July 26, 1949. T. K. RIGGEN 2,477,547

MODULATION OF RADIO-FREQUENCY OSCILLATIONS

Filed Jan. 3, 1945 2 Sheets-Sheet 1

Fig. 1

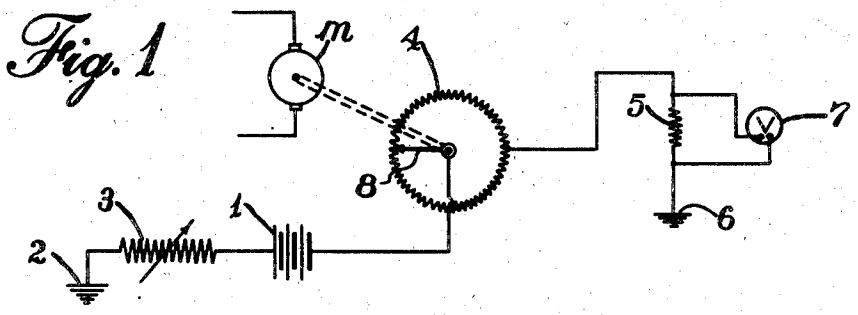


Fig. 2

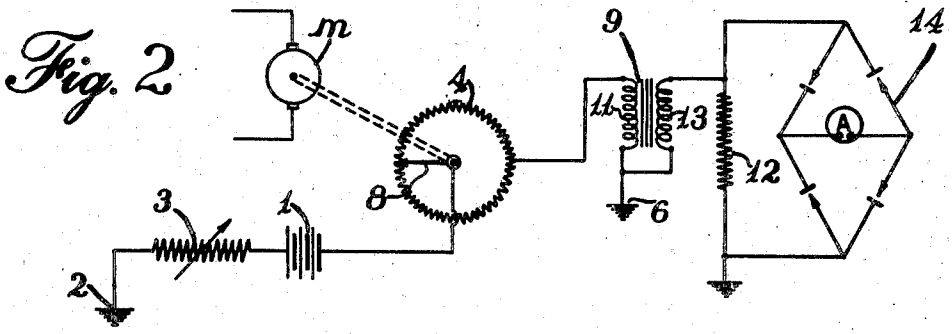
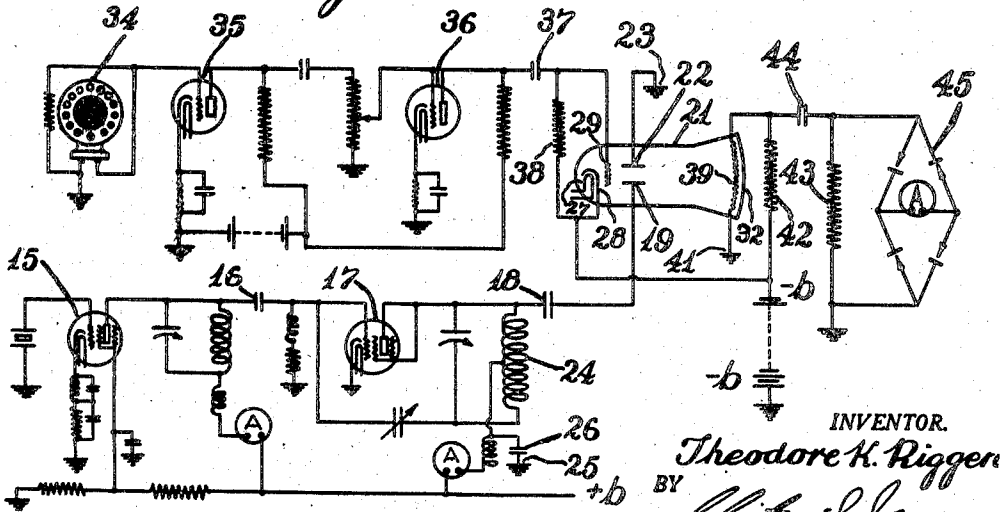


