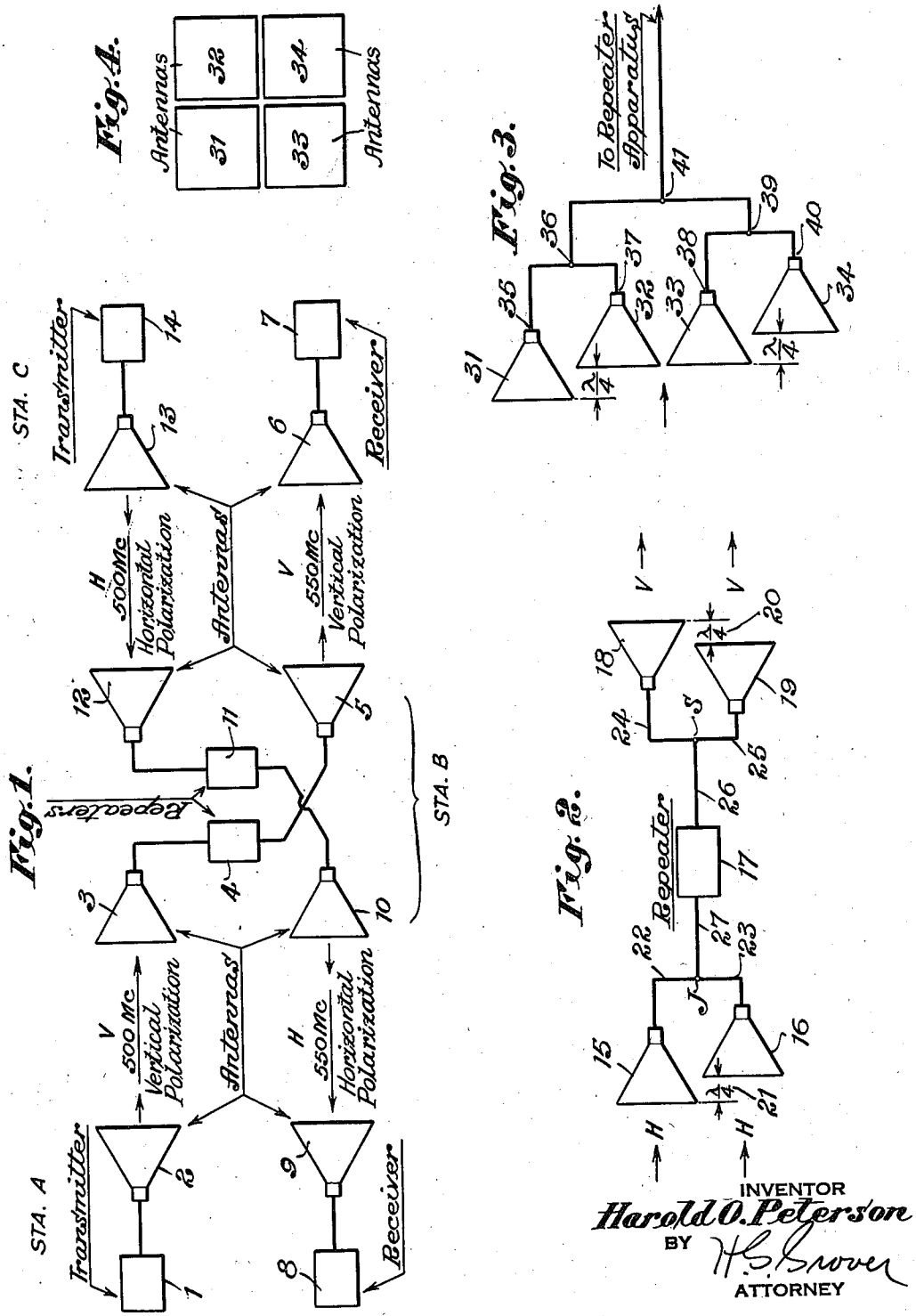
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RADIO RELAYING SYSTEM

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RADIO RELAYING SYSTEM

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8 Claims. (Cl. 250—15)

This invention relates to a radio relaying system, and particularly to such a system for use on ultra short waves.

