EMI Considerations for 10GBASE-T

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Outline for Discussion

- Analysis of issues
- Sample test configurations
- Antenna and current-probe measurements
- General observations

Objectives of Initial Study

- Determine media suitability for wideband signaling
  - Cat 5e UTP
  - Cat 6 UTP
  - Cat 5e ScTP (with floating screen ONLY)
- Identify components/configurations which may be limitations
  - Connectors
  - Patch cords
  - Span length
  - Distance from ground plane
  - Cable deformations (sharp bends, etc.)

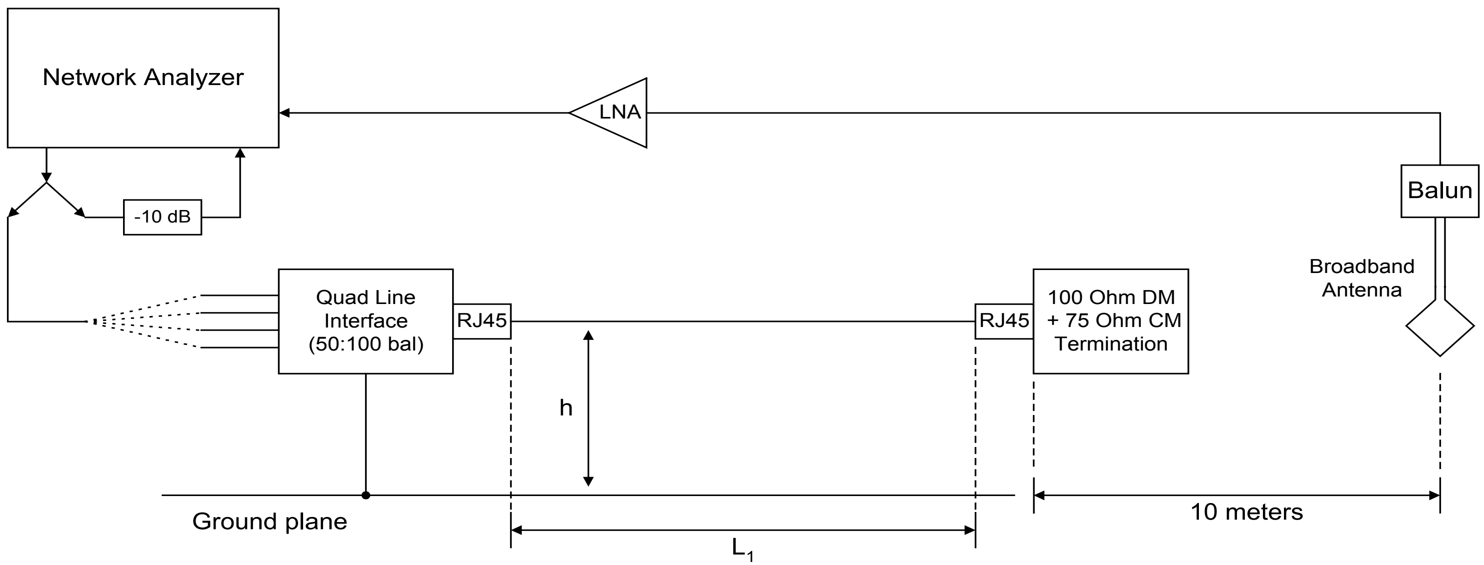
Factors Affecting EMI Levels

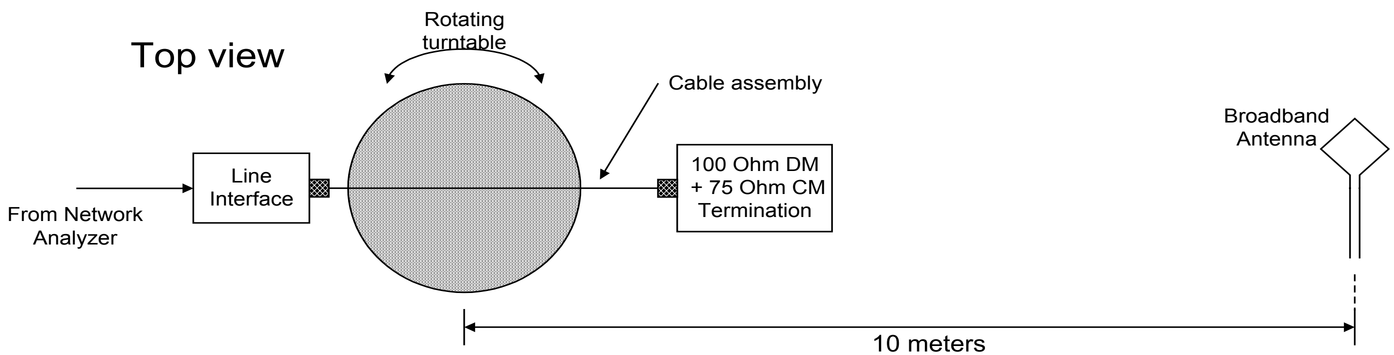
- Signaling design
  - Line code bandwidth
  - Launch power
  - Transmit PSD
- Line interface and cable components
  - Common-mode conversion at line interface balun
  - Channel discontinuities
  - Distance from balun interface
    - Strongest radiation occurs within 10 meters of interface
- Common-mode radiation is dominant
  - Cable acts as lossy long wire antenna
- Differential-mode radiation is small
  - Proximity of pair conductors (small radiating loop area)
  - Twisting conductors causes field cancellation

