Jan. 2, 1951 D. G. C. LUCK 2,536,509

RADIO AID TO NAVIGATION

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Fig. 1

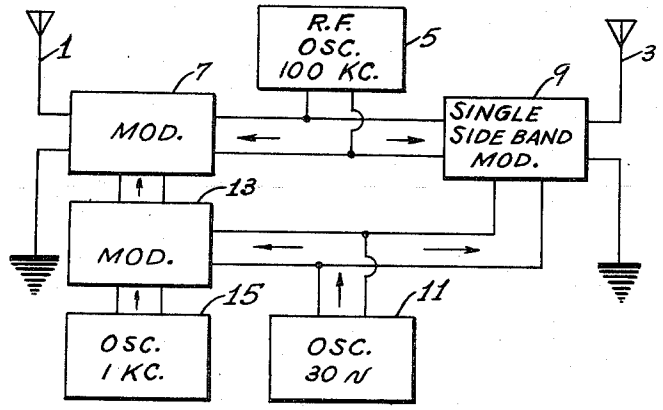


Fig. 2 Fig. 3 Fig. 4 Fig. 5

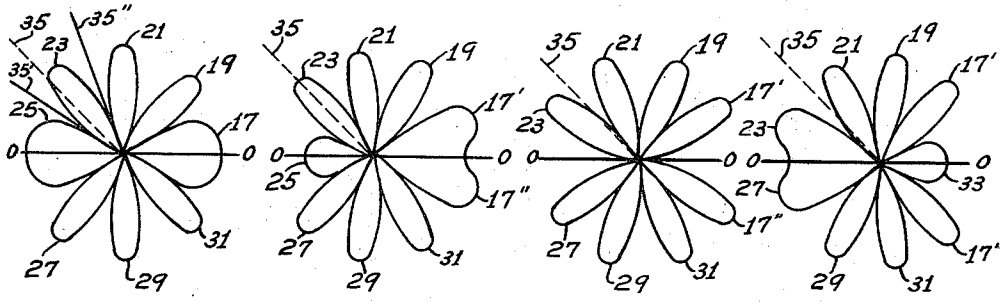
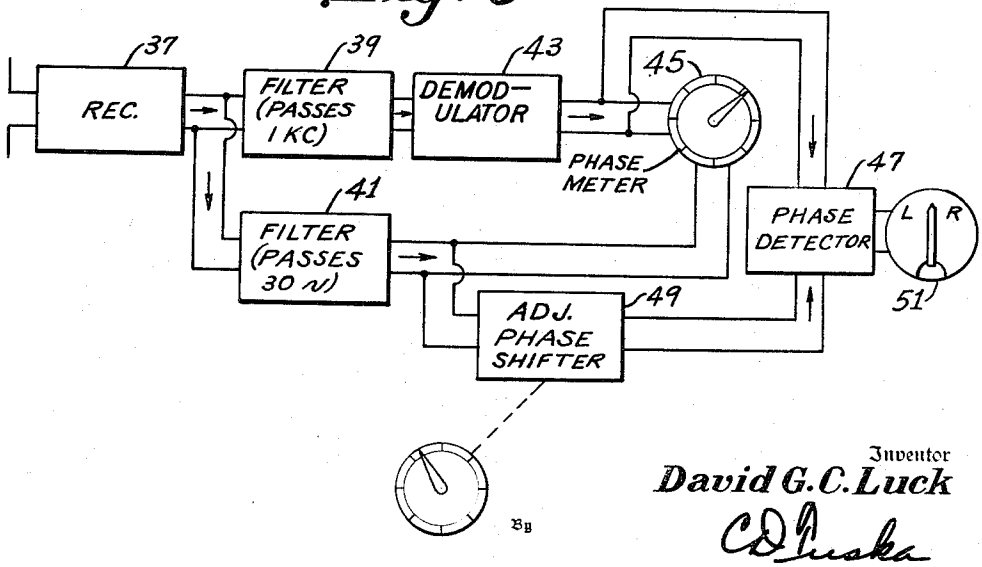


