

WHITEPAPER

Applying Superior Performance 3 Gb/s in a Practical Manner

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March 2013

Signal infrastructure that is installed today must be ready for 3 Gb/s transport, even if there are no immediate plans to exploit it for rates above 1.5 Gb/s HD-SDI. However, the data rate increase from 1.5 Gb/s to 3 Gb/s has created some technical challenges that must be overcome for signal infrastructure investments to retain their value over the long term.

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Introduction

This whitepaper will demonstrate that it is possible to build products today that overcome the technical hurdles of offering superb signal performance at 3 Gb/s. This assures that upgrading to 3 Gb/s does not result in a downgrade in performance. This whitepaper will address how long cable lengths—approaching 200 meters (656 ft.)—transporting 3 Gb/s signals are possible. Techniques to obtain very low jitter specifications are described. The

added benefits of this superior performance approach are outlined where the result is in signals that are more robust.

The conclusion demonstrates that investing in 3 Gb/s infrastructure today is entirely practical and even desirable to be ready and capable when it is necessary to make the transition to the higher data rate.

Technical Challenges

As the data rate increases from 1.5 Gb/s to 3 Gb/s, nearly microwave-level performance is expected in coax cables as well as in circuit board traces. Using the same coax cable used at 1.5 Gb/s rates, the cable run decreases by ~40% at 3 Gb/s. Each trace on a circuit board becomes a transmission line.

Ultimately, this far higher signal bandwidth increases crosstalk potentials, which adds noise to the digital signal and makes it far harder to identify “zero” and “one” values. Additionally, connector discontinuities become twice as significant. This all occurs under circumstances where infrastructure signals presented

as digitized numbers should be transported without any additional loss in quality. The challenge is to tell the difference between the two binary values (“zero” and “one”) at the destination, with sufficient accuracy to recover all of the numbers correctly.

When taking a closer look at coax cables, the first thing to remember is that worst case specifications should be used to provide for adequate headroom. To achieve a good result, reflection should be better than 20 dB at 4.5 GHz and level loss after 100 meters (328 ft.) should be better than -25 dB at 1.5 GHz.

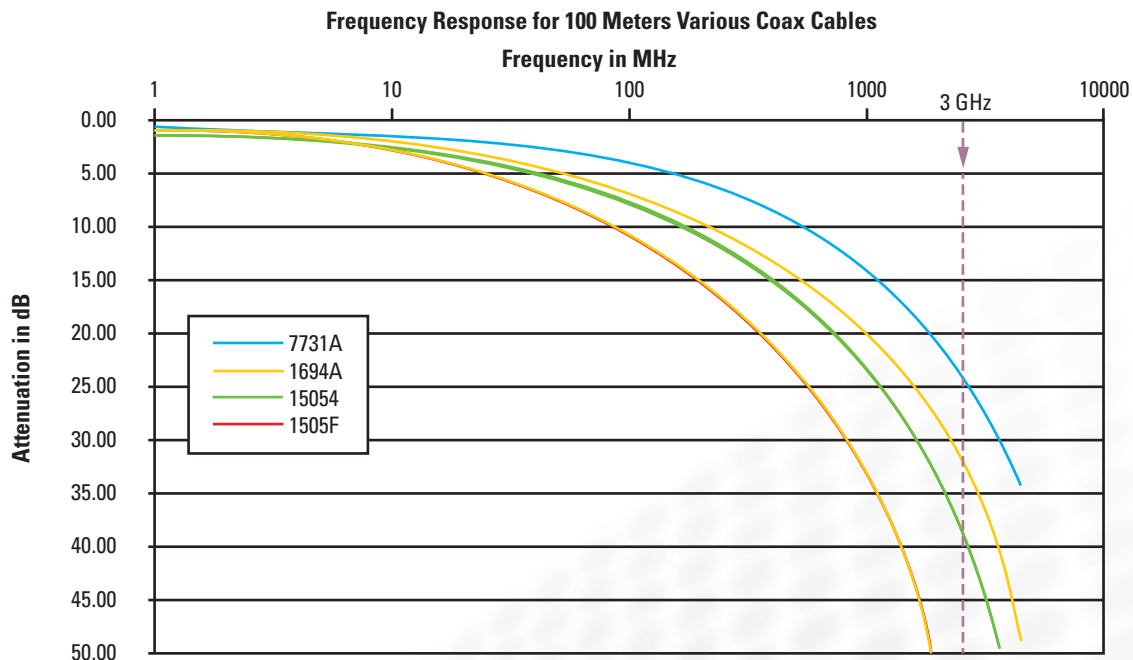


Figure 1 - Frequency response comparison between different Belden coax cables.

