

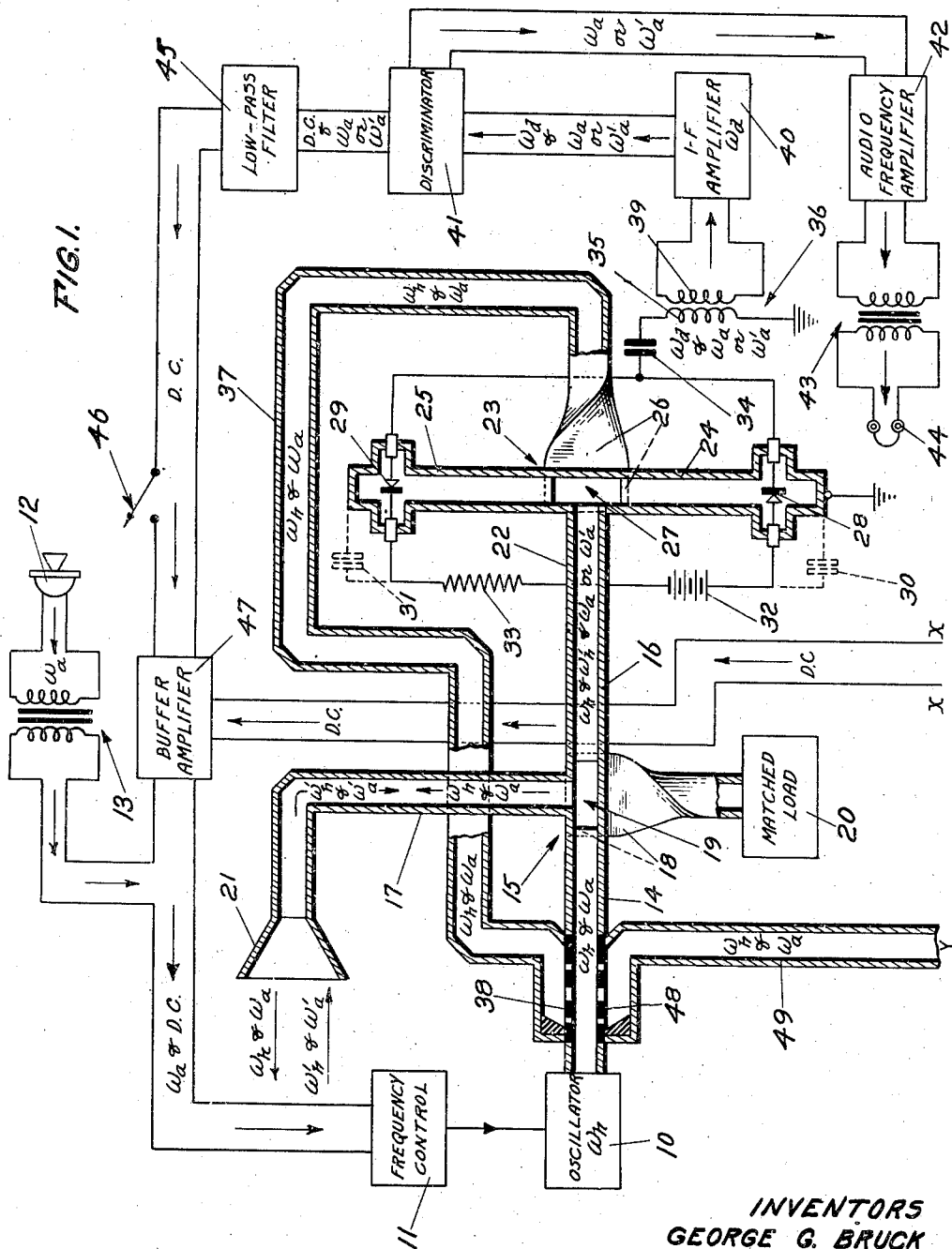
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G. G. BRUCK ET AL
RADIO COMMUNICATION SYSTEM

