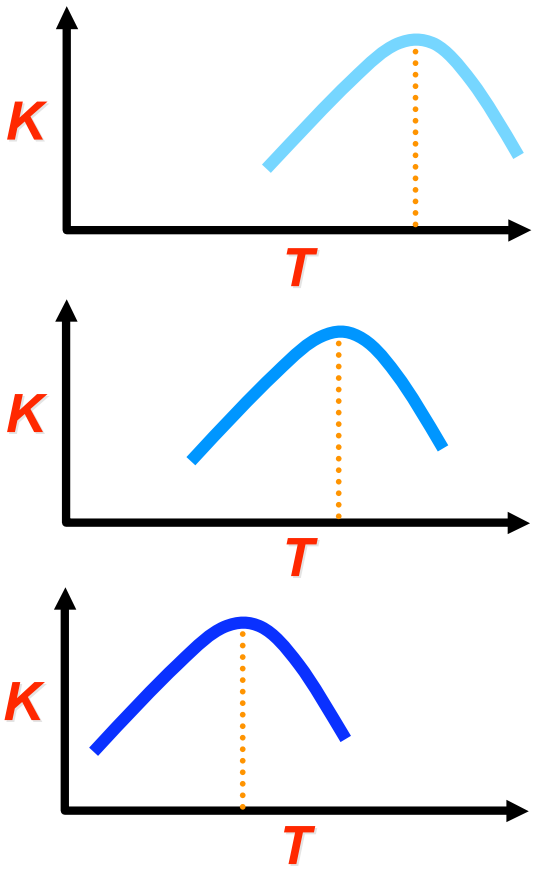
Nano-Engineered Dielectric Stack

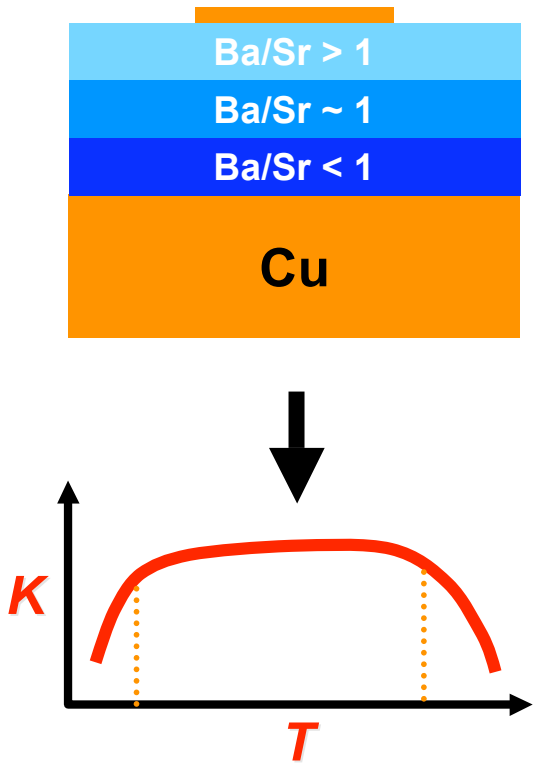


$$\frac{Ba}{Sr} > 1$$

$$\frac{Ba}{Sr} \approx 1$$

$$\frac{Ba}{Sr} < 1$$

superposition



Superposition of three layers gives broad temperature window with small temperature dependence

