Spectrum Interference Testing in L-Band

May 1 - 3, 2007

Briefing Outline

- Background
- Methodology
- Interim Results
- Conclusions

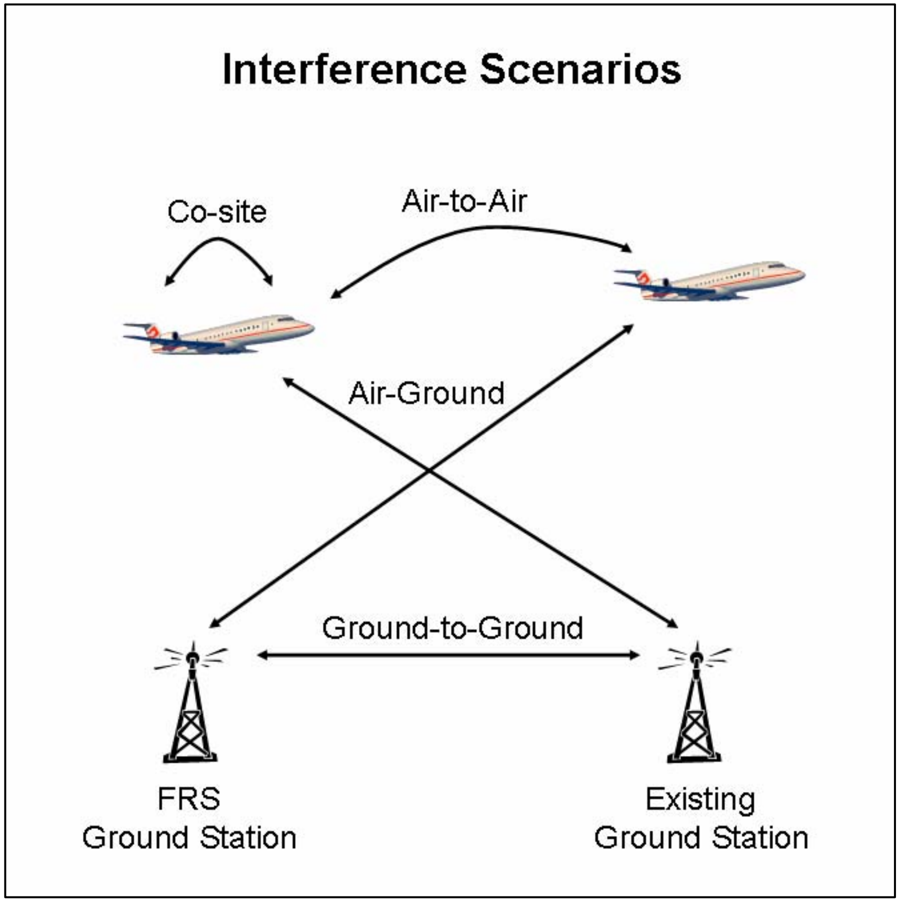
Background – Motivation for Study

- ICAO is considering the use of L-Band to employ the next generation aeronautical communication system

- In order to assess the viability of proposed communication systems in L-Band, a compatibility analysis must be performed that investigates the potential for interference from Future Radio System (FRS) candidates to systems already utilizing this spectrum

Background – Motivation for Study (2)