2,475,474

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2 Sheets-Sheet 1



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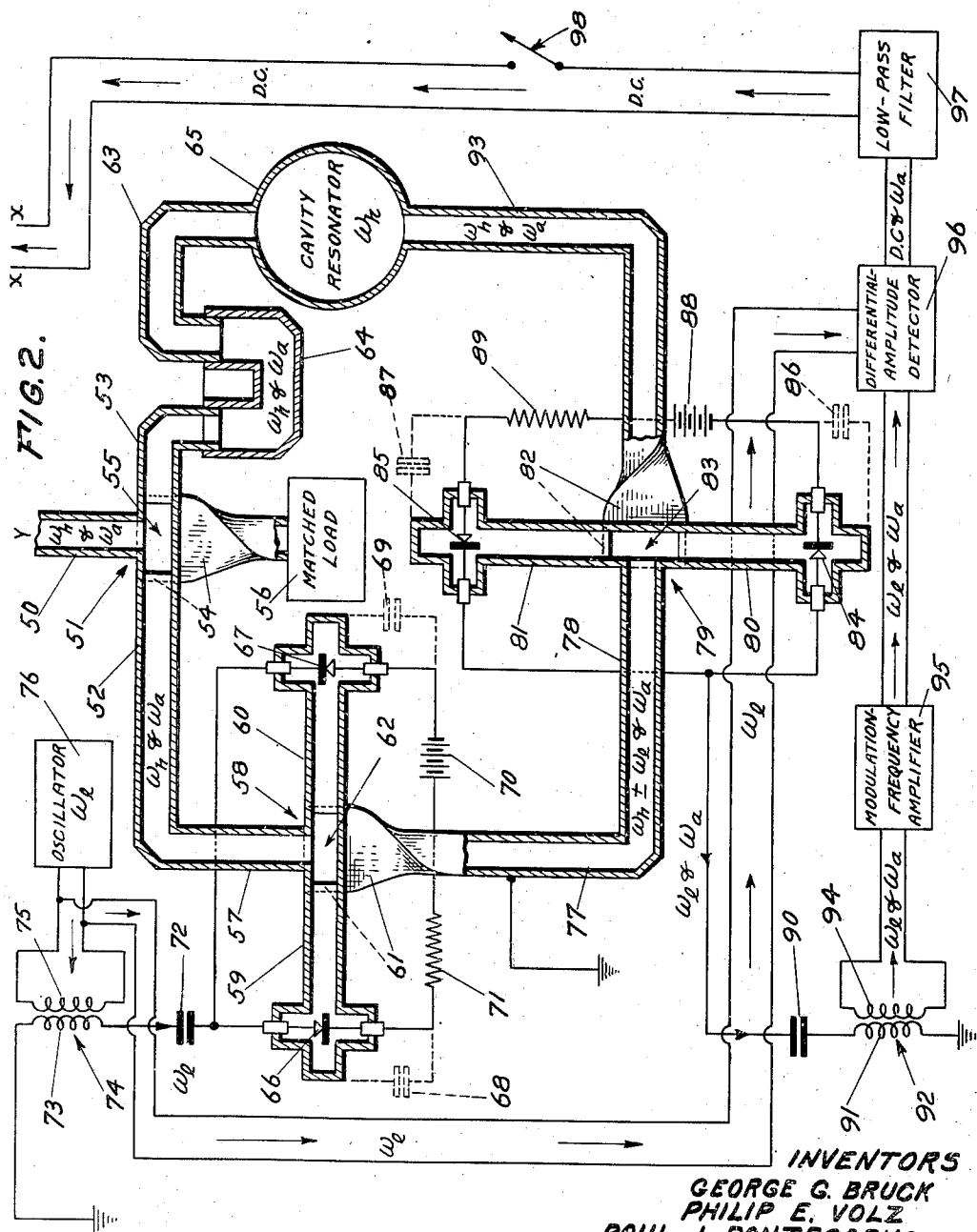
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RADIO COMMUNICATION SYSTEM

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4 Claims. (Cl. 250—6)

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This invention relates to radio communication systems, and more particularly to a terminal station for a frequency-modulated, radio communication system comprising, for example, two widely separated terminal stations and a plurality of intermediate relay stations, all operating on different mean carrier frequencies, the system permitting two-way transmission of intelligence between any and all of the stations included therein, with the carrier wave emanating from one of the terminal stations and from each intermediate relay station, hereinafter referred to as the slave stations, under the control of the carrier wave received at each such station, and all under the control of the carrier wave originating at the remaining terminal station, hereinafter referred to as the master station.

While not limited thereto, the terminal station of the present invention is especially well suited for use in a communication system which, in addition to having the foregoing characteristics, is further designed simultaneously to transmit several intelligence channels, for example, four, each of which covers a frequency band of from zero to, say, 3000 C. P. S., said individual channels being transposed by suitable channelizing equipment which forms no part of the present invention, to present a single frequency band extending from zero to, say, 12,000 C. P. S.

In a system functioning as above described, it is apparent that cross-talk must be held to a minimum, the overall distortion permissible being, preferably, less than 1%. In furtherance of this limitation, it is necessary that the carrier waves emanating from the various stations in the system be frequency stabilized within very close limits.

It is, therefore, the main object of the present invention to provide a terminal station for a communication system of the foregoing general description which is so designed as to satisfy the critical requirements thereof above referred to.

Now, within a terminal station of the type contemplated by the present invention it is of the utmost importance that, in so far as the transfer from one component to another of radio-frequency energy is concerned, reflection be held to a minimum. This normally presents impedance matching problems which are difficult of solution.

It is, therefore, another object of the present invention to so design the radio-frequency portions thereof as to minimize the necessity of obtaining critical impedance matches.

As previously stated, the carrier wave emanating from each slave station in the system to

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which reference has been made is under the control of the carrier wave received thereby. As a result, it is necessary to eliminate in all such stations the effect thereon of reflections of the energy radiated thereby.

It is, therefore, a further object of the present invention to design a terminal station for a communication system operating as aforesaid in which the effect thereon of reflection of the energy radiated thereby is eliminated.

