Non-Destructive Fault Location on Aging Aircraft Wiring Networks
Part 2 – Live Wires in Flight

Paul Smith, Alyssa Magelby, Deekshit Dosibhatla, Chet Lo, Cynthia Furse, Jacob Gunther

University of Utah

Center of Excellence for Smart Sensors

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Non-Destructive Fault Location on Aging Aircraft Wiring Networks

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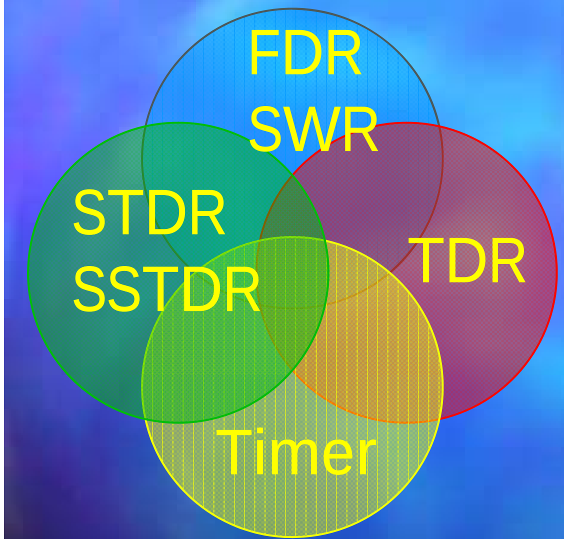
Aging aircraft wiring has been identified as an area of critical national concern. As the system ages, the wires become brittle and crack, break, or develop short circuits. Short circuits, in particular, have been implicated in a variety of smoke incidents, in-flight fires, and crashes. Some of these faults are intermittent, occurring only sporadically as the physical vibration, stresses, temperatures, electrical loads, moisture condensation, etc. change throughout the flight. When the plane is on the ground, no fault can be found. These types of problems are among the most frustrating for aircraft maintainers, resulting in a typical "no fault found" incident taking tens or even hundreds of hours to locate. Some planes even remain grounded for extended periods of time until basic electrical systems can be fully replaced at great cost and labor. One of the greatest hazards of these systems is that they may foreshadow a more serious in flight hazard as a small fault grows, yet for all intents and purposes, the system checks out OK.

This paper describes two systems based on spread spectrum technology that are the first known sensors that can actively locate faults on live wires in flight without disrupting or interfering with existing 400 Hz power or 1553 data bus signals. These systems are found to be highly robust to in-line noise, connection mismatches, etc. They provide measurements accurate to within inches or feet over several hundred feet of both shielded and unshielded cables. They can function accurately within a realistic network environment, and can locate intermittent short circuits (wet or dry arc events) in flight. The sensor development and testing for realistic situations, algorithms for enhanced data processing, and real-time analysis methods are described.

Spread Spectrum Methods



- Many Signals
- Noisy Channels
- Interference Rejection
- Jamming
- Loss / Attenuation
- Multiple Channels
- Multiple Paths
- Stealth Communication
- !! Communication PLUS Ranging

CSS
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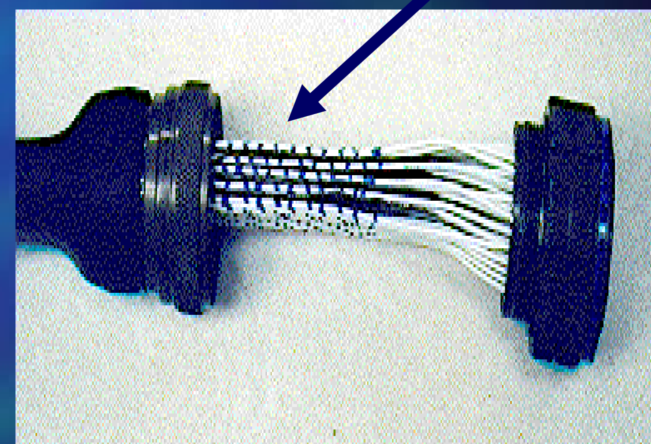
SafeWire Commercialization Path

Handheld

SafeBreaker

SafeConnector (Saver)

SafeWire



SafeConnector

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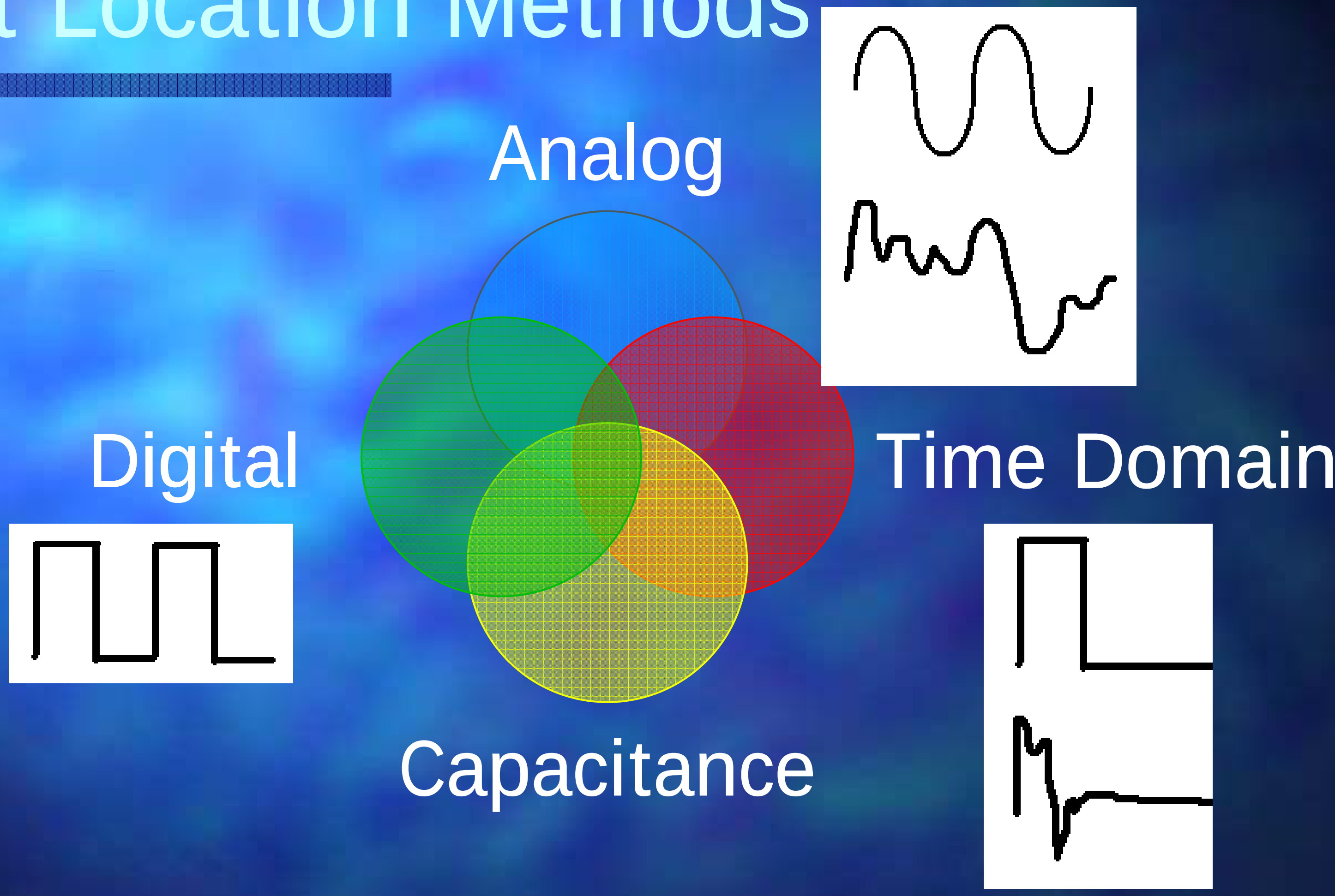
AFCI Application

