MICROWAVE SYSTEM

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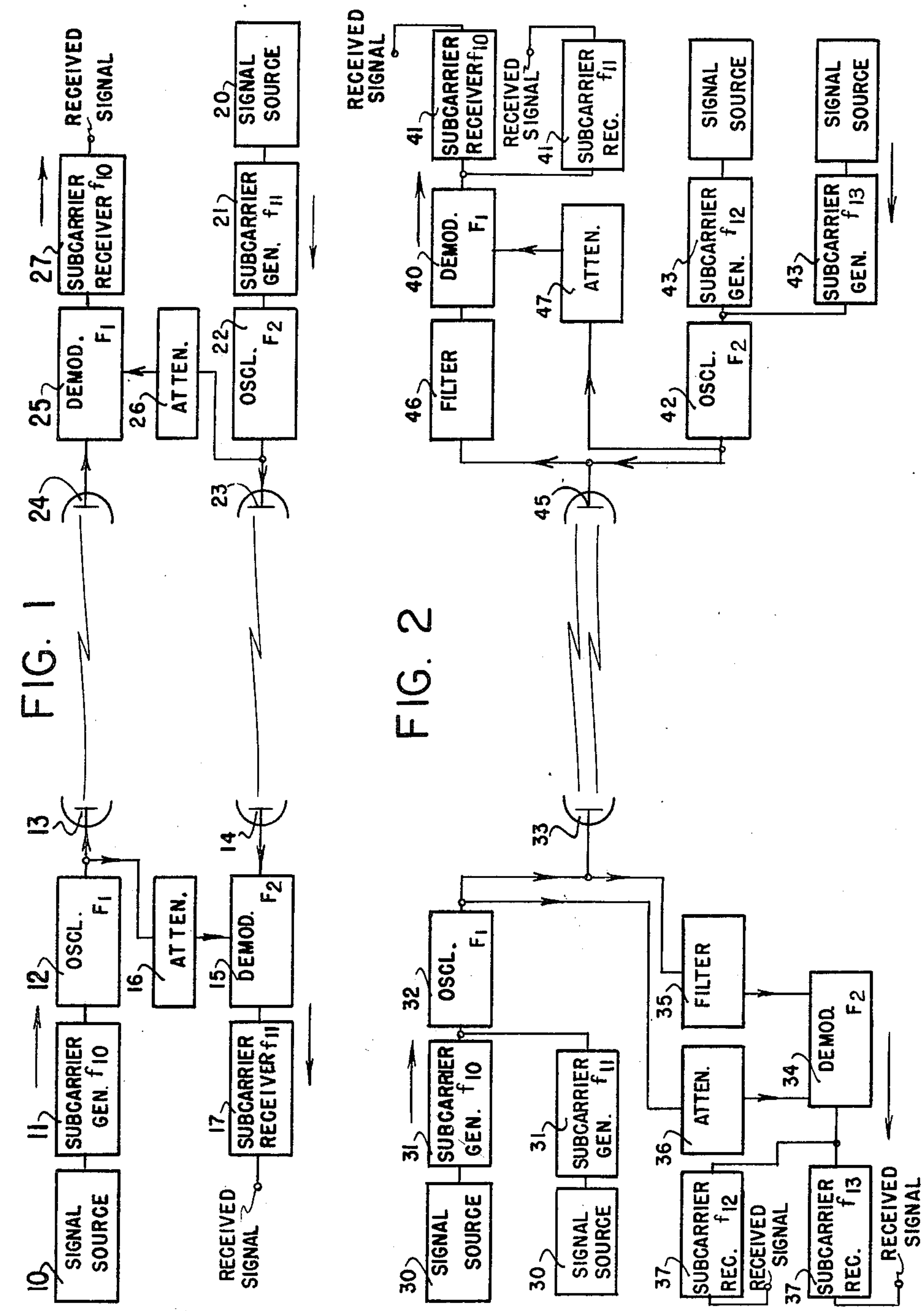

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March 15, 1955 K. N. BERGAN 2,704,362

