Welcome to

DesignCon® 2023

WHERE THE CHIP MEETS THE BOARD

Conference
January 31 – February 2, 2023

Expo
February 1 – 2, 2023

Santa Clara Convention Center

Limits of High-speed Connector & Cable Technology, Part 2

Mick Felton (ACES) – Chiphead Theater

February 2, 2023 - Thursday

SPEAKERS

Mick Felton

Director of Engineering, Aces

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Mick has more than 30 years of experience with hardware design and manufacturing. He is an industry recognized signal integrity expert, with 30 patents issued. He has participated in committees for over 25 years, including FC, PCIE, SNIA, SFF, SAS, OCP, GENZ, EDSFF, QSFP-DD. Mick has worked with over 15 companies to improve their signal integrity experience, by mentoring and teaching classes and improving their designs. He currently has built from the ground up a high speed cable manufacturing division and leads the US high speed connector development for ACES.

Abstract

Today's connectors and cables must be studied together in their actual application for best form/fit/function. Years ago, it was said as speeds increase technology must shrink to match the performance, this statement is mostly true until the limits of manufacturing and SI start to diverge. In this talk, the manufacturing of cables and connectors will be discussed and how SI performance is increased until certain limits are reached as the technology shrinks in size. Once the data and results are presented a feedback session will be started to solicit feedback on stated results and generate ideas for future DesignCon discussions.

What limits size of Connector?

- connectors usually by # pins
- connectors in last few years have been moving to number of diff pairs with “single ground” on each side of diff pair
- connectors in last few years also been dominated by power requirements, balance of size of power contact to current to heat dissipation.

Ok picked the number of pins, now what?

Lets…

- **Add a overmold**
- **Add a latch?**
- **Add a pull tab?**

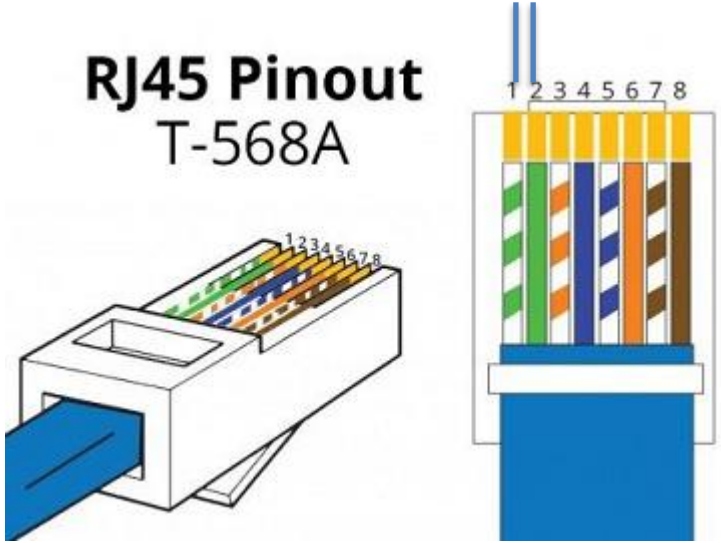
--- Are we done ????

We would be if this was 1999 and speeds topped at 500 Mhz..

Rj45 was designed in 1973…

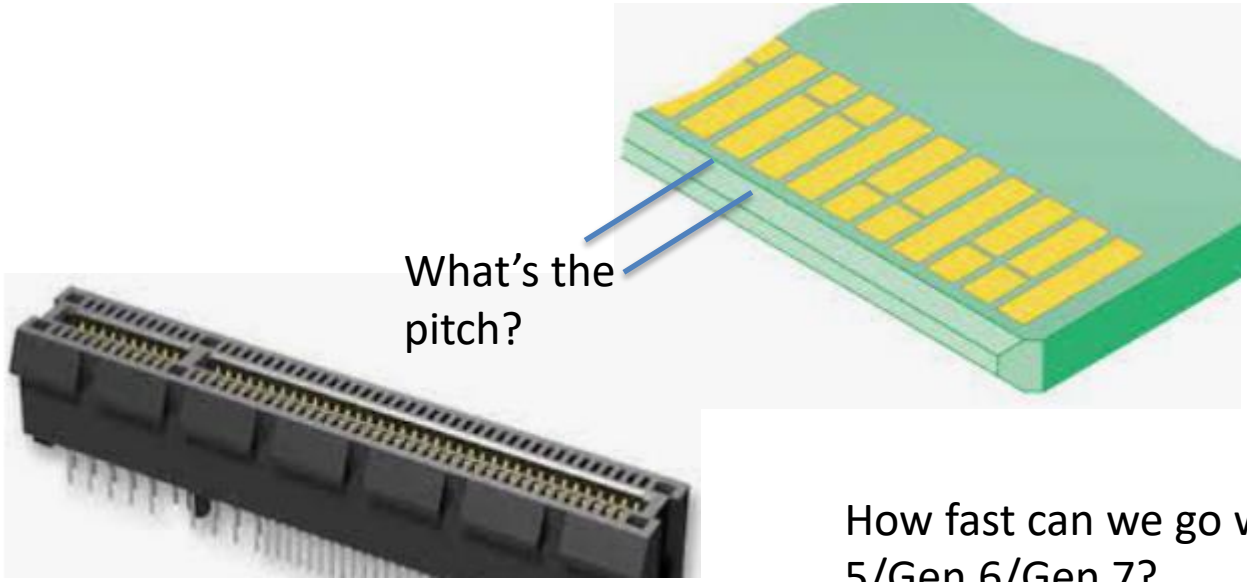
Yes I'm older…

What's the pitch of the RJ45 contacts?



How fast can we go? 1G/10G/100G/ ?
How far can we go? Km, meter, inches?

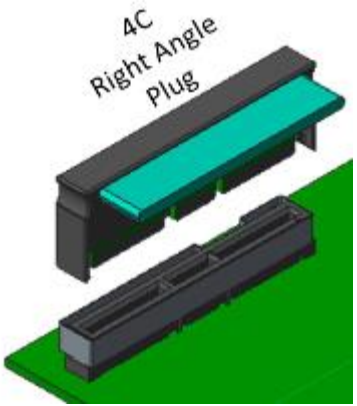
PCIE connector been around for decades!



How fast can we go with it? Gen 5/Gen 6/Gen 7?

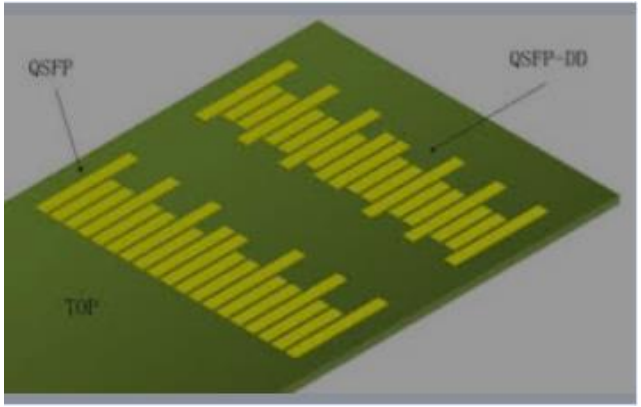
Latest Release Standard Connectors

4C – 0.6mm pitch



GEN Z, EDSFF,
OCP, COBO

QSFP / QSFP-DD
0.8mm pitch



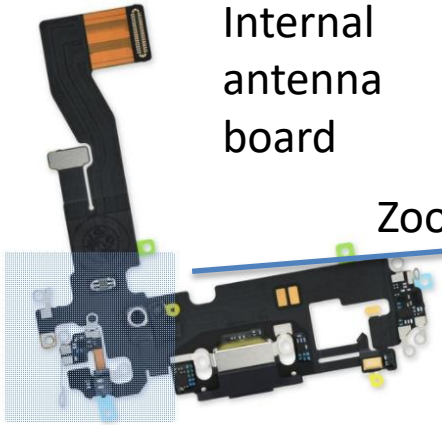
200/400/800G Ethernet

MCIO
0.6mm pitch

PCIE Gen 5

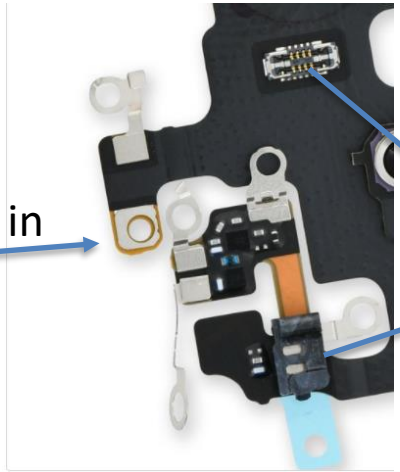
Large phone manufacturer, using 0.35 and 0.45mm connectors

This is state of the art!

