Welcome to

DESIGNCON® 2022

WHERE THE CHIP MEETS THE BOARD

Limits of High-speed Connector & Cable Technology

Authors: Mick Felton (ACES), Mountain (ACES)

SPEAKERS

Mick Felton

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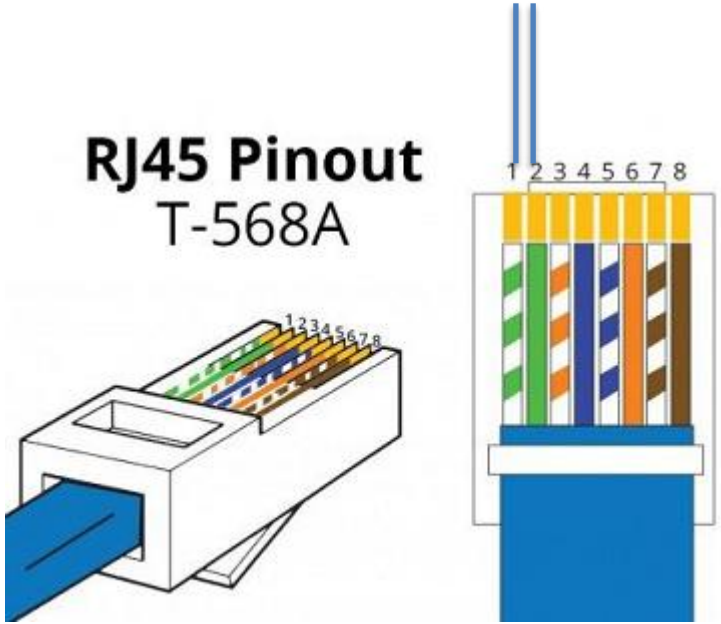
Mick has more than 30 years of experience with hardware design and manufacturing. He is an industry recognized signal integrity expert, with 30 patents issued. He has participated in committees for over 25 years, including FC, PCIE, SNIA, SFF, SAS, OCP, GENZ, EDSFF, QSFP-DD. Mick has worked with over 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.

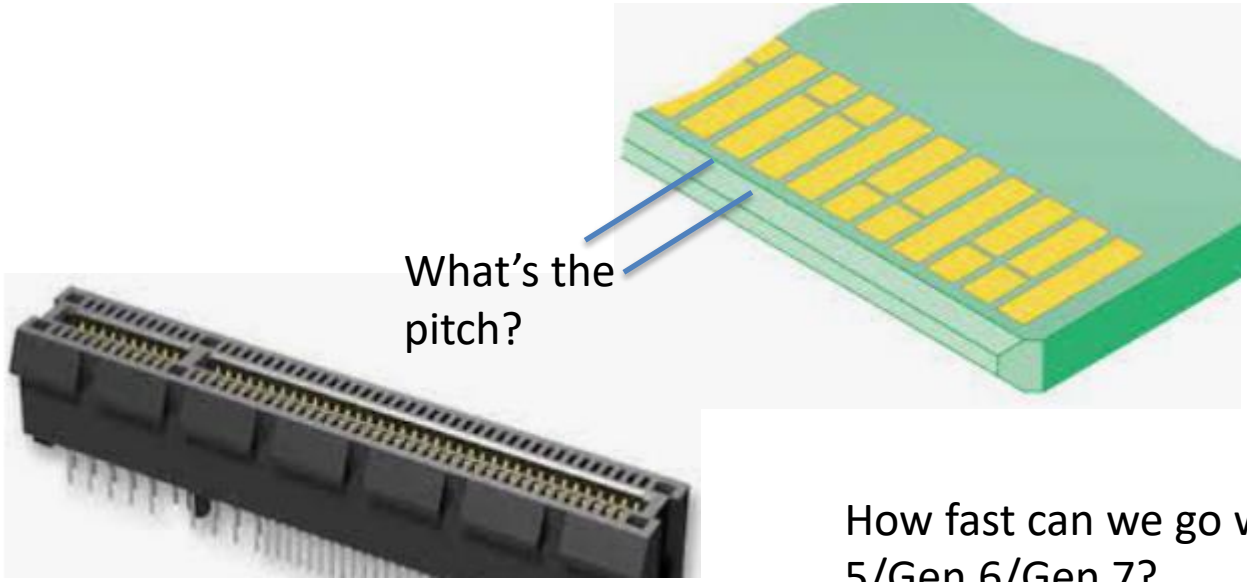
Rj45 has been around for decades…

Pitch of the
RJ45 contacts?



How fast can we go? 1G/10G/100G/ ?

