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

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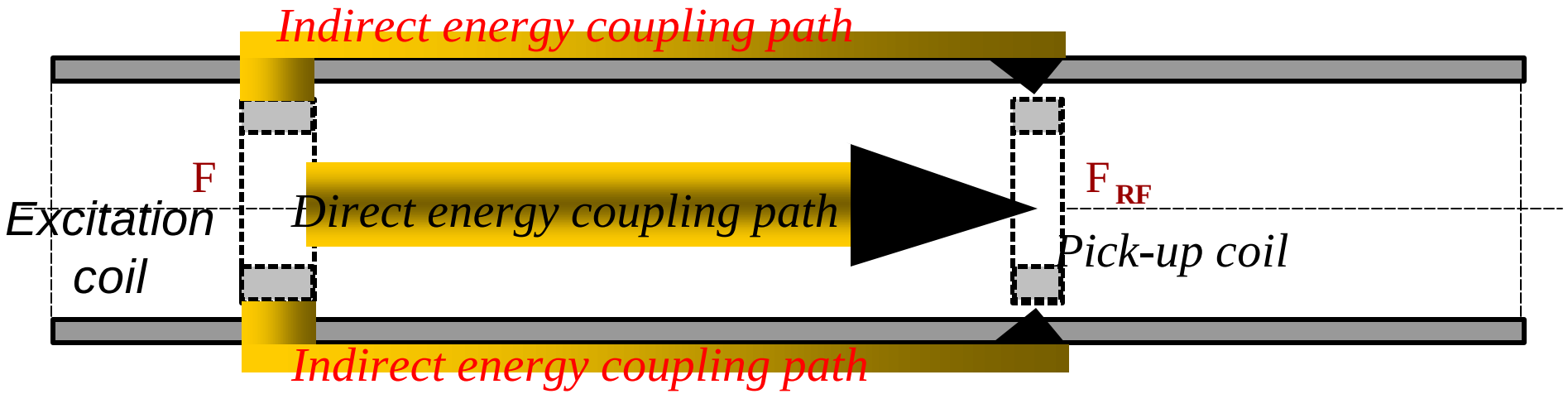
INTRODUCTION

- **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**

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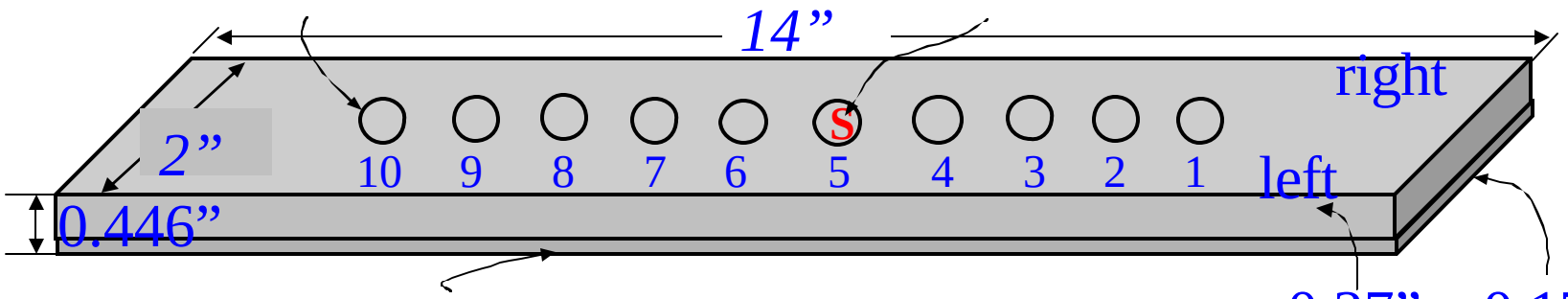
* The detailed information is available upon request from the presenter, Professor Y. Sun directly or via email: suny@iastate.edu

Recent Extension of RFEC To Inspection of Objects with Flat Geometries

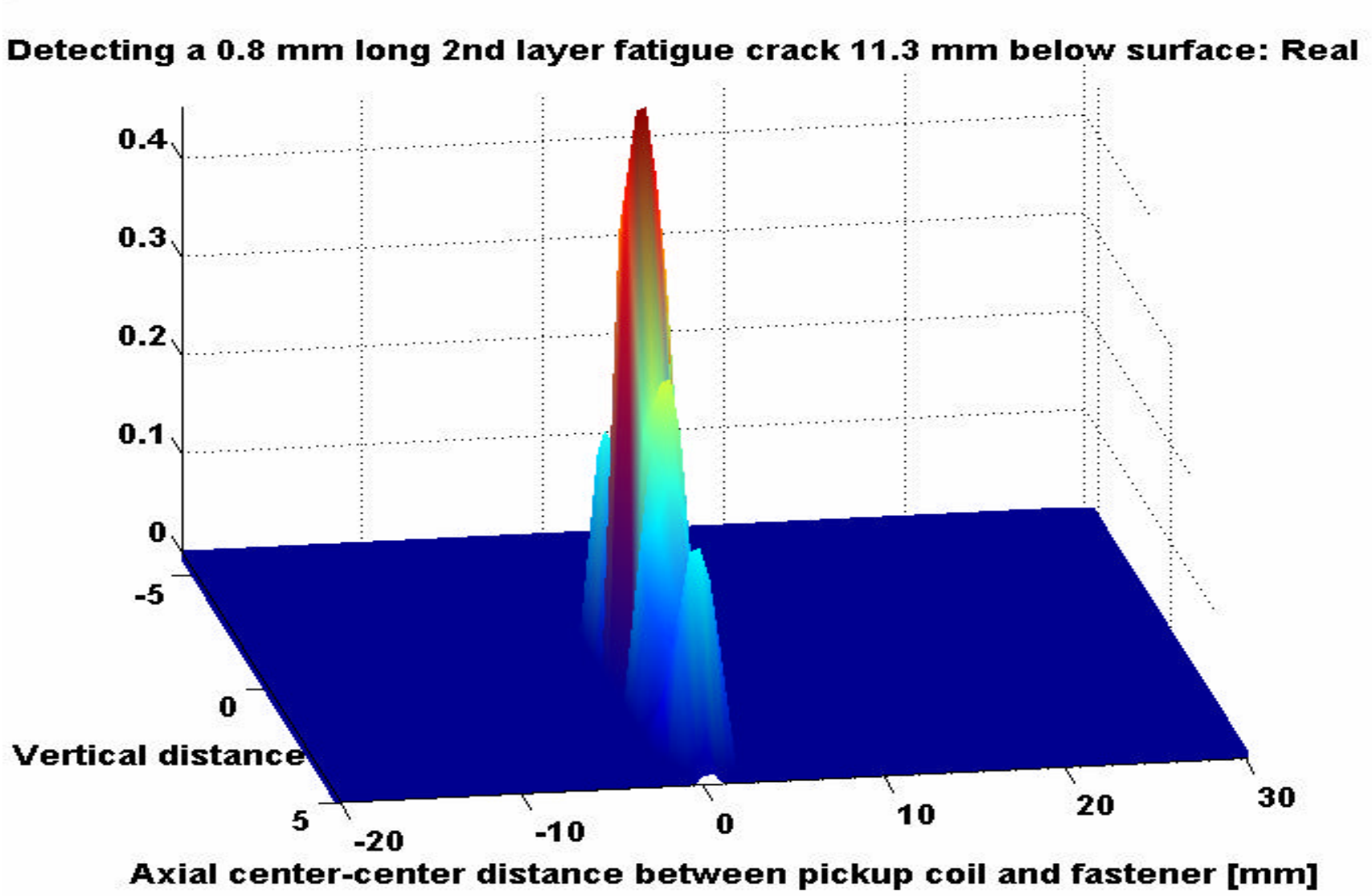
10 fasteners in ¼” holes 0.73” apart.

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



Probes & Specimens

Specimens

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

Thin Panel

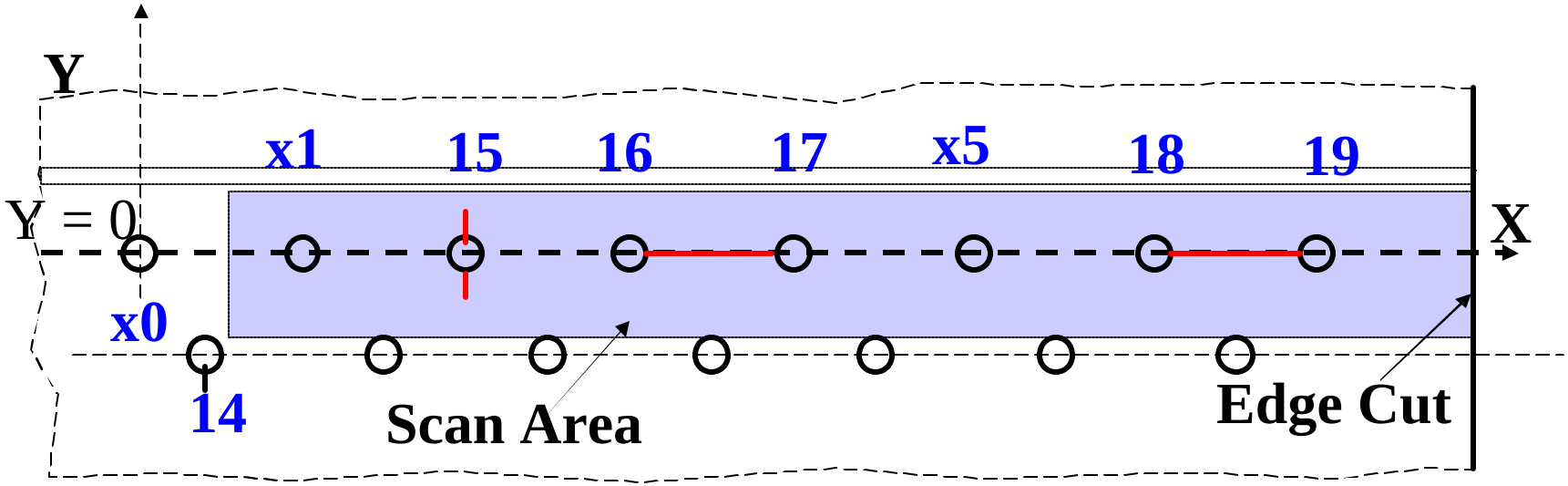
- Each layer: 0.125” thick
- Total thickness: 0.25”
- Total fasteners: 69
- Total slots: 17
- Axially oriented: 8
- Vertically oriented: 8
- Diagonally oriented: 1
- In 1st layer: 3
- In 2nd layer: 14
- Slot lengths: 0.1” to 1.2”

