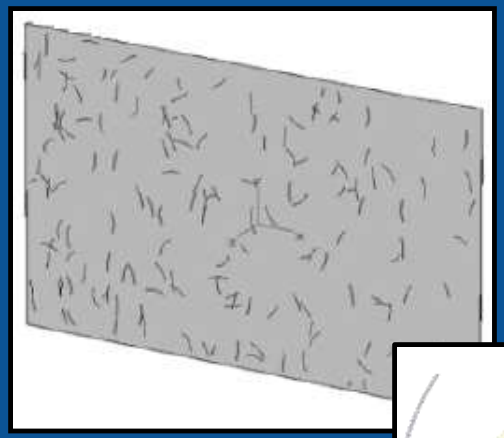
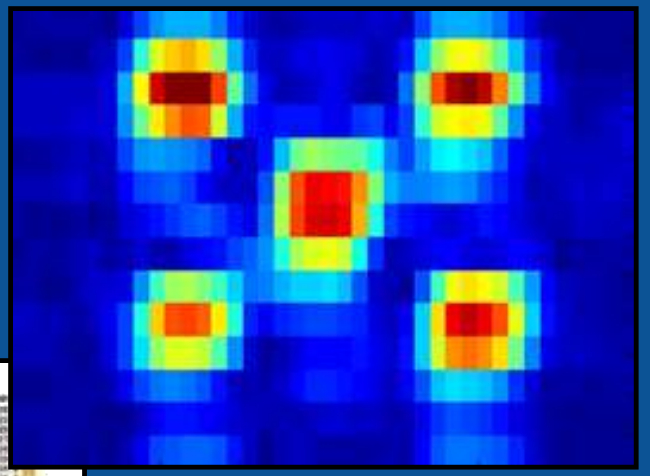
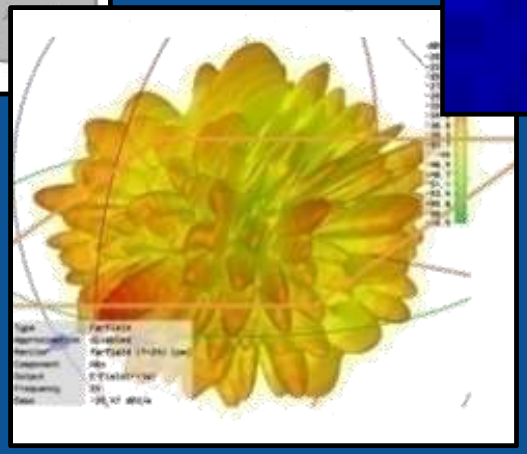
VERSA:

V-band Enhanced RFID/Sensing Architecture







Intelligent Engineering
with Maximum Centricity

Passive Wireless Sensor Tag Workshop
Houston, TX
7/27/2011

MaXentric
Technologies LLC

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- **Discussion**

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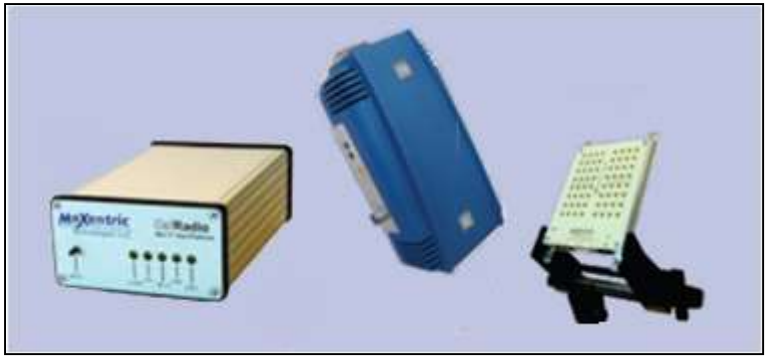
Wireless Systems

Developing next generation wireless technologies to introduce capabilities and enhance proficiencies.

V-band Wireless Network, Label Based RFID, Indoor Mapping, Manpack Satellite Terminals, Software Defined Radios, Digitizing Transceivers, and ...

Customer Base: DoD, NASA, and Primes



GreenAmp

Developing Novel Power Amplifier System, pushing the technology toward greater Efficiency, Linearity, and Bandwidth

Airborne, Satcom, Manpack, Handheld, Cellular Base Stations, and ....

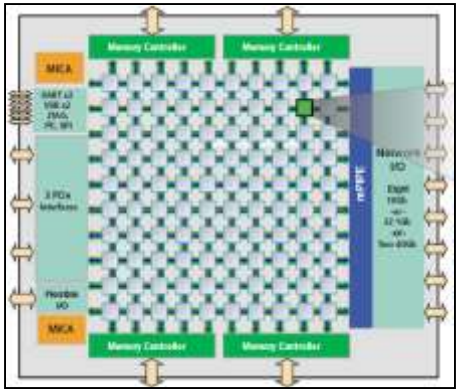
Customer Base: DoD, NASA, and Commercial Base Station Developers.

MaX ManyCore

Exploiting multi-core and heterogeneous architecture processing technologies for power-performance efficiency in mobile platforms

Communications signal processing, radar processing, image processing and machine vision, heterogeneous architectures, and ....

Customer Base: DoD, NASA, and Commercial Base Station Developers.



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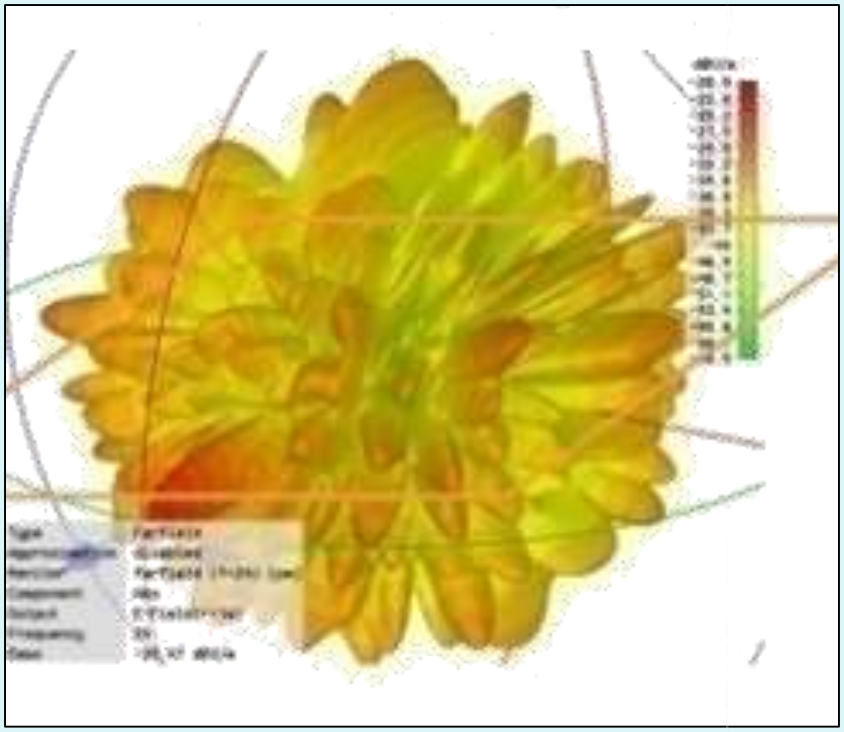

