Wireless Eddy Current Probe for Engine Health Monitoring

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Sponsor

- NASA (*Contract No. NAS3-98005 Task Order 21)*
- Pratt & Whitney

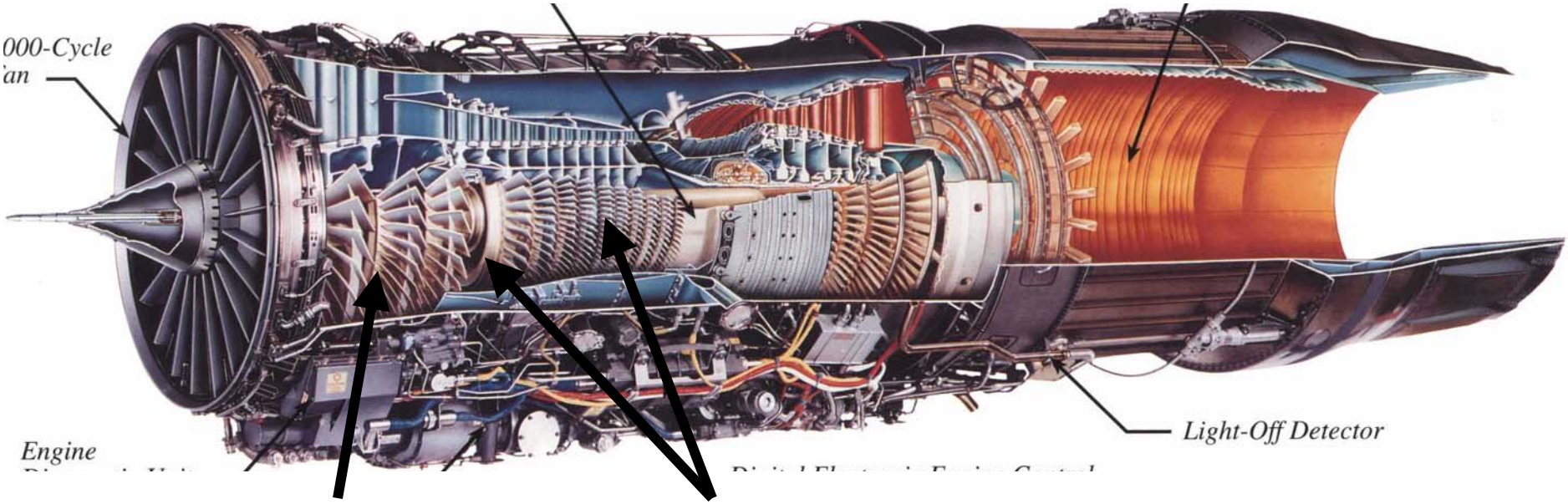
Outline

- Why make a wireless probe?
- Issues
- Hardware
- Software
- Results
- Future Work
- Conclusion

Why make a wireless probe?

- Reduce time to complete Preventive Maintenance of on-wing-inspection
- Potentially improve quality by removing the cable between the probe and instrument
- Save Money