Technical Challenges (cont.)

As coax cable can be bent and crushed during installation, a resistance to deformation is required to ensure stable impedance and low return loss figures. As there are many coax cable variants available, the choice is sometimes driven by weight, space, and price.

The coax cable offering the highest performance does have the highest weight and does occupy more space. The coax cables with low weight and little space required have lower performance. Simply stated, thin diameter coax cable can be used only for short runs, but large diameter coax cable is required for long runs. In this respect, space is always an important subject to be considered—especially when equipment is mounted in the rack.

For a standard 19-inch rack, a maximum of ~1,500 coax cables (at 7 mm diameter) can be entered and if 11 mm coax cables are going to be used, no more than ~1,000 cables can be deployed. As manufacturers are making products with higher densities, the wiring of the product is often forgotten. There are many cases in which the wiring occupies more space than the actual product used.

Figure 2 is an example of an installation with very dense cabling.



Figure 2 - Wiring example with 1,000 coax cables (7 mm diameter) per rack.

Defining the Signal Infrastructure

The signal infrastructure consists of more than just the routing switcher—considered the heart of the broadcast and professional media infrastructure. It is important to consider all elements needed to properly prepare the complete infrastructure for the future as very high frequencies are going to be transported. These frequencies are high enough that the circuit design for digital signal transport must consider analog design techniques.

This approach is difficult because the digital impact of not being able to identify whether a bit represents a “zero” or a “one” is significant. In the analog video realm, as signal performance decreases, it results in continual signal degradation. In the digital video realm, as signal performance decreases, it soon results in destroyed signals. Obviously destroyed signals are a big problem for 24/7 broadcast operations. Moreover, all elements of the infrastructure must pass these high

frequency signals today as well as into the future to constitute a robust design. These elements include coax cables, BNC connectors, BNC barrels, patch panels, as well as the routing switcher itself.

Ideally the coax cables, BNC connectors, and other interconnections should be capable of supporting high frequencies to at least 4.5 GHz. Considering only the 1.5 GHz clock frequency of the 3 Gb/s signal as sufficient will result in overall performance degradation. Ignoring the higher frequency harmonics causes difficulties for the destination device to recover the signal. The same impact can be expected by not considering 75Ω impedance matching. Small impedance variations do have big impact on reflections measured as return loss.

Figure 3 shows actual measured impedance along three coax cables connected via BNC barrels.

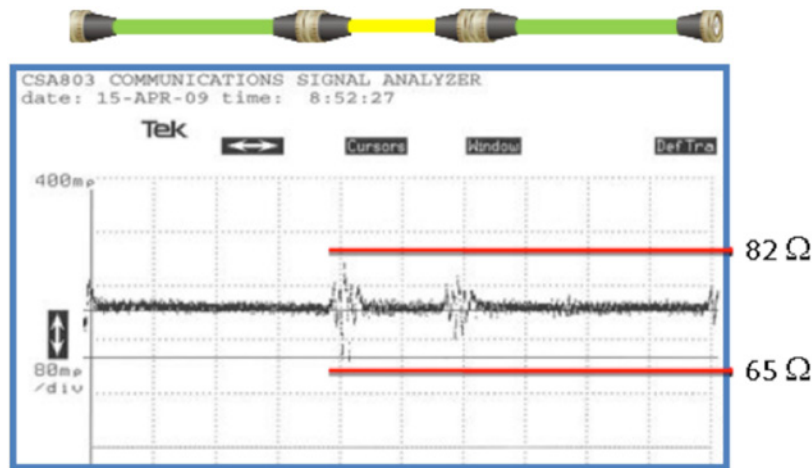


Figure 3 - Impedance of coax cables connected via standard sized BNC barrels.

Defining the Signal Infrastructure (cont.)

When considering the number of BNC connectors, coax connections, and cables that are currently installed, it is apparent that many are not usable for 3 Gb/s signals. Most existing signal infrastructures were not designed with 3 Gb/s data rates in mind. Therefore they were not built with sufficient headroom beyond the 1.5 Gb/s data rate.

