Built from Unobtanium:

An ATDM Multiband Reconfigurable Synthetic Aperture Radar Antenna

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VP & Chief Technology Officer, QorTek, Inc.

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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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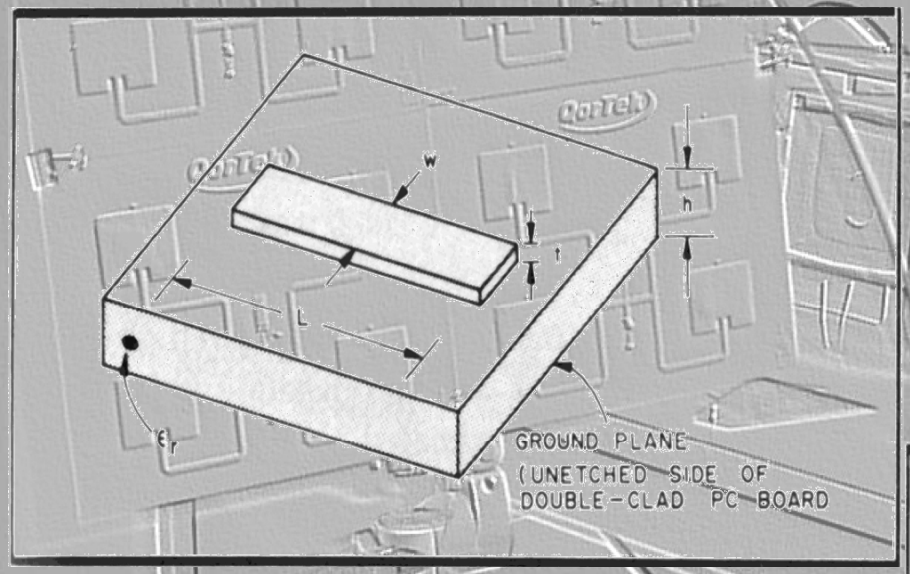
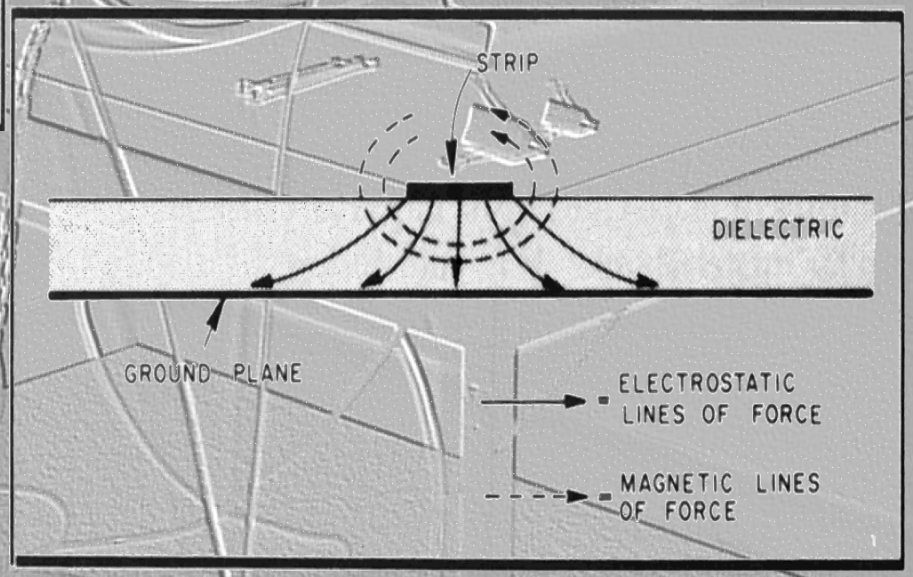
Microstrip Basics



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



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

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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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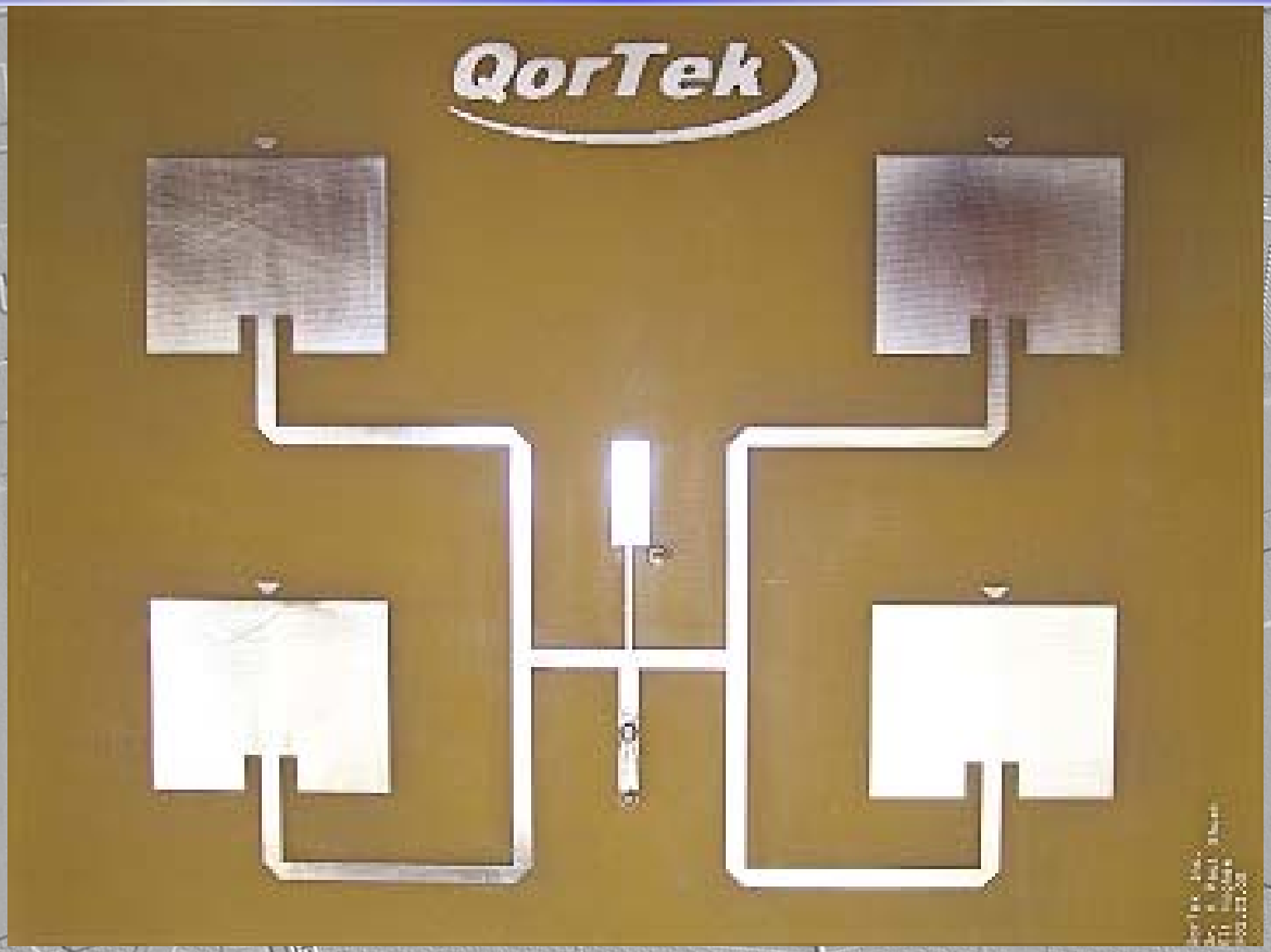

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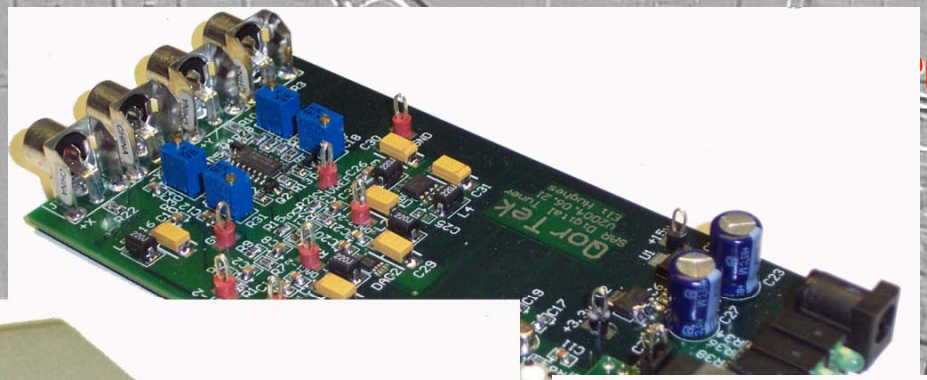

ray Controller

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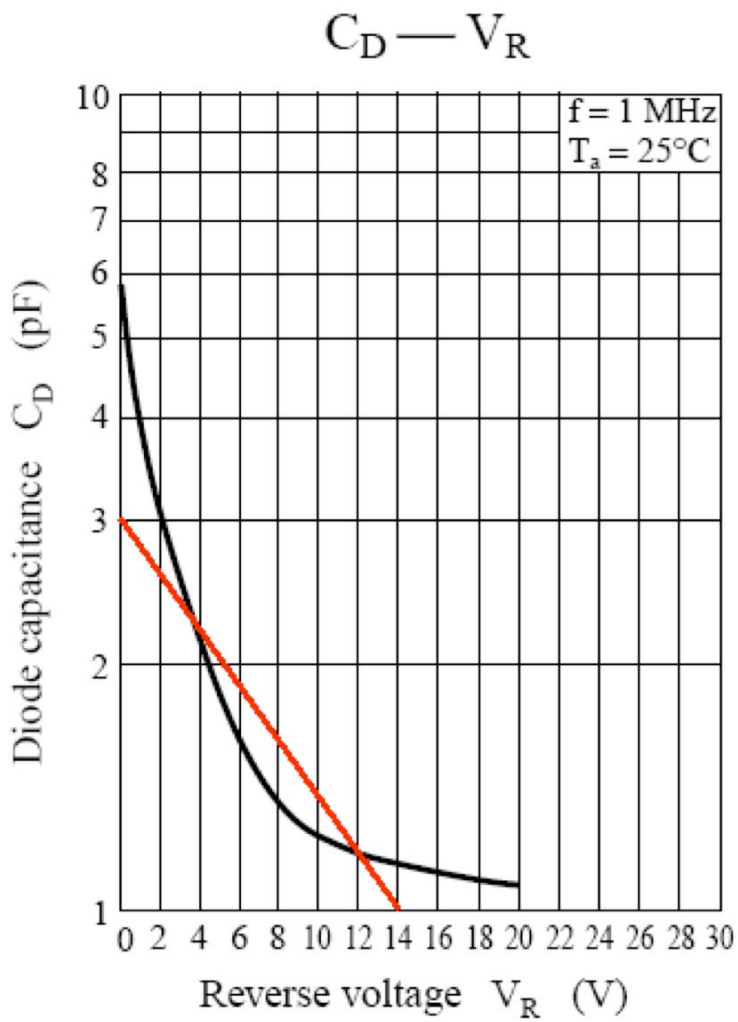