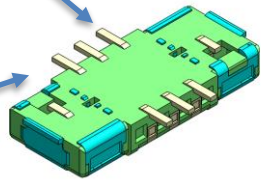


Internal antenna board

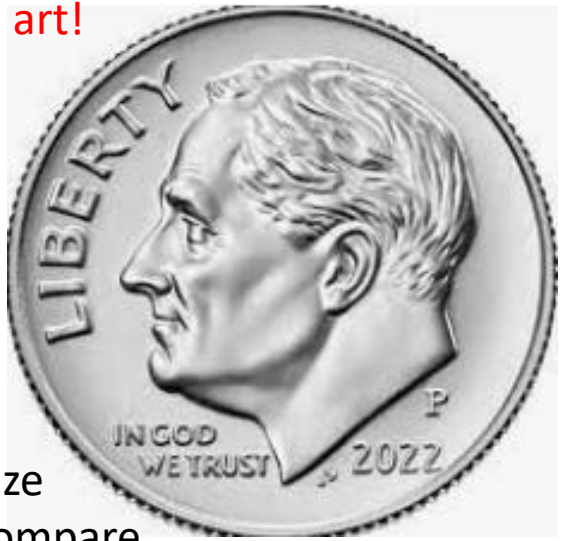
Zoom in



Zoom in



Size compare



Connector/Cable technology has shrunk a little more than 50% in 50 years for the majority or cables/connectors.

Why? What's hindering the success of shrinking dimensions?

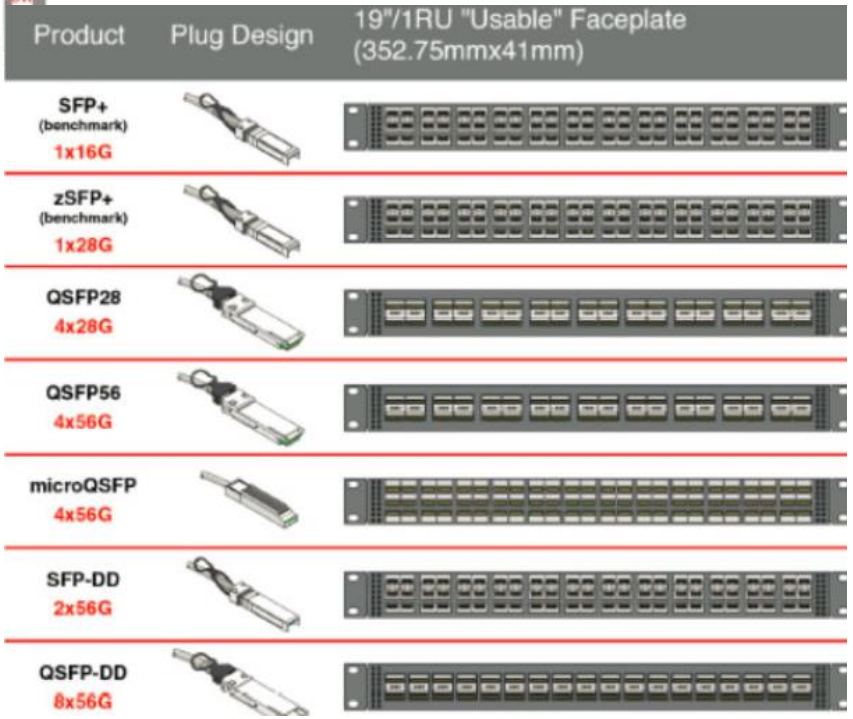
What limits size of External Connector Face?

- External connectors usually by bulk head
- Bulkhead of PCIE long been the standard
- Bulkhead of network switch the 2nd standard in the industry
- The best external connectors balance the use of space in both network and PCIE physical dimensions.

Product	Plug Design	19"/1RU "Usable" Faceplate (352.75mmx41mm)
SFP+ (benchmark) 1x16G		
zSFP+ (benchmark) 1x28G		
QSFP28 4x28G		
QSFP56 4x56G		
microQSFP 4x56G		
SFP-DD 2x56G		
QSFP-DD 8x56G		

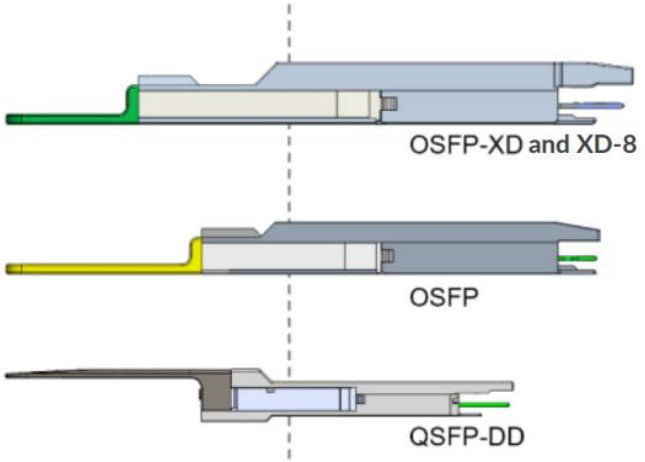
What limits size of External Connector Face?

- **Height:**
  - Can't be higher than a PCIE thickness
  - Can't be too high if needs a heat sink
  - Maybe possible to have stacked if not too tall
- **Width:**
  - Can't be too mechanically wide so the port density doesn't match ASIC lanes.
  - Typically want an even multiple on a PCIE faceplate (like 2, 4, 8 ports)



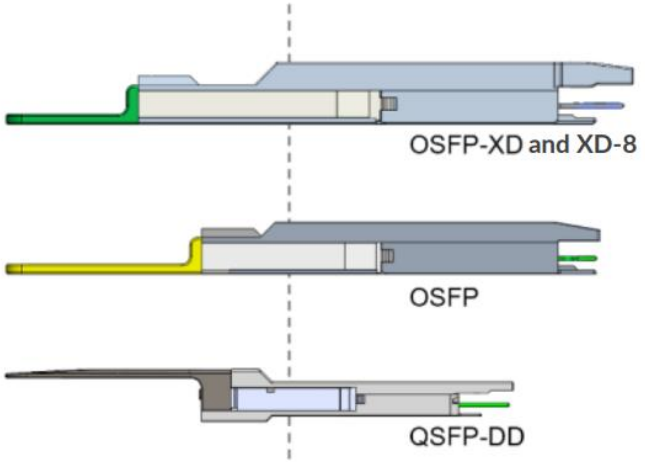
What limits size of External Connector length?

- **Length:**
  - The Longer the body, the more room for active devices inside the plug (active optical/active copper)
  - The longer the body, the easier to place more cable pads / Connector pads (OSFP XD) 2 rows of contacts!
  - The longer the body the better the heat dissipation
  - The longer the body the easier to route copper wires inside with ample strain relief
  - EMI can typically get easier when grounding plug is far away from bulk head
  - Disadvantage – useless board real estate, paying for square inches that are for no etches/chips.
  - Disadvantage - Mechanical support becomes challenging to hold heavy plug/heavy wires.



