Fault Location on Branched Wire Networks

Dr. Chet Lo*, Kedarnath Nagoti*, Dr. You Chung Chung**, Dr. Cynthia Furse*,***
University of Utah*,
Center of Excellence for Smart Sensors
LiveWire Test Labs, Inc.***
Salt Lake City, Utah
Dae Gu University, Korea**

Chet Lo, Kedarnath Nagoti, Arthur Mahoney, You Chung Chung, Cynthia Furse, “Detection and Mapping of Branched Wiring Networks from Reflectometry Responses,” Joint FAA/DoD/NASA Conference on Aging Aircraft, Palm Springs, CA, Jan 31-Feb 4, 2005

Abstract:
Reflectometry methods including time, frequency, sequence, and spread spectrum reflectometry methods are capable of providing highly accurate location of faults on aircraft wiring. One of the significant challenges in applying these methods in practice is that many wires, particularly power wires, branch into tree-shaped networks from which multiple reflections create extremely difficult-to-interpret reflectometry responses. In this presentation, we will discuss the complexity of the branched network problem and why accurate measurements of the length and magnitude are so critical for solving this problem. We will also introduce two functional novel systematic approaches to solve this problem, which do not require prior measurements as baselines. Additionally, we will present results from our approaches with both simulated and measured reflectometry data of branched networks.Sources of error including measurement error and topology ambiguity are considered, and an assessment of network mapping strategies is given for both ideal and nonideal data.

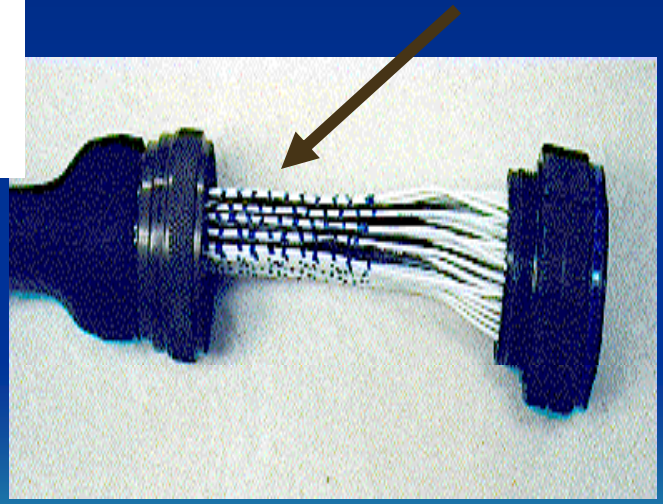
Potential Sensor Locations

Handheld

Connector Saver

CircuitBreaker

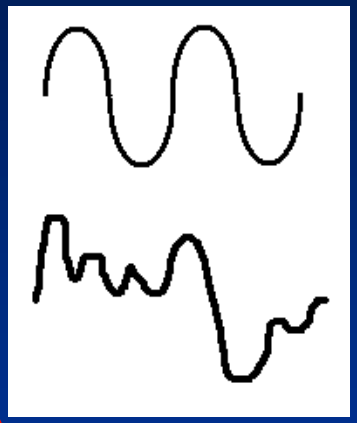
Wire

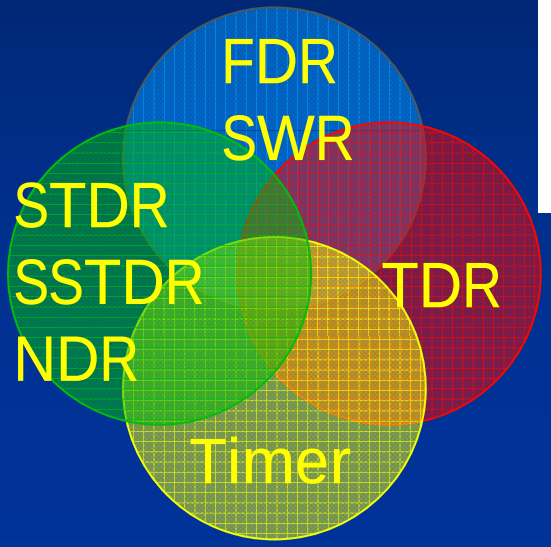


Connector

Reflectometry-Based Fault Location Methods

Analog





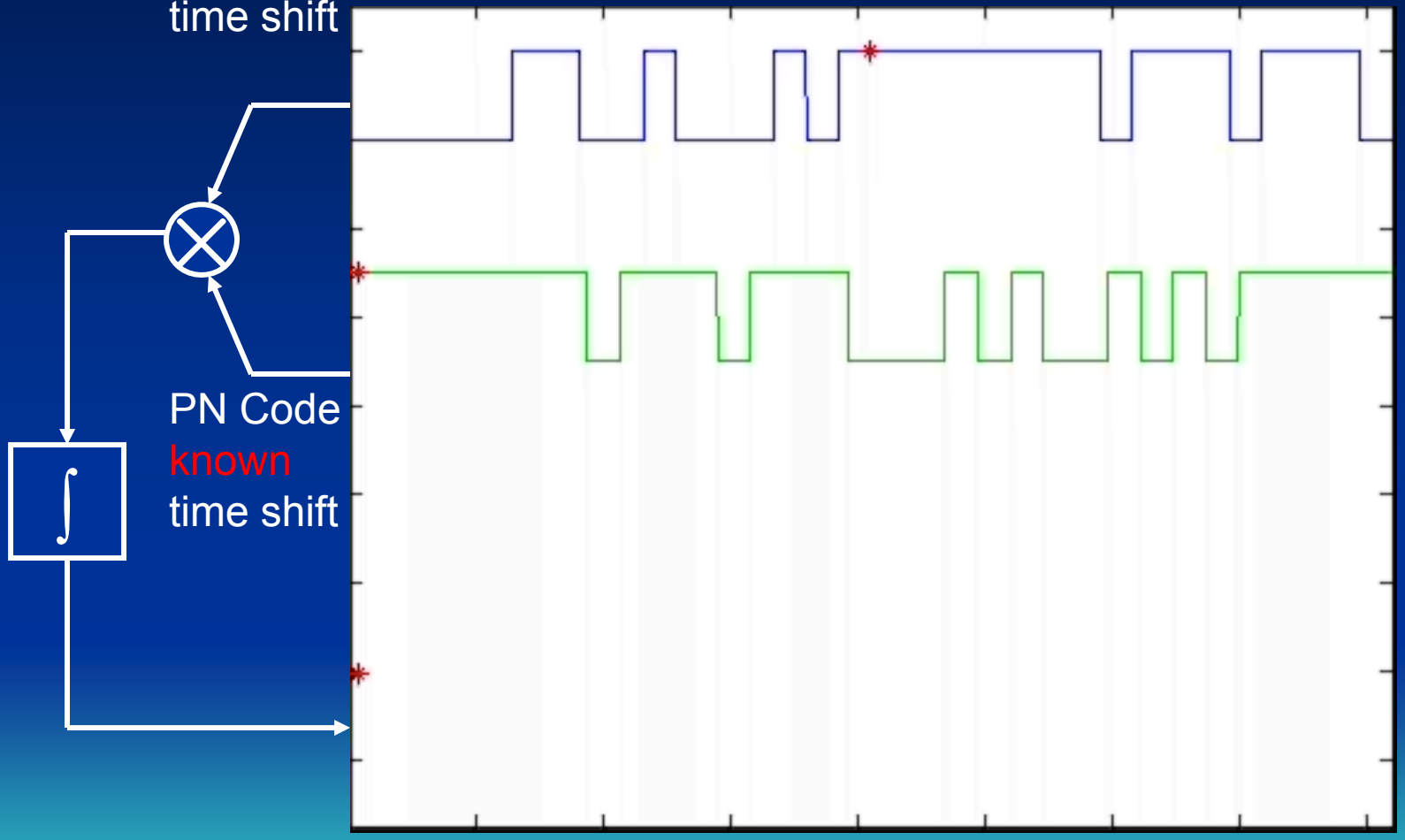
Digital

Time Domain

Capacitance / Inductance

STDR

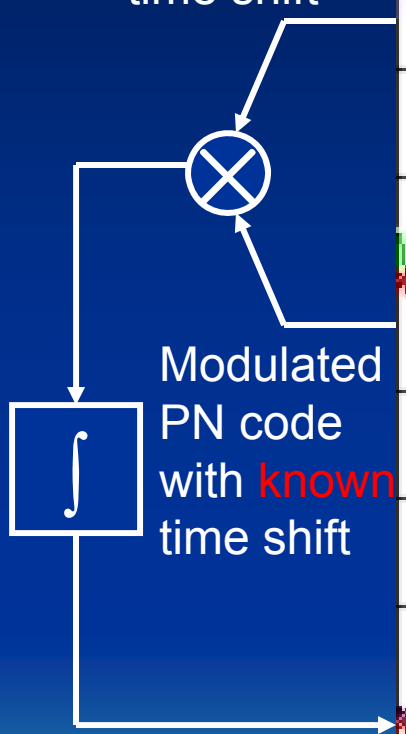
PN Code
unknown
time shift



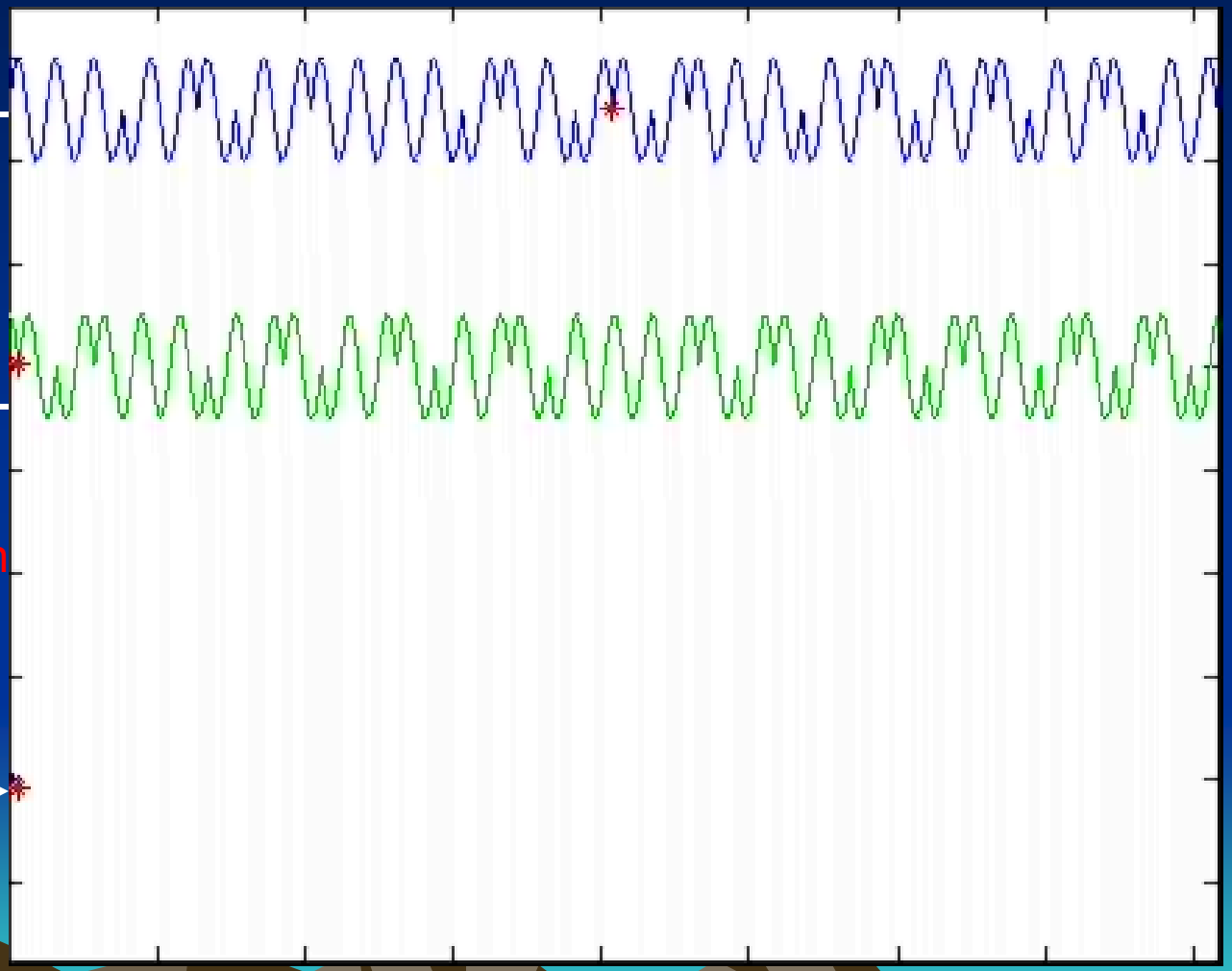
PN Code
known
time shift

SSTDR

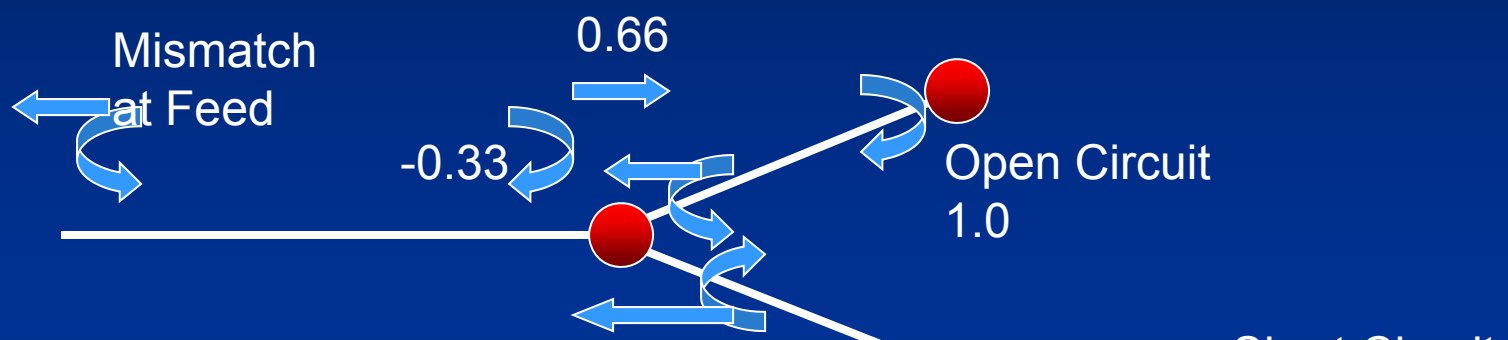
Modulated PN code with unknown time shift



Modulated PN code with known time shift



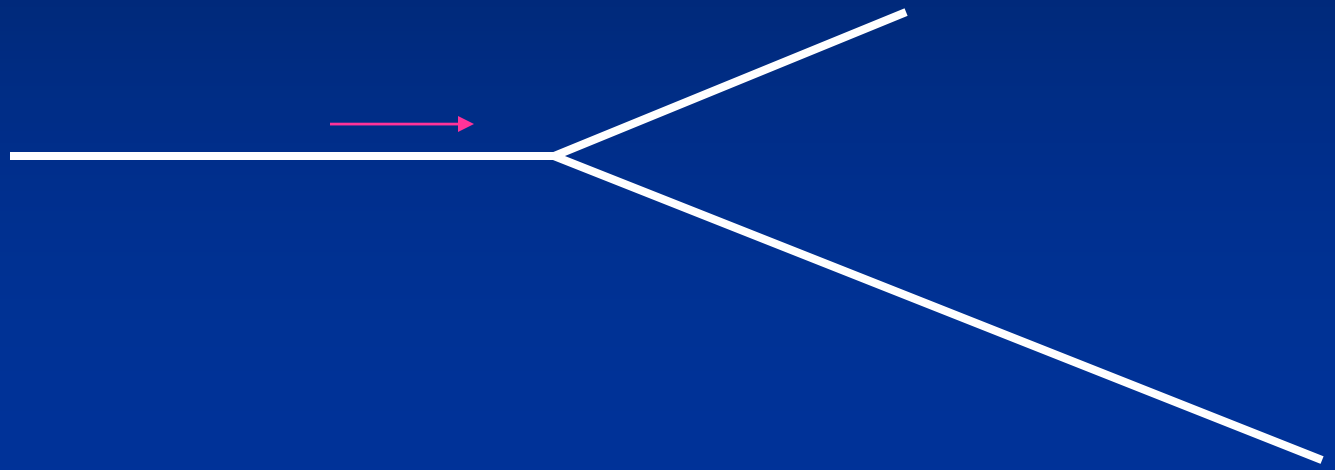
Reflectometry Measures the Reflection at every Impedance CHANGE on the wire



$$\Gamma = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

Branched Networks Make Multiple Reflections

Branched Networks Make Multiple Reflections



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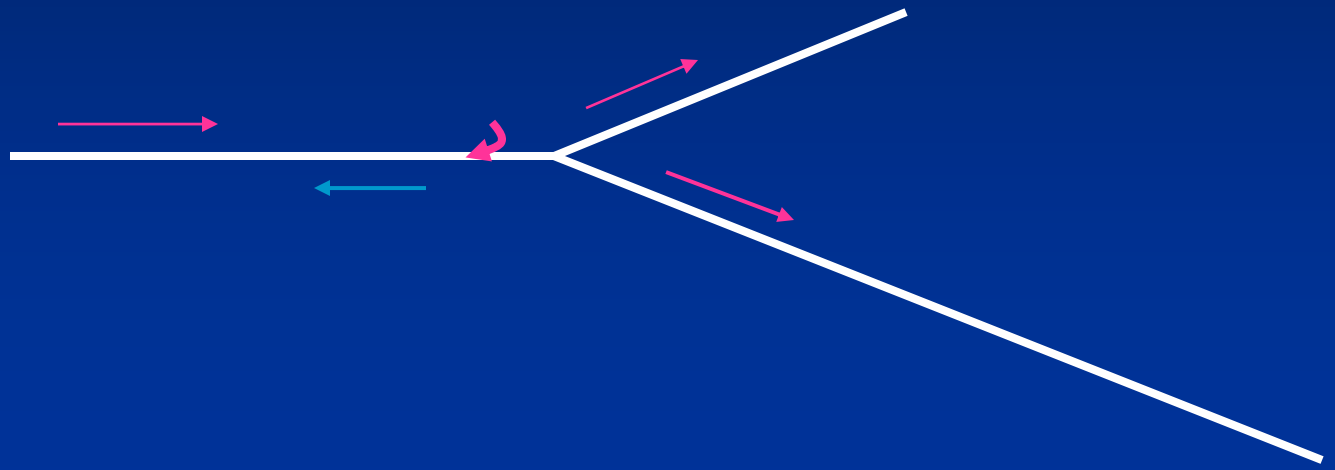