60GHz Resonant Passive Tags

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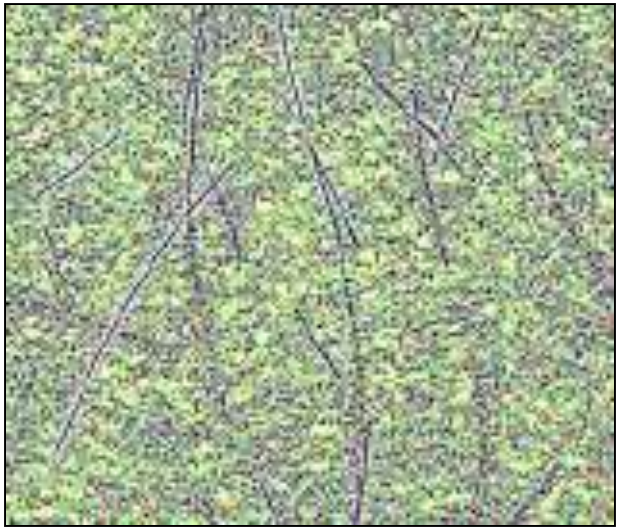
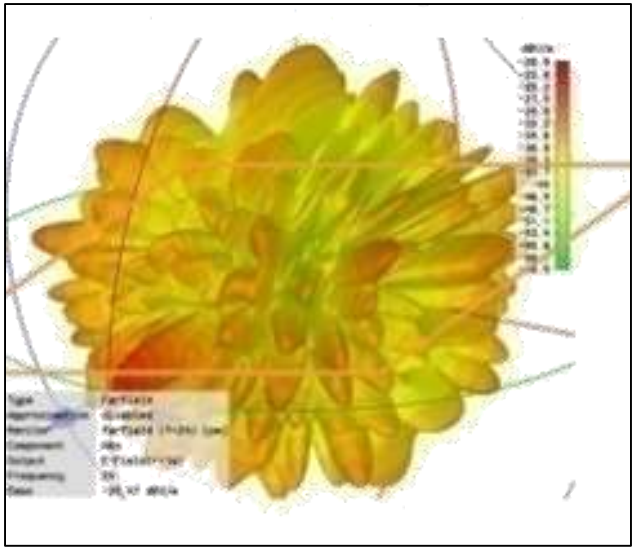
VERSA Tags

- **V**-band **E**nhanced **R**FID **S**ensing **A**rchitecture
- VERSA tags are completely **passive**
- VERSA tags are embedded with thin metal dipoles called **taggants**
  - Length of the taggant and type of material determine resonant frequency
  - Current taggant implementations are several millimeters long, several micrometers wide, and hundreds of nanometers thick
- Can be manufactured on a **variety of materials**: paper, wood, plastic
- **Unique RF signature** depends on many parameters
  - Taggant orientation
  - Relative positions of taggants



Randomly Distributed Taggants



3-D Radar Cross Section (RCS)

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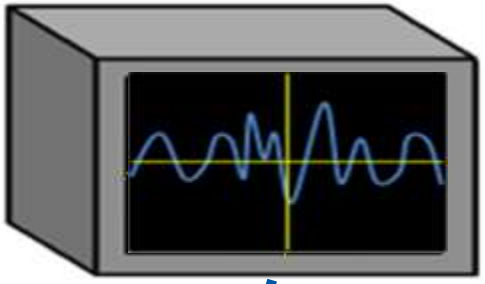
VERSA Interrogation Process

1 – Illumination – Reader transmits RF energy at a resonant frequency is directed at the VERSA tag

2 – Tag Reflection – VERSA tag scatters RF energy back at Reader based on the arrangement of taggants

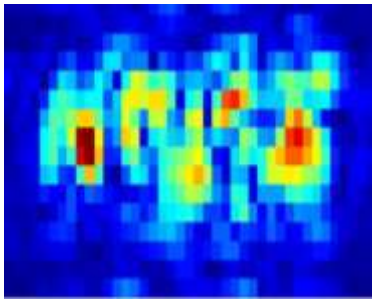
VERSA Reader



Transmitted Waveform

Reflected Signal

VERSA label/tag



3 – Collection – Reader receives and records the reflected signal

4 – Processing – Signal processing is performed by Reader to generate a "fingerprint"

5 – Identification – "Fingerprint" is compared to a database of enrolled signatures