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

Description of Slots In the Thin Panel

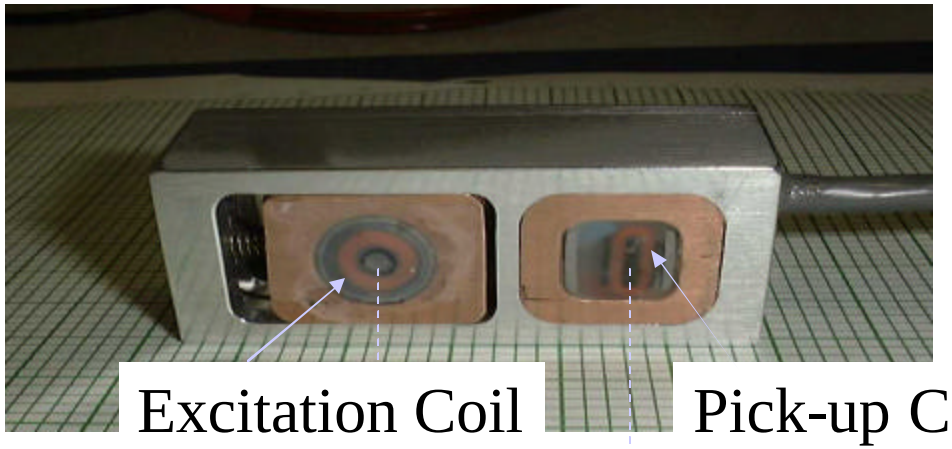
Hole Number	1a + 1b	6-7	20	8	9-10	A	19	14-15	18
Fastener material	Al	Al-Fe	Fe	Fe	Fe-Fe	Al	Fe	Al	Al
Slot location	2nd layer	2nd layer	2nd layer	2nd layer	2nd layer	1st layer	2nd layer	2nd layer	2nd layer
Slot Length inches	0.1+0.25	0.550	0.175	0.500	1.100	0.375	0.275	1.200	0.350
Detection	hit	hit	hit	hit	hit	hit	hit	hit	hit

Description of Slots In the Thick Panel

Hole Number	1+1-2	4	A	7-8	12	13	14	15a-15b	16-17	18-19
Slot location	2nd layer	2nd layer	1st layer	2nd layer	2nd layer	2nd layer	2nd layer	2nd layer	1st layer	2nd layer
Fastener material	Al	Fe	Al	Fe-Fe	Fe	Fe	Al	Al	Al-Al	Al-Al
Slot Length inches		0.500	0.385	1.055	0.250	0.455	0.455	0.100+ 0.245	1.050	1.050
Detection	hit	hit	hit	hit	hit	hit	hit	hit	hit	hit

Probes & Specimens

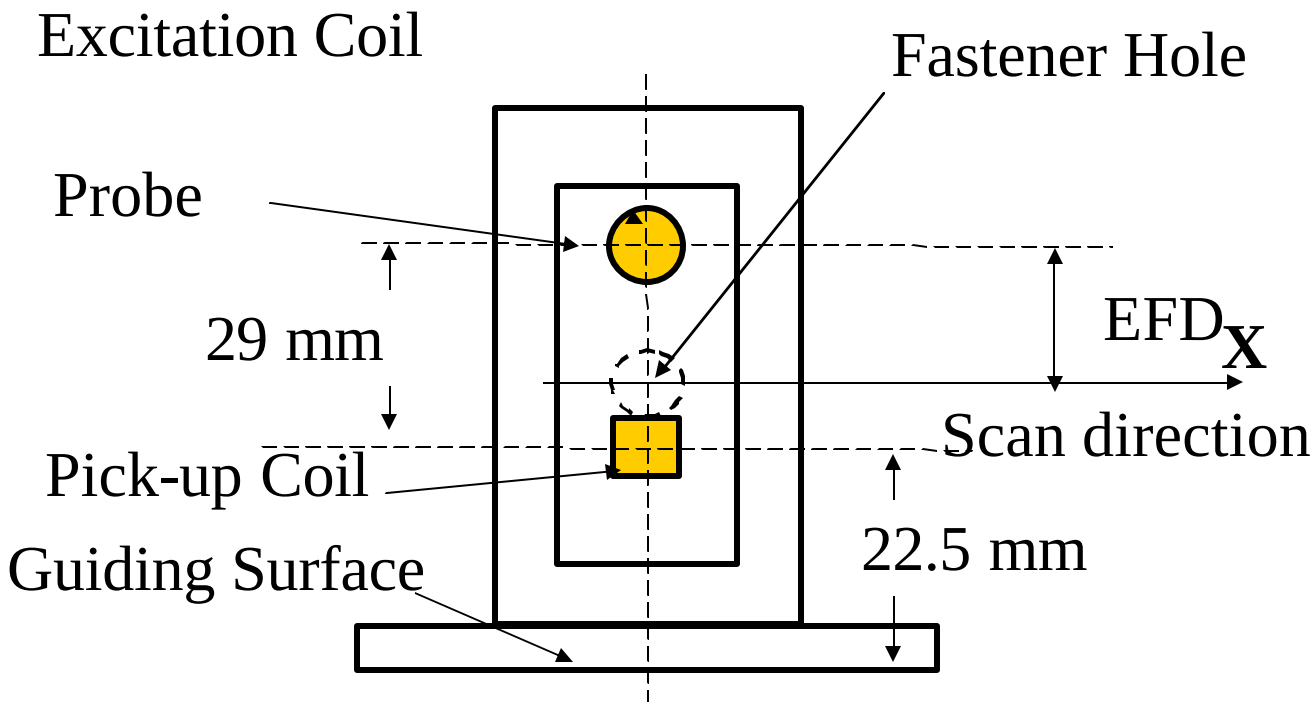
RFEC Probe RF-4mm



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

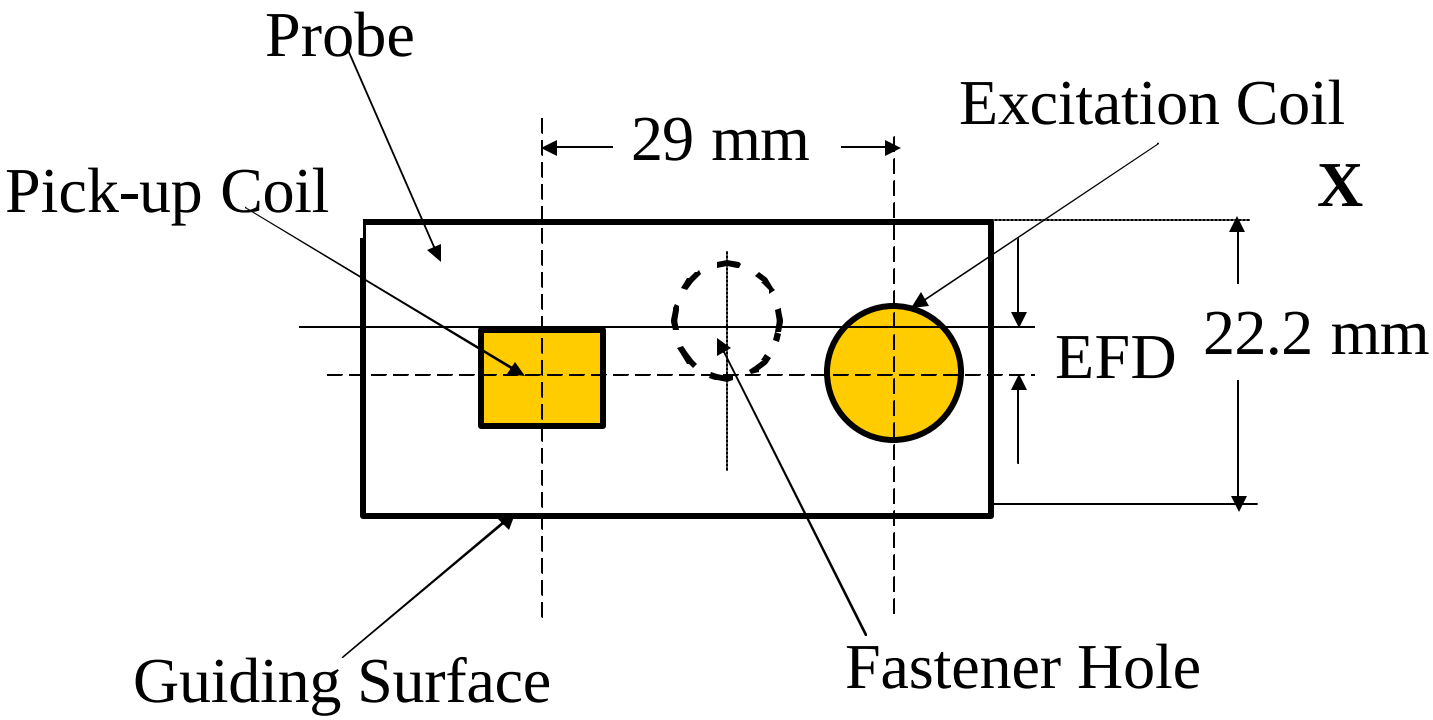
SCAN MODES

Mode 1: vertically oriented probe and axial scan.



