May 8, 1934. C. F. JENKINS 1,957,537

MULTIPLEX RADIOCOMMUNICATION

Original Filed Sept. 1, 1926 2 Sheets-Sheet 1

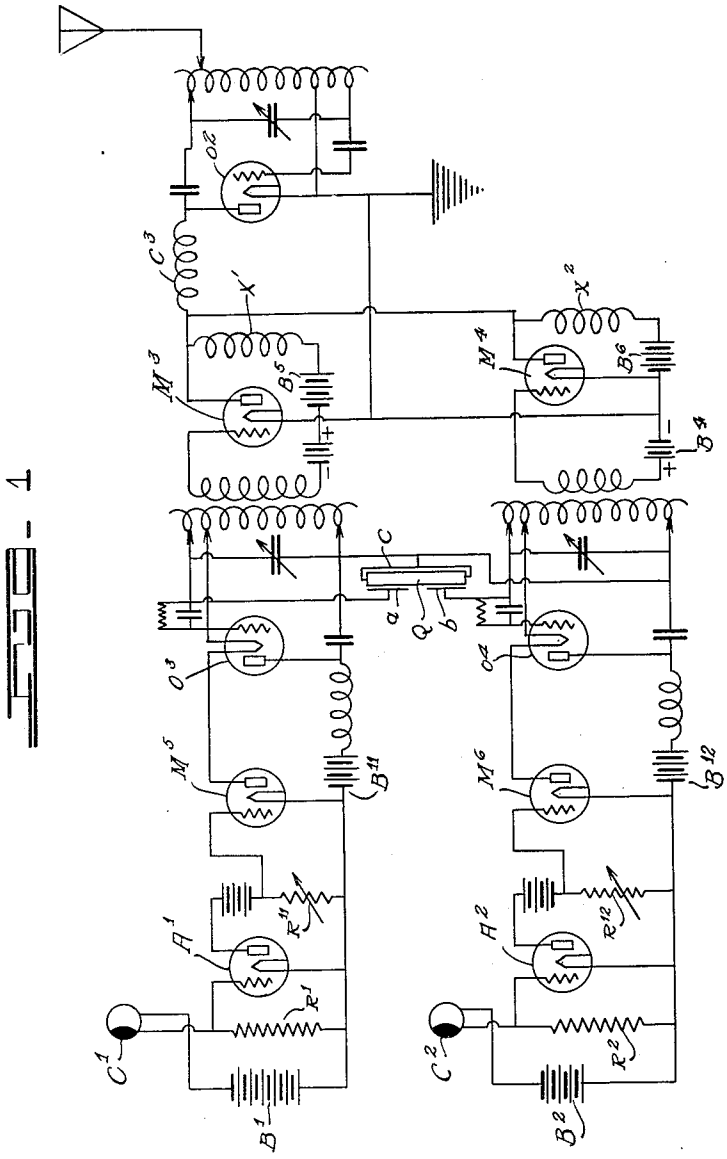


FIG. 1

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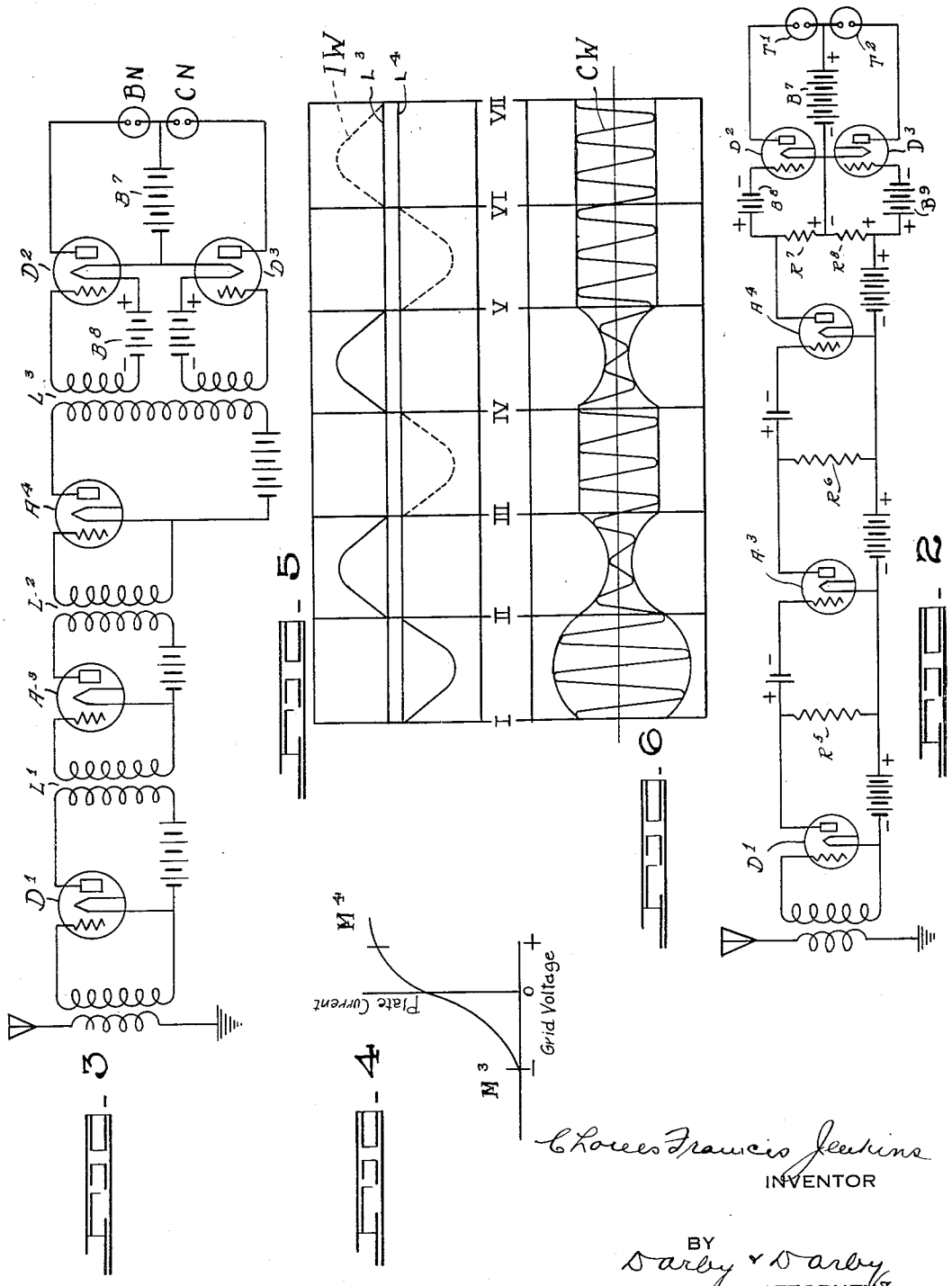


FIG. 5

FIG. 6

FIG. 2

FIG. 3

FIG. 4

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MULTIPLEX RADIOCOMMUNICATION

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Original application September 1, 1926, Serial No. 132,979, now Patent No. 1,914,570, dated June 20, 1933. Divided and this application November 19, 1931, Serial No. 576,005

15 Claims. (Cl. 250—9)

This invention relates to signalling systems, and with particularity to a system for transmitting and receiving a plurality of signals simultaneously.

An object of the invention is to provide a system in which a plurality of signals (or messages or other communications) may be transmitted on a single carrier wave.

With these objects in view the invention contemplates an arrangement in which a composite carrier wave is produced with one portion above a certain amplitude modulated in accordance with one signalling device, and a portion of said composite wave below said certain amplitude modulated in accordance with a second signalling device.

The invention also contemplates a receiving station where the composite wave is received, detected, and the two messages separated and applied to separate signal indicators.

More particularly the invention contemplates an arrangement for generating two separate carrier waves of the same frequency, together with means for insuring the proper phase and synchronism between said carrier waves, and means for modulating only the portion of one wave above a selected amplitude in accordance with signals, and means for modulating the portion of the other wave below said selected amplitude in accordance with a different signal.

In other words, the invention contemplates the generation of two carrier waves of the same frequency and phase, the independent modulation of said waves by separate signal devices, and the recombining of the modulated waves to produce a single composite wave bearing a plurality of modulations.