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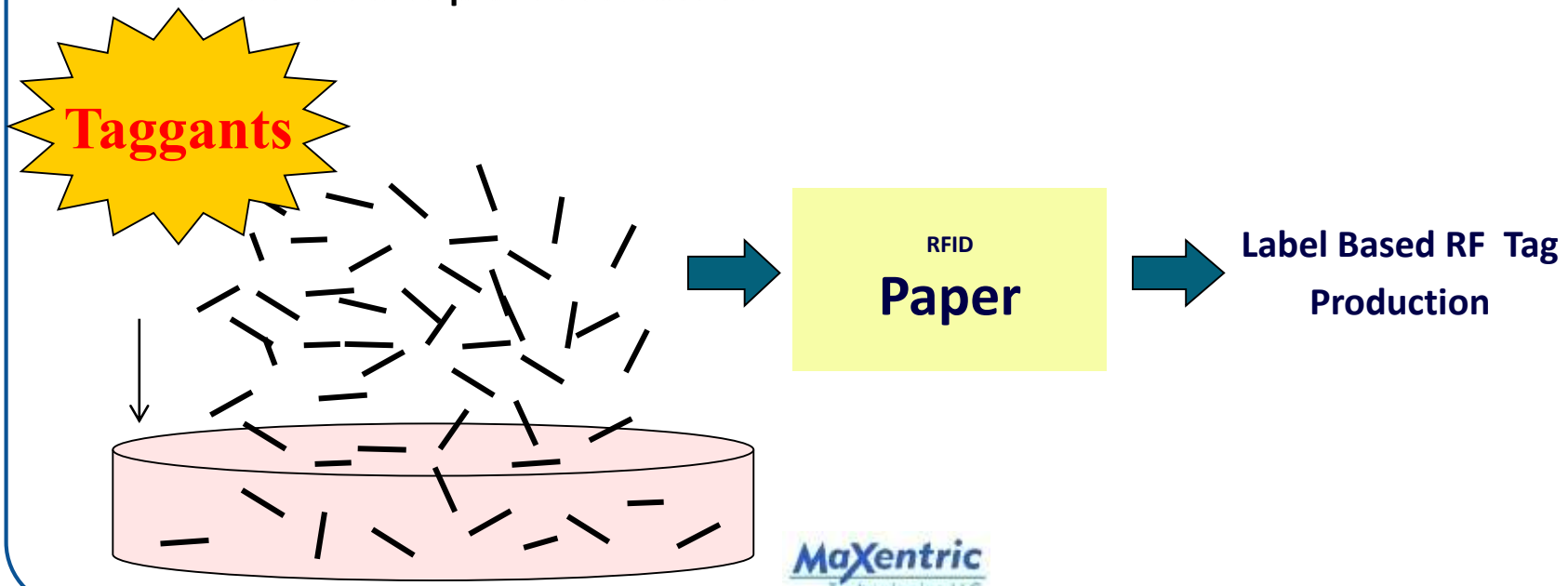
Passive Tag Production

- Any existing label material (paper, plastic, polyester, clear film) can be made into a VERSA Label Based RF Tag
- VERSA Paper
  - RF Nano Resonators called "Taggants" are mixed with the paper making furnish.
  - Taggant distribution controlled to assure the customer maximum performance



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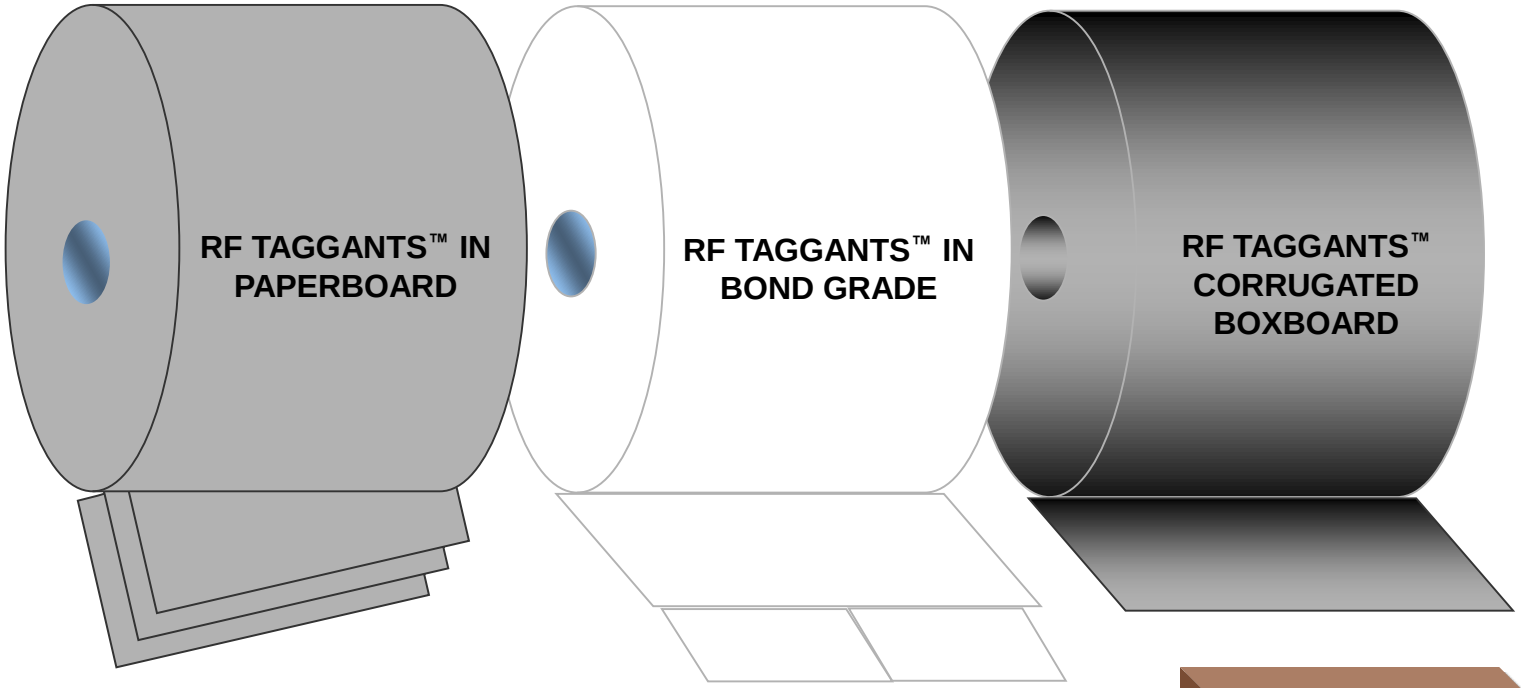
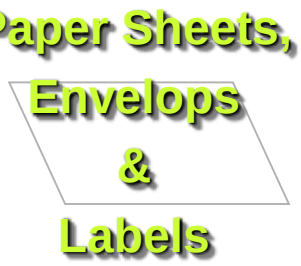
Current Form Factors