A still further object of the present invention is the provision of a terminal station which may be utilized, in a communication system of the foregoing description, either as a master station or as a slave station, its mode of functioning being controlled by a suitable switching arrangement.

These, and other objects of the present invention, which will become more apparent as the detailed description thereof progresses, are attained, briefly, in the following manner:

Throughout the remainder of this specification it will be assumed that the system comprises merely two widely separated terminal stations, with no intermediate relay stations, and with one of said terminal stations functioning as a master station and the other as a slave station. It is to be understood, however, that it is preferred that both terminal stations be so designed as to be operable, at will, as either a master or a slave station.

Each terminal station includes means for locally generating a carrier wave, preferably, in the microwave region of the electromagnetic spectrum, and means for frequency modulating said carrier wave with locally-generated intelligence. Normally, there is a predetermined difference between the frequencies of the carrier waves generated at each station. For example, the frequency of one of the carrier waves may be 10,000 mc. and the frequency of the other, 10,003 mc., a difference therebetween of 3 mc.

A portion of the carrier wave generated at the slave station is radiated into space, and another portion thereof is mixed with a portion of the carrier wave remotely generated at the master station, and received at said slave station, to derive therefrom a substantially constant-amplitude, intermediate-frequency wave whose frequency normally corresponds to the aforesaid frequency difference between said carrier waves. Preferably, the means for deriving said intermediate-frequency wave are such that variations in the amplitude of the locally-generated carrier wave, due, for example, to reflections of the radi-

ated portions thereof, or to mismatches between the component parts of the station, have no effect upon the amplitude of said intermediate-frequency wave.

The intermediate-frequency wave thus derived is passed through a broad-band amplifier, whose center frequency corresponds to the frequency difference between said locally and remotely-generated carrier waves, and thence, to a discriminator to obtain an output, having a D.-C. or unidirectional component whose sense and magnitude are functions, respectively, of the sense and magnitude of any deviation of the frequency of said intermediate-frequency wave from the predetermined difference between said carrier waves, and having an audio-frequency component corresponding to any intelligence impressed upon either the locally or remotely-generated carrier waves. The audio-frequency component of the discriminator output is amplified and applied to phones, and the D.-C. component of said output is separated from the audio-frequency component by appropriate low-pass filters, said D.-C. component being applied, through a buffer amplifier, to any preferred electronic or mechanical tuning control to adjust the frequency of the local carrier wave to compensate for any deviation from the desired mean frequency thereof. Now, as will hereinafter be pointed out, the remotely-generated carrier wave, emanating from the master station and received at the slave station, is frequency-stabilized within very close limits, and inasmuch as the apparatus just described assures the maintenance of a constant frequency difference between the remotely and locally-generated carrier waves, the locally-generated carrier wave, likewise, becomes frequency stabilized.

At the master station, a portion of the locally-generated carrier wave is radiated, and another portion thereof is divided into two parts, one of which is amplitude modulated at a relatively low frequency, say, 50 mc., and the other of which is transmitted through a cavity resonator whose natural resonant frequency constitutes a reference frequency corresponding to the mean frequency desired of the master-station carrier wave. The amplitude-modulating means just referred to, preferably, is such that the carrier wave itself is suppressed, and only the resulting sidebands subsequently utilized. By so doing, as will hereinafter become more apparent, once again the effects of mismatches between the components of the station are eliminated.

The lengths of the paths of the portions of the slave-station carrier wave which are amplitude modulated and applied to the cavity resonator, respectively, are made to differ by $n\lambda/4$, where n is an odd integer and λ is the transmission-system wavelength corresponding to the desired frequency of said carrier wave. Hence, when the sidebands, produced as aforesaid, and a portion of the carrier wave coming from the cavity resonator are subsequently combined in a mixer, the effect is the same as combining a portion of the carrier wave which is varying in amplitude at the modulation frequency with a portion of the carrier wave which is of constant amplitude and 90° out of phase with said first portion, and produces a substantially constant-amplitude resultant wave, provided the frequency of said carrier wave corresponds to the hereinbefore referred to reference frequency, in other words, to the natural resonant frequency of the cavity resonator. If, on the other hand, the frequency of said carrier

wave has drifted from the frequency desired thereof, said sidebands and the carrier wave coming from the cavity resonator do not meet at the mixer in phase quadrature, and, therefore, the in-phase components of said sidebands cause the resonator-transmitted, carrier-wave portion to become substantially amplitude modulated.

The modulation envelope of the last-named resultant wave has a phase, relative to the amplitude modulation initially applied to the carrier wave, and a magnitude, which are functions, respectively, of the sense and magnitude of any deviation of the frequency of said carrier wave from the reference frequency. Preferably, said modulation envelope is either in phase with said initially applied modulation, or it is in phase opposition thereto.

