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MONO-OSCILLATOR U.H.F. TRANSMITTER-RECEIVER

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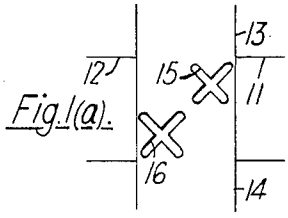


Fig. 1(a).

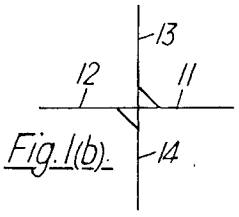


Fig. 1(b).

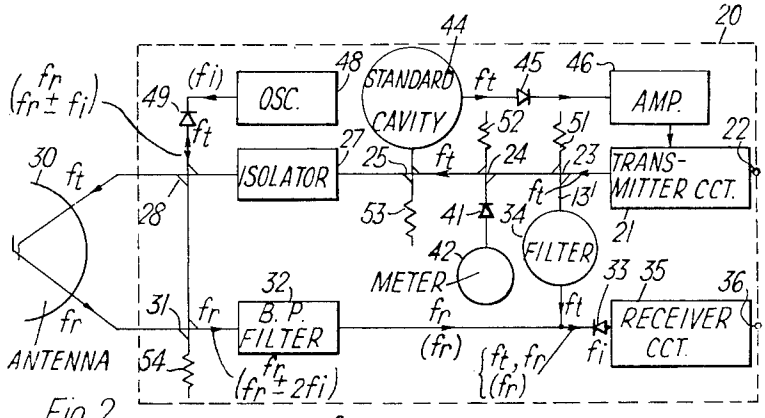


Fig. 2.
(PRIOR ART)

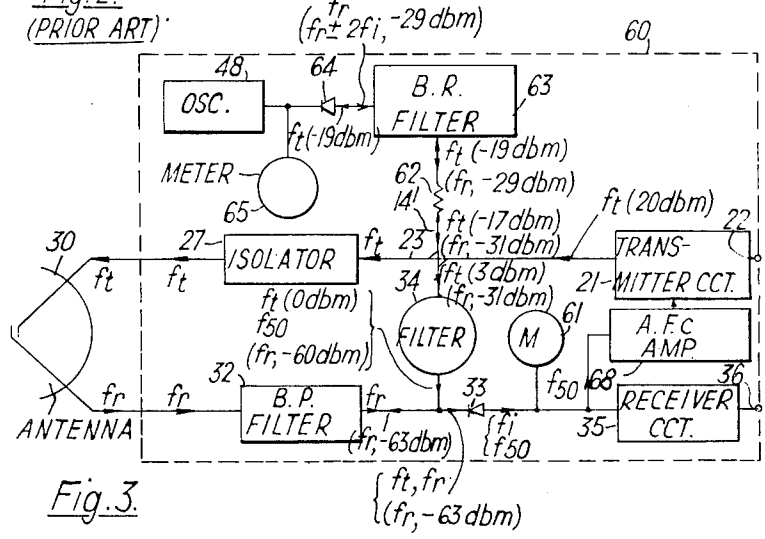


Fig. 3.

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MONO-OSCILLATOR U.H.F. TRANSMITTER-RECEIVER

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6 Claims. (Cl. 325—20)

This invention relates to a transmitter-receiver for frequencies above 1,000 mc., and more particularly to an ultrashort wave or U.H.F. or S.H.F. transmitter-receiver of the heterodyne type in which a portion of the transmitter power is used as the local oscillation power for the receiver.

Because U.H.F. transmitter-receivers of the above type are of simple construction, requiring only one microwave tube, they have been widely adopted. Their simplicity, however, is only relative, and conventional transmitter-receivers of this type still need at least two directional couplers, two dummy loads, and two microwave detectors; one provided with a conversional self-check circuit requires four directional couplers, three dummy loads, and three microwave detectors; and one with the transmitter A.F.C. requires four directional couplers, four dummy loads, and four microwave detectors.

Hence one object of the invention is to provide a more simplified U.H.F. transmitter-receiver, which may operate with only one directional coupler and without any dummy loads.

Another object of this invention is to provide a U.H.F. transmitter-receiver which has a reduced number of microwave detectors, but comparable reliability.

A further object of this invention is to provide a U.H.F. transmitter-receiver of simplified circuitry with a conversional self-check circuit.