Fig. 6



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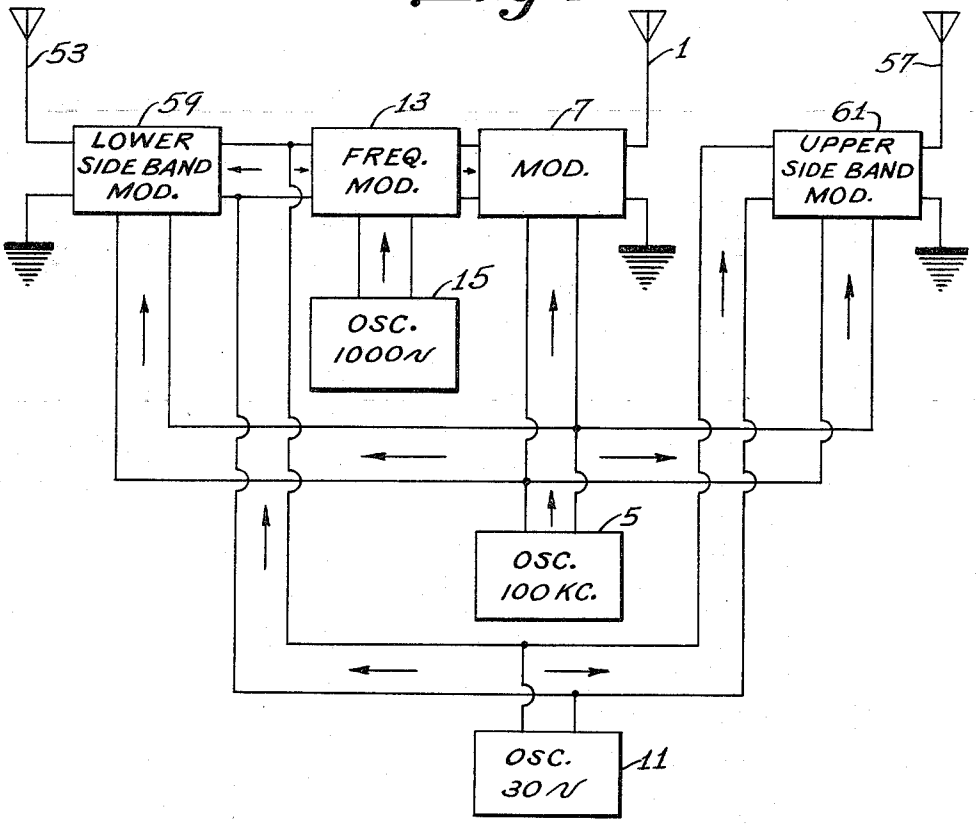
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RADIO AID TO NAVIGATION

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Fig. 7



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RADIO AID TO NAVIGATION

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6 Claims. (Cl. 343—106)

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This invention relates to radio aids to navigation, and more particularly to improvements in radio ranges of the "omnidirectional" type. The term "omnidirectional" in the present description is intended to mean a radio range providing continuous bearing indications throughout a sector which does not necessarily extend through a full 360 degrees.

The principal object of the present invention is to provide an omnidirectional radio range system affording a higher degree of sensitivity or sharpness of bearing indication than has been achieved heretofore by omnidirectional ranges.

Another object of the invention is to provide a system of the described type which is readily adapted for direct visual indications of bearing, using substantially the same equipment ordinarily employed with conventional omnidirectional radio ranges.

The invention will be described with reference to the accompanying drawing, wherein:

Figure 1 is a schematic block diagram of a range transmitter system embodying the invention; Figures 2, 3, 4 and 5 are polar graphs showing typical radiation patterns produced in the operation of the system of Fig. 1; Figure 6 is a schematic block diagram of a typical omnidirectional radio range receiver which may be used in conjunction with the system of Fig. 1; and Figure 7 is a schematic diagram of a modification of the system of Fig. 1.

Refer to Figure 1. Two antennas 1 and 3, each by itself having a substantially circular directive pattern in the horizontal plane, are spaced horizontally apart by a distance $n\lambda$, substantially greater than one wavelength λ at the frequency at which the range is to operate. The antennas 1 and 3 may be in the form of vertical towers, as high as is structurally and economically feasible, and a typical spacing between them may be two wavelengths. For long-range operation, a low carrier frequency of the order of 100 kilocycles per second, is preferred.

A radio frequency oscillator 5 is coupled to the antenna 1 through a modulator 7, and to the antenna 3 through a single sideband modulator 9. The single sideband modulator 9 may comprise a balanced modulator and sideband filter, or any other known apparatus providing suppression of the carrier and one sideband of a modulated radio frequency signal.

The modulation input terminals of the modulator 9 are connected to an oscillator 11 which provides an output of a low audio frequency, for example 30 cycles per second. The oscillator 11

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is also coupled to the modulation input terminals of a third modulator 13. An oscillator 15, operating at an intermediate audio frequency such as 1000 cycles per second, is coupled through the modulator 13 to the modulation input terminals of the modulator 7.

