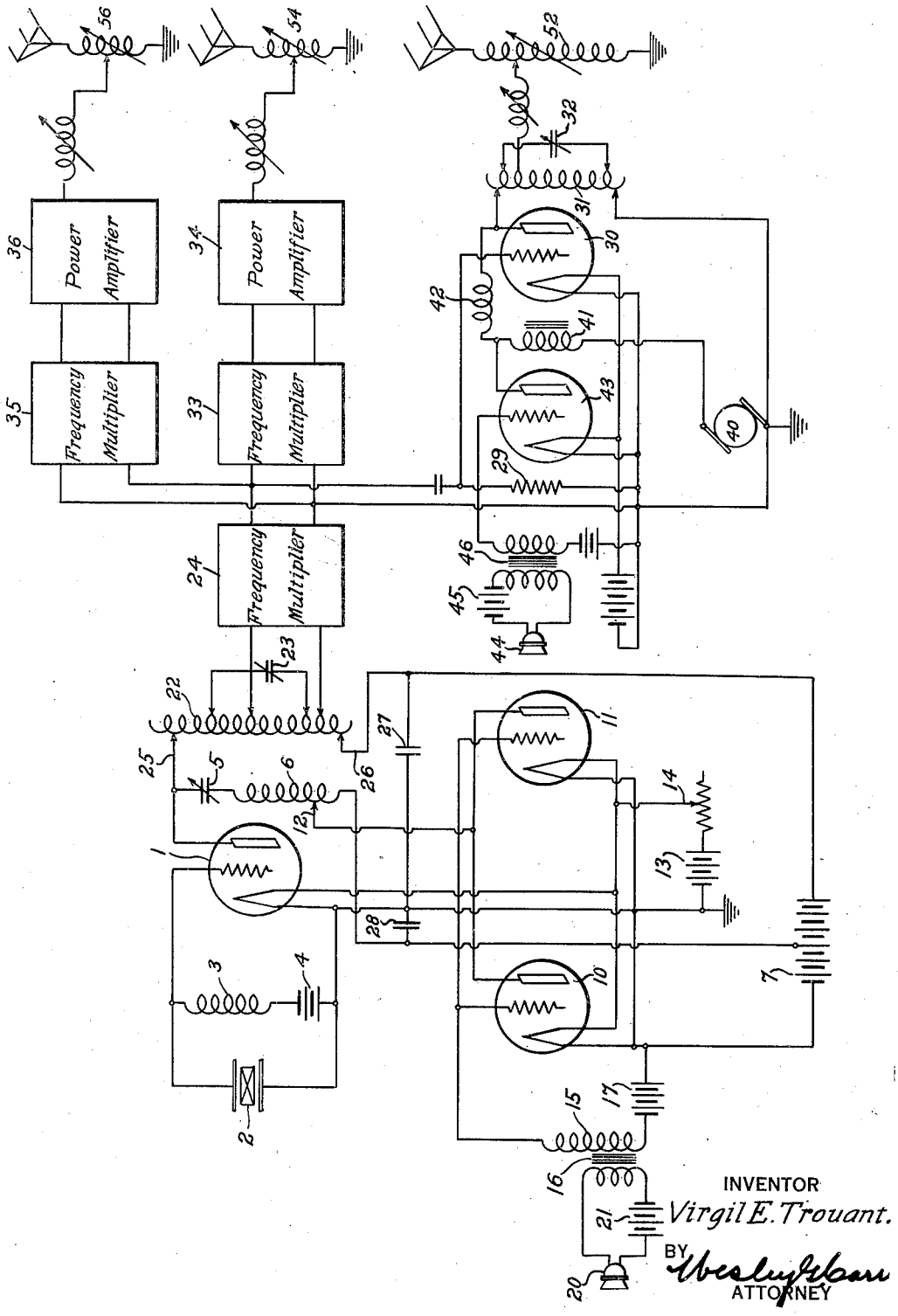
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RADIO STATION

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RADIO STATION

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This invention relates to radio broadcasting and particularly to that method of broadcasting in which the modulation is effected by small changes in the frequency of the radiated wave.

It is common practice to control the frequency of the output of a radio broadcasting station by means of a master oscillator. It has recently been found that a signal may be impressed upon the output by varying the frequency of the master oscillator, the changes in frequency being so small that, although the degree of response of the tuned circuit in the receiving set is altered by such frequency changes, the response is not sufficiently reduced thereby to cause the signal to be lost.

