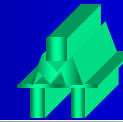


FG RFEC Technique for Thick Multilayer Aircraft Structures Inspection

Part III Thru Composite Crack Detection

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3141 W. Torreys Peak Drive
Superior, CO 80027
Tel: 303 554 8000
Fax: 303 554 8001
Email. Suny@imtt-usa.com



Part III – Crack detection through thick composite layer

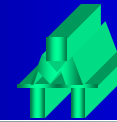
1. Introduction

2. Raster scan using a sliding probe

- **Al layer crack thru 1.5” thick polycarbonate layer**
- **Al layer crack thru 0.9” thick graphite epoxy layer**

3. Detecting Ti layer fatigue crack thru 0.5” thick graphite epoxy layer using rotary probe

4. Detecting Ti layer corner EDM notch thru 0.5” thick graphite epoxy layer using manual rotary probe or automated rotary scanner

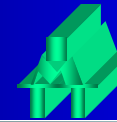


Part III – Crack detection through thick composite layer

Topic 1 - Introduction

Challenges in Crack Detection in Titanium Layer through A Thick Composite Layer

- 1. Removal of composite for crack detection is practically impossible in new aircraft structures**
- 2. Conventional ECT has limited capability in detecting a small crack after penetrating thru thick composite layer**
- 3. Unknown capability of ultrasonic technique in this application**
- 4. Our choice – Flat Geometry Remote Field Eddy Current (FG_RFEC) technique driven by Super Sensitive Eddy Current (SSEC) instrument.**



Part III – Crack detection through thick composite layer

Topic 2

Raster Scan Using a Sliding Probe

A. Photos of FG RFEC Sliding Probes for Crack Detection



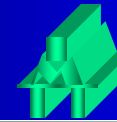
RF4 V3

Footprint: 0.85" x 2.15"
Coil Center-to-Center Distance,
CCD = 1.15"



RF2 V3

Footprint: 0.3" x 0.62"
Coil Center-to-Center Distance,
CCD = 0.3"



Part III – Crack detection through thick composite layer

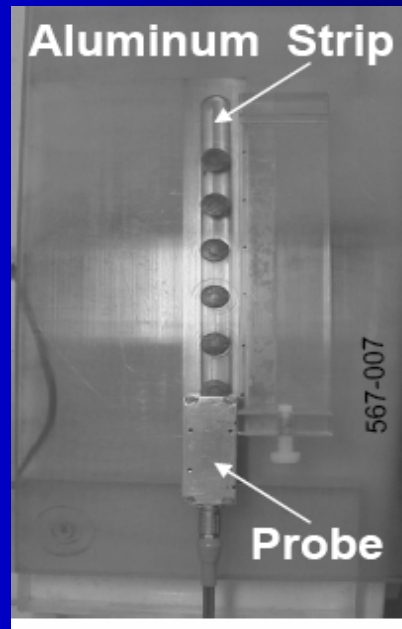
Example #1: Detection of aluminum layer crack through 1.5” of polycarbonate using sliding probe RF4 V3A*

Three 7”x13” polycarbonate pieces with thicknesses:

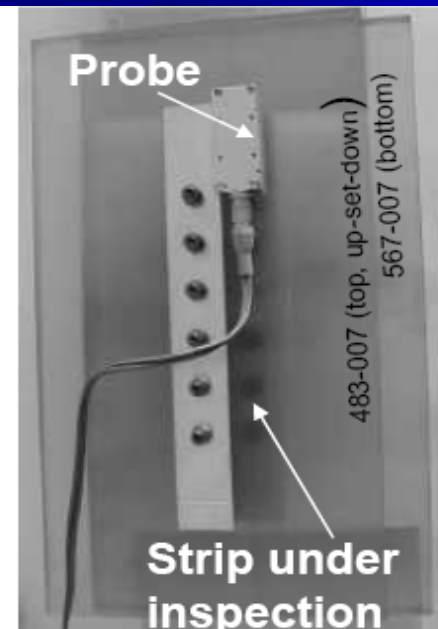
- 567-007 – 0.567”;
- 483-007 – 0.483”
- 442-007 – 0.442”

