Protecting the DSN from RFI from Earth Orbiters: Experience, Tools Development Status and Lessons Learned

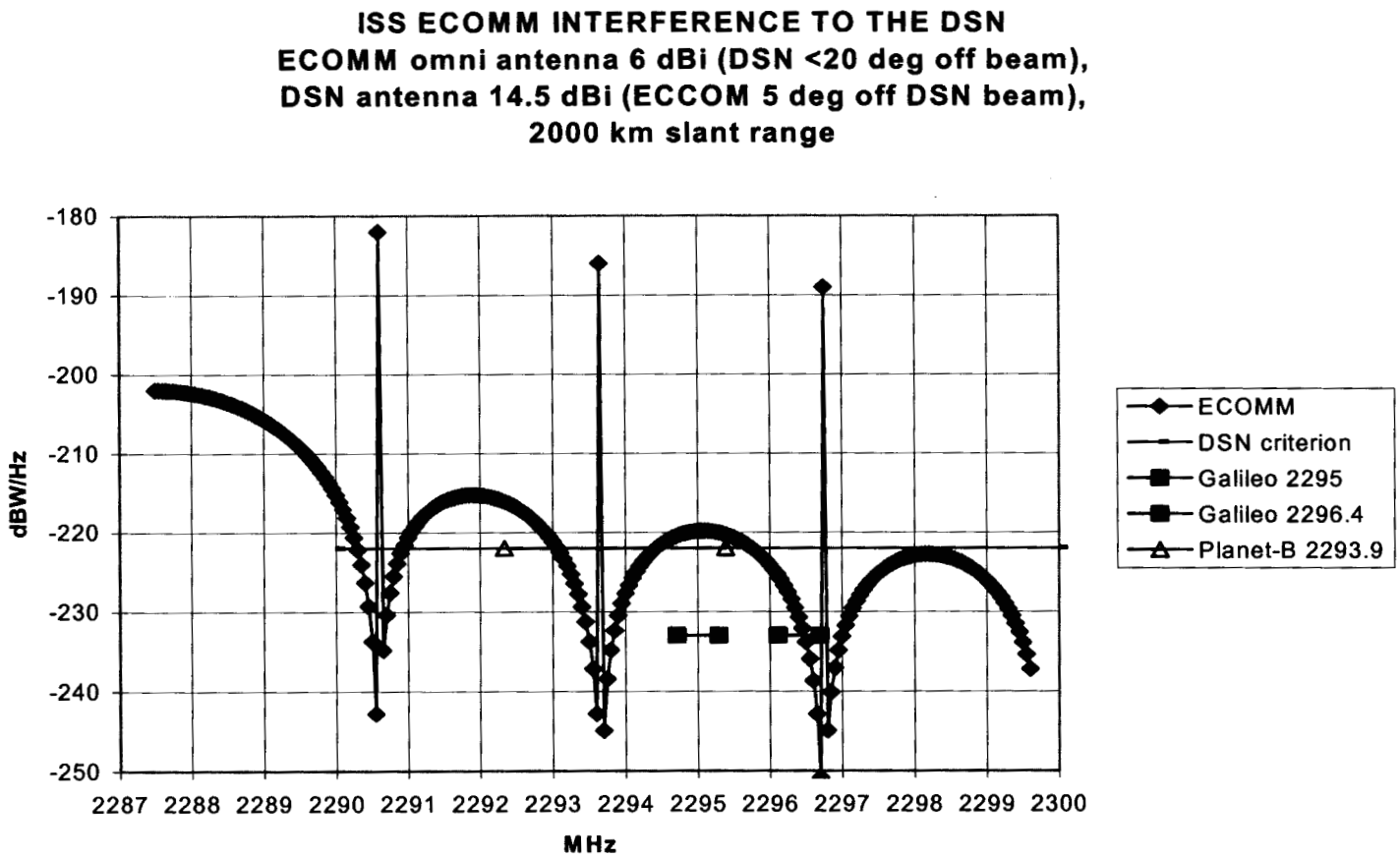
Presentation at the 2003 Radio Frequency Interference Forum,
March 18-19, 2003, Intelsat, Washington, D.C.

