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H. A. AFFEL

NONSINGING REAMPLIFYING CIRCUITS

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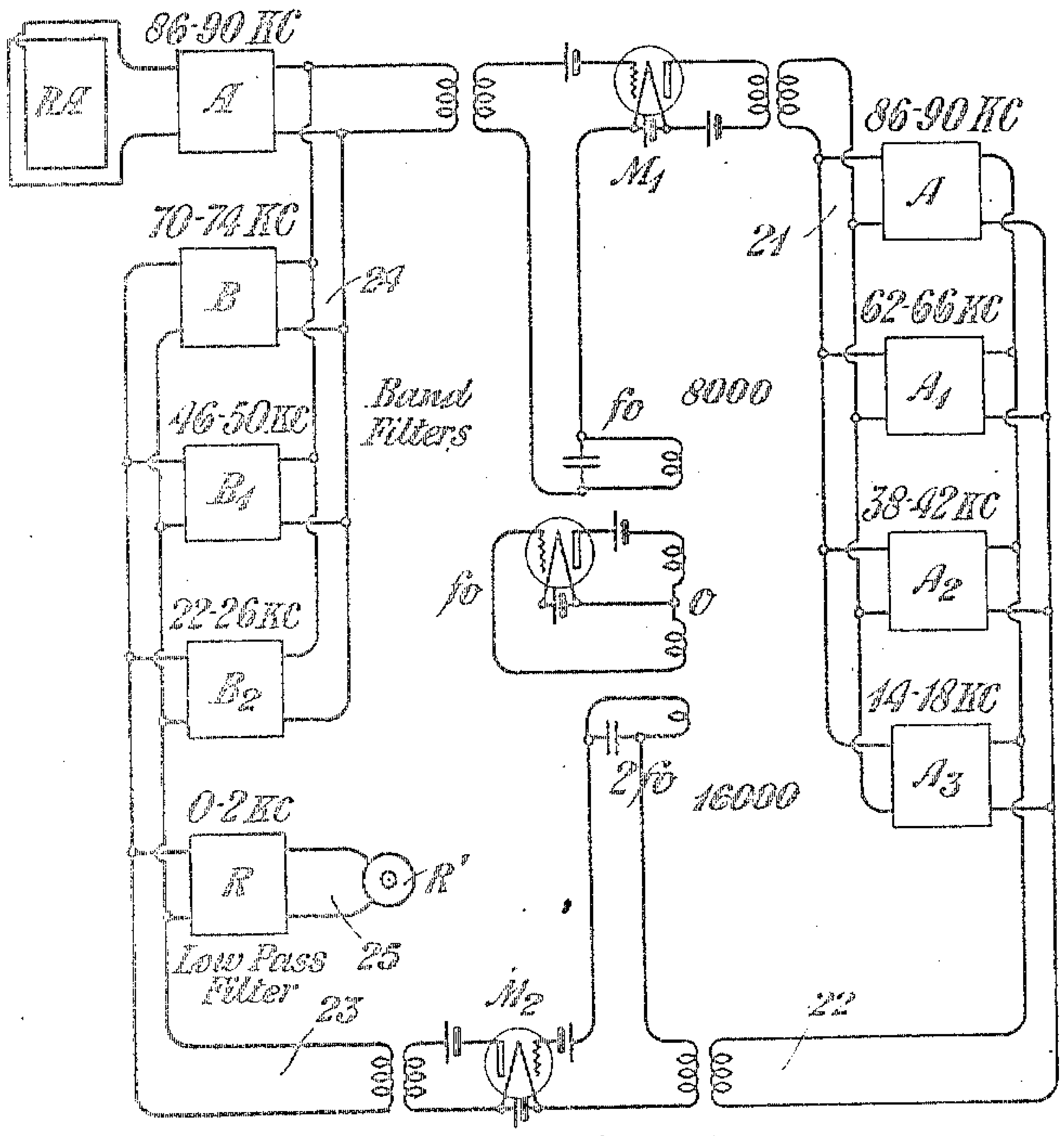

