United States Patent

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[54] **BROADBAND APERIODIC ATTENUATOR APPARATUS**
3 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** ..... **333/6,** 333/8, 333/24 C, 333/32, 333/81 R, 330/24, 330/29, 330/145

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[50] **Field of Search** ..... 333/81, 24 C, 28 R; 330/29, 145, 24; 323/66; 307/320

[56] **References Cited**

UNITED STATES PATENTS

3,135,934	6/1964	Schoenike	333/81
3,543,174	11/1970	Burgert	330/29
2,157,582	5/1939	Wilhelm	333/33 X
2,329,544	9/1943	Larsen	333/24 C
2,871,305	1/1959	Hurtig	330/29 X
2,897,429	7/1959	Jochems	323/66 X
2,971,164	2/1961	Saari	330/164 X
3,151,302	9/1964	Hyman	330/145
3,222,609	12/1965	Ulmer et al.	330/145 X
3,324,417	6/1967	Garner	333/96 X
3,325,754	6/1967	Frisch et al.	333/81
3,416,101	12/1968	Van Sandwyk	333/81 X

FOREIGN PATENTS

249,709	2/1964	Australia	333/81

OTHER REFERENCES

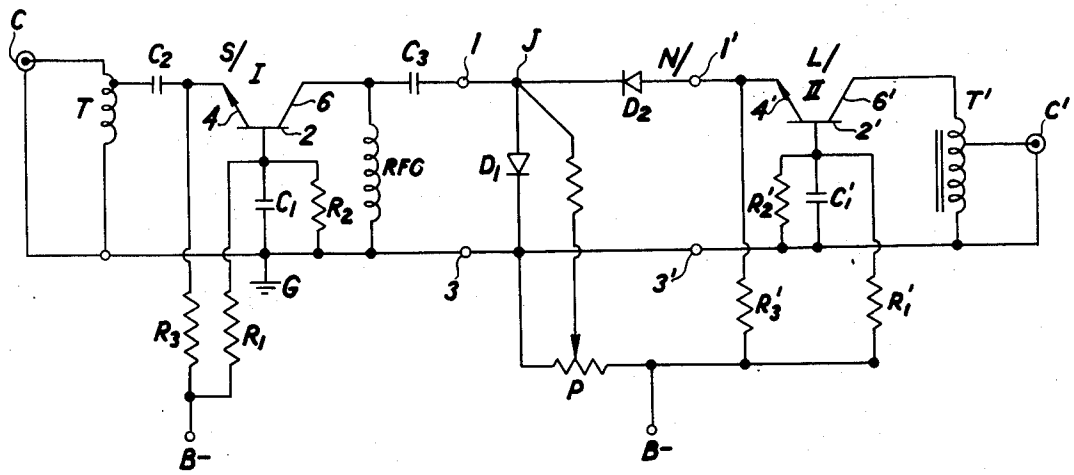
ITT, " Reference Data For Radio Engineers," Howard W. Sams & Co. Inc., 10-68 pp. 18-45

Uhlir, Jr., " The Potential of Semiconductor Diodes in High-Frequency Communications," Pro. IRE. 6-1958, pp. 1099-1115

Hunton, J. K., Microwave Variable Attenuators & Modulators Using Pin Diodes, MTT 10, 1962 pp. 262-273

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ABSTRACT: This disclosure deals with a broad band aperiodic attenuator using networks of nonlinear direct-current-energy controllable variable impedance elements with critical relationships between signal source and load to eliminate third order distortion effects and the like despite the presence of such nonlinear elements.



