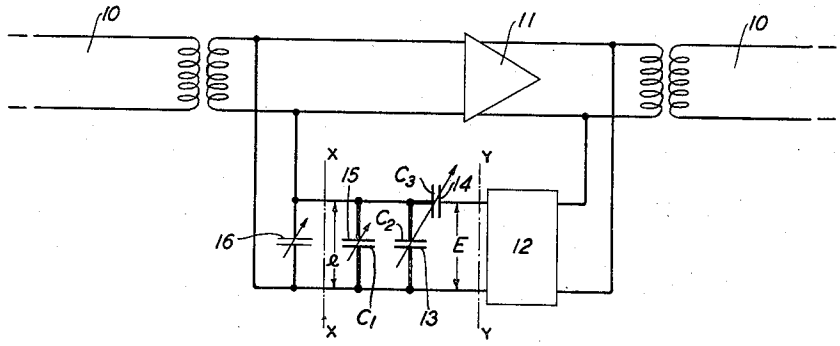
Jan. 25, 1938. F. B. ANDERSON ET AL 2,106,336

VOLTAGE OR GAIN CONTROL

Filed Oct. 8, 1935

FIG. 1



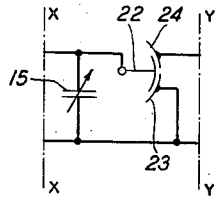
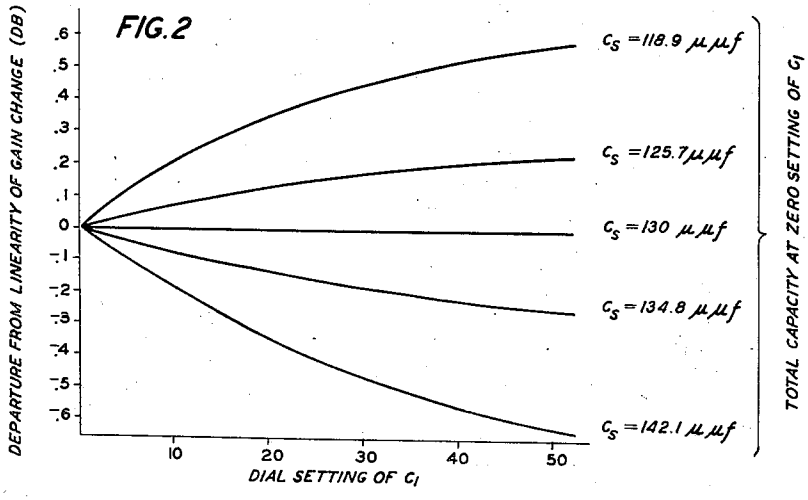


FIG. 1A

FIG. 2



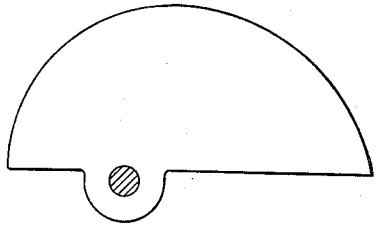


FIG. 3

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VOLTAGE OR GAIN CONTROL

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4 Claims. (Cl. 178—44)

The present invention relates to a method and means for facilitating deriving from a given voltage desired fixed or variable portions of the voltage.

A feature of the invention comprises separate means of variation between a point of application of a voltage to a circuit and a point at which a desired portion of the voltage is to be taken off, such that these means are enabled to vary the voltage taken off, separately and independently of one another.

More specifically, the invention comprises use of capacities in place of resistance potentiometers, with the rate of variation of capacity made to effect desired rate of change of voltage, and with this rate of change unaffected by other capacity means in the circuit for separately varying the voltage.

The invention is of general application but will be illustrated and described as embodied in a gain control system which is specifically disclosed and claimed in a patent of F. A. Brooks, No. 2,075,975 issued April 6, 1937. In that patent an amplifier is disclosed as having its gain controlled by means of a variable condenser in the gain-reducing feed-back circuit of the amplifier. The changes in gain thus produced are made to compensate for variable transmission characteristic of the system by suitable automatic control. An additional gain control is also provided in the form of variable capacity in the gain-reducing feed-back path, and it is desirable that the gain changes effected by this latter control should be independent of those produced by the first-mentioned control means. The second control may be used, for example, to adjust to the normal gain at the time of installation, after which it is left fixed.

