

March 16, 1948.

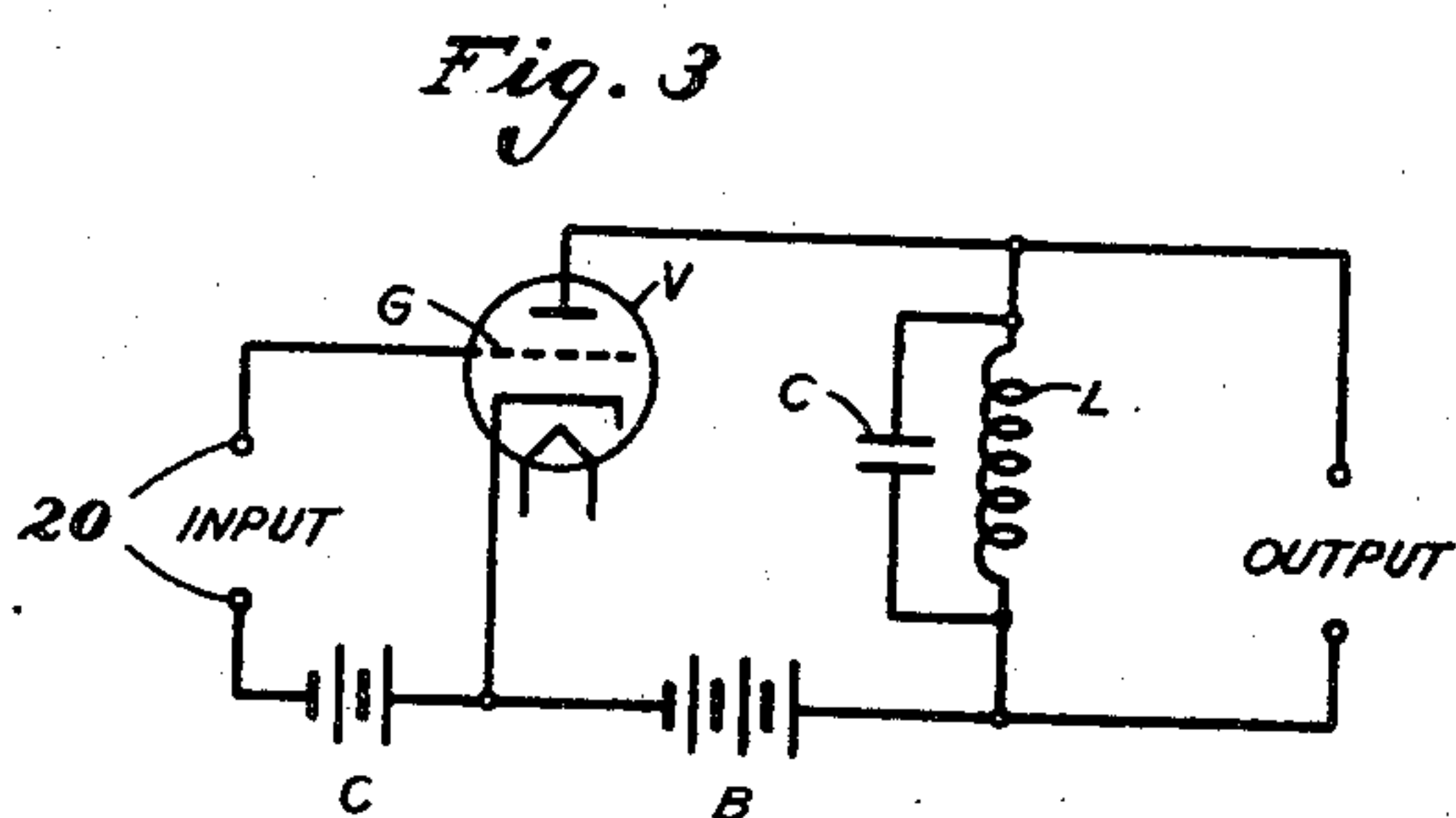