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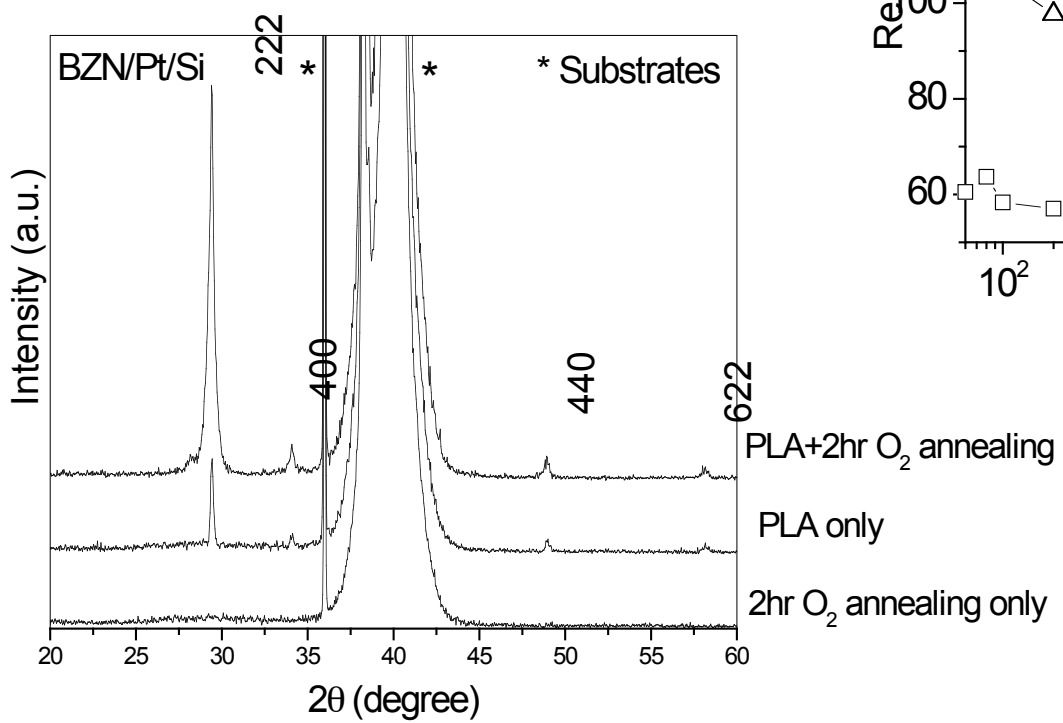
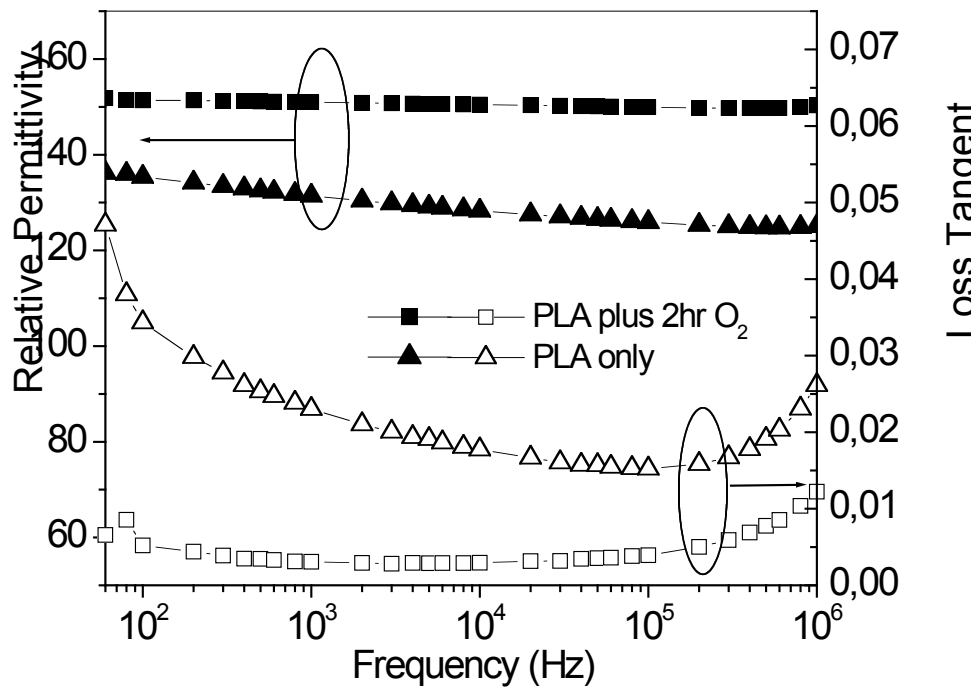
Pulse Laser Annealing