A feature of the invention relates to a receiving station for a composite carrier wave of the character disclosed, the receiving station being provided with means for receiving and detecting the modulations in the composite wave so as to derive therefrom simultaneously two separate signals.

In accomplishing this latter feature the receiving station is preferably provided with a pair of oppositely poled detectors, each detector being provided with a separate signal indicator.

A still further feature of the invention is to provide a novel high speed electric switching arrangement whereby a plurality of messages transmitted over a single channel may be diverted into separate individual channels.

The invention is a division of application Serial No. 132,979, filed September 1, 1926, issued as Patent No. 1,914,570, dated June 20, 1933.

The present invention is illustrated in the accompanying drawings, in which

Figure 1 is a diagram of one preferable form of transmitting circuit and arrangement for accomplishing the purposes of the invention;

Fig. 2 s a circuit diagram of a preferred form and arrangement of receiving apparatus for accomplishing the purposes of the invention;

Fig. 3 is a circuit diagram of a modified form of receiving arrangement that may be used in practising the invention;

Fig. 4 is a characteristic curve to be used in explaining the operation of the circuits disclosed in Fig. 1; and

Figs. 5 and 6 are schematic wave diagrams employed in explaining the operation of the transmitting arrangement of Fig. 1.

Referring more particularly to Fig. 1, designations O^3 and O^4 represent generators preferably of sustained oscillations of high or intermediate frequency, preferably the latter.

While any well known form of oscillator generator may be employed it is preferable to employ the so-called vacuum tube oscillator which is schematically illustrated in the drawing as being of the three electrode type having a cathode, anode and control electrode. Each of the oscillators O^3 and O^4 is provided with a feedback circuit arrangement of known type for generating the desired frequency of oscillations. Thus there is shown connected across the grid and anode of each of these oscillators, a tunable circuit comprising an inductance and adjustable condenser. A portion of this inductance is also included across the grid cathode and being in inductive relation to the remaining portion of the coil there is produced in the well known manner a sustained oscillating wave whose frequency may be controlled by the adjustable condenser or by the variable nature of the inductances as shown. Ahead of each of the oscillators O^3 and O^4 are respective modulating devices M^5 and M^6, also preferably of the grid control type. These modulators are shown schematically in the drawings as of the vacuum tube type comprising a cathode, anode and control grid. Connected across the grid and cathode of each of the modulator devices is a variable coupling resistance R^{11}, R^{12}. The resistance R^{11} for example, is connected in the output circuit of an amplifier tube A^1, the input circuit of this amplifier being controlled by a suitable signalling device.

The invention contemplates the employment of any known type of signalling devices, and while

the drawings schematically represent a light sensitive signalling device C^1, it will be understood that the invention is not limited thereto. The manner of coupling the signalling device C^1 to the amplifier A^1 or the signal device C^2 to the amplifier A^2 may be in accordance with any well known circuit arrangement. For example, in the drawings the light sensitive cell C^1 is connected in series with a battery B^1 and the coupling resistance R^1, whereby the variations of light shining on the cell C^1 are translated into corresponding potential changes on the grid of the amplifier A^1.

Furthermore, it will be understood that it is not necessary to employ the same type of signalling device for each of the amplifiers A^1 and A^2. For example, the device C^1 may take the form of a television pick-up cell, while the device C^2 may be a microphone that picks up the sounds coincident with the television images to be transmitted, and it will be understood that other combinations of signalling devices may be employed. The modulated output of the oscillators O^3 and O^4 are impressed upon respective rectifier modulators M^3 and M^4. However, in order that the system may function properly, it is necessary that the oscillations from the devices O^3 and O^4 be maintained not only in accurate synchronism, but also in the proper phase relation with respect to each other.

