June 1, 1937. I. WOLFF 2,082,042

RADIO SYSTEM

Filed April 26, 1934 3 Sheets-Sheet 1

Fig. 1.

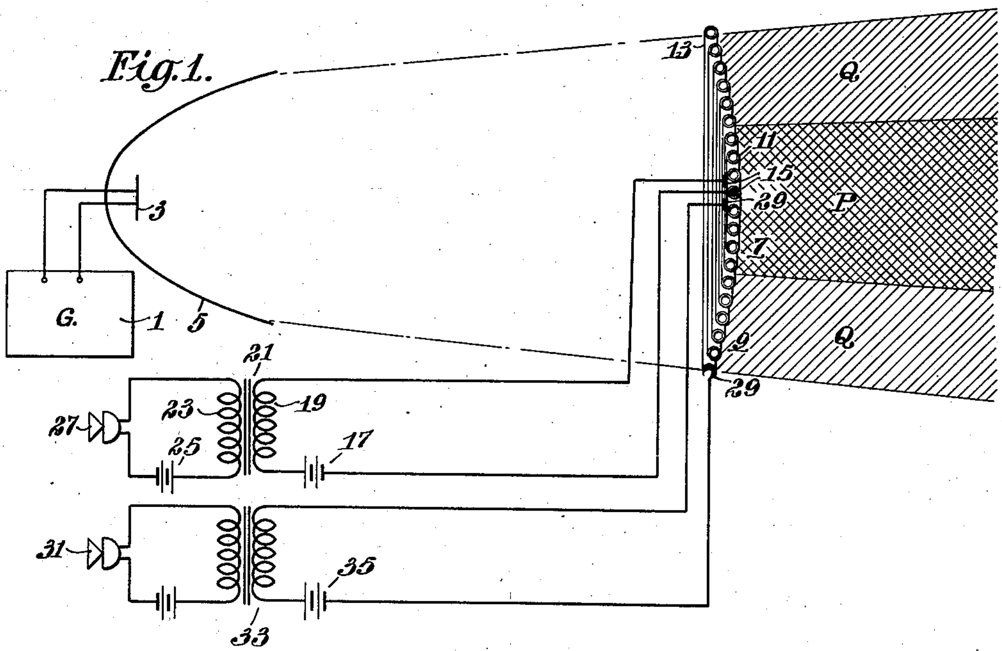
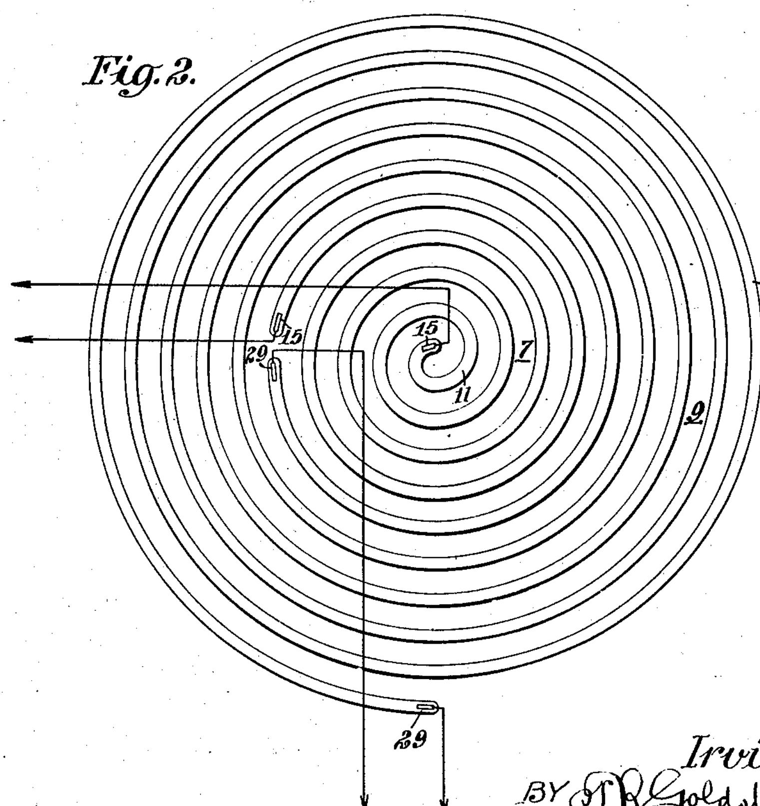


Fig. 2.