Problem Description



Transmitter and EC sensor

Receiver

- Difficult to get instrument plus power, signal, and other cables into engine

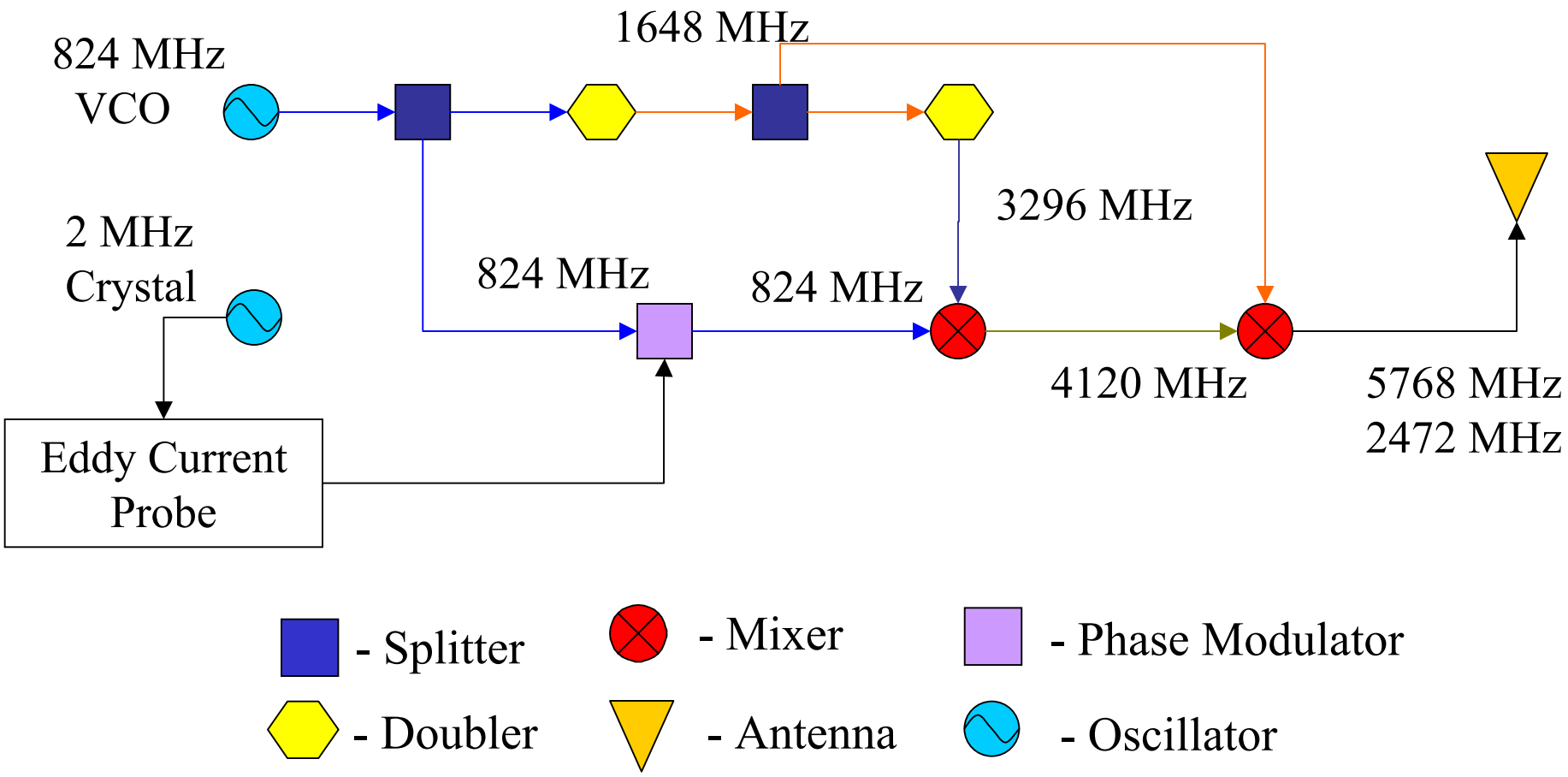
Issues

- Multi-path transmission medium
- Testing revealed that a single frequency band cannot be used throughout the entire engine
- Power and Size limitations of the transmitter

