

Detecting 1st and 2nd Layer Simulated Cracks in Aircraft Wing Spanwise Splice Standards Using Remote-Field Eddy Current Technique

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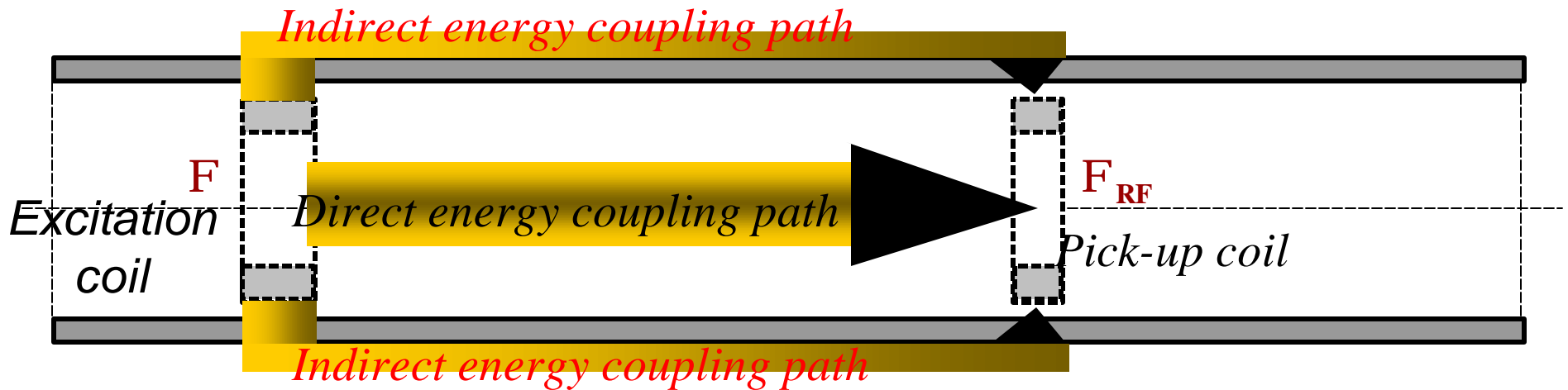
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INTRODUCTION

- **Detection of aircraft hidden corrosion and cracks is of great concern.**
- **The existing Eddy Current Testing does not to meet the demand for deeply hidden flaw detection.**
- **Recent development of Remote Field Eddy Current (RFEC) technique shows promise in this area.**
- **Recent test results of Detecting 1st and 2nd Layer Simulated Cracks in Aircraft Wing Spanwise Splice Standards Using RFEC Technique.**

Remote Field Eddy Current Technique



Phenomenon:

Signals received by pick-up coil is closely related to the wall condition: thickness, conductivity, and permeability.

Underlying Physics:

1. Direct energy coupling is restricted by EC in the wall.
2. Pick-up coil signal, F_{RF} , is dominated by the energy diffusing along the indirect coupling path that traverses the wall twice.
3. Phase of F_{RF} has a linear relation with the wall thickness.

Recent Extension of RFEC To Inspection of Objects with Flat Geometries

The current test data* show that the system can detect:

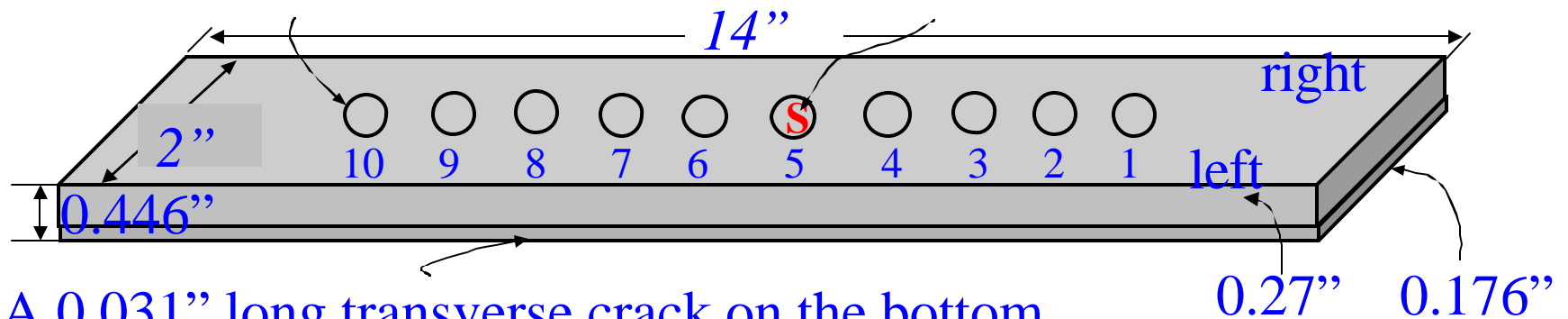
- 1. aluminum material discontinuity 1.0” below the inspection surface;**
- 2. a 12.7 mm x 12.7 mm x 0.15mm corrosion thinning 9.5 mm below surface;**
- 3. a 12.7 mm x 0.9 mm x 0.25 mm saw-cut 6.7 mm below surface; and**
- 4. a 0.78 mm long second layer fastener hole fatigue crack 11.3 mm below surface**

* The detailed information is available upon request from the presenter, Professor Y. Sun directly or via email: suny@iastate.edu

Recent Extension of RFEC To Inspection of Objects with Flat Geometries

10 fasteners in $\frac{1}{4}$ " holes
0.73" apart.

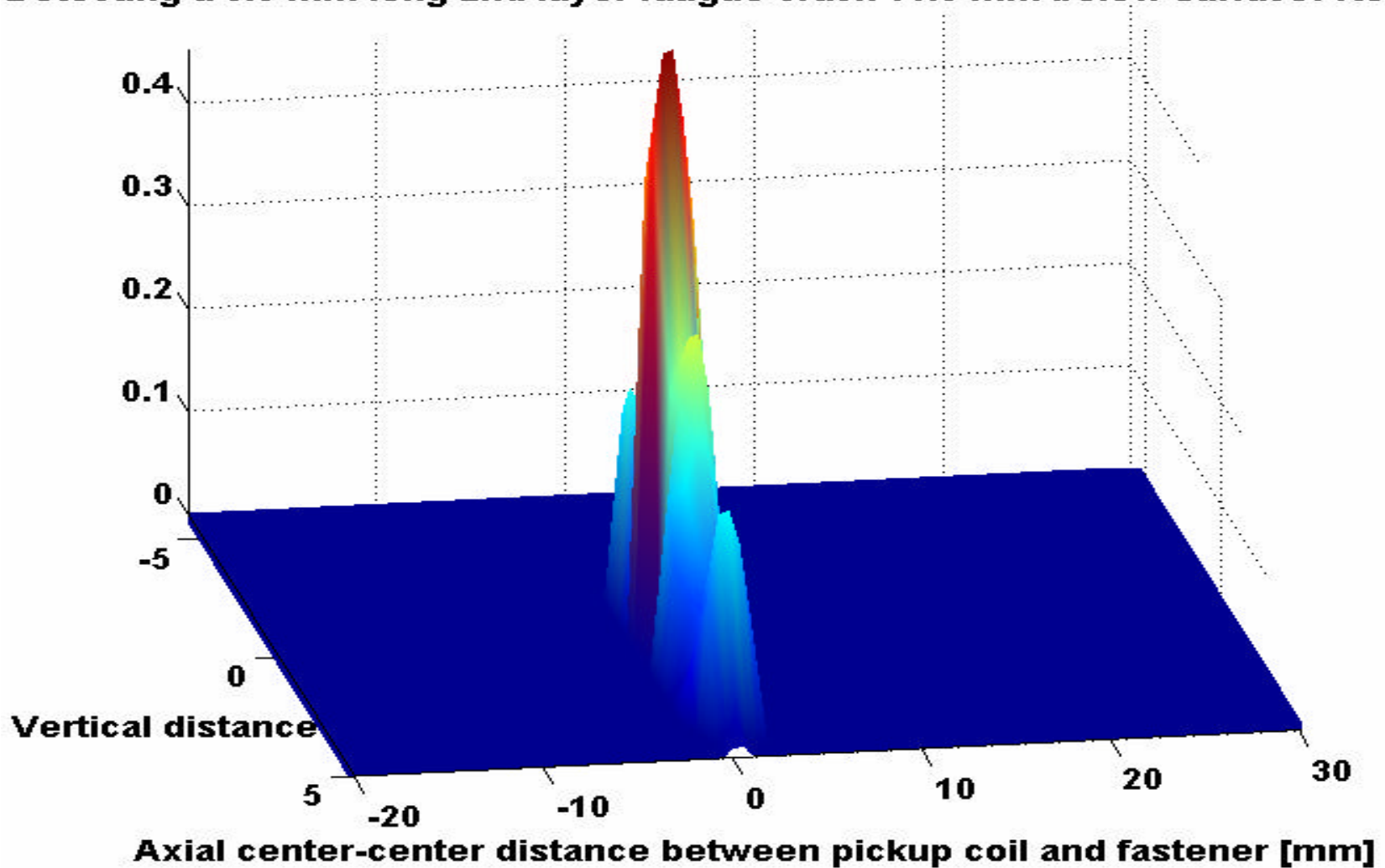
A steel fastener at the
hole #5



A 0.031" long transverse crack on the bottom
surface of the second layer at the left side of
fastener #8

Recent Extension of RFEC To Inspection of Objects with Flat Geometries

Detecting a 0.8 mm long 2nd layer fatigue crack 11.3 mm below surface: Real



Probes & Specimens

Specimens

- ❖ Aircraft wing spanwise splice standards
- ❖ Aluminum wing skin/spar cap arrangements

