

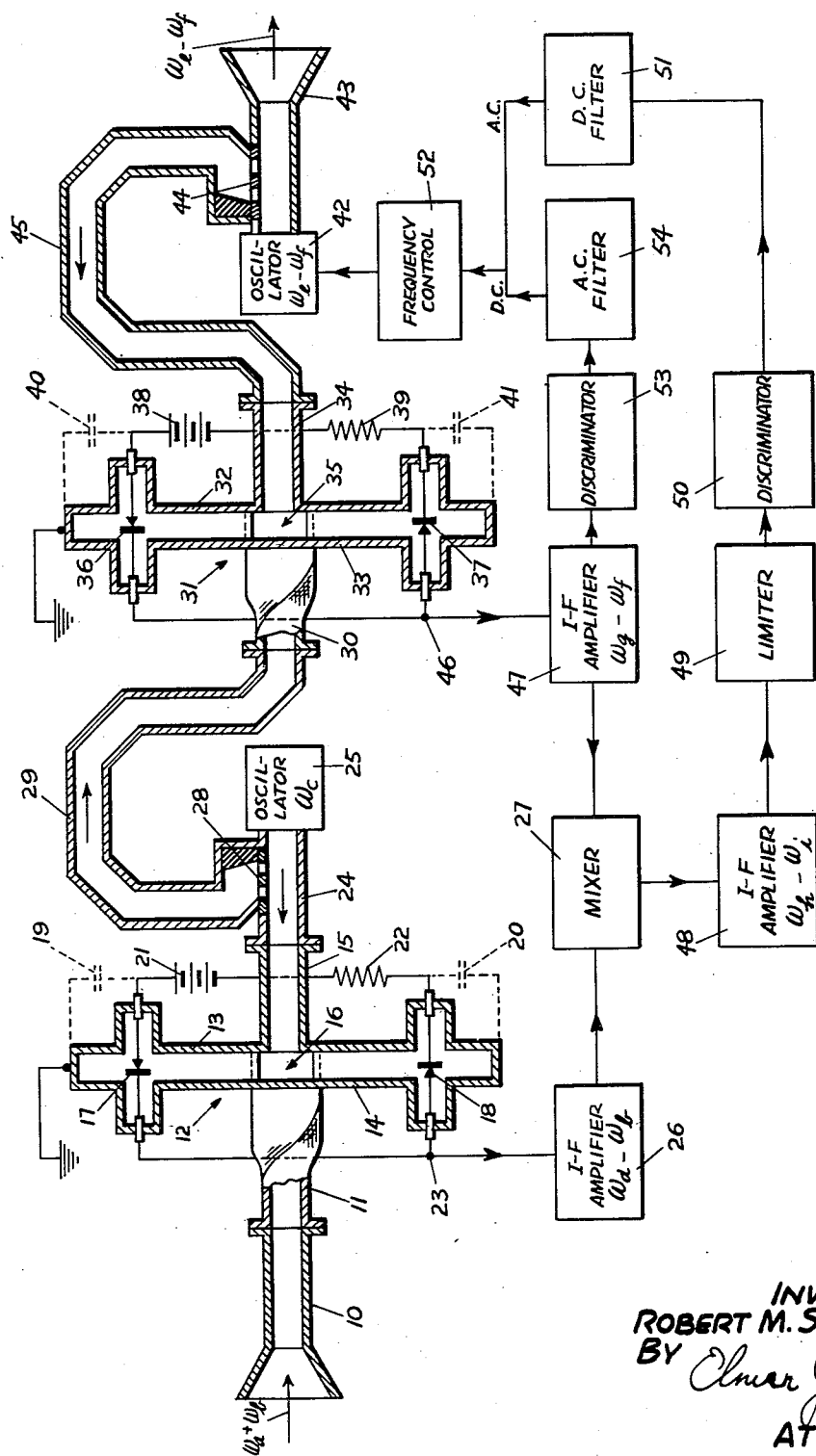
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RELAY STATIONS FOR MICROWAVE COMMUNICATION SYSTEMS

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RELAY STATIONS FOR MICROWAVE COMMUNICATION SYSTEMS

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This invention relates to microwave communication systems, and more particularly to a relay station therefor.

One of the objects of the present invention is the provision of a microwave relay station in which signal distortion is held to a minimum.

Another object of this invention is the provision of a microwave relay station the carrier of which is frequency stabilized within close limits.

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.

A portion of the output of a local, highly stabilized, microwave generator is mixed with a frequency-modulated carrier received from a remotely located transmitting station to derive an intermediate-frequency wave including the remotely incorporated intelligence. Another portion of the output of said local, highly stabilized, microwave generator is mixed with a portion of the output of another local microwave generator, which is to be stabilized, to derive another intermediate-frequency wave.

