June 21, 1938. H. DIAMOND 2,121,024

RADIO TRANSMITTING AND RECEIVING SYSTEM

Filed April 25, 1933 3 Sheets-Sheet 1

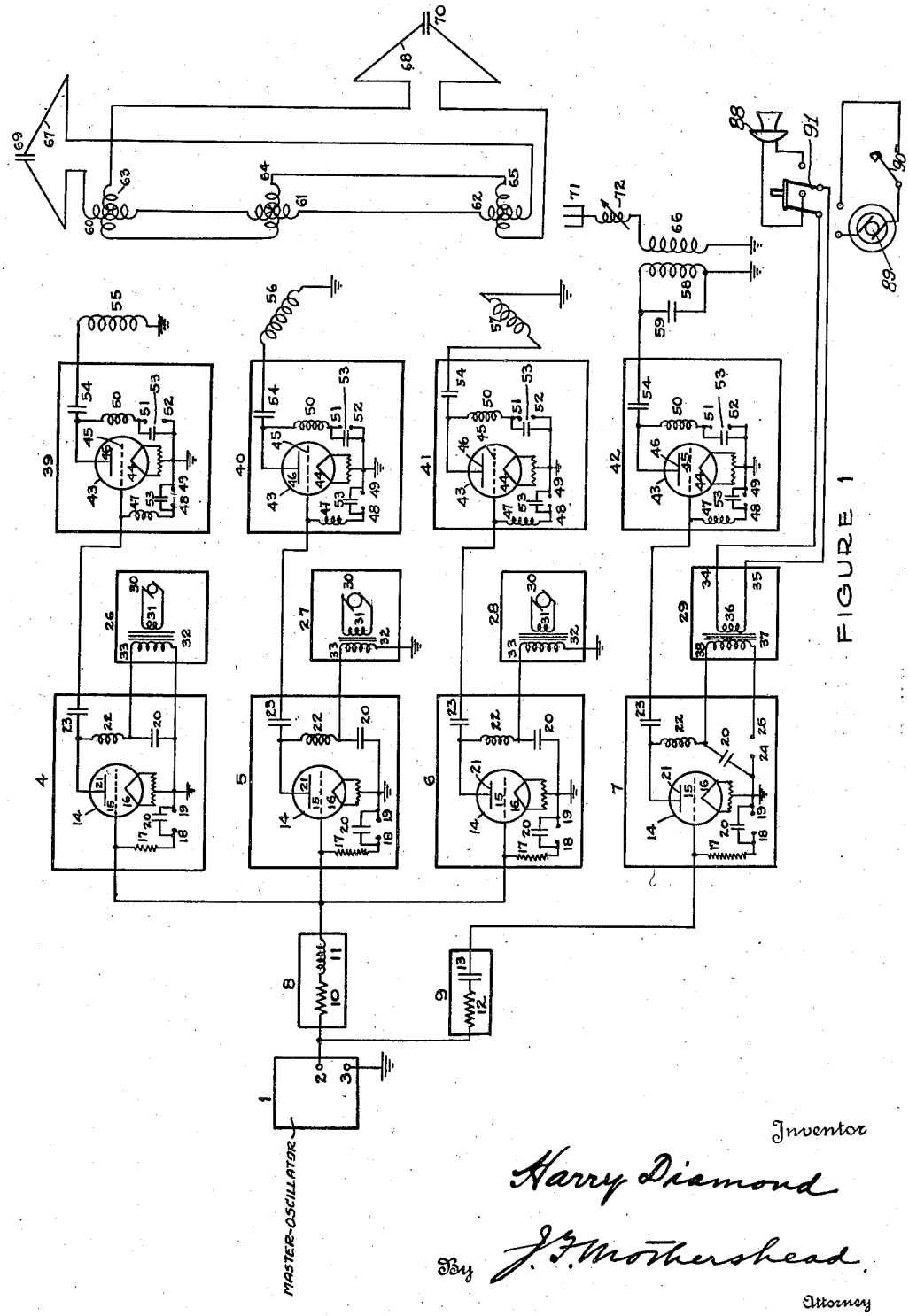

FIGURE 1

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RADIO TRANSMITTING AND RECEIVING SYSTEM