Disadvantage of a big wide cable / connector?

- **Length:**
  - HEAVY! Connector needs to be very strong
  - Hard to route all the lanes into the connector from PCB
  - Xtalk, typically more lanes = more Xtalk
  - Cable routing is very difficult with at number of cables
  - EMI becomes more challenging on wider hole/less supportive bulk heads
  - Insertion force becomes higher
  - Latch mechanism has to be stronger.
  - Expensive, typically could cost more than 2 smaller cables in labor and scrap costs due to lack of automation at this size



What limit size of Cable?

- **Any size wire is possible….**

!!!The bigger the wire the further the signal can travel!!!

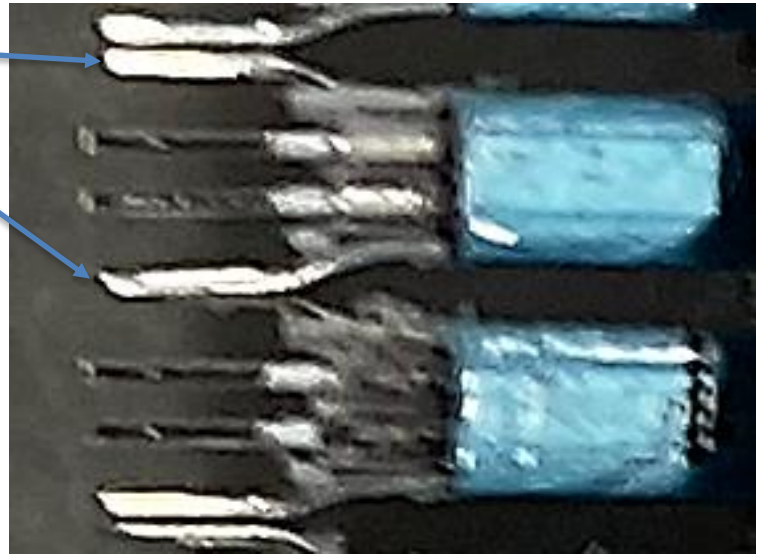
However…

- **The bigger the wire, the harder to bend**
- **The bigger the wire the heavier**
- **The bigger the wire the hard to attach to a PCB**
- **The bigger the wire the more expensive!**

How did 34-24 become the standard twinax range?

- **Below 34---**
  - Insertion loss becomes higher
  - Breakage in ground, and conductor more common
  - It's the point where transition to micro-coax or FPC/or FFC type cables is more likely
- **Above 24 ---**
  - Insertion loss great, but improvement from 26 not as significant
  - So big that xtalk affects are more common
  - Wire tends to break on more flexing

GND is typically smaller gauge



Some of the biggest issues with shrinking connectors…

High current or low voltage signals require a larger quality mating point, maybe 2 points of contact

1. **Cross talk**
2. **DC resistance/mating point**
3. **Strength of mated connector**
4. **Strength of a single side of the connector**

Not only NEXT but FEXT requires a lot of space in the connector

Simply staying on the board is an issue with weight or warping pcb or getting a proper height

Once mated, a locking mechanism is needed, possibly larger for heavy duty connections

Some of the biggest issues with shrinking connectors…

The lower the impedance the smaller the connector, except most connectors still want 100 ohm!

Larger connectors have longer durability cycles as there is more room for wear and tear

5. Mechanical durability

6. Compliance

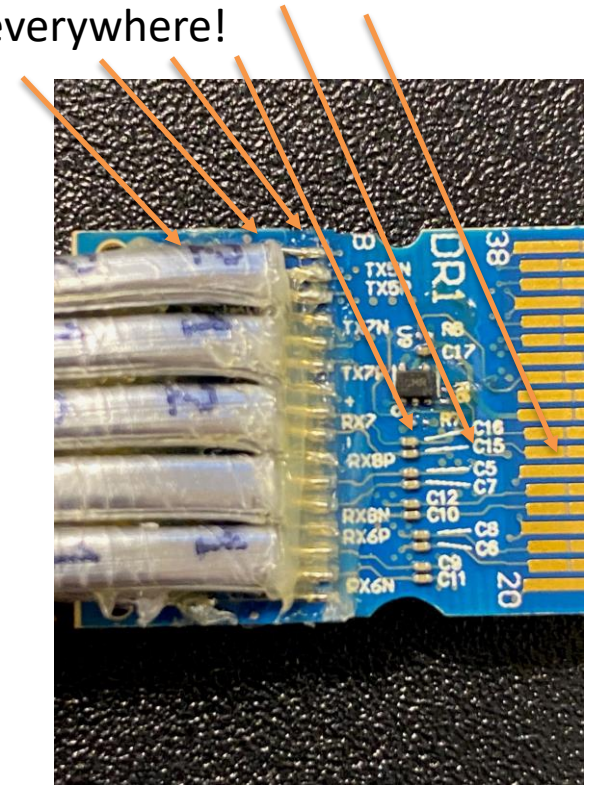
7. Impedance

Regulatory and Compliance standards require thicker materials, larger space and bigger contacts in some cases

XTALK – Biggest Concern….

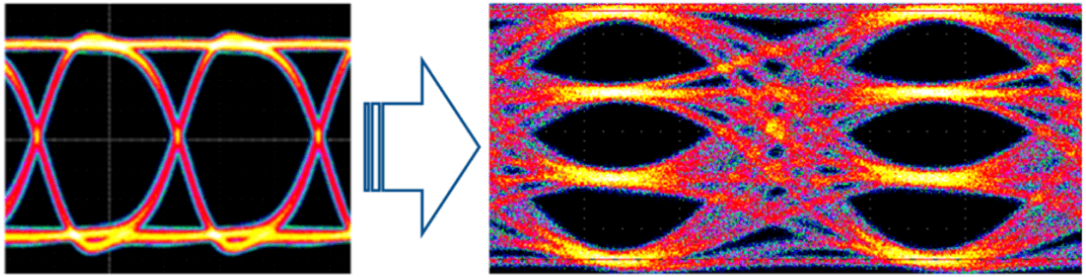
- **PAM4 vs NRZ ?**
- **NEXT and FEXT ?**
- **Pitch! - Physical spacing of Diff pair itself**
- **Pitch Again! - Physical spacing of grounds**
- **Pitch Again Again! Physical spacing of TX to RX**
- **Spacing-Grounding Again… Why- there is usually another point in the plug body or connector that have some other issue.**
- **Width of pins impacts spacing which impacts power handling, which impacts impedance…**

Crosstalk is everywhere!



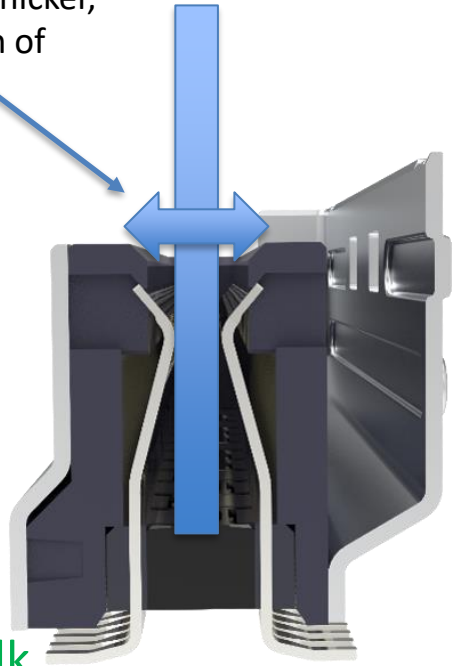
1. XTALK: PAM4 vs NRZ

PAM4 requires more XTALK margin vs NRZ. Its clear from the eye size less noise = improved margin



