

# 40 Gbit/s GaAs MMIC Signal Processor for Optical Communication Systems

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## ABSTRACT

We will present the design and characterisation of a transversal microwave filter as a signal processor for 40 Gbit/s optical receivers. The work reports, for the first time, a versatile transversal filter, implemented as a monolithic microwave integrated circuit (MMIC) with capacity to adjust the frequency response for signal processing at these very high bit rates. The main features are the electrical response tuning facility and signal gain.

## INTRODUCTION

In the design of optical communication systems for multigigabit transmission rates, a special care must be given to the post-detection receiver filter. This filter has the main function to reshape the received pulses giving at the input of the decision circuit a well-defined signal, with low intersymbol interference (ISI) and telegraph distortion (TD). A well-designed post-detection filter, effecting appropriate pulse shaping/noise reduction, can reduce significantly the degradation caused by the system impairments such as the fibre dispersion, signal dependent noise and pulse/clock jitter. However, there are practical constraints in filter design: it must be easily fabricated, insensitive to manufacturing tolerances, have a reasonable physical size and integrate easily with the other components of the optical receiver.

Microwave distributed filters based on microstrip structures, Monteiro et al (1), Hussain et al (2) and MMIC lumped element filters, O'Reilly et al (3), have been successfully used to produce signal-post detection filters in the multigigabit regime. In spite of the good results achieved by using these filters, it is difficult, and in most cases impossible, to adjust their response for different system operating conditions and therefore they must be carefully designed for a specific system. Transversal filters, have the advantage of electrical tunability, a desirable characteristic for the implementation of transmission length tolerant optical receivers. They can also be made easily adaptive to track the changes in nonideal receiver response or other distortions due to ageing and temperature variations.

Signal processors based on transversal filters suitable for optical transmission systems at 2.5 Gbit/s have been presented by Lee and Freundorfer (4) and for a transmission rate of 10 Gbit/s by Monteiro et al (5). We present here for the first time the design and measured results of an adaptive transversal filter suitable for an optical receiver at 40 Gbit/s. The presented filter was produced and tested in the context of the ATLAS (All-optical Terabit per second Lambda-Shifted) project, of the European program IST (Information Society Technologies).

## IMPLEMENTATION OF THE DISTRIBUTED-BASED TRANSVERSAL FILTER

A generalized transversal structure normally used for low frequency signal processing applications is illustrated in Fig. 1.

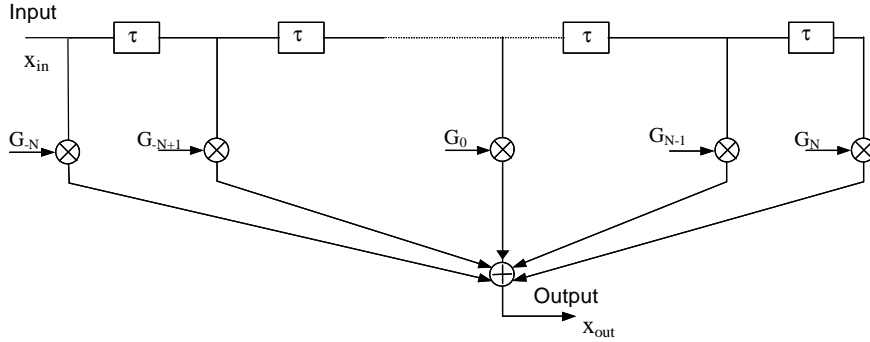


Fig. 1- A generalized transversal-filter block diagram.

The filter consists of a delay line with maximum delay  $2N\tau$  and with  $2N+1$  taps, where  $2N$  is the number of delay line sections and  $\tau$  is the section delay. A signal travelling along the delay lines is sampled at each tap output. The sampled outputs are multiplied by the gain coefficients  $G_{-N}$ ,  $G_{-N+1}, \dots, G_N$  and summed to form the final output. The frequency response of such structure is given by:

$$H(f) = \left[ \sum_{k=-N}^N G_k e^{-j2\pi f k \tau} \right] e^{-j2\pi f N \tau} \quad (1)$$

Standard implementation of this structure at the millimetre/microwave frequencies operation is rather complicated and difficult to produce in an integrated form. Fig. 2 shows an alternative transversal filter based on a distributed structure suitable for MMIC implementation. In this figure  $\tau_i, \tau_o$  are the respective interstage delays of the input and output artificial transmission lines and  $G_k$  is the gain block of the stage  $K$  that provides the transversal filter tap weights. In order to obtain a transversal filter with positive and negative tap weights the gain blocks are based on Gilbert Cells (4). It can be demonstrated, Borjak et al (6), that the transfer function of this distributed arrangement is identical to a generalised transversal filter with an equivalent tap delay  $\tau = \tau_i - \tau_o$ . Therefore, the same standard time and frequency domain techniques can be applied to calculate the gain coefficients and tap delays, to produce the desired signal processing.