In the operation of the system of Figure 1, the antenna 1 radiates a signal comprising a 100 kilocycle carrier modulated by a 1000 cycle subcarrier which is in turn modulated at 30 cycles per second. Both sidebands of the 100 kilocycle carrier are present, each including components differing from the carrier frequency by 1000 cycles per second, 1030 cycles per second, and 970 cycles per second.

The antenna 3 radiates only one sideband of the 100 kilocycle carrier modulated at 30 cycles per second. Assuming the lower sideband to be suppressed with the carrier in the modulator 9, the antenna 3 radiates a signal comprising a single component whose frequency is 100,030 cycles per second. This may be regarded as, and in fact is, the same thing as a 100 kilocycle signal which is being advanced in phase continuously at the rate of 10,800° per second or 360 degrees per cycle of the low frequency oscillator 11.

The 100 kilocycle carrier signal radiated from the antenna 1 combines with the signal radiated from the antenna 3 to provide a space pattern which varies cyclically at 30 cycles per second.

Referring to Figure 2, two antennas spaced two wavelengths apart along the line 0—0 and excited in phase with each other will produce a radiation pattern substantially as illustrated, comprising a broad lobe 17, three approximately evenly spaced narrow lobes 19, 21 and 23, another broad lobe 25 extending opposite the lobe 17, and three further lobes 27, 29 and 31 similar to and symmetrically disposed with respect to the lobes 23, 21 and 19 respectively.

Now, using the in-phase condition of Figure 2 as a starting point, let us advance the phase of the excitation of one of the antennas. As this is done, the lobes 19, 21 and 23 move counterclockwise and the lobes 27, 29 and 31 move clockwise. The broad lobe 17 gradually splits into two lobes 17' and 17'' which move counterclockwise respectively, as indicated in Figure 3 and Figure 4. Figure 3 shows the pattern obtained when the phase has advanced 90°, and Figure 4 shows the 180° condition.

As the right hand lobe 17 expands and splits, the lobe 25 contracts and disappears. With continued advance in phase, the lobes 23 and 27

merge into a single lobe replacing the lobe 25, and a new lobe 33 appears in the place of the original lobe 17. Figure 5 shows the pattern existing when the phase has advanced 270°. A further advance to 360° produces a pattern like the original pattern of Figure 2.

The system of Figure 1 provides a radiation pattern which varies through the foregoing cycle 30 times per second. A radio receiver within range of the transmitter and at some definite azimuth with respect thereto (say along the dash line 35) will receive a signal which varies cyclically in amplitude. This is caused by the passage of successive lobes through the line 35.

Referring to Figures 2, 3 and 4, it is seen that the lobe 23 passes through the line 35, and will be followed by the lobes 21, 19 and 17', and other subsequent lobes which develop from the right as the phase advances. With a phase rotation frequency of 30 cycles per second, the frequency of variation in signal amplitude along the line 35 (or any other radial line from the midpoint between the antennas 1 and 3) is 30 cycles per second. It may be noted that this frequency of modulation caused by rotation is not a function of the antenna spacing.

Referring to Figure 6, a suitable receiver and indicator system is shown. This is substantially the same as that commonly used with conventional omnidirectional radio ranges, except for the calibrations. A receiver 37, tuned in the present example to respond to 100 kilocycles, has its audio output circuit connected to two narrow band pass filters 39 and 41. The filter 39 passes the one kilocycle subcarrier, with its 30 cycle modulation, which is impressed on the carrier radiated by the transmitter antenna 1. The filter 41 passes the 30 cycle rotation frequency modulation produced by the cyclical "slipping" of radiation lobes across the line between transmitter and receiver, as described above.

The modulated 1000 cycle output of the filter 39 is applied to a demodulator 43, which demodulates the subcarrier to provide a constant phase 30 cycle output. This is applied to one pair of terminals of a phase meter 45, which may be of the wattmeter type or any other known type. The 30 cycle output of the filter 41 is applied to the other pair of terminals of the phase meter 45.

In addition to the phase meter 45, a phase deviation indicator may be provided, comprising a phase detector 47 connected to the demodulator 43 and through an adjustable phase shifter 49 to the filter 41. The phase detector 47 may be of the balanced rectifier type, which provides a D.-C. output whose magnitude and polarity depends on the difference in phase between the two inputs. The output is applied to a zero-center D.-C. meter 51, marked L–R like the visual course indicator of a conventional radio range.