NRZ PAM4

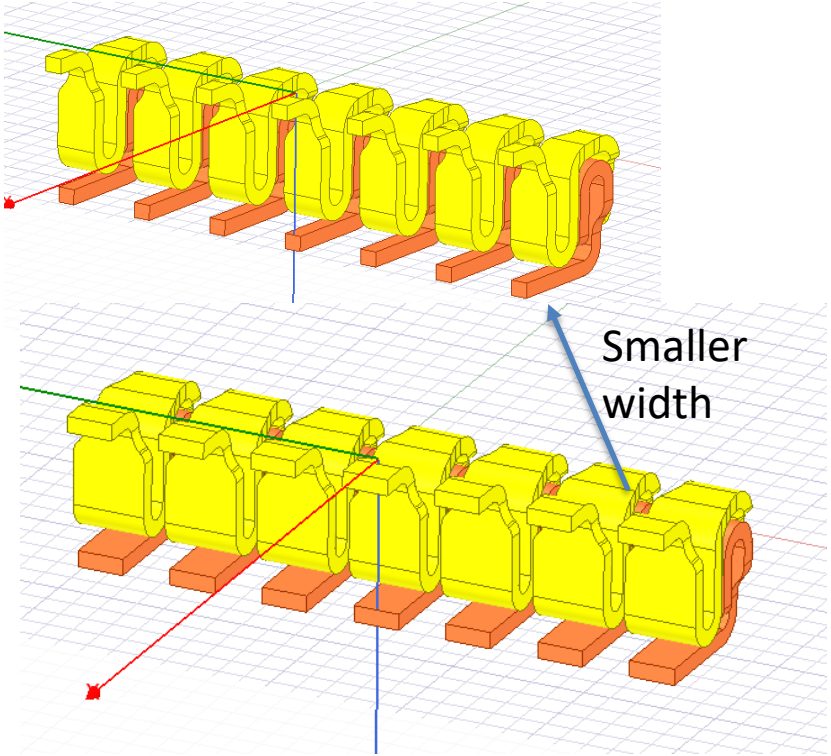
One simple trick to make xtalk bigger just make the PCB thicker, and grow width of connector!

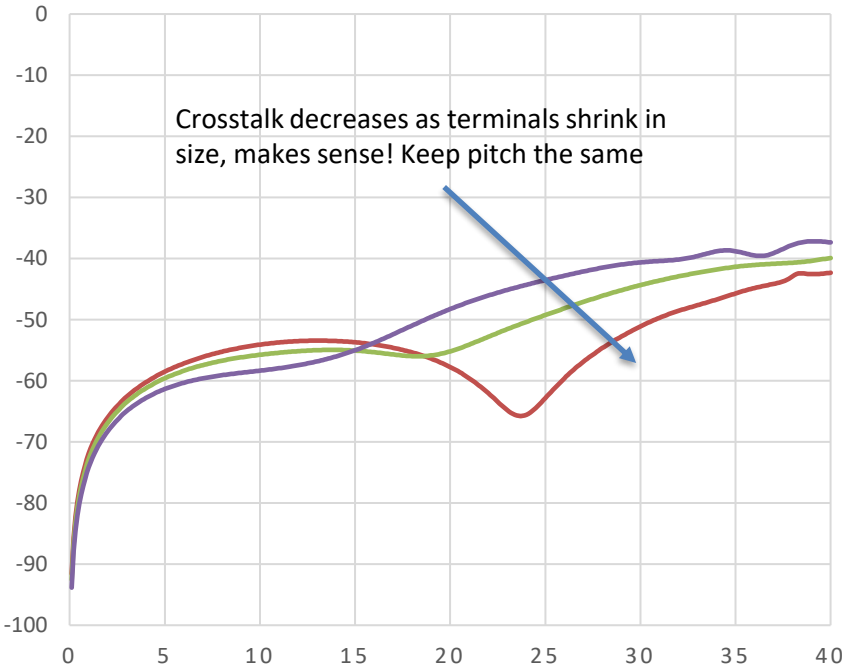


A connector that was fine for NRZ may need to:

1. increase in size for PAM4 to achieve better spacing for xtalk
2. Change pinout, larger pinout is a bigger connector, 2 grounds or larger spacing

Xtalk: Change connector terminal width?

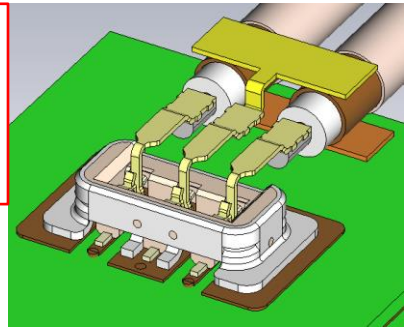




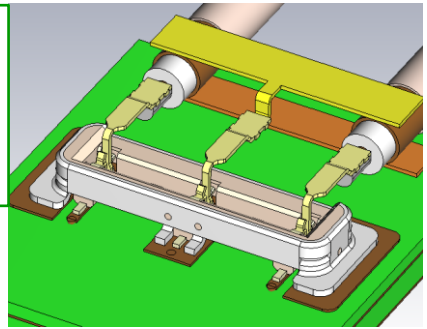
Making width smaller, but connector size still larger

Example of 0.4mm connector but cable at 0.6mm w/wo gnd or 1.5mm

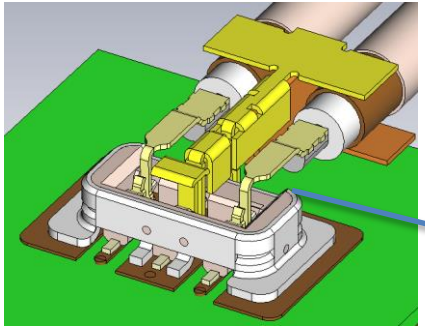
Normal Type Pitch 0.6mm



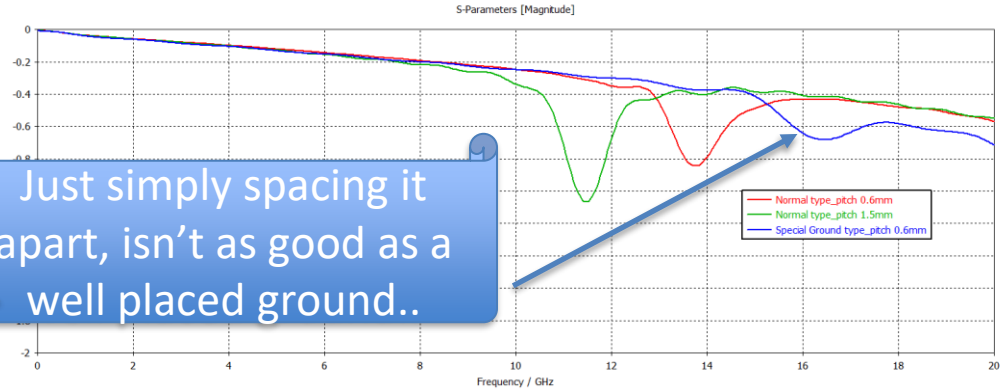
Normal Type Pitch 1.5mm



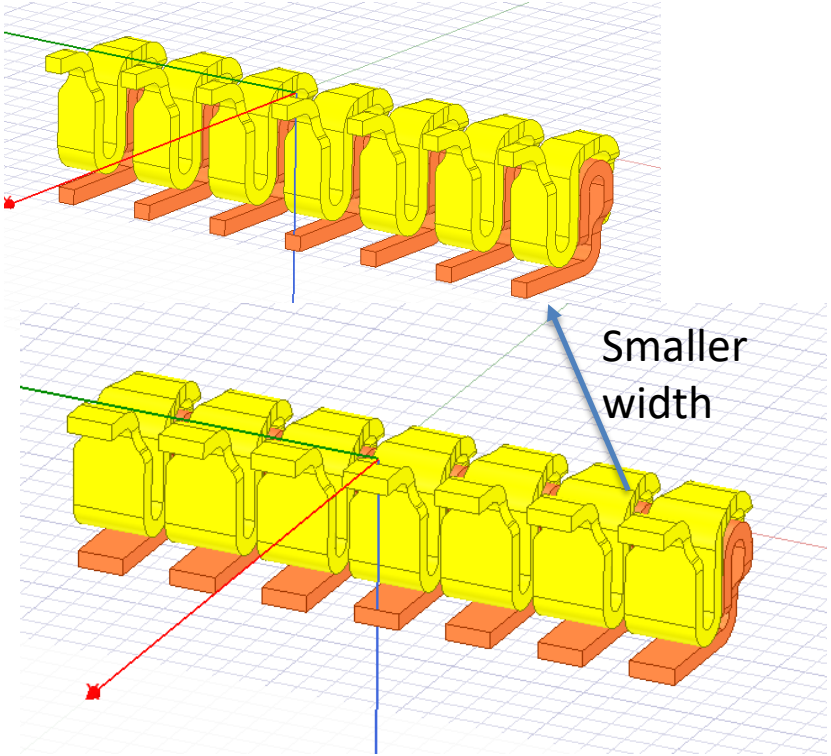
Special Ground Type Pitch 0.6mm



Just simply spacing it apart, isn't as good as a well placed ground..

