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Measurement Best Practices

Jim Linehan, Alion Science and Technology

ISART 2018 Measurement Panel

Personal Background

- Electrical engineer (BSEE/MSEE)
- RF and EMC measurement background, emphasis practical versus theoretical
- Supported DoD, Federal Agencies, Commercial Projects for 42 years
- Experience
  - **RF/EMC measurements (frequency response, gain compression, intermodulation, coupling, etc.)**
  - **Antenna Characteristics (gain, pattern, off-axis response, etc.)**
  - **RF surveys (occupancy, unregistered emitters, RFI)**
  - **Spectrum monitoring system development and deployment**
  - **Electromagnetic compatibility measurements**
  - **Measurement automation and data processing**
- Current projects
  - **Spectrum monitoring system development**
  - **Ground-to-Ground Clutter Measurements for DSO (consulting)**

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Types of Measurements

- Bench measurements, Component and System Level
- RF Surveys
- Real-time monitoring
- Mobile measurements

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Bench Tests

- Purpose: to measure performance of components under controlled conditions
- Examples
  - **Receiver front-end performance (gain, noise figure, 1-dB compression, 3rd-order intercept, frequency response)**
  - **Transmitter power, emission spectrum, harmonic spectrum, intermodulation (front-door and back-door)**
  - **System sensitivity, dynamic range, frequency response, no interference**
  - **System performance versus interference (e.g., BER vs S/I vs Δf)**
- Considerations
  - **Use quality, calibrated equipment and understand the limitations**
  - **Develop or use established procedures (e.g., MIL-STD-461, 449)**
  - **Maximize dynamic range by using filters, amplifiers**
  - **Minimize internally-generated artifacts by using high dynamic range passive components**
  - **Characterize the measurement setup to determine its frequency response**
  - **Present the data in a suitable graphical format to maximize intelligibility**
  - **Show intermediate steps in the process**

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RF Surveys

- Purpose of a survey: to determine suitability of a particular site for permanent installation (e.g., Satcom terminal)
- Motivations
  - **Visually assess the site, determine if there any show-stoppers in terms of RF emissions, soil quality, obscura, etc.**
  - **Evaluating alternative locations**
  - **Identify unexpected emissions**
- Possible issue: satellite and point-to-point microwave systems coexist in same allocated bands
  - **Point-to-point system frequency use can often be de-conflicted**
  - **Databases may show P2P networks but not associated frequency plans**
- Considerations
  - **Determine what bands need to be surveyed and develop system accordingly**
  - **Use directional antennas stepped in azimuth to capture 360-degree view of environment**
  - **Set up antenna at expected feed height of Satcom system**
  - **Use automated process to capture data in a consistent and repeatable manner**
  - **Characterize the measurement system to calibrate out gains and losses**
  - **Repeat survey over extended period of time, if possible**