Thin Panel

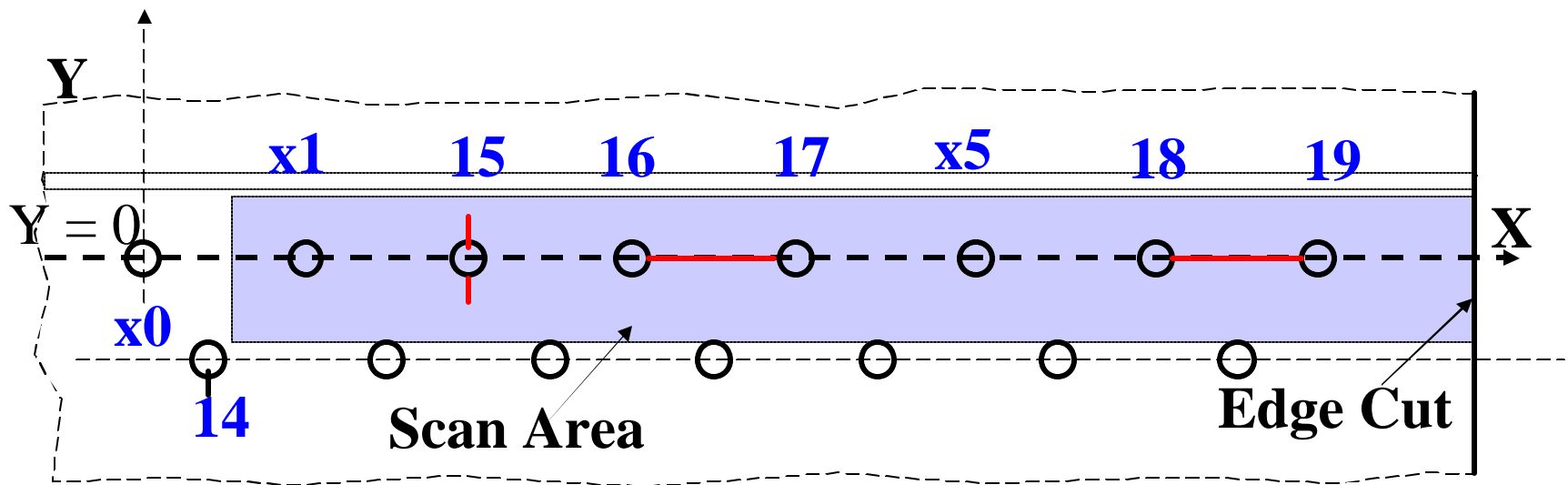
- ❖ Each layer: 0.125" thick
- ❖ Total thickness: 0.25"
- ❖ Total fasteners: 69
- ❖ Total slots: 17
- ❖ Axially oriented: 8
- ❖ Vertically oriented: 8
- ❖ Diagonally oriented: 1
- ❖ In 1st layer: 3
- ❖ In 2nd layer: 14
- ❖ Slot lengths: 0.1" to 1.2"

Thick Panel

- ❖ Each layer: 0.25" thick
- ❖ Total thickness: 0.5"
- ❖ Total fasteners: 72
- ❖ Total slots: 18
- ❖ Axially oriented: 10
- ❖ Vertically oriented: 7
- ❖ Diagonally oriented: 1
- ❖ In 1st layer: 1
- ❖ In 2nd layer: 17
- ❖ Slot lengths: 0.1" to 1.05"

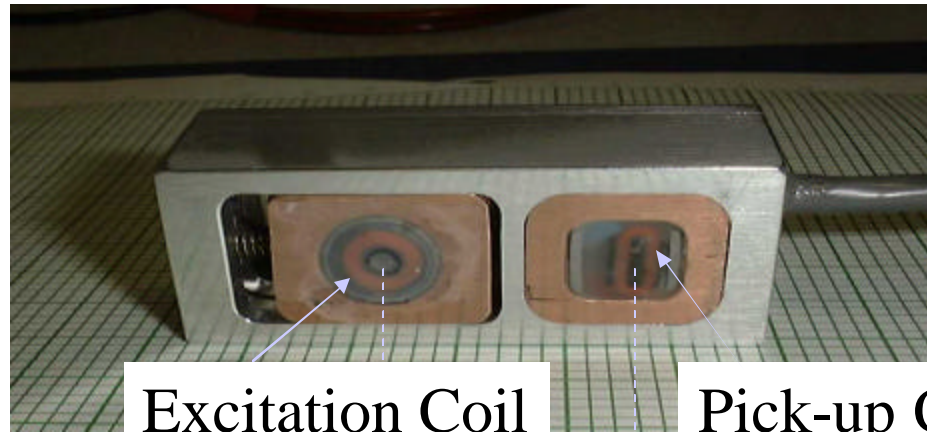
Probes & Specimens

Typical fastener distribution and slot orientation



Probes & Specimens

RFEC Probe RF-4mm



Excitation Coil

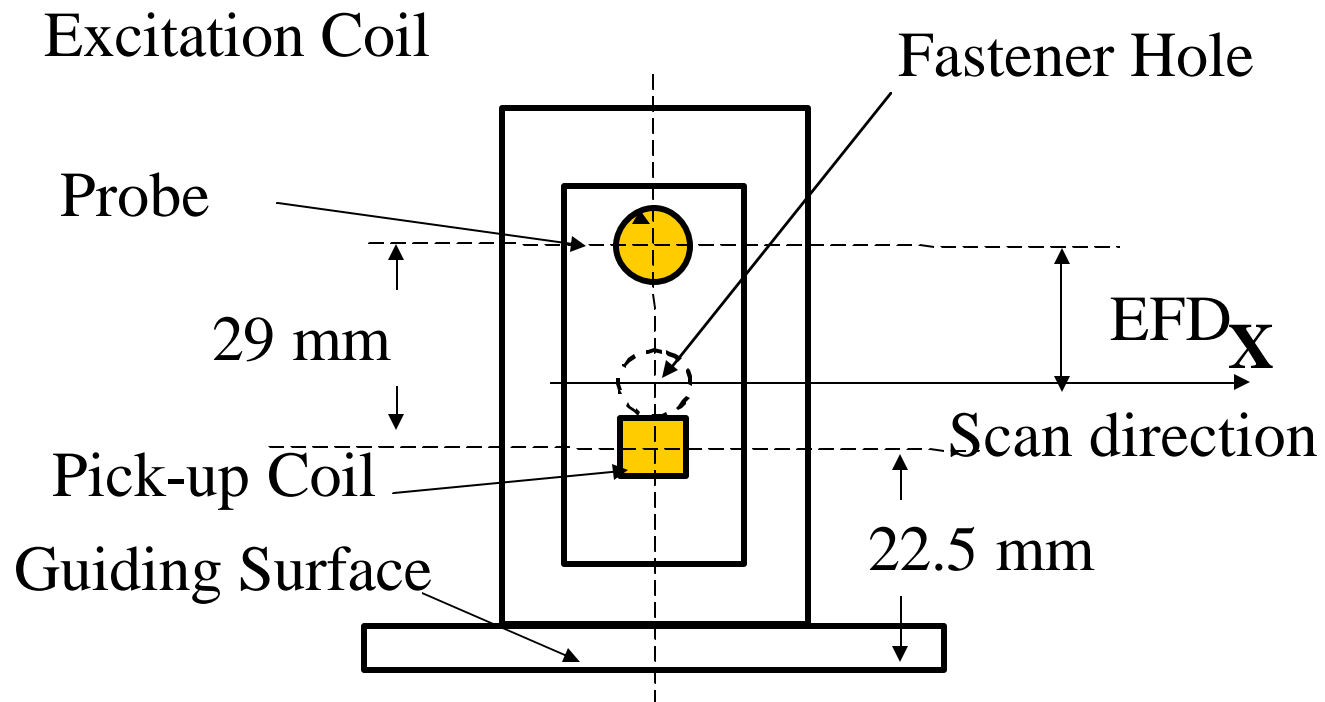
Pick-up Coil

← 29 mm

Footprint: 55mm(L) x 22 mm(W) x 22 mm (H)