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RADIO SYSTEM

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Fig. 3.

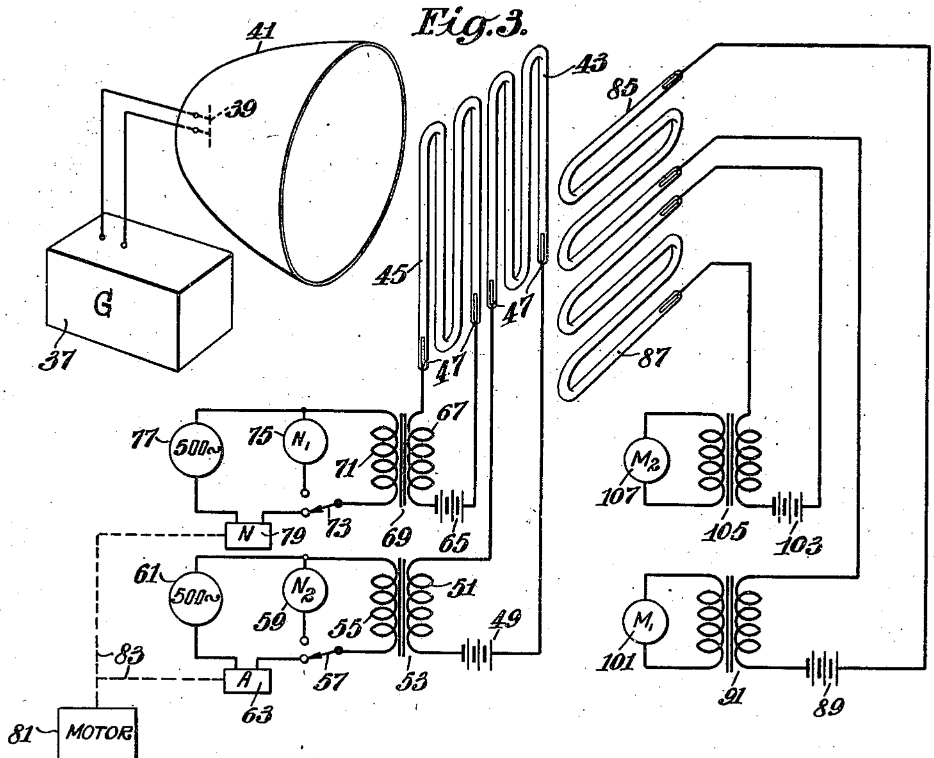


Fig. 4.

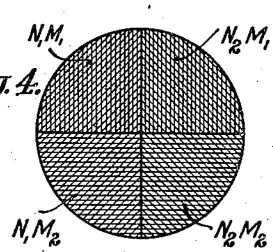


Fig. 5.

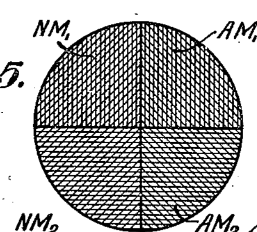
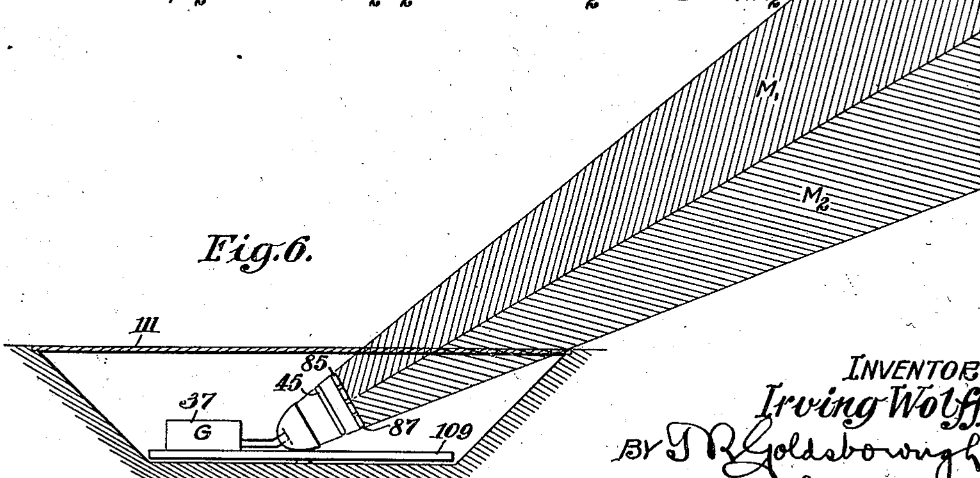


Fig. 6.