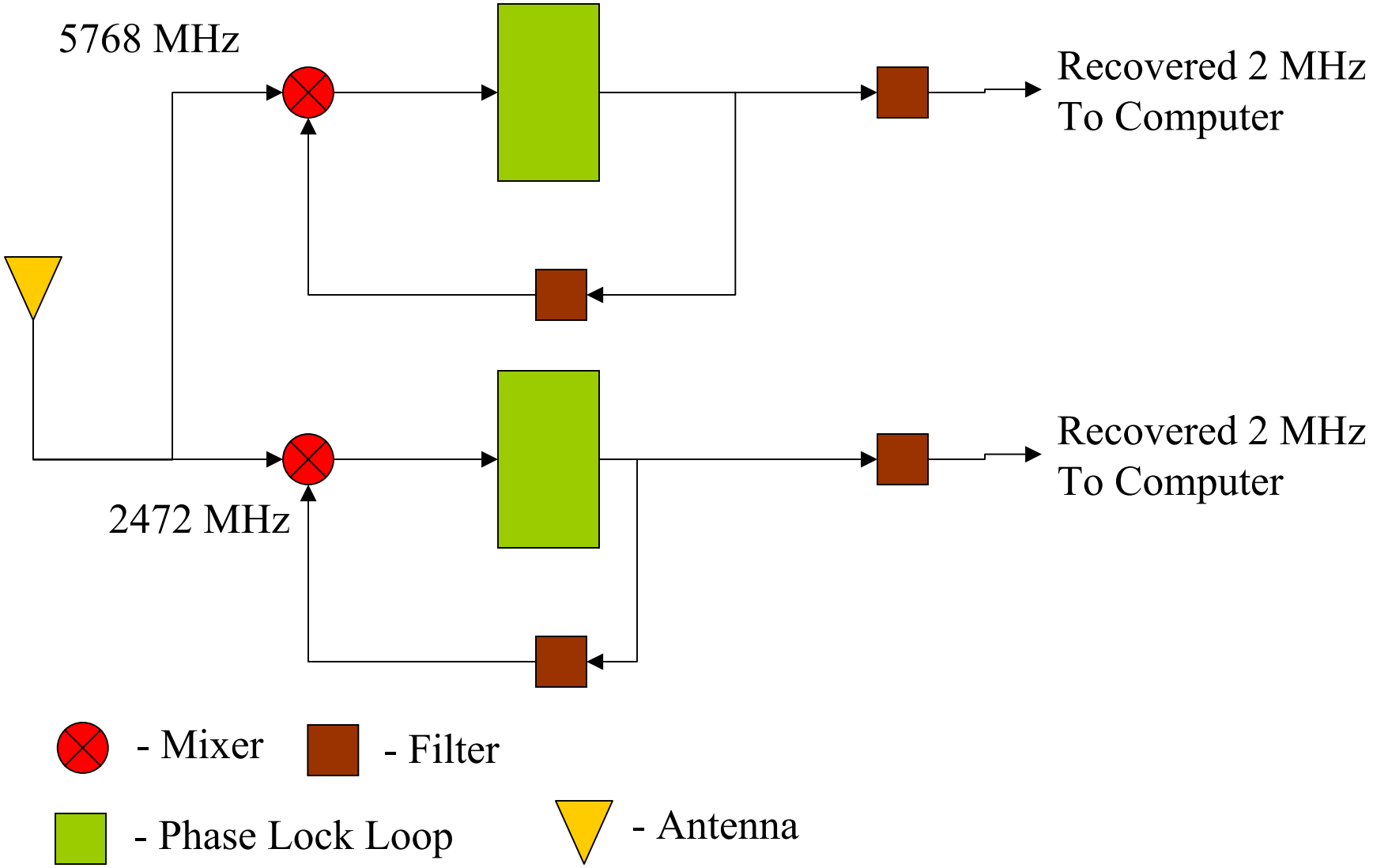
Hardware

- Prototype system with a 2 MHz differential eddy current probe
- Frequency diversity transmitter
- Phase modulation for information transfer
- Transmit power: 0.5 mWatts
- Only transmit the reflected signal from the probe (Software will estimate the reference signal)

Hardware Block Diagram Transmitter

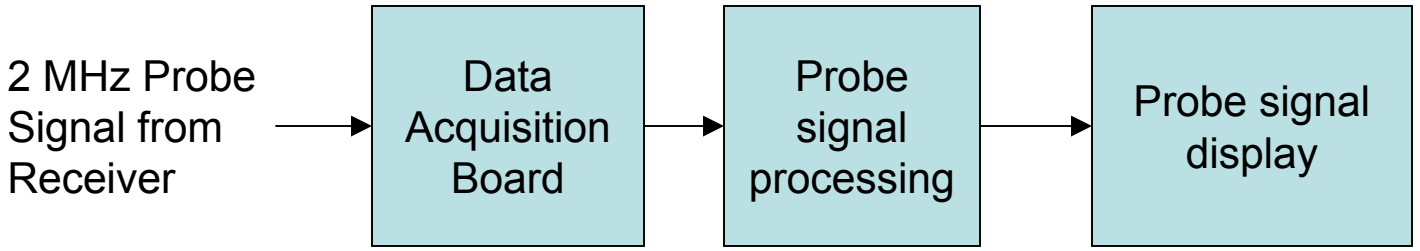


Hardware Block Diagram Receiver



Data Acquisition and Display

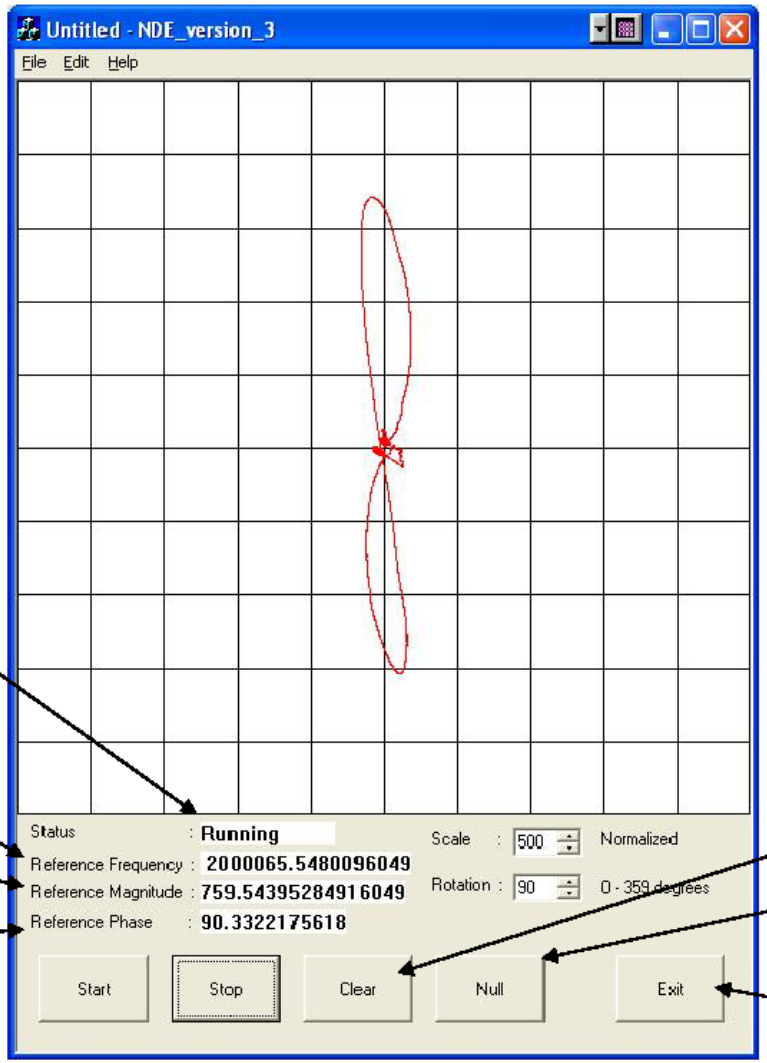
- Demodulated 2 MHz signal from both channels is digitized using a 4 channel, 12 bit data acquisition board for a PC, sampled at 5 MHz.
- Estimates phase, amplitude, and frequency of the probe reference signal
- Track changes in phase and amplitude of probe signal