EMI Radiation Measurement

- Measurement method
  - Direct radiation measurement on FCC certified test range.
- Transmit 10 dBm frequency sweep on each pair
  - Measure resulting electric field at 10 meters
  - Maximize over various orientation angles and antenna polarizations
    - Generates VERY pessimistic result (worst-case envelope)
- Generate signal-to-radiation transfer function from data
- Plug transmit PSD into transfer function
  - Calculate electric field at over 100 kHz bandwidth
    - Add 50 dB to PSD level (dBm/Hz) to obtain power over 100 kHz BW
  - Use shaped PAM-10 PSD (10 dBm) for all evaluations
- Add 12 dB for peak power measurement requirement
- Measure simple 3.6 meter terminated span
  - Maximum span measurement limited by physical size of test facilities, specifically DUT mounting table

EMI Radiation Measurement Setup

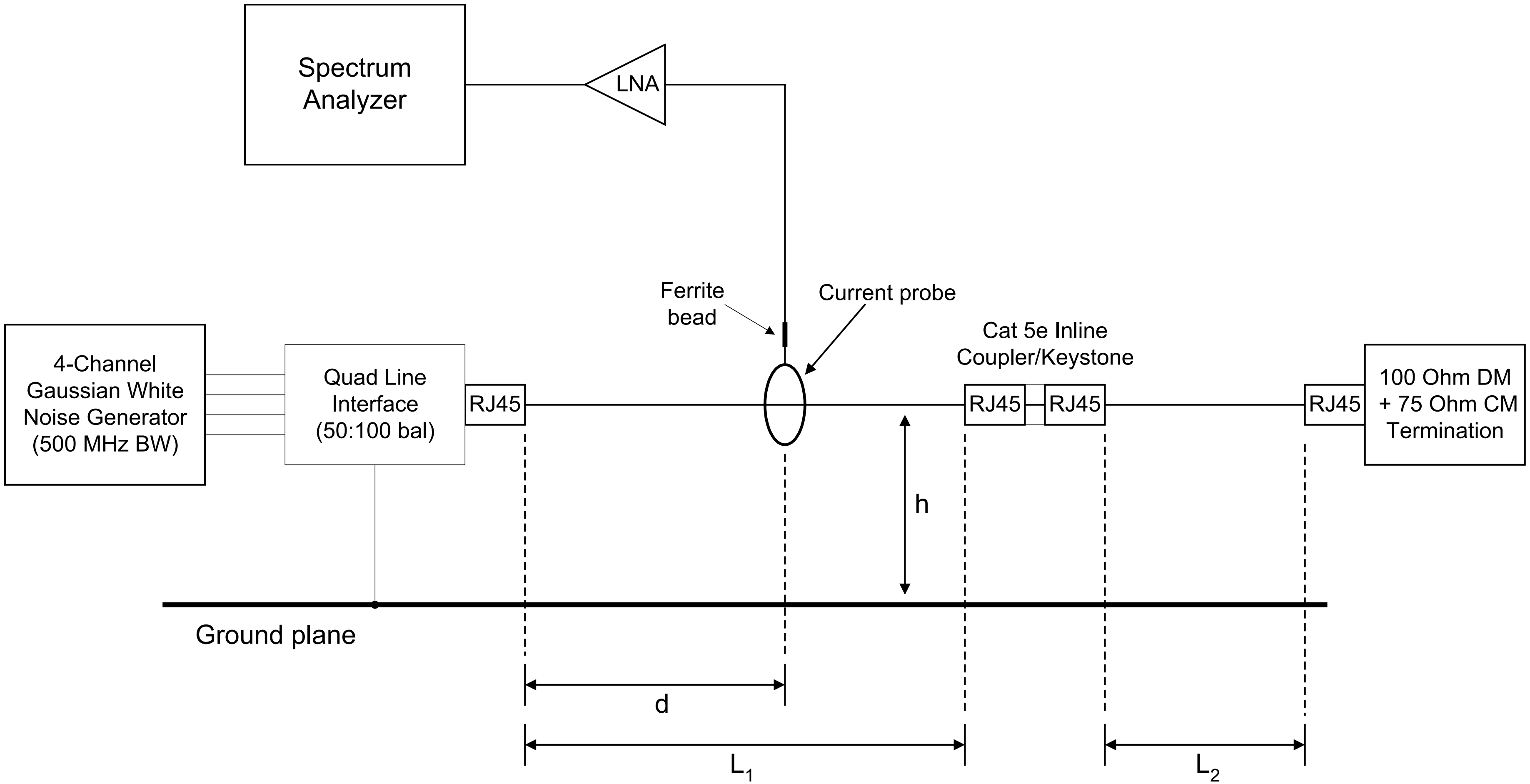