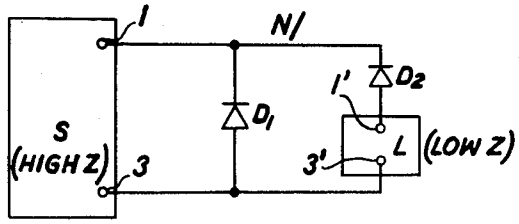


FIG. 1

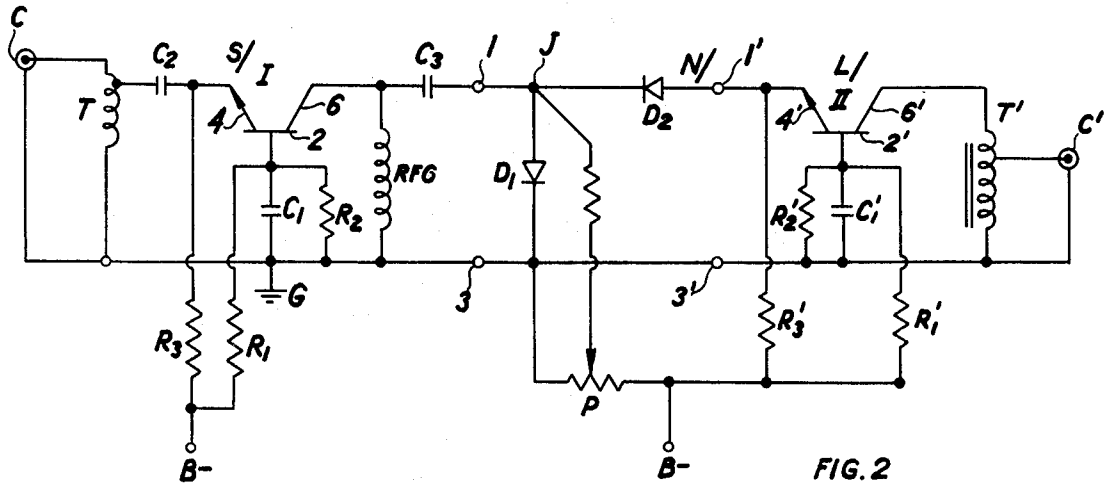


FIG. 2

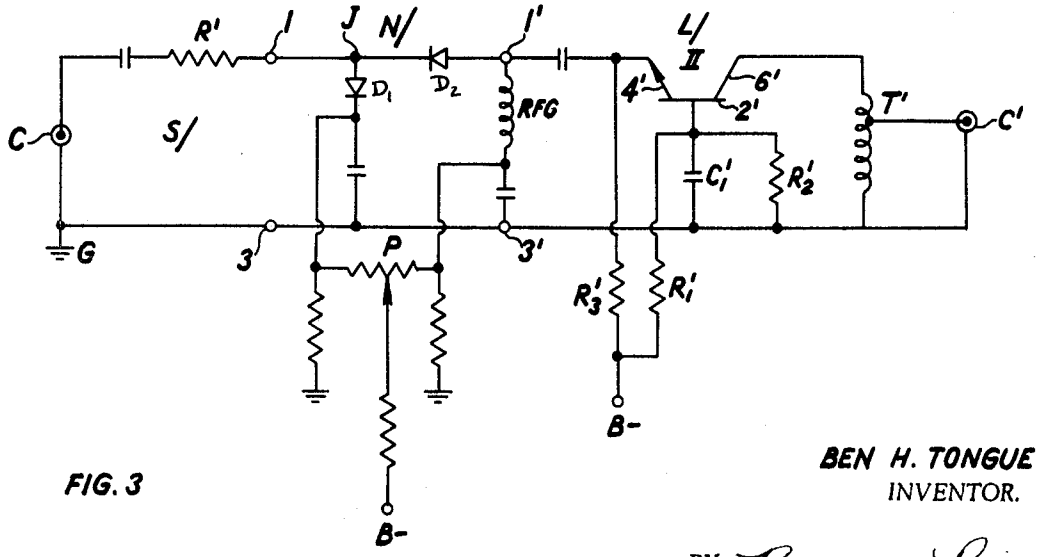


FIG. 3

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BROADBAND APERIODIC ATTENUATOR APPARATUS

This application is a continuation of Ser. No. 561,103, filed June 28, 1966, now abandoned.

The present invention relates to broadband aperiodic attenuator apparatus, being more particularly directed to such apparatus embodying networks of nonlinear, direct-current energy-controllable, variable-impedance elements.

