DCS Interference Issues
The 00-06z Problem
Ionospheric Scintillation

Presented by

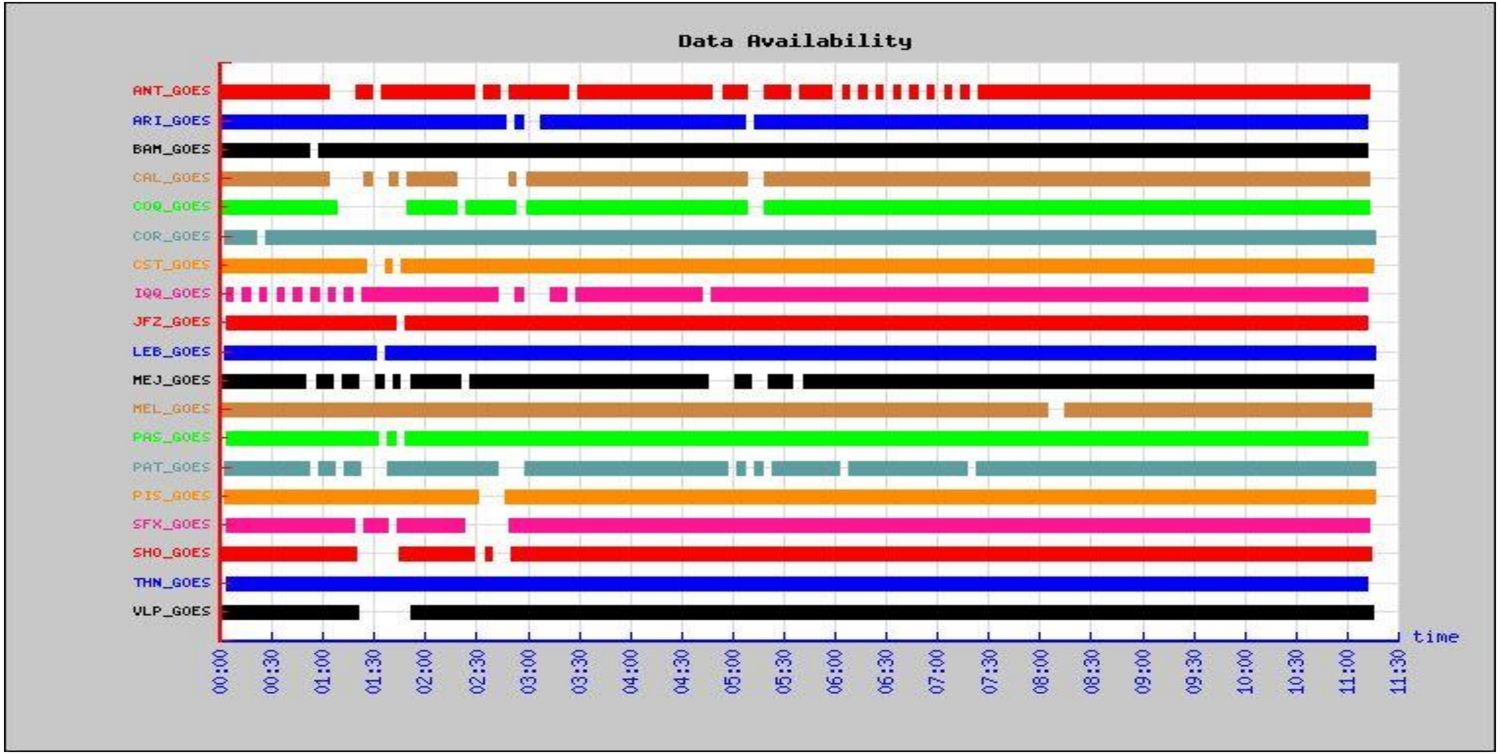
Microcom Design, Inc.

May 2012

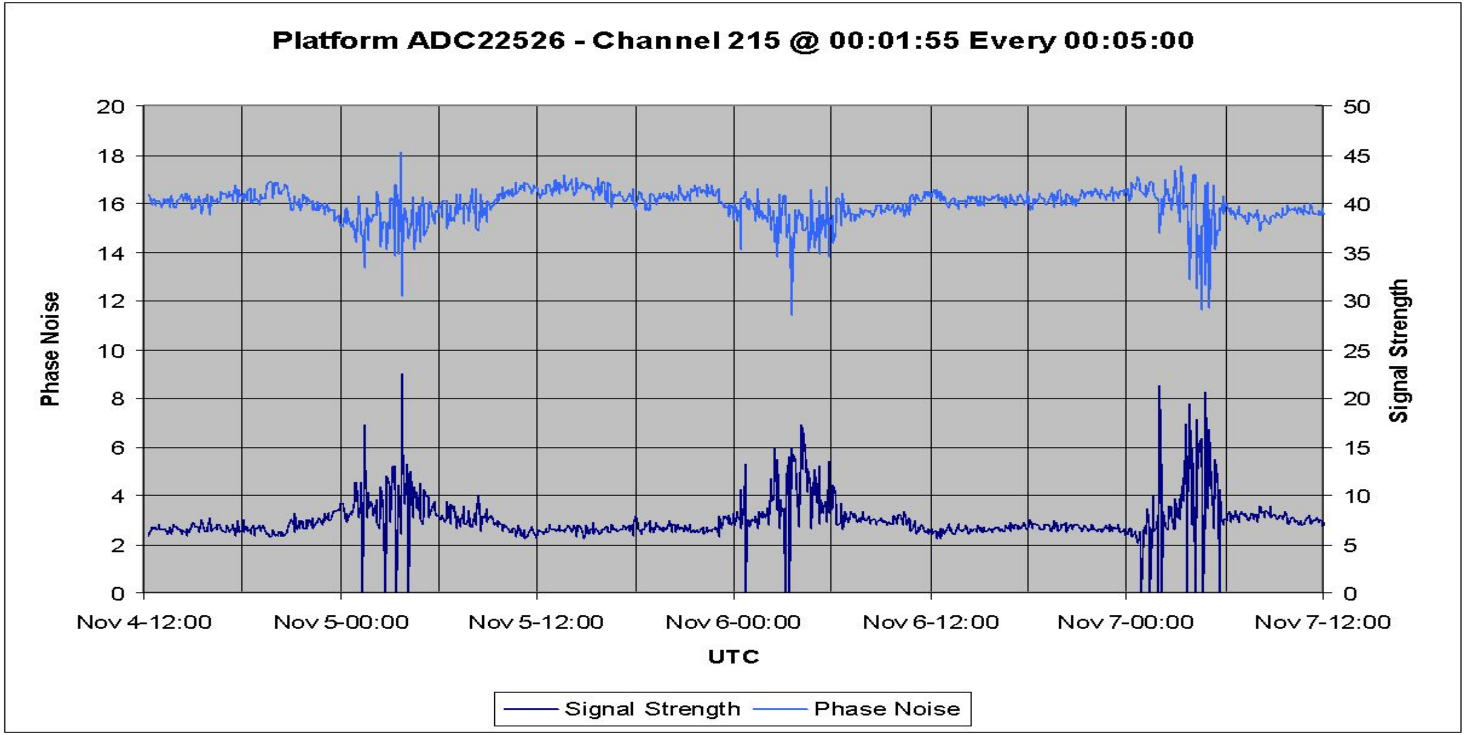
The Story Begins …

- In Mid-October 2011 NOAA was contacted by a representative of the Chilean Tsunami Warning Center:
  - "During the last couples of months, GOES transmissions have been very unstable. I can't detect any pattern but from time to time all our transmission suffer a lot of interruptions during the ***first 6 hours*** of the day."
  - The user further noted that they did not believe the outage was related to their DCS receive system.
  - Microcom was also able to independently confirm the outages across the various receive sites (Wallops, NSOF & EDDN) .
  - Messages were either missing altogether or were garbled toward end of message.
- In Early November 2011 NOAA authorized Microcom to investigate further …

