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Advances in High-speed and Adaptive Microwave Photonic Signal Processing

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Abstract

Photonic signal processing, using photonic approaches to condition wideband microwave signals, is attractive due to the inherent advantages of high time-bandwidth product and immunity to electromagnetic interference. In this keynote paper, we describe recent advances in wideband microwave photonic signal processing. This includes programmable microwave photonic phase shifters and true-time delay elements for phased array beamforming, and single bandpass tunable filtering approaches that overcome spectral periodicity. We also present optoelectronic oscillators with wideband frequency operating range, high-resolution multiple frequency microwave photonic measurement systems, and photonic RF memory structures that can realise a long reconfigurable storage time with wide instantaneous bandwidth.

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Keywords: Microwave photonics; Photonic signal processing.

1. Introduction

Photonic signal processing, using photonic approaches to condition microwave signals, offers the advantages of large time-bandwidth capabilities to overcome inherent electronic limitations, together with immunity to electromagnetic interference (EMI) [1-6]. It opens up new possibilities for overcoming the inherent bottlenecks

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caused by limited sampling speeds in conventional electrical signal processors [1]. In-fibre signal processors are directly compatible with fibre optic microwave systems, and can provide connectivity with in-built signal conditioning.

Microwave photonics is a unique technology that brings key benefits including the inherent speed, parallel signal processing capability, and very high sampling frequency ability [6]-[8]. These have led to diverse applications such as defence, fibre-radio, and radioastronomy areas, for tackling the problems of processing wideband fibre-fed distributed antenna signals, and for providing essential EMI immunity. These new techniques transcend the limitations of existing electronic methods, and enable new structures to be realised which not only can process high speed signals but which can also realise adaptive operation.

In this paper, we present recent new methods in wideband signal processors including ultra-wideband phase shifters and true time delays for phased array beamforming; single-passband programmable microwave photonic filters, optoelectronic oscillators, high-resolution multiple frequency microwave photonic measurement systems, and photonic RF memory structures.

2. Phase shifters and true time delays for beamforming networks

Optically controlled beamforming techniques for phased array antennas are of significant interest due to the advantages photonics can offer that include a wide operating bandwidth, remote antenna feeding, and EMI immunity [9]–[13]. Programmable phase shifters are required for adaptive beamforming. Thus, an optically controlled beam forming network that can operate over a wide frequency range, and which features the integration of the array phase taper and the array amplitude taper within a single unit, is highly attractive. A two-dimensional array of liquid crystal on silicon (LCoS) pixels that are configured with one input fiber and multiple output fibers, can be used to realise multiple wideband photonic microwave phase shifters [14]. The LCoS pixels enable dynamic wavelength routing to the output ports, and optical to radio frequency (RF) signal conversion with direct phase and amplitude translation control. This beamforming network is highly flexible and reconfigurable since it is software

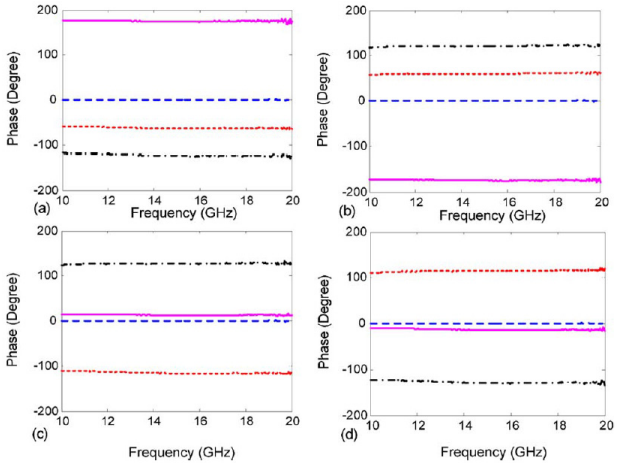

Fig. 1. Measured phase shifts corresponding to the scanning angle of (a) 20°, (b) -20°, (c) 40°, (d) -40° (phase shifter 1- - -, 2 ·····, 3 -·-·-, 4 ——).

programmable, and since the microwave phase shifters in the array are independent and have quasi-continuous phase control from 0 to 2π, arbitrary scanning beam angles can be realized.