# THE NEW STRUCTURES OF CONTROLLABLE ATTENUATORS

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Abstract

The new practical circuits of the electrical controllable diode attenuator has been developed. The characteristic feature of attenuators is very small phase shift at smooth regulation of the transfer factor. It is shown, that use of the correction circuits conducts to essential reduction of the phase shift. For picosecond attenuators the phase stability of 1...5 degrees in working frequency band up to 2 GHz and attenuation range up to 25 dB is achieved.

At designing of the superbroadband high accuracy amplifiers, attenuators and other devices with a controlled transfer factor the account of the requirement independence of the phase shift is necessary at regulation of the transfer factor. Else, for the most exact reproduction of the signal form at change of the transfer factor the keeping of constancy of the group delay time in the transfer factors range and working frequency band is required [1-4].

For example, illustrating of the phase stabilization principle, we shall consider the characteristics of the simple circuit of controllable diode attenuator (fig. 1). The diodes were simulated by parallel connection of resistance 5...3000 Ohm and parasitic transition capacity 0,3 pF and consecutive connection of parasitic inductance of diodes L=0,2 nH. The resistance of generator and load are 50 Ohm.

If L1=0, attenuator is not correction. Its characteristic is shown on a fig. 2 by dotted line 1. From figure is visible, that phase stability is not present. If attenuator resistance R changes in small limits (from 3 kOhm up to 25 Ohm), the phase-frequency characteristic (PFC) of attenuator remains practically constant (fig. 2, line 2). In frequency band up to 1,5 GHz the maximum of amplitude-frequency characteristic (AFC) changes from 0,496 up to 0,46, PFC changes from 11 up to 16 degrees.

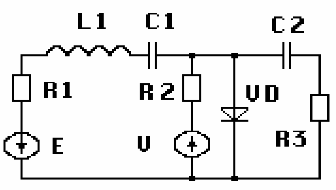



Fig. 1

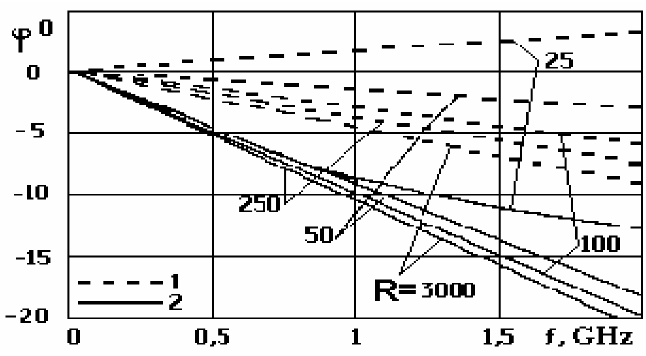
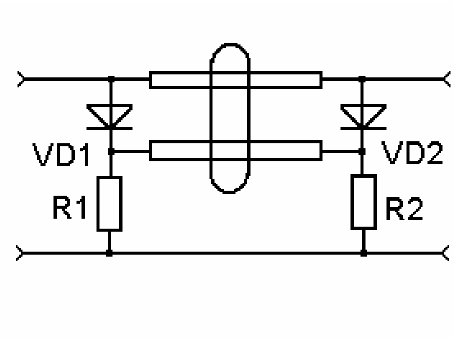



Fig. 2

As researches shows, that essential reduction of the phase shift at regulation of the transfer factor in the many practical cases can be reached just thus. The considered phenomenon is physically explained by indemnification of the diodes reactance by the out of phase reactance of correction circuit, or indemnification of the phase shift by creation of the additional channel of the signal transfer.

Aforesaid illustrates an example of the parameter optimization of the following controllable attenuator circuit (fig. 3), in which the matching line for creation of the additional channel of the signal transfer is used. The circuit is showed without the control circuits of diodes resistance.



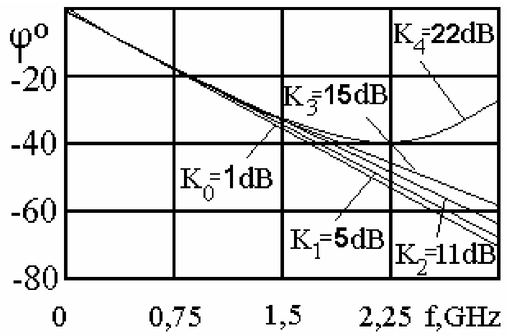




Fig. 3 Fig. 4

Length of the matching line in a frequency band of 0,1...3 GHz and attenuation range K(w) =1...22 dB has been optimized. The optimization results are showed on a fig. 4. Minimum of phase shift in a attenuation range $K_i(0)$ =1...15 dB, i=0,...,4 have been received. For the last $K_4$ (0) =22 dB the phase error becomes essential. To reduce phase shift is possible it only increasing of the frequency band, but it is difficultly, or with application of diodes with smaller parasitic parameters.