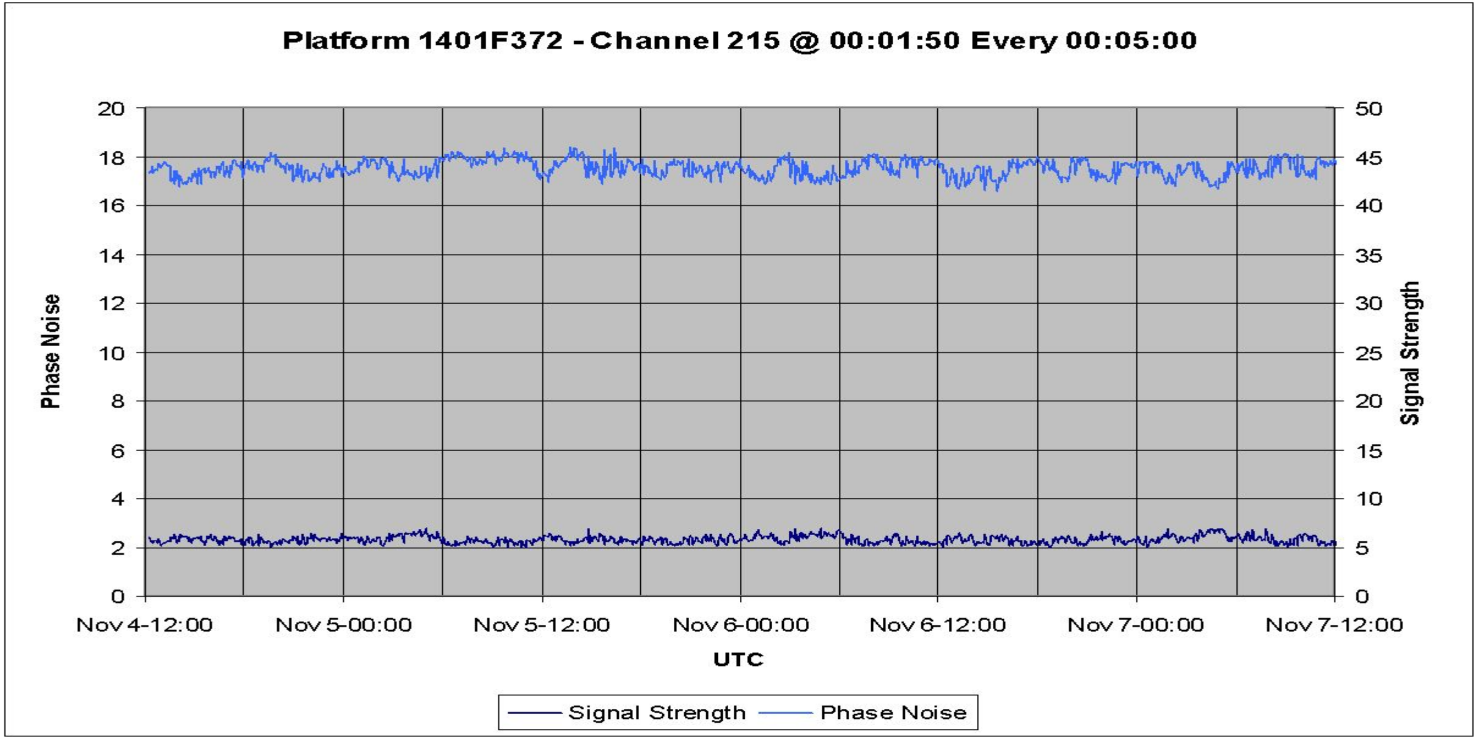
Outage Graph from Chilean User



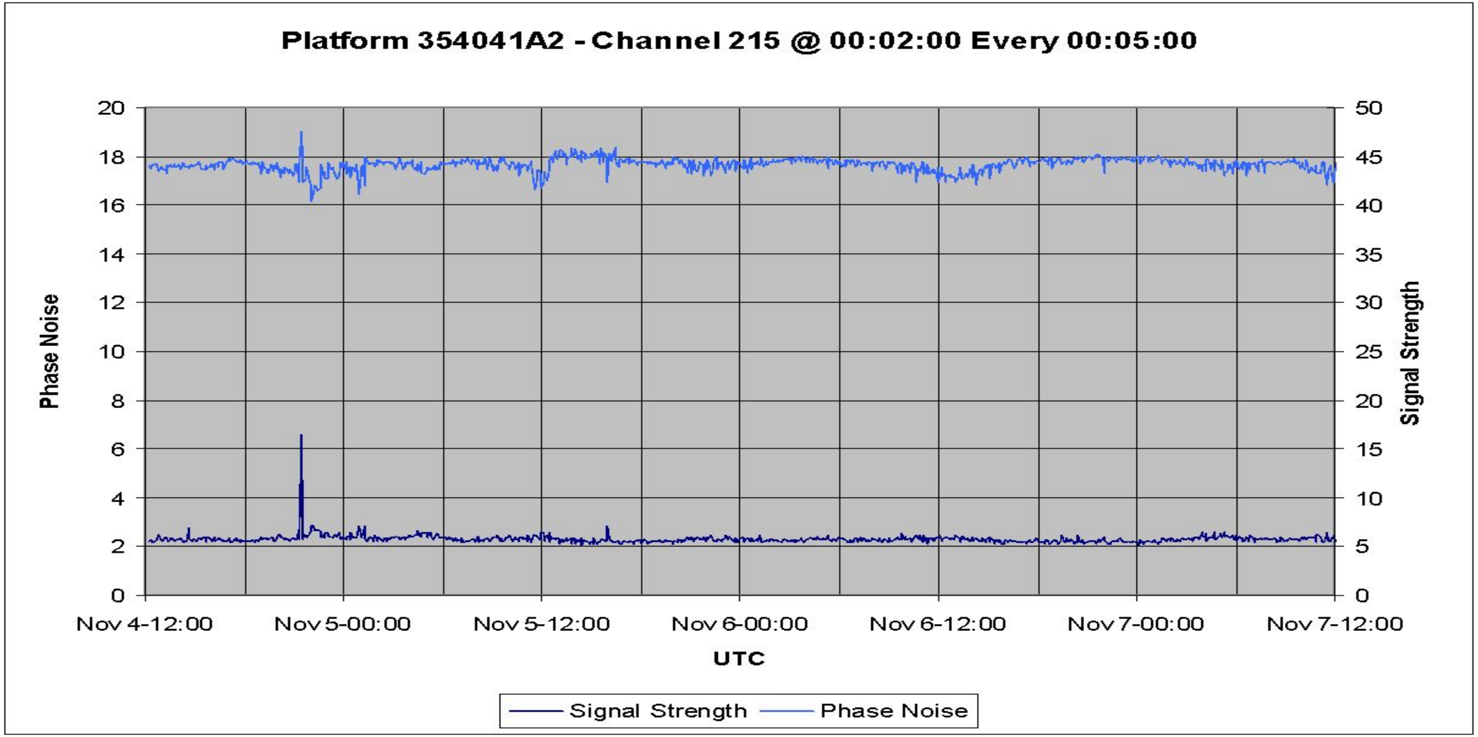
Chilean Tsunami Platform 1



Chilean Tsunami Platform 2