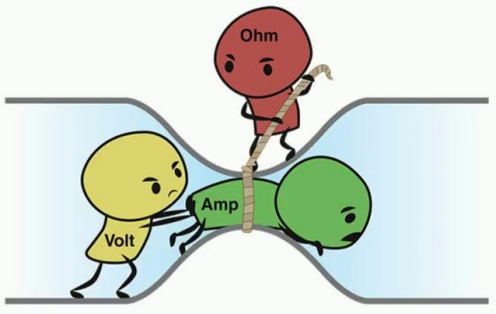


2. DC Resistance: Change terminal width?



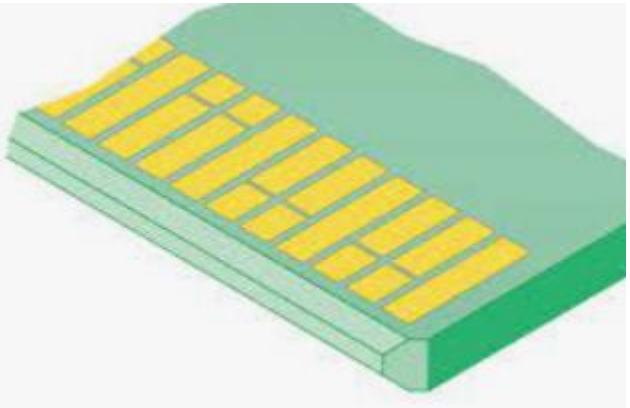
Making width smaller is going to impact the DC resistance as higher power SERDES are requiring more power.

Many vendors have pushed the high power off to the side or a different connector. This still increases the overall size of the solution.



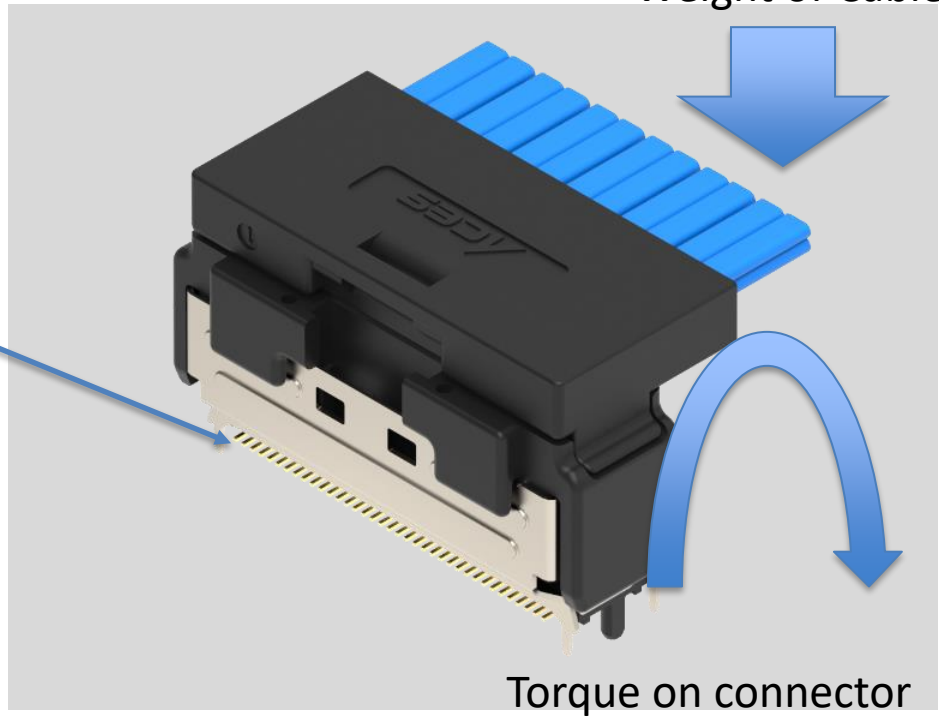
3. Strength of Mated Connection

- **PCIE connectors have not typically been latched, they have a simple screw on top of the chassis/pcb. Therefore there needs a large amount of retention of the pins to the gold fingers to maintain contact under vibration/or accidental chance of removal.**
- **Larger spring moments on the connector mean less consistency in the air/plastic as there needs to be room for the spring, but balance to impedance of mated connection.**



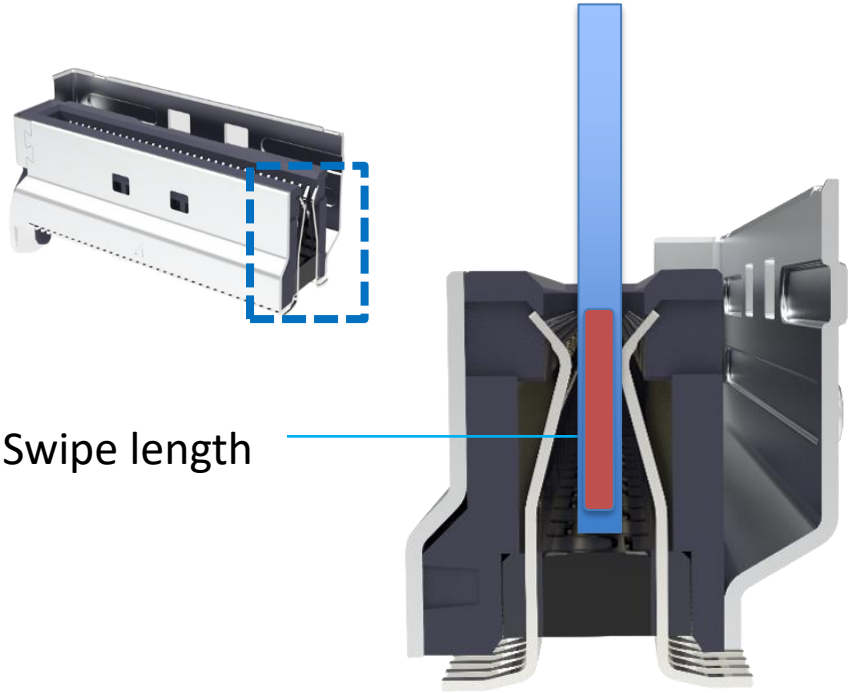
4. Strength of Single Side

- **Weight of a 34 gauge wire may be acceptable, but the weight of a 30 gauge or thicker wire may cause a lot of torque on the connector and solder joints. Even with solid hold downs on the sides of a connector the middle will tend to pull up causing stress and issues with smaller pads/pins.**
- **A balance is needed between strength of pads and size for correct impedance.**



