White Paper

When Ethernet Rotates: Ethernet and Slip Rings

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Key Messages

- Slip ring designers meet the challenge of more exacting performance parameters with innovative methods of matching impedance, controlling crosstalk, and managing losses
- There are a wide variety of network applications where rotary platforms are required -- industrial robots to wind turbines to radar antennae. It is typical these include power, sensor, and control circuits to be run to and / or from these platforms, and slip rings are used to carry these channels across the rotary interface
- This white paper addresses the issues presented when a rotary connection must be inserted into the 1000BaseT transmission line

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- Attenuation (dB): The reduction in signal power through a cable or interconnect; also known as insertion loss.
- NEXT (dB): Near End Crosstalk (NEXT) is the coupling noise induced on other pairs of a cable by a single energized pair of the cable and measured on the transmitter end.
- FEXT (dB): Far End Crosstalk (FEXT) is the coupling noise induced on other pairs of a cable by a single energized pair of the cable and measured on the receiver end.
- AXT (dB): Alien Crosstalk (AXT) is the coupling noise induced on a cable by other cables in proximity. There are a variety of ways to break AXT out and evaluate.
- Return Loss (dB): The loss in signal power that results in reflections from discontinuities in the transmission line.
- Delay Skew: The difference in propagation delay between any two pairs within a cable.
- SNR (dB): The ratio of the signal power to noise power level.

Introduction

There are cases when a slip ring must be utilized to carry the conductors of copper transmission line (cable) from a rotating platform to a stationary structure. The sharp growth in the use of Gigabit Ethernet has sparked a renewed interest in the ability of slip rings to function within a CAT 5 or CAT 6 network environment. Slip ring designers are able to meet the challenge of more exacting performance parameters with innovative methods of matching impedance, controlling crosstalk, and managing losses.

There are a wide variety of network applications where rotary platforms are required. These applications vary from industrial robots to wind turbines to radar antennae. It is typical that these requirements include power, sensor, and control circuits to be run to and / or from these platforms, and slip rings are used to carry these channels across the rotary interface. Is it practical to include copper channels in the slip ring to carry LAN? Ethernet has become the primary LAN technology, and many new LAN installations / applications are using IEEE 802.3 1000BaseT Ethernet at the network of choice. This white paper addresses the issues presented when a rotary connection must be inserted into the 1000BaseT transmission line. Figure 1 shows a typical slip ring with power, signal and control, as well as LAN circuits.

IEEE 802.3 along with the associated cabling specifications is tailored for permanent LAN installations in buildings and similar infrastructures. For this reason, the specifications build the requirements around a description of:

- A permanent cabling length, with connectors at each end, of no more than 90 m.
- Patch cords on either end of no more than a total of 10 m in length for both which in turn are terminated (by connectors) to the Ethernet cards.

However, the advantages of ethernet as a robust, inexpensive, widely supported format have led to its implementation in a wide variety of custom data communication networks that do not look anything like those described above. In these cases, it is important to have a very clear understanding of the critical features of 1000BaseT to be able to define cabling and component parameters that are both realistic and effective.

The Specifications

Our specific interest in IEEE 802.3 1000BaseT is the physical layer or PHY which is the media that connects network devices. The primary function of the PHY is to support the data transmission requirements imposed by the upper layer protocols. The IEEE 802.3-2008 specification, Section 3, Clause 40.1.3 provides a good overview of the 1000BaseT architecture:

> The 1000BaseT PHY employs full duplex baseband transmission iew of the 3new oe.4AIc eaETEMC<10.090.s th008ansriqnk<2.51MC 2.51 >3(PHY)20 k which is the media that connec

Table 1: 1000BaseT performance requirements evaluated at 100 MHz

The overall SNR and timing jitter requirements presented in clauses 4.6 and 4.7 of the 802.3 specification are built around noise requirements with an understanding of the cancellation and compensation capabilities of standard Ethernet electronics (see Table 1 for a summary of the requirements). The cabling requirements defined in the ANSI / TIA / EIA 568 and ISO / IEC 11801 were developed to provide these performance requirements over a copper cable up to 100 m long. Figure 5 illustrates the SNR parameters.

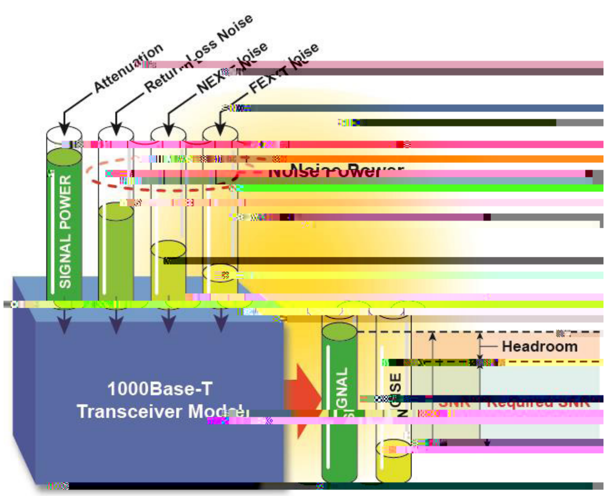
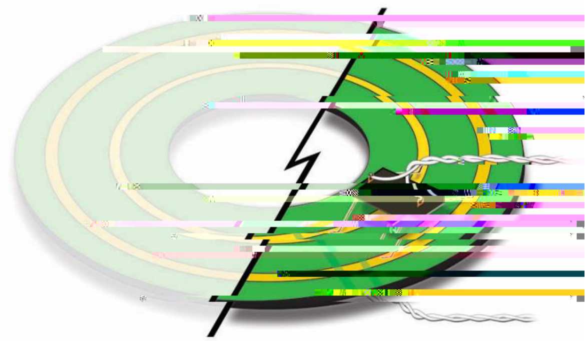


Figure 5: SNR Illustration

Slip Ring Effect

What is the effect of placing a slip ring into a 1000BaseT cable? Physically, this means dedicating one ring and brush set to each of the 8 conductors of a CAT 5e cable. Figure 6 shows ring brush configuration for one pair of conductors in a platter configuration. It should be clear from this simple illustration that this wire-ring-brush-wire transition does not exactly duplicate the cable or connectors addressed in the ANSI / TIA / EIA specification. However, the slip ring designer can come “close enough” to the cable requirements to satisfy the Ethernet performance requirements. There are two specific areas that we should address and clarify.



The first area of concern that often arises is the sliding contacts themselves and their possible effect on random jitter. Slip rings transfer signals across rotating interfaces by the use of sliding electrical contacts. These contacts are designed to minimize variation in contact resistance during sliding by the use of precious metal contacts, and typical values of 20 mohms results in noise less than 0.2 mV which is a full 2 orders of magnitude less than the allowable coupled noise value of Clause 40.7.6. This -74 dB noise contribution is insignificantly compared to other noise contributions outlines in Table 1. A recent paper presented at the IEEE Conference on Electrical Contacts discusses the negligible effect of electrical contact on data transfer[1].

The more significant effect of placing a slip ring in the transmission line is the effect that an impedance discontinuity has on the quality of the transmission line and the potential effect on deterministic jitter. Special design provisions are made in slip rings for impedance matching, crosstalk protection, and low attenuation, but there is inevitably some effect on all the parameters listed in Table 1. Since the TIA / EIA 568 cabling specification provides no assistance in evaluating noncable, non-connector hardware, some judgment is required to develop appropriate specifications. There