Many types of nonlinear variable impedance element networks have been proposed and used for such purposes as automatic gain and other control circuits, generally, for employment in tuned or resonant circuits and with loads of impedance substantial as compared with the impedance of the networks. Such circuits, moreover, have inherently been subject to considerable third-order or cross-modulation distortion. There are occasions, however, where it is desired to provide automatic gain or other control circuits with networks of this character for operation over broad frequency bands in an aperiodic or untuned system, with the requirement that the flat band-pass characteristic be maintained substantially constant irrespective of setting or impedance values of the network elements. In certain of such broadband applications, moreover, it is also important to avoid third-order distortion effects, including third harmonic generation and intermodulation products, despite the use of nonlinear elements.

It has been discovered that, through a novel utilization of networks embodying appropriate nonlinear direct-current energy-controllable variable-impedance elements with signal sources and loads of very critical relative impedance values, operation over broad bands can be attained with the desired flat response substantially unaffected by variations in the network attenuator and with negligible third harmonic distortion effects. It is thus, to the provision of a novel attenuator apparatus of this type, solving the above-mentioned problems, that the present invention is primarily directed.

A further object is to provide a novel network apparatus of the character described of more general utility, also.

Other and further objects are later explained and are delineated in the appended claims.

The invention will now be described with reference to the accompanying drawings:

FIG. 1 of which is a combined block and schematic circuit diagram illustrating underlying principles of the invention;

FIG. 2 is a schematic circuit diagram of a preferred form of the invention; and

FIG. 3 is a circuit diagram of a modification.

Referring to FIG. 1, a network generally designated at N is shown provided with input terminals 1 and 3 and corresponding output terminals 1′ and 3′, comprising a shunt-connected nonlinear direct-current energy-controllable or variable-impedance element D_1 and preferably a similar series-connected element D_2. The elements D_1 and D_2, as later explained, may be varactor diodes or variable resistance PIN diodes or similar devices, the impedance of which varies depending upon the direct-current voltage or current applied thereto, such as between limits of a relatively low impedance value Z_1 (for example, of the order of 7 ohms, more or less, in the case of PIN diodes) and a relatively high impedance value Z_2 (for example, of the order of kilohms, more or less) in response to currents ranging from about 30 milliamps to approximately zero.

For broad frequency band aperiodic operation, as before stated, a flat nonresonant response characteristic is to be maintained substantially constant and unchanged with gain variation, despite variations in the impedance values of the network elements D_1 and D_2, in response to different voltages or currents applied thereto. It has been found that to achieve this end, an alternating-current signal source S must be connected to the input terminals 1 and 3 with a rather critical relative impedance valve, later explained; and that the load L connected between output terminals 1′ and 3′ must also be of critical relative impedance value to produce the phenomenon underlying the invention. Specifically, the load L has been found necessarily to be restricted in impedance to a value low (below about one-fifth) compared with the value of the series combination of the impedance of elements D_1 and D_2 for any

combination of values assumed by these elements during operation of the network N in response to different signal levels from the source S. The further condition must also be satisfied that the source S present an impedance to the input terminals 1 and 3 that is large (at least about five times) compared with the value of the of the parallel combination of the impedances of D_1, D_2 and L. Only under such circumstances is voltage difference across the diodes D_1 and D_2 avoided such that operation becomes restricted to current division (point J), and the result, as contrasted with other uses of diode networks, has been found that third-order and other nonlinear distortion effects are substantially absent over a wide range of gain adjustments.

In FIG. 2, this operation is illustrated in connection with a source S assuming the form of a constant-current grounded base input stage I receiving alternating-current signals from a coaxial input line C in conventional fashion. The base 2 is grounded at G through capacitor C_1 with bias voltage supplied from the terminal B− through resistor voltage divider R_1–R_2. The emitter 4 receives input signals through coupling capacitor C_2 from a matching transformer T, and is biased from terminal B− through resistor R_3. The output of the amplifier stage I at its collector 6 is coupled through C_3 to the input terminal 1 of the network N. A radio-frequency choke RFC is shown connected between the collector 6 and the ground terminal G to supply a DC path for the collector; the the ground terminal G also connecting to input terminal 3 of network N. From the junction J of the shunt and series elements D_1 and D_2, a variable gain control in the form of a potentiometer P is provided for varying the simultaneous increase and decrease of impedance values of D_1 and D_2, respectively, or vice versa. The variable gain control P enables the tapping off of different values of direct-current voltage between B− and ground G and splitting this in any desired proportion between D_1 and D_2, thus correspondingly to vary their relative impedance in opposite directions. It is to be understood, of course, that any conventional automatic gain control voltage for attaining this junction could similarly be employed in place of potentiometer P, as is well known.