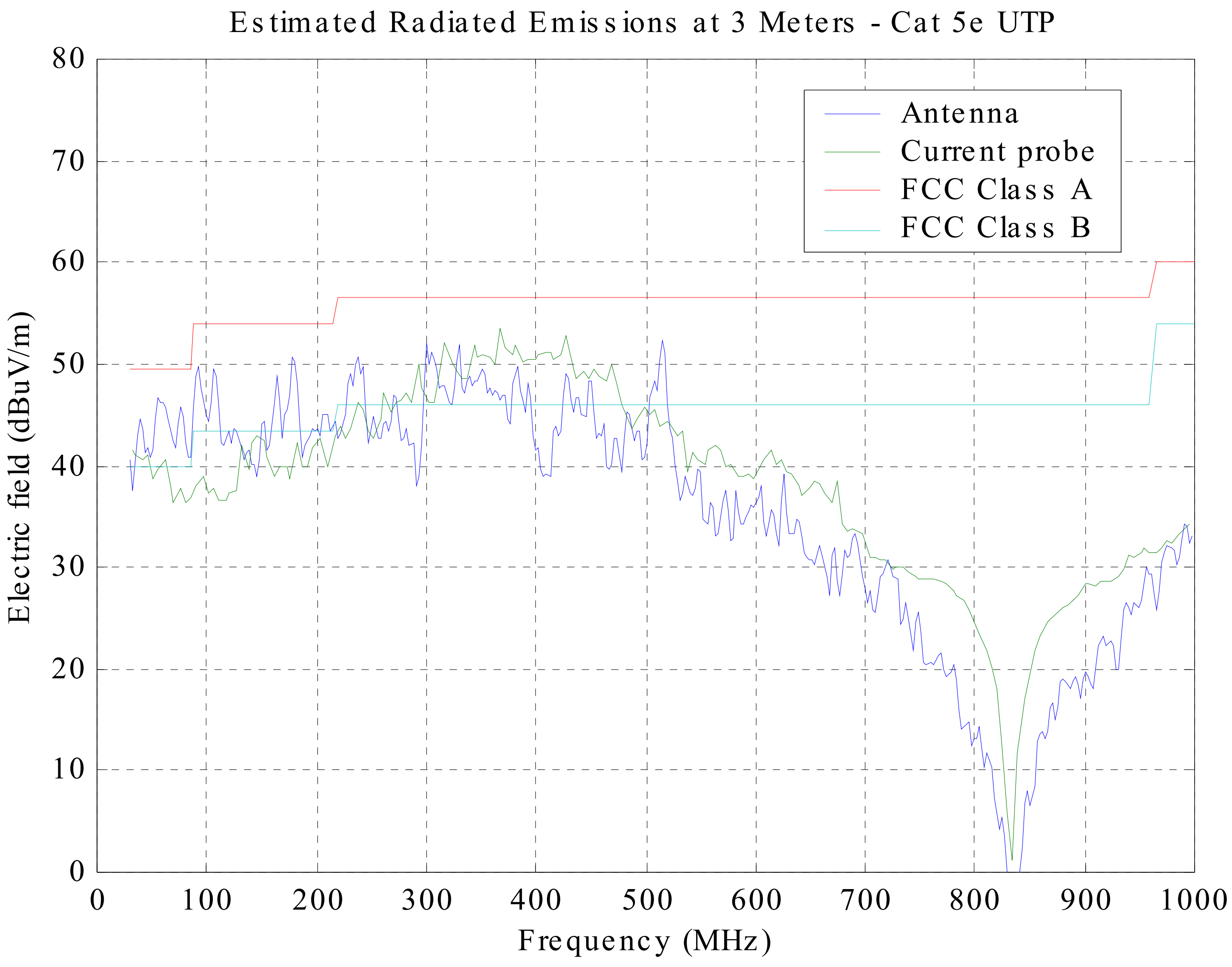
Current Probe EMI Measurement

- Introduced to allow frequent measurements
  - Valuable for line interface and termination design
- Estimate radiated field from common-mode antenna current
  - Measured with magnetic current probe
  - Correlated to direct EMI radiation measurements
  - Common-mode radiation dominates differential mode radiation
- Wideband Gaussian white noise generator signal source
  - Test signal launch power = 8 dBm (after line interface)
    - Measurement corrected for actual 10 dBm transmit PSD
- Repeat measurements many times
  - Probe position *d* is moved in small steps along cable span *L1*
  - Captures min/max of standing waves
- Maximum current at each frequency used in equation
  - Derive estimate of radiated electric field strength (Terman)
- Equation calculates worst case (pessimistic) estimate
  - Open terminated resonance condition