For this purpose there is provided in common to both oscillators a resonator member of any known type. Preferably, however, this resonator is of the piezo electric crystal type. Thus, in Fig. 1 the resonator comprises a piezo or quartz crystal having mounted on one side thereof two separated conducting plates *a* and *b*, and a third conducting plate *c* on the opposite side. Plate *a*, which forms a pair with plate *c* is connected across the frequency determining circuit of oscillator O^3, namely across the grid anode circuit of said oscillator. Similarly the plate *b* which functions as a pair with plate *c* is connected across the frequency determining circuit of the oscillator O^4. The dimensions of crystal Q are preferably so chosen that it has a natural frequency equal to the frequency of the oscillators O^3 and O^4. It will be readily understood that if the frequency determining circuits of oscillators O^3 and O^4 are adjusted even approximately to the frequency of crystal Q, that the action of said crystal, when set in operation, will be to maintain the oscillators in synchronism and proper phase relationship.

As shown in the drawings, the grid electrode of the rectifier modulator M^3 is normally maintained at a negative potential by the battery B^3, while the grid electrode of rectifier modulator M^4 is normally maintained at a positive potential by battery B^4. These respective potentials are preferably adjusted to such values that rectifier modulator M^3 operates on the lower part of the characteristic curve, while rectifier modulator M^4 operates preferably at a point on the upper part of the characteristic curve, the respective points being indicated at M^3 and M^4 in the characteristic curve shown in Fig. 4.

The output circuits of modulators M^3 and M^4 are connected in parallel with the plate circuit of the oscillator O^2, a radio frequency choke coil C^3 being interposed between the rectifier modulators and the said oscillator O^2 for the purpose of preventing radio frequency currents from oscillator O^2 passing into the rectifier modulator. The elements X^1 and X^2 are radio frequency choke coils (whose value is determined by the frequency of oscillators O^3, O^4) placed in the plate circuits of the modulator devices M^3 and M^4 to provide a constant current supply to the rectifier modulators and to the oscillator O^2. The coils X^1 and X^2 function in the well known manner to modulate the output of oscillator O^2 in accordance with the outputs from the devices M^3 and M^4. Batteries B^5 and B^6 supply the necessary plate potential for the devices M^3 and M^4 and the oscillator O^2. It will be understood, of course that a single battery or any other well known source of plate potential may be used for the plate current instead of the separate batteries B^5 and B^6. The oscillator O^2 is preferably designed and provided with a frequency determining circuit of known construction, so as to generate sustained high frequency oscillations which may be radiated in any well known manner from the antenna shown, or if desired, these high frequency currents may be transmitted over line wires to the receiving station. As one illustrative example the oscillator O^2, for example, may generate sustained waves of the order of 3000 kilocycles, while the oscillators O^3 and O^4 generate the intermediate frequency wave of a frequency such as is ordinarily employed in the intermediate frequency portion of super-heterodyne receivers. However, it will be understood that the invention is not limited in this respect so long as the intermediate frequency wave is well outside of the frequency range of the signals to be transmitted.

The operation of the transmitter arrangement shown in Fig. 1 is substantially along the following lines. Varying signals impressed upon the signalling devices C^1 and C^2 produce corresponding varying currents in the output circuits of amplifiers A^1 and A^2. The potentials on the grids of modulators M^5 and M^6, will therefore, vary in accordance with the varying plate currents of amplifiers A^1 and A^2, thereby resulting in corresponding variations of the filament to plate resistance of modulators M^5 and M^6. The variations in internal resistance of modulators M^5 and M^6 will produce corresponding changes in the plate currents of the oscillators O^3 and O^4, thereby modulating the current generated by the oscillators in accordance with the signal impressed upon the respective signalling devices. It will be seen that intermediate frequency currents from the oscillators O^3 and O^4 (which are maintained in synchronism and proper phase relationship by the device Q as above described) will be supplied to the input circuits of rectifier modulators M^3 and M^4, the current supplied to the device M^4 being modulated in accordance with signals impressed upon the signalling device C^2, while the current supplied to the device M^3 is modulated in accordance with signals impressed upon the signalling device C^1.

Assuming for the present that the oscillators O^3, O^4 are not operating, then oscillator O^2 generates a high frequency current of constant amplitude represented by the curve CW in Fig. 6. The unmodulated portions of the current being represented between vertical lines III and IV, and V and VII.

