

A Method to Measure the 1090 MHz Interference Environment

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Many Uses of 1090 MHz

- Secondary Surveillance Radar (SSR) – ATCRBS, Mode S
- Traffic Collision Avoidance System (TCAS)
- Automatic Dependent Surveillance – Broadcast (ADS-B) – including TIS-B and ADS-R
- Military Modes

- All Applications are Tolerant of Missed and Garbled Messages – ***To A Point***

The Problem

- Congestion at 1090 MHz May Already be Compromising Some Applications (SSR, TCAS)
- Trend Will Continue
 - Transponders Left On for Surface Multilateration
 - 1090 ADS-B Worldwide
 - Growing Traffic Density

Need to Quantify the Problem in Order to Engineer a Solution

The Modeling Challenge

- What is the 1090 MHz Message Density at a Point?
- Model Parameters
 - Number of Aircraft
 - Location of Aircraft
- Assumptions to be Made – *Often Unknown*
 - Aircraft Equipage (ATCRBS, Mode S, TCAS)
 - Make and Model of Equipage – Different Behavior
 - Antenna Configuration
 - SSRs in Area, and Operating Mode
- Accuracy of Model Results is Dependent on Accuracy of Assumptions

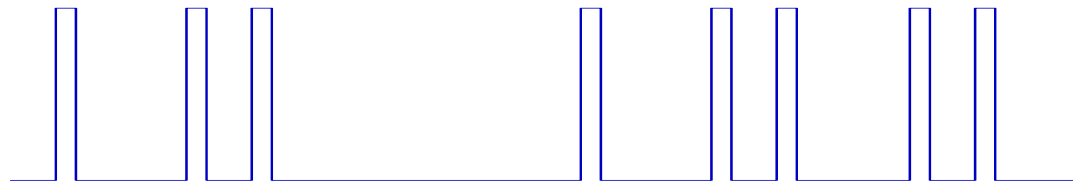
The Measurement Challenge

- **Make Field Measurements to Validate Models**
 - How??
- **Place Antenna/Receiver/Decoder at the Point**
 - Can't Count the "Missed" Messages
- **How to Make a Modified Measurement to Accurately Measure the Interference Environment**

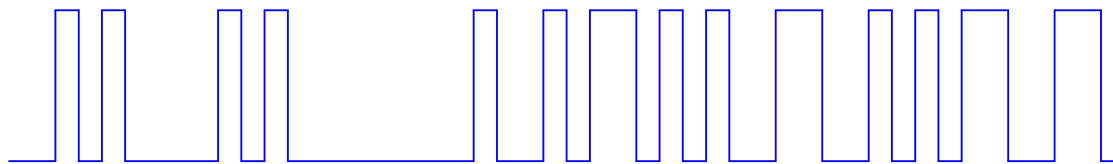
Message Types

■ Message Type Details

Message Type	Modulation	Duration	Other Characteristics
ATCRBS	Pulse Modulation (on/off)	20.3 μ sec	Starts and ends with framing pulses, others are sparse
Mode S Short	Pulse Position Modulation	64 μ sec	50% average duty cycle
Mode S Long	Pulse Position Modulation	120 μ sec	50% average duty cycle



