A MULTIPATH FADING MICROWAVE SIMULATOR FOR STUDYING SPACE DIVERSITY SYSTEMS

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ABSTRACT

This article describes the microwave structure of a multipath fading simulator for studying space diversity systems. This simulator has two independent channels and is controlled in real time by a PC (or compatible). It is used for developing control software for space diversity and the automatic registering of signatures.

1. INTRODUCTION

1.1 The necessity

Digital radio links are mainly disturbed by the phenomenon of multipath propagation. In a random way, this phenomenon produces selective fading in the receiving band of a microwave link (see figure 1).

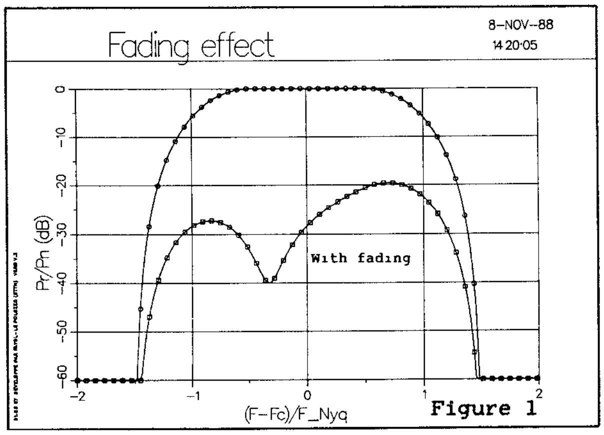


Figure 1
Calculated transfert fonction of a radio channel with and without multipath fading. (-3 MHz from the center frequency 7400MHz, depth notch 30 dB,flat fading 10 dB) (This is a 16QAM 2x34 Mbits/s radio channel with a 50% rolloff factor F_Nyq=9.19 MHz)

Some countermeasure systems [1] [2] [3] have been developed whose use has become necessary with the appearance of more and more complex modulation (64 QAM, 256 QAM). Space diversity is a system which is currently used (see figure 2). In it, we combine the signals coming from two antennas An and Ad in such a way that the output signal S has minimal distorsion and/or a maximal power according to the strategy.

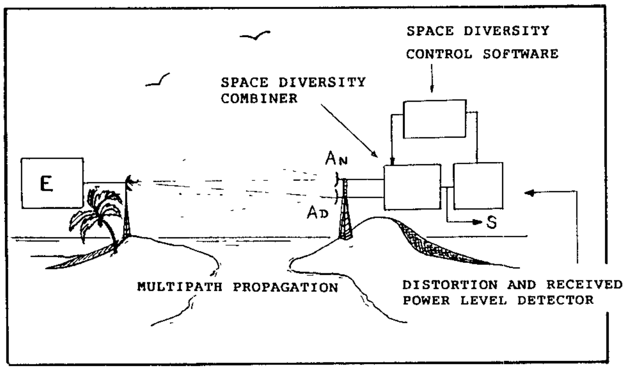


Figure 2:
Radio link with space diversity system.

The development of such systems, and particularly the control software for the combiner, requires using a multipath fading simulator. Simulators working in intermediate frequency have appeared recently on the market. They only simulate one channel and cannot be used during the tuning of a space diversity system set up in microwave [4]. Here we describe a multipath fading microwave simulator with two channels controllable in real time, which we have developed to test our systems. This device can also automatically perform the signature registrations.

1.2 Modelling the phenomenon

Rummler's model is currently used to simulate the fading due to multipath propagation. In this model [5] [6] it is considered that three rays come on a receiving antenna, i.e. one direct ray and two delayed rays (one weakly and the other strongly). The weakly delayed ray causes a constant attenuation throughout the band, called flat attenuation. The strongly delayed ray causes a selective fading. The mathematical expression of this model is given by (1)

$$Hr(F)=a.\left[1-b.e^{-j2\pi(F-Ff)\tau}\right] \qquad (1)$$

$0<a<1$
$0<b<\infty$
$\tau=6.3$ ns

Ff is the selective fading frequency.