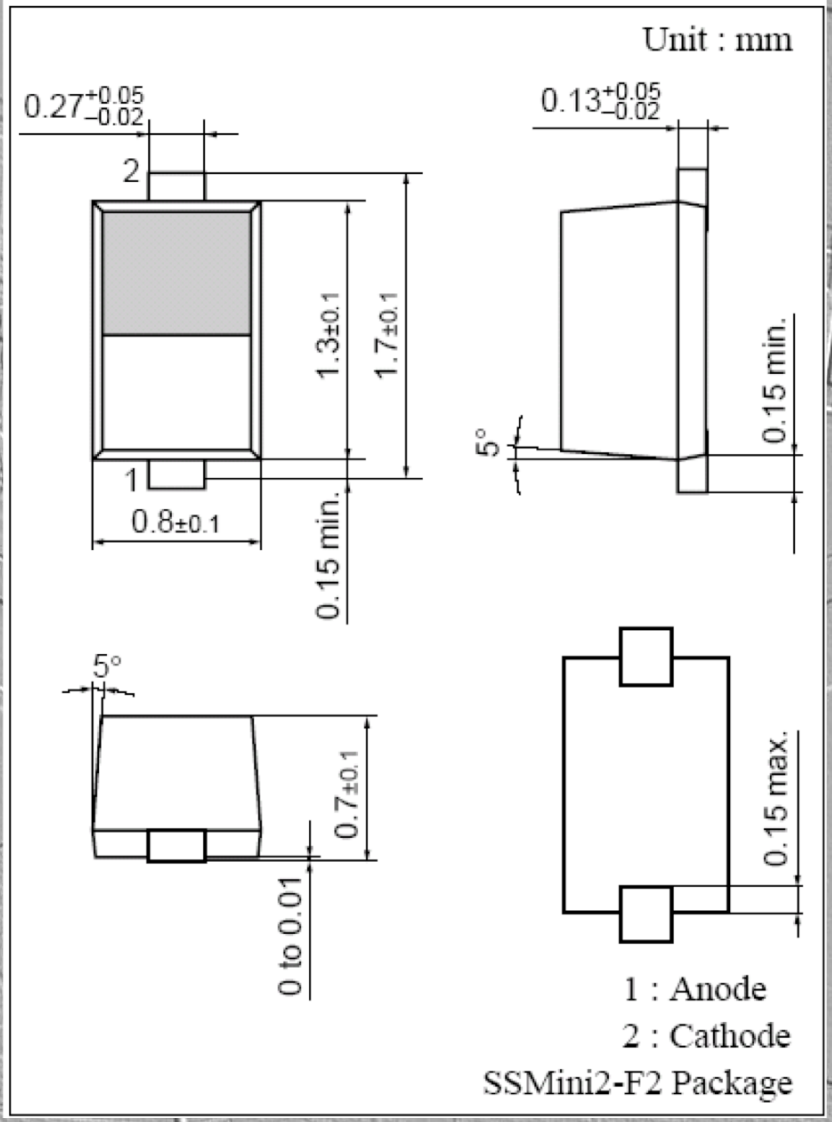

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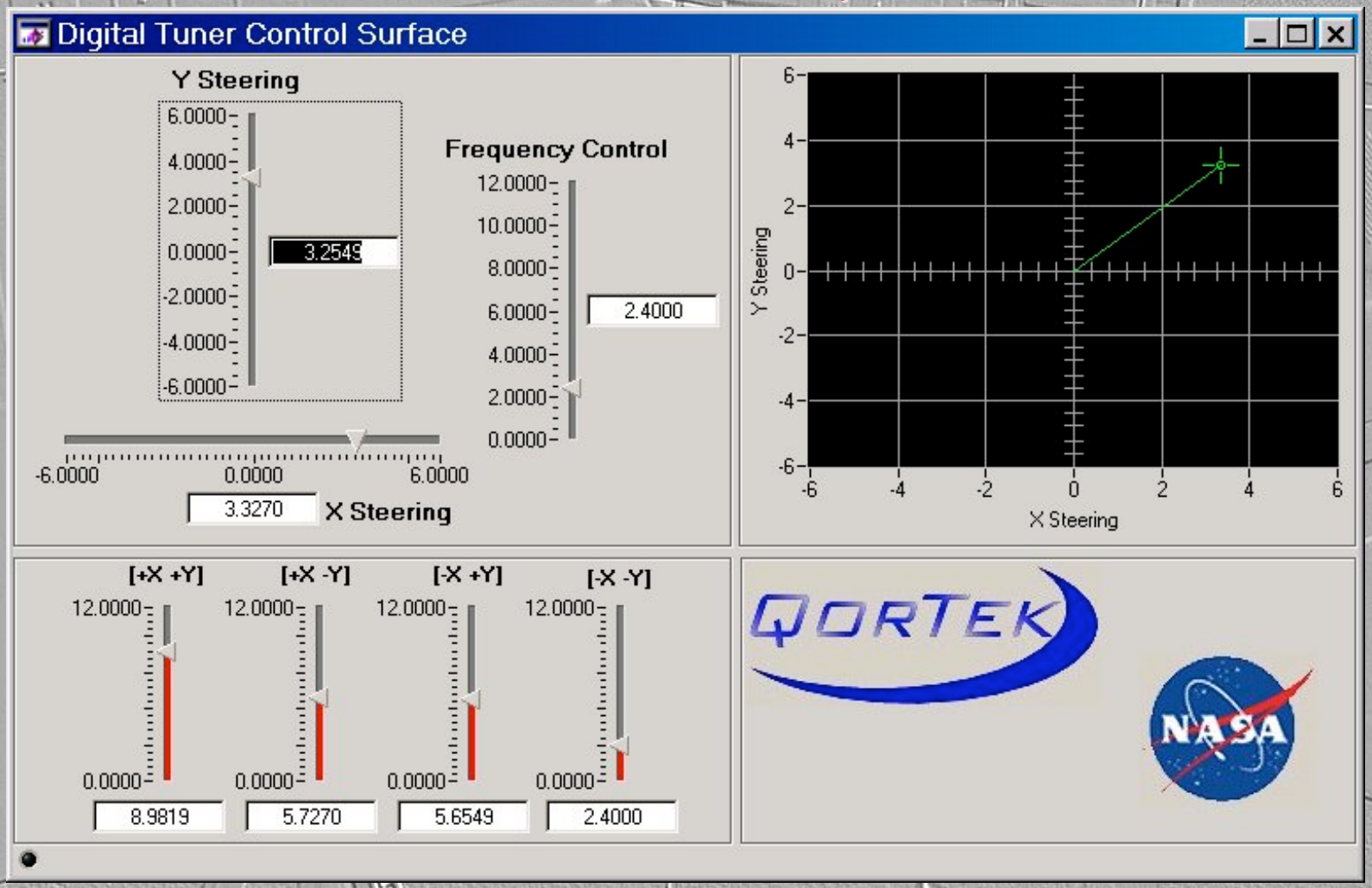
Graphical User Interface