5. Mechanical Swipe Capability

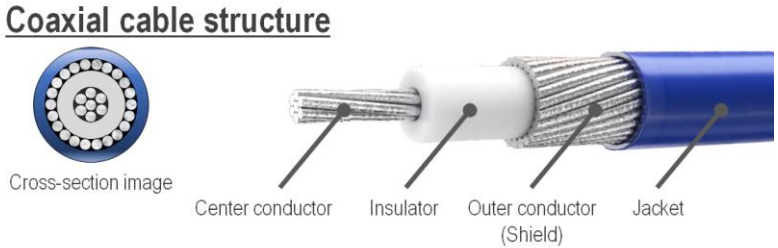
- **The swipe of the connector allows for slight mis-alignment of mating interface**
- **This swipe length affects the length of the interface which in turn affects loss and crosstalk and impedance among others SI parameters**
- **The wipe could be 2 points of connect, a wide connect, or other types of connections to make the interface more reliable electric-mechanically, but its almost always a SI distraction and forcing the connector larger in pitch and size.**



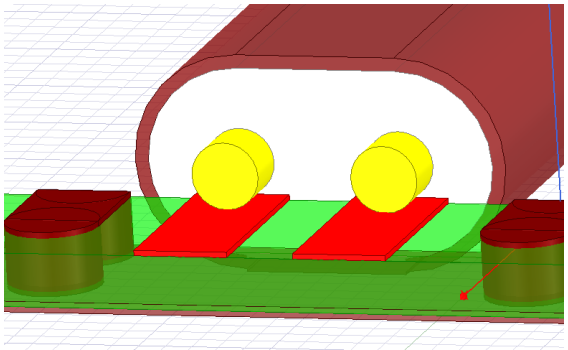
Cable topologies:

All are capable of good impedance profiles and low loss length cable constructions

Could be stranded or solid wire constructions.



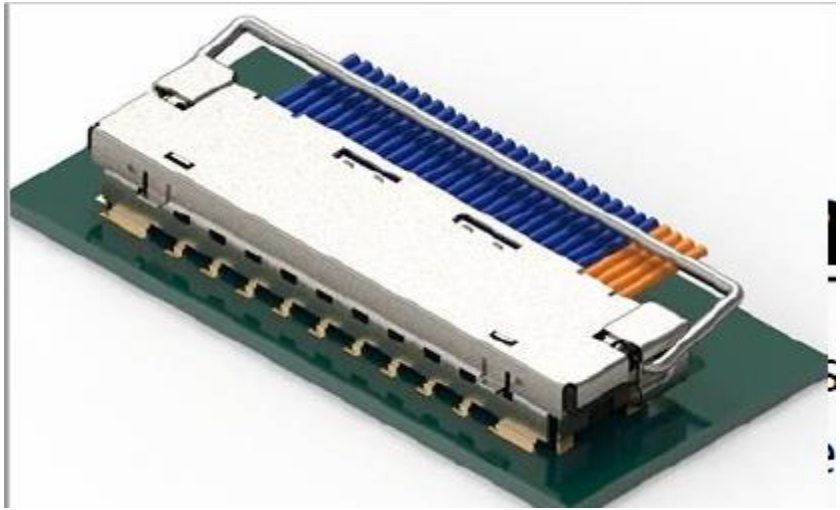
FFC wire:
Row of conductors with variable spacing for impedance or gauge changes
Wrapped or taped with foils or insulators

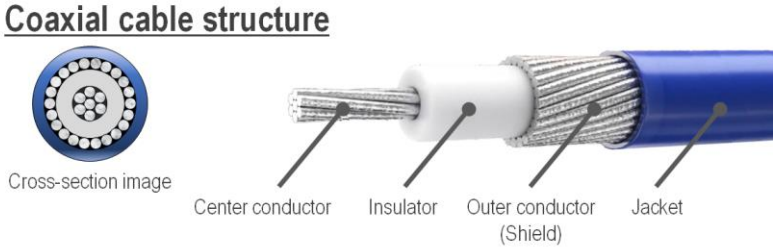


Twinax wire:
Oval shaped wire with at least 2 conductors and ground shielding

0.4mm pitch micro coax 40 gauge design

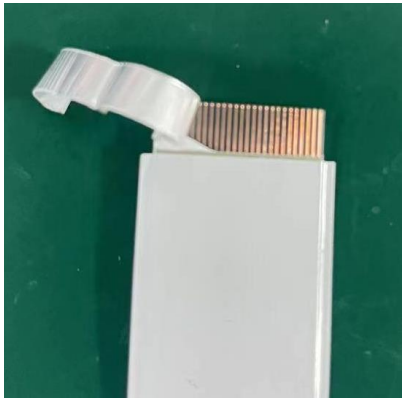
- Here's an example of a very small pitch micro-coax design.
- While the cable is very small and flexible, the number of cycles of flexing may become an issue at such a small gauge.
- The insertion loss is very high for small gauge
- The crosstalk inside of the connector is lower due to coax design but when brought to connector interface it tends to increase special IP needed to make best crosstalk and shielding



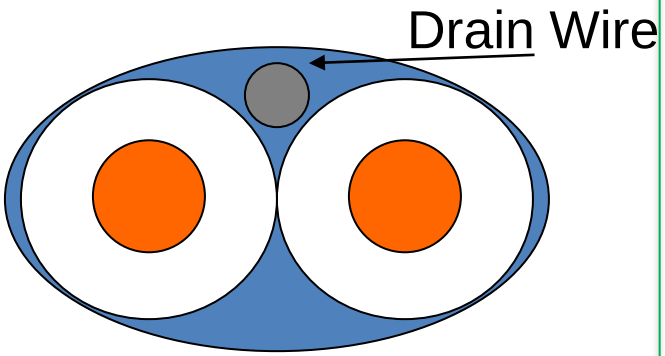


FFC 30-36 gauge, pitch 0.4mm or smaller

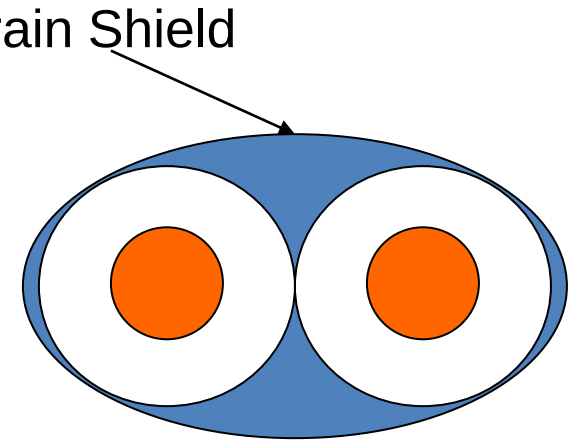
- Design used for years in laptop screen attachment.
- Very flexible
- Very durable
- Good impedance control due to controlled tolerance of conductors
- Better tolerance controls overall since a comb tools pitch of cable
- More precise xtalk, smallest strip lengths possible