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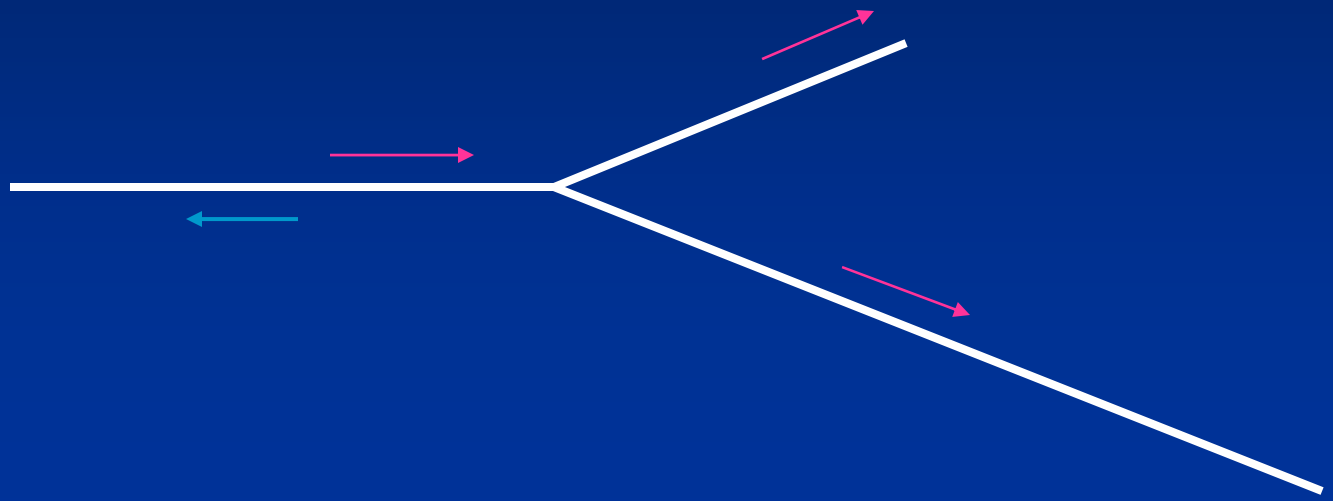

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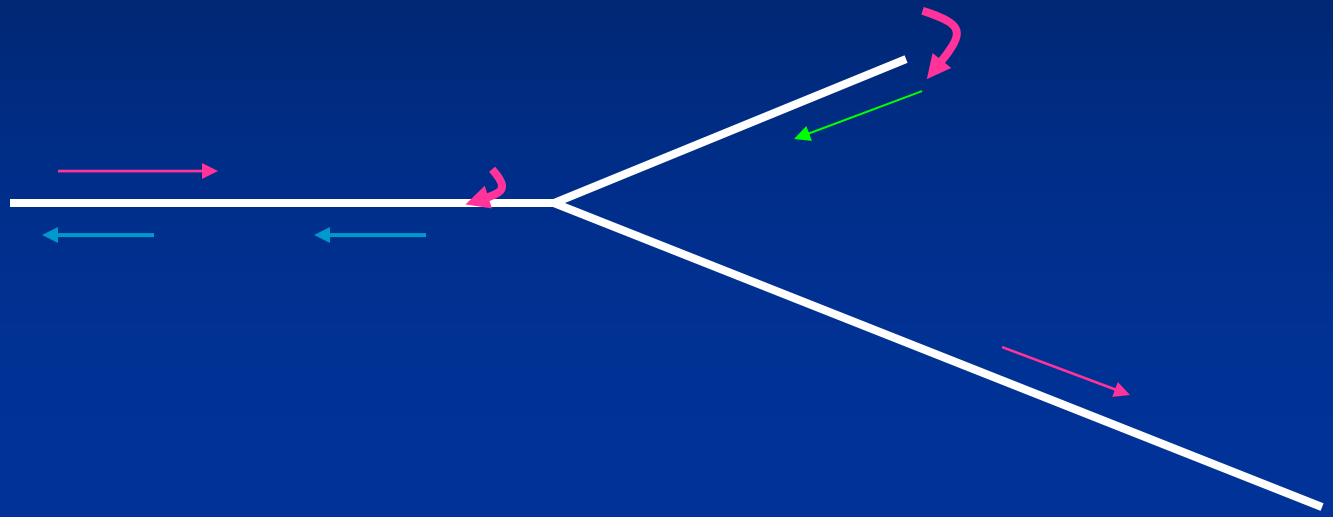

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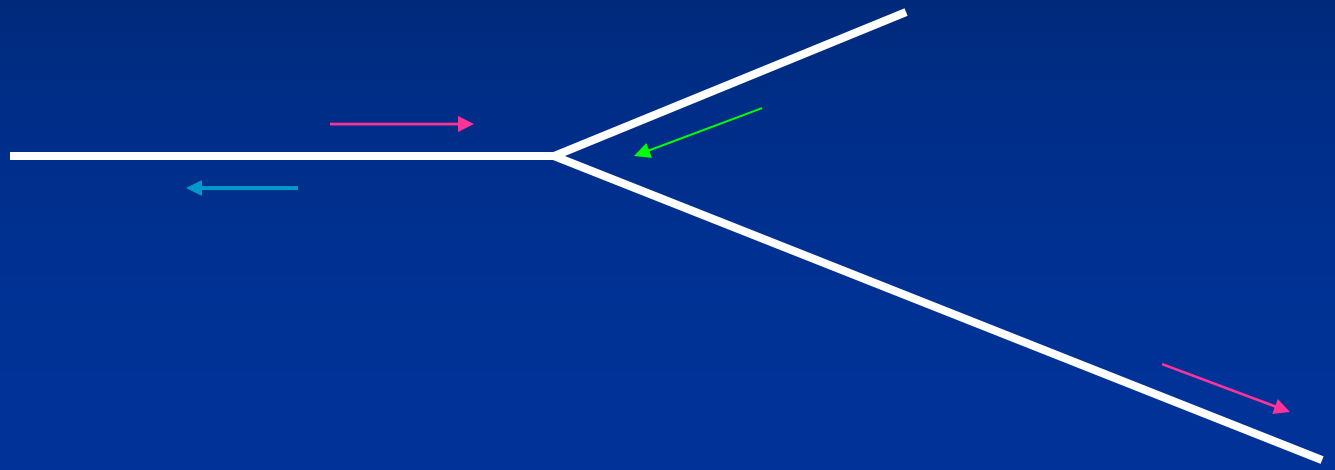

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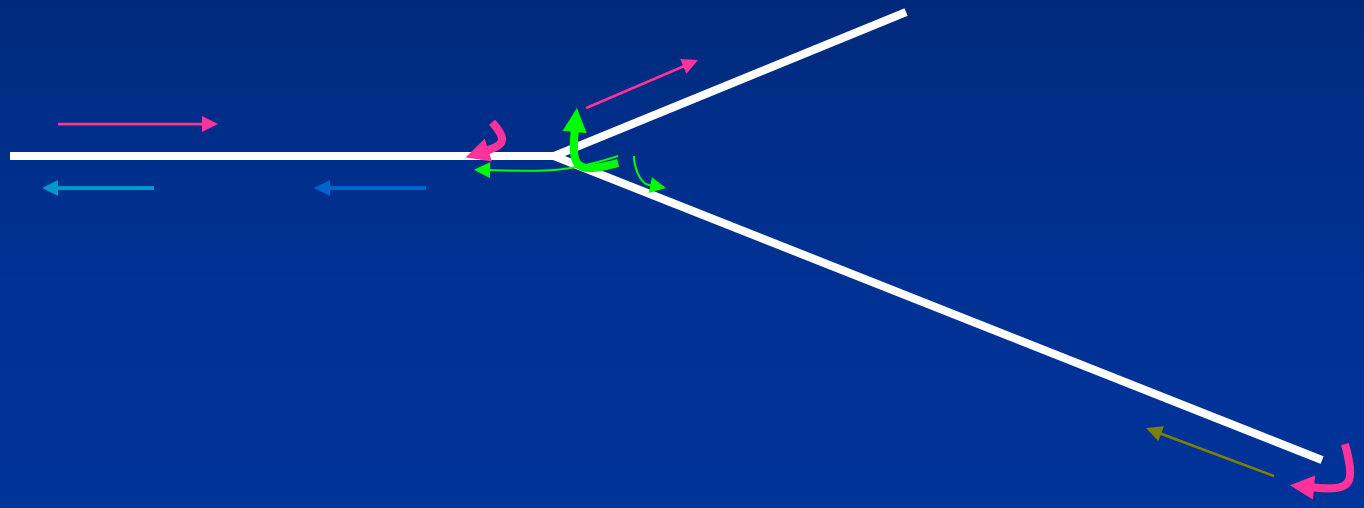

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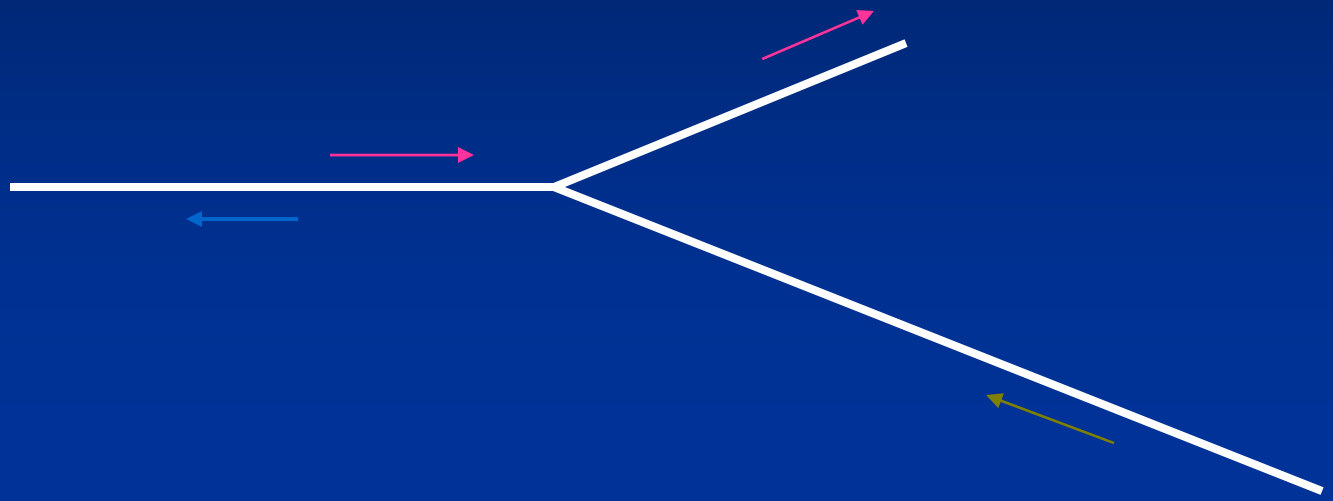

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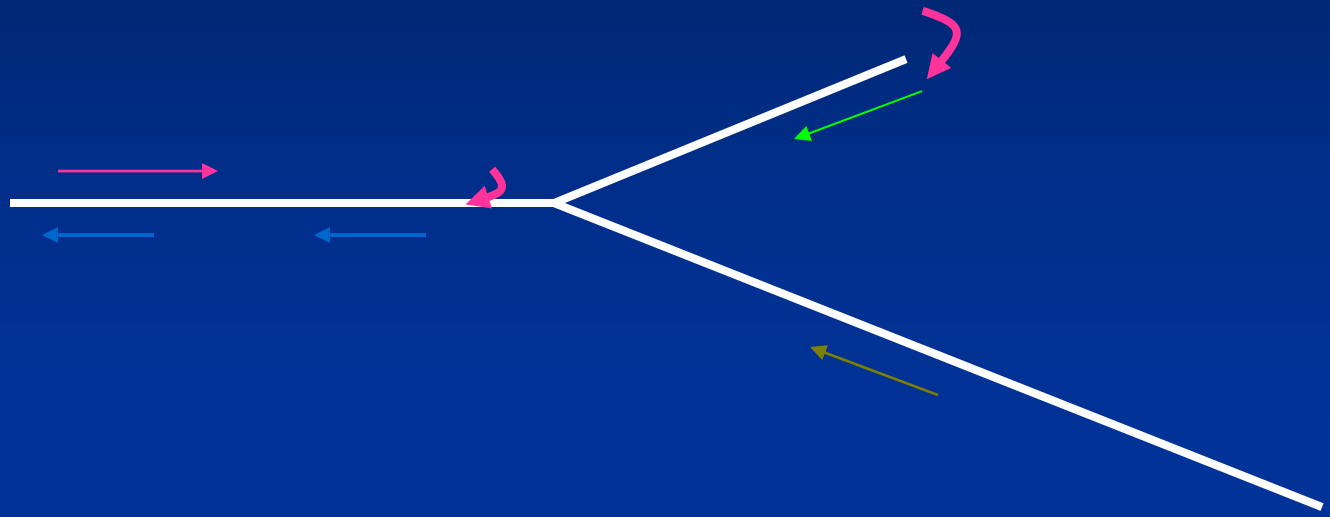

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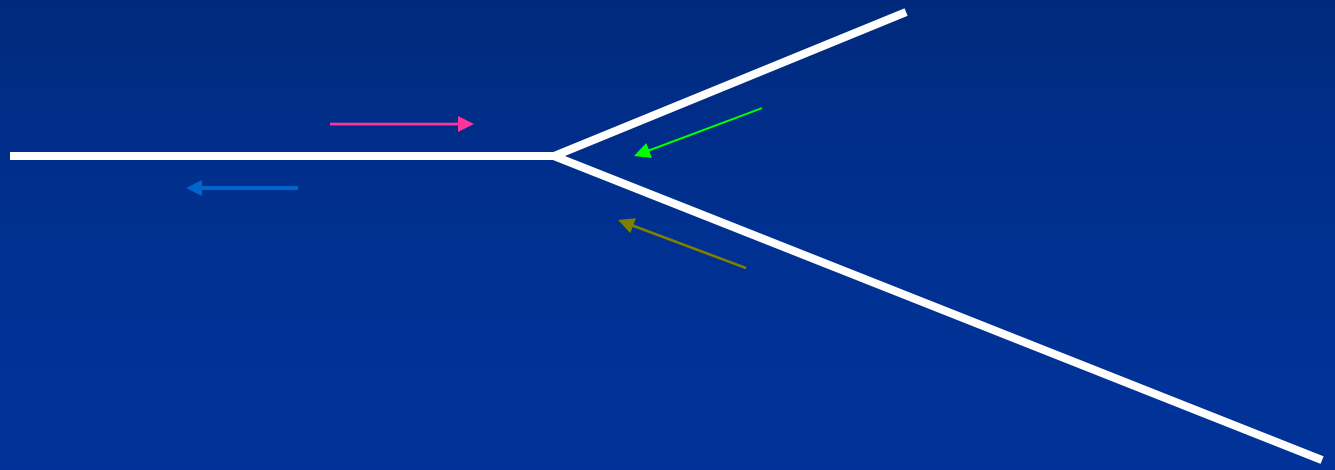

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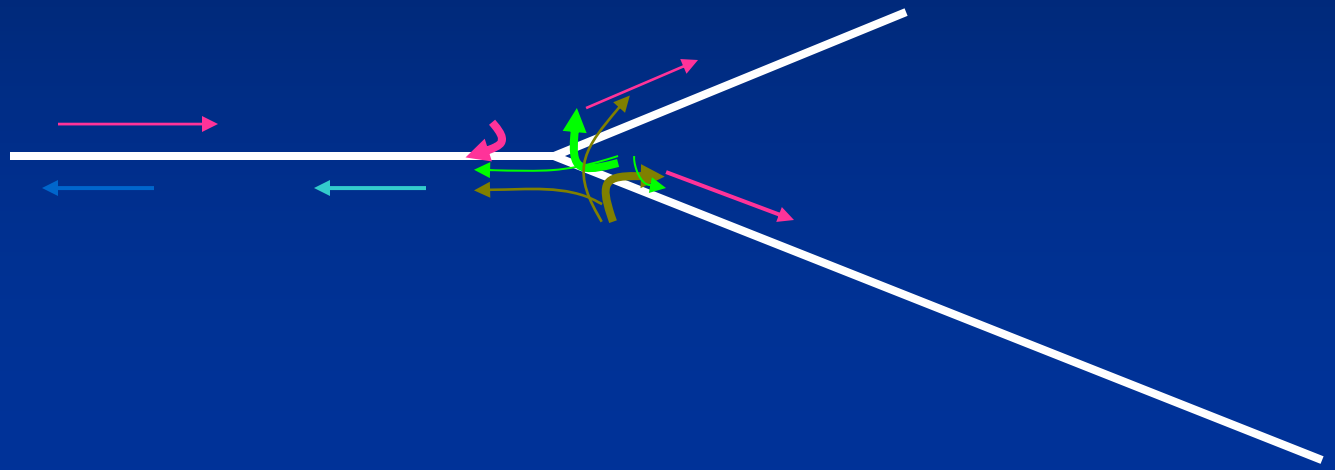
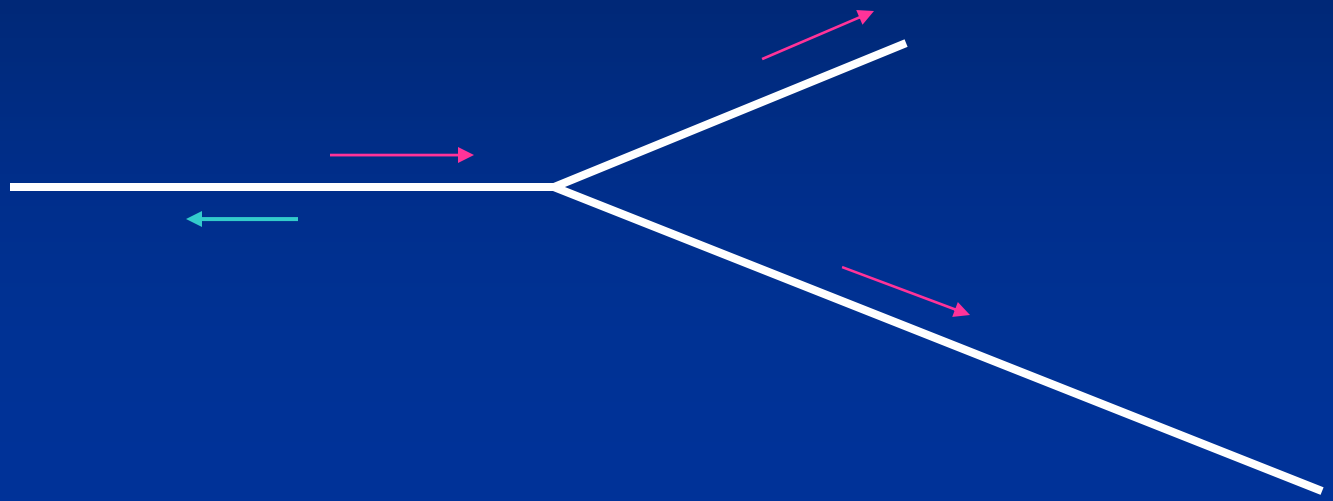