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Key Benefits of 60GHz

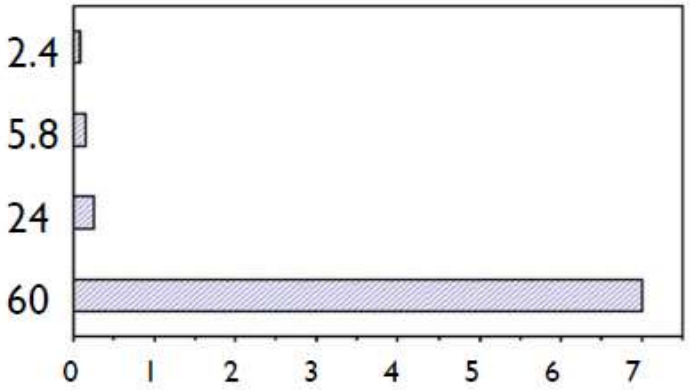
Shorter Taggant → Smaller Tags

2.4GHz → 62.5mm

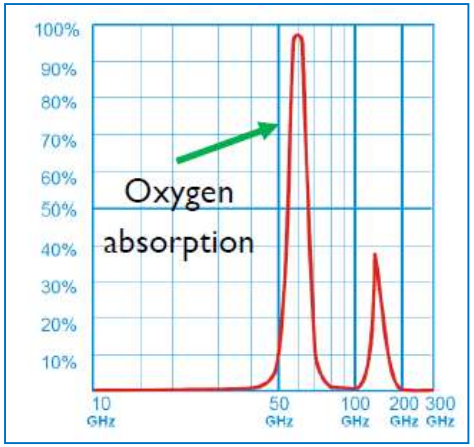
24GHz → 6.25mm

60GHz → 2.5mm

7GHz of ISM Spectrum



Signal Confinement



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Attractive Features of VERSA

- **V-band Enhanced RFID Sensing Architecture (VERSA)**
  - Allows labels to operate as tags
  - VERSA tags are completely passive
  - Extremely simple label/tag design with no complex circuits
  - All processing performed in the reader
  - Low label/tag cost drives overall system cost down
  - Robust to harsh environments
- **mm-Wave Technology**
  - 24 GHz and 60 GHz free ISM bands
  - Low risk of interference
- **Compact and Flexible Implementation**
  - Readers can be mounted, handheld, or implemented as a distribution of network nodes
  - Embeddable with small, covert footprint

VERSA Market Potential

- **VERSA is a label-based chip-less NLOS RFID technology**
  - Can be fully integrated with existing printed labeling and tracking technologies currently in use, including optical barcodes
  - Long range combined with small, covert footprint
- **VERSA offers lowest label/tag cost**
  - 1-2cents increase in label/tag production cost
  - The lowest cost commercialized RFID technology being pursued by Wal-Mart suppliers costs 15 cents per tag, yet,
    - "…they don't expect any return on their RFID investments for years, if at all." (Wall Street Journal, 2007)
- **Commercial Applications**
  - Long range asset tracking
  - Validation of important paper documents
  - Electronic article surveillance
  - Currency tracking and anti-counterfeiting

Passive RFID Development Efforts

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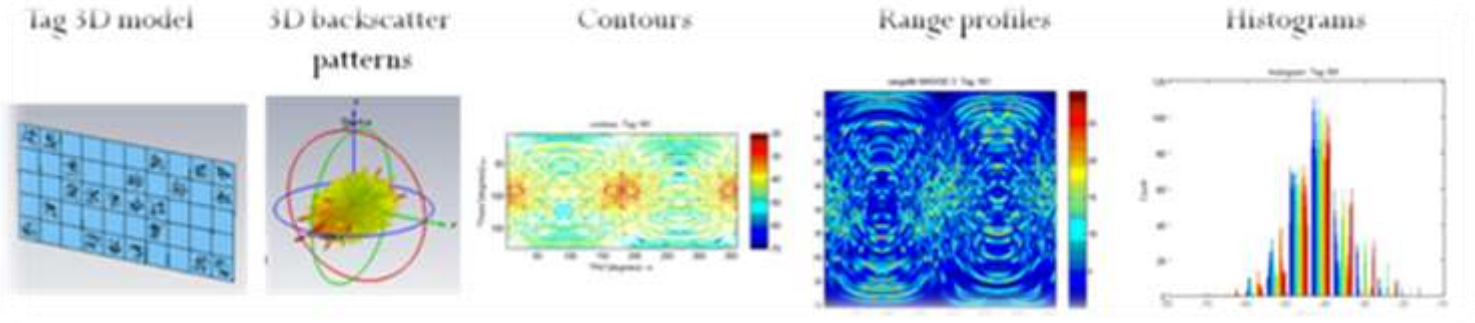
Tag Design, Simulation, and Engineering

- **3-D Electromagnetic Simulation with CST from Sonnet**
  - Random resonant taggants can produce unique radar signatures
  - Signature dependency on taggant size, density, and orientation
  - Tag's radar cross section can be converted into a 2-D fingerprint
  - Simulation of curved and planar tags



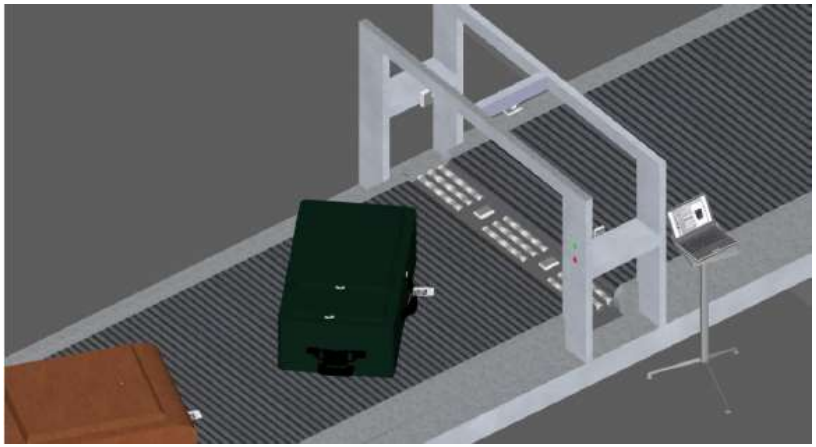
- **Empirical Measurements with VERSA Hardware Platforms**
  - Responses of random tags have low cross-correlation
  - Developed and measured PCB-based "Test" Tags
    - Empirical results for several taggant dimensions and spacings
    - Responses of structured and structured/random hybrid tag types

DoD Munitions Tagging/Tracking

- **Motivations**
  - Improved range and flexibility over linear optical barcodes
  - Compliance with strict electromagnetic radiation regulations for ordnance asset management
- **Development Effort**
  - Prototype development through Navy SBIR Phase II funding
  - Proof-of-concept provided with K-band (24GHz) tags and hardware
  - Portal-based K-band reader system

