Why Use Flyover® Cable Systems?

White Paper

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Abstract

Flyover® cable systems are designed to get signals off the PCB in order to improve signal integrity, increase design flexibility, and optimize thermal performance. These products route high-speed signals through low-loss, low-skew twinax cable. They operate across distances that can be up to several feet long while removing the need for exotic clock data recovery circuits (CDRs) or retimers. Including measured data and examples, this white paper explains why a cable solution can be better in a high-speed design. It also addresses concerns such as cable management and cost.

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As a Sr. Field Applications Engineer and Business Development Manager for Samtec, **Anthony Fellbaum** offers technical consultation and collaboration to help customers identify the ideal interconnect solution for their unique application. His design experience with backplanes, high-speed test equipment, RF multiplexers, and FPGAs across the telecom, space, smartphone and ODM industries uniquely qualify him as a leading technologist. Anthony received his Electrical Engineering degree from Lakehead University and is a member of the Professional Engineers of Ontario.

Integration Leads To Innovation

Samtec is structured like no other company in the interconnect industry: we work in a fully integrated capacity that enables true collaboration. The result is innovative solutions and effective strategies supporting optimization of the entire signal channel.

For more information contact SIG@samtec.com

Introduction

Flyover® cable systems are designed to get signals off the PCB in order to improve signal integrity, increase design flexibility, and optimize thermal performance. These products route high-speed signals through low-loss, low-skew twinax cable. They operate across distances that can be up to several feet long while removing the need for exotic clock data recovery circuits (CDRs) or retimers. Including measured data and examples, this white paper explains why a cable solution can be better in a high-speed design. It also addresses concerns such as cable management and cost.

Cable Offers Better Performance

The insertion loss vs frequency of typical PCB materials is well known and documented [1, 2, 3]. In comparison, Samtec's Flyover cable demonstrates significantly lower loss than any PCB grade material. Figure 1 compares the magnitude (in dB) of insertion loss for three typical PCB materials and two gauges of Samtec Flyover cable (30 and 34 AWG). A 10" length comparison is displayed for easier scaling.