Filed April 25, 1933 3 Sheets-Sheet 2

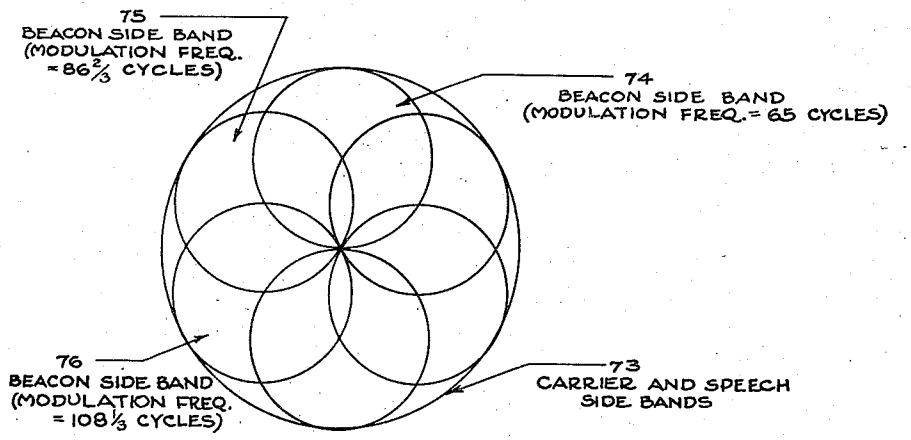

FIGURE 2

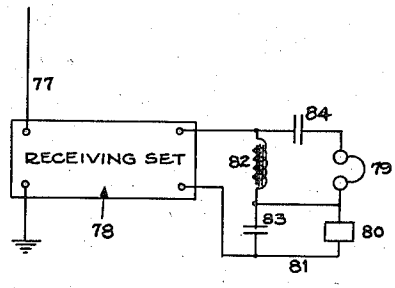

FIGURE 3

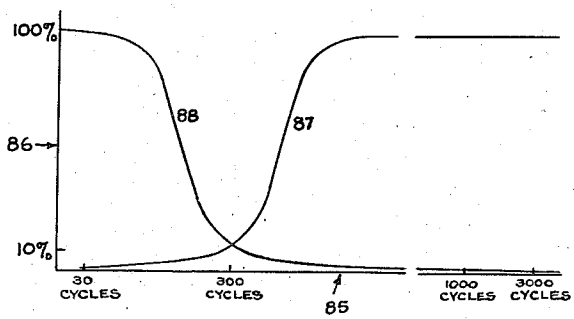

FIGURE 4

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RADIO TRANSMITTING AND RECEIVING SYSTEM