Fig. 1

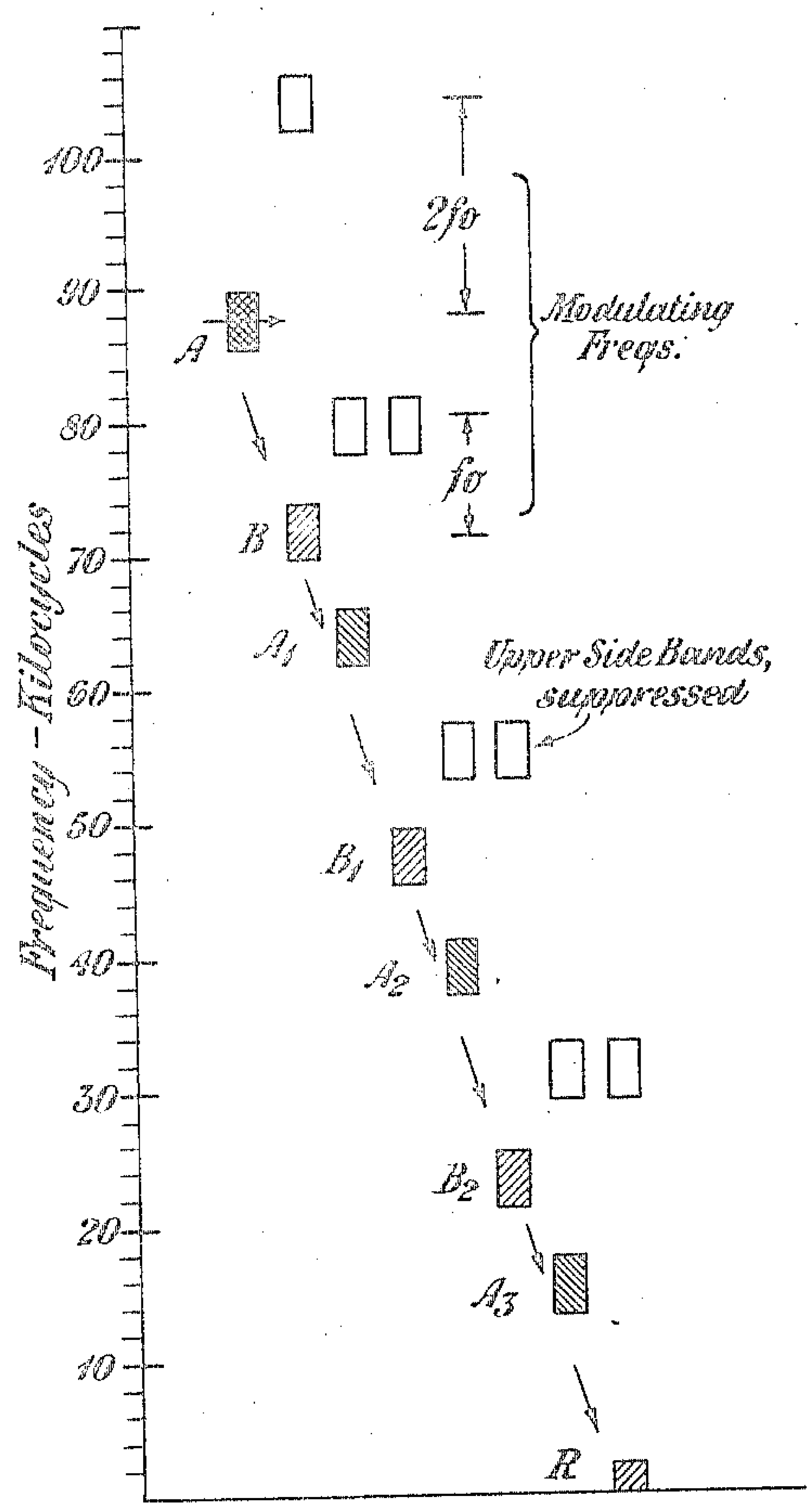

Fig. 2

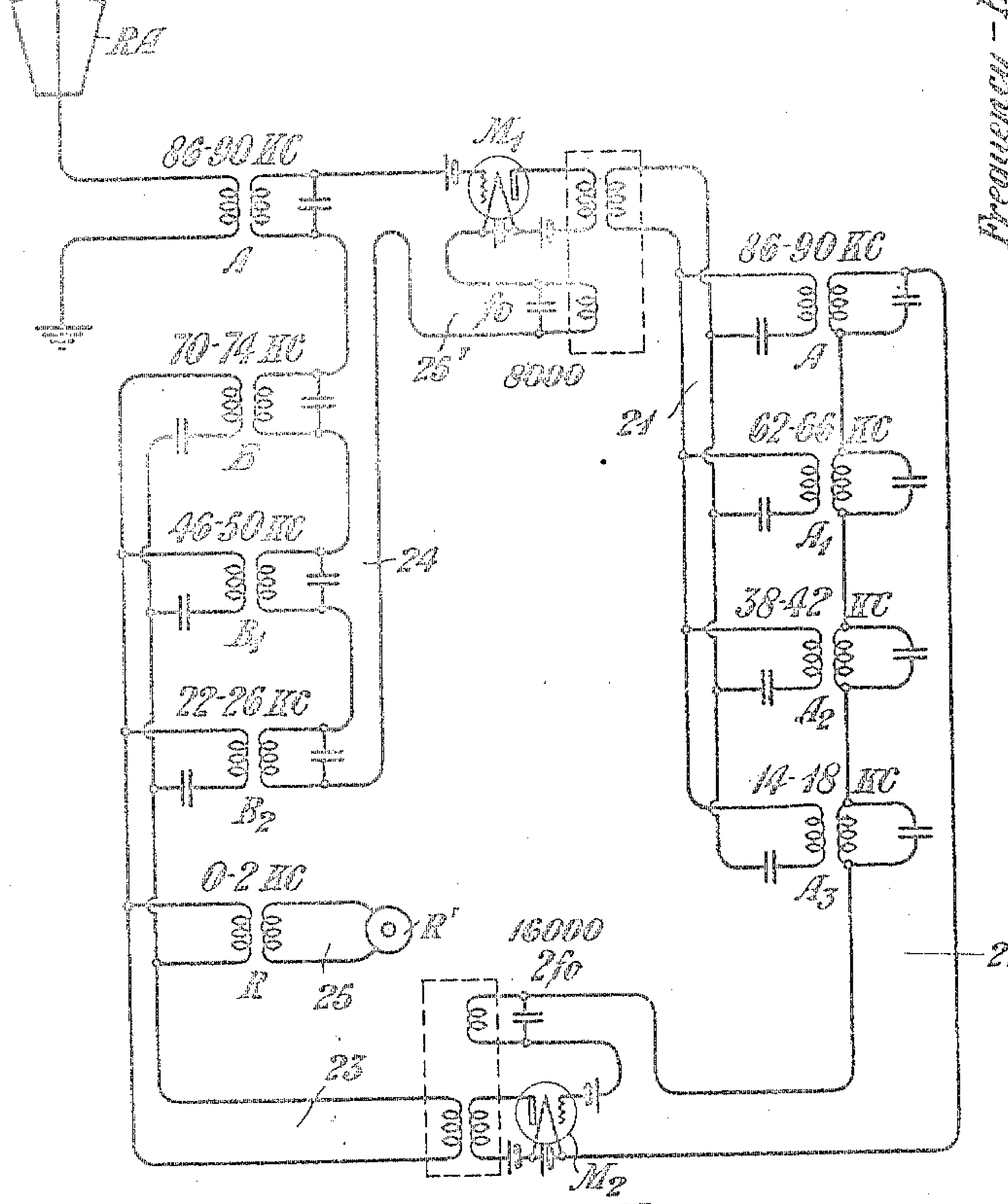

Fig. 3

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NONSINGING REAMPLIFYING CIRCUITS.

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This invention relates to amplifying arrangements and more particularly to an amplifying arrangement provided with multiple feed-back connections.