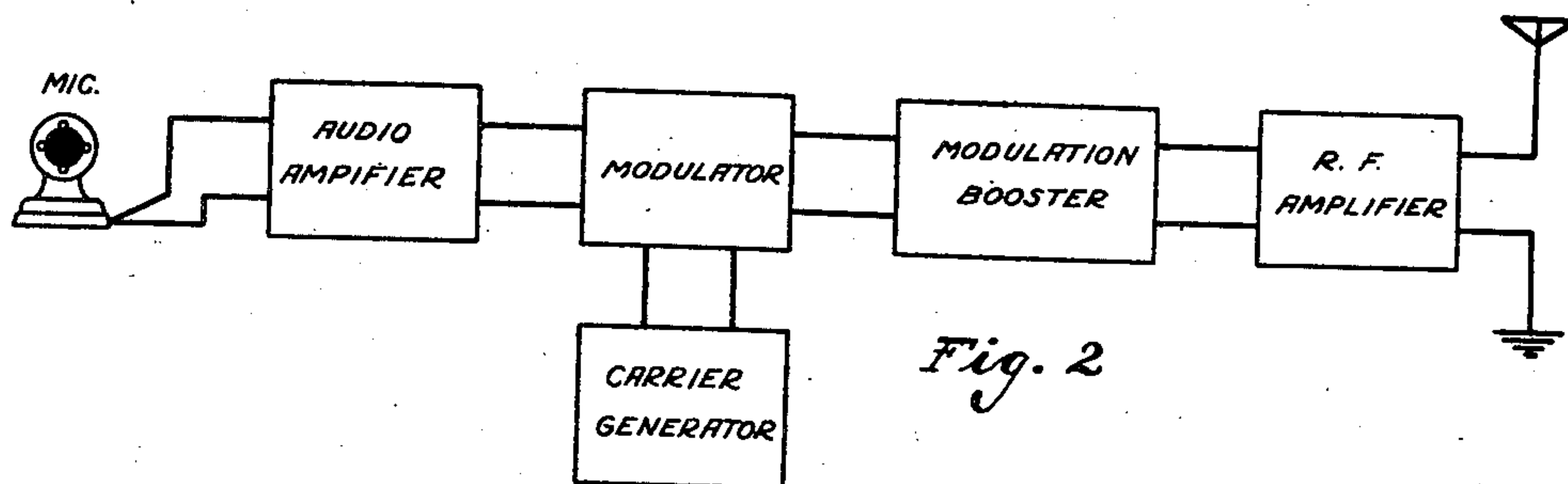
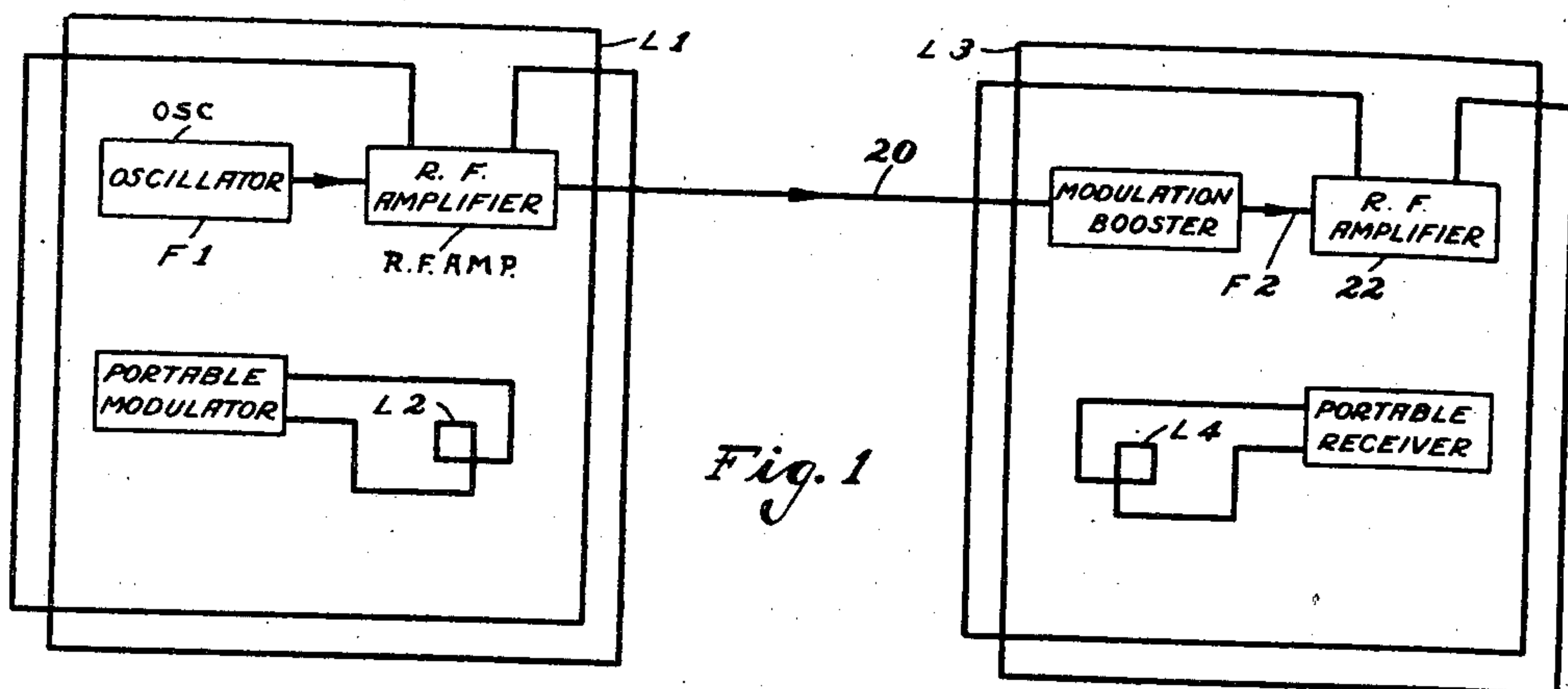
F. H. SLAYMAKER