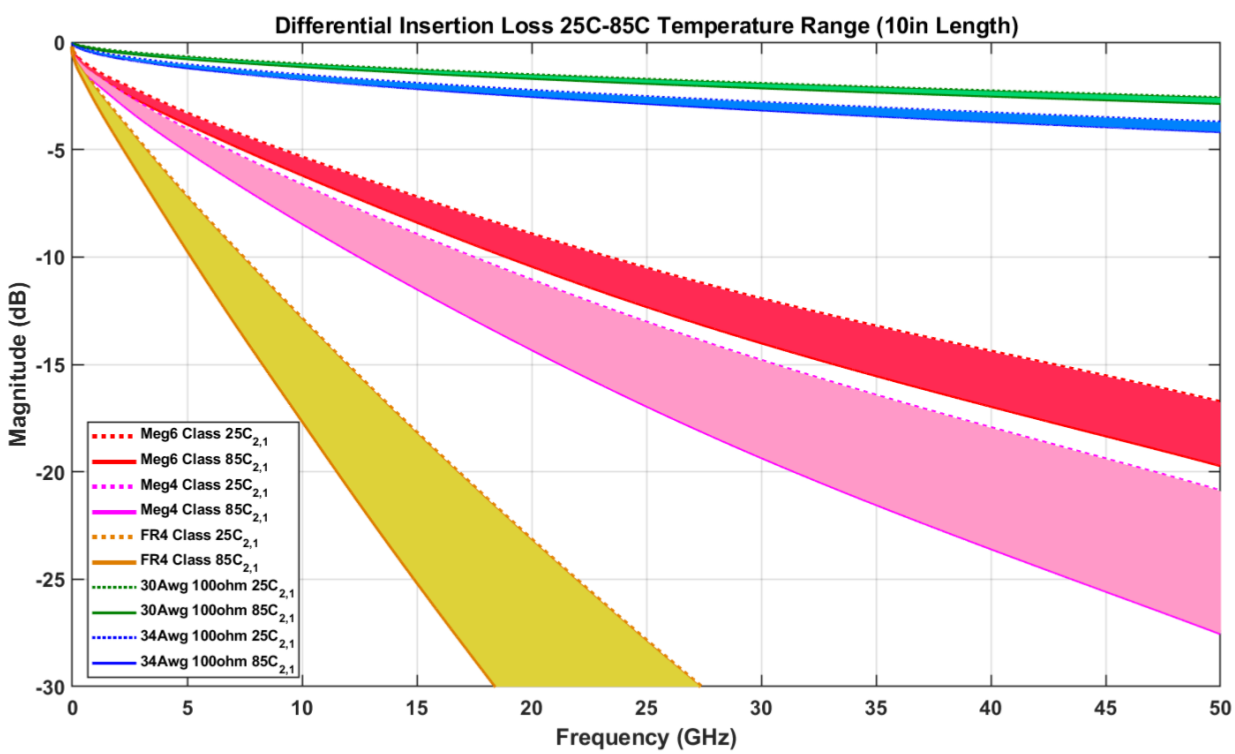


Figure 1: Differential insertion loss for a 10-inch Samtec Flyover cable (blue and green lines) as compared to typical PCB materials, across 50 GHz. 0-60% relative humidity is included in the temperature plots.

In Figure 1, for a typical high-speed signal running at 14 GHz Nyquist, the traditional PCB material (shown in yellow) is very lossy. So, the designer would likely select a higher-grade material (shown as light and dark pink in the graph), where the loss characteristics are significantly better. (Note that temperature variations can also degrade loss performance significantly.) However, even the best PCB performance is well below the Samtec low-skew high-speed twinax (green 30 gauge, blue 34 gauge in Figure 1) cable.

Within a Samtec Flyover system, a 30 AWG cable demonstrates insertion loss of 1.21 dB for 56 Gbps PAM4/14 GHz Nyquist or -1.8 dB for 112 Gbps PAM4/28 GHz Nyquist. The Samtec 34 AWG cable demonstrates insertion loss of -1.9 dB for 56 Gbps PAM4/14 GHz Nyquist or -2.9 dB for 112 Gbps PAM4/28 GHz Nyquist.

It is worth discussing the stability of these materials over temperature and relative humidity (0-60% relative humidity included in the temperature plot). As seen in the chart above, PCB materials have a significant drop in loss performance over temperature. Samtec's Eye Speed® Twinax cable, on the other hand, has very stable performance, thanks to the low moisture absorption properties of the dielectric used in the cable.

The plots above only compare PCB trace vs. cable conductors. In order to implement a cable system, a connector is required. To provide a full picture of the loss of a cabled solution, Figure 2 displays insertion loss with added connectors. The plot describes the measured insertion loss performance of Samtec's NovaRay® Flyover system with a length of 0.25 m. You can see added loss for the interconnect, which includes the footprint and breakout region design. Test cables and traces are de-embedded up to ~2 mm of the connector footprint.

