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# Exploiting transmission line theory to calculate temporal derivatives

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In 2014 Silva *et al* introduced the concept of "computational metamaterials"[1], since then various metamaterial and metasurface processors have been demonstrated performing mathematical operations such as differentiation integration and convolution directly onto the wavefront of an incident optical or acoustic signal[2]–[4]. While many of these devices have been demonstrated operating in the spatial domain, few have been shown operating in the time domain.

In this work we present a device capable of computing the temporal derivatives of incident signals[5]. To achieve this functionality, we exploit the splitting and superposition of electromagnetic (EM) waves at the intersections between parallel plate waveguides. The operational frequency of this device is controlled by correctly selecting the length of a pair of stub waveguides, which connect to a central waveguide at a 4-way parallel plate junction.

It is shown how this device is capable of calculating the time derivative of both non-modulated and modulated incident signals and can be used in either transmission or reflection configurations. Full-wave numerical simulations of our device using the commercially available software CST Studio Suite® are presented for an incident gaussian pulse with an 8GHz central frequency. All numerical simulations are in excellent agreement with the theoretically calculate transmission and reflection spectra.

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