Fig. 3



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Fig. 4

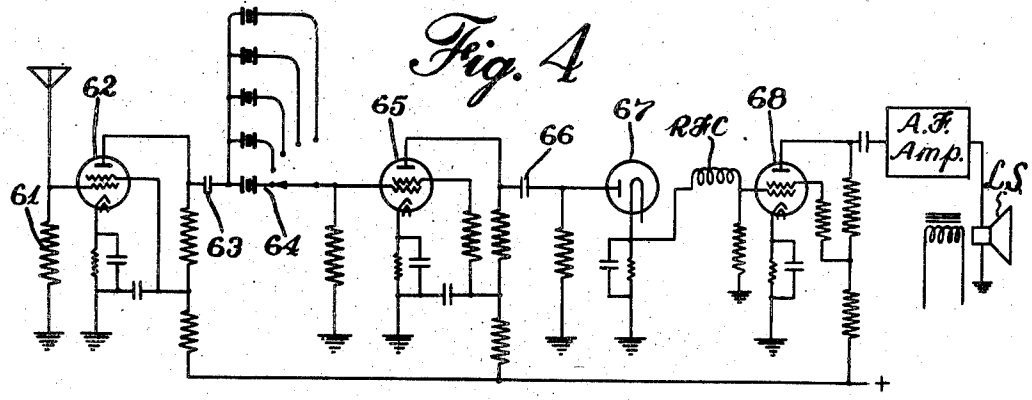
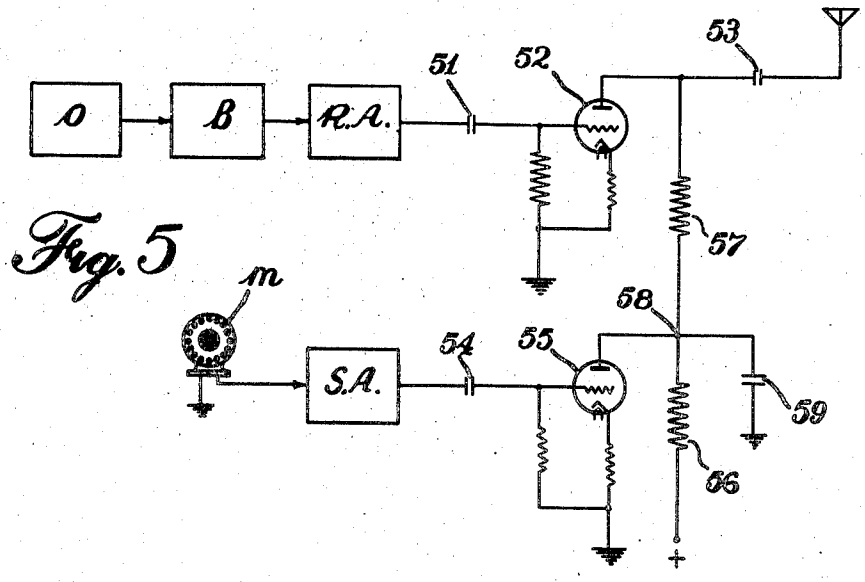


Fig. 5



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MODULATION OF RADIO-FREQUENCY OSCILLATIONS

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1 Claim. (Cl. 332—58)

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The present invention relates to a method and apparatus for modulation of radio-frequency oscillations, and more particularly to controlling the amplitude of radio-frequency oscillations without affecting their frequency.

In known methods of amplitude modulation of carrier frequencies the modulation produces additional frequencies known as side bands, constituted by the sum and difference of the carrier and modulating frequencies. Examination of this phenomenon indicates that it is due to the effects of variations of power input on oscillatory tank circuits containing inductance and capacity.

Amplitude modulation of radio-frequency oscillation is now commonly accomplished by varying the plate voltage or the grid bias of the radio-frequency output tube in accordance with the audio-frequency signal to be transmitted, or sometimes by applying the modulating frequency to the cathode. All of these systems result in variations of voltage across the plate tank circuit of the radio-frequency output tube, and consequent variations of output frequency. This effect is so universally accepted as a phenomenon of amplitude modulation that the term "to modulate" in an electrical sense is commonly defined as "to change the frequency of electrical oscillations or waves by imposing upon them others of another, usually a lower, frequency."

The creation of side bands by present methods of amplitude modulation has made it necessary to divide the broadcast band of frequencies into channels separated sufficiently to prevent interference between adjacent side bands. The presently accepted channel width is ten kilocycles, which thus allows only one hundred channels of communication in the whole broadcast band. On the other hand, the broadcast stations are required to maintain their mean carrier frequency within plus or minus twenty-five cycles per second, so that if no side bands were formed, over twenty thousand channels would be available in the broadcast band.

It is an object of the present invention to provide a novel system of impressing a signal on a radio-frequency carrier without affecting the frequency of the carrier.