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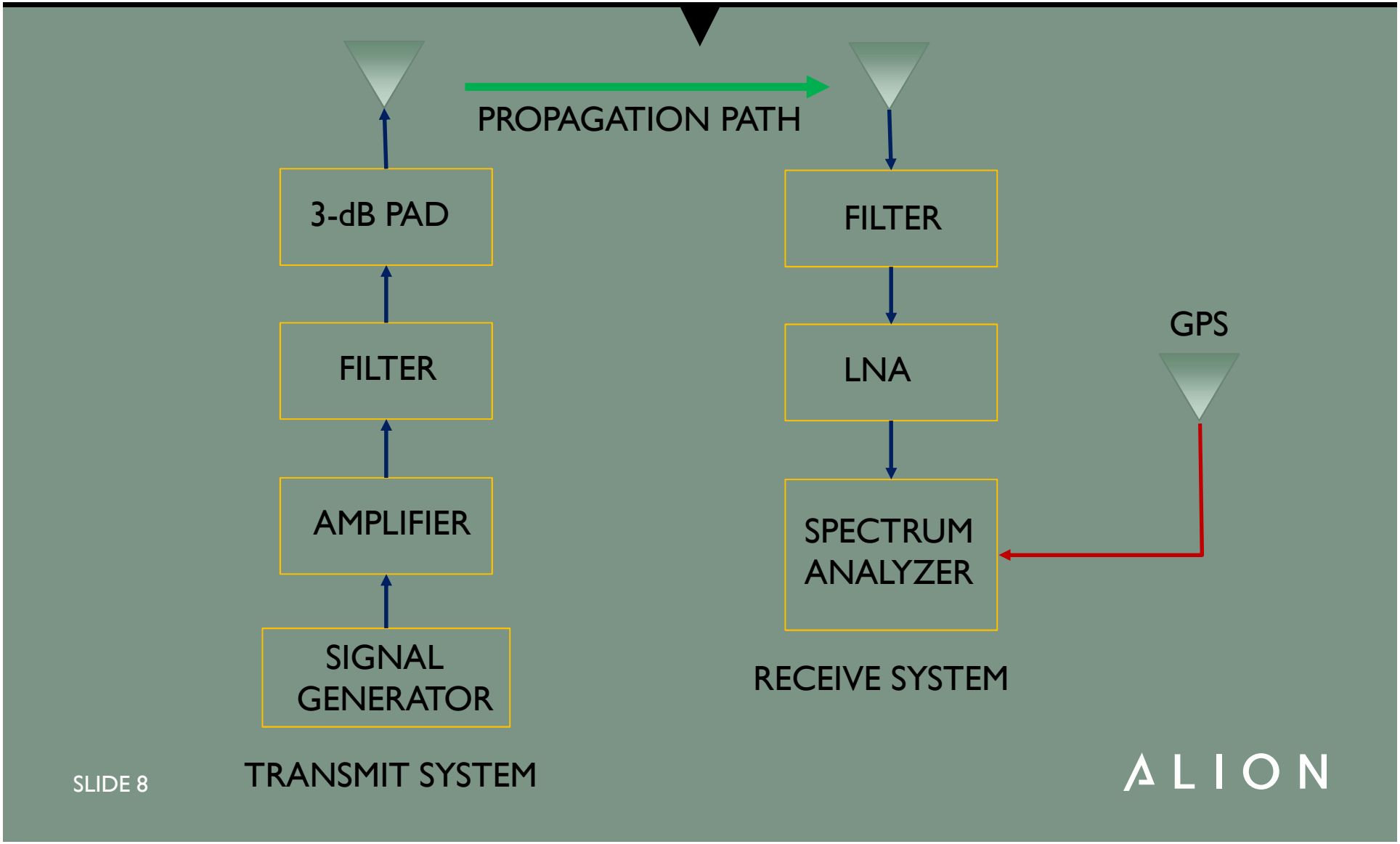
Real-Time Monitoring

- Purpose
  - **Establish usage patterns in a band of interest**
  - **Detect changes in the electromagnetic environment over time**
  - **Detect potential harmful interference to a particular system**
  - **Verify the absence of potentially interfering signals**
- Example - Alion RAMS (Remote Automated RF Monitoring System)
  - **Used at NASA Wallops to detect potential interference from AWS-3/Ligado system in bands adjacent to NOAA downlinks**
  - **Captures spectrum and I-Q data when a threshold is exceeded**
  - **Uses moderately-priced sensors from Keysight (adaptable to other sensors)**
- Considerations
  - **Define bands of interest and the environment in which the system operates**
  - **Use front-end filtering to prevent adjacent-band affects**
  - **Limit the amount of data captured to that which meets criteria**
  - **Make it useful to the end-user**
  - **Incorporate real-time reporting, archiving, remote access**

Mobile Measurements

- Purpose: to determine signal level variation of a single signal or dominant signal(s) in a band of interest
- Examples
  - **Drive test to locate AWS emitters**
  - **Drive/walk test to measure prop loss from cooperative emitter**
- Considerations
  - **Location tracking is an essential part of mobile testing**
  - **Portable test equipment capable of field use on vehicle power may have different performance characteristics than more familiar bench equipment**
  - **GPS system can lose location or report erroneous location due to building shadowing – perform concentrated measurements at known locations as part of the survey**
  - **Component variation due to vehicle power and temperature must be considered**