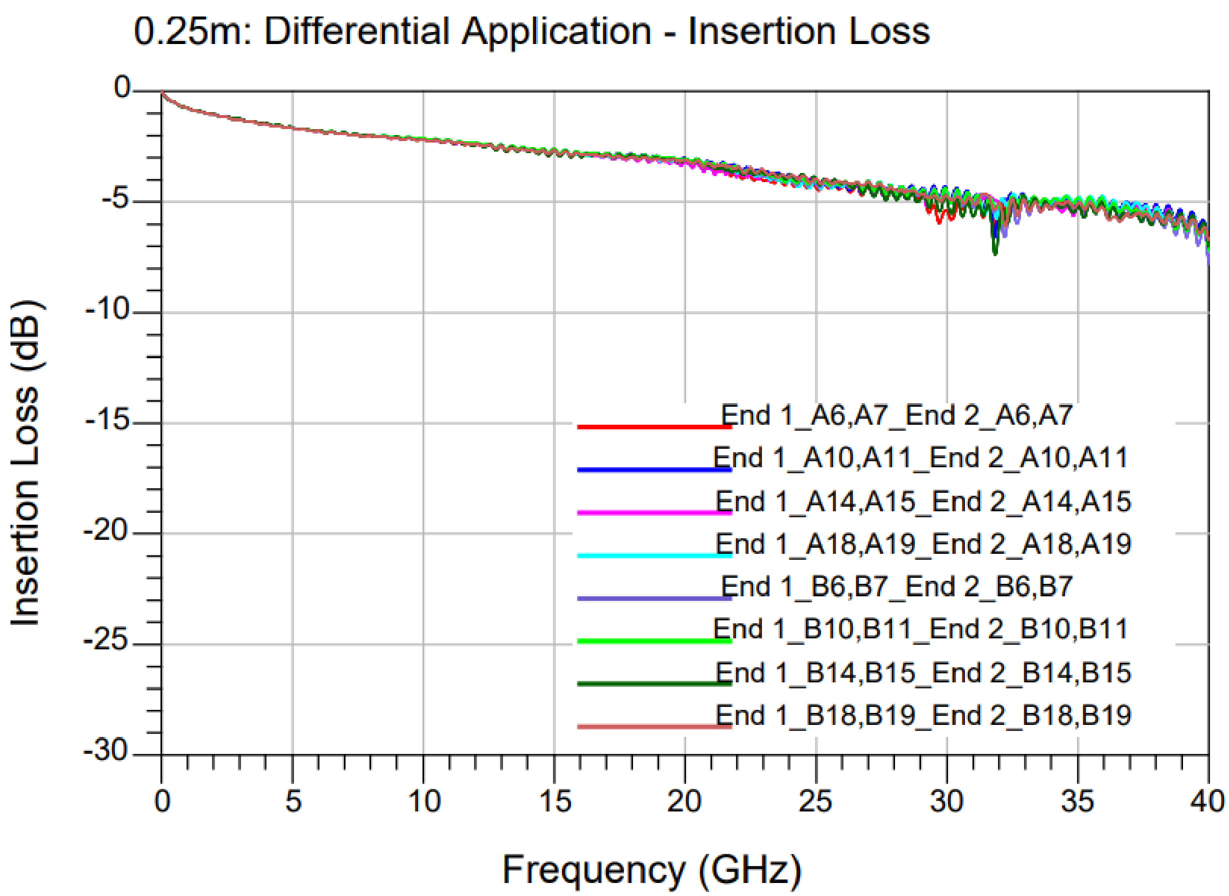


Figure 2: Performance plot for a Samtec NovaRay Flyover system at 0.25 m length shows excellent loss performance.

Why is cable better than PCB?

Simply put, cable provides better signal integrity than a PCB transmission line; specifically, this means that Flyover cables have better loss characteristics as compared to PCB transmission lines in a given application. This improved performance is primarily due to two things: the insulating (dielectric) material used and the electrical properties of the conductor.

The insulating material surrounding the copper in Samtec's Eye-Speed® Twinax cable has significantly lower relative permittivity (leading to an electrically shorter path) than the weave material used to support transmission lines in PCBs, and a much lower dissipation factor as well, lower by an order of magnitude (see Figure 3). PCBs are manufactured with a high-end fabric, similar to fiberglass, which has excellent electrical properties, but its overall dielectric properties are not as good as the fluoropolymers used in the Eye Speed® 100 ohm twinax cable.

Specifically, fluoropolymers have a dielectric constant (Dk) in the low 2's, as compared to high-end PCB material, such as Megatron 8 with a dielectric constant of around 3.

Samtec uses a proprietary fluoropolymer that has a very low Dk and loss tangent, allowing for even better loss performance compared to cables using similar materials. Samtec continues to advance the state of the art with dielectric materials and performance in its cables, such as with its Eye Speed® ultra-low skew twinax products.

Eye Speed® Ultra Low Skew Twinax			28 AWG	30 AWG	32 AWG	34 AWG	36 AWG
Nominal Performance Specifications							
14 GHz (28G NRZ/ 56G PAM4)	0.25 m	IL (dB)	-1.0	-1.2	-1.5	-1.8	-2.2
	1.00 m		-3.9	-4.7	-5.9	-7.2	-8.7
28 GHz (56G NRZ/ 112G PAM4)	0.25 m		-1.5	-1.8	-2.2	-2.6	-3.2
	1.00 m		-6.0	-7.0	-8.7	-10.6	-12.7
Density/Flexibility			Good	Good	Better	Best	Best

* Eye Speed® Ultra Low Skew Twinax Cable is available in engineered impedance configurations of 85 Ω, 92 Ω and 100 Ω.