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RADIO SYSTEM

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Fig. 7.

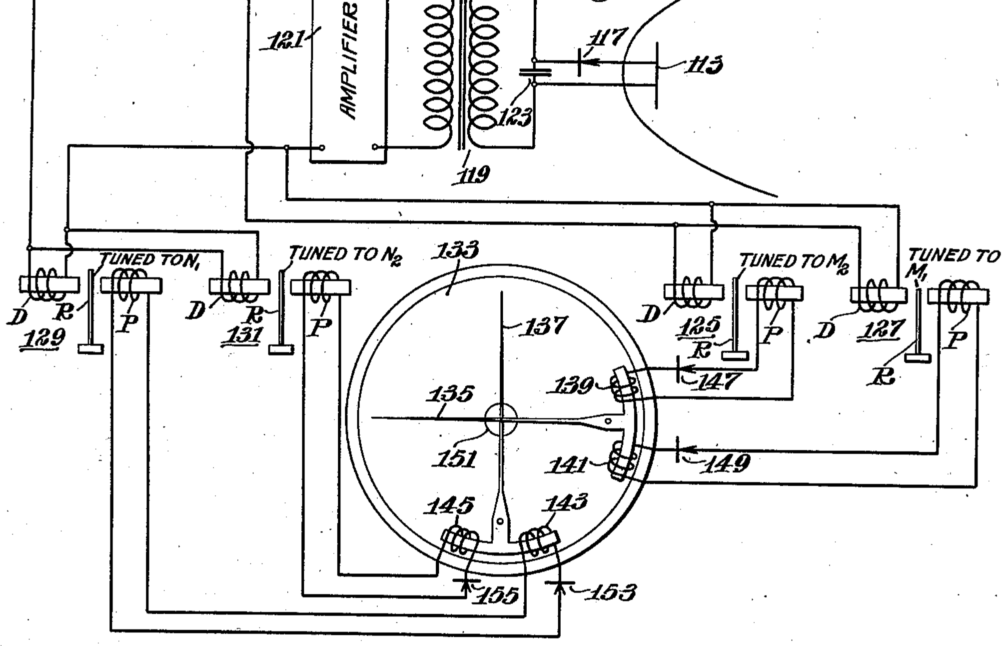
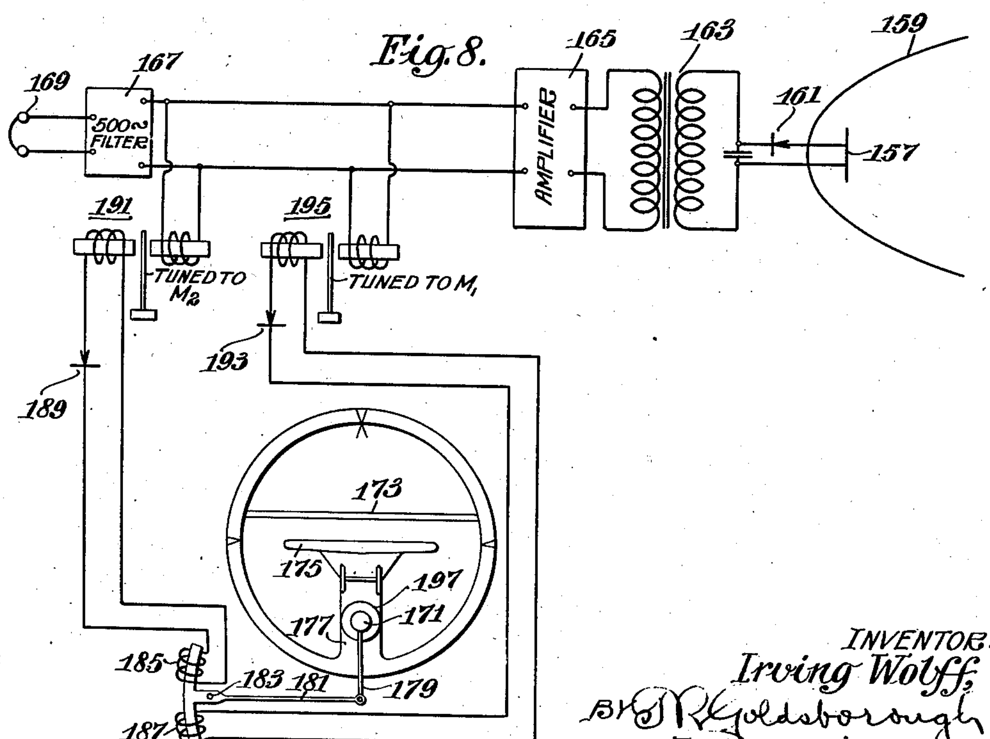