An object of the present invention is to provide a unidirectional antenna or wave directive structure which reduces to substantially zero the effect of an undesired wave received from a direction opposite to that in which the antenna is intended to operate.

Another object of the invention is to provide a unidirectional antenna or wave directive structure which neutralizes the effect of waves emanating therefrom but traveling in a direction opposite to that intended.

A further object of the invention is to provide a unidirectional antenna or wave directive structure which discriminates substantially completely between the desired wave arriving from one direction and an undesired wave arriving from an opposite direction.

A further object is to provide a signal repeater system for a radio relaying system, having antennas positioned in substantially opposite directions, in which there is an improved front-to-back ratio of the directive pattern of each antenna.

A more detailed description of the invention follows in conjunction with a drawing, wherein:

Fig. 1 illustrates diagrammatically a radio relaying system of the type to which the principles of the present invention are applicable;

Fig. 2 illustrates in detail only those elements of a repeater station necessary for an understanding of the invention and equipped in accordance with the principles hereof;

Fig. 3 illustrates an expansion of the system of Fig. 2; and

Fig. 4 illustrates one arrangement of the antennas of Fig. 3.

Referring to Fig. 1 in more detail, there is shown a radio relaying system having terminal stations A and C, each equipped with a transmitter and a receiver, and a repeating station B located between the terminal stations for relaying or repeating the signals between station A and station C. As indicated in the drawing by the direction of the arrows, terminal station A is provided with a transmitter 1 arranged to transmit signals over directive antenna 2 to the intermediate station B, and station A is also provided with a receiver 8 arranged to receive signals over directive antenna 9 from intermediate station B. Similarly, terminal station C is provided with a transmitter 14 arranged to transmit signals over directive antenna 13 to intermediate station B, and a receiver 7 arranged to receive signals over directive antenna 6 from intermediate station B. Intermediate station B is illustrative of any one or more repeater stations which can be used in a relay system, and is provided with a directive antenna 3 for receiving the signals transmitted from station A and another directive antenna 5 for relaying or repeating the received signals from A toward terminal station C. Intermediate station B is also provided with another directive antenna 12 for receiving the signals transmitted from terminal station C and for relaying or repeating the signals over another directive antenna 10 toward the terminal station A. Apparatus 4 and 11 constitute suitable equipment for converting the signals received respectively on antennas 3 and 12 to new frequencies which are then transmitted over antennas 5 and 10. The directive antennas shown in Fig. 1 may be any suitable wave directive structure, such as a parabolic antenna having a dipole at its focus or an electromagnetic horn. If a horn is used, it is preferred, though not necessary, that it be of the type described in copending Katzin applications Serial No. 363,248, filed October 29, 1940, and Serial No. 381,264, filed March 1, 1941.

In a system of Fig. 1, transmitter 1 is arranged to transmit over directive antenna 2 a signal carrier wave at, let us say, 500 megacycles, which is received at station B on directive antenna 3 and converted by apparatus 4 to a new frequency of, for example, 550 megacycles. The new 550 megacycle carrier wave is then transmitted over directive antenna 5 to be received at terminal station C on antenna 6. Terminal station C is arranged to transmit a signal carrier wave of 500 megacycles over directive antenna 13, which is received at intermediate station B by directive antenna 12, then converted by apparatus 11 to a new frequency of 550 megacycles which is retransmitted over antenna 10 toward terminal station A and received at station A on directive antenna 9. Apparatus 4 and 11 at intermediate station B are, in effect, repeaters which amplify the received signals and convert them to a new frequency by heating with oscillations produced by a local oscillator of suitable frequency in known manner.