In accordance with the present invention, the same amplifying tube may be used for reamplifying the same signal a number of times by passing the energy to be amplified through the tube successively each time at a different frequency. The invention in one of its aspects contemplates employing the tube not only for amplifying the translated frequencies but also for producing a translation in the frequency of the energy each time it is fed back to the input side of the tube. This frequency translation may be accomplished by arranging the tube to act as a modulator and supplying to its circuit a beating frequency in a manner well known in the art. As a still further refinement, the tube may in some instances be arranged to oscillate at a definite frequency thereby supplying its own beating frequency, so that in effect the same tube combines the functions of amplification, modulation and generation of the modulating frequency. While the present invention is applicable to any situation in which signals are translated in frequency either during transmission or reception, it is illustrated as being applied to a radio receiving system in which the modulated radio frequencies are stepped down to audible signals by a plurality of steps.

The invention may now be more fully understood by reference to the following description when read in connection with the accompanying drawing, Figure 1 of which illustrates schematically a circuit arrangement embodying one form of the invention, Fig. 2 of which is a chart showing the frequency relations involved in the circuit, and Fig. 3 of which is a schematic diagram illustrating another embodiment of the invention.

Referring to Fig. 1, RA designates a receiving antenna connected through a filter A to the input circuit of a vacuum tube M_1, said vacuum tube being arranged to operate both as an amplifier and a modulator. In connection with its modulating function, the tube M_1 is supplied from a source O with some desired beating frequency as f_0. The source O may, for example, be a vacuum tube oscillator of well known type generating a fundamental frequency f_0.

The output circuit of the modulator M_1 is connected to an outgoing circuit 21 which is connected through filters A, A_1, A_2 and A_3 to an incoming circuit 22 leading to the input side of a vacuum tube device M_2. The vacuum tube M_2 may likewise be adjusted to operate both as a modulator and as an amplifier, and in connection with its former function has its input circuit connected through a tuned circuit to the oscillator O. As is well known, a vacuum tube type of oscillator normally generates a second harmonic of its fundamental frequency in addition to the fundamental, and it is frequently necessary to take considerable pains in order to eliminate said harmonic when it is undesired. In the present instance advantage is taken of the fact that the oscillator generates the second harmonic, and accordingly the input circuit of the modulator M_2 is tuned to the frequency $2f_0$. Consequently the vacuum tube M_2 acting as a modulator is supplied with a beating frequency twice as great as the beating frequency supplied to the modulator M_1.

The output circuit of the tube M_2 is connected to the outgoing circuit 23 which is connected through the filters B, B_1 and B_2 to the incoming circuit 24 leading to the input side of the vacuum tube M_1. The circuit 23 is also provided with a branch 25 including a suitable filter R and leading to a receiving instrument R′.

Further details of the apparatus may be understood from a description of the operation. For assistance in understanding the operation of the circuit, the chart shown in Fig. 2 is provided, and definite frequencies have been assigned to the various filters involved. Let us assume that a carrier frequency of 88,000 cycles modulated in accordance with the voice band extending from zero to 2,000 cycles is being received by the antenna RA. If both side bands are being transmitted, the received band will extend from 86,000 cycles to 90,000 cycles, as indicated by the cross-hatched block designated A in Fig. 2. This band of frequencies, upon being impressed upon the modulating amplifier M_1, beats with a locally supplied frequency of 8,000 cycles to produce sum and difference frequencies as well as original frequencies extending from 86,000 to 90,000 cycles. As it is not desired to take advantage of any frequency translation during the first transmission of the energy through the modulating amplifier M_1, the filter A, connecting circuits 21 and 22, is designed to pass the same range of frequencies as the filter A, connecting the receiving antenna RA with the modulator M_1. Consequently the sum and difference frequencies are eliminated, and the original frequency band extending from 86,000 cycles to 90,000 cycles is transmitted through the filter A to the input circuit of the modulating amplifier M_2.

A beating frequency of 16,000 cycles is impressed upon the modulating amplifier M_2, so that sum and difference frequencies result. The difference frequency corresponds to a range of frequencies extending from 70,000 cycles to 74,000 cycles corresponding to the section-lined rectangle designated B in Fig. 2. The sum frequencies correspond to a range extending from 102,000 to 106,000 cycles as indicated by the plain rectangle directly above the rectangle B of Fig. 2. As the filter B interconnecting circuits 23 and 24 is designed to pass only a range from 70,000 to 74,000 cycles, the band marked B in Fig. 2 will be passed, and consequently the energy amplified by the devices M_1 and M_2 will again be impressed upon the input circuit of the modulating amplifier M_1 translated in frequency by being stepped down 16,000 cycles.

