10-Gb/s Pulse-Shaping Distributed-Based Transversal Filter Front-End for Optical Soliton Receivers

P. Monteiro, A. Borjak, F. da Rocha, J. O'Reilly, and I. Darwazeh

***Abstract*—The design and performance of a microwave filter as a signal processor for a 10-Gb/s soliton receiver are described. The work reports, for the first time, a versatile transversal active filtering structure, implemented as a monolithic microwave integrated circuit (MMIC) and featuring an accurate, yet straightforward, response tuning facility based on dc bias variation and allowing for optimization of the received eye patterns and therefore error-rate minimization. Tests are reported for 10-Gb/s input optical solitons, showing the efficacy of receiver output eye shape variation using the techniques described.**

***Index Terms*—Active filters, GaAs, MMIC's, optical receivers, solitons.**

I. Introduction

In THE DESIGN of optical systems for multigigabit transmission rates, special care must be given to the post-detection receiver filter. The filter's main function is to reshape the received pulses, giving a well-defined signal with low noise, low intersymbol interference (ISI), and telegraph distortion (TD) at the input of the decision circuit. A well-designed post-detection amplifying filter, effecting appropriate pulse shaping, can reduce significantly the performance degradation caused by such impairments. However, there are constraints in filter design: It must be easily fabricated, tolerant to processing variations, have a reasonable physical size, and must also easily integrate with the other components of the optical receiver.

Microwave passive circuits based on microstrip structures [1] and monolithic microwave integrated circuit (MMIC) lumped-element filters [2] have been successfully used to produce signal-post detection filters in the multigigabit regime. MESFET and HEMT MMIC's, based either on simple common source (CS) structures [3] or on distributed amplifier (DA) ones [4], were produced to effect a combination of signal amplification and shaping. In spite of the good results achieved by using both active and passive 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, on the other hand, have the advantage of tunability to produce link-length-tolerant optical receivers [5]. They can also be made adaptive to track the changes in nonideal receiver response or other distortions due to ageing and temperature variations. In this work we report a practical design of a GaAs MMIC transversal filter (TF) to be used as postdetection filter for 10-Gb/s optical soliton system.[1]

II. Practical Implementation of the Distributed-Based Transversal Filter

For a good receiver performance, the pulse-shaping filter must reshape the incoming soliton pulses producing output pulses satisfying the first and second Nyquist criteria, such as those belonging to the family of raised cosine. By using this procedure, noise reduced signals with low ISI and TD are obtained at the input of the decision circuit. To produce the desired transfer function a transversal filter composed of five common-source stages was used with synthesized equivalent tap delay of 33.33 ps. The normalized gain coefficients were obtained by sampling the desired impulse response at time intervals equivalent to the tap delays, following a technique similar to that used for a distributed amplifier in [6]. For incoming solitons, with full-width half-maximum (FWHM) less than 20 ps, the normalized gains were converted to the optimized field-effect transistor (FET) sizes, taking into account the line losses and the degeneracies associated with the process used. A MESFET-GaAs process with $f_T = 20$ GHz was used to implement the transversal filter. Different inter-stage delays were implemented by using different lengths of microstrip transmission line elements, and different stage gains were obtained using MESFET's of different sizes. The MESFET sizes were selected to maximize the gain and effect the required response. The sizes before and after optimization are illustrated in Table I. The photomicrograph of the transversal filter is shown in Fig. 1 and its dimension is approximately 1.8×3.2 mm^2. The pulse-shaping function design is tunable by employing a separate bias for each MESFET gate.

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[1] The filter will be used in the ESTHER (Exploitation of Soliton Transmission Highways for European Ring) program, incorporated in the European program ACTS (Advanced Communications Technologies and Services).

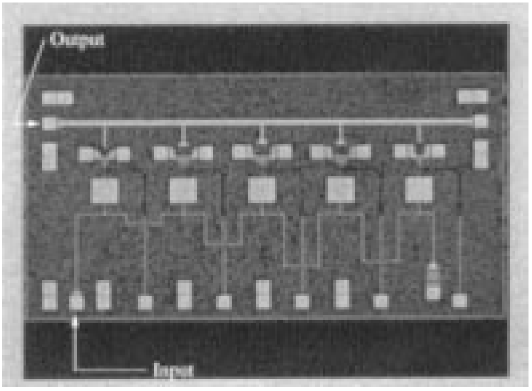
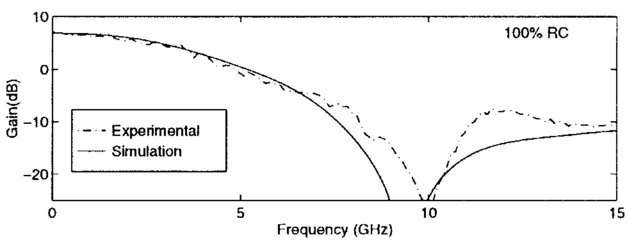