The output terminals 1′ and 3′ of the network N are connected between the emitter 4′ and, through capacitor C_1′, the base 2′ of a further grounded base transistor stage II. The stage II is biased by emitter resistor R_3′ and base voltage divider resistors R_1′ and R_2′ to present a very low impedance compared with any possible series combination of the impedances of D_1 and D_2. The collector 6′ passes output current through transformer T′ to an output coaxial line C′.

In actual operation, with Texas Instrument Company, A660 variable capacitor diodes D_1 and D_2 employed in the circuit of FIG. 2, operating within the broad radio-frequency range from about 54 to 216 megacycles, the values of capacitance elements D_1 and D_2 were varied from approximately 35 down to 7 pf. for a direct-current voltage variation range of ½ to 20 volts. The impedance presented by stage II, comprising the load L, was of the order of 3 to 7 ohms and the effective shunt capacitance presented by the source S at terminals 1–3 (between 6 and G) was of the order of 3 pf. Thus, the impedance at the operating frequencies of the source S was high compared to the parallel combination of the impedance of D_1 and D_2 and stage II; and the impedance presented at output terminals 1′ and 3′ by the load II was very small compared to the series combination of the impedance of D_1 and D_2. (Any resistive component of the output impedance of stage I is very high compared to the impedance from point J to terminal 3, so that the total impedance presented at 1–3 is large).

If it is desired to make the value of the effective shunt capacitance presented by the source S more comparable with the capacitance of the network N, this may be cone consistent with obtaining the results of the invention by increasing the shunt capacitance, but not be decreasing the shunt resistance. Under these circumstances it has been found that the gain can be varied over a 12 db. range without changing the shape of the band-pass characteristic more than about 0.5 db. It has

further been found that with the above relative values and construction, loss of Q is avoided in the network N by operating it with the very low impedance load L; thus, degeneration and other third-order distortion products are not substantially developed.

In the modified system of FIG. 3 the source S comprises the coaxial line C (such as a 75-ohm line, for example), in series with a corresponding 75-ohm resistor R', connected for impedance-matching purposes so as to provide an effective current source at input terminals 1–3 that is of relatively large impedance, as before discussed. In this embodiment, in view of the fact that the source S is now effectively resistive, the elements D_1 and D_2 are variable-resistance direct-current-controllable elements, such as PIN diode or second base-to-emitter junction diodes of unijunction transistors, such as GE No. 2N 2646, which vary their effective resistance in response to direct-current voltage. The gain may be adjustable by a gain control potentiometer P or an automatic circuit, as before discussed. With this circuit, a good impedance match is presented to the input cable C irrespective of the gain adjustment of the attenuator network N because the parallel impedance of D_1 and D_2 is always low compared to R', as contrasted with a mere transistor input stage at S.

Further modifications will also occur to those skilled in this art, and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. Broadband aperiodic direct-current energy-controllable attenuator apparatus having, in combination, a network having a pair of input and a pair of output terminals and comprising a pair of direct-current energy-controllable variable nonlinear reactive impedance elements, one connected in parallel with the input terminals and the other in series between one input terminal and the corresponding output terminal, a load connected between the output terminals of impedance no more than substantially one-fifth the value of the series combination of the impedance of the pair of impedance elements over said broadband, and a source of alternating-current signal current over said broadband connected to the said input terminals and of impedance at least substantially five times the value of the parallel combination of the impedance of the pair of impedance elements and the load over said broadband, said source presenting a substantially shunt reactive impedance to the said input terminals and said network comprising means for varying the reactance of said impedance elements and for dividing substantially the entire signal current supplied by said source between said elements in direct proportion to the susceptance of said elements, throughout the range of variation of said reactance of said impedance elements and substantially independent of frequency over said broadband.

2. Apparatus as claimed in claim 1, wherein said impedance elements are capacitive impedance elements and said source presents a substantially shunt capacitive impedance to said input terminals.

3. Apparatus as claimed in claim 1, wherein said broadband is from substantially 54 to substantially 216 mc./s.

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