- AFCI
  - Aircraft 2003-5
  - Homes 2002
- Spread Spectrum
  - (STDR / SSTDR)
  - Requires Miniaturization

SSTDR: Patent Pending

The Tool Box :
Fault Location Methods



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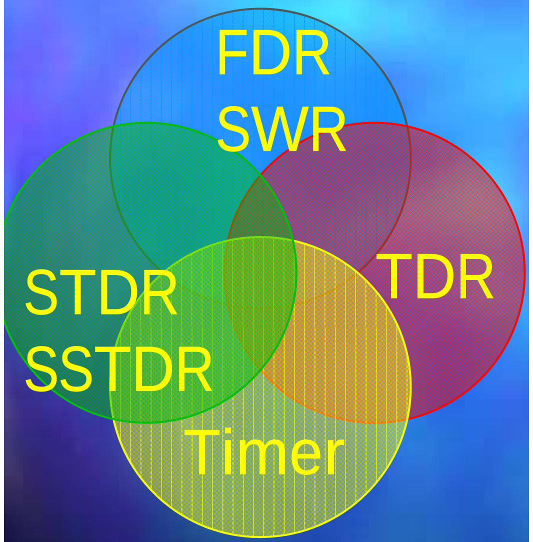
Fault Location Methods
from the Utah Center of Excellence for Smart Sensors



	Arc / Fray	Live	Cost	Netwk	In Situ
Timer	No?	No?	<$2	No	Yes
FDR	No	<150kHz	<20	Yes	Yes
SWR	No	<150kHz	<20	Yes	Yes
STDR SSTDR	Yes Live	"All Freqs", and Digital	<200	Yes	Yes
TDR	Yes/ Base line	No	~$3k	Yes	No

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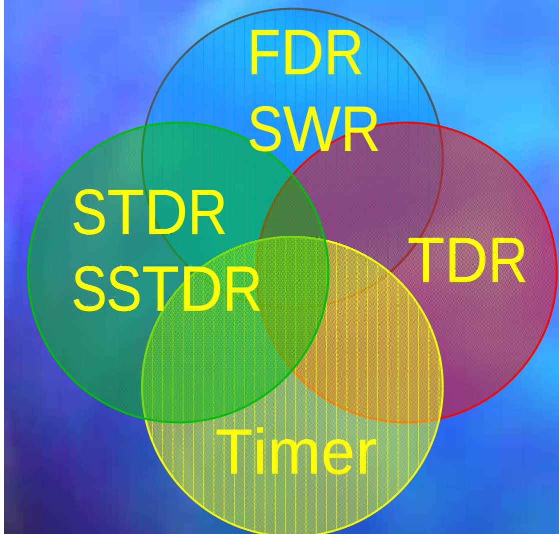
STDR / SSTDR



- Many Signals
- Noisy Channels
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FDR / SWR for Fray Detection

- “Hard Fault” required
- May run on live 400 Hz wires, but have poor noise immunity
  - Cannot detect intermittent faults

MilStd 1553 Plus SSTDR

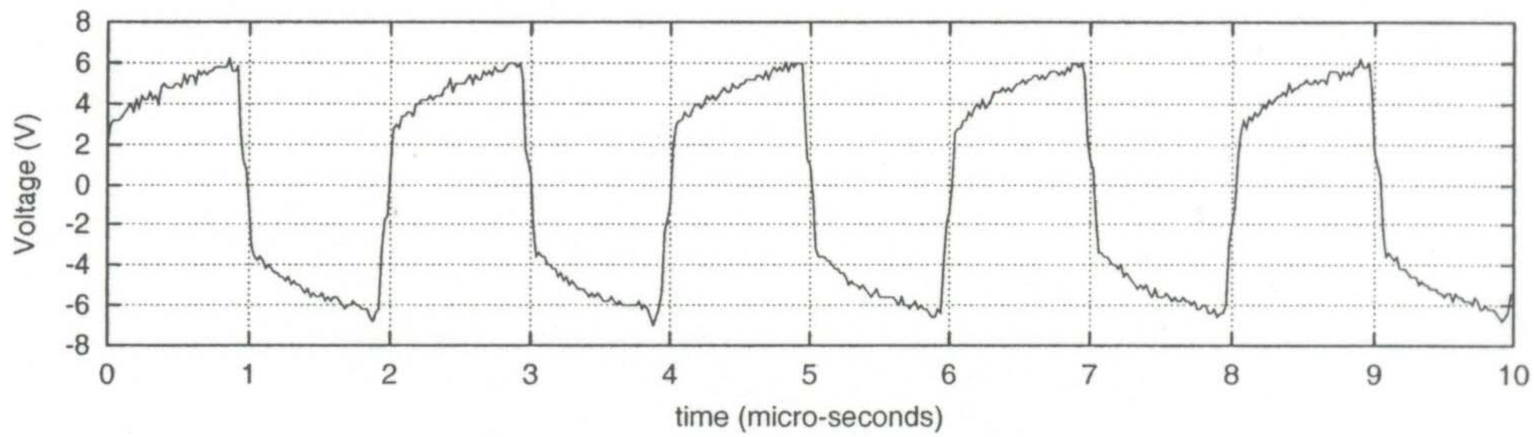

Fig. 7.98: SSTDR test on a $25ft$ 75Ω cable with Mil-Std 1553 at $5.0V$ RMS. This figure shows how small the SSTDR waveform is on the Mil-Std 1553 signal. Neither signal interferes with the other signal. If the Mil-Std 1553 signal amplitude is doubled, SSTDR will not be able to reliably detect reflections.

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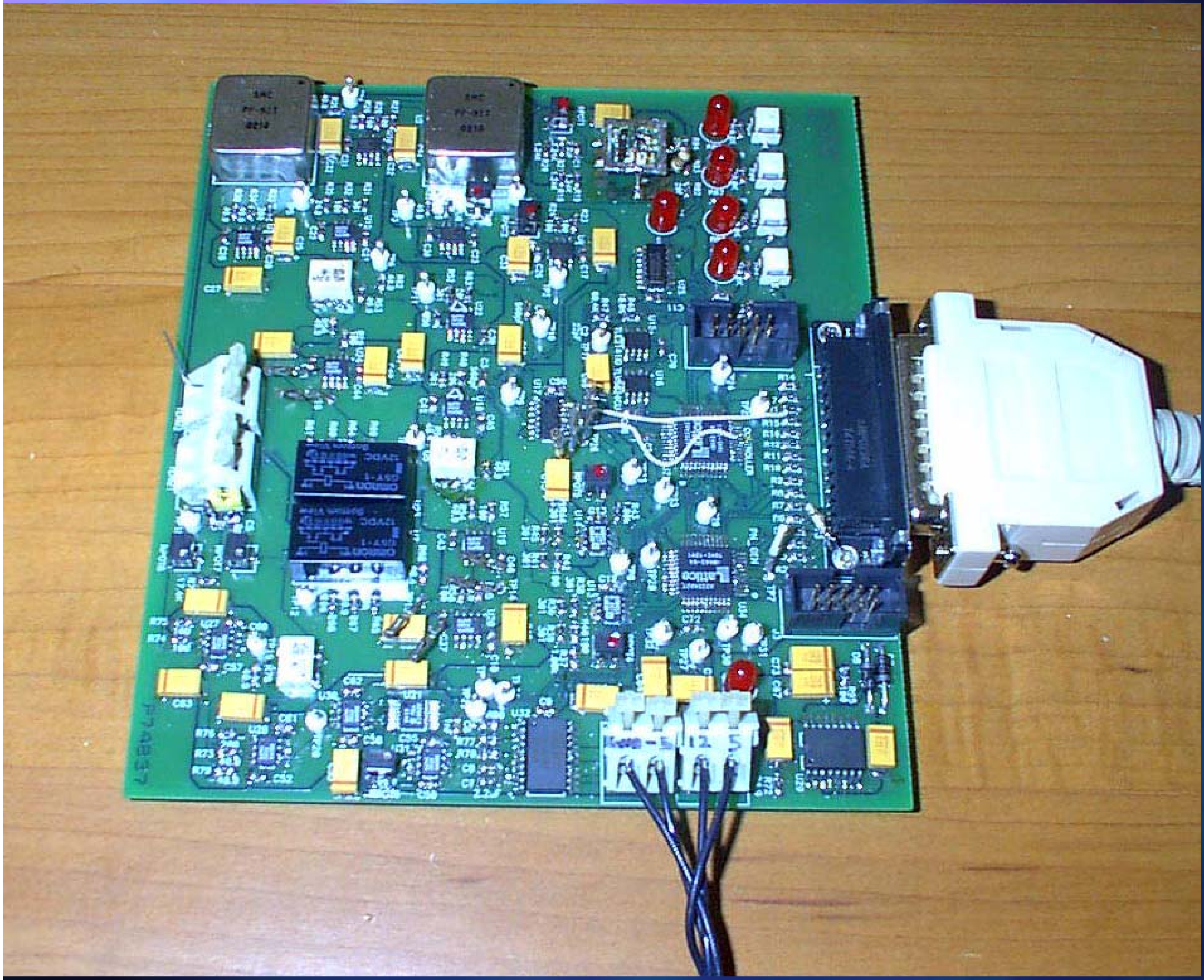