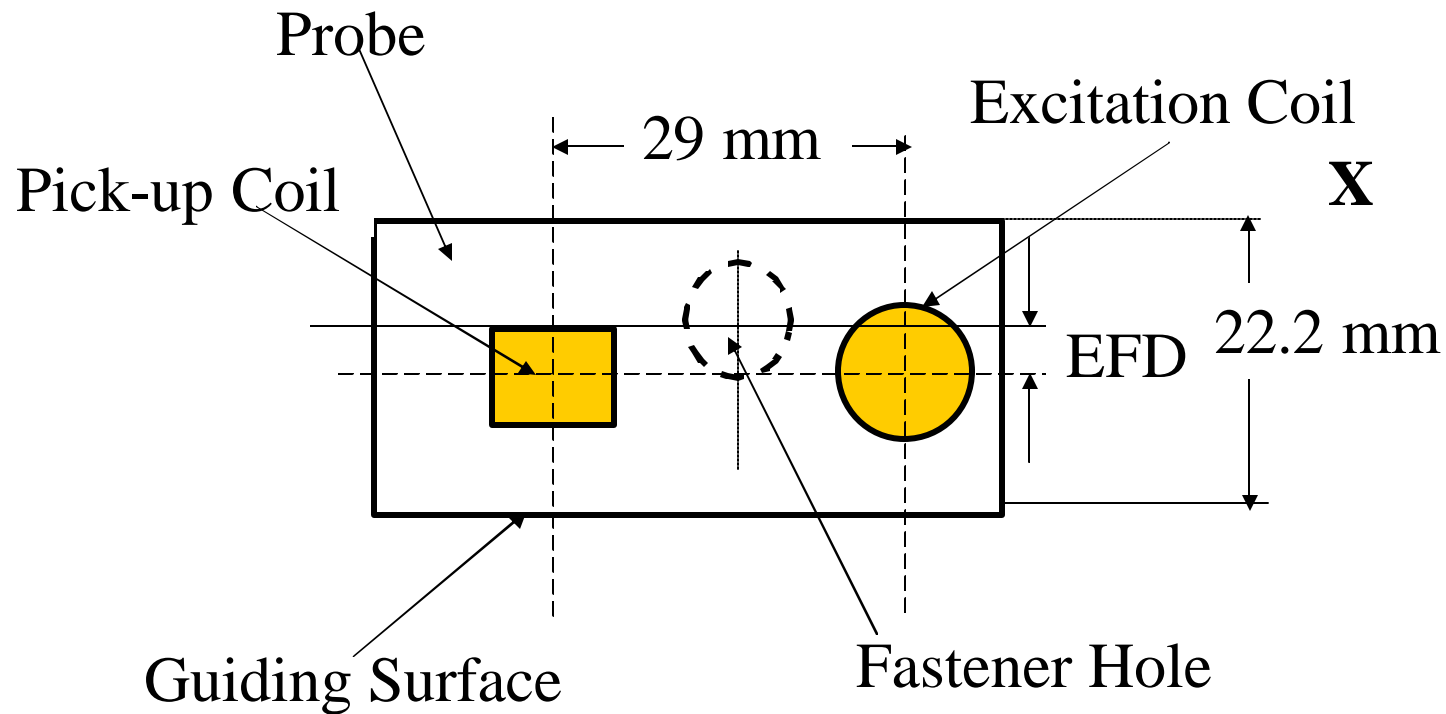
SCAN MODES

Mode 1: vertically oriented probe and axial scan.



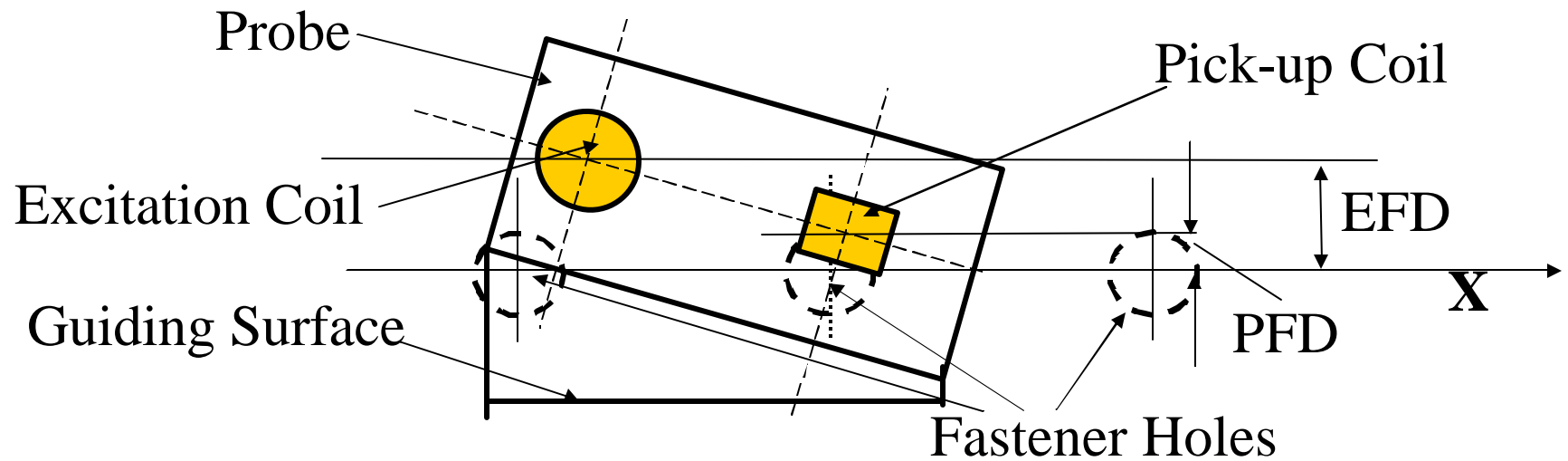
SCAN MODES

Mode 2: axially oriented probe and axial scan.

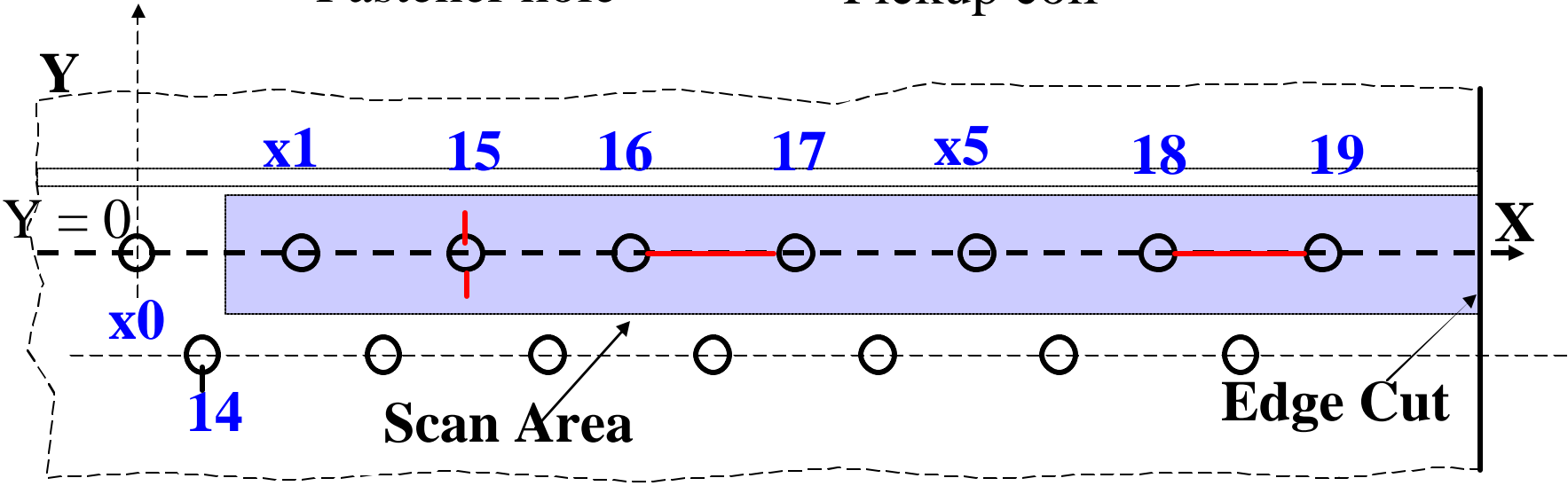
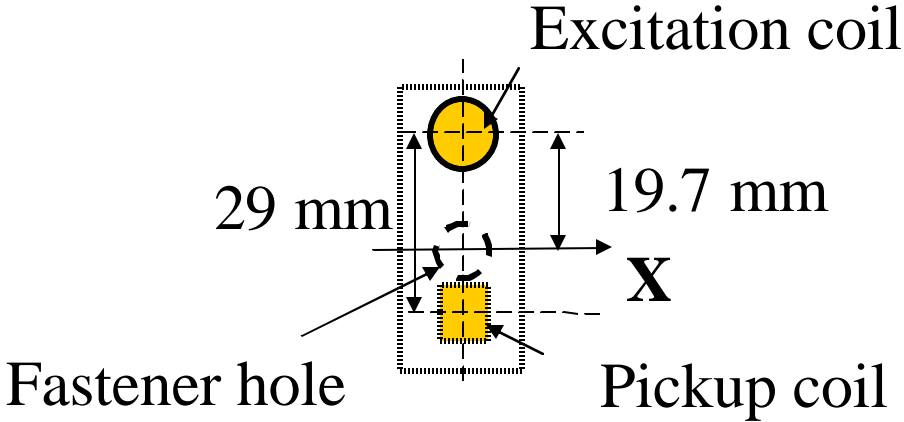


SCAN MODES

Mode 3: angularly oriented probe and axial scan.