Miles K Sue, Farzin Manshadi, Ted Peng
Jet Propulsion Laboratory
(818) 354-4394
Miles.k.sue@jpl.nasa.gov

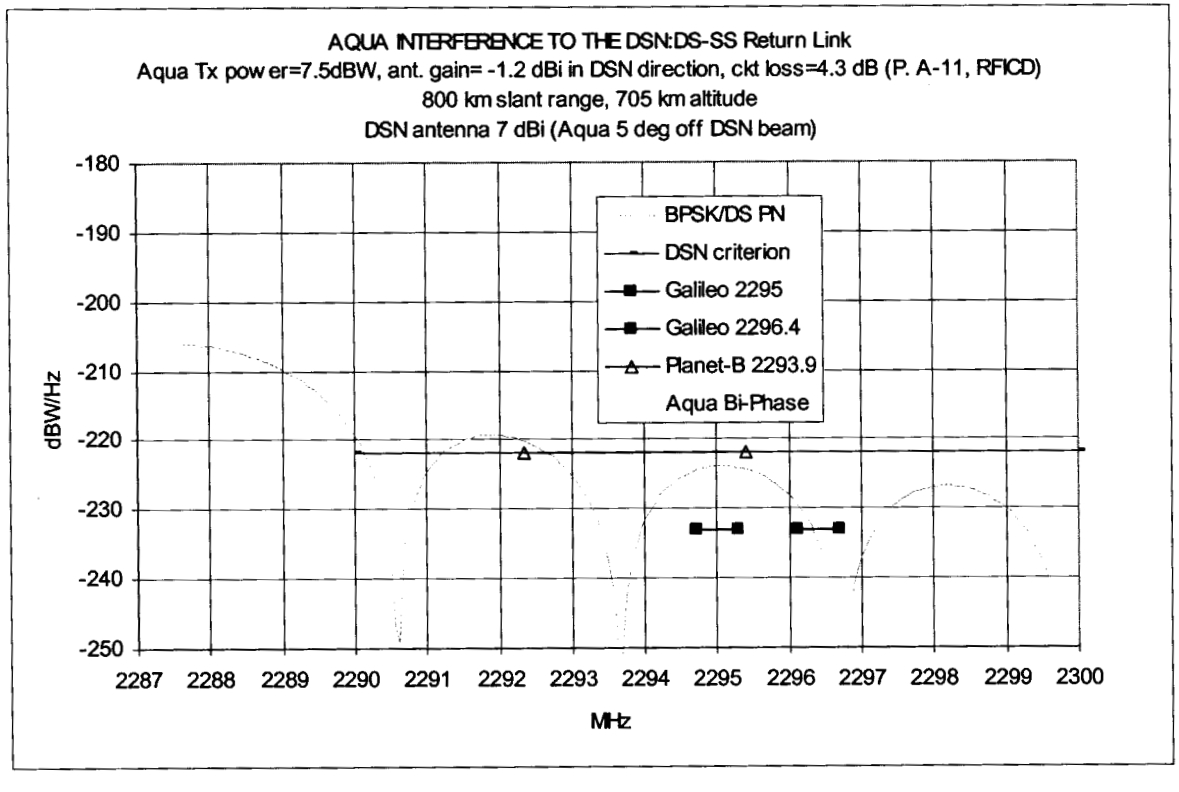
Introduction

- DSN is susceptible to RFI from Earth Orbiters operating in bands adjacent to the DSN bands. DSN bands most vulnerable to RFI are
  - 2290-2300 MHZ (S-band)
  - 8450-8500 MHz (X-band)
- Earth Orbiters operating in adjacent bands can interfere with the DSN, because
  - Signals from a spacecraft in deep-space are extremely weak, requiring an extremely sensitive receiver. The DSN protection criteria are
    - -222.5 dBW/Hz for S-band, and
    - -220.9 dBW/Hz for X-band
  - The sidebands of a high-rate earth orbiter can easily spillover in the DSN bands and interfere with the DSN
- Deep-space communications links need to be free from harmful interference because of the unique deep-space environment
  - Interference can result in a loss of receiver lock and a loss of data
    - re-acquisitions can take up to tens of minutes depending on the received signal strength
  - Loss of critical science or engineering data due to RFI can impact the success of a mission
    - Lost data may not be readily retrieved, due to the long propagation time and loading of the DSN
    - Recovery of lost data is costly
- The challenge is to prevent potential RFI at the source