Filed April 25, 1933 3 Sheets-Sheet 3

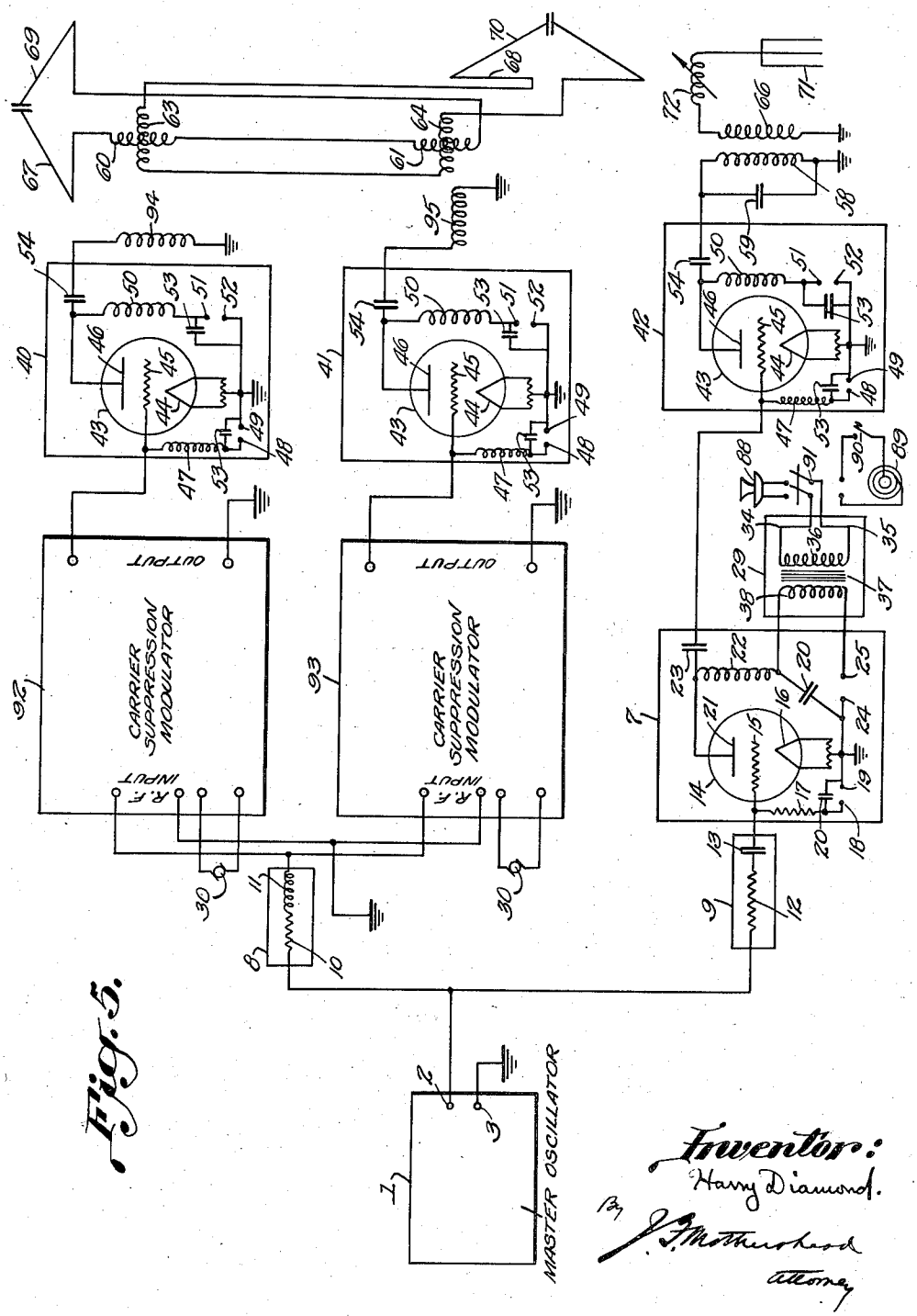

Fig. 5.

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UNITED STATES PATENT OFFICE

2,121,024

RADIO TRANSMITTING AND RECEIVING SYSTEM

Harry Diamond, Washington, D. C., assignor to the Government of the United States, represented by the Secretary of Commerce

Application April 25, 1933, Serial No. 667,848

17 Claims. (Cl. 250—9)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes only, without the payment of any royalty thereon.

The invention relates to a system for the simultaneous transmission of radiotelephone and radio range-beacon signals and their simultaneous reception on aircraft or at other receiving stations. The need for this system will be apparent from the following brief discussion.

In order to facilitate traffic over the airways of the United States, the Department of Commerce provides two types of radio aids to aviation. One consists of the broadcast of radiotelephone messages giving the pilot en route information on weather and landing conditions along his route. The second aid consists of radio range-beacon service which furnishes the pilot with point-to-point guidance so that he may proceed unerringly toward his destination even though no landmarks are visible, and no bearings from astronomical observations can be obtained.

For some time the weather information was broadcast on a different radio frequency from that used for the radio range-beacon service. This proved impracticable, however, both because of the scarcity of available radio frequency channels and because it required constant tuning of the aircraft receiving set on the part of the pilot or observer. As a result, both services are now transmitted on the same radio frequency, the radio range-beacon signals being interrupted for the weather broadcasts.

This produces an essential limitation of one service upon the other. A cardinal requirement for any system of radio navigation is that the service be available at all times. Interrupting the radio range-beacon service violates this requirement, the service being unavailable often when most needed. Pilots depend upon the radio range-beacon signals for locating the station and thereby the landing field. If the signals cease when a pilot is near the station, he frequently misses the field entirely and suffers a consequent loss of time during reorientation. This may prove quite dangerous, particularly in cases where the fuel supply on the aircraft is limited.

In an attempt to reduce the disadvantages resulting from interruption of the radio range-beacon signals, it has become the practice to limit the length of the weather broadcasts. However, this is not practicable beyond a certain limit without omitting important and necessary information. Moreover, the interruptions are quite frequent, particularly at stations located at the intersection of a number of airway routes, so that the time taken up by weather broadcasts is necessarily an appreciable percentage of the entire time. As itinerant pilots begin to equip their airplanes with radio, the problem will become even more difficult. Emergency messages to such pilots will still further reduce the continuity of the radio range-beacon service.

The purpose of my invention is to eliminate this limitation of each of the two services upon the other through the use of the system which I shall now describe.

One object of my invention is to provide a combination transmitter which shall function as both the radiotelephone and radio range-beacon transmitter and which shall transmit the radiotelephone and radio range-beacon signals simultaneously on a single radio-frequency channel and in such manner that the radiotelephone signals are radiated in substantially equal intensity in all directions while the radio range-beacon signals mark out a plurality of equisignal zones or courses.

Another object of my invention is to provide a receiving circuit on the aircraft whereby the radiotelephone and radio range-beacon signals are received simultaneously, the former being directed to the pilot's or observer's phones and the latter to the visual course indicator.

Other and further objects of my invention will appear from the following description, in which—

Fig. 1 shows a transmitting circuit arrangement for the simultaneous transmission of the radiotelephone and radio range-beacon signals.

Fig. 2 shows the space pattern radiated with the transmitting circuit arrangement of Fig. 1.

Fig. 3 shows a receiving circuit arrangement for the reception of the combined signals and for separating them and directing the radiotelephone signals to the telephones and the radio range-beacon signals to the course indicator.