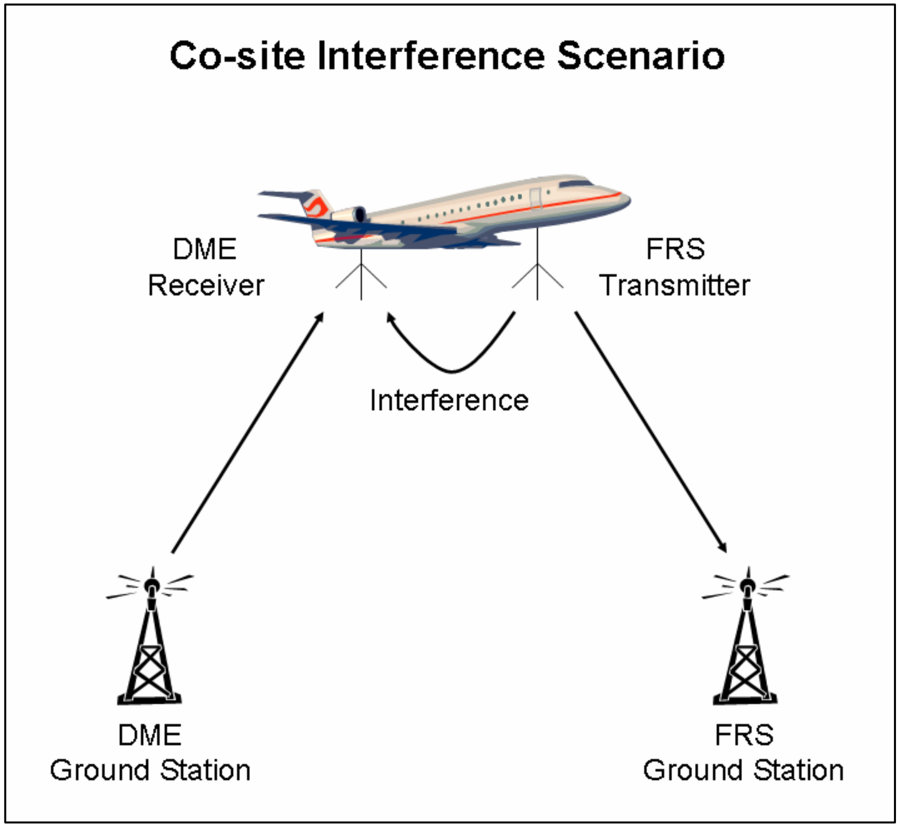
- A compatibility analysis of FRS's with existing systems in L-Band involves many potential interference scenarios
  - Co-site Compatibility onboard the aircraft
  - Air-to-Air Compatibility
  - Air-Ground Compatibility
  - Ground-to-Ground Compatibility



* Graphic recreated from: Vega, Elena, *Framework for Spectrum Compatibility Analysis in L-Band for FCI technology Candidates, AENA.*

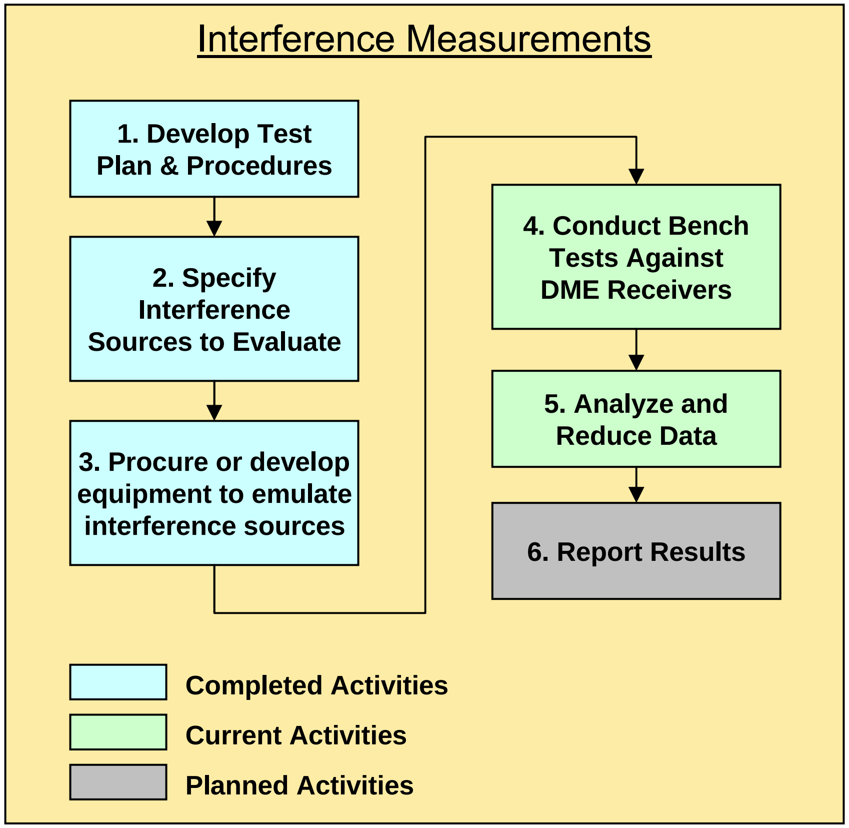
Background – Motivation for Study (3)

- The co-site scenario results in the largest interference power and serves as a guide for specifying the bounds on interference measurements
- Specifically, the co-site scenario lets test engineers know how much interference power is sufficient (i.e., should the measured data collection be satisfied with interference power levels of -20 dBm or are higher interference powers likely to be encountered in practice?)
- The measurements should encompass the power ranges that will be seen in practice