Fig. 8.



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Patented June 1, 1937

2,082,042

UNITED STATES PATENT OFFICE

2,082,042

RADIO SYSTEM

Irving Wolff, Merchantville, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application April 26, 1934, Serial No. 722,471

8 Claims. (Cl. 250—11)

My invention relates to radio systems and particularly, to systems which utilize electromagnetic energy having such a high frequency that it may be transmitted in the form of a beam.

An object of my invention is to provide an improved method and means for modulating electromagnetic energy.

A further object of my invention is to provide an improved method and means for transmitting a plurality of signals simultaneously on a single radio wave or beam.

A still further object of my invention is to provide an improved method and system for guiding mobile vehicles such as water craft or air craft.

A still further object of my invention is to provide an improved method and system for guiding air craft to a landing.

In the preferred embodiment of my invention, I produce one modulation in one part of a radio beam and another modulation in another part thereof by intercepting different parts of the beam by means of modulating devices such as tubes containing an ionized gas. Thus, for example, in a radio beam which is cone shaped, the central portion of the beam may be modulated in accordance with one signal while the outer portion of the beam is simultaneously modulated in accordance with a different signal.

In accordance with one embodiment of my invention, I modulate adjacent sections of a radio beam by signals differing in frequency whereby a sharply defined path is provided which may be followed by an air craft or the like. If the source of the beam is located at a landing field, and projected upwardly at an angle to the field, an air craft equipped with suitable receiving apparatus may follow down the beam to make a landing.

Other objects, features and advantages of my invention will appear from the following description taken in connection with the accompanying drawings, in which

Figure 1 is a schematic diagram of one embodiment of my invention showing a side view of the modulating device;

Figure 2 is a schematic diagram of a portion of the apparatus illustrated in Figure 1 showing an end view of the modulating device;

Figure 3 is a schematic diagram, partly in perspective, of an air craft landing system constructed in accordance with one embodiment of my invention;

Figures 4 and 5 are diagrams which are referred to in explaining the operation of the apparatus shown in Figure 3;

Figure 6 is a view showing the apparatus of Figure 3 installed at a landing field; and

Figures 7 and 8 are schematic diagrams of receiving apparatus which may be utilized in connection with the apparatus shown in Figure 3.

Referring to the embodiment of my invention shown in Figure 1, the apparatus comprises any suitable means for producing a beam of electromagnetic energy, the apparatus illustrated consisting of a generator of high frequency radio energy indicated at 1 which is connected to a dipole antenna 3 positioned in a parabolic reflector 5. In accordance with my invention, I intercept different portions of the radio beam with different modulating devices whereby the said portions of the beam may be modulated independently. While various types of modulating devices may be employed, such as shutters or screens, I prefer to employ an ionized gas device of the type described and claimed in U. S. Patent No. 2,047,930, which issued on July 14, 1936, to Ernest G. Linder, and is assigned to the same assignee as this application.

As shown in Figures 1 and 2, two modulating devices 7 and 9 are utilized, one being positioned at the center of the radio beam to modulate the central part of the beam and the other being positioned to modulate the outer part of the beam. The central modulating device 7 comprises a long tube 11 filled with gas at a low pressure and bent into a spiral to form a circular sector disc of gas. The other modulating device 9 consists of a long tube 13 filled with gas at a low pressure and bent into a spiral to form a circular sector ring of gas.