Passive RFID Airline Luggage Tagging

- **Motivations**
  - Lost luggage has an annual cost of $1 billion for airlines
  - Tracking system more robust to damaged tags
- **Commercial Effort**
  - Formed an airline industry consortium composed of label manufacturers, baggage handling equipment manufactures, among others
  - Embedded RFID technology can be integrated into existing barcode-based tags
  - Developed a K-band portal-based VERSA reader system
  - VERSA demonstration performed with industry conveyor system



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Current State of VERSA Development

- **Multichannel 24GHz VERSA CW Radar Transceiver**
  - Currently at 8 channels with operational range of 1m
  - Highly scalable, phase coherent design
  - Computer-controlled, gain adjustable
  - Supporting acquisition and monitoring hardware/software
- **Imaging and Identification Algorithms**
  - Fingerprint creation through Synthetic Aperture Radar-based approach
  - Tag Identification through feature extraction and database lookup
  - Graphical User Interface
- **High Precision Test and Measurement Environment**
  - Linear Actuator passes tag through portal reader
  - Detachable Pan/Tilt Unit adjusts tag orientation
- **Taggant/Tag Simulation, Design, and Characterization**
  - Extensive E/M simulations performed using CST
  - Empirical measurements using 24GHz transceiver and test environment
- **V-band (60GHz) Development**
  - Developed and tested V-band transceiver with several GHz of bandwidth
  - Current efforts targeted towards communication, radar, RFID, and passive sensor applications

Candidate Sensor Applications

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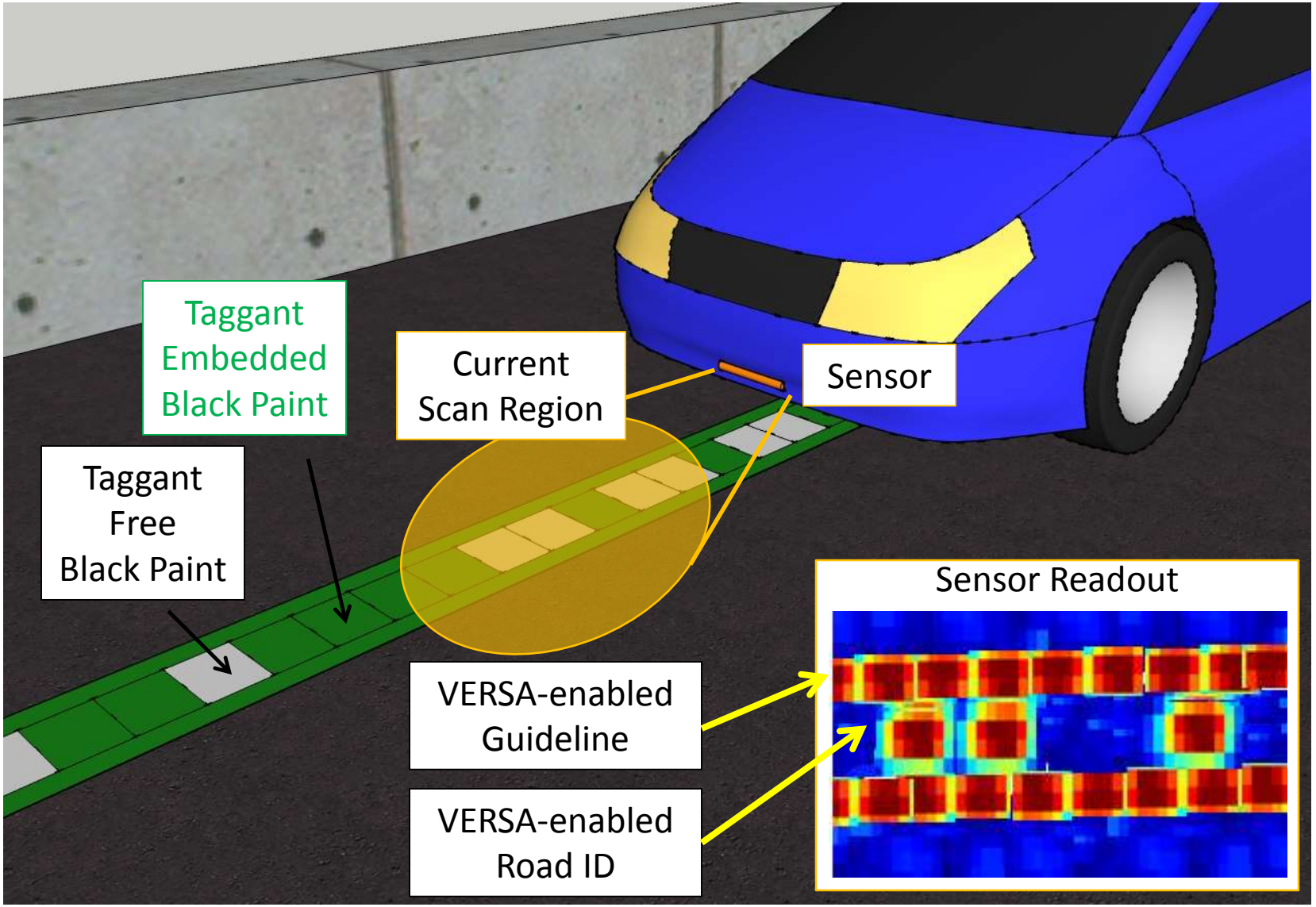
Intelligent Highway

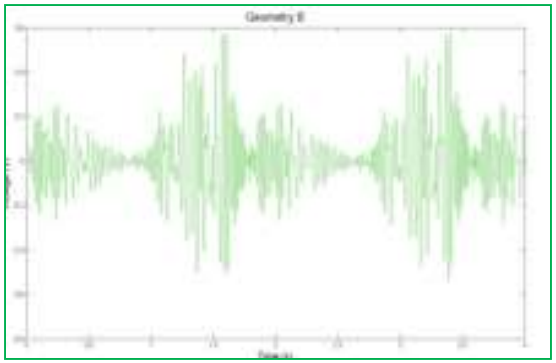


Monitoring through Tag Deformation

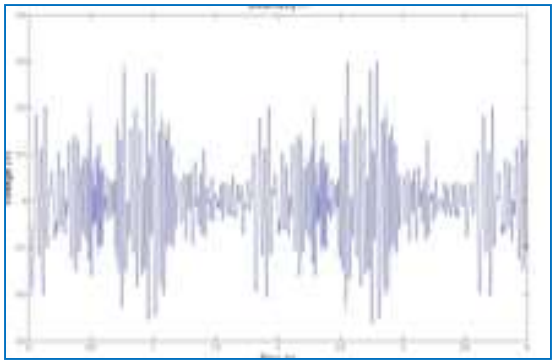
- Deformation of VERSA substrate alters return signature
- Substrate can be designed to deform based on:
  - Temperature
  - Pressure
  - Voltage
- Measuring and analyzing the return signature can provide information on operating conditions
- Passive, chip-less sensors can be deployed in harsh, hard-to-access environments