The selective fading depth is given by :

$$Ps = -20 \log |1-b| \text{ in dB} \quad (2)$$

and that of flat fading by :

$$Pf = -20 \log (a) \text{ in dB} \quad (3)$$

Figure 3 gives the example of a modelized selective fading Pf=10 dB Ps=30 dB Ff-Fc=-10MHz (Ff=7390 MHz Fc=7400MHz).

It is possible to fairly easily set up the Rummler's function with the aid of microwave circuits, whence the idea of constructing a multipath fading simulator in microwave.

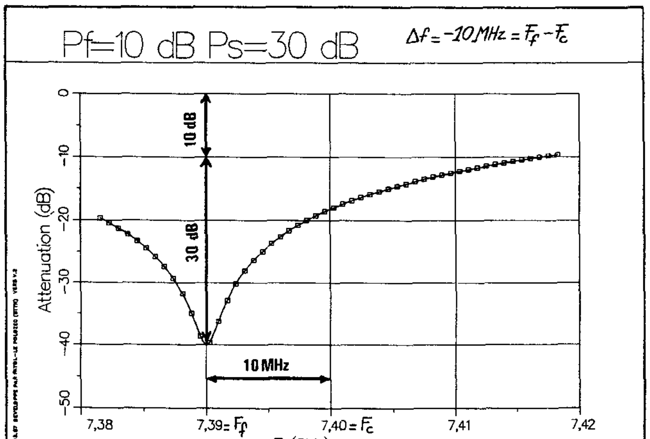


Figure 3

The simulator presented here has the following characteristics :

The device can be calibrated for a band of 50 MHz, centered on any one of the frequencies from 7050 MHz to 7750 MHz.