Typical Propagation Measurement System



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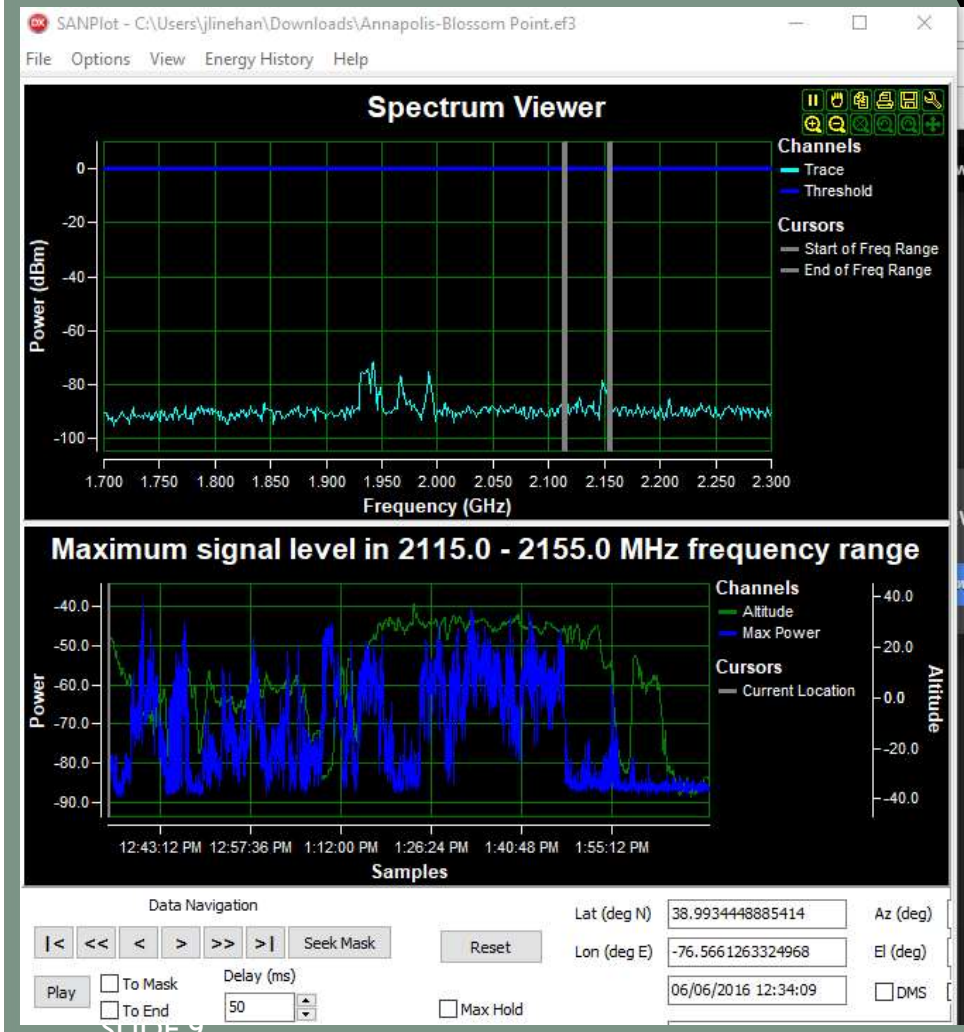
