A Low Phase Shift Step Attenuator Using p-i-n Diodes Switches

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Abstract—**A fast *S*-band MIC high dynamic range (0÷70 dB) step attenuator is described, with a very small phase change versus attenuation levels. To obtain this, three similar two-paths sections are cascaded, each being able, by means of a couple of SPDT p-i-n diodes switches, to attenuate 0 dB or, respectively, 10, 20, and 40 dB. Experimental results are given, referring to a circuit breadboard operating from 2 to 4 GHz, the phase change being less than ~11° over all the octave band.**

I. Introduction

VERY OFTEN, in modern microwave systems, devices are required which electronically control the attenuation and/or the phase shift of transmitted/received signals. By driving these devices with appropriated computer-controlled numeric sequences, it is possible to obtain the best system performances. For instance, the various radar and acquisition systems using phased arrays antennas need the capability of suitably controlling both phase and amplitude characteristics of RF signal, to perform the desired time-varying beams and signal processing. In general, one of the most important requirements is that the variation of attenuation should not, unless otherwise desired, affect the phase, which very often constitutes the true information carrier.

In this paper the design and the realization is described of a fast switching (<20 ns) wide-range (from 0 to 70 dB) 10-dB step attenuator in *S*-band (50 Ω loaded), which electronically switches from one attenuation level to another maintaining a phase change between switching states as low as possible.

II. Design and Realization

Because of high dynamic range and of required discrete varying attenuation characteristics, the design has been made by considering 3 cascadable sections, whose attenuation is switchable from 0 dB to, respectively, 10, 20, and 40 dB (see Fig. 1). In this way, with a 3-digit words driving sequence, it is possible to obtain $2^3=8$ different 10-dB spaced attenuation levels from 0 to 70 dB. Besides, by suitably characterizing the resistive networks —which, in practice, are not the desired lumped elements —in a manner that their attenuation and phase shift features be sufficiently known, it is not too difficult to adjust the transmission lines electrical lengths so that the difference between the two phase shifts of each section arms be theoretically zero in a wideband of frequencies (mainly depending on resistor electrical lengths behaviors versus frequency). Finally, by miniaturizing as much as possible these resistive components, their phase shifts can be maintained very small, so reducing at minimum the lines balancing.

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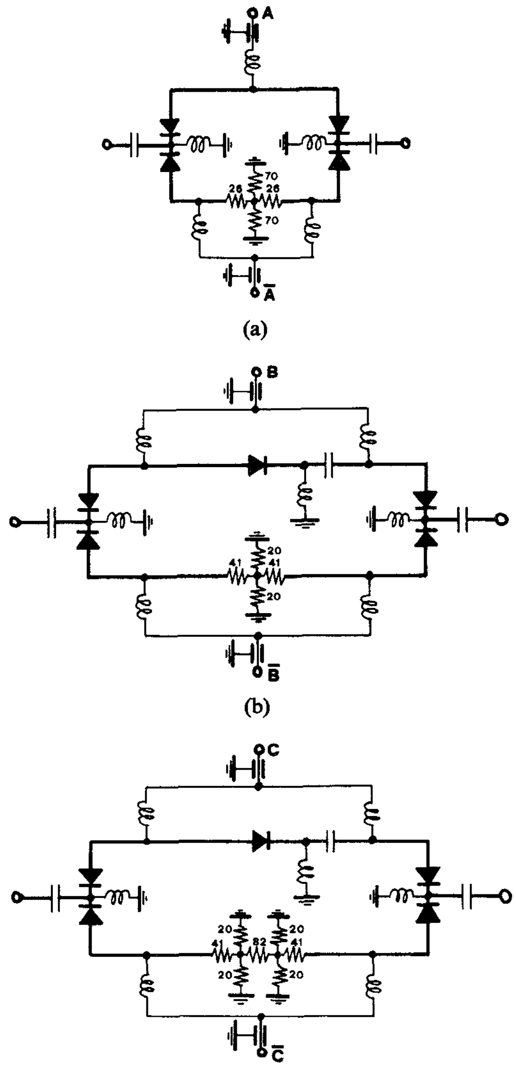

Fig. 1. Electrical schemes of the attenuation sections. (a) 10-dB section. (b) 20-dB section. (c) 40-dB section. $A-\bar{A}$, $B-\bar{B}$, and $C-\bar{C}$ represent the p-i-n diodes dc biasing. The resistances values are in ohms.