A 9.0”x1.25”x0.20” aluminum strip attached below each of them
Titanium fasteners

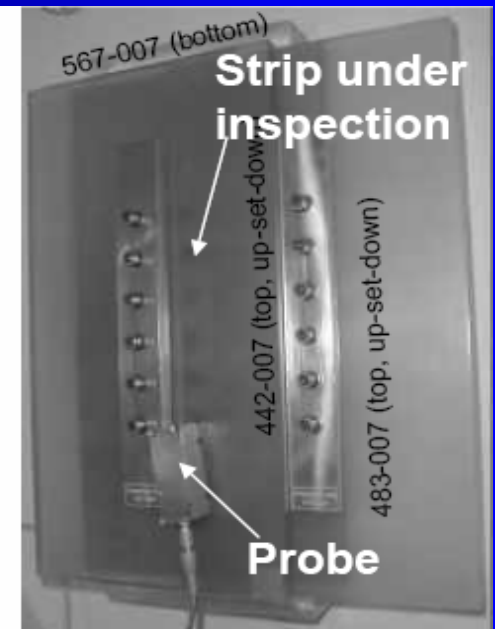
One layer



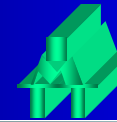
Two layers



Three layers

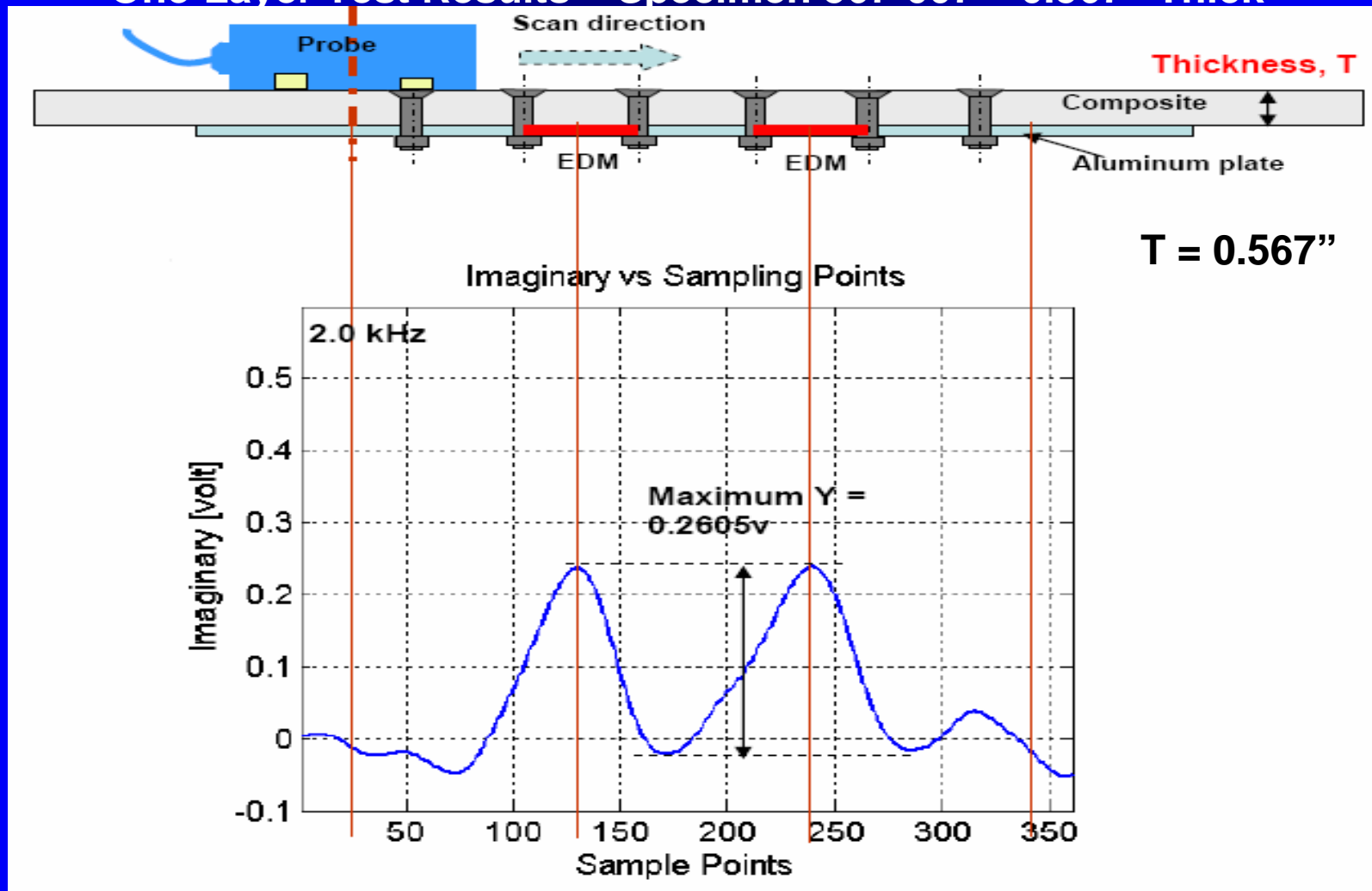


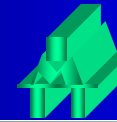
* Specimens provided by NAVAIR.



Part III – Crack detection through thick composite layer

One-Layer Test Results – Specimen 567-007 – 0.567” Thick



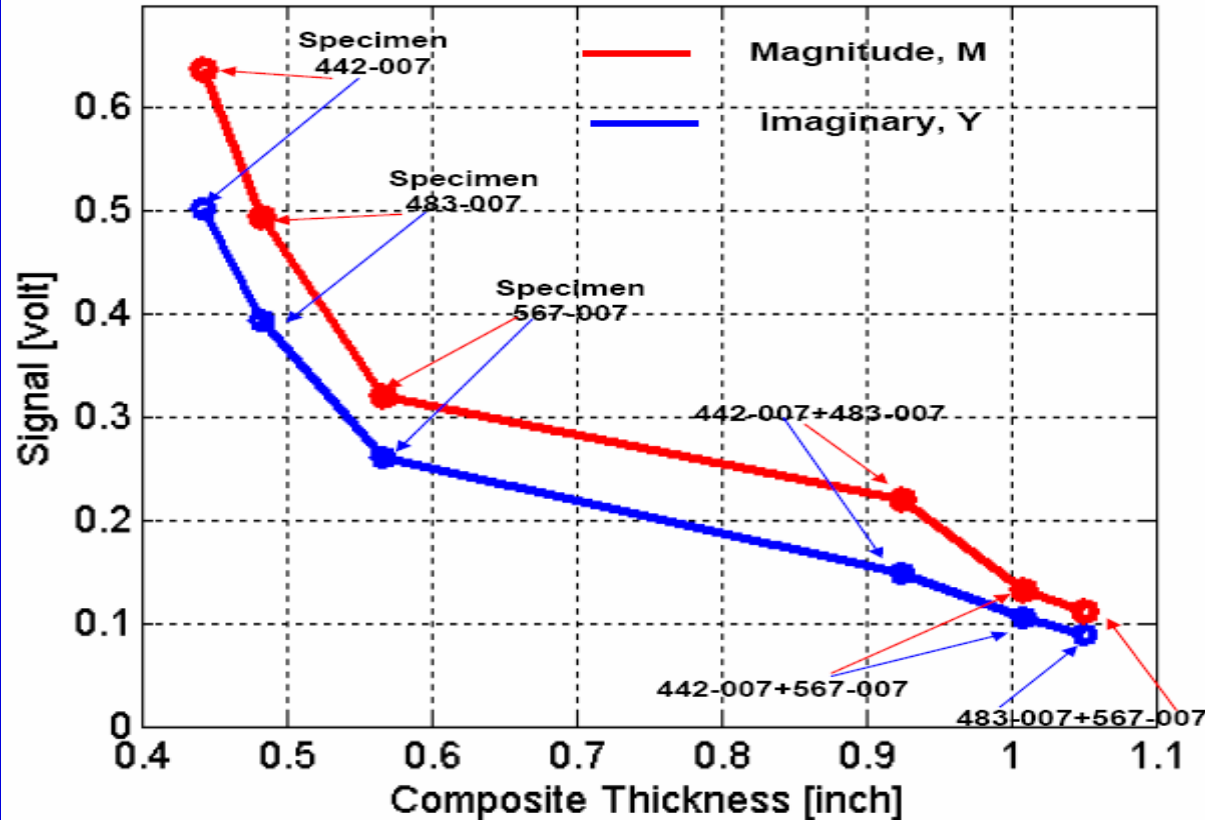


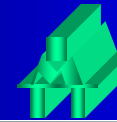
Part III – Crack detection through thick composite layer