The energy transmitted through the band filter B, upon being impressed upon the modulating amplifier M_1, beats with the locally supplied frequency of 8,000 cycles to produce a lower side band from 62,000 to 66,000 cycles and an upper side band extending from 78,000 to 82,000 cycles. The lower band is represented by the rectangle A_1 in Fig. 2, and the upper band is designated by the plain rectangle immediately above the rectangle A_1. The upper band is suppressed by the filter A_1 while the lower band is passed through said filter and impressed upon the modulating amplifier M_2.

The range of frequencies extending from 62,000 to 66,000 cycles impressed upon the modulating amplifier M_2 is stepped down in frequency by a further step of 16,000 cycles, the stepped down band extending from 46,000 to 50,000 cycles being passed through the filter B_1 to the modulating amplifier M_1. Here another step down in frequency of 8,000 cycles occurs, so that a stepped down band extending from 38,000 to 42,000 cycles is selected by the filter A_2 and impressed upon the modulating amplifier M_2. The energy is now amplified and stepped down in frequency to a band extending from 22,000 to 26,000 cycles which band is passed through the filter B_2 and impressed upon the modulating amplifier M_1. The modulating amplifier M_1 steps this band down to a range extending from 14,000 to 18,000 cycles, the latter band being selected by the filter A_3 and impressed upon the modulator M_2.

Recalling that the band of frequencies extending from 14,000 to 18,000 cycles corresponds to a band of the same width originally received from the transmitting station and that the original band involved two side bands and a carrier, it is apparent that the band extending from 14,000 cycles to 18,000 cycles corresponds to an upper and lower side band associated with a carrier of 16,000 cycles. Consequently when this band is impressed upon the modulating amplifier M_2, the 16,000 cycle frequency locally supplied to the modulator beats with the band to detect from the two side bands a single signal band extending from zero to 2,000 cycles. This signal band is selected into the circuit 25 from the circuit 23 by the filter R and actuates the receiver R'.

If we examine the chart of Fig. 2, it will be seen that each of the selected lower side bands is represented by a rectangle shown in section lines, while the corresponding side band which is suppressed is represented by a plain rectangle immediately above the rectangle representing the selected band. The stepping down in frequency, it will be noted, occurs alternately in steps of 8,000 and 16,000 cycles. The advantage of stepping down by unequal steps resides in the fact that if each step should be made equal interference would occur between upper side bands which it is desired to suppress and lower side bands of some preceding step in the operation. For example, suppose we consider the band B_1 in Fig. 2 which has been stepped down from the band A_1 by a step of 16,000 cycles. If the band B_1 should in turn be stepped down by beating with 16,000 cycles, the band A_2 would occur 8,000 cycles lower in the frequency spectrum, and the corresponding upper side band which is to be suppressed would lie in the same range as the band A_1. As the band to be suppressed would be inverted with respect to the band A_1, this would produce interference.

There is a further advantage in making the successive steps unequal in the ratio of two to one, for, as will be observed from the diagram, this brings two of the upper side bands to be suppressed within the same frequency range. For example, the upper side bands corresponding to A_2 and B_2 are both in the range from 54,000 to 58,000 cycles. If the steps were so chosen that these two bands did not coincide, it would obviously be necessary to increase the distance between bands A_1 and B_1, for example, with the result that the stepping down of the frequencies would have to take place by larger steps.

Consequently, the energy to be amplified could not be repassed through the amplifying apparatus as great a number of times as might be necessary in a given situation where the energy to be amplified is very weak.

A modified arrangement is illustrated in Fig. 3 in which tuned circuits are used instead of band filters and in which the tubes M_1 and M_2 are arranged to oscillate and generate each its own stepped down frequency. For example, the tube M_1 is provided with a feed-back connection 25 tuned to a frequency f_0, so that the tube generates its own beating frequency. Likewise the tube M_2 is provided with a feed-back connection tuned to $2f_0$, so that the tube will generate a beating frequency twice that supplied to the tube M_1. Each of the tubes M_1 and M_2 is arranged to operate not only as a modulator and an amplifier but also as an oscillator.