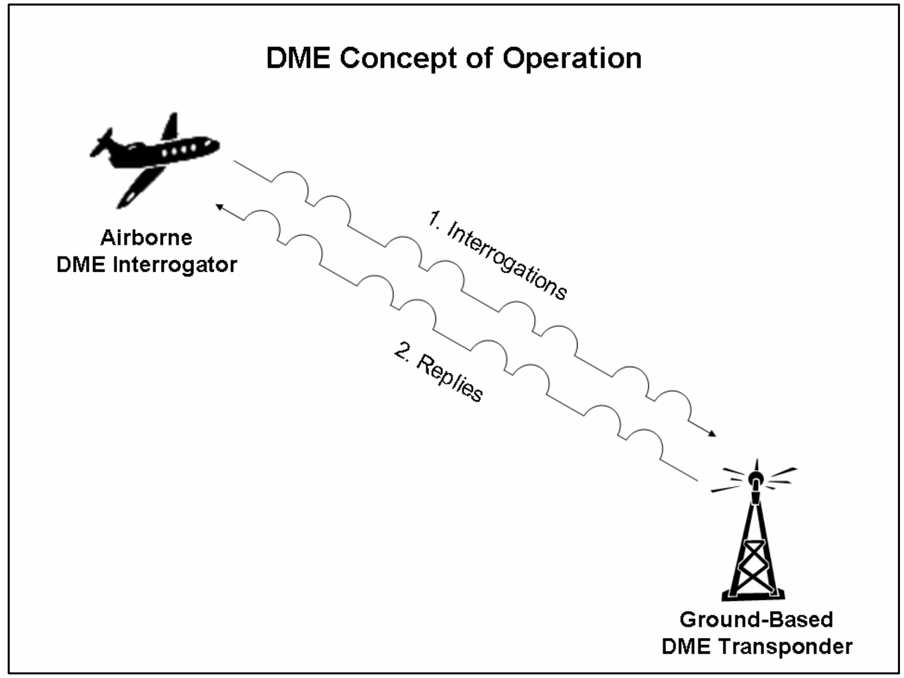
Background – Objective & Approach

- Objective
  - To further characterize the susceptibility of Distance Measuring Equipment (DME) to interference from the proposed FRS candidates
    - WCDMA
    - APCO P34 (TIA 902)
    - LDL
- Approach
  - This activity consists of the six interrelated tasks shown in the figure



Background – DME System Overview

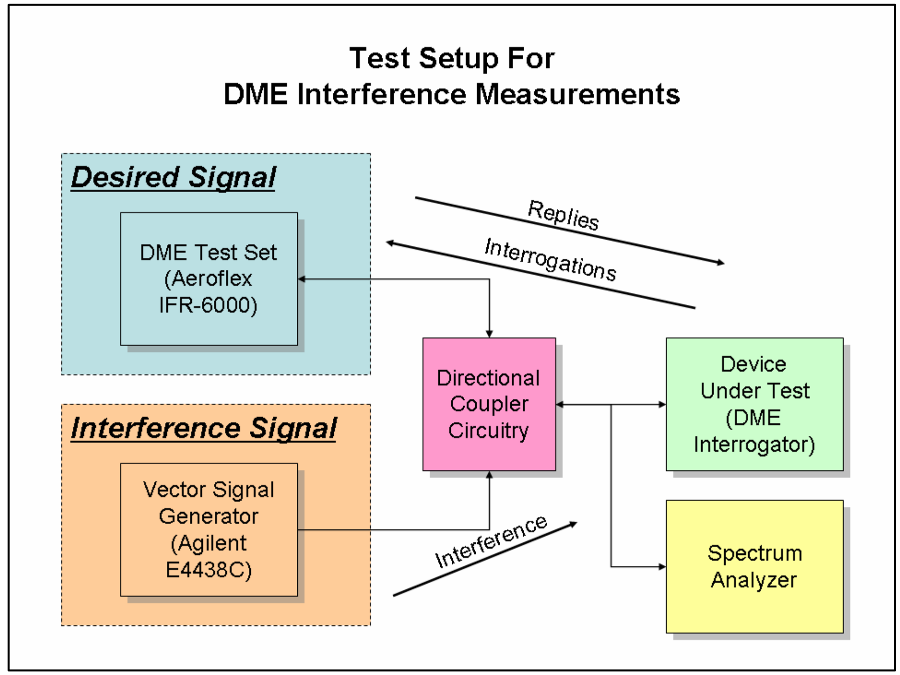
- The DME system is a navigational aid that provides slant range distance to aircraft
- DME consists of airborne and ground-based equipment, called interrogators and transponders, respectively
- The interrogator transmits paired pulses to the transponder which replies with its own paired pulse message
- The interrogator measures the time elapsed between its own transmission and reception of the transponder's response, which is then used to calculate the slant range distance