From the foregoing, it will be apparent that directive antennas 3 and 12 both receive signals on the same carrier frequency, but from approximately opposite directions. The amount of energy received on antenna 3 from antenna 13 will obviously be less than the amount of energy

received by antenna 3 from antenna 2, by a factor which corresponds to the front-to-back ratio of the directive pattern of antenna 3. Likewise, the amount of energy received on antenna 12 from antenna 2 is less than the amount of energy received by antenna 12 from antenna 13, by a factor which corresponds to the front-to-back ratio of the directive pattern of antenna 12.

Since it is desired to increase the factor of discrimination between the desired and undesired carrier wave received on the antennas 3 and 12, it is proposed to polarize either vertically or horizontally the electromagnetic wave emanating from antenna 2 and to polarize at a 90° relation to the first polarization, i. e., either horizontally or vertically the wave emanating from antenna 13, and to arrange the antennas 3 and 12 to respectively receive these polarized waves from antennas 2 and 13. Obviously, the arrangements for polarizing the antennas 2, 3, 12 and 13 are not limited solely to vertical and horizontal directions, since other angles such as a 45° angle can be used, provided the aforementioned 90° relation is maintained between transmitting antennas 2 and 13 and between receiving antennas 3 and 12.

We have a similar problem in the case of the transmitting antenna 5. Here again it is desired to radiate a signal from antenna 5 to be received by antenna 6. The undesired radiation from antenna 5 in the back-end or reverse direction will reach antenna 9 along with the desired signal from antenna 10 and may produce interference. This interference can be reduced by polarizing the waves radiated by antennas 5 and 10 perpendicular to each other, and arranging the antennas 6 and 9 to be responsive, respectively, solely to the polarized waves radiated by 5 and 10.

Fig. 2 shows an improved system for increasing the factor of discrimination between the desired and undesired waves arriving from opposite directions. This system is primarily intended for use at the repeater station B, although it may also find other applications.

In Fig. 2 the antenna elements 15 and 16 replace the single antenna element 3 of station B of Fig. 1, while the antenna elements 18 and 19 replace the single antenna 5 of station B of Fig. 1. These antenna elements 15 and 16, it should be noted, are an even number of units which are displaced along the direction of propagation by a distance 21 of approximately one-quarter wavelength at the operating frequency or an odd multiple thereof. Antenna units 15 and 16 are connected respectively by lines 22 and 23 to a common point J from which the energy is passed through line 27 to repeater amplifier 17. Repeater 17 may or may not be a frequency converter, as desired. Line 22 is made sufficiently longer than line 23 so that the desired received energies from antenna units 15 and 16 reach the junction point J in phase. If the velocity of the wave along the lines 22 and 23 approximates the velocity of the wave in free space, then line 22 should be longer than line 23 by a quarter wavelength or an odd multiple thereof at the operating frequency. If, however, the velocity of the wave traveling along the lines 22 and 23 do not approximate the velocity of the wave in free space, then the difference in lengths between lines 22 and 23 should be such that a wave traveling over line 22 will take longer to reach junction point J by 90° than a wave traveling over line 23 to reach the same point. With this condition fulfilled, it will be noted that waves arriving at units 15 and 16 from the desired direction indicated by the arrows, will reach junction point J in phase, due to the fact that the signal arriving at 15 is a quarter wavelength earlier than the signal arriving at 16, but will take 90° longer to arrive at junction point S. As for a signal wave arriving from the opposite direction, such a wave would reach antenna 16 ninety degrees earlier in phase than the same wave reaches antenna 15, in view of which the energy from antenna 16 would reach junction point J another ninety degrees earlier than the energy from antenna 15, thus making the energy arriving from antenna 16 one hundred and eighty degrees earlier in phase than the energy from antenna 15. In other words, the undesired signal from the reverse direction is substantially neutralized by this balance between the undesired energies from antenna units 15 and 16.