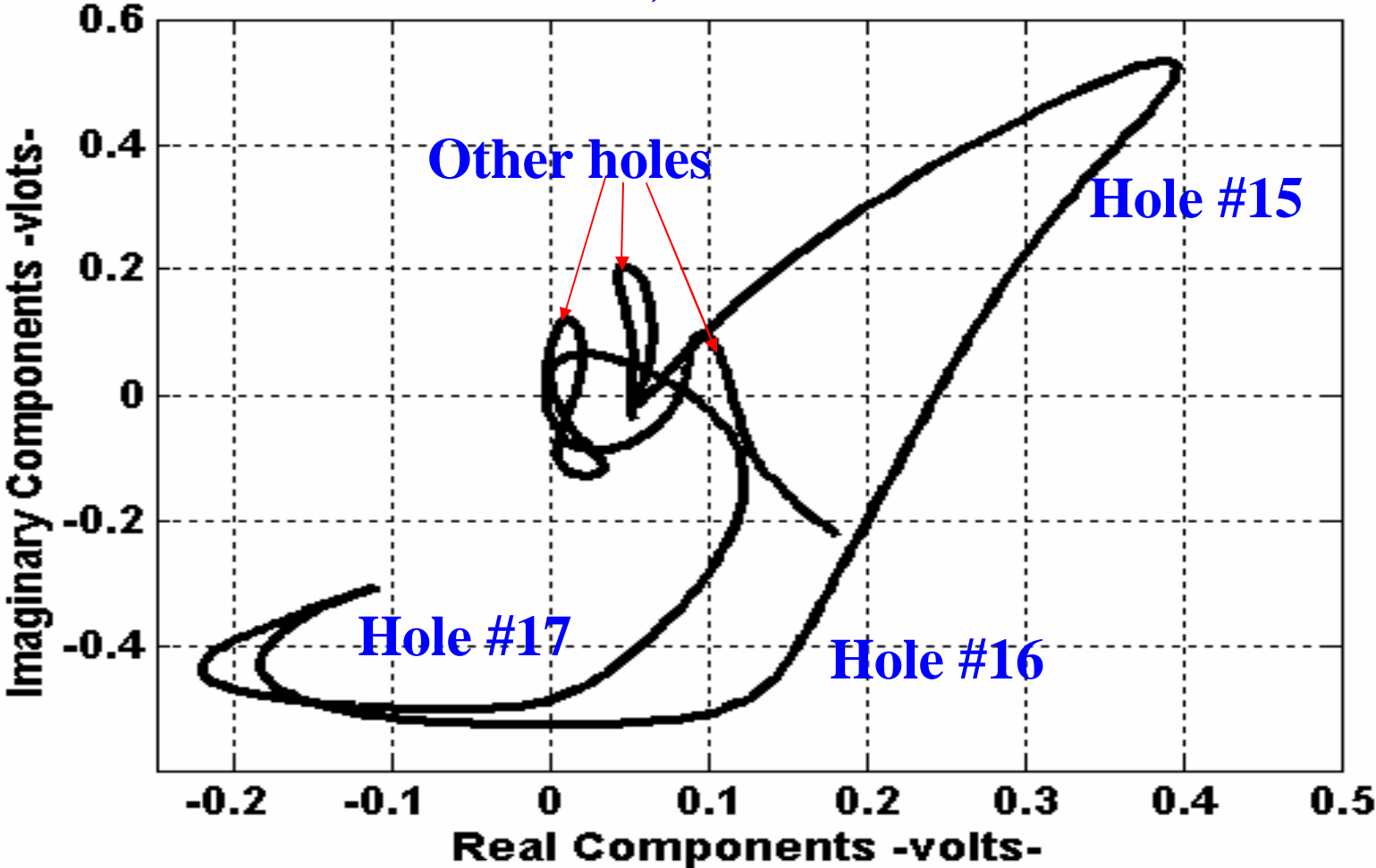


Mode 1 Non-Steel Fasteners



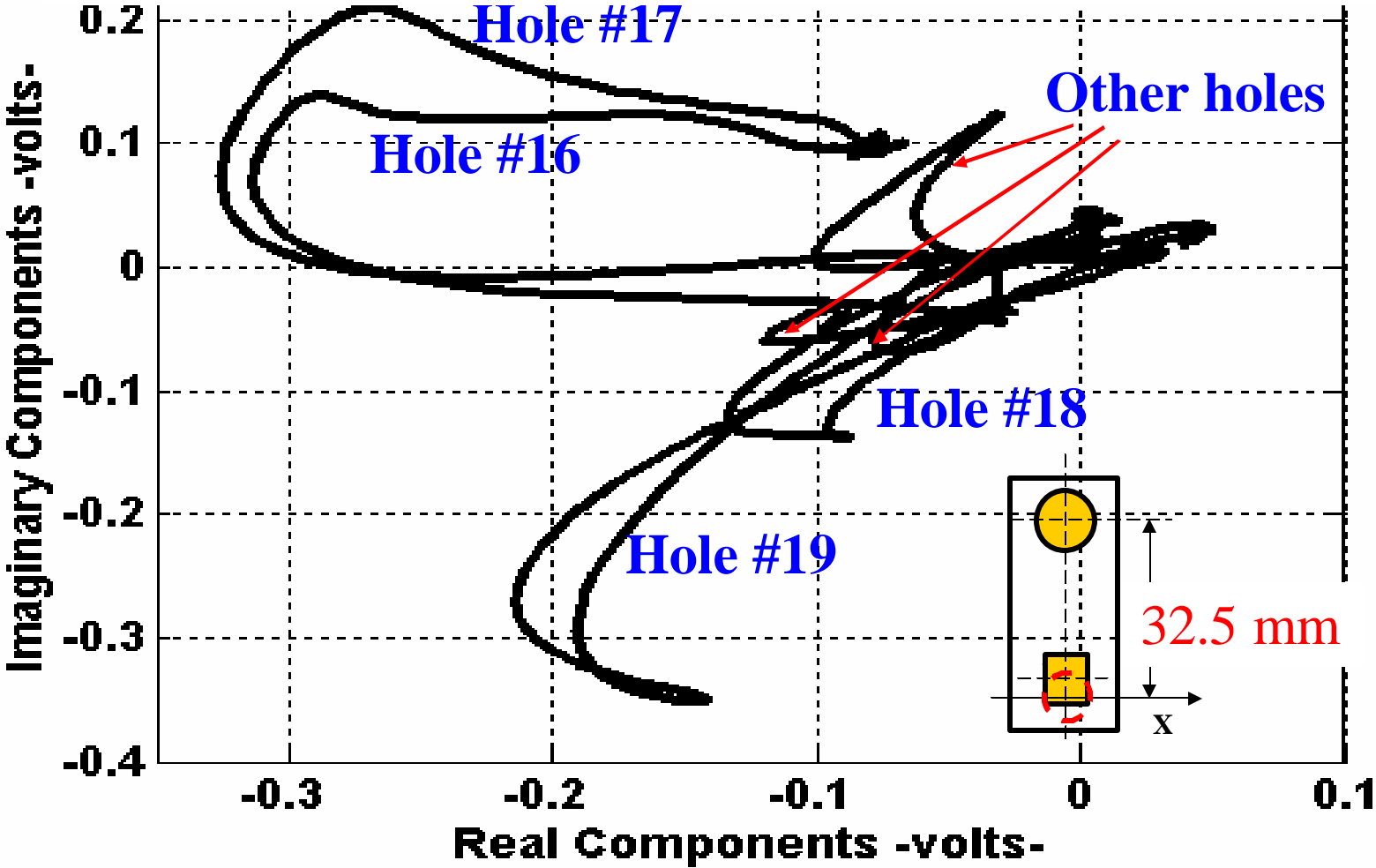
Mode 1 Non-Steel Fasteners

$f = 100 \text{ Hz}$, $EFD = 19.7 \text{ mm}$



Mode 1 Non-Steel Fasteners

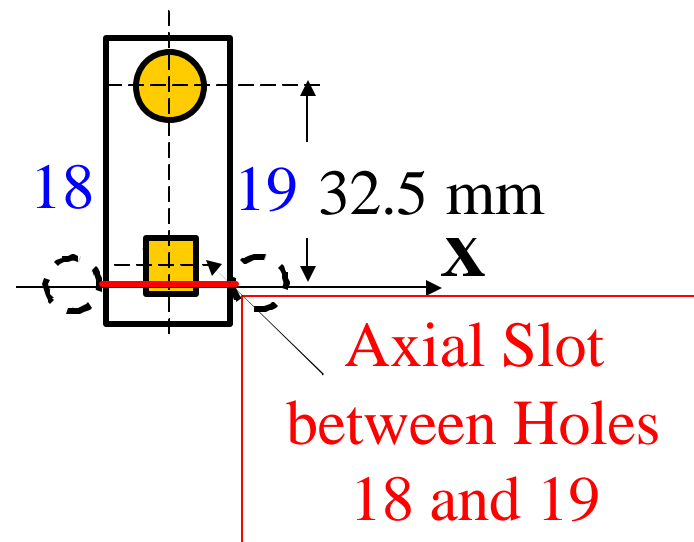
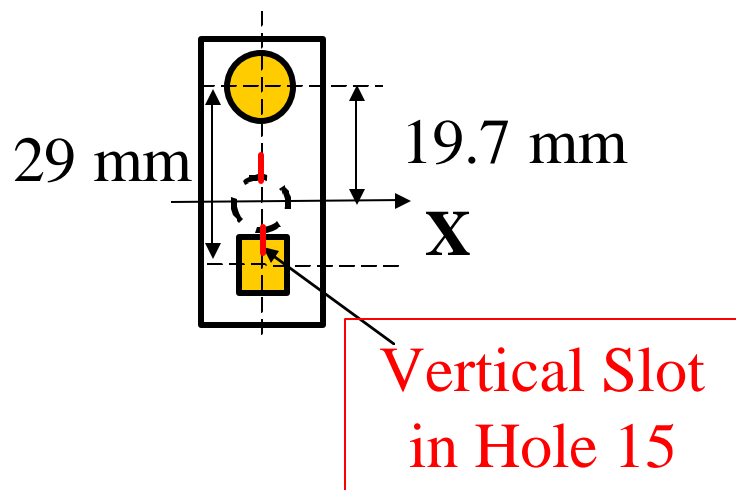
$f = 300 \text{ Hz}$, $\text{EFD} = 32.5 \text{ mm}$