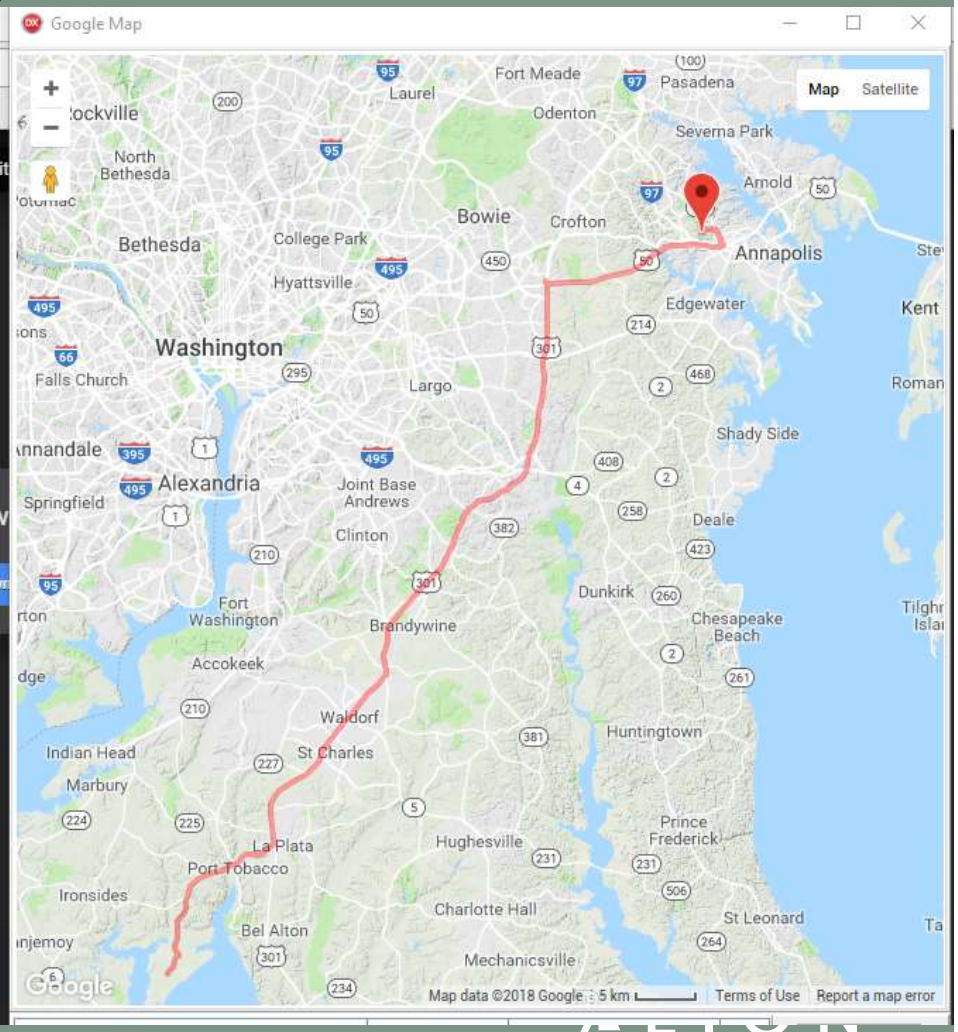
Typical Data Visualization for Mobile Measurements