If there has been no deviation from the reference frequency, and, as a result, a substantially constant-amplitude wave is produced at the aforesaid mixer; there is no modulation envelope to recover, but if there has been a deviation, the modulation envelope of the amplitude-modulated resultant wave produced at said mixer, whether it is in phase with the initially applied modulation, or in phase opposition thereto, is recovered, the sense and magnitude of the recovered envelope being functions, respectively, of the sense and magnitude of said deviation.

The recovered modulation envelope is combined, for example, in a differential-amplitude detector, with a portion of the initially applied modulation to obtain an output having a D.-C. or unidirectional component whose sense and magnitude, likewise, are functions, respectively, of the sense and magnitude of the deviation of the frequency of the carrier wave from its desired frequency, and having an audio-frequency component corresponding to any locally-generated intelligence impressed upon said carrier wave. The output of the differential-amplitude detector is passed through a low-pass filter to remove the audio-frequency component thereof, and the remaining D.-C. or unidirectional component is applied, through a buffer amplifier, to any preferred electronic or mechanical tuning control to adjust the frequency of the carrier wave to compensate for the deviations above referred to.

In the accompanying specification there shall be described; and in the annexed drawings shown, an illustrative embodiment of the terminal station of the present invention. It is, however, to be clearly understood that the present invention is not to be limited to the details herein shown and described for purposes of illustration only, inasmuch as changes therein may be made without the exercise of invention, and within the true spirit and scope of the claims hereto appended.

In said drawings,

Fig. 1 is a partial block, partial schematic diagram of one portion of the terminal station of the present invention; and

Fig. 2 is a similar view of another portion of said terminal station.

Referring now more in detail to the aforesaid illustrative embodiment of the present invention, with particular reference to Fig. 1 of the drawings, the numeral 10 designates an oscillator for locally generating, at a terminal station, a carrier wave ω_n , preferably, in the microwave region of the electromagnetic spectrum. It is the mean frequency of this carrier wave that it is desired to stabilize, either under the control of a stabilized, remotely-generated carrier wave received

from a master station, or by means incorporated in the local station itself.

For the present, this description will be addressed to the case where the carrier wave which is locally generated at a slave station is to be stabilized under the control of a carrier wave which is remotely generated at a master station.

The oscillator 10 is adapted to be frequency modulated, by any preferred frequency control 11, in accordance with locally-generated intelligence ω_a which is applied to said frequency control through a microphone 12 and an audio-frequency transformer 13. The output of the oscillator 10, consisting of the carrier wave ω_h and any intelligence ω_a impressed thereon, is applied to one of the side branches 14 of a wave-guide assembly 15, known as a "magic T". Such a wave-guide assembly comprises, in addition to the side branch 14, another side branch 16, extending in the same direction as the side branch 14, a so-called "E" arm 17 extending outwardly from said side branches 14 and 16, at right angles thereto, and a so-called "H" arm 18 extending outwardly from said side branches 14 and 16, mutually perpendicular to said side branches and said "E" arm, said side branches, said "E" arm, and said "H" arm all extending from a common junction 19. As shown in the drawings, the "H" arm 18 recedes from the observer for a short distance from the common junction 19, then bends downwardly, and is then twisted through an angle of 90°.

As the energy travelling along the side branch 14 from the oscillator 10 reaches the common junction 19, it splits, part travelling along the "H" arm 18 to a matched load 20 which absorbs the same, part leaking across the T and travelling along the side branch 16, and part travelling along the "E" arm 17 to an electromagnetic horn 21 adapted to directionally radiate the same. The horn 21 is also receptive, in the opposite direction, of a remotely-generated carrier wave, of a frequency ω'_h , which may be frequency modulated with intelligence ω'_a , and which emanates from another terminal station, in the case under consideration, a master station, the master and slave station carrier waves normally differing, as hereinbefore stated, by a predetermined frequency ω_d .

Now in certain instances, depending upon the location of the slave station, the horn 21 is additionally receptive of reflections of the energy radiated thereby, that is reflections of the carrier wave ω_h . These reflections travel along the "E" arm 17, and combine with the energy travelling along the side branch 16 to cause variations in the amplitude of the latter, and upon combination, as indicated in earlier portions of this specification, of the locally and remotely-generated carrier waves, to obtain an intermediate-frequency wave corresponding in frequency to the difference ω_d between the frequencies of said carrier waves, said intermediate-frequency wave becomes undesirably amplitude modulated. In order to eliminate this undesirable amplitude modulation, the intermediate-frequency wave is derived in the following manner.

The side branch 16 of the "magic T" 15 is extended, at 22, to form, in effect, the "E" arm of another "magic T" 23, which also includes two oppositely-extending side branches 24 and 25, and an "H" arm 26, all projecting from a common junction 27. The side branches 24 and 25 are terminated in oppositely-disposed crystals 28 and 29, between one side of each of which and

the "magic T" itself, capacitances 30 and 31 exist, said "magic T" being grounded, and said crystals being connected, in series with a source 32 of direct current and a resistor 33, to provide parallel outputs to ground through a capacitor 34 and the primary winding 35 of a radio-frequency transformer 36. The source 32 of direct current is for the purpose of operating the crystals 28 and 29 at a favorable point along their characteristic curve, and the series circuit is for the purpose of passing equal currents through said crystals to assure their similar action even though they both be mismatched to the wave-guide system. The "H" arm 26 is connected, through a wave guide 37 and a unidirectional coupler 38, to the side branch 14 of the "magic T" 15, whereby said "H" arm is receptive only of energy ω_h coming directly from the oscillator 10, and cannot receive any energy ω'_h travelling from the common junction 19 toward said oscillator 10.