In Fig. 2 a photograph is given showing the circuit

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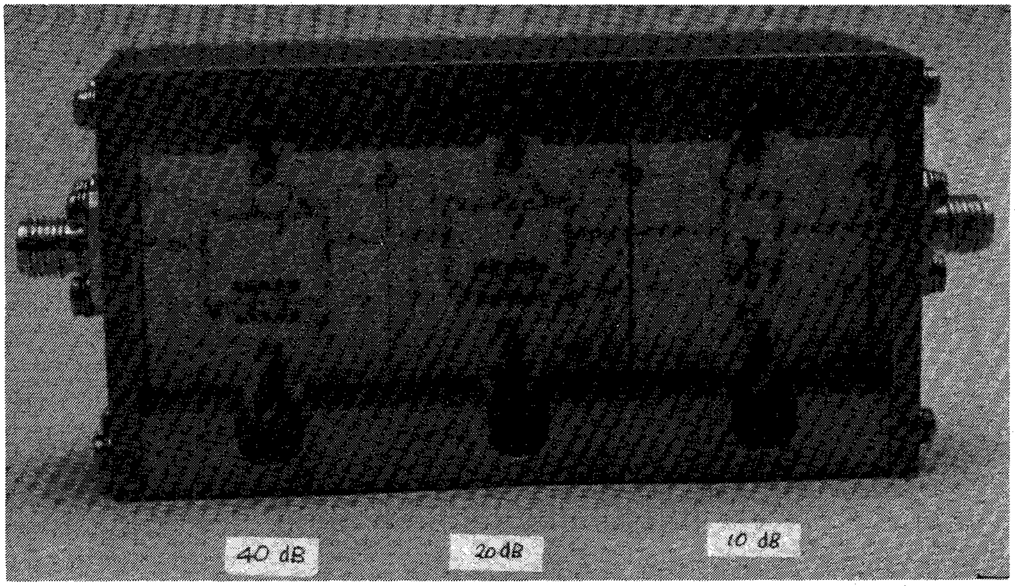

Fig. 2. Attenuator breadboard photograph. Notice the thin-film resistor shielded, in the 20-dB and 40-dB cases, with a pair of parallel ground holes rows, to prevent spurious propagations.

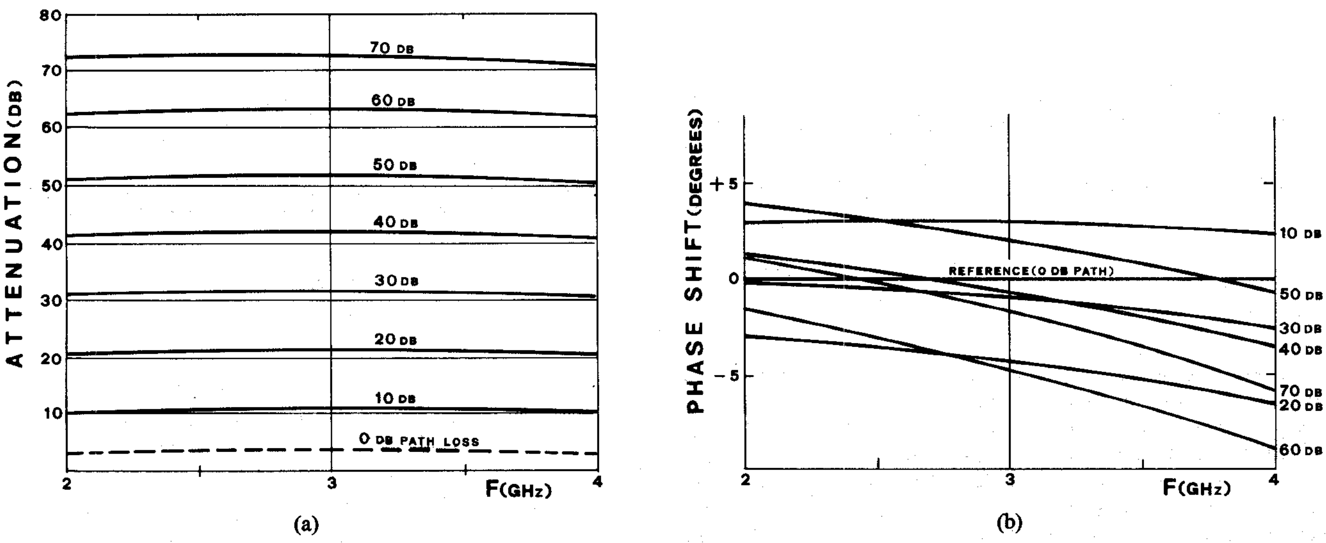

Fig. 3. Electrical performances of the Fig. 2 breadboard. The attenuation levels and phase shifts are referred to the device 0-dB condition (~3-dB loss).

breadboard, realized in a MIC fashion on three 1 in × 1 in alumina substrates. p-i-n diodes (type VSDC-300 in chip form from Varian Associates, Beverly, MA) act as very fast SPDT (theoretical switching time ~1 ns), being driven, through bypass capacitors and microinductors, by a digital signal which, depending on the desired attenuation level, switches on—by means of a suitable forward direct current—the appropriated paths, contemporaneously excluding—by means of a reverse voltage—the other ones.