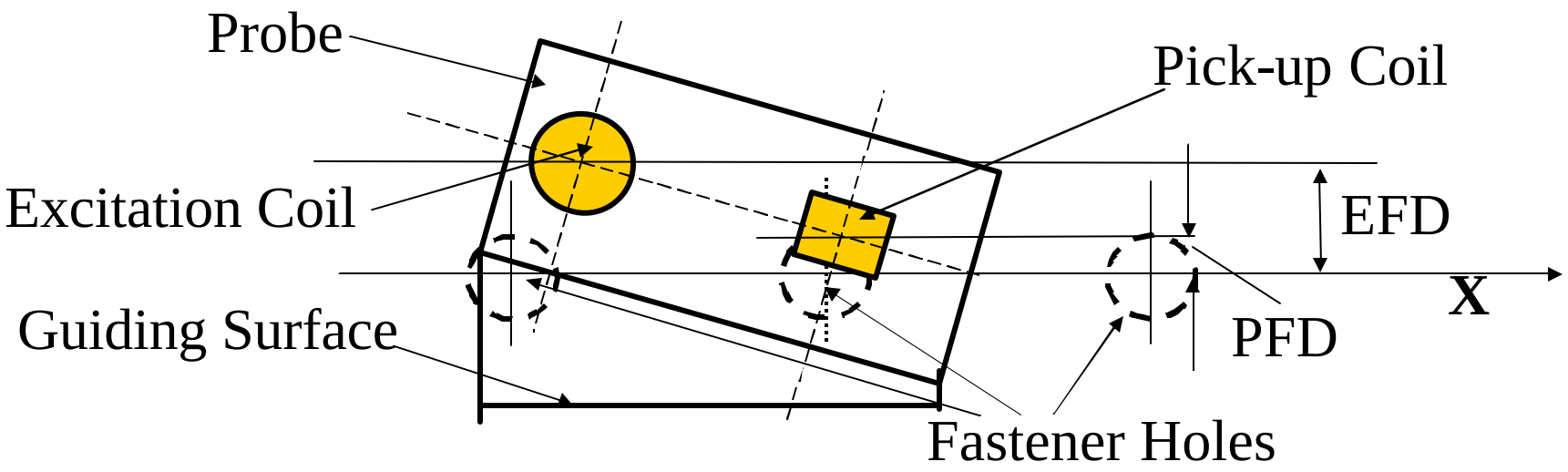
SCAN MODES

Mode 2: axially oriented probe and axial scan.