Summary of all results at 2.0 kHz

8. A Complete Signal – Thickness Relation Curve at $f = 2.0\text{kHz}$

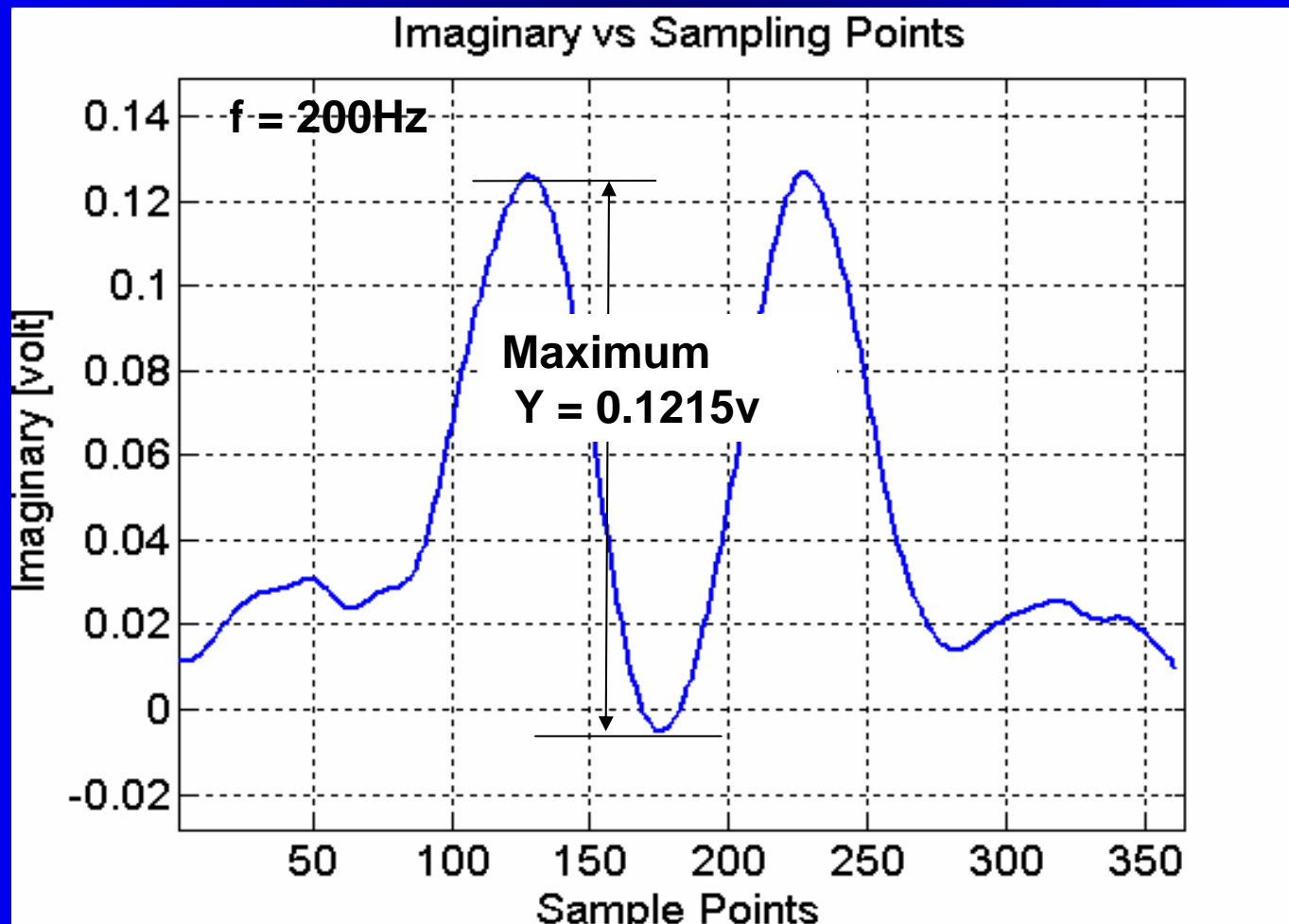
Crack Signal vs Composite Thickness

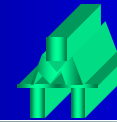




Part III – Crack detection through thick composite layer

Tree-Layers Test Results – All 3 Specimens on Top each other
Total Thickness $\approx 1.500''$, $f = 0.2\text{kHz}$

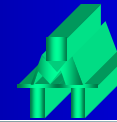




Part III – Crack detection through thick composite layer

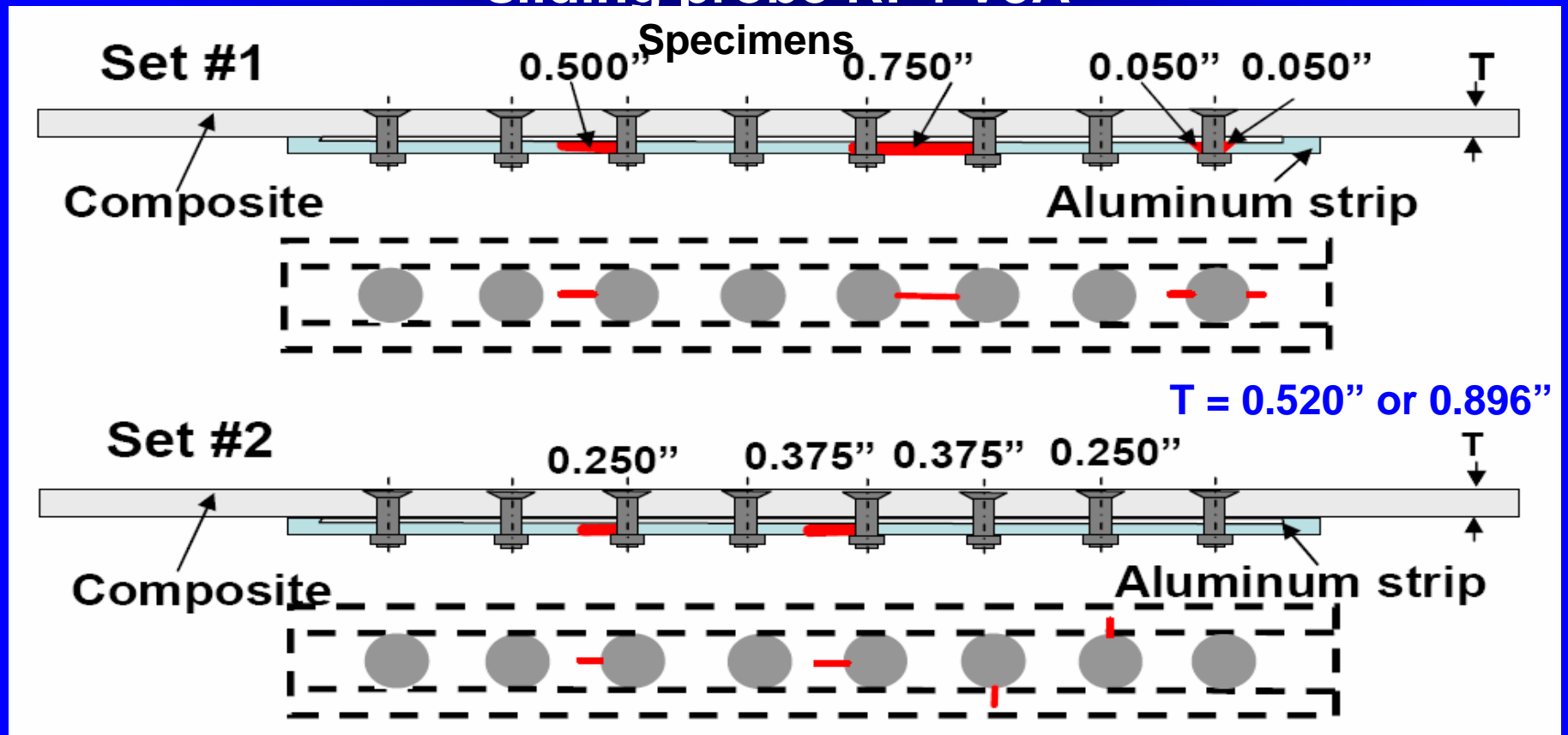
Summary for Example #1

- 1. The two EDM notches in the aluminum strip can be detected through polycarbonate layers with a total thickness of up to 1.050” at $f = 2.0$ kHz using the FG RFEC sliding probe RF4 V3A**
- 2. The two EDM notches can be detected through polycarbonate layers with a total thickness of up to 1.500” at $f = 0.2$ kHz using the FG RFEC sliding probe RF4 V3A**

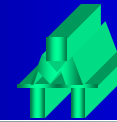


Part III – Crack detection through thick composite layer

Example #2: Detection of aluminum layer crack through 0.52" – 0.90" graphite epoxy composite using sliding probe RF4 V3A*