Tag Deformation Example

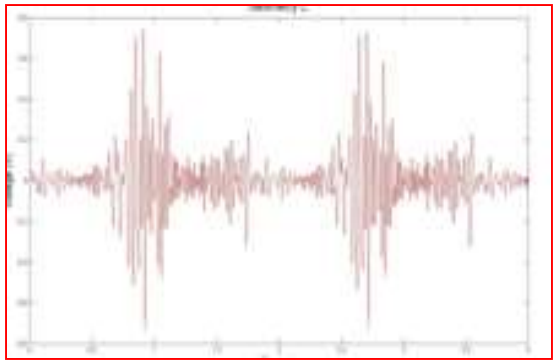
Flat

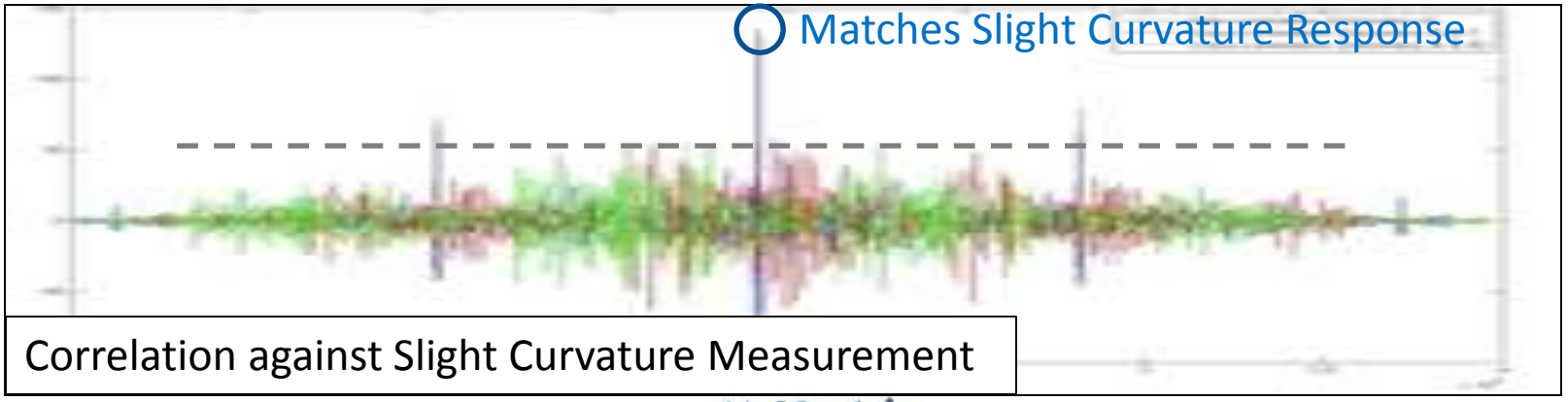


Slight Curvature



Medium Curvature

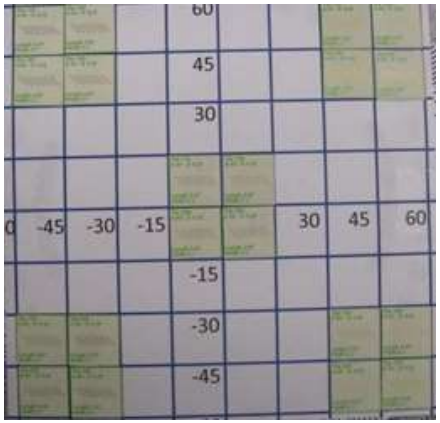




Correlation against Slight Curvature Measurement

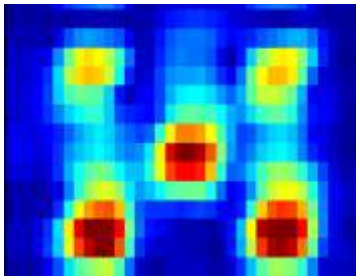
Monitoring through Orientation Change

- VERSA sensor can be mounted on platform that rotates as conditions change
- Change of tag orientation alters return signature
- Monitoring change in signature provides information on condition change

