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CIRCUIT FOR AMPLIFYING CARRIER FREQUENCIES

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2 Sheets-Sheet 1

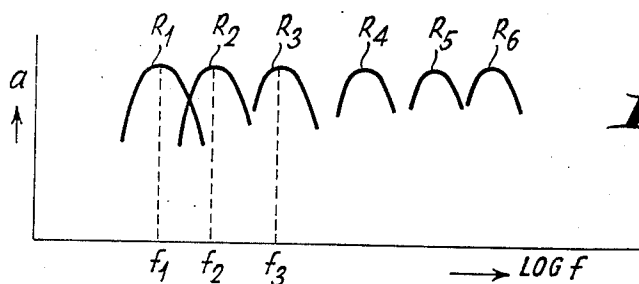
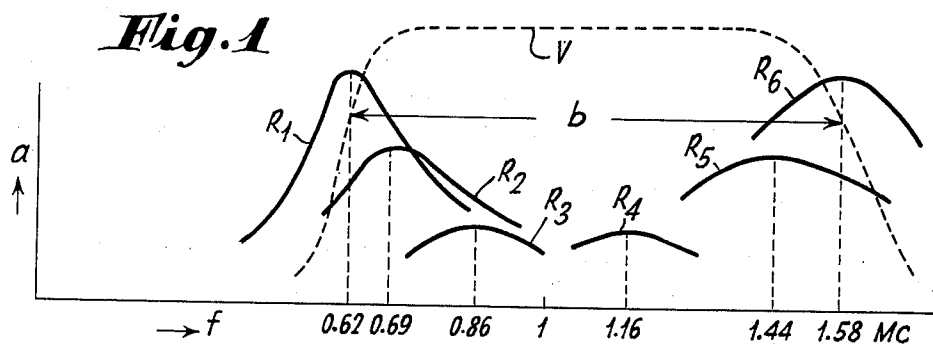


Fig. 3

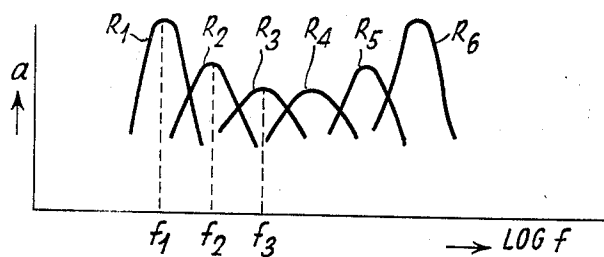
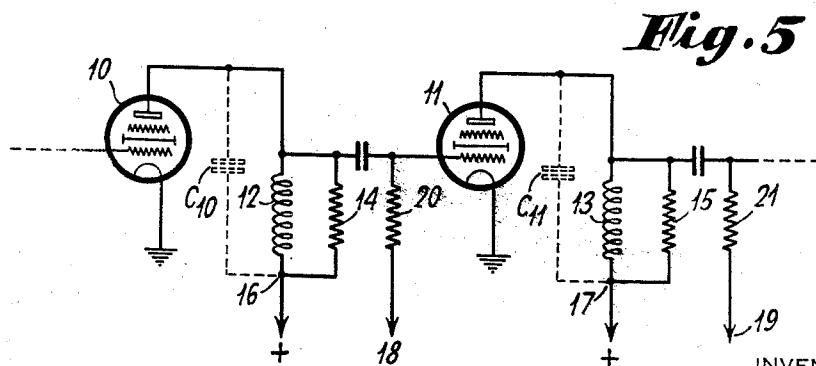