2,437,839

MODULATION BOOSTER

Filed April 3, 1946

3 Sheets-Sheet 1



BY

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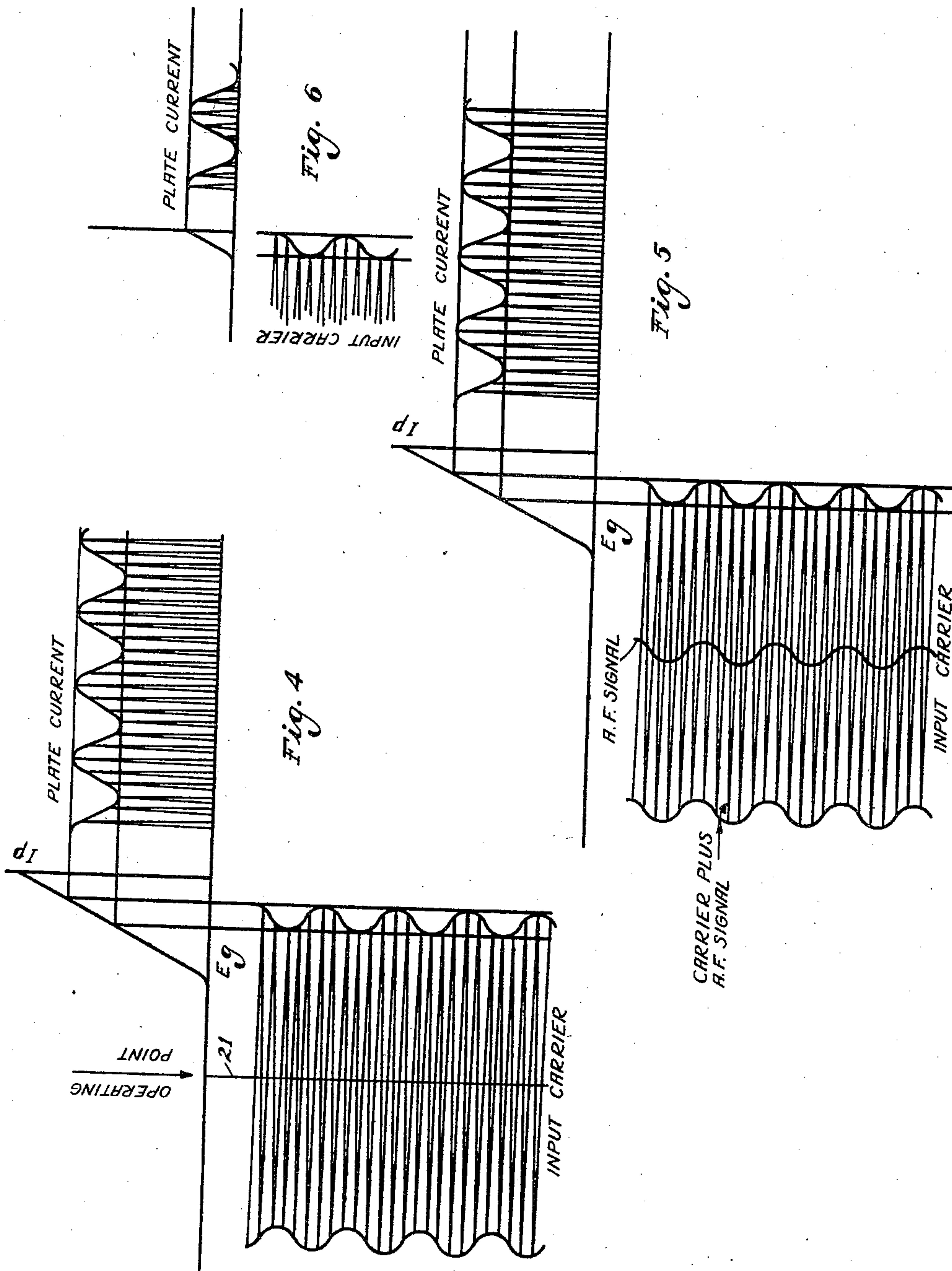
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3 Sheets-Sheet 2