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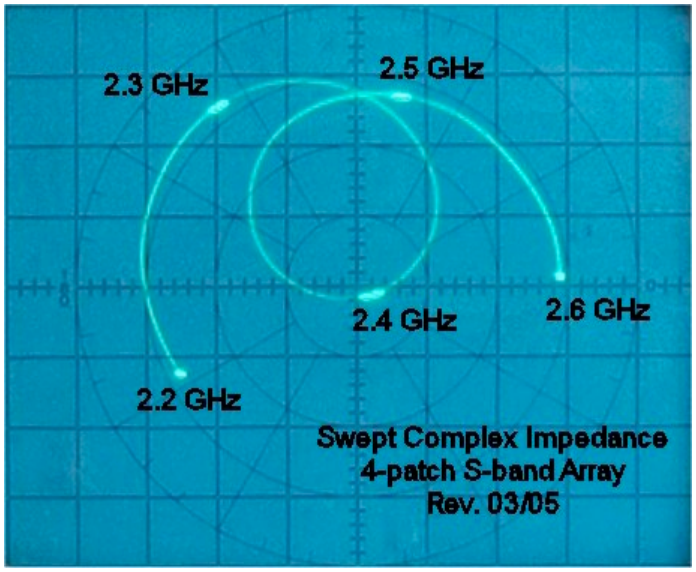
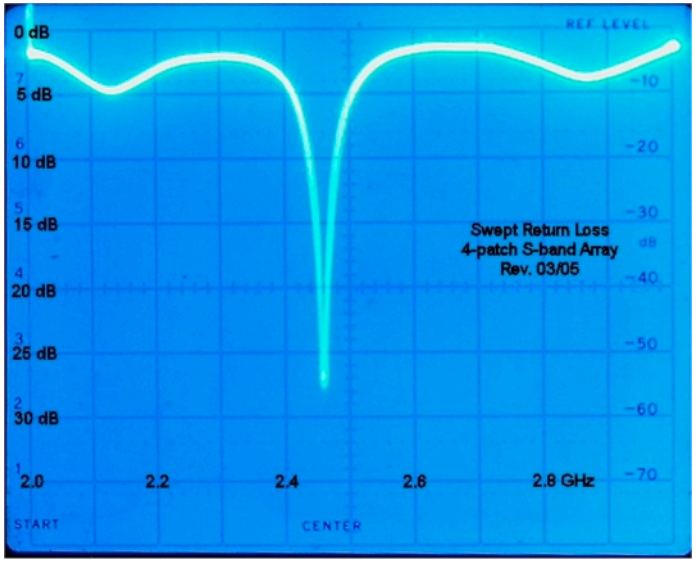
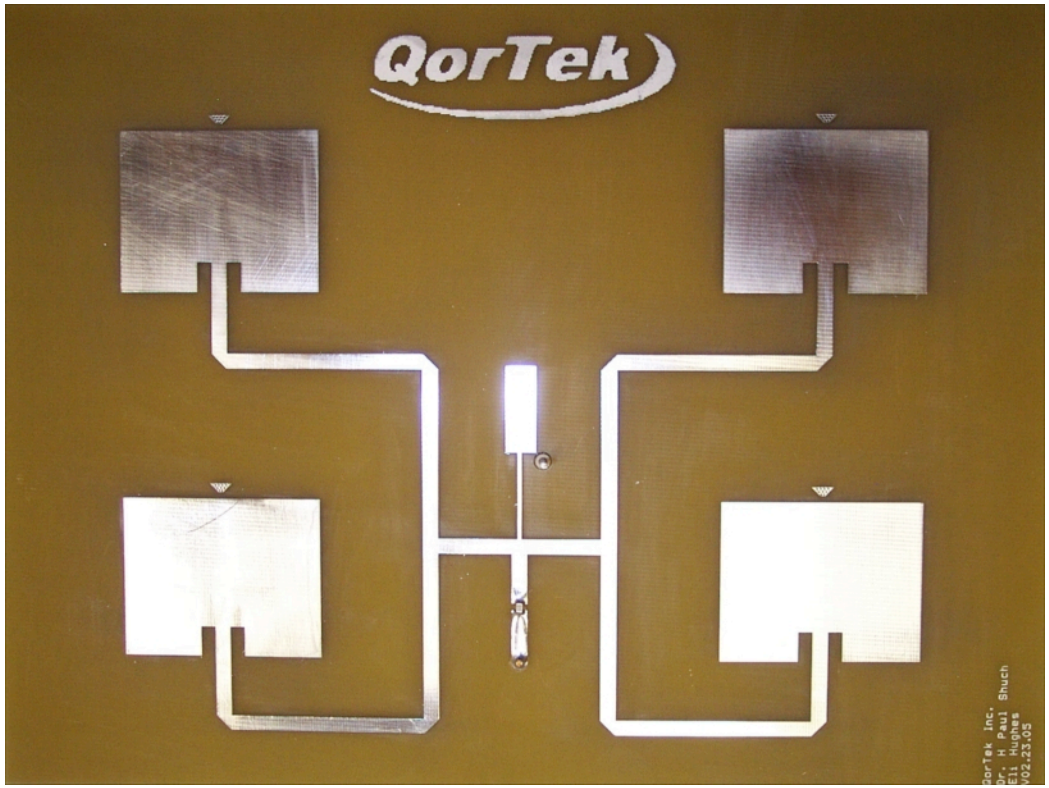
Four-Element Test Substrate Performance Sweeps, prior to addition of tuning elements







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Key Design Features

- Active Substrate
- Electrostatic Tuning
- Locally Tunable
- Minimizes discrete components
- Eliminates active devices
- No switching in the RF path
- Antenna elements and beam forming circuitry all share a common substrate