A still further object of this invention is to provide a U.H.F. transmitter-receiver in which the local oscillation frequency filter, normally used for deriving a portion of the transmitter power for the receiver local oscillator function, serves also as a standard cavity for the automatic frequency control of the transmitting frequency, and in which the microwave detector normally used for the frequency conversion of the received signal also serves as a detector for an A.F.C. signal as well as a detector for monitoring the transmitting power.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings in which:

FIGS. 1(*a*) and 1(*b*) illustrate schematically and symbolically a typical directional coupler used in a U.H.F. transmitter-receiver.

FIG. 2 shows a conventional U.H.F. transmitter-receiver.

FIG. 3 illustrates a U.H.F. transmitter-receiver according to the invention.

In order to lay a proper foundation for an explanation of the invention, a directional coupler, typical of that generally used in U.H.F. transmitter-receivers, will first be described with reference to FIGS. 1(*a*) and 1(*b*). The coupler comprises a first waveguide forming first and second arms **11** and **12**, and a second waveguide forming third and fourth arms **13** and **14**. The waveguides are mutually perpendicular and are integrally disposed with a common wall portion containing coupling windows **15** and **16** in the first and the third quadrants as visualized with respect to the axes of the waveguides.

Although most of the electromagnetic wave entering the directional coupler through the first arm **11** is emitted from arm **12**, a portion seeks arm **13** via the coupling window **15**. If the electromagnetic power entering the first arm **11** is P_{11} and the power transferred to the third arm **13** is P_{13},

$$\alpha=P_{11}/P_{13}$$

where α is the degree of coupling of the directional coupler. A very small portion of the power flows from arm **11** to the fourth arm **14**. If the power transmitted to the fourth arm **14** is P_{14},

$$\eta=P_{13}/P_{14}$$

where η is the directivity of the directional coupler. The attenuation which the electromagnetic wave undergoes while being transferred from arm **11** to arm **12** is determined by the coupling degree (which is approximately equal to the directivity).

Referring now to FIG. 2, the conventional U.H.F. transmitter-receiver shown therein comprises a transmitter circuit **21**, which in turn comprises a microwave oscillator having a klystron or other microwave vacuum tube, for generating a carrier wave of frequenty f_t, which is so arranged that the carrier wave may be either directly or indirectly (via a video frequency amplifier contained therein) modulated by the input signal supplied to terminal **22**. The transmitter output power thus obtained is applied, via four directional couplers **23**, **24**, **25**, and **28** and an isolator **27** (for preventing the deterioration in the modulation characteristics of the microwave tube), to antenna **30**. This antenna is capable of transmitting and concurrently receiving electric waves in different planes of polarization. The incoming wave of frequency f_r is applied through a fifth directional coupler **31** and a receiving band-pass filter **32**, for suppressing the image frequency, to a receiving crystal detector **33** which acts as a frequency converter. The detector is also fed, through a filter **34** tuned to the local oscillation frequency f_l (which is equal to the transmitting carrier frequency f_t) with a portion of the transmitter output which appears through the first directional coupler **23** at its third arm **13'**. The intermediate-frequency signal of the frequency

$$|f_t-f_r|=f_l$$

which is thus obtained at the output side of the crystal detector **33** is amplified, amplitude-limited, demodulated, and amplified in the well known manner in a receiver circuit **35**. The resultant signal is available at output terminal **36**. It is to be noted that where the local oscillation frequency f_l or, in this case, the transmitting carrier frequency f_t, is greater than the receiver carrier frequency f_r of the incoming electric wave, then

$$f_r=f_t-f_l$$

and the image frequency is

$$f_t+f_l=f_r+2f_l$$

A portion of the transmitter output separated at the second directional coupler **24** is sent through a detector **41** to a meter **42** where the transmitter output is monitored with respect to its output level. A further portion of the transmitter output obtained at the third directional coupler **25** is delivered through a standard cavity **44**, tuned precisely to the transmitting carrier frequency f_t, to an automatic frequency control signal detector **45** which, after detection, produces at its output a signal which is amplified at amplifier **46** and then fed to the transmitter portion **21** to control the oscillation frequency of the microwave oscillator to ensure its coincidence with the transmitting carrier frequency f_t.