One practice structure of controllable attenuator is submitted on fig. 5 yet. Its essential feature is availability of the optimum regulation of diodes resistance circuit in series and parallel arm of attenuator [1]. Really, the same attenuation level can be achieved or increase of diodes resistance in the series attenuator arm, or equivalent reduction of diodes resistance in the parallel arm. However the phase significance will be different. Therefore it is important not only correctly to choose of the matching circuit parameters, but also law of regulation of diodes resistance.

As elements with controllable resistance the p-i-n diodes of 2A517A are used. Inductance and capacity of diodes are L=0,1 nH, C=0,3 pF. The high-frequency part of the circuit represented the thin-film hybrid integrated module, assembled on the good dielectric properties substrate.

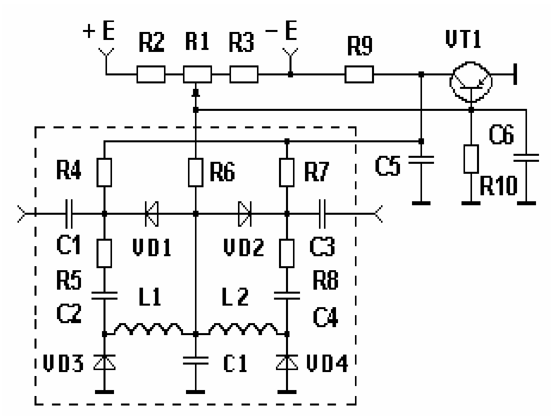



Fig. 5

Phase stability provide the inductance L1, L2 and capacity C1. Combined with the diode's parasitic parameters, they form a low-pass filter and thus compensate for the phase shift variation when the attenuation is adjusted. The attenuator operates as follows.

When the movable contact of R1 is at its left position on the diagram, the diodes VD3 and VD4 of the parallel arm of the attenuator are closed and have a maximum resistance, the diodes VD1 and VD2 of the serial arm are open and have minimum resistance, and the transistor VT1 is closed by a positive voltage on its base. In this case the attenuation is minimum. When the movable contact is shifted to the right, the voltage at the cathodes of the diodes VD3 and VD4 is low and the diodes are open. In order to increase the attenuation with a minimum variation in the phase, the diodes VD1 and VD2 of the in-series arm should be closed more rapidly than diodes VD3 and VD4. This can be achieved using the transistor VT1. The optimal diode control during continuous adjustments of attenuation allows to achieve following phase frequency characteristics (fig. 6, 7).

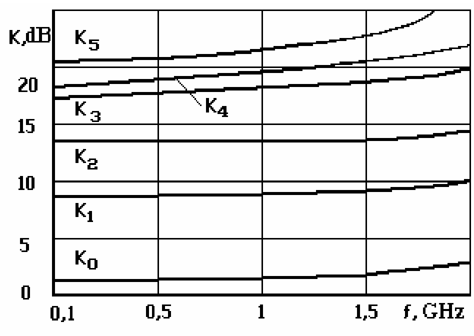



Fig. 6

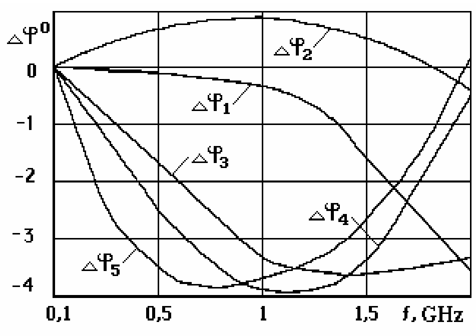



Fig. 7

The phase shift, defined as the difference of phases $\Delta\varphi_i=\varphi_i(f) - \varphi_0(f)$, i=1,5 was measured for different introduced attenuations within the range 1,5...24 dB in frequency band 0,1...2 GHz. Fig. 6 shows that the maximum phase shift variation within the attenuation range up to 24 dB does not exceed 5 degree in a frequency band of 0,1...1 GHz. In other attenuation ranges the phase shift changes much less. The maximum attenuation is 40 dB, VSWR in all range of frequencies and attenuations less 2,2.

As a rule, the phase stability is reached only in the attenuation range, in 1,5-2 time smaller from maximum. For increase of the attenuation level the attenuators can be cascaded, thus the phase shift remains reasonably stable.

Thus, use of the correction circuits permits to achieve the constant of phase shift at regulation of the transfer factor by a simple method. It permits to come nearer to potential achievable characteristics, that opens wide opportunities of improvement of the quality parameters of radio-devices. The wide application of the offered structures can be founded in transmitters, broadcast systems, as well as in other systems, where phase distortions because of adjustment of frequency characteristics are inadmissibled.

## References

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