- The DME system operates in the frequency band 960 – 1215 MHz
- DME allocations are spaced in 1 MHz increments allowing for 126 channels for interrogations and 126 channels for transponder replies

Methodology – Test Setup

- The test setup for the interference measurements study is shown in the figure
- The basic testing methodology is to observe the response of the Device Under Test (DUT) in the presence of interference
- Interference is injected into the system at various frequency separations where signal levels are adjusted to levels that induce a standard response from the DUT
- For DME, the standard response is defined by two metrics: Acquire Stable Operating point (ASOP) and Break Stable Operating Point (BSOP)



Term	Definition*
ASOP	Desired Signal Level at which bearing, ident, & range lock on consistently
BSOP	Desired Signal Level at which either bearing, ident, or range breaks lock

* Source: EMC Analysis of JTIDS in the 960-1215 MHz Band (March 1978)

Methodology – Test Equipment

- This study focuses *only* on the existing airborne avionics

- Device Under Test
  - Two DME interrogators have been selected as the DUT
    - **BF Goodrich Flight System TX-670 DME/TACAN Transceiver**
    - **Rockwell Collins 900 (still being procured)**

- Test Set
  - A multi-mode Test Set was selected for this task that receives and replies to DME interrogations
    - **Aeroflex IFR-6000**

- Interference Source
  - The interference source is being emulated by the
    - **Agilent E4438C Vector Signal Generator with options**
      - 005: 6 GB Hard Drive for storing waveform files
      - 400: W-CDMA Personality
      - 504: Up to 4 GHz
      - 602: Baseband Generator

- Spectrum Analyzer
  - The spectrum analyzer being used for this study is the
    - Hewlett Packard 8591E

Methodology – Test Cases

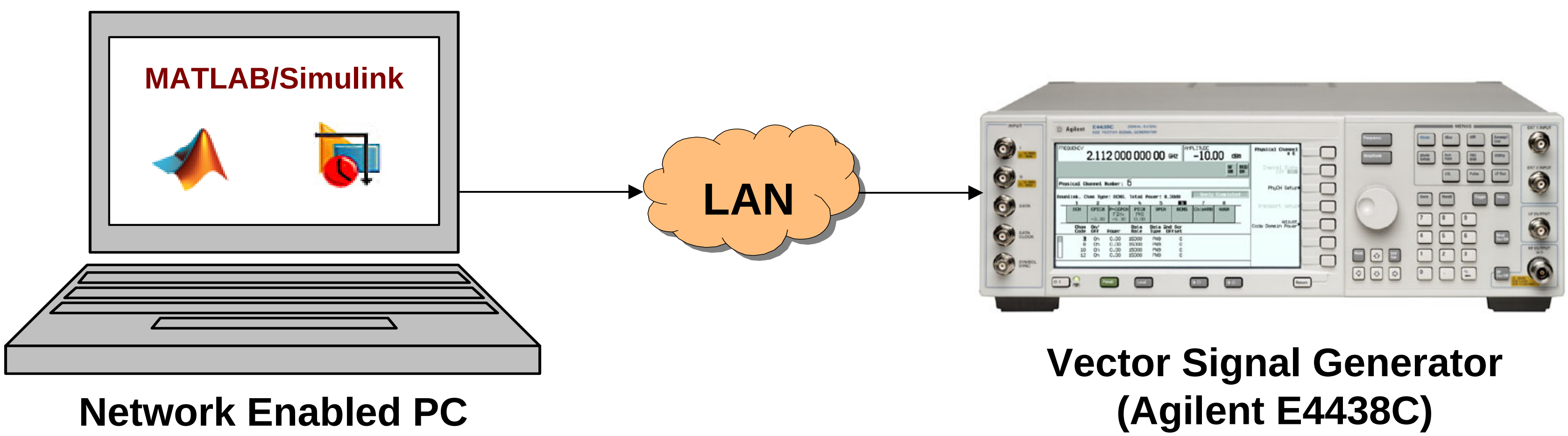
- The test cases that comprise the interference measurements study are
  1. Receiver Sensitivity
  2. Transmission Emission Spectrum
  3. Co-channel Interference
  4. Adjacent-channel Interference

- The test procedures for each test case were derived from MIL-STD-449D: *Measurement Of Radio Frequency Spectrum Characteristics*