For an understanding of the operation of the "magic T" 23, assume that the carrier waves ω_h and ω'_h are both travelling from the junction 19, along the side branches 16 and 22, toward the junction 27, with their electric vectors in the same direction, arbitrarily, upwardly. As they reach the junction 27, each splits into two constituent waves, the waves travelling along the side branch 24, toward the crystal 28, having their electric vectors pointing in the same direction, and the waves travelling along the side branch 25, toward the crystal 29, having their electric vectors, likewise, in the same direction, which is the opposite direction to that of the vectors at the crystal 28. At the crystal 28, a beat-frequency wave, whose frequency corresponds to the frequency difference between the carrier waves, and whose phase may be considered positive because its component waves are in phase, is produced; and at the crystal 29, another beat-frequency wave, having the same frequency as said first-named beat-frequency wave, and having a phase which may also be considered positive because its component waves are also in phase, is produced. However, as to each other, the two beat-frequency waves thus obtained are 180° out of phase and set up equal voltages of opposite polarity across the crystals. Inasmuch as parallel outputs are taken from these crystals, cancellation occurs and no output appears across the primary winding 35 of the transformer 36. Thus, the effects of variations in the amplitude of the locally-generated carrier wave ω_h , due, for example, to reflections of said carrier wave received by the horn 21, are eliminated from the system.

When the remotely-generated carrier wave ω'_h , received at the slave station and travelling along the "E" arm 22 toward the junction 27, is mixed with the locally-generated carrier wave ω_h , coming directly from the oscillator 10 through the unidirectional coupler 38, and travelling along the "H" arm toward the junction 27, a different result is obtained. Assume, as before, that the electric vector of the remotely generated carrier wave ω'_h , travelling along the "E" arm 22, is pointing upwardly, and further assume that the electric vector of the locally generated carrier wave ω_h , travelling along the "H" arm 26, is pointing to the left at the junction 27. When the former reaches the junction 27, it splits into two constituent waves, one, having its electric vector pointing to the right, travelling toward the crystal 28, and the other, having its electric vector pointing to the left, travelling toward the crystal 29. When the latter reaches the junction 27, it, too, splits

into two constituent waves, one travelling toward the crystal 28 and the other travelling toward the crystal 29, with both having their electric vectors pointing in the same direction, namely, to the left. Thus, there arrive at the crystal 28 two constituent carrier waves which are out of phase, and there arrive at the crystal 29 two constituent carrier waves which are in phase. Therefore, there is produced at the crystal 28, a beat-frequency wave whose frequency corresponds to the difference between the frequencies of the carrier waves, and whose phase may be considered negative because its component waves are out of phase; while at the crystal 29, there is produced a beat-frequency wave having the same frequency as said first-named beat-frequency wave, and having a phase which may be considered positive because its component waves are in phase. However, as to each other, the two beat-frequency waves thus obtained are in phase, and set up equal voltages of like polarity across the crystals. Inasmuch as parallel outputs are taken from these crystals, addition occurs, and a constant-amplitude intermediate-frequency wave appears across the primary winding 35 of the transformer 36.

Through a secondary winding 39 of the transformer 36 this intermediate-frequency wave is applied to a broad-band amplifier 40 whose center frequency corresponds to the normal difference ω_d between the frequencies of the locally and remotely-generated carrier waves. The output of the amplifier 40, consisting of the difference frequency ω_d and any audio-frequency modulation ω_a or ω'_a originating, respectively, at the slave and master stations, is applied to a frequency discriminator 41 whose center frequency corresponds to said normal difference frequency ω_d between the carrier waves. The discriminator extracts any intelligence impressed upon the intermediate-frequency input applied thereto, which intelligence is then conveyed, through an audio-frequency amplifier 42 and an audio-frequency transformer 43, to phones 44.

As long as the mean frequency of the intermediate-frequency wave derived from the heterodyning of the remotely and locally-generated carrier waves corresponds to the predetermined difference ω_d therebetween, the only output from the discriminator 41 is an audio-frequency output corresponding to the intelligence ω_a or ω'_a ; but, should the oscillator 10 drift, resulting in a deviation of the frequency of the intermediate-frequency wave from the difference ω_d between the carrier-wave frequencies, the discriminator 41 will have an output including, in addition to that resulting from the intelligence applied thereto, a D.-C. or unidirectional component whose sense and magnitude will depend, respectively, on the sense and magnitude of any such deviation. Therefore, the output of the discriminator is applied to a low-pass filter 45 to recover said D.-C. component, which may then be applied, through a switch 46, to a buffer amplifier 47, and thence, to the frequency control 11 to adjust the oscillator 10 and compensate for any frequency deviation from the mean frequency desired of said oscillator.

