ADAPTIVE PHOTONIC SPACE-TIME CODING AND ROUTING FOR WIRELESS ANTENNA ARRAYS

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Abstract

A photonic processing method employed for the control of phased array antennas (PAA), in wireless communications, is described. The photonic processing method utilizes an optical threshold function architecture, which was developed earlier using a multimode injection laser with controlled external feedback. A fibre prism structure is used to drive the PAA with a true-time-delay (TTD) signal; using the optical threshold function's output. The preliminary results presented in this paper, demonstrate how this optical method can be applied to drive PAA, used to route data packets with space-time coding, in an adaptive fashion.

I. Introduction

Photonic methods, using fibre and integrated-optic circuits, can be effectively used for obtaining true-time-delay (TTD) signals needed to feed antenna arrays [5]-[7]. In this paper a novel approach is presented for an all optical method of feeding the antenna arrays, whereby an optical information packet is switched and routed using optical techniques as described in [12] and an optical delay line circuit is used to obtain the desired time-delays needed by the antenna array. The point of departure for this paper is the results derived in [12]. This paper deals with the optical routing of optical information packets.

The rest of this paper is organised as follows. In section 2, the antenna steering concepts are explained. In section 3, experimental results are presented to verify the delay line concept. The paper is concluded with a discussion on the results.

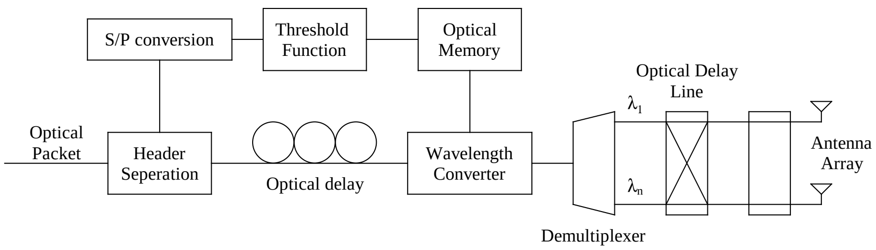

Figure 1: Schematic of all-optical packet switching and routing.

II. Background

An optical information packet, consisting of optical header bits and an optical payload, arrive at the header-separator. The header-separator separates the header and payload bits. Subsequently, the payload is routed to an all-optical wavelength switch, while the header bits undergo optical signal processing. First the header bits undergo serial to parallel (S/P) conversion. This can be achieved with a delay line circuit. Further header processing is performed with an all-optical threshold function. The concepts and operation principles of the optical threshold function are explained in [9,10] with a similar function presented in [12]. It should also be noted here that, although the issue of adaptivity is not explicitly emphasized in the present work, this functionality is implicitly available in the optical threshold function architecture, which we plan to employ it in future studies.

Presently, processing has only been performed on a single header bit. The optical threshold function converts a parallel input pattern to an output pattern pulse of unique wavelength. The output pulse from the optical threshold function is injected into an all-optical memory, which converts this pulse into a continuous wave of unique wavelength. The continuous wave is injected as a control signal into the wavelength switch, which is responsible for switching the payload to an output wavelength. This output wavelength depends on the header bits contained in the information packet. The optical payload can also be switched in space using a demultiplexer. The fibre prism delay line circuit described below is used for steering the antenna array.

III. Experiments

In order to verify the antenna steering concepts, we executed the experiment shown in Fig. 2. This experiment consists of a subset of the components shown in Fig. 1. In this experiment an optical threshold function is used as a header processor. The optical threshold function's output signal is modulated with a 2.5 Gbit/sec data pattern. The modulation is performed with a Mach-Zehnder interferometer (MZI) modulator. The laser based all-optical threshold function, as presented in Fig. 2, is used to test the all-optical signal processing method needed for steering the antenna arrays. The threshold function is implemented with a laser and an extended cavity, which allows two separate lasing modes to exist. The threshold function is made from two semi-conductor optical amplifiers (SOA) (acting as gain mediums) and two fibre Bragg-gratings (acting as wavelength selective mirrors). A directional coupler is used as a wavelength independent mirror. SOA2 acts as the main gain medium while SOA1 is used as a saturatable absorber in one of the cavities.

It should be noted that this experiment, in which the output of the header processor is modulated, acts a first experiment to verify the concepts. Later experiments will include all-optical modulation by wavelength conversion principles as indicated in [12].

The system is constructed such that lasing occurs at wavelength λ_1. If the laser injects external light into SOA1, gain quenching of SOA1 inhibits lasing at wavelength λ_1 but enables lasing at wavelength λ_2. The Bragg wavelengths of the two fibre Bragg-gratings used are: 1554.23 nm (λ_1) and 1558.92 nm (λ_2). The optical threshold function therefore produces two continuous waves at these wavelengths.