Sources of Measurement Error

- Test Equipment (sources and analyzers)
  - **Amplitude Uncertainty**
  - **Frequency Uncertainty (drift)**
  - **Internal noise, limits in sensitivity**
  - **Non-linearities (gain compression)**
- Antennas and Cables
  - **Pattern variations**
  - **Pointing errors (directional antennas)**
  - **Impedance mismatch**
  - **Connector interaction**
  - **Interaction with nearby objects**
  - **Ground plane limitations**
- Propagation related variances
  - **No direct path between source and receiver**
  - **Imperfect modeling of structures**

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Summary – Measurement Best Practices

- Define the problem thoroughly, work with the analysts to establish scope
- Use quality equipment and make sure the calibration is current
- Follow established procedures or develop custom procedures
- Value quality versus quantity of data
- Evaluate the data as soon as possible and repeat measurements when data appears questionable
- Don't assume
- Document clearly and succinctly and show your work

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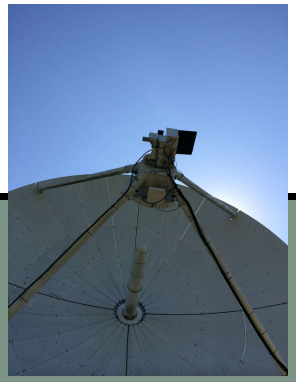
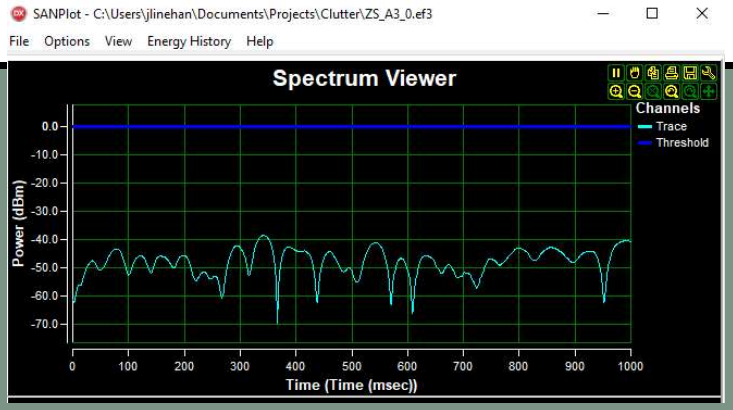
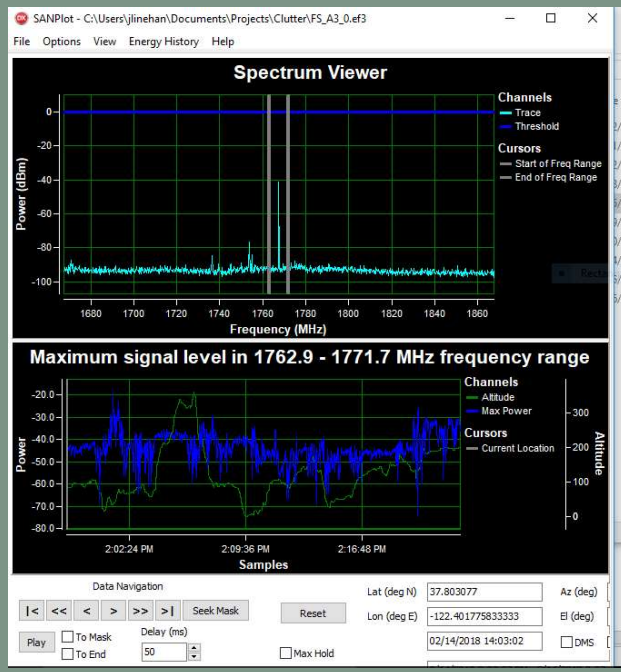
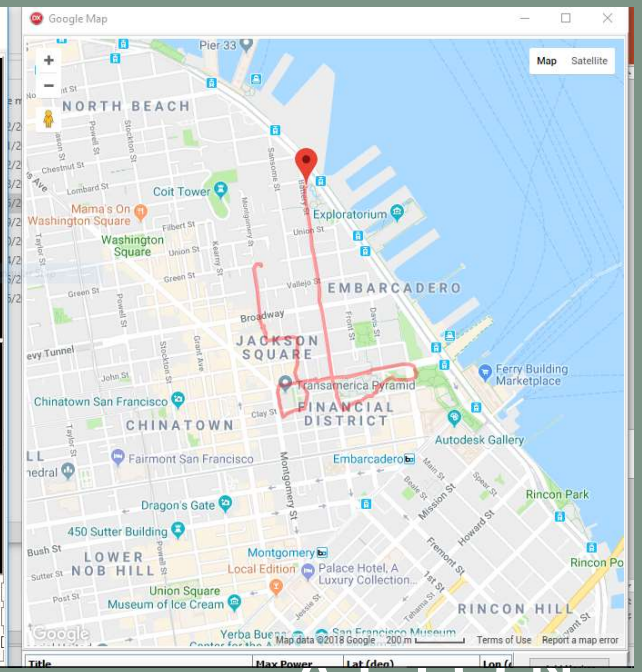


SATCOM
RFI Mitigation







RF Surveys

Propagation Measurements

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