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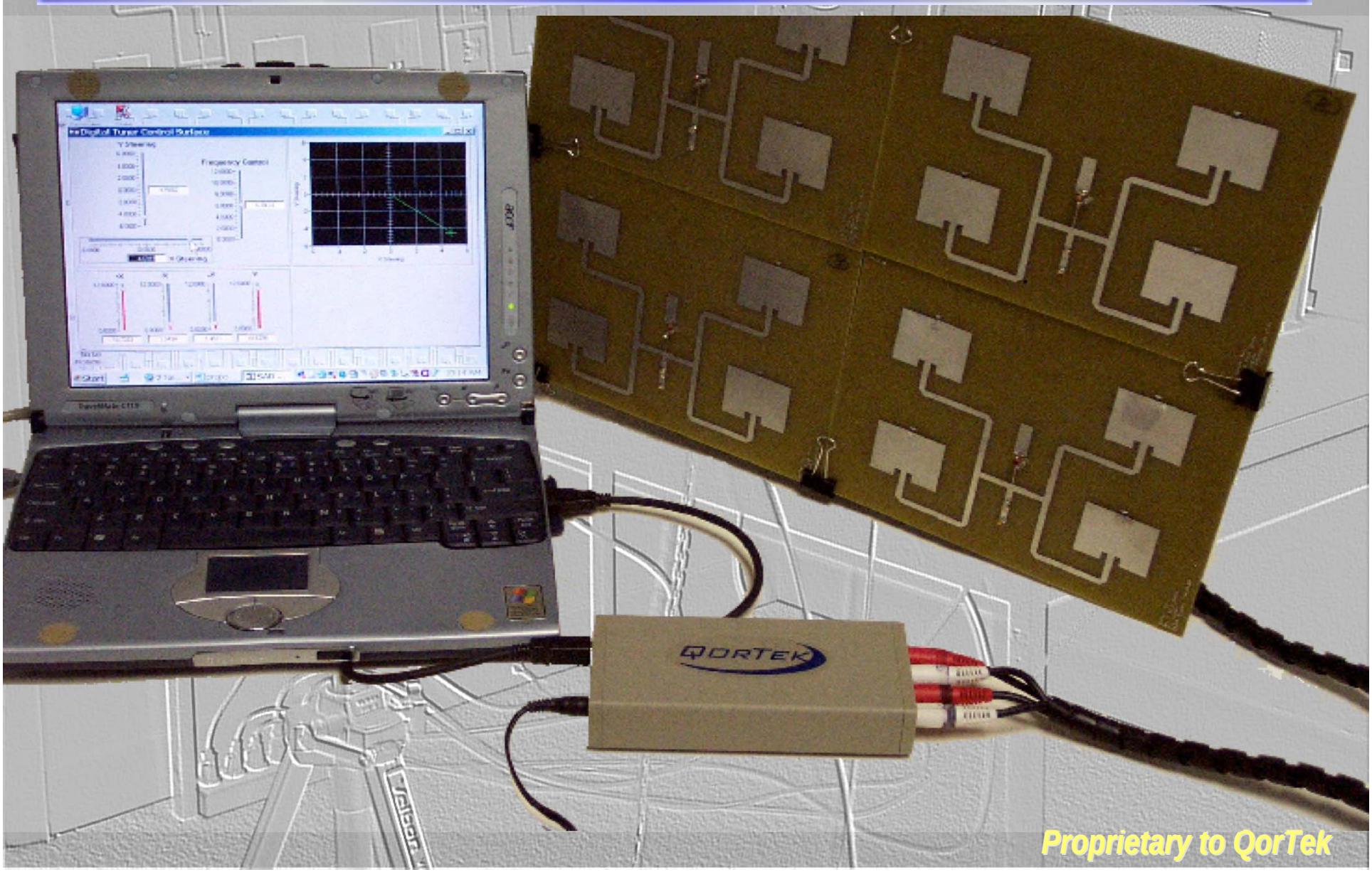

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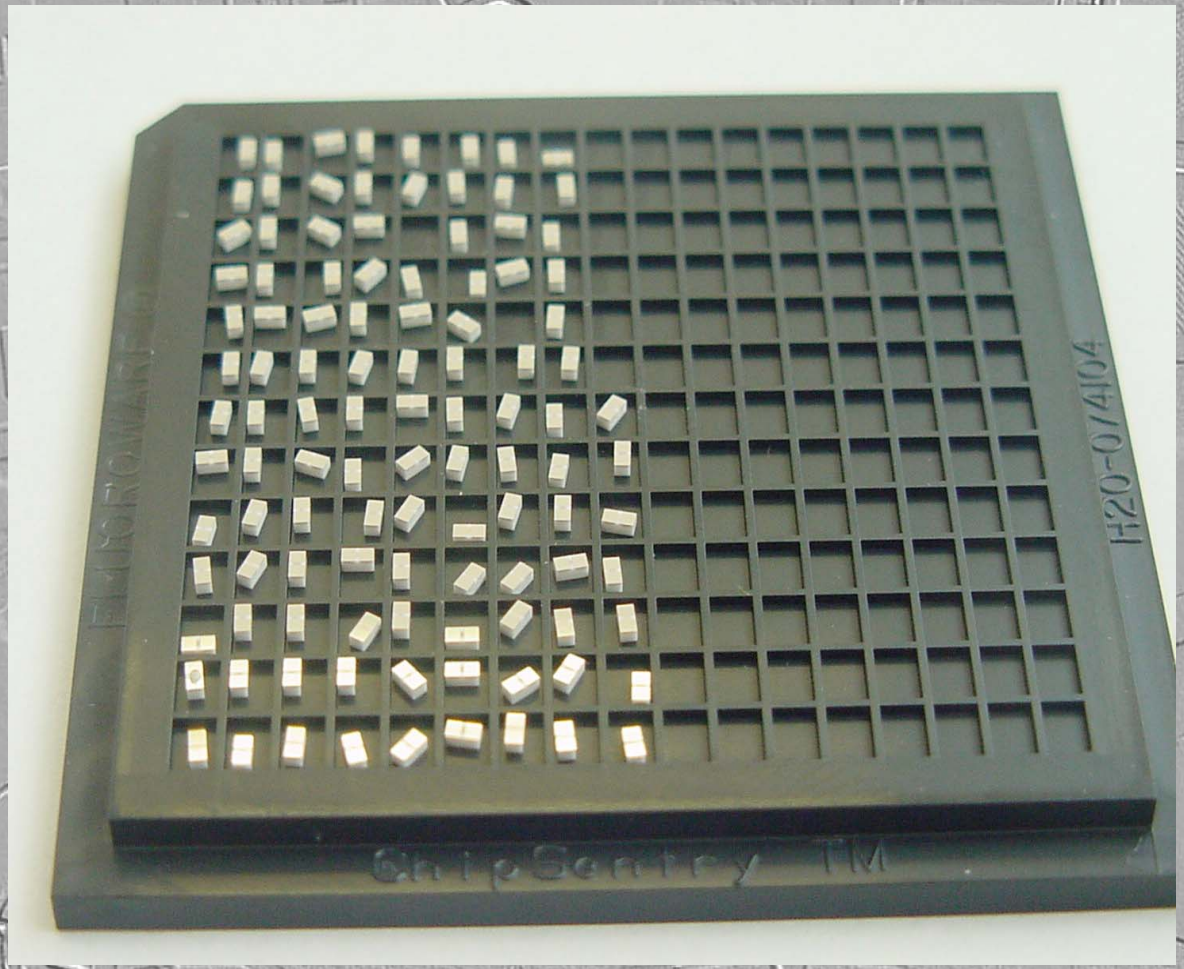

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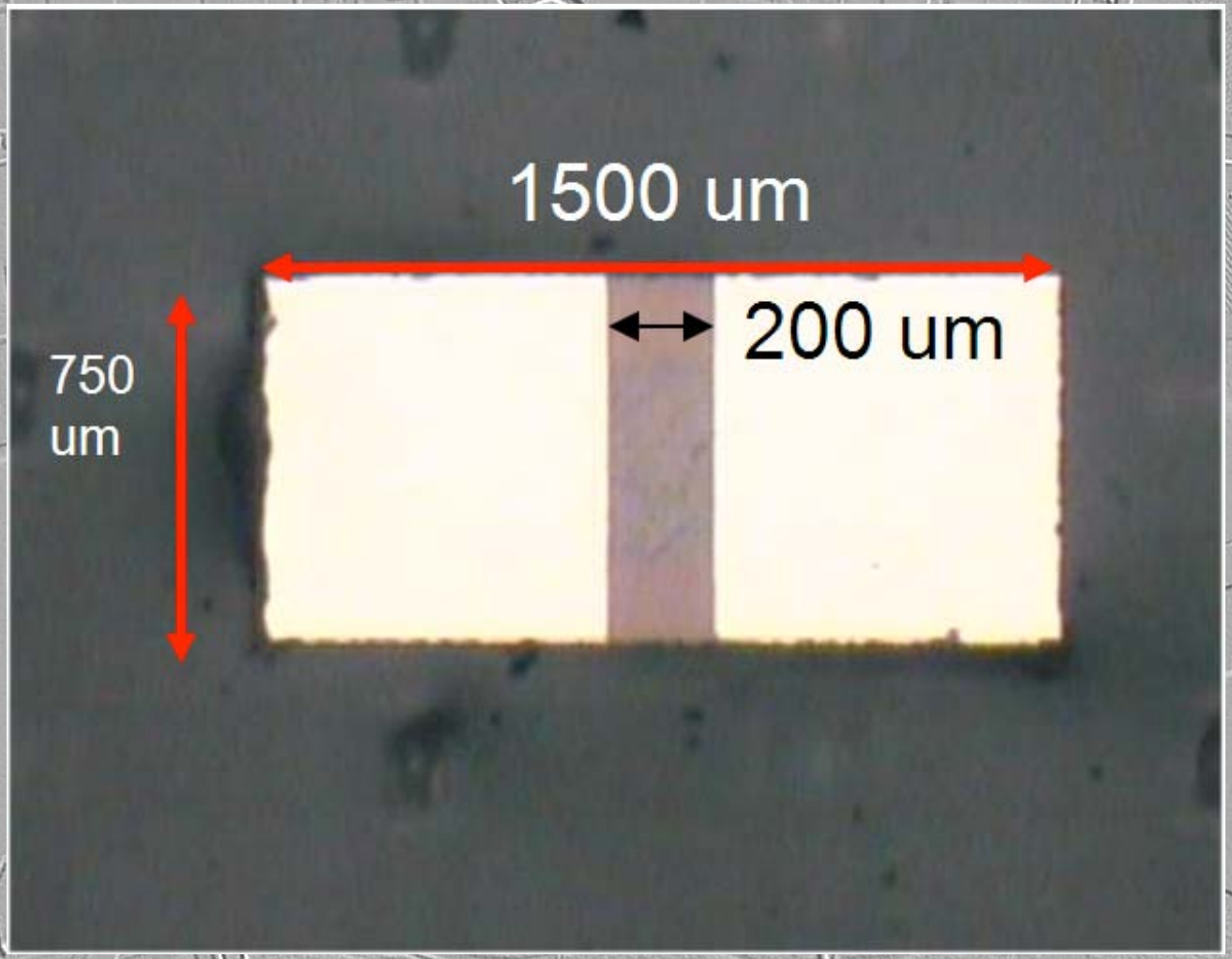

