June 8, 1943. R. L. FREEMAN ET AL 2,321,478

ULTRA HIGH FREQUENCY CARRIER-SIGNAL TRANSLATING SYSTEM

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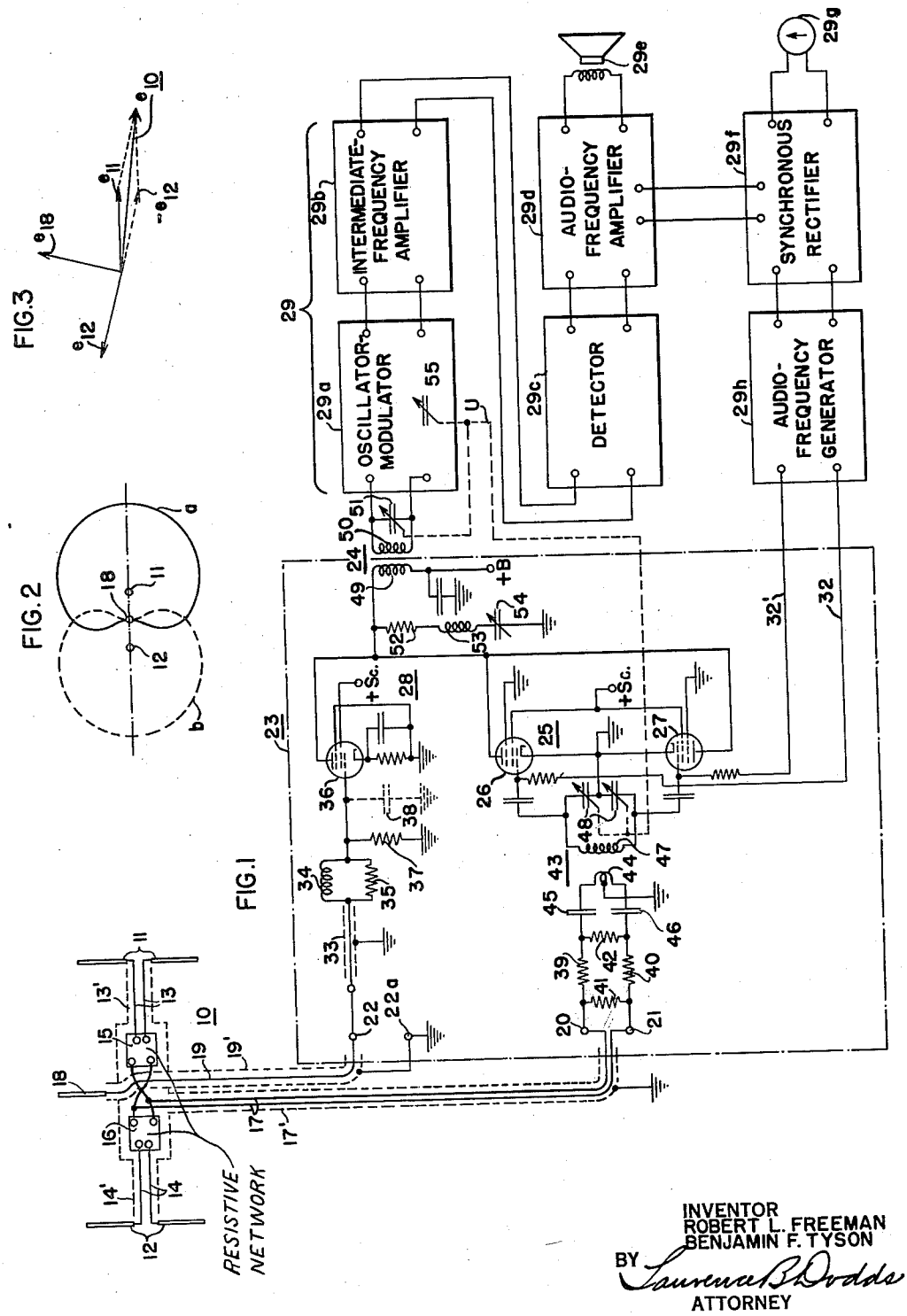

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FIG.4

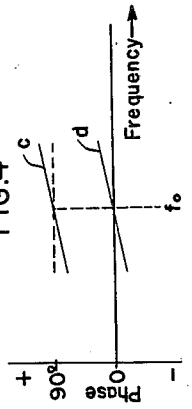

FIG.5

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ULTRA-HIGH-FREQUENCY CARRIER-SIGNAL TRANSLATING SYSTEM

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9 Claims. (Cl. 250—11)

The present invention relates to ultra-high-frequency signal-translating systems and, particularly, to systems of this nature which are adapted to translate two carrier signals having a predetermined constant phase relationship. More particularly, the invention relates to a system of the type described wherein the desired phase relationship between two such carrier signals after translation by the system is maintained substantially constant, irrespective of the frequencies of the signals over a wide range of signal frequencies. While not limited thereto, the invention has particular utility in a direction-finding system and will be described in that connection.

