

May 12, 1936.

P. S. CARTER

2,040,079

REVERSIBLE BEAM SYSTEM

Filed Sept. 1, 1932

3 Sheets-Sheet 1

Fig. 1

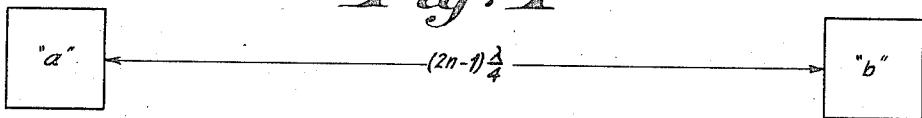


Fig. 2a

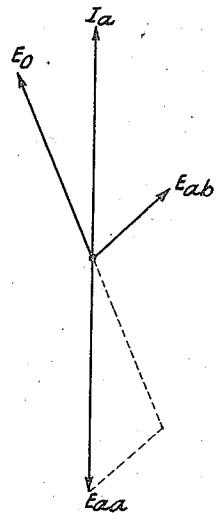


Fig. 2b

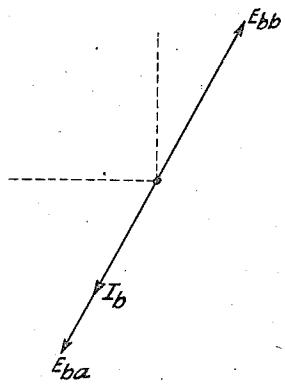


Fig. 3a

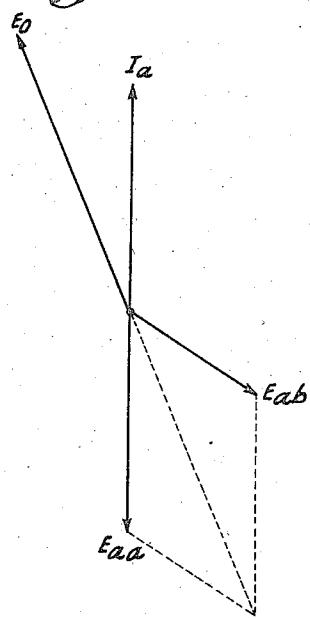
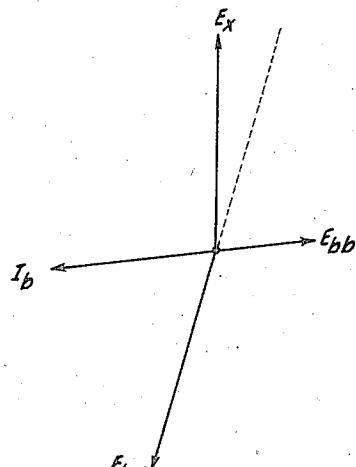


Fig. 3b



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Fig. 4a



Fig. 4b

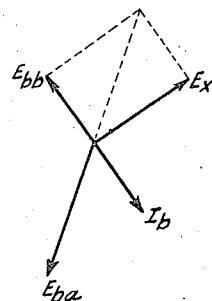


Fig. 5

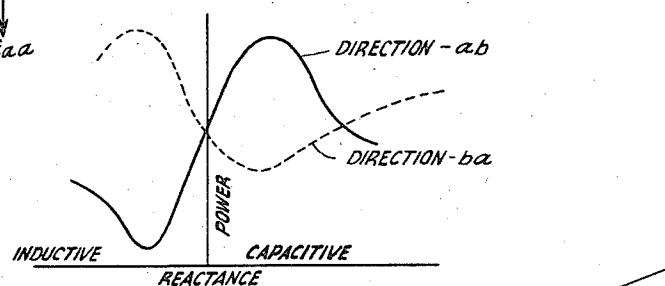
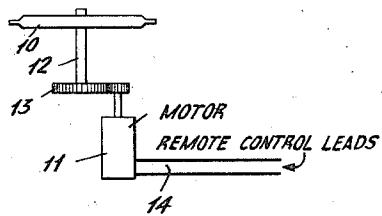