By means of the apparatus thus far described, the frequency of a locally-generated, slave-station carrier wave may be stabilized under the control of a remotely-generated, master-station carrier wave.

In order to enable the terminal station of the present invention to function as a master station

as well as a slave station, another portion of the locally-generated carrier wave from the oscillator 10 is conveyed, through a unidirectional coupler 48, to a wave guide 49, and thence, (see Y, Y, Figs. 1 and 2) to the "E" arm 50 of a "magic T" 51. The latter includes, in addition to the "E" arm 50, side branches 52 and 53 and an "H" arm 54, all extending from a common junction 55.

The energy travelling along the "E" arm 50 splits at the junction 55, part travelling along the side branch 52, part travelling along the side branch 53, and part travelling along the "H" arm 54 which is terminated in a matched load 56.

The side branch 52 communicates with the "E" arm 57 of another "magic T" 58 including side branches 59 and 60 and an "H" arm 61, all extending from a common junction 62, and the side branch 53 communicates, through a wave guide 63 incorporating a "line stretcher" 64 for adjusting the electrical length thereof, with a cavity resonator 65 the natural resonant frequency ω_n of which constitutes the reference frequency with respect to which it is desired to maintain the frequency of the oscillator 10 in a fixed relationship.

The side branches 59 and 60 of the "magic T" 58 terminate in oppositely-disposed crystals 66 and 67, between one side of each of which and the "magic T" itself, capacitances 68 and 69 exist, the wave-guide system, as previously indicated, being grounded, and said crystals being connected, in series with a source 70 of direct current and a resistor 71, to provide parallel inputs to ground through a capacitor 72 and the secondary winding 73 of a radio-frequency transformer 74. The primary winding 75 of the transformer 74 is connected to an oscillator 76 adapted to generate relatively low, radio-frequency energy ω_i for amplitude modulating the locally-generated carrier wave ω_n . The frequency of the modulating energy may be, for example, 50 mc.

The "magic T" 58 functions as a balanced modulator. The carrier wave ω_n travelling along the "E" arm 57 toward the junction 62, with or without locally-generated intelligence ω_a , splits at said junction, part travelling along the side branch 59 toward the crystal 66, and part travelling along the side branch 60 toward the crystal 67. The oppositely-travelling parts of the carrier waves incident upon said crystals are, it will be noted, 180° out of phase, and each become amplitude modulated by the energy injected into said crystals in parallel from the oscillator 76. Thus, sidebands, having frequencies equal to the sum of and difference between the frequencies of the carrier and modulation waves, are produced at the crystals 66 and 67, which sidebands, together with any carrier wave components resulting from mismatching of the crystals to the wave-guide system, travel back along the side branches 59 and 60 toward the junction 62. The sidebands, upon reaching said junction, travel along the "H" arm 61 of the "magic T" 58, but the reflected carrier-wave components, being in phase opposition, are cancelled along said "H" arm 61, so that the final output of the "magic T" 58 is a carrier-suppressed, amplitude-modulated wave.

The sidebands comprising said last-named wave are conveyed, through a wave guide 77, to the "E" arm 78 of still another "magic T" 79 which, like those previously described, includes side branches 80 and 81 and an "H" arm 82, all extending from a common junction 83. The side branches 80 and 81 are terminated in crystals 84 and 85, between one side of each of which

and the "magic T" itself, capacitances 86 and 87 exist, said "magic T" being grounded, and said crystals being connected, in series with a source 88 of direct current and a resistor 89, to provide parallel outputs to ground through a capacitor 90 and the primary winding 91 of a radio-frequency transformer 92. The "H" arm 82 of the "magic T" 79 is connected, through a wave guide 93, to the output side of the cavity resonator 65.

By adjusting the "line stretcher" 64, the electrical lengths of the paths taken by the energy travelling from the junction 55 of the "magic T" 51 to the junction 83 of the "magic T" 79, through the balanced modulator "magic T" 58 on the one hand, and through the cavity resonator 65 on the other, are made to differ by $n\lambda/4$, where n is an odd integer and λ is the wave-guide wavelength corresponding to the natural resonant frequency of the cavity resonator 65, in other words, to the mean frequency desired of the locally-generated carrier wave coming from the oscillator 10.

Now at the junction 83 of the "magic T" 79 which, as will now be described, functions as a balanced demodulator and a buffer isolating the balanced modulator "magic T" 58 from the cavity resonator 65, the sideband waves travelling along the "E" arm 78 split, part travelling along the side branch 80 toward the crystal 84, and part travelling along the side branch 81 toward the crystal 85. Also at said junction 83, the carrier wave ω_c , travelling along the "H" arm 82 from the cavity resonator 65, splits, part travelling along the side branch 83 toward the crystal 84, and part travelling along the side branch 81 toward the crystal 85.