It is frequently desirable that two carrier signals of the same frequency and of a predetermined constant phase relationship be translated through a translating system to a predetermined point therein and that the signals at this point shall have the same or different predetermined phase relationship which remains substantially uniform over a relatively wide range of signal frequencies. A system of this type is exemplified by one form of direction-finding system in which the same carrier signal is received by a non-directional antenna and an Adcock antenna and individually applied to two signal-translating paths which constitute the initial circuits of the system. The circuit elements of the paths have constants so proportioned that the carrier signals during translation through the paths undergo a ninety-degree relative phase shift and are combined so that the directional radiation characteristic of the direction-finding system is of cardioid pattern. It is necessary in such systems that this phase relationship be maintained constant over a wide range of operating frequencies.

At relatively low frequencies, for example, below 60 megacycles, the required ninety-degree phase relationship between carrier signals translated through two translating paths of the type described has been effected in accordance with one prior art arrangement by providing in one of the paths an impedance having a predominantly reactive characteristic, for example, a condenser. At higher frequencies, for example, from 65 to 140 megacycles, however, arrangements of this nature have such low impedance that the loss of carrier-signal energy during translation through the one path becomes prohibitive. In another prior art arrangement, the required phase relationship between the translated carrier signals has been effected by including in one of the signal-translating paths a transformer having its primary and secondary windings tuned to the same operating frequency. Such arrangements have the disadvantage that that the primary and secondary tuned circuits must be "tracked" or tuned together over the entire operating frequency band. It is exceedingly difficult, if not impossible, to accomplish this in practice since the circuits to which the windings of the transformer are individually coupled have quite distinctly different impedance characteristics.

It is an object of the invention, therefore, to provide an ultra-high-frequency carrier-signal translating system of the type described and one which avoids one or more of the disadvantages and limitations of the prior art systems of this nature.

It is a further object of the invention to provide an ultra-high-frequency signal-translating system particularly suited for use in a direction-finding system and one in which a desired phase relationship between two carrier signals translated through the system is maintained substantially constant over a wide range of operating frequencies.

It is an additional object of the invention to provide an ultra-high-frequency carrier-signal receiver adapted for use with an antenna system including an Adcock antenna and a nondirectional antenna wherein the receiver has a desired directional carrier-signal radiation characteristic which remains substantially uniform over a relatively wide frequency band.

It is a further object of the invention to provide an ultra-high-frequency carrier-signal receiver adapted for use with an antenna system of the type described wherein the receiver has a directional carrier-signal radiation characteristic approximately of cardioid pattern which remains substantially uniform over a relatively wide frequency band.

In accordance with a feature of the invention, an ultra-high-frequency carrier-signal translating system adapted to have a desired directional carrier-signal radiation characteristic substantially symmetrical about a line and substantially favoring one direction along this line over a relatively wide ultra-high-frequency band, comprises a carrier-signal translating channel having at least three terminal circuits, two of the terminal circuits being adapted to be coupled through individual lead-in transmission lines to individual ones of a pair of antennas of different relative directional characteristics and the other being adapted to be coupled to a carrier-signal trans-

lating apparatus. One of the foregoing two terminal circuits is untuned and has a frequency-band characteristic at least as wide as the above-mentioned wide frequency band. The system also comprises a means included in the aforesaid one of the two terminal circuits for establishing at a predetermined point in the signal-translating channel at a given operating frequency in the vicinity of the frequency band a predetermined phase relationship between carrier signals translated through the two terminal circuits, whereby the signal-translating apparatus has the desired directional characteristic at the given operating frequency. The other of the two above-mentioned terminal circuits is tunable over the frequency band to select a desired carrier signal therein. The system includes phase-shifting means in the other of the two terminal circuits which has a phase-frequency characteristic substantially of the same form as that of the last-named means for substantially maintaining at the predetermined point and over the frequency band the predetermined phase relationship between carrier signals translated through the two terminal circuits, thereby to maintain the desired directional characteristic of the system over the aforesaid frequency band.

In a particular form of the invention, an ultra-high-frequency carrier-signal translating channel comprises a pair of carrier-signal translating paths adapted to have applied thereto carrier signals within a wide range of carrier-signal frequencies, a first of the paths being untunable, and means included in the first path for imparting thereto over the range of frequencies a substantially linear phase-frequency characteristic. The system also includes means included in the other of the paths for tuning it to any desired carrier signal within the aforesaid range and for imparting thereto over the range of frequencies a substantially linear phase-frequency characteristic of different absolute value but of substantially the same slope as that of the first path, whereby carrier-signal outputs of the paths corresponding to any selected carrier-signal input have a predetermined substantially constant and relative phase difference, and means coupled to the signal-translating paths to utilize the carrier-signal outputs having the aforesaid predetermined relative phase difference.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring now to the drawings, Fig. 1 is a circuit diagram, partly schematic, of a carrier-signal translating system comprising a complete carrier-signal receiver embodying the invention; Fig. 2 illustrates the radiation pattern characteristic of the carrier-signal receiver of Fig. 1; Fig. 3 is a vector diagram representing the phase relationships of carrier signals at selected points in the arrangement of Fig. 1 and is used as an aid in explaining the operation of the invention; Fig. 4 is a graph representing at a selected point in the arrangement of Fig. 1 the phase shift-frequency characteristic of translated carrier signals; and Fig. 5 is a circuit diagram, partly schematic, of a modified form of carrier-signal translating system comprising a carrier-signal transmitter embodying the invention.