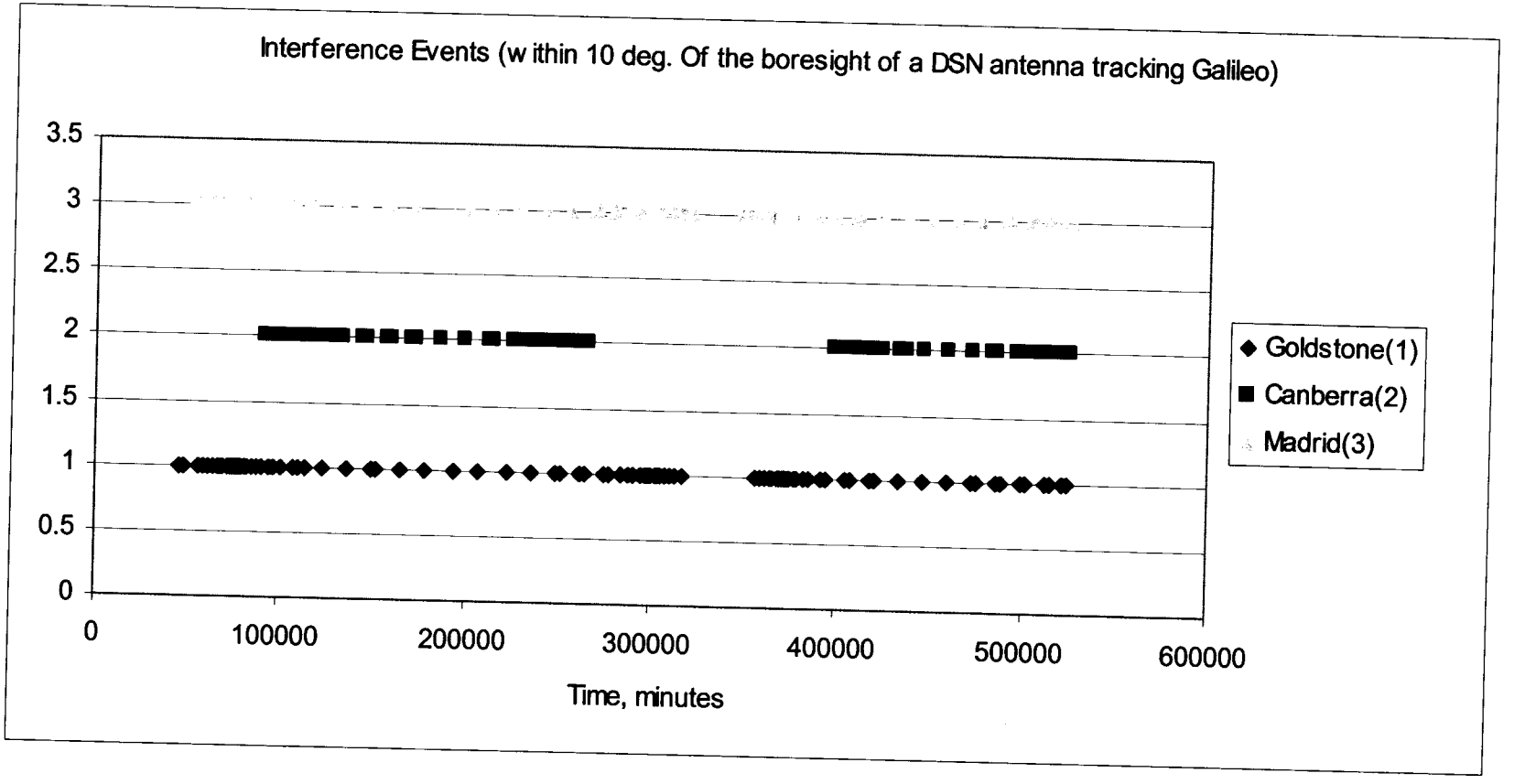
An Example of S-band Interference: ECOMM Interference to DSN, at 5 deg off DSN Antenna Beam



An Example of S-band Interference: Aqua Interference to DSN, at 5 deg off DSN Antenna Beam