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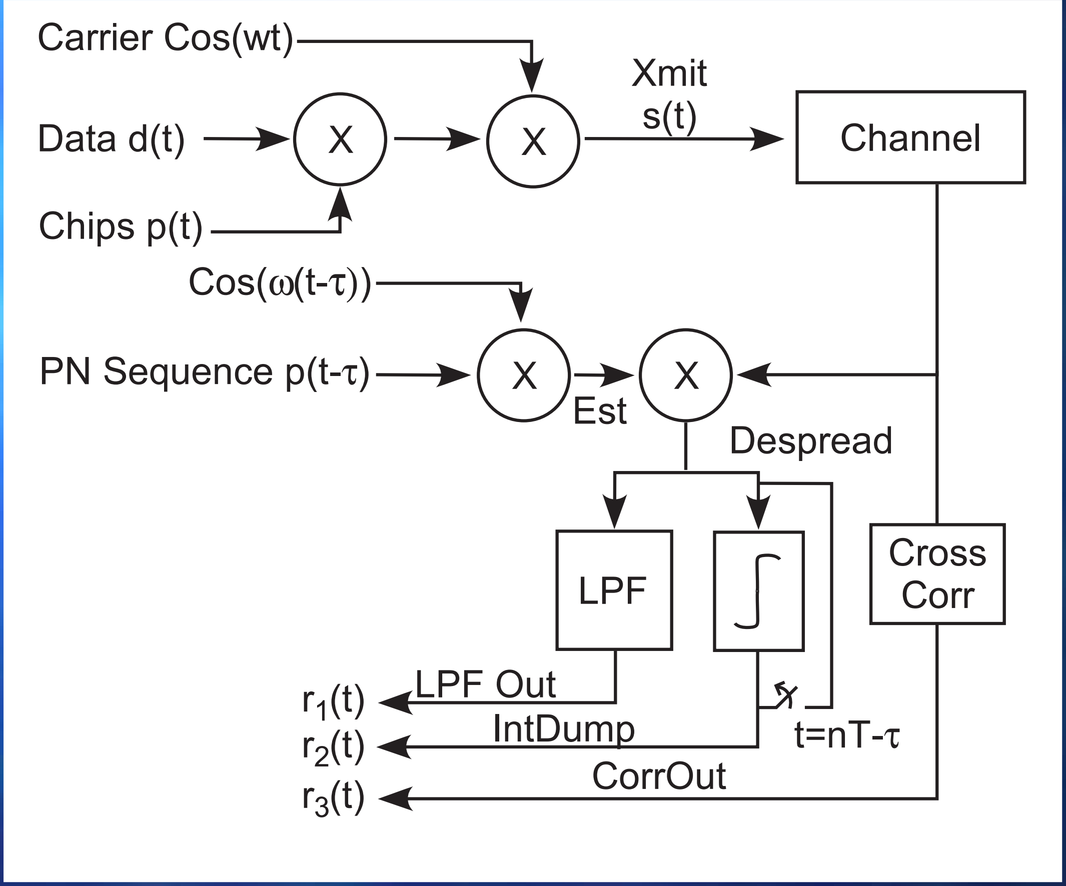
DSSS Communication