Figure 3: Samtec's Eye Speed co–extruded twinax cables eliminate the performance limitations and inconsistencies of individually extruded dielectric twinax cabling, improving signal integrity, bandwidth, and reach for high-performance system architectures.

Another reason Samtec's Ultra-Low Skew Twinax cable has better loss characteristics than a PCB transmission line is the size of the conductor. Typical high-speed traces have a cross-sectional area of approximately 4 mil^2 depending on trace width (in this case, using 6 mil wide x 0.6 mil height per conductor), but the cross-sectional area of Samtec's most popular twinax gauge cable, at 34 AWG, is about 31 mil^2 (6.3 mil diameter per conductor).

This is nearly 8x the relative cross-sectional area of a high-speed trace, and the outcome is significantly lower insertion loss for the Samtec Flyover cable in the same length conductor. Considering skin effect causes high-speed signals to use the outer perimeter of the conductor, the conductor size becomes even more critical as frequency rises.

Additionally, Samtec high-speed cable is plated with silver, which has significantly better conductive properties than copper, leading to even lower insertion loss across high frequencies. Cable conductors use rolled copper which has a much lower surface roughness compared to etched PCB traces. All of this plays a consequential role in high frequency transmission.

For PCB materials, in addition to the inherent electrical properties of the material, the effects of the weave of the dielectric can also impact signals with data rates as low as 10 Gbps. When a high-speed conductor is running through a weave, the geometry of that weave will affect the signal. This is known as "fiber weave skew." As data rates and/or frequencies increase, the effect of the fiber weave skew will be greater [4].

To improve signal integrity and avoid fiber weave skew effects, PCB manufacturers continue to create new, higher-end materials with tighter weaves, but designers must still be concerned about the angles their traces experience, and then compensate for the geometry limitations as much as possible.

In contrast, Samtec's Flyover cable is manufactured using extrusion, so the dielectric around the copper is a uniform material with no weave or grain (see Figure 4). This creates an even material around the conductors to maintain signal integrity. For instance, with the Samtec Eye Speed Cable, intrapair skew is <3.5 ps (measured in a meter).

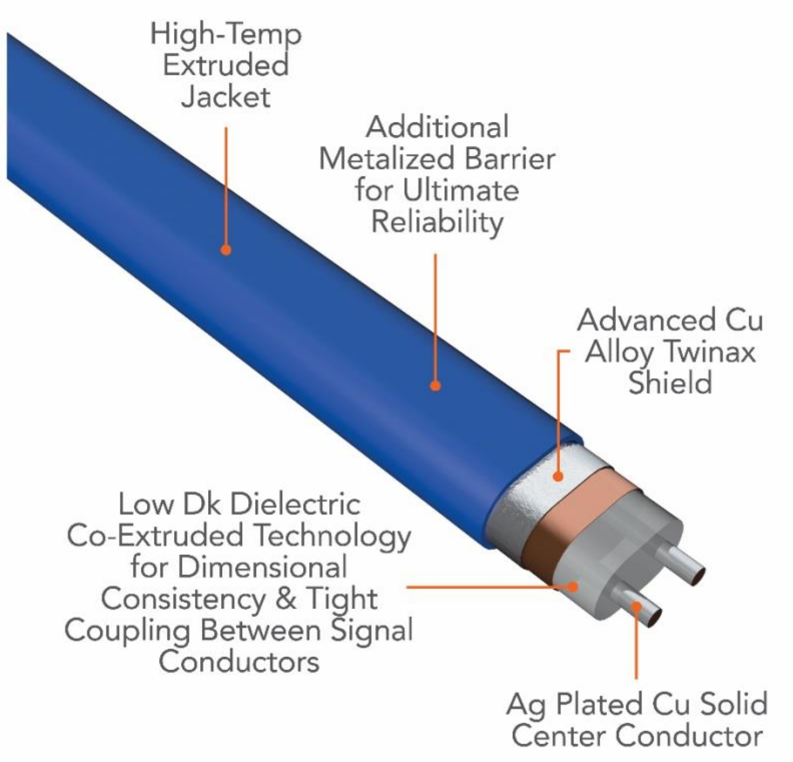


Figure 4: Samtec's proprietary Eye Speed co–extruded twinax cable technology eliminates the performance limitations and inconsistencies of individually extruded dielectric twinax cabling, improving signal integrity, bandwidth and reach for high-performance system architectures.