I have discovered that, when the modulation is produced by means of frequency changes, the number of amplifiers may be reduced and the amplification effected in each stage increased because it is no longer necessary to restrict the operation of the amplifying tubes to those portions of their characteristics which are substantially straight.

It is an object of my invention to take advantage of this circumstance to obtain faithful reproduction of the signal by amplifiers working over greater parts of their characteristics than has heretofore been practical and thus to provide the necessary increase in frequency and in amplitude between the master oscillator and the antenna by a minimum number of tubes.

It is a further object of my invention to provide for sending the same signal at a plurality of different carrier-wave frequencies.

It is a further object of my invention to provide for the simultaneous broadcasting of two signals upon a single carrier frequency.

It is a further object of my invention to provide frequency-shift modulation and amplitude modulation of the same carrier wave in such a way that the two modulations may both be received.

Other objects of my invention and details of the construction used may be learned from the following description in connection with the accompanying drawing, in which the single figure is a diagram of the circuits and apparatus embodied.

The master oscillator 1 may be of any standard or well known type. A master oscillator of the type controlled by a piezo-electric crystal has been chosen for illustration. The crystal 2, in parallel with an inductance 3 and a C battery 4, is placed, as usual, in the grid circuit of the master oscillator 1. One portion of the plate circuit, including a condenser 5 and an inductor 6, is energized, in the usual way, from a portion of the B battery 7.

An adjustable portion of the inductor 6 is shunted by an impedance controlled by the signal. This impedance includes a tube or several tubes 10 and 11 in parallel. The plates of the tubes 10 and 11 are connected together and to the adjustable contact 12 upon the inductor 6. The filaments of the tubes 10 and 11 are connected together and to the filament of the master-oscillator tube 1, all of said filaments being supplied from a common A battery 13 and adjusted by a common rheostat 14.

The grids of the tubes 10 and 11 are connected together and, through the secondary 15 of a transformer 16, to the C battery 17 and, through this battery, to the filaments. The primary of the transformer 16 is supplied with signal-frequency current, as indicated by the microphone 20 and the battery 21.

The master oscillator 1 is coupled to a frequency changer 24 through a tuned coupling circuit, constituting another portion of the plate circuit and including an inductor 22 and a condenser 23 in parallel. The coupling includes adjustable connections 25 and 26 from the master oscillator to the inductor 22.

The coupling between the connection 26 and the lower end of the inductor 6 is through two condensers 27 and 28 in series. The condenser 27 serves to conduct the high-frequency current in the inductor 22 around the whole of the battery 7 which supplies the plate current for tube 1, and the condenser 28 serves to conduct the high-frequency current in the inductor 6 around that portion of the battery 7 which supplies the plate potential

needed to prevent tubes 10 and 11 from being merely rectifiers.

The frequency changer 24 may be of any desired or well known form. For most of the objects of this invention, it is necessary that the frequency of the output of the frequency changer shall be a constant multiple of that of the input thereof. The output circuit of this frequency changer is connected in parallel to the input circuits of several frequency changers and to a power amplifier 30. The output of the frequency multiplier 24 is impressed upon the grid and the filament of the tube 30. The oscillations delivered by the tube 30, are, therefore, of the frequency supplied by the output of the frequency multiplier 24.

A resistor 29 may be connected across the line from the frequency multiplier 24 to the tube 30, to serve as a grid-leak. When the line is long enough to make the consideration of surges necessary, the resistance of resistor 29 should equal the surge impedance of the line, to minimize reflection. If desired, a grid condenser may be included in the line to provide the grid bias for the tube 30.

The tuned circuit, including an inductor 31 and a condenser 32 in the output of the tube 30 is adjusted to the frequency of the output of the multiplier 24. The frequency in the circuit 31—32 is, consequently, a constant multiple of the frequency delivered by the master oscillator 1.

The output circuit of the frequency multiplier 24 is also connected to the input circuit of the frequency multiplier 33. The output of the frequency multiplier 33 is connected to the input of the power amplifier 34. The power amplifier, therefore, delivers energy at a frequency which is a constant multiple of the frequency generated by the master oscillator 1 but a different multiple thereof from the frequency in the circuit 31—32.

Similarly, the output of the frequency multiplier 24 is connected to the input of a frequency multiplier 35 having a different frequency-multiplying factor from that of the frequency changer 33. The output of the frequency changer 35 is delivered to the power amplifier 36. The output of the power amplifier 36 is thus a constant multiple of the frequency of the master oscillator 1 but the multiple is different from that for the power amplifier 34 and also different from that for the amplifier 30.