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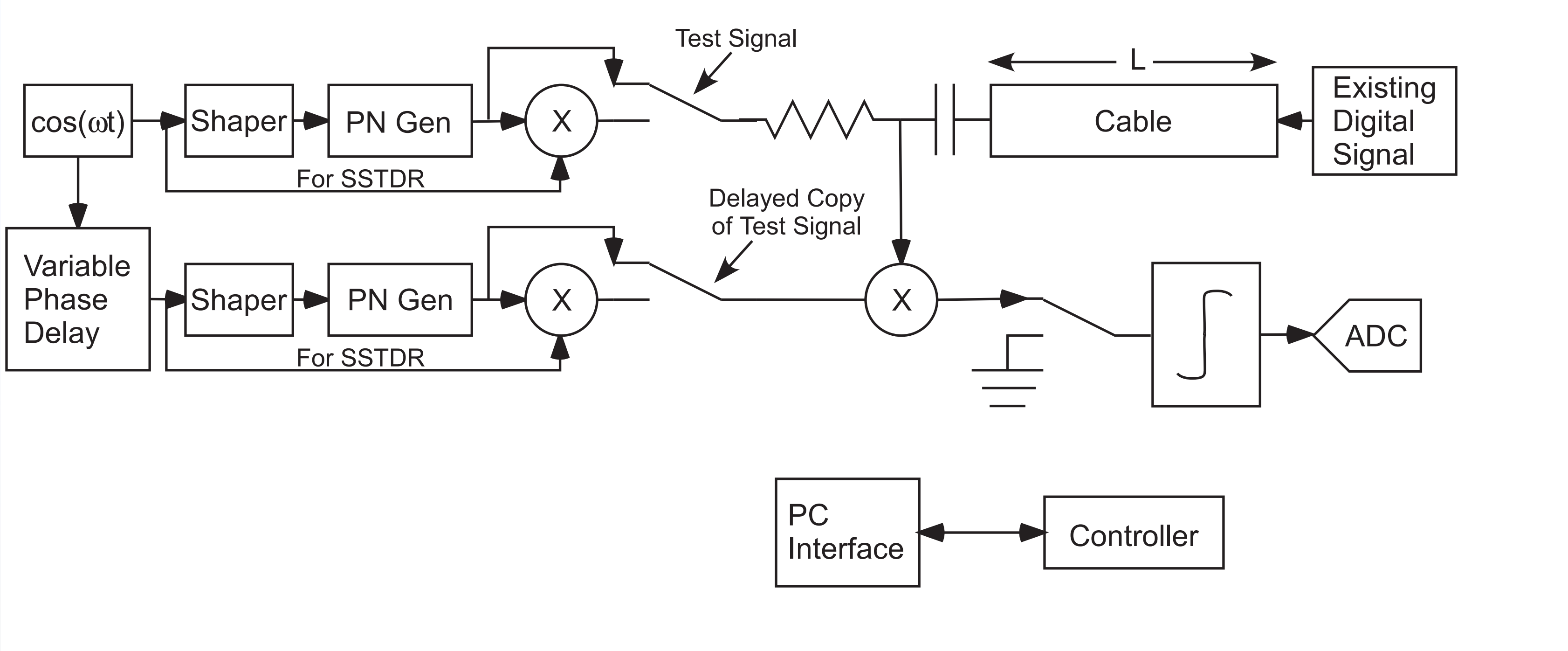
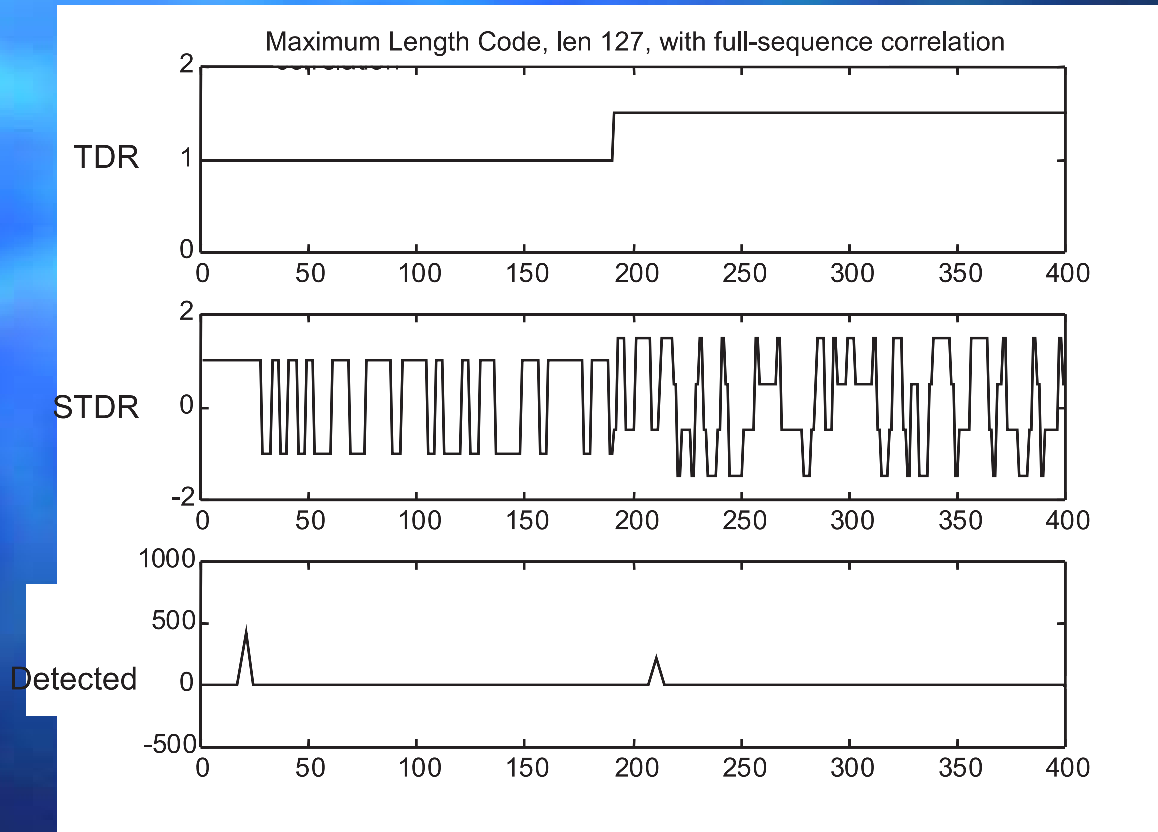
STDR/SSTDR Circuit





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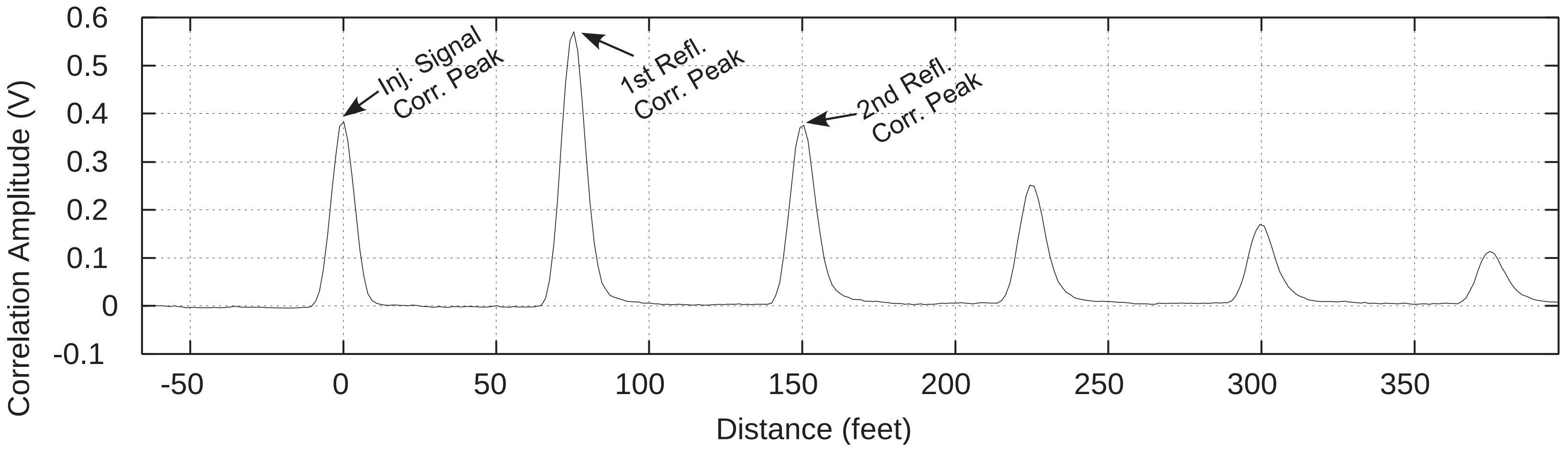
STDR with Open Circuited Cable



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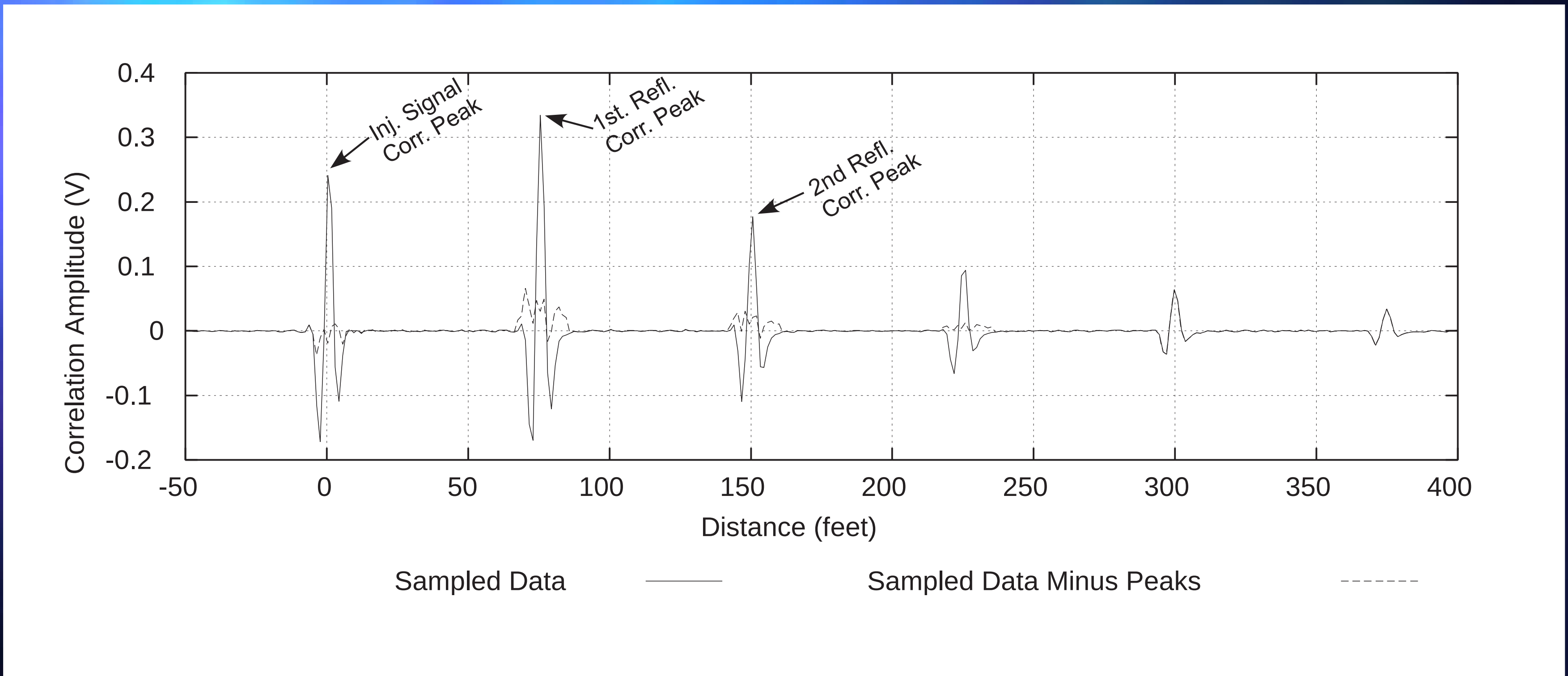
SSTDR with Open Circuited cable