- Example Test Procedures
  – Find receiver sensitivity
  – Set interference level to maximum allowable power (~ +20 dBm)
    - Set DME Reply Signal Level to 3 dB above receiver sensitivity
  – Find frequency separation, Δf, where (desired signal) induces standard response
  – Then for each frequency pair, ±Δf
    - Set DME Reply Signal Level to 3 dB above receiver sensitivity
    - Adjust Interference Source Signal Level to find ASOP/BSOP
    - Increase DME Reply Signal Power in 10 dB increments
    - Adjust Interference Source Signal Level to find ASOP/BSOP
  – Repeat test by cutting Δf in half until frequency separation is within 3 dB bandwidth of DME Reply Signal (±½Δf, ±¼Δf, etc.)

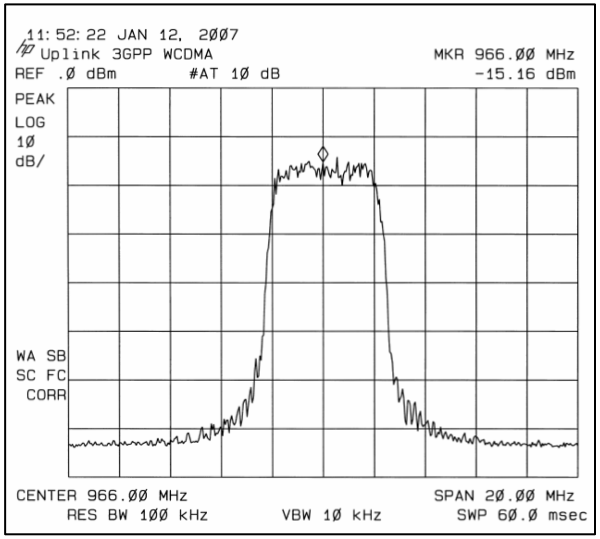
Methodology – FRS Waveform Development

- For WCDMA
  - Option 400: WCDMA Personality was preinstalled on the E4438C
- For P34 & LDL
  - Develop Transmitter models in MATLAB/Simulink
  - Capture & format waveforms in MATLAB workspace
  - Transfer waveforms over LAN to Vector Signal Generator
    - Using Agilent Download Assistant (MATLAB Library)
  - Verify Waveform Spectrums on the Spectrum Analyzer

