CASE STUDY

Full Coherent Receiver Tests Enabled At Record Speeds

Introduction

Nokia Bell Labs is researching long haul fiber-optic communication. In March 2018, it set new world records for the fastest optical transmission ever, enabled by Keysight's UXR-Series oscilloscope. The Nokia Bell Labs team was led by Dr. Peter Winzer, the Director of Optical Transmission Subsystems Research, along with Dr. Xi Chen and Dr. Greg Raybon, Principal Investigators at Nokia Bell Labs.

Data Transmission Across the Globe

Long haul optical communication is vital to telecom companies like AT&T, Google, and Facebook who need to transmit information across the globe. The need for more data sent at faster speeds is driving the Nokia Bell Labs team to reach new boundaries of optical technology. Not only are they setting records for the fastest speeds, but they are sending signals through thousands of kilometers of transoceanic optical fiber cables.

Because of the vast distance the signal must traverse, the speed at which they are sending signals, and the need to convert from optical to electrical signals, they must combat distortion and noise within every aspect of their design to ensure the best possible signal is sent and received. Therefore, their most important consideration is the signal integrity of their generators and receivers.

New UXR-Series Oscilloscopes

Keysight's UXR series oscilloscopes come in models with 13 GHz to 110 GHz to address all high-speed digital technologies like USB, Ethernet, PCIe, DDR, and Terabit optical.

To find the bandwidth right for you, visit www.keysight.com/find/UXR

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To transmit optical signals across the planet, they are sending a 193 THz sine wave (this is in the infrared light spectrum) out of a laser, which is modulated and multiplexed to represent 4 distinct characters.

In optical communication, a sine wave will represent a digital 0. This signal flipped, or phase shifted by 180 degrees, represents a 1. Additionally, this sine wave can be multiplexed to get a cosine, a phase shift of 90 degrees. This cosine can also be modulated to represent either a digital 0 or a digital 1. With sine and cosine components together, 2 bits per symbol are transmitted in what is known as quadrature phase shift keying (QPSK). Nokia Bell Labs is achieving this with an electrical bandwidth of 100 GHz.

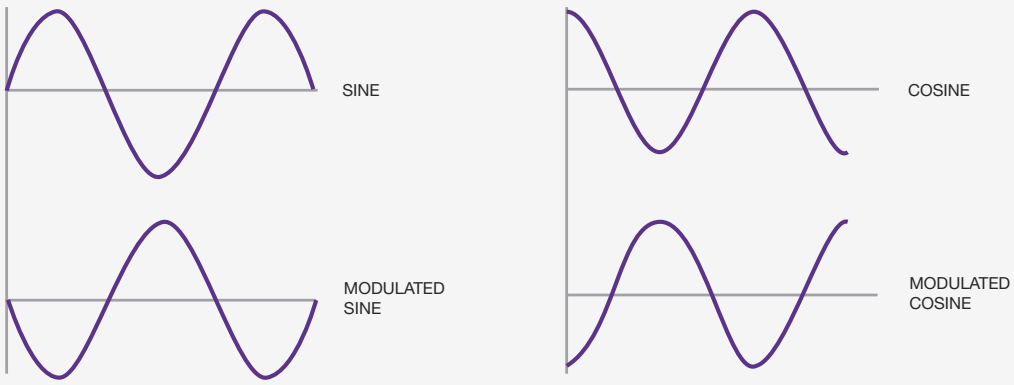

Figure 1: 4 modulations of a sine wave provide 4 unique characters transporting 2 bits of information.

The polarization of light is also used to send both sets of information at once. For instance, the x polarization of the light can be used to send the sine and cosine wave information, and the y polarization can send the sine and cosine information. So, on a single light wave, they can imprint two parallel channels, each carrying two bits of information, for a total of 4 parallel channels.

Because of this modulation scheme, everything in coherent optical communications relates back to a multiple of 4. Therefore, it is imperative to have the ability to detect 4 channels simultaneously to implement a full optical coherent receiver.

Testing Ultra-High Bandwidth Optical Modulation

As previously mentioned, Dr. Winzer and team are primarily concerned with the signal integrity of their generator and receiver. As noise and distortions are introduced by the channel they are transmitting across, they need to make sure they are sending the cleanest possible signal with the ability to precisely detect the transmission at the other end. To validate the signal integrity of their designs they need test equipment with precise detection capabilities.

Keysight's UXR series combines cutting-edge oscilloscope bandwidth with the required 4 synchronized channels, enabling Peter Winzer, Xi Chen, and Greg Raybon to validate their innovative optical designs.

Some oscilloscopes provide substantial bandwidth, but only on 1 channel. This is not enough. This only enables the detection of the sine of one polarization. That is 1/4th the information needed to decipher the optical signal.