Reference Signal Estimation

- Estimate Frequency
  - Zero crossings of signal and average
  - Bounds Check Frequency must be between 1,999,000 and 2,001,000 Hz
  - Convergence using Phase Error Method
    - Measure Phase using Goertzel Method
    - Compare measured and estimated Phase to fine tune Frequency
  - Estimate Frequency error
    - Measure Phase using Goertzel Method
    - Compare measured and estimated Phase
- Estimate Phase and Magnitude
  - Calculate Magnitude & Phase using Goertzel Method

Software Display



Program State:

Calibration, Running, etc.

Measured Frequency (Hz)

Measured Magnitude (out of 1024)

Reference Phase (degrees)

Clears trace

Moves origin to center of display

Exit Program

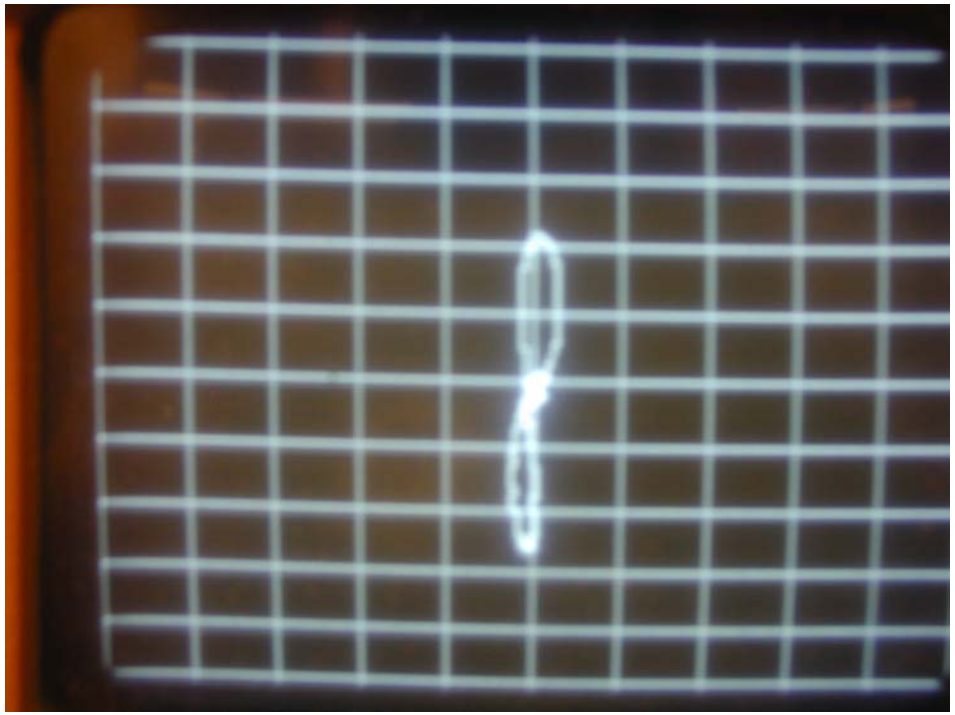
Comparison With Commercial Instrument

- EC instrument (NDT-19E) Data collection using same probes and same samples
  - EDM notches: 0.025”,0.020”, 0.015”, 0.010”
- Results and ratios between notch sizes are comparable to those obtained by the wireless system