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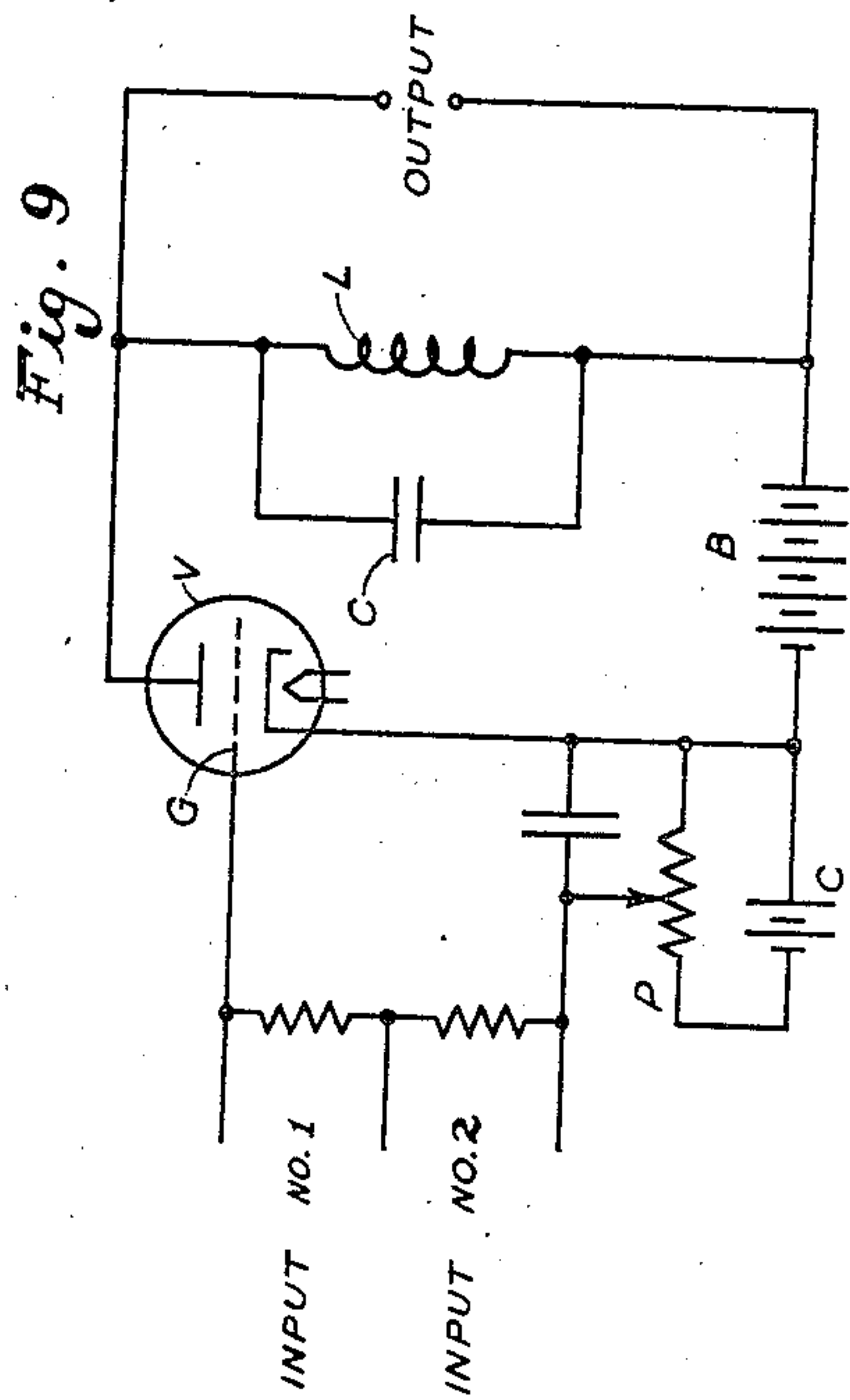
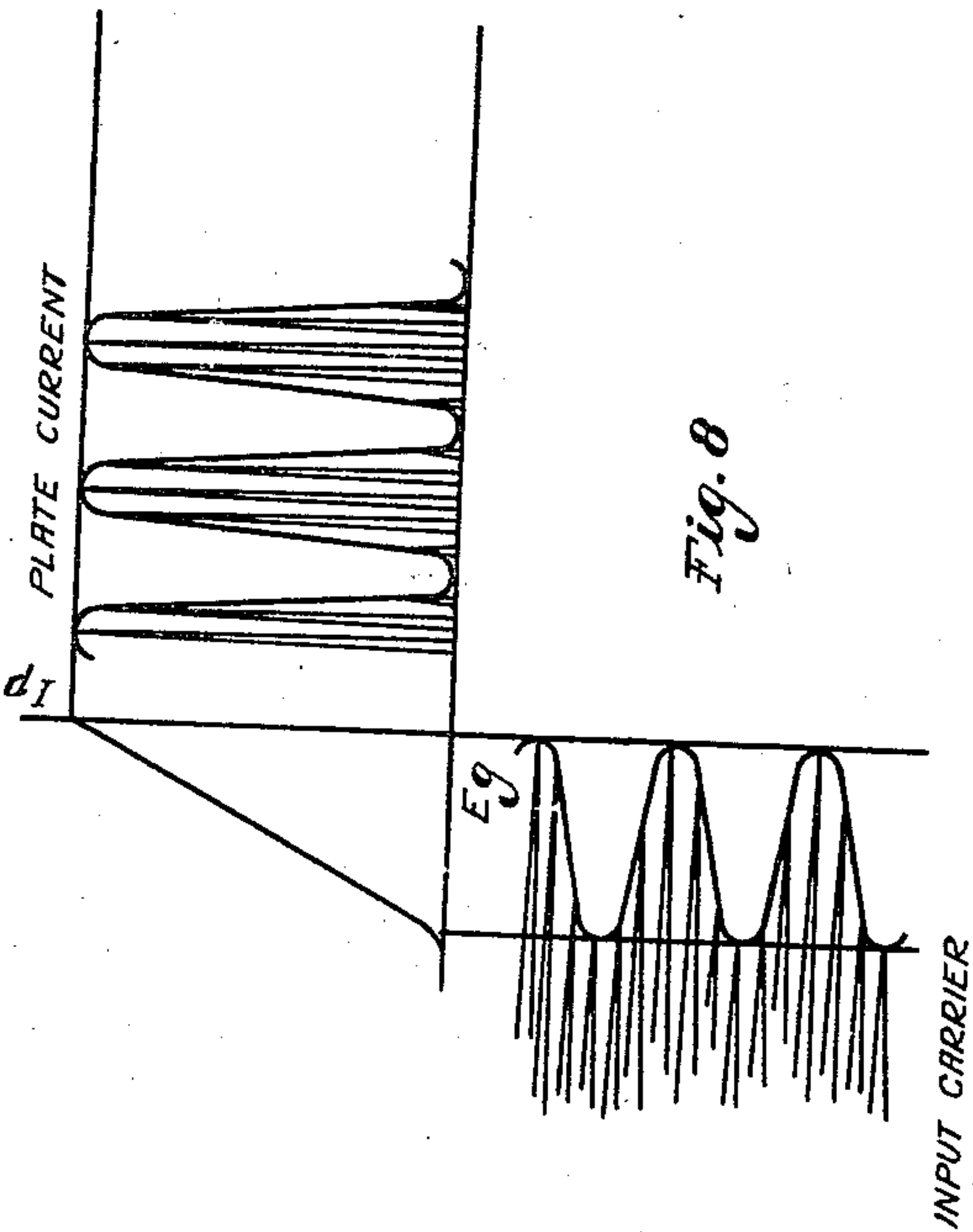