Referring now more particularly to Fig. 1, there is represented schematically a carrier-signal translating system adapted to have a desired directional carrier-signal radiation characteristic, for example, of cardioid pattern, which is substantially symmetrical about a line and substantially favors one direction along this line over a relatively wide frequency band. By the term "carrier-signal radiation characteristic" as used in this specification and the appended claims is meant the variation, with respect to direction, in the ability of the system to radiate carrier signals or to receive radiated carrier signals. By the term "relatively wide frequency band" as used in this specification and the appended claims is meant a frequency band of a width of the same order of magnitude as its mean frequency, usually at least 0.2. By the term "ultra-high-frequency band" is meant a band the lowest frequency of which is not lower than about 40 megacycles. The carrier-signal translating system of Fig. 1 comprises a complete carrier-signal receiver of a conventional design embodying the present invention in a preferred form. In general, the system includes an Adcock antenna 10 having a pair of vertical dipoles 11, 12 interconnected with reversed phase by a balanced transmission line including two sections 13, 14. Included in each of the transmission line sections 13, 14 adjacent their junction is a respective resistive network 15, 16 of a type disclosed and claimed in the copending application of Harold A. Wheeler, Serial No. 411,292, filed September 18, 1941, entitled Directive antenna system, which is assigned to the same assignee as the present invention. Coupled to the Adcock antenna 10 at the junction of the transmission-line sections 13, 14 is a balanced transmission line 17. Positioned midway between the dipole antennas 11, 12 is a nondirectional vertical antenna 18 having a transmission line 19 coupled thereto. The transmission-line sections 13, 14 and the transmission lines 17 and 19 are enclosed within grounded metallic shields, as indicated by the respective broken lines 13', 14', 17', and 19', in conventional manner.

The transmission lines 17 and 19 are individually coupled to input circuit terminals 20, 21 and 22, 22*a* of a carrier-signal translating channel 23 which includes an output circuit comprising an output transformer 24. The signal-translating channel 23 includes a balanced amplifier 25 including vacuum tubes 26, 27 which couple the input circuit terminals 20, 21 to the output circuit transformer 24. Also included in the signal-translating channel 23 is an amplifier stage 28 which couples the other input circuit comprising terminals 22, 22*a* to the output circuit transformer 24. The output circuit of the signal-translating channel 23 is coupled to the input circuit of a carrier-signal translating apparatus such as a carrier-signal receiver 29 which may include, in the order named, an oscillator-modulator 29*a* for converting received carrier signals to intermediate-frequency carrier signals, an intermediate-frequency amplifier 29*b* which may include one or more stages of intermediate-frequency amplification, a detector 29*c*, a pair of output circuits one of which may include an audio-frequency amplifier 29*d*, and a sound-reproducing device 29*e*. Coupled to the output circuit of amplifier 29*d* is a synchronous rectifier 29*f* having an output circuit coupled to a zero-center scale indicating meter 29*g* of the direct-current type and having a synchronous control circuit coupled to the output circuit of a generator 29*h* of audio-frequency oscillations of pulse wave form. The output cir-

cuit of the latter is also coupled through a pair of circuits 32, 32' to the input circuits of individual ones of the vacuum tubes 26, 27 of amplifier 25.

It will be apparent, therefore, that the carrier-signal translating channel 23 has at least three terminal circuits. These circuits comprise the input circuits including terminals 20, 21 and 22, 22a and also the output circuit including the output transformer 24. It will also be clear that two of the above-mentioned terminal circuits are adapted to be coupled through individual lead-in transmission lines 17 and 19 to individual ones of the pair of antennas 10 and 18 of different relative directional characteristics and the other of the three terminal circuits is adapted to be coupled to the carrier-signal translating apparatus 29.