Fig. 9



Fig. 9a



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Fig. 6

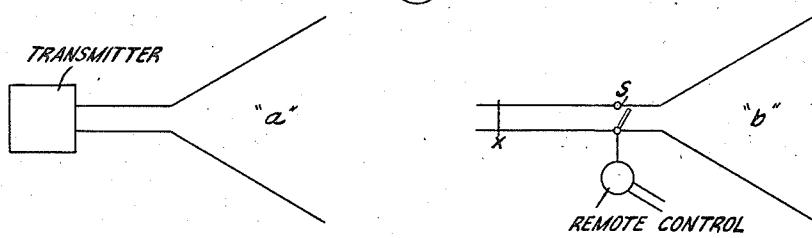


Fig. 7

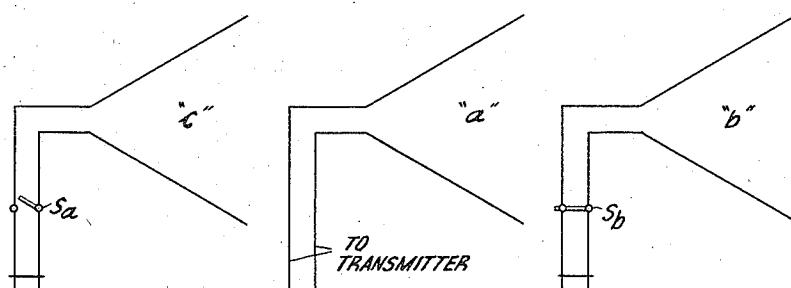
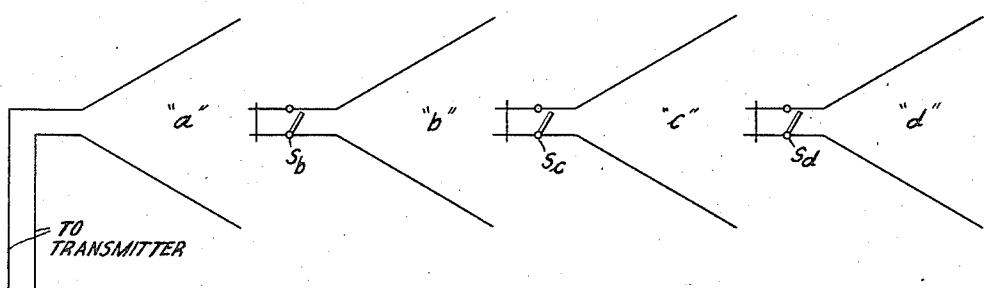


Fig. 8



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UNITED STATES PATENT OFFICE

2,040,079

REVERSIBLE BEAM SYSTEM

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Application September 1, 1932, Serial No. 631,320

11 Claims. (Cl. 250—11)

This invention relates to directive antennæ and is especially concerned with antennæ of the unidirectional type.

In the communication of intelligence by radio between stations it is the practice to employ directional antennæ which have the property of radiating or receiving radio waves in a larger proportion along the direction of transmission than other directions. Such antennæ may be either of the bi-directional or unidirectional type. The latter type, to which this invention has reference, has been found to be more desirable both from an engineering and economic standpoint since it is highly efficient in communication and has the advantage, to a certain extent, of secrecy.

A system of this kind is disclosed in my United States Patent No. 1,974,387, granted September 18, 1934 wherein there is described one way of obtaining a directive antenna system by means of long V wires energized in phase opposition and disposed at an angle such that principal radiation takes place along the bisector of the angle. To effect the unidirectional characteristic, a similar parallel pair of V wires are placed an odd number of quarter wave lengths away from the radiators proper in a direction along the bisector of the angle formed by the wires. This second pair of wires may be left unenergized or floating, or may be energized in proper phase such that in one direction radiation cancellation occurs, whereas in the other direction there is a strengthening of the propagated radiated waves.

In practice it is frequently desirable, in the interest of economy, to use a single unidirectional antenna system of the type described above for communication in opposite directions. Due to the reaction which takes place between the unit acting as the antenna and the unit acting as the reflector it has not been heretofore possible to reverse the direction of radiation of a beam system constructed in the usual manner. It has been the custom in the past in reversing a beam system to completely retune and readjust the circuit in order to obtain the same high degree of efficiency, a matter of adjustment which usually required several days. This retuning has been found to be necessary due to the upsetting of the phases and the current balance between antenna and reflector.

A primary object of the present invention is to overcome the foregoing disadvantage by enabling the reversal of the direction of radiation of a beam system in a small fraction of time, of the order of a second or so.

A further object is to accomplish such reversal by remote control means.

An important advantage of the present invention resides in the fact that a single unidirectional antenna system may now be used for communication in two opposite directions, whereas heretofore two antenna systems were required. Accordingly, there are effected appreciable savings in cost of construction, maintenance and operating personnel.