Typical ATCRBS

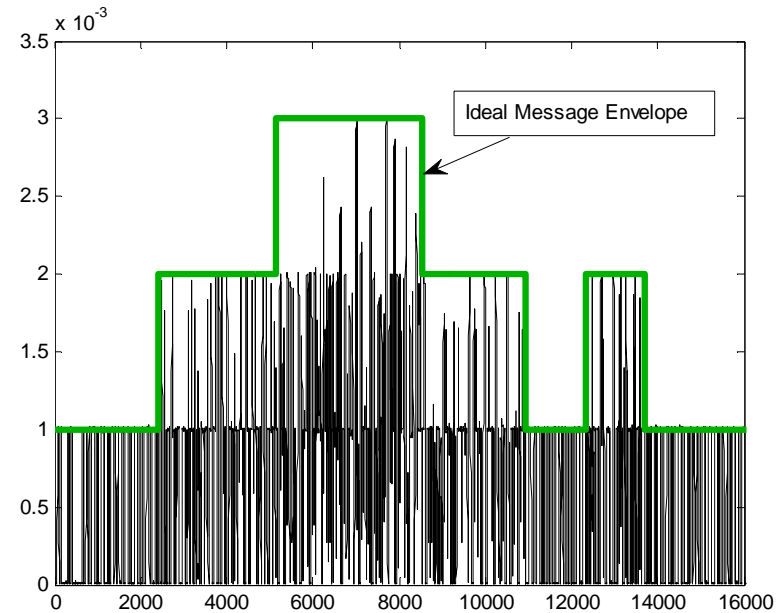
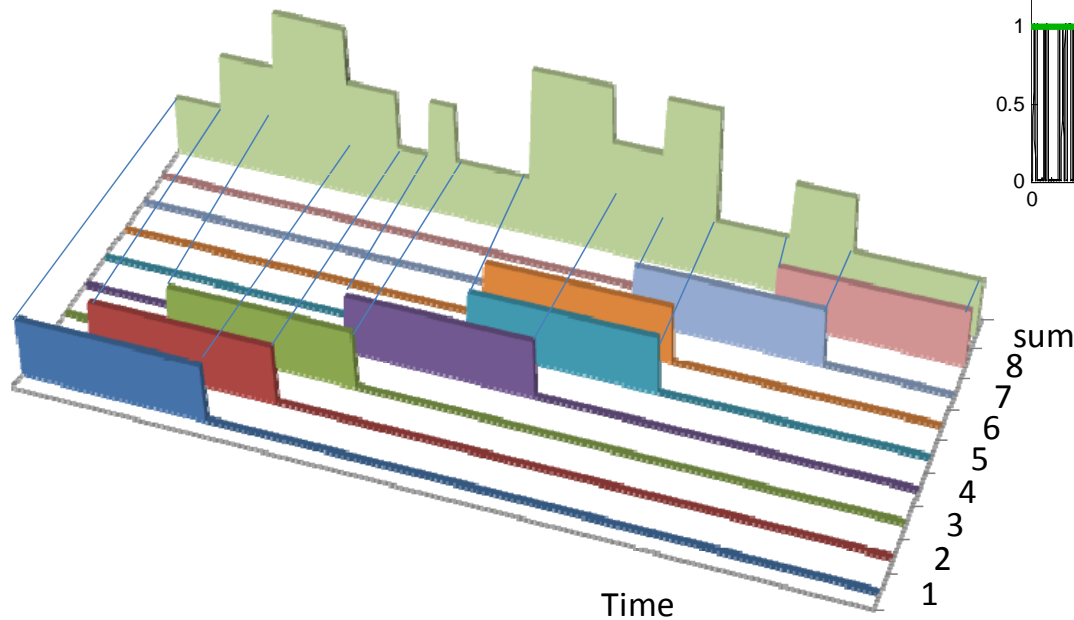


... Mode S Short ~3x
Mode S Long ~6x

- Message Pulses Overlap Only Occasionally
- ATCRBS Very Sparse – Overlap Even Less

■ Power Envelopes

- Look for Amplitude Changes to Identify Overlaps
- Problems
 - Pulsed Waveforms
 - Destructive Interference