* Depth of flat attenuation

  0 < Pf < 30 dB Fixed

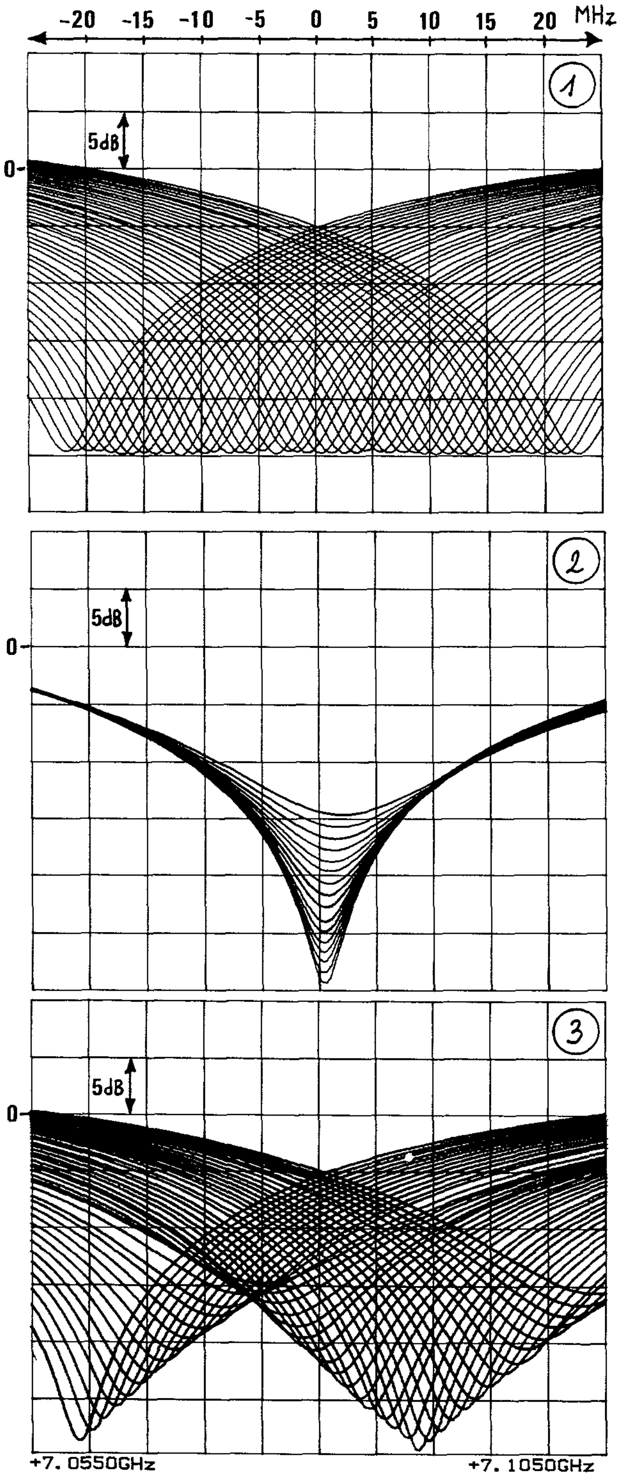
* Depth of the selective attenuation

  0 < Ps < 30 dB variable (step = 1 dB)
  0 < variation speed < 100 dB/s

* Frequency of the selective fading

  - 20 < F_f-F_c < 20 MHz variable (step = 1 MHz)
  0 < variation speed < 100 MHz/s

The simulator is controlled by a PC (whose RS232 printer output is used). Each channel can be controlled independently from the other. For each channel, we can vary the frequency and/or the selective fading depth according to two laws of time domain evolution (triangle, random) ; see figure 4. Various scenarios can be considered, combining the two channels.



(1) FREQUENCY SWEEP :
-22 MHz to +23 MHz from the center frequency (7080 MHz). The depth of the notch is 25 dB and the flat fading is 0 dB.

(2) DEPTH SWEEP :
variable notch from 15 dB to 30 dB at 7081 MHz.

(3) DEPTH AND FREQUENCY SWEEP :
mix of 1 and 2

figure 4

II.1 Microwave parts

The general diagram of the simulator is given in figure 5. A power divider (Wilkinson) separates the two channels (normal and diversity). The delay τ_o enables the static balancing of the two channels ($0 < \tau_o < 2$ ns).

The isolators are used to adapt the input and output and to adapt the vairiable phase shifters.

The fixed attenuators of 7 and 5 dB compensate the losses of each phase shifter (12 dB).

The transfert function of each channel is identical to (1).

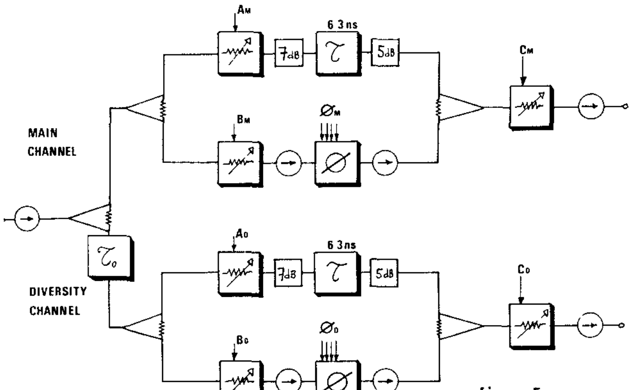
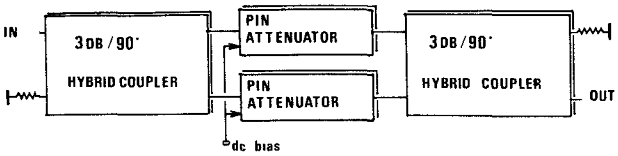


figure 5

II.1-a The variable attenuators

The general diagram, the implementation and the performances are given in figure 6. These are PIN diode attenuators, made on alumina 1"x 1", thickness = 0.025",
$\varepsilon_r = 9.7$ with beam lead PIN diodes HPND 4038 from Hewlett Packard. Each attenuator is made with two attenuation functions placed between two 90° 3 dB hybrid couplers in order to maintain both the input and the output match under all attenuation conditions.