Fig. 4 shows graphs which indicate the functioning of a portion of the circuit arrangement of Fig. 3.

Fig. 5 shows a transmitting circuit arrangement for a 4-course type beacon in which the carrier wave of each directional transmission is suppressed in accordance with this invention.

Referring to Fig. 1, an oscillator 1 supplies radio-frequency voltage from its output terminals 2, 3 to a plurality of intermediate amplifiers 4, 5, 6 and 7, respectively, the phase of the radio-frequency voltages being impressed upon the input circuits of said intermediate amplifiers being controlled by means of the phasing units 8 and 9. The phasing unit 8 comprises a resistor 10 and

an inductor 11 and is inserted in the lead from the output terminal 2 of oscillator 1 to the terminals of the grid elements 15 of the transmitting tubes 14 in each of the intermediate amplifiers 4, 5 and 6. The phasing unit 9 comprises a resistor 12 and a condenser 13 and is inserted in the lead from the output terminal 2 of oscillator 1 to the terminal of the grid element 15 in the transmitting tube 14 of intermediate frequency amplifier 7. The grid elements 15 of tubes 14 are made negative with respect to the filaments 16 by means of a voltage connected in series with the grid resistors 17 through connection to the terminals 18 and 19, the condensers 20 serving as radio-frequency by-pass condensers across these terminals. The input circuit of each of the intermediate amplifiers 4, 5, 6 and 7 comprises the grid resistor 17 in parallel with the internal impedance between the grid and filament elements of the transmitting tube 14. The resultant input impedance is substantially resistive. The phasing unit 9 serves to delay the voltages impressed upon the input circuits of amplifiers 4, 5 and 6 behind the voltage appearing across the output terminals 2, 3 of oscillator 1 by a time phase depending upon the values of resistor 10, inductor 11 and the combined impedance of the input circuits of intermediate amplifiers 4, 5 and 6 acting in parallel. The phasing unit 9 serves to advance the voltage impressed upon the input circuit of intermediate amplifier 7 ahead of the voltage appearing across the output terminals 2, 3 of oscillator 1 by a time phase depending upon the values of resistor 12, condenser 13 and the input impedance of intermediate amplifier 7. The time phase angle between the voltage impressed upon the input circuit of each of intermediate amplifiers 4, 5 and 6 and that impressed upon the input circuit of intermediate amplifier 7 is equal to the sum of the retardation angle introduced by phasing unit 8 and the angle of advance introduced by phasing unit 9. As will be shown later in this specification, the time phase angle is adjusted to secure desired optimum operation of the system.

The radio-frequency outputs from the tubes 14 in the intermediate amplifiers 4, 5 and 6 are modulated to a plurality of selected low frequencies, which may be sixty-five cycles, eighty-six and two-thirds cycles and one hundred eight and one-third cycles, by means of a plurality of modulator units 26, 27 and 28, respectively. In the preferred form, the latter comprise alternating current generators 30 having the proper frequencies and connected to the primary windings 31 of voltage step-up transformers 32, the secondary windings 33 of which are connected in the plate circuits of the intermediate amplifiers 4, 5 and 6. The radio-frequency choke coils 22 serve to keep the radio-frequency outputs of the tubes 14 from shorting between the plate elements 21 and the filament elements 16 by way of the audio-frequency equipment, while the condensers 20 by-pass stray radio-frequency voltages from the audio-frequency equipment.

The intermediate frequency amplifier 7 differs from the intermediate amplifiers 4, 5 and 6 only in the modulation arrangement. This amplifier is modulated to voice signals from the microphone 88 which are impressed between terminals 34 and 35 of the primary winding 36 of the modulation transformer 37 in the modulation unit 29 (see Fig. 5 also). The secondary winding 38 of this transformer is connected in series with the plate circuit of the intermediate amplifier 7, a suitable high direct voltage being inserted in this circuit between terminals 24 and 25 to prevent over-modulation.

This amplifier may also be modulated to telegraph signals by impressing between terminals 34 and 35 of the primary winding 36, a low voltage of suitable pitch, say 500 to 1500 cycles per second, which may be obtained from any conventional source such as a rotating generator 89, and connecting in series with said source of voltage a conventional key 90 for applying this voltage at successive intervals in accordance with the desired coded signals. A switch 91 may be provided for rapid change-over from voice to telegraph transmission or vice-versa, if desired.