It is another object to provide such a system in which the amplitude of the carrier may be varied to any desired degree and at any desired frequency without changing the frequency of the carrier, or causing any mixing, drifting, or heterodyne effect.

It is another object to provide a novel system for reception of the carrier-frequency and detection and faithful reproduction of the signal

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impressed thereon in accordance with said system.

Further objects and advantages will be apparent in the following description taken in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatic representation of a simple form of apparatus for demonstrating the principle of applicant's invention;

Fig. 2 is a similar view of such apparatus with the addition of a means for rectifying or demodulating the output;

Fig. 3 is a diagram of a complete radio-frequency generator and modulator constructed in accordance with the principle of the invention;

Fig. 4 is a diagram of one form of receiver capable of amplifying and detecting a modulated radio-frequency carrier of a single frequency; and

Fig. 5 is a diagram of an embodiment of the invention in which modulation is secured in a manner analogous to the common methods of plate modulation.

In Fig. 1 of the drawing there is diagrammatically illustrated a device for showing the principle of applicant's invention. As there shown, a battery 1 has one terminal grounded at 2 through a variable resistor 3. The opposite terminal of the battery is connected through a continuously variable resistor 4 to a load resistor 5 which is grounded at 6 to complete the circuit. A voltmeter 7 is used to measure the voltage drop across the load. The arm 8 of the variable resistor 4 is rotatable by any suitable means, such as a motor M.

If the potentiometer arm 8 is rotated at a constant speed, the voltage drop across the load 5 will vary at a corresponding frequency. If now the variable resistor 3 be adjusted to change its value, the amplitude of the pulsations of voltage across the load will vary in accordance therewith, but this variation will obviously not affect the frequency of said oscillations as determined by the rotation of the potentiometer arm.

In Fig. 2 the output of the device is passed through a transformer 9, the primary 11 of which forms the ground connection for the pulsating circuit. A load resistor 12 is connected across the secondary 13 of the transformer whereby the alternating output of the transformer is expressed across the resistor. A bridge rectifier indicated generally by numeral 14 is connected to the ends of the load resistor 12 and an ammeter A placed in the common lead to measure the flow of rectified current.

As the motor M drives the variable resistor

arm 8, the direct current change caused by such rotation will produce an alternating voltage at the terminals of the secondary 13 of transformer 9. The frequency of this alternating current will be governed entirely by the rotation of the arm 8. As long as the arm is moving there will be a change of flux in the transformer 9 and, therefore, a current reading in the ammeter A. The frequency of the output current will be dependent entirely upon the angular velocity of the arm 8, but the instantaneous value of the current passing through the ammeter A will be dependent both on the instantaneous position of the potentiometer arm, and on the setting of the variable resistor 3.

If we assume that the movement of the arm 8 is so fast that an R. M. S. meter is necessary at A, then the instantaneous values of the current will be read as averages on the meter. If the resistor 3 is now varied at a rate considerably slower than the frequency of rotation of the arm 8 this variation will be read on the meter A entirely as an amplitude change. It will be seen, therefore, that the change in amplitude caused by variation of the resistor 3 has no effect on the frequency of the alternating current delivered by the transformer 9.

In Fig. 3 of the drawing there is illustrated a device for accomplishing the result above set forth at radio-frequencies by means of a special cathode-ray tube used in place of the motor and variable resistor. As there shown, a crystal oscillator of conventional type indicated generally by numeral 15 is coupled by the condenser 16 to an amplifying tube 17, the output of which is tuned to the frequency of the crystal, and applied through a coupling condenser 18 to one deflector plate 19 of a cathode-ray tube 21.

The opposite deflector plate 22 of the cathode-ray tube is grounded at 23, and the tuned tank circuit 24 of the amplifying tube 17 is also grounded at 25 as to radio-frequency through a condenser 26 so that the alternating voltage produced by the amplifier is expressed across the deflecting plates 19—22 of the cathode-ray tube 21.

The cathode-ray tube is provided with the usual means including heater 27, cathode 28, and control grid 29, whereby an electronic beam is formed and directed between the plates 19—22 to the screen 32 of the tube. Means are provided for varying the intensity of the electronic beam by varying the potential of the control grid 29. As here shown the voltage of grid 29 is controlled by a modulator system comprising a microphone 34 and resistance coupled amplifying tubes 35 and 36. The output of the final amplifier tube 36 is coupled to the control grid 29 by a condenser 37, the output voltage being expressed across a resistor 38 connected to the cathode 28 and grid 29 of the cathode-ray tube.