The operation of the system of Figure 6 in response to signals of the type transmitted by the system of Figure 1 is as follows:

The receiver and indicator system is carried aboard an airplane or other mobile craft. The bearing from the transmitter must be known approximately, or determined by auxiliary means such as a direction finder, with an accuracy corresponding to or better than the width of one lobe (say ten degrees). Suppose the mobile craft to be on a line within five degrees either way from the line 35 of Figures 2, 3, 4 and 5.

As already described, the received signal is modulated in amplitude owing to the rotation of the directive pattern. The phase of this modulation depends on the bearing of the receiver from the transmitter. Thus, if the line 35 is moved clockwise from its illustrated position, the modulation phase will advance. However, the phase of the 30 cycle modulation of the 1000 cycle subcarrier is independent of azimuth. The difference in phase between the output of the filter 41 and the output of the rectifier 43 is accordingly a measure of the angle of the bearing line 35.

Suppose, for example, that the two modulations are in phase when the bearing line 35 coincides with the line 35' in Figure 2. Then, as the line 35 moves clockwise, the phase of one modulation advances with respect to the other. The advance will be approximately, though not necessarily exactly, proportional to the angle a between the lines 35' and 35. When the line 35 reaches the line 35'', the phase angle has advanced 360°. Further clockwise motion of the line 35 will cause further phase rotation.

It will be evident that the low frequency phase reference signal may be impressed on the subcarrier as a frequency modulation, rather than as amplitude modulation. This may afford some reduction in "crosstalk" between the two low frequency channels in the receiver system. It is also feasible to frequency modulate the radio frequency carrier with the modulated subcarrier. With such modulation, the pattern lobes will wobble at a 1000 cycle rate about mean positions which move at 30 cycles as described. This will not affect the accuracy of the system, since the detector will integrate to provide 30 cycle output corresponding to the mean positions of the pattern lobes.

Since a change in bearing through an angle of θ degrees will cause a change in phase through an angle of $n\theta$ degrees, where n is a constant depending on the spacing of the transmitter antennas, the accuracy of bearing determination within any sector (such as that between the lines 35' and 35'') may be approximately n times that which would be obtained with the usual single-lobed pattern of prior art omnidirectional ranges. This results from the fact that the instrumental errors of the system are about the same in both cases, while the change in phase in response to a change in bearing is n times as great in the present system as in previously used systems.

The price of increased accuracy in this case is loss of uniqueness of indication, since the phase relations appearing in the sector between the lines 35' and 35'' of Figure 2 are duplicated along corresponding bearing lines in various other similar sectors. The scale 45 may be calibrated in terms of bearing angle, rather than in terms of phase angle. In this event, the scale must be replaced with another when the desired course lies in a different sector. Sector identification may be made by means of a direction finder on the mobile craft, as mentioned above, or by means of an auxiliary omnidirectional range of the single-lobed pattern type.

The course deviation indicator is used, as in ordinary radio range systems, to set and maintain a prescribed radial course to or from the transmitter station. The phase shifter 49 is adjusted so that the output of the phase detector 47 is zero when the craft is on the desired course. Deviation from course will cause the output of the phase shifter 49 to advance or retreat in phase with respect to the output of the rectifier 43. The phase detector will accordingly provide an output whose polarity and magnitude depends

on the direction and the amount of deviation, and the deviation is indicated on the meter 51.

The described transmitter system does not provide bearing information in all directions. Thus, along the line 0—0 in Figures 2 through 5, there is no rotary motion of the pattern lobes, but only expansion and contraction. Complete angular coverage through 360 degrees, if it is required, may be obtained by providing another transmitter system like that shown in Figure 1, but with the antennas in a line at right angles to the line 0—0.

For clarity of description and simplicity of illustration, it has been assumed that the antennas 1 and 3 are energized equally, causing the radiation patterns of Figures 2 through 5 to go to zero between lobes. In actual practice, this would be undesirable because the percentage modulation of the reference phase signal would become infinite (i. e. the carrier would disappear) each time a pattern null swept through the position line 35. This difficulty is avoided very simply by supplying one antenna, for example the antenna 3, with less power than the other. The resulting radiation patterns will be similar to those shown, except that the minima will be partial rather than complete.