The modulated outputs of the intermediate amplifiers 4, 5 and 6 are supplied through coupling condensers 23 to the input circuits of a second set of radio-frequency amplifiers 39, 40 and 41. Each of these power amplifiers comprises a power amplifying tube 43 having a filament element 44, a grid element 45 and a plate element 46. Suitable negative grid voltage is supplied through a radio-frequency choke coil 47 by means of a supply connected to terminals 48 and 49 while suitable positive plate voltage is supplied through a radio-frequency choke coil 50 by means of a supply connected to terminals 51 and 52. The by-pass condensers 53 serve to protect the sources of supply for these voltages from the effects of stray radio-frequency voltages. The amplified outputs from power amplifiers 39, 40 and 41 are fed through coupling condensers 54 to the primary windings 55, 56, and 57, respectively, of a goniometer.

The secondaries of said goniometer 60, 61, and 62 are connected in series with one loop antenna 67, while the secondaries 63, 64, and 65 are connected in series with a companion loop antenna 68. These loop antennae constitute a directional antenna system having a figure-of-eight directional characteristic, and are tuned to the frequency of the oscillator 1 by means of condensers 69 and 70, respectively.

The goniometer herein referred to is more fully described in my Patent No. 1,992,197, issued February 26, 1935, on application Serial Number 597,757, in which the three stator windings are fixed in space at angles of 120 degrees with each other. The carrier voltages impressed upon these stator windings are in exact time phase, which is accomplished by providing that the retardation of or advance in phase while passing through the intermediate and power amplifiers is the same in each of the three amplifier branches. In this manner the voltages induced in each of the rotor windings by the carrier waves in the three stator windings will be zero, since the carrier waves are all of the same frequency. The sideband voltages, however, are induced in the two rotor windings, the frequencies of the sidebands in each stator winding differing from that in the other two stator windings. I have shown in my Patent No. 1,992,197, that the combination of the three stator windings fixed at 120 degrees and the two crossed rotor windings each in series with one of the two crossed loop antennas produces three figure-of-eight sideband space patterns, the axes of which intersect at 120 degrees. So far, then, I have suppressed the carrier radiation from the two loop antennas 67 and 68 while I have at the same time produced the radiation of three sideband figure-of-eight space patterns, modulated respectively at the selected frequencies and intersecting each other at 120 degrees. As will be

shown later in this specification, these space patterns are used in the production of radio-beacon courses. It is to be noted that the modulation frequencies should be below about 150 cycles, as will appear from the following text.

I have already shown that the intermediate amplifier 7 is connected substantially in parallel with the intermediate amplifiers 4, 5 and 6 to the output of oscillator 1 and that said intermediate amplifier 7 may be modulated to voice frequencies by means of the modulation unit 29. Elimination of frequencies below about 300 cycles in the voice signals has no injurious effects upon the intelligibility of these signals. It is therefore feasible to introduce filter-circuits well known to the art in the circuits connecting to terminals 34 and 35 of the voice modulation transformer in order that no frequencies are present in the voice signals which may interfere during the operation of the system with the modulation frequencies of the intermediate amplifiers 4, 5 and 6. The modulated output of the intermediate amplifier 7 is impressed through the coupling condenser 23 upon the input circuit of a power amplifier 42, said power amplifier being similar in all details to power amplifiers 39, 40 and 41. The output of the power amplifier 42 is fed to a circuit tuned to the frequency of oscillator 1, comprising a condenser 59 and a primary winding 58 of an antenna transformer. The secondary winding 66 of this transformer is connected in series with a non-directional antenna 71 which is tuned to the frequency of oscillator 1 by means of a tuning coil 72. The phase of the current in the antenna 71 is preferably such that at a distant receiving point the combination of the radiated carrier with the beacon sidebands yields maximum output from the receiving set. This is accomplished by regulating the phase shift between the voltage on the input of the intermediate amplifier 7 and that on the inputs of the intermediate amplifiers 4, 5 and 6 by means of the phasing units 8 and 9, such phasing units being adjusted so that the current in antenna 71 differs in phase by exactly 90 degrees from the currents in loop antennas 67 and 68. The basis of my invention may now be understood. The non-directional antenna transmits a carrier wave which is of substantially equal intensity in all directions, and in addition speech sidebands which are also of equal intensities in all directions. Thus, normal weather broadcast service is provided. In addition, the loop antennas transmit figure-of-eight sidebands which, when beating with the circular carrier transmitted from the non-directional antenna, gives normal 12-course radio range-beacon service.

Fig. 2 shows the space pattern radiated with the system of my invention. 73 represents the circular carrier space pattern and also the circular pattern for the speech sidebands. The three figure-of-eight sidebands corresponding to the three beacon modulation frequencies are shown by 74, 75 and 76, respectively. The beating of the circular carrier with the circular speech sidebands gives radiotelephone service in all directions, while the beating of the circular carrier with the beacon sidebands produces twelve equisignal zones or beacon courses. While Figs. 1 and 2 show the application of my invention to the combination of the radiotelephone and 12-course type radio range-beacon transmitter, it is understood that similar application may be made to the case of the 4-course type radio range-beacon transmitter. In the latter case, the suppression of the carrier in the beacon branch of the transmitter may be accomplished by any of the arrangements well known to the art.