Electrodes 15 are provided at the ends of the tube 11 and connected to a suitable voltage supply such as a battery 17 through the secondary winding 19 of a transformer 21, the voltage of the battery being high enough to maintain the gas in the tube 11 in an ionized condition. The primary winding 23 of the transformer 21 is connected through a battery 25 to a microphone 27 whereby the voltage applied to the electrodes 15, and consequently the ionization of the gas, may be varied in accordance with speech.

In the same way, the ionization of the gas in the tube 13 may be varied by means of a varying voltage applied to electrodes 29 provided at the ends thereof through a circuit including a second microphone 31, a transformer 33 and a battery 35. As fully explained in the above mentioned Linder docket, the radio beam is modulated in accordance with the variations in the ionized gas as the beam passes therethrough. The microphones are merely illustrative; they may, of course, be replaced by any suitable sources of modulating energy such as constant frequency generators.

It will be apparent that if different signals are impressed upon the two modulating circuits, the above described apparatus will produce a radio beam having one modulation P on its central portion and a different modulation Q on its outer portion, as indicated in Figure 1. Thus, if desired, two conversations may be transmitted over the same radio beam simultaneously by positioning one receiver to pick up energy from the central portion of the beam and another receiver to pick up energy from the outer portion of the beam.

It is well known that, depending upon the relative size of the reflector compared to wave length, and also depending upon the shape of the reflector, the radio beam travels a certain distance from the reflector, without spreading much and then goes out in the form of a cone. While the modulating devices may be positioned at any point in the radio beam, they are preferably positioned at a point where the beam has spread out into the form of a cone. Also, the surfaces of the modulating devices which are impinged on by the radio waves should either correspond as nearly as possible to the wave front of those waves, or they should have a very slight converging action. The shape of the strata of ionizing gas also should lie along wave fronts for best results in order to keep from distorting the beam.

Referring to the airplane guiding and landing equipment shown in Figure 3, it includes a generator of high frequency radio energy indicated at **37** having its output connected to a dipole antenna **39** positioned in a parabolic reflector **41** whereby a beam of radio energy may be radiated.

Two modulating devices **43** and **45** are positioned in the path of the beam for putting one modulation on the right-hand half of the beam and a different modulation on the left-hand half of the beam. In practice, the two modulating devices usually will be positioned in substantially the same plane. Each modulating device consists of a long tube filled with gas at a low pressure and having electrodes **47** at each end for ionizing the gas.

The modulating device **43** is connected through a battery **49** to the secondary winding **51** of a transformer **53**. The primary winding **55** of the transformer **53** may be connected through a switch **57** either to a generator **59** which produces a signal having a constant frequency N_2 or to a generator **61** (which may have a 500 cycle output) and a keying device **63** by means of which the letter A may be impressed upon one half of the beam.

The modulating device **45** is connected through a battery **65** to the secondary winding **67** of a transformer **69**. The primary winding **71** of this transformer may be connected through a switch **73** either to a generator **75** which produces a signal having a constant frequency N_1 or to a generator **77** (which may have a 500 cycle output) and a keying device **79** which will put the signal N on the other half of the beam.

The keying devices **63** and **79** are operated by synchronism by a motor **81** as indicated by the dotted line **83** whereby the A and N signals are interlocked in the same manner as in the well known radio beacons. That is, the right-hand and left-hand portions of the radio beam are so modulated that if a signal is picked up on the right-hand side of the beam, an A signal is heard, while if a signal is picked up on the left-hand side of the beam, an N signal is heard. However, if a signal is picked up at the center of the beam, a continuous tone is heard due to the overlapping of the N and A signals. From the above description, it will be apparent that the beam has one modulation thereon on one side of a vertical plane passing through the center of the beam and another modulation thereon on the opposite side of the said plane.

Additional modulations are put on the upper and lower halves of the radio beam by means of modulating devices **85** and **87** similar to the modulating devices **43** and **45**. The upper modulating device **85** is connected through a battery **89** and a transformer **91** to a signal source **101** of constant frequency M_1. The lower modulating device **87** is connected through a battery **103** and a transformer **105** to a signal source **107** of constant frequency M_2. Thus, after the beam has been modulated by the first modulating devices **43** and **45**, it is again modulated, the upper half of the beam being modulated by the signal M_1 and the lower half of the beam being modulated by the signal M_2.