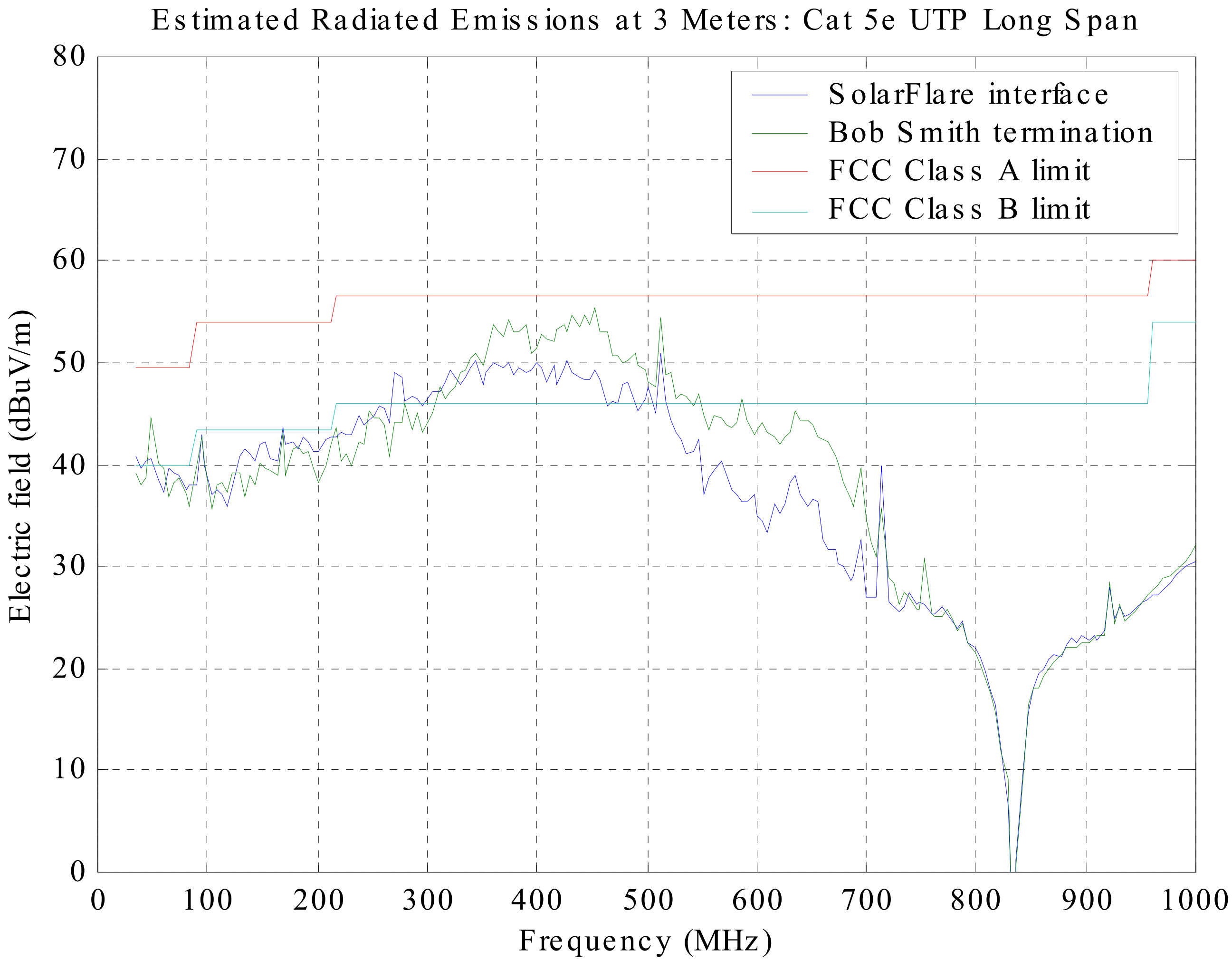
Current Probe EMI Measurement Setup



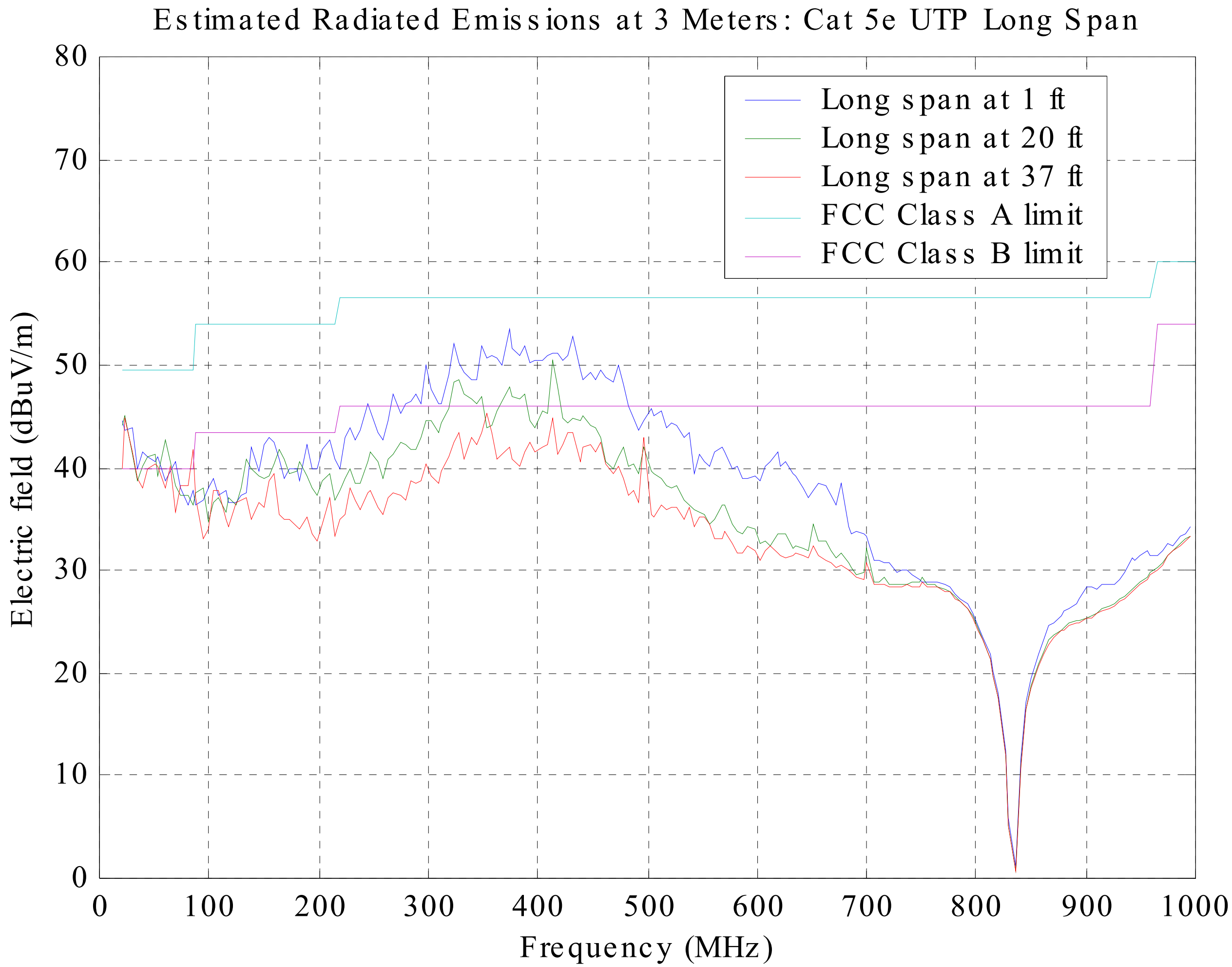