Energy for the power amplifier 30 is supplied from a direct-current source 40, through an audio-frequency choke coil 41. Between the choke coil 41 and the plate of the tube 30, a radio-frequency choke coil 42 is inserted. The audio-frequency choke coil 41 is also connected to the plate of the tube 43.

The grid of the tube 43 is influenced by any suitable signalling device. A microphone 44, with the accompanying battery 45 and transformer 46, similar to the corresponding elements associated with the microphone 20, is illustrative of the signalling device. The tube 43 is thus associated with the tube 30 in a way closely similar to the constant-current modulation systems already known.

The tube 30 and each of the power amplifiers are coupled to respective antennæ 52, 54 and 56. Antennæ are chosen for illustrative purposes only. The sending or signaling circuits may be either directly connected wire lines or power lines connected through antenna couplings, instead of the radiating antennæ illustrated.

In the operation of the device, sounds impressed upon the microphone 20 alter the impedance in shunt to a portion of the inductor 6 and correspondingly alter the frequency of the current generated by the master of oscillator 1. This frequency is multiplied by the frequency multipliers, and the currents impressed upon the several signalling circuits have respective frequencies equal to the frequency at the master oscillator multiplied by the product of the multiplying factors of the frequency-increasing devices between the master oscillator and the respective signalling circuits.

Since the multiplying factor of each frequency changer or each combination of frequency changers is different, the radiations delivered by the several antennæ will be of different frequencies. If, for example, the frequency multiplier 24 delivers the third hormonic of the master-oscillator frequency, the frequency multiplier 33 delivers the seventh harmonic of the frequency received by it, and the frequency multiplier 35 delivers the fifth harmonic of the frequency received by it, the antenna 52 will send a frequency three times that of the master oscillator; the antenna 54 will send a frequency twenty-one times that of the master oscillator and the antenna 56 will send a frequency fifteen times that of the master oscillator.

These numbers are chosen for illustration only. In usual practice, the multiplying factors are ordinarily much larger than this, in order that the frequencies delivered to the antennæ may be large enough to be readily radiated even when the master oscillator delivers a frequency which is not very high.

The signal impressed upon the microphone 20 causes changes in the frequency of the master oscillator and changes, which are larger in absolute value although not larger in percentage value, occur in each of the frequencies radiated from the several antennæ.

Practically all receiving sets have a tuned circuit. The response in said circuit is of different intensity for different frequencies. The characteristic curve, showing the intensity of response in such circuit throughout a range of frequencies, comprises a peak, the summit of which corresponds to the fre-

quency to which the circuit is tuned, and low portions each side of the peak, corresponding to frequencies so far removed from the frequency to which the circuit is tuned that the response of the circuit thereto is small.

Frequencies between that to which the circuit is tuned and those for which the response is small produce responses in the tuned circuit represented by the sloping sides of the peak. Throughout a large portion of their lengths the sloping sides are substantially straight. This means that, in the corresponding parts of the frequency range, changes in frequency produce proportional changes in intensity of response in the tuned circuit.

If, therefore, the receiving circuit be so tuned that the average frequency of the received wave corresponds to a point in the midst of one of the straight parts of the curve, the changes in intensity being proportional to the frequency changes impressed upon the carrier wave by the frequency-shift modulation, will reproduce the signal. So long, therefore, as the changes in frequency do not extend beyond the straight part of the curve, the signal impressed upon the microphone 20 will be faithfully reproduced in the receiving set.

By tuning the receiving set, as described, so that the carrier-frequency from one antenna, say 54, corresponds to a point slightly to one side of the resonance peak, the signals are received by frequency-shift modulation over one channel.

Another receiving set tuned to the carrier frequency radiated by the antenna 56 would receive the signal in the same way, but over a different channel.

It frequently happens that atmospheric conditions cause a greater fading at one carrier frequency than at another. If two or more frequencies are conveying the same signal and one fades, the operator of the receiving set may obtain the signal over the other.

Again, by cooperation between the operator of the receiving set and the operator of the sending set, a prearrangement may be effected by which the frequency upon which the signal is to be sent is known only to the sender and receiver and other listeners will be prevented, or at least hindered, from receiving the message.

Obviously, any number of different frequencies may thus be used for sending and any predetermined change from one to another of these frequencies may be effected instantly by switching on or off any one or more of the frequency multipliers.

Since the change to be delivered to the signalling circuit in order to communicate the signal is a change not of amplitude but of frequency, it is unnecessary that the operating characteristics of the tubes used in the several amplifiers shall be linear. This applies not only to the power amplifier but to any amplifying tubes used in the frequency-multiplying devices. The total number of amplifying tubes needed in order to modulate a powerful carrier wave is thus reduced, because each amplifier may be used to produce a much greater amplification than is possible when the output current must be proportional to the input.