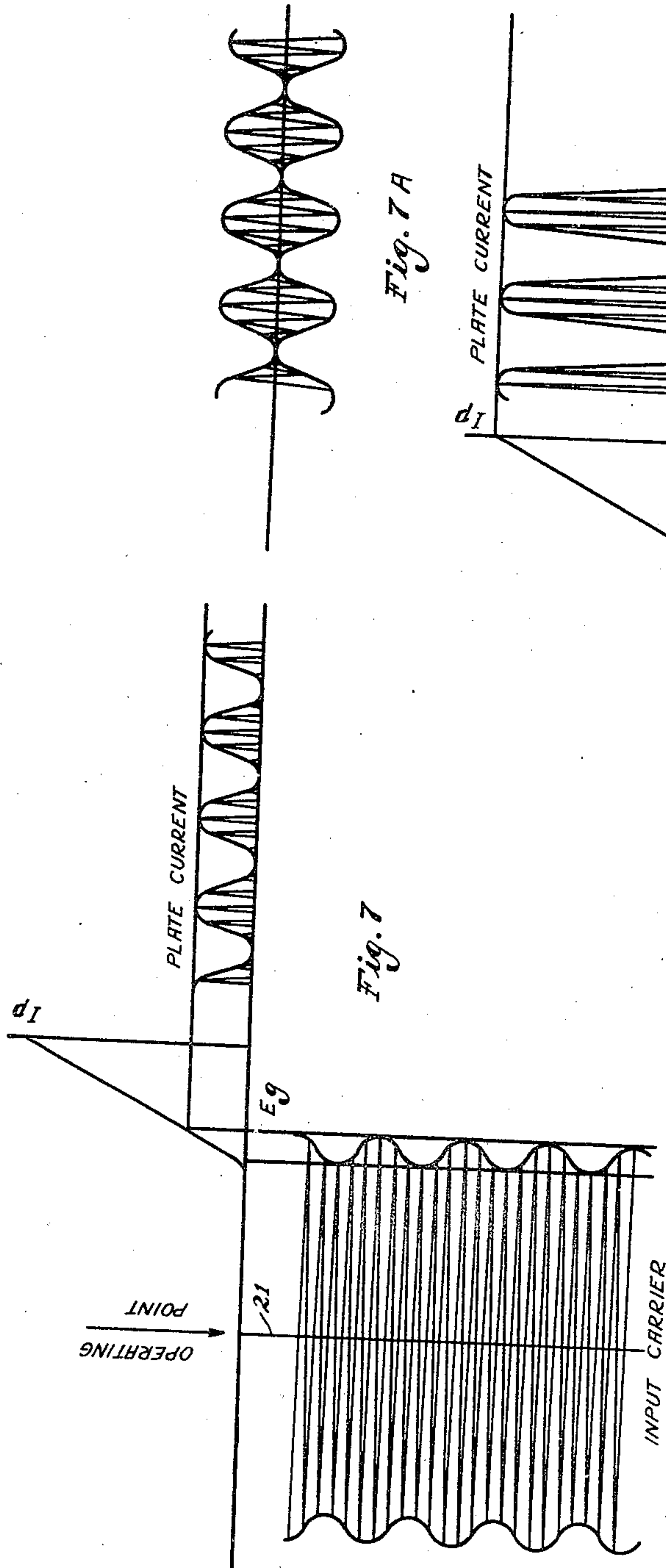
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UNITED STATES PATENT OFFICE