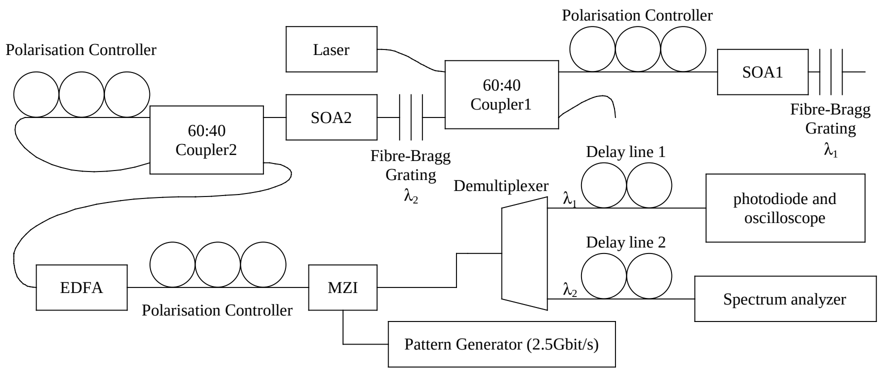

Figure 2: *Experimental Set-up.*

The experiment was conducted as follows. The signal from the optical threshold function was modulated with an external MZI modulator. The modulator is controlled by 2.5 Gbit/s PRBS signal generated by a pattern generator. The modulator's output signal was directed in a fibre delay line circuit, which was designed to generate a phase-shift of 0.6254 rad. In order to achieve this phase-shift, a relative delay of 40 ps is required, which can be achieved with a delay line circuit in which there is an 8 mm difference in optical fibre length. As can be seen in Fig.2, the oscilloscope only measures one output from the demultiplexer, the other is measured at a later stage. This effectively decreases the number of variable parameters that could influence the experimental measurements. The other delay line is used to test the effectiveness of the filter in the experimental set-up.

The aim of the experiment was to test the functioning of the optical threshold function and the delay line. Ultimately, success will be measured by the integrity of the information signal obtained subsequent to transmission.

The results obtained from the experiment are indicated in Fig.3 and Fig.4. Fig. 3 shows a portion of the oscilloscope trace obtained while testing the time delay circuit in the experimental set-up of Fig. 2. From the data collected during the experiment, the calculated averaged time delay is 39.998 ps. This is extremely close to the desired results. It must be noted that the oscilloscope used has a limited step size, which may somewhat distort the accuracy of the data. Fig. 4 is the eye pattern of the PRBS information signal that was modulated onto the optical threshold function's output signal.

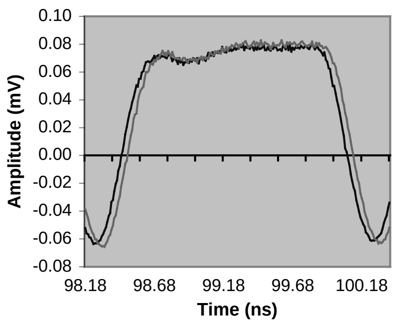

Figure 3: *Waveform of experimental results.*

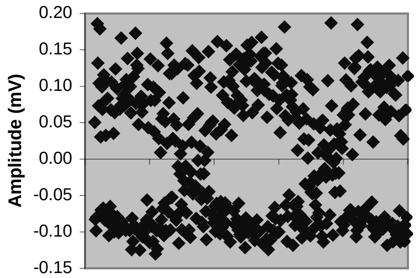

Figure 4: *Eye pattern generated by delay line.*

Although the data has large noise content, we believe that the results obtained here are satisfactory for the purpose of this initial proof-of-concept study. Additional work on the experimental set-up should lead to an improvement in the results, especially the eye pattern. The time delay circuit seems to be operational.

The poor quality of the eye pattern is primarily due to the length of the cavity, used to construct the optical threshold function, and the bandwidth of the fibre Bragg-gratings used. The large cavity length allows for the existence of numerous modes in the optical threshold function. The laser therefore undergoes mode hoping and this instability causes the MZI's output to be less than ideal.

IV. Conclusions

From these results, we can conclude that although the delay line circuit works, future work should concentrate on improving the transmission of optical information to the antenna array. The difficulty experienced in this experiment is primarily due to the line width of the optical threshold function's output. The bandwidth of the fibre Bragg-gratings means that the output of the optical threshold function has some spectral width. This means that the modulated signal is not modulated onto a single wavelength but a few wavelengths that surround the primary wavelength. The large cavity length allows for the existence of numerous modes in the optical threshold function. The laser therefore undergoes mode hoping and this instability causes the MZI's output to be less than ideal. Filtering of the signal, prior to detection, corrupts the integrity of the information signal, as some of the information is lost because the wavelength, onto which it was modulated, is filtered out. A second problem that was encountered was the lack of output power from the optical threshold function. Should this be rectified, an improvement in the eye pattern should be seen.

As a final concluding point, we note that the eventual benefit of the presented approach lies in the fact that the optical threshold function architecture provides an adaptive platform suitable for the changing and noisy environment of the wireless access systems.

V. Acknowledgements

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VI. References

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