At each of the crystals 84 and 85, the upper sideband may be considered as a vector rotating in a counter-clockwise direction at the frequency of the carrier wave ω_c plus that of the modulation wave ω_m , and the lower sideband may be considered as a vector rotating in the same direction at a frequency of the carrier wave minus that of the modulation wave. These two vectors, rotating at different frequencies, periodically become in phase, and so, they may be considered as oppositely-rotating vectors combining to produce a non-rotating vector constituting a resultant sideband. The latter is, actually, the carrier wave varying in amplitude at the modulation frequency, and when combined, in each of the crystals 84 and 85, with carrier-wave portions coming from the cavity resonator 65, with which they are 90° out of phase, the amplitudes of said carrier-wave portions remain substantially unaffected. Therefore, no modulation envelopes are recovered at the crystals 84 and 85.

However, should the oscillator 10 drift, so that the frequency of the locally-generated carrier wave differs from the reference frequency, that is, from the natural resonant frequency of the cavity resonator 65, the latter causes the phase of the carrier wave transmitted therethrough to the balanced demodulator "magic T" 79 to shift in a direction and to an extent depending, respectively, on the direction and extent of the frequency drift. Hence, at the crystals 84 and 85, the sideband resultant waves and the carrier-wave portions coming from the cavity resonator are no longer in phase quadrature, and as a result, in-phase portions of said sideband resultant waves cause said carrier-wave portions to become amplitude modulated.

If the frequency of the carrier wave generated by the oscillator 10 drifts above the reference fre-

quency, the carrier-wave portions coming from the cavity resonator 65 acquire "+ amplitude modulation," and if said frequency drifts below the reference frequency said carrier-wave portions acquire "- amplitude modulation."

In any event, the modulation envelopes thus produced are recovered across the crystals 84 and 85, and add to each other to appear across the primary winding 91 of the transformer 92.

It now remains to extract from the output of the balanced demodulator "magic T" 79, a D.-C. or unidirectional component of proper sense and magnitude to adjust the frequency control 11 and compensate for the deviations of the oscillator 10. For this purpose, the secondary winding 94 of the transformer 92 is connected to an amplifier 95 which is tuned to the frequency ω_m of the modulation oscillator 76. The output of the amplifier 95 is applied to a differential-amplitude detector 96 to which there is also applied a portion of the output of the modulation oscillator 76. Such a differential-amplitude detector may, for example, be similar to the one disclosed in the copending application of George G. Bruck and Philip E. Volz, entitled "Frequency-stabilizing systems," Serial No. 647,008, filed February 12, 1946.

The differential-amplitude detector 96 is so designed that, in the case where the oscillator 10 has not drifted at all, and as a result, no modulation envelope appears across the transformer 92, said detector has a balanced output which cancels itself. Said detector is so further designed that, in the case where the oscillator 10 has drifted, and, as a result, a modulation envelope does appear across the transformer 92, said detector produces a unidirectional output whose sense and magnitude are functions, respectively, of the sense and magnitude of said drift.

In order to remove from the output of the differential-amplitude detector any intelligence ω_a which may have been initially impressed upon the carrier wave ω_c , said output is applied to a low-pass filter 97, thereby obtaining a final D.-C. output. This output is then applied, through a switch 98, (see X, X—X, Figs. 1 and 2) to the buffer amplifier 47, and thence, to the tuning control 11 to compensate for any drift in the oscillator 10.

Obviously, when the terminal station of the present invention is functioning as a master station, the switch 46 is open and the switch 98 is closed, and when the station is functioning as a slave station, the switch 46 is closed and the switch 98 is open.

This completes the description of the aforesaid illustrative embodiment of the present invention, including the mode of operation thereof as either a master or a slave station in a communication system having the characteristics set forth in the opening paragraphs of this specification.

It will be noted from all of the foregoing that the present invention enables the stabilization of a communication system carrier wave within very close limits. Further, it enables the designing of a communication system terminal station in which the necessity of critical impedance matches between the component parts is minimized. Still further, it avoids the deleterious effects on the entire system of reflections of the energy radiated by the various stations included therein. Finally, it provides a terminal station which may be made to function either as a master station controlling the various carrier waves employed in the system, or as a slave station whose carrier wave is controllable under the influence of a remotely-

generated carrier wave emanating from another terminal station, itself functioning as a master station.

Other objects and advantages of the present invention will readily occur to those skilled in the art to which the same relates.