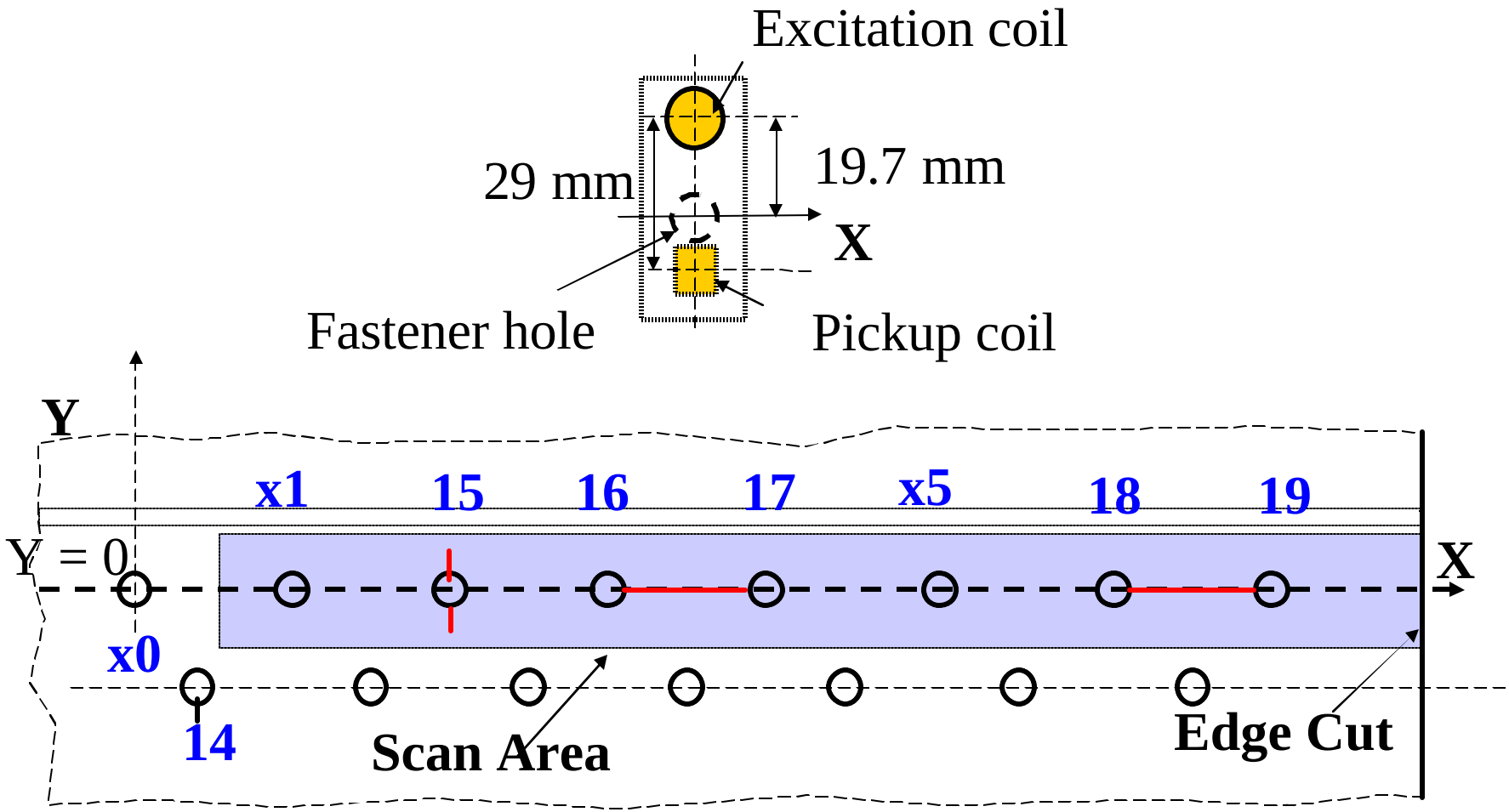


SCAN MODES

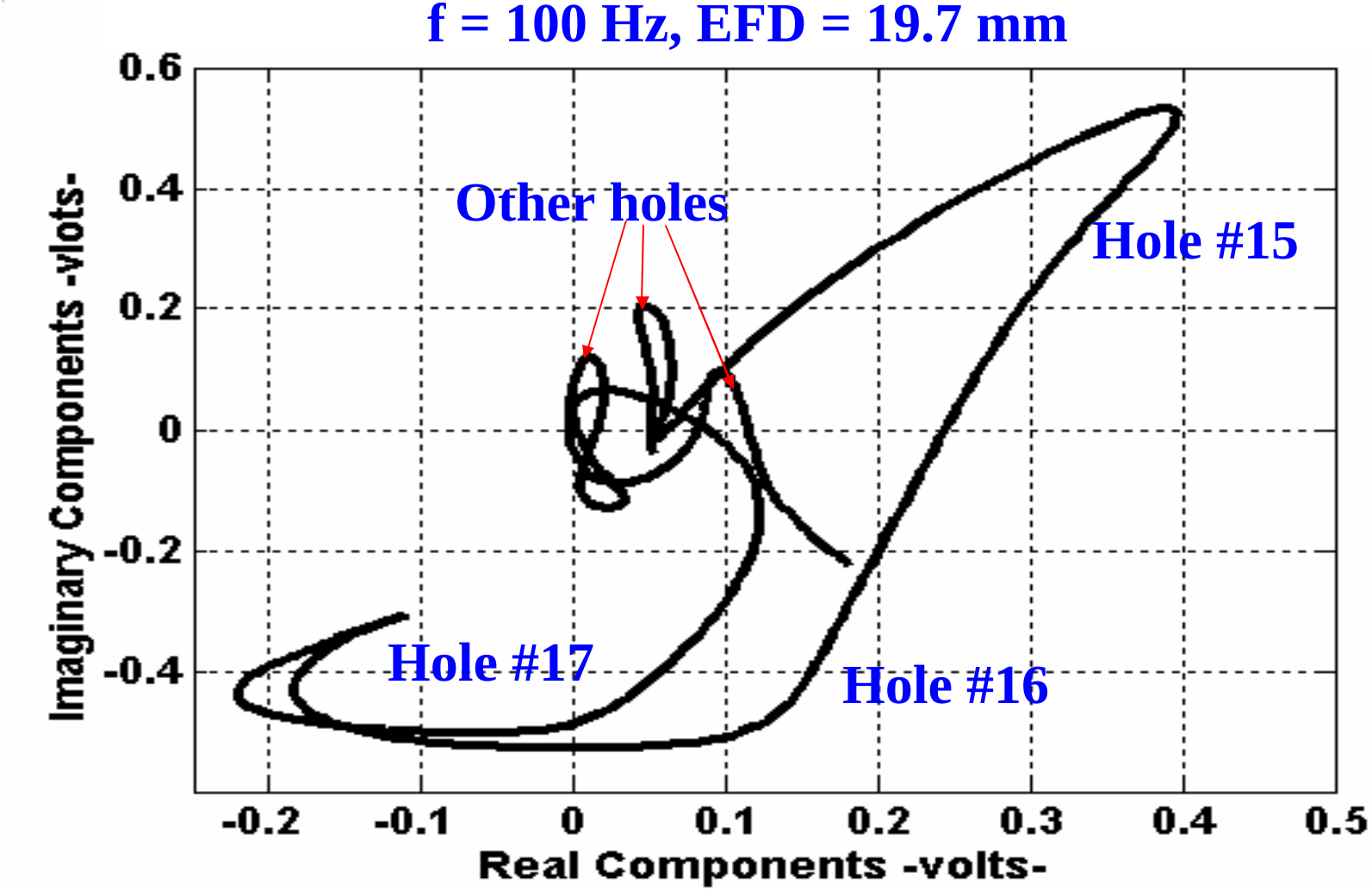
Mode 3: angularly oriented probe and axial scan.



