Methods for Testing Impulse Noise Tolerance

AQUANTIA®

May,6,2015

Larry Cohen

Overview

- Purpose: Describe some potential test methods for impulse noise tolerance
- What we will cover in this presentation:
  - Discuss need for impulse noise immunity test in standards
  - Proposed test methods and example test setups
    - EM (Campbell) clamp coupling (as shown in 1000Base-T)
    - Absorbing clamp coupling (standard EMC device)
    - Direct injection (custom test fixture circuit)
  - Initial observations of different test methods
  - Next steps and discussion points

Why Study Impulse Noise?

- Standard EMC regulations cover compliance requirements for very large impulse noise events caused by high-voltage ESD events and large switch contact arc transients (EFT)
  - Typical ESD test levels are 4 kV contact discharge and 8 kV air discharge
  - Main intent is to insure that terminal equipment does not get <u>damaged or destroyed</u> by strong ESD and EFT events during normal operation

- EMC standards are not designed to verify operational integrity (Bit error degradation) of data links under normal operating conditions
  - EMC standards do not test the operational effects (Bit error degradation) of more frequent low-level ESD (or EFT) events <u>below</u> potentially damaging energy levels
  - ESD test waveforms are not fully representative of the interference that may be encountered in the enterprise environment under normal operating conditions

- NGEA Base-T standards should provide necessary test guidance for impulse noise interference from low-level ESD and EFT sources to ensure proper operational integrity across products from different manufacturers

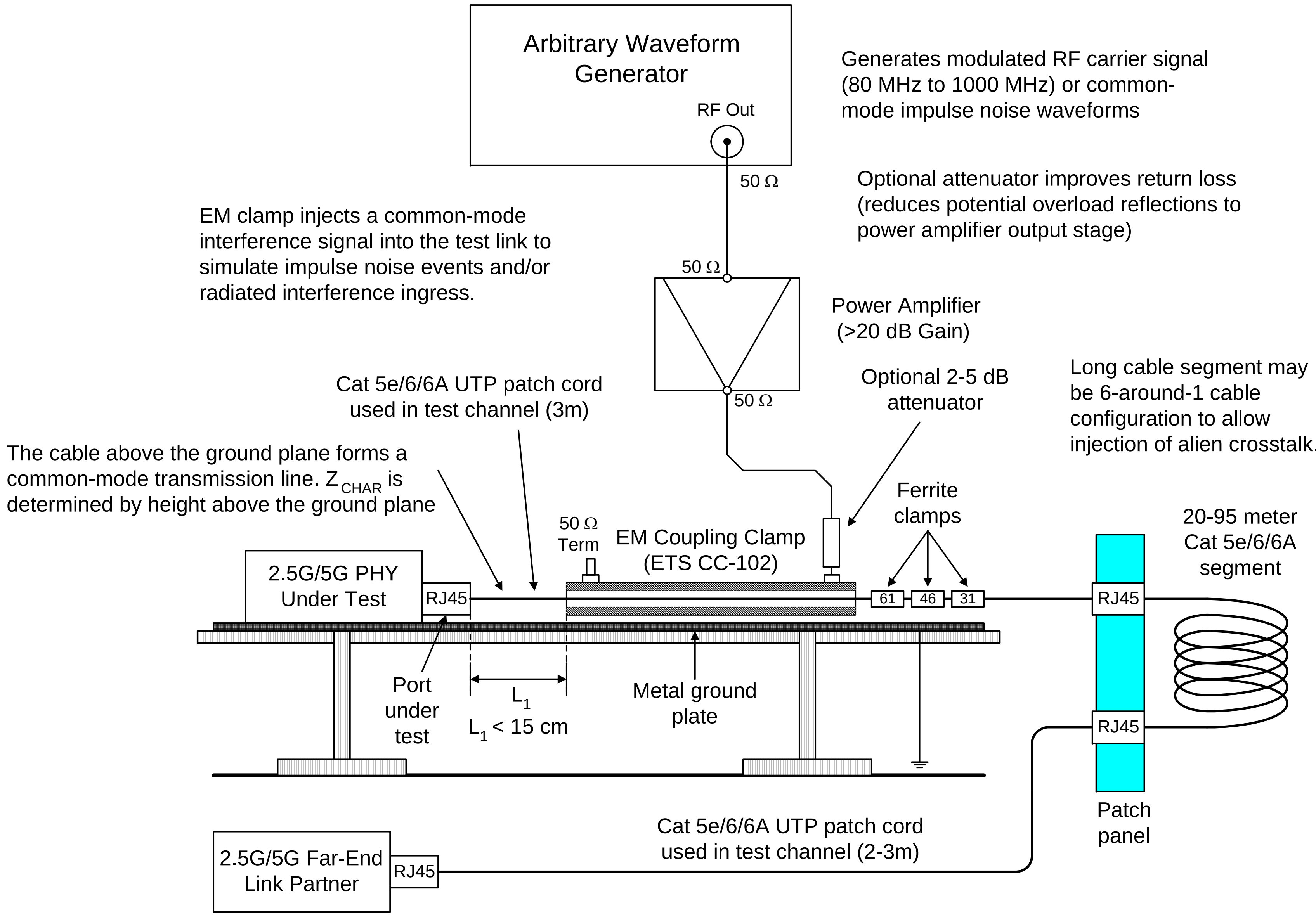
Potential Methods for Injecting Test Disturbance