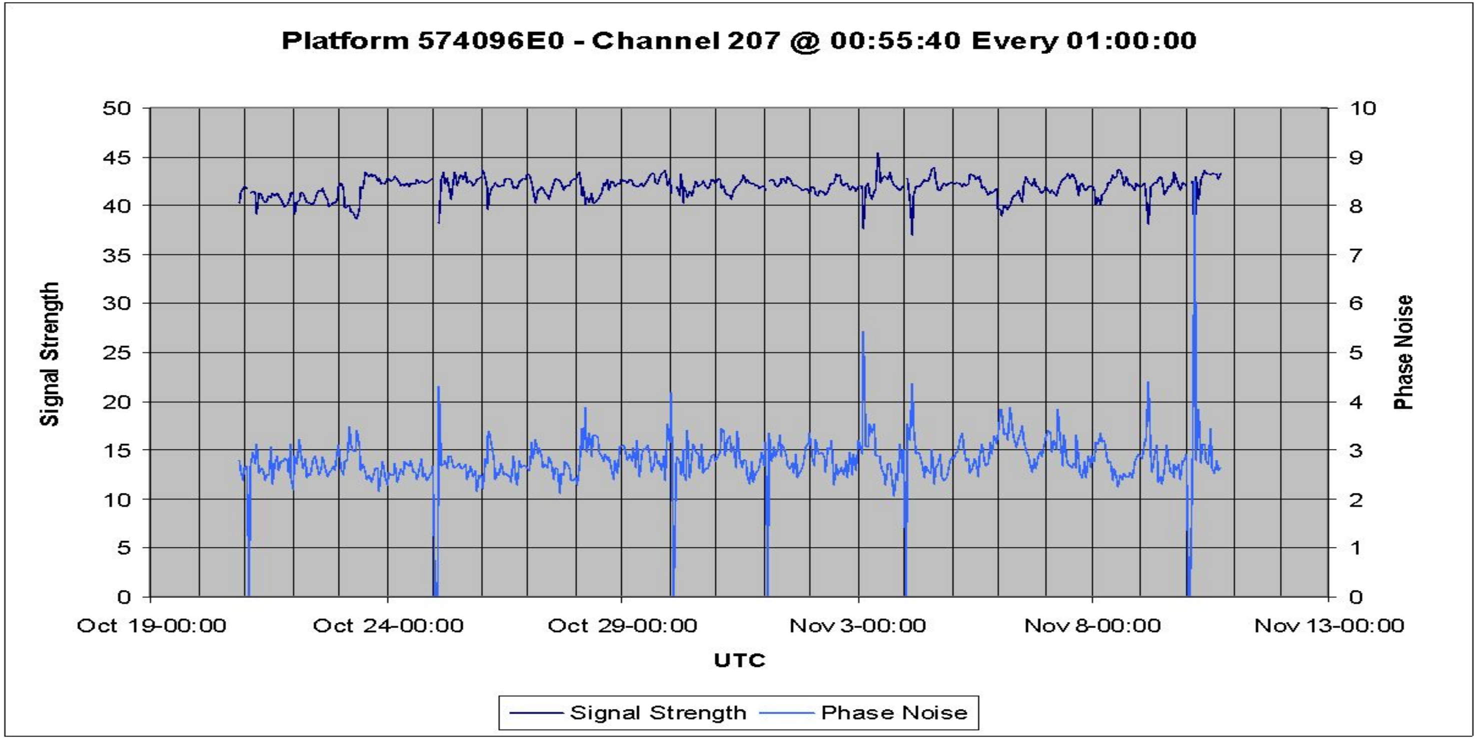
Hawaiian Tsunami Platform



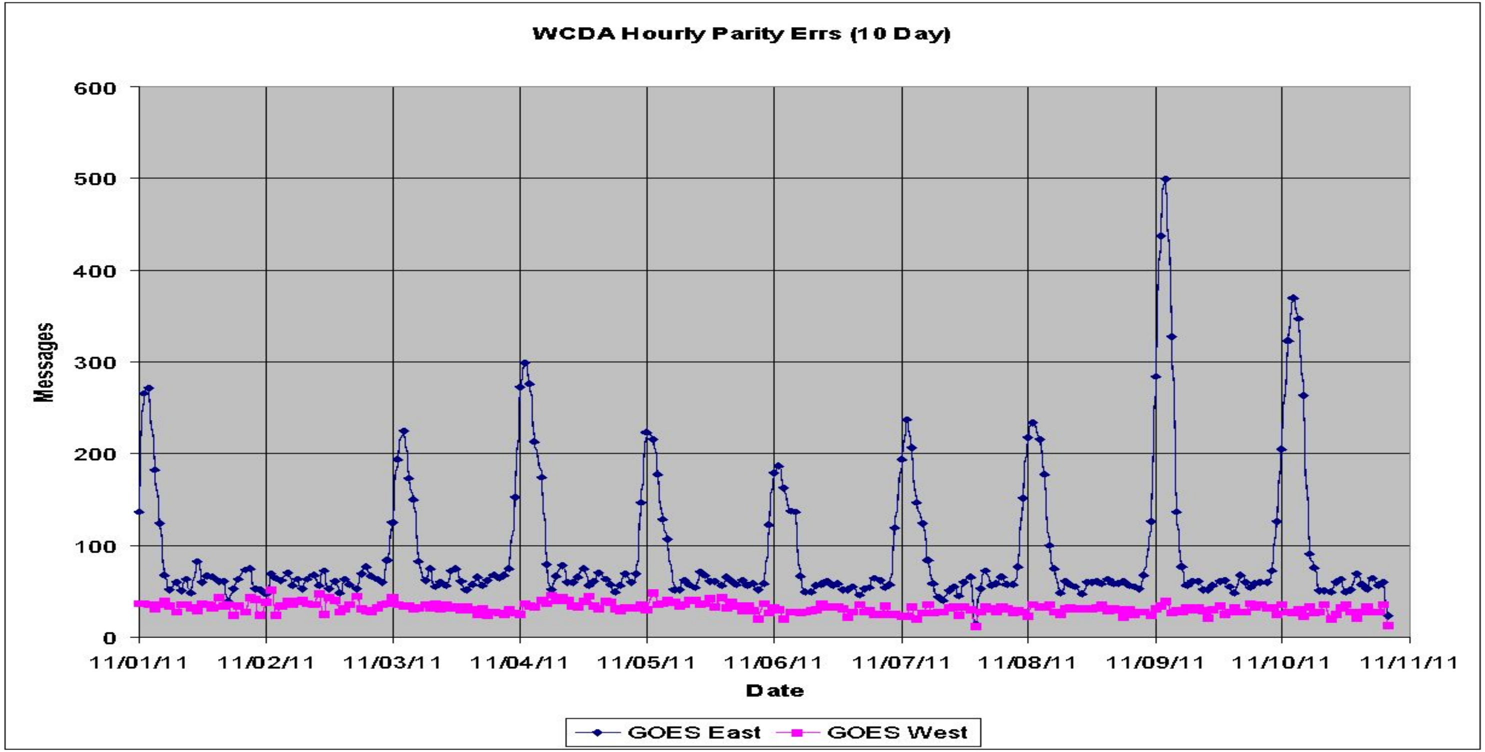
Initial Conclusions – Platform Problem?