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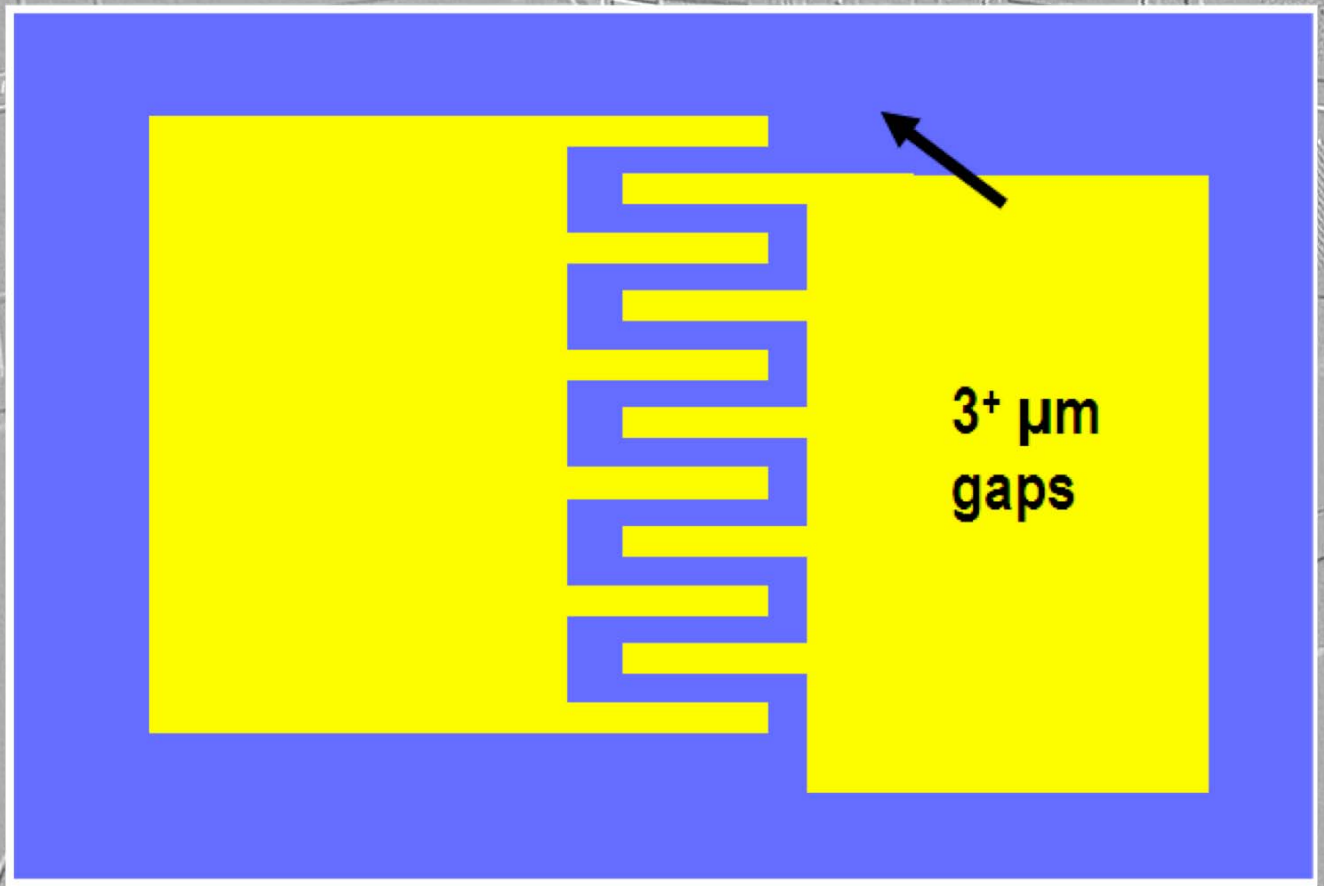

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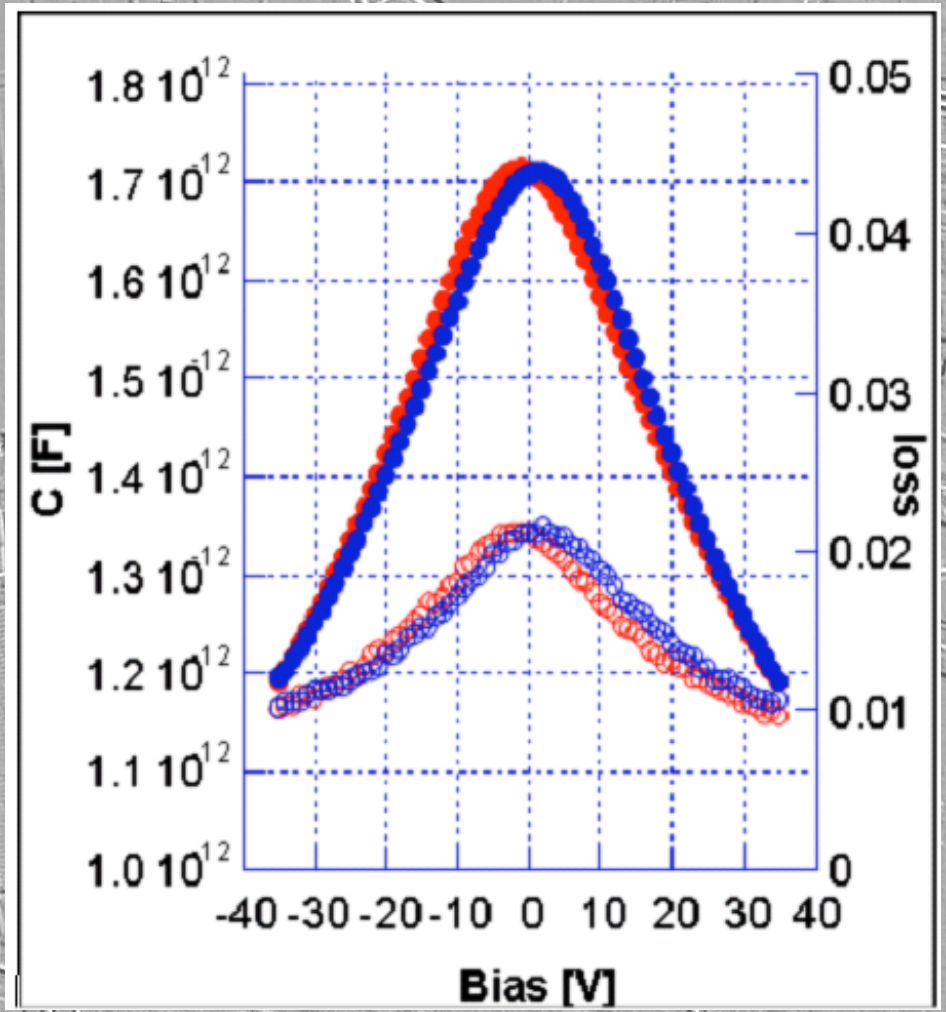

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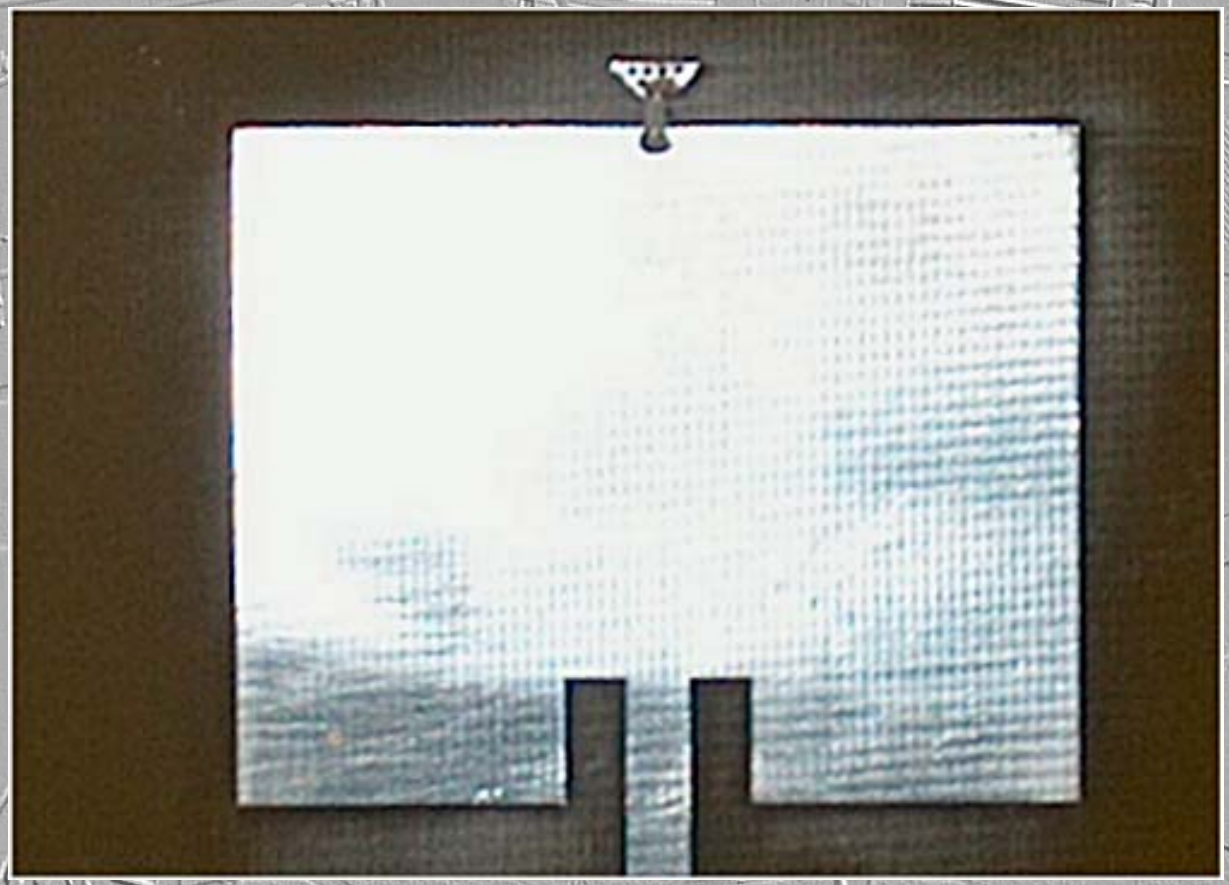