It will be understood that the various units just described may, with the exception of the signal-translating channel 23, be of a conventional construction and operation, the details of which are well known in the art, rendering detailed descriptions thereof unnecessary. Considering briefly the operation of the signal-translating system as a whole, and neglecting for the moment the operation of the signal-translating channel 23 presently to be described, a desired carrier signal is received by the antenna system comprising the Adcock antenna 10 and the vertical antenna 18 and is applied through the transmission lines 17 and 19 to the input circuits of the signal-translating channel 23. The received carrier signal is amplified by amplifiers 25 and 28 and combined in their common output circuit. Assume that it is desired that the signal-translating system shall have a directional radiation characteristic in a horizontal plane of cardioid pattern, as represented by the solid-line curve *a* or broken-line curve *b* of Fig. 2. This is accomplished by so phasing the carrier signals translated by the amplifiers 25 and 28 that they are combined in the output circuit of these amplifiers either in the same phase or 180 degrees out of phase at a time when the source or transmitter of the carrier signals is horizontally displaced from the Adcock antenna 10 and in line with the dipoles 11, 12. The audio-frequency oscillations applied from the generator 29*h* to the vacuum tubes 26 and 27 of amplifier 25 cause these tubes to be periodically and alternately biased to cutoff at an audio-frequency rate. This has the effect of periodically reversing the phase of the carrier signal translated by amplifier 25. Further assume that the transmitter is not only in line with the dipoles 11, 12 but that it is closer to dipole 11 and that the antennas 10 and 18, their respective transmission lines 17 and 19, and the signal-translating channel 23 have been so adjusted, in a manner to be considered in greater detail hereinafter, that when the vacuum tube 26 is conductive the carrier signals translated by the amplifiers 25 and 28 are combined in the same phase in the common output circuit of the amplifiers, whereby the system has the desired directional radiation characteristic of cardioid pattern, for example, that represented by curve *a*, Fig. 2. A short interval later, the oscillations from the generator 29*h* bias the tube 26 to cutoff and allow tube 27 to become conductive. The phase of the carrier signal translated by amplifier 25 is now reversed and is exactly out of phase with the carrier signal translated by amplifier 28. The system thereupon has the desired directional radiation characteristic of cardioid pattern, but the major lobe thereof is now pointed in the opposite direction, as represented by the broken-line curve *b*, Fig. 2.

It will now be evident that when the station which transmits the received carrier signal is located on an axis perpendicular to the plane of the dipoles 11, 12, the carrier signal applied from the output circuit of the signal-translating channel 23 to the input circuit of the oscillator-modulator 29*a* has the same intensity during each half-cycle of the audio-frequency oscillations generated by unit 29*h*. Thus, the output of the detector 29*c* is unchanged during each complete cycle of the audio-frequency oscillations and no sound is produced by the sound-reproducing device 29*e*. The synchronous recifier 29*f* includes two rectifier tubes connected in parallel with opposite polarities, the rectifier tubes being rendered alternately conductive during individual half-cycles of the audio-frequency oscillations applied thereto from the generator 29*h*. The output of the synchronous rectifier 29*f* thus comprises an alternating potential, the relative magnitudes of the positive and negative half-cycles of which vary with the amplitudes of the combined carrier signal applied to the input circuit of oscillator-modulator 29*a* during corresponding half-cycles of the audio-frequency oscillations generated by unit 29*h*. Thus, when the transmitting station is located as hereinbefore assumed, the alternating potential applied to the direct-current indicating meter 29*g* has positive and negative half-cycles of equal amplitude and the latter shows no deflection from its zero-center position. However, when the transmitting station is in any other direction from that just considered, the carrier signal developed in the output circuit of unit 23 has unequal intensities during opposite half-cycles of the audio-frequency oscillations developed by unit 29*h*; that is, it is effectively amplitude-modulated at the frequency of the pulse generator 29*h*. An audio-frequency output is thus applied to and reproduced by the sound-reproducing device 29*e*. Likewise, there is applied to the indicating device 29*g* an alternating potential having half-cycles of unequal amplitude which produces a deflection to one side of zero-center position of this device, thereby to indicate the relative direction of the transmitting station from the plane of the dipole antennas 11, 12. In practice, the Adcock antenna is rotatable about its vertical axis, whereby it may be oriented with respect to the transmitting antenna. Correct orientation is obtained by orienting either for zero audio-frequency output of the receiver or zero deflection of the indicating device 29*g*.

Considering now the portion of the system embodying the present invention, the terminal or input circuit of unit 23 comprising the input circuit terminals 22, 22*a* is fixed tuned to have a band-pass characteristic at least as wide as the frequency band over which the system is to operate. The system includes means included in one of the two terminal circuits for establishing at a predetermined point in the signal-translating channel and specifically in the output circuit of unit 23 at a given operating frequency in the vicinity of the frequency band over which the system is to operate a predetermined phase relationship between carrier signals received by the antennas 10 and 18, whereby the receiver has the desired directional characteristic, for

example, of cardioid pattern as represented by the curves of Fig. 2, at this given frequency. This means comprises a short length of transmission line 33, either real or artificial or a combination of both, which couples the input circuit terminals 22, 22a through an impedance network comprising an inductor 34 and shunt-connected resistor 35 to the control electrode of a vacuum tube 36 included in amplifier 28. The input electrodes of vacuum tube 36 are connected by a grid leak resistor 37 and their interelectrode capacitance is represented by a condenser 38 shown in broken lines for the reason that it may be comprised in whole or in part by the inherent capacitance of these electrodes. The inductor 34, resistors 35, 37, and the condenser 38 comprise a half-section filter network having constant resistance over the operating-frequency band and are proportioned to terminate the transmission line 19 and the transmission-line section 33 in their combined image impedance.