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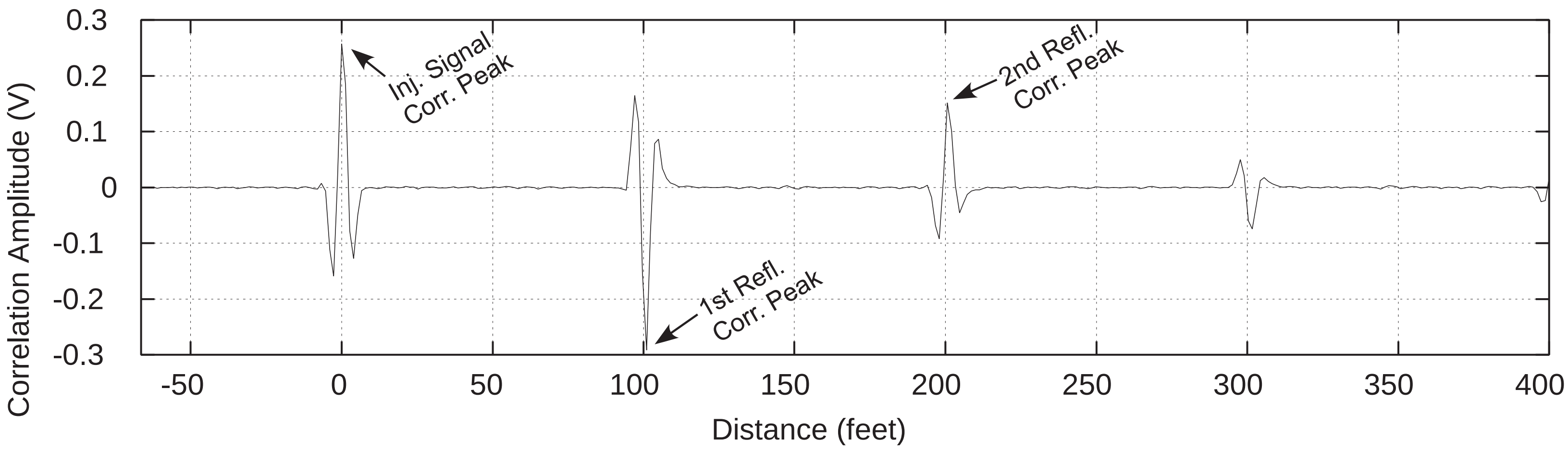
SSTDR with Short Circuited Cable



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75 ohm Coax with 28 V 60 Hz

298

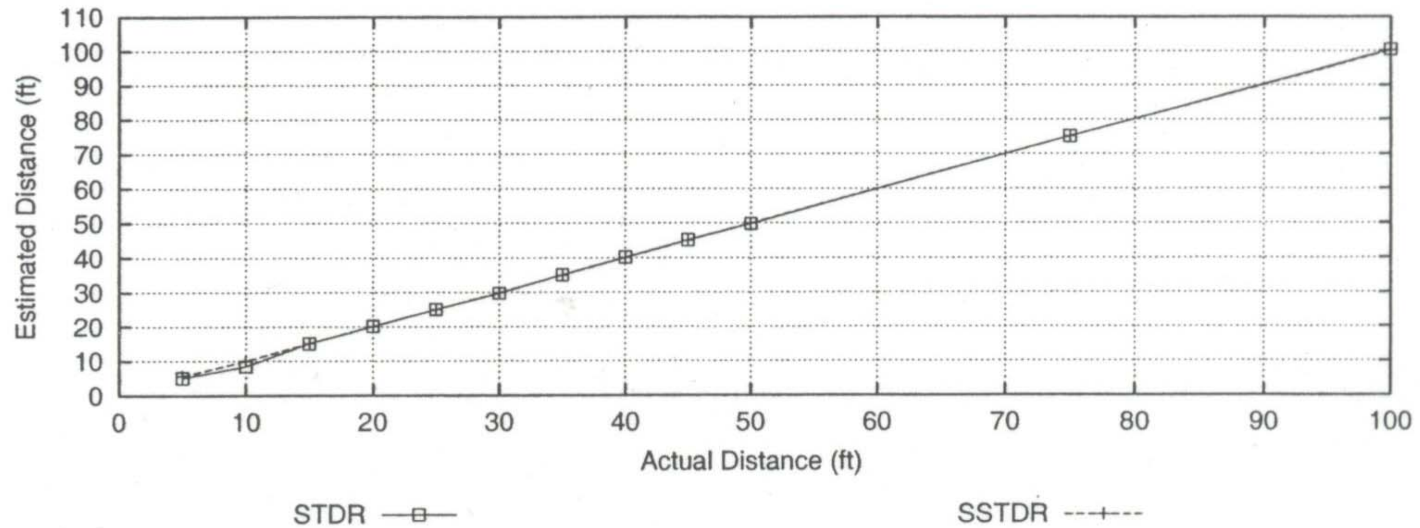


Fig. 7.54: Estimated distance versus measured distance to an open circuit. The background signal was $60Hz$ $28V$ AC. The coax cable was 75Ω, and capacitor *C5* was used.