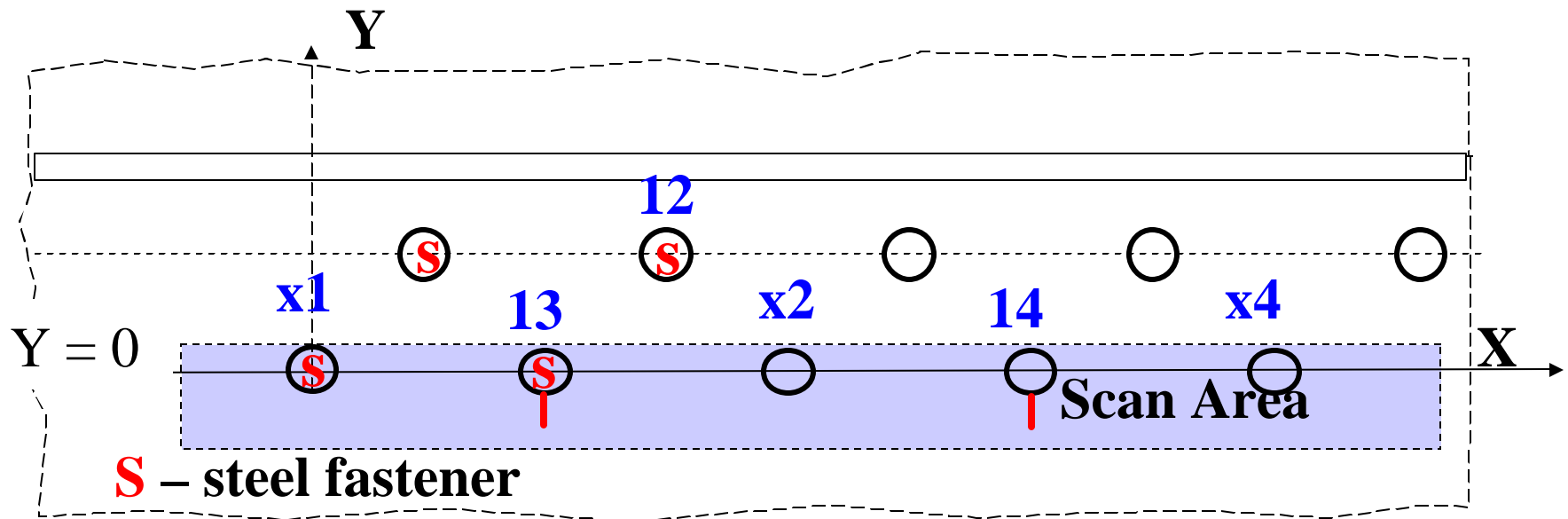
Mode 1 Non-Steel Fasteners

The pickup-coil-to-slot-relationship:

A 2nd layer slot in a non-steel fastener hole is detected by an RFEC probe when an edge of its pickup coil is running over the slot.



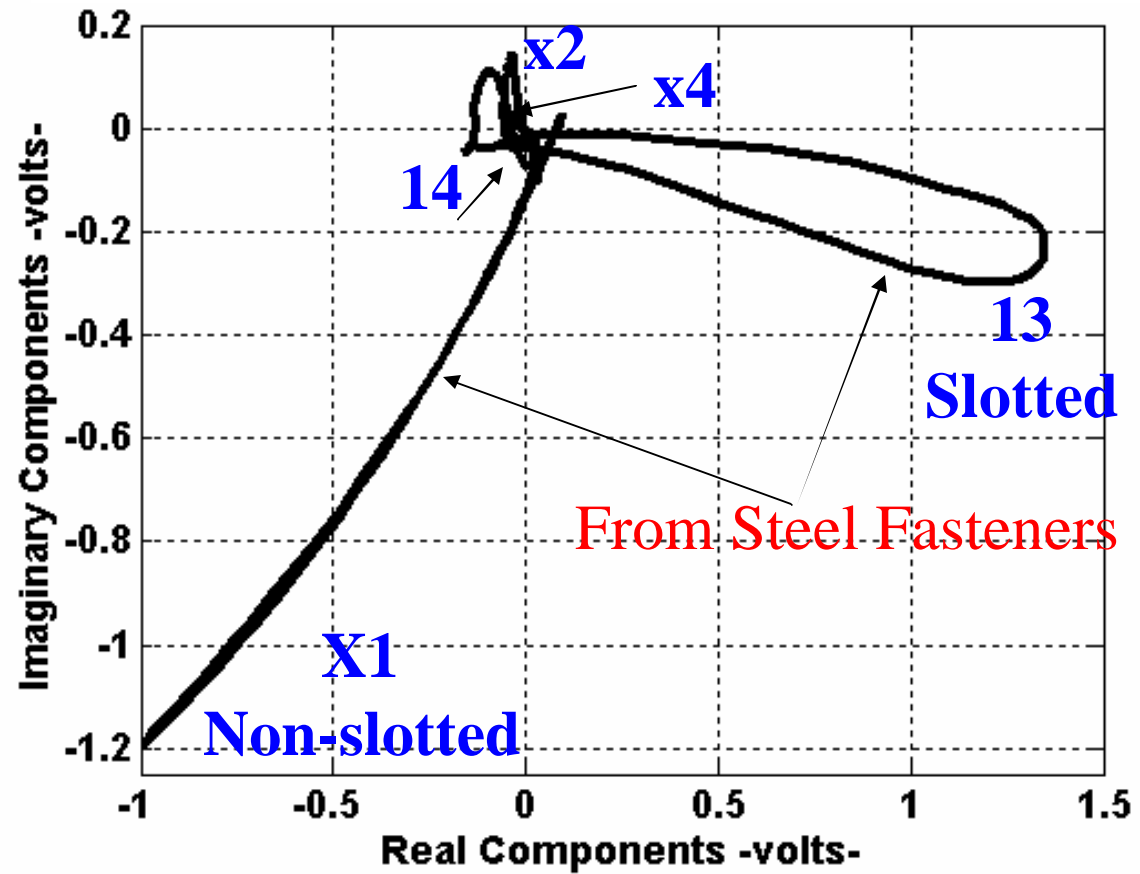
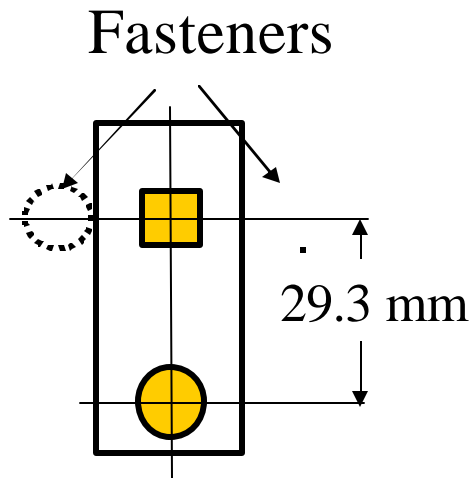
Mode 1 Mixed Steel And Non-Steel Fastener Distribution



Mode 1 Mixed Steel And Non-Steel Fastener Distribution

Complete Signal

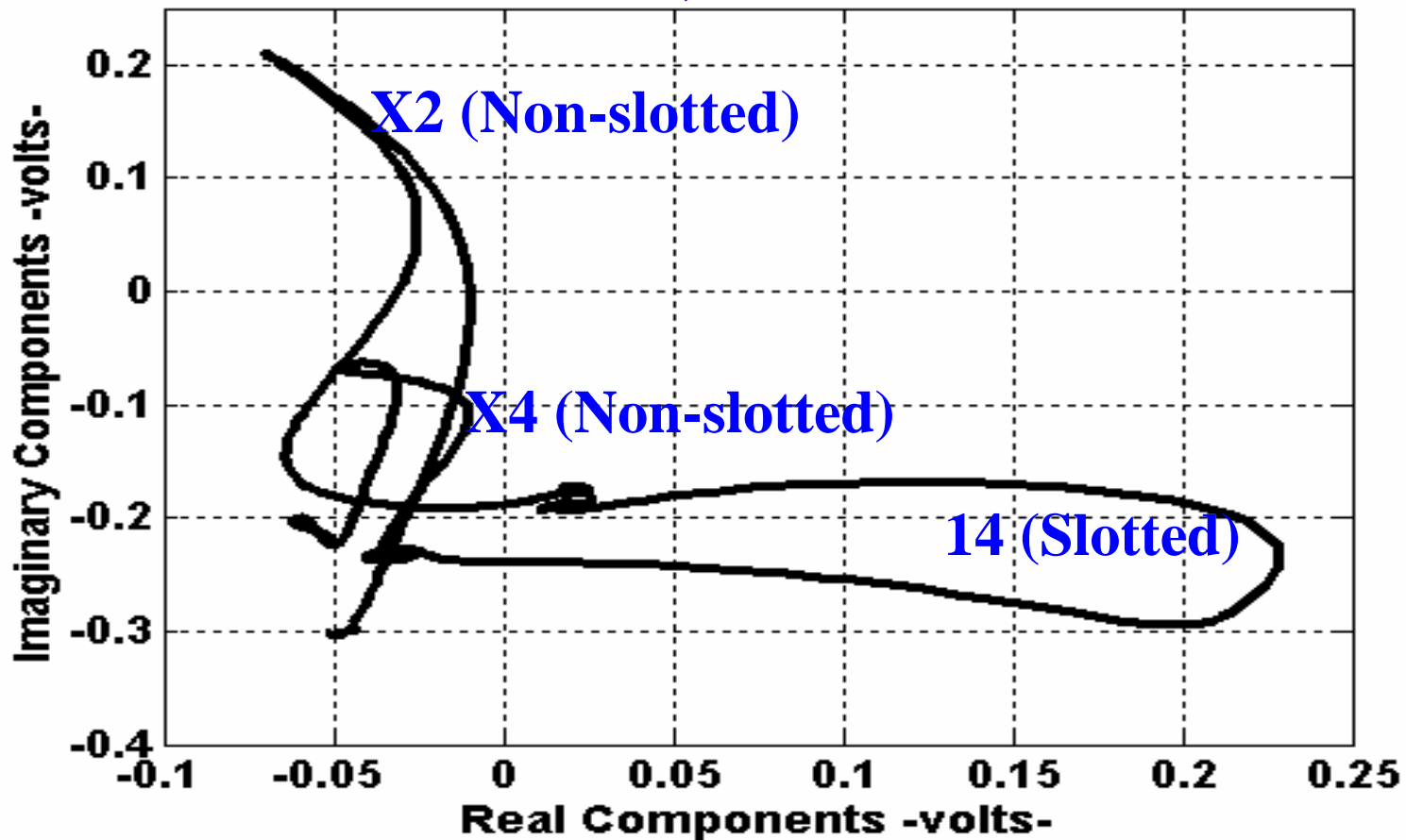
$f = 100 \text{ Hz}$, $\text{EFD} = 29.3 \text{ mm}$