Branched Networks Make Multiple Reflections



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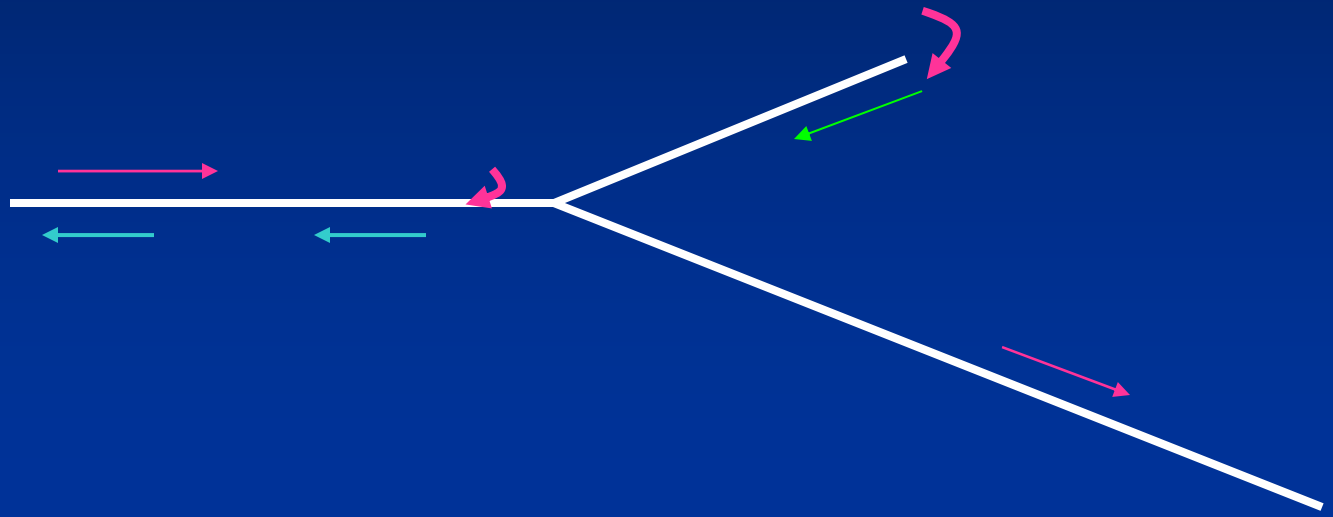

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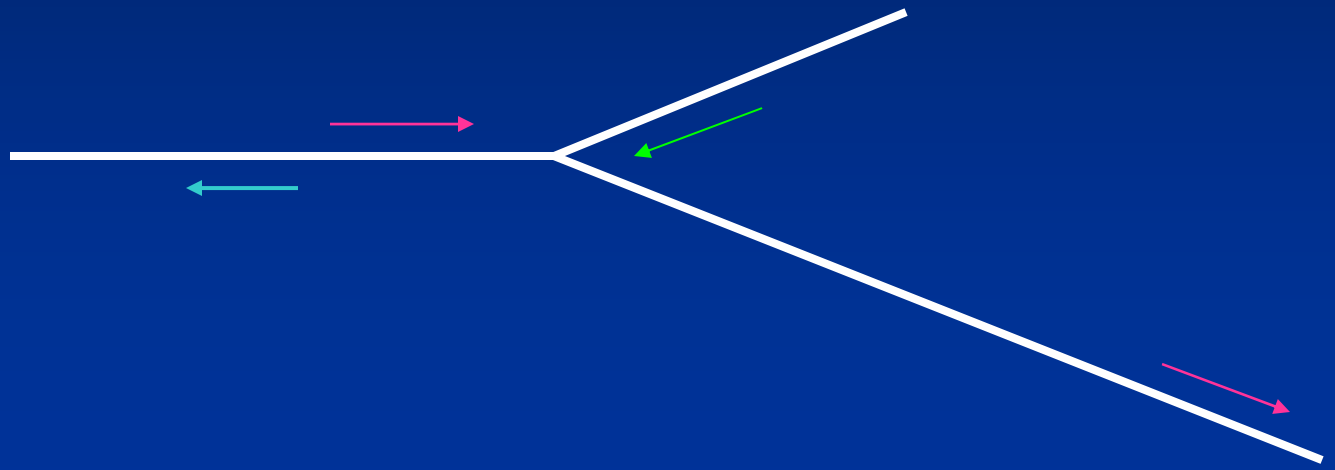

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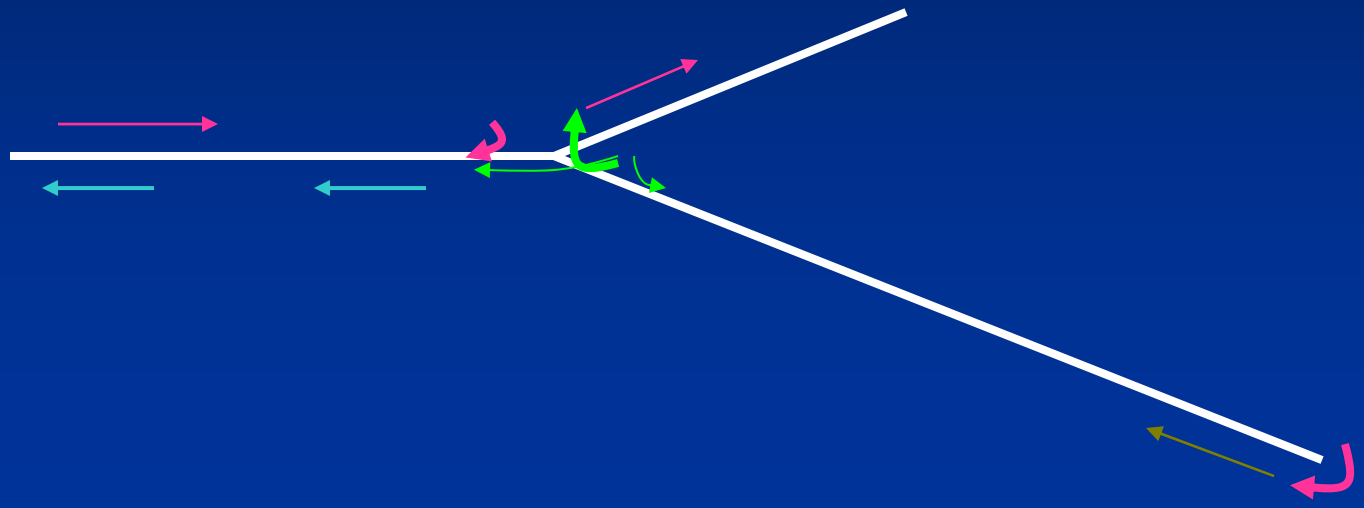
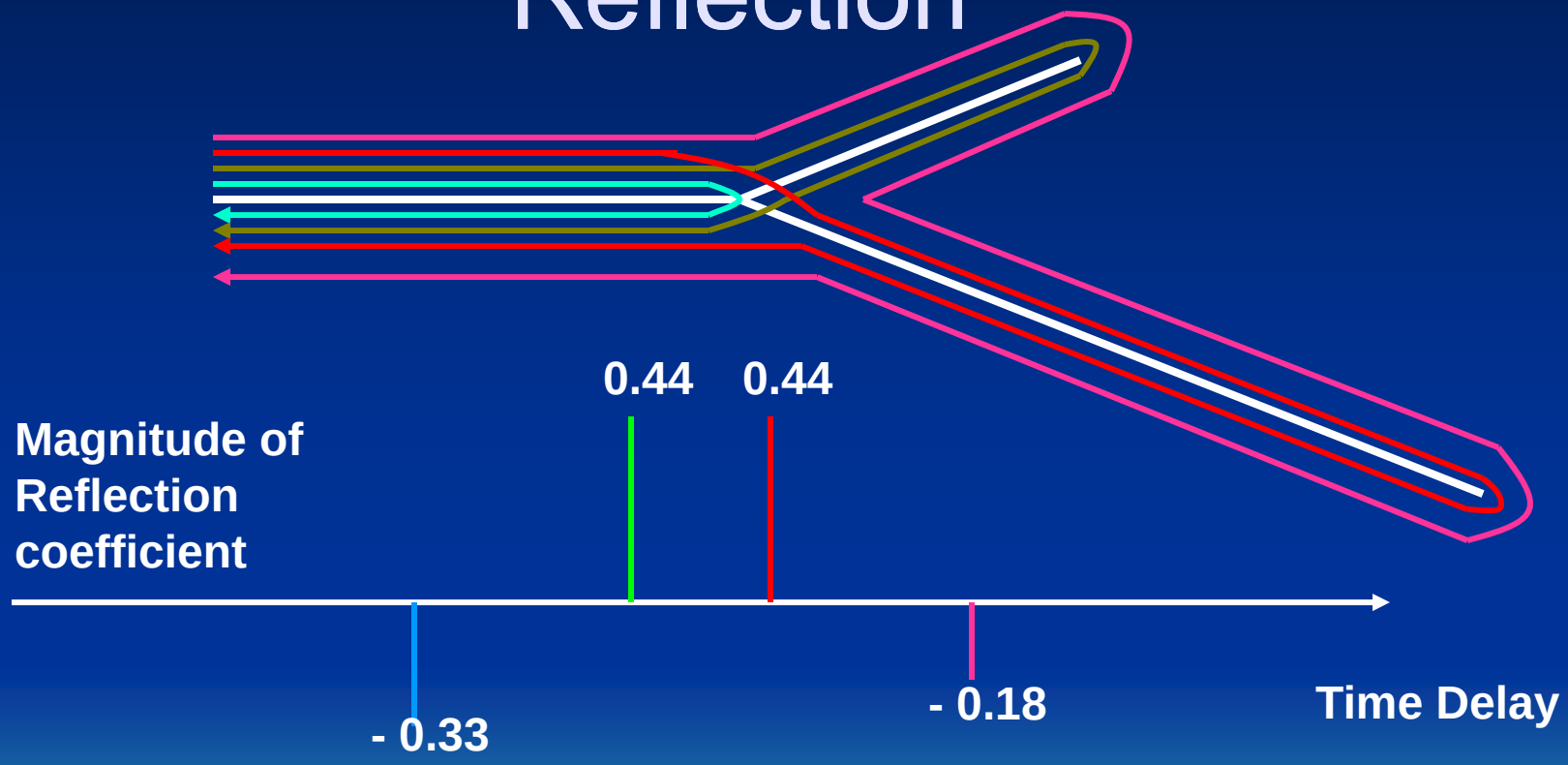
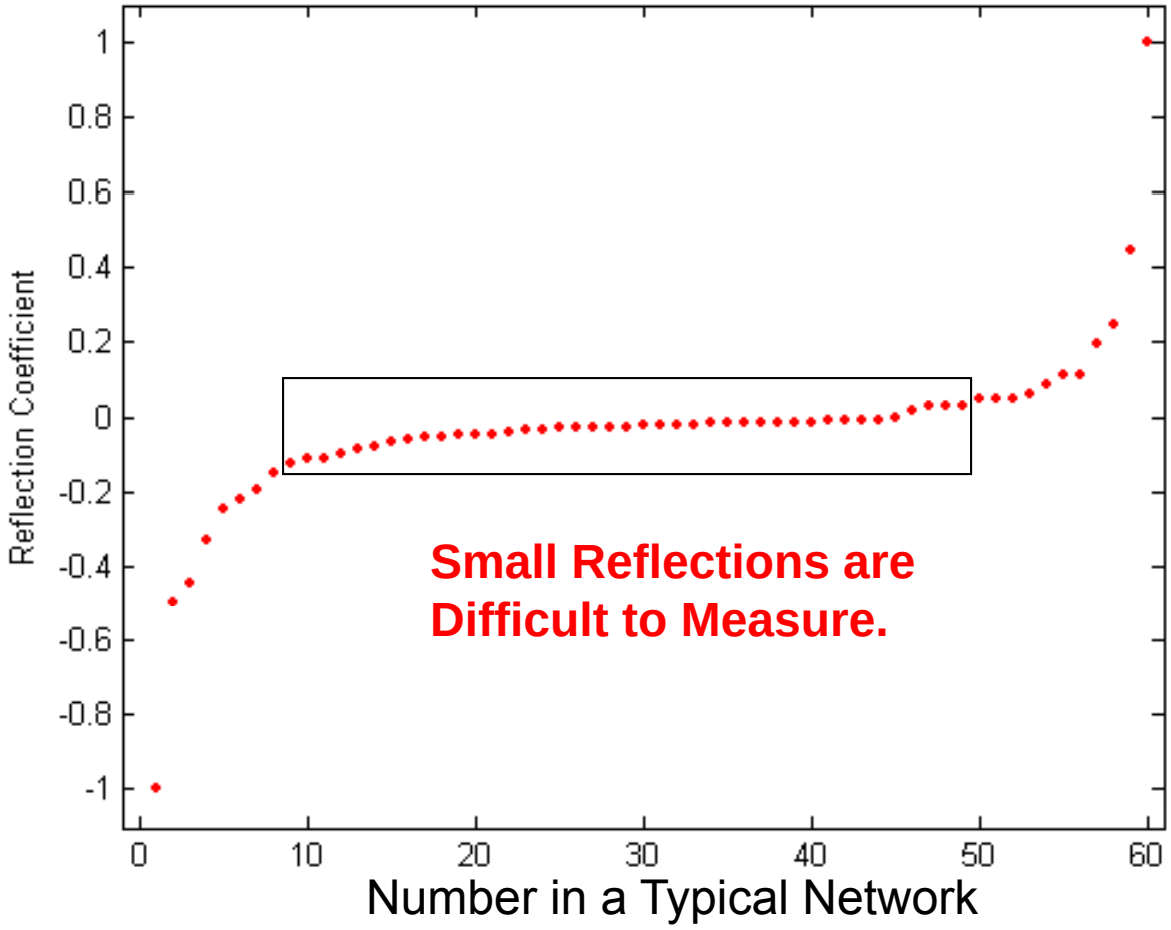


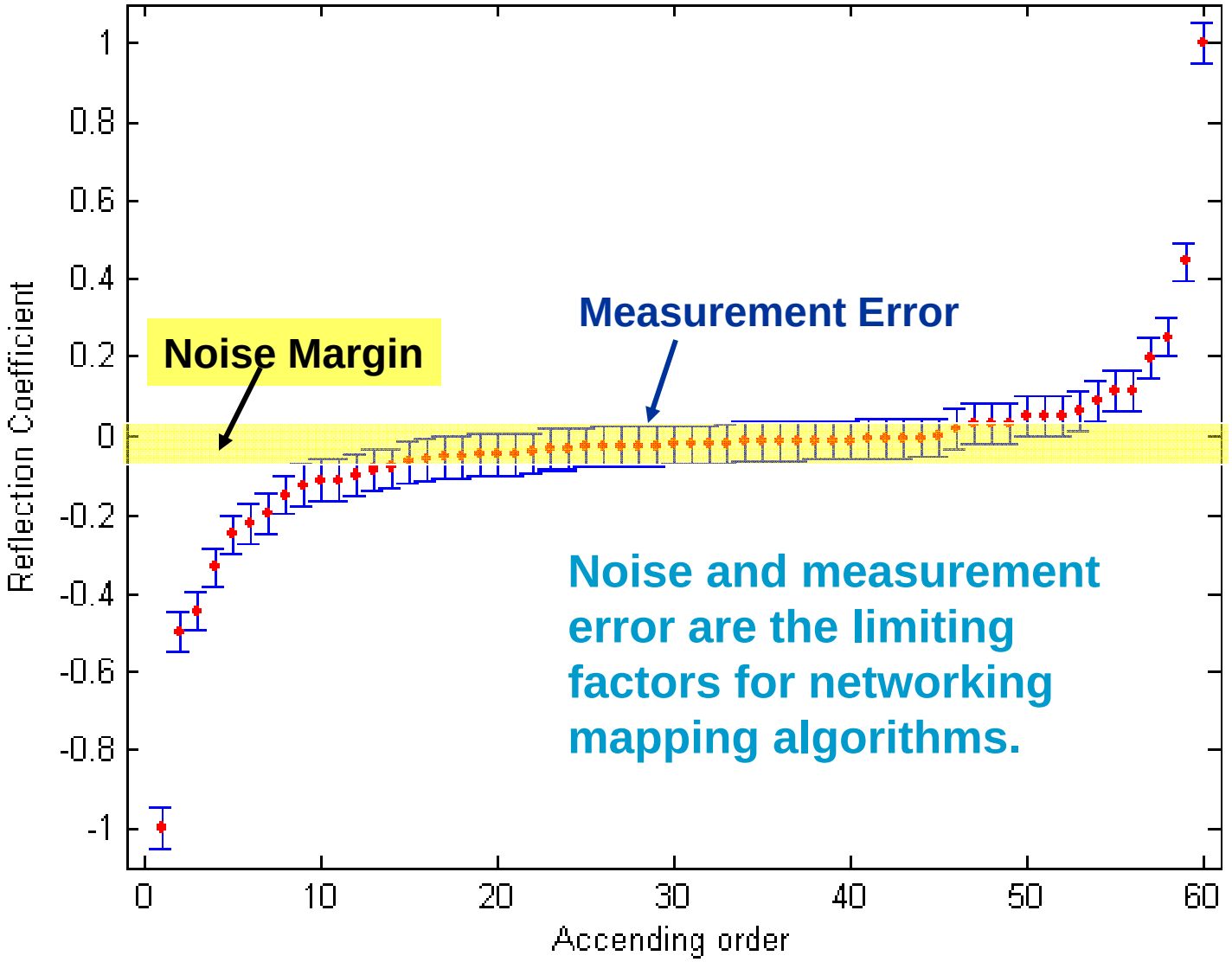
Impulse Response Shows Magnitude and Delay of Each Reflection



Typical Branched Network Has Many SMALL Reflections

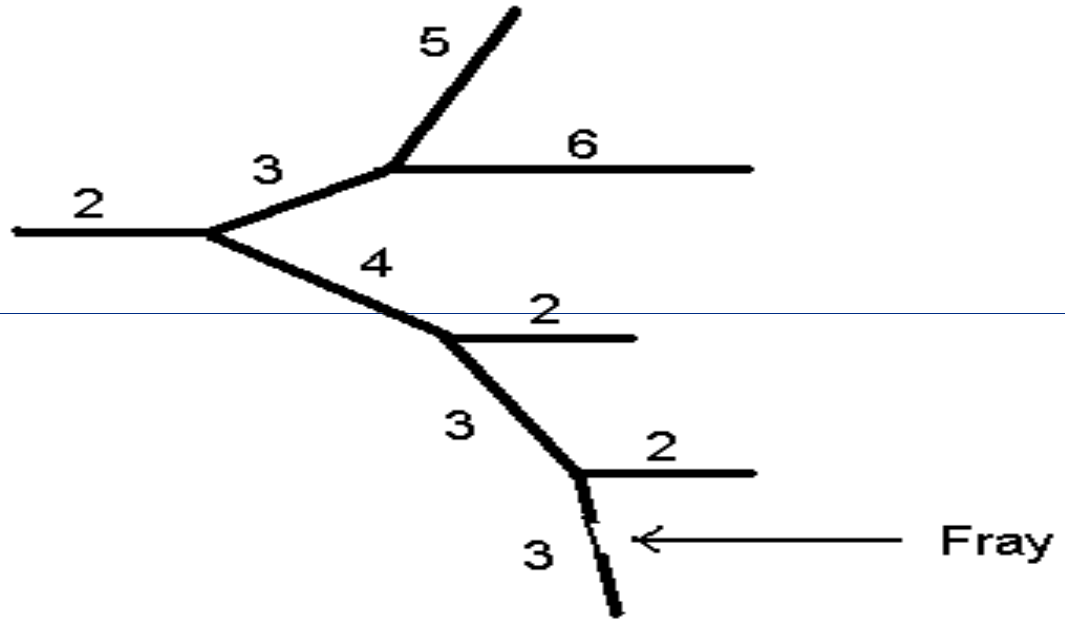


Noise Masks Small Reflections



What About FRAYS and ARCS?