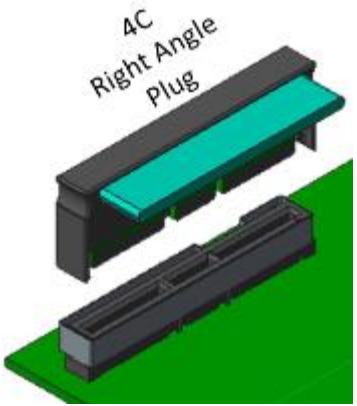
PCIE connector been around for decades



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

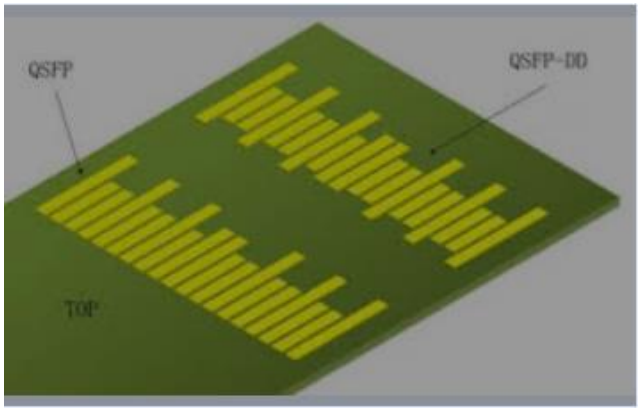
Latest Release Standard Connectors

4C – 0.6mm pitch



GEN Z, EDSFF,
OCP, COBO

QSFP / QSFP-DD
0.8mm pitch



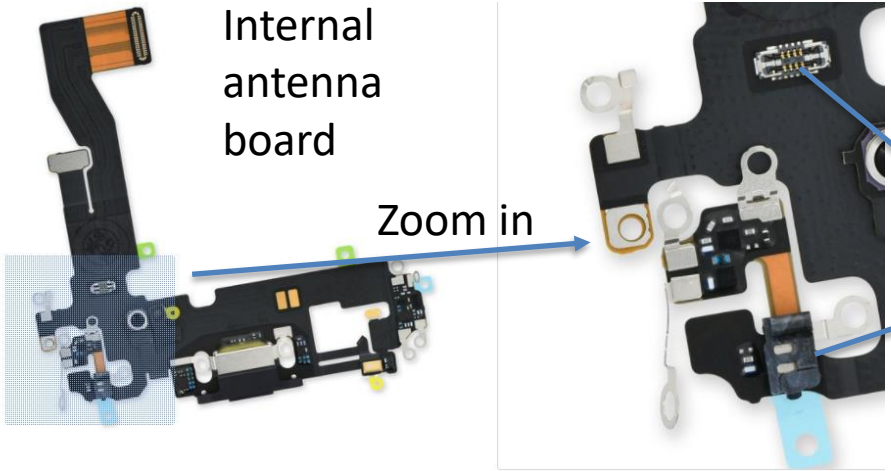
200/400/800G Ethernet

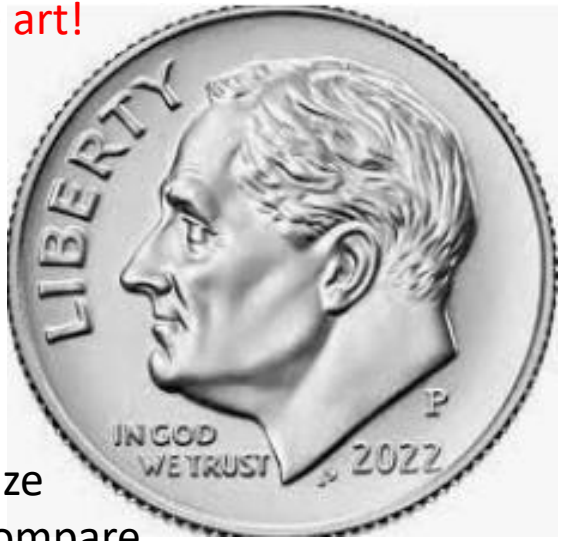
MCIO
0.6mm pitch

PCIE Gen 5

Large phone manufacturer, using 0.35 and 0.45mm connectors

This is state of the art!





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?

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!

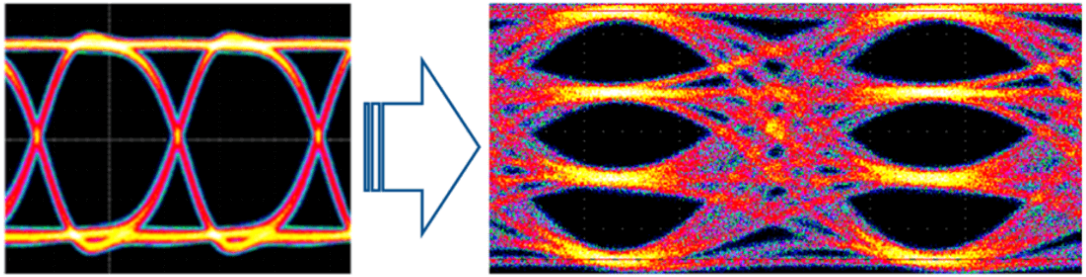
5. **Mechanical durability**
6. **Compliance**
7. **Impedance**

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

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

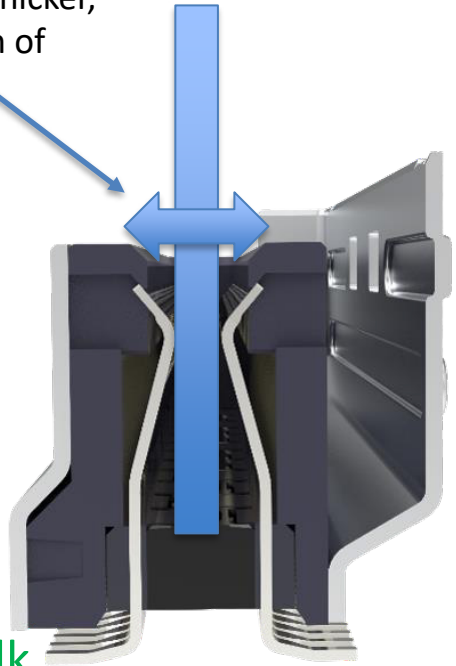
1. XTALK: PAM4 vs NRZ

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



NRZ PAM4

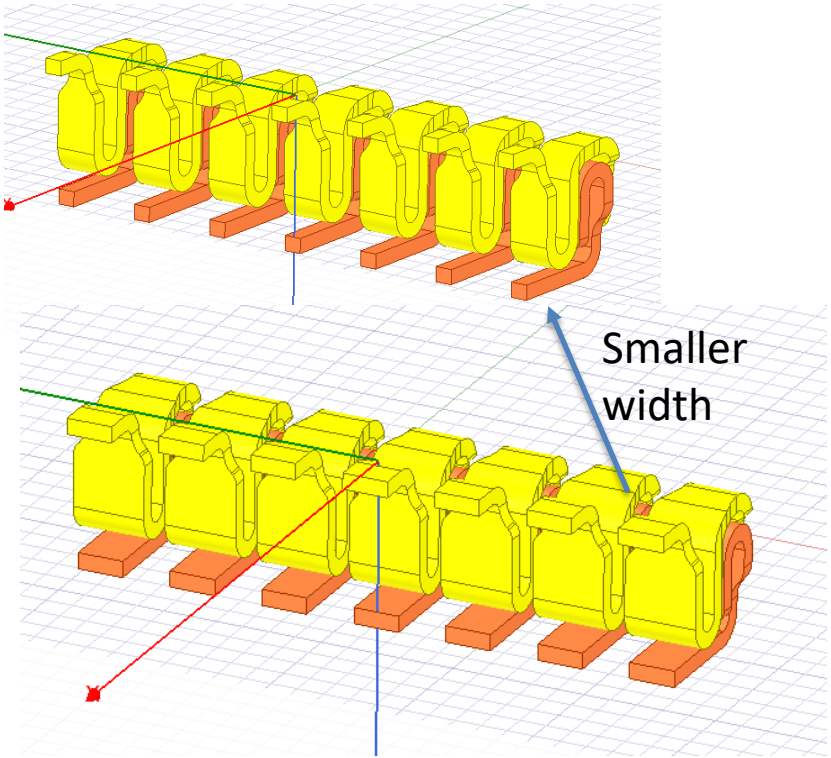
One simple trick to make xtalk bigger just make the PCB thicker, and grow width of connector!