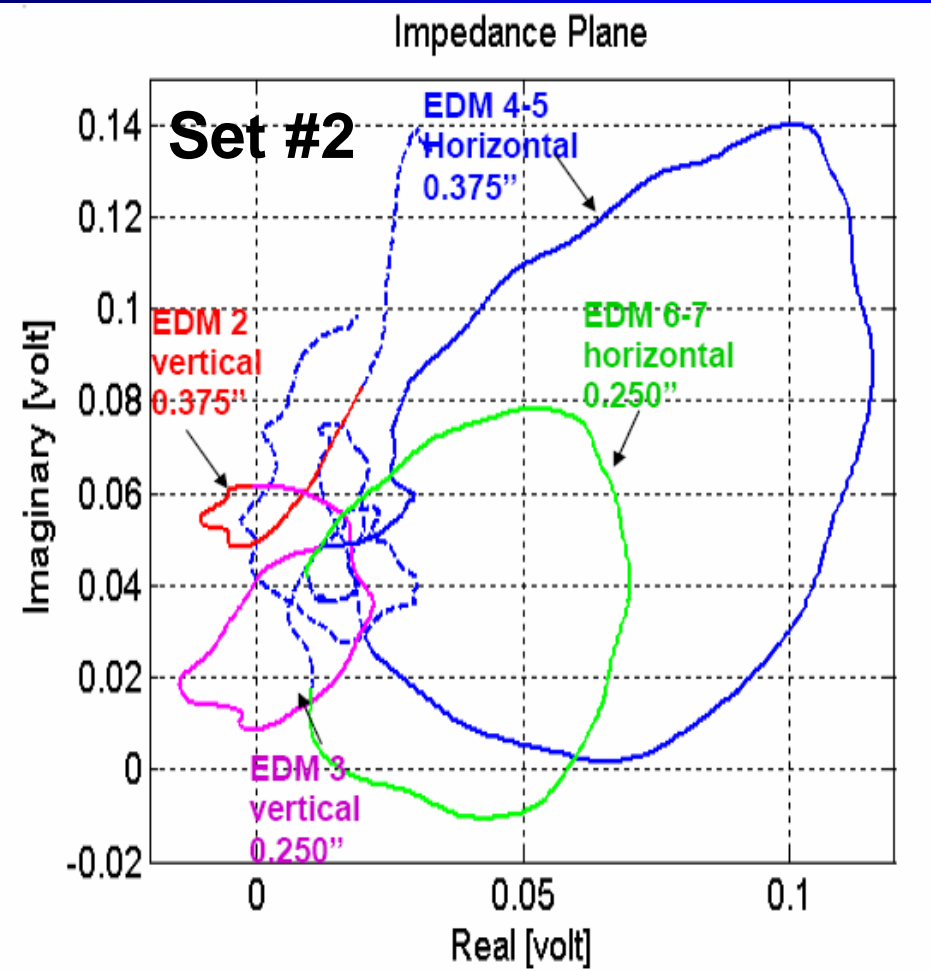
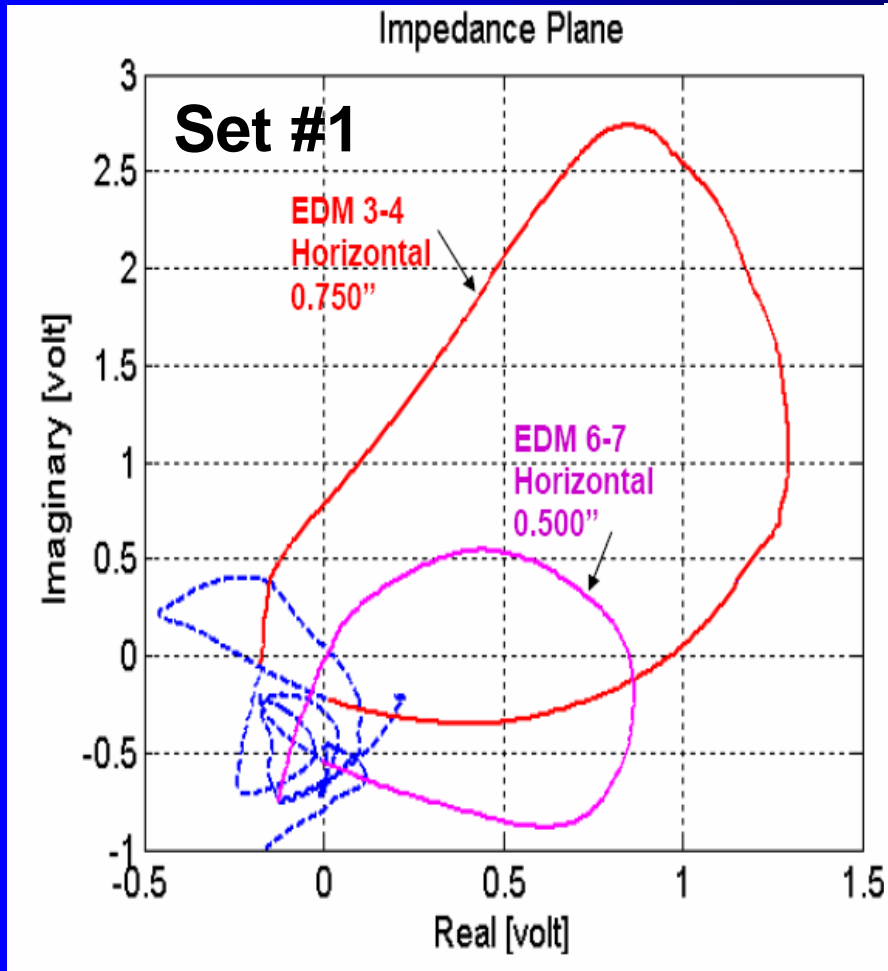


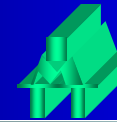
* Specimens provided by NAVAIR.