What is claimed is:

1. In a terminal station for a communication system: means for locally generating a carrier wave; means in common, for radiating said locally generated carrier wave, receiving any reflections thereof, and receiving a remotely generated carrier wave; said locally and remotely generated carrier waves normally having a predetermined frequency difference therebetween; means, receptive of portions of said locally generated carrier wave, any reflections thereof, and said remotely generated carrier wave from said last-named means, for dividing the same into two pairs of constituent waves, the waves of each pair being of like phase and the pairs being of opposite phase, and receptive of a portion of said remotely generated carrier wave from said last-named means and a portion of said locally generated carrier wave directly from said means for generating the same, for dividing the same into two additional pairs of constituent waves, the waves of one of said additional pairs being of like phase and the waves of the other additional pair being of opposite phase; means for mixing the constituent waves of each of said first-named pairs to derive therefrom two beat-frequency waves of equal amplitude and like phase, and for mixing the constituent waves of each of said second-named pairs to derive therefrom two beat-frequency waves of equal amplitude and opposite phase; means for so combining said first-named beat-frequency waves as to produce a zero output, and for so combining said second-named beat frequency waves as to produce a single substantially constant-amplitude, intermediate-frequency wave whose frequency normally corresponds to said predetermined difference between the frequencies of said carrier waves; and means, receptive of said intermediate-frequency wave, for deriving therefrom an output for so controlling the frequency of said locally generated carrier wave as to maintain substantially constant said predetermined difference between the frequencies of said carrier waves.

2. In a communication system: a master station; a slave station remotely located with respect to said master station; means at each of said stations for locally generating a carrier wave; the carrier waves so generated normally having a predetermined frequency difference therebetween; means at said master station for automatically stabilizing the frequency of the carrier wave generated thereat independently of any drift in the frequency of the carrier wave generated at said slave station; means at said slave station, receptive of portions of both said carrier waves, for deriving from one, two constituent waves of equal amplitude and opposite phase, and from the other, two constituent waves of equal amplitude and like phase; means for deriving from all of said constituent waves an intermediate-frequency wave whose frequency normally corresponds to said predetermined frequency difference between said carrier waves; means, receptive of said intermediate-frequency wave, for deriving therefrom a unidirectional output whose sense and magnitude are functions, respectively, of the sense and magnitude of any deviation of the frequency of said intermediate-frequency

wave from said predetermined frequency difference between said carrier waves; and means, receptive of said unidirectional output for automatically so controlling the frequency of the carrier wave generated at said slave station as automatically to maintain substantially constant said predetermined frequency difference between said carrier waves, thereby automatically stabilizing the frequency of the carrier wave generated at said slave station.

3. In a communication system: a master station; a slave station remotely located with respect to said master station; means at each of said stations for locally generating a carrier wave; the carrier waves so generated normally having a predetermined frequency difference therebetween; means at said master station for automatically stabilizing the frequency of the carrier wave generated thereat independently of any drift in the frequency of the carrier wave generated at said slave station; means at said slave station, receptive of a portion of one of said carrier waves, for dividing the same into two constituent waves of equal amplitude and opposite phase; means at said slave station, receptive of a portion of the remaining carrier wave, for dividing the same into two constituent waves of equal amplitude and like phase; means for mixing said first-named constituent waves, respectively, with said second-named constituent waves to derive therefrom two beat-frequency waves of equal amplitude and opposite phase; means for so combining said beat-frequency waves as to produce a single intermediate-frequency wave whose frequency normally corresponds to said predetermined frequency difference between said carrier waves; means, receptive of said intermediate-frequency wave, for deriving therefrom a unidirectional output whose sense and magnitude are functions, respectively, of the sense and magnitude of any deviation of the frequency of said intermediate-frequency wave from said predetermined frequency difference between said carrier waves; and means, receptive of said unidirectional output, for automatically so controlling the frequency of the carrier wave generated at said slave station as automatically to maintain substantially constant said predetermined frequency difference between said carrier waves, thereby automatically stabilizing the frequency of the carrier wave generated at said slave station.

4. In a communication system: a master station; a slave station remotely located with respect to said master station; means at each of said stations for locally generating a carrier wave; the carrier waves so generated having a predetermined frequency difference therebetween; means at said master station, receptive of a portion of the carrier wave generated thereat, for deriving therefrom a carrier-suppressed, amplitude-modulated wave; means at said master station, receptive of another portion of the carrier wave generated thereat, for deriving therefrom a wave whose phase has been shifted through an angle of 90°; means at said master station, responsive to any drift in the frequency of the carrier wave generated thereat, for altering the phase of said phase-shifted wave; means at said master station for combining said amplitude-modulated and phase-shifted waves whereby, in the event no frequency drift has occurred, the resultant wave is a substantially constant-amplitude wave, and, in the event a frequency drift has occurred, the resultant wave is a substantially amplitude-modu-

lated wave the sense and magnitude of whose modulation envelope are functions, respectively, of the sense and magnitude of said frequency drift; means at said master station, receptive of said resultant wave, for deriving therefrom a unidirectional output whose sense and magnitude likewise are functions, respectively, of the sense and magnitude of said frequency drift; means at said master station, receptive of said unidirectional output, for so controlling the frequency of the carrier wave generated thereat as to compensate for said frequency drift and thereby stabilize said carrier wave; and means at said slave station, receptive of a portion of the carrier wave generated at said master station and a portion of the carrier wave generated at said slave station, for maintaining substantially constant said predetermined frequency difference therebetween, thereby stabilizing the frequency of the carrier wave generated at said slave station.

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