With the switches **57** and **73** moved to their upward positions to connect the sources **59** and **75** to the modulating devices **43** and **45**, respectively, the radio beam is modulated in the manner indicated in Figure 4. It will be seen that the upper right-hand quarter of the beam (looking into the reflector **41**) is modulated by the signals N_2 and M_1; that the lower right-hand quarter is modulated by the signals N_2 and M_2; that the lower left-hand quarter is modulated by the signals N_1 and M_2; and that the upper left-hand quarter is modulated by the signals N_1 and M_1.

With the switches in the position illustrated in Figure 3 to connect the 500 cycle signal sources **61** and **77** to the modulating devices **43** and **45**, respectively, through the keying apparatus, the beam is modulated in the manner shown in Figure 5. It will be seen that the upper right-hand quarter of the beam is modulated by the signals A and M_1; that the lower right-hand quarter is modulated by the signals A and M_2; that the lower left-hand quarter is modulated by the signals N and M_2; and that the upper left-hand quarter is modulated by the signals N and M_1.

While the above described apparatus may be employed for guiding air craft in horizontal flight, it is most useful when employed for guiding air craft to a landing. In Figure 6, the apparatus is shown installed for this purpose. In Figures 3 and 6, similar parts are indicated by the same reference numerals. As indicated in Figure 6, the transmitting and modulating apparatus is preferably mounted upon a turntable **109** located in a pit in the landing field. The pit has a cover **111** thereover upon which an airplane may land, the cover being of some material which is electrically non-conducting and which, therefore, is transparent to the radio waves.

The reflector **41** is directed to project the beam out over the landing field at such an angle that air craft may follow the beam down to the landing field for making a landing. By positioning the transmitting apparatus at approximately the center of the field, the beam may be pointed into the direction of the wind at any time by rotating the turntable 109. The manner in which the beam is employed for making "blind" landings will be better understood after a consideration of the receiving equipment.

The receiving equipment shown in Figure 7 preferably comprises a dipole antenna 113, positioned inside a parabolic reflector 115, and connected to a suitable detector 117 for demodulating the radio beam signal. The demodulated signal is fed from the detector 117 through an audio frequency transformer 119 to an amplifier 121 and from the amplifier 121 to a plurality of mechanical filters 125, 127, 129, and 131. The primary of the transformer 119 is preferably shunted by a radio frequency by-pass condenser 123.

Each mechanical filter comprises a driving coil D, a pick-up coil P and a tuned reed R. Filters 125 and 127 are tuned to the frequencies M_2 and M_1, respectively, whereby filter 125 will pass the signal picked up from the lower half of the radio beam, while the filter 127 will pass the signal picked up from the upper half of the beam.

An indicating instrument 133 is provided which comprises two pivoted pointers 135 and 137, the pointer 135 being connected to opposing solenoids 139 and 141 whereby the position of the pointer 135 depends upon the current flowing through their coils. The pointer 137 is connected to opposing solenoids 143 and 145 so that its position, also, is determined by the value of the current flowing through the solenoid coils.

The coil of solenoid 139 is connected to the pick-up coil P of the filter 125 through a rectifier 147 while the coil of solenoid 141 is connected to the pick-up coil P of filter 127 through a rectifier 149.

If the solenoids 139 and 141 have the same amount of current flowing therethrough, the needle 135 will intersect a circular marking 151 on the instrument dial. Therefore, if an air craft is following down a radio beam at the center of the beam, the needle 135 will be in a horizontal position intersecting the circle 151 since the signals M_1 and M_2 picked up by the air craft will be of equal magnitude.

Referring now to the circuit for controlling the needle 137, the coil of solenoid 143 is connected to the pick-up coil P of filter 129 through a rectifier 153 while the coil of solenoid 145 is connected to the pick-up coil P of filter 131 through a rectifier 155. Assuming that the beam is being modulated in the manner indicated in Figure 4, if an air craft is in the center of the beam, the needle 137 will be in a vertical position to intersect the circle 151, since the received signals N_1 and N_2 are of equal magnitude. If the air craft moves to one side of the center of the beam, the needle 137 will be deflected away from the circular marking 151 and the pilot will know that he must correct his course.

In utilizing the above-described system with the beam modulated as indicated in Figure 4, certain precautions should be taken in selecting the frequencies of the modulating signals because of the appearance of sum and difference frequencies in the modulated beam. These sum and difference frequencies, which serve no useful purpose, are produced by the successive modulation of the beam as it passes through two modulating devices in succession. For example, as the beam passes through the device 45 it is modulated by the signal having frequency N_1, and, as it next passes through the device 87, it is not only modulated by the signal having frequency M_2 but it is so modulated as to include signals of the frequencies M_2+N_1 and M_2-N_1.