- Direct differential injection
  - Can inject precise common-mode or differential signals into each pair; disturbers may be different or identical for each pair
  - Adds an additional connector junction to channel and injection circuits will degrade channel insertion loss and return loss; this is the main disadvantage
- EM coupling clamp (Campbell clamp)
  - Injects identical common-mode signal on all four pairs; differential disturber signal created by channel imbalance
  - Does not physically break cable and degrade channel insertion loss and return loss
  - Works as a coaxial transformer; slightly directional coupling
  - External ferrite clamps (of various materials) are required at far-end port for isolation
  - Produced by only one supplier (ETS)
- EM Absorbing clamp
  - Current transformer (inductive) injection of common-mode signal at port under test; differential disturber signal created by channel imbalance
  - Does not physically break cable and degrade channel return loss
  - Far-end port is isolated by internal ferrite clamps; provides some directional coupling
  - Common EMC test instrument; units available from several different suppliers

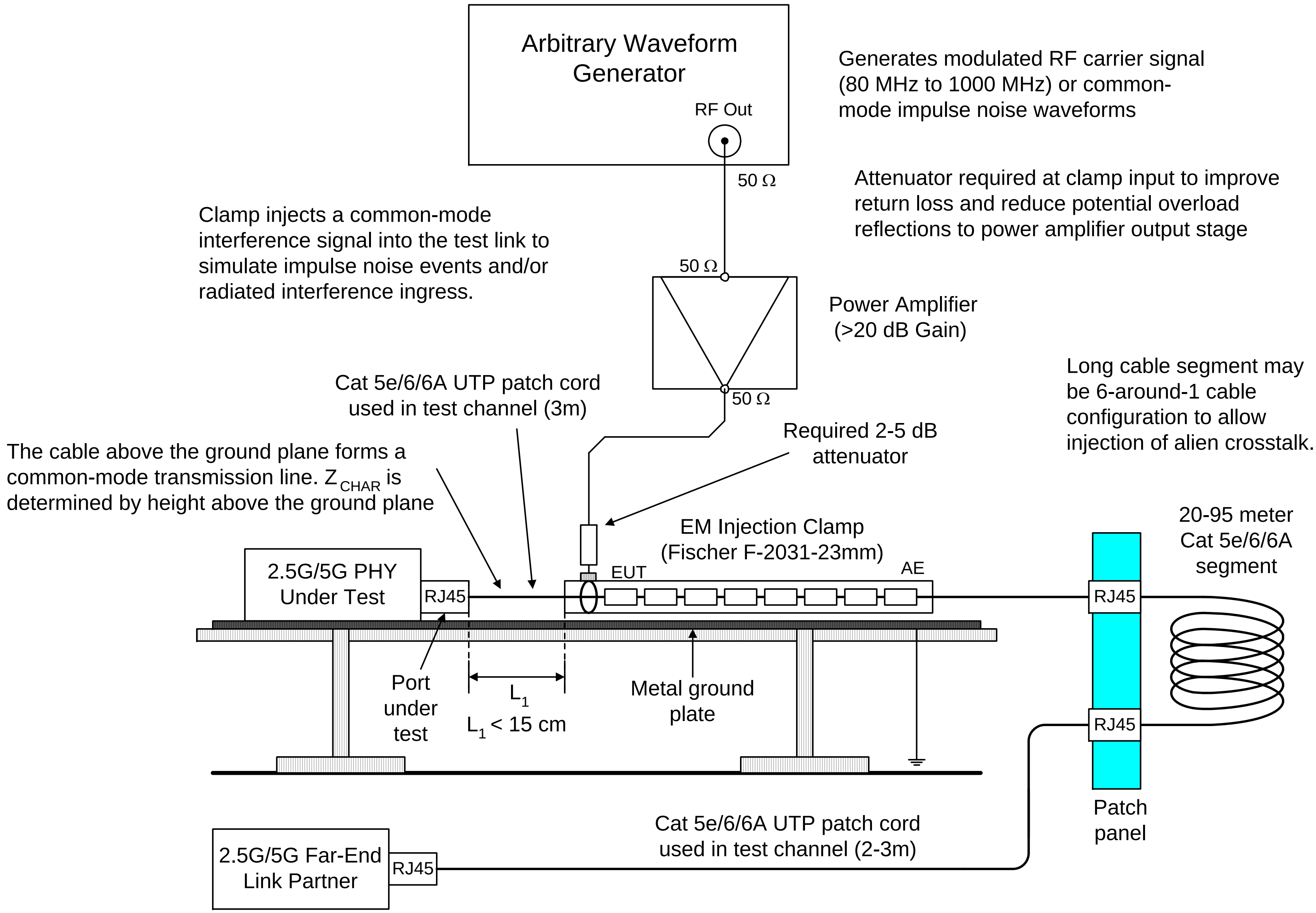
Basic Description Test Procedure

- For all test setups, the test procedure is a two step process