Another consideration is the elements which are close to, but not part of, the switching infrastructure. One example is general processing equipment such as conversion and multiplexing. There are reasons to exclude these from the actual switching infrastructure list. Using built-in processing as part of the routing switcher results in a higher granularity of failure and in a higher risk to losing the signal path. Because lowering

the cost per signal path is the primary objective, built-in processing is a compromise on quality. In addition, any kind of built-in processing is influencing the signal transparency as it requires additional impedance conversion, introduces potential crosstalk issues, and adds path delays.

In general, any required signal processing should be used as a so-called loop-in-path device to avoid these compromises. In doing so, signal processing becomes a truly manageable resource for any signal path with better processing quality and operational flexibility. In this manner, the focus of the signal infrastructure is kept where it should be, and kept ultra-reliable.

Figure 4 shows the simple idea of a loop-in-path device with the routing switcher.

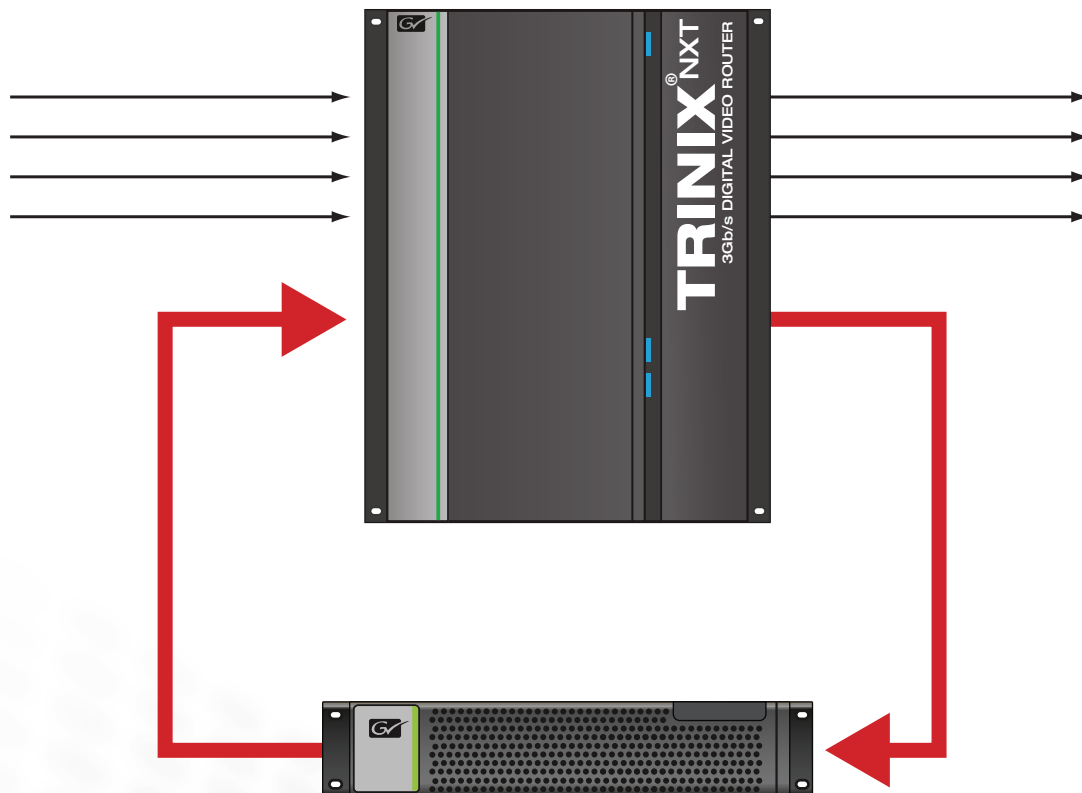


Figure 4 - Loop-in-path processing application for video.

Defining the Signal Infrastructure (cont.)

While signal processing is normally not considered part of switching infrastructure, there are other non-traditional methods that could be considered.

One example would be a redundant routing switcher. In this case, the redundant routing switcher is put in service and allows the user to replace patch panels. It is very common in broadcast infrastructures to protect the signal path by using patch panels surrounded by input patches as well as output patches. Considering the cable run where a patch is made, along with the impact of any interconnects and the use of different coax cable types, in most cases there will be no signal present for the next device.