It will be understood that under normal conditions current from batteries B^5 and B^6 is distributed among the plate circuits of rectifier modulators M^3, M^4, and oscillator O^2 in such proportion that oscillator O^2 receives a plate current of a certain normal value, rectifier modu-

lator M^4 receives a plate current of high value (indicated at point M^4, Fig. 4), rectifier modulator M^3 receives very little plate current (indicated at point M^3, Fig. 4). Assuming now that oscillators O^3 and O^4 are in operation, intermediate frequency currents having the same phase and frequency will then be supplied to the devices M^3 and M^4.

Referring to Figs. 5 and 6, the vertical lines indicated by the numerals I to VII indicate the half cycle divisions of the alternating current of intermediate frequency generated by the oscillators O^3 and O^4. Line L3 is an origin line for rectifier modulator M^3, and line 4 is an origin line for rectifier modulator M^4. Assuming that negative alternations from the source O^3 and O^4 are simultaneously impressed upon the respective grid electrodes of devices M^3 and M^4, it will be seen from Fig. 4 that the plate current of the device M^3 will be practically unaffected because of the negative bias resulting from the battery B^3, which normally maintains the plate current very low. However, since modulator M^4 is biased positively by the battery B^4 the effect of this negative modulating potential on the device M^4 will be to increase the filament to plate resistance of the said device M^4 which results in a decrease in the plate current of said device, and a corresponding increase of plate current in oscillator O^2.

The increased plate current supplied to oscillator O^2 results in an increase in the amplitude of the high frequency wave, as indicated between the lines I and II in Fig. 6. Assuming next that a positive alternation of the intermediate frequency waves is impressed upon the grid elements of devices M^3 and M^4, it will be seen from Fig. 4 that the plate current in device M^4 will be practically unaffected since due to the high positive bias from battery B^4 this tube is normally working at the saturation point, but in the case of device M^3 the positive alternation will act to oppose the negative bias from battery B^3, and thereby decrease the filament-to-plate resistance with the result that the device M^3 will take an increased plate current. The decrease in resistance of device M^3 will rob the plate circuit of oscillator O^2 of more of its current, which will result in a decrease in the amplitude of the high frequency waves as indicated between lines II and III, and between lines IV and V of Fig. 7.

It will readily be understood that the amplitudes of the positive and negative alternations of the intermediate frequency waves supplied to devices M^3 and M^4 are controlled respectively by the signalling devices C^1 and C^2. The wave which is radiated from the antenna is, therefore, a doubly modulated wave, i. e., a high frequency wave modulated by an intermediate frequency wave which in turn is modulated by signal modulations. The positive alternations of the intermediate frequency wave are modulated in accordance with one signal, while the negative alternations are modulated in accordance with another signal.

In other words the two signalling devices cause a modulation of the intermediate frequency waves in opposite senses, that is one signalling device causes an increase in amplitude while the other signalling device causes a decrease in amplitude. It will be understood, of course, that the invention is not limited to the selection of zero amplitude as the datum line to which the increase and decrease of the waves is to be referred. The broad aspect of the invention being in the selection of a certain amplitude of oscillation of the high frequency wave, and the increase of this amplitude by one signalling device, and the decrease of the amplitude by the other signalling device.

From the foregoing description it will be apparent that the output of the devices M^3 and M^4 is what may be termed a composite wave of the same frequency as the intermediate frequency waves from which it is derived, and that the positive alternations of this composite wave are modulated in accordance with one signal and the negative alternations are modulated in accordance with another signal. It is, therefore, obvious that instead of modulating oscillator O^2 directly from devices M^3 and M^4, the composite wave produced by the devices M^3 and M^4 may be biased or impressed upon a resistance coupled intermediate frequency power amplifier which would then modulate the oscillator O^2.

If a wire channel is used with the transmitting medium in place of the radiating antenna shown, the composite wave produced by devices M^3 and M^4 need not be transmitted by the carrier wave from oscillator O^2. As a matter of fact, the oscillator O^2 may be omitted and the composite waves may be impressed directly upon the line and transmitted to the distant receiving station. With this latter arrangement a detector at the receiving station will not be necessary.