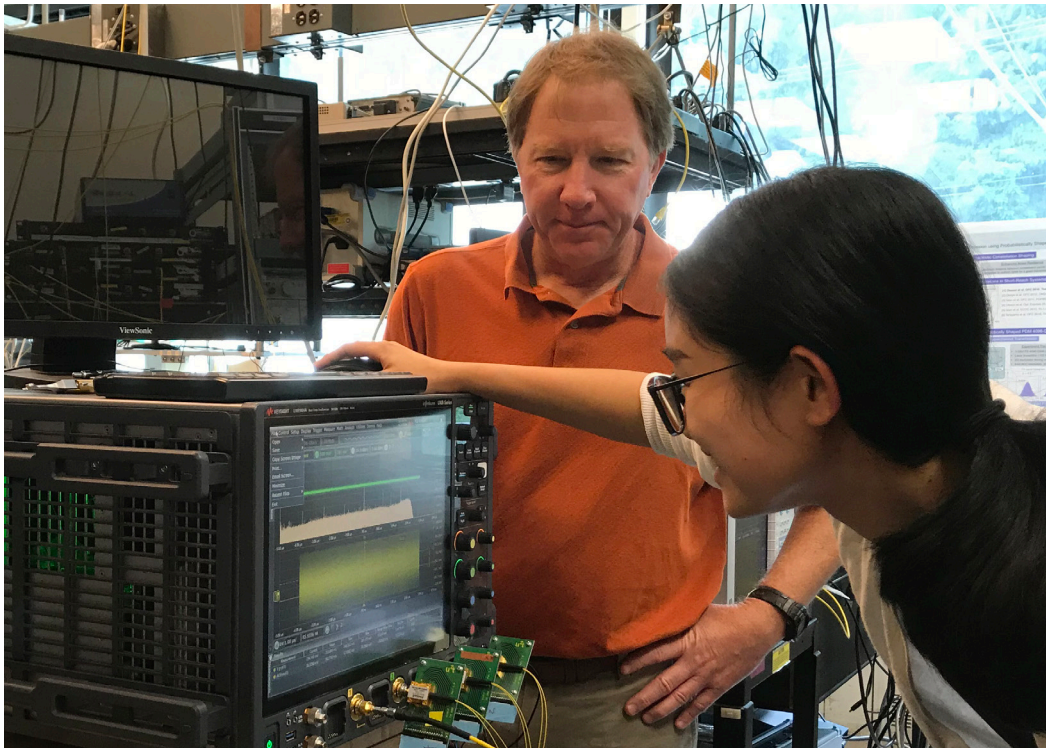

Figure 2: Dr. Xi Chen and Dr. Greg Raybon of Nokia Bell Labs performing test with Keysight UXR oscilloscope.

> "We achieved two world records immediately upon receiving the oscilloscope. With four channels at these bandwidths, the oscilloscope enabled us to design a full coherent receiver at the highest symbol rate ever.
>
> – Dr. Peter Winzer, Director of Optical Transmission Subsystems Research, Nokia Bell Labs

Now, Dr. Peter Winzer's team uses Keysight's 4 channel, 110 GHz UXR oscilloscope to access and capture all 4 polarizations enabling him to decipher and validate his designs. The UXR provides 110 GHz on all 4 channels simultaneously. This is the first and only oscilloscope to provide these speeds on 4 channels in an integrated form.

With the UXR Greg Raybon et al. demonstrated data operations at 720 Gb/s with QPSK signals and Xi Chen et al. achieved a per-carrier line rate of 1.6 Tb/s. To learn more about these break throughs, links to their Optical Fiber Communication Conference post-deadline papers have been provided below:

G. Raybon et al., "180-GBaud All-ETDM Single-Carrier Polarization Multiplexed QPSK Transmission over 4480 km," Proc. Optical Fiber Communication Conf., post-deadline paper Th4C.3 (2018).[1]

X. Chen et al., "Generation and Intradyne Detection of Single-Wavelength 1.61-Tb/s Using an All-Electronic Digital Band Interleaved Transmitter," Proc. Optical Fiber Communication Conf., post-deadline paper Th4C.1 (2018).[2]

Conclusion

While Nokia Bell Labs is at the bleeding edge of technology it is likely several other research labs will follow in their footsteps in the next couple of months and years. Before the UXR, designers and researchers were constrained by test equipment. Now, they are no longer limited by bandwidth or channel availability. Without having to make these tradeoffs with their test equipment, they can focus on improving their transmitters and making new breakthroughs in optical research.

Learn More

To learn more about Keysight's UXR-Series oscilloscopes and how they can help with your test applications, visit www.keysight.com/find/UXR. The UXR series oscilloscopes are available in models from 13 GHz to 110 GHz, with full bandwidth upgradability to suit all high-speed data test needs.

1 https://www.osapublishing.org/abstract.cfm?uri=OFC-2018-Th4C.3
2 https://www.osapublishing.org/abstract.cfm?uri=ofc-2018-Th4C.1

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