  - Different from clamp noise impairment test in 1000Base-T where the injection source is simply fixed at a specified level
- Calibration phase
  - Set up test desired test channel; do not turn on other impairment sources (e.g. alien crosstalk in clamp setup)
  - Substitute a 4-pair RJ45-to-SMA breakout test fixture for the MDI port of the PHY under test; substitute a CM/DM termination block at the far end of the test channel
  - Use a 4-port vector network analyzer (or fixed-level swept sine wave signal source) to measure common-mode and differential coupling of the injection apparatus to the each of 4 pairs at the MDI port (under test) breakout test fixture
  - Use measured coupling transfer function to “pre-distort” the test signal source so to provide the desired target signal at the port under test
- Test phase
  - Replace the port under test breakout fixture with the actual PHY under test; replace the far-end termination with the actual link partner
  - Apply “pre-distorted” signal sources to the injection apparatus; add additional impairments (e.g. 6-around-1 alien crosstalk) as necessary
  - Initialize data link between the PHY under test and the far-end link partner and perform all required impairment tolerance tests

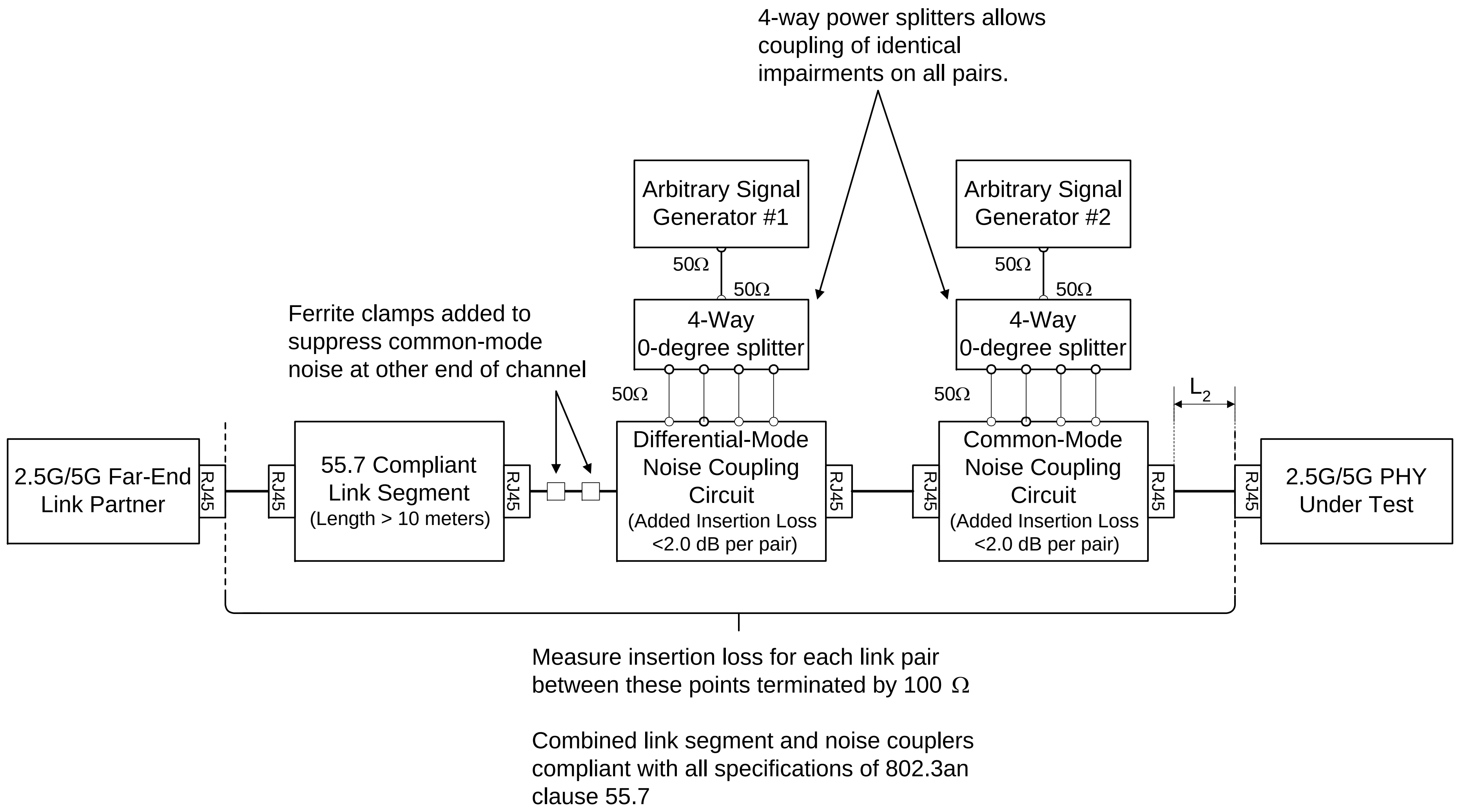
Example EM Clamp Setup for Impulse Noise (and Radiated Immunity) Testing