The other of the two terminal circuits is tunable over the frequency band to select a desired carrier therein.

This other input circuit of unit 23 comprising the input circuit terminals 20, 21 includes a balanced resistive attenuator network comprising series resistors 39, 40 and shunt resistors 41, 42 and additionally includes phase-shifting means for substantially maintaining in the output circuit of unit 23 at the above-mentioned predetermined point and over the operating frequency band of the system the desired predetermined phase relationship or substantially constant phase difference between the translated carrier signals, thereby to maintain the desired directional radiation characteristic of the apparatus over the operating-frequency band. This means comprises a phase-shifting network including inductive and capacitive elements comprising a coupling transformer 43 having primary winding 44 fixed-series-tuned to the mid-frequency of the above-mentioned band and coupled through series condensers 45, 46 to the resistor 42 of the attenuator network, the center point of winding 44 being connected to ground as indicated. The phase-shifting network has a phase-frequency characteristic which is substantially of the same form as that of the means including the transmisison line 33. The transformer 43 has a secondary winding 47 loosely coupled to the primary winding 44 and shunt tunable by adjustable series condensers 48 to a desired carrier signal in the operating-frequency band of the system. The tuned circuit 47, 48 comprises the input circuit of the push-pull amplifier 25.

The outputs of the amplifiers 25 and 28 are applied in parallel to the output transformer 24 which includes a primary winding 49 and a secondary winding 50 tunable by an adjustable condenser 51 to the desired carrier signal. The primary winding 49 has coupled in shunt thereto a series circuit comprising a resistor 52, an inductor 53, and a condenser 54, the elements 49 and 52 to 54 comprising a primary circuit tuned to the mean frequency of the operating-frequency band and having a pass band of the same width. The condensers 48, 51 and the tuning condenser of the oscillator-modulator 29a, represented by the condenser 55, are mechanically connected for unicontrol operation as indicated by the broken lines U. As thus arranged, the amplifiers 25 and 28 couple individual ones of the input circuits of unit 23 to the output circuit thereof while at the same time isolating the input circuits from each other for received carrier signals.

It is, in general, desirable that the vertical antenna 18 and the dipoles 11, 12 be as long as possible in order to obtain maximum effective antenna height. The length of the antennas must be less than one wave length, however, to insure a vertical-plane directional pattern having appreciable response at right angles to the axis of the Adcock antenna 10. The maximum length is thus set by the highest frequency of the operating-frequency band of the system. When the system is operated over a very wide frequency band, for example, a band 65 to 140 megacycles or a relative band width of 0.73, the dipoles 11, 12 thus preferably have a length corresponding to three-quarters wave length near the upper end of the frequency band. The antenna impedance consequently varies considerably over the range of operating frequencies. For this reason, each section 13, 14 of the transmission line interconnecting the dipoles 11, 12 preferably is designed to have a characteristic impedance of a value approximately equal to the geometric mean of the boundary values of the Adcock antenna impedance. It would be preferable that the vertical antenna 18 be of the dipole type exactly similar to the dipoles 11, 12. Structurally this is frequently quite inconvenient and hence the vertical antenna 18 is made one-half the total length of either of the dipoles 11, 12. In order that the delays along the transmission lines leading from the Adcock antenna 10 and the antenna 18 be equal over the operating-frequency band, the transmission line 19 is made longer than the transmission line 17 by an amount equal to the length of one of the transmission-line sections 13 or 14.

Considering now the operation of the circuit just described, and referring to the vector diagram of Fig. 3, the vectors e_{11} and e_{12} represent the voltage vectors of a carrier signal of a given frequency, within the operating-frequency band, received by the respective antennas 11 and 12. Since the vertical antenna 18 is positioned midway between the antennas 11, 12 the voltage vector e_{18}, representative of the same carrier signal received by the antenna 18, bisects the angle between the vectors e_{11} and e_{12}. The magnitude of the carrier signal applied to the transmission line 17 is equal to the vectorial difference of the vectors e_{11} and e_{12} and is represented in Fig. 3 by the resultant vector e_{10}. While the phase angle between the vectors e_{11} and e_{12} varies with frequency over the operating-frequency band, the vector e_{18} always bisects the angle therebetween and, consequently, always has a phase displacement of ninety degrees from the resultant vector e_{10}. Furthermore, the phase delay of the transmission line 17 plus either of the transmission-line sections 13 or 14 is equal to that of the transmission line 19. Consequently, the received carrier signal applied to the input circuit terminals 20, 21 always has a phase displacement of ninety degrees with respect to that applied to the input circuit terminals 22, 22a over the operating-frequency band.