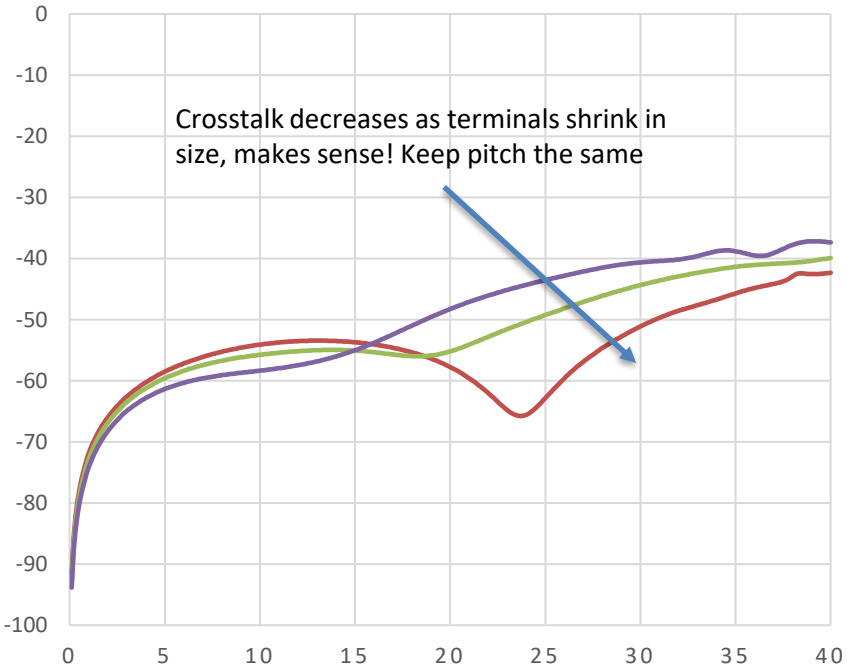


A connector that was fine for NRZ may need to:

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

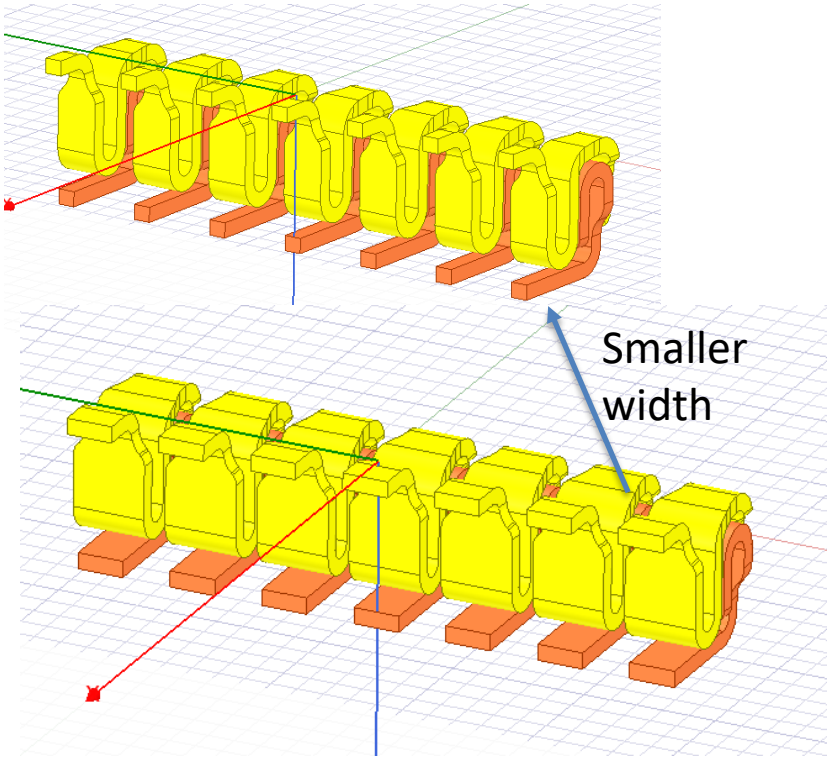
1. XTALK: Change connector terminal width?





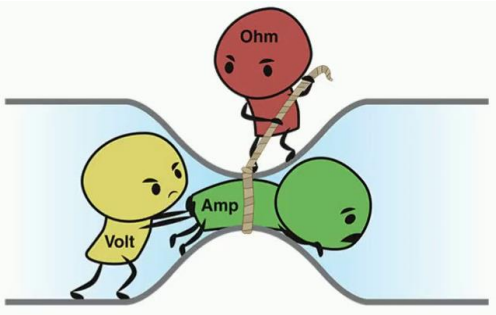
Making width smaller, but connector size still larger

2. DC Resistance: Change terminal width?

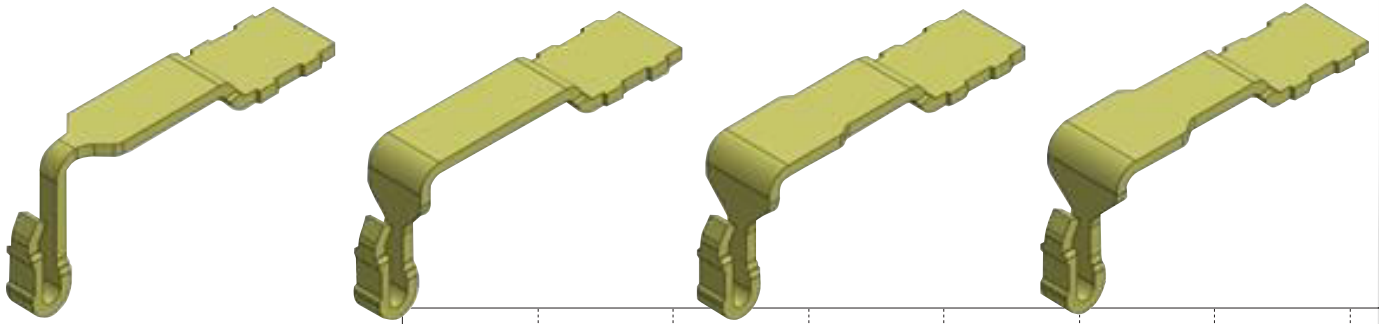


Making width smaller is going to impact the DC resistance as higher power SERDES are requiring more power.

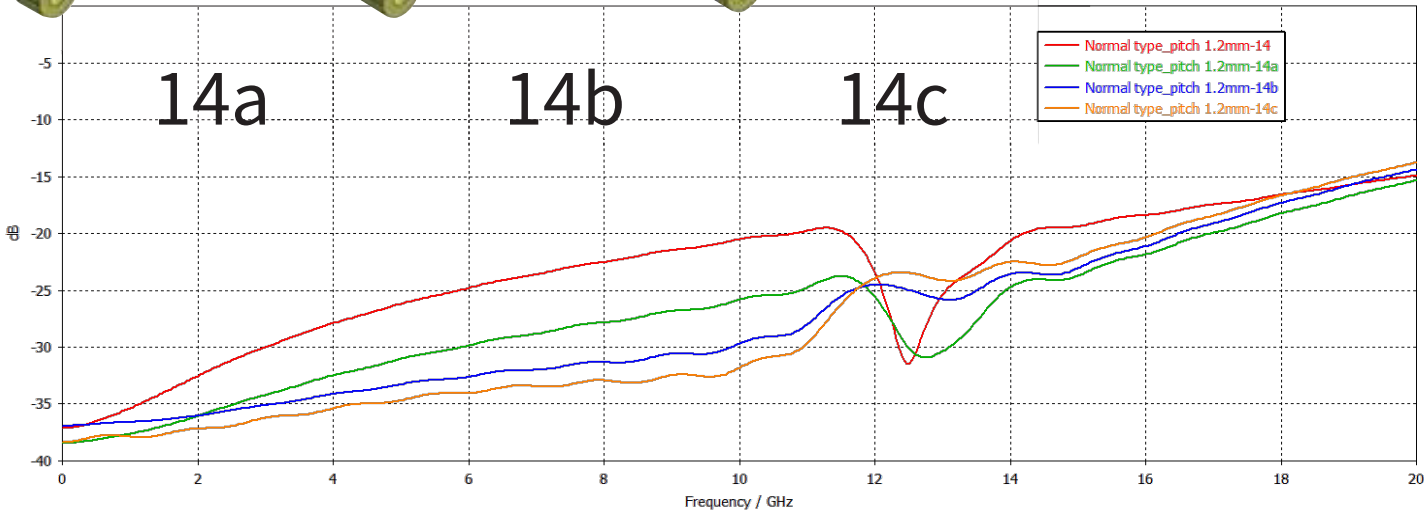
Many vendors have pushed the high power off to the side or a different connector. This still increases the overall size of the solution.