The antenna elements 18 and 19 are shown coupled to the repeater amplifier 17 through transmission lines 24, 25 and 26. Lines 24 and 25 differ in length by a desired amount and are joined at junction point S to the line 26. Antenna element 18 is displaced along the direction of propagation from antenna element 19 by approximately one quarter of a wavelength at the operating frequency. Likewise, transmission line section 24 is sufficiently longer than transmission line 25 so that the energies radiated by the two elements 18 and 19 are practically in phase with respect to the propagation in the desired direction. Here again, if the velocity of the wave along the lines 24 and 25 approximates the velocity of the wave in free space, then line 24 should be longer than line 25 by one-quarter of a wavelength at the operating frequency. With this condition fulfilled, it will be noted that the energy from the output of repeater 17 will be in phase with respect to the propagation in the desired direction indicated by the arrows, due to the fact that the signal arriving at 18 arrives there one-quarter of a wavelength or ninety degrees later in phase than the signal arriving at 19. Because of the quarter wavelength space displacement of antenna elements 18 and 19, the waves add in space in the desired direction. However, as for the energies radiated by elements 18 and 19 in the back-end direction, that is in the reverse direction toward amplifier 17, such radiated energies are undesired and are caused to cancel. This cancellation occurs by virtue of the fact that the energy radiated in the back-end direction by 19 is substantially one hundred eighty degrees out of phase with respect to the energy radiated by 18 in the back-end direction, thus causing neutralization.

Obviously, it is contemplated to provide means where desired, to enable a mechanical adjustment of the relative displacement of the antennas 15, 16, 18 and 19, and also an adjustment of the relative lengths of the transmission lines 22, 23, 24 and 25. It is preferred that the mechanical adjustment for the antennas 15 and 16 be unicontrolled with respect to the adjustment of the relative lengths of line sections 22 and 23. This should also be the case for antenna elements 18 and 19 and for lines 24 and 25.

Fig. 3 is an expansion of the ideas described above in connection with Fig. 2. In Fig. 3, there are employed two pairs of antennas 31, 32 and 33, 34 arranged side by side, but with one pair displacing 90° relative to the other pair along the direction of polarization. The outputs are

combined in proper phase relationship by means of the interconnected transmission line sections. The arrow represents the direction of propagation. Units 31, 32, 33 and 34 represent antennas which, in this case, are horn antennas. Considering the aperture of the antenna as the "front," I have shown antenna 32 as being approximately one-quarter wave length behind antenna 31 along the direction of propagation and antenna 34 is similarly approximately one-quarter wavelength behind antenna 33. The apertures of antennas 32 and 33 are approximately in the same plane. The differences in orientation of antennas along the direction in propagation is made up in the transmission line system by differences in length of the connections. Thus, the electrical length of transmission line section 35, 36 is approximately one-quarter wavelength longer than that of transmission line section 36, 37. A similar relationship exists between the electrical length of transmission line sections 38, 39 and 39, 40 and between sections 36, 41 and 41, 39. By virtue of this relationship, the effects of all four antennas add substantially in phase for the desired direction, while in the opposite direction the effects of antennas 31 and 32 tend to be 180 degrees out of phase and the effects of antennas 33 and 34 likewise tend to be one hundred eighty degrees out of phase, and the resultant residual component from antennas 31 and 32 tends to be one hundred eighty degrees out of phase with the residual component from antennas 33 and 34. Putting it in other words, the four antennas operate in phase for signals in the desired direction and the effects in the reverse direction are doubly balanced.

The relative positions of the four antennas as viewed from a point at a distance along the direction of propagation need not be that suggested in Fig. 3, but it may be such as shown in Fig. 4, or still other arrangements at the discretion of the designer.

Obviously, an arrangement similar to Fig. 3 can be used to radiate waves as well as to receive waves.

Although the invention has been described in connection with relay systems employing different frequencies between terminal stations, it should be understood that the principles of the invention are equally applicable to relay systems where the incoming and outgoing energies are relayed at a single carrier frequency for a given channel.