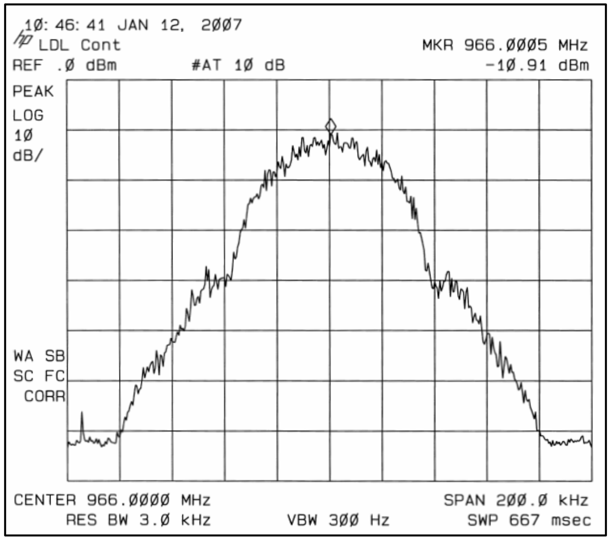


Interim Results – Simulated Emission Spectra

W-CDMA

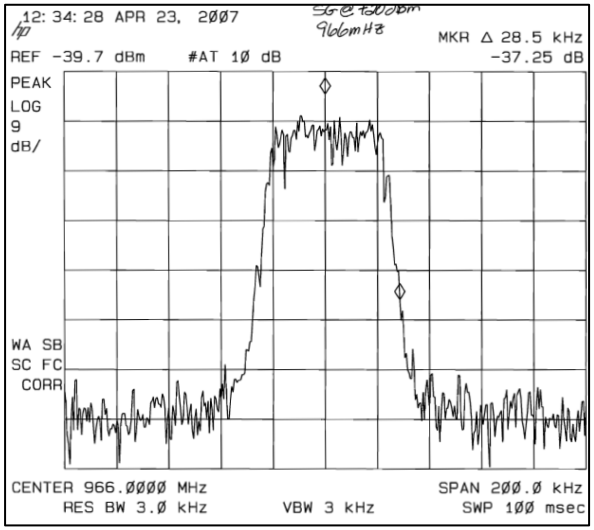


LDL

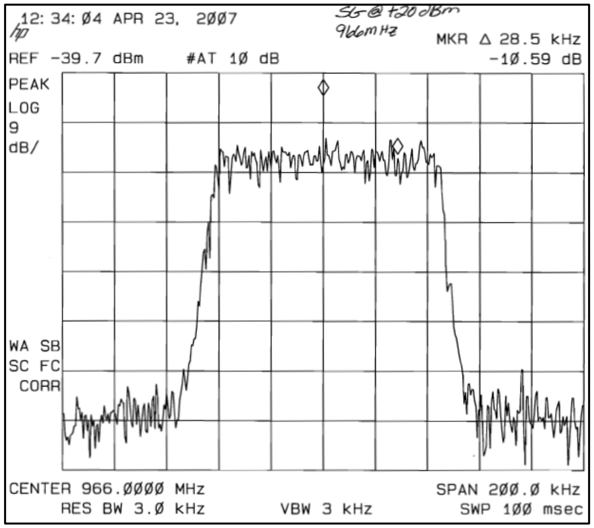


Note: The horizontal axes in these plots are not all the same scale

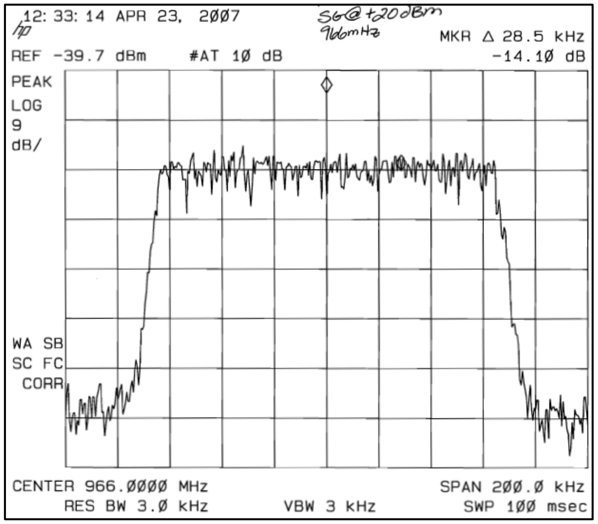
P34-50kHz



P34-100kHz



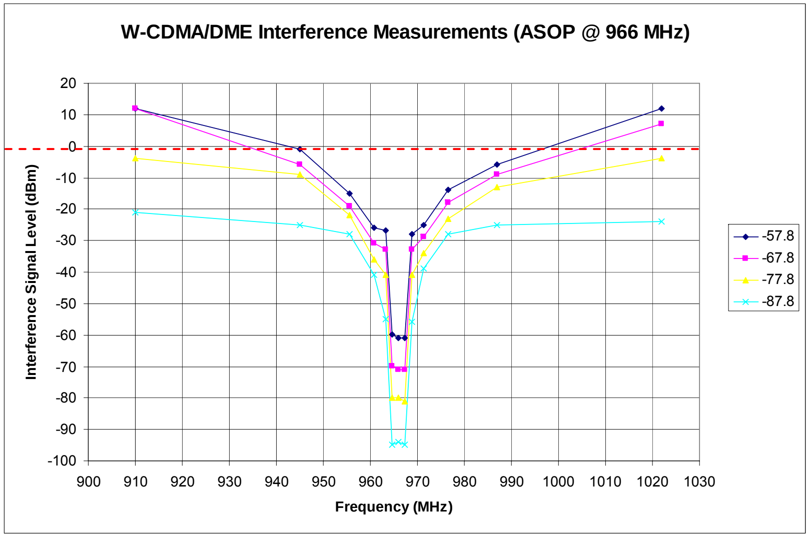
P34-150kHz

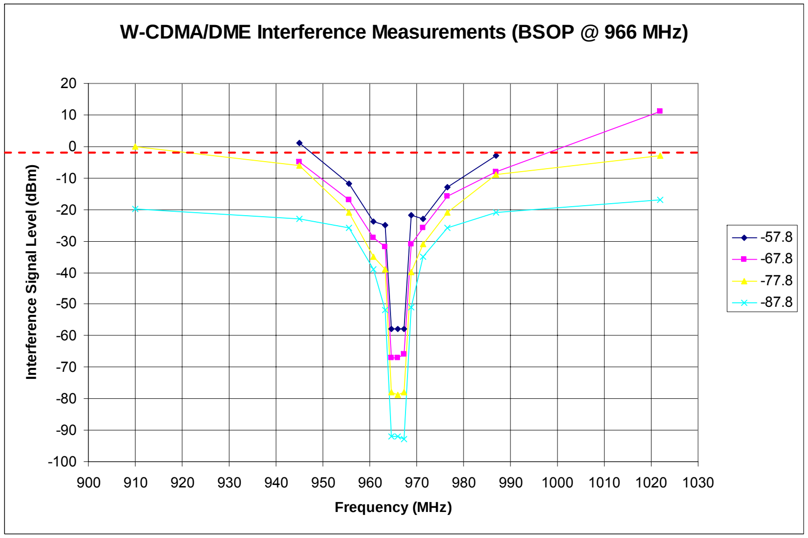


Interim Results – W-CDMA Interference to DME

- These charts show results for W-CDMA/DME interference measurements
  - DME is tuned to 966 MHz
- Conclusions:
  - Link budgets for W-CDMA use a transmit power of 33 dBm[1]
  - Typical values for antenna isolation range from 30-35 dB
  - Even at frequency separations of 10-20 MHz, W-CDMA would cause DME to lose lock

$$P_U = P_T - C_L$$
$$P_U = 33\text{ dBm} - 35\text{ dB}$$
$$P_U = -2\text{ dBm}$$





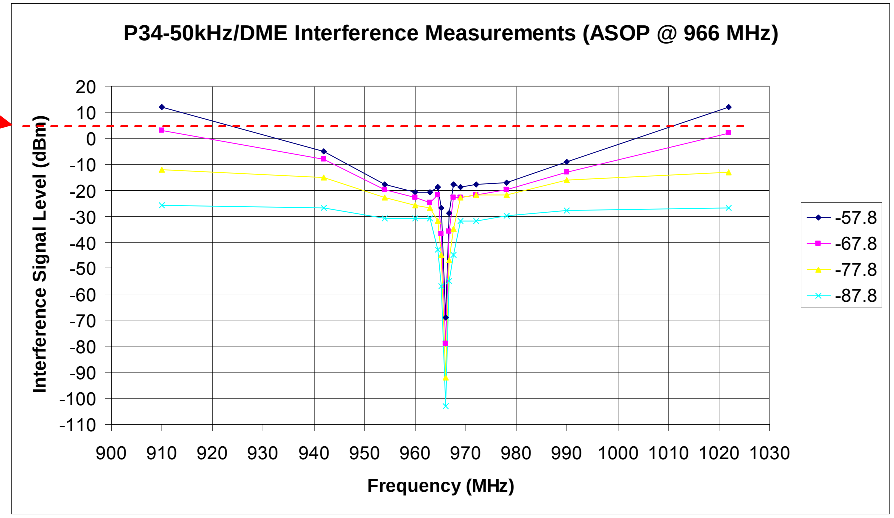
[1] *Dobrosavljevic, Z, A. Arumugam, 2006, L-Band 3G Ground-Air Communication System Interference Study, Issue 1, Hampshire, UK, Roke Manor.*

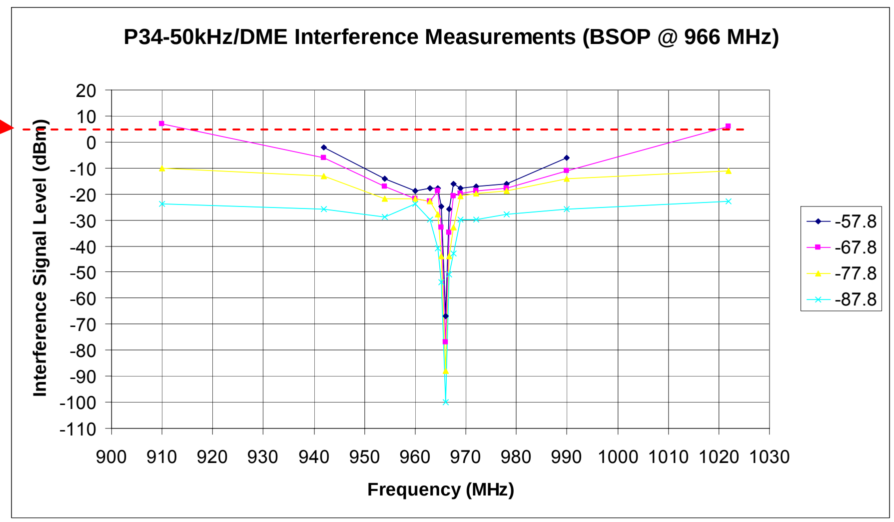
Interim Results – P34 (50 kHz) Interference to DME