Unshielded 22g with 28V 60 Hz

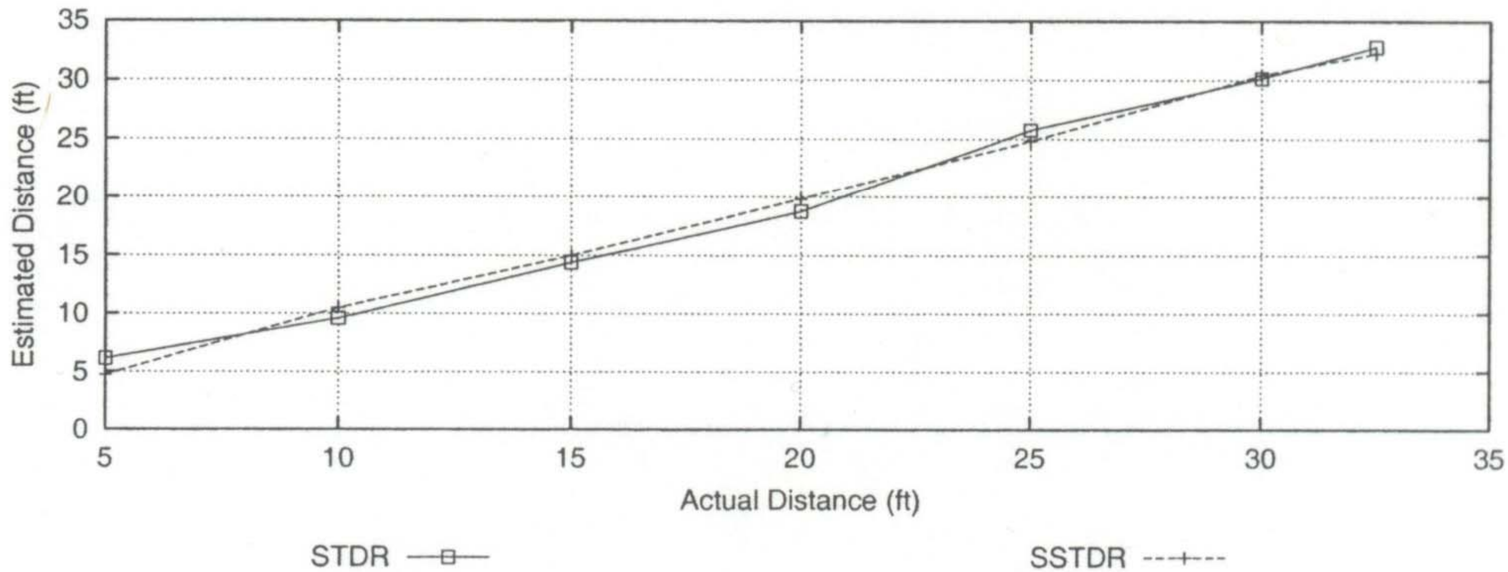


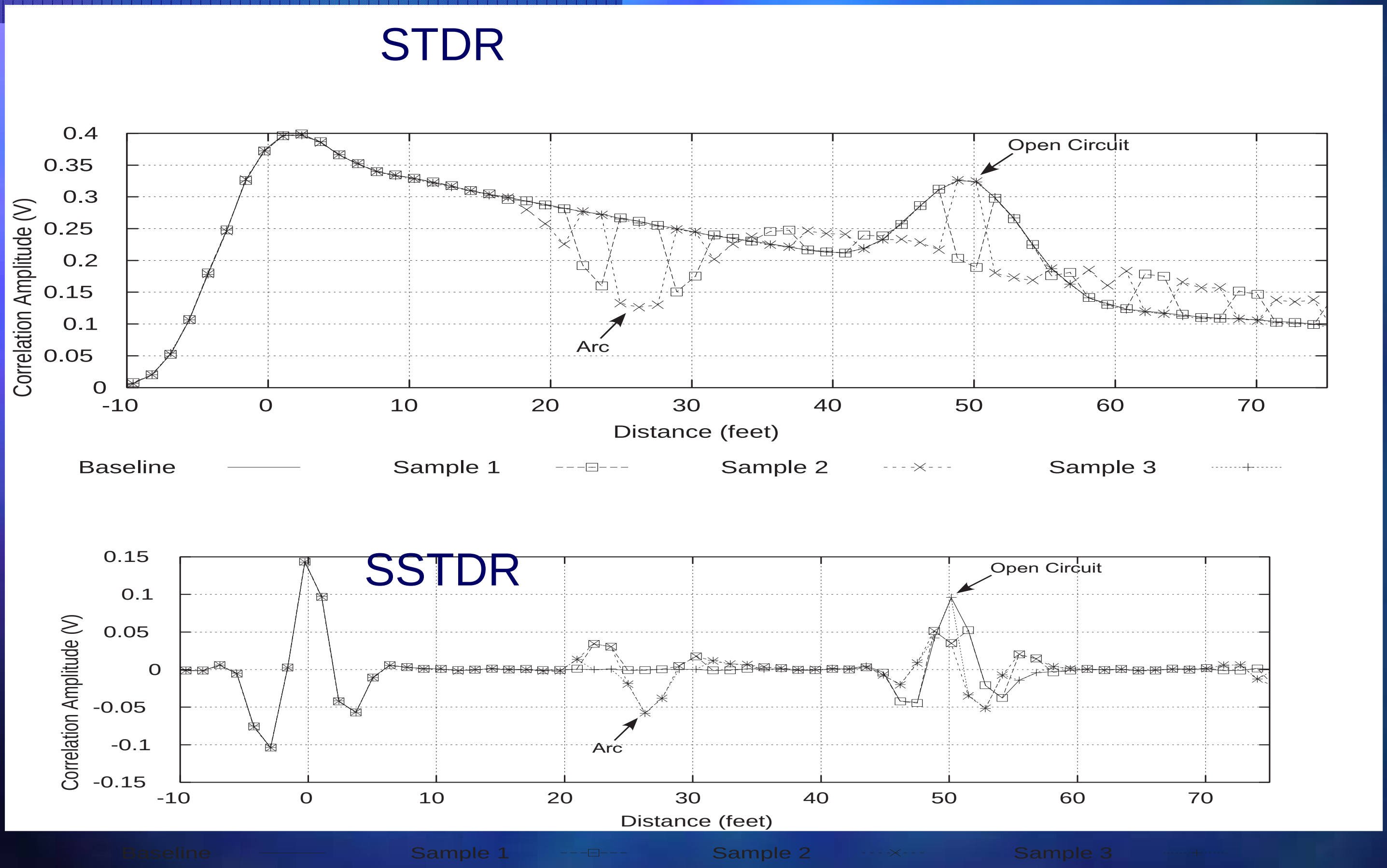
Fig. 7.72: Estimated distance versus measured distance to an open circuit. The background signal is $60Hz$ $28V$ AC. The cable is a 22 conductor aircraft cable made with 22 gauge discrete wires. Capacitor $C5$ was used.

Mil-Std 1553 Test Data

Table 7.3: ML Codes: Effects of Scaling

Mil-Std 1553 Amp. RMS (V)	Mil-Std 1553 SNR with STDR (dB)	Mil-Std 1553 SNR with SSTDR (dB)	STDR Signal to Noise Ratio (dB) Observed/Calc.	SSTDR Signal to Noise Ratio (dB) Observed/Calc.	STDR Dist. Est. (ft)	SSTDR Dist. Est. (ft)
0.0	$-\infty$	$-\infty$	$40.1/\infty$	$43.2/\infty$	25.0	25.0
0.5	25	27	* 8.7/4.9	32.5/32.8	24.2	25.0
1.0	31	33	* 2.8/-1.1	26.3/26.8	35.5	25.1
2.5	39	41	* -4.0/-9.1	18.6/20.8	64.2	25.0
5.0	45	47	* -7.6/-15.1	15.5/14.8	110.4	24.8
10.0	51	53	* -9.2/-21.1	* 12.7/8.8	42.7	25.2