The two intermediate-frequency waves thus obtained are mixed to derive a third intermediate-frequency wave which also includes the aforesaid remotely incorporated intelligence.

The last-named intermediate-frequency wave is demodulated to obtain a unidirectional voltage, the magnitude and sense of which are functions, respectively, of the magnitude and sense of any deviation of the frequencies of the carrier of said second-named local microwave generator and said received, frequency-modulated carrier from the mean frequencies thereof. Said voltage contains two components, a direct current component corresponding to any drift of the local microwave generator, and an alternating current component corresponding to the intelligence remotely incorporated in the received carrier.

This voltage is applied, through a high-pass filter, to a suitable frequency control which is connected to the local microwave generator to frequency modulate the same and thereby impress thereon the intelligence incorporated in the received carrier.

The second intermediate-frequency wave obtained as above is also demodulated to obtain another unidirectional voltage similar to that just described. This voltage is also applied to the aforementioned frequency control, through a low-pass filter, to stabilize the mean frequency of the local microwave generator.

In the accompanying specification there shall be described, and in the annexed drawing shown, an illustrative embodiment of the relay 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

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the exercise of invention, and within the true spirit and scope of the claims hereto appended.

In said drawing, the single figure is a schematic diagram of a microwave relay station assembled in accordance with the present invention.

Referring now more in detail to the aforesaid illustrative embodiment of the present invention, with particular reference to the drawing illustrating the same, the numeral 10 designates an electromagnetic horn adapted to receive a remotely generated, frequency-modulated carrier wave $\omega_a + \omega_b$, wherein ω_a represents a microwave carrier of a center frequency, for example, of 4,000 megacycles per second, and ω_b represents an instantaneous frequency deviation, for example, of 5 megacycles per second, effected upon the carrier by the intelligence intended to be transmitted.

The horn 10 is coupled, for example, to the so-called H arm 11 of a wave guide assembly 12, known as a magic T. Such a wave guide assembly comprises, in addition to the H arm 11, a pair of side branches 13 and 14 extending in opposite directions outwardly from said H arm, perpendicular thereto, and a so-called E arm 15 extending outwardly from said side branches, mutually perpendicular to said side branches and to said H arm, said H and E arms and said side branches all extending from a common junction 16. As shown in the drawing, the H arm 11 recedes from the observer for a short distance from the junction 16, then bends to the left, and is then twisted through an angle of 90°. The side branches 13 and 14 are terminated in oppositely disposed crystals 17 and 18, between one side of each of which and the magic T itself capacitances 19 and 20 exist, said magic T being grounded, and said crystals being connected, in series with a source 21 of direct current and a resistor 22, to provide parallel outputs between a point 23 on their series connection and ground. The source 21 of direct current is for the purpose of operating the crystals 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 both possess dissimilar characteristics.

The E arm 15 of the assembly 12 is coupled through a wave guide section 24 to an oscillator 25 adapted to generate microwave energy of a frequency ω_c which may, for example, be of 4,100 megacycles per second. The oscillator 25 should be extremely stable and is, preferably, of the cavity-controlled klystron type.

For an understanding of the operation of the magic T 12, assume that the received modulated carrier $\omega_a + \omega_b$ is traveling along the H arm 11 with its electric vector pointing upwardly. As this energy reaches the twist in said H arm, its vector is rotated through 90° and points toward the observer, and, as this energy reaches the bend in said H arm, its electric vector is again rotated through 90° and points toward the left, which is its position when it arrives at the junction 16. At said junction, the wave splits into two constituent waves, one traveling along the side branch 13 toward the crystal 17 and the other traveling along the side branch 14 toward the crystal 18, both constituent waves having their electric vectors pointing in the same direction, namely, toward the left.

Now further assume that the locally generated carrier wave ω_c is traveling along the E arm 15 from the oscillator 25 with its electric vector pointing upwardly. As this energy reaches the junction 16 of the magic T 12, it splits into two constituent waves, one having its electric vector pointing toward the right, traveling along the side branch 13 toward the crystal 17, and the other having its electric vector pointing toward the left, traveling along the side branch 14 toward the crystal 18.

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Thus, there arrives at the crystal 17 two constituent waves whose electric vectors point in opposite directions and which therefore may be considered out of phase, and there arrives at the crystal 18 two constituent waves whose electric vectors point in the same direction and which therefore may be considered in phase. Therefore, there is produced at the crystal 17 a beat-frequency wave whose frequency corresponds to the difference between frequencies of the constituent waves, and whose phase may be considered negative because its component waves are out of phase, while, at the crystal 18, 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, because the crystals are oppositely poled, and set up equal voltages of like polarity across the crystals. Inasmuch as parallel outputs are taken from these crystals, addition occurs, and an intermediate-frequency wave $\omega_d - \omega_b$ appears between the point 23 and ground. In the case under consideration, the mean frequency ω_d of this intermediate-frequency wave is 100 megacycles per second.