- Daily pattern of signal strength and phase noise variations clearly evident from 00-06 UTC in platform ADC22526.
- Problem platform bounded by two good platforms.
- Virtually identical results were seen on another set of platforms.
- Signal strength and phase noise was not receive site specific.
- No indications of an interfering platform.
- Initial conclusion was that this was a platform issue.
- However, just before sharing this preliminary conclusion with NOAA, Microcom received an e-mail from a Colombian user complaining of a similar problem …
  - "For the past several weeks the DCP of ISAGEN and SOPO(Bogota) have been missing transmissions in the hours between 20:00 – 23:00 local time *01:00-04:00 UTC*."

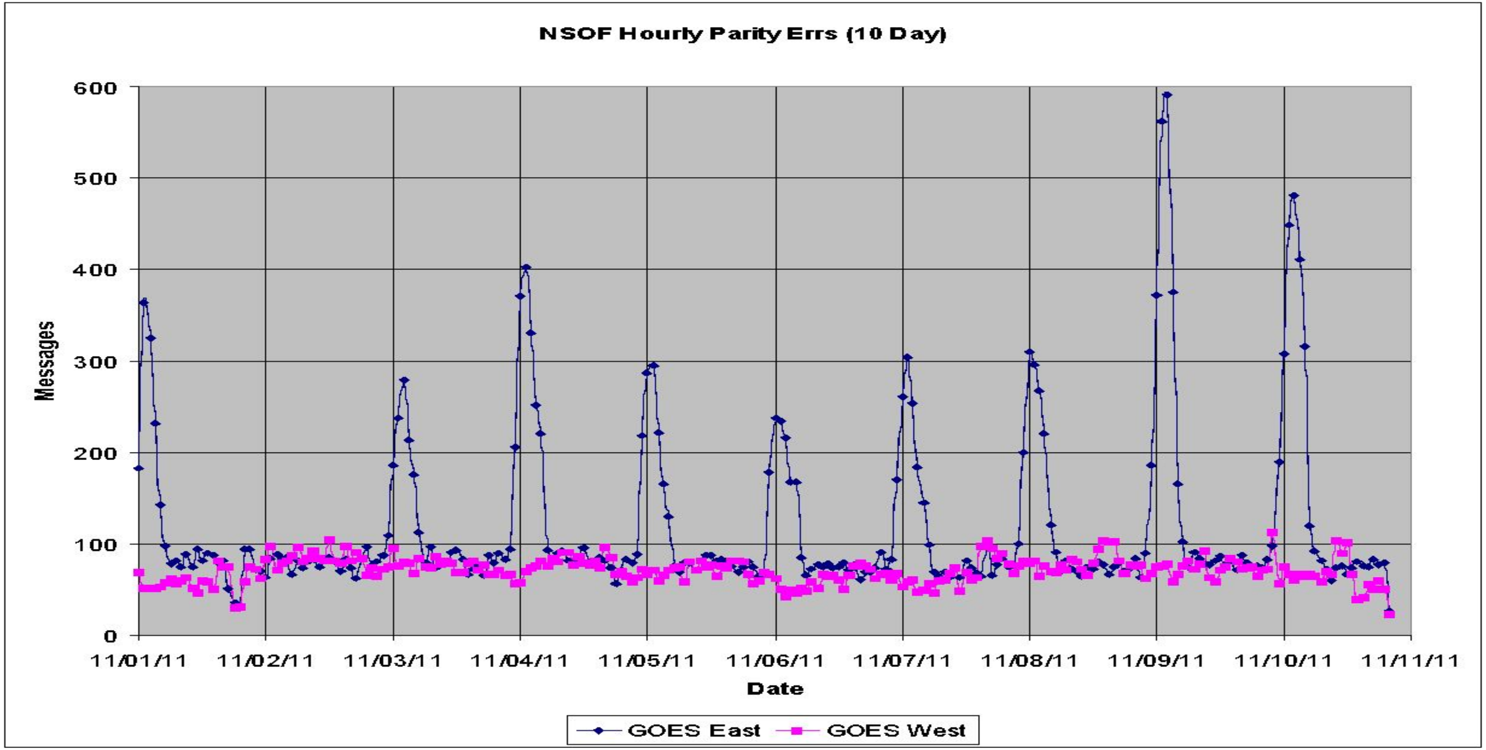
Colombian Platform



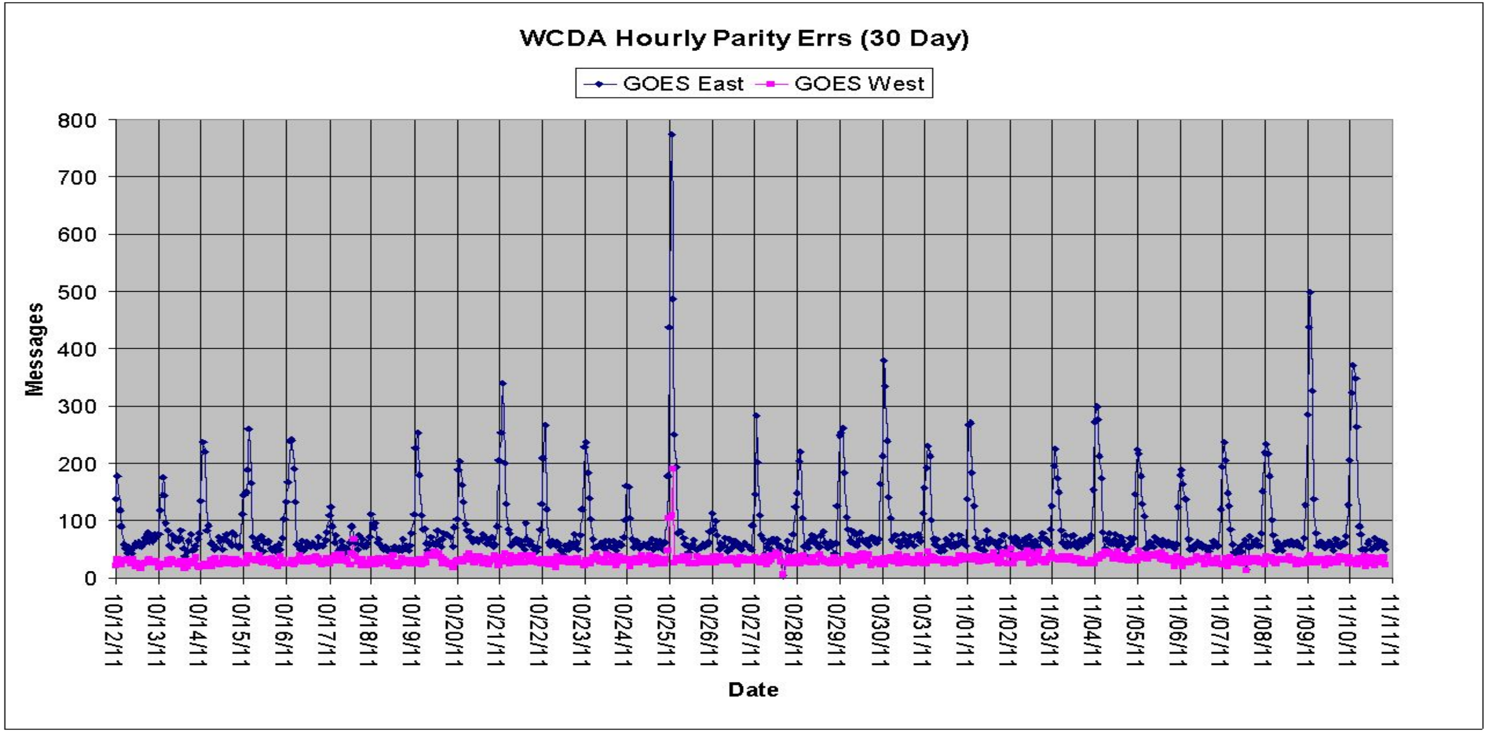
Wallops Parity Errors - First 10-Days of Nov



