AN ACTIVE MICROWAVE TRANSMISSION DELAY EQUALIZER

Jean-Pierre Le Normand and Robert Alain Périchon

LEST, URA CNRS n° 1329, UFR Sciences et Techniques, Brest, France

Abstract

A new group delay equalizer, operating at microwave frequencies, is presented here. It consists in an active transmission path which includes three amplifier stages. The middle stage has an all-pass transfer function when a feedback branch is placed between input and output. The feedback branch is an external stop-band cavity which produces the desirable amount of group delay. The amplifier stages are carried out by using GaAs MMIC technology, while the external cavity consists in a dielectric resonator coupled to a microstrip line. A 285 ns group delay is measured.

Introduction

Group delay equalizers, operating at microwave frequencies, find their application in multichannel communication systems. Correcting group delay in microwaves is necessary in repeater-fitted systems which do not translate into an intermediate frequency. All microwave delay equalizers described up to now are passive. Most of them work in a reflection mode and use either a circulator, a hybrid [1] or a Wilkinson divider [2] (Fig. 1a). The reflection coefficient is performed by means of a single or multiple cavity and has the form of an all-pass transfer function. The cavity creates the desirable amount of group delay in the prescribed bandwidth, in order to correct, for example, the group delay of a microwave band-pass filter. In this paper, an active transmission delay equalizer is proposed. The all-pass transfer function is realised by an active amplifier with one parallel feedback stage (Fig. 1b). The branch of the parallel feedback is a stop-band cavity which gives the desirable amount of group delay.

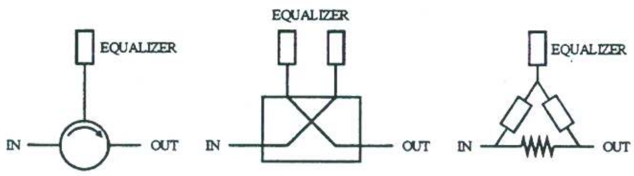

Fig. 1a

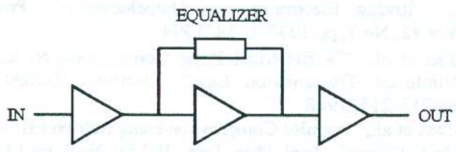

Fig. 1b

Principle of the equalizer

The topology of the feedback amplifier (Fig. 2), consists in a MESFET with a feedback resistance and an external parallel resonant circuit, which represents the external stop-band cavity. Using only the transconductance Gm to represent the MESFET equivalent circuit, it can be shown that the transfer scattering parameter S_{21} can be written as a biquadratic all-pass transfer function :

$$S_{21}(s) = K \cdot \left[1 - \frac{1}{Q} \cdot \frac{s}{\omega_0} + \left(\frac{s}{\omega_0}\right)^2\right] \Big/ \left[1 + \frac{1}{Q} \cdot \frac{s}{\omega_0} + \left(\frac{s}{\omega_0}\right)^2\right]$$

providing that the following all-pass condition is satisfied :

$$g_T = g_p + g = \left(g_m - 1/(2 + g_m)\right)/2$$

where small letters stand for reduced parameters (i. e. $g_m = G_m/Y_0$).

K and Q are defined by : $K = -2/(2 + g_m)$

$$Q = \frac{1}{G_m - G_p - G} \cdot \left(\frac{C}{L}\right)^{1/2} \quad \text{and} \quad L \cdot C \cdot {\omega_0}^2 = 1$$

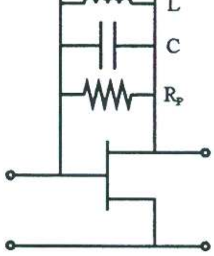

Fig. 2

The experimental active group delay equalizer

The one-stage amplifier group delay equalizer has a loss in transmission. Moreover, its input and output return loss is poor. To solve these problems, the solution is to insert the equalizer between two amplifier stages which provide efficient isolation for the intermediate stage and allow to add an input and output matching network to provide gain and good match in the bandwidth of the equalizer. It can be shown again that S_{21} can always be written as a biquadratic all-pass function with Q unchanged. The novel all-pass condition is written as follows :

$$g_T = g_p + g = g_{m2}/2$$

where g_{m2} is the reduced transconductance of T_2. K is now written :

$$K = -2 \cdot g_{m1} \cdot g_{m3} / g_{m2}$$

where g_{m1} and g_{m3} are the reduced transconductances of T_1 and T_3.