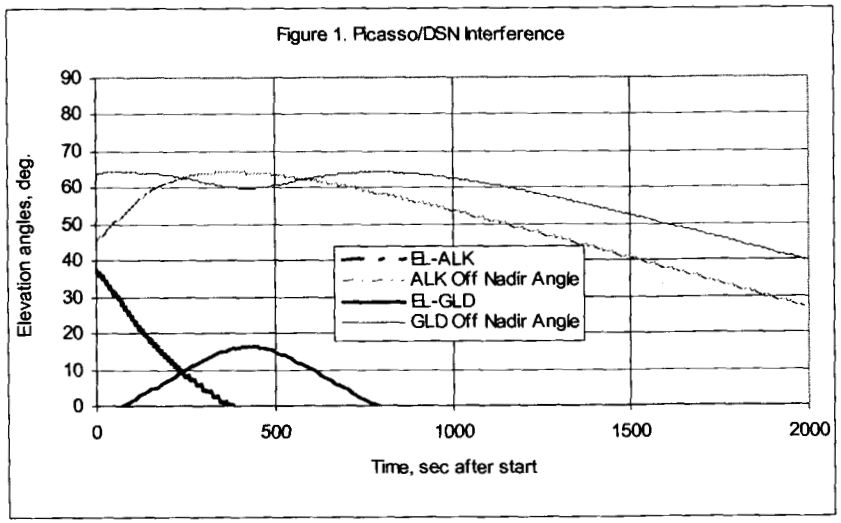


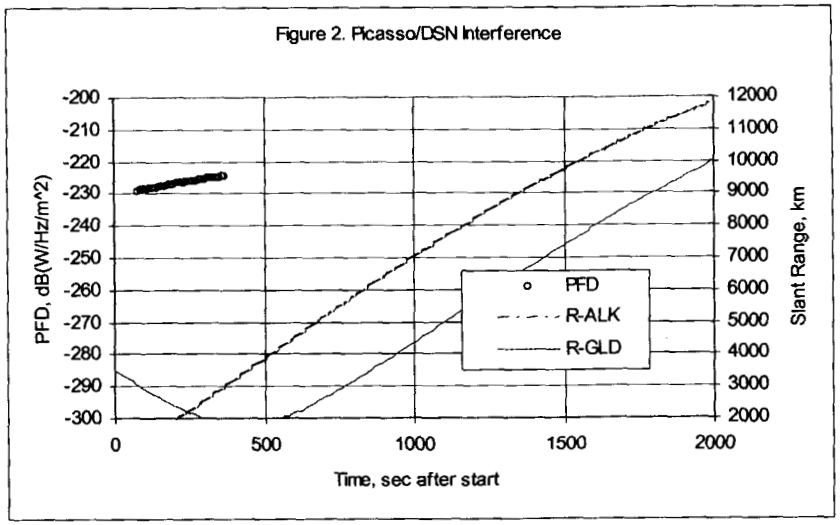
Simulation of Interference Events



-A SOAP simulation for 1 year indicates that an polar orbiter (with 700 km circular orbit) would come within a 10 degrees cone angle of a DSN antenna tracking Galileo 70-100 times for a total of 100-120 minutes, depending on the specific DSN site

An Example: Picasso Interference to DSN





-Deep-Space Stations protection criterion for X-band:
-255.1 dB(W/m^2-Hz)

-Picasso when downlinking to a station in Alaska can interfere with the DSN stations in Goldstone through sidelobe coupling

-For example, Picasso downlink can exceed the DSN protection criterion by about 30 dB

Tx power (9W)	9.5 dBW
Tx circuit loss	1 dB
Tx ant. gain towards Goldstone	0 dBi
Spreading loss (2150km)	138 dB/m^2
Signal bandwidth	79 dB-Hz
(80 Mbps, QPSK, 80 MHz Null-to-Null)	
PSD roll-off (8450 MHz, 8333MHz)	18 dB
SPFD at DSN	-226 dB(W/m^2-Hz)

-Similar interference to other deep-space stations exists if and when they are visible by Picasso when downlinking to a near-by ground station

-Filtering is needed to avoid interference

Approaches in Protecting the DSN against Harmful RFI from Earth Orbiters: Operational Coordination