So why is cable better than PCB? A combination of better dielectrics, coextrusion technology, as well as larger, silver-plated conductors with lower surface roughness all add up to significantly better loss performance for high-speed signals in Samtec's Ultra Low Skew Twinax as compared to PCB traces.

How can cables reduce design complexity?

As noted above, high speed PCB transmission lines, such as those carrying PCIe® or Ethernet signals, are affected by fiber weave skew. One traditional approach to mitigate fiber weave skew is to incorporate CDRs or retimers to improve signal integrity.

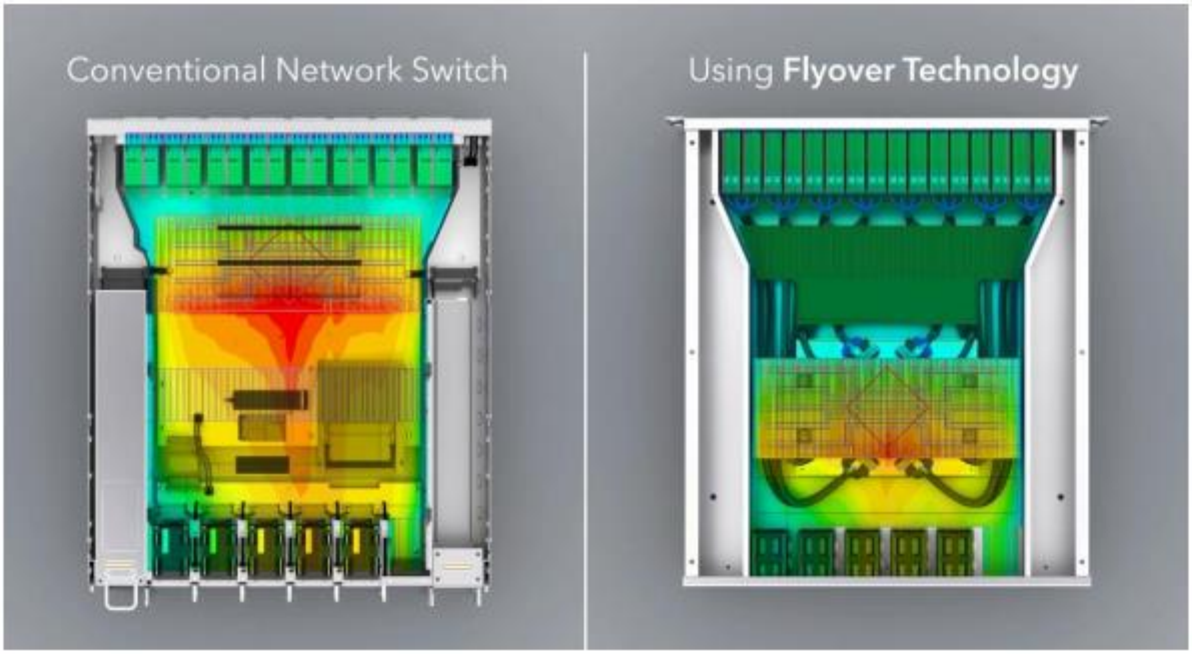
As a signal propagates across transmission lines on a PCB, it is affected by noise and other signals, passes through vias or around corners, and those geometry changes introduce skew (where the P and N of the differential pair will become out of sync). Simply put, a CDR corrects the signal as it travels through the PCB.

In addition, a CDR can also have some equalization properties that improve signal strength (to make up for loss). Unfortunately, once the signal leaves the CDR circuitry, it is once again susceptible to skew, noise, and interference. In addition, adding CDRs to a design increases cost, complexity, real estate, power consumption, thermal effects, and heat. In contrast, a Flyover cable is a passive solution, so it does not add heat and requires no power.