A better understanding of the invention may be had by referring to the following detailed description in connection with the accompanying drawings. It is to be distinctly understood, however, that although the invention is described with reference to the V type antenna this is done for purposes of illustration only and it is not limited thereto since it lends itself readily for use with other types of antenna systems.

Figure 1 shows in conventional box form two radiators indicative of an antenna and a reflector, separated from each other by a distance equal to an odd number of quarter wave lengths. This figure is given to aid in the explanation of the principles underlying the present invention.

Figures 2a, 2b, 3a, 3b, 4a and 4b are vector diagrams showing the phase relations of currents and voltages in the two radiators of Figure 1 for non-reactive and reactive conditions existing in the reflector.

Figure 5 shows the relative radiated power in two opposite directions as the reactance in the reflector of Figure 1 is changed.

Figures 6, 7, and 8 illustrate the present invention applied to different types of antenna systems.

Figures 9 and 9a show one suitable type of remote control switch which may be employed.

Referring to Figure 1, there are shown two boxes *a* and *b* representing an antenna and a reflector respectively, separated from each other by an odd number of quarter wave lengths equal to

$$(2n-1) \times \frac{\lambda}{4}$$

where *n* is an integer and λ is the length of the communication wave. Assuming that radiator *a* is energized and *b* unenergized, it will be evident that an electromotive force will be induced in *b* which falls off in intensity as *b* is moved away from *a*. This induced E. M. F. will also shift in phase with a movement of *b*, due to the finite time taken for the energy to travel through the space between the radiators.

It has been found, however, that when the

spacing between radiators becomes a quarter wave length the induced E. M. F. will not have rotated in phase ninety degrees from that of zero spacing. The reason for this is discussed by me at some length in an article entitled "Circuit relations in radiating systems and applications to antenna problems" published in the proceedings of the Institute of Radio Engineers for June 1932, pages 1004 to 1041. Since the theoretical analysis 10 is quite involved and the circuit relations complicated they will not be repeated herein. In general, I have shown by theoretical analysis that the phase of the E. M. F. induced in a radiator *b* (note Figure 1) by a current I_a in a radiator "a" 15 is not equal to an angle

$$2\pi \frac{s}{\lambda}$$

where *s* is the spacing, but depends upon a number of factors in addition to the spacing, such as the type and length of each radiator. The amplitude and phase of the current in *b* due to the induced E. M. F. will depend upon the effective impedance of *b*, the phase angle being capable of being shifted through a wide range of variation of the effective reactance. The present invention is based upon an understanding of this phenomenon.

Figure 2a represents a vector diagram of the currents and voltages in a perfectly tuned radiating system "a" shown in Figure 1, and Figure 2b represents a vector diagram of the conditions existing in reflector "b" spaced from "a" by a distance equal to

$$(2n-1) \times \frac{\lambda}{4}$$

where *n* is an integer and λ is the wave length, when said reflector *b* is non-reactive.

Referring to Figure 2a, let it be assumed that E_0 is the E. M. F. impressed upon "a" which results in a current I_a and an induced E. M. F. therein of E_{aa} . Assuming that reflector *b* is perfectly tuned, there results phase relations of currents and E. M. F.'s approximately as shown in these figures, where E_{ba} is the E. M. F. induced in *b* by the current I_a in "a" and E_{bb} is the effective back E. M. F. in *b* due to current I_b in *b*. E_{ab} is the induced E. M. F. in "a" due to the current I_b in *b*. E_0 , of course, is equal and opposite to the vector sum of E_{aa} and E_{ab} .

For *b* to act as the most efficient reflector for antenna *a*, I_b must lead I_a by a phase angle of $(2n-1) \times 90^\circ$ the spacing distance being

$$(2n-1) \frac{\lambda}{4}$$

and this can be accomplished by the addition of an inductive reactance to reflector *b*. Maximum radiation will then take place in the direction of *b* to *a*. The resulting vector diagrams are shown in Figures 3a and 3b which represent conditions existing when an inductive reactance is inserted in series with the reflector *b*. It will be noted that this insertion results in the current in *b* lagging the voltage by a phase angle depending upon the value of the inductive reactance inserted in series. It is assumed, of course, that the reactance is that required to rotate the phase of the current so that it becomes in quadrature relation with the current in the primary radiator.