Fig. 3 shows the photomicrograph of the designed transversal filter with five Gilbert gain stages. The filter was implemented using the  $0.15\mu\text{m}$  gate pseudomorphic HEMT process from United Monolithic Semiconductors (PH15 technology). The implemented transversal filter uses thirty five transistors and the chip size is  $2.8 \times 1.2$  mm.

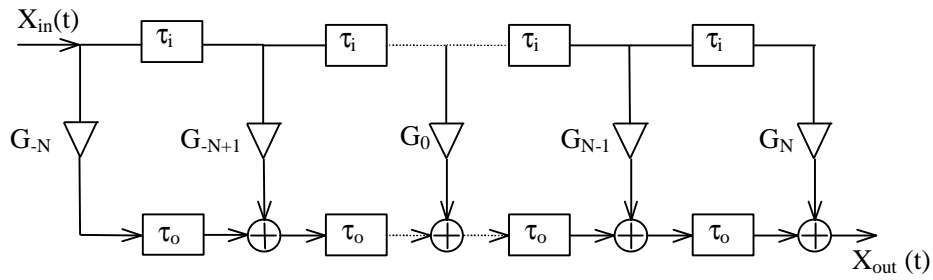


Fig. 2 Simplified diagram of a distributed based transversal filter

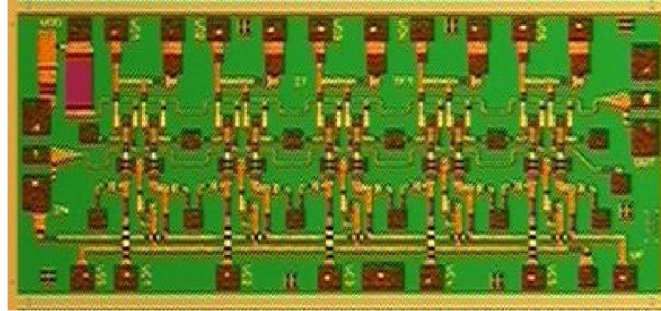


Fig. 3 - The MMIC transversal filter photomicrograph.

## EXPERIMENTAL RESULTS

Fig. 4 shows the on-wafer S parameter measurements for different control voltages. From  $|S_{21}|$  measurements we can observe that the filter presents a wide band electrical tuning control, with the possibility of providing signal gain. From  $|S_{11}|$  and  $|S_{22}|$  measurements we can observe that the filter provides a good input and output impedance match up to 30 GHz, where most of the spectral energy is concentrated for 40 Gbit/s signalling.

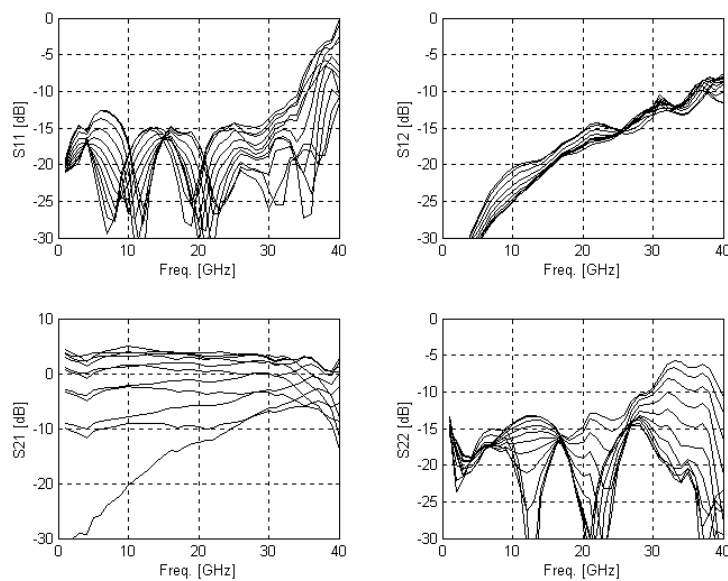


Fig. 4 - Measured transversal filter S parameters for different control voltage.

## CONCLUSIONS

We have reported a MMIC transversal filter based on a distributed structure, to be used as signal processor for a 40 Gbit/s optical receiver.

The structure is versatile and can be used to produce various signal-shaping and filtering functions. The electrical adjustable frequency response and gain of this filter will allow the implementation of link length tolerant optical receivers. They can also be made adaptive to changes on system response or other distortions due to ageing and temperature variation. To the best of the authors' knowledge, this is the first MMIC tunable active filter produced to operate at such very high frequencies.

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