Now, since it is necessary that the carrier signals translated by the amplifiers 25 and 28 be combined in the output circuit of the translating channel 23 either in phase or 180 degrees out of phase to provide a directional carrier-

radiation characteristic of cardioid pattern, as represented by the curves of Fig. 2, it is necessary that an additional ninety-degree phase delay be provided in one of the carrier-signal translation paths comprising the amplifiers **25** and **28**. This is effected in accordance with one embodiment of the invention by tuning the primary winding **44** of the transformer **43** by the condensers **45** and **46** to resonance at a predetermined operating frequency, preferably the geometric mean frequency of the operating-frequency band of the system. At this frequency, the phase delay from the input circuit terminals **20, 21** to the output circuit of unit **23** is zero or some arbitrary value. The transmission-line section **33** of the other input circuit comprising the input circuit terminal **22** is then so proportioned at this same frequency that the phase delay of a carrier signal translated from the input terminal **22** to the output circuit of unit **23** is equal to ninety degrees. The transmission-line section **33**, therefore, comprises a means included in one of the two terminal circuits for establishing at a predetermined point in the signal-translating channel at the geometric-mean freqeuncy of the frequency band a quadrature phase relationship between carrier signals translated through the two terminal circuits, whereby the signal-translating apparatus has the desired directional characteristic at the geometric-mean frequency. Referring to Fig. 4, curve *c* represents the phase-frequency characteristic of the signal-translating path comprising the amplifier **28** with the transmission-line section **33** proportioned in the manner described, the frequency f_0 representing the geometric-mean frequency of the operating-frequency band. The phase delay of this signal-translating path varies linearly with frequency. It is necessary that the phase delay of the path comprising the amplifier **25** vary in similar relation with frequency, as represented by curve *d*, in order that the carrier signals translated by the amplifiers **25** and **28** and combined in the output circuit of unit **23** shall always be exactly in phase or 180 degrees out of phase over the entire operating-frequency band. It can be shown that the desired phase-delay characteristic for the signal-translating path comprising the amplifier **25** to effect this result can be provided in accordance with the invention by proportioning the primary winding **44** of the transformer **43** and the condensers **45** and **46** in accordance with the following relation:

$$\phi = \tan^{-1}\frac{x_a}{r_a}$$

where:

ϕ=the required phase shift at one limit of the operating-frequency range, for example, the lower limit;

x_a=the total reactance of the primary circuit comprising the primary winding **44** and condensers **45** and **46** at the aforesaid limiting frequency; and

r_a=the characteristic impedance of the transmission line **17**.

The amplitude of a carrier signal translated by the amplifier **28** and appearing in the output circuit thereof must be equal to that of the corresponding carrier signal translated by and appearing in the output circuit of amplifier **25** to obtain a directional radiation characteristic of cardioid pattern. The proportioning of the amplitudes of the carrier signals translated by these amplifiers may be effected by proper adjustment of the gain of the amplifiers and by suitably proportioning the resistor elements of the attenuator network comprising the resistors **39–42**, inclusive, which not only attenuate the carrier signal received by the Adcock antenna **10** and applied to the amplifier **25** but additionally serve properly to terminate the transmission line **17** in its image impedance. As previously stated, the transmission line **19** is terminated in its image impedance by the filter network comprising the inductor **34**, the resistors **35** and **37**, and the inherent input capacitance **38** of vacuum tube **36**.

Resonance involving the electrical length of conductors between the tip of one of the dipoles **11, 12** and a tip of the other, for example, between the upper tip of the dipole **11** and lower tip of dipole **12**, must be taken into account. When this distance becomes an odd-multiple of a half wave length, a current maximum occurs at the junction of the transmission-line sections **13, 14** and magnifies any unbalance of the dipoles **11, 12** and the transmission-line sections **13, 14** with respect to the point thereof to which the transmission line **17** is coupled. The resistive attenuator networks **15, 16** damp the transmission-line sections **13** and **14**, thereby to reduce the magnitude of the resonance current at these frequencies, as more fully explained in the copending Wheeler application previously referred to.

From the above description of the invention, it will be evident that the signal-translating channel **23** includes a pair of carrier-signal translating paths, comprising the amplifiers **28** and **25**, adapted to have applied thereto carrier signals within a wide range of carrier-signal frequencies, the first path comprising the amplifier **28** being untunable. It will further be evident that the transmission line **33** and the filter network comprising the inductor **34**, the resistors **35** and **37**, and the condenser **38** comprise means included in the first path for imparting thereto over this range of frequencies a substantially linear phase-frequency characteristic. The transformer **43** and condensers **45, 46** and **48** comprise means included in the other of the paths for tuning it to any desired carrier signal within the range of carrier-signal frequencies and for imparting thereto over this range of frequencies a substantially linear phase-frequency characteristic of different absolute values but of substantially the same slope as that of the first path, whereby carrier-signal outputs of the two paths corresponding to any selected carrier-signal input have a predetermined substantially constant relative phase difference. The carrier-signal receiver **29** including the sound reproducing device **29e** comprises a means coupled to the signal-translating paths to utilize the carrier-signal outputs having this predetermined relative phase difference.