Part III – Crack detection through thick composite layer

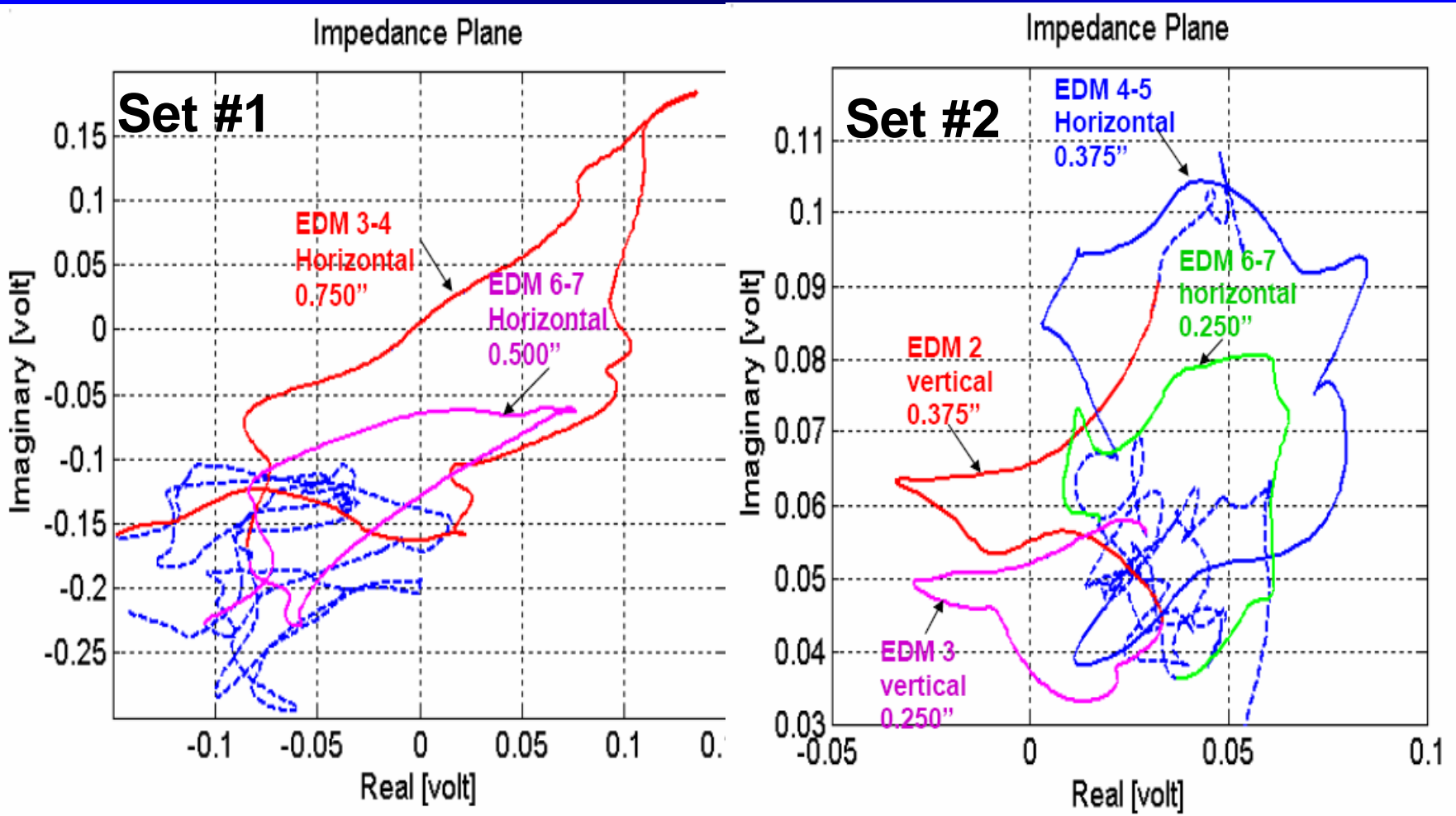
T = 0.520"

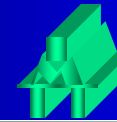




Part III – Crack detection through thick composite layer

T = 0.896"

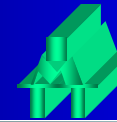




Part III – Crack detection through thick composite layer

Summary for Example #2

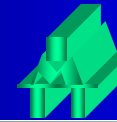
- 1. The two horizontally aligned cracks in the aluminum strip of Set #1, which are of 0.500” and 0.750” in length respectively, can be detected through either of the two graphite epoxy layers, 0.520” and 0.896” thick respectively, using the FG RFEC sliding probe RF4 V3A**
- 2. The two horizontally aligned cracks in the aluminum strip of Set #2, which are of 0.250” and 0.375” in length respectively, can be detected through either of the two graphite epoxy layers, 0.520” and 0.896” thick respectively, with lower S/N ratios.**
- 3. We can see some indications of the two vertically aligned EDM notches, which are of 0.250” and 0.375” in length, can also be seen with lower S/N ratios. Change probe orientation in the scan would get better detection.**



Part III – Crack detection through thick composite layer

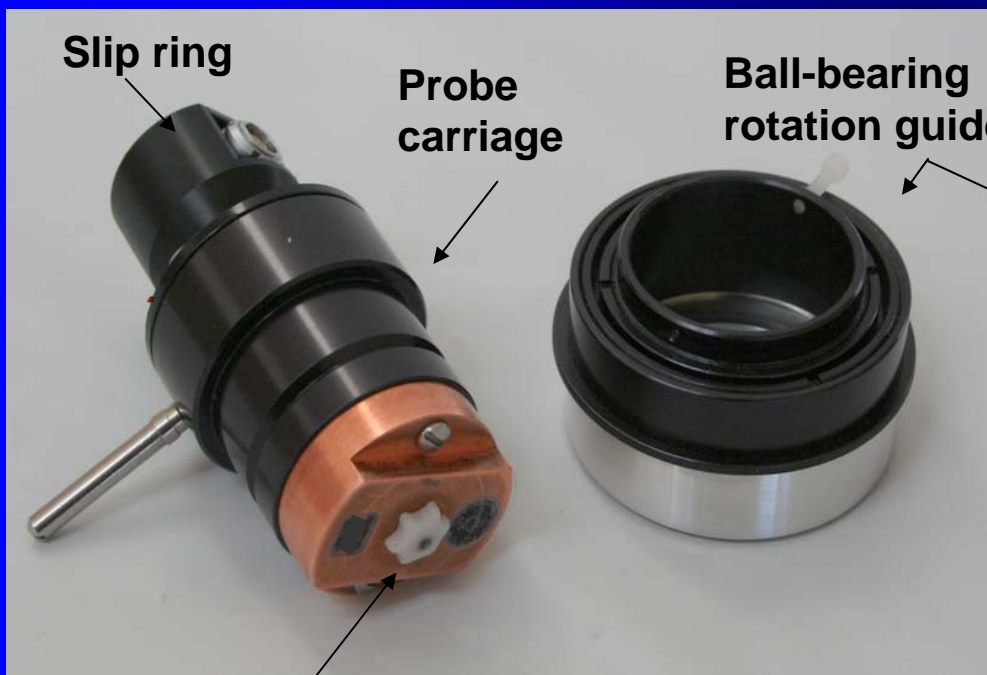
Topic 3

Rotational Scan Using a Rotary Probe Detecting Ti layer Fatigue crack thru Graphite Epoxy layer



Part III – Crack detection through thick composite layer

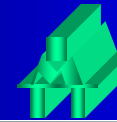
Newly Developed Manually Rotary Probe and Accessories