- These charts show interim results for P34-50kHz/DME interference measurements
  – DME is tuned to 966 MHz

- Conclusions:
  – Link budgets for P34 use a transmit power of 40 dBm
  – Typical values for antenna isolation range from 30-35 dB
  – Even at frequency separations of 10-20 MHz, P34 would cause DME to lose lock

$$P_U = P_T - C_L$$
$$P_U = 40\ \text{dBm} - 35\ \text{dB}$$
$$P_U = +5\ \text{dBm}$$

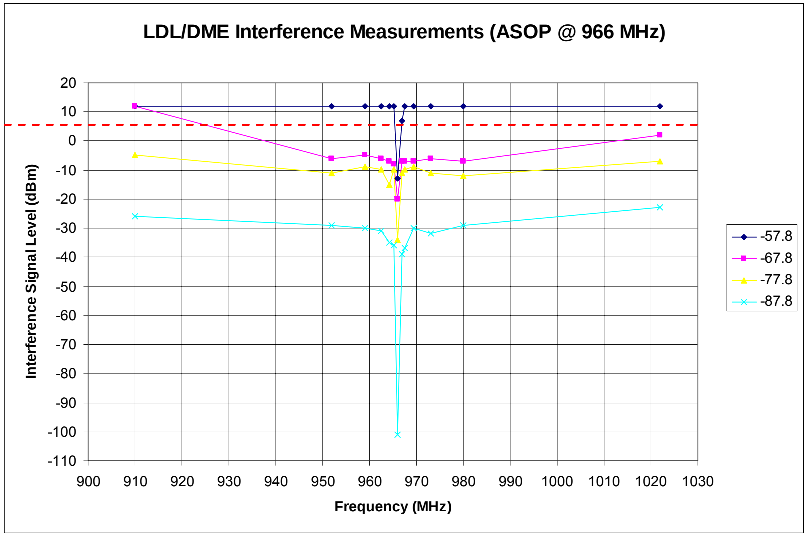


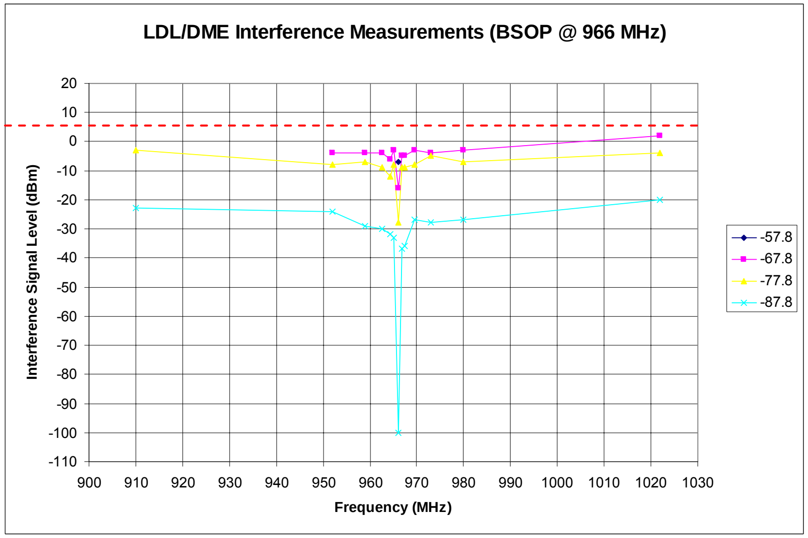


Interim Results – LDL Interference to DME

- These charts show interim results for LDL/DME interference measurements
  - DME is tuned to 966 MHz
- Conclusions:
  - Link budgets for LDL assume a transmit power of 40 dBm
  - Typical values for antenna isolation range from 30-35 dB
  - Even at frequency separations of 10-20 MHz, LDL would cause DME to lose lock

$$P_U = P_T - C_L$$
$$P_U = 40 \text{ dBm} - 35 \text{ dB}$$
$$P_U = +5 \text{ dBm}$$





Conclusions

- The first pass of measurements indicates the presence of transmitter broadband noise in the interference source
  - This can be attributed to excess quantization noise in the vector signal generator
- A second pass of measurements will be conducted using additional filtering
  - An L-Band tunable bandpass filter has been procured to facilitate these additional measurements
  - The bandpass filter will be used to reduce the noise floor from the interference source
  - Results for these measurements should be available in the May 2007 timeframe