CMNR Test Applications and Limitations

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Overview

- **Purpose:** Discuss the practical application and limitations of the common-mode noise rejection (CMNR) test as defined in 802.3 for various high-speed data rates.
  - Intended for use in the 802.3 CMNR tutorial document
- Introduction and origin of the CMNR test
- Discussion of the need for the CMNR test in the standard
- Discussion of potential common-mode (CM) impairment injection test methods
- Discussion of limitations of CMNR testing and why it is still extremely useful
- Description of possible CMNR test methods
- Next steps
- **This presentation is an initial version which will be revised for future meetings**

Introduction to the CMNR Test

- The present clamp-based CMNR test was introduced in 1000Base-T as a method of determining PHY sensitivity to interference from external electromagnetic (EM) fields
  - Old common-mode rejection test (from 10Base-T and earlier) was not suitable for the wider bandwidth of 1000Base-T and succeeding higher data rate standards
- What is the relationship between common-mode signals and external EM fields?
  - External EM fields directly induce common-mode voltages (with respect to ground) in cabling wire pairs, NOT differential voltages across each wire pair
  - Induce similar common-mode (CM) voltages across all four pairs at the same time
  - The resulting differential impairment component is created from unbalanced impedances to ground in the link segment cabling components and PHY DUT interface
- The CMNR test consists of verifying data link integrity (maximum bit-error rate) when a controlled CM impairment signal is applied simultaneously to all four pairs of a test channel at a point in close proximity (within 30 cm) to the PHY DUT
- Initial test was intended to simulate the observed CM signal induced into UTP cabling (and consequent PHY ingress) when exposed to a 3 Volts/meter external electric field commonly used in standard EMC conducted and radiated immunity testing
  - Common-mode noise rejection correlates with immunity from external EM interference

The Need for a Common-Mode Noise Rejection (CMNR) Test

- Existing EMC radiated immunity standards are designed to test the radiated interference tolerance of end terminal equipment, <u>not</u> the data links attached to the equipment
  - Conducted immunity testing (IEC 61000-4-6) provides some form common-mode noise rejection (CMNR) testing for the attached data links but only up to 80 MHz (150 kHz to 80 MHz)
  - CMNR may be indirectly tested during standard EMC radiated immunity testing from 80 MHz to 1000 MHz (IEC 61000-4-3) depending upon the type and configuration of the attached data cables
- Existing EMC radiated and conducted immunity standards tests do not specify consistent test conditions for the data links connected to the equipment under test
  - EMC standards allow a large amount of latitude and manufacturer's discretion in the selection of the test configuration for connected data links in both radiated and conducted immunity tests
  - Considerable variability of test conditions from differences in test equipment, even when following EMC test standard to the letter (e.g. signal generator harmonics)
  - Considerable variability of external field intensity outside of calibrated 1.5 meter square box region defined per IEC 61000-4-3 (radiated immunity testing from 80 MHz to 1000 MHz)
- The intent of a dedicated CMNR test in the 802.3 standard is to provide the equivalent channel impairment of a consistent reproducible conducted and/or radiated immunity test where the “device” under test is now the connected data link channel
  - Providing some means of testing the immunity of a data link improves the overall quality of the standard and its associated end products
  - The CMNR test can provide assistance and guidance in a production EMC compliance process

Possible Methods of Injecting a Common-Mode Test Signal

- Direct injection (good for differential signals, not so good for common-mode signals)
  - Can inject precise differential signals into each pair independently, or a common-mode signal into one pair
  - With the same common-mode (CM) signal injected on all four pairs at the same time, test channel becomes a cable over ground plane where the impedance and coupling are no longer well behaved
  - Unbalance (component mismatch) in coupling network can cause excessive CM-to-differential conversion
  - High coupling loss because need for high-impedance "bridging" across the test channel
  - Needs external ferrite clamps on AE (auxiliary equipment) side to isolate far-end transceiver link partner
  - Adds additional connector junction(s) to channel; will degrade channel insertion loss and return loss
  - Requires a customized test fixture; not available commercially
- EM clamp from IEC 61000-4-6 (not all units work from 80 MHz to 1000 MHz)
  - Injects same common-mode signal on all four pairs; differential disturber from channel imbalance
  - Designed to operate from 150 kHz to 80 MHz, but some units specified to operate up to 1000 MHz
  - Provides directional coupling above 10 MHz eliminating need for external ferrite clamps at the side to isolate the far-end link partner PHY; but needs external ferrite clamps (#75 material) for operation below 10 MHz
  - Non-intrusive, does not disturb channel or degrade channel insertion loss and return loss
  - Common EMC test instrument; units available from several different suppliers
- Coaxial cable clamp (originally defined in Annex 40B, enhancements in Annex 113A of 802.3)
  - Injects same common-mode signal on all four pairs; differential disturber from channel imbalance
  - Non-intrusive, does not disturb channel or degrade channel insertion loss and return loss
  - Needs external ferrite clamps on AE side to isolate the far-end link partner PHY
  - Some narrowband nulls in the common-mode coupling that must be addressed by the test procedure
  - Available off-the-shelf from only one supplier; different versions with slightly different characteristics