Mode 1 Non-Steel Fasteners

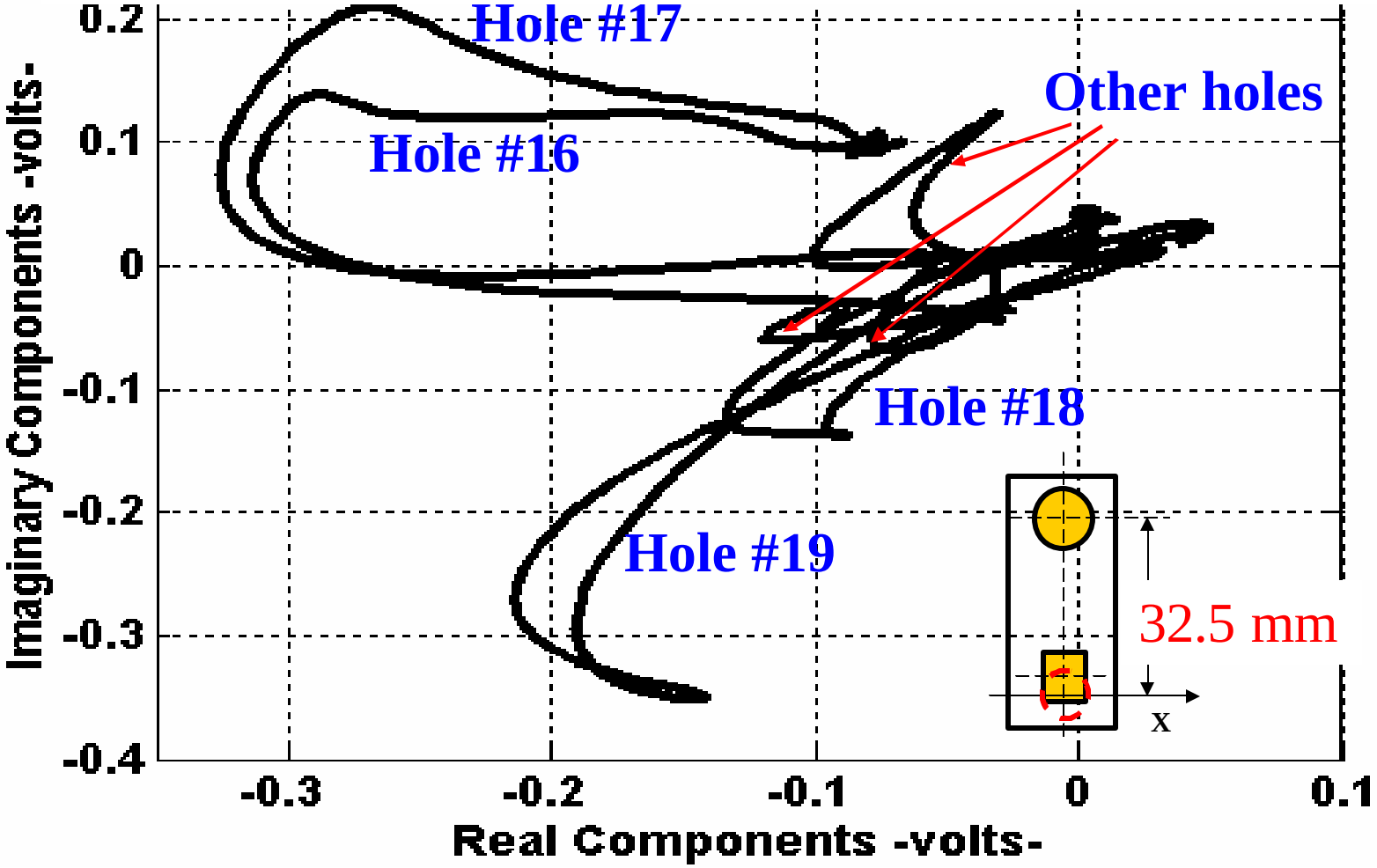


Mode 1 Non-Steel Fasteners



Mode 1 Non-Steel Fasteners

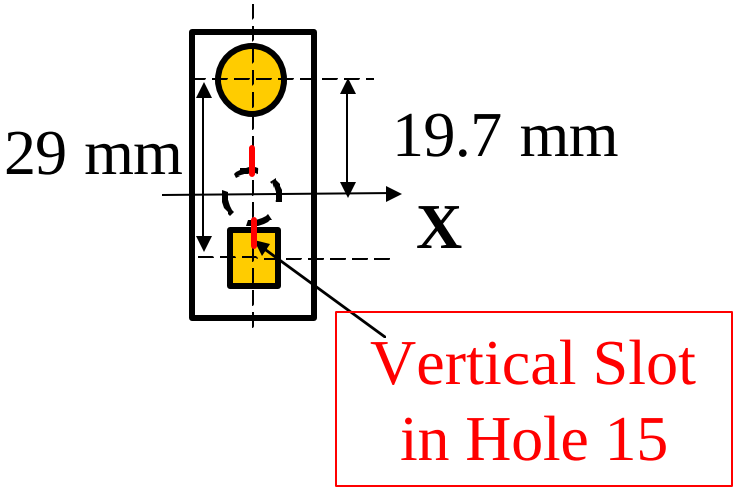
f = 300 Hz, EFD = 32.5 mm

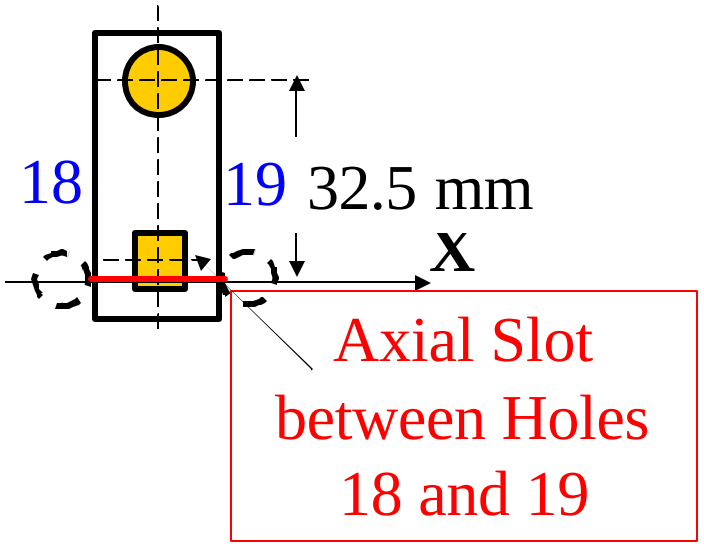


Mode 1 Non-Steel Fasteners

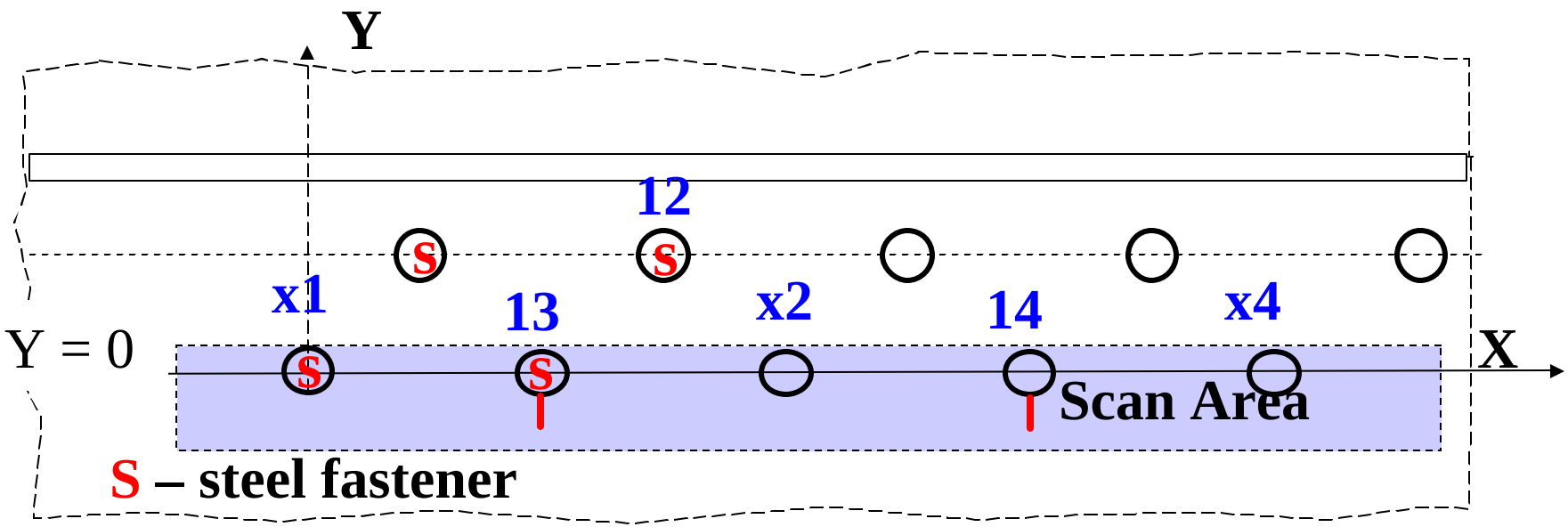
The pickup-coil-to-slot-relationship:

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.





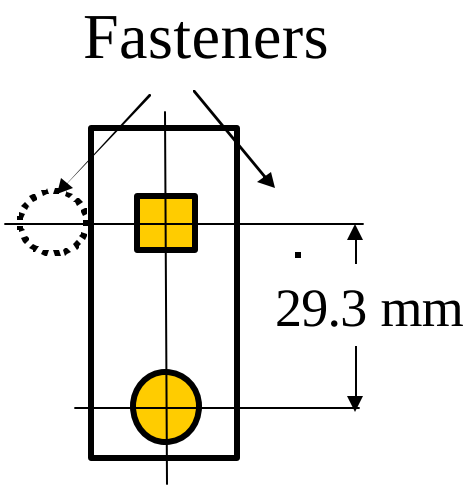
Mode 1 Mixed Steel And Non-Steel Fastener Distribution