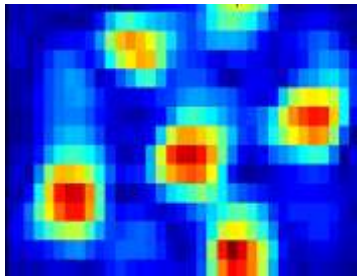


Engineered Structured Tag

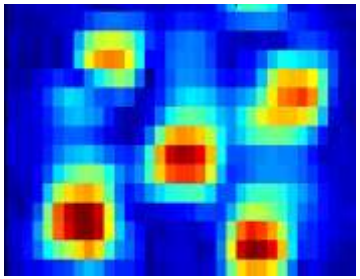
0° Rotation



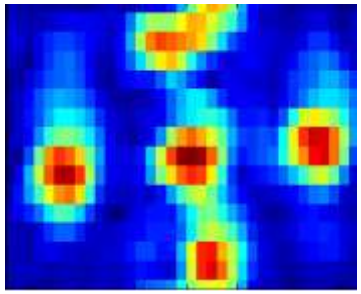
24° Rotation



12° Rotation



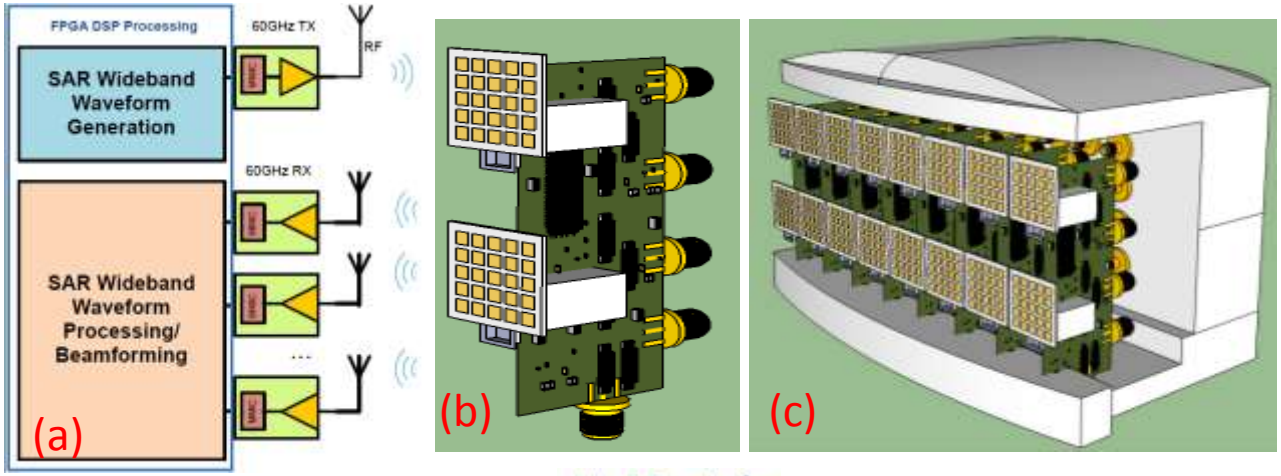
36° Rotation



Next Steps of VERSA Development

- **Next Generation VERSA Tags/Sensors**
  - Embedded taggants in deforming substrates
  - Investigate new, promising taggant technologies
    - Carbon Nano Tubes (CNTs)
    - Alloy Nano Wires (ANWs)

- **Next Generation VERSA Reader**
  - Improved imaging resolution through benefits of 60GHz:
    - Larger bandwidth, smaller aperture, reader, tag sizes, higher output power
  - Wideband illumination, collection, and processing
  - Handheld form factor



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Hardware Demonstration

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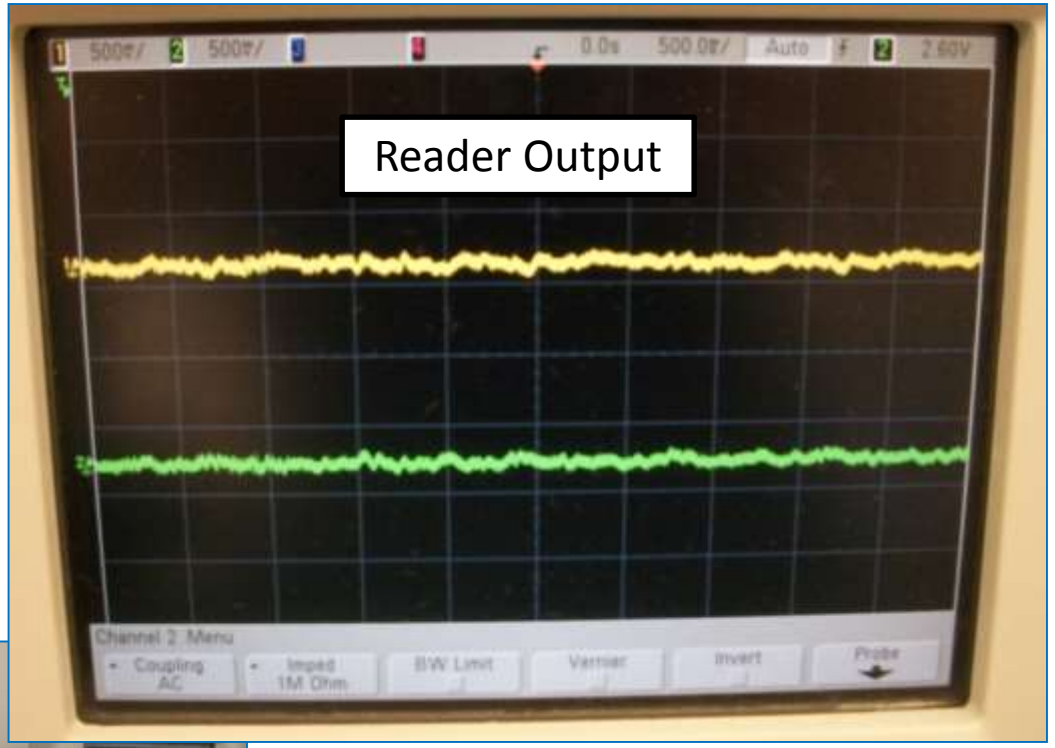
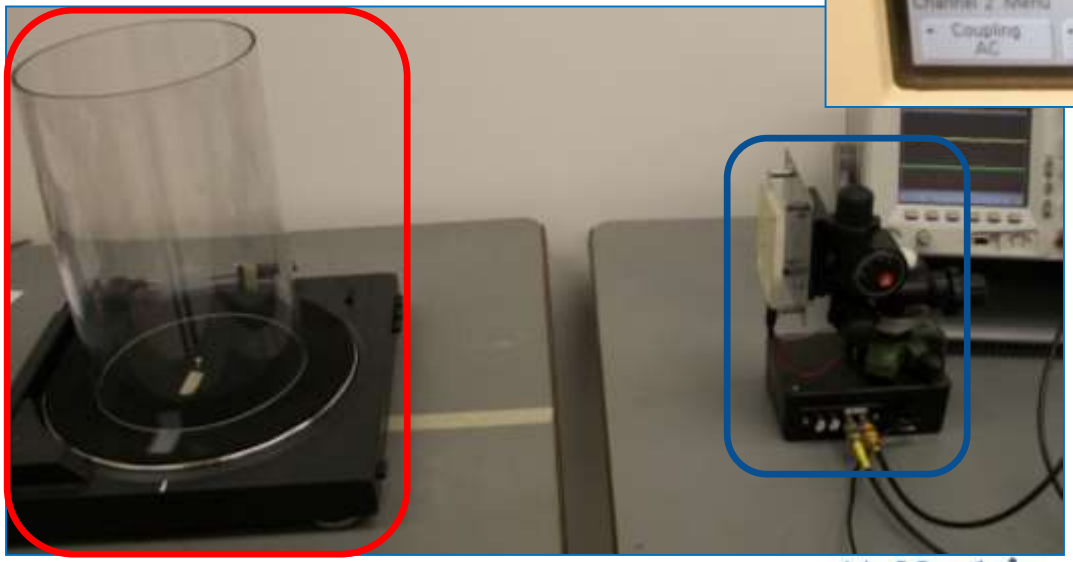
No Tags