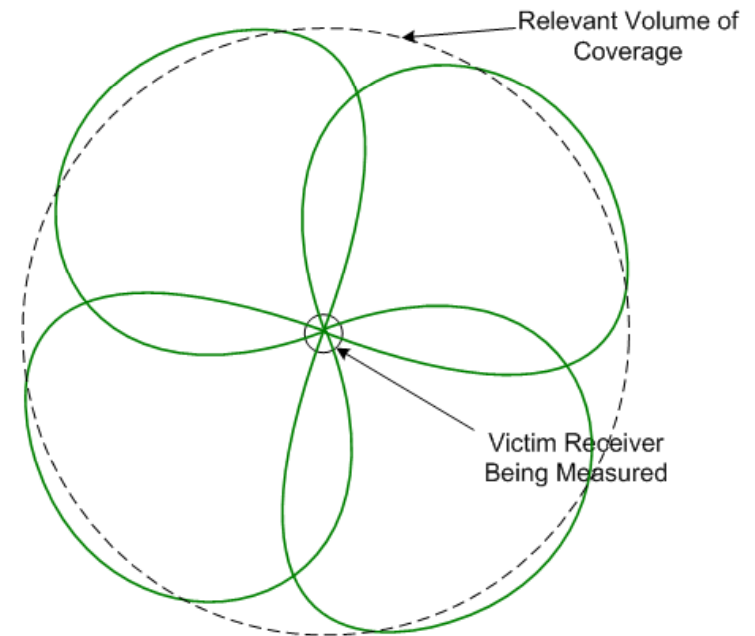


■ Sectorized Antennas

- Lower the Number of Messages in Each Receiver
- Fewer Overlaps – More Accurate Count

■ Problems

- Coverage Areas Overlap
- Different Antenna Gains Over Region – Not Representative of a Single Receiver
- Need a Model to Combine the Sectorized Results



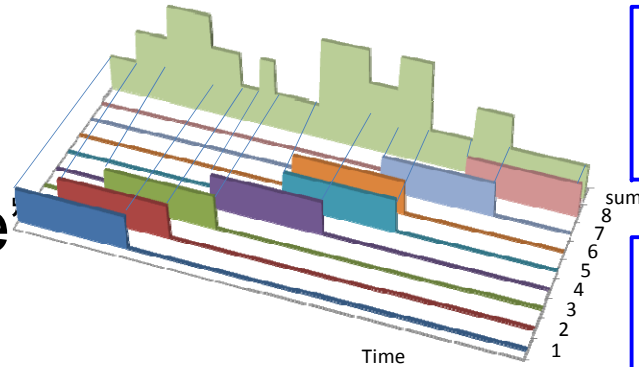
Verifying a Model by Using Another Model

A Multichannel Algorithmic Approach

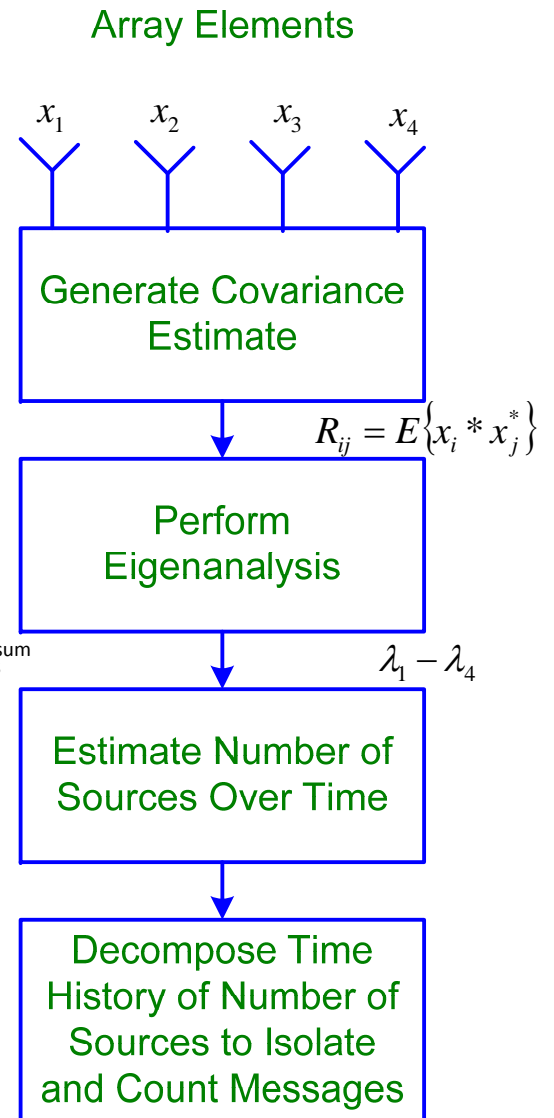
■ Perform MUSIC Analysis on Multiple Channels

- Classically for Frequency or Direction of Arrival
- Here, Use Number of Sources at a Given Time