The transmitter-receiver 20 further comprises a conversional self-check circuit, which almost all of the transmitter-receivers of this type include, in order to make possible an operational check without an incoming signal. This circuit consists of the fourth directional coupler 28, a converted check signal oscillator 48 whose oscillation frequency is approximately equal to the intermediate frequency f_i, a crystal detector 49 which serves as a frequency converter to mix the output of the oscillator 48 with the derived portion of the transmitter output of frequency f_t, and a fifth directional coupler 31 for transferring to the band pass or image suppression filter 32 the converted signal containing frequencies of, as the case may be, f_r and f_r+2f_i or f_r and f_r-2f_i. When the converted check signal oscillator 48 is set into operation, only the receiver carrier frequency f_r is obtained on the output side of the image suppression filter 32. It is therefore possible even without an incoming wave to check whether or not the transmitter-receiver 20 is in normal operation. Those arms of the directional couplers from which no power is derived are terminated with dummy loads 51, 52, 53, and 54 in order to suppress any possible reflection.

Having laid the groundwork, the transmitter-receiver of the invention will now be described with reference to FIG. 3. In the following description it will be understood that similarly labelled blocks and circuit elements are similar in construction to the conventional transmitter-receiver shown in FIG. 2.

The most pertinent distinctions between the two circuits will first be enumerated. The receiving crystal detector 33 serves both as the transmitter output monitoring detector 41 (in FIG. 2) and the automatic frequency control signal detector 45 (in FIG. 2), while the local oscillation frequency filter 34 acts additionally as the automatic frequency control cavity 44. The second, third, fourth, and fifth directional couplers 24, 25, 28, and 31 and the dummy loads 51–54 in the conventional transmitter-receiver are dispensed with. Instead of the dummy load 51 connected to the first directional coupler 23, the fourth arm 14' of this coupler is connected serially to a variable or semi-fixed attenuator 62, a band-rejection filter 63 (for rejecting that frequency band encompassing either the sum of, or difference between the carrier frequency f_r of the incoming wave and twice the intermediate frequency f_i of the transmitter-receiver, which corresponds to the image frequency of the incoming wave) a crystal detector 64, and a meter 65 (for checking the existence of an oscillation) in parallel with a converted check signal oscillator 48. Furthermore, an automatic frequency control amplifier 68 is disposed between the output of the receiving crystal detector 33 and the microwave oscillator of the transmitter circuit 21.

During normal operation of the transmitter-receiver, a part of the transmitter output of frequency f_t, derived at the directional coupler 23, is applied through the local oscillation frequency filter 34, tuned to the local oscillation frequency f_1 (equal to the transmitter carrier frequency f_t), to the receiving crystal detector 33 together with the incoming wave of frequency f_r. Here it is frequency-converted to an output of intermediate frequency f_i. Even when there is no incoming wave, the transmitter carrier frequency f_t is supplied through the local oscillation frequency filter 34 to the receiving crystal detector 33 where it is rectified and applied to the meter 61 for monitoring the transmitter output and carrier frequency. In other words, the receiving crystal detector 33 serves additionally as a detector for monitoring the transmitter output and as a detector for monitoring the transmitter carrier frequency.

If the oscillation frequency of the microwave oscillator in the transmitter portion 21 either shifts from, or is being adjusted to the desired carrier frequency f_t, because of either a malfunction or tube replacement, the

portion of the oscillation derived at the directional coupler 23 is reflected by the local oscillation frequency filter 34, because of the frequency shift, and accordingly cannot reach the receiving crystal detector 33. Consequently, it is impossible merely with the meter 61, for monitoring the oscillation output and frequency, to judge whether the oscillation frequency has shifted or is not being generated at all because of an inadequacy, for example, in the voltages applied to the tube. It is to be noted that the local oscillation power necessary for the receiving crystal detector 33 is generally of the order of 1 mw. (0 dbm). It follows, therefore, that if the output of the transmitter portion 21 is 100 mw. (20 dbm) and the transmission loss of the local oscillation frequency filter 34 is 3 db at the carrier frequency f_t, the coupling degree of the directional coupler 23 should be 17 db. In this connection, it should also be noted that the transmission loss of the directional coupler 23 is less than 0.1 db for a signal which goes through the aligned arms. Also if the directivity of the directional coupler is 20 db, only a small portion of the signal, about −17 dbm, emerges from the fourth arm 14'. If the oscillation frequency of the microwave oscillator is not the desired one, the 3-dbm power derived at the third arm 13' is reflected at the filter 34, again passing through the directional coupler 23, this time with minimal loss, and reaches the rejection filter 63. So long as the oscillation frequency of the signal applied to the rejection filter 63 is not approximately equal to the image frequency, it passes through filter 63 and is rectified at the checking crystal detector 64, appearing at the meter 65 for checking the existence of an oscillation. Thus, it is possible with the transmitter-receiver of the invention to easily judge whether the microwave oscillator is producing an oscillation having a frequency other than the prescribed one or is not generating any oscillation at all. It will, therefore, be appreciated that the checking crystal detector 64 assumes the function of detector of the oscillator output in cases of adjustment and/or malfunction of the microwave oscillator.