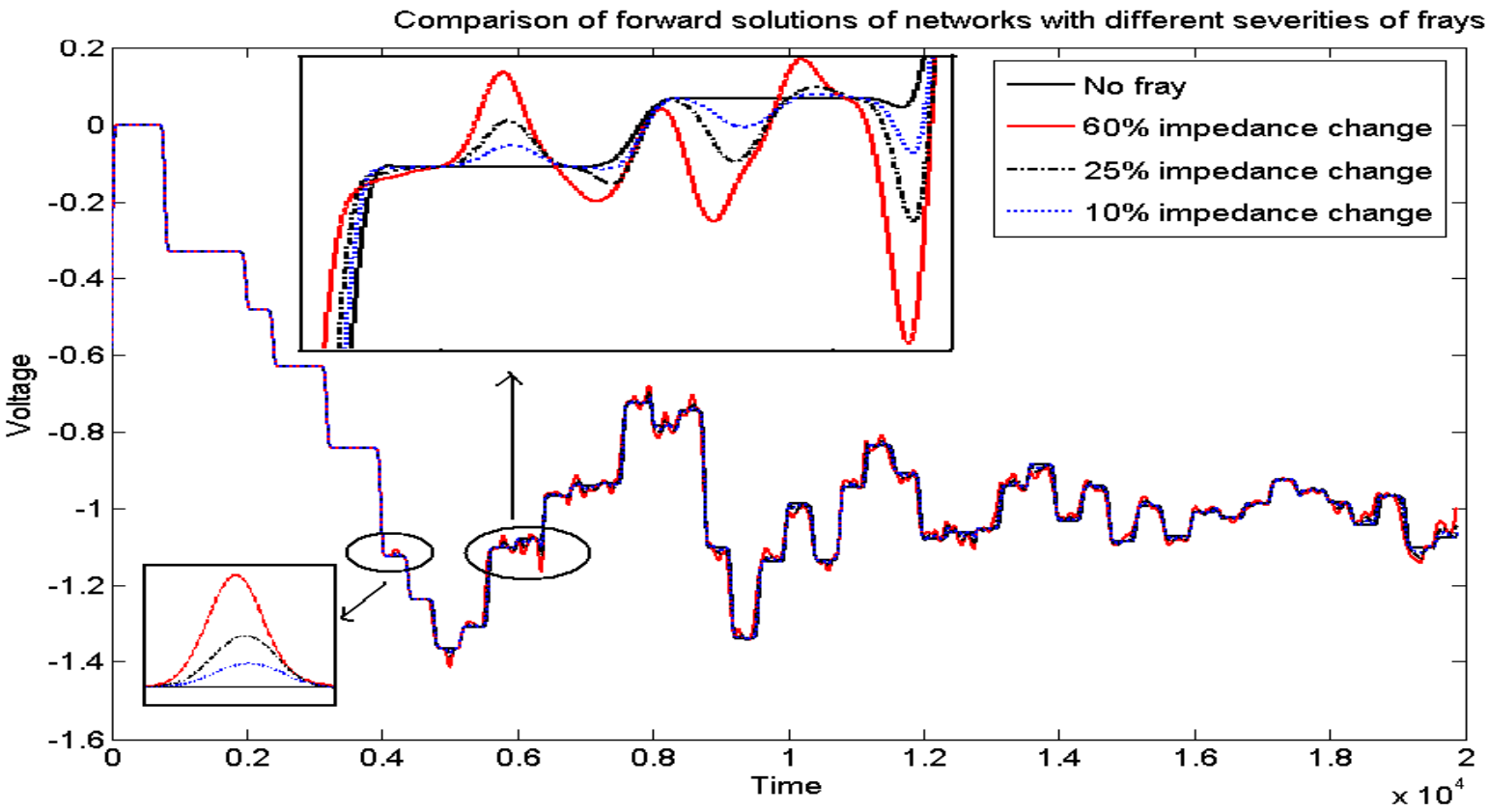
Fray on a Network



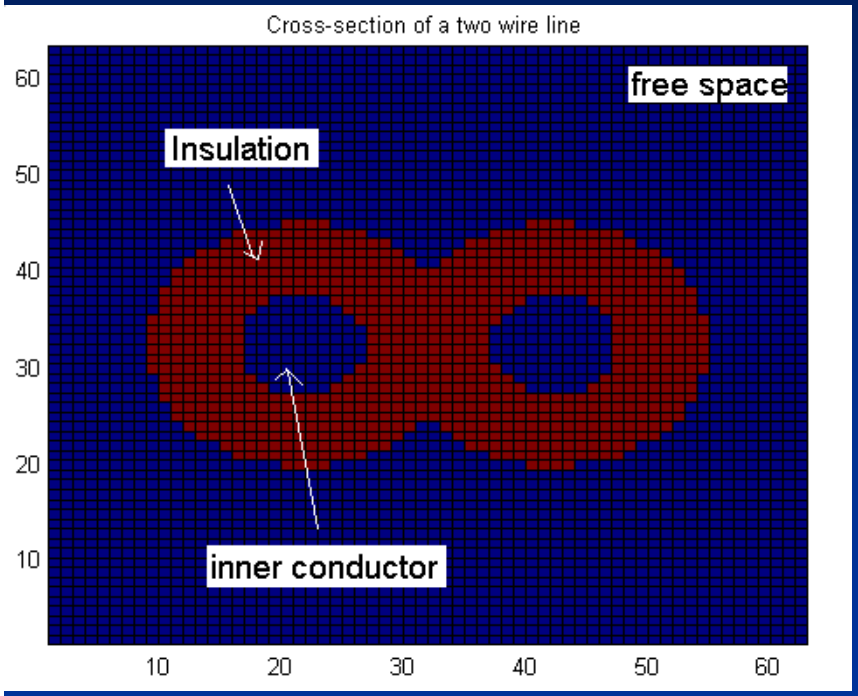
All the lines have characteristic impedance Z0= 50 ohms.

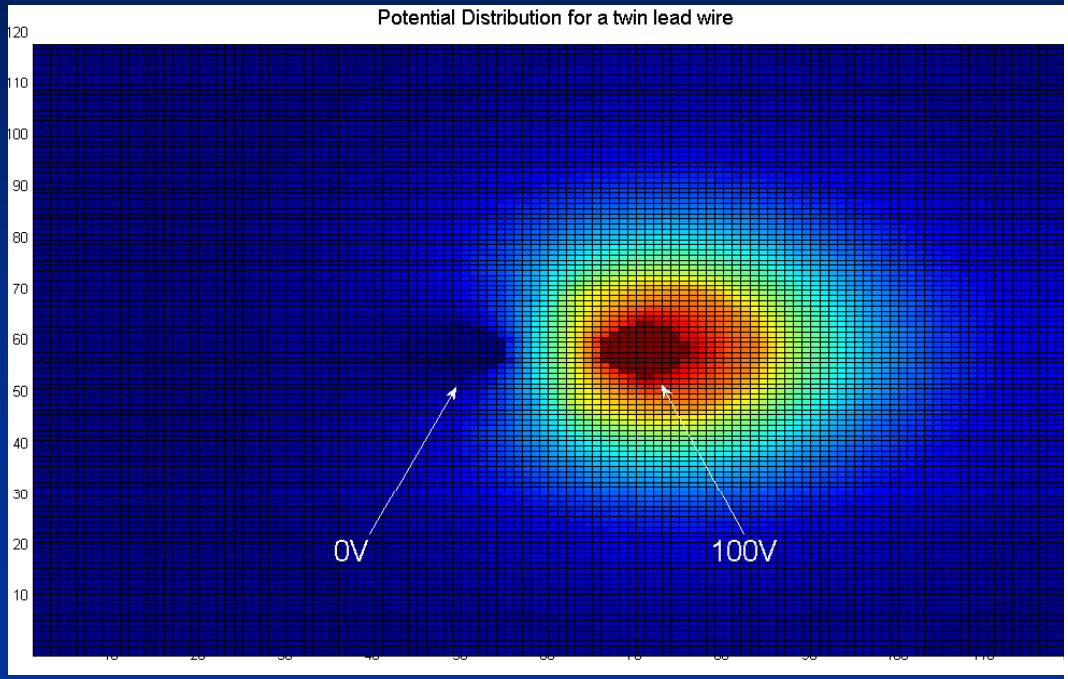
The lines are terminated by shorted ends.

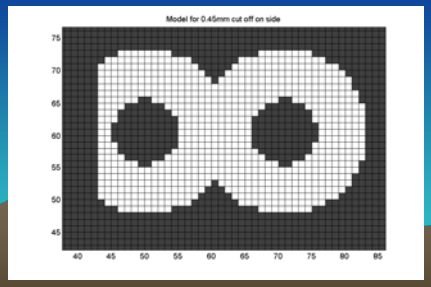
Reflectometry Response

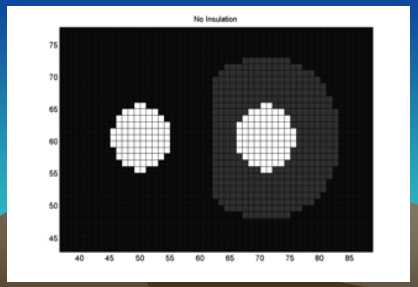


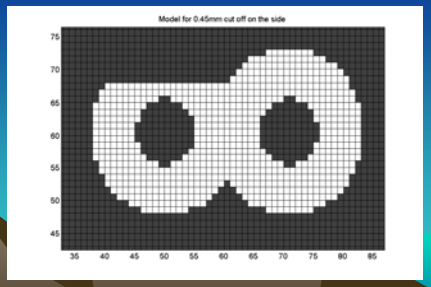
Simulated Frays

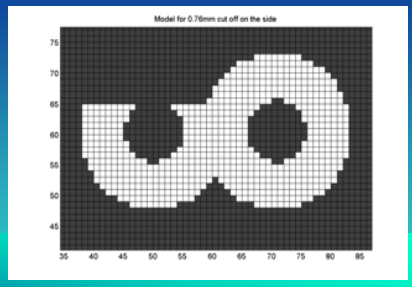










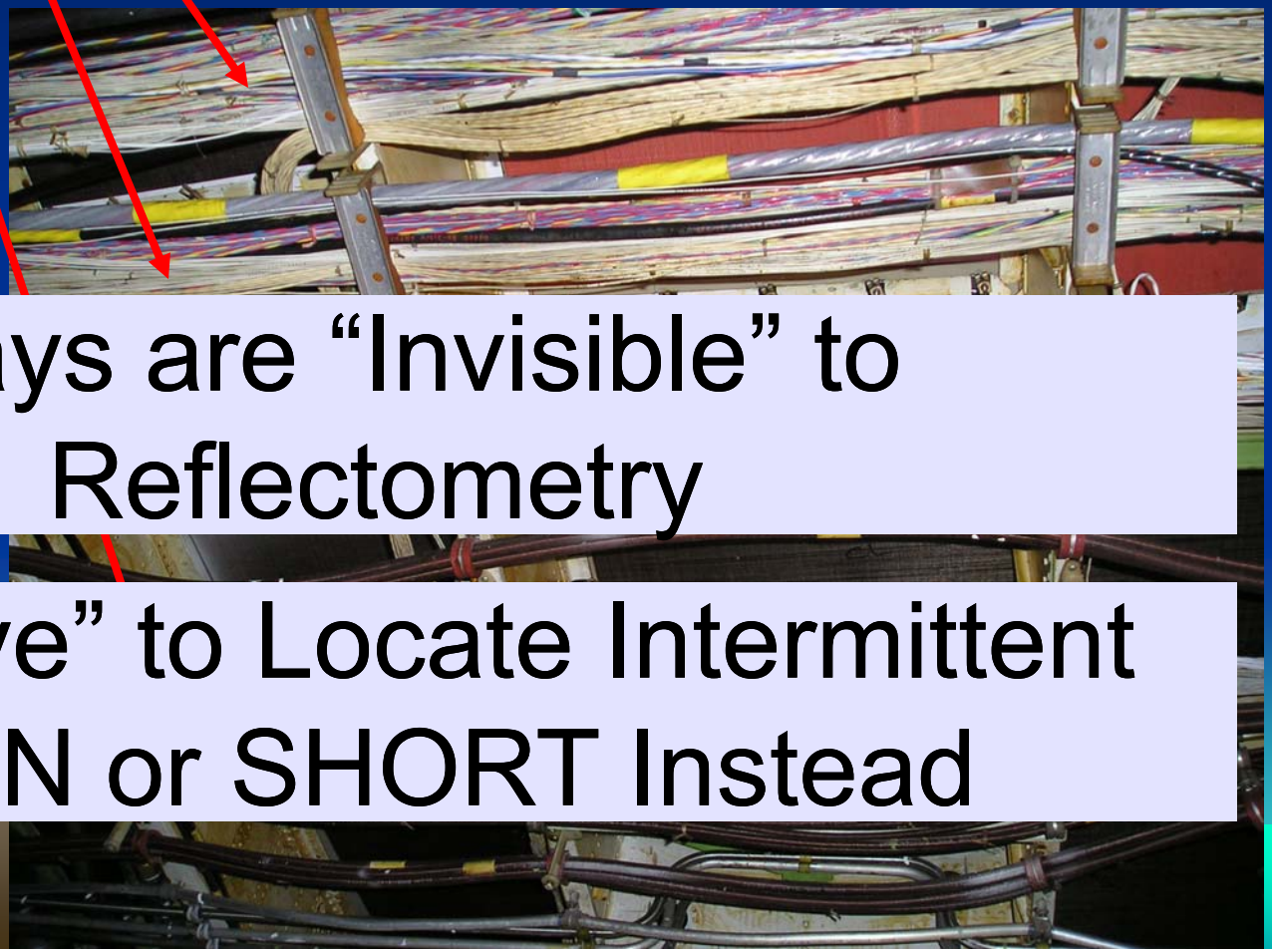


University of Utah

Fray impedances and reflection coefficients

	Scenario	Characteristic Impedance (Ω)	Reflection Coefficient
1	Short Circuit		-100 %
2	Open Circuit		100 %
3	No changes	77.57	0
4	Water Drop	73.81	-2.4 %
5	Cut .15 mm off top	77.59	0.014%
6	Cut .45 mm off top	77.64	0.044%
7	Cut .76 mm off top	78.01	0.28%
8	Cut .15 mm off side	77.57	0.0021%
9	Cut .45 mm off side	77.58	0.0056%
10	Cut .76 mm off side	77.60	0.017%

Fray Impedance is Similar to Normal Impedance Variation on UnControlled Impedance Wire