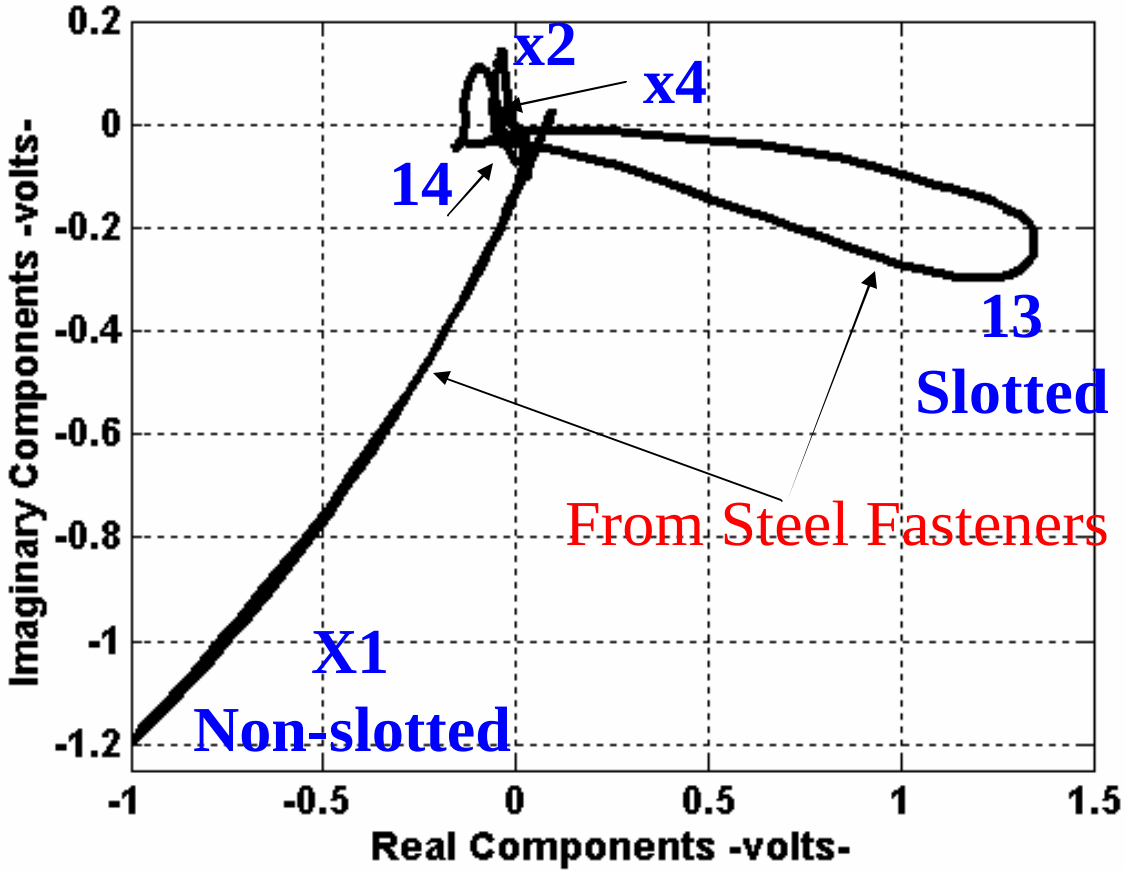


Mode 1 Mixed Steel And Non-Steel Fastener Distribution

Complete Signal

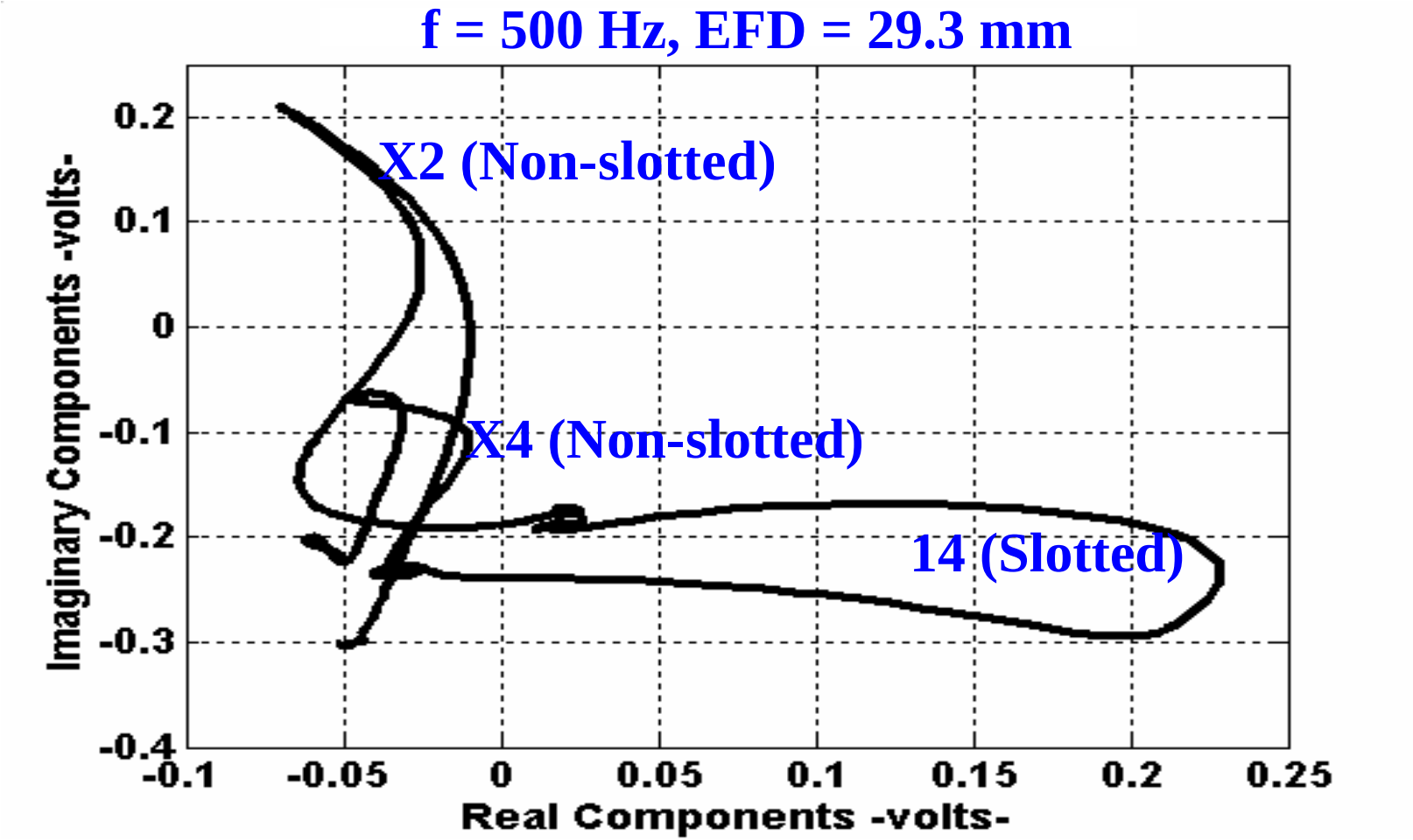
f = 100 Hz, EFD = 29.3 mm





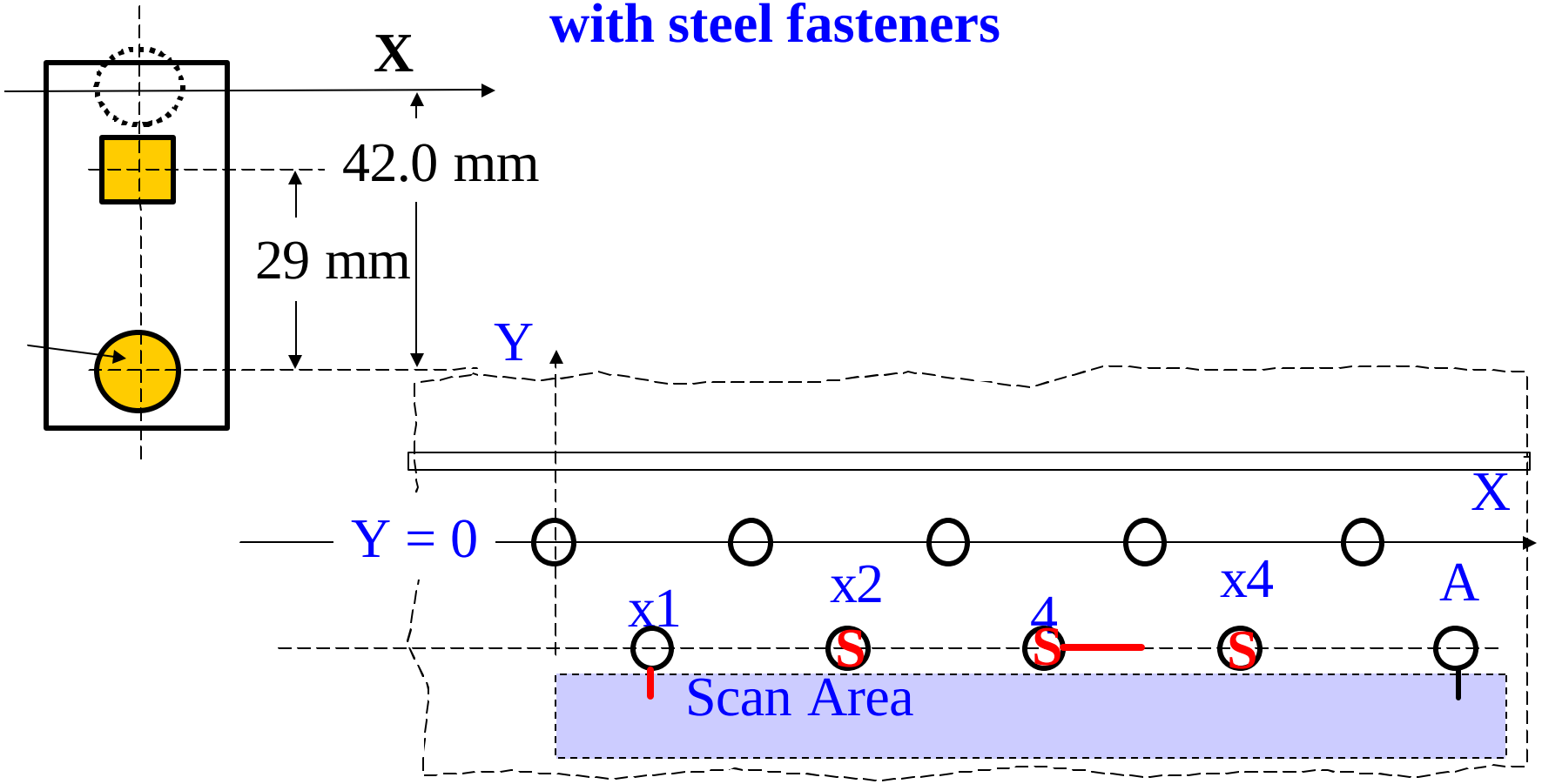
Mode 1 Mixed Steel And Non-Steel Fastener Distribution

(Signals from steel Fastener holes are excluded)



Mode 1 Mixed Steel And Non-Steel Fastener Distribution

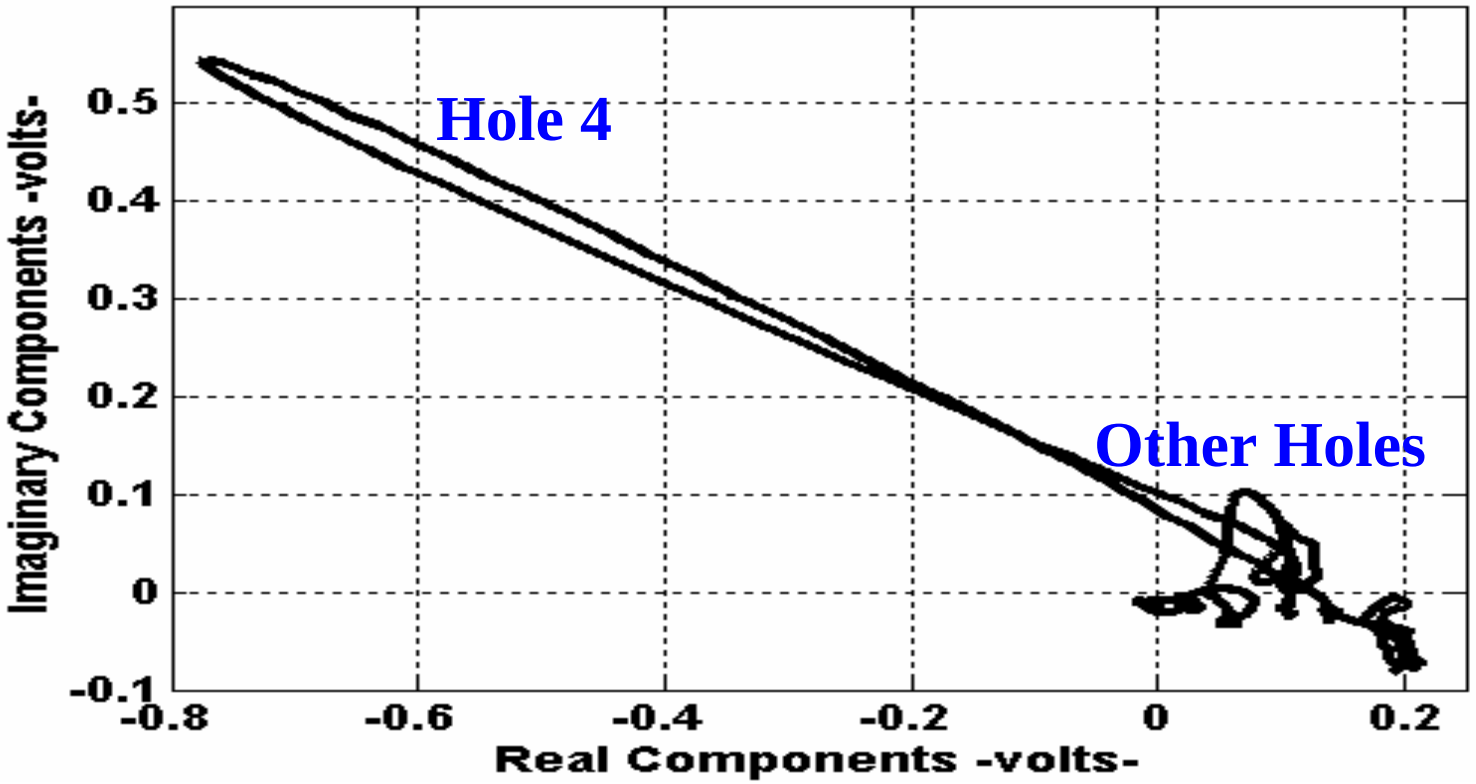
Arrangement for improving response from holes with steel fasteners



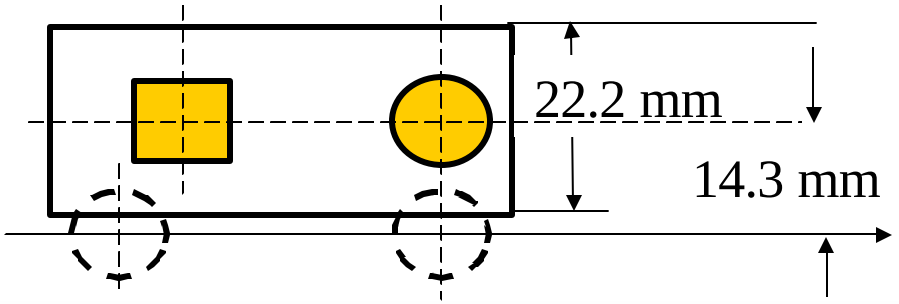
Mode 1 Mixed Steel And Non-Steel Fastener Distribution