Fig. 4



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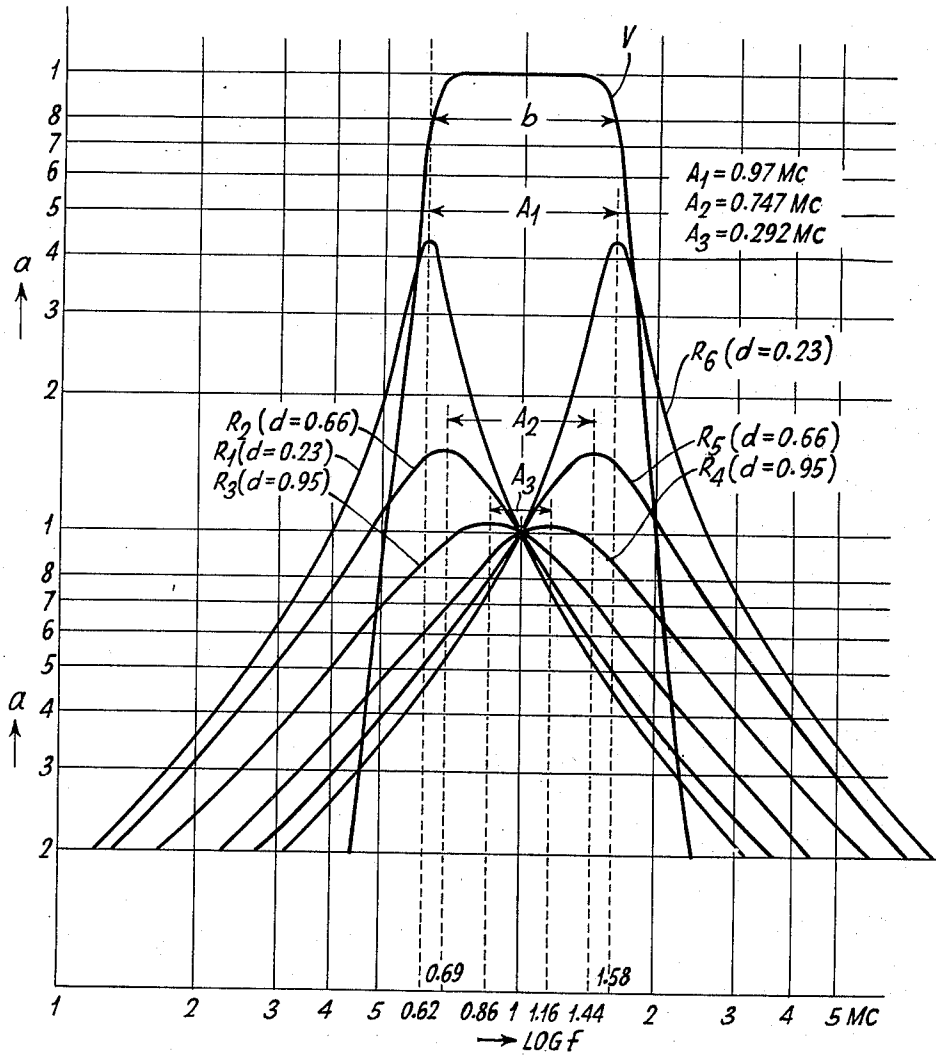
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2 Sheets-Sheet 2

Fig. 2



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CIRCUIT FOR AMPLIFYING CARRIER
FREQUENCIES

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3 Claims. (Cl. 179—171)

The invention relates to circuits for amplifying carrier frequencies which comprise resonant circuits tuned to different frequencies. Such arrangements are necessary, e. g., for television or telephony purposes in order to amplify the band of frequencies to be transmitted.

The invention more particularly is concerned with the problem of obtaining approximately constant amplification over the whole band with a given width of the band of frequencies to be amplified. The independent variables which are available for obtaining this desired uniform amplification are the resonance frequencies of the different circuits and their attenuations. At the outset it was assumed that, with a view towards insuring the desired straight frequency characteristic, the distances or intervals between the separate resonance frequencies had to be made equal, and that also the attenuations of the resonant circuits had to be equal. At most it might have been anticipated that the optimal frequency interval and the optimal attenuation would have to be increased or decreased steadily in the direction from the lower towards the higher frequencies within the band to be amplified.