Therefore new solutions need to be considered in case a routing switcher path or larger part of the

infrastructure is lost. The implementation of redundant matrix boards does not solve the problem as a path can still be lost. Furthermore, the internal required 2:1 or 3:1 switching will reduce reliability as those additional parts introduce a higher risk of failure, and can be considered as a single point of failure per path. Apart from that, there are the electronics required to make the switch—also a single point of failure added into the system. To avoid patch panels and to maximize reliability, a routing switcher should offer protected paths as well as being a protected router solution.

Figure 5 shows the arrangement needed for a protected router and uses passive input splitting and passive output combining to maximize reliability.

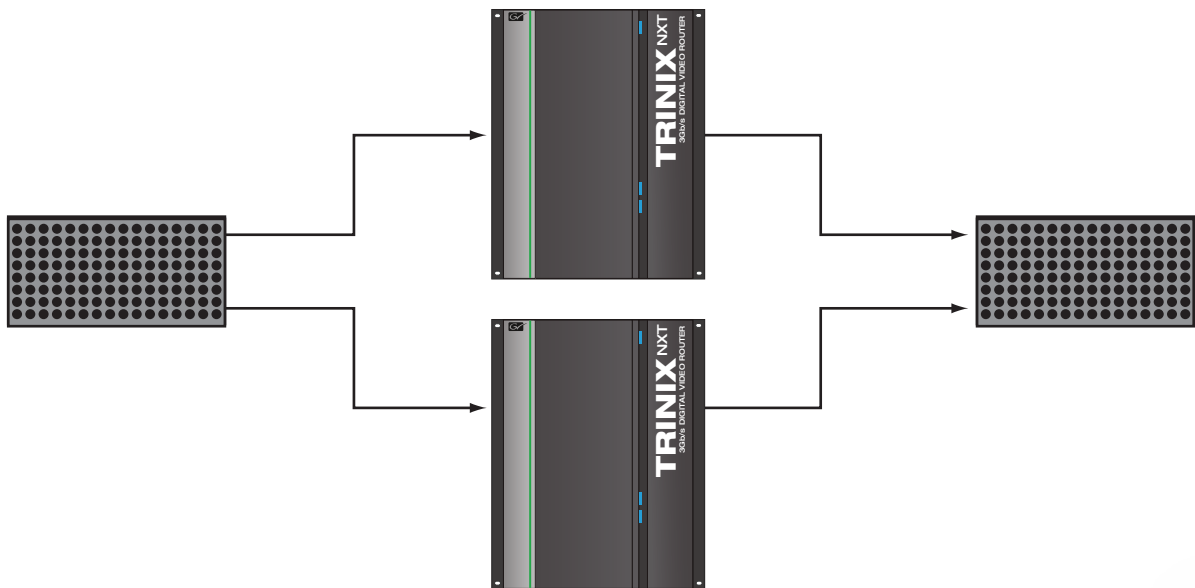


Figure 5 - A fully redundant routing switcher solution called “Protected Router.”

Specific Routing Switcher Technologies

The routing switcher itself needs to be as signal-transparent as possible and should be able to recover the signal even after long cable runs. Signal transparency can only be achieved by avoiding performance losses between input recovery and output driver. It is self-evident that the signal quality from input BNC to output BNC needs to be kept transparent. This sounds logical and easy to achieve, but in actuality requires a lot of specific details to be considered.

As previously discussed, signal transparency is a necessary requirement. This is extremely important inside the routing switcher, as this is the only place where many paths with many signals are very close to each other. Therefore, one of the biggest challenges is to avoid crosstalk—especially so-called hostile crosstalk, where strong signals crosstalk into weak signals. Crosstalk is not an issue between coax cables in a cable tray as those are normally sufficiently isolated/shielded. Crosstalk is, however, an important subject matter of routing switchers, and occurs immediately after the signal has left the BNC connector.

Before fully addressing the internal workings of the routing switcher, the subject of using smaller connectors instead of standard full-sized BNC connectors needs to be addressed. The requirement of dense products is very well understood and as of today the limiting factor is often the full-sized BNC connector. Miniature connectors can help in tight places, but they pose risks and limitations.

One major risk is the impedance mismatch caused by these small connectors. They are not 75Ω impedance, but rather are 50Ω and therefore cause impedance bumps. Another limitation of small connectors is that they require thin cable defeating the objective of longer distances. It is possible to translate this into a full-sized BNC by using a transition panel, but this causes further loss and degradation to the signal. Additionally, there is evidence of non-locking SMB connectors exhibiting non-repeatable return loss characteristics. All of these problems can be avoided by using full-sized connectors.