Fig. 5 shows the circuit diagram for a 4-course type radio range-beacon transmitter, with simultaneous voice or telegraph broadcast. Only two amplifier chains are now required in the beacon branch of the transmitter, and but two primary windings in the goniometer. These windings 94 and 95 are disposed at right angles as required with the 4-course beacon. The circuit arrangement of Fig. 5 is essentially the same as for Fig. 1 except insofar as the intermediate amplifiers 92 and 93 are concerned, carrier suppression being accomplished in these stages. Modulation to the beacon signals, say 65 and 86⅔ cycles per second respectively, is also accomplished in these stages. In the rest of the circuit diagram the numerals denote the same parts denoted in Fig. 1 and will therefore not be explained again.

Referring to the carrier suppression modulating amplifiers 92 and 93, the circuit arrangements which may be employed are well known to the art and no specific arrangement is therefore here indicated. The radio-frequency output of the master oscillator is fed in part, through phasing unit 8, to the input circuits of amplifiers 92 and 93 in parallel. Modulation is introduced in the preferred form by the alternators 30 of suitable audio frequencies. The modulated outputs of amplifiers 92 and 93, with carrier suppressed are fed, respectively, to power amplifiers 40 and 41, in the usual manner. A preferred embodiment of the receiving circuit arrangement used for reception of the combined radiotelephone and radio range-beacon signals is shown in Fig. 3. The voltage induced in an antenna 77 is fed to a standard type receiving set 78, the detector of which beats the carrier and the speech side-bands to give speech signals and the carrier and the beacon-sidebands to produce the beacon signals. The two sets of signals appear in the output of the receiving set. To separate them the output terminals of the receiving set are connected to a filter unit which, for example, separates out all frequencies above about 300 cycles and applies them to a telephone receiver 79 while it separates out all frequencies below about 300 cycles and directs them to a visual course indicator 80. Since the speech signals are all above 300 cycles and the beacon modulation frequencies all below 300 cycles, this means that the speech signals only reach the telephone receiver 79 while the beacon signals only reach the course indicator 80. A simple filter unit 81 for accomplishing these results is shown in Fig. 3. This unit comprises a choke coil 82, condensers 83 and 84, the telephone receiver 79 and the course indicator 80. The theory of operation of this filter unit is self-evident. Performance graphs are given in Fig. 4, showing the separation of the high and low frequencies. In this figure, the abscissa scale 85 represents audio frequencies while the ordinate scale 86 represents percent of voltage applied to either the headphones 79 or the course indicator 80. Graph 87 is for the telephones and graph 88 for the course indicator. It will be evident that below 300 cycles substantially all the voltage appearing in the output of the receiving set is impressed upon the course indicator, while above 300 cycles substantially all

the voltage is impressed upon the telephones. The separation of the two sets of signals in the receiving set output may be obtained through the use of other types of filters. Moreover, the separation may be accomplished in the output of the detector stage if desired, provided separate amplifiers are then used for the two sets of signals. These variations are all claimed to be a portion of my invention.

This invention has been described and illustrated in an article published in the Bureau of Standards Journal of Research, vol. 7, for August 1931, entitled "A simultaneous radiotelephone and visual range beacon for the airways" by Frank G. Kear and Gerald H. Wintermute, each of whom obtained their knowledge of my invention and prepared this article describing the same in the course of their official duties, there being no intention to abandon said invention by said publication.

While I have described and illustrated different examples of my invention, I do not wish to be limited to these specific examples since modifications may be made both in the circuits and apparatus within the scope of my invention.

What I claim is:

1. A method for the simultaneous transmission on a single radio frequency channel of a group of selected signals for use in direction indication, the intensities of said selected signals being fixed functions of the azimuth angle of direction of transmission, and a second group of signals for conveying a message or intelligence, the intensity of said second group of signals being substantially the same for all azimuth angles, which comprises suppressing the carrier wave in the radio transmissions containing the directional signals and transmitting the non-directional signals on a carrier wave having proper time phase relationship with the directional transmissions remaining after said carrier suppression.

2. A method for the simultaneous transmission on a single radio frequency channel of both directional and non-directional signals, said directional and nondirectional signals being in different ranges of audio frequencies, which comprises suppressing the carrier wave in the radio transmissions containing the directional signals and transmitting non-directional signals on a carrier wave having proper time phase relationship with the directional transmissions remaining after said carrier suppression.

3. A method in accordance with claim 2 including the additional steps of receiving and detecting radio signals of the frequency of the directional and nondirectional transmissions, separating said signals after detection and routing the directional signals to one signal indicating device and the non-directional signals to a second signal indicating device.