If desired, maximum radiation may be caused to occur in the direction "a" to "b" by the introduction of sufficient capacity reactance in *b* to

make I_b lead E_{ba} by a phase angle sufficient to result in *b* giving a boosting action to the radiation from *a*. Vector diagrams showing the conditions existing when a capacitive reactance is inserted in *b* to effect this result are illustrated in Figures 4a and 4b.

Figure 5 shows curves illustrating the relative radiated power in the two opposite directions *a* to *b* and *b* to *a* as the reactance in *b* is changed from an inductive to a capacitive value.

From the foregoing it will be seen that if a reactance is inserted in *b* of exactly the right amount to give maximum radiation in the direction *b* to *a* and a switch used to change to the condition giving maximum radiation in the direction *a* to *b* there results a quickly changeable reversible system, which briefly comprises the present invention. A switch suitable for this purpose is shown in Figures 9 and 9a, wherein a switch blade 10, connected to a motor 11 through a shaft 12 and gears 13, is controllable from a remote point over leads 14. Blade 10 is arranged when in the closed position to insure the desired reversal by short-circuiting contacts 15, 15. In order to avoid the need for insulation, shaft 12 is connected to the center of switch blade 10 and is thus always at neutral potential whether the switch is in the open or closed position.

Referring to Figure 6 of the drawings, there are shown a transmitting radiator "a" and a reflector "b" of the type described in my United States patent referred to above, adapted for the quick reversal of the direction of radiation in accordance with the teachings of the present invention. In the V type of system this is readily accomplished by simply opening and closing a short-circuiting strip on the tuning loop of the reflector *b*, as indicated in the drawings. By adjusting the tuning loop, any value of capacity or inductive reactance from zero to infinity may be obtained. For this purpose use may be made of the knowledge that a short circuited section of transmission line less than one-quarter wave length long acts as an inductive reactance whereas a short circuited section of transmission line greater than one-quarter wave length but less than one-half wave length acts as a capacitive reactance, the value of either being equal to

$$Z_0 \tan 2\pi l/\lambda$$

where *l* is the length of line section and Z_0 the surge impedance. In the adjustment of the circuit, short-circuiting strip *X* is first regulated to the position giving maximum radiation in the direction *b* to *a*. A second strip is then adjusted to the position giving maximum radiation in the direction *a* to *b*, and at this position there is placed a control switch *S* for controlling the opening or closing of the tuning loop at this point. Switch *S* may be of any suitable type controllable either by a relay or dashpot and is preferably remotely controlled through any suitable means.

Considerable improvement in the radiation characteristics may be obtained by using a system of three units where power is fed to the middle unit as shown in Figure 7. In these drawings there are illustrated three units *c*, *a*, and *b* of which only unit *a*, the middle one, is energized from the transmitter. In this case there are used two switches S_a located on unit *c* and S_b located on unit *b*, both of which are suitably adjusted with respect to the tuning loops in the manner indicated above. These switches are preferably operated simultaneously by remote control although, if desired, they may function independ-

ently. In the system indicated in the drawings, maximum radiation is in the direction *a* to *b* whereas by opening switch *S_b* and closing switch *S_a* this direction is reversed so that radiation occurs in the direction *b* to *a*.

Figure 8 illustrates a "booster" system of a type wherein the present invention may be used. This system makes use of the principle of advancing the phase by tuning the unfed units so 10 that the several units act as a "booster" system for the first. These units *b*, *c*, and *d* may also be tuned for radiation in the opposite direction, that is, inductively, so that they act as a multiple reflector system. A system of switches similar to those indicated in Figures 6 and 7 is shown 15 designated as *S_b*, *S_c*, and *S_d* for effecting quick reversal.

Although the present invention has been described with particular reference to the V type 20 antenna, it will be apparent that its scope is not limited thereto since it may be used in various other arrays where the principles outlined above are used, such as with three half wave dipoles, three units where each unit is an array, and other 25 similar combinations of long wires. It will also be apparent that the invention described above may be extended to include several units of V antenna systems in the usual broadside arrangement and to systems in which the V's lie in a 30 vertical plane as well as any of the modified arrangements shown in my above-mentioned patent.

I claim:

1. A reversible unidirectional antenna system 35 having, in combination, two radiating elements, one of said elements having a two wire line connected thereto, and switching mechanism in circuit with said one element for shunting out a portion thereof of said line for reversing the direction of radiation of said system.