Arrangement for improving response from holes with steel fasteners

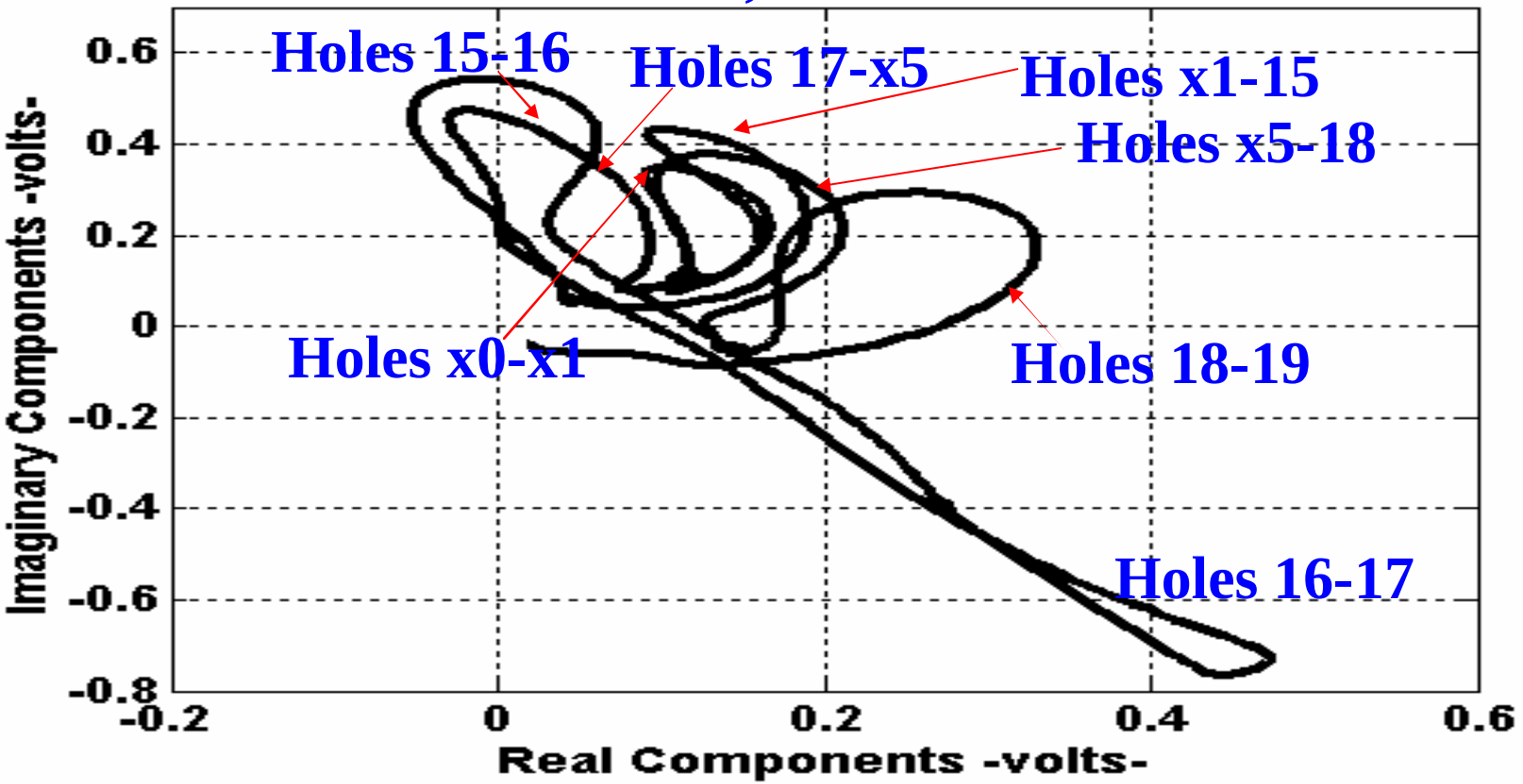
f = 300 Hz, EFD = 42.0 mm



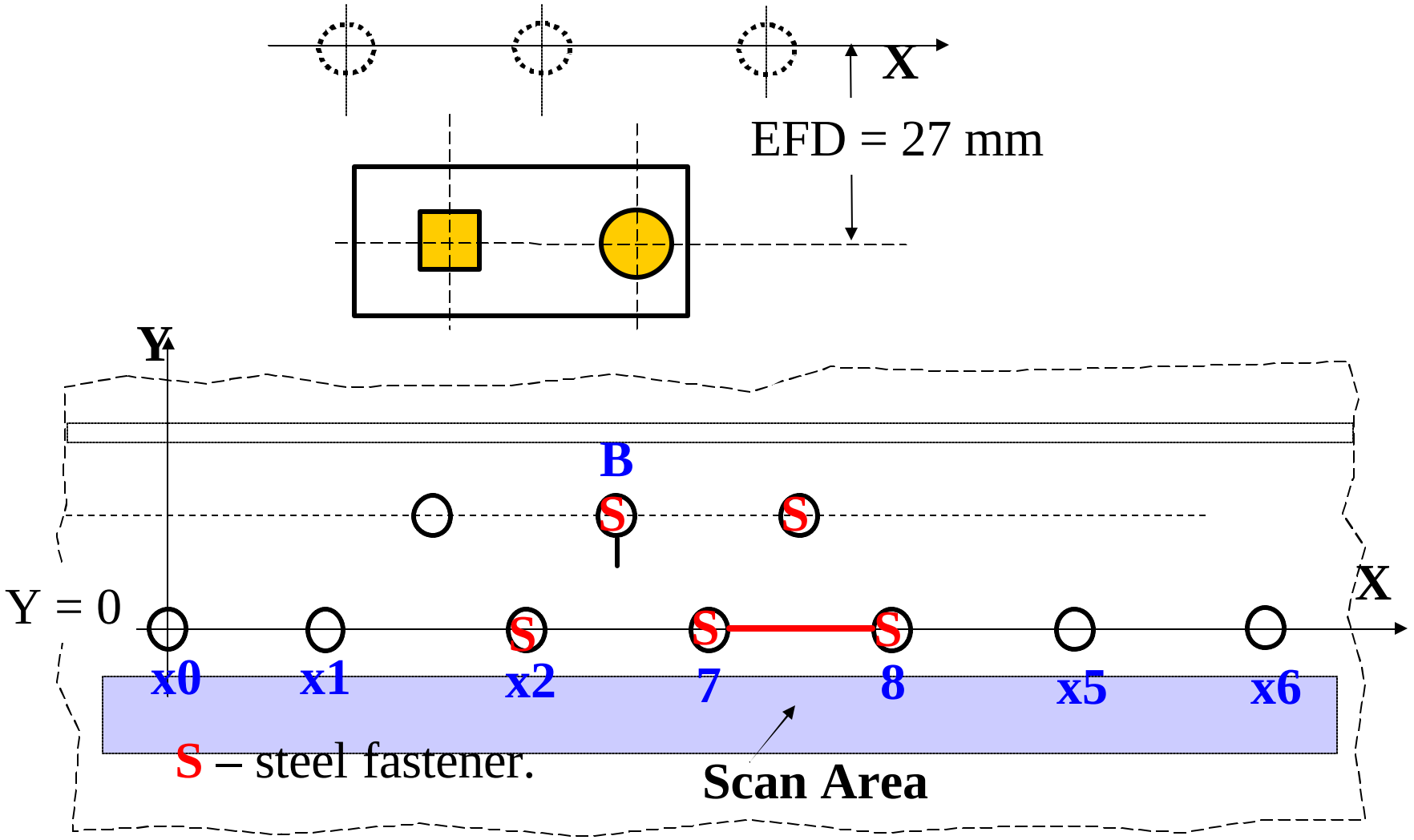
Mode 2 Non-Steel Fasteners



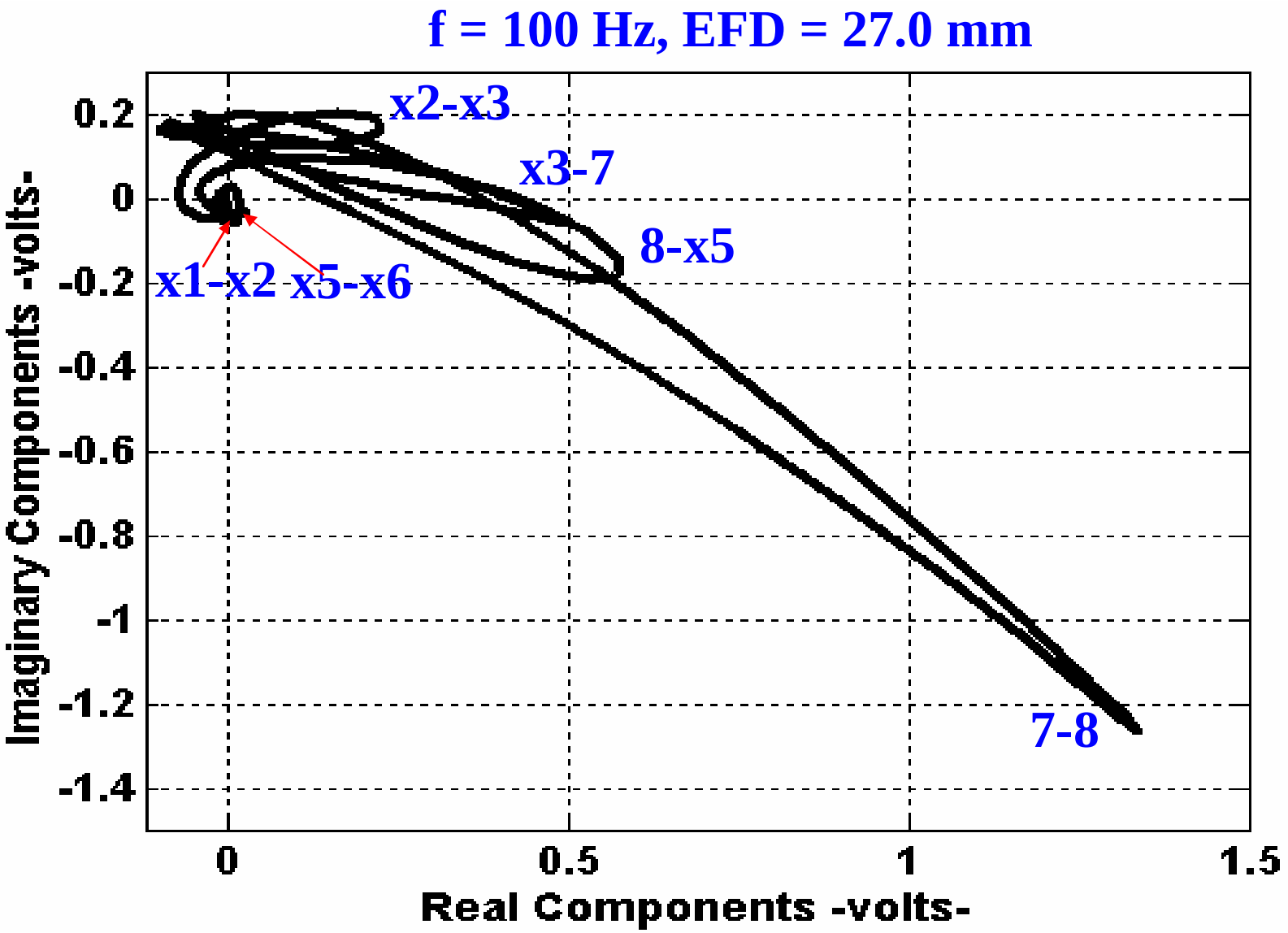
f = 100 Hz, EFD = 14.3 mm



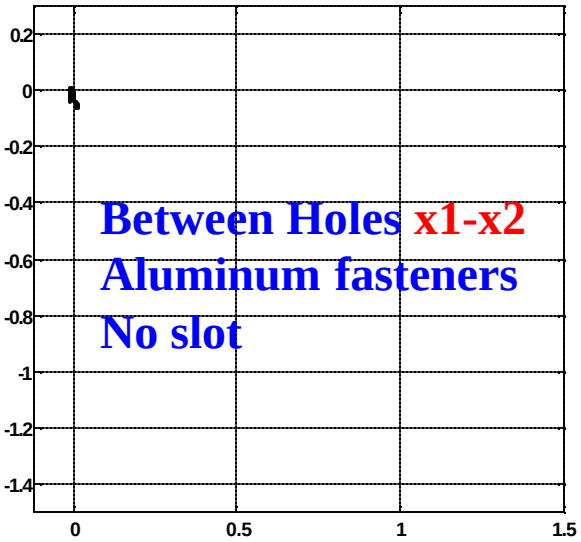
Mode 2 Detecting Slotted Holes Among Steel Fasteners