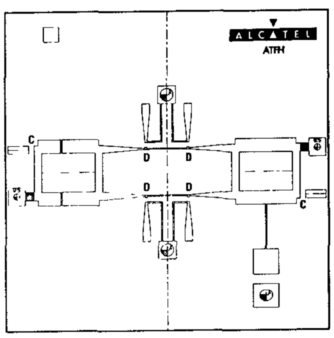
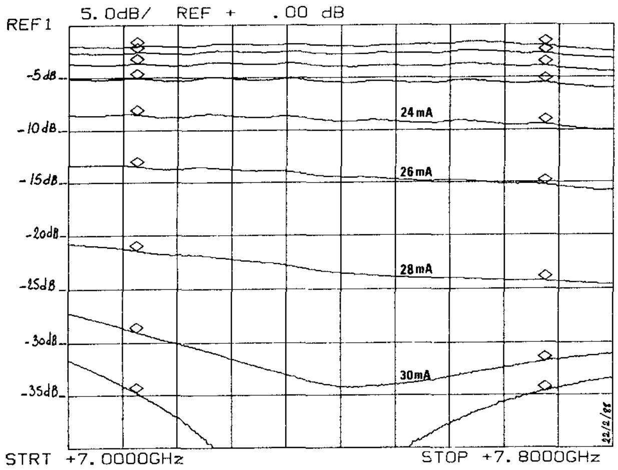
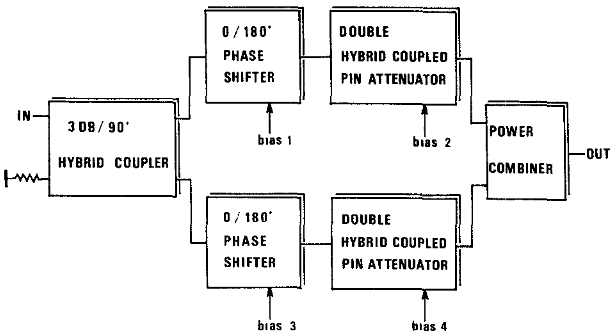


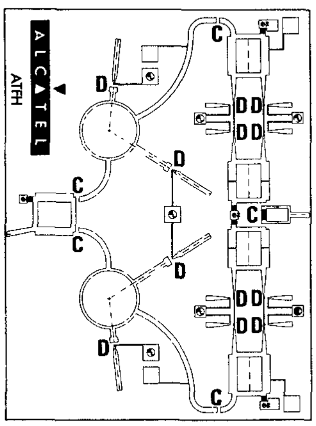
Figure 6

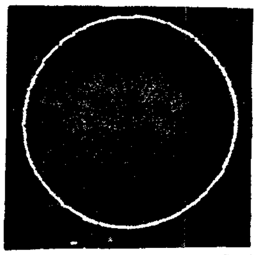


II.1-b The phase shifters

The general diagram, the implentation and the performances are given in figure 7. These are endless phase shifters, built with a vectorial modulation approach. Two attenuators and two changeover switches (two states phase shifter 0-180°) are used hence any phase and amplitude value can be obtained by adjusting the four control currents. The circuit is made on alumina 1.5" x 2", thickness = 0.025", $\varepsilon_r = 9.7$ with beam lead PIN diodes HPND 4038 from Hewlett Packard.







Measured result of the endless phase shifter at F=7080 MHz

"D" shows the PIN diode location and "C" the DC-block location

Figure 7

II-2 Control part

The general diagram is given in figure 8. The eight control bytes are transmitted in serial form by the PC. A serial-parallel interface (built around an UART : Universal Asynchronous Receiver Transmitter) makes it possible to use each of these words, either as data to be directly converted (for the six attenuators), or as the adress of the four control data elements necessary for each phase shifter and placed in the associated buffer memories. On the PC, a programming acquisition software provides maximum simplicity in the man-machine interface.