2. Changing size of terminal may also affect return loss

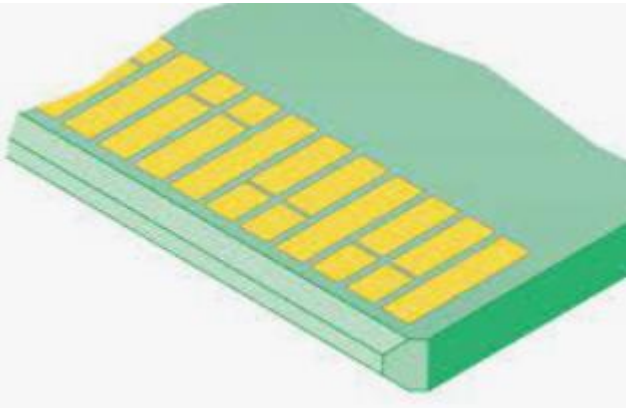


14 14a 14b 14c



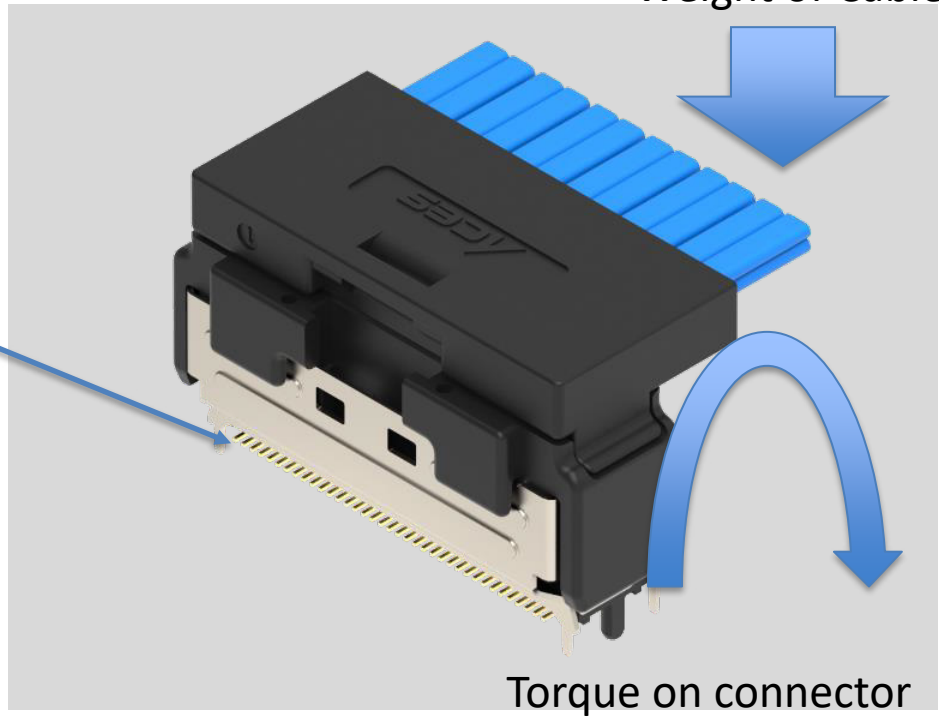
3. Strength of Mated Connection

- 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.