Limitations of CMNR Testing

- The CMNR test method is useful for introducing a controlled and reproducible CM voltage impairment into link segment cabling and PHY interfaces
  - Eliminates the induced CM voltage variability of a standard EMC radiated immunity test
- But…the differential voltage component determines the BER performance of the PHY DUT
- Unfortunately the differential component is not well-controlled and is strongly affected by the test channel configuration and the characteristics of its constituent cabling components
  - Part of the observed differential component is from common-mode to differential (C2D) conversion at the PHY interface; this is the "desired" signal impairment determined by the PHY DUT
  - Additional differential component from the C2D conversion due to the cabling components and test channel RJ45 junction reflections; this is the uncontrolled (and unwanted) test signal impairment
- The PHY cannot distinguish between the PHY interface impairment and the uncontrolled test channel impairment; the uncontrolled test channel impairment may be dominant
- Extremely difficult to build and <u>verify</u> a test channel with C2D conversion low enough to ensure the uncontrolled impairment cannot significantly affect PHY performance test results
  - The C2D characteristics of a test channel are also sensitive to any physical movement of the test setup, including the cable and cable placement with the cable clamp
- Uncontrollable variations of test channel C2D conversion cause unacceptable differences in PHY performance test results across otherwise identically configured test channels
- **Since it is not possible to build a test setup capable of providing proper reproducible test results, the CMNR test is not suitable as a normative PHY test**

Why is CMNR Testing Useful?

- The uncontrolled differential component in the CMNR test makes the test unsuitable for directly providing an <u>absolute</u> metric of PHY tolerance to the induced CM voltage from an external EM field
- But…with a properly calibrated test setup, CMNR testing is extremely useful for providing <u>relative</u> PHY tolerance results
- If a CMNR induced test voltage and/or PHY test result can be correlated with actual test chamber radiated immunity measurements, the CMNR test becomes an extremely useful and cost-effective EMC pre-compliance test method
  - Relative CMNR test results based upon CM ingress test levels derived from (or similar to) anechoic chamber CM ingress measurement levels correlate with relative chamber radiated immunity test results

Possible CMNR Test Methods

- Fixed CM source injection level
  - Apply a fixed preset signal level to the CM injection apparatus
  - When used with the coaxial cable (CC) clamp (described in Annex 40B and Annex 113A of 802.3), method provides a fairly good reproduction of RF immunity test effects from 80 MHz to 300 MHz
  - Very simple to calibrate; need only validate CM source output level
  - Also useful with EM clamp from 61000-4-6, especially below 80 MHz
- Target CM level at CC clamp output (defined in 802.3 standard)
  - The CM injection source signal amplitude is calibrated to provide a specified output level at the opposite and of the CC clamp; requires use of the CC clamp
  - Method defined in Annex 40B and Annex 113A of 802.3
  - Calibration is still simple; adds an extra step to compute a possible signal generator correction factor necessary to maintain the specified output level at the opposite end of the clamp
  - Similar result to fixed CM source method; good reproduction of chamber effects up to 300 MHz
- Target CM ingress level (not defined in 802.3 standard)
  - Injected CM signal is calibrated to provide a specified target CM ingress level at the PHY interface
  - Proper calibration can extend the useful bandwidth of the CM injection device
  - Not restricted for use with a CC clamp; can be used with the EM clamp from 61000-4-6 (conducted immunity) or a direct injection test fixture
  - Calibration is still simple; adds an extra step to compute the signal generator correction factor necessary to maintain the target CM ingress level at the PHY interface
  - Requires specification of a target CM voltage vs. frequency profile
  - Method best used with a CM target profile derive from anechoic chamber measurement data

Next Steps

- This presentation will be revised and expanded for future meetings
- Additional items for next revision(s)
  - Test setup diagrams
  - CC clamp measurement data
  - RF chamber measurement data
  - Discussion of required equipment specifications (e.g. signal generator harmonic distortion)
  - Effect of EMC test condition variables not covered in EMC standards