2. A unidirectional antenna system comprising 40 a pair of angularly disposed linear conductors, means for exciting the conductors in phase opposition for effecting bidirectional radiation, another pair of conductors parallel and similar to 45 said first mentioned pair and spaced therefrom an odd number of quarter wave lengths measured in a direction along the bisector of the angle of the conductors for effecting unidirectional radiation 50 from said system as a whole, and switching mechanism connected to said second pair of conductors for shunting a portion thereof whereby reversal of the direction of unidirectional radiation from said system is effected.

3. A unidirectional antenna system comprising 55 a pair of angularly disposed linear conductors, means for exciting said conductors in phase opposition, a second pair of conductors parallel and similar to said first mentioned pair of conductors 60 and spaced therefrom an odd number of quarter wave lengths measured in a direction along the bisector of the angle of the conductors and in the direction of radiation, a third pair of conductors similar to said first pair of conductors and also 65 spaced along the bisector of the angle of the conductors, but in the direction away from the direction of radiation, switches connected to said second and third pairs of conductors and arranged such that when one is in an operative position 70 the other is in an inoperative position and vice versa, said switches when operated being adapted to change the tuning of said system in the direction of radiation.

4. A direction changing beam system comprising 75 an antenna, means for energizing said antenna, an unenergized reflector spaced an odd number of quarter wave lengths away from said antenna, said reflector having a short-circuited section of transmission line less than one-quarter wave length long arranged as an inductive reactance for the directional radiation of energy from said system and means for changing the effective length of said section of transmission line to a length greater than one-quarter wave length but less than one-half wave length arranged as a capacitive reactance for effecting a change in the direction of radiation, the value of said sections being equal to

$$Z_0 \tan \frac{2\pi l}{\lambda} \quad 15$$

where *l* is the length of the section, λ the wave length, and Z_0 the surge impedance.

5. A reversible uni-directional antenna system 20 having, in combination, two parallel radiating elements, each of said elements having two arms, the arms of one of said elements being coupled to high frequency apparatus and the arms of said other element being connected together by a 25 transmission line, and means for effectively shunting out at will a portion of said transmission line.

6. A direction changing antenna system comprising 30 an antenna having a pair of arms, high frequency apparatus coupled to said antenna, a second antenna spaced from said first antenna and having a similar pair of arms which are respectively parallel to the arms of said first pair, a short-circuited transmission line having a 35 length greater than one-quarter of the length of the communication wave, but less than one-half of the communication wave connected to the pair of arms of said second antenna, and switching mechanism for effectively shortening said transmission line to a length less than one-quarter of 40 the length of the communication wave.

7. A uni-directional antenna system comprising 45 a pair of linear conductors, means for exciting said conductors, a second pair of conductors respectively parallel and similar to the corresponding conductors of said first pair and spaced therefrom an odd number of quarter wave lengths measured in the direction of radiation, a third 50 pair of conductors similar to said first pair of conductors and also spaced from said first pair of conductors but in a direction away from the direction of radiation, switches connected to said second and third pair of conductors and arranged such that when one is in an operative position the other is in an inoperative position and vice 55 versa, said switches when operated being adapted to change the tuning of said system in the direction of radiation.

8. A uni-directional antenna system comprising 60 a pair of linear conductors, means for exciting said conductors, a second pair of conductors respectively parallel and similar to the corresponding conductors of said first pair and spaced therefrom an odd number of quarter wave lengths measured in one direction, a third 65 pair of conductors similar to said first pair of conductors and also spaced therefrom in said one direction, switches connected to said second and third pair of conductors and arranged such that both are either in operative or inoperative 70 positions simultaneously, said switches when operated being adapted to change the tuning of said system for reversing the direction of radiation as compared to the direction when said switches are inoperative. 75

9. A reversible unidirectional antenna system having, in combination, two radiating elements, each of said elements comprising two arms, one of said elements including a short-circuiting connection coupling together the two arms of said element, and a switch for shunting out a portion of said short-circuiting connection for reversing the direction of radiation of said system.
10. A reversible unidirectional antenna system having, in combination, two radiating elements, means for energizing only one of said elements, the other of said elements comprising two arms which are angularly disposed with respect to each other and energized in phase opposition, a connection between said two arms and switching
- 15

mechanism in circuit with said connection for changing the effective impedance thereof between said two arms for reversing the direction of radiation of said system.

11. A reversible unidirectional antenna system having, in combination, an antenna and a reflector, said reflector comprising two arms which are angularly disposed with respect to each other and energized in phase opposition, a conductive connection between said two arms and switching mechanism in circuit with said connection for changing the effective impedance thereof between said two arms for reversing the direction of radiation of said system.

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