Types of Twinax wire



Twin-Ax Typical Construction
Asymmetric Electrical Field

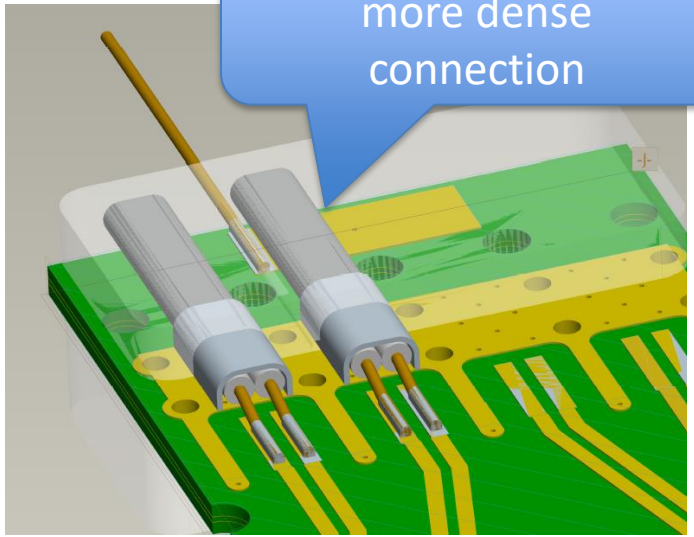


Twin-Ax (Drainless)
Symmetric Electrical Field

Typical construction today, requires more pitch space for each drain wire attach

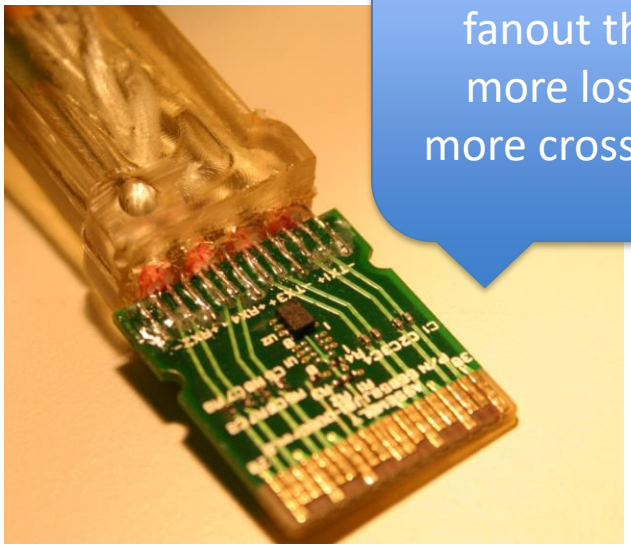
Examples of Cables attached to PCB

Drainless



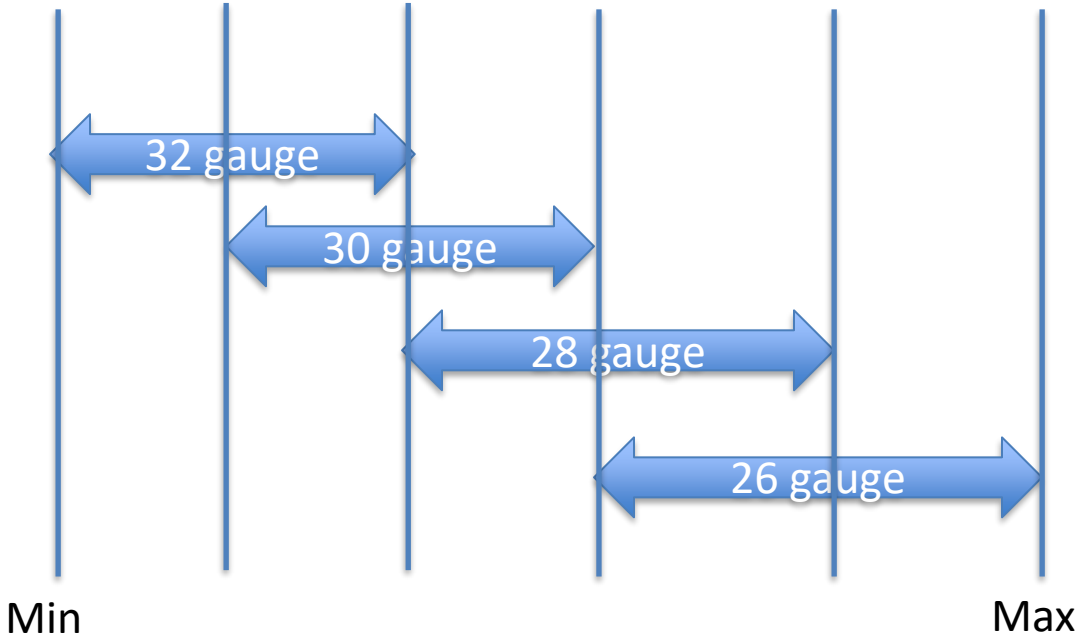
Drainless allows for more dense connection

Dual Side Drains



Wider the fanout the more loss, more crosstalk

Length of Twinax to gauge of wire



- Each Speed/technology has this same graph where there is a correct length vs insertion loss for the wire
- There is always some amount of overlap
- There is always a max size!
- There is always a min size due to flexible durability of the wire or min return loss issues

Examples of Cables attached to PCB

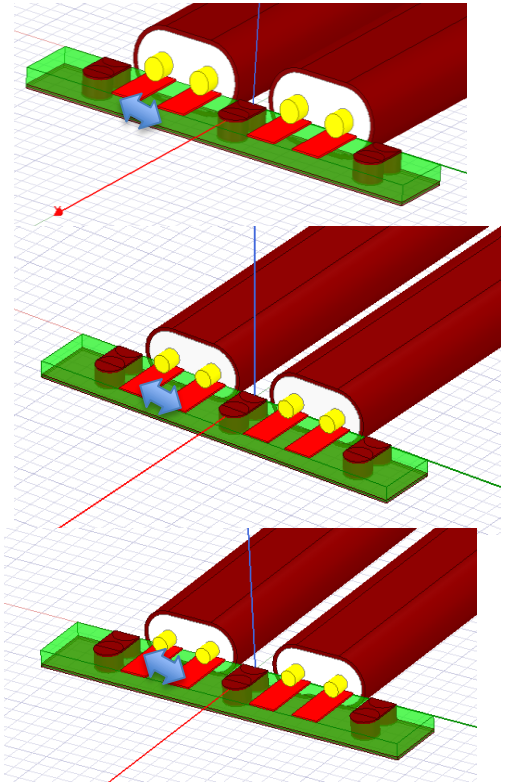
As wire gets smaller can use it on smaller connectors– need to match width to connector else fan out has increased loss and crosstalk

SFF 8612 uses 0.5mm pitch for wire and connector but only capable of short lengths