The experimental active group delay equalizer circuit is shown in Fig. 3 (electric circuit) and is built using a 0.7 µm MMIC technology. A photograph of the MMIC is shown in Fig. 4. The parallel feedback resistance consists in a cold MESFET placed between the gate and drain of the intermediate transistor T_2 and is of course adjustable by means of its gate bias voltage. T_2 is active-loaded while T_1 and T_3 are not. The input matching circuit is a pi section. The output matching circuit is also a pi section which includes the bias inductance of T_3. The external cavity consists in a dielectric resonator coupled to a microstrip line. A photograph of the complete MIC device is shown in Fig 5. Electrical length of each microstrip line joining the MMIC circuit to the symmetry axis of the dielectric resonator must be an integer of 180° at the operating frequency, so as to keep the parallel behaviour of the resonant circuit.

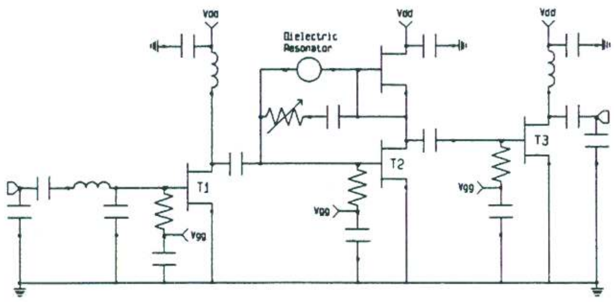

Fig. 3

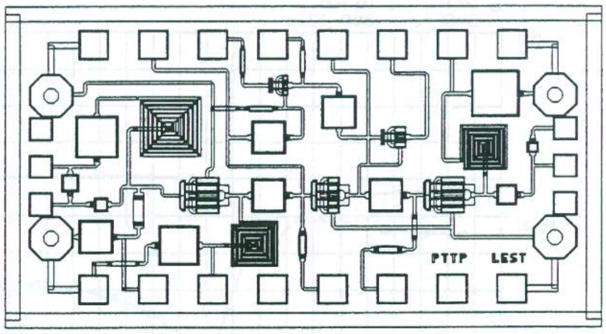

Fig. 4

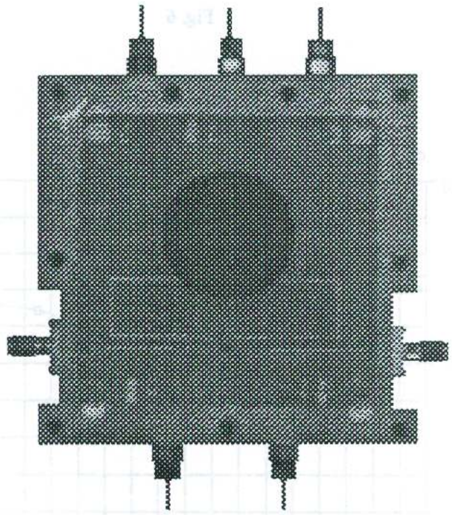

Fig. 5

Experimental results

The working frequency f_0 is equal to 2.5 GHz. The experimental results are presented in Fig. 6 to 8. The input return loss is better than 15 dB while the output return loss is better than 12 dB (Fig. 6). The transmission scattering parameter S_{21} shows a 4 dB gain out of resonance and a notch of about 6 dB at f_0 (Fig. 7). The experimental notch amplitude is relatively deep because of an inadequate coupling of the dielectric resonator to the microstrip line which is weaker than presumed. The parallel loss resistance is therefore too low at the resonance frequency. The MMIC circuit has been designed for a larger parallel loss resistance and consequently the width of T_2 is inadequate and should have been chosen lower, in order to reduce the notch observed at f_0. The maximum group delay is 285 ns (Fig. 8). It must be noticed that a revisited design would allow to obtain a flat gain around f_0 when the cold MESFET is off. Then, the opening of its channel makes it possible to adjust the notch amplitude.