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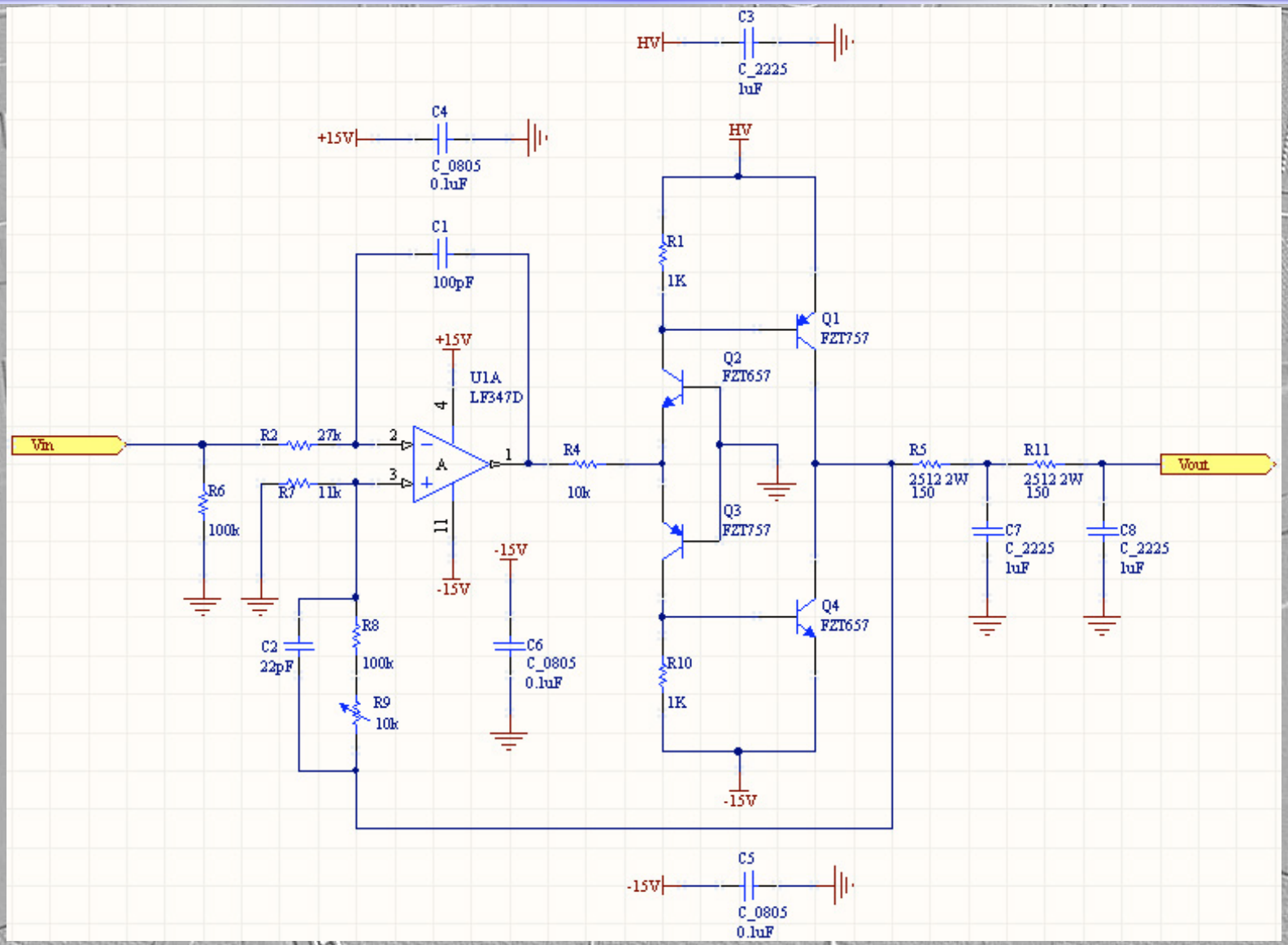

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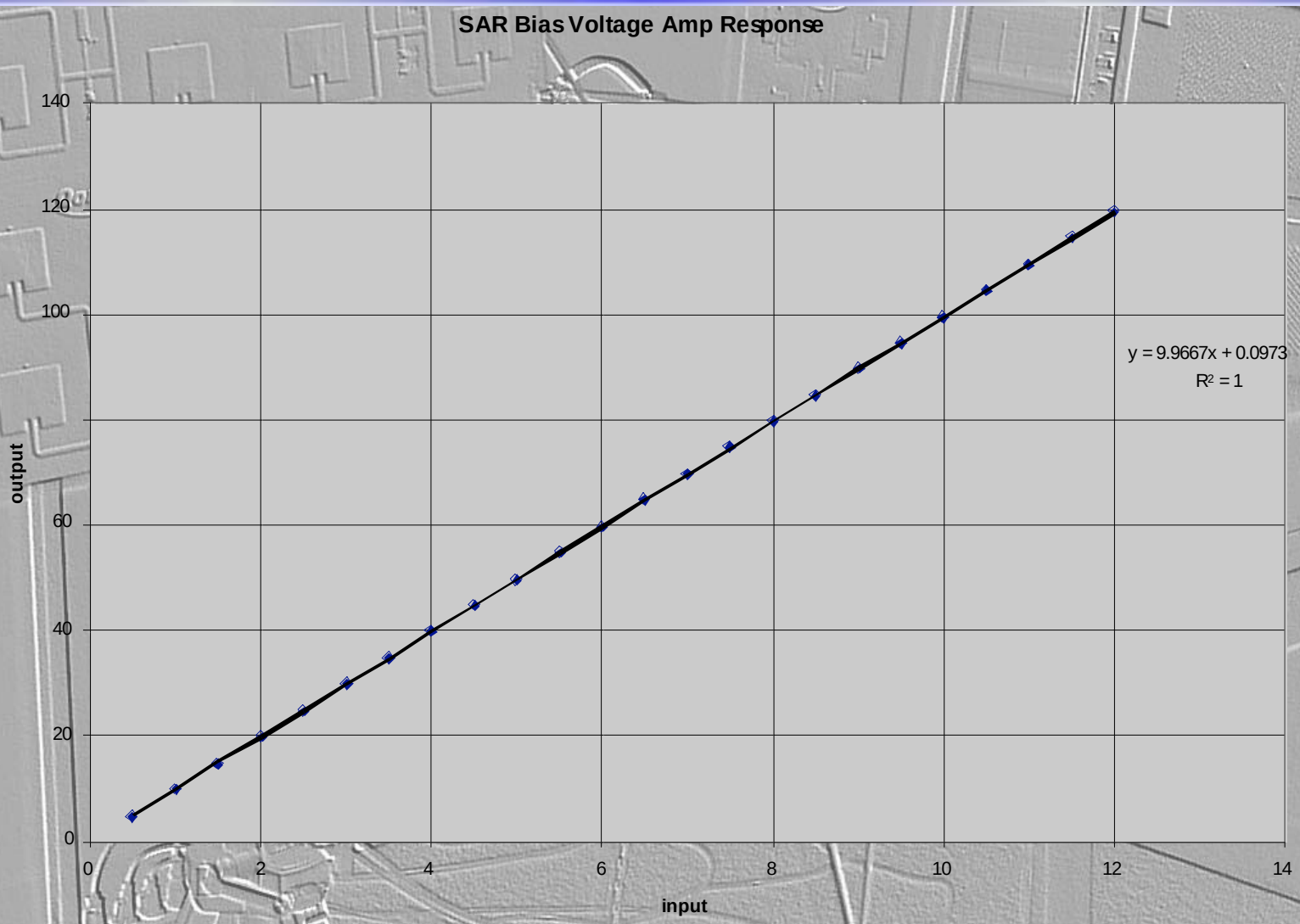

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```
GetCtrlVal(MainCtrl,MAIN_CTRL_FSTEER,&VFSteer);
GetCtrlVal(MainCtrl,MAIN_CTRL_XSTEER,&VXSteer);
GetCtrlVal(MainCtrl,MAIN_CTRL_YSTEER,&VYSteer);

/*
To steer right, V(+X,+Y) and V(+X,-Y) increase
            V(-X,+Y) and V(-X,-Y) unchanged.

To steer left,  V(-X,+Y) and V(-X,-Y) increase
            V(+X,+Y) and V(+X,-Y) unchanged.

To steer up,    V(+X,+Y) and V(-X,+Y) increase
            V(+X,-Y) and V(-X,-Y) unchanged.

To steer down,  V(+X,-Y) and V(-X,-Y) increase
            V(+X,+Y) and V(-X,+Y) unchanged.