Radiation vs. Current Probe Correlation



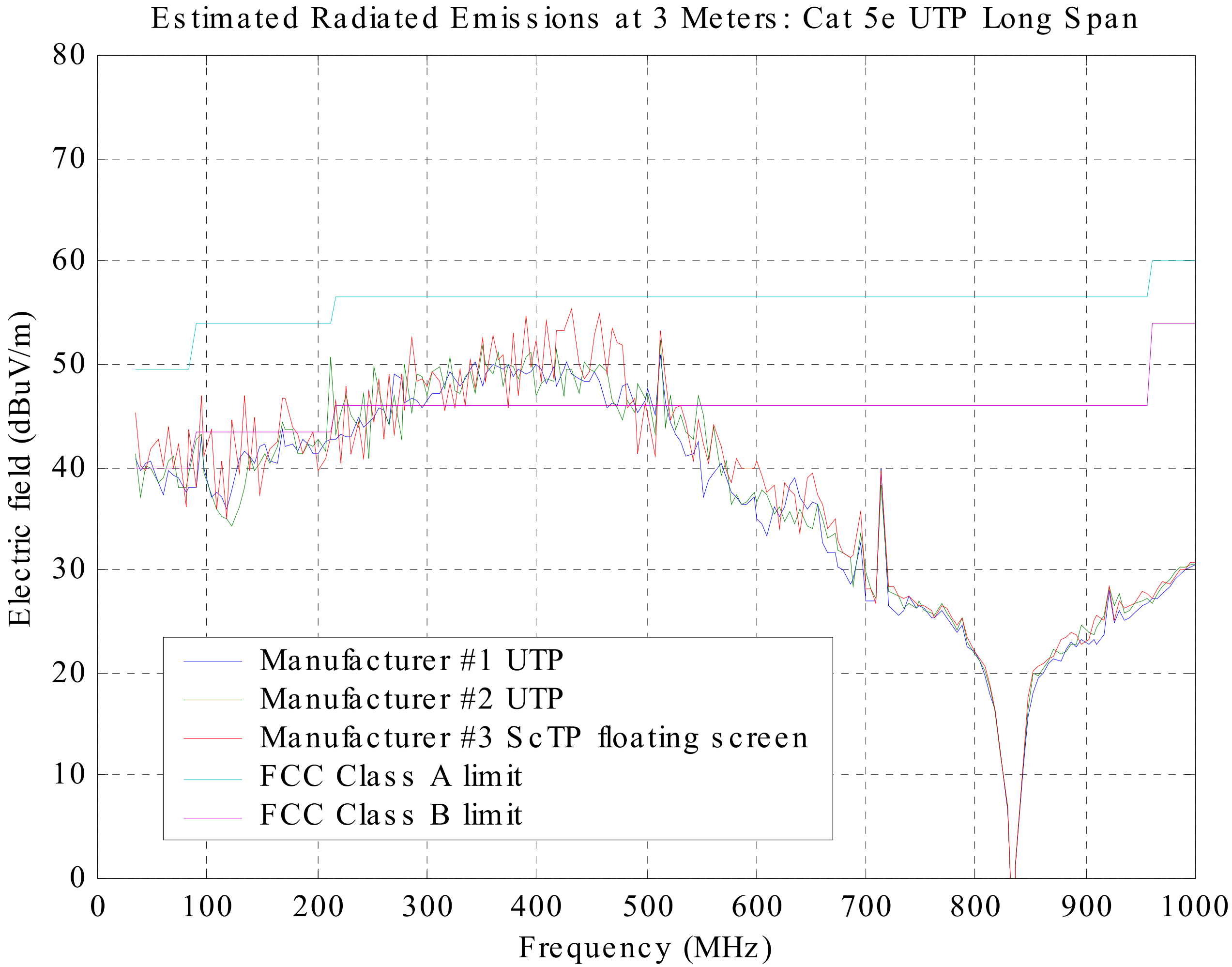