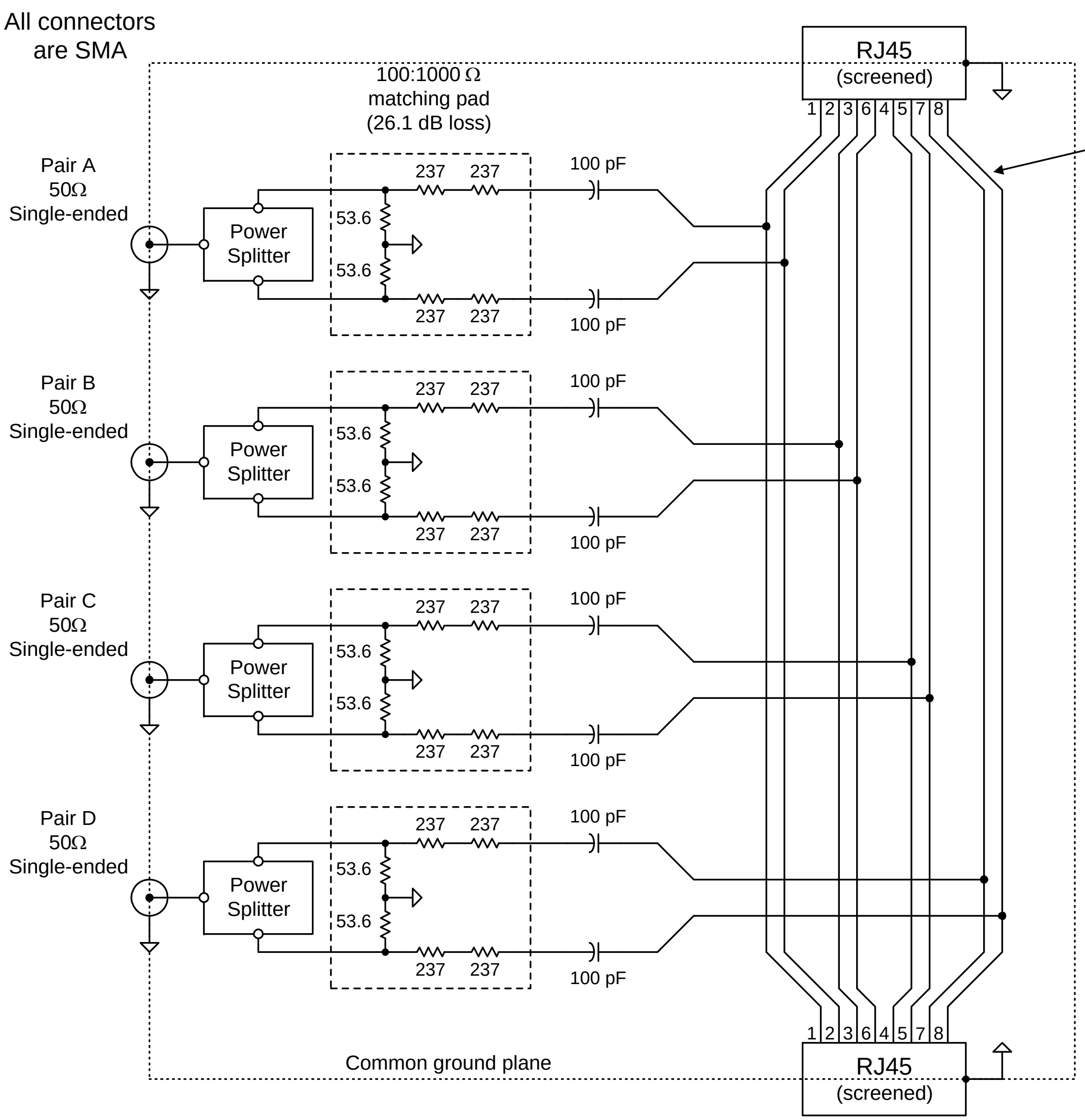
Example Absorbing Clamp Setup for Impulse Noise (and Radiated Immunity) Testing