- One of the approaches is to establish an operation coordination agreement with the interfering satellite to terminate transmission when potential RFI to the DSN exists
  - Conduct necessary analysis and/or testing to
    - Establish a protection zone around the DSN, and, in some cases, demonstrate the existence of potential harmful RFI
  - Establish agreed-to coordination procedures, which generally require
    - Transfer on a regular basis information between the DSN and the interfering Earth orbiter mission/ project
      - DSN tracking schedules, critical events, etc.
      - Updated Earth orbiter trajectory and link parameters
    - Conduct necessary analysis to predict potential RFI, i.e., identify conflict periods
    - Implement and upload necessary commands to turn off transmissions during conflict periods
- Examples: Terra, ATV, and GP-B
- Drawbacks
  - Added costs to both the project and the DSN
  - Loss of coverage for the earth-orbiters
  - Errors in trajectory/schedules can miss a conflict period, resulting in harmful interference

Operational Coordination with Terra
An Example

- Terra is an Earth Observing System, also known as EOS AM-1. It has an X-band direct broadcast mode operating at 8212.5 MHz. The data rate is 52.5 Mbps, using QPSK modulation. The 7th harmonic falls into the DSN X-band spectrum (8400-8450 MHz)
- Pre-coordination analysis based on the Terra link parameters indicated that Terra could cause interference to the DSN
  - At 40 degrees elevation, 15 dB increase in noise temperature
  - A spur at 8422.5 MHz with a magnitude of -139 dBm.
- Pre-coordination testing was performed to demonstrate existence of potential RFI

Operational Coordination with Terra
An Example (cont'd)

- Test Setup
  - Two tracks were chosen, each about 10 minutes, two DSN antennas in Goldstone (DSS13 and DSS24) supported this test, antenna pointing predicts were generated using two line elements
- Test Results
  - No signal was detected during the tracks, due to errors in antenna pointing predicts
  - Both the spur and increase in system noise temperature were observed and recorded at the end of the tracks after the DSN antenna had reached and stowed at the minimum elevation angle
    - Signal level and frequency were consistent with predicts
- Error in Trajectory (or antenna pointing predicts)
  - Post experiment analysis indicates the trajectory used to generate the antenna pointing predicts was about 13 sec too early, making it impossible for either DSN stations to detect the signal during the track
- Based on the analysis and test results, an Operational Coordination Agreement was established to protect the DSN

