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ELECTRONIC REACTANCE CIRCUITS

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My present invention relates to electronic reactance circuits, and more particularly to improved circuits of this type.

One of the principal objects of my present invention is to provide admittances of the electronic type which are simulated by an electron discharge tube having input and output circuits coupled in such a fashion that the ratio of input to output voltage varies in a desired fashion with frequency whereby an apparent admittance is obtained between the output terminals of the tube which varies similarly.

Another important object of this invention is to provide an electron discharge tube having input and output terminals, and a network connecting the input to the output terminals which produces at the input terminals a voltage whose ratio to the voltage across the output terminals is imaginary, negative in sign and proportional to frequency, whereby there is simulated across the output terminals a negative capacity effect.

Another object of my invention may be stated to reside in the provision of an electronic reactance which may be used to compensate for reactive effects appearing across a signal transmission network, the electronic reactance being provided by one of the signal amplifier tubes which includes between its output electrode and one of its other cold electrodes a network which functions to provide across the output terminals of the amplifier tube the balancing reactive effect.

Still another object of my invention is to provide a method of compensating for detuning effects produced in a signal amplifier in response to automatic gain control variation, the compensation being accomplished by an electronic reactance device which may be part of one of the signal amplifier tubes of the signal transmission system, or may, if desired, be an electron discharge tube independent of any of the signal amplifier tubes.

Still other objects of the invention are to improve generally the simplicity and efficiency of electronic reactance devices, and more especially to provide electronic reactances, and circuits therefor, which are not only reliable and efficient in operation, but are economically manufactured and assembled.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have

indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawing:

Fig. 1 schematically shows an electronic admittance circuit embodying the invention,

Fig. 2 shows one of the networks employed to provide a simulated reactance,

Fig. 3 shows an amplifier circuit employing an electronic reactance,

Fig. 4 is a modification of the arrangement in Fig. 3,

Fig. 5 shows a signal receiver system embodying a modification of the invention to compensate for detuning effects produced by action of the automatic volume control.

Referring now to the accompanying drawing, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 an electron discharge device 1, which may be a tube of the screen grid type. The tube has a network T connecting its input and output electrodes. Between the terminals 2 and 3 appears the reactive effect. The reactive effect depends in magnitude and sign upon the constants and composition of network T and tube 1.

Let it be assumed that the network T produces a voltage on the control grid 4 which is t times the voltage between terminals 2—3 where t may be any number, real or complex. If a voltage is applied between terminals 2 and 3, the plate current is therefore gt per volt applied, where g is the transconductance of the tube. Since the application of voltage between terminals 2 and 3 causes a flow of current gt per volt applied, the effective or electron admittance between these terminals is gt . Of course, in addition to this admittance there is the admittance of the network T, but usually this may be made very small, and in any case the ratio t may be so adjusted that the total admittance between terminals behaves in the desired fashion. This electron admittance is adapted for many uses. All that is required in a particular case is to determine the required admittance, and then to construct network T so that the expression gt equals the desired admittance, less the inherent admittance of the network, if appreciable.

If, for example, it is desired to operate a resistance-coupled amplifier free of the effects of unavoidable capacity shunting the coupling resistor, then the network T may be given a composition as shown in Fig. 2. The unavoidable capacity shunting a coupling resistor in a

resistance-coupled amplifier has an admittance $j\omega C$, where C is the capacity. This may be completely wiped out by an equal and opposite electronic admittance connected in parallel with it. The problem, then, is to obtain a structure for network T that makes t negative, imaginary and proportional to ω . In Fig. 2 such a network is shown.

In this network there is connected in series between terminals 5 and 6 a high resistance R and the primary winding 7 of the transformer M . The secondary winding 8 of the transformer is connected between terminals 9 and 10. Of course, terminals 5 and 6 are those connected between the plate and cathode of tube 1 in Fig. 1, while terminals 9 and 10 are those connected between the input electrodes of tube 1. The network shown in Fig. 2 approaches closely the ideal condition set forth above at frequencies where the magnitude of resistor R is high compared to the reactance of the primary winding 7. If the secondary coil 8 is suitably poled it may be shown that:

$$t = \frac{-j\omega M}{R + j\omega L_7} \quad (1)$$

This last expression is approximately as follows:

$$t = -j\omega \frac{M}{R} \quad (2)$$

Now, the required relation among the constants is such as will make the total of the admittances, capacitive and electronic, equal to zero, i. e.:

$$gt + j\omega C = 0 \quad (3)$$

Substituting in this equation the value of t derived above we have:

$$-j\omega g \frac{M}{R} = -j\omega C \quad (4)$$

or,

$$\frac{M}{R} = \frac{C}{g}$$

as the relation between constants required to wipe out the effect of capacity C . More elaborate networks may be readily designed to yield a still closer approximation to the desired variation of t .