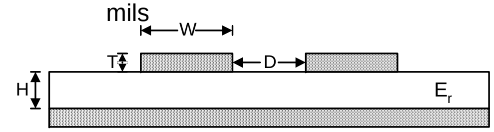
Example Direct Injection Setup for Impulse Noise (and Radiated Immunity) Testing



Example DM/CM Noise Coupling (Direct Injection) Circuit



Differential trace for each pair:
100Ω Differential
75Ω Common-mode
Example microstrip dimensions:
H=62.5 mils
D=10 mils
W=30 mils
T=1.2 mils (1 oz)
Er=4.2 (FR-4)
Trace pair separation > 400 mils



- Coupling circuits placed as close as possible to corresponding differential trace
- Impedance matching pad provides high-impedance feed to preserve through pair insertion loss and return loss

- Use 180-degree splitters for differential-mode signal coupler and use 0-degree splitters for common-mode signal coupler
- Designated pad loss is for differential-mode only. Pad loss for common-mode signal is different.

Observations for Clamp Injection Methods

- Does not physically invade the test channel; preserves channel return loss
- Injects common-mode disturber signal on all four pairs simultaneously as would occur in the real world
  - The differential disturber is generated by individual pair channel imbalances
  - Identical differential disturber signal cannot be generated across all four pairs; note four identical disturber signals would not occur in the real world
- Can be calibrated to inject a consistent target common-mode ingress signal across all four pairs
  - Can only be calibrated to inject an a specified target differential disturber signal on a single pair; the remaining three pairs are uncontrolled
- Each individual setup must be calibrated before performing the actual test
  - Coupling may be sensitive to physical movement of test setup
- The cable above the ground plane forms a (common-mode) transmission line
  - The height of the RJ45-to-SMA breakout test fixture and the PHY under test must be selected to provide a reasonable match to the (common-mode) characteristic impedance within the clamp and the MDI port under test (L_1 section of test cable)
  - The common-mode impedance match must be good enough to prevent deep nulls in the clamp coupling function; compensating for large coupling nulls would require an excessive power amplifier (and undesired harmonic distortion)

Observations for Direct Injection Methods

- Physically modifies the test channel; degrades channel insertion loss and return loss; may cause significant errors for wide bandwidth data links
  - Design of injector circuit is conceptually simple, but may be difficult in practice because required precision and the need to follow high-frequency layout methods
  - May be difficult to test a full 100 meter channel because of added loss of injection circuits
- Can be calibrated to inject precise common-mode and/or differential disturber signal on each of four pairs individually or all pairs simultaneously
  - Allows precise reproduction of a differential impairment
  - Can generate customized or identical common-mode and/or differential signals across all four pairs; note four identical disturber signals would not occur in the real world
- May not require full calibration before each test; injection coupling not as sensitive to physical movement as clamp setups

Next Steps and Discussion Points

- Measurement of various injection apparatus to determine calibration and reproducibility requirements
  - What is the usable bandwidth
  - Determine limits of source signal pre-distortion in creating target impairment signals
- Measure the actual impairment of effects of direct injection with clamp coupling
  - Is this a serious problem
- Should impairment injection method be specified at all?
  - Is it better to simply define the injection apparatus as a black box with specific electrical characteristics?