The industry has made excellent progress by introducing 3G-capable BNC connectors which have a peak frequency of 7.5 GHz while maintaining very low 75Ω impedance variations. This is another good reason to stay with standard-sized BNC connectors.

Miniature BNCs are used only for obtaining density of design. Is it worth trading higher density for imperfect signal performance? The entire discussion about dense products goes much further. One of the subjects often forgotten is the heat generated in a very small space. Any temperature increase decreases equipment lifecycle as well as reliability—and this is a very important subject to be considered especially for a routing switcher. Furthermore, keeping with a more standard-sized model enables a lower cost of ownership, because of the convenience required to wire a product and maintain it on air. Finally, as signals being transported are even physically closer together, increased crosstalk between inputs/outputs will occur.

Specific Routing Switcher Technologies (cont.)

Taking a look at the specifics of the routing switcher itself, the first task is to bring the signal transparently into the receiving circuit, which is the input equalizer. It is quite common to use mid-plane concepts to build the internal connection between the BNC rear-panel to the input board which is hosting the input equalizer. This mid-plane is used to enable a dense design.

However, it is not a good choice for signal quality. This method requires a long trace length to reach the equalizer. Depending on the size of the routing switcher, this length is at least 20 cm (7.9 in.) and in most cases far longer. This mid-plane design also requires two connections: an imperfect coax connection followed by an additional imperfect edge connector, which are used between the mid-plane and the input board. With just

that short internal signal run, all the effort previously taken by selecting the best coax cable and cleanest coax connection have an extremely high risk of being totally lost. This additional crosstalk usually shows up as increased jitter and shorter cable equalization capability. Furthermore, standing waves between the connectors attenuate high frequencies creating a degraded return loss as well as high frequency losses. As a result, the 3 Gb/s incoming signal is not recovered and therefore blocked right at the input stage of the routing switcher even after quite short cable runs.

Figure 6 shows a typical mid-plane architecture and illustrates the issues of long trace lengths and multiple connections.

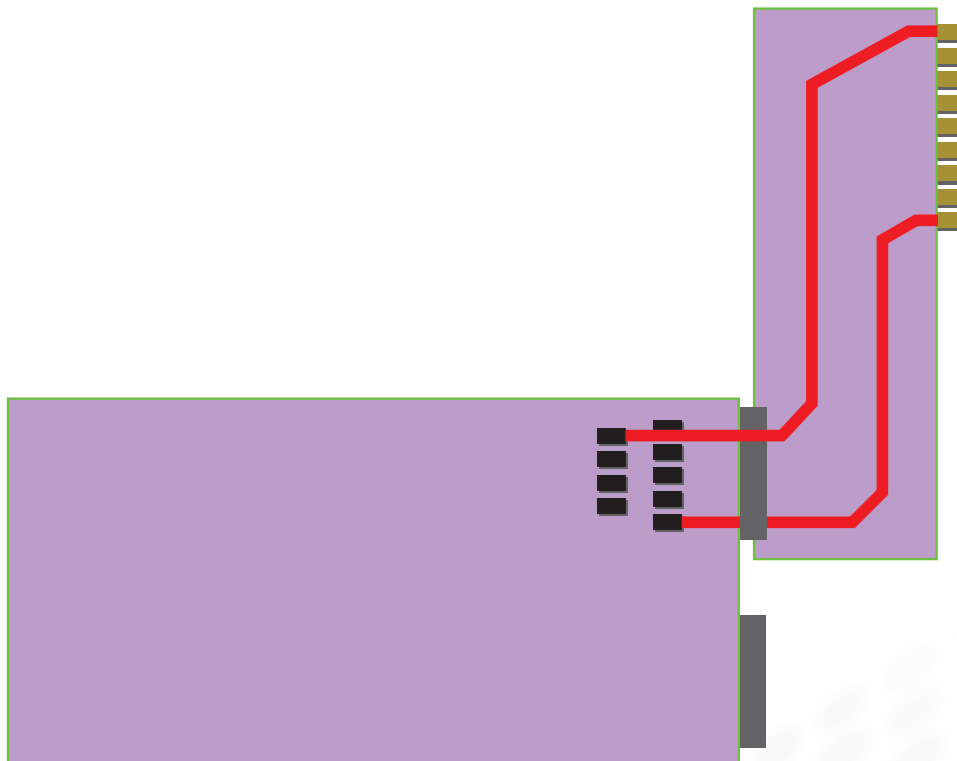


Figure 6 - A typical mid-plane design showing long trace lengths and multiple connections.