The invention is based on the knowledge that a constant amplification is obtained, on the contrary, when either the distances of the separate resonance frequencies or their attenuations are made to decrease towards the upper and lower cut-off limits of the frequency band to be transmitted. Preferably the distances as well as the attenuations should simultaneously decrease.

For a better understanding of the invention reference will be made to the accompanying drawings wherein Fig. 1 is a graphical representation on a linear frequency scale of a plurality of resonance curves which serve to explain the invention; Fig. 2 is a similar representation on a logarithmic scale, Fig. 3 is a graphical representation of the resonance curves when the distances between the resonant frequencies of the several circuits are decreased toward the limits of the band but with equal attenuations of the circuits; Fig. 4 is a graphical representation of the resonance curves when the attenuations of the several circuits are decreased towards the limits of the band but with equal intervals between the resonant frequencies of the circuits; and Fig. 5 is an amplifier circuit embodying the features of this invention.

A rough idea of the most favorable conditions is given by the curves shown in Fig. 1 which are based upon the calculated values and where-
in the most favorable position of the resonance

curves R_1 to R_6 of the different circuits ascertained in a given instance is plotted against a usual linear scale for the frequency f and the corresponding attenuations at the same time are at least qualitatively indicated by the magnitude of the resonance maxima. The curve V indicates the course of the amplification factor for this position of the different curves. The ordinate in Fig. 1 is designated by a . The result is extraordinarily surprising in that the crowding together of the resonance maxima or crest values towards the both ends or limits of the frequency band and the simultaneous decrease of the damping values or attenuations of the corresponding circuits, were not to be expected.

The technical rule forming the object of the invention, namely to decrease the intervals between the resonance frequencies and/or the attenuations of the resonant circuits towards the both ends or limits of the frequency band to be transmitted, shall be illustrated and explained in more detail in what follows by reference to Figures 2, 3 and 4, wherein a logarithmic scale is used for the frequency axis. Such a logarithmic scale offers the advantage that the resonance curves will then be symmetrical to their resonance frequency and that their shape remains the same or unvaried with the same or constant attenuation, regardless of the magnitude of the resonance frequency.

The case illustrated in Fig. 1 appears as shown in Fig. 2 when logarithmic scales are used for the frequency axis as well as for the ordinate axis. The range at the limits of which the curve V falls off to the amount 0.7 is called the width b of the band to be amplified. The corresponding attenuations d are indicated at the different curves R_1 to R_6 .

With reference to Fig. 3 it shall first of all be pointed out that with equal attenuations of the different resonance circuits, the distances between the resonance frequencies must be decreased towards the limits of the band to be transmitted in order to obtain an approximately constant amplification factor. It is to be noticed, thereby, that the amplification factor for a single frequency within the band to be transmitted is proportional to the product of the amplitudes of all resonance curves at this position. Thus, for instance, when proceeding from the frequency f_2 to the frequency f_1 , the resonance curves R_2 to R_6 fall off, while only the resonance curve R_1 rises. Hence, in order that the amplification factor at the frequency f_1 may again have approximately the same value as at the