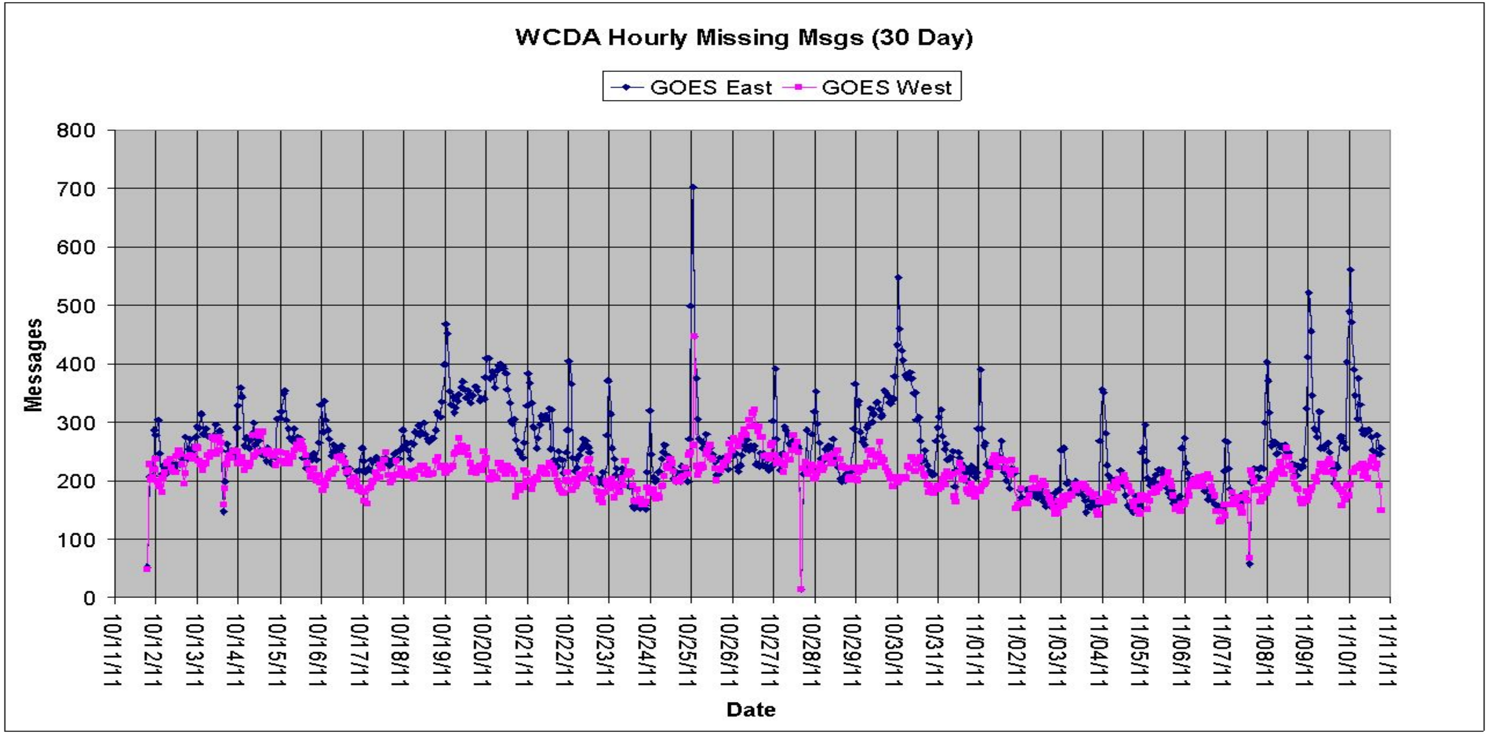
NSOF Parity Errors - First 10-Days of Nov



Wallops Parity Errors - 30-Days



Wallops Missing Messages - 30-Days



Revised Conclusions – Systemic Problem!

- Daily pattern of missed messages and messages with parity errors clearly evident from 00-06 UTC.
- Issue was not receive site specific (WCDA vs. NSOF).
- Certain channels appeared to be affected more so than others, but no real pattern.
- Seemed to be affecting southern platforms more so than northern ones.
- Dominant affect was on GOES-East (GOES-13).
  - Could this be a spacecraft issue?
  - GOES-13 was only operational GOES-N series satellite at the time.

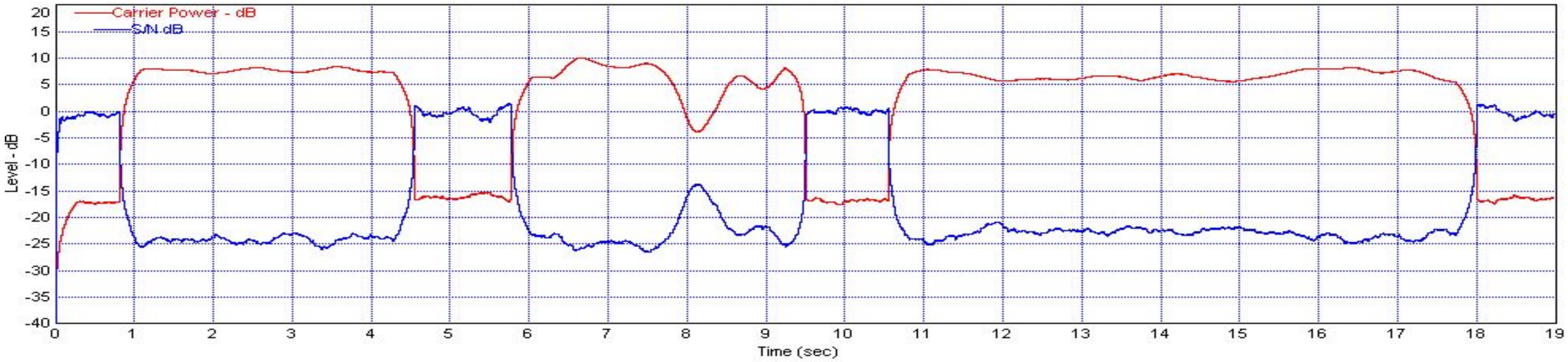
A Satellite Problem?

- Satellite Comparison:
  - GOES-11 (West, I-M Series):
    - Not exhibiting the same phenomenon.
  - GOES-12 (South America, I-M Series):
    - Using Microcom's DRGS and NSOF, Microcom took a look at the reception of DCS messages from GOES-12 located at 60º.
    - Data indicates a similar problem on GOES-12 but results were inconclusive due to excessive satellite drift.
  - GOES-13 (East, N-P Series):
  - GOES-15 (West, N-P Series):
    - Online in mid-December. West still showed no significant impact.
  - Problem did not appear to be tied to the satellite series.
- Could still have been an isolated problem on GOES-13.
  - Needed to look deeper.