Specific Routing Switcher Technologies (cont.)

The correct solution is based on a so-called BNC-to-board design, which limits the trace run. With a very good design, it is less than 1 cm (0.4 in.) between the end of the incoming cable to the input equalizer circuit. Actually, the input and output boards are plugged directly into the back of the BNC connector. This design minimizes crosstalk from nearby strong signals into weak signals and avoids all previously discussed issues.

Another factor that significantly improves signal performance is having every input and output on the circuit board identically spaced and placed near the BNC connector. This guarantees optimized matching between any signal path for consistent performance.

Figure 7 is a detailed view of the BNC-to-board circuit design.

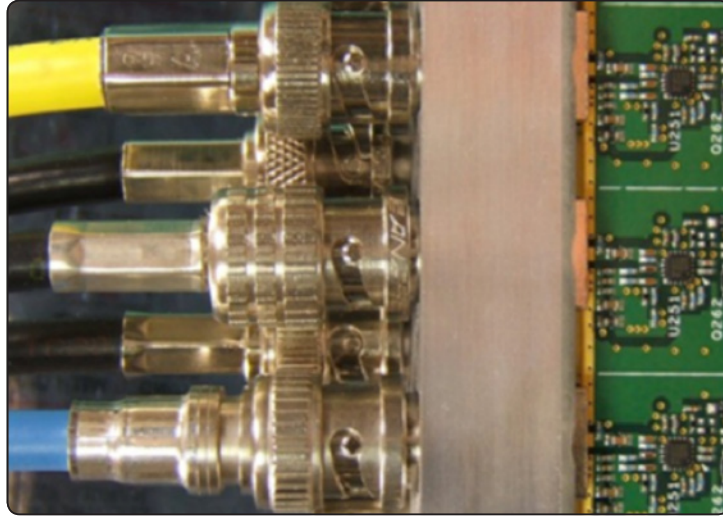


Figure 7 - BNC-to-board design limiting the trace run.

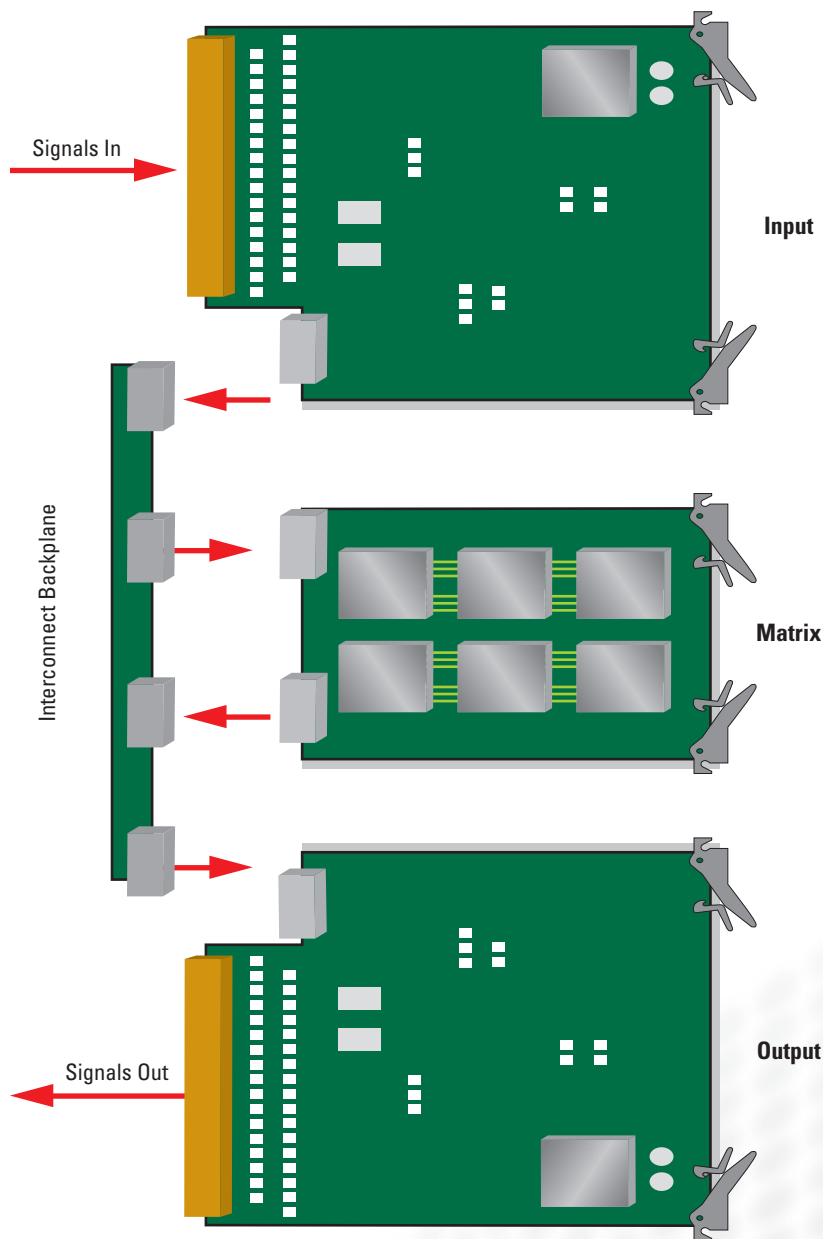
Specific Routing Switcher Technologies (cont.)