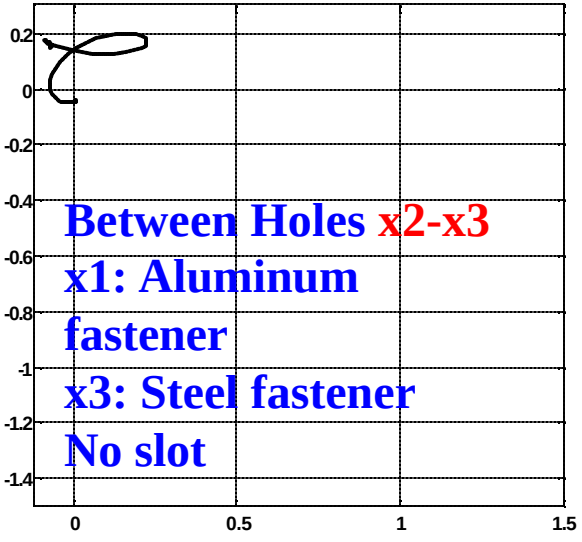


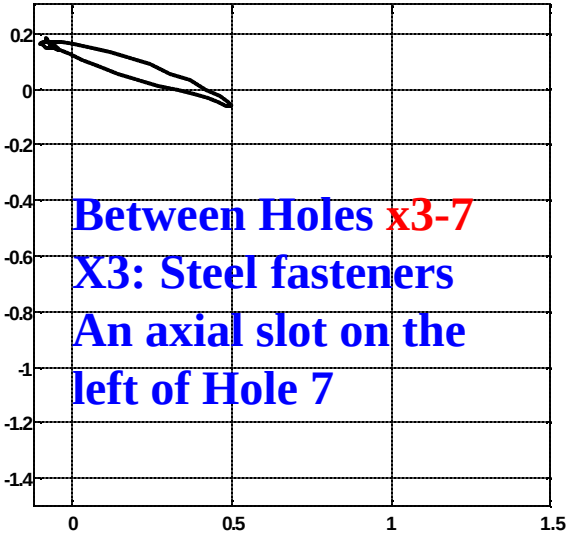
Mode 2 Detecting Slotted Holes Among Steel Fasteners

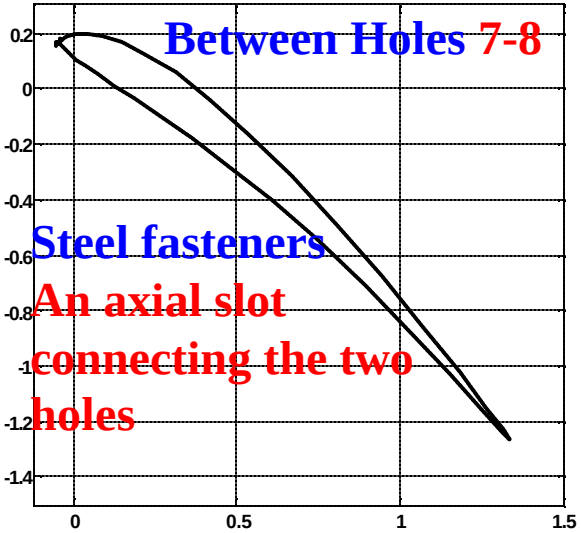


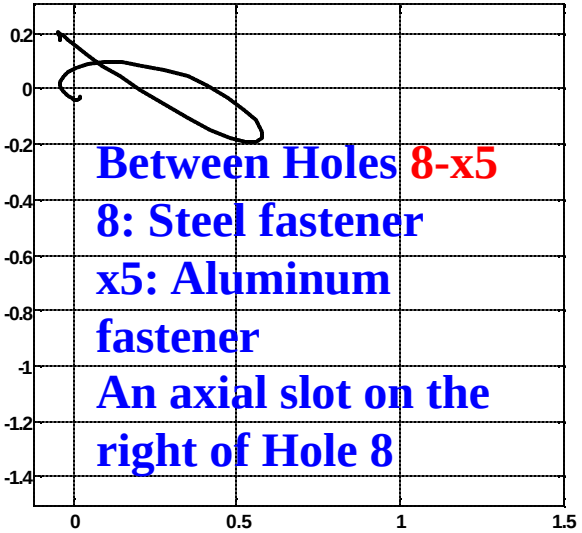
Mode 2 Detecting Slotted Holes Among Steel Fasteners

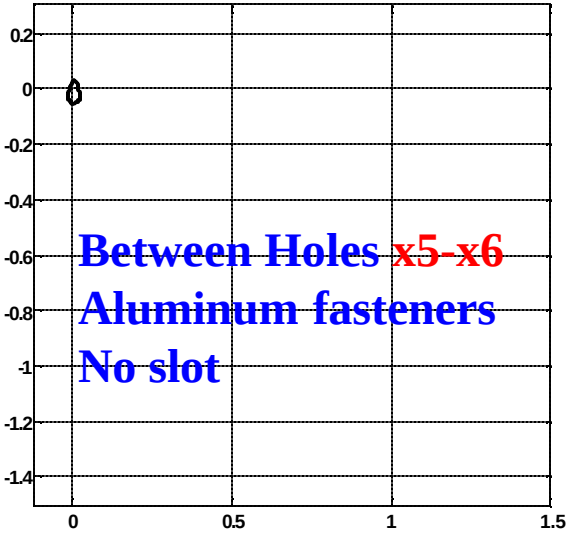












Conclusions

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.