Probe head with centering pin



Titanium layer under inspection



Part III – Crack detection through thick composite layer

Complete SSEC System for Thru Composite Crack Detection Using Rotary Scanner

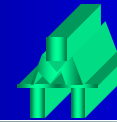
Automated
Rotary
Scanner

Specimen
under
inspection



Laptop

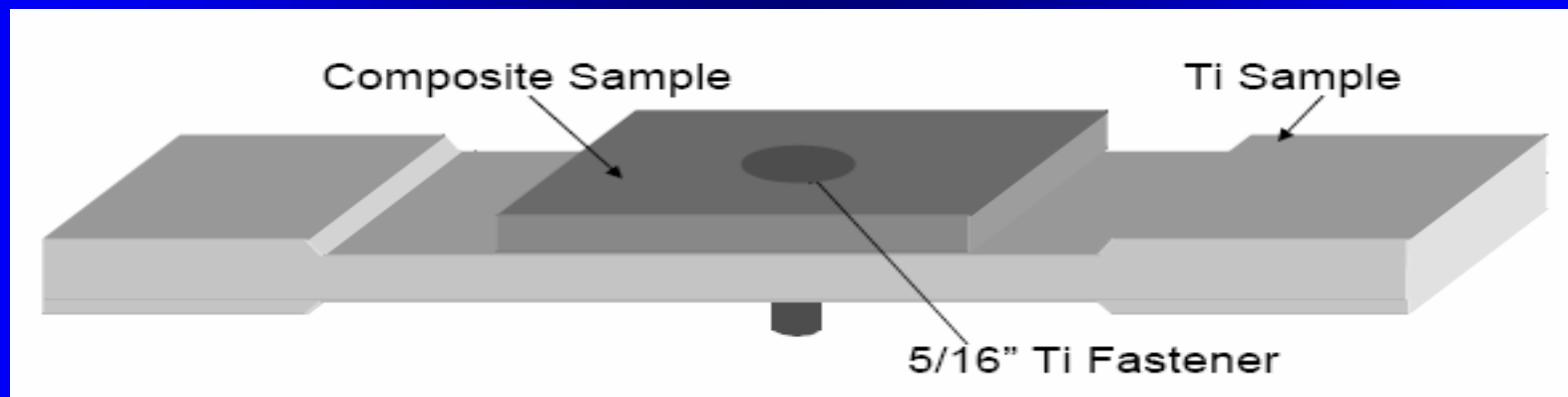
Instrument
SSEC II-S



Part III – Crack detection through thick composite layer

**Example #3: Detection of titanium layer crack
through 0.25" – 0.50" graphite epoxy composite*
Using rotary probe RF4 ROT**

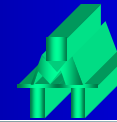
Specimens



Fatigue Crack sizes: 0.250", 0.500" and 0.750"

Composite Thickness: 0.250", 0.333" and 0.500"

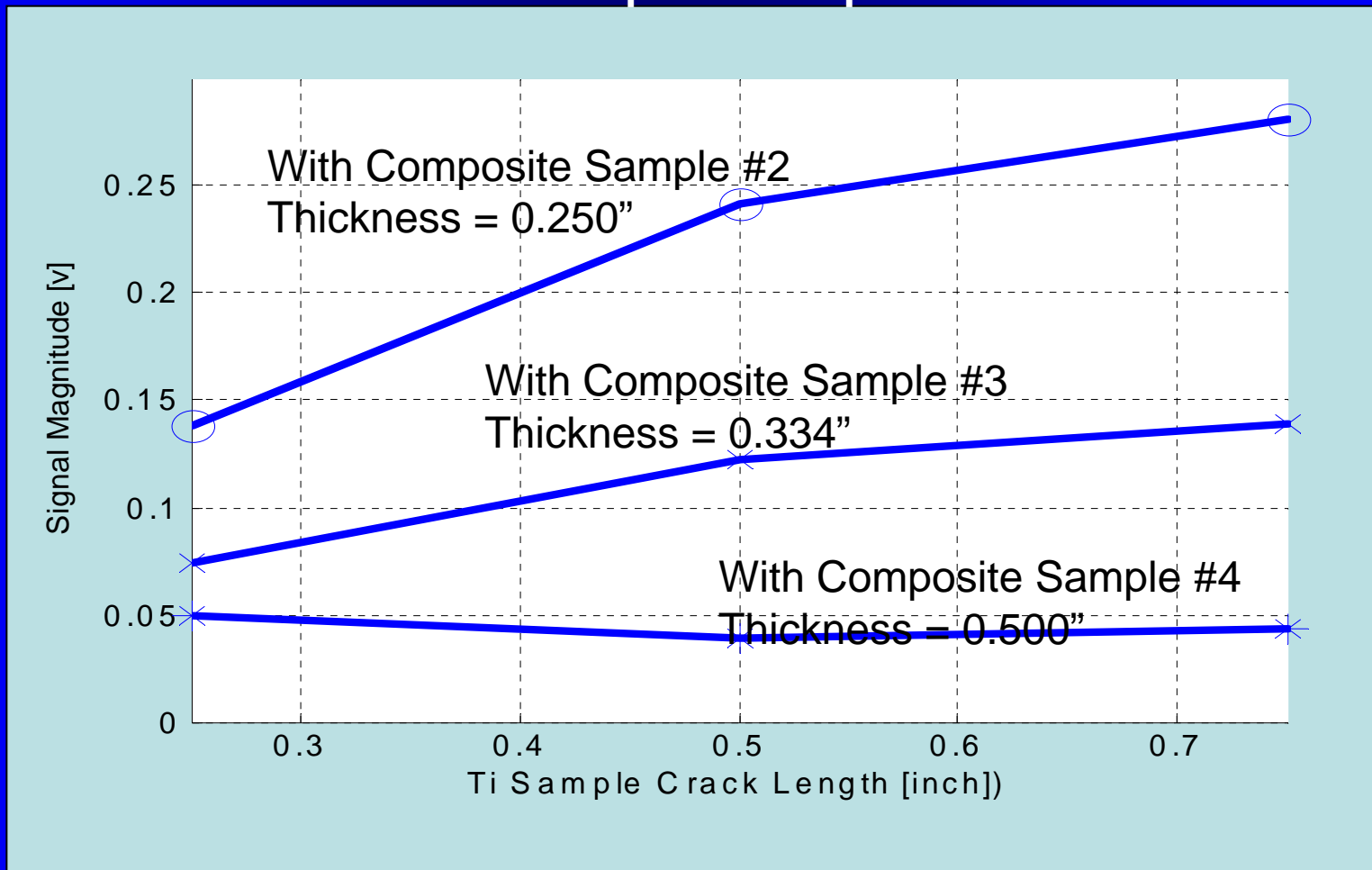
* Specimens provided by AFRL.