4. In a radio beacon system the combination of a directional antenna system having a figure-of-eight directional characteristic for each element of said system, a non-directional antenna, means for transmitting from said directional antenna system side bands of a plurality of modulation frequencies with a suppressed carrier, means for transmitting from said non-directional antenna a carrier having a definite phase relation to said suppressed carrier, and means for modulating said transmitted carrier with audible signals.

5. In a radio beacon system the combination of a directional antenna system having figure-of-eight directional characteristic for each element of said system, a non-directional antenna, means for transmitting from said directional antenna system side bands of three modulation frequencies with a suppressed carrier, means for transmitting from said non-directional antenna a carrier having a definite phase relation to said suppressed carrier, and means for modulating said transmitted carrier with audible signals.

6. In a radio beacon system the combination of a directional antenna system having a figure-of-eight directional characteristic for each element of said system, a non-directional antenna, means for transmitting from said directional antenna systems a series of radio signals having characteristics of three figure-of-eight side band space patterns with suppressed carrier, the axes of which intersect at one hundred and twenty degrees, means for transmitting from said non-directional antenna a carrier having a definite phase relation to said suppressed carrier, and means for modulating said transmitted carrier with voice frequencies.

7. In a radio beacon system the combination with a master oscillator, of a plurality of intermediate amplifiers excited by said master oscillator and operating in exact phase relation with each other, individual means for modulating the outputs of each of said intermediate amplifiers at different frequencies, individual power amplifiers for amplifying the modulated output of said intermediate amplifiers, two directional antennas disposed at right angles to each other, a goniometer having three primary windings crossed at 120 degrees and two secondary windings crossed at right angles, each of said primary windings being connected to the output of a corresponding one of said power amplifiers and each of said secondary windings connected in series with a corresponding one of said directional antennas, whereby the carrier is suppressed and there are produced three figure-of-eight side band space patterns of said modulating frequencies with the axes of said patterns intersecting at angles of one hundred and twenty degrees, another intermediate amplifier excited by said master oscillator and operating in a different phase relation to said first named intermediate amplifiers, means for modulating the output of said other amplifier with audible or voice frequencies, a power amplifier for amplifying the output of said other amplifier, and a non-directional antenna system connected to said last named power amplifier whereby the circular carrier modulated at audio or speech frequencies produces radio telephone signals in all directions around said beacon and the beating of the circular carrier with the side bands transmitted by said directional antenna system produces a plurality of equi-signal directional zones radiating from said radio beacon.

8. The combination with a radio beacon having three modulation frequencies and providing twelve courses of the visual type, of means for suppressing the carrier on each modulation frequency, means for radiating the side bands of each modulation frequency from two directive antenna systems arranged at right angles to each other and giving the figure-of-eight directional characteristic, a non-directional antenna, means associated with said non-directional antenna whereby radio telephony signals may be radiated from said non-directional antenna and means whereby the carrier wave of said radio telephony signal is radiated in a definite phase relation to the said suppressed carrier.

9. In a radio beacon of the twelve course type the combination with a master oscillator supplying radio frequency voltages to four amplifiers, three of said voltages to said amplifiers being in time phase while the voltage supplied to the fourth amplifier differs in time phase from that supplied to the first three of said amplifiers, means for modulating the outputs of the said first three amplifiers each at a different low audio frequency in the lower end of the speech range, means for modulating the output of the said fourth amplifier at speech frequencies, means for amplifying the output of said four amplifiers, means for supplying the output of each of said first three amplifiers to one of three stator coils, said stator coils being arranged at an angle of 120 degrees and mounted about a common axis, two rotor coils arranged at 90 degrees to each other and arranged to rotate about the common axis of said stator coils, two directional antenna systems arranged at 90 degrees with respect to each other having the figure-of-eight directional characteristic one of each said antennas being connected to one of said rotor coils, and a non-directional antenna coupled to the output of said fourth amplifier.

10. In a radio beacon the combination of a master oscillator, four amplifiers supplied with radio frequency voltages from said master oscillator, three of said voltages being in time phase the fourth said voltage differing in time phase from said first three voltages by a definite amount, means for modulating the outputs of said first three amplifiers each at a different audio frequency and means for modulating the output of said fourth amplifier at speech frequencies, means for suppressing the carriers and supplying the side band output from said first three amplifiers through a suitable goniometer comprising three stator coils one of each of said coils being connected to the output of one of said three amplifiers to two rotor coils arranged at 90 degrees with respect to each other and connected to two directive antenna systems arranged at 90 degrees with respect to each other and having the figure-of-eight directional characteristic, and a non-directional antenna connected to the output of said fourth amplifier.