Amplifiers intended to respond to amplitude modulation need a constant-bias device to keep the average grid potential near the center of the straight part of the tube operating characteristic. Amplifiers intended for frequency-shift modulation are not thus restricted and such fixed grid-biasing devices are not needed with them. The amplifier at any relaying station may be a duplicate of that at the original sending station when frequency-shift modulation is used.

The receiving set may, if adjusted to the carrier frequency delivered by the antenna 52, obtain the signal from the microphone 20 in the same way as from either of the other antennæ. In order to obtain the signal corresponding to the frequency-shift modulation, the receiving set must be so adjusted that the average frequency from the antenna 52 is not very near the peak of the characteristic curve of the resonant circuit in the receiving set.

If the adjustment is so chosen that the average or carrier frequency falls near the lower end of the straight part of the characteristic curve, changes in amplitude of the waves radiated from the antenna 52 will cause but little difference in the intensity of the signal received.

Even this small change of intensity may be sufficient to interfere with satisfactory reception of voice or music over the frequency-shift apparatus, but the reception of code signals is easy with this adjustment. On the other hand, changes in frequency will produce nearly as great a change in intensity as if the adjustment were such as to bring the average frequency at the middle of the side of the peak. With this adjustment, therefore, signals, or at least, code signals, impressed upon the microphone 20 may be received even in the presence of the signal impressed upon the microphone 44.

If, instead of an adjustment which brings the average frequency upon the side of the peak, the adjustment be so made that the average frequency is at the crest of the peak, changes in frequency will make but a small change in the resulting intensity in the receiving set, while changes in amplitude will, with this adjustment, make maximum changes of intensity in the receiving set.

A receiving set, therefore, tuned approximately to the carrier frequency of the radiation from the antenna 52 may, by adjustment of the tuning, be made to reproduce either the signal from the microphone 20 or the signal

from the microphone 44. In this way, it is possible to send two signals simultaneously over the same wave length.

Moreover, when the adjustment is made to obtain the signal corresponding to frequency-shift modulation, it is possible to minimize the signal corresponding to amplitude modulation and, when the signal corresponding to amplitude modulation is desired, that corresponding to frequency modulation may be practically completely eliminated.

When the tone impressed upon the microphone 20 is of constant pitch, as is frequently the case in code signalling, a band-pass filter may be added in the receiving set to prevent interference with the frequency-shift signal by the amplitude modulation. When such a set is used to receive the signal by amplitude modulation, the filter should be switched out of use. It is thus possible to obtain either signal without interference from the other.

When using code signals of constant pitch, an audio-frequency generator and a key may be substituted for the microphone 20 and battery 21. Code signals may also be sent, if the receiving set is of the heterodyne type, by charging the direct-current bias of tubes 10 and 11 by means of a key.

Again, the invention is useful in systems, like television, where synchronizing must be carried on at the same time as other signalling. For example, the amplitude modulation may correspond to light variation and a shift of frequency at regular intervals, corresponding to the keying of tubes 10 and 11 may correspond to synchronizing. The latter will not interfere with the amplitude modulation or with the reception thereof and, because of the regularity of the frequency shift, the amplitude modulation will not interfere with the reception of the synchronizing signal and the consequent change of heterodyne beat note.

Many modifications of the circuits and apparatus and many other applications of my invention will readily occur to those skilled in the art. That the above description mentions only a few of these is not to be construed as a limitation. No limitation is intended, except such as is required by the prior art or stated in the claims.

I claim as my invention:

1. In combination, a plurality of sending circuits, a common master oscillator therefor, different frequency-multiplying means between said master oscillator and said sending circuits, whereby the frequencies impressed on said circuits, respectively, are different multiples of the frequency of the master oscillator, means for varying the master-oscillator frequency in accordance with a signal and signal-controlled means for varying the amplitude in at least one of said sending circuits.

2. In combination, a plurality of sending circuits, a common master oscillator therefor, different frequency-multiplying means between said master oscillator and said sending circuits, whereby the frequencies impressed on said circuits respectively are different multiples of the frequency of the master oscillator, means for varying the master-oscillator frequency in accordance with a signal and means controlled by a different signal for varying the amplitude in at least one of said sending circuits.

In testimony whereof, I have hereunto subscribed my name this 27th day of April 1928.

VIRGIL E. TROUANT.