STDR/SSTDR: “Dry” Arc Controlled Impedance Cable



32.5’ cable
RG59 Coax
(75-ohm
controlled Z)
60 Hz 28V

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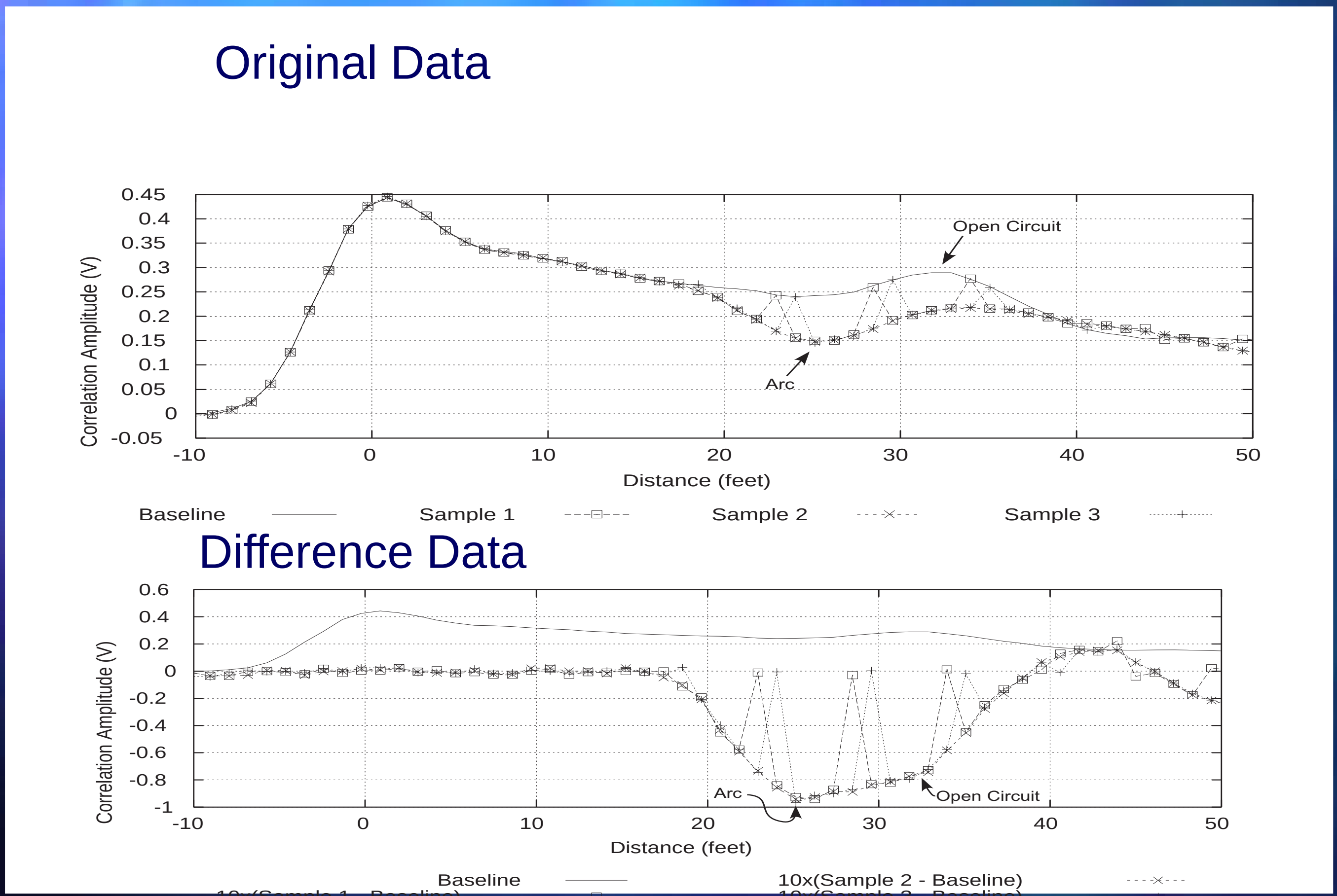
STDR: “Dry” Arc
Non-Controlled Impedance Cable



32.5’ cable
Multistrand Cable
(non-controlled Z)
60 Hz 28V

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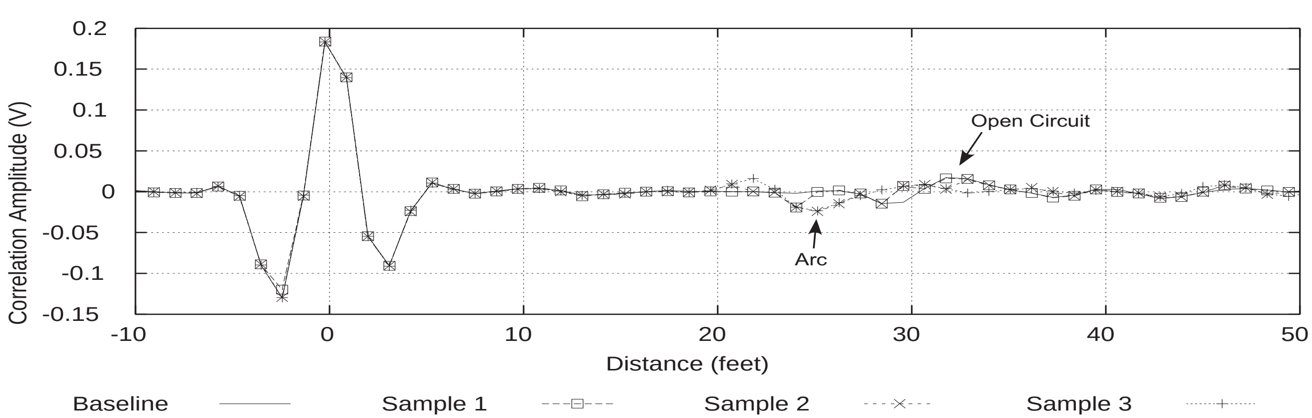
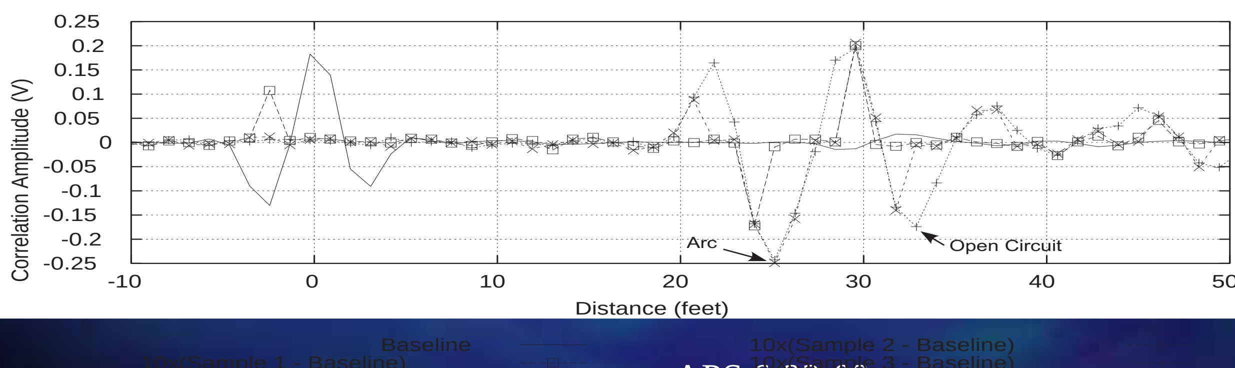
SSTDR: “Dry” Arc
Non-Controlled Impedance Cable