Unfortunately, CDRs can add up to several nanoseconds of latency to a system, depending on the chip, which may be significant in a mission critical application that is time sensitive. Notably, PAM4 adds more complexity in cleaning up a signal, which can add even more latency. Because of the dielectric qualities of the cable, designs using Flyover cables have significantly lower latency than those using a PCB or a PCB with CDRs. In addition, getting the signal off the board can reduce the number of layers in the PCB stack up, which can reduce cost and complexity as discussed in detail later in this paper.

How can cables improve thermal management?

Flyover cable can add significant flexibility to a design, allowing designers to locate boards, chips, and components at the optimal location to lessen thermal effects and maximize performance. Figure 5 shows a typical telecom network switch design from the early days of PAM4 56 Gbps switch development which compares a real-world prototype using conventional PCB transmission lines (left) and a re-designed version using Samtec Flyover Technology (right). The system looped 1m passive DACs between the top and bottom QSFP-DD front ports.



- Thermal Management of up to 1.2kW systems
  - 14 W per QSFP-DD
  - 500 W ASIC
  - 150 W miscellaneous

Figure 5: By redesigning the network switch (left) using Flyover Technology (right), designers realized significant improvement in thermal management.

In Figure 5, note how in the Flyover design using an 18” cable the FPGA chip has been moved towards the back of the box, which dramatically impacts the heat within the chassis, including to the optics on the front panel (which should improve the lifetime and reduce the need for service of the optics).

As systems move to higher data rates, there will be more ports on the ASIC. This will increase the amount of heat in the system, so thermal management will become more important. High throughput systems such as these could easily dissipate 1000 W or more. Strategically placing heat-producing components in the system in cooler areas can have a large impact on signal integrity, cost, power consumption, product lifetimes, and thermal management.

How can Flyover cables improve design flexibility?

In addition to improved thermal conditions and signal integrity, Flyover cable provides the flexibility to place components in the optimal location to simplify assembly and improve serviceability.

For example, if a design has a stack configuration or a port that needs to be put on a different plane, this can be easily accomplished with the Flyover cable while providing the best signal integrity. This approach could also help with mechanical tolerances, with the cable allowing more movement in a system than a PCB would.

With a modular system, smaller cards can be used for components that require servicing. For instance, a system might contain a very complex card with a high-end FPGA ASIC. From that card, the designer could run a Flyover cable to the optical ports where everything is plugged in to a simpler card. Then, if the complex circuit fails, the service person does not have to unplug the optics; they can simply replace the processing card.

Flyover systems can also provide flexibility in front port choices because designers would not need to consider different skews of a PCB. For example, a system designer may require QSFP ports in one system and SFP ports in another, but the fundamental switch or computing card is the same for both systems. Using Flyover cable with a modular approach allows designers to swap out the port type without affecting the high-speed design on the PCB. This reduces cost, production complexity, and design time. With Flyover solutions, designers gain the flexibility to connect chip to chip, chip to backplane, and/or chip to port while maintaining the best possible signal integrity and optimizing for thermal dissipation. Samtec carries a variety of end options, including low-profile, dense, blind mate, or industry standard.

How can using Flyover cables reduce power consumption?

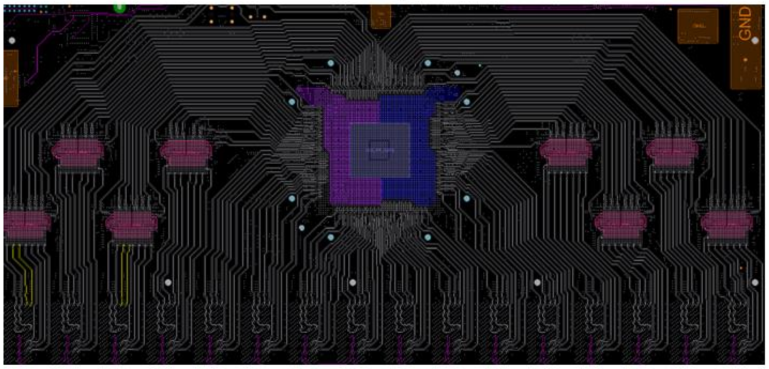
As mentioned above, using a Flyover design eliminates the needs for CDRs, which are active components, so their elimination improves the power budget. In addition, the better loss performance in the cable can reduce the burden on including additional SerDes TX and RX equalization, which can help reduce power consumption.

