Photonics for Broadband Microwave Measurement

Shilong Pan* and Xiangchuan Wang
Key Laboratory of Radar Imaging and Microwave Photonics, Ministry of Education
Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China.

Microwave measurement refers to the acquisition of parameters of a microwave signal or the identification of properties of an object using microwave-based approaches. Thanks to the broad bandwidth and high speed provided by modern photonics, microwave measurement in the optical domain can provide better performance in terms of bandwidth and speed which may not be achievable using the state-of-the-art electronics. Various photonics-based techniques have been proposed and developed recently [1-3]. In this paper, techniques for photonics-based broadband or high-speed microwave measurement are discussed. Fig.1 shows a typical photonics-based microwave measurement system [4]. The microwave signal to be measured is first converted to the optical domain using a modulator, and then the microwave-modulated optical signal is sent to an optical processing module where the parameter to be measured is eventually converted to an amplitude change. As the microwave signal is measured and processed in the optical domain, the frequency range of the microwave measurement can be dramatically broadened.

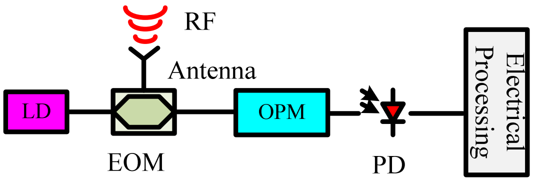

Figure 1. Schematic diagram of photonics-based microwave measurement system. LD: laser diode. EOM: electro-optical modulator. OPM: optical processing module. PD: photodetector.

In general, photonics-based microwave measurements can be divided into two categories: the measurements of parameters of a microwave signal such as power, phase noise, instantaneous frequency and spectrum, and the measurement of properties of an object using microwave as a medium such as position, velocity, and direction of arrival. Electric-field measurement technologies realized using electro-optic sensors are overviewed, with an emphasis on the improvement of measurement sensitivity, spatial resolution and bandwidth. Phase noise measurement system based on a frequency discriminator is also emphatically introduced. Combined with a two-channel cross-correlation technique, a noise floor as low as -170 dBc/Hz at an offset frequency of 10 kHz from a carrier frequency of 10 GHz can be achieved. In addition, spectrum measurement using an optical channelizer or spatial-spectral material is discussed, together with instantaneous frequency measurement (IFM) based on microwave power measurement, optical power measurement and frequency-to-time mapping technologies. In the photonics-based measurement system for non-contact acquisition of objects' properties, typical schematic diagrams and performance of photonics-based radars and fiber-connected distributed antenna systems are reviewed.

In addition to the techniques discussed above, an overview of emerging photonic techniques in broadband microwave measurement, such as microwave passive direction finding, Doppler frequency shift estimation, and multi-antenna based GPS positioning are also given.

References

1. J. Yao, "Microwave photonics," *Journal of Lightwave Technology,* 27, 3, February 2009,pp. 314-335, doi: 10.1109/JLT.2008.2009551.
2. S. Pan, D. Zhu, S. Liu, K. Xu, Y. Dai, T. Wang, J. Liu, N. Zhu, Y. Xue, and N. Liu, "Satellite Payloads Pay Off," *IEEE Microwave Magazine,***16**, 8, September 2015, pp. 61-73, doi: 10.1109/MMM.2015.2441619.
3. D. Marpaung, C. Roeloffzen, R. Heideman, A. Leinse, S. Sales, and J. Capmany, "Integrated microwave photonics," *Laser& Photonics Review*,**7**,4, July 2013, pp. 506-538, doi: 10.1002/lpor.201200032.
4. S. L. Pan and J. P. Yao, "Photonics-based broadband microwave measurement," *Journal of Lightwave Technology*, to be published, doi: 10.1109/JLT.2016.2587580.**[**