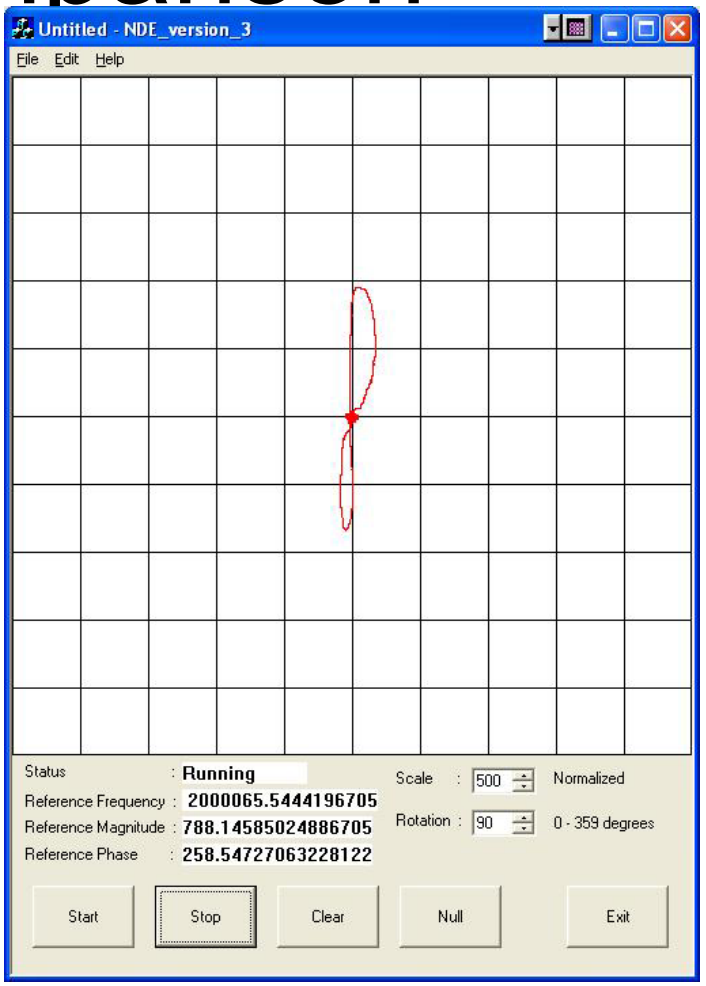
NDT 19 E Parameters

- 2 MHz, ϕ = 190 °
- Gain = 45.75° $\Rightarrow$ 0.025” notch = 6 div
- Filter = 0 HP, 100 LP

Notch 1 Comparison



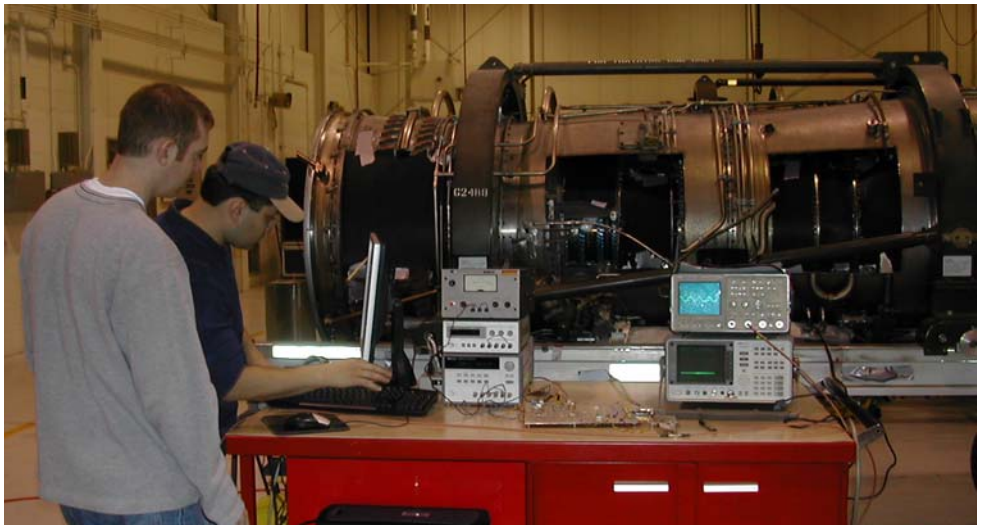
NDT 19E



Wireless Probe Display

Field Testing

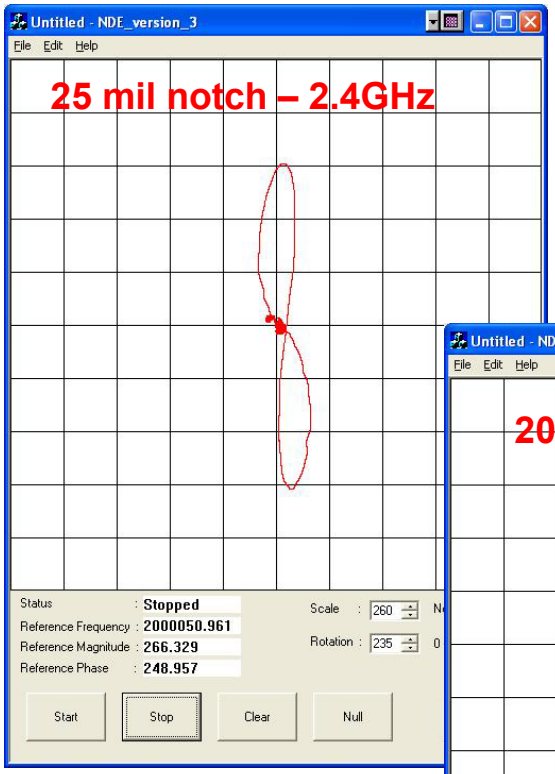
- Used Iowa Air National Guard engine with accessible inner stages
- Allows testing of the wireless probe concept in a realistic environment
  - Assess power levels for transmitter circuit
  - Assess signal processing algorithms in a more realistic environment