How can using Flyover cables simplify system layout?

In a system with a high number of SerDes/differential pairs, running a Flyover cable can significantly ease routing. This means the layout engineer may not need as many layers of the PCB, and getting the signal off the board onto Flyover cable near the chip can greatly simplify the layout of the system.

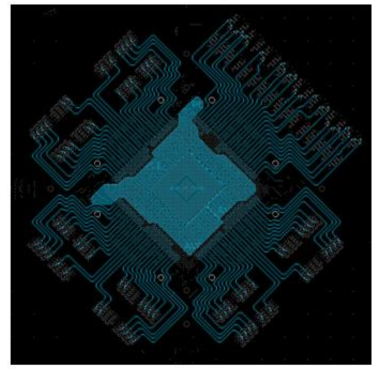
Many designs now have regions of the PCB that contain incredibly dense routing, which is traditionally eased with more layers or increased routing lengths. Flyover solutions can help avoid both of these expensive alternatives. Figure 6 illustrates a high port-count network switch layout, showing that the Flyover layout is much less complex than the traditional switch layout using PCB traces.

Traditional Switch Layout to Front Port



2" to 6.5" traces center ports
> 12" traces on outside ports – re-timers

Flyover Layout



2" – 3" traces on any port

Figure 6: Traditional switch layout to front port (left) as compared to an alternative less complex Flyover layout (right).

The flyover approach uses 18" cables and pushes the ASIC further back into the system for better thermal performance (Figures 7 and 8). The simplified routing of the Flyover solution enables better overall signal integrity, and the measured performance proves it. Figure 9 shows a significantly improved BER in the Flyover approach versus the traditional approach. Note that the BER is measured pre-FEC.

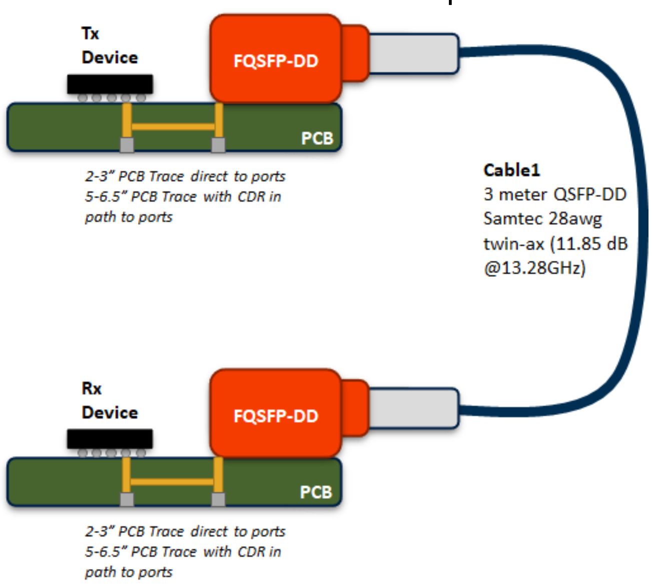


Figure 7: Traditional routing channel depicted in Figure 6 (left).