However, by properly choosing the modulating frequencies N_1, N_2, M_1 and M_2, no sum or difference frequency will be equal to a modulating frequency and, therefore, the sum and difference frequencies cannot pass through the four mechanical filters to effect a false operation of the indicator. While various frequency combinations may be chosen for satisfactory operation, the following are given by way of example: $N_1=50$ cycles per second, $N_2=75$ cycles per second, $M_2=175$ cycles per second, and $M_1=200$ cycles per second.

By referring to Figure 4 it will be seen that the possible frequency combinations are $M_2 \pm N_1$, $M_1 \pm N_1$, $M_2 \pm N_2$, and $M_1 \pm N_2$. Using the frequency values specified above, none of these frequency combinations is equal to one of the modulating frequencies.

The receiving apparatus shown in Figure 8 is designed for use with a beam modulated in the manner shown in Figure 5. The receiver preferably comprises the usual dipole antenna 157, which may be positioned in a parabolic reflector 159, and a detector 161 for demodulating a radio beam signal. The demodulated signal is supplied through a transformer 163 to an audio frequency amplifier 165 and through a filter 167 to a pair of headphones 169. The filter 167 is designed to pass the N and A signals having the 500 cycle tone, but to eliminate the frequencies M_1 and M_2. Therefore, in the headphones 169 only the N and A signals will be heard.

The vertical position of the air craft on the beam is indicated by the position of a disc 171 which preferably is mounted upon the face of a "blind" flying instrument such as the well known Sperry artificial horizon. The artificial horizon, which is illustrated, comprises a movable bar 173 and a stationary indicating device 175 representing an airplane, the indicating device being the upper portion of an upright 177. The position of the bar 173 with respect to the indicating airplane 175 shows the angle of the airplane with respect to the horizontal. Also, the angle of the bar 173 indicates whether the wings of the plane are level. By combining with this instrument my indicating device for showing the position of an airplane in a landing beam, the pilot can keep the wings of his airplane level and also keep in the landing beam by looking at only one instrument.

The landing beam indicator comprises the disc 171 which is attached to one end of a vertically movable rod 179. The rod 179 may be moved either up or down by means of a horizontal arm 181 pivoted at the point 183 and actuated by means of solenoid coils 185 and 187. The coil 185 is connected to the output of the amplifier 165 through a rectifier 189 and a mechanical filter 191 tuned to frequency M_2. The solenoid coil 187 is connected to the output of the amplifier 165 through a rectifier 193 and a mechanical filter 195 tuned to the frequency M_1.

If the air craft is half way between the upper and lower portions of the radio beam, the signals M_1 and M_2 will be of equal intensity and the indicating disc 171 will be positioned in the center of a circular marking 197 on the upright 177. If the air craft moves into the lower half of the beam, for example, the indicating disc 171 will move below the center of the circle 197 and the pilot will know that he must pull the plane up to reach the center of the beam.

With the system shown in Figure 8, the pilot determines his horizontal position by means of the signals appearing in the headset 169. If he receives either an A or an N signal, he knows that he is either to the right or to the left of the center of the beam. He then corrects his course until he hears a steady tone and, if the indicating disc 171 is in the center of the circle 197 at the same time, he knows he is in the center of the beam and in position to make a good landing.

Various other modifications may be made in my invention without departing from the spirit and scope thereof, and I desire, therefore, that only such limitations shall be placed thereon as are necessitated by the prior art and are set forth in the appended claims.

I claim as my invention:

1. In a system for signalling with electromagnetic energy having a radio frequency, means for radiating said energy, a plurality of modulating devices, each containing a gas capable of being ionized, one of said devices being positioned to intercept a portion of said radiated energy, another of said devices being positioned to intercept a different portion of said radiated energy, and means for varying the ionization of said gas in accordance with desired signals.

2. In a system for guiding an air craft, means for producing a beam of radiant energy at an angle to the vertical, means for modulating an upper portion of said beam in accordance with one signal, means for modulating a lower portion of said beam in accordance with another signal, receiving apparatus on said aircraft including means for demodulating said beam portions whereby said two signals appear in the output of said receiving apparatus, a visual indicating device, means for moving said indicating device in one direction in response to one of said signals and means for moving said indicating device in the opposite direction in response to the other of said signals.

