Connectors - Precision or Not?

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The choices are many

• Metrology
• Instrument grade
• Commercial grade

Influenced by...

• Nature of application
• Cost involved
Objective

• Multiple choices available in industry and the hunt for good interconnects can be confusing without sound knowledge of expectations vs. actual performance.
• These simple interconnects are the building blocks of a test system and establish reference planes for accurate device measurements.
• This presentation helps answer the following questions -
  – What level of precision do I need for my application?
  – Are there any obvious grading scales I can use to qualify connector performance?
Connectors and Standards

- Mil Specs and IEEE specs control -
  - Electrical performance specifications (cut off freq, impedance tolerance, repeatability)
  - Mechanical performance specifications (inner and outer conductor diameters, pin depth, insertion/withdrawal force, connect/disconnect life)
- These standards govern the interface dimensions and performance of the available connectors in the industry
Connectors and Standards

- Lab versus General precision
- True metrology grade connectors as per IEEE standards
- What is more suitable for my application?
Lab vs. General Precision

- LPC or Lab Precision Connector - only air dielectric

- Permitted impedance uncertainty - ±0.5% for 1.85mm

- Tight tolerances for inner and outer conductor diameters

- Important for airlines and calibration standards

- More expensive due to stringent mechanical and electrical requirements

- GPC or General Precision Connector - low reflection dielectric support recessed from reference plane

- Permitted impedance uncertainty - ± 1% for 1.85mm

- Bead support essential for adapters, terminations, etc

- Rigorous design & simulation for optimum performance over bead sections to maintain 50 Ohm
Slotless vs. Slotted contacts

- Smooth 50\(\square\) surface when making electrical contact with male pin
- Slotted spring contact inserted into the ID of the female contact for captivation
- Metrology grade connector as it provides seamless transition
- Use limited to precision lab environment (proper alignment, connect/ disconnect life)

- Female contacts are slotted and closed to smaller dia that expand when making electrical contact with male pin
- The closed dia flares out to appropriate 50\(\square\) diameter when male pin is inserted
- Male pin diameters and tolerance is very critical to maintain constant impedance
Critical Parameters

- Pin Depth and Interface Discontinuity
- Concentricity
- Repeatability
- Mating surfaces
- Inter mating between connector families
- Torque wrenches and pin depth gages
- Connector wear and tear
Pin Depth & Interface Discontinuities

- Pin depths present discontinuities at mated interface junctions (varying center conductor diameters).
- In mated condition, the match presented at the junction is affected by this high impedance discontinuity.
- With increasing frequencies, the effects become more significant.

Impedance discontinuity -
TDR Z( Port 1) vs. Time (pS)
Pin depth @ 1mil
Pin Depth & Interface Discontinuities

Effects of Pin Depth on VSWR
Pin Depth & Interface Discontinuities

- Varying male pin diameters and improperly machined female contacts also result in interface mismatch.
- Commercial grade connectors for example have looser tolerances as compared to metrology and instrument grade connectors.
- When mated with precision devices with excellent match characteristics, the interface impedance is affected.
- Can lead to damage of the precision interfaces.
Pin Depth & Interface Discontinuities

Male pin undersized
Contact still closed and does not deliver constant 50Ω impedance

Male pin oversized
Contact flared out beyond 50Ω condition
Concentricity

• Concentricity affects both mechanical and electrical performance and are defined by IEEE standard specs.
• Connection alignment - The match presented by a mated pair is affected when one of them is off center.
• It causes damage to the mating connector when oriented beyond the tolerant spec.
• Important to visually inspect connectors always before using them in a test setup.
Mating Surfaces

• This surface establishes the reference plane and the continuity between the connector pairs in mated condition.
• A seamless transition is very important for best performance.
• Dirt, dings, high spots due to bad surface finish, burrs, flared or unevenly closed female contacts lead to high reflection and thus poor match at the interfaces.
• Rotating the component itself (and not the coupling nut) while connecting to a mating part and/or forceful torque of mis-aligned connectors damages the mating surfaces
• Can degrade over time by repeated use and affects all other interfaces mated with it.
Mating Surfaces

• Seamless transition with clean smooth surfaces

Good mating surface

Surface damaged with improper use (and bad concentricity)
Repeatability

- This parameter establishes the measurement uncertainty introduced by the connector when disconnected and connected back in a system.

- When repeatability data is “in spec”, it also implies that the connector is free of any uneven defects on the mating surface, female contacts are well machined (heat treated and closed to appropriate diameter for 50Ω)

- Very critical for calibration kit standards and adapters used in a lab setup where connectors may be used off and on during measurements.
Repeatability

- Measured by making at least two measurements on the same connector and the scalar magnitude difference between them presents the repeatability results.
- IEEE standard specifies the minimum repeatability values for each connector type.

Repeatability of 3.5mm connectors (slotted) - 4 orientations
Mating between connector families

• It is an industry wide standard that SMA, 3.5mm and 2.92mm & similarly 2.4mm and 1.85mm connectors can be mated without any mechanical damage.

• Common male pin diameters between the two acceptable pairs allow the connectors to be mated.

• However there is always some question with the electrical integrity since there is a discontinuity in diameters between the pair.
Connectors - Precision or Not?

Mating between connector families

- Equal pin depth distribution between mated connectors assumed for this plot - Here pin depth acts as step compensation between the two diameters.
Torque Wrenches

- The integrity of an electrical connection is established with torque wrenches
- Important that the right amount of torque is applied
- Over torque damages mating surfaces and under torque implies a weak connection for good electrical performance
Torque Wrenches

- Incorrect means of applying torque
  - Holding too close to breakaway
  - Breaking the wrench completely
  - Torque with opposite side of wrench
  - Without open ended wrenches that prevent component from rotating

Recommended

NOT Recommended
Gage Kits

- Connector gages help ensure that pin depths are within the allowable spec.
- The warning is particularly useful when a contact protrudes beyond the outer conductor. This will damage the mating connectors.
- Hence an integral tool in the regular maintenance of interconnects.
- Important to torque DUT to gage for accurate pin depth.
- Gages and set masters are the calibration standards for pin depth measurements and must be well maintained.
- Options available -
  - Push on or Thread on gages
  - Digital or Analog gages
Connector Wear and Tear

• Regardless of the connector chosen -
  – In lab or production environments where the connectors are re-used multiple times through the day, they are limited by the connect/ disconnect cycle of each connector type
  – Normal wear and tear of interconnects degrades performance over time and should be qualified from time to time
  – Mating commercial grade connectors (with loose diameter tolerances like SMA) with lab grade connectors (like 2.92mm) can speed up the wear and tear
Good Practices

• Well maintained connectors based on the parameters explained in this presentation extend its life
  – Regularly inspected and cleaned connectors
  – Careful torque methods (torque wrench and open ended wrench)
  – Gauging connectors before using in a test setup

• Gage kits and torque wrenches must be calibrated annually or depending on frequency of use

• Proper storage with connector covers
Maury Microwave Solutions

• We offer the right choice of metrology or instrument grade connectors to meet your industry needs based on our sound knowledge base

• Our calibration kits (coax or waveguide), gage kits and torque wrenches enable accurate device measurements

• The adapters offered compliment these calibration kits and provides a complete solution for your measurement needs.