Original Data



Difference Data



32.5’ cable
Multistrand Cable
(non-controlled Z)
60 Hz 28V

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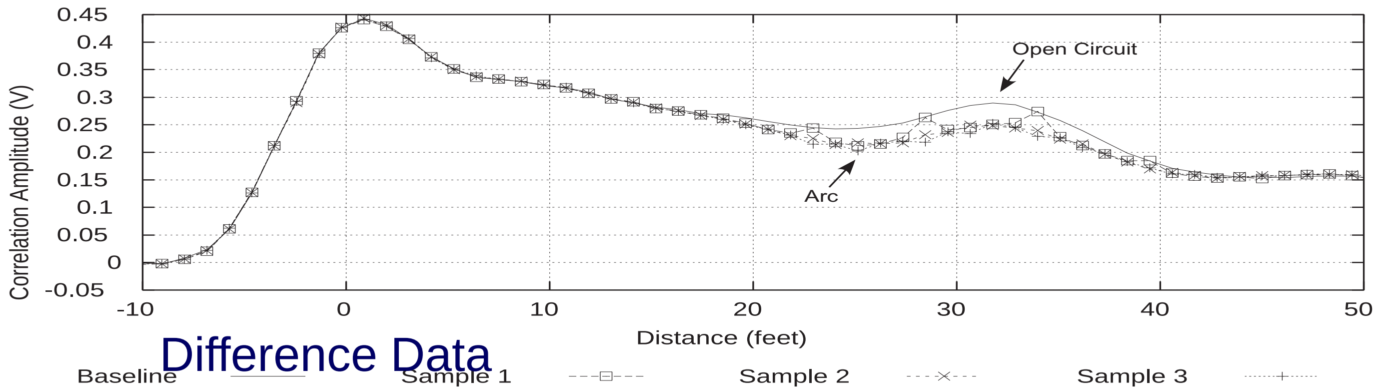
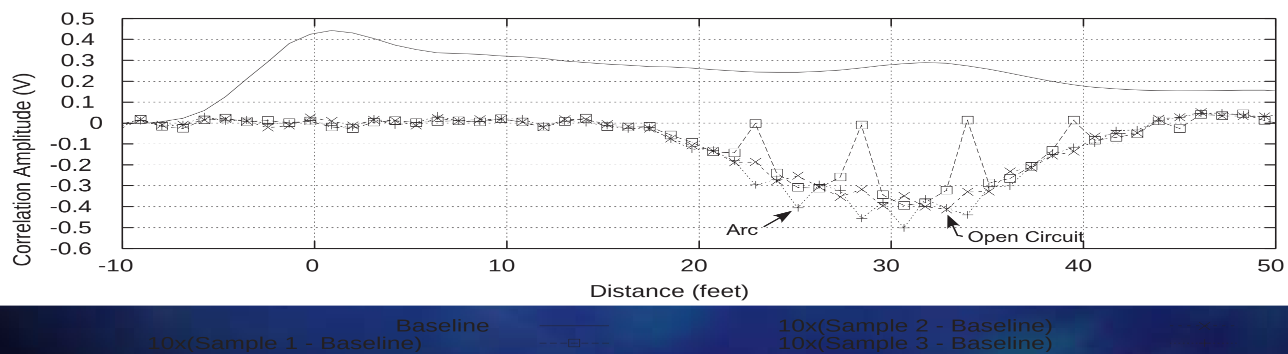
STDR: “Wet” Arc
Non-Controlled Impedance Cable

Original Data



Difference Data



32.5’ cable
Multistrand Cable
(non-controlled Z)
60 Hz 28V

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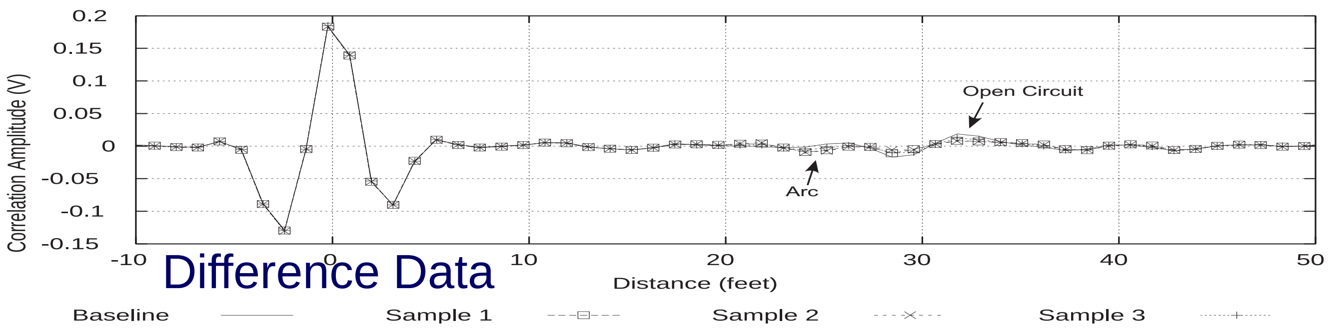
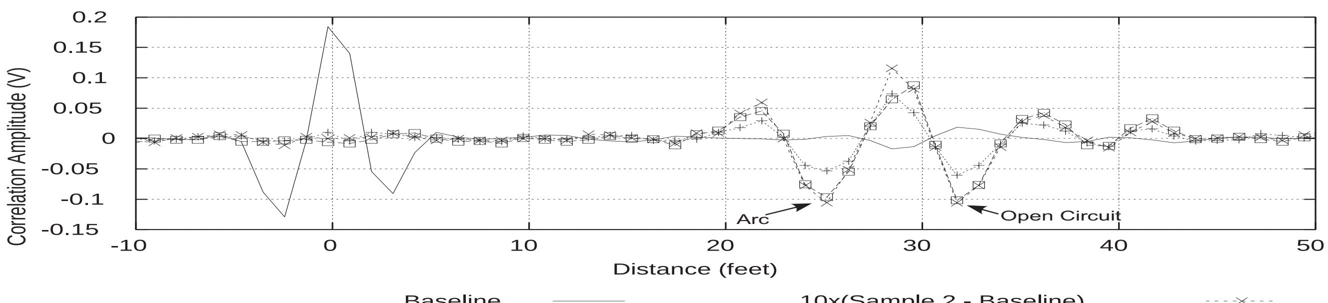
SSTDR: “Wet” Arc
Non-Controlled Impedance Cable

Original Data



Difference Data



32.5’ cable
Multistrand Cable
(non-controlled Z)
60 Hz 28V

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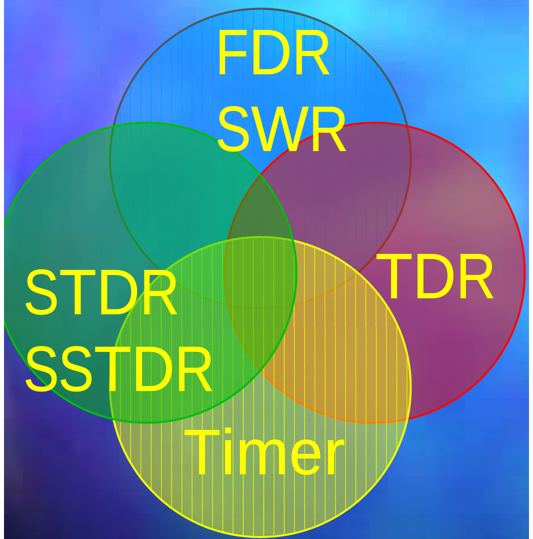

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STDR SSTDR	Yes Live	"All Freqs", and Digital	<200	Yes	Yes
TDR	Yes/ Base line	No	~$3k	Yes	No

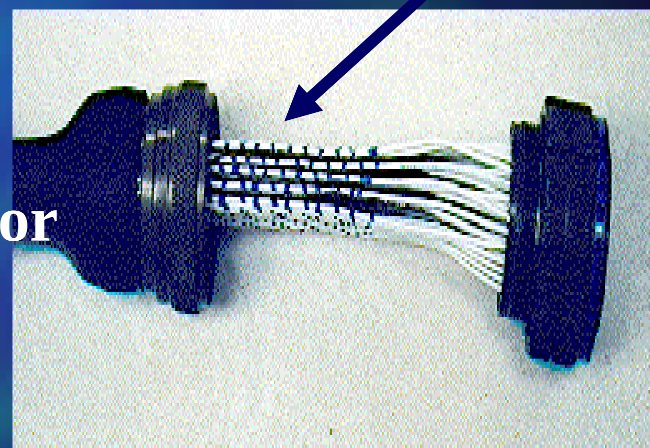
Application of Spread Spectrum to Wire Testing

Handheld

Smart Breaker

Smart Connector (Saver)

Smart Wire



Smart Connector

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