Turning now to the conversional self-check feature of the invention, it will be recalled that in the case where the output frequency of the transmitter portion 21 is normal and equal to the resonance frequency f_1 of the local oscillation frequency filter 34, only a very small portion (in the numerical example given above, −17 dbm) of the transmitter output is derived from the fourth arm 14' of the directional coupler 23. If the attenuation of the variable or semi-fixed attenuator 62 is 2 db, the power of the transmitter carrier frequency f_t applied to the checking crystal detector 64 is −19 dbm. The oscillation ouput whose frequency is nearly the intermediate frequency f_i, if produced by the converted check signal oscillator 48 while there is no incoming electric wave, is also applied to the checking crystal detector 64, which then mixes the powers to produce a frequency-converted output of frequencies f_t-f_i and f_t+f_i. If the conversion loss of the checking crystal detector 64 is 10 db, the power of each such converted output is −29 dbm. Inasmuch as the rejection filter 63 rejects an oscillation whose frequency is about the image frequency, the converted check signal that passes through the variable or semi-fixed attenuator 62 towards the directional coupler 23, and reaches the local oscillation frequency filter 34, is approximately equal in frequency to the receiver carrier frequency f_r and in power to −31 dbm. The transmission loss L of the local oscillation frequency filter 34, for the converted check signal whose frequency is equal to the receiver carrier frequency f_r, is

$$L \approx [Q \times 2(f_t - f_r)/f_t]^2$$

which for a filter quality factor Q of 2,000, a transmitter carrier frequency f_t of 10,000 mc., and an intermediate frequency f_i of 70 mc. is:

$$L \approx 29 \text{ db}$$

The power of the converted check signal having passed through the local oscillation frequency filter **34** is, therefore, —60 dbm. Although the local oscillation power, whose frequency is equal to the transmitter carrier frequency f_t, cannot pass through the image suppression filter **32**, the converted check signal whose frequency is equal to the receiver carrier frequency f_r can. The converted check signal applied to the receiving crystal detector **33** is, therefore, a half of —60 dbm, or —63 dbm, which is sufficient for the conversional self-check.

Since in the transmitter-receiver of the invention a, portion of the transmitter output, branched at the directional coupler **23**, goes through the local oscillation frequency filter **34** and is rectified by the receiving crystal detector **33**, if either the transmitting carrier frequency f_t or the resonance frequency f_1 of the local oscillation frequency filter **34** is slightly modulated with a specific frequency (such as 50 c./s.) which does not affect the quality of the transmission, a component of the specific frequency can be detected at the receiving crystal detector **33**. It is, therefore, possible to control, by the automatic frequency control signal obtained by amplifying the detected component at the automatic frequency control amplifier **68**, the oscillation frequency of the microwave oscillator contained in the transmitter portion **21** so that it may be exactly equal to the desired transmitter carrier frequency f_t. In this case, the receiving crystal detector **33** serves three functions: frequency conversion of the received carrier, detection of the transmitter output for monitoring, and detection of the automatic frequency control signal.

As has been described, the conventional U.H.F. transmitter-receiver **20** shown in FIG. 2 has five directional couplers, four dummy loads, and four microwave detectors, while in the transmitter-receiver **60** of the invention, the numbers of such components are 1, 0, and 2, respectively, and the circuitry is greatly simplified. The transmitter-receiver **60** of the invention, therefore, not only has comparable performance to the conventional transmitter-receiver **20**, but also is very simple and economical. Microwave detectors are very apt to deteriorate, and their reduction from four to only two means the elimination of approximately 50% of one of the main causes of frequency troubles, and an increased reliability. Furthermore, it will be appreciated that while in conventional transmitter-receivers, having both a frequency filter for the receiver local oscillator function and a standard cavity for the automatic frequency control of the microwave oscillator, the provision of temperature compensation means is essential for maintaining the resonance frequencies precisely equal; the invention, containing as it does, only one local oscillation frequency filter for both functions, has no such requirement.