11. A radio beacon having three modulation frequencies providing twelve courses of the visual type, in combination with means for suppressing the carrier on each modulation frequency, means for radiating the side bands of each modulation frequency from two directive antenna systems arranged at right angles to each other and giving the figure-of-eight directional characteristic, a non-directional antenna, means associated with said non-directional antenna whereby radio telephony signals may be radiated from said non-directional antenna, means whereby the carrier wave of said radio telephony signal is radiated in a definite phase relation to the said suppressed carrier, means for receiving the signals sent from said radio beacon, filtering means connected to the output of said receiving means for supplying the said side band modulations without the voice frequencies to a visual course indicator and filtering means connected to the output of said receiving means for supplying to suitable voice reproducing means the voice frequencies necessary for intelligibility without the side band modulation.

12. The combination with a radio beacon of the multiple course type of means for suppressing the carrier on each modulation frequency, means for radiating the side bands of each modulation frequency from two directive antenna systems arranged at right angles to each other and giving the figure-of-eight directional characteristic, a non-directional antenna, means associated with said non-directional antenna whereby radio telephony signals may be radiated from said non-directional antenna and means whereby the carrier wave of said radio telephony signal is radiated in a definite phase relation to the said suppressed carrier.

13. A radio beacon of the four course type, including two carrier waves each modulated at a selected audio frequency in combination with means for suppressing the carrier waves on each modulation frequency, which carrier waves are in the same time phase, a non-directional antenna, and means for supplying radio intelligence signals to said antenna with carrier frequency in a definite phase relation to the above said suppressed carrier frequencies.

14. In a radio beacon of the four course type, including two carrier waves each modulated to a selected audio frequency the combination with means for suppressing the carrier waves on each modulation frequency, which carrier waves are in the same time phase, a non-directional antenna, means for supplying radio intelligence signals to said antenna with carrier frequency in a definite phase relation to the above said suppressed carrier frequencies, means for receiving the signals sent from said radio beacon, filtering means connected to the output of said receiving means for supplying the said beacon modulation frequencies without the intelligence frequencies to a visual course indicator, and filtering means connected to the output of said receiving means for supplying the frequencies necessary for intelligence without the beacon modulation frequencies to suitable intelligence signal reproducing means.

15. In a radio beacon system the combination with a master oscillator, of four circuits excited by said oscillator, a phasing unit in each of said circuits, a plurality of intermediate amplifiers each excited from the output of a corresponding phasing unit, individual means for modulating the outputs of each of said intermediate amplifiers, individual power amplifiers for amplifying the modulated output of said intermediate amplifiers, two directional antennas disposed at right angles to each other, a goniometer having three primary windings crossed at 120 degrees and two secondary windings crossed at right angles, each of said primary windings being connected to the output of a corresponding one of said power amplifiers and each of said secondary windings connected in series with a corresponding one of said directional antennas, whereby the carrier wave is suppressed and three figure-of-eight side band space patterns of said modulating frequencies with the axes of said patterns intersecting at angles of one hundred and twenty degrees are produced, a non-directional antenna inductively coupled to the output of said fourth circuit the phasing unit of said fourth circuit providing a means for operating the same in a different phase relation to said first three circuits and said amplifiers of said fourth circuit providing a means for modulating the output with voice frequencies whereby there may be produced a circular carrier wave modulated at speech frequencies and the beating of the circular carrier with the side bands transmitted by said directional antenna system produces a plurality of equi-

signal directional zones radiating from said radio beacon.

16. In a radiobeacon system the combination of transmitting equipment and a plurality of antennas for transmitting radio signals having directional and non-directional space characteristics, means for suppressing the carrier waves from said radio signals having the directional characteristics, each of said directional radio signals being distinguished by a particular characteristic suitable for radiobeacon purposes, means for modulating said radio signals having the non-directional characteristics by speech or other intelligence signals, and means for controlling the phase of the carrier of said non-directional modulated signals to be in definite relation to the phase of said suppressed carriers in the said directional radio signals, whereby simultaneous transmission on a single radio frequency may be had of directive radiobeacon signals and intelligence messages.

17. In a radio-beacon of the four-course type having two characteristic modulated signals, the carrier waves of which are in time phase means for suppressing said carrier waves from said characteristic directional signals, two directive antenna systems arranged at right angles to each other and giving figure-of-eight directional radiation characteristics, means for radiating the side bands of said signals from said two directive antennas, means for producing radio intelligence signals, auxiliary non-directional radiating means, and means for supplying said radio intelligence signals to said auxiliary radiating means so as to be radiated with the carrier wave in definite time phase relation with said suppressed carrier whereby said carrier serves as a resupplied carrier for combination with the said directional radio beacon signals so that the normal radio beacon transmissions as well as the radio intelligence transmissions are radiated simultaneously on the same radio frequency.

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