Considering, now, the manner of utilization of the network T in the resistor-coupled amplifier stage, there is shown in Fig. 3 such a resistance-coupled amplifier wherein the numeral 11 designates an electron discharge tube whose signal grid is connected to any desired source of signal voltage. For example, the source can be any frequency from as low as a few cycles up to frequencies in the megacycles, such as is used in television practice. The coupling resistor 12 is shown connected in series with the plate current source 13, and the cathode circuit includes the usual grid biasing network 14. The signal voltage developed across resistor 12 is transmitted through the coupling condenser 15 to a succeeding utilization network which may include additional amplifiers, if desired. The dotted line capacity C_1 represents the unavoidable shunting capacity which exists across the load resistor 12, and which causes usually a droop at the high frequency end of the response curve of the transmission system. The electronic reactance of the present invention is used to simulate in parallel with the capacity C_1 a balancing negative capacity which is shown in dotted lines as being effectively across the former, and indicated by the symbol $(-C_1)$.

This is accomplished by connecting the plate 20 of tube 1 to the high potential end of resistor 12 whereby it is effectively connected in series with load resistor 12 and the positive terminal of current source 13. The cathode of tube 1 is connected to ground through biasing network 21, while the signal grid 4 is connected to the high potential end of the winding 8 of the transformer located in network T. The opposite end of the secondary winding 8 is grounded, while the primary winding 7 has its high potential terminal connected through resistor R and direct current blocking condenser 22 to the high potential side of the network. The low potential ends of both windings of the transformer M are at ground potential, and the dotted rectangle T denotes the network common to the input and output electrodes of tube 1 which cooperates with the tube to provide the negative balancing reactance $(-C_1)$. Of course, the constants of tube 1 and network T are chosen so as to have the simulated reactance $(-C_1)$ equal in magnitude, and opposite in sign, to the capacity C_1 . This results in a restoration of the high frequency end of the response curve to approximately the same value as the low frequency end.

The network of Fig. 3 can be further simplified as shown in Fig. 4 by using a single tube 30 both for the amplification and reactance—simulation functions. The signal voltage is applied to signal grid 31, the cathode being connected to ground through the usual grid bias network 14'. The plate 32 is connected to the positive terminal of current source 13 through a path comprising the resistor R and primary winding 7 of network T. The secondary winding 8 is included in circuit with the auxiliary grid 33. The latter is surrounded by a positive screen grid; the grid 33 is at ground potential by virtue of the connection of winding 8 to ground. The signal voltage developed across resistor R is transmitted to the following circuit through coupling condenser 15. The dotted line condenser C_1 designates the unavoidable shunt capacity which is to be compensated for. Across the path $R-7$ is simulated the negative capacity which balances out the capacity C_1 . It is not altogether necessary to use a tube with two control grids. The voltage from transformer 7-8 may be applied to the same control grid to which the signal voltage is applied. It should be noted that Fig. 4 is a simplification of Fig. 3 not only in that a single tube is used in place of two tubes, but also, in that the single resistor R is used both as coupling resistor for the amplifier and also as the resistor of the network T. One way of describing the action of Fig. 4 would be to say that the voltage impressed on grid 33 is such as to create an additional component of plate current just equal to the current taken by capacity C_1 in the presence of uniform amplification.

In Fig. 5 there is shown an additional use to which the present invention can be put. In this figure there is shown a signal receiving system comprising a signal amplifier 40 followed, if desired, by further amplification networks 42. The amplified signal energy is detected by any desired type of detector 43, and the detected signal energy is then utilized by any desired type of audio utilization network. For example, if the system is of the superheterodyne receiver type then there may be impressed intermediate frequency energy upon the tuned input circuit 44. The amplified intermediate frequency energy is

developed across the tuned output circuit 45, and the amplified signal energy is then transmitted through coupling condenser 46 to the signal grid of amplifier tube 41. In order to provide automatic gain control of the receiving system there may be utilized any desired type of automatic volume control circuit (AVC). In the figure there is shown one well known manner of securing automatic volume control, the numeral 50 designating any desired type of rectifier upon which is impressed amplified intermediate frequency energy. The numeral 51 denotes the AVC connections to the signal grid of amplifier tube 40. As is well known, the AVC circuit functions to increase the negative bias on the signal grids of the amplifier tubes as the carrier amplitude increases.