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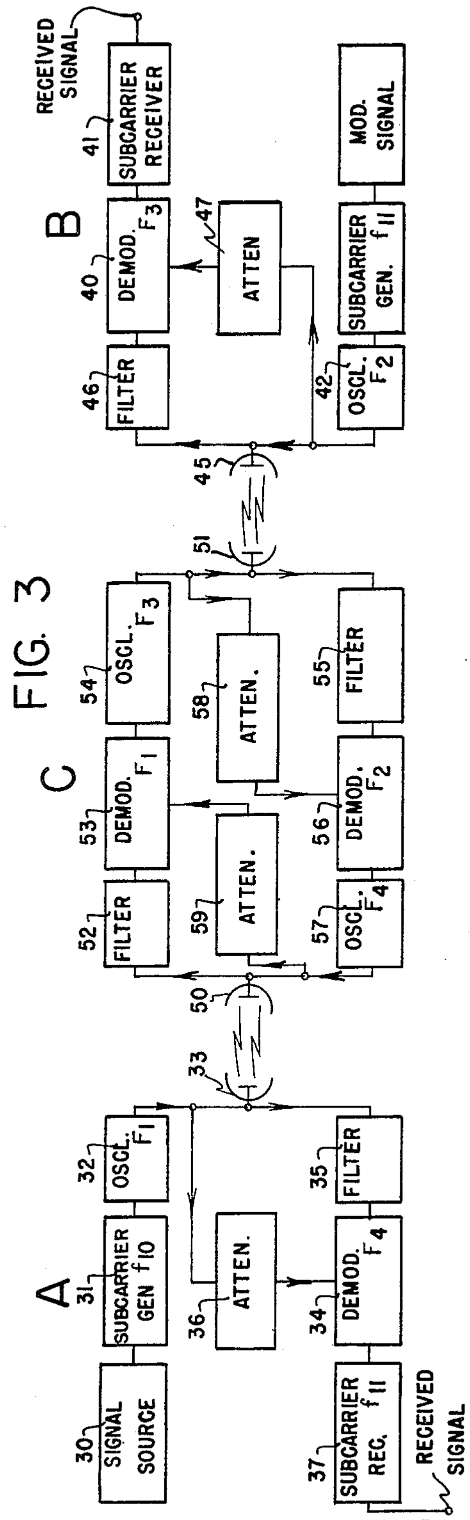