*/

Tpxpy = VFSteer;
Tpxmy = VFSteer;
Tmxpy = VFSteer;
Tmxmy = VFSteer;
if(VFSteer <= 6)
{
        if(VXSteer > 0)
        {
            Tpxpy += VXSteer;
            Tpxmy += VXSteer;
        }
        if(VXSteer < 0)
        {
            Tmxpy -= VXSteer;
            Tmxmy -= VXSteer;
        }
        if(VYSteer > 0)
        {
            Tpxpy += VYSteer;
            Tmxpy += VYSteer;
        }
        if(VYSteer < 0)
        {
            Tpxmy -= VYSteer;
            Tmxmy -= VYSteer;
        }
}
else
{
        if(VXSteer > 0)
        {
            Tmxpy -= VXSteer;
            Tmxmy -= VXSteer;
        }
        if(VXSteer < 0)
        {
            Tpxpy += VXSteer;
            Tpxmy += VXSteer;
        }
        if(VYSteer > 0)
        {
            Tpxmy -= VYSteer;
            Tmxmy -= VYSteer;
        }
        if(VYSteer < 0)
        {
            Tpxpy += VYSteer;
            Tmxpy += VYSteer;
        }
```

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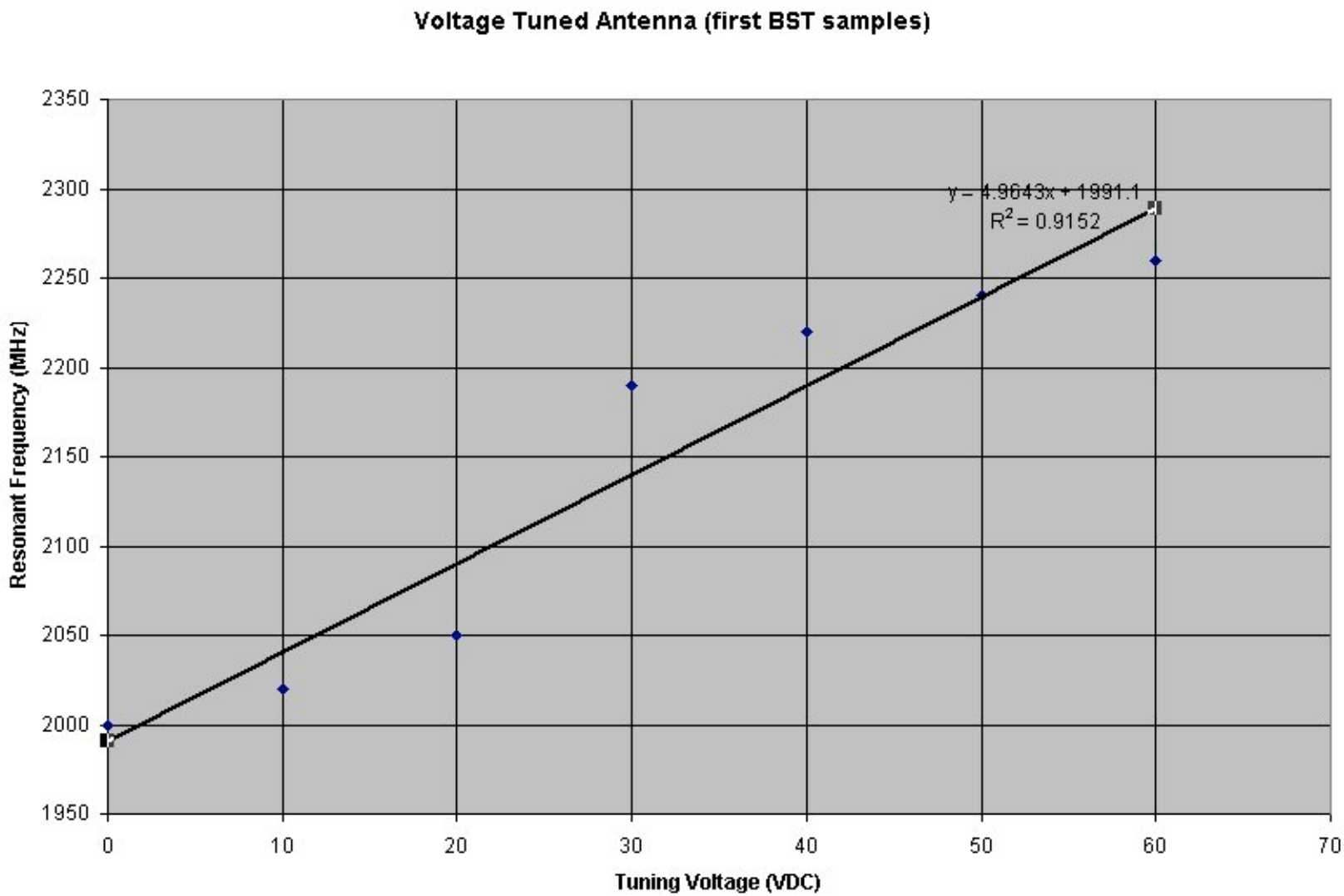
Tuning Linearity



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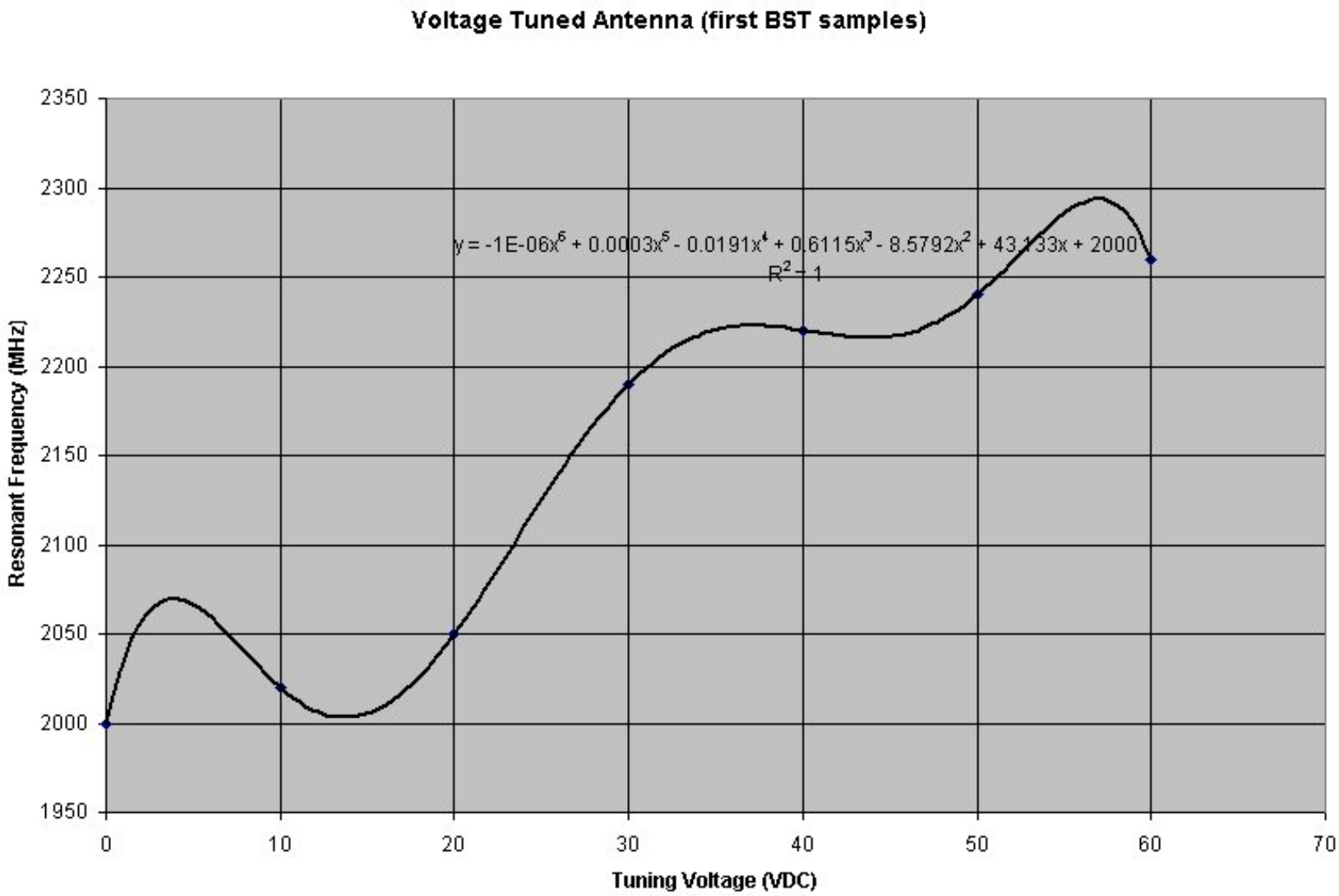
Tuning Linearity



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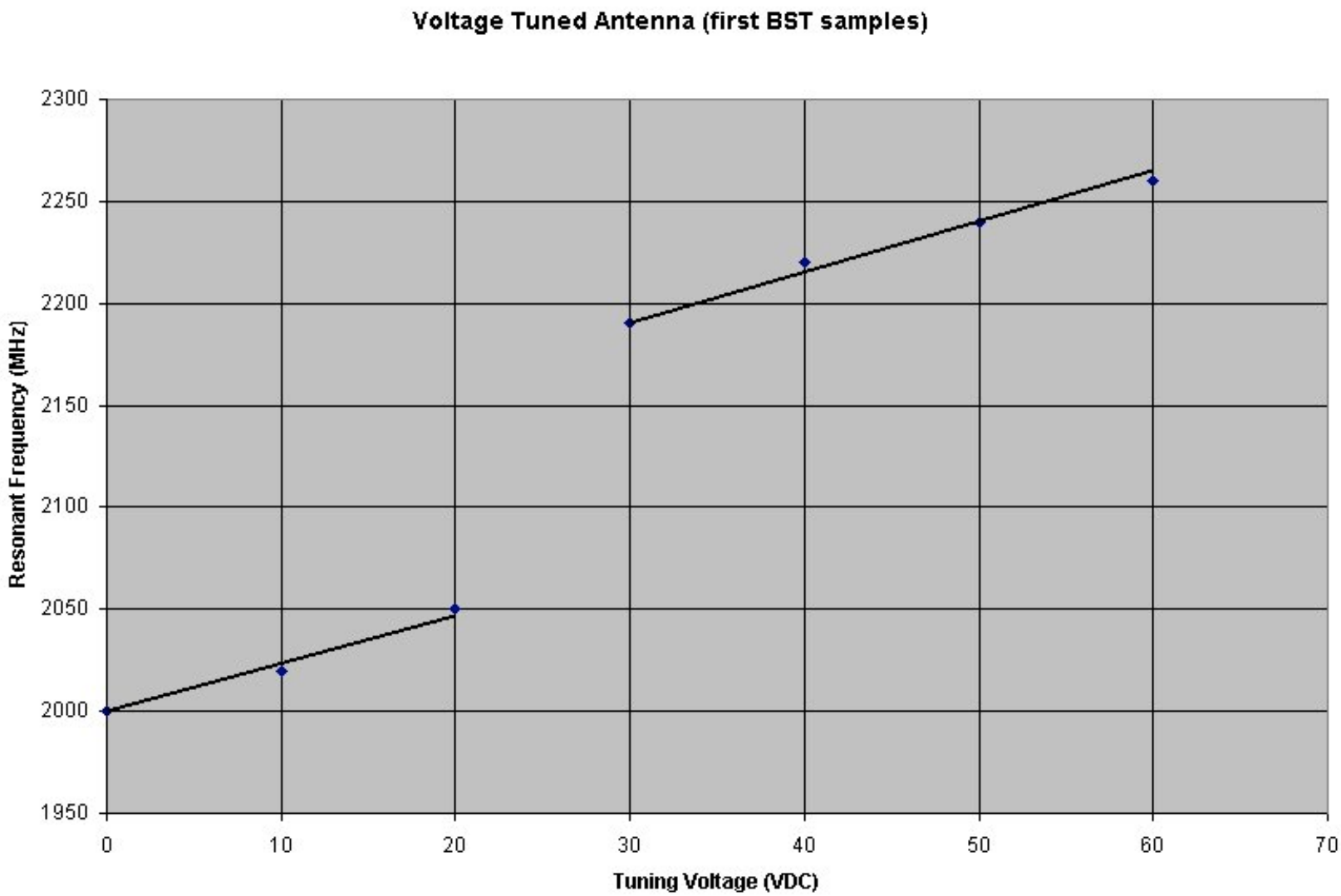
Tuning Linearity



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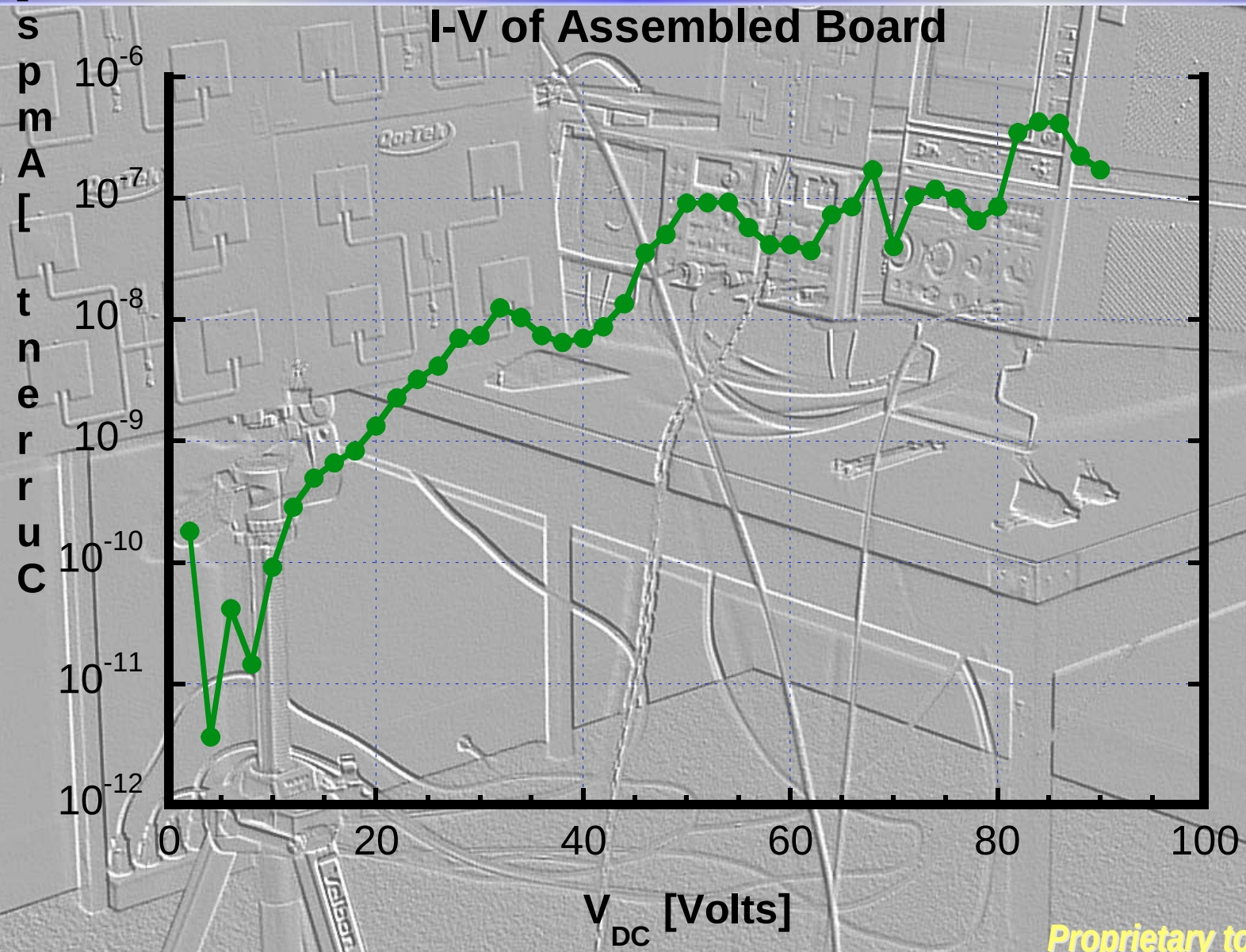
High Voltage Performance



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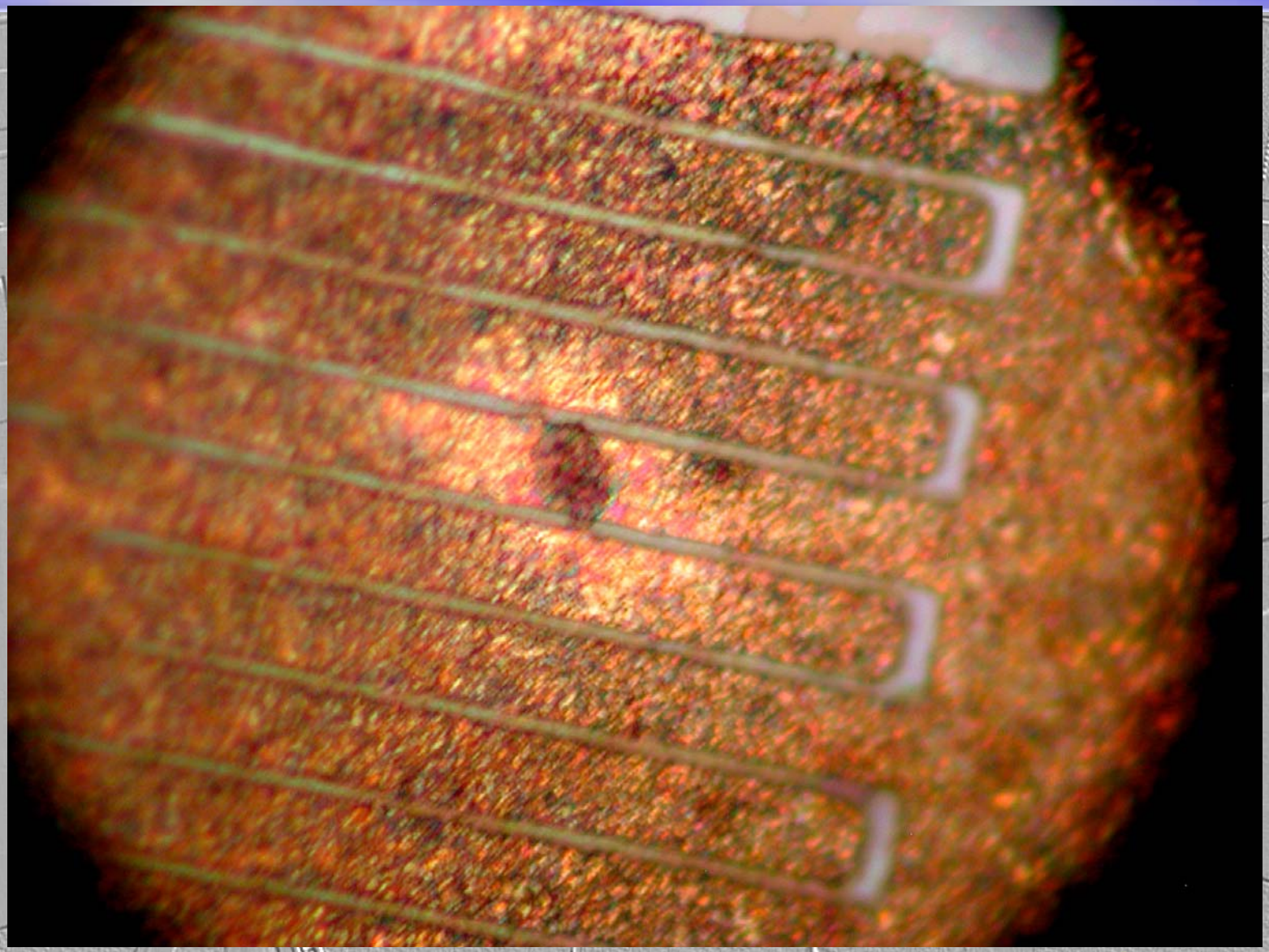