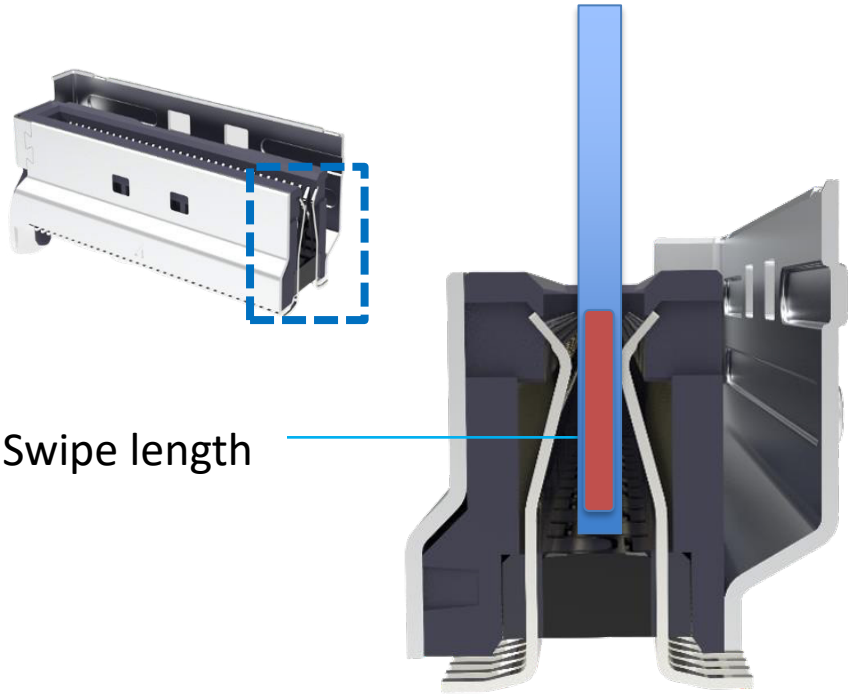
4. Strength of Single Side

- **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.**

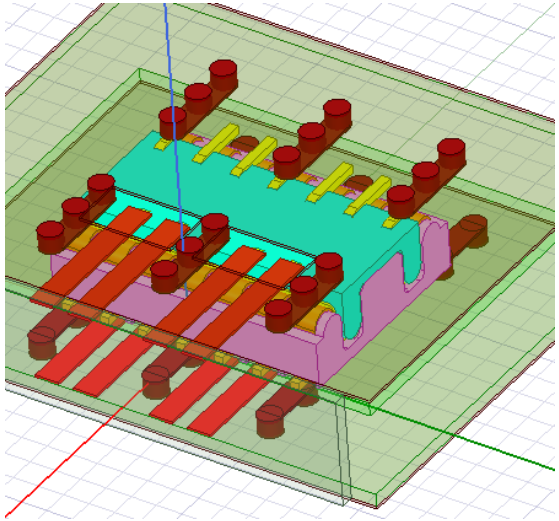


5. Mechanical Swipe Capability

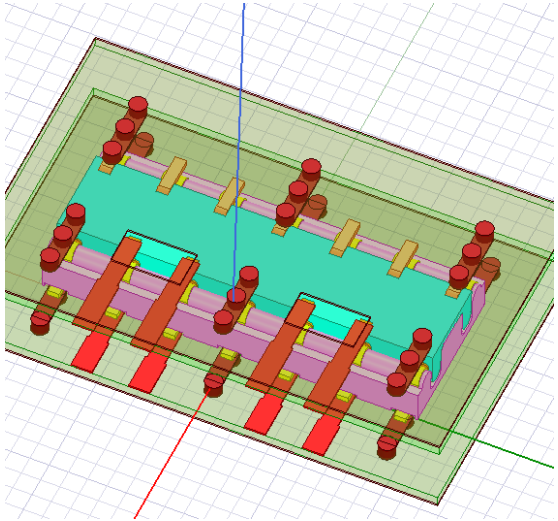
- The swipe of the connector allows for slight mis-alignment of mating interface
- This swipe length affects the length of the interface which in turn affects loss and crosstalk and impedance among others SI parameters
- The wipe could be 2 points of connect, a wide connect, or other types of connections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



PAD Pitch change



0.3 pitch



0.6 pitch

What if I change the pad pitch?

leave the same antipad,

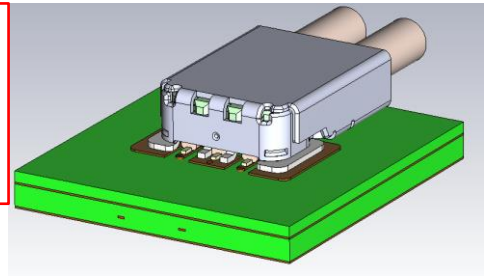
Leave the same ground pitch(G-G)

Feedback

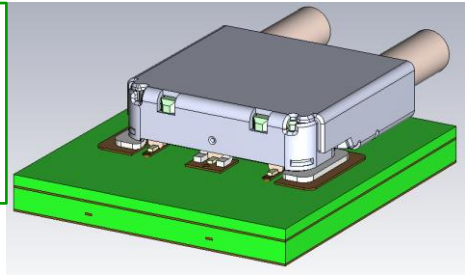
The anti pad will be wider if the pitch from 0.3 to 0.6

Pitch may increase but still need ground!

