Real World Single Fiber Single Wavelength Transceivers with integral Micro-OTDR and Reflection Immune Operation

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Abstract— Network operators and users may enjoy the benefits of SFSW operation, without any of the drawbacks associated with legacy systems, along with the additional functionality of Micro-OTDR. Reflection Immune Operation - RIO® resolves self-reflection from an open connector and/or other reflectors. Only remote data is transferred into the host equipment.

Keywords— optical; fiber; SFSW; reflections; ORL; UPC; PC; RIO®; fault; monitoring; physical; layer; single; wavelength

I. Introduction

Single Fiber Single Wavelength (SFSW) Transceivers transmit and receive at the same wavelength, on single fiber, doubling the optical fiber plant capacity. SFSW transceivers offer many potential benefits to the Network Operator – e.g. seamless CWDM integration, half the fiber, half the passives and easier fiber management, among other advantages.

Fig. 1. Block Diagram of SFSW SFP with Micro-OTDR and RIO®.

II. Overlay Functionality

A. Micro-OTDR

The SFSW operation enables an overlay functionality of Micro-OTDR since the transceiver can detect optical power from reflections of optical power emitted by its own transmitter. The benefit of such detection is implemented in an integrated SFP, which also includes full data transport capabilities, to provide an efficient, fast, physical layer monitoring capability. This approach can instantaneously identify, locate and report (through the IIC to the host equipment and then via SNMP) any optical fiber cuts, breaks or other faults (as well as, any open, damaged or dirty optical connectors) in the optical fiber cable plant [6]. Detailed operation of the Micro-OTDR and the methodology of fiber break detection probability has been presented previously [8, 9] and is described in [7]. Reference [1] proposed Optical Time Domain Reflectometry (OTDR) designed to provide rapid measurement of a fiber fault location. Early typical and commonly used fault location systems [2] exploit a standalone OTDR tester that is shared [3], via an optical switch [4], among many access links to lower the cost per monitored line. These systems require additional fiber connections in the central office and extra rack space. Furthermore, the optical switch loss will impact the overall link budget and may, itself, become a new point of failure. My colleagues and I have, however, shown that if the transceiver used for the data connection also had the dual function of identifying and locating a fiber fault, this would enable rapid fault diagnosis and resolution to the benefit of both the subscribers and the service providers [5].

B. Optical Reflections

Open connectors, fiber faults and intermittent connections, which commonly occur in field deployments, create optical reflections of varying intensities. SFSW transceivers’ data transport capability can be susceptible to signals generated by these reflections in the optical fiber cable plant. For example, the reflection from an open non-angle polished (PC or UPC - Blue) optical connector is about 15 dB. The reflected signal may return to the receiver section of the originating transceiver at power levels well within the operating sensitivity range of the receiver. This may cause the originating transceiver to detect this false signal, appearing to the network switch (or any host equipment) as though it was receiving a viable signal. But, in fact, an optical loopback condition is created in the network, wreaking havoc with network operations.

C. Legacy SFSW Drawbacks

Since SFSW transceivers suffer such drawbacks in the presence of optical reflections, their application under real-world conditions has been limited compared to that of their two-wavelength single fiber or two-fiber cousins. Because SFSW transceivers offer many potential benefits to the...
network operator, a comprehensive solution to the reflection sensitivity would provide significant benefits.

III. Reflection Immune Operation - RIO®

To resolve this problem and enable data transport free of interference, with the additional Micro-OTDR capabilities, a hardware and firmware solution which is totally automatic in operation while transparent to the host network gear and optical network (UPC Blue or APC Green optical connector types) is required. We call this approach Reflection Immune Operation - RIO®.

A. RIO® – Initial Link Start-Up

When first plugged in or powered up, the SFSW SFP Transceivers with RIO® on either end of the Link turn themselves on in a specific sequence. First, the receiver section becomes active, while the transmitter remains off. The receiver listens for an incoming signal. Since its own transmitter is off, if the receiver detects an inbound signal, it knows that it must be legitimate because it can only be coming from the remote transceiver. Then the local transmitter section becomes active and the Link is created between the local and remote transceivers.

The remote transceiver goes through the same sequence. Random timing delays and collision avoidance algorithms are built into the start-up sequence to guarantee linking (each transceiver ensures that the incoming signal is from an external source). The extra processing guarantees data link under any circumstances between the two (2) transceivers within less than 700 milliseconds. The overall timing delay in such an event is well within the typical delays inherent in network “handshake” protocols, so all of this remains invisible to the network operation and the network users.

B. RIO® – Interruption of Established Link

The case where a Link is functioning correctly and then is interrupted, is bit more complex...for RIO®, not for the network operator or users.

The case of a UPC Blue connector being inadvertently opened somewhere in the span of the Link presents a different scenario, since the reflected signal can be similar or identical in amplitude to the incoming signal from the other side. RIO® employs sophisticated digital filtering capabilities which allow it to distinguish between the original inbound signal from a remote source and a signal reflected back to the originating local transceiver. Any interruption of the optical Link will cause brief fluctuation in the optical power levels due to temporary interference patterns in the connector. Fast optical power changes below 0.25 dB are detected and processed by RIO®. Following such a brief disruption, RIO® will analyze the signal origins and distinguish between a fluctuation in the Link (e.g. due to an optical power change from a patch panel) and an open Link with reflection.

Once a potential break is detected, the algorithm of a startup sequence, as described above, is initiated. The key to successful implementation of RIO® is the detection of very small, abrupt, optical power changes which may be associated with the opening of an active Link, while being insensitive to the power fluctuation generated by the remote transmitter, fiber movements, etc.

In designing a network, overall Optical Return Loss (ORL) needs to be taken into account because it may affect the sensitivity of the data receiver. The user must ensure that the supplier tests and guarantees Link budget within the ORL performance of the stated network.

IV. Summary

Network operators and users may enjoy the benefits of SFSW operation, without any of the drawbacks associated with legacy systems, along with the additional functionality of Micro-OTDR. Reflection Immune Operation – RIO® resolves self-reflection from an open connector and/or other reflectors. Only remote data is transferred into the host equipment.

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<tr>
<th>Technology</th>
<th>Network Cable Plant Type</th>
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<td>Single Fiber 2-Wavelength</td>
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* Number of CWDM Passive Mux required per Full-Duplex CWDM Channel.
③ Number of SMF strands required per Full-Duplex point to point optical Link

Fig. 2. Table of Network Cable Plant Technology Comparison

It is only with RIO® that you gain the quadruple advantages of half the number of passive mux per full duplex CWDM channel, half the optical fiber needed per Link (or 100% optical fiber recovery), operation anywhere conventional 2-Fiber Links now exist and Fast Fiber Fault Finder capability with Micro-OTDR.

References