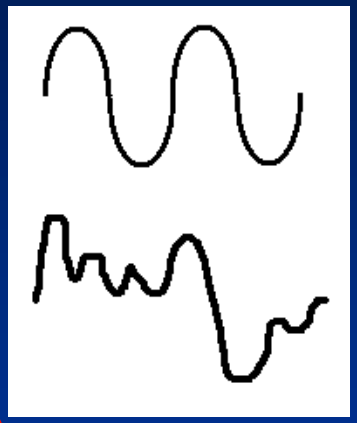


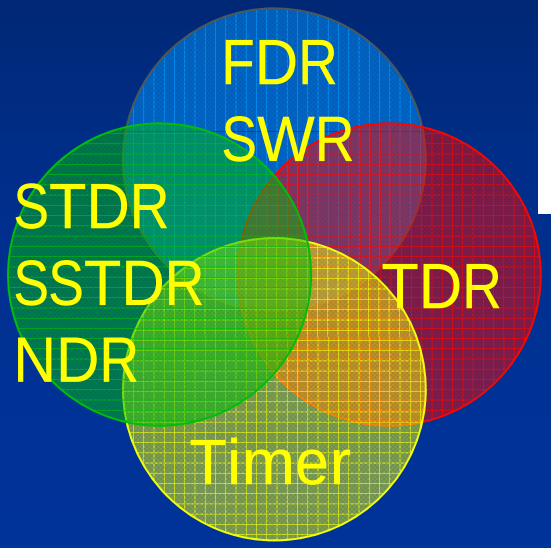
Frays are “Invisible” to Reflectometry

Run “Live” to Locate Intermittent OPEN or SHORT Instead

Reflectometry-Based Fault Location Methods

Analog



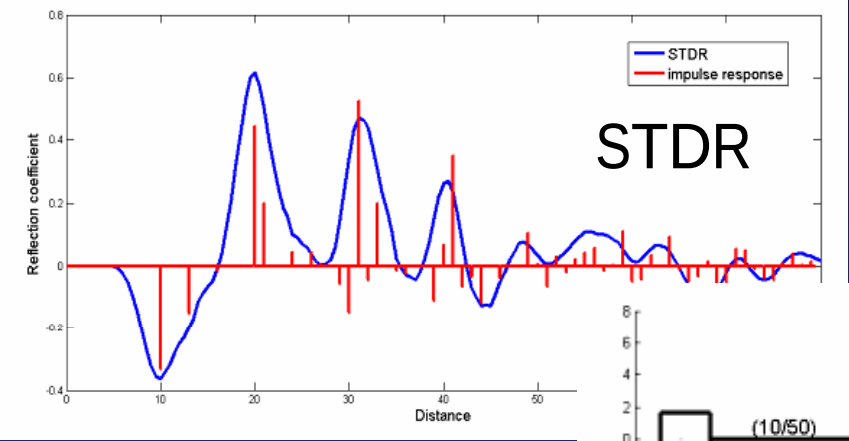


Digital

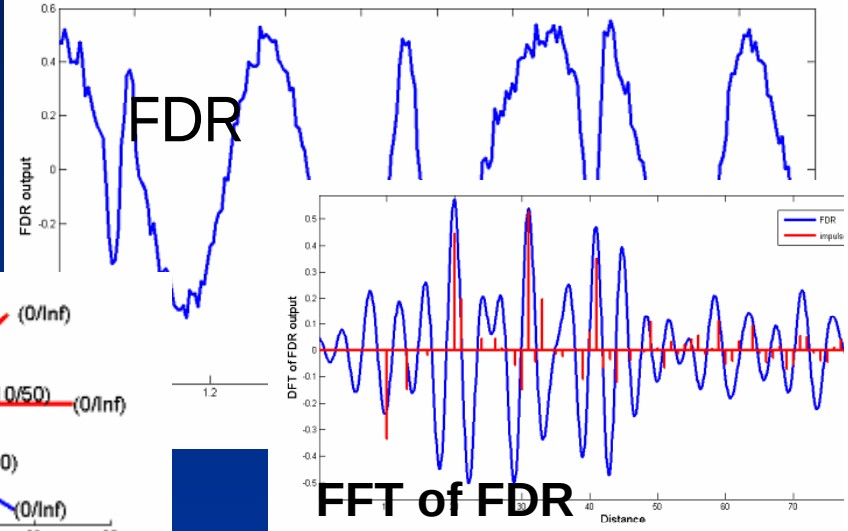
Time Domain

Capacitance / Inductance

Reflectometry-Based Fault Location Methods

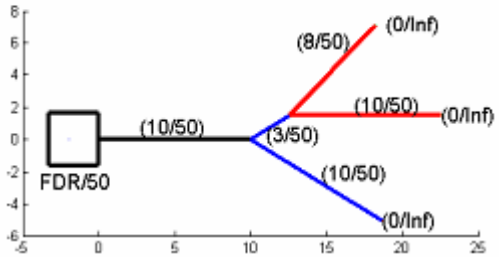


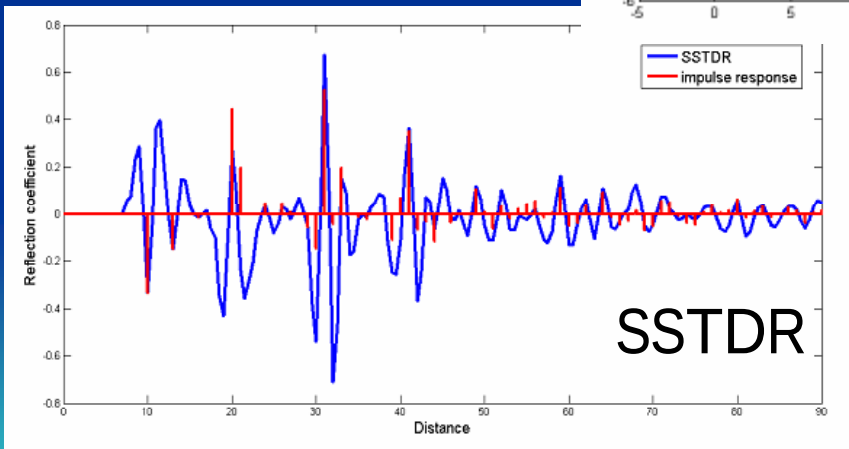
STDR



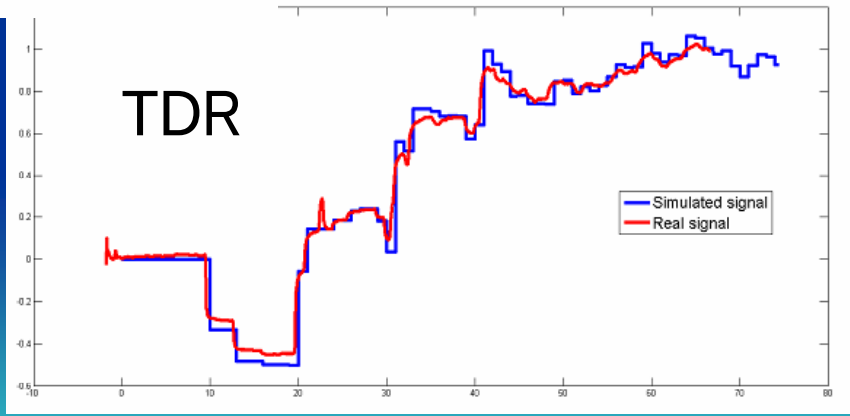
FDR

FFT of FDR



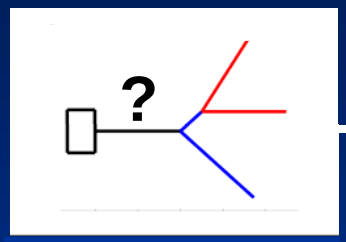


SSTDR



TDR

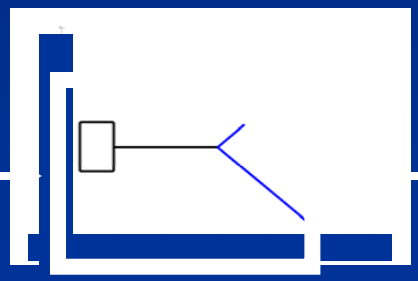
Location of Faults on Branched Network



Actual network

Reflectometer
TDR,S/SSTDR
MSR,etc

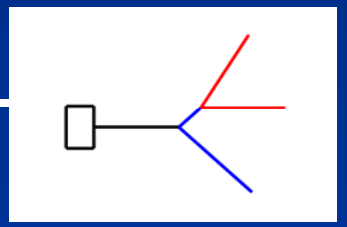
Impulse detection



Intermediate network

Simulation Algorithm

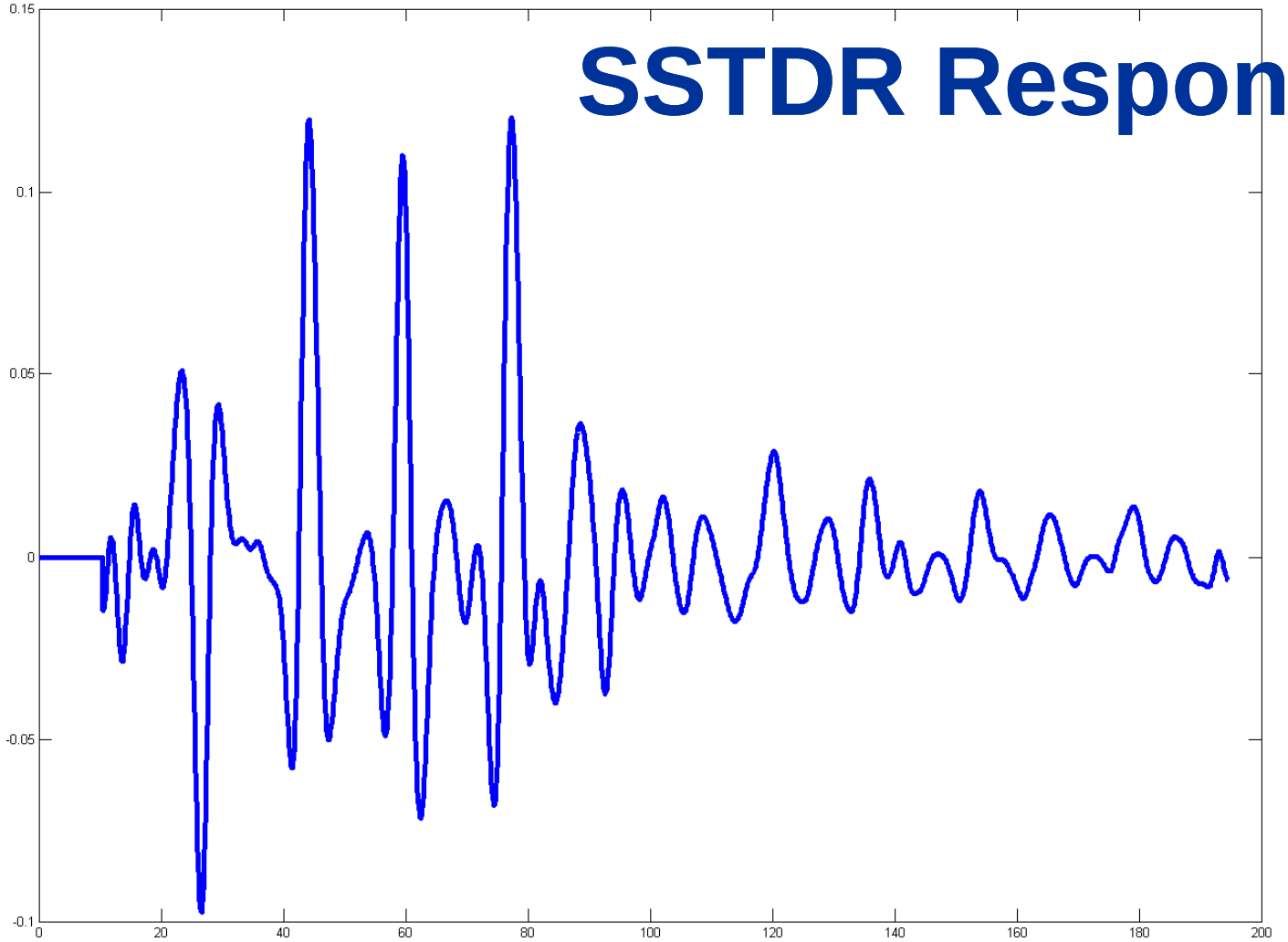
Mapping Algorithm



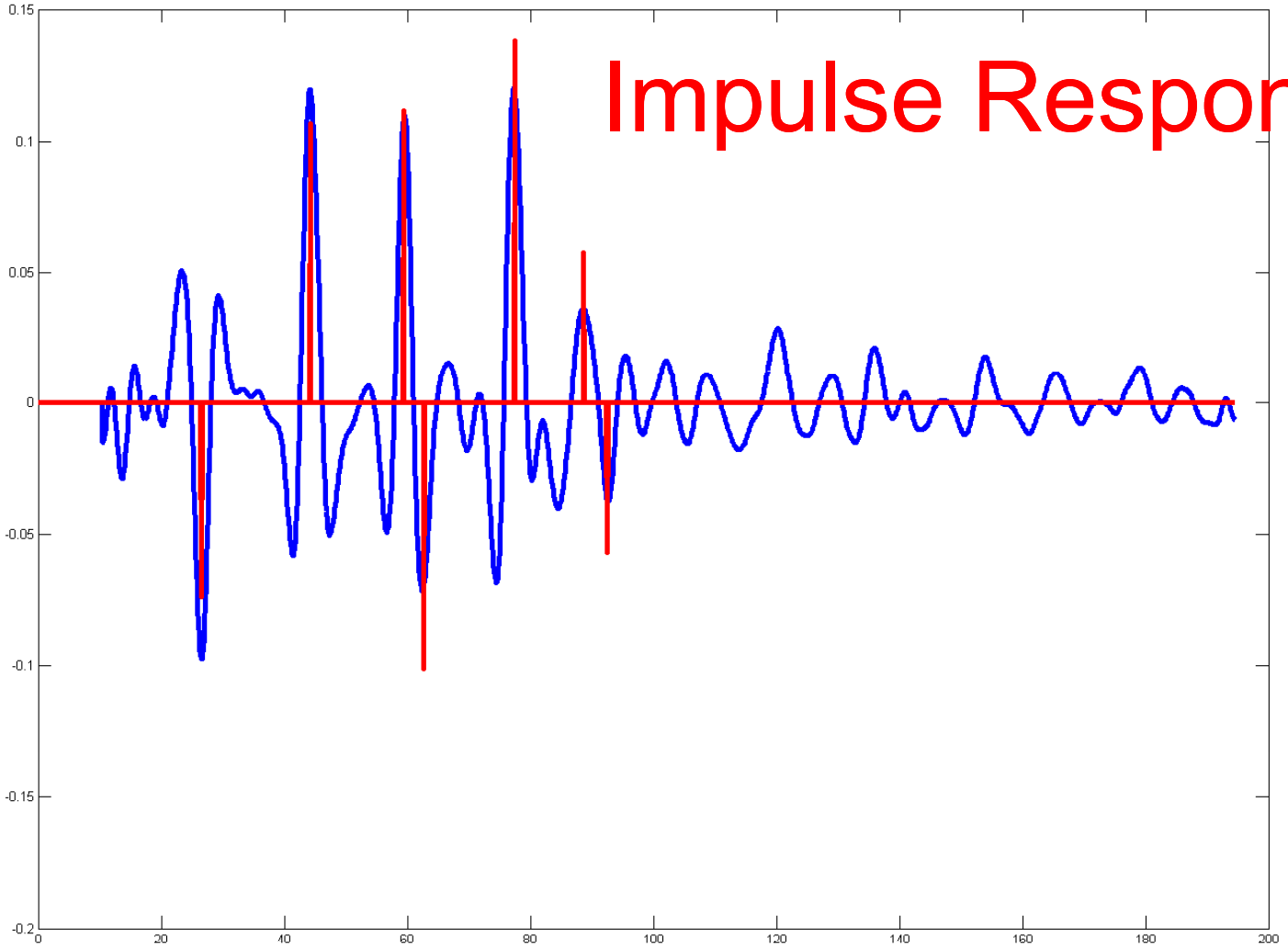