2,437,839

MODULATION BOOSTER

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Application April 3, 1946, Serial No. 659,229

5 Claims. (Cl. 179—171.5)

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The present invention relates generally to signal modulated high frequency transmission systems and more particularly to a modulation booster for boosting the degree of modulation.

This application is a continuation in part of the invention disclosed and claimed in Patent 2,403,245, issued July 2, 1946, and assigned to the same assignee as the present invention.

While my invention is applicable to and usable in any system where it is desirable to increase the modulation intensity, it finds particular utility in the intra-tank communication system disclosed in Patent 2,362,692, of Harold Goldberg, J. Russell Stewart and myself, issued November 14, 1944, and assigned to the same assignee as the present invention.

It is, therefore, one object of my invention to handle carrier currents which are very weakly modulated without overloading the amplifying equipment.

Another object of my invention is the increase in modulation intensity from a very low degree, say 3 per cent, to a very high degree, say 100 per cent.

Still another object of my invention is to increase the modulation of the radio frequency carrier by operating on the carrier envelope itself without requiring the use of audio frequency in securing the increase.

Various other objects and advantages of the invention will appear from the following description when read in conjunction with the appended drawings, in which:

Figure 1 is a block diagram illustrating the above mentioned intratank communicating system, with the modulation booster connected therein;

Figure 2 illustrates, in diagrammatic form, a typical carrier frequency transmission system, having my modulation booster incorporated therein;

Figure 3 shows the fundamental, schematic circuit of the modulation booster, with the bypass filters, filament supply and other parts of the circuit, not necessary for illustrating the present invention, omitted;

Figures 4 and 7 show the control grid voltage-plate current characteristic for a tube used as a modulation booster in accordance with my invention.

Figure 7A shows the potential across the tuned plate load of the circuit of Figure 3 and it will be noted that these waves are modulated to a greater degree than those of the input carrier of Figure 7. It will be understood that the output

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load may be tuned to any desired multiple of the input frequency to provide any desired harmonic of the input frequency in the output circuit, as later explained.

Figures 5, 6 and 8 are curves which will be referred to in pointing out various features and advantages of the present invention; and,

Figure 9 shows a modification of the circuit shown in Figure 3.

Referring now to Figure 1, L1 and L3 represent two antennas strung around the inside of a tank or other mobile unit. L2 and L4 indicate two portable loop antennas which are carried in the clothing, such as being sewed in the user's belt, of the members of the tank crew. The portable modulator comprises a telephone transmitter (not shown) which functions to modulate a tuned circuit comprising a condenser (not shown) and loop L2. The portable receiver comprises a telephone headset and a detector (not shown) connected to a tuned circuit comprising a condenser (not shown) and loop L4.

Oscillator OSC may be an electronic oscillator which supplies radio frequency oscillations F1 to radio frequency amplifier R. F. AMP, the output of which is connected to loop L1. A radio frequency electromagnetic field is therefore set up in the space within loop L1, which field is absorptively modulated in accordance with the variations provided by the portable modulator, all as disclosed in the above mentioned Patent 2,362,692.

In any system where the modulated radio frequencies are weakly modulated, as for example in the system illustrated, these radio frequencies may be connected to the circuit 20, illustrated in Figure 3 and the per cent modulation boosted. The potential of battery C is such that grid G is biased to an operating point such as 21 of Figure 4 or Figure 7, whereby one edge of the modulated radio frequency or carrier envelope will fall on the linear portion of the E_g-I_p curve. The plate current in the output of tube V will then consist of a series of unidirectional pulses varying in amplitude with the modulation and occurring at the same frequency as the carrier. Furthermore, the various harmonics of the carrier fundamental frequency are also present in the plate current.