frequency f_2 , the increase of the amplitude of the curve R_1 must approximately compensate the decrease of the amplitudes of the curves R_2 to R_6 . If, however, one proceeds from the frequency f_3 to the frequency f_2 , it is only the curves R_3 to R_6 which decrease (as compared with the curves R_2 to R_6 proceeding from f_2 to f_1), while two curves increase namely R_1 and R_2 (in contrast to only the curve R_1 when proceeding from f_2 to f_1). In other words, in order that the amplification factor at the frequency f_2 may again have the same value as at the frequency f_3 , the decrease of the curves R_3 to R_6 (in contrast to R_2 to R_6 in the former case) must at least approximately be compensated by the increase of R_1 and R_2 . What follows therefrom is that the maximum or crest value of R_2 , i. e., the frequency f_2 , may be spaced farther apart from f_3 than the frequency f_1 from the frequency f_2 . Moreover, it will be noted that the curves R_3 to R_6 have a greater amplitude at the frequency f_2 than at the frequency f_1 so that also by this reason the distance $f_2 - f_1$ must be smaller than the distance $f_3 - f_2$. Referring to Fig. 4, in similar manner, it can be demonstrated that also by decreasing the attenuation of the different resonant circuits towards the ends or limits of the band to be transmitted, with equal frequency intervals of the resonant circuits, an approximately constant amplification factor within the frequency range to be transmitted may be obtained. Again assume that it is the frequencies f_1 to f_3 , at which the maxima of the resonance curves R_1 to R_3 are situated. Proceeding from the frequency f_2 to the frequency f_1 , the curves R_2 to R_6 decrease, while only the curve R_1 increases. In order that for frequency f_1 the product of all amplitudes of the curves R_1 to R_6 may have again approximately the same value as at the frequency f_2 , the increase of the curve R_1 must approximately compensate the decrease of all other curves R_2 to R_6 . For this aim a distinct magnitude of the maximum of R_1 , the position of which on the frequency scale is assumed to be fixed in this case, is necessary. If, however, proceeding from the frequency f_3 to f_2 , it is only the curves R_3 to R_6 which decrease (in contrast to R_2 to R_6 in the former case), while the both curves R_1 and R_2 increase (in contrast to only R_2 in the former case). Therefore, in order to obtain at the frequency f_2 again approximately the same amplification factor as at the frequency f_3 , the maximum of R_2 ought not to be as great as the maximum of R_1 in the first treated case. Besides, also in this case the curves R_3 to R_6 have smaller amplitudes at the frequency f_1 than at the frequency f_2 so that also for this reason the attenuation of the circuit R_1 must be smaller than that of the circuit R_2 . Particularly favorable conditions, i. e., a scarcely perceptible decrease of the amplification factor up to the neighborhood of the both limits of the band, are obtained, if one makes both the intervals between the resonance frequencies and the attenuation of the respective resonant circuits decrease towards the ends of the band. This fact shall be demonstrated by calculation in a manner as hereinafter to be outlined, without however a proof thereof furnished. For the curve V the following equation may be derived, wherein

$$\frac{L}{C}$$

is the ratio of inductance to capacity of each of

the several resonant circuits, n their number and, as above, the mid frequency of the band is designated by f and the width of the band by b .

$$V = \left(\frac{L}{C} \right)^{\frac{1}{2}} \cdot [(f^2 + k_1 b^2 f^2 + b^4)(f^2 + k_2 b^2 f^2 + b^4) \dots (f^2 + k_{n/2} b^2 f^2 + b^4)]^{-\frac{1}{2}} \quad 5$$

If the multiplications in the term under the root of this equation are carried out and the resulting expression is arranged according to the powers of f , all coefficients of f except that of the highest power of f may be made equal to zero by suitable choice of the quantities $k_1 k_2 \dots k_{n/2}$ which are coefficients dependent on the dampings and separations in frequency of the pairs of circuits. This results in the curve V being rendered nearly flat over the band of frequencies b . Once the values of the coefficients $k_1 k_2 \dots k_{n/2}$ which produce the above result have been determined by solution of the simultaneous equations resulting from setting each of the coefficients above mentioned equal to zero, the frequency intervals A between the resonant frequencies of each pair of symmetrical tuned circuits and the damping d of each pair may be determined from the following equations, in which the value of k used is that whose subscript corresponds to the pair of circuits in question. 10

$$A^2 = -\frac{4+b^2}{2} + \left[\left(\frac{4+b^2}{2} \right)^2 - b^2(2+k) \right]^{\frac{1}{2}} \quad 30$$

$$d^2 = \frac{4+b^2}{2} + \left[\left(\frac{4+b^2}{2} \right)^2 - b^2(2+k) \right]^{\frac{1}{2}} \quad 35$$