Detected network

Location of Faults on Branched Network

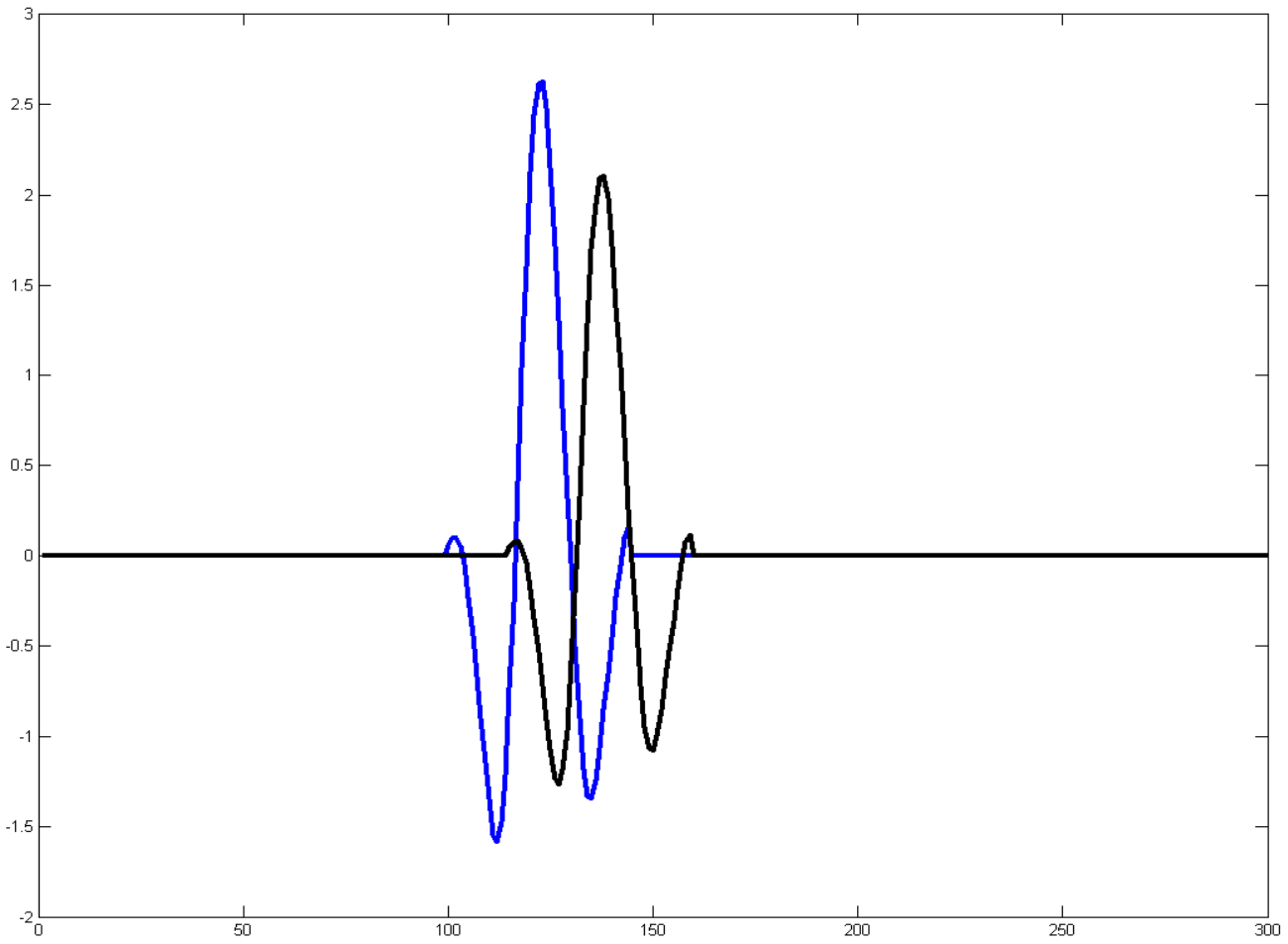
SSTDR Response



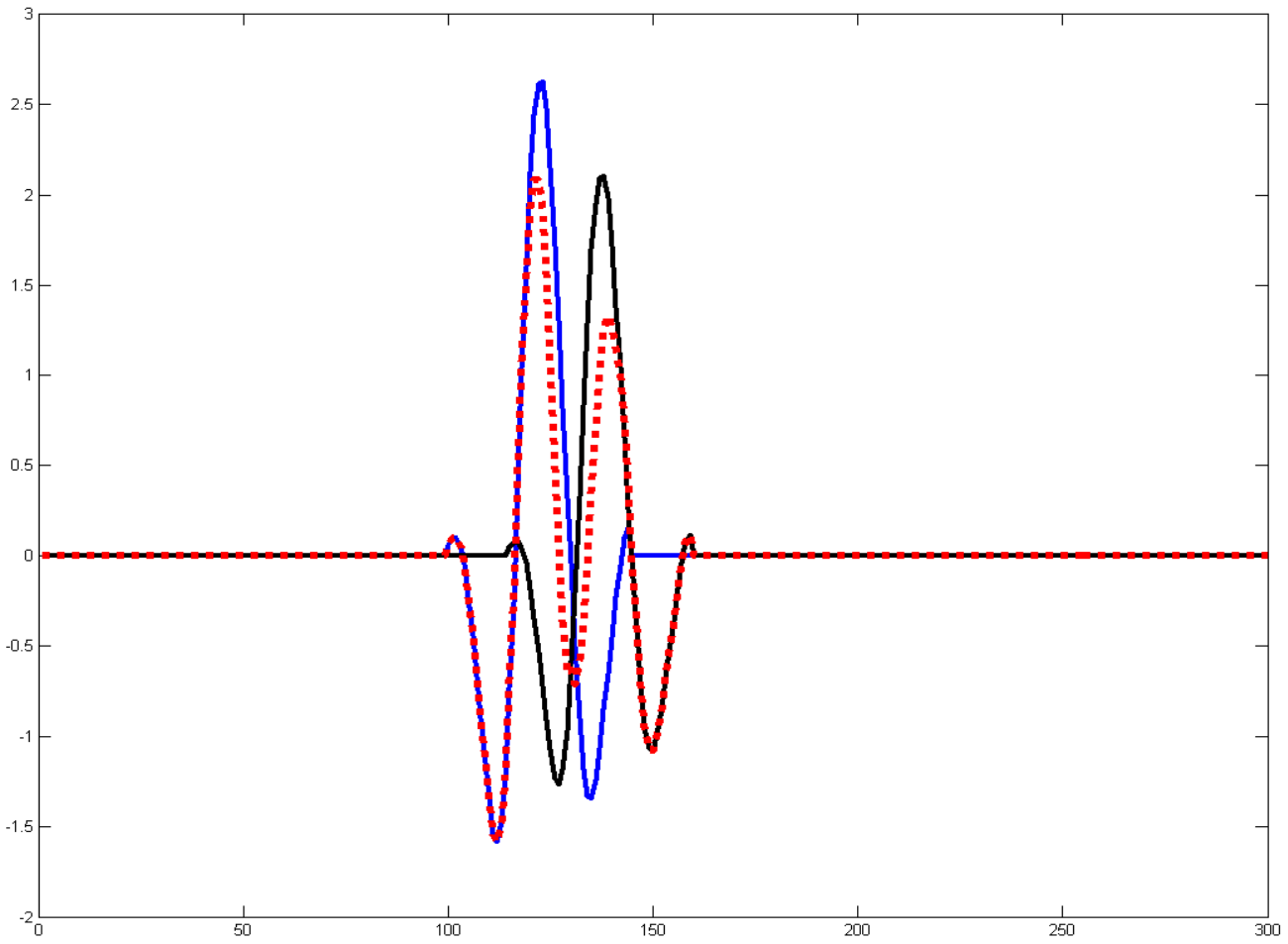
Impulse Response



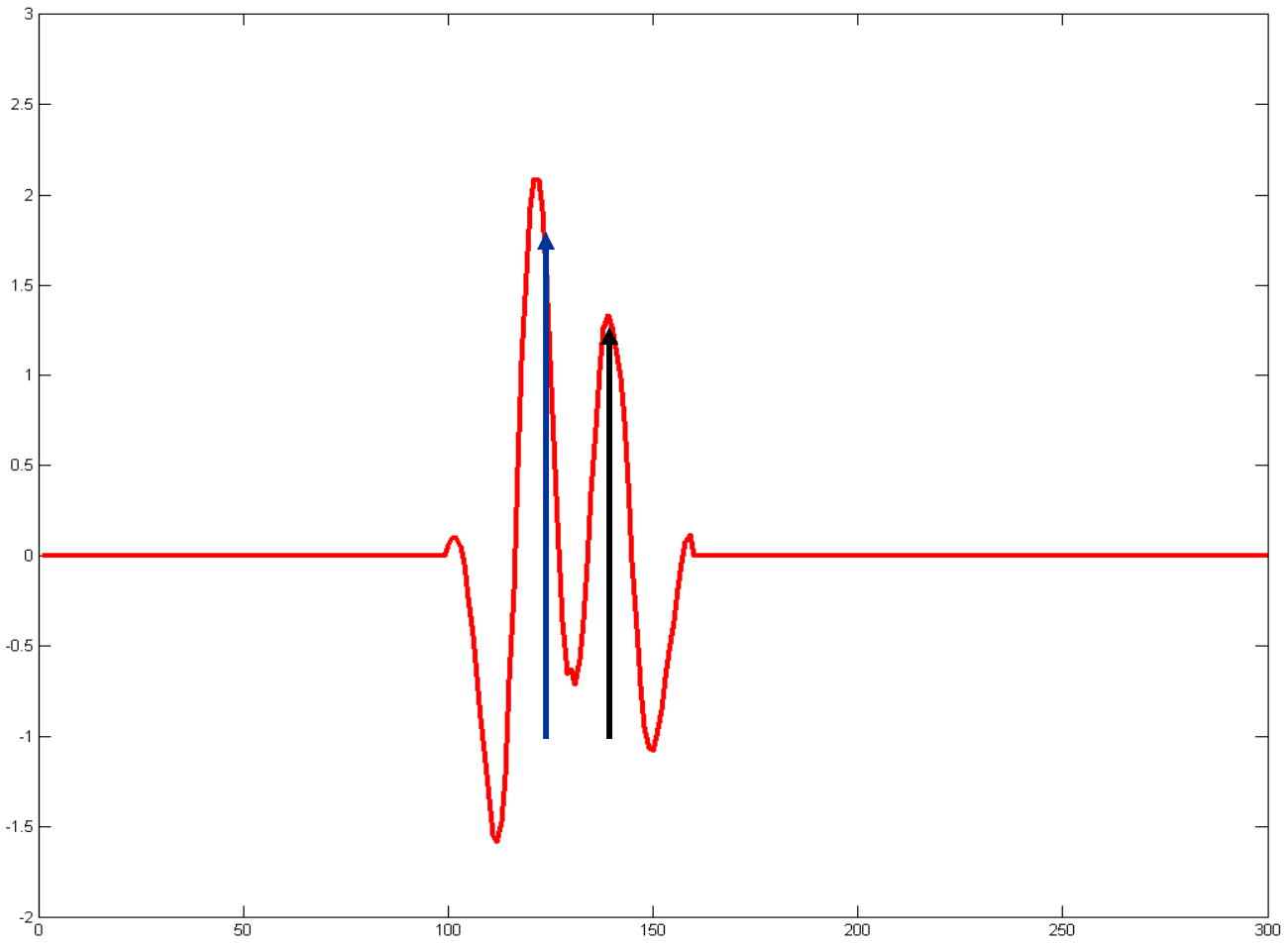
Overlapping Peaks Occur when Reflections are Close Together



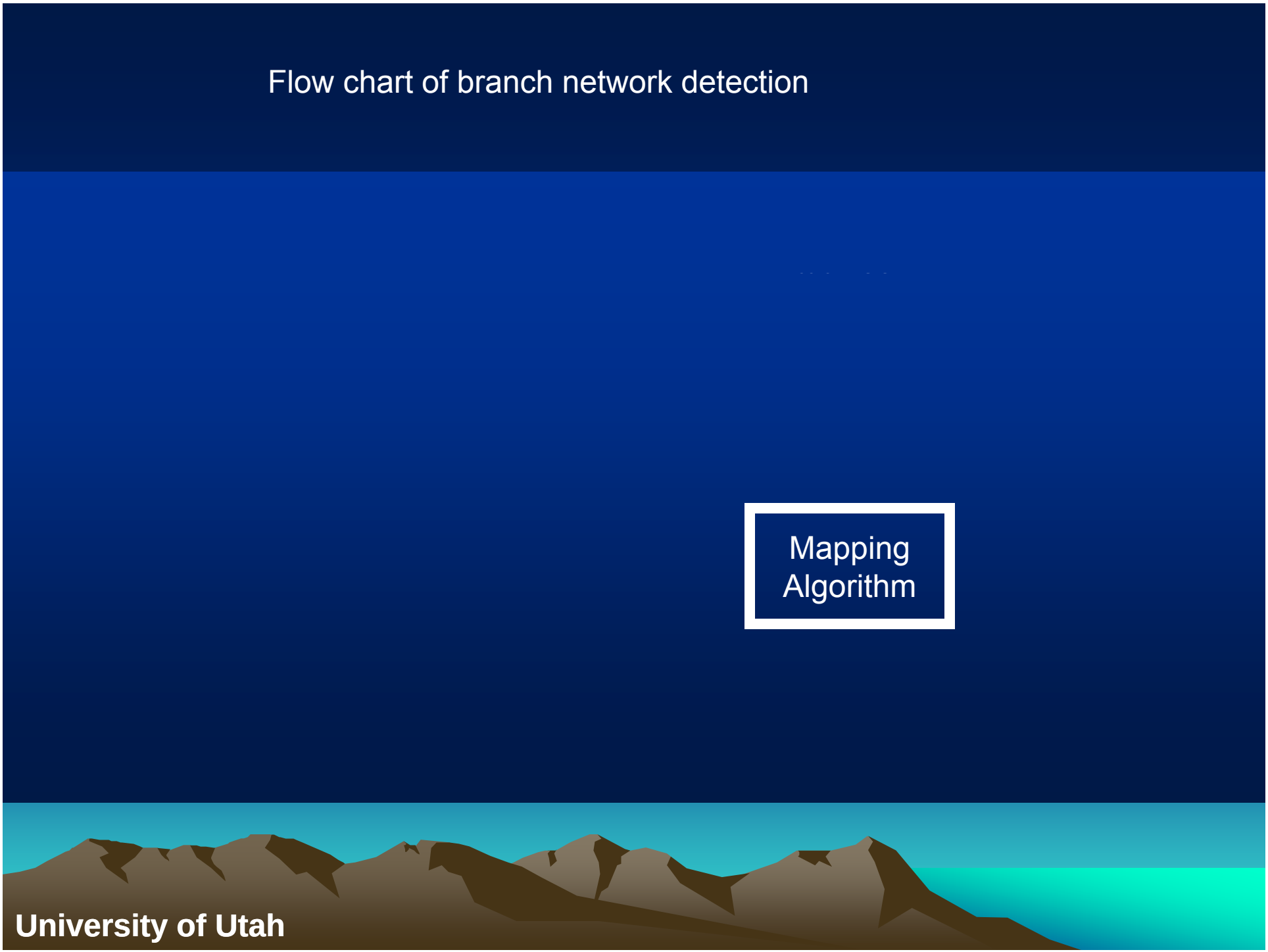
Reflections Add Up

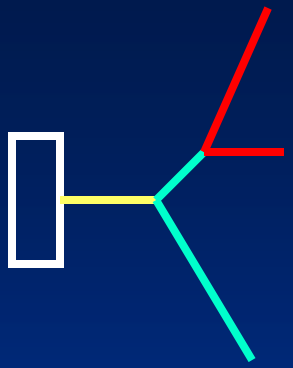


Overlapping Peaks Must be Filtered to Find Impulse Response

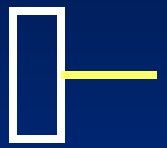


Flow chart of branch network detection

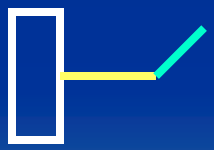




Actual network



1



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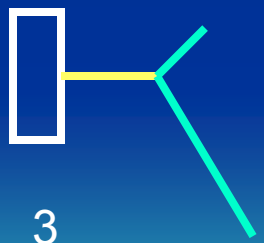

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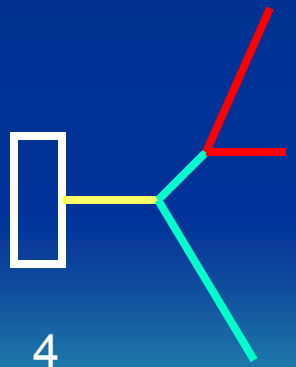
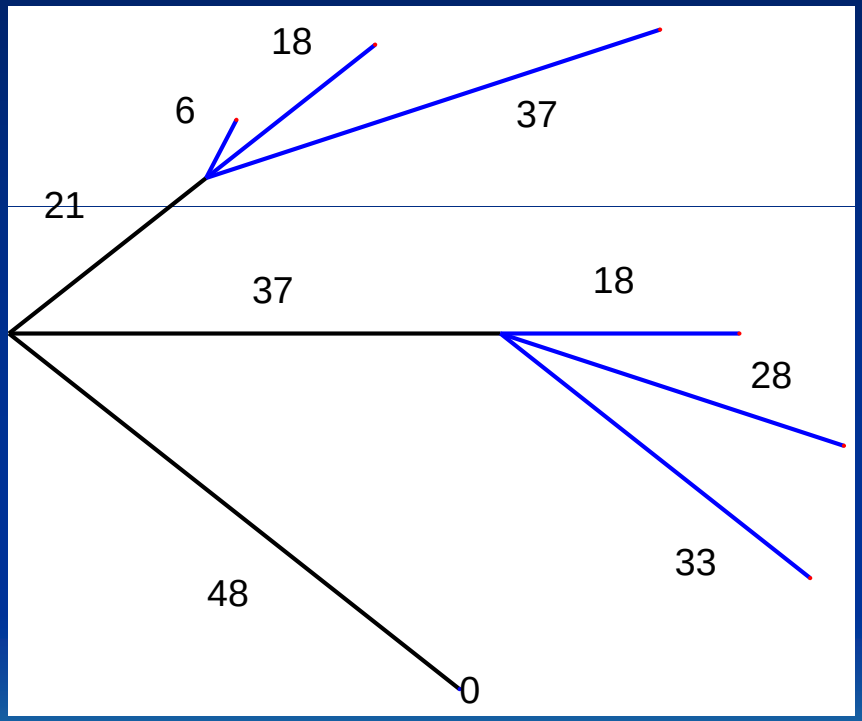
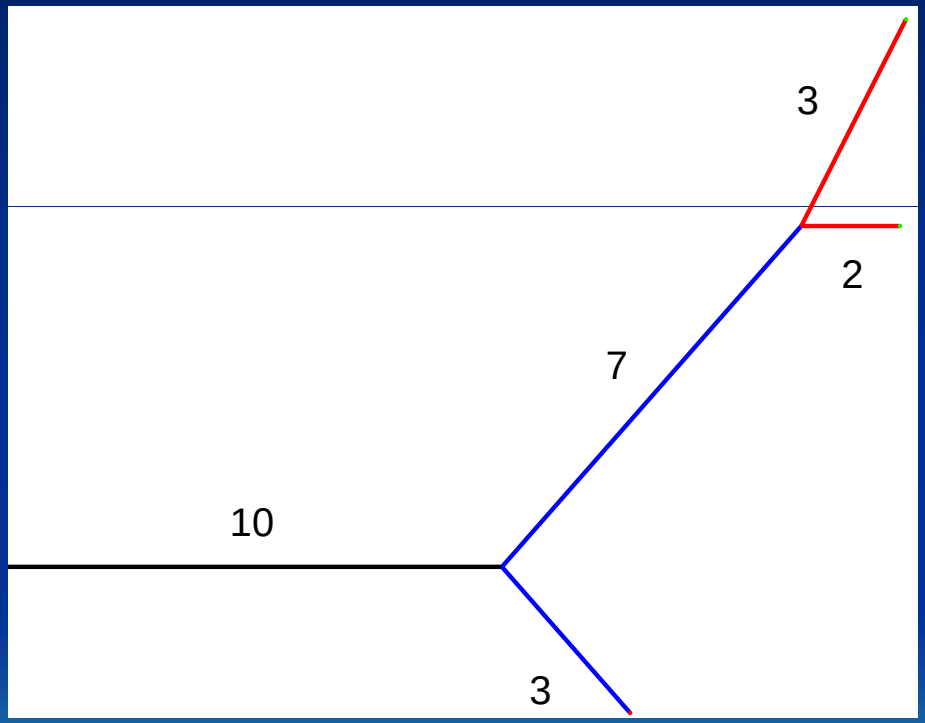


4

Successful Detection

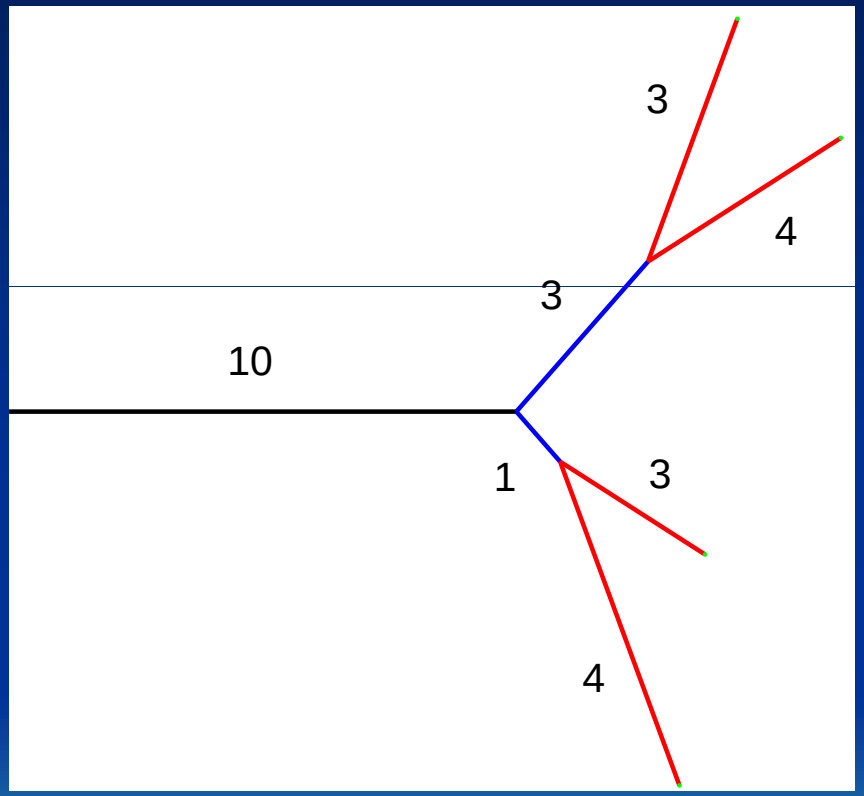
(simulated Network)