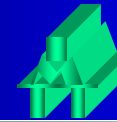


Part III – Crack detection through thick composite layer

Summary for Example #3

Cracks are detected in all composite-Ti-specimens combinations

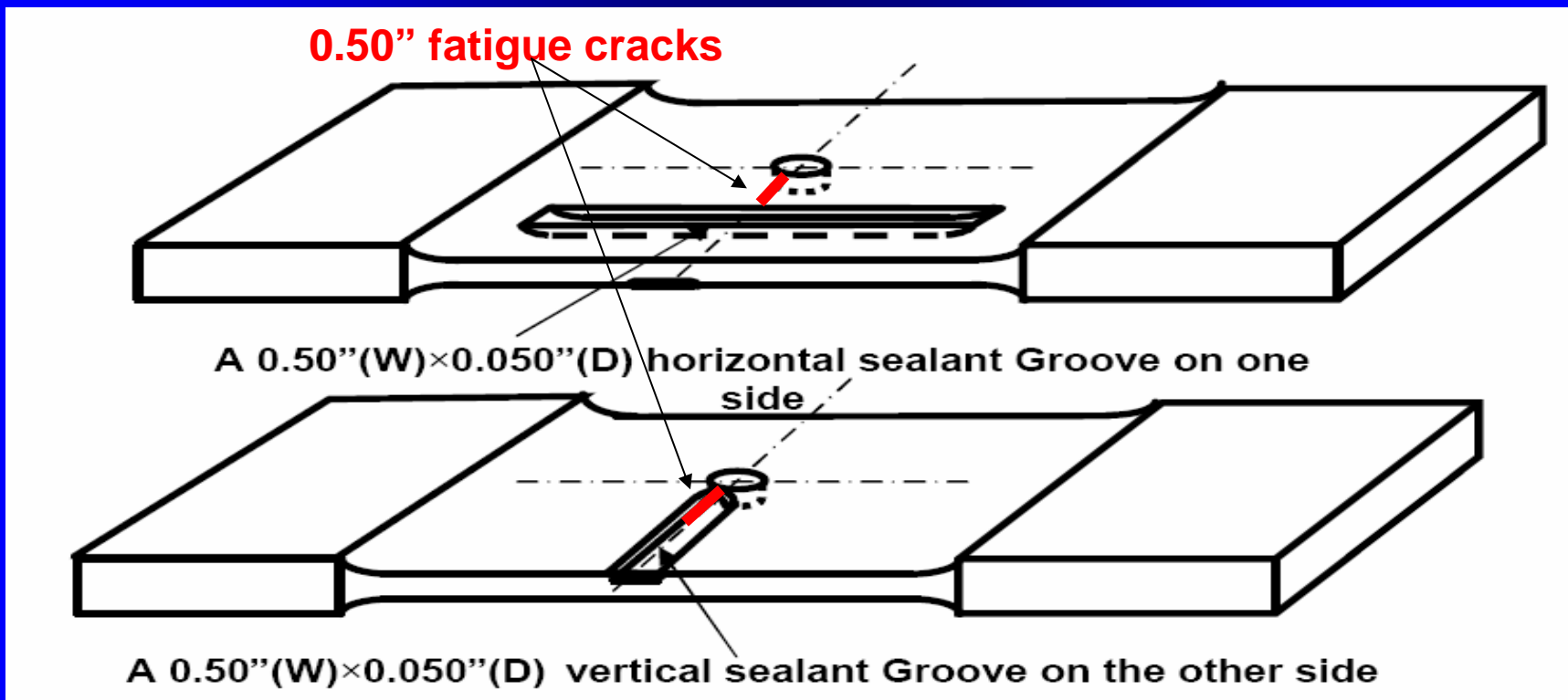




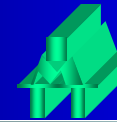
Part III – Crack detection through thick composite layer

Example #4: Detection of Ti layer crack through graphite epoxy composite and suppression of sealant groove signals*

Specimen

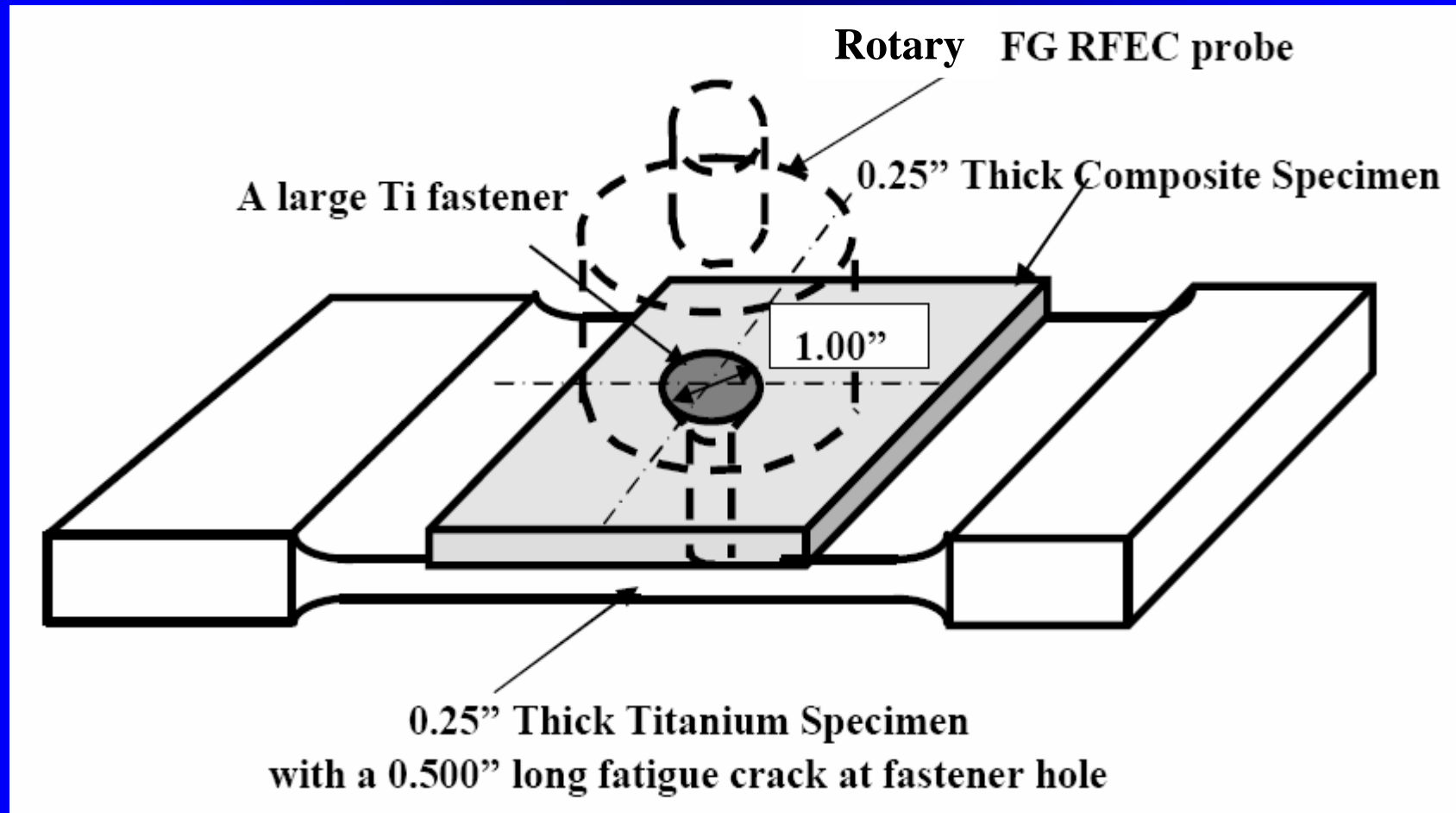


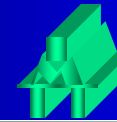
* Specimens provided by AFRL.