With the two antenna systems of Figure 1 there is in addition to the above-described effects, an undesired amplitude modulation at 30 cycles of the 1000 cycle subcarrier. This may tend to introduce crosstalk between the two 30 cycle channels in the receiver-indicator system and cause error unless the detectors 43 and 47 are completely non-responsive to amplitude variations.

Amplitude modulation of the subcarrier may be prevented by providing a third antenna and an additional single sideband modulator, as shown in Figure 7. As in the system of Figure 1, the antenna 1 is excited by the carrier oscillator 5 through the modulator 7, which impresses on the carrier a 1000 cycle subcarrier frequency modulated at 30 cycles per second. Instead of the single antenna 3 of Figure 1, two antennas 53 and 57 are provided, one on each side of the antenna 1. The antenna 53 is energized by the 100 kilocycle source 5 through a single sideband modulator 59 controlled by the 30 cycle oscillator 11, and transmits only the lower sideband, whose frequency is 99,970 cycles per second. The antenna 57 is similarly energized through a single sideband modulator 61 to transmit only the upper sideband of 100,030 cycles per second.

The radiation patterns produced by the system of Figure 7 are substantially identical with those shown in Figures 2 through 5, providing the antennas 53 and 57 are each two wavelengths from the central antenna 1. The signal at the receiver is the same as described with reference to the system of Figure 1, except that the 1000 cycle subcarrier is purely frequency modulated. As in the system of Figure 1, it is preferable to divide the power unevenly between the central antenna 1 and the side antennas 53 and 57 to fill in the nulls of the radiation patterns to some extent.

I claim as my invention:

1. A radio range transmitter system, including two omnidirectional antennas spaced horizontally from each other by a distance d, a source of radio frequency energy of wavelength substantially less than d, means providing a composite modulation signal including a constant-phase signal of relatively low audio frequency and a signal of substantially higher frequency modulated by said low frequency signal, means for modulating a portion of said radio frequency energy with said composite modulation signal and for applying the resultant modulated energy to one of said antennas, and means simultaneously and continuously changing the phase of another portion of said radio frequency energy at a constant rate of 360° per cycle of said low audio frequency signal and for applying the resultant phase-shifted radio frequency energy to the other of said antennas.

2. A radio range system including means generating in space a multiple-lobed radiation pattern which is substantially symmetrical with respect to a predetermined line and means moving the lobes on one side of said line clockwise continuously at a constant rate and moving the lobes on the other side of said line counterclockwise continuously at said constant rate, and means modulating the radiation in said pattern as a whole to provide a distinguishable phase reference signal of a frequency corresponding to the rate of motion of said lobes.

3. A radio range system including two antennas spaced apart horizontally, a source of radio frequency energy, a modulator connected between the first of said antennas and said source, a second source of A.-C. energy of a frequency substantially lower than that of said first source, a second modulator connected between said source and said first modulator, a third source of A.-C. energy of a frequency substantially lower than that of said second source and means for applying the output of said third source to said second modulator; a single sideband modulator connected between said first source and the second of said antennas, and means for applying the output of said third source to said single sideband modulator.

4. A radio range system including two horizontally spaced antennas, means exciting one of said antennas with a signal including a radio frequency carrier, means modulating said carrier by a subcarrier which is of substantially lower frequency than said carrier and means modulating said subcarrier by a constant frequency signal of still lower frequency, and single sideband modulating means exciting the other of said antennas with a signal sideband signal of radio frequency differing in frequency from said carrier by the frequency of said lowest frequency signal.

5. A radio range system including a central antenna and two side antennas equally distant from said central antenna and on a line including said central antenna, a source of radio frequency signal of wavelength substantially less than the spacing between said antennas, a source of low frequency signal, means modulating said radio frequency signal with said low frequency signal to provide separately the upper and lower sidebands of said radio frequency signal, means applying said upper and lower sidebands respectively to said two side antennas, a further source of signal of intermediate frequency, means frequency modulating said last-mentioned signal with said low frequency signal to provide a composite modulation signal, means modulating said radio frequency signal with said composite modulation signal, and means applying the resultant signal to said central antenna.

6. A radio range system including a central antenna and two side antennas, a source of radio frequency signal, a source of low frequency signal, means modulating said radio frequency signal with said low frequency signal to provide

separately the upper and lower sidebands of said radio frequency signal, means applying said upper and lower sidebands respectively to said two side antennas, a further source of signal of intermediate frequency, means modulating said last-mentioned signal with said low frequency signal to provide a composite modulation signal, means modulating said radio frequency signal with said composite modulation signal, and means applying the resultant signal to said central antenna.

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