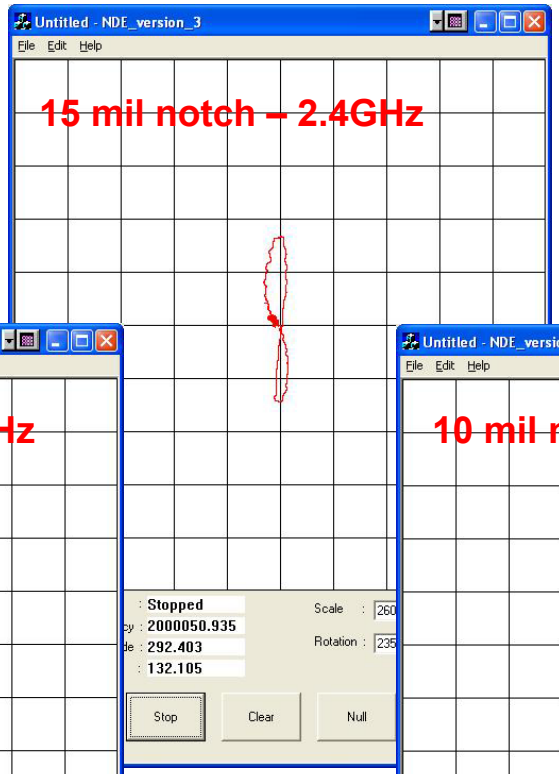


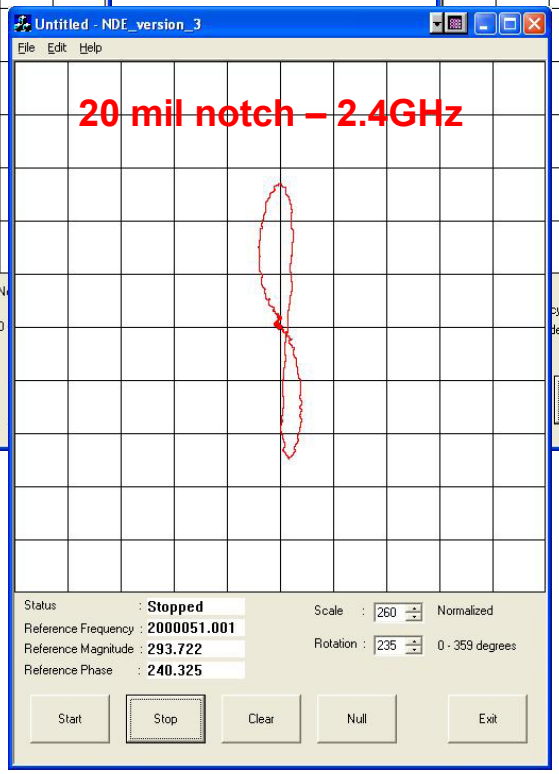
Field Test Results

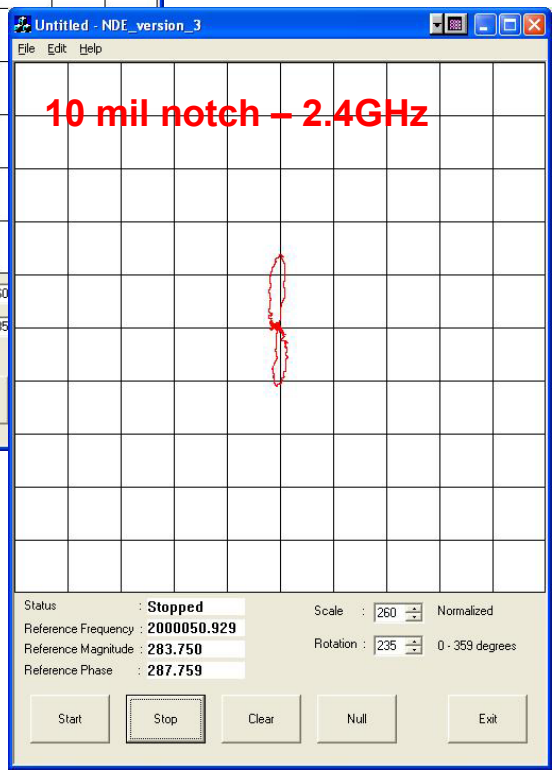
- Probe signal transmitted, demodulated and displayed notch samples
  - 2.4 and 5.7 GHz Signals worked from:
    - 3rd stage – low compressor to 6th stage – high compressor
    - 3rd stage – low compressor to 12th stage – high compressor
    - 3rd stage – low compressor to turbine
    - 3rd stage – engine inlet
- Results exceed design range of borescope to borescope transmission for 2.4 GHz signals
- Interference environment inside of engine has less interference than lab environment $\Rightarrow$ lead to improved results

Fan to Low Compressor (6th stage)