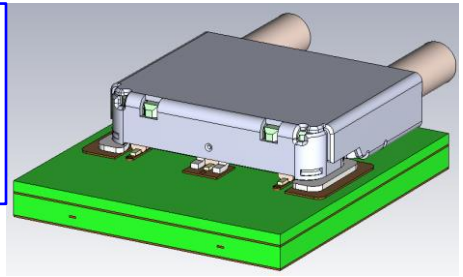
Normal Type Pitch 0.6mm

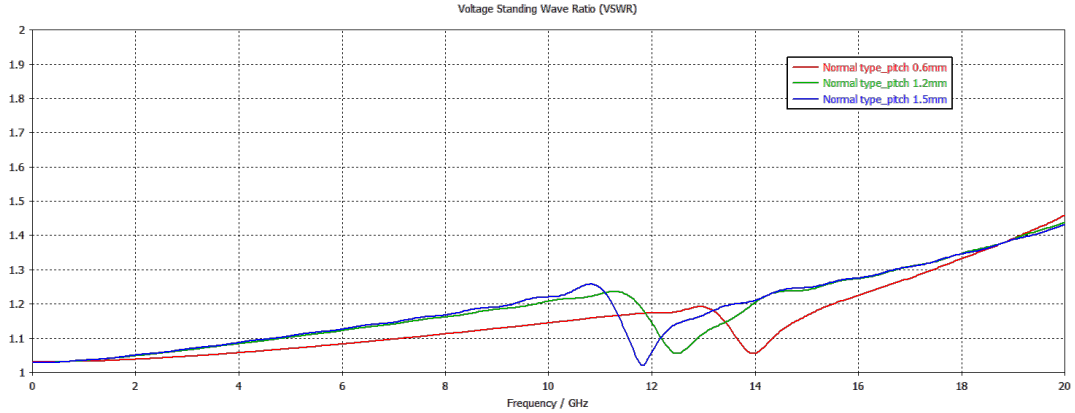


Normal Type Pitch 1.2mm



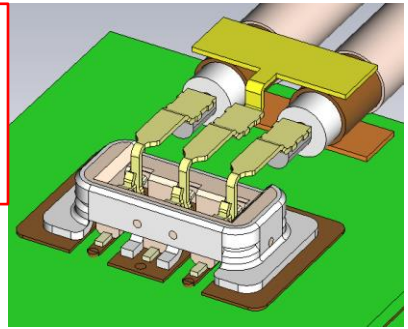
Normal Type Pitch 1.5mm



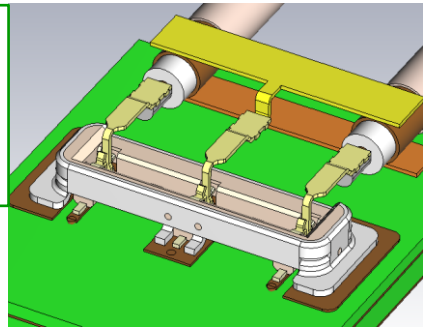


Example of 0.4mm connector but cable at 0.6mm w/wo gnd or 1.5mm

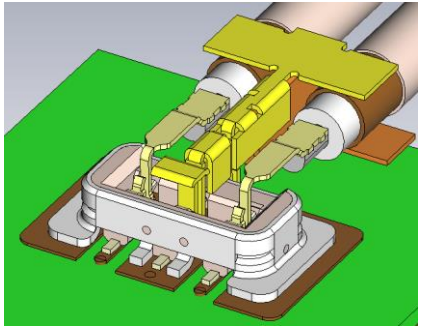
Normal Type Pitch 0.6mm

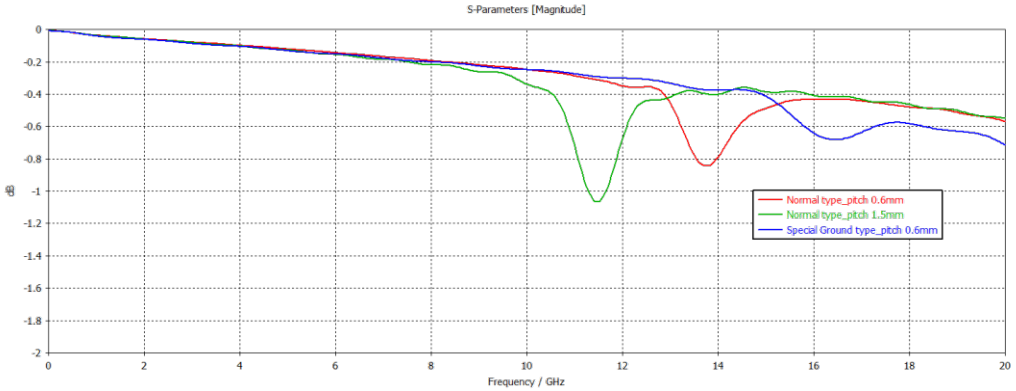


Normal Type Pitch 1.5mm



Special Ground Type Pitch 0.6mm

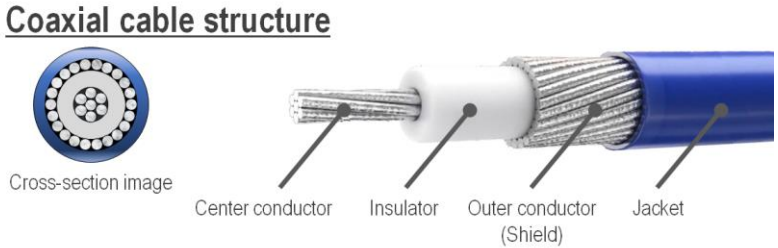




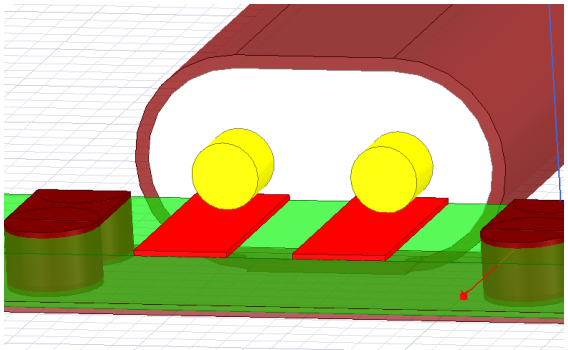
Cable topologies:

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

Could be stranded or solid wire constructions.



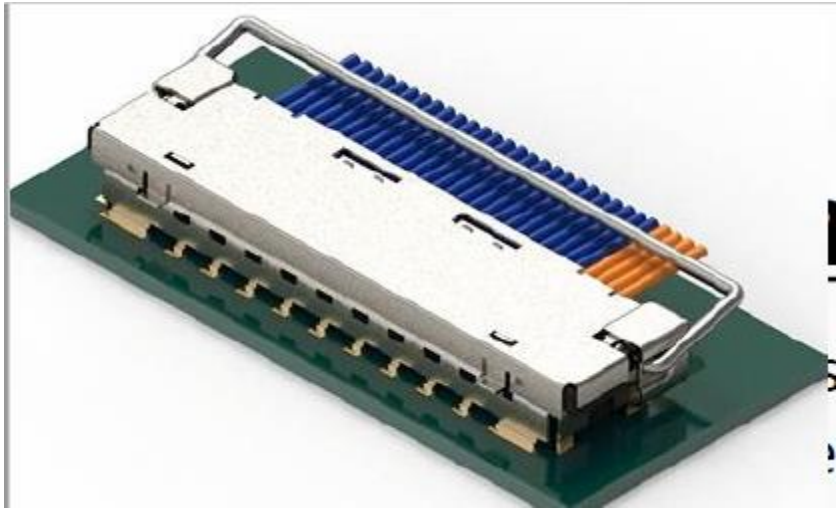
FFC wire:
Row of conductors with variable spacing for impedance or gauge changes
Wrapped or taped with foils or insulators

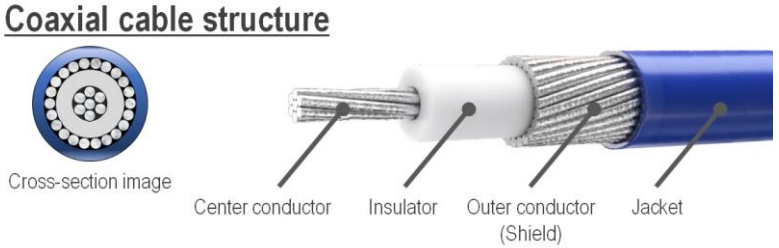


Twinax wire:
Oval shaped wire with at least 2 conductors and ground shielding

0.4mm pitch micro coax 44 gauge design

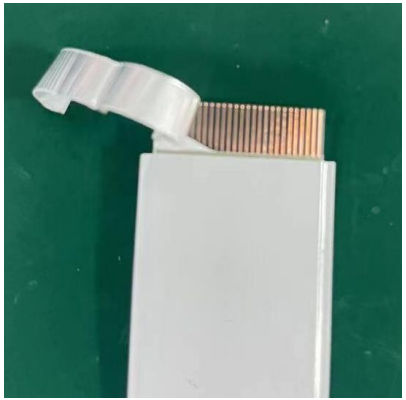
- Here's an example of a very small pitch micro-coax design.
- While the cable is very small and flexible, the number of cycles of flexing may become an issue at such a small gauge.
- The insertion loss is very high for small gauge
- The crosstalk inside of the connector is lower due to coax design but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



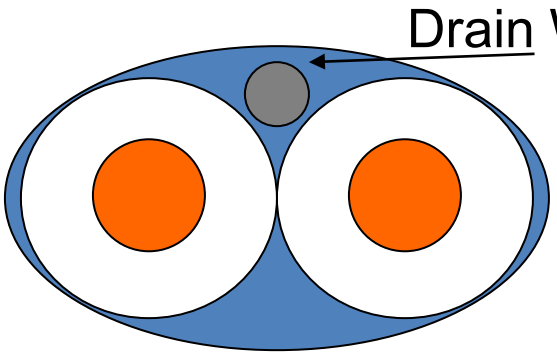


FFC 30-36 gauge, pitch 0.4mm or smaller

- 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

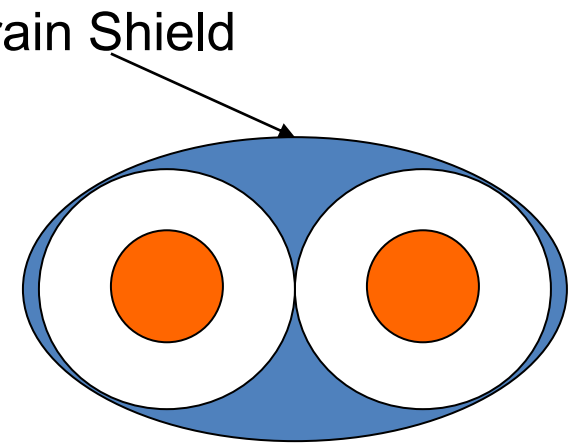


Types of Twinax wire



Twin-Ax Typical Construction
Asymmetric Electrical Field

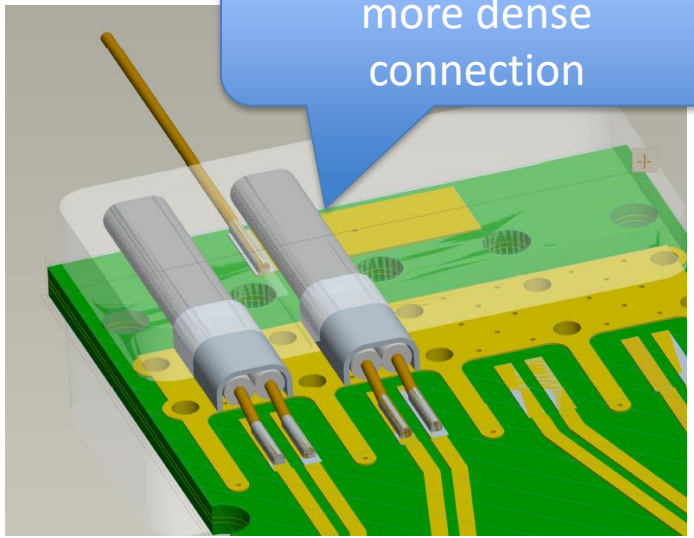
Typical construction today, requires more pitch space for each drain wire attach