In the 20-dB and 40-dB sections another p-i-n diode is provided in the 0-dB path to increase its isolation (at least 20–25 dB higher than the resistive network attenuation) when the other arm is activated, to allow the phase change between the two switching conditions to be small (within 3–5 deg). To maximize this isolation all the diodes are about one fourth wavelength spaced.

Piconics microinductors, together with 27-pF MOS capacitors and high impedance one fourth wavelength transmission lines (dc return) have been employed for the p-i-n chip biasing.

A *T*-configuration has been chosen for the dissipative networks because of easily realizable components values to be provided to ensure a good match in 50-Ω transmission lines. The single shunt resistors have been realized by pairs of double resistance shunt resistors to improve the network symmetry and so their matching. All the resistors have been integrated into the microstripline circuit using the Nichel–Chromium thin-film technique. Finally, the 20-dB and 40-dB attenuative networks—the latter is realized with two cascaded 20-dB networks, because of easier implementation—have been provided with a couple of parallel ground holes rows (modal filters), to prevent undesired alumina superficial modes propagations across the dissipative networks, superimposing to the desired signal. With the explained precautions, no problems should be existing about a good agreement of experimental results to the theoretical design.

In fact, very good performances have been obtained, as indicated in Fig. 3, referring to the breadboard experimental measurements. It is worthwhile to notice that in designing the three sections no particular cares have been taken in obtaining exact attenuation levels and phase shift balances—to allow for the latter, experimental transmission lines adjustments have been done on the 0-dB paths of the 20-dB and 40-dB sections. A better resistive networks characterization, if desired, is possible, however, to further improve the overall circuit performance.

III. Conclusions

In this paper a S-band 10-dB step attenuator from 0 to 70 dB has been described which exhibits very small phase changes versus attenuation levels. To obtain this performance, p-i-n diodes are employed as fast microwave switches, while thin-film resistors networks act as fixed attenuators. It is worthwhile to notice that the obtained performances are theoretically independent on frequency; in fact, reducing the p-i-n diodes spacing—and eventually increasing their number on the 0-dB ways if the isolation is not too high—it is possible to obtain the same characteristics in a higher frequency band (provided that the p-i-n diodes and the thin-film resistors electrical performances do not vary too). Remembering the explained considerations it should be theoretically possible to realize broad-band attenuators with a phase change versus attenuation as small as desired.

Diplexer Operation of Stripline *Y* Circulators: Part 1—Basic Performance of Diplexer Operation

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***Abstract*—The diplexer operation as another version of the double circulation frequency operation (DCFO) was recently performed with stripline *Y*-junction loaded with conductor–ferrite (CF) composites. Experimental results demonstrated that the large insertion losses appeared in association with higher order circulations. This paper treats circulation adjustments for basic performances of the diplexer operation. Theoretical analysis presents a criterion upon which to test circulation adjustments in getting an ideal DCFO performance in the instances of the diplexer operation. Better combinations of circulating modes for the diplexer operation, and relevant circulation adjustments are discussed. It is concluded that the main cause to the large insertion losses is insufficiency in circulation adjustments. Experimental results are also presented. In this paper, phenomenological explanation of various circulations is given in preparation for subsequent treatment of the diplexer operation. All ferrites used are treated above resonance.**

I. Introduction

This paper treats basic performance of the diplexer operation in the double circulation frequency operation (DCFO) approach that the recently reported DCFO performance of a stripline *Y* circulator [1] has demonstrated. To clarify the situation, similar diplexer performances of a *Y*-junction circulator loaded with circular ferrites (hereafter termed a disk-ferrite *Y* circulator) should be mentioned, which was reported first by Brown and Clark [2], a little later by Kint and Schanda [3], and very recently by Hansson and Filipsson [4]. The former two were a simultaneous operation at two circulation frequencies using different dominant modes existing in regions below and above ferromagnetic resonance. Two circulations were inherently separated from one another by the ferromagnetic resonance absorption, so that separation between the two circulations was almost constant with a given saturation magnetization. The latter is the simultaneous operation at different circulation frequencies pertaining to various roots of the lowest order mode, so that separation between any two circulations is inherently constant, and alternate change of circulating senses corresponds with the radially periodic dependency of the magnetic field of this mode.

Apart from such diplexer performances the diplexer operation can be effected favorably in a conductor–ferrite

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