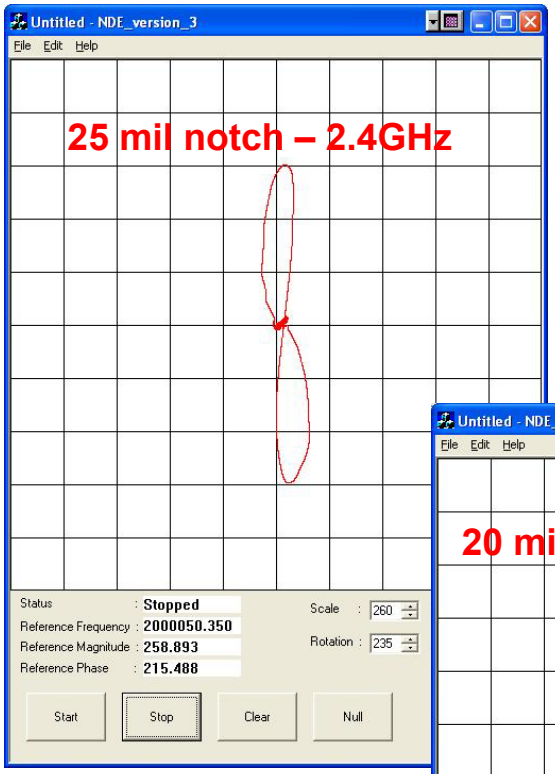


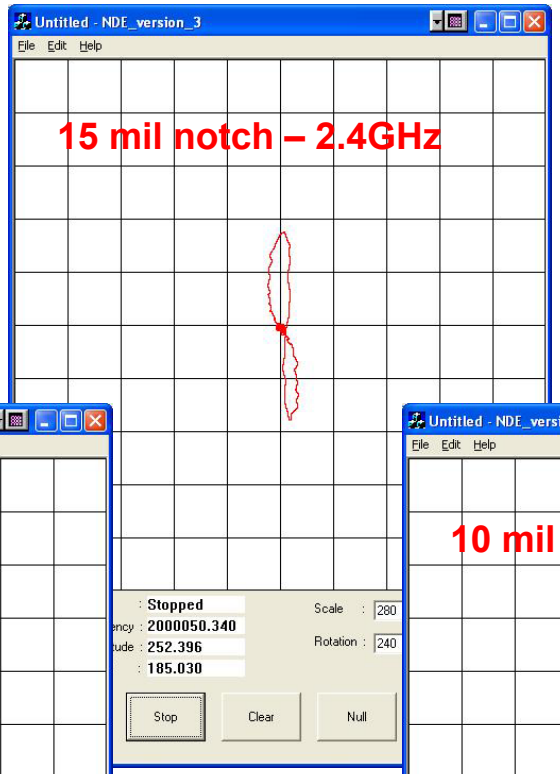


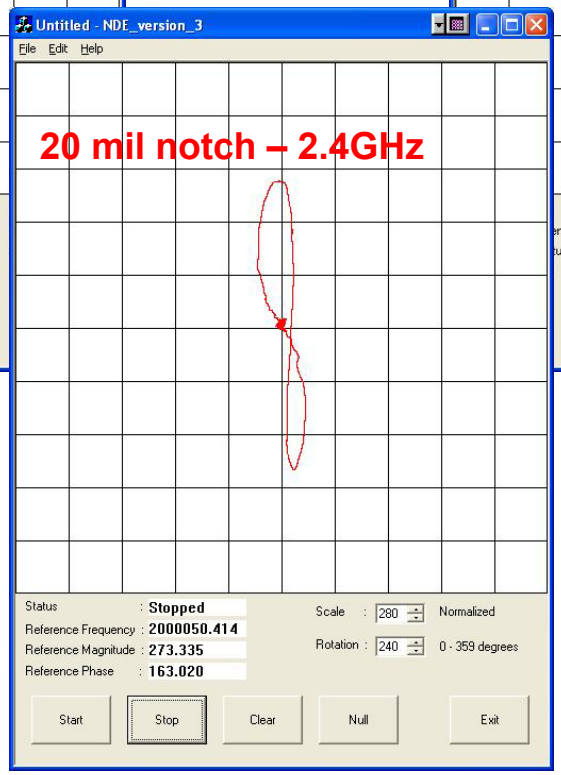


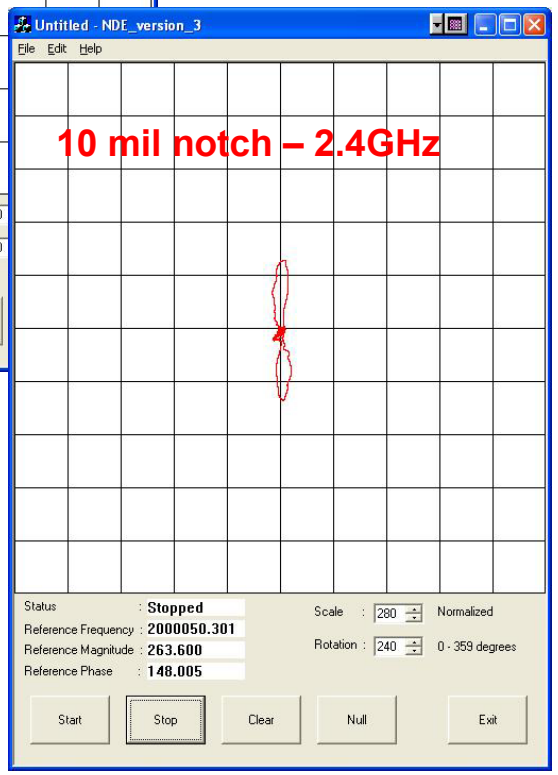


Fan to High Compressor (11th stage)