Twin-Ax (Drainless)
Symmetric Electrical Field

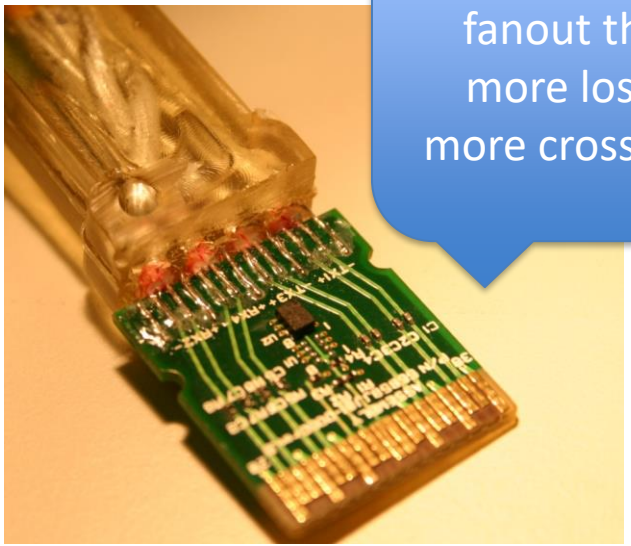
Examples of Cables attached to PCB

Drainless



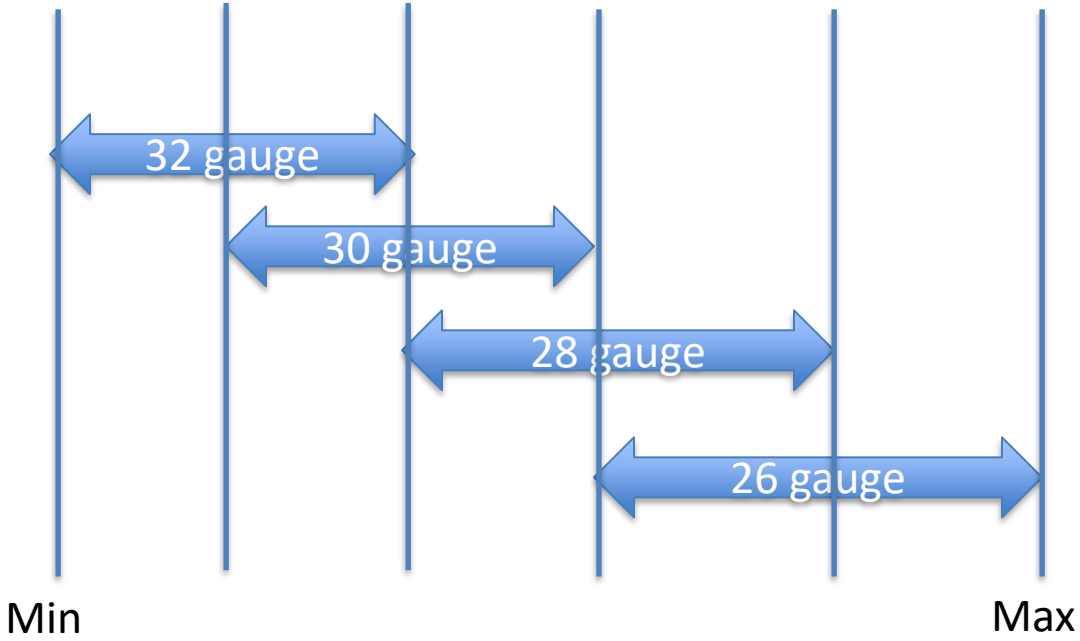
Drainless allows for more dense connection

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

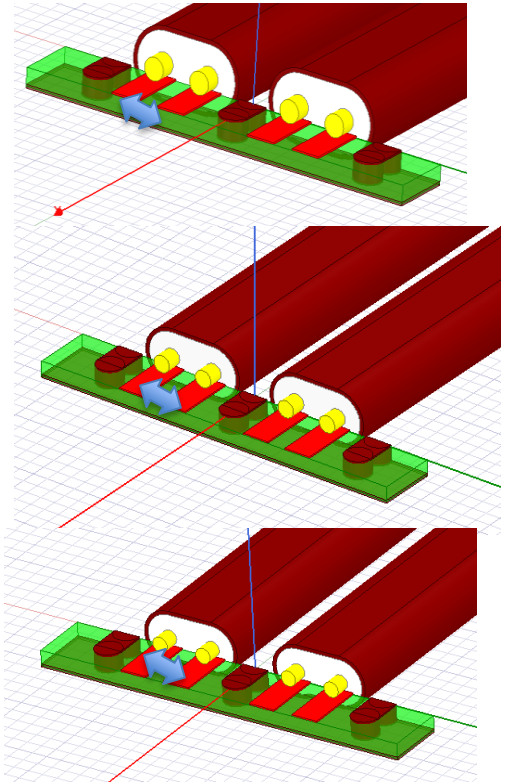
As wire gets smaller can use it on smaller connectors– need to match width to connector else fan out has increased loss and crosstalk