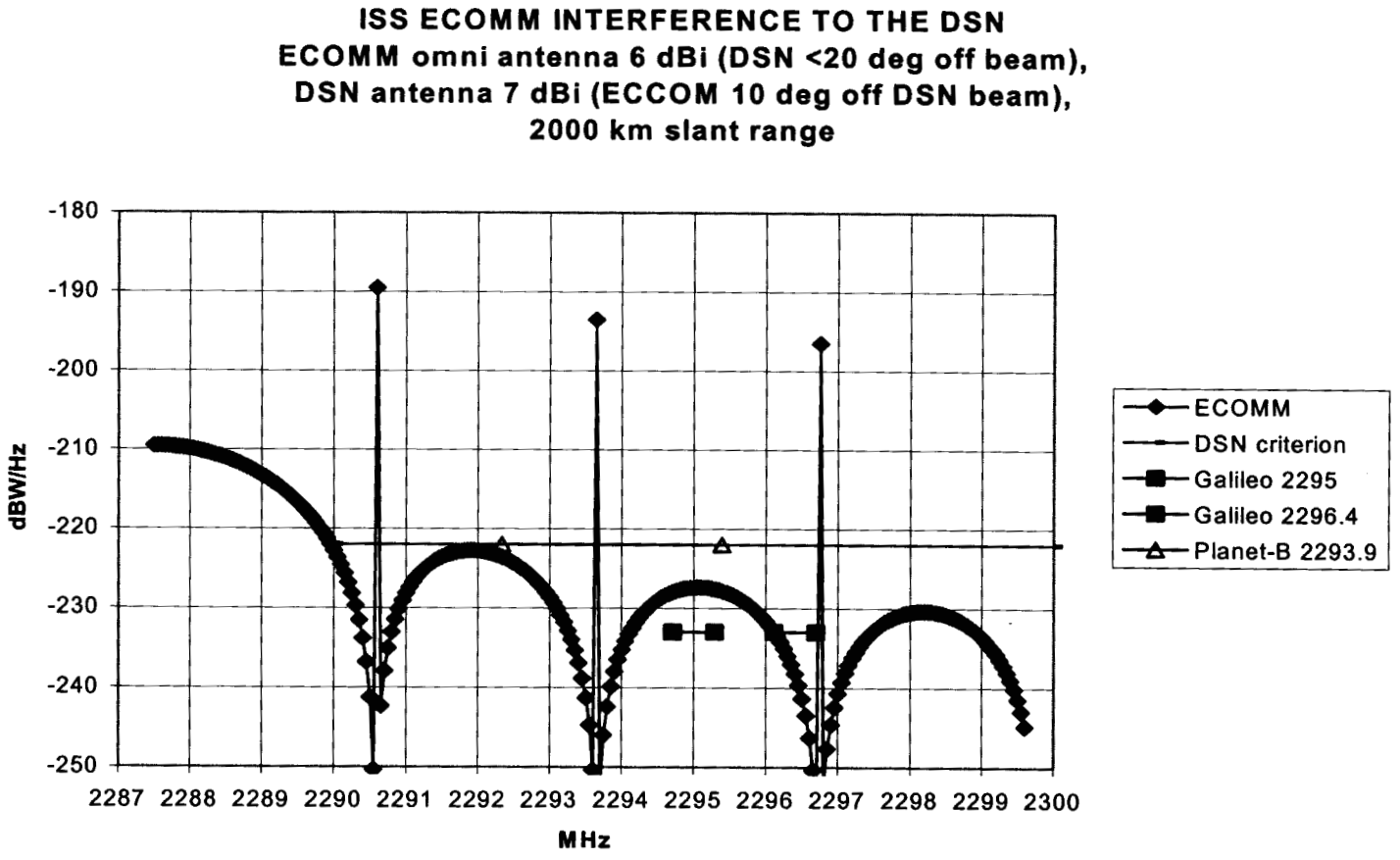
Approaches in Protecting the DSN against Harmful RFI from Earth Orbiters-On-board Filtering

- Another approach is for the Earth-orbiter to to employ filtering or other spectral shaping techniques to reduce the out-of-band emission
- Baseband pulse shaping can significantly reduce the out-of-band emissions and with little performance loss
  - Must be designed into the transmitter early, and
  - May require modifications on the ground
- Post-modulation filtering can also reduce the out-of-band emission, but can result in a larger mass and performance penalty
  - Examples: HTV, AQUA
- Advantages
  - Solves the RFI problems once for all; avoids the costs associated with operational coordination
    - Even if the filter does not provide 100% of the out-of-band attenuation needed to protect the DSN, it still can result in significant benefits by reducing the coordination zone , say form 10 degrees to 5 degrees
  - Little or no impact on coverage for the earth-orbiters

SOAP-based RFI Analysis and Prediction Tools Development Status Update

- Current approach and drawback
  - Interference analysis has been performed with a two step process
    - Generate link geometry using SOAP
    - Link and interference calculations were performed using Excel spreadsheet of Matlab, which can take various factors into account depending on the required accuracy:
      - Spectral shapes
      - Frequency offsets
      - Receiving filtering
    - Drawback
      - No direct interface between SOAP and Matlab/Excel
      - Geometry data from SOAP are passed to Matlab/Excel as ASCII files
        - For long simulation runs, the output files are huge
        - Loading these large files to Excel can be tedious and problematic
- New approach
  - Started an effort to modify SOAP to provide customized features for analyzing DSN RFI problem
  - First phase modification-added a feature to SOAP to reduce the size of the output file
    - Modifications completed
  - Second phase modification is to provide SOAP/Matlab interface
    - Allows Matlab functions/scripts be called from SOAP
    - This phase is or about soon to completed

DSN RFI Prevention
Lessens Learned

- The Terra example shows that RFI protection relying on operational coordination must use a very conservative approach because it is prone to errors
- Every effort should be made to prevent RFI at the source using ob-board filters to attenuate out-of-band emissions

An Example: ECOMM Interference to DSN, at 10 deg off DSN Antenna Beam