■ Combine with “Power Envelope Approach Above

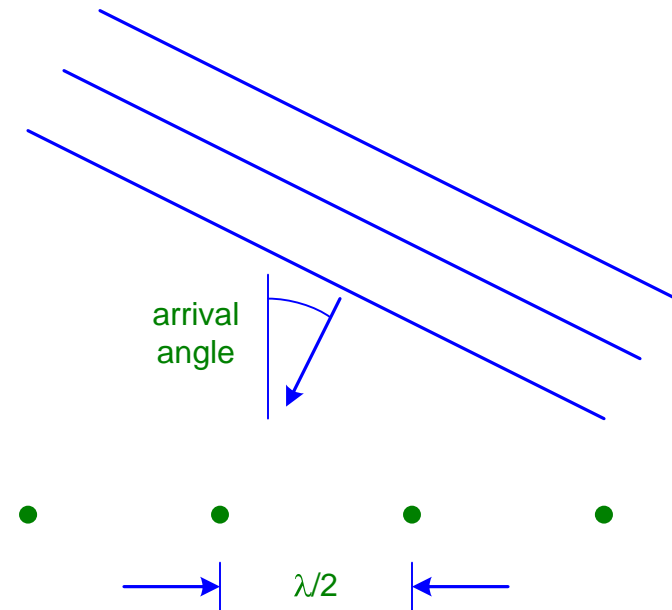


■ Direction of Arrival is Useful “By-Product”



- 4-Element Array, $\lambda/2$ Spacing
- Multiple Signals Arriving at Different Angles

Message Number	Frequency (MHz)	Power (dBm)	Angle (deg)
1	1090.00	-50	0
2	1091.10	-57	-6
3	1092.00	-55	-11
4	1088.30	-45	6
5	1091.02	-48	11
6	1089.70	-57	17
7	1091.00	-52	-17
8	1090.00	-49	23

