



# AFRL HERITAGE 1917-2017

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#### Automated Quality Control Algorithms for Ionospheric Scintillation Measurements

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#### Overview



- Background and Motivation
- Phenomena and potential algorithms
- Data sets
- Test cases examined so far
- Future plans



Apparent scintillation activity in daytime hours Can we determine whether this is real?







## **Background and Motivation**

- Only crude semi-manual quality control implemented in legacy scintillation monitoring systems
  - Mask in elevation angle for GPS to minimize false readings from multipath
  - ✓ Filter by local time—daytime events discarded
  - ✓ Simple filters for spike removal
- Some of the most interesting events are those that occur outside "typical" conditions



- Interference, internal/external noise, moving objects, signal modulation
- Robust systems need to perform quality control automatically and in real time, for both research and routine monitoring purposes













- Amplitude and phase spectra and distributions
  - ✓ Reflects physics of scintillation
    - Roll-off, Power law, etc.
  - ✓ Shows receiver noise floor (internal white noise)
- Decorrelation time
  - Rule out multipath depending on angular motion of TX and/or RX
  - Interference spikes should have extremely small decorrelation times
- Simultaneity on spread spectrum signals (GPS, SATCOM, etc.)

✓ Noise, interference affect all channels at same time





#### Data Sets: Singapore UHF S<sub>4</sub>





# Can we possibly believe daytime measurements when there is so much noise and it goes against climatology?



#### **Another Case from Singapore**



- Data from one month later
- The noise background seems much better....
- But how confident can we be?
- For this particular data set, the S<sub>4</sub> & drift velocity is all we have to go on for event analysis







## Test Case: Interference in Taiwan



- Taiwan site with known interference problem
- Daytime enhancements sometimes look similar to Singapore events
- For this site we have 125 Hz high-resolution time series
  - ✓ Can look at spectra



# **Taiwan Spectral Analysis**

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- A closer look at the high-rate data
- Focused on data "spikes" near 18 UT during what appears to be moderate scintillation coincident with noise spikes











# **Taiwan Amplitude Spectra**







#### UNCLASSIFIED UHF Amplitude Data from Bahir Dar, Ethiopia





DISTRIBUTION A: Approved for public release (OPS-17-13346)



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- Is this real?
- How should this be interpreted by an automated algorithm in real-time?

- Another event at Bahir Dar that shows realistic appearing scintillation during the daytime hours
- This time, the decorrelation time & drift velocities are very uniform
  - Cross Correlation between spaced antenna provides uniform drift of ~100 m/s West







## **GPS Data Analysis**



- PRN 28 from Kwajalein
- Orbit dips below 20° elevation then rises, staying on the horizon
- Stacking daily plots, you see evidence of multipath interference shifting in time by ~4 mins due to orbit precession
- But the pattern changes and you see what appears to be "real" scintillation riding on top of the multipath
- Current methodology to filter potential multipath from analysis is to employ an elevation cutoff





### **GPS** Data Analysis









## Summary



- AFRL in the early stages of developing automated quality control tools for scintillation measurements
- Numerous "anomalous" cases identified from multiple data sets
  - ✓ Limited availability of high-resolution data
  - Clear spectral signatures in amplitude confirm some nighttime cases as natural
    - One daytime case clearly ruled out as unnatural
  - ✓ Study ultimately will include GPS/GNSS signals
    - Both amplitude and phase information





#### Questions