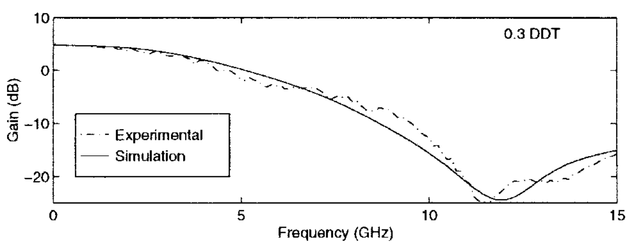
Fig. 1. The MMIC transversal filter photomicrograph.

TABLE I
THE FET SIZES (NUMBER OF FINGERS × GATE LENGTH) OF THE TF BEFORE AND AFTER THE OPTIMIZATION

Coefficient	Normalized	Initial FET Size	Optimised FET Size
G_1	0.27	$2 \times 40.5\mu m$	$2 \times 41.4\mu m$
G_2	0.74	$4 \times 55.5\mu m$	$4 \times 54.4\mu m$
G_3	1.00	$4 \times 75.0\mu m$	$4 \times 70.4\mu m$
G_4	0.74	$4 \times 55.5\mu m$	$4 \times 62.5\mu m$
G_5	0.27	$2 \times 40.5\mu m$	$2 \times 70.0\mu m$



(a)

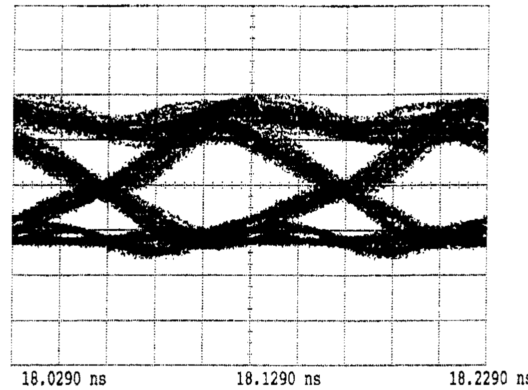


(b)

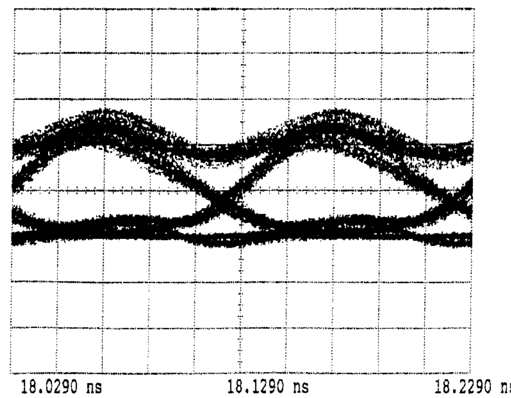
Fig. 2. Measured and simulated filter frequency responses for two output pulse shapes. (a) 100% RC. (b) 0.3 depressed decision threshold.

III. RESULTS

By changing only the gate bias voltages, Fig. 2 was obtained, showing the measured frequency responses. The respective eye diagrams for two different pulse shaping strategies (targets A and B) are shown in Fig. 3. These results show that response tunability can be obtained giving the responses as predicted. Target (a) corresponds to the traditional 100% raised cosine (RC) pulse shaping and target (b) to a particular signal shape suitable for optical systems with significant jitter and signal dependent noise, where the optimum decision threshold must be depressed below the mid-range of the eye opening [1]. In both cases we are considering input solitons with FWHM close to 20 ps. Fig. 3 shows time domain test results carried out using such solitons. The eye diagrams are measured at the output of the filter when a high speed p-i-n diode is connected to its input. From the two diagrams, it is clear that this filter provides adequate gain and that an excellent agreement between the filter responses and the targets is achieved, up to the highest frequencies of interest, for the two cases considered. For both cases, good vertical and horizontal eye opening with small ISI and TD is obtained.



(a)



(b)

Fig. 3. Measured 10-Gb/s eye diagrams obtained by tuning the filter for targets (a) and (b).

IV. CONCLUSION

We have reported a novel design of an MMIC filter based on a transversal filter-distributed amplifier structure to operate as a receiver for optical soliton system. The structure is versatile and can be used to effect various signal-shaping and -filtering functions. To the best of the authors' knowledge, this is the first MMIC tunable active filter produced to operate at such very high frequencies and bit rates.

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