EMI Effect of Line Interface



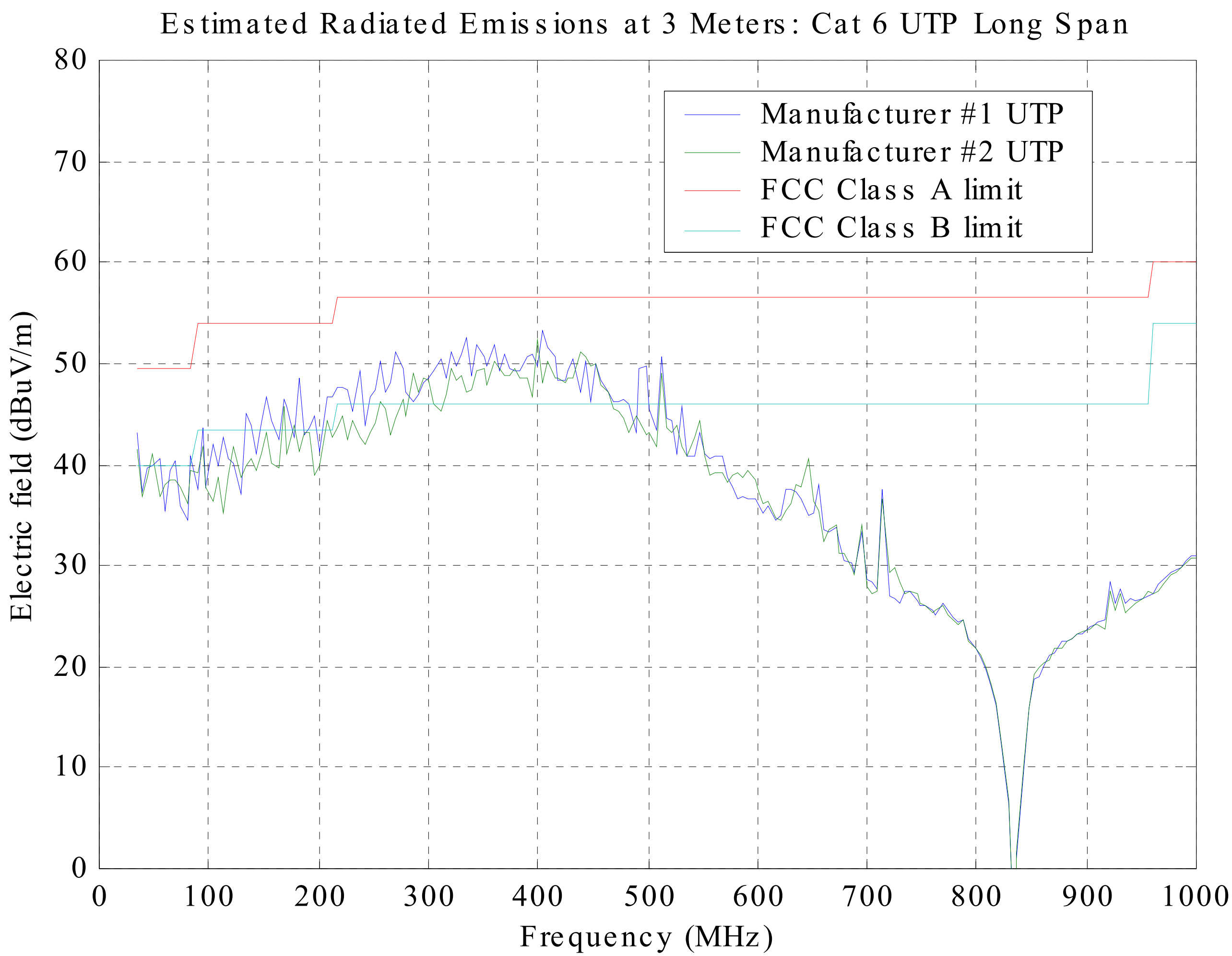
Radiation vs. Distance from Line Interface