III CONCLUSIONS

This multipath fading simulator described in this paper operates over a 700 MHz RF band centered at 7400 MHz. This laboratory simulation facility provide, a useful tool to the radio system designers, and means of measuring and comparing performance of radio hardware over multipath fading. Future efforts will consist to built a broadband simulator.

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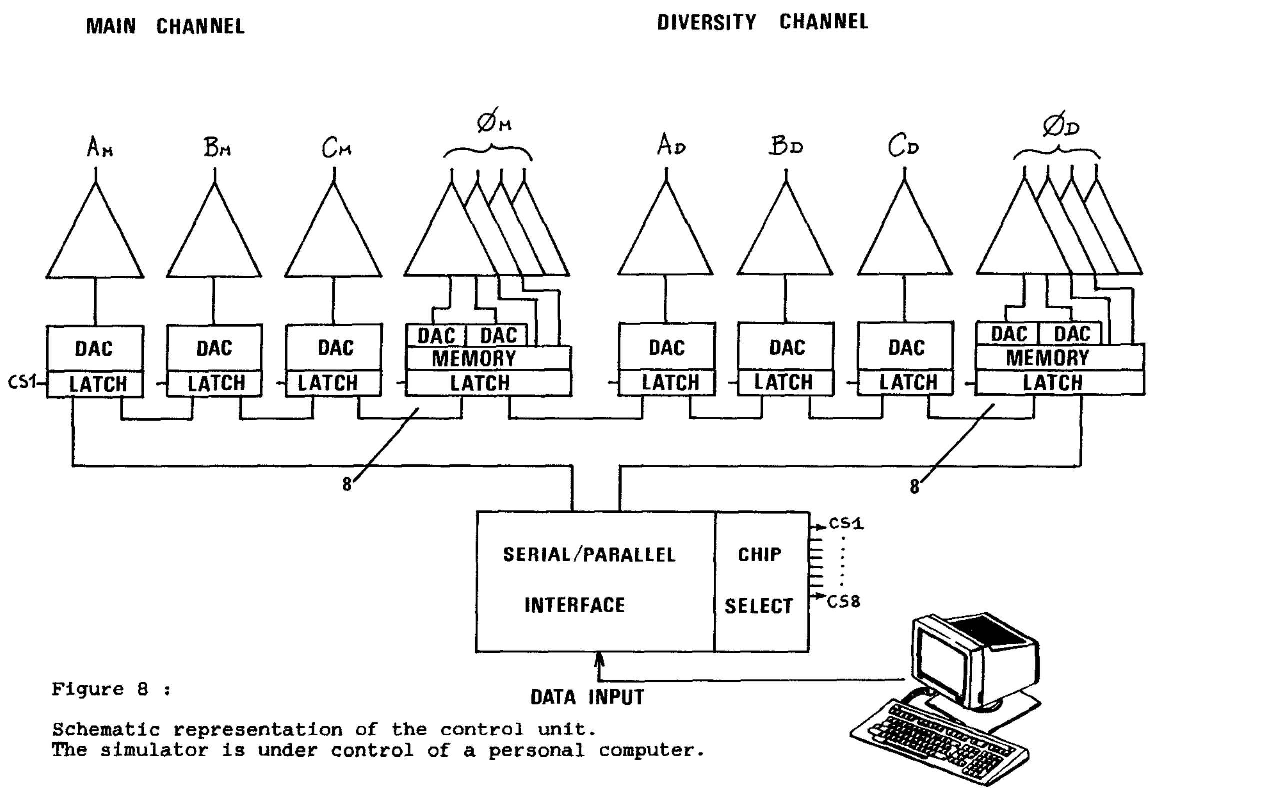

Figure 8 :

Schematic representation of the control unit.
The simulator is under control of a personal computer.