Fig. 5 represents a modified form of carrier-signal translating system which is essentially similar to the arrangement of Fig. 1, identical circuit elements being designated by the same reference numerals and analogous circuit elements by the same reference numerals primed, except that the system of Fig. 5 comprises a transmitter of carrier signals. In the present arrangement, the input and output circuits of the signal-translating channel **23'** correspond respectively to the output and input circuits of the signal-translating channel **23** of Fig. 1. Thus, the transformer **24'** comprises the input

circuit of unit 23' and the secondary winding 49' of the transformer 24' is coupled to the input electrodes of the vacuum tubes 26, 27 and 36 of the respective amplifiers 25' and 28'. The primary winding 50' of the input transformer 24' is coupled to the output circuit of a carrier-signal generator 29' which may include oscillator and amplifier stages of conventional form. Since it is desired that the carrier signal applied to the output circuit terminals 20', 21' have a 90-degree phase displacement with respect to the carrier signal applied to the output circuit terminals 22', 22a' in order that the system may have a radiation characteristic of cardioid pattern, and since the carrier signal from unit 29' is applied in the same phase to the input circuits of the amplifiers 25' and 28', it is necessary that one of the signal-translating paths comprising the amplifiers 25' and 28' shall have a relative phase delay of ninety degrees between the input circuit transformer 24' and the output terminals 20', 21' or 22', 22a'. Moreover, this relative phase displacement must be substantially maintained over the operating-frequency band in order that the carrier-signal radiation characteristic of cardioid pattern shall be substantially maintained over the frequency band. This is accomplished as in Fig. 1 by tuning the winding 44 of the transformer 43 to resonance by condensers 45 and 46 at the geometric mean frequency of the frequency band, by proportioning the winding 44 and the condensers 45 and 46 to satisfy the equation at one limiting frequency of the frequency band, and by proportioning the transmission-line section 33 to provide the desired ninety-degree phase delay at the geometric mean frequency of the frequency band. The operation of this modified form of the invention is essentially similar to that of Fig. 1 and will therefore not be repeated.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An ultra-high-frequency carrier-signal translating system adapted to have a desired directional carrier-signal radiation characteristic substantially symmetrical about a line and substantially favoring one direction along this line over a relatively wide ultra-high-frequency band comprising, a carrier-signal translating channel having at least three terminal circuits, two of said terminal circuits being adapted to be coupled through individual lead-in transmission lines to individual ones of a pair of antennas of different relative directional characteristics and the other of which is adapted to be coupled to a carrier-signal translating apparatus, one of said two terminal circuits being untuned and having a frequency-band characteristic at least as wide as said wide frequency band, means included in said one of said two terminal circuits for establishing at a predetermined point in said signal-translating channel at a given operating frequency in the vicinity of said frequency band a predetermined phase relationship between carrier signals translated through said two terminal circuits, wherby said signal-translating apparatus has said desired directional characteristic at said given frequency, the other of said two terminal circuits being tunable over said frequency band to select a desired carrier signal therein, and phase-shifting means in the other of said two terminal circuits and having a phase-frequency characteristic substantially of the same form as that of said last-named means for substantially maintaining at said predetermined point and over said frequency band said predetermined phase relationship between carrier signals translated through said two terminal circuits, thereby to maintain the desired directional characteristic of said apparatus over said frequency band.

2. An ultra-high-frequency carrier-signal translating system adapted to have a desired directional carrier-signal radiation characteristic substantially symmetrical about a line and substantially favoring one direction along this line over a relatively wide ultra-high-frequency band comprising, a carrier-signal translating channel having at least three terminal circuits, two of said terminal circuits being adapted to be coupled through individual lead-in transmission lines to individual ones of a pair of antennas of different relative directional characteristics and the other of which is adapted to be coupled to a carrier-signal translating apparatus, means included in one of said two terminal circuits for establishing at a predetermined point in said signal-translating channel at the geometric mean frequency of said frequency band a quadrature phase relationship between carrier signals translated through said two terminal circuits, whereby said signal-translating apparatus has said desired directional characteristic at said geometric mean frequency, and phase-shifting means including a transformer in the other of said two terminal circuits and having a winding tuned by a capacitive element to series resonance at said geometric mean frequency for substantially maintaining at said predetermined point and over said frequency band said quadrature phase relationship between carrir signals translated through said two terminal circuits, thereby to maintain the desired directional characteristic of said apparatus over said frequency band.