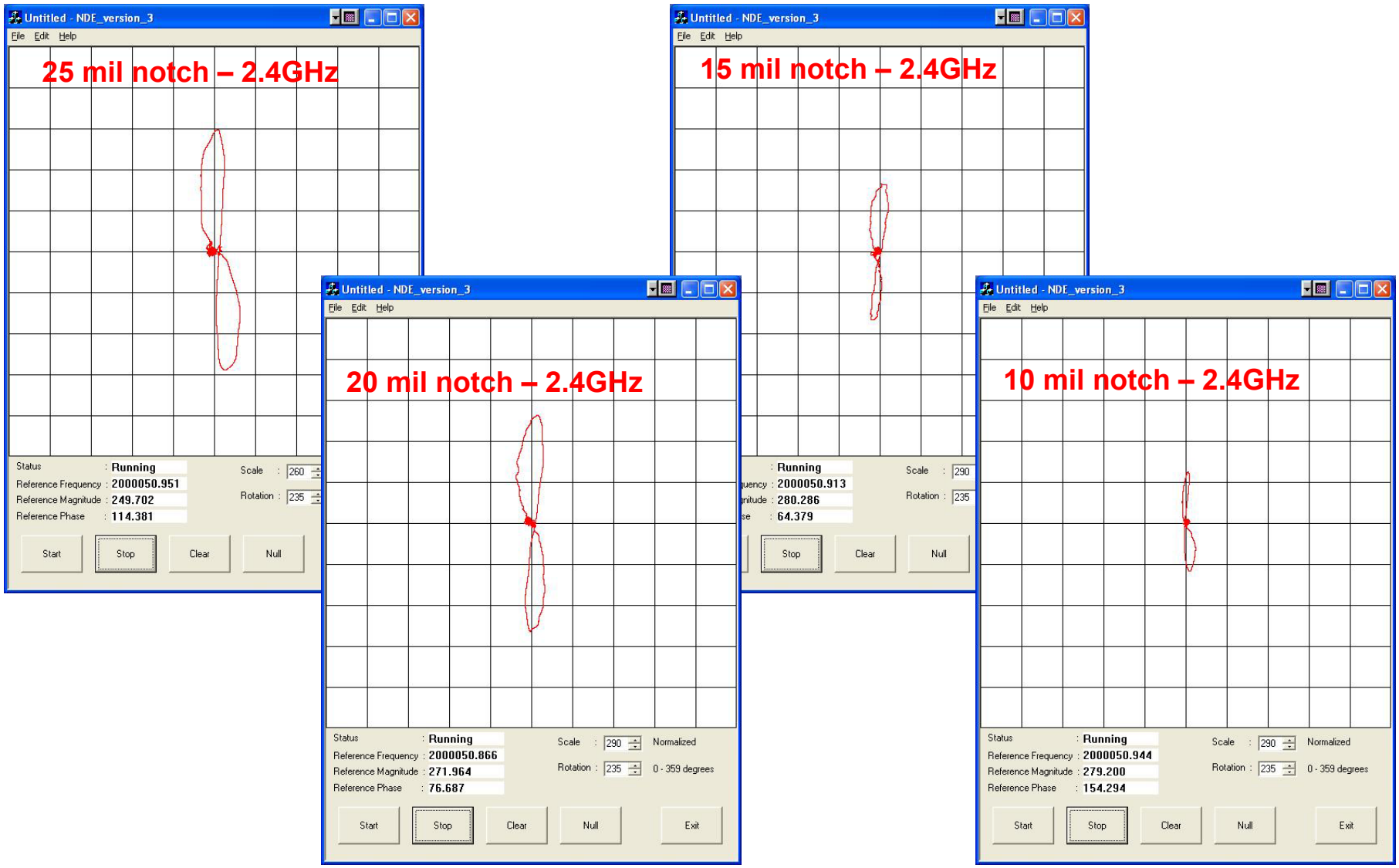








Test Results: Fan to Engine Inlet



Future Work

- Next generation will be a digital communication system
  - Improve quality of information
  - Increase number of bits from A/D converter
- Handle other types of probes
- Process other probe driver frequencies
- Multiple transmitters to a single receiver

Conclusion

- Reduce maintenance cost
- Issues that needed to be addressed to produce a prototype
- Design
  - Hardware
  - Software
- Results from testing of jet engine

Questions ?

Commercial Instrument Measurements