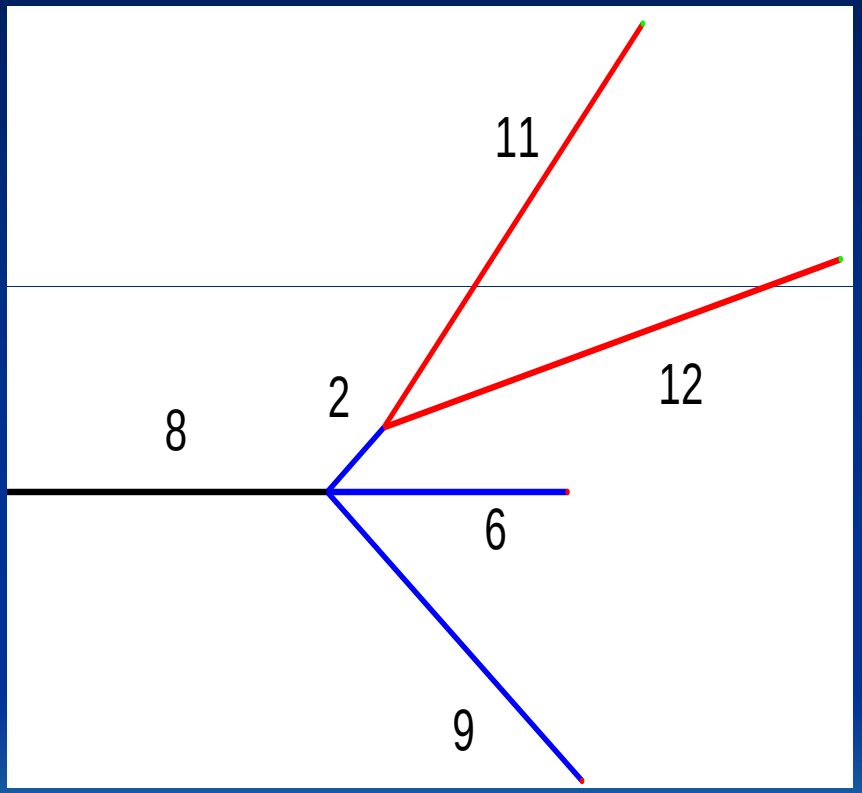




Successful Detection

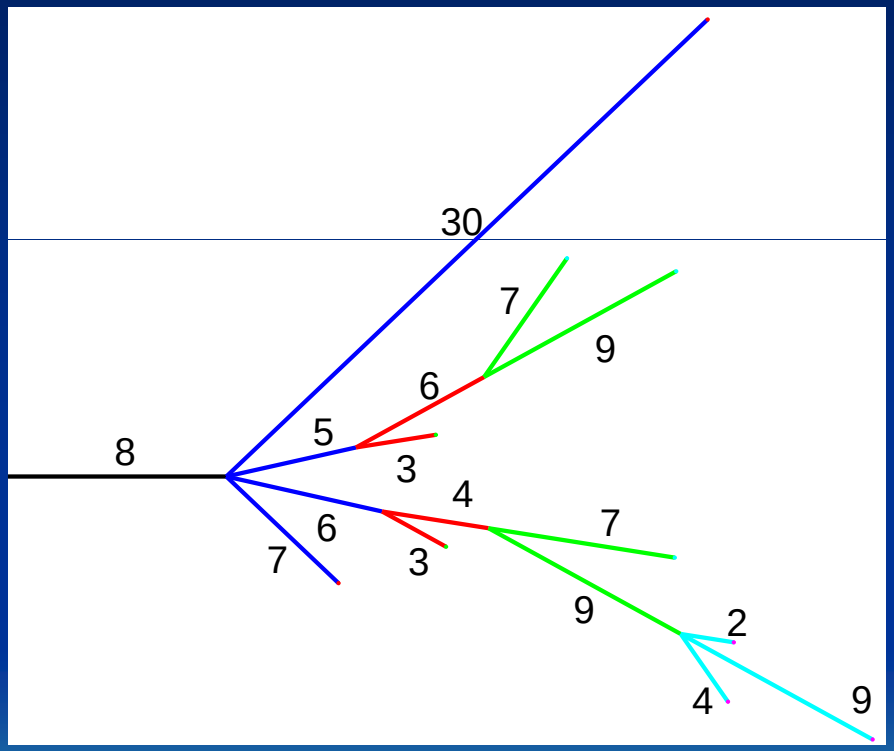
(simulated Network)

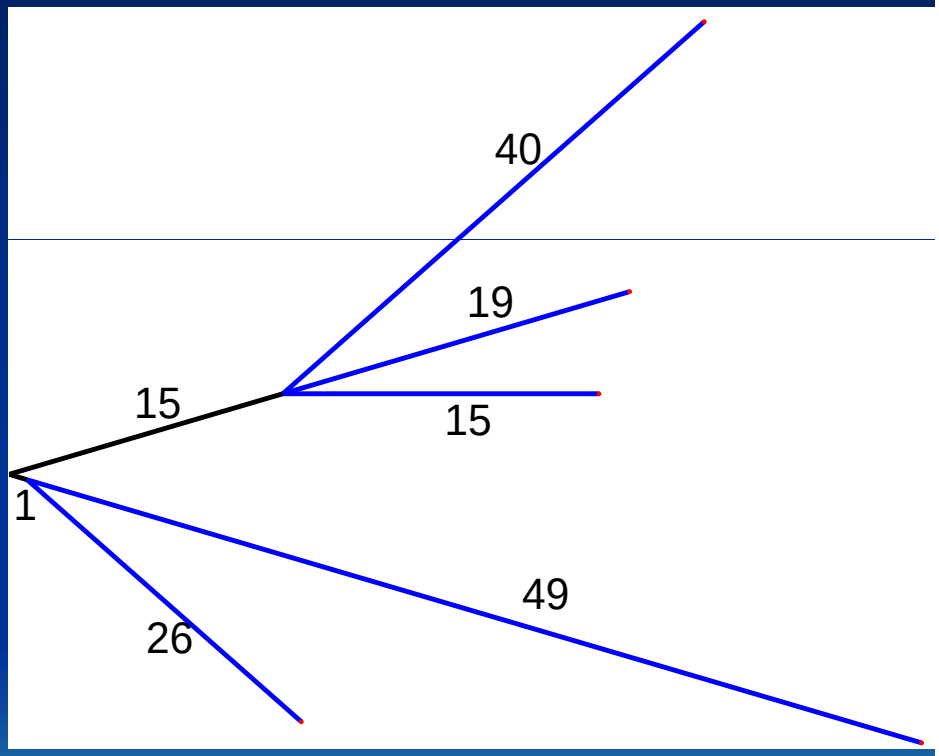




Successful Detection

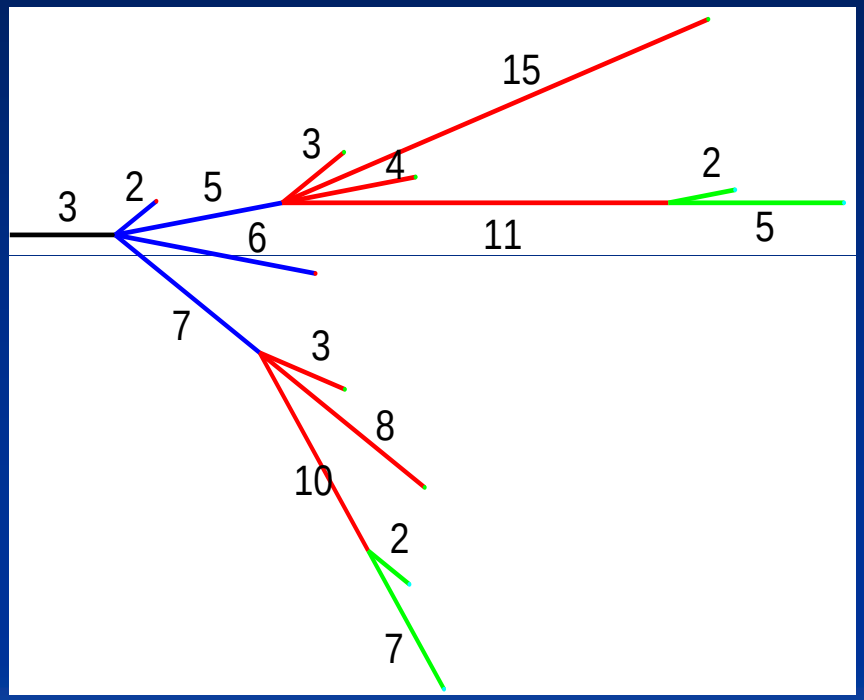
(simulated Network)

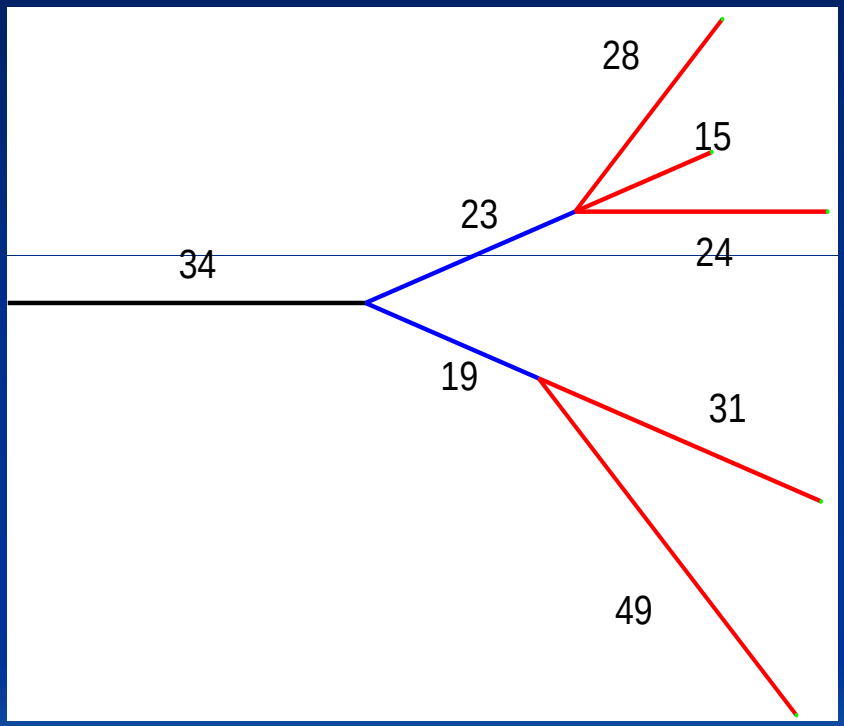




Successful Detection

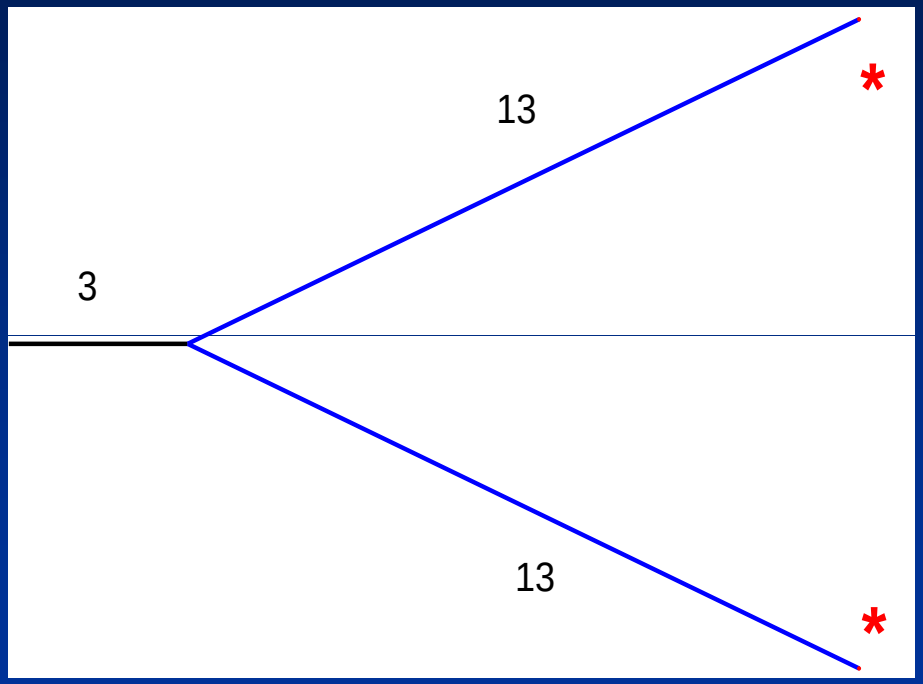
(simulated Network)

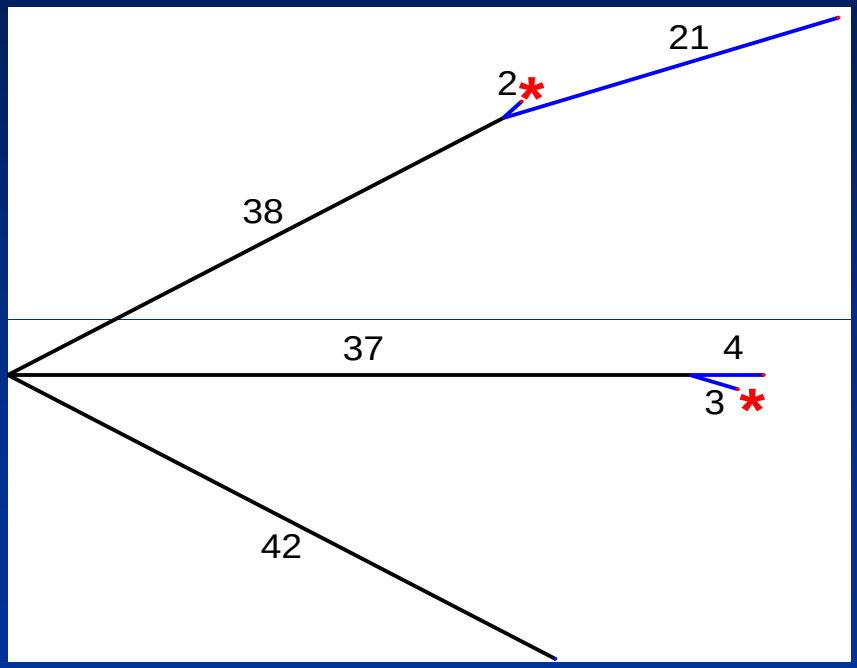




Unsuccessful Detection

(simulated network)

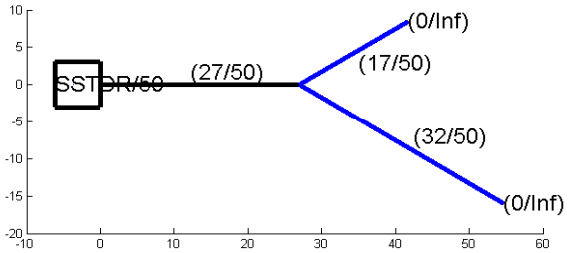




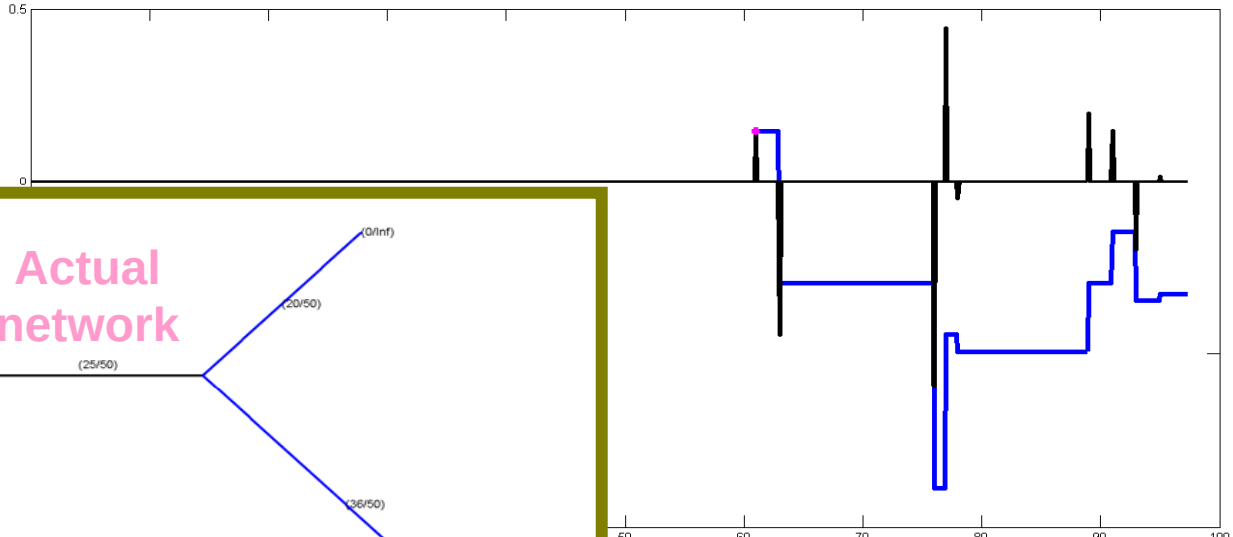
Reason:
Ambiguity at 16’

Reason:
Ambiguity at 40’

