Precise characterization of opto-electric devices for microwave photonics

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Opto-electric devices including optical-to-electric (OE) and electric-to-optical (EO) conversion devices such as photo-detectors, optical modulators, play important roles in microwave photonics systems [1, 2]. Preciseness of OE or EO conversion is very important as well as conversion efficiency and response time of such devices. The important figures, which specify the performance of photo receivers are frequency response bandwidth, conversion efficiency and non-linearity [3]. In order to measure such figures, we have to prepare an optical signal modulated by high-speed frequency components, where high-speed OE conversion devices whose 3-dB bandwidth would be close to 100 GHz are commercially available. In conventional techniques, a standard intensity modulation scheme has been used to generate an optical signal to stimulate DUTs. The optical signal has three spectral components; optical carrier, upper sideband and lower sideband. The ratio between the sideband components and the optical carrier depends on the modulation index which is proportional to the modulation signal fed to the modulator. Electric output from the DUT depends on the ratio and the total power of the optical input. Thus, the modulation index and optical input power should be precisely calibrated in wide frequency range.

Recently, we have proposed a measurement method for frequency response of OE conversion devices, by the use of an optical two-tone signal [4, 5]. The electric output of the DUT depends only on the total power, if the two-tone signal is stable enough and undesired spurious components are negligibly small. Stable pure optical two tone signals can be generated by high extinction-ratio Mach-Zehnder modulators, which have active trimmers to compensate imbalance in the modulators [6], where precise measurement of modulators would be also very important [7]. We can generate an optical two-tone signal consisting of the first order upper and lower sideband components with suppressed carrier by using the minimum transmission bias point of the high extinction-ratio modulator. When the extinction ratio is very high, the difference in powers of the upper and lower sidebands would be very small. The frequency difference would be double the modulation signal frequency. Measurement of nonlinearity would be also very important particularly in radio-over-fiber based systems, to generate radio-waves complying with radio regulations. We can perform two-tone test for OE conversion devises by using a pair of optical two tone signals. A single tone electric signal would be generated from an optical two-tone signal. For two-tone test, arrangement of stimulus signals would be very difficult, where the two tone signals would be well-balanced and spurious signal generation due to nonlinearity in the signal source should be suppressed largely. We can easily prepare such test signals by using a pair of optical two-tone signals.

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References

[1] T. Kawanishi, A. Kanno, T. Kuri and N. Yamamoto, "Transparent waveform transfer for resilient and low-latency links," IEEE Photonics Society Newsletter, 28 (2014) 4
[2] APT Report on "Wired and Wireless Seamless Connections using Millimeter-Wave Radio over Fiber Technology for Resilient Access Networks, "APT/ASTAP/REPT-11
[3] APT Report on "Characteristics and Requirements of Optical and Electric Components for Millimeter-wave Radio on Fiber systems”, "APT/ASTAP/REPT-03 (Rev.3)
[4] K. Inagaki, T. Kawanishi and M. Izutsu, “Optoelectronic frequency response measurement of photodiodes by using high-extinction ratio optical modulator,” IEICE Electronics Express, Vol. 9, 220-226 (2012)
[5] IEC 62803:2016 Transmitting equipment for radiocommunication - Frequency response of optical-to-electric conversion device in high-frequency radio over fibre systems - Measurement method
[6] T. Kawanishi, T. Sakamoto, A. Chiba, and M. Izutsu, “Study of precise optical modulation using Mach-Zehnder interferometers for advanced modulation formats,” Proc. of European Conference on Optical Communication (ECOC), Berlin (Germany), Sep. 2007, 6.2.3.
[7] IEC 62802 ED1, Measurement Method of a Half-Wavelength Voltage and a Chirp Parameter for Mach-Zehnder Optical Modulator in High-Frequency Radio on Fibre (RoF) Systems