3. In a system for guiding an air craft, means for producing a beam of radiant energy at an angle to the vertical, means for modulating a portion of said beam in accordance with a first signal, said portion being below a plane which passes through said beam and which is substantially parallel to the axis thereof, means for modulating a portion of said beam above said plane in accordance with a second signal, means for putting two additional modulations on said beam, one of said additional modulations being put on a portion of said beam located on one side of a substantially vertical plane and the other additional modulation being put on a portion of said beam on the other side of said vertical plane, receiving apparatus on said air craft, said apparatus including means for demodulating said beam portions whereby said signals and additional modulations appear in the output of said receiving apparatus, an indicating device, means for actuating said indicating device in one manner in accordance with said first signal, means for actuating said indicating device in a different manner in accordance with said second signal, and means for producing an audible signal in accordance with said additional modulations.

4. In a system for guiding an air craft, means for producing a beam of radiant energy at an angle to the vertical, means for modulating a portion of said beam in accordance with a first signal, said portion being below a plane which passes through said beam and which is substantially parallel to the axis thereof, means for modulating a portion of said beam above said plane in accordance with a second signal, means for putting two additional modulations on said beam, one of said additional modulations being put on a portion of said beam located on one side of a substantially vertical plane and the other additional modulation being put on a portion of said beam on the other side of said vertical plane, receiving apparatus on said air craft, said apparatus including means for demodulating said beam portions whereby said signals and additional modulations appear in the output of said receiving apparatus, a visual indicating device having two pivotally mounted pointers so positioned that they intersect as they are moved through a certain angle, means for controlling the position of one of said pointers in accordance with said first and second signals, and means for controlling the position of the other of said pointers in accordance with said additional modulations.

5. In a system for guiding an air craft, means for producing a beam of radiant energy at an angle to the vertical, means for modulating a portion of said beam in accordance with a first signal, said portion being below a plane which passes through said beam and which is substantially parallel to the axis thereof, means for modulating a portion of said beam above said plane in accordance with a second signal, means for putting two additional modulations on said beam, one of said additional modulations being put on a portion of said beam located on one side of a substantially vertical plane and the other additional modulation being put on a portion of said beam on the other side of said vertical plane, receiving apparatus on said air craft, said apparatus including means for demodulating said beam portions whereby said signals and additional modulations appear in the output of said receiving apparatus, a visual indicating device having a pointer pivotally mounted to move to either side of a horizontal line and a pointer pivotally mounted to move to either side of a vertical line, said pointers being so positioned that they intersect as they are moved through a certain angle, means for controlling the position of said first pointer in accordance with said first and second signals, and means for controlling the position of said second pointer in accordance with said additional modulations.

6. In a system for guiding an air craft, means for projecting a beam of radiant energy over at least a portion of a landing field for said air craft and at an angle thereto, means for modulating the upper portion of said beam in accordance with one signal, means for modulating the lower portion of said beam in accordance with another signal, receiving apparatus on said air craft including means for demodulating said beam portions whereby said two signals appear in the output of said receiving apparatus, an instrument comprising a horizon bar and an indicator, said indicator being below said bar when the nose of said air craft is pointed downward, a vertically movable indicator, a fixed reference point for said indicator, means for moving said indicator above said point in response to said one signal, and means for moving said indicator below said point in response to said other signal.

7. In a signalling system, means for producing a beam of electromagnetic energy having a fre-

quency within the radio frequency spectrum, and a plurality of modulating devices so positioned in the path of said beam that it passes through said devices successively.

8. In an air craft landing system, means for projecting a solid beam of electromagnetic energy having a frequency lower than ordinary light over at least a portion of a landing field for said air craft and at an acute angle thereto, means for modulating one portion of said beam in accordance with one signal, means for modulating another portion of said beam in accordance with a different signal, one of said portions being located adjacent the other of said portions, means relatively positioning the first and second modulating means whereby one of said means modulates the upper portion of said beam and while the other modulates the lower portion of said beam, and means for effecting two additional modulations of said beam, one modulating one vertical portion of said beam and the other modulating an adjacent vertical portion of said beam.

IRVING WOLFF.