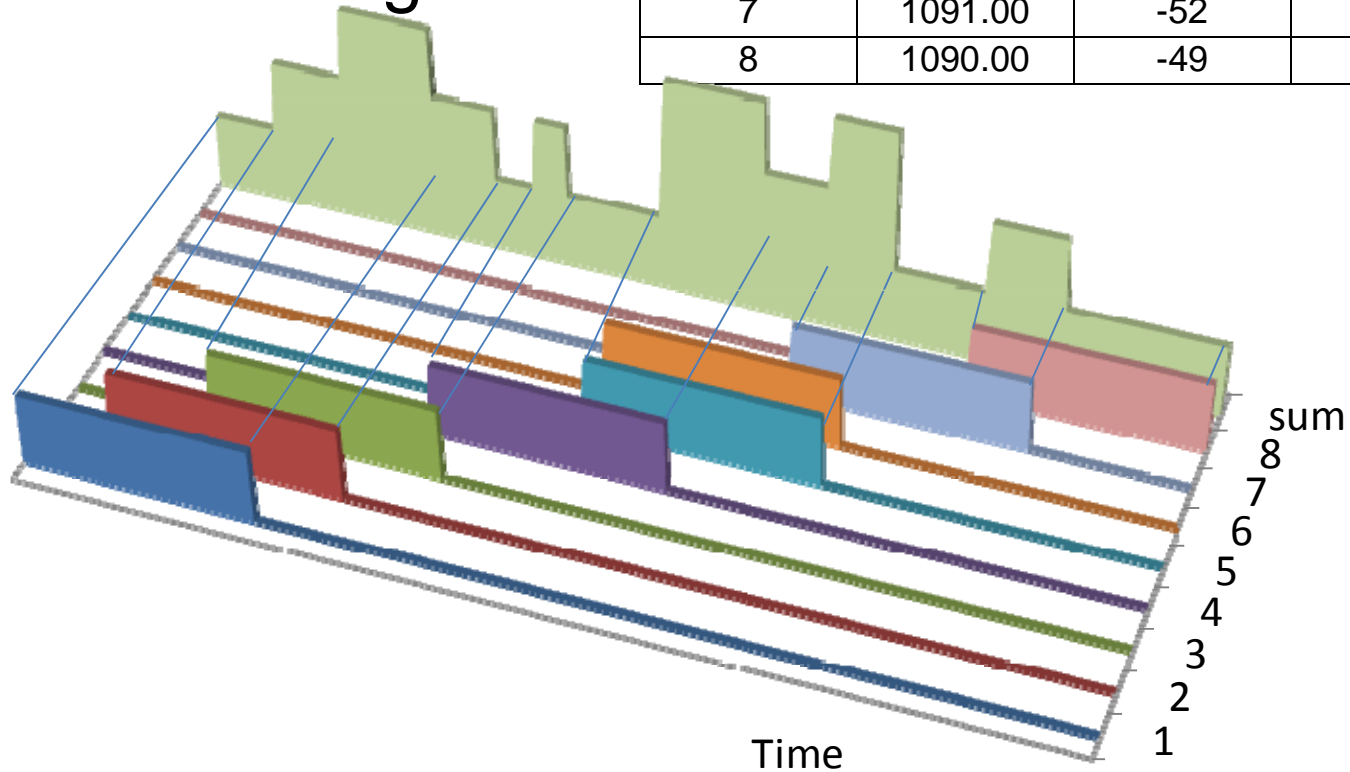


Sample Messages

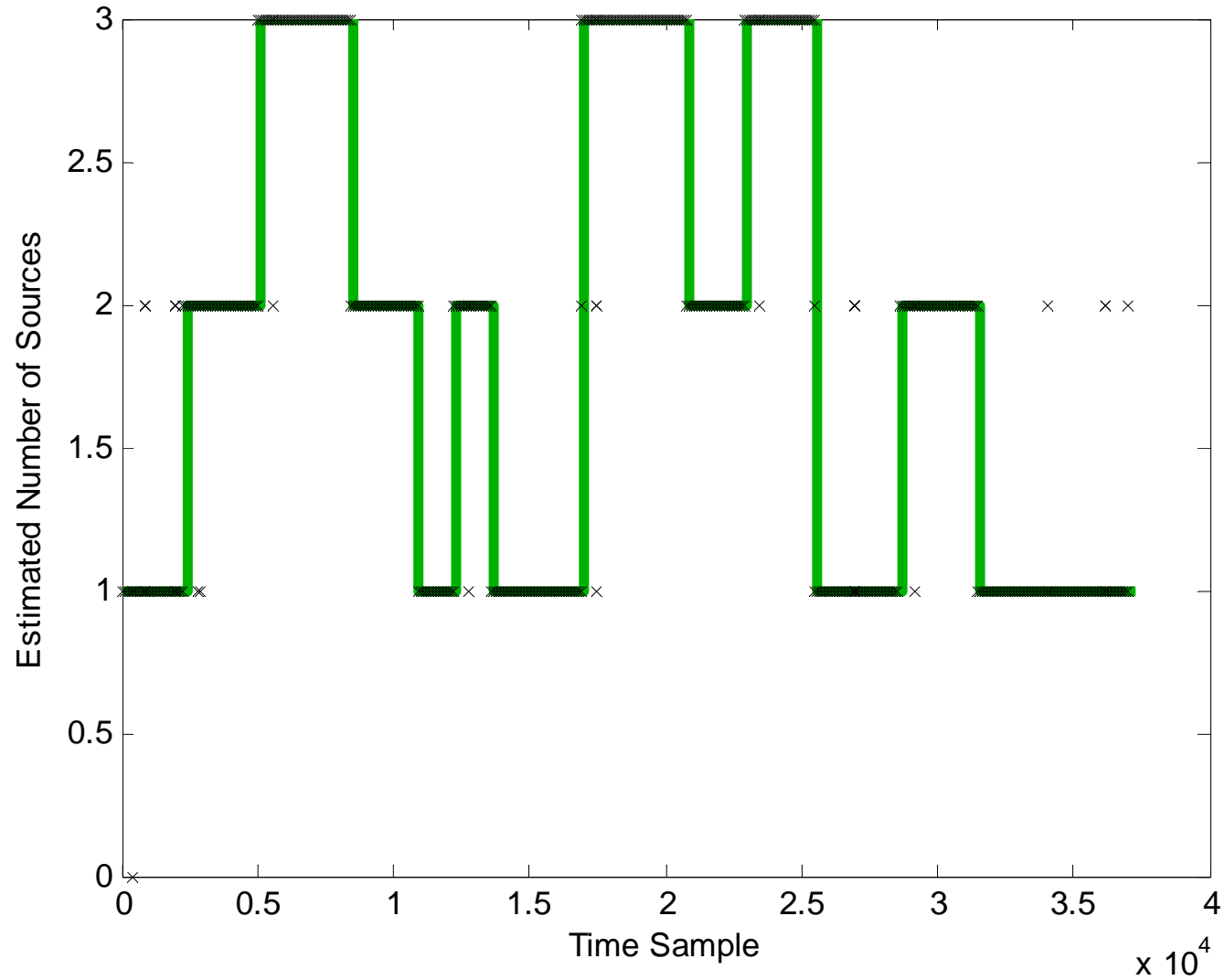
- Frequency
- Power
- Angle