I claim:

1. In a radio relay system, a repeater station having a unidirectional wave directive structure composed of a pair of horn antenna elements positioned for effective operation in the same direction, said horn elements being spaced one from another along the line of said direction a distance equal to an odd multiple including unity of a quarter of the operating wavelength, connections differing by an electrical length of an odd multiple including unity of a quarter of the operating wavelength extending from said elements to the input of an amplifier system to produce a cophasal relationship for waves arriving from said direction, and a similar unidirectional wave directive structure coupled by connections arranged similarly to said first connections to the output of said amplifier system and positioned for effective operation in a substantially opposite direction than said first structure.

2. In a radio relay system, a transmitting station radiating a carrier wave of one frequency, a receiving station for receiving a carrier wave of another frequency, and a repeater station located intermediate said stations and having thereat a unidirectional antenna system positioned to receive the wave from said transmitting station, another unidirectional antenna positioned to transmit a carrier wave to said receiving station and a frequency converter for converting the frequency of the received wave from the transmitting station to a frequency to which the receiving station is responsive, at least one of said unidirectional antennas at said repeater station comprising a pair of elements positioned for effective operation in the same direction, said elements being spaced one from another along the line of said direction a distance equal to an odd multiple including unity of a quarter of the operating wavelength, means connecting said elements in parallel to the input of an amplifier system in a mutual in-phase relationship for waves arriving from said direction.

3. In a radio relay system, a pair of terminal stations both having transmitters for radiating a carrier of frequency f_1 and receivers for receiving a carrier wave of frequency f_2, a repeater station located intermediate said stations and having a first unidirective antenna positioned to receive the wave f_1 radiated from one terminal station, a second unidirective antenna positioned to transmit a wave f_2 to the other terminal station, a third unidirective antenna positioned to receive the wave f_1 radiated from said last terminal station, and a fourth unidirective antenna positioned to transmit a wave f_2 to said one terminal station, repeater apparatus coupled between said first and second unidirective antennas and between said third and fourth unidirective antennas, one pair of said unidirective antennas which are coupled to the same repeater each comprising two wave directive elements positioned for effective operation in the same direction and spaced from one another along the line of said direction a distance equal to an odd multiple including unity of a quarter of the operating wavelength, lines coupling said wave directive elements to a common junction, said lines differing in length by an amount sufficient to compensate for the phase shift produced by the spacing between said directive elements for waves traveling in a predetermined direction.

4. A system in accordance with claim 1, characterized in this that said elements comprise electromagnetic horns.

5. A system in accordance with claim 2, characterized in this that said transmitting station has an antenna polarized in a particular direction and the antenna at said repeater station which is positioned to receive the wave radiated from said transmitting station is also polarized in the same direction.

6. A system in accordance with claim 2, characterized in this, that said transmitting antenna at said repeater station is polarized in a particular direction and said receiving station has an antenna which is positioned to receive the wave radiated from said repeater station and also polarized in the same direction.

7. In a radio relay system, a repeater station having a unidirectional wave directive structure composed of a pair of elements positioned for effective operation in the same direction, said elements being spaced one from another along the line of said direction a distance equal to an odd multiple including unity of a quarter of the operating wavelength, means connecting said

elements in parallel to the input of an amplifier system in a mutual in-phase relationship for waves arriving from said direction, and a similar unidirectional wave structure also coupled to the input of said amplifier system but displaced in space along the direction of propagation from said first wave structure, said two wave structures being positioned for effective operation in the same direction.

8. In a radio relay system, a repeater station having a unidirectional wave directive structure composed of a pair of elements positioned for effective operation in the same direction, said elements being spaced one from another along the line of said direction a distance equal to an odd multiple including unity of a quarter of the operating wavelength, means connecting said elements in parallel to the output of an amplifier system in a mutual in-phase relationship for waves to be transmitted by said structure in said direction, and a similar unidirectional wave structure, also coupled to the output of said amplifier system but displaced in space along the direction of propagation from said first wave structure, said two wave structures being positioned for effective operation in the same direction.

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