High Voltage Performance



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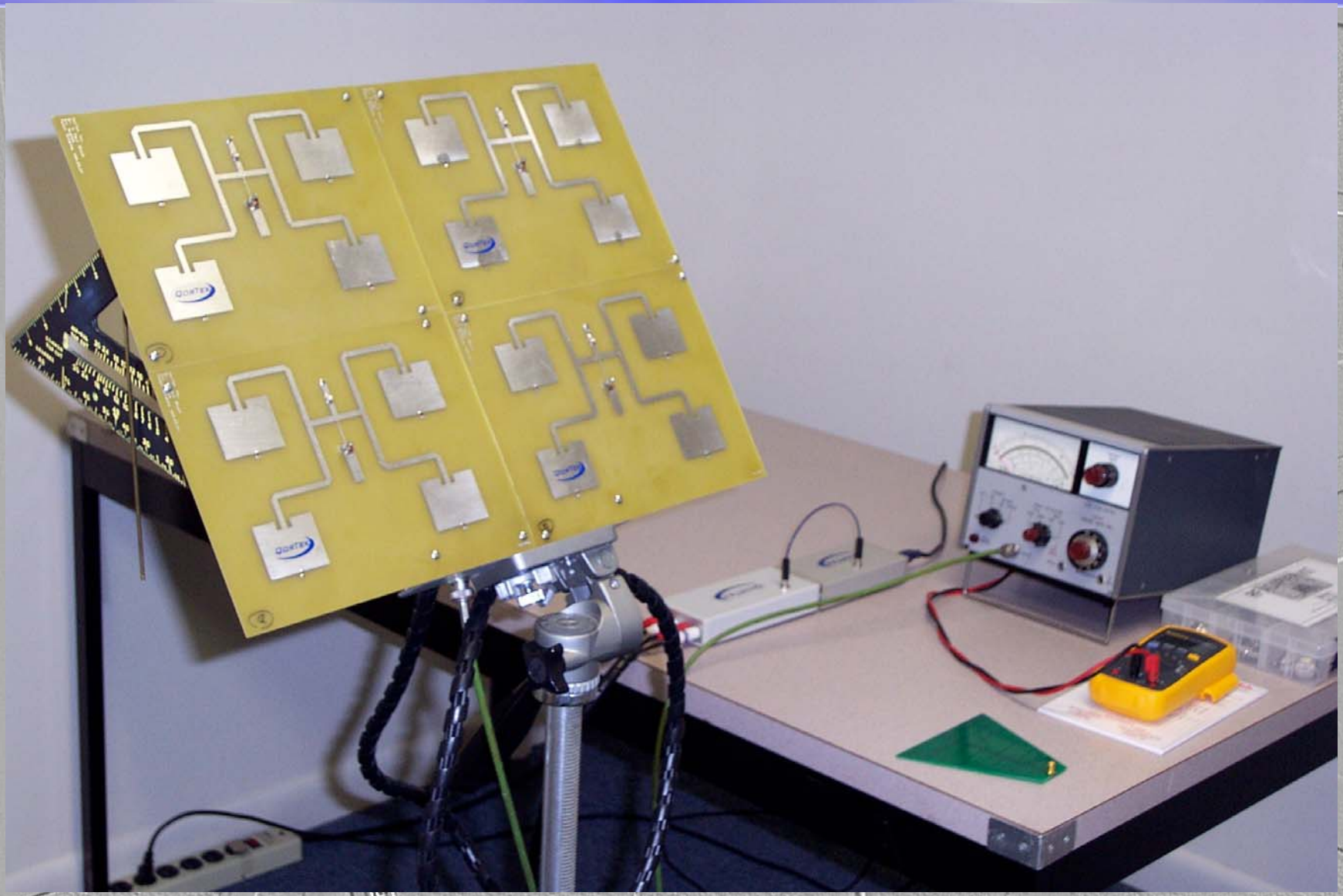
Antenna Range Testing



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Compact Antenna Range

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Initial Test Results:

Center Frequency	=	2.4 GHz			
Bandwidth	=	60 MHz	=	2.5	%
Loaded Q	=	40			
Tuning Range	~	300 MHz	=	12.6	%

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

Compact range, tested at mutual Rayleigh distance

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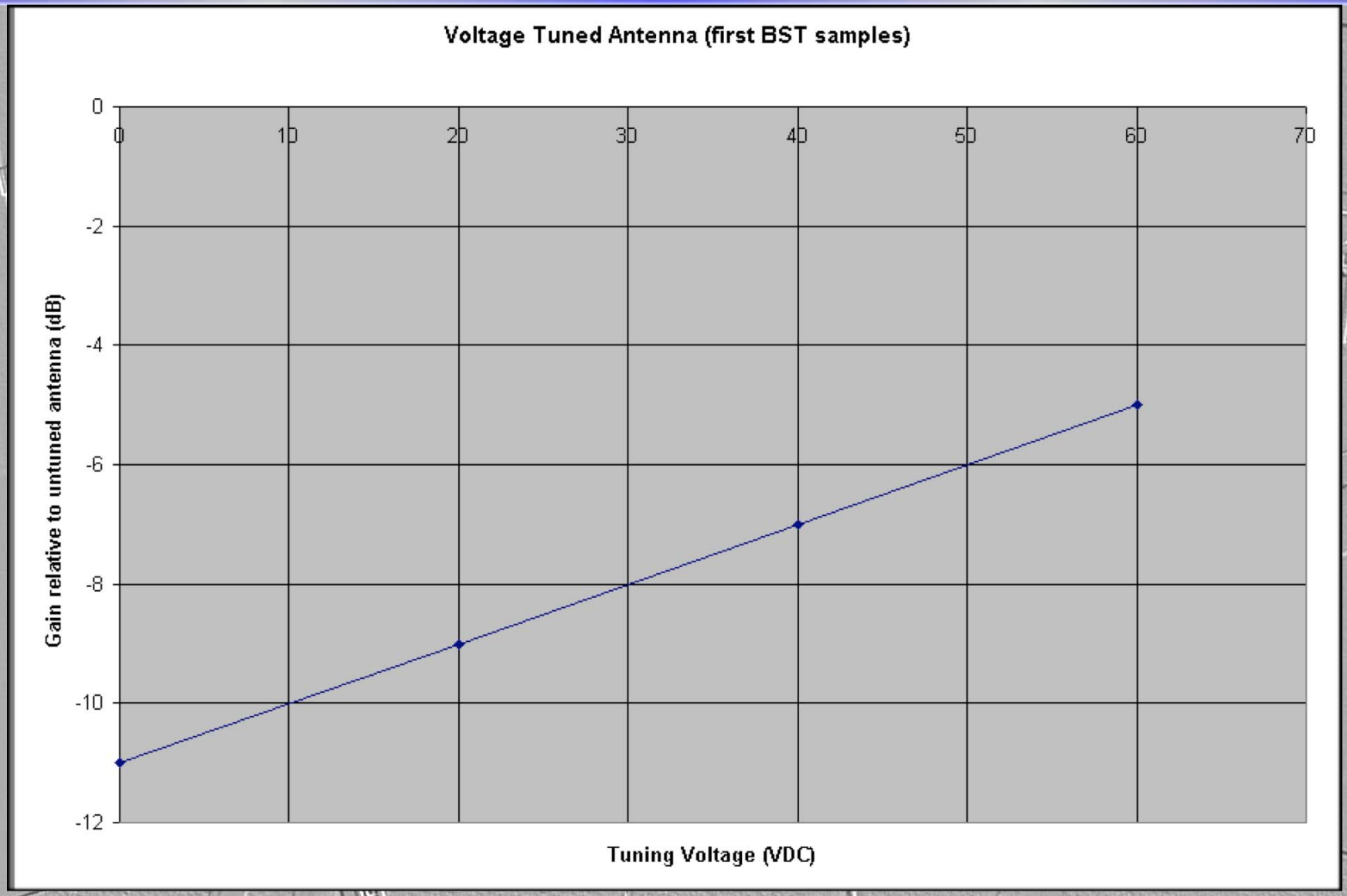
Initial Test Results:



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Current NASA Missions

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

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Future NASA Missions

- Ground Penetrating Radar – Mars surface analysis; Earth soil hydrology
- Interferometric Synthetic Aperture Radar
- Unmanned Aerial Vehicle Synthetic Aperture Radar – JPL UAVSAR program

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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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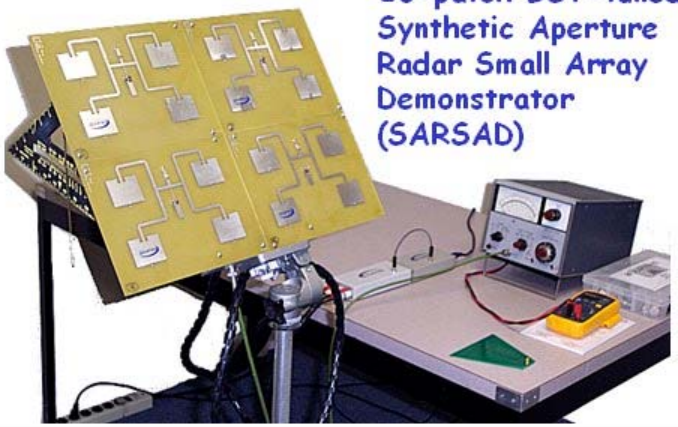
Final Accomplishments

Multiband Reconfigurable Synthetic Aperture Radar Antenna

Principal Investigator: Dr. H. Paul Shuch, Chief Technology Officer, QorTek Inc.

Objectives:

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