In systems operating in signal ranges of the order of megacycles it is found that variation of the signal grid bias of an amplifier tube produces a detuning effect on the tuned input circuit of the amplifier. For example, in amplifier tube 41 the dotted line capacity 60 existing between the grid and cathode of the tube 41 changes in magnitude as the negative bias of the signal grid of this tube varies. The variation of capacity 60 results in a change in the resonant frequency of the preceding tuned circuit 45. Hence, there exists the problem of compensating for the variable magnitude of capacity 60 produced by the AVC action.

The compensatory capacity variation across tuned circuit 45 is secured by inserting the network T in shunt across the tuned circuit 45. For example, the resistor R is connected in series to ground with the primary winding of the transformer M, and the secondary winding of the latter is connected in series with the signal grid of amplifier 40, a direct current blocking condenser 70 connecting the low potential end of the secondary winding to ground. It will, therefore, be seen that network T is inserted across the output circuit of amplifier 40 in much the same manner as shown in Fig. 4, and that between the cathode and anode of tube 40 there is produced a capacity reactance which is negative in sign and which acts to compensate for variations in the dotted line capacity 60. The reactance simulation network in Fig. 5 differs from that shown in Fig. 4 in that the output voltage of the transformer M is impressed on the signal grid of the tube instead of upon the auxiliary grid as shown in Fig. 4.

Application of the AVC bias to the signal grids of tubes 40 and 41 will now result in a continuous compensation effect for capacity 60. It will be noted that the AVC connection 51 is made to the low potential end of the secondary winding of transformer M through a filter resistor 80, while the biasing connection is made to the signal grid of tube 41 through a filter resistor 90 and a choke coil 91. It will, now, be seen that as the capacity 60 increases or decreases in magnitude due to changes in AVC voltage, simultaneously the variation in bias on the signal grid of tube 40 causes an increase or decrease in the negative capacitance effect produced across tuned circuit 45 by virtue of the network T. The constants of the network T are chosen so that the electronic negative capacitance effect produced across circuit 45 varies with AVC voltage substantially equally with the change in the

positive capacity 60 thereby preventing detuning of the circuit 45.

Of course, it is not necessary to have the amplifier 40 function both as a signal amplifier and as a reactance simulation device. It is possible to use a separate tube for the reactance simulation function, and in this case the network T would be arranged to feed the input electrodes of an electron discharge tube which is independent of either of tubes 40 and 41, while the output electrodes of this auxiliary tube would be connected effectively across capacity 60.

The AVC bias in that case would be applied to the signal grid of the special tube in a manner such that the electronic capacity effect would balance out the capacity 60. It can be shown that the effective compensating capacity produced across the tuned circuit 45 would be equal to Mg divided by R , where g is the transconductance of the reactance tube, whether it be a special reactance tube or the amplifier tube 40 in Fig. 5. Hence, it will be seen that the compensating capacity effect depends on g and may be either positive or negative. Hence, by properly choosing the ratio of M to R it is possible to get an effective compensatory capacity which varies properly with AVC bias.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In a signal amplifier network having a tube with signal input and output electrodes, a tuned signal input circuit coupled to said input electrodes, means, responsive to signal amplitude variation, for varying the gain of said tube thereby to vary the magnitude of the capacity existing between the input electrodes and in shunt with the tuned circuit thereby causing detuning of the latter, a preceding signal amplifier circuit responsive to signal voltage across said tuned circuit for simulating a negative capacity effect in shunt with said first named capacity, and said signal-responsive means being connected to said preceding amplifier circuit for varying the value of the negative capacity in such a manner that said first capacity magnitude variation is compensated.

2. In a signal amplifier network having a tube with signal input and output electrodes, a tuned signal input circuit coupled to said input electrodes, means, responsive to signal amplitude variation, for varying the gain of said tube thereby to vary the magnitude of the capacity existing between the input electrodes and in shunt with the tuned circuit thereby causing detuning of the latter, a preceding signal amplifier tube including means responsive to signal voltage across said tuned circuit for simulating a negative capacity effect in shunt with said first named capacity, and said first named signal-responsive means being arranged for varying the gain of said preceding tube thereby to adjust the value of the negative capacity in such a manner that said first capacity magnitude variation is compensated.

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