Mode 1 Mixed Steel And Non-Steel Fastener Distribution

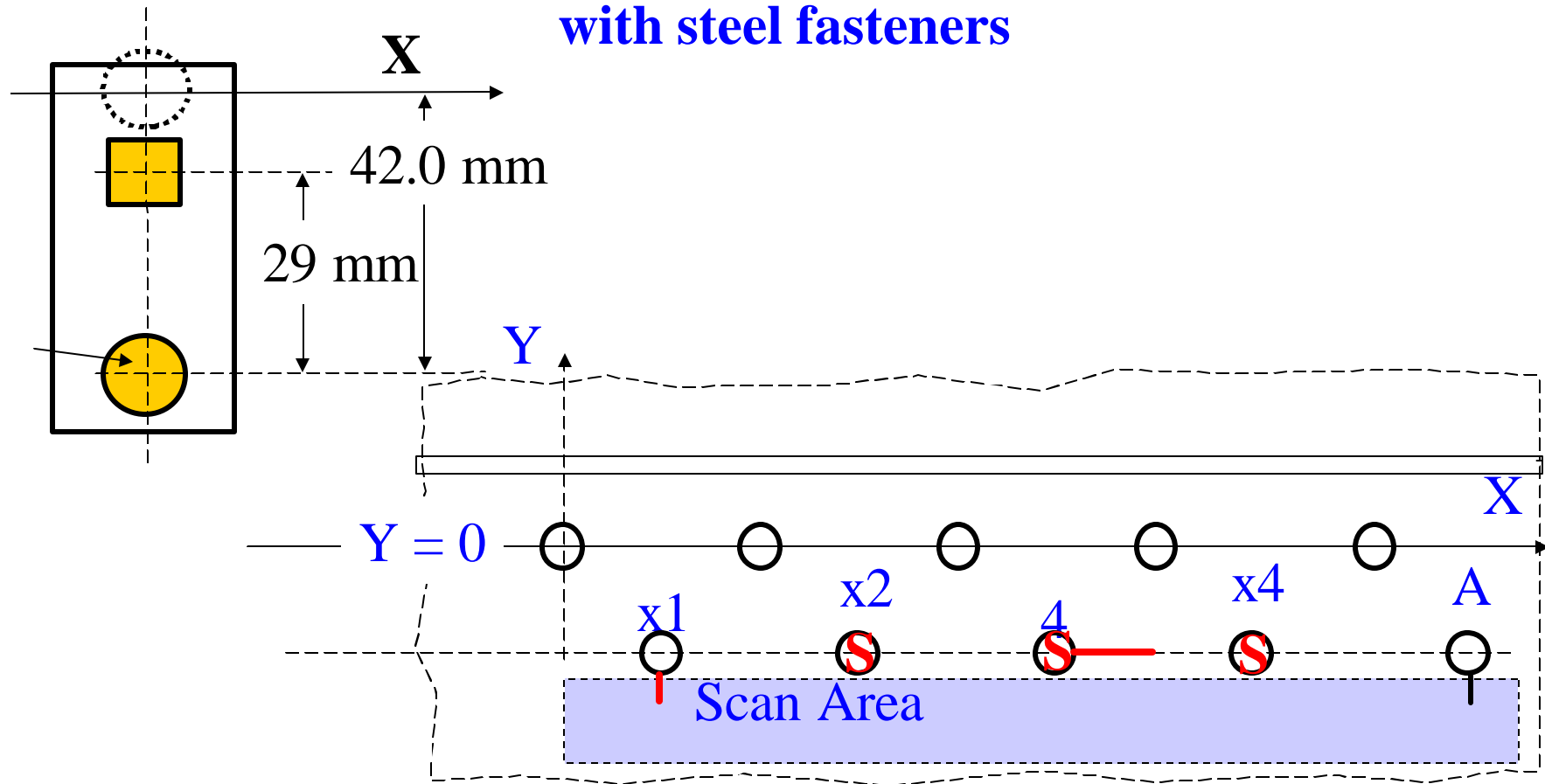
(Signals from steel Fastener holes are excluded)

$f = 500 \text{ Hz}$, $\text{EFD} = 29.3 \text{ mm}$



Mode 1 Mixed Steel And Non-Steel Fastener Distribution

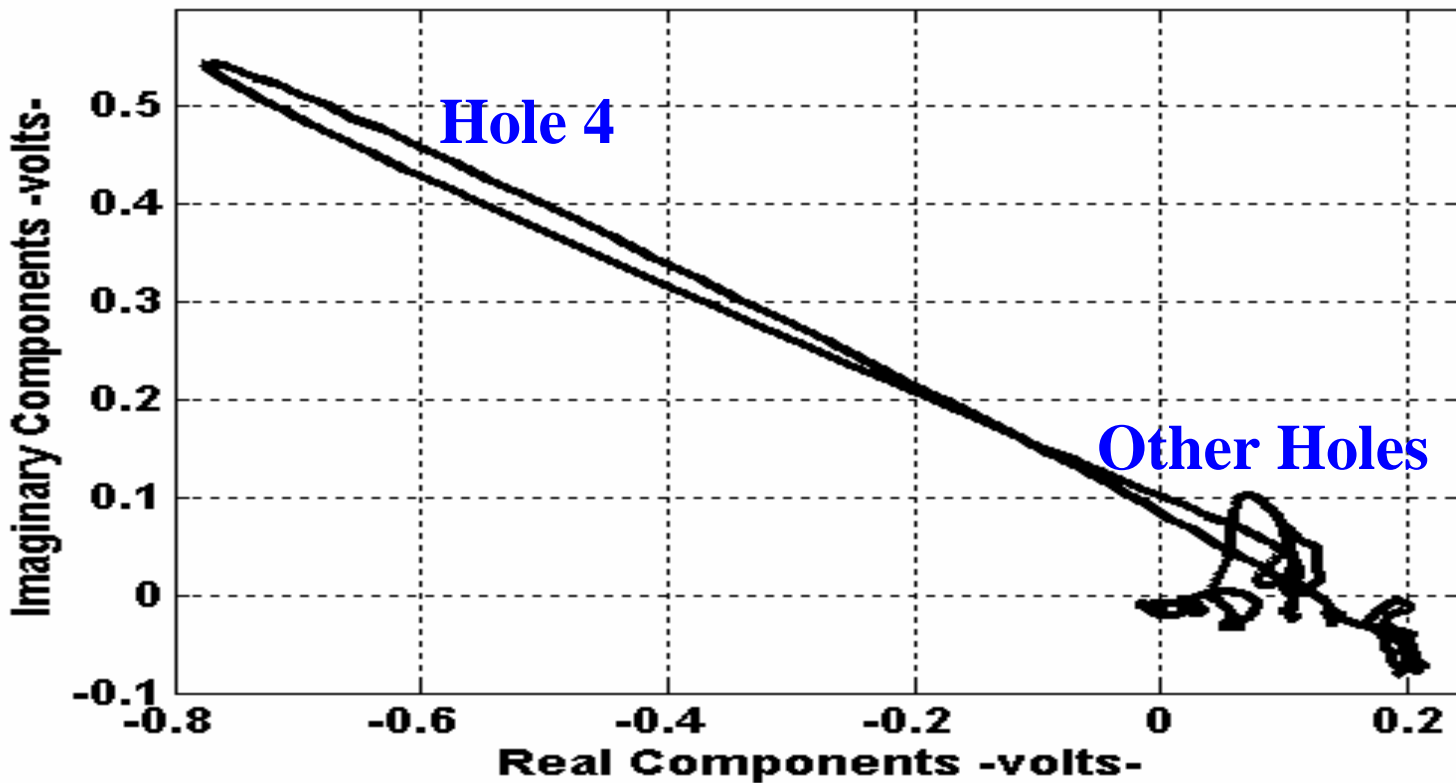
Arrangement for improving response from holes with steel fasteners



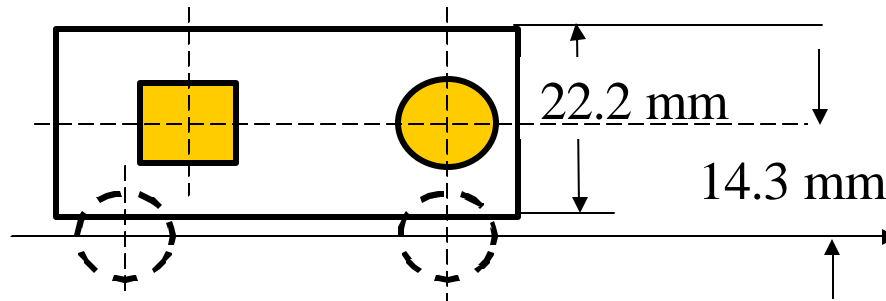
Mode 1 Mixed Steel And Non-Steel Fastener Distribution