16-patch BST-tuned Synthetic Aperture Radar Small Array Demonstrator (SARSAD)

Accomplishments:

- Designed and prototyped various sixteen-patch steerable and tunable microstrip antenna arrays.
- Developed digital antenna controller hardware, software, and high-voltage interface for ATDMs.
- Explored the fabrication of pulse laser annealed Bismuth-Zinc-Niobate capacitors on Kapton.
- Fabricated low-value Barium-Strontium-Titanate interdigital variable capacitors on Alumina.
- Integrated BST capacitors as steering/tuning elements onto microstrip patch antenna substrates.
- Demonstrated limited frequency tuning and azimuth/elevation steering under computer control.
- Explored issues related to excessive dielectric losses and high-voltage breakdown of ATDMs.

Technology Development Partners:

Prof. Susan Trolier-McKinstry, Materials Research Laboratory, Pennsylvania State University
Dr. Jon-Paul Maria, Materials Science and Engineering Dep't, North Carolina State University

TRL in = 2 **TRL out = 4** **Submitted: 7 January 2006**

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- Dr. Jon-Paul Maria, Co-I, North Carolina State University
- Dr. Daniel D. Evans, External Reviewer, Aerospace Corporation

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PI Wearing Two Hats:

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VICE PRESIDENT AND CHIEF TECHNOLOGY OFFICER

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