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Design Advantages

- Phased Array Of Multiple Patch Antennas
- Steerable by either Quadrant or Matrix
- Dynamic, Electrostatically Tunable Substrate
- Adjustable Frequency via Applied DC Potential
- Adjustable Azimuth via Applied DC Potential
- Adjustable Elevation via Applied DC Potential
- Adjustable Beamwidth via Applied DC Potential
- Adaptive Beamforming via Applied DC Potentials

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Conformal Antenna Test Unit

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Applicable NASA Missions

- Mars Subsurface Hydrology –
  survey from polar orbit for water and CO_2 ices
  [chirped UHF GPR]
- Global Topography Mapping Mission –
  high resolution, digital topography mapping
  [L-band SAR]
- Ocean Phenomenology Mission –
  low-wind wakes and high-wind mountain waves that form in the atmosphere downwind of rugged islands
  [L-/C-band SAR]
- Dual Frequency, Multi-Polarization Global Mapping - biomass and soil moisture, and provide high resolution

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Sample Spacecraft Application

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Other Applications

- Satellite Television
- Mobile wireless networking
- Aerospace Telemetry
- Remote Sensing
- Weather Monitoring
- Air Traffic Control
- Missile Defense
- Electronic Countermeasures
- Command, Control, Communications & Intelligence
- National Defense and Homeland Security

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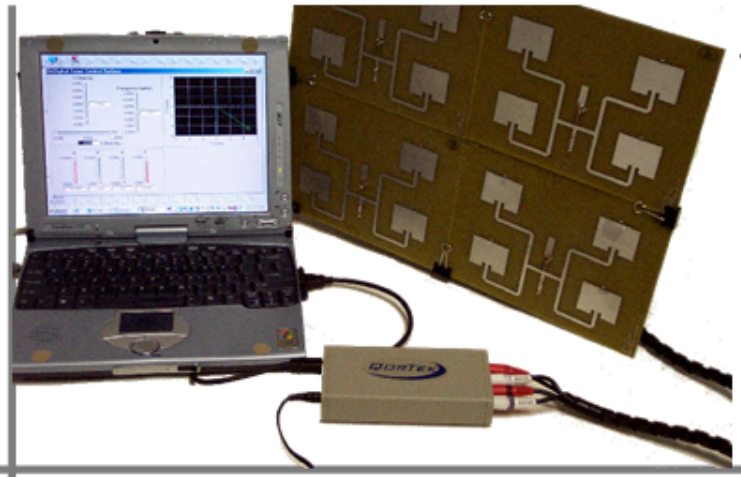
Multiband Reconfigurable Synthetic Aperture Radar Antenna

Project: NAS5-03014 **PI: Dr. H. Paul Shuch, QorTek Inc. (pshuch@qortek.com)**

Description and Objectives

- Project combines advanced antenna engineering concepts with Active Tuned Dielectric Materials (ATDM) to achieve both tuning and steering by electronic means
- Provides thin, lightweight, reconfigurable, and conformal multiband antenna arrays
- Enhances the capability of NASA to deploy space-based Synthetic Aperture Radar (SAR) systems by designing frequency agile phased array antennas



SAR 16-patch antenna array prototype is validated for computerized steering and tuning using QorTek's new GUI - based Digital Array Controller

Approach

Synthesis of three distinct technologies:

- tunable dielectrics
- quadrant steering architecture
- microprocessor tuning/pattern control

to enable frequency and pattern agile multiband capability on thin, flexible substrates

Partners

Prof. Susan Trolier-McKinstry, Penn State Univ.

Dr. Jon-Paul Maria, North Carolina State Univ.

Schedule Milestones and Deliverables

	Target
Year 1: 4-Patch Sub-array Breadboard	January 2004
Year 2: 16-Patch Steerable Array Prototype	December 2004
Year 3: SARSAD (SAR Small Array Demonstrator) Migrated to Tunable Dielectric Substrate (In process, behind schedule – awaiting ATDM)	December 2005

Applications

- L - Global Topography Mapping Mission: high resolution, digital topography mapping
- L/C - Ocean Phenomenology Mission: low-wind wakes and high-wind mountain waves that form in the atmosphere downwind of rugged islands
- L/X - Dual Frequency, Multi-Polarization Global Mapping SAR Mission: biomass and soil moisture, and provide high resolution regional-scale measurements

TRL = 3

Revised: 7 July 2005

Keywords: NASA Earth Science Technology Office, Instruments, Active Microwave, Synthetic Aperture Radar

Acknowledgments

- NASA ESTO ACT contract NAS5-03014
- Ms. Janice Buckner, ESTO technical representative
- Dr. Susan Trolier-McKinstry, Co-I, Pennsylvania State University
- Dr. Jon-Paul Maria, Co-I, North Carolina State University
- Dr. Daniel D. Evans, External Reviewer, Aerospace Corporation

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