Rotating Platform



VERSA K-band Reader

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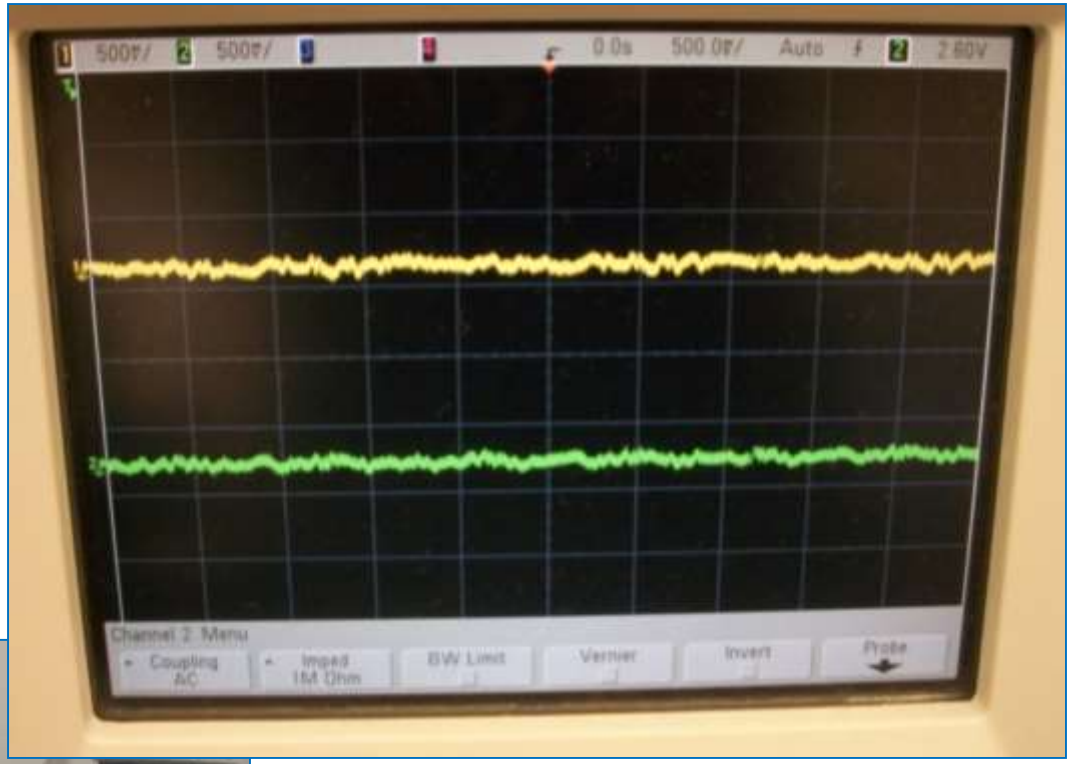
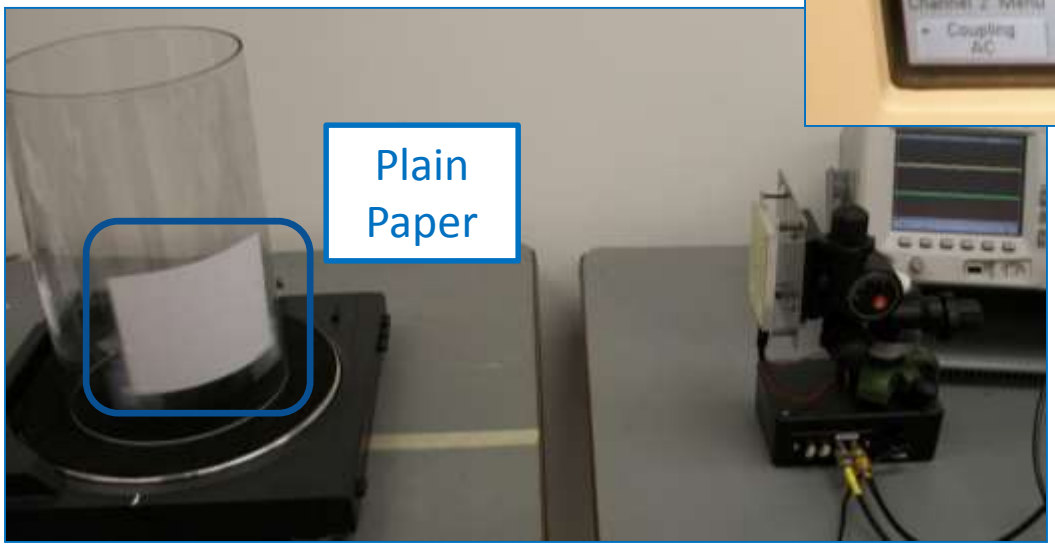
Plain Paper Tag





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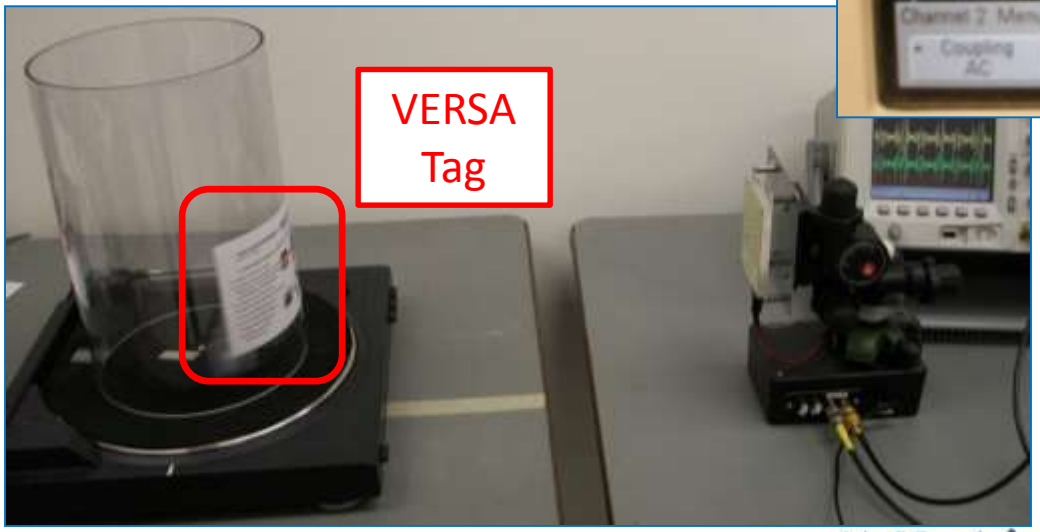
VERSA Tag



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Questions & Discussion