The nature of the invention and its various objects and features will be more fully understood from the following detailed description taken in conjunction with the drawing in which:

Fig. 1 is a simplified schematic diagram of the circuit of a line containing a repeater adapted to have its gain regulated in accordance with this invention;

Fig. 1A is a detail modification of the portion of the circuit of Fig. 1 between the lines X—X and Y—Y;

Fig. 2 shows graphs to be referred to in the description; and

Fig. 3 shows the shape of condenser plate used by applicants in practicing one form of the invention.

In Fig. 1, the line 10 may be any transmission line such as the multiplex carrier transmission line of the Brooks patent, having inserted at a point along it the repeater circuit comprising amplifier 11. This amplifier is provided with a feed-back circuit shown as including attenuation equalizer 12 and gain changing condensers 13, 14, 15, and 16. The purpose of the feed-back circuit is primarily to feed back from the output to the input of the amplifier a portion of the output waves in a manner to reduce the gain of the amplifier, the improvements in stability of the amplification and reduction in modulation being substantially proportional to the gain reduction by feed-back as disclosed by H. S. Black in his application Serial No. 606,871, filed April 22, 1932. Equalizer 12 has a characteristic similar to that of the line 10 and influences the feed-back waves in such manner as to produce a gain-frequency curve for the repeater such as to compensate for unequal attenuation of the line over the utilized frequency range, for example 12 to 60 kilocycles.

The attenuation of line 10 in practice varies with temperature or other conditions and it is necessary or desirable to change the repeater gain to compensate such line changes. This may be done by varying the capacity (C_1) of condenser 15 by any suitable control means such as a pilot wire regulator as shown by Brooks. If the degree of feed-back is large, under certain circuit conditions to be pointed out below, changes in C_1 produce like change in gain over the entire frequency band. The rate or law of variation of C_1 may be whatever the designer wishes to make it.

The gain of the repeater can also be changed by varying the capacity (C_2) of condenser 13 and the capacity (C_3) of condenser 14, and if these two condensers be varied in unison such that C_2+C_3 is a constant, the gain change so produced is independent of the gain changes effected by varying C_1. In installing the repeater, the gain setting for mean temperature of the line 10 may be adjusted to the proper value by changing both condensers 13 and 14 together while keeping the sum of their capacities C_2+C_3 constant. Then as the line attenuation changes, condenser 15 may be changed by an automatic pilot control or otherwise and the gain changes will be of proper value and sign if the operation of the control mechanism is properly related to the line attenuation changes of the line, even though in different repeater locations in which the repeater may need to be installed different settings of the condensers 13 and 14, as de-

scribed, may be necessary to give the repeater its normal gain. Thus, the same design of pilot control mechanism can be used at all repeater stations even though the repeater sections may vary in length and require repeaters of different normal gain.

That this independence of the two gain controls exists may be shown in the following manner: Where a high value of amplification factor μ is used for amplifier **11**, if β indicates the feed-back factor, the product $\mu\beta$ is large and the amplification may be made to approach numerically the value

$$\frac{1}{\beta}$$

as shown by Black. Where a large amount of feed-back is used approaching this condition, the change in amplifier gain is nearly equal to the change in the ratio

$$\frac{E}{e}$$

where these quantities are the voltages measured at the points indicated in Fig. 1. It is also assumed that the impedance of C_3 is large compared with the impedance of the feed-back circuit to the right of C_3 in the drawing. In one example used by applicants the impedance of C_3 was never less than 50,000 ohms at the frequencies transmitted, whereas the impedance of the feed-back circuit was about 4,000 ohms.