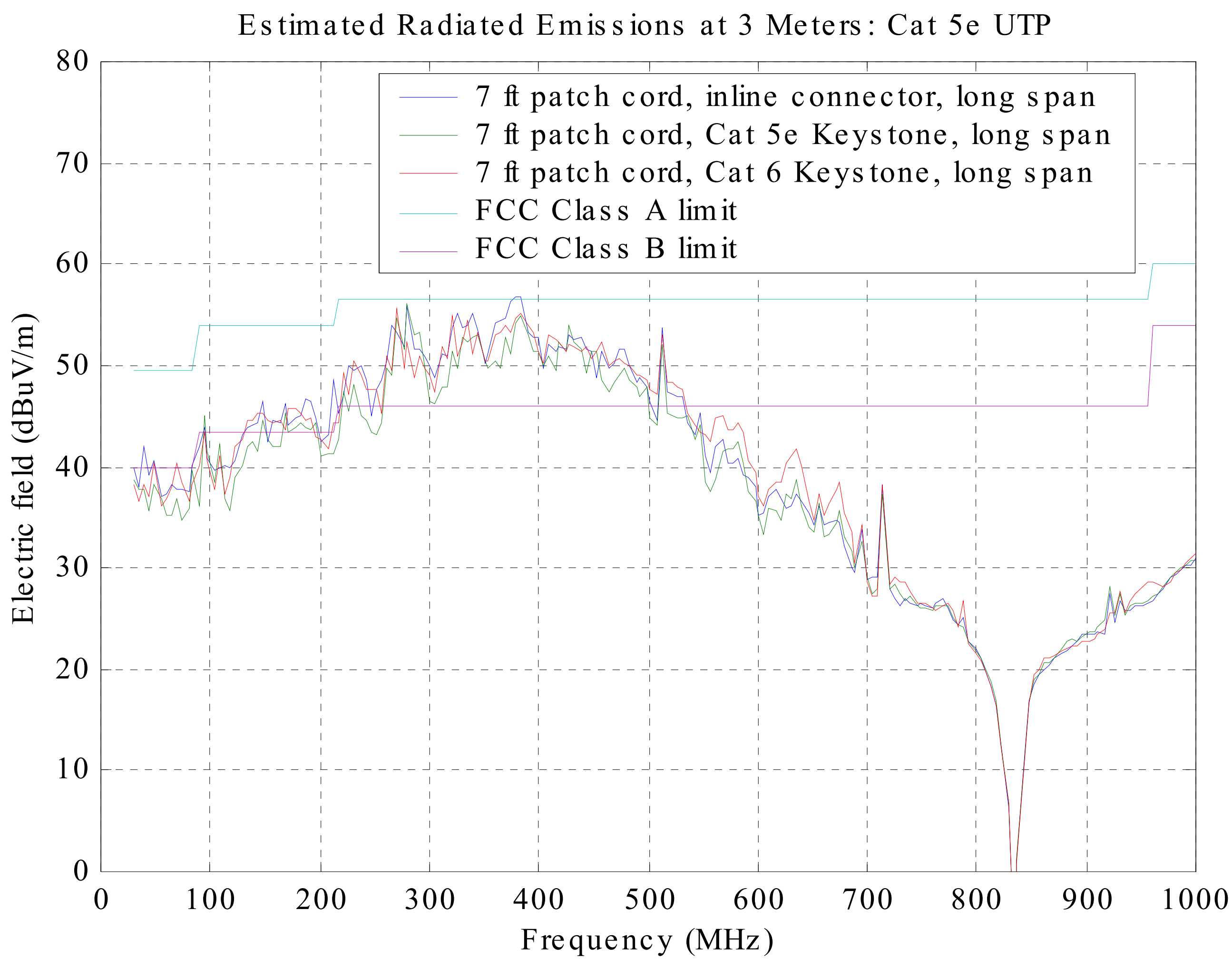
EMI Comparison of Cat 5e Cables



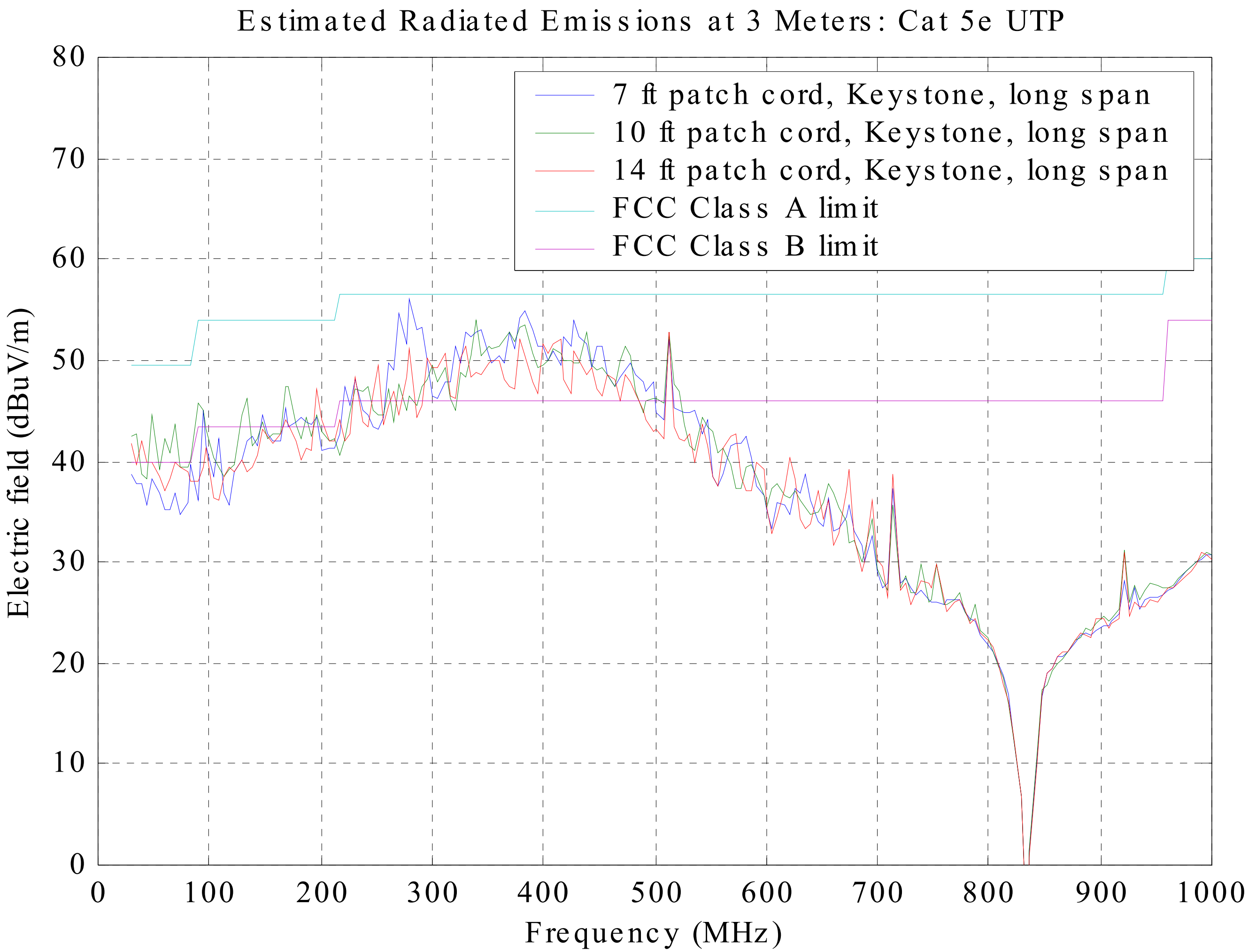
EMI Comparison of Cat 6 Cables



EMI Effect of Connector Discontinuity



EMI Effect of Patch Cord Length



General Observations

- Cat 5e and Cat 6 UTP cabling systems can support wideband signals without violating FCC Class A limits
- The cable itself does not present a problem
- Dominant EMI issues
  - Common-mode radiation
  - Line interface design
    - Refinement will only improve results
  - Common-mode discontinuities: connectors, sharp bends, etc.
  - Screen termination (ScTP only with floating screen)
- Testing should concentrate on higher frequencies
  - Signal level below 50 MHz is at or below 1000BaseT levels
- SF will assist others with independent verification

References

- [1] Terman, F., Radio Engineers' Handbook, McGraw-Hill, New York, 1943.
- [2] Paul, C.R., Introduction to Electromagnetic Compatibility, John Wiley & Sons, Inc., New York, 1992.