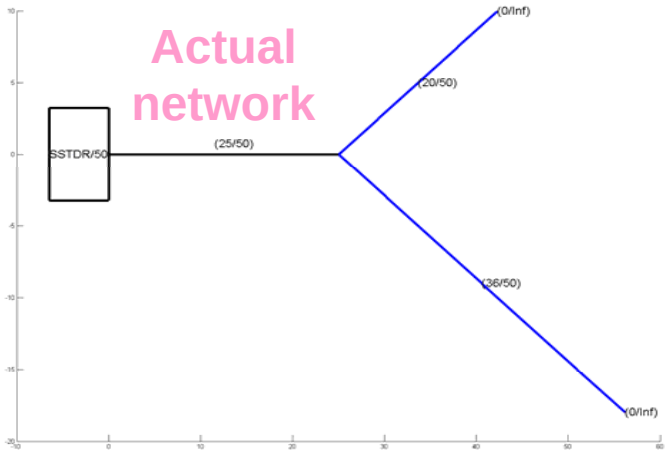
Detection with measured data



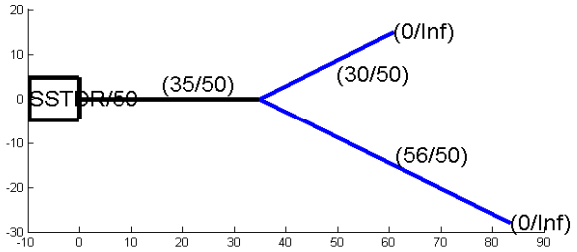
Detected network



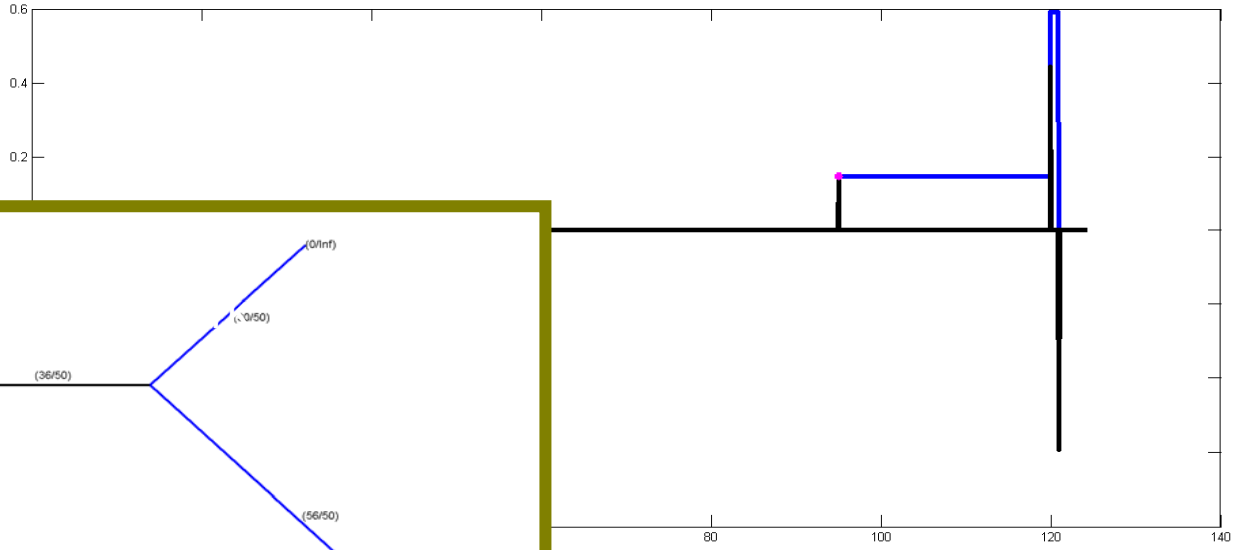
Actual network

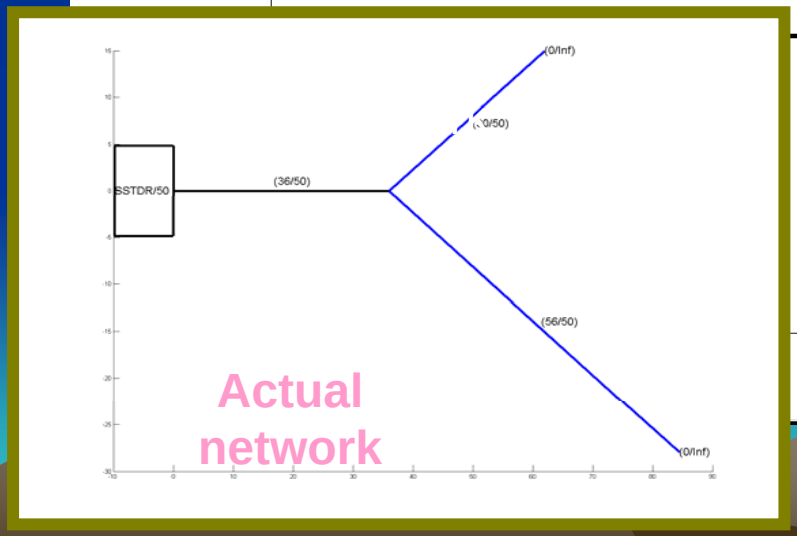


Detection with measured data

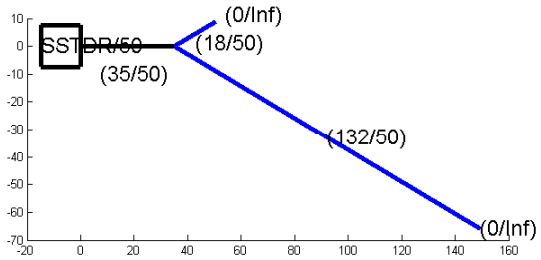


Detected network

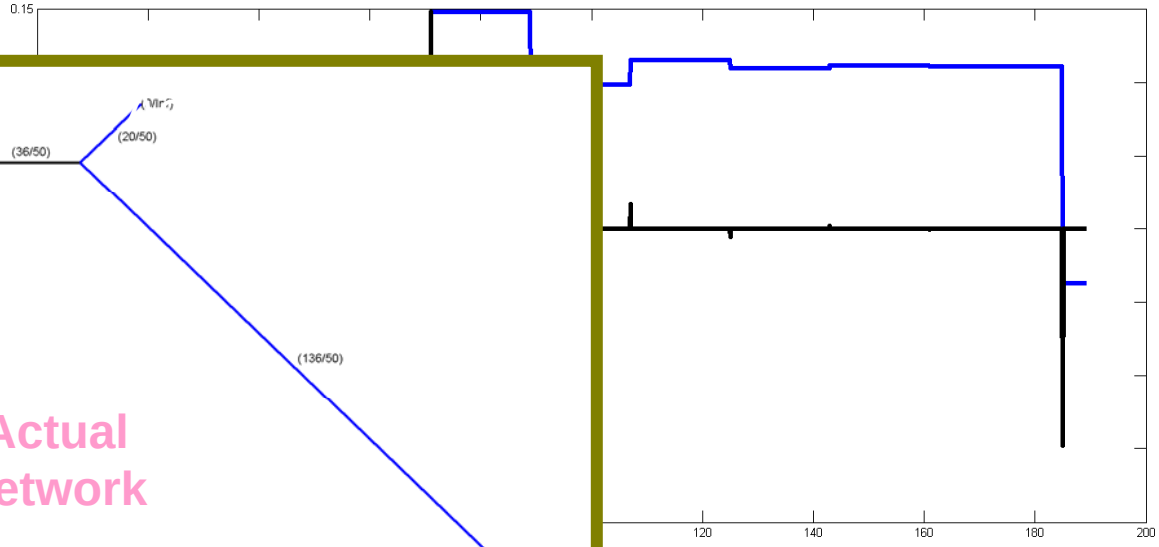


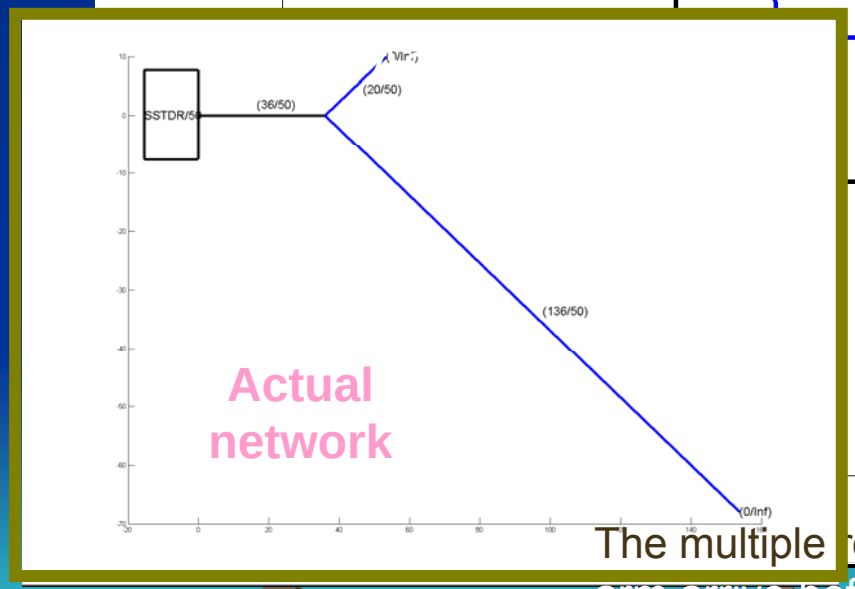


Detection with measured data



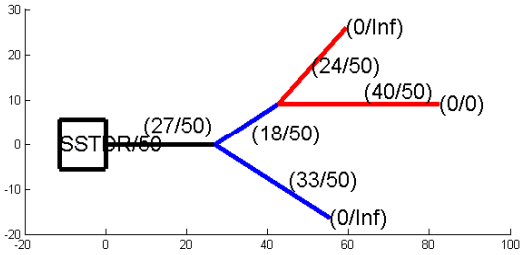
Detected network



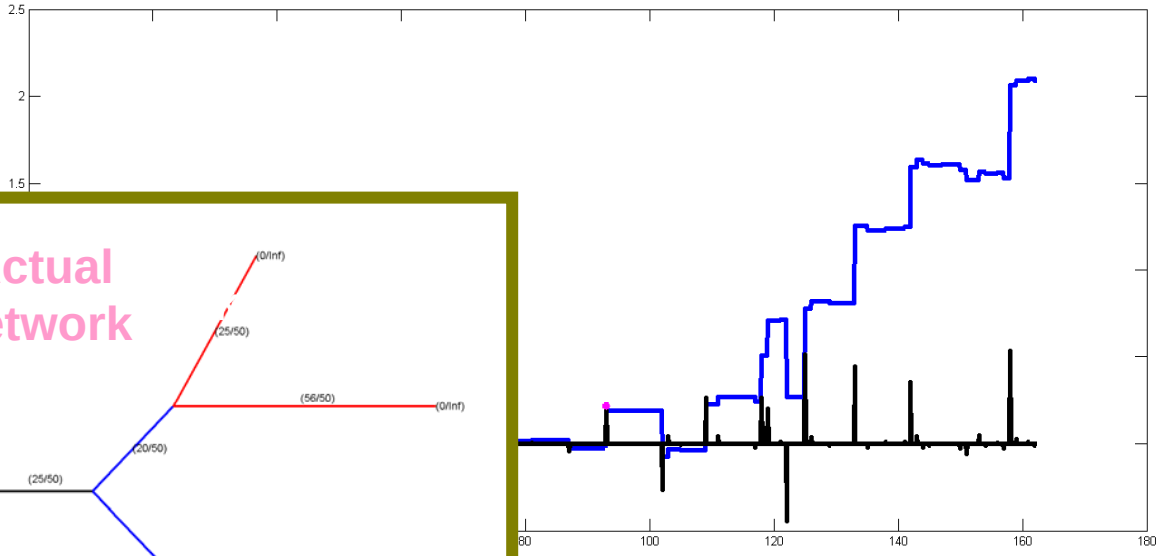


The multiple reflections from the shorter arm arrive before the primary reflection of the longer arm.

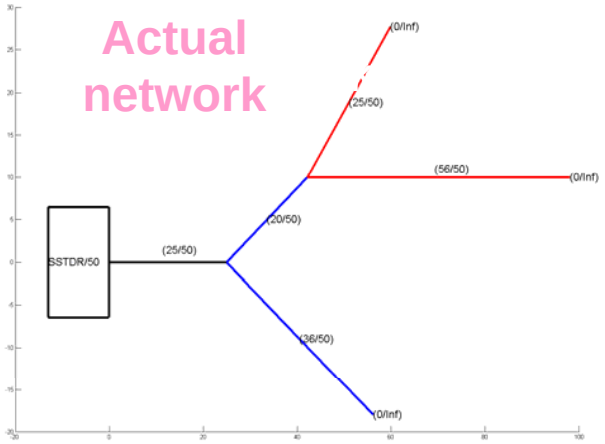
Detection with measured data



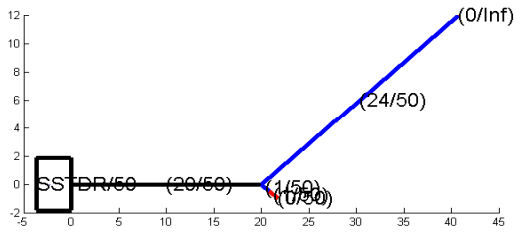
Detected network



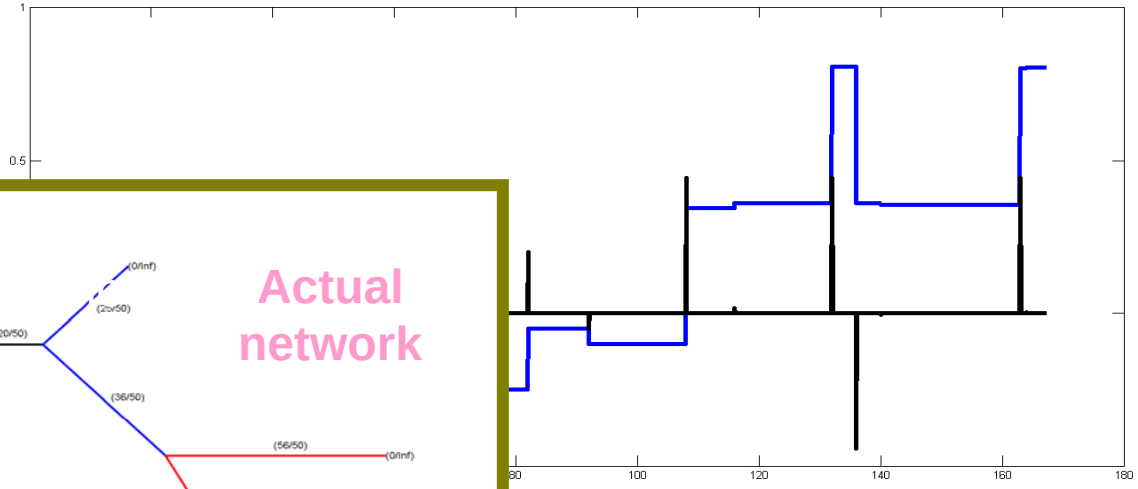
Actual network



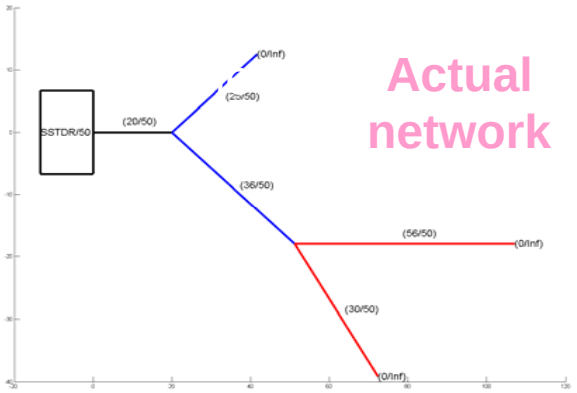
Detection with measured data



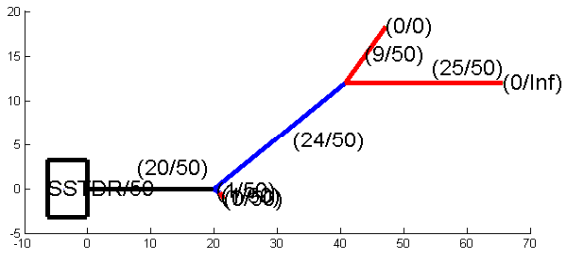
Detected network



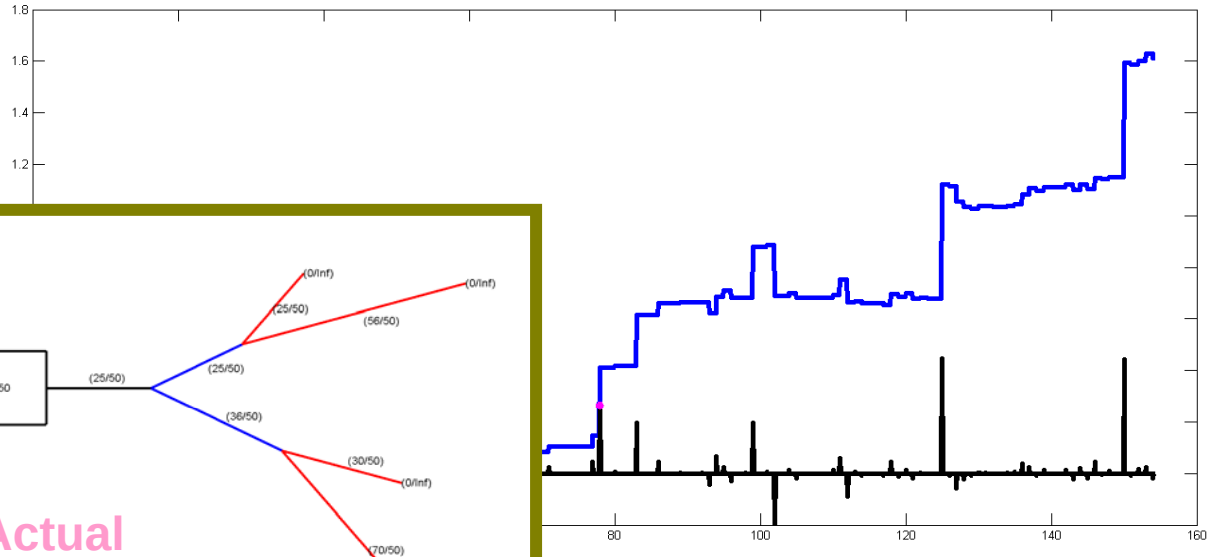
Actual network

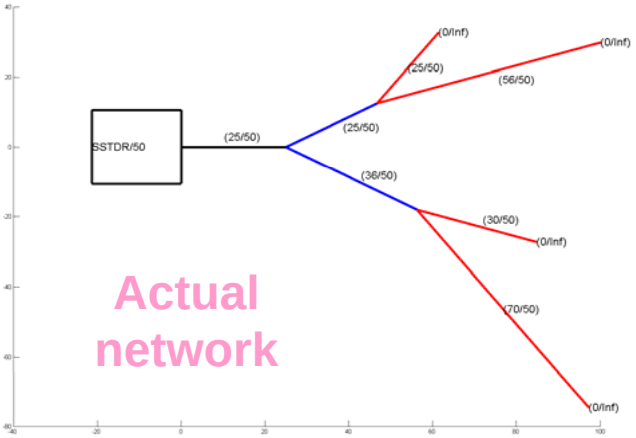


Detection with measured data



Detected network





Actual network

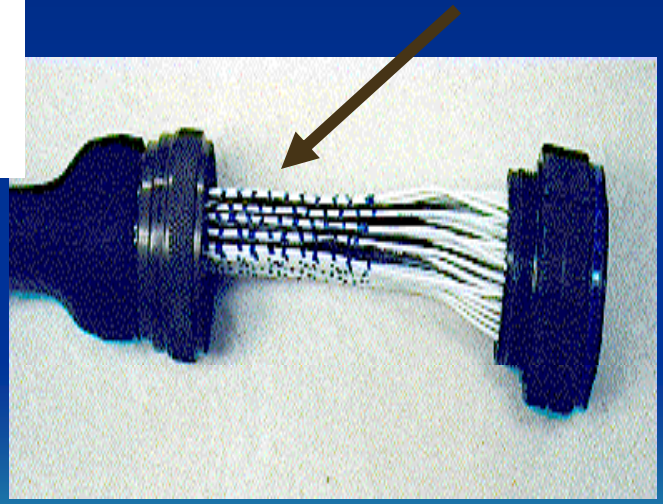
Potential Sensor Locations

Handheld

Connector Saver

CircuitBreaker

Wire



Connector

Dr. Cynthia Furse
Associate Professor and Director, Center of Excellence for Smart Sensors
Dept. Electrical and Computer Engineering
University of Utah
www.ece.utah.edu/~cfurse cfurse@ece.utah.edu
Phone: (801) 585-7234

Questions ?

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  Dr. Cynthia Furse

www.ece.utah.edu/~cfurse

cfurse@ece.utah.edu