From inspection of the drawing, Fig. 1, we may write down the equation:

$$\frac{e}{E}=\frac{C_3}{C_3+C_1+C_2}$$

or

$$\frac{E}{e}=1+\frac{C_2}{C_3}+\frac{C_1}{C_3}$$

$$=1+\frac{C_2}{C_3}+\frac{C_1(C_2+C_3)}{C_3(C_2+C_3)}$$

$$=1+\frac{C_2}{C_3}+\frac{C_1}{C_2+C_3}+\frac{C_1C_2}{C_3(C_2+C_3)}$$

$$=1+\frac{C_2}{C_3}+\frac{C_1}{C_k}+\frac{C_1C_2}{C_3C_k}$$

$$=\left[1+\frac{C_2}{C_3}\right]\left[1+\frac{C_1}{C_k}\right]$$

This last expression is in the form of a product of two factors. The lack of dependence of the factors on each other is clear if C_2+C_3 is always kept equal to C_k as postulated. The fed back voltage can be varied by changing either factor, and hence by changing the value of

$$\frac{C_2}{C_3}$$

or the value of C_1. Moreover, the rate or law of change of the fed back voltage produced by varying C_1 is the same for various settings of

$$\frac{C_2}{C_3}$$

(their sum being constant).

As stated, the plates of condenser **15** may be shaped so that a given rate of angular movement under control of suitable control mechanism produces capacity changes suitable for compensating attenuation changes of a line. Fig. 3 shows a shape of plate used by applicants in an actual system. The rotor and stator plates were both of the same contour. This same type of condenser and the same pilot wire mechanism was used at all repeater points on the line notwithstanding that some repeater sections were of greater attenuation than others, requiring different normal repeater gains.

By use of a trimming condenser **16**, the gain change characteristic of the regulating condenser **15** may be modified considerably thus adapting the same condenser design to various situations. If the total capacity C_s obtained by adding together C_1 at its minimum setting, C_2, C_3 and the capacity of 16 equalled 130 $\mu\mu$f in a particular circuit used by applicants, then as C_1 above was varied from minimum to maximum, a 12 decibel linear change in amplifier gain was made as indicated by the middle curve of Fig. 2, which is a straight line. As the capacity of **16** was changed to produce other values of total capacity C_s, the gain changes for variations of C_1 followed different shaped curves as shown in this figure. The trimming condenser **16** thus offers a convenient means of compensating for lack of correspondence between gain changes produced by C_1 and the gain changes required for exact compensation for variations in line attenuation. Condenser **16** may be set at a value corresponding to one of the curves of Fig. 2 or some other desired curve and kept at that value so long as the characteristic of the rest of the system remains unchanged.

In Fig. 1A the two condensers **13** and **14** of Fig. 1 have been replaced by a three-plate construction consisting of fixed plates **23** and **24** and movable plate **22** which moves so that as its capacity with respect to plate **23** decreases, its capacity with respect to plate **24** increases by a like amount. This construction may be used to facilitate keeping the sum C_2+C_3 a constant.

Various departures may be made from the illustrative embodiment that has been given, and from the values stated, without departing from the spirit and scope of the invention as defined in the claims.

What is claimed is:

1. An aperiodic circuit for transmitting waves of a broad band of frequencies, having a pair of input terminals across which a voltage comprising said broad band of frequencies is impressed, two variable capacities connected in series across said terminals, means for varying said capacities while keeping their sum constant, whereby a fraction only of said impressed voltage appears across one of said two capacities, separate, adjustable means to vary the transmission loss through said circuit over said frequency band comprising a third variable capacity connected across said one only of said two capacities, and an output utilization circuit of high impedance connected across said third capacity.

2. An amplifier having a gain-reducing feed-back circuit feeding back such a large voltage that the change of gain of the amplifier circuit as a whole including the feed-back path is substantially proportional to the change of the ratio of the terminal voltages of the feed-back path, one gain changing means, comprising a pair of capacities respectively in series and in bridge of the feed-back path with means to vary said capacities while keeping their sum constant, and a second gain changing means comprising a variable capacity in bridge of said feed-back path in parallel with one of said pair of capacities.

3. In a gain regulating circuit for a repeater adapted for insertion in a transmission line, one variable capacity type gain changing means for setting the repeater gain to its required normal value, another variable capacity type gain chang-

ing means operating independently of the first gain changing means for adjusting the gain of said repeater to other values in accordance with a predetermined relationship.

4. A repeater adapted for use in connection with line sections of different attenuation, comprising one gain changing means for setting the normal gain of the repeater to the value required for a particular normal attenuation of line section, and a second gain changing means adapted to be controlled in accordance with changes in attenuation of the line, said second means operating to change the repeater gain according to a predetermined law regardless of the gain setting of the first means, both of said gain changing means comprising variable capacity.

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