Arrangement for improving response from holes
with steel fasteners

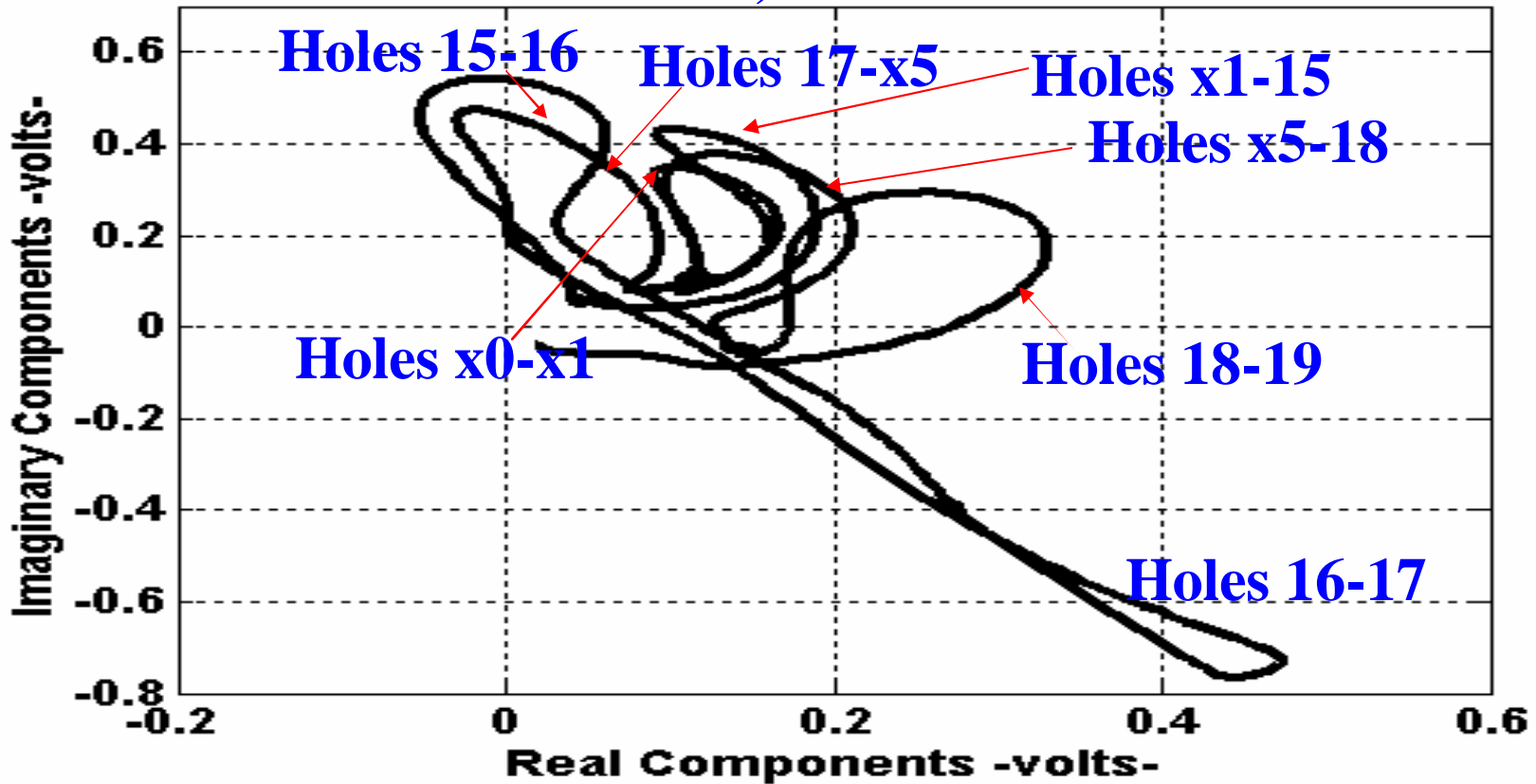
$f = 300 \text{ Hz}$, $\text{EFD} = 42.0 \text{ mm}$