GOES DCS Signal Analyzer (GDSA)

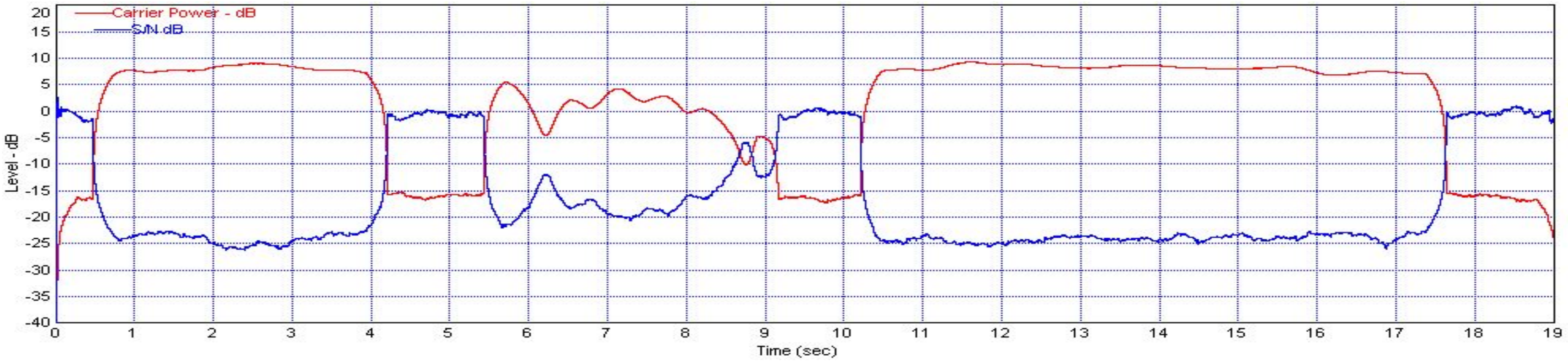
- Developed by Microcom specifically for NOAA/NESDIS.
  - Deployed at WCDA in summer of 2010.
- Functions:
  - GOES DCS Message Reception and Capture
  - Spectrum Analyzer (SA)
  - Time Domain Signal Viewer
  - IF Signal Capture
    - Capturing raw IF DCS signal allows for detailed analysis.
- Analysis can identify or eliminate:
  - Potential interferers that may not be readily visible on SA.
  - Excessive frequency drift.
  - Phase and/or frequency transients.
  - Amplitude variations.

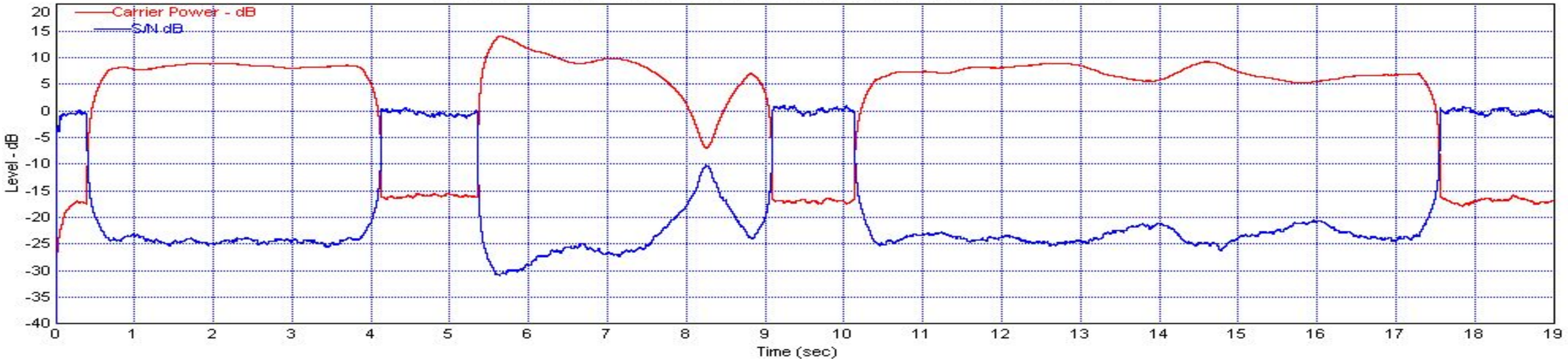
Chilean Tsunami Platforms – A Deeper Look



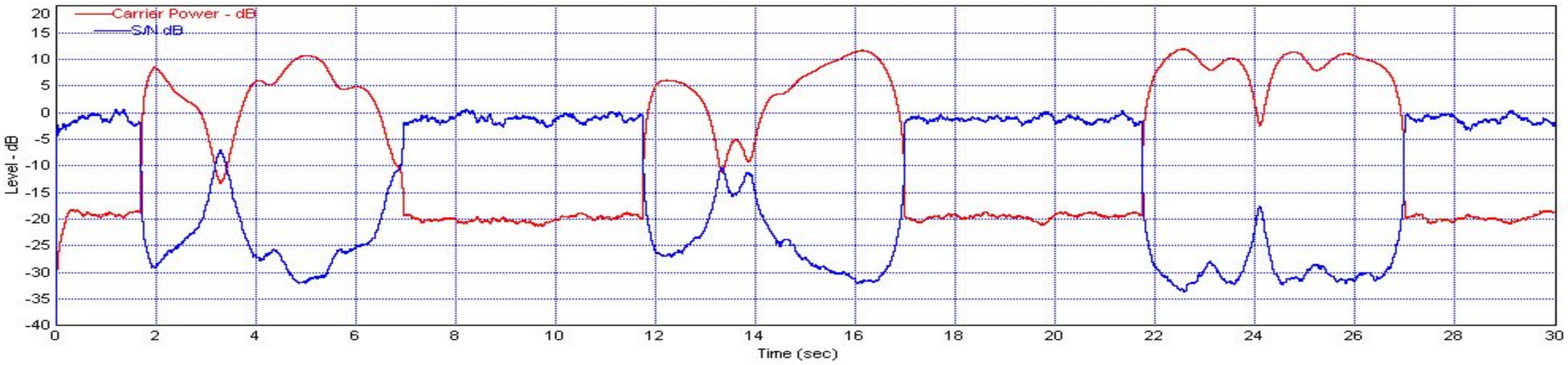
- Chilean Tsunami platforms did NOT show:
  - Corruption from outside interferers.
  - Phase or frequency issues.
- Chilean Tsunami platforms did show
  - Extreme amplitude fluctuations. Rapid signal level drops in excess of 10 dB.
    - Red Trace: Signal Power
    - Blue Trace: Signal-to-Noise Ratio (SNR)