wherein A signifies the distance between every two neighboring resonant circuits of equal attenuation (indicated in Fig. 2). The attenuation is herein as above the so-called parallel attenuation, i. e., it is calculated by the formula 40

$$d = \frac{1}{R} \left(\frac{L}{C} \right)^{\frac{1}{2}}$$

wherein R is the resistance in parallel to the resonant circuit L and C . Once the damping d for a pair of circuits is known, the value of R is determined since 45

$$\frac{L}{C}$$

is made the same arbitrarily chosen value for all circuits. And a knowledge of A determines the frequencies of each of the corresponding pair of circuits and hence the product LC . With both the ratio 50

$$\frac{L}{C}$$

and the product LC determined, the required individual values of L and C may be deduced for each circuit. 55

The circuit arrangement of an amplifier in accordance with the invention is as usual in carrier-frequency amplifiers and is for exemplification shown in Fig. 5. Therein 10 and 11 designate two five-electrode tubes of a multi-stage amplifier, in the plate circuits of which the coils 12 and 13 are inserted. These coils represent together with the capacities in parallel to them, preferably with the plate-earth capacities C_{10} and C_{11} drawn in dotted lines, the resonant circuits. The requisite attenuation may be obtained, e. g., by suitably dimensioning the parallel resistances 14 , 15 or the inherent resistances of the coils 12 and 13 . The terminals 16 and 17 are connected to the positive pole of the plate-voltage source, 60

while a negative bias is applied to the terminals 18, 19 of the grid-leak resistances 20, 21 of the control grids fed through the capacities.

As already mentioned in the beginning, the invention inter alia also may be applied to the amplification of speech currents. If, e. g., along a telephone line eight repeater stations comprising four tubes each are provided, according to the invention all 32 resonant circuits forming part of them may be differently tuned and damped. Likewise one may perhaps distribute the resonance frequencies of the first 16 circuits over the whole band according to the rules given by the invention and choose the frequencies of the second 16 circuits in the same manner as the frequencies of the first circuits. In this manner also the subdivision of the whole amplifying channel even may be carried on by forming four groups comprising eight resonance circuits each or eight groups comprising four differently tuned and/or damped circuits each. Within each group then the frequencies and/or the attenuations are graduated according to the invention. With eight groups comprising four differently tuned and/or damped resonant circuits each of the four circuits are differently designed, but the various repeater stations are conformable to each other. Within the scope of the invention one may likewise place the first four circuits of the first four stations in the first repeater station, the second four circuits of the first four stations in the second repeater station and so on. Then the first station contains throughout circuits equal to each other, the second station likewise nothing but circuits equal to each other, which, however, are different from the circuits of the first sta-

tion etc. For all that the first four stations of the whole channel represent then an embodiment of the inventive idea, as in the first four stations a circuit arrangement for amplifying carrier frequencies is provided, which comprises 5 resonant circuits tuned to different frequencies.

I claim:

1. A circuit for substantially uniformly amplifying a relatively wide band of carrier frequencies, comprising a plurality of cascaded resonant circuits which are tuned to different frequencies within said band, characterized in that the distances between the resonance peaks of successive resonant circuits progressively decrease in each direction from the center of the frequency band 15 to be transmitted towards the limits of said band.

2. A circuit for substantially uniformly amplifying a relatively wide band of carrier frequencies, comprising a plurality of cascaded resonant circuits which are tuned to different frequencies 20 within said band, characterized in that the attenuations of the several resonant circuits progressively decrease in each direction from the center of the frequency band to be transmitted towards the limits of said band. 25

3. A circuit for substantially uniformly amplifying a relatively wide band of carrier frequencies, comprising a plurality of cascaded resonant circuits which are tuned to different frequencies 30 within said band, characterized in that both the distances between the peaks of successive resonant circuits and the attenuations of said circuits progressively decrease in each direction from the center of the frequency band to be transmitted towards the limits of said band. 35

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