- Time

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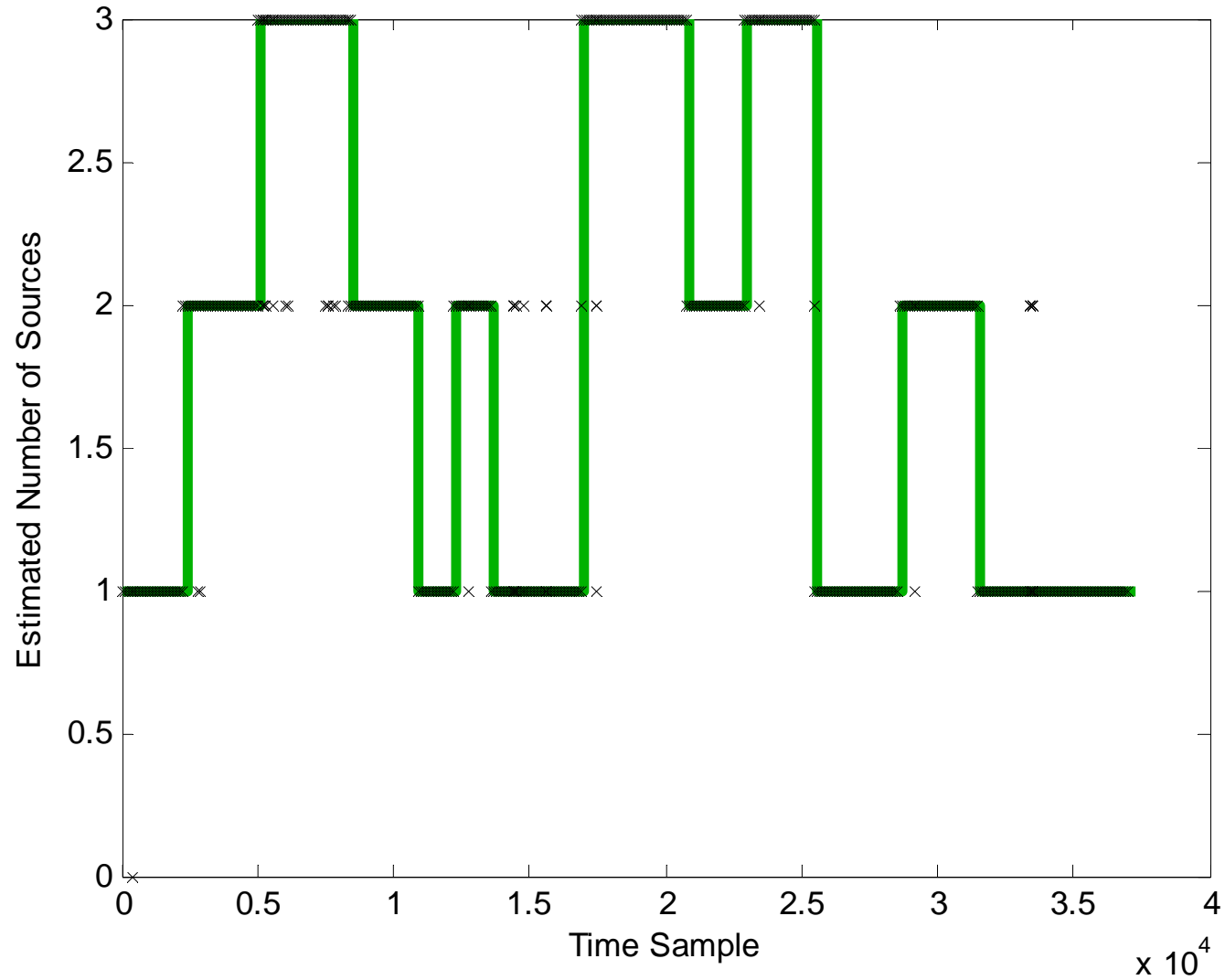
■ All Mode S Long