This intermediate-frequency wave is applied to a broad-band amplifier 26 whose center frequency corresponds to the difference ω_d between the normal mean frequencies of the remotely and locally generated carrier waves hereinbefore referred to.

The output of the amplifier 26, $\omega_d - \omega_b$, is applied to a mixer 27. A second input to the mixer 27 is derived as follows.

A portion of the output ω_c of the oscillator 25 is fed, through a directional coupler 28, to a wave guide section 29 which, in turn, is coupled to the H arm 30 of another magic T wave guide assembly 31. This assembly, like the assembly 12, includes, in addition to the H arm 30, side branches 32 and 33 and an E arm 34, all extending from a common junction 35. The side branches 32 and 33 are terminated in oppositely-disposed crystals 36 and 37 connected in series with a source 38 of direct current and a resistor 39. Capacitances 40 and 41 exist between one side of each crystal and the assembly, and the entire assembly is grounded.

An oscillator 42, adapted to generate a modulated microwave carrier $\omega_c - \omega_f$, wherein ω_c represents a center frequency, for example, of 4,260 megacycles per second, and ω_f represents an instantaneous deviation which is less than the deviation ω_b , is coupled to an electromagnetic horn 43 whereby said energy may be radiated into space. This oscillator is, preferably, of the magnetron type, and it is this oscillator that it is desired, in accordance with the principles of the present invention, to frequency modulate with the intelligence incorporated in the carrier received from the previous-mentioned, remotely-located transmitter. It is this oscillator, also in accordance with the principles of the present invention, whose mean frequency it is desired to stabilize.

For the above purposes, a portion of the output of the oscillator 42 is applied, through a directional coupler 44, to a wave guide section 45 which, in turn, is coupled to the E arm 34 of the magic T 31. It will be noted that there is applied to the magic T 31 a portion of the carrier ω_c generated by the oscillator 25 and a portion of the carrier $\omega_c - \omega_f$ generated by the oscillator 42. The operation of the magic T 31 is similar to that above described in connection with the magic T 12 and there is therefore produced, between a point 46 in the series connection of the crystals 36 and 37 and ground, a second intermediate-frequency wave $\omega_g - \omega_f$ of a center frequency corresponding to the difference between the carrier waves ω_c and $\omega_c - \omega_f$, in the case under consideration, 160 megacycles per second. This intermediate-frequency wave is amplified in a broad-band amplifier 47 and a portion of the amplified output is applied as a second input to the mixer 27.

In the mixer 27 there is produced a third, frequency-

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modulated, intermediate-frequency wave $\omega_h - \omega_f$, wherein $\omega_h = \omega_g - \omega_d$ and $\omega_i = \omega_b - \omega_f$, in other words, the difference between the first frequency-modulated, intermediate-frequency wave $\omega_d - \omega_b$ and the second intermediate-frequency wave $\omega_g - \omega_f$. In the case under consideration, the difference center frequency ω_h is 60 megacycles per second.

This third intermediate-frequency wave is amplified in a broad-band amplifier 48, and the amplified output is applied to a limiter 49 to remove undesired amplitude modulation.

The output of the limiter 49 is applied to a frequency-sensitive circuit, for example, a discriminator 50, the output of which is a unidirectional voltage whose magnitude and sense are functions, respectively, of the magnitude and sense of any deviation of the third intermediate-frequency wave from its mean frequency ω_h . Such deviations may result from two things, one, any slow drift in the mean frequency of the carrier ω_c generated by the oscillator 42, and, two, the deviation ω_b incorporated in the originally received carrier ω_a . The slow drift of the carrier ω_c produces what may be considered a direct current component and the deviation ω_b produces an alternating current component.

In any event, the output of the discriminator 50 is applied to a high-pass filter 51 which, in turn, is coupled to any suitable tuning mechanism 52 for controlling the frequency of the oscillator 42. Thus, the direct current component of the output of the discriminator 50 is removed, and the alternating current component of said output operates the frequency control 52 to frequency-modulate the oscillator 42 and thereby impress thereon the intelligence originally received.