Chilean Tsunami Platforms – More Examples



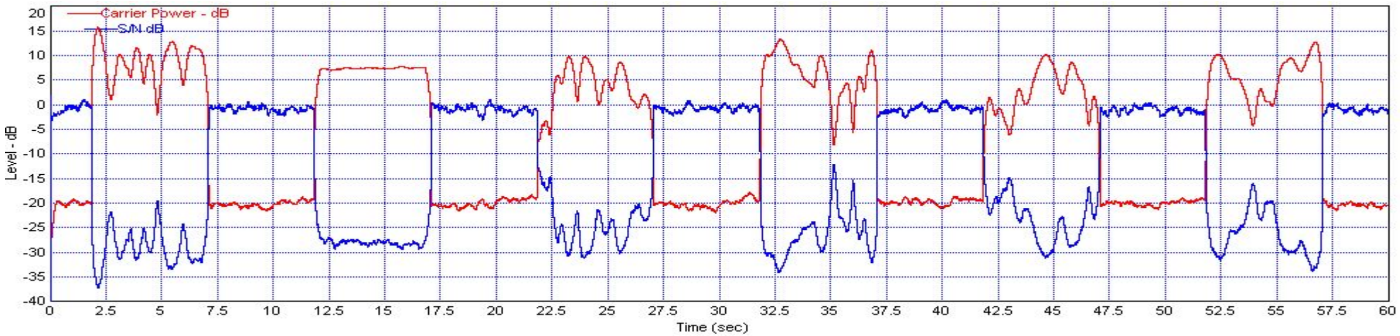


Brazilian Platforms – A Land Based Example

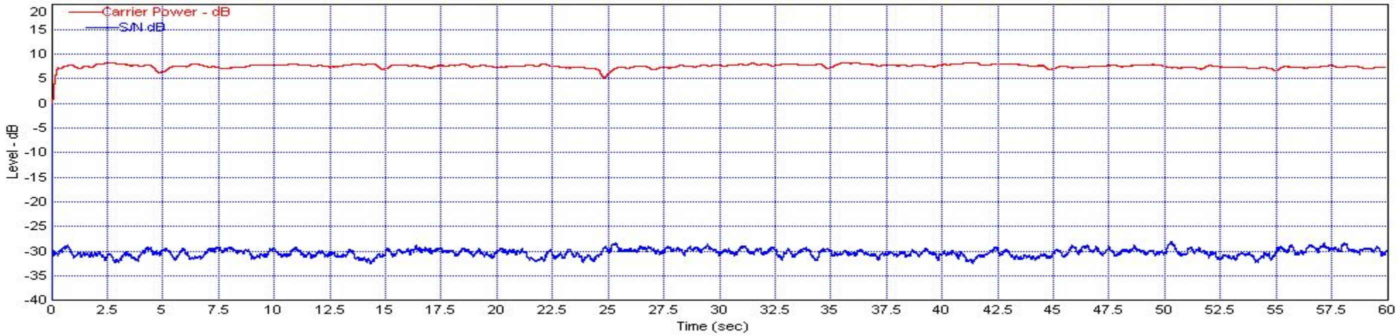


- Tsunami Platforms are typically Buoy installations:
  - Susceptible to wave affects and rough seas.
  - Amplitude variations could be caused to uplink antenna motion.
- Brazilian Platforms:
  - Identified through DADDS database as experiencing similar problems.
  - Known to be land-based deployments.

Brazilian Platforms – Not the Pilot …

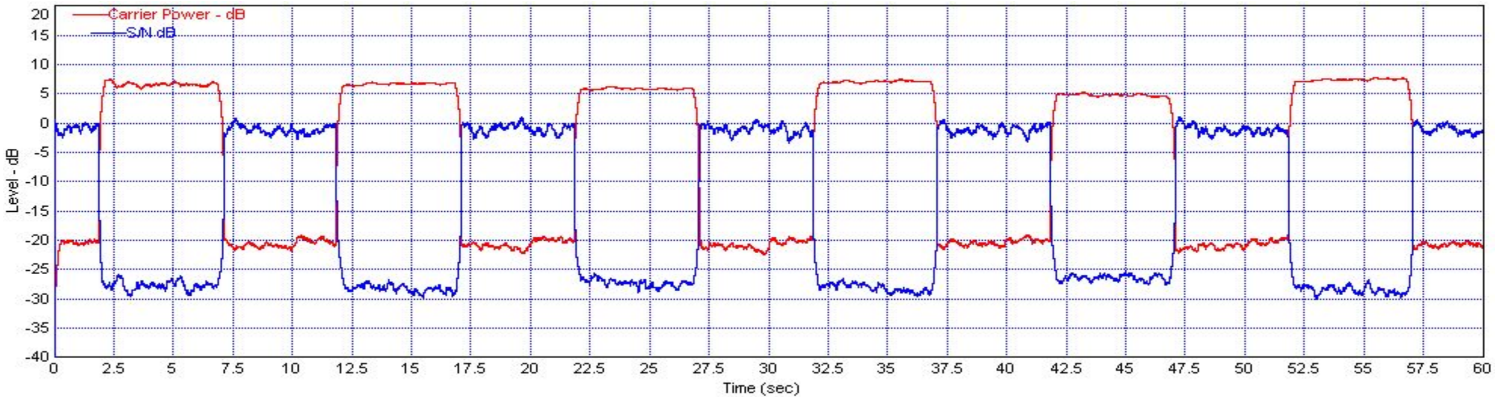


- Message amplitude variations did not coincide with any Pilot variations.

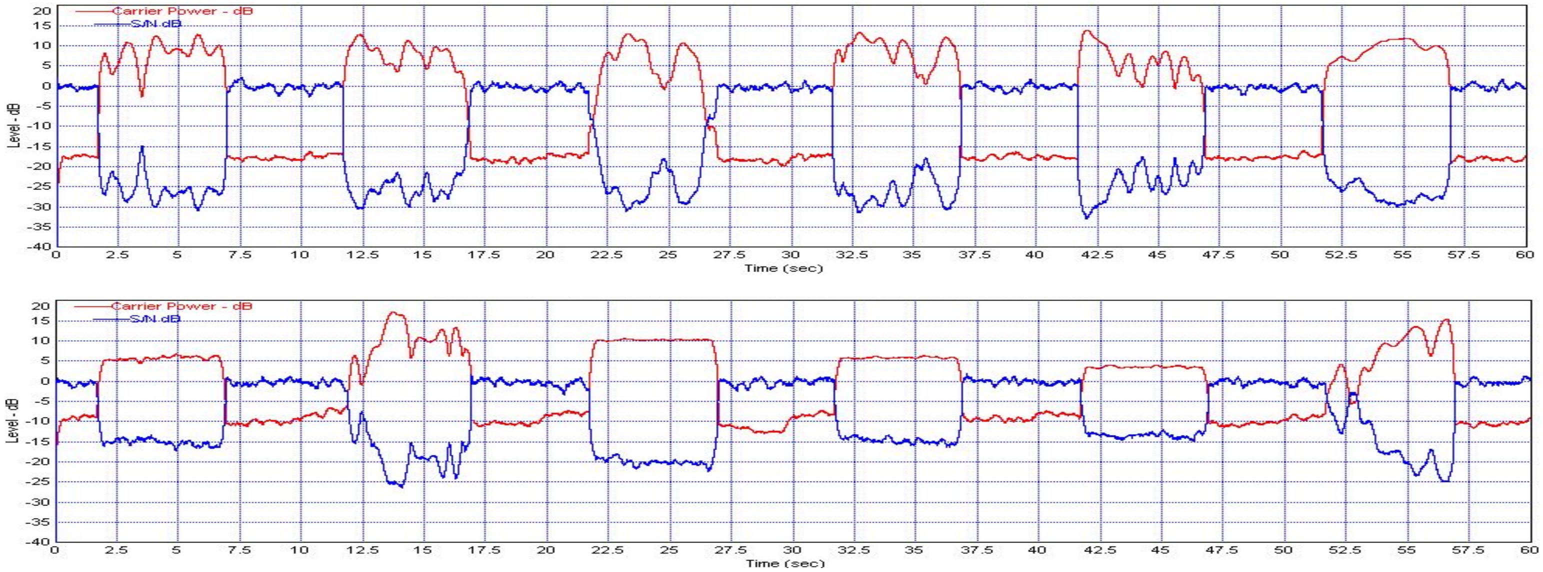


Not the Spacecraft … Not the Platform …

- Nothing in the Satellite can produce rapid amplitude fluctuations, time of day effects or frequency selective effects (ie. on isolated channels).
- Nothing Common between platforms:
  - Not from a single transmitter manufacturer.
  - Different users – Chile, Colombia, and Brazil – albeit all in South America.
  - Same platforms showed normal signal characteristics outside 00-06z.