Referring to Fig. 2, a description will now be given of one form of receiving circuit for separating the composite doubly modulated wave to derive therefrom the two separate signals or messages. In this figure D^1 is a vacuum tube detector, the input circuit of which is coupled to a suitable receiving antenna, as shown and the output circuit of which is coupled to a vacuum tube amplifier A^3 by means of a coupling resistance R^5. The output of amplifier A^3 is likewise coupled to the input circuit of amplifier A^4 by a coupling resistance R^6. The output circuit of amplifier A^4 is connected to a double detector arrangement comprising two vacuum tube detectors D^2 and D^3, two signalling indicator tubes T^1, T^2, and a common plate battery B^7. The indicating devices T^1, T^2 are preferably audible signal indicators, for example telephones, buzzers, or telegraphic sounders or visual or light indicators, or any combination of these may be employed, and are connected respectively in the plate circuits of detectors D^2 and D^3. The input circuits of these detectors are coupled to the output circuit of amplifier A^4 through coupling resistances R^7, R^8, respectively. Each input circuit contains a grid biasing battery indicated at B^8, B^9. The potentials of these batteries are so chosen that normally no current flows through the signal indicating devices T^1 and T^2.

It will be seen that detectors D^2 and D^3 are connected in a differential arrangement with respect to the output circuit of amplifier A^4, that is, they are so connected that the drop in potential across the coupling resistance will produce a negative biasing voltage in one grid circuit, and a positive biasing voltage in the other grid circuit. Consequently the combining voltage of batteries B^8 and B^9 are so adjusted that the plate currents of detectors D^2 and D^3 are reduced substantially to zero. The polarity of the voltage drop across each resistance is indicated by appropriate signs in the drawings.

The operation of the receiving arrangement is as follows:

The incoming wave is received and detected by detector D^1 to derive therefrom the interme-

diate frequency wave bearing the original signal modulations, the positive alternations bearing the modulations of one signal and the negative alternations bearing the modulations of the other signal. The intermediate frequency wave is amplified successively by amplifiers A^3 and A^4 and fed into the double detector arrangement coupled to the output circuit of amplifier A^4. Assuming that a positive alternation of the intermediate frequency wave is flowing in the output circuit of amplifier A^4, and further assuming that the positive alternation tends to increase the normal plate current and produce a corresponding increase in voltage drop across resistances R^7 and R^8 in the input circuits of detectors D^2 and D^3 respectively, the increase in voltage drop across resistance R^7 has the effect of rendering the grid more negative than normally and, therefore, there will be no change in current and no response in signal indicator T^1, but since the voltage drop across resistance R^8 tends to oppose the negative bias on the grid of the detector D^3, a plate current will flow and produce a response in signal indicator T^2. Assuming next that a negative alternation of the intermediate frequency wave is impressed upon the output circuit of amplifier A^4, the result will be a decrease in the plate current of the amplifier. The decrease in the plate current of the amplifier A^4 will again unbalance the biasing voltages in the detector circuits, but in an opposite manner, with the result that plate current will flow and produce a response in signal indicator T^1, and there will be no response in indicator T^2. Thus it will be seen that the receiving arrangement is selective with respect to the positive and negative alternations of the intermediate frequency wave, and the separate messages may be received independently upon indicators T^1 and T^2.

From the foregoing it will be seen that the action of the receiving arrangement is that of a high speed switching device for automatically and instantaneously switching the successive positive and negative alternations, bearing the different signals, into their respective signal detecting and indicating circuits. It is obvious that this arrangement has general utility, and may be used in various situations where it is desired to separate positive and negative pulsations from a single channel and divert them into individual channels.

Fig. 3 shows a modified form of receiving apparatus which differs from the form of Fig. 2 merely by the substitution of coupling transformers L^1, L^2, L^3, for the corresponding coupling resistances R^5, R^6, R^7, R^8. The operation of this embodiment is that of Fig. 2, and will be readily understood in view of the foregoing description of the operation of the arrangement of Fig. 2.

From the foregoing it will be seen that there is provided a system including both method and apparatus for transmitting and receiving multiple signals representing any desired intelligible communication over the same carrier wave, so that it is possible to send and receive a plurality of sets of signals, of which one or more may be messages of voice or code, music or speech, visual effects or audible effects.