The foregoing will be better understood from a consideration of the following. That portion of the system which includes the wave guide 45 and the magic T assembly 31 constitutes the β or degenerative circuit of a feedback loop. That portion of the system which includes the amplifier 48, limiter 49, discriminator 50, filter 51, frequency control 52 and oscillator 42 constitutes the μ or amplification circuit of the loop. The β circuit contains no elements that will introduce substantial distortion and the gain of this circuit is unity. The deviation of the μ circuit herein shown is ω_f , which is small, and generates little distortion, and the gain of this circuit depends on the sensitivity of the discriminator 50 and the frequency control 52, and determines the loop gain of the system as a whole. The deviation ω_f of the oscillator 42 is

$$\frac{x}{1+x}\omega_b$$

where x is the loop gain, so that if, for example, the loop gain is 9, the deviation ω_f of the oscillator 42 is $0.9\omega_b$, and the difference ω_f between the deviations ω_b and ω_f is $0.1\omega_b$. It will thus be seen that the higher the loop gain, the less the reduction of deviation at the relay station, and, consequently, the greater the reduction of distortion.

Now, it is also desirable to stabilize the oscillator 42, and, for this purpose, resort may be had to the following expedient.

A portion of the output of the second intermediate-frequency amplifier 47 is also applied to a discriminator 53 to obtain a unidirectional output whose magnitude and sense are functions, respectively, of the magnitude and sense of any deviation of the frequency of the intermediate-frequency wave ω_g from its normal frequency corresponding to the difference between the frequencies of the carriers ω_c and $\omega_c - \omega_f$. Obviously, a drift in the frequency of the carrier ω_c will produce a drift in the frequency of the wave ω_g . The voltage obtained as a result is applied to a low-pass filter 54 to remove any alternating current component and the direct current output of said filter is applied to the tuning or frequency control 52 of the oscillator 42.

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This completes the description of the aforesaid illustrative embodiment of the present invention. It will be noted from all of the foregoing that the present invention provides a microwave relay station in which distortion is held to a minimum and in which the carrier generated at the relay station is frequency stabilized within close limits under the control of the received carrier or under the control of a local feedback circuit.

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. A relay station for a microwave communication system comprising: means for locally generating a first carrier wave; means for locally generating a second carrier wave; means for receiving a third carrier wave; all of said carrier waves being of different frequencies; means, receptive of said second and third carrier waves, for deriving therefrom a first intermediate-frequency wave; means, receptive of said first and second carrier waves, for deriving therefrom a second intermediate-frequency wave; means, receptive of said first and second intermediate-frequency waves, for deriving therefrom a third intermediate-frequency wave; means, receptive of said third intermediate-frequency wave, for deriving therefrom a unidirectional voltage the magnitude and sense of which are functions, respectively, of the magnitude and sense of the difference between any instantaneous deviations of the frequencies of said first and third carrier waves from their initial frequencies; and means, receptive of said unidirectional voltage and connected to said first-named means, for altering the frequency of said first carrier wave to modulate the same in response to such frequency deviation difference.

2. A relay station for a frequency-modulated microwave communication system comprising: means for locally generating a first carrier wave and radiating the same into space; means for locally generating a second carrier wave; means for receiving a third, frequency-modulated carrier wave; all of said carrier waves being of different mean frequencies; means, receptive of said second and third carrier waves, for deriving therefrom a first, frequency-modulated intermediate-frequency wave; means, receptive of said first and second carrier waves, for deriving therefrom a second intermediate-frequency

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wave; means, receptive of said first and second intermediate-frequency waves, for deriving therefrom a third, frequency - modulated intermediate - frequency wave; means, receptive of said third intermediate-frequency wave, for deriving therefrom a unidirectional voltage the magnitude and sense of which are functions, respectively, of the magnitude and sense of any deviation of the frequency of said third carrier wave from its mean frequency; means, receptive of said unidirectional voltage and connected to said first-named means, for modulating the frequency of said first carrier wave in response to such frequency deviation.

3. A relay station for a microwave communication system comprising: means for locally generating a first carrier wave; means for locally generating a second carrier wave; means for receiving a third carrier wave; all of said carrier waves being of different frequencies; means, receptive of said second and third carrier waves, for deriving therefrom a first intermediate-frequency wave; means, receptive of said first and second carrier waves, for deriving therefrom a second intermediate-frequency wave; means, receptive of said first and second intermediate-frequency waves, for deriving therefrom a third intermediate-frequency wave; means, receptive of said third intermediate-frequency wave, for deriving therefrom a unidirectional voltage the magnitude and sense of which are functions, respectively, of the magnitude and sense of any deviation of the frequency of said first carrier wave from its initial frequency; means, receptive of said second intermediate-frequency wave, for deriving therefrom a unidirectional voltage similar to said first-named unidirectional voltage; and means, receptive of both said unidirectional voltages and connected to said first-named means, for altering the frequency of said first carrier wave to compensate for any such frequency deviation and to modulate said first carrier wave in accordance with any intelligence incorporated in said third carrier wave.

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