Brazilian Platforms – The Smoking Gun



- Signals received simultaneously from GOES-13 (top) and GOES-12 (bottom) conclusively show amplitude variation is travel path specific.

Summarizing What We Know

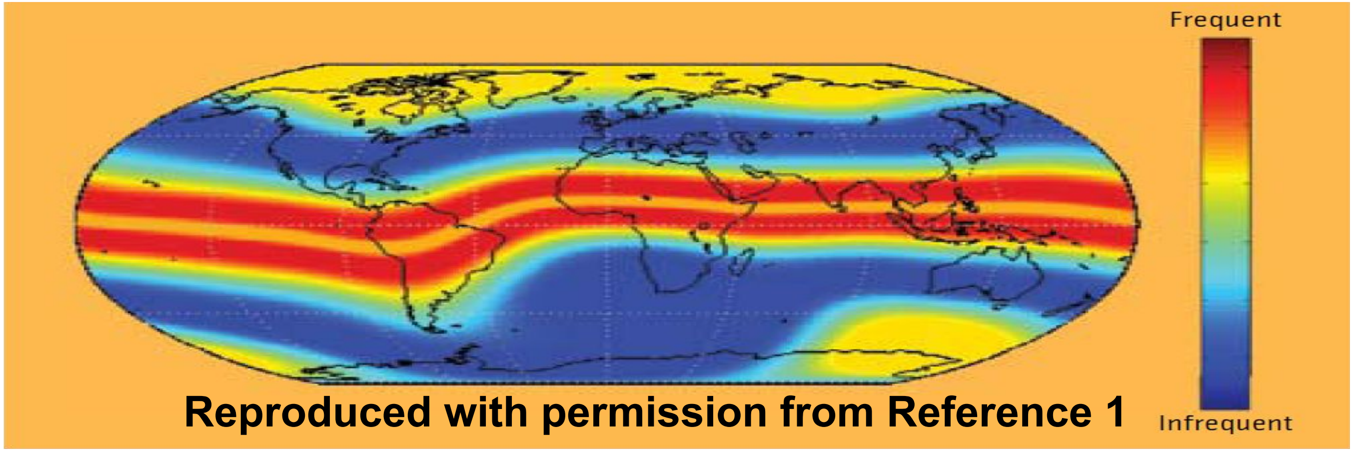
- The phenomenon is not specifics to, or produced by, the platform, satellite or receive site.
- The phenomenon is…
  - Travel path dependent.
  - Time varying both on diurnal and sub-second scales.
  - Primarily affecting platforms located in South America.
  - Causing extreme amplitude fluctuations in DCS messages.
- Varying Amplitude
  - Short time scales only caused by coherent effects, e.g. multipath interference.
  - Early in the transmission can prevent carrier lock resulting in missed messages.
  - Later in the transmission can cause loss of phase reference resulting in parity errors.
- Conclusion …

Ionospheric Scintillation

- Ionosphere:
  - Part of the upper atmosphere, it consists of multiple layers beginning at 85 km and ranging to 600 km. Scintillation effects occur around 350 km.
  - Consists of electrons and molecules ionized by UV radiation from the Sun.
  - Creates refraction and diffraction of DCS radio signals.
- Scintillation:
  - Refraction: Creates unexpected phase shifts.
  - Diffraction: Creates amplitude and phase variations due to multipath summing and cancellation.
- Solar Cycle:
  - Approximately every 11 years the Sun enters a period of increased solar activity, known as the solar maximum.
  - During this time the UV radiation increases, which increases ionospheric scintillation.

Ionospheric Scintillation Impact

- Affects frequencies from HF (3 MHz) to L-Band (2 GHz).
  - DCS Uplink UHF (402 MHz)
  - DCS Downlink L-Band (1.694 GHz)
- Tropical latitudes are effected the most, with scintillation typically begins after sunset and last several hours.
- Most significant around the equinoxes, but can occur year round



Reproduced with permission from Reference 1

Why Now?

- Approaching solar maximum (May 2013).
- Growth in DCS usage since last solar maximum (2000).
  - Especially growth in South America.
- Transition to HDR since last maximum.
  - 100 bps modulation is not impervious to scintillation effects.
  - However, ±60º bi-phase modulation has more phase margin than 8-phase modulation.
  - Also, HDR also led to more frequent transmissions.
- Deployment of additional large receive sites.
  - EDDN and NSOF have provided ability to do receive site comparisons.
- Improvements in reception equipment (DAMS-NT) and database software (DADDS).
  - Address message issues on much smaller percentage scale.
  - Database provides historical research tool.

What Can Be Done in the Short Term?

- Advise GOES DCS Users of the problem.
  - GOES-East platforms in South America, southern Central America, and the southeastern Caribbean will be most affected.
  - GOES West platforms located within 20° of the equator will be most affected.
  - Receive sites located in South America and in the equatorial anomaly region could experience time-of-day outages in the GOES DCS downlink.
- Focus on Data Loss Mitigation
  - Since there is no immediate solution to minimizing transmission impact from ionospheric scintillation.
  - Send prior data in each transmission.
    - Repeat data in 2 or even 3 transmissions where possible.
    - Use Pseudo-Binary to reduce message length to allow for prior data.

What Can Be Done in the Long Term?

- Implementation of a Binary Message Format to better allow more redundant information in each transmission.
- Reception from Multiple Paths?
  - Receive East channels from GOES-West and vice versa.
  - Not all locations have visibility to both satellites.
- More Frequent/Redundant Transmissions?
- Resurrection of the Interleaver?
  - Since scintillation affects individual messages on a sub-second time scale, interleaving ***may*** help reduce message data loss.
- Use of Linear Polarized Antenna?
  - Since scintillation can affect the horizontal and vertical components of a circularly polarized transmission differently, using linear polarized antenna ***may*** improve transmission throughput.
  - Using linear polarization will require 3 dB increase in uplink power.
- Wait it Out? Will never completely go away, but will subside after solar maximum.

References

1. Paul M. Kintner, Jr., Todd E. Humphreys, and Joanna C Hinks, "GNSS and Ionospheric Scintillation How to Survive the Next Solar Maximum", *Inside GNSS*, July/August 2009. www.insidegnss.com
2. Dave Anderson and Tim Fuller-Rowell, "The Ionosphere", *Space Environment Topics*, NOAA, SE-14 1999, http://sec.noaa.gov.
3. Guozhu Li, Baiqi Ning, and Hong Yuan,"Analysis of ionospheric scintillation spectra and TEC in the Chinese low latitude region", *Earth Planets Space*, 59, 279–285, 2007.
4. Stephen M. Hunt, Sigrid Close, Anthea J. Coster, Eric Stevens, Linda M. Schuett, and Anthony Vardaro, "Equatorial Atmospheric and Ionospheric Modeling at Kwajalein Missile Range", *Lincoln Laboratory Journal*, Volume 12, Number 1, 2000.
5. Darrel Emerson, "Elliptical Polarization in the Ionosphere", 1998 http://www.tuc.nrao.edu/~demerson/ionosphere/ionopol.html

END OF PRESENTATION

“THANK YOU” FOR YOUR ATTENTION