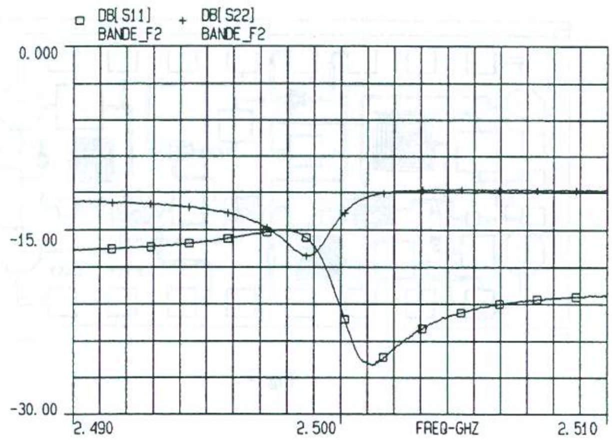

Fig. 6

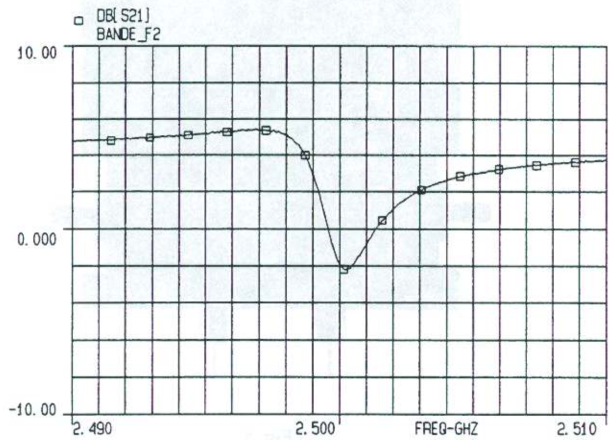

Fig. 7

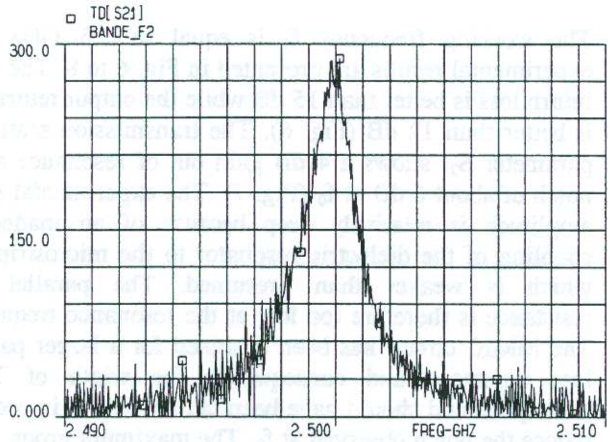

Fig. 8

Conclusion

A new way of correcting group delay directly at microwave frequencies has been proposed and demonstrated experimentally here. The device presents good match and gain. It is built in MIC technology which enables to correct group delay of filters carried out in this same technology. Several dielectric resonators, with slightly different resonance frequencies can be placed in a similar manner so as to achieve a prescribed group delay correction curve.

References

[1] M. H. Chen, « The design of a multiple cavity equalizer », *IEEE Trans. MTT*, vol. MTT-30, pp. 1380-1383, Sept. 1982.

[2] P. Janer, « Circuit for correcting group delay at microwave frequencies », *US Patent 4 988 952*, Jan. 29, 1991.

Acknowledgement

This work was supported by the Centre National d'Etudes Spatiales, Toulouse and the Conseil Regional de Bretagne.