The plate load, comprising inductance L and capacity C, may be tuned to the input frequency F1, or any of its harmonics, and the potential across the output terminals of the tube V will consist of a true modulated radio frequency wave, but modulated at a much higher degree or per-

centage than the applied radio frequency in the input. This boost is illustrated by the envelopes of the input and output waves in Figures 7 and 7A. These boosted waves appearing across the output terminals of Figure 3 are applied to the input of the radio frequency amplifier of Figure 1 which has its output connected to loop L3. By tuning the LC circuit of Figure 3 to the second harmonic of the oscillator frequency F_1 , a frequency F_2 , which is double that of F_1 , is applied to the R. F. amplifier whose output is connected to antenna L3. Thus, the boosted modulations are carried by carrier F_2 which is twice the frequency of F_1 and are then received and detected by loop L4 and the portable receiver, the loop circuit being tuned to frequency F_2 .

From the above explanation and with particular reference to Figure 7, it will be noted that a series of pulses, of the same frequency as the input carrier, appear in the plate current of tube V in Figure 3. Furthermore, since the pulses in the plate circuit are not sinusoidal, harmonics are present and by tuning the output circuit to the fundamental or any desired harmonic thereof, it is possible to extend the modulated fundamental, or harmonic, to a work circuit, such as the R. F. amplifier 22 of Figure 1. It is an observed fact that the harmonics in the output circuit are modulated to substantially the same degree or per cent boost as the fundamental.

It will be seen from Figure 4 that, while the modulation has been considerably increased, it is not nearly 100 per cent. Modulation of the order of 100 per cent may be obtained by adjusting the grid bias C so that the dips in the modulated portion of the carrier F_1 fall exactly at the cut-off point on the E_g-I_p curve as illustrated in Figure 7. This may also be obtained by adjusting the amplitude of the input potentials so that the dips in the modulated portion of the carrier F_1 fall exactly at the cut-off point on the E_g-I_p curve as illustrated in Figure 8. Of course serious distortion will be evidenced if the above mentioned dips fall back of the cut-off point of the characteristic curve.

As long as the average radio frequency input to the modulation booster remains constant, fixed bias for the booster stage can be used. Likewise, other types of bias can be used. If the average carrier amplitude is likely to change spontaneously, fixed bias may not be desirable since overmodulation of the output can occur if the carrier strength drops enough to place the modulation dips back of cut-off. The use of a selfbiasing scheme, such as a grid leak bias, with the grid leak and condenser having a sufficiently long time constant to prevent the bias from following the modulation, will eliminate many of the difficulties arising from a shifting input intensity.

With a grid leak bias, the peaks in the modulation come just on the edge of zero bias regardless of the input intensity. When the output is to be modulated 100 per cent, either the absolute amplitude of the input modulation should be such that the dips fall at cut-off or the position of the cut-off point should be moved until it coincides with the dips in the modulation. The position of the cut-off point can be controlled by using a pentode for the tube V of Figure 3 and adjusting the screen or suppressor-grid potentials.

As an example of the above described control, Figures 6 and 8 are illustrative. Figure 4 shows the cut-off set at a value such that it is at a remote point with respect to the modulation dips,

which dips illustrate a low degree of modulation. In this case the modulation is boosted but falls far short of reaching 100 per cent.

Figure 6 shows the cut-off set at a point near zero and a low degree of input modulation. In this case the percent modulation is boosted to approximately 100 per cent.

Figure 8 shows an absolute amplitude increase in the input modulation by an increase in the carrier strength. Similar results can be accomplished by an increase in the per cent modulation. In this case the modulation is boosted to around 100 per cent.

It has already been explained that, in addition to the fundamental radio frequency carrier in the output, the plate circuit also contains harmonics of the fundamental. The output circuit may, therefore, be tuned to any of these harmonics and the tube then serves as both a modulation booster and a frequency multiplier. For example, the fundamental frequency F_1 (say, 1100 k. c.) supplied by oscillator OSC in Figure 1 may be modulated very weakly in the above mentioned intra-tank communication system, this frequency is then multiplied to 2200 k. c. and the modulation boosted by the modulation booster, so that the signal may be satisfactorily received by the receiver tuned to 2200 k. c.

As long as the modulated portion of the radio frequency envelope falls on the linear portion of the E_g-I_p characteristic curve there is no troublesome distortion introduced into the modulation of the various harmonics and the modulation percentage is substantially the same at the harmonics as at the fundamental.

I am aware that frequency multipliers are old in the art, but as far as I know they have been used only on unmodulated carriers because it was felt that such multipliers would introduce serious modulation distortion if an attempt was made to multiply a modulated carrier. I am cognizant of the fact that, in my system, distortion will appear if the modulated portion of the carrier does not fall on the linear portion of the characteristic curve of the tube, but with an input of a very low percentage of modulation it can very readily be made to fall on this portion of the curve.

Another application of my modulation booster system is that it may serve as a conventional grid modulated class C amplifier, in addition to its function as a modulation booster and frequency multiplier. To accomplish this, an audio frequency can be added to the radio frequency input of Figure 3 and applied to the grid circuit, as shown by the lower curve of Figure 5. This audio frequency will, in effect, swing the operating point of the tube and the output circuit will contain a radio frequency, modulated with the audio frequency signal, as illustrated in Figure 5.