A resistor 39 is mounted adjacent the screen 32 of the cathode-ray tube in position to be impinged upon by the electronic beam. One end of the resistor 39 is grounded at 41, and the other end is connected to an output load resistor 42 which is connected to the cathode to complete the circuit of the electronic beam. The alternating component of the voltage across the load resistor 42 is expressed across a resistor 43 by means of a coupling condenser 44, and a bridge rectifier 45 having an ammeter A in its common lead is arranged to indicate the amplitude of the oscillations in the output in the same manner as described in connection with Fig. 2.

Changes in voltage between the deflecting plates 19—22 of the cathode-ray tube 21 cause the electronic beam to oscillate in accordance therewith, whereby it traverses the resistor 39 and thereby places more or less of said resistor in the circuit of the electronic beam. The changes in current through said circuit caused thereby are expressed as an alternating voltage across the output resistor 43, the average amplitude of which oscillations is indicated by the reading of the meter A.

Inasmuch as the voltage across the plates 19—22 is controlled by the oscillations of the radio-frequency oscillator-amplifier 15—16—17, it will be seen that a radio-frequency wave having the exact frequency of the crystal 15 will be produced across the output resistor 43. When the voltage of the control grid 29 is varied at audio-frequency by modulator 34—35—36, the intensity of the beam will be varied accordingly, without, however, having any effect upon the frequency of the oscillations of the beam. The variations in intensity of the beam are accordingly expressed across the terminals of the meter A, and if a signal reproducing device such as a loud speaker be placed in the position of the meter, an audio-frequency signal impressed on the microphone 34 will be reproduced by the loud speaker.

Obviously the coupling condenser 44 might be replaced by antennae connected to the output load 42 and the input resistor 43 respectively, suitable amplification being provided in the receiver to secure the necessary strength in the output signal.

It will be seen that the structure illustrated in Fig. 3 is essentially analogous to the simpler circuits illustrated in Figs. 1 and 2, the cathode-ray tube 21 being substituted for the variable resistor 4, the beam of electrons in the tube corresponding to the arm 8 of the variable resistor, and the crystal-controlled oscillator 15—16—17 corresponding to the motor M. The movement of the beam of electrons in the cathode-ray tube is controlled entirely by the oscillator 15—16—17 whereas the intensity of the beam is controlled by the modulator 34—35—36. The instantaneous current across the output resistor 42 is, therefore, a resultant of the intensity of the beam and the position of the point of impingement of the beam on the resistor 39.

A study of circuits containing inductance and capacity shows that the inductive reactance of any coil is a function, in part, of the current traversing the coil. This is true because the inductance is affected by the amount of flux produced by the current. Thus when the current through the coil is increased, the flux is increased, which in turn increases the counter E. M. F. developed by the coil, and, therefore, the ability of the coil to resist the flow of current. This ability to resist the flow of current is inductive reactance.

In the normal transmitter wherein the plate load of the amplifier is a circuit containing inductance and capacity and the grid is driven from a self-controlled oscillator, it is a recognized fact that a considerable change in plate voltage on the amplifier will tend to alter materially the frequency delivered by the amplifier. In order to explain this phenomenon, let us suppose that we have such an amplifier with means for altering the plate voltage. If the plate voltage be increased the current drawn by the plate through the circuit containing inductance and capacity will be increased. The inductive reactance of

the coil will, therefore, be increased and the frequency to which the circuit is tuned will accordingly be decreased. When the plate voltage is returned to its normal value the inductive reactance of the coil will return to its normal value and the frequency of oscillation of the circuit will be the same as before the voltage was increased. The converse of this action will, of course, take place if the plate voltage be lowered instead of increased. This same effect also occurs even when a crystal-controlled oscillator is used, but in this case the effects referred to occur only during the raising and lowering of the plate voltage and if the plate voltage be held for an appreciable time at the new level the frequency of the oscillating circuit will return to its frequency at the original voltage as determined by the crystal oscillator. This phenomenon is true whether the circuit containing inductance and capacity is a part of a transmitter or a receiver or a tuner or a wave trap.