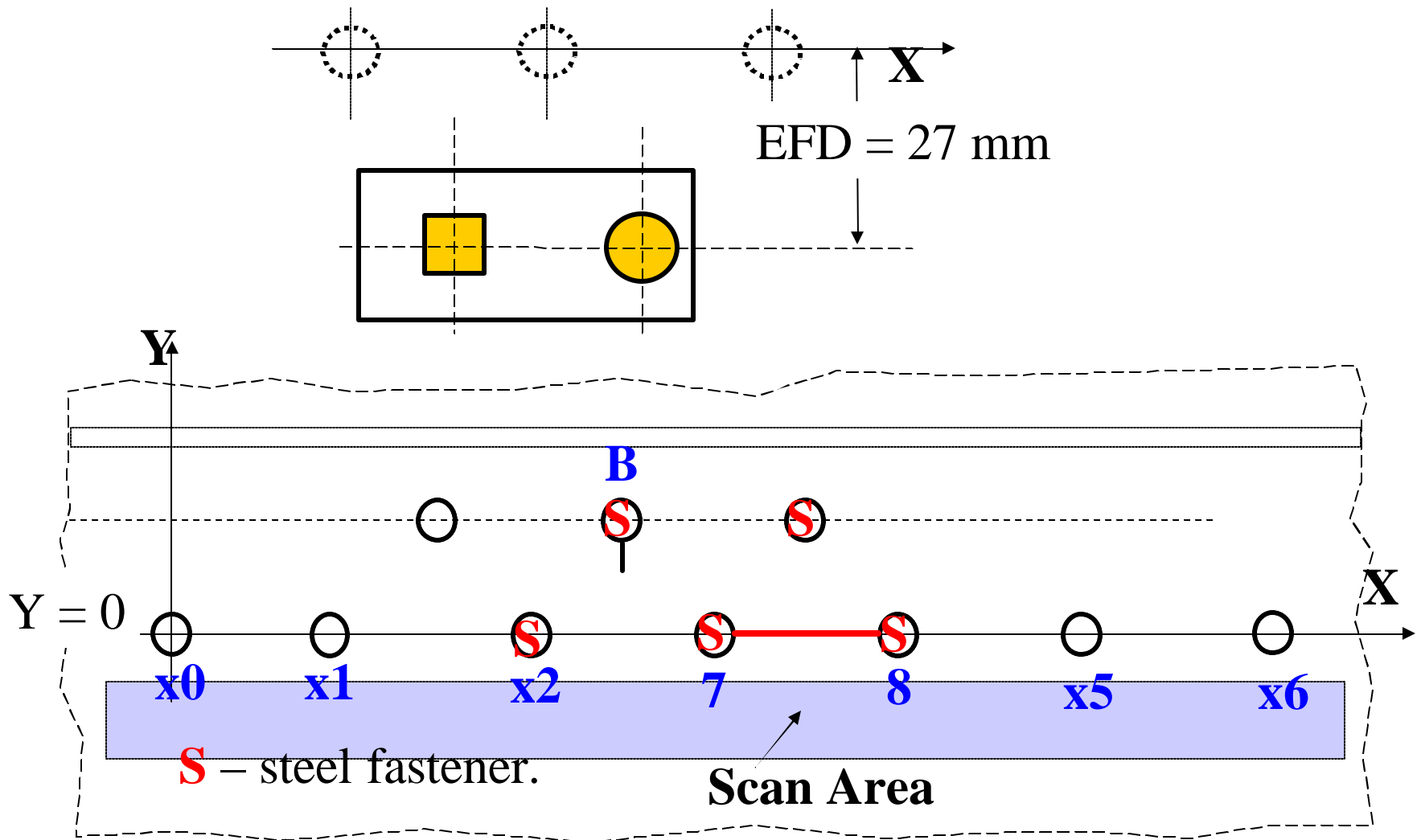
Mode 2 Non-Steel Fasteners



$f = 100 \text{ Hz}$, EFD = 14.3 mm

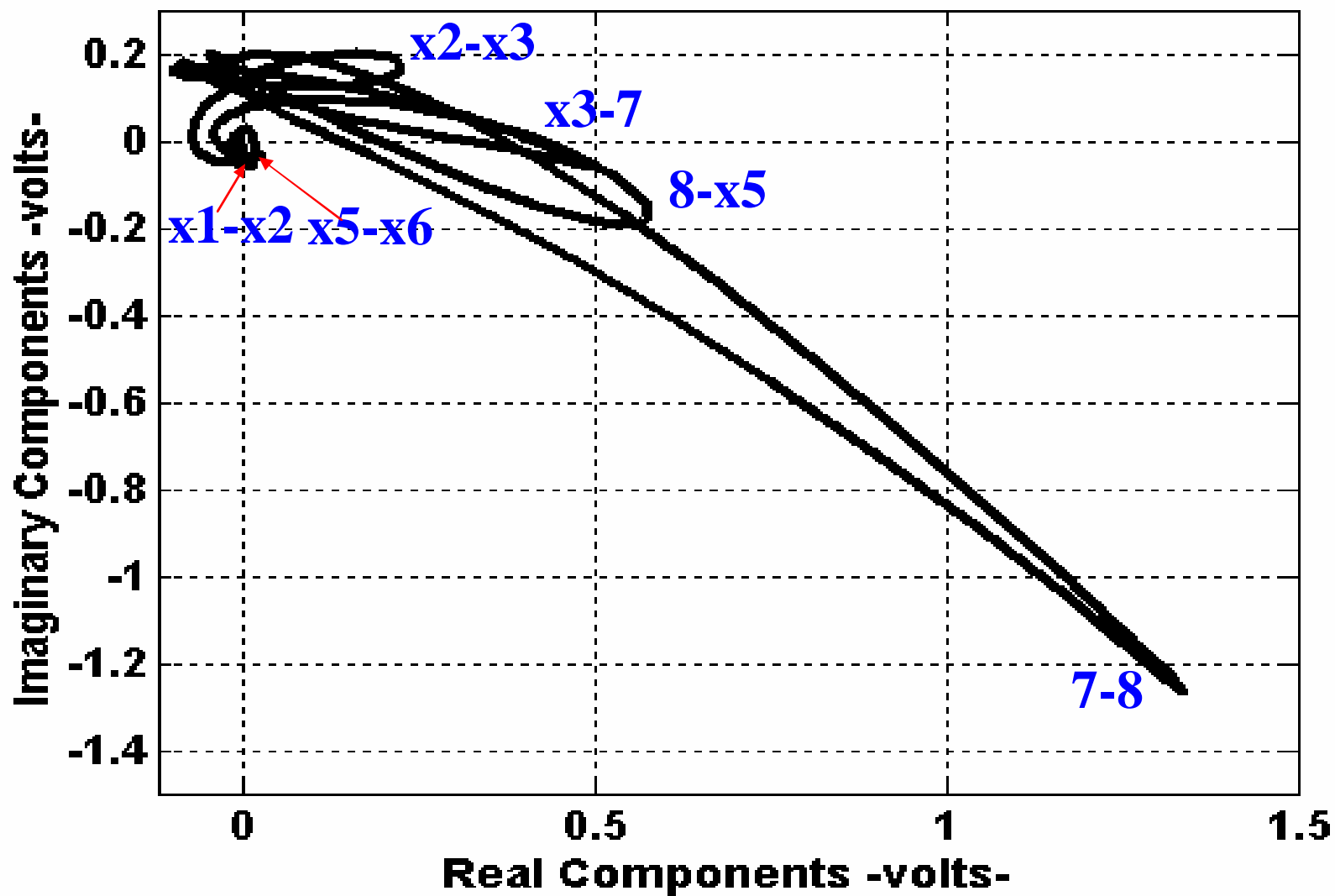


Mode 2 Detecting Slotted Holes Among Steel Fasteners

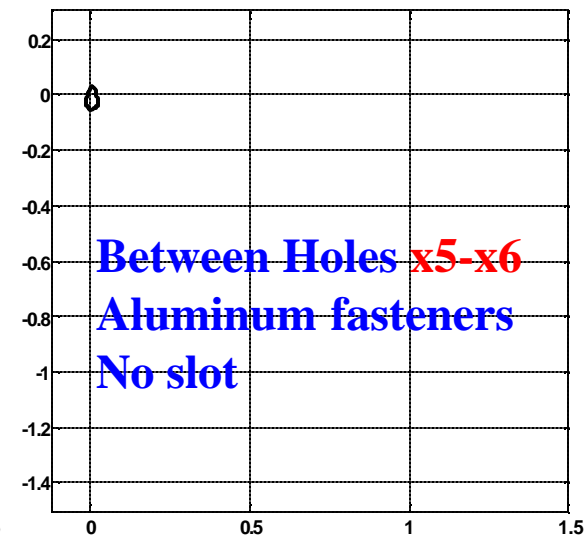
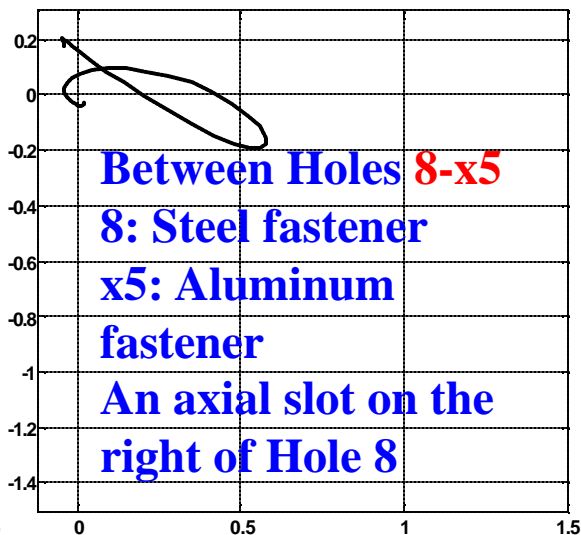
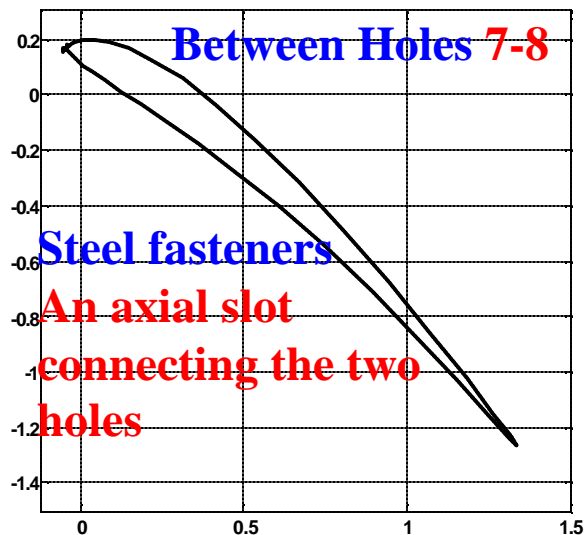
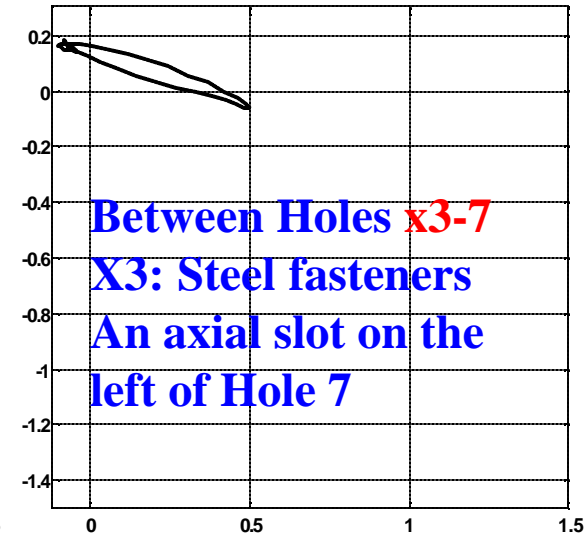
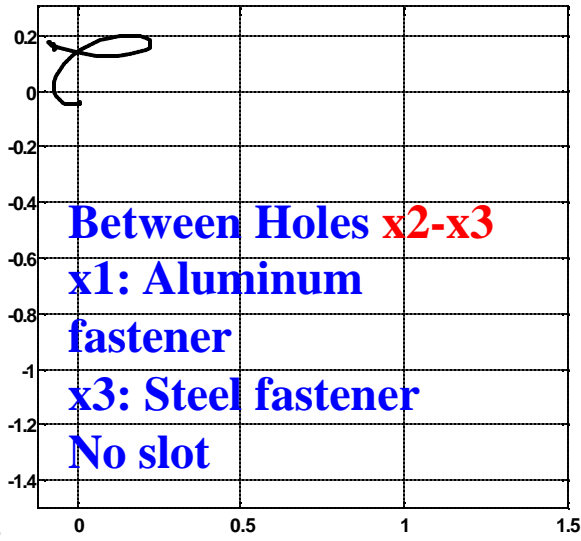
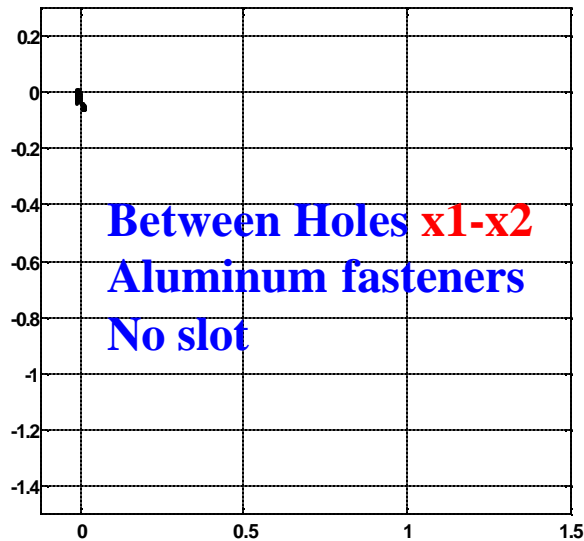


Mode 2 Detecting Slotted Holes Among Steel Fasteners

$f = 100 \text{ Hz}$, $\text{EFD} = 27.0 \text{ mm}$



Mode 2 Detecting Slotted Holes Among Steel Fasteners



Conclusions

- 1. The first and second layer slots in the two wing spanwise splice standards were detected using the RFEC technique.**
- 2. Three different scan modes were used to perform the tasks. While Mode 1, axially oriented probe and vertical scan, provides the best sensitivity to slots, Mode 2 and Mode 3 provide better flexibility in negotiating a probe among fastener holes and other structure restrictions.**

(Continued on Next Page)

Conclusions (contd.)

3. Preliminary results include:

A. To detect a slotted hole:

- Non-steel fastener - one edge of its pickup coil close or right on top of the slot.
- Steel fastener - the pickup coil should be placed away from the slotted hole, as well as away from other steel fasteners.
- Mixed fastener distribution - separate the signals into two groups: non-steel fastener hole signals and steel fastener hole signals.

B. For second layer slots a slotted hole signal is different from a non-slotted hole signal in both its magnitude and phase angle, but the phase angle has the more pronounced difference.