Furthermore, while specific apparatus and circuit arrangements are disclosed, the invention is not to be limited thereto, and various changes and modifications may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A radio transmission system comprising a first generator of super-audible alternating current, a second generator of super-audible alternating current, both of said generators generating at the same frequency, means for modulating the currents from said generators with different signals, and means for rectifying only the positive components of one modulated wave, and only the negative components of the other modulated wave.

2. A system according to claim 1 in which the modulated portions of the two currents are combined to form a single composite wave having alternate portions modulated in accordance with separate signals.

3. A radio transmission system comprising a first generator of super-audible alternating current, a second generator of super-audible alternating current of the same frequency as the first current, a first rectifier to which the first current is applied, a second rectifier to which the second current is applied, means for separately modulating currents passed by said rectifiers, and means for combining the rectified currents to produce a single composite carrier wave.

4. A system according to claim 3 in which the said rectifiers are oppositely conductive.

5. The method of transmission which comprises separately generating two alternating currents at the same carrier frequency above audibility, modulating the components of one current, separately modulating the components of the other current, rectifying only the positive components of one modulated wave, rectifying only the negative components of the other modulated wave, and transmitting both said modulated components as a single composite carrier wave.

6. The method of transmission which comprises separately generating two super-audible waves at the same intermediate frequency, generating a third super-audible carrier wave at a different frequency, modulating said two first mentioned super-audible waves, rectifying only the positive components of one of the first mentioned super-audible waves, rectifying only the negative components of the other of the first mentioned super-audible waves, and modulating the super-audible carrier waves by the modulated portions of the first mentioned super-audible waves.

7. The method according to claim 6 in which one of the said first mentioned super-audible waves effects only an increase in amplitude of the second mentioned super-audible waves, while the other of the first mentioned super-audible waves effects only a decrease in the amplitude of the second mentioned super-audible waves.

8. The method of signal transmission which comprises generating a super-audible carrier wave, separately generating two modulated alternating currents, said currents being modulated in accordance with different sets of signals, and modulating said carrier wave by said modulated currents so that one current effects only an increase in the amplitude of the carrier wave, while the other current effects only a decrease in the amplitude of said carrier wave.

9. The method of transmission which comprises separately producing at the same frequency, two intermediate frequency modulated alternating currents, separately rectifying said currents, generating a carrier wave, and modulating said carrier wave by said rectified cur-

rents so that one current effects an increase of the carrier wave amplitude while the other current effects a decrease in the carrier wave amplitude.

10. The method of signal transmission which comprises generating two separate sustained alternating currents at the same frequency, separately modulating said currents in accordance with signals, generating a carrier wave, applying said modulated currents so that one current effects only an increase in the amplitude of the carrier wave while the other current effects only a decrease in the amplitude of the carrier wave receiving said carrier current, and detecting therefrom the original intermediate frequencies and diverting said detected frequencies into respective signal reproducing channels.

11. In a system of the character described, a first generator of super-audible alternating current, a second generator of super-audible alternating current at the same frequency as the first current, means for modulating said currents independently by respective signals, means for generating a carrier wave, and means for modulating said wave only by the positive alternations of one of said modulated currents, and only by the negative alternations of the other of said modulated currents.

12. A system according to claim 11 in which the positive alternations of one modulated current effect only an increase in the carrier wave amplitude while the negative alternations of the other modulated current effect only a decrease in the carrier wave amplitude.

13. A system of the character described comprising a pair of super-audible alternating current generators, means for independently modulating the output of said generators by different signals, a positively poled rectifier to which the output of one generator is applied, a negatively poled rectifier to which the output of the other generator is applied, means for combining the outputs of said rectifiers to form a single composite wave, means for receiving said wave, a positively poled rectifier and a negatively poled rectifier upon which said composite wave is impressed, and a pair of signal reproducing devices connected in the output circuits of said rectifiers so that one signal device is energized only by the detected positive alternations and the other signal device is energized only by the detected negative alternations.

14. A system according to claim 13 comprising means for transmitting the composite wave in the form of a modulated carrier wave.

15. A system according to claim 13 in which the composite wave is transmitted in the form of a carrier wave having its amplitude increased only by the positive portions of the composite wave and having its amplitude decreased only by the negative portions of the composite wave.

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