Part III – Crack detection through thick composite layer

Rotary Probe RF4 ROT Scanning around Fastener

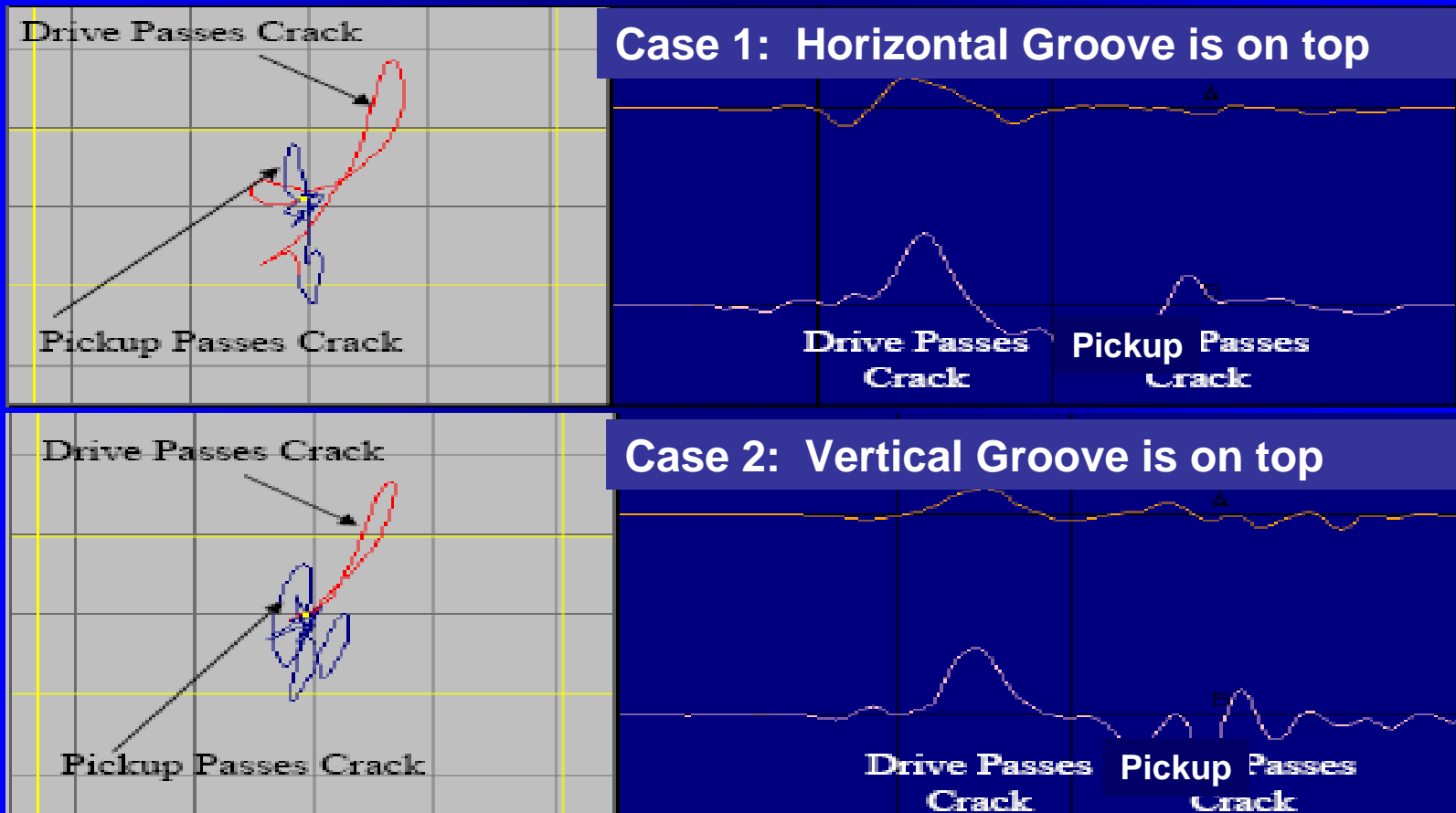


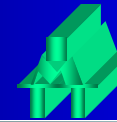


Part III – Crack detection through thick composite layer

Screen Cuts from SSEC Window

Crack detected in both cases, horizontal and vertical grooves

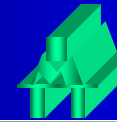




Part III – Crack detection through thick composite layer

Topic 4

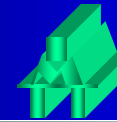
Ti layer Corner EDM Notch detection Thru 0.35” – 0.50” Graphite Epoxy Layer



Part III – Crack detection through thick composite layer

Photos of Standards Provided by AFRL

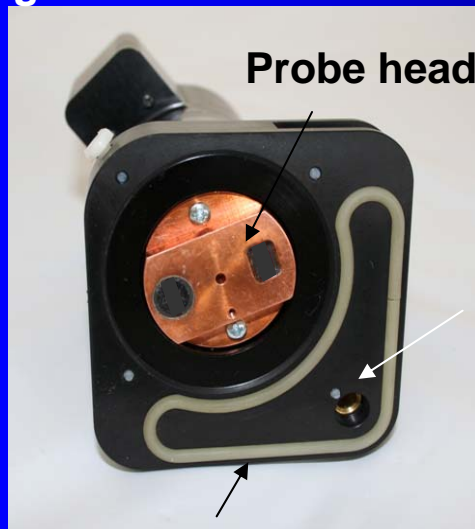




Part III – Crack detection through thick composite layer

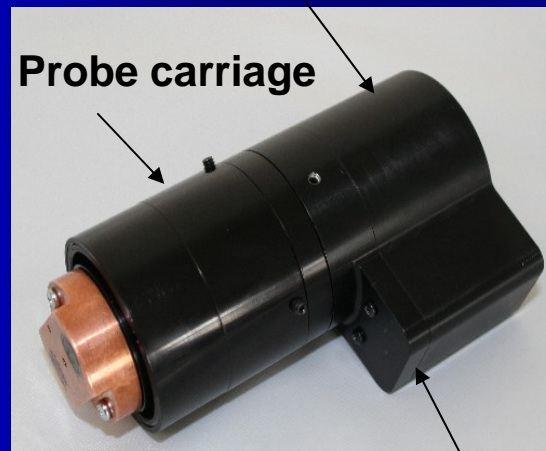
Automated Rotary Scanner and On-Line Signal Processing and Crack ID

Ball bearing rotation
guide with suction base



Sealing rubber tube

Step motor inside



Motor controller inside

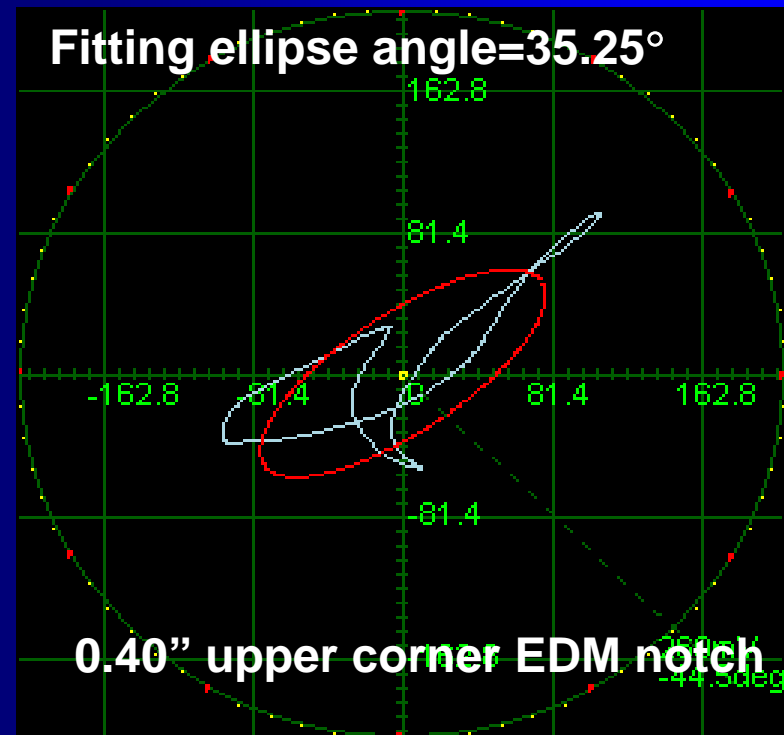


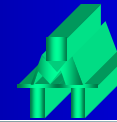
Rotation
guide &
suction
base

Example 1

Detecting 0.40" upper corner notch Thru 0.350" thick composite layer

A 0.35" thick composite on top of 0.60" thick Ti layer
with a curved groove





Part III – Crack detection through thick composite layer

Example 2

Detecting 0.250" upper corner notch

Thru 0.500" thick composite layer

A 0.50" thick composite on top of 0.60" thick Ti layer
with a curved groove