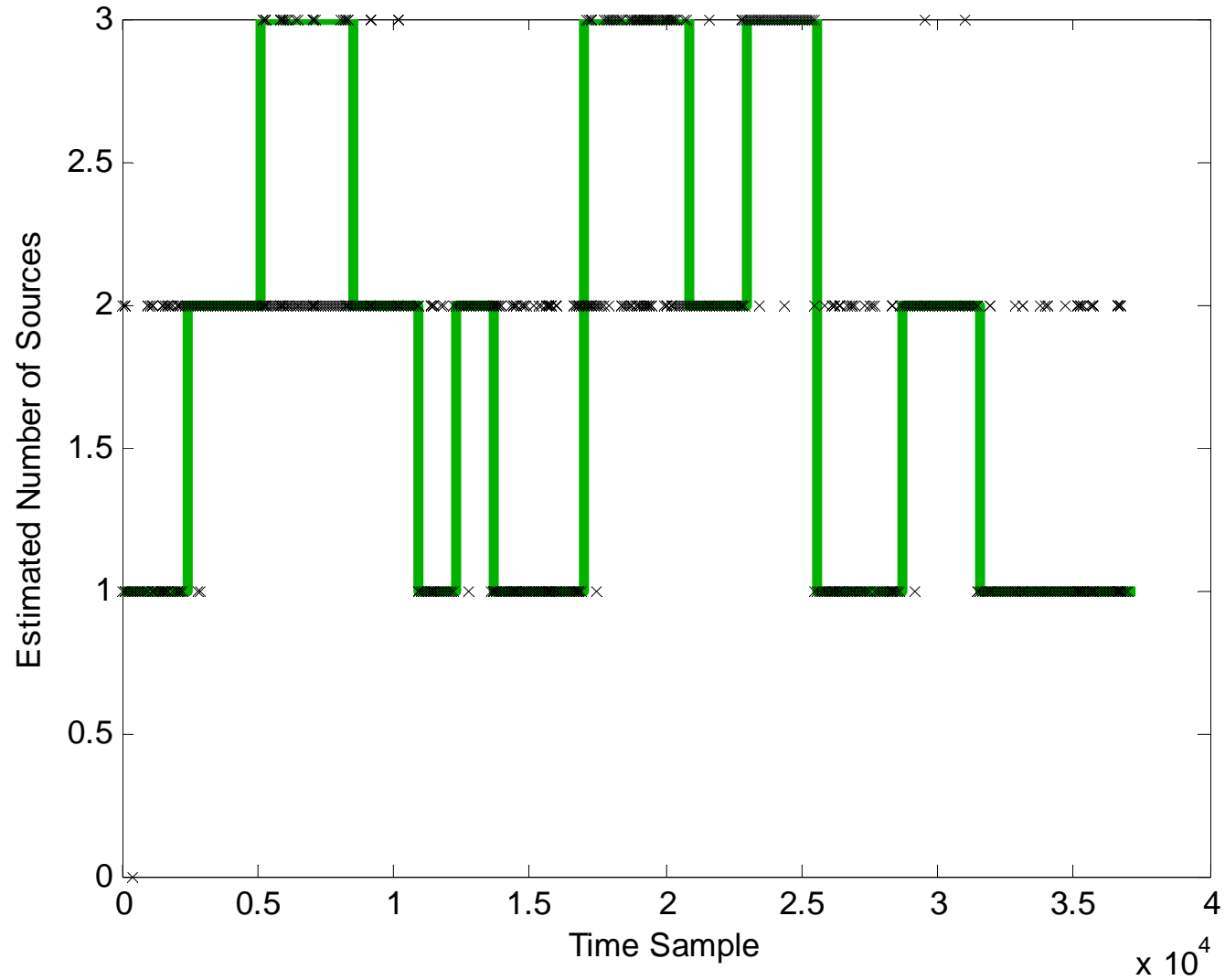
Noise at -90 dBm



Noise at -80 dBm



Noise at -70 dBm



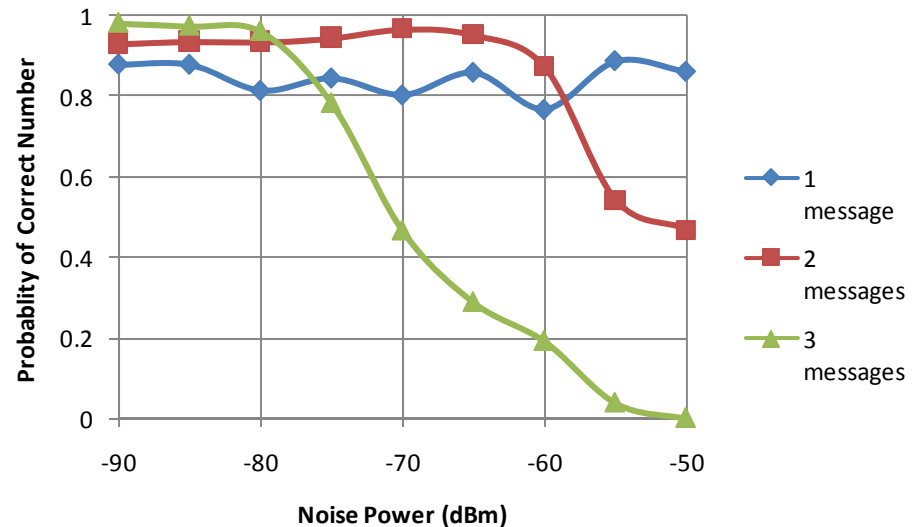
Summary – Message Number Estimate

■ Number Estimate Degrades with:

- Decreasing SNR
- Increasing Number of Overlapping Messages

■ Other Parameters

- Power Level Difference
- Frequency Separation
- Angular Separation
- Number of Elements
- Spacing of Elements



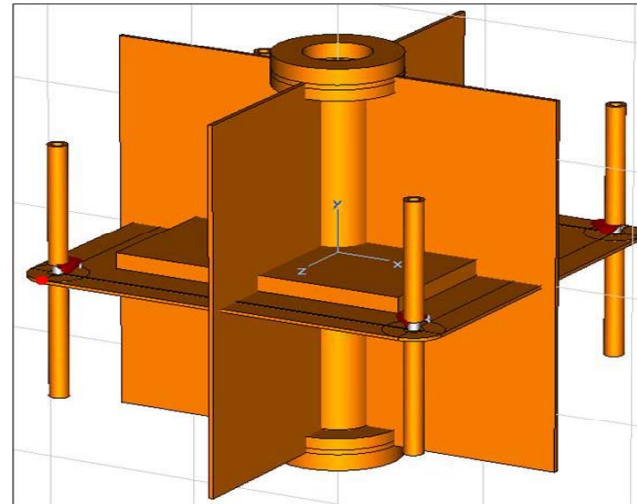
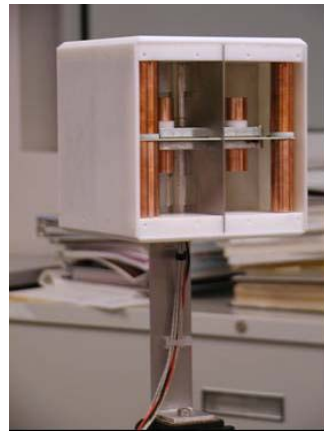
Preliminary Conclusions & Thoughts

- With only 4 elements (channels), less than 3 foot aperture, can resolve down to 2° (with adequate SNR)
 - Contrast with four 90° sectors

- What promise does this hold?
 - For a given number of channels (electronics), can get better interference estimate than with fixed sectorized antennas
 - Angle of arrival could characterize the environment with additional information
 - Can be compact enough to make airborne measurements

Further Work

- Expand Above Plots to Better Show Parameters (SNR, Frequency, Angular Separation)
- Integration of Power Envelope Tool and Multichannel Algorithm
- Comparison of Multichannel Algorithm with Sectorized Antenna Approach
- Measurements with Actual Array and Receive Hardware (patents pending)



■ DISCUSSION