To maintain the recovered signal performance through the routing switcher architecture, all possible paths should be identical. This is referred to as a symmetrical-input-to-output architecture, which ensures that all traces have the same physical distance. In addition, this trace length needs to be as short as possible to avoid high frequency losses.

To interconnect input and output boards with matrix boards, a routing backplane is used. It is extremely important that the design of the routing backplane—as well as the connectors used—matches the same

impedance. A mismatch of this important connection drastically affects overall signal transparency. Furthermore, the routing backplane should be only a few centimeters in length. There are many architectures using a very large routing backplane, which can range up to more than 90 cm (35.4 in.) in length.

Figure 8 shows a routing switcher architecture in which the routing backplane is small compared to the overall design.



On the output board, final re-clocking and output amplifying takes place. The re-clocker requires adaptive phased-locked loop (PLL) technology to recover the signal at multiple data rates. This is because a routing switcher handles data rates ranging from 3 Mb/s up to 3 Gb/s and the re-clocking technology used is far more complex and critical compared to other devices which use a single data rate. This is especially true for the 3 Gb/s data rate—the output amplifier needs to be very clean with respect to noise which would be shown as jitter. At that stage the same methods used for BNC-to-board design are required to again avoid mid-plane use.

All of these factors describe a routing switcher architecture called CleanFlow™. CleanFlow addresses all of the subjects discussed previously including matched differential pair trace length, avoiding long signal runs over traces, using a non mid-plane design, and minimizing connectors to match the impedance of the entire path. It is this attention to every detail that enables CleanFlow superior performance.

Figure 8 - Routing backplane with shortest possible and symmetrical trace length.

3 Gb/s as a Practical Solution

Preparing the overall signal infrastructure to be ready for 3 Gb/s is gaining a lot of attention. Investments into infrastructures are always long-term decisions and therefore this is the first place where 3 Gb/s will be in practical use. A 3 Gb/s signal infrastructure will ensure that the highest picture resolution displayed progressively, multichannel audio, and auxiliary data can be securely transported, duplicated, and switched. It will also support far better headroom, performance, and reliability for 1.5 Gb/s, or even lower data rate signal transport. Taking the step of carefully designing a 3 Gb/s signal infrastructure is truly the right decision and will protect broadcast infrastructure investment over a very long term.

So far the practical use of 3 Gb/s infrastructures has been compromised with short cable runs and overall poor performance. In many cases, this early implementation of 3 Gb/s technology inside products has impacted the SD as well as HD performance already achieved. The routing switcher implementations as described provide superior performance in spite of all the issues discussed here. The many kinds of technology components available have been studied and evaluated. Choices have been made to arrive at the right combination of technology components to achieve the best performance.