In order to simplify the drawings, only one edge of the input carrier is illustrated in Figures 6 and 8. Since the omitted portion of the carrier falls back of cut-off, it is believed unnecessary to show it.

The circuit of Figure 9 is similar to that shown in Figure 3. However, a potentiometer P is provided to permit variation of the bias on tube or discharge device V and there are provided two sets of input connections as indicated, so that one or two microphones, for example, can be used at any one time. The resulting modulation envelope consists of the modulation from one or both sources of signal input.

It will be understood that cathode modulation

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can be used if desired by introducing one or both signal inputs into the cathode lead. Moreover, grid modulation through the agency of multi-grid tubes can also be employed in the practice of my invention.

This explanation of my invention has dealt primarily with operation in connection with an intra-tank communication system, in which a very low degree of modulation is primarily produced and then stepped up or boosted to a very high degree, without the introduction of distortion, and operating on the high radio frequency currents. Application of this invention may, however, be found in other classes of service, such as in the radio art or in carrier system telephony. For example, in radio broadcast transmitters, particular care is required to design a class C stage which can be modulated to 100 per cent without introducing distortion, but by removing the necessity of securing 100 per cent in the modulated stage, distortionless modulation is secured and a weakly modulated carrier can be fed into my modulation booster to secure 100 per cent modulation. Such an expedient would require a comparatively small amount of audio power and the desired radio frequency power could be secured by either class A or class B amplifiers following the modulation booster.

While I have gone into considerable detail in pointing out the various features of my invention, it will be apparent that many modifications thereof might suggest themselves to those skilled in the art and I accordingly do not desire to limit my invention to the specific details disclosed except as may be necessitated by the prior art and the appended claims.

What I claim is:

1. Means for producing a high degree of modulation of a source of carrier waves, a plurality of amplifiers of the space current type connected in tandem, means associated with said amplifiers and normally effective to prevent the flow of space current therethrough, an output circuit for the first amplifier in tandem tuned to the frequency of said source, means for coupling said source to said first amplifier, an output circuit for the last amplifier in tandem tuned to a harmonic of the frequency of said source, and means for appreciably increasing the percentage of modulation between said source of carrier waves and said harmonic of said source.

2. In a high frequency transmitting system including a thermionic valve, a source of unmodulated high frequency waves, means for modulating said high frequency waves to a comparatively low degree, a biasing source for supplying a fixed negative potential to the control electrode of said valve, means for connecting said sources to the control electrode of said valve, and means controlled by the relationship between said sources for providing high frequency waves in a circuit connected to the output of said valve which are modulated to a comparatively high degree and which are of a frequency which is a harmonic of said high frequency.

3. In a thermionic amplifier, a cathode, an anode, a control electrode, input and output circuits

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and a source of current in said output circuit, means for applying a series of modulated high frequency impulses to said control electrode, means for applying a negative potential to said control electrode which is so related to said high frequency impulses that only the positive and modulated portion of said high frequency impulses are effective to liberate positive impulses in said output circuit whereby said positive impulses are modulated to a greater degree than said high frequency impulses, means for swinging the negative potential applied to said control electrode for providing the modulation of said high frequency impulses, and means for tuning said output circuit for providing positive impulses which are a multiple of the frequency of said high frequency impulses.

4. In a thermionic amplifier, a cathode, an anode, a control electrode, input and output circuits and a source of current in said output circuit, means for applying a plurality of series of modulated high frequency impulses to said control electrode, means for applying a negative potential to said control electrode which is so related to said high frequency impulses that only the positive and modulated portion of said high frequency impulses are effective to liberate positive impulses in said output circuit whereby said positive impulses are modulated to a greater degree than said high frequency impulses, means for swinging the negative potential applied to said control electrode for providing the modulation of said high frequency impulses, and means for tuning said output circuit for providing positive impulses which are a multiple of the frequency of said high frequency impulses.

5. In a thermionic amplifier, a cathode, an anode, a control electrode, input and output circuits and a source of current in said output circuit, means for applying a series of modulated high frequency impulses to said control electrode, means for applying an adjustable negative potential to said control electrode which is so related to said high frequency impulses that only the positive and modulated portion of said high frequency impulses are effective to liberate positive impulses in said output circuit whereby said positive impulses are modulated to a greater degree than said high frequency impulses, means for swinging the negative potential applied to said control electrode for providing the modulation of said high frequency impulses, and means for tuning said output circuit for providing positive impulses which are a multiple of the frequency of said high frequency impulses.

FRANK H. SLAYMAKER.

REFERENCES CITED

The following references are of record in the file of this patent:

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Number	Name	Date
1,687,245	Heising	Oct. 9, 1928
2,215,672	Terman	Sept. 24, 1940
2,403,245	Slaymaker	July 2, 1946