3. An ultra-high-frequency carrier-signal translating channel comprising, a pair of carrier-signal translating paths adapted to have applied thereto carrier signals within a wide range of carrier-signal frequencies, a first of said paths being untunable, means included in said first path for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic, means included in the other of said paths for tuning it to any desired carrier signal within said range and for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic of different absolute value but of substantially the same slope as that of said first path, whereby carrier-signal outputs of said paths corresponding to any selected carrier-signal input have a predetermined substantially constant relative phase difference, and means coupled to said signal-translating paths to utilize said carrier-signal outputs having said predetermined relative phase difference.

4. An ultra-high-frequency carrier-signal translating channel comprising, a pair of carrier-signal translating paths adapted to have applied thereto carrier signals within a wide range of carrier-signal frequencies, a first of said paths being untunable, means included in said first

path for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic, a transformer included in the other of said paths and having one winding fixed tuned and another winding adjustably tunable to any desired carrier signal within said range for imparting to said other path over said range of frequencies a substantially linear phase-frequency characteristic of different absolute value but of substantially the same slope as that of said first path, whereby carrier-signal outputs of said paths corresponding to any selected carrier-signal input have a predetermined substantially constant relative phase difference, and means coupled to said signal-translating paths to utilize said carrier-signal outputs having said predetermined relative phase difference.

5. An ultra-high-frequency carrier-signal translating channel comprising, a pair of carrier-signal translating paths adapted to have applied thereto carrier signals within a wide range of carrier-signal frequencies, a first of said paths being untunable, means included in said first path for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic, a transformer included in the other of said paths and having a primary winding fixed series tuned and a secondary winding adjustably shunt tunable to any desired carrier signal within said range to impart to said other path over said range of frequencies a substantially linear phase-frequency characteristic of different absolute value but of substantially the same slope as that of said first path, whereby carrier-signal outputs of said paths corresponding to any selected carrier-signal input have a predetermined substantially constant relative phase difference, and means coupled to said signal-translating paths to utilize said carrier- signal outputs having said predetermined relative phase difference.

6. An ultra - high - frequency carrier - signal translating channel comprising, a pair of carrier-signal translating paths adapted to have applied thereto carrier signals within a wide range of carrier-signal frequencies, a first of said paths being untunable, means included in said first path for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic, a transformer included in the other of said paths and having a primary winding fixed series tuned to the mid-frequency of said range and having a secondary winding adjustably shunt tunable to any desired carrier signal within said range to impart to said other path over said range of frequencies a substantially linear phase-frequency characteristic of different absolute value but of substantially the same slope as that of said first path, whereby carrier-signal outputs of said paths corresponding to any selected carrier-signal input have a predetermined substantially constant relative phase difference, and means coupled to said signal-translating paths to utilize said carrier-signal outputs having said predetermined relative phase difference.

7. An ultra - high - frequency carrier - signal translating channel comprising, a pair of carrier-signal translating paths adapted to have applied thereto carrier signals within a wide range of carrier-signal frequencies, a first of said paths being untunable, means included in said first path for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic, means included in the other of said paths for tuning it to any desired carrier signal within said range and including phase-shifting means for maintaining a substantially constant phase difference between the signals translated by said carrier-signal translating paths over said wide range of carrier-frequency signals, and means coupled to said signal-translating paths to utilize said carrier-signal outputs having a predetermined relative phase difference.

8. An ultra - high - frequency carrier - signal translating channel comprising, a pair of signal-translating paths adapted to have applied thereto carrier signals within a wide range of carrier-signal frequencies, a first of said paths being untunable, means included in said first path for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic, means included in the other of said paths and including a phase-shifting network having conductive and capacitive elements for tuning it to any desired carrier signal within said range and for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic of different absolute value but of substantially the same slope as that of said first path, whereby carrier-signal outputs of said paths corresponding to any selected carrier-signal input have a predetermined substantially constant relative phase difference, and means coupled to said signal-translating paths to utilize said carrier-signal outputs having said predetermined relative phase difference.

9. An ultra - high - frequency carrier - signal translating channel comprising, a pair of carrier-signal translating paths adapted to have applied thereto carrier signals within a wide range of carrier-signal frequencies, a first of said paths being untunable, means included in said first path for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic, means included in the other of said paths and including a phase-shifting means comprising a coupling transformer having one winding thereof in the circuit of said other signal-translating path and tuned to series resonance in the vicinity of said frequency range for tuning said other carrier-frequency path to any desired carrier signal within said range and for imparting thereto over said range of frequencies a substantially linear phase-frequency characteristic of different absolute value but of substantially the same slope as that of said first path, whereby carrier-signal outputs of said paths corresponding to any selected carrier-signal input have a predetermined substantially constant relative phase difference, and means coupled to said signal-translating paths to utilize said carrier-signal outputs having said predetermined relative phase difference.

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