The operation is as follows: Assuming, for example, that a frequency band extending from 86,000 to 90,000 cycles is received by the antenna RA and impressed upon the tube M_1, inasmuch as the tube is oscillating at 8,000 cycles, it will produce in its output circuit bands corresponding to the sum and difference frequencies and also to the original band extending from 86,000 to 90,000 cycles. This first amplifying step is not designed to produce any frequency translation, consequently the tuned circuit will be tuned to select a band of from 86,000 to 90,000 cycles and exclude the upper and lower side bands. The selected band is impressed upon the tube M_2 which is oscillating at 16,000 cycles. Consequently the output circuit of the tube will transmit an amplified component corresponding to the original band stepped down 16,000 cycles. This stepped down amplified component will be selected by the tuned circuit B and impressed upon the modulator M_1, which, by beating it with the self-generated frequency of 8,000 cycles will step it down 8,000 cycles further. This process is continued as in the case of Fig. 1 until finally an amplified detected band of from zero to 2,000 cycles is selected from the output of the tube M_2 and impressed upon the receiving device R′.

It will be obvious that the general principles herein disclosed may be embodied in other forms widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. An amplifying system in which the energy to be amplified is passed through the amplifier successively a number of times, comprising an amplifier, a plurality of re-entrant connections from the output of said amplifier to its input, each connection being arranged to pass a different frequency, and means associated with said amplifier to supply a beating frequency thereto, said beating frequency being such as to produce a change in the frequency of the energy each time it is passed through said amplifier, and each change corresponding to the frequency passed by a different one of said re-entrant connections.

2. An amplifying system in which the energy to be amplified is passed through the amplifier successively a number of times, comprising an amplifier, a plurality of re-entrant connections from the output of said amplifier to its input, each connection being arranged to pass a different frequency, and means associated with said amplifier to supply a beating frequency thereto, said beating frequency being such as to modulate the energy each time it passes therethrough to produce sum and difference frequencies, one of the frequencies thus produced for each translation corresponding to the frequency passed by a different one of said re-entrant connections.

3. An amplifying system in which the energy to be amplified is passed through the amplifier successively a number of times, comprising an amplifier, a plurality of re-entrant connections from the output of said amplifier to its input, each connection being arranged to pass a different frequency, means associated with said amplifier to supply a beating frequency thereto, said beating frequency being such as to modulate the energy each time it passes therethrough to produce sum and difference frequencies, one of the frequencies thus produced for each translation corresponding to the frequency passed by a different one of said re-entrant connections, and means associated with each re-entrant connection to render it selective of a different one of the successively produced difference frequencies, thereby successively stepping down the energy in the frequency spectrum as it is amplified.

4. An amplifying system in which the energy to be amplified is passed through the amplifying apparatus successively a number of times, comprising a plurality of amplifiers each arranged so that its output transmits to the input of the other, the arrangements for transmitting from the output of each amplifier to the input of the succeeding amplifier each comprising a plurality of re-entrant connections, each connection being arranged to pass a different frequency, and means associated with each amplifier to change the frequency of the energy each time it passes through the amplifier, each change corresponding to the frequency passed by a different one of the re-entrant connections associated with its output circuit.

5. An amplifying system in which the energy to be amplified is passed through the

amplifying apparatus successively a number of times, comprising a plurality of amplifiers each arranged so that its output transmits to the input of the other, the arrangements for transmitting from the output of each amplifier to the input of the succeeding amplifier each comprising a plurality of re-entrant connections, each connection being arranged to pass a different frequency, and means associated with each amplifier to supply a beating frequency thereto to change the frequency of the energy each time it passes through the amplifier, each change corresponding to the frequency passed by a different one of the re-entrant connections associated with its output circuit.