Using the routing switcher architecture outlined here, 140 meters (499 ft.) of Belden 1694A coax cable at 3 Gb/s with surrounding inputs can be reached. This means the surrounding inputs are all being driven through short coax cables from other 3 Gb/s signals

creating a hostile crosstalk environment. As a result, the routing switcher described has the extra performance capability that allows the use of the same 100 meters (328 ft.) of coax cable installed for a 1.5 Gb/s system to be properly 3 Gb/s ready. It also gives the extra margin to go longer distances or simply solve problems in the existing cable infrastructure.

This kind of signal performance has been demonstrated publicly since April 2009 at the National Association of Broadcasters (NAB) tradeshow in Las Vegas, and in independent tests. Belden showed this routing switcher architecture without hostile crosstalk running 3 Gb/s signals with no errors through 180 meters (591 ft.) of 1694A on the input.

Additionally, this routing switcher architecture and several others were tested by a respected independent laboratory in Germany. One test was running a 3 Gb/s signal through five loops, and the routing switcher implementation described here was the only one that passed with no CRC errors.

In fact, 3 Gb/s signal has been run with 64 loops producing no CRC errors. The independent laboratory was amazed by the length of coax cable that the inputs can accept. They were also surprised by the good and consistent return loss at the inputs and outputs as well as the overall performance achieved in all standards (SD, HD, 3G), which gives plenty of headroom compared to EBU/SMPTE specifications.

Figure 9 shows the configuration used for the independent laboratory multi-loop test.

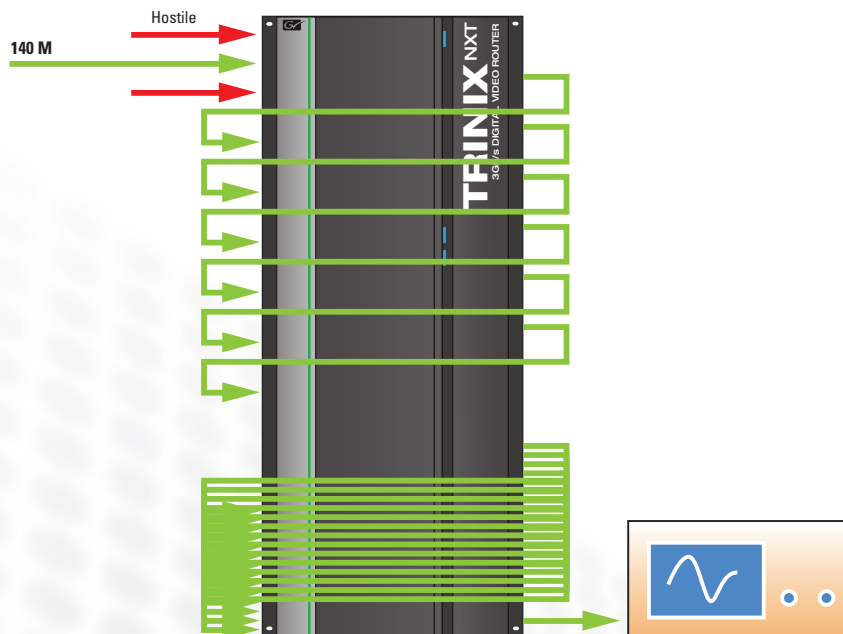


Figure 9 - Hostile crosstalk evaluation.

Conclusion

For very future-proof installations, 3 Gb/s infrastructures should be built based on larger diameter coax cable—even 11 mm cable. Mixing of different coax cable types and diameters should be avoided. Each 3 Gb/s path should be designed with a very low number of interconnections such as barrels, patch panels, and so on. All of this will provide enough headroom on cable runs and signal performance at any data rate from 3 Mb/s up to 3 Gb/s.

Using a “Protected Path” or “Protected Router” design can ensure that signals stay on air. Anything else included as part of the signal path reduces reliability and therefore will put on-air signals at a higher risk of failure. For this same reason, processing devices should not be part of the permanent path, but rather as a loop-in-path device. This processing architecture also maximizes the

efficiency of any processing investment. It minimizes the number of processors needed and delivers the flexibility to upgrade to the latest available, and highest quality processing technology.

The routing switcher, as the heart of the broadcast infrastructure, needs to be as signal-transparent as possible and should be able to recover signals to their original form. The solution is to choose a routing switcher with CleanFlow technology. This adds significant headroom for all signal paths and maintains the highest possible signal performance.

Implementing a signal infrastructure to provide superior performance will ensure that all kinds of practical applications can be supported today and tomorrow.

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