AWG:30
conductor to conductor ~0.6mm

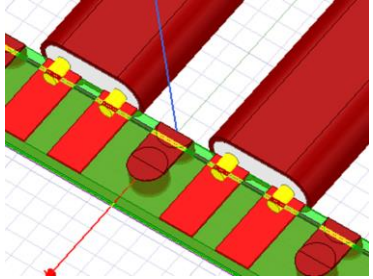
AWG:31
conductor to conductor ~0.55mm

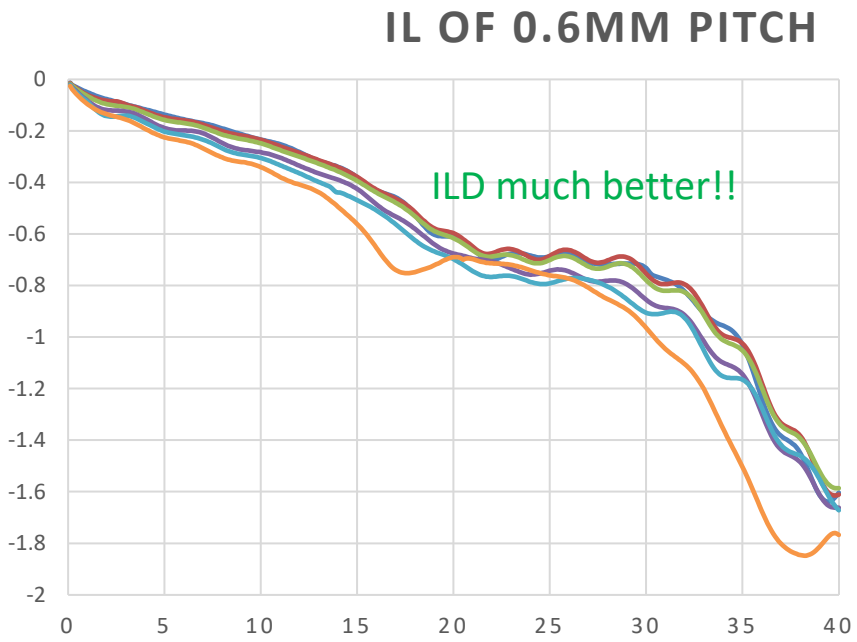
AWG:32
conductor to conductor ~0.5mm

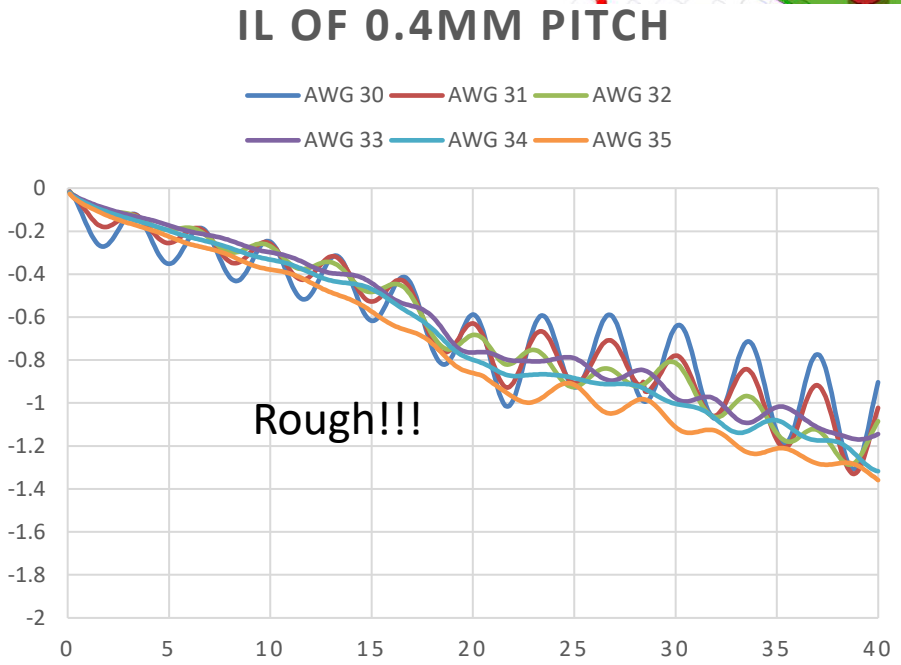


Pitch of Twinax Wire

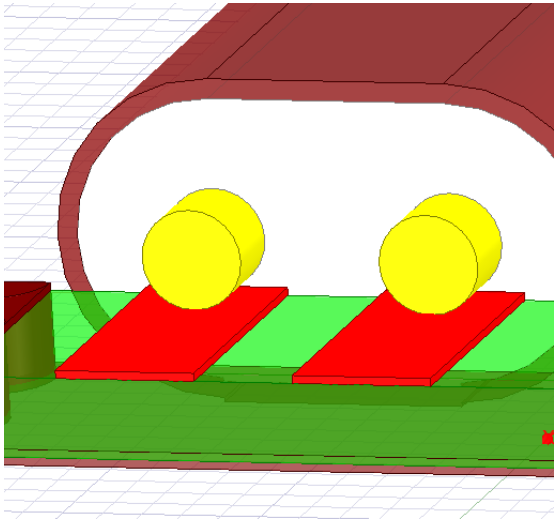
- As gauge increase, and pitch decreases, return loss/crosstalk influence the overall Insertion loss…. Why most impedance/larger gauge wire systems use bigger pitch.



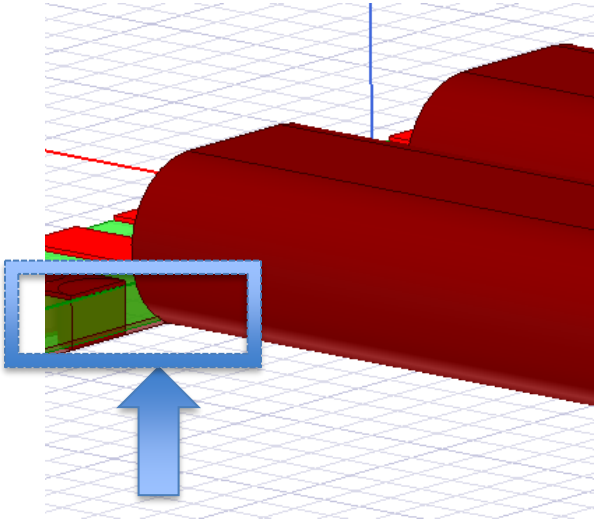




What about drain/drainless?



How could the Shield connect with PCB GND?



Shield GND touch the PCB GND by this part

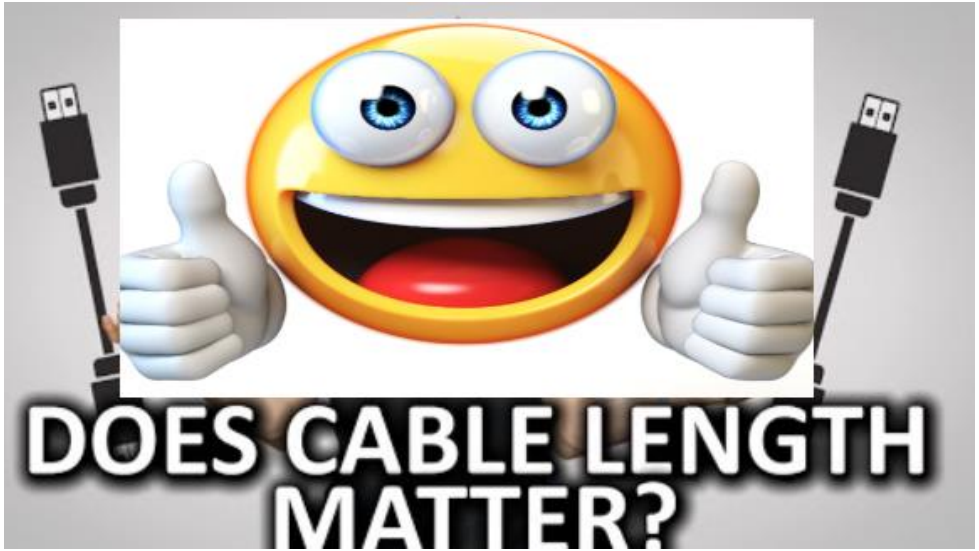
There are many ways to connect drainless configurations, some are IP driven, others are obvious.

If can remove ground wires, connector system could shrink!

However closer diff pairs yield more crosstalk!

Conclusions

- Wire length determines net channel loss which then creates…
- Wire size will determine the Insertion loss which then creates..
- Wire pitch determines the width of the connector
- The Crosstalk determines the grounding pitch and row to row pitch
- The overall connector system is finally determined.
- Going backwards and starting with a connector size and moving to a cable is where many connector systems fail.



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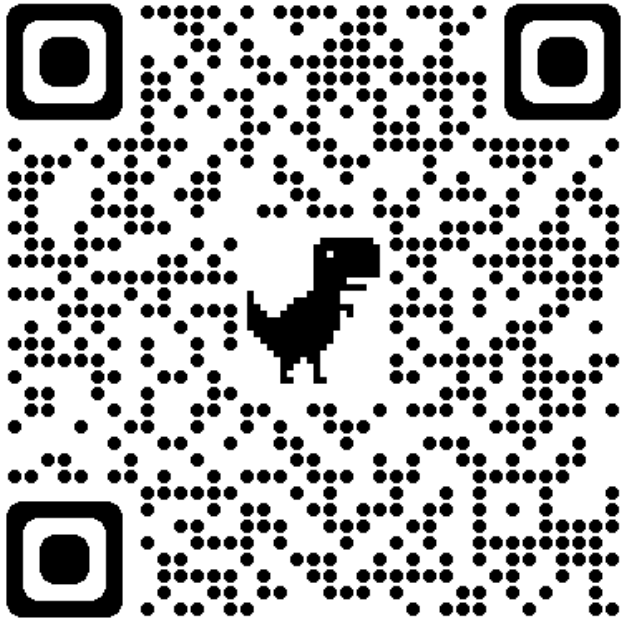

Thank you!

QUESTIONS?