The only permanent change that can be made by a change in plate voltage when a crystal-controlled oscillator is used is to reduce the amplitude of the output signal in the same way that the amplitude would be reduced by detuning the tank circuit by a physical change in inductance or capacity. It, therefore, follows that the elimination of inductance from such circuits would eliminate the existence of side bands. The method shown in the structure so far described constitutes one means of modulating a carrier frequency without recourse to circuits containing inductance and capacity. Another means of accomplishing this is the substitution of resistance coupling for tuned circuit coupling throughout the transmitter and receiver. Such arrangements are shown in Figs. 5 and 4 of the drawing respectively.

In Fig. 5 there is illustrated by conventional block symbols, a constant radio-frequency oscillator O, a buffer stage B, and a radio-frequency amplifier RA which is coupled by a condenser **51** to an output tube **52**, the plate of which is connected through a coupling condenser **53** to an antenna whereby a carrier wave of the frequency of the oscillator is radiated.

Modulation of the carrier wave is effected by means of a microphone M and speech amplifier SA coupled by a condenser **54** to the modulator tube **55**. The plate voltage for the output tube **52** is supplied through resistors **56** and **57** in series, and the plate of the modulator tube **55** is connected to the junction **58** between said resistors, which junction is preferably grounded as to radio-frequency through a condenser **59**. The resistor **57** thus becomes in effect the load resistor for the output oscillator tube **52** while the resistor **56** is the load resistor for the modulator tube **55**.

With the oscillator in operation, and a carrier frequency emitted by the output tube **52** being radiated by the antenna, if a signal is impressed on the modulator tube **55** by the speech amplifier, the voltage of the junction point **58** is caused to vary by virtue of the varying voltage drop across the audio-frequency load resistor **56**. This variation in voltage correspondingly varies the amplitude of the oscillations radiated by the antenna, but since there are no inductive elements in the plate circuit of the output tube **52**, these variations in amplitude have no effect upon the frequency of the radiated oscillations.

Fig. 4 shows one form of receiver capable of receiving and detecting such a modulated single radio-frequency transmission. As there shown, the voltage received by the antenna is expressed across a resistor **61**, and impressed on the grid of a resistance-coupled amplifier tube **62**. The alternating current component of the output of the tube **62** is conducted by a condenser **63** through a crystal filter indicated generally by numeral **64**. The output of the crystal filter is impressed on the grid of a second resistance coupled amplifier tube **65**, which is connected by a capacitive coupling **66** to a detector tube **67**. The audio frequency output of the detecter is transmitted through the radio-frequency choke R. F. C. to the grid of the resistance-coupled audio-amplifier tube **68**, the output of which is further amplified and conducted to the loud speaker L. S.

The crystal filter **64** can be made to pass only a single frequency and variations therefrom within the limitations of commercial operation. Since, however, that frequency is the only one which is being radiated by the station in Fig. 4, the radiated signal passes freely through the filter and the non-inductive circuits of the receiver, and is detected and reproduced with fidelity. It thus becomes possible to separate and satisfactorily receive pure amplitude modulated carrier waves radiated from stations the carrier frequencies of which are separated only by a few cycles per second.

If more than one frequency is to be received, a separate crystal must be provided for each frequency, and a selector switch used as indicated to connect the desired crystal.

When in the specifications and claims, a circuit or an element of a circuit is described as being substantially non-inductive, it is intended to define that circuit or element as such that its predominent characteristics are not determined or controlled by inductive factors. It is recognized, of course, that even straight conductors have some inductance, but a circuit composed of tubes, resistors, and condensers with proper connections, having no coils or "lumped" inductances is here defined as "substantially non-inductive."

Although certain structure has been shown and described in detail, and certain theories of operation and explanations of phenomena have been given as constituting the present understanding of applicant, it will be understood that other embodiments of the invention are possible, and the theories set forth may not in fact eventually prove to be the accurate or complete explanation of the phenomena, so that the invention is not to be restricted further than as defined in the claim appended hereto.

What is claimed is:

A source of purely amplitude-modulated electrical oscillations including a cathode-ray tube having a cathode an accelerating grid and a pair of deflecting plates, means for impressing an alternating voltage of substantially constant frequency across the plates to cause the electronic beam to be correspondingly deflected, means for impressing a variable voltage on the grid of the cathode-ray tube to correspondingly vary the intensity of the beam, a non-inductive linear resistor in the tube in position to be traversed by the sweep of the beam, and a non-inductive return circuit to the cathode of the tube in which said resistor is more or less included depending upon the position of the beam.

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