While the principles of the invention have so far been explained in conjunction with specific circuitry disposed in a prescribed manner, it is to be clearly understood that where necessary specific functions and their inherent circuitry may be eliminated. Moreover, the specific elements involved have a wide range of equivalents in the art, and these may be easily substituted for practical or specific reasons. Likewise, certain elements such as amplifiers, attenuators, etc. may be added where necessary to boost or limit signals as is well known.

The description has been made only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claims.

What is claimed is:

1. A simplified U.H.F. transmitter-receiver in which antenna means radiate a first modulated carrier signal and receive a different second modulated carrier signal, comprising: a four arm directional coupler for tranferring signals, without substantial attenuation between the first and second arms and between the third and fourth arms thereof, and for transferring a first portion of signals entering said first arm to said third arm and for transferring a second portion, smaller than said first portion of signals, entering said first arm to said fourth arm; a transmitter circuit for generating said first modulated carrier signal connected to supply said first modulated carrier signals to said first arm; means for supplying the first modulated carrier signal appearing at said second arm to said antenna means for radiation therefrom; a local oscillator frequency filter having a resonant frequency corresponding to the carrier frequency contained in said first modulated carrier signal, connected to said third arm for deriving from said first signal portion supplied to said third arm a local oscillator power signal; frequency conversion means connected to receive both said second modulated carrier signal from said antenna means and said local oscillator power signal from said filter for deriving a modulated intermediate frequency signal therefrom; detector-monitor means connected to the fourth arm of said coupler for detecting and monitoring said second signal portion and the signals reflected by said filter when the carrier signal contained in the first modulated carrier signal differs from said resonant frequency; and a receiver circuit connected to said frequency conversion means for demodulating said modulated intermediate frequency signal.

2. A simplified U.H.F. transmitter-receiver as set forth in claim **1** wherein said detector-monitor means comprises: detector means, including a crystal diode, for detecting the carrier frequency contained in said first modulated carrier signal; a rejection filter connected between the fourth coupler arm and one side of said crystal diode for rejecting the image frequency of said first modulated carrier signal with respect to said resonant frequency; and I.F. signal oscillator, for generating self-check oscillations which have a frequency approximately equal to said modulated I.F. output of said frequency conversion means, said I.F. signal oscillator being connected to supply said self-check oscillations to the other side of said crystal diode, said crystal diode further functioning as a frequency converter for deriving a converted output signal from said second signal portion supplied thereto and said self-check oscillations, at a frequency substantially equal to the carrier frequency contained in said second modulated carrier signal, said converted signal being applied to said frequency converter through said local oscillator frequency filter.

3. A simplified U.H.F. transmitter-receiver as set forth in claim **1**, wherein the transmitter circuit includes: means for generating and modulating a first carrier signal with a first modulating signal thereby to provide a modulated carrier signal, and means for superimposing a second automatic frequency control modulating signal, having a frequency lower than that of the first modulating signal, on the thus modulated carrier signal, the frequency of said second signal being selected to prevent deterioration of the quality of transmission; and wherein said local oscillator frequency filter output power signal includes components of both said first and second modulating signals; and wherein means are provided and connected to supply a component of the modulated I.F. signal output of said frequency conversion means, to said transmitter circuit for automatically controlling the frequency of said first carrier signal.

4. A simplified U.H.F. transmitter-receiver as set forth in claim **3**, wherein the frequency conversion means comprises: a crystal diode which operates simultaneously to: not only mix the local oscillator signal with the second modulated carrier signal to derive said modulated I.F. signal but also to detect and monitor the first modulating carrier signal along with the automatic frequency control signals contained in the thus mixed signals.

5. A simplified U.H.F. transmitter-receiver as set forth in claim **1** wherein said local oscillator frequency filter includes means for superimposing a predetermined automatic frequency control modulating signal on said local oscillation power signal, said predetermined signal having a frequency which is lower than that of the mod-

ulating signal contained in said first modulated carrier signal, and which is selected to prevent deterioration of the quality of reception; and wherein means are provided and connected to supply a component of the modulated I.F. signal output of said frequency conversion means to said transmitter circuit for automatically controlling the carrier frequency contained in said first modulated carrier signal.

6. A simplified U.H.F. transmitter-receiver as set forth in claim 5 wherein the frequency conversion means includes a crystal diode which functions simultaneously not only to mix the local oscillator signal with said second modulated carrier signal thereby to derive said modulated I.F. signal but also to detect and monitor the

automatic frequency control signal contained in the thus mixed signals.

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