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

AWG:30
conductor to conductor ~0.6mm

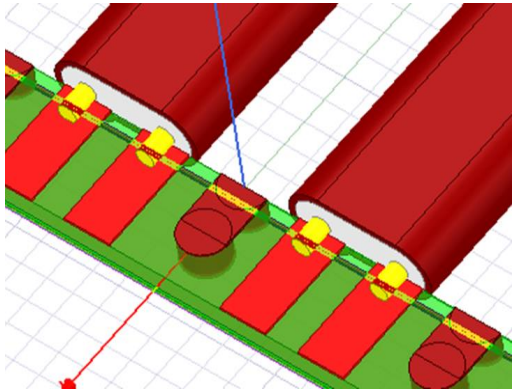
AWG:31
conductor to conductor ~0.55mm

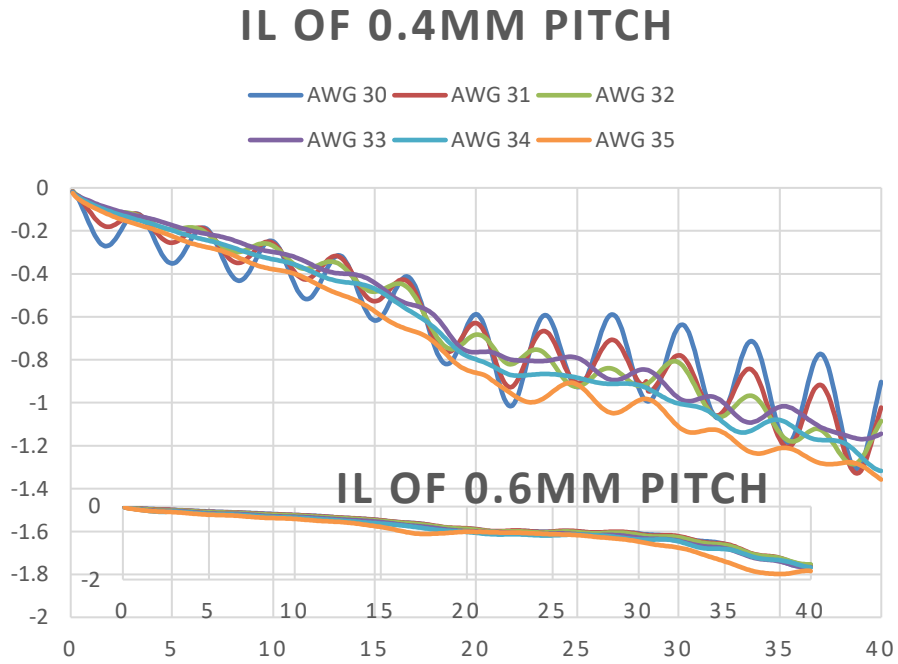
AWG:32
conductor to conductor ~0.5mm



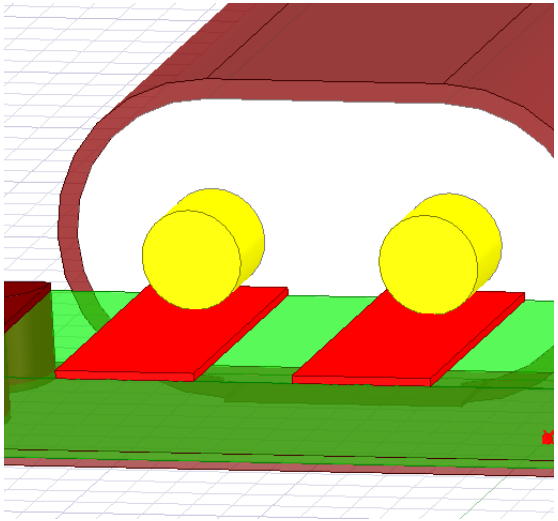
Pitch of Twinax Wire

- **As the AWG become smaller the 0.4 pitch will be hard to control the impedance , this will make the spacing (pitch) wider (as below pic is pitch 0.6mm)**

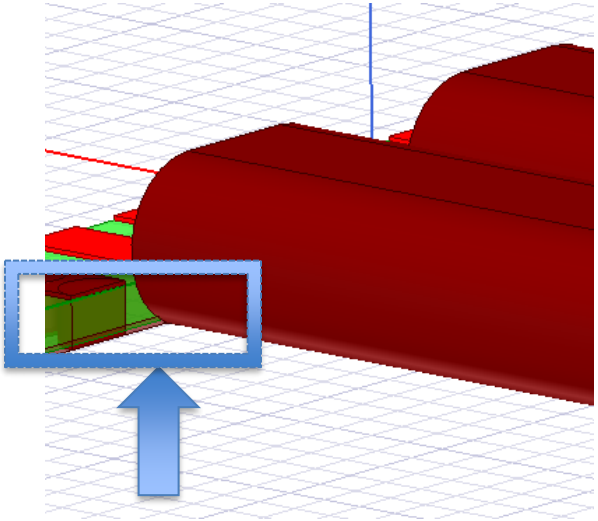




Cable topologies how to connect drain?



How could the Shield connect with PCB GND?

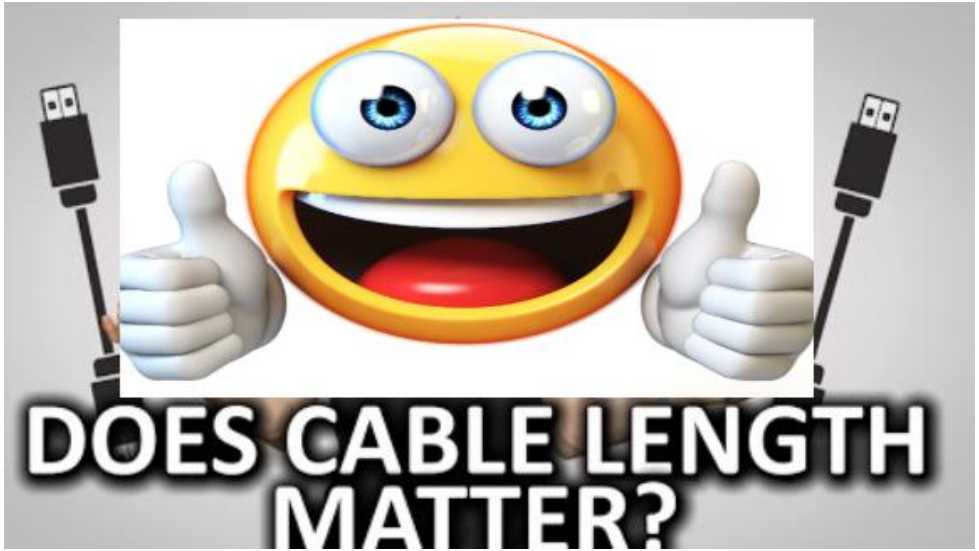


Shield GND touch the PCB GND by this part

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

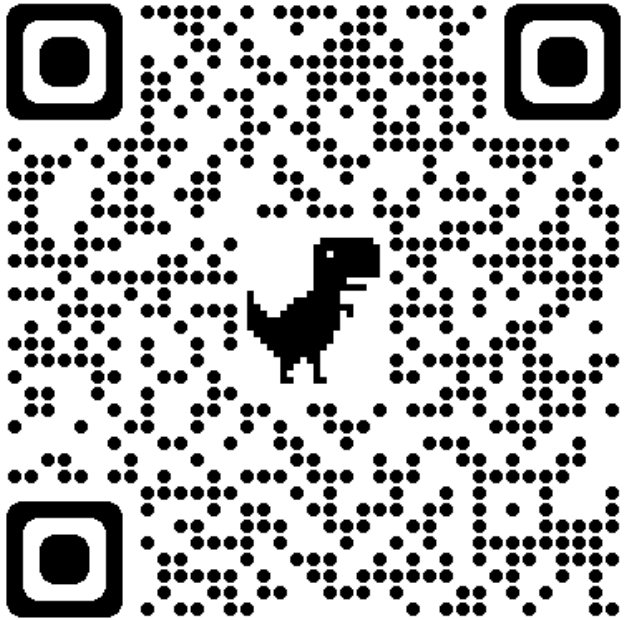
Conclusions

- 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.



MORE INFORMATION

- www.acesconn.com
- www.genesis-connected.com
- www.linkedin.com/in/mickey-felton-b7a87ba4
- Mickey.Felton@acesconn.com



Thank you!

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QUESTIONS?