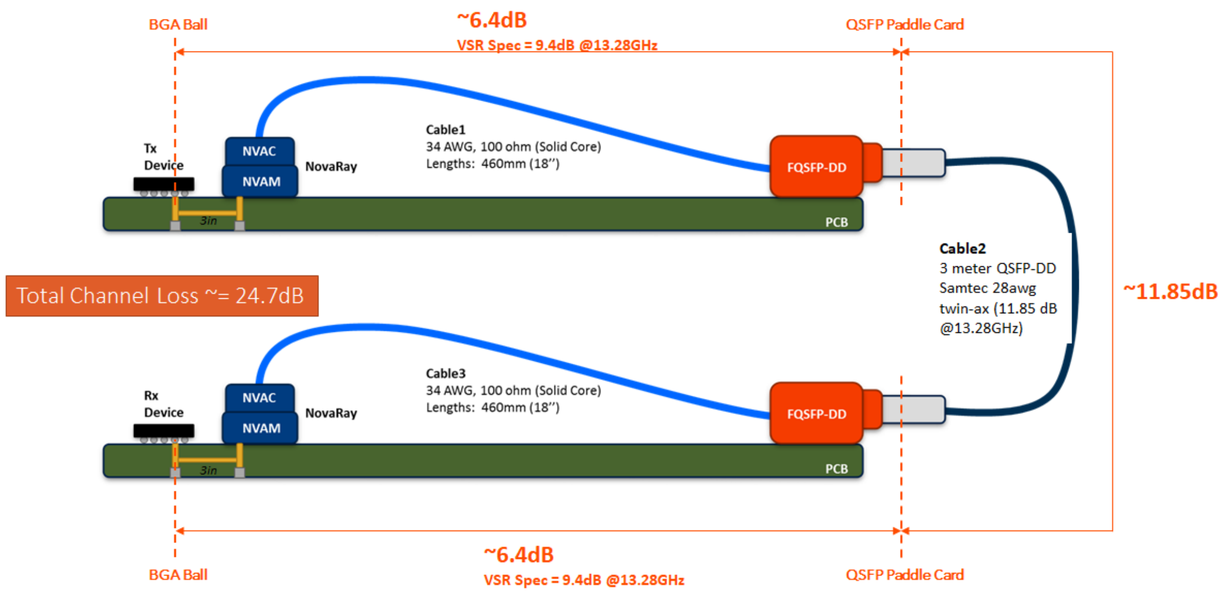


Figure 8: Flyover channel depicted in Figure 6 (right).

Figure 9: Bit-error rates (BER) of the ASIC in Figure 6 running at 56G PAM4 per lane in conventional (top) and Flyover (bottom) configurations show significantly better BER performance in the Flyover configuration.

What about cost?

Using Flyover can eliminate the need for CDRs and high-end PCB materials, as well as reduce the number of PCB layers, all of which improves system cost. Also, reducing the complexity of the design can improve time to market and circumvent performance complications in densely routed regions of PCB. Finally, Flyover cable allows design flexibility, which improves serviceability and product lifetimes due to reduced thermal effects. The bottom line: Flyover will provide better signal integrity and thermal management without adding to overall system cost.

What about cable management?

Designers who are new to using Flyover cable may be concerned about cable management. One question often asked is: What about the effects of airflow by using cables? It is true that cables will affect airflow, but because they are typically much longer than the traces they replace, the cables can be routed to minimize their impact on air flow. Samtec has a team of system architects available to help with cable management in new designs, helping to optimize for signal integrity and distribution of the thermal load [5,6].

The kinds of questions Samtec's cable management team can assist with include:

- Does my cable or bundle need to be secured to the chassis? How? Where?
- How will cables impact airflow in my design?
- How will unsecured cables discrete or bundled behave in shock and vibe?
- How do we run bundled cables?
- Can we use sleeves or forms to hold the cables in place?
- How can I get help with thermal management design?

Samtec's SI group can provide information on footprint design and BOR support [7], such as:

- Allocating layout for connector footprint is a challenge as board space adjacent to silicon is often in high demand, so how do I design a launch pattern?

Why Samtec?

Samtec remains committed to advancing the state-of-the art in cable design. As a result, Samtec cables offer a unique construction with industry-leading loss performance. Samtec is the service leader in the industry, offering unmatched engineering support, full system optimization assistance, quick turn product samples and prototypes, as well as access to online resources, models, and innovative tools to help streamline the design process.

The Samtec Flyover product line includes Flyover panel assemblies, Flyover mid-board assemblies, Si-Fly™ ASIC adjacent technology, FireFly™ Micro Flyover System™ (copper or optical), and backplane cable assemblies [8].

For more information on Flyover solutions, visit the Samtec website, contact your local Samtec field sales engineer, our distribution partners, or email hdr@samtec.com.

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6. Samtec - Cable Management | Samtec
7. Signal Integrity Group, World-Class Signal Integrity Support from Samtec | Samtec
8. Samtec Flyover Technology Brochure