6. An amplifying system in which the energy to be amplified is passed through the amplifying apparatus successively a number of times, comprising a plurality of amplifiers each arranged so that its output transmits to the input of the other, the arrangements for transmitting from the output of each amplifier to the input of the succeeding amplifier each comprising a plurality of re-entrant connections, each connection being arranged to pass a different frequency, and means associated with each amplifier to change the frequency of the energy each time it passes through the amplifier, each change corresponding to the frequency passed by a different one of the re-entrant connections associated with its output circuit, and the change in frequency produced by each amplifier being different from that produced by the other.

7. An amplifying system in which the energy to be amplified is passed through the amplifying apparatus successively a number of times, comprising a plurality of amplifiers each arranged so that its output transmits to the input of the other, the arrangements for transmitting from the output of each amplifier to the input of the succeeding amplifier each comprising a plurality of re-entrant connections, each connection being arranged to pass a different frequency, and means associated with each amplifier to supply a beating frequency thereto to change the frequency of the energy each time it passes through the amplifier, each change corresponding to the frequency passed by a different one of the re-entrant connections associated with its output circuit, and the change in frequency produced by each amplifier being different from that produced by the other.

8. An amplifying system in which the energy to be amplified is passed through the amplifier successively a number of times, comprising an amplifier, a plurality of re-entrant connections from the output of said amplifier to its input, each connection being arranged to pass a different frequency, and means comprising a feed-back coupling associated with said amplifier, said feed-back coupling being so adjusted and proportioned as to produce a beating frequency for the amplifier, said beating frequency being such as to produce a change in the frequency of the energy each time it is passed through said amplifier, and each change corresponding to the frequency passed by a different one of said re-entrant connections.

9. An amplifying system in which the energy to be amplified is passed through the amplifier successively a number of times, comprising an amplifier, a plurality of re-entrant connections from the output of said amplifier to its input, each connection being arranged to pass a different frequency, and means comprising a feed-back coupling associated with said amplifier, said feed-back coupling being so adjusted and proportioned as to produce a beating frequency for the amplifier, said beating frequency being such as to modulate the energy each time it passes therethrough to produce sum and difference frequencies, one of the frequencies thus produced for each translation corresponding to the frequency passed by a different one of said re-entrant connections.

10. An amplifying system in which the energy to be amplified is passed through the amplifier successively a number of times, comprising an amplifier, a plurality of re-entrant connections from the output of said amplifier to its input, each connection being arranged to pass a different frequency, means comprising a feed-back coupling associated with said amplifier, said feed-back coupling being so adjusted and proportioned as to produce a beating frequency for the amplifier, said beating frequency being such as to modulate the energy each time it passes therethrough to produce sum and difference frequencies, one of the frequencies thus produced for each translation corresponding to the frequency passed by a different one of said re-entrant connections, and means associated with each re-entrant connection to render it selective of a different one of the successively produced difference frequencies, thereby successively stepping down the energy in the frequency spectrum as it is amplified.

11. An amplifying system in which the energy to be amplified is passed through the amplifying apparatus successively a number of times, comprising a plurality of amplifiers each arranged so that its output transmits to the input of the other, the arrangements for transmitting from the output of each amplifier to the input of the succeeding amplifier each comprising a plurality of re-entrant connections, each connection being arranged to pass a different frequency, and means comprising a feed-back coupling associated with each amplifier, each feed-back

coupling being so adjusted and proportioned as to produce a beating frequency for the corresponding amplifier to change the frequency of the energy each time it passes through the amplifier, each change corresponding to the frequency passed by a different one of the re-entrant connections associated with its output circuit.

12. An amplifying system in which the energy to be amplified is passed through the amplifying apparatus successively a number of times, comprising a plurality of amplifiers each arranged so that its output transmits to the input of the other, the arrangements for transmitting from the output of each amplifier, to the input of the succeeding amplifier each comprising a plurality of re-entrant connections, each connections being arranged to pass a different frequency, and means comprising a feed-back coupling associated with each amplifier, each feedback coupling being so adjusted and proportioned as to produce a beating frequency for the corresponding amplifier to change the frequency of the energy each time it passes through the amplifier, each change corresponding to the frequency passed by a different one of the re-entrant connections associated with its output circuit, and the change in frequency produced by each amplifier being different from that produced by the other.

In testimony whereof, I have signed my name to this specification this 14th day of May, 1923.

HERMAN A. AFFEL.