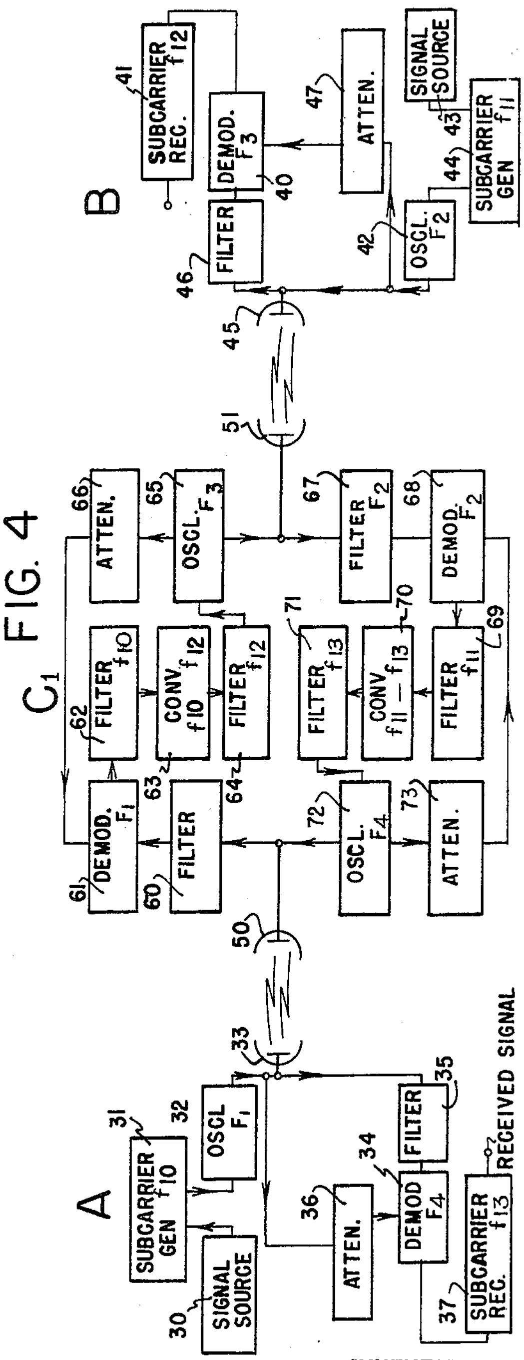

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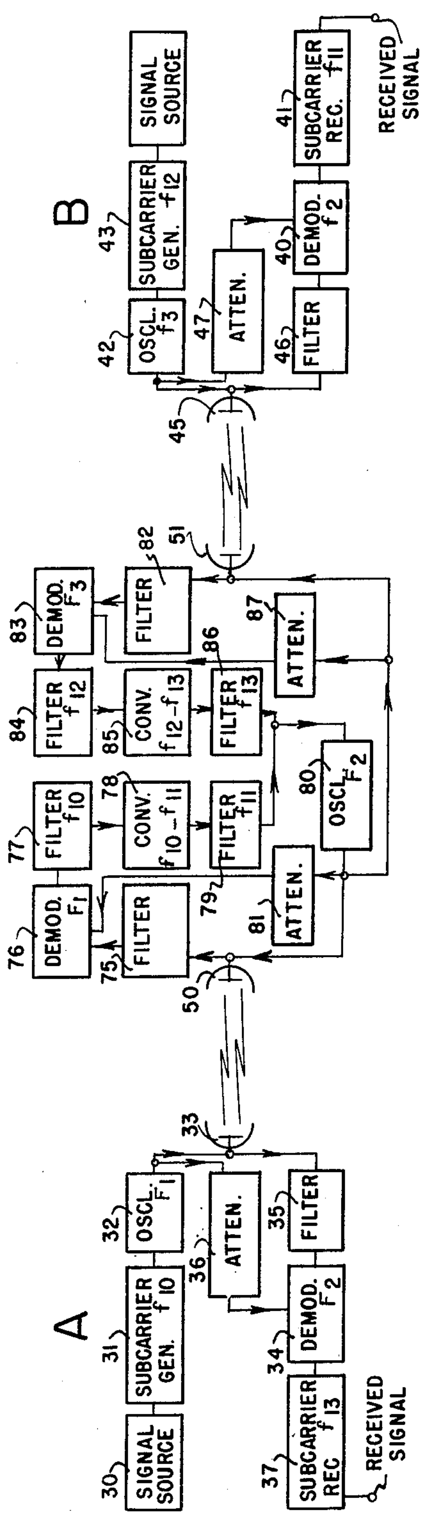
FIG. 5



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MICROWAVE SYSTEM

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This invention relates generally to radio communication systems and more particularly to such systems which operate at microwave frequencies.

Much interest has been indicated in the use of microwave frequencies for point-to-point communication. The words microwave frequencies are used hereinafter to designate frequencies of 1,000 megacycles and higher, which in general fall within the bands designated as the ultrahigh frequency and superhigh frequency bands. Such high frequencies are advantageous in that large band widths are available so that a plurality of separate communications can be provided over a single channel. Microwave operation is also advantageous in that the radiated waves at these frequencies are highly directional and can be accurately directed to a receiving point thereby providing highly efficient transmission and at the same time avoiding interference between various communication systems operating in the same general area.

Although a great amount of work has been done in developing microwave communication systems, the equipment required is relatively expensive and critical in adjustment. Oscillators for generating waves at this frequency utilize tubes such as klystrons and magnetrons which are expensive and relatively delicate so that extreme care must be taken in the use thereof.

Therefore, it is an object of the present invention to provide a simplified system for providing simultaneous transmission and reception at microwave frequencies.

A further object of this invetnion is to provide a combined transmitting and receiving system for microwaves which utilizes a single oscillator.

Another object of this invention is to provide a simplified microwave relay system in which a single oscillator produces oscillations which may be used for providing a plurality of functions at the same time.

A feature of this invention is the provision of a radio communication system providing simultaneous two-way operation in which a single oscillator operating at a microwave frequency functions as the oscillator of the transmitter and also as the local oscillator of the receiver.

A further feature of this invention is the provision of a system for simultaneously transmitting and receiving microwaves with the transmitted and received carrier waves being at different frequencies and being modulated by subcarriers of different frequencies, so that the oscillator which is modulated to provide the transmitted wave may be used for demodulating the received wave and the received subcarriers may then be derived.

Another feature of this invention is the provision of a microwave relay system including an oscillator which can be directly modulated for providing a modulated carrier wave to be transmitted and in which the modulated wave is applied to means for demodulating a received wave.

Further objects and features will be apparent from a consideration of the following description taken in connection with the accompanying drawings in which:

Fig. 1 illustrates a communication system in accordance with the invention;

Fig. 2 illustrates a modified system in accordance with the invention in which a single antenna at each terminal provides both reception and transmission;

Fig. 3 is a microwave relay system in accordance with the invention; and

Figs. 4 and 5 illustrate modified microwave relay systems.

In practicing the invention there is provided a continuous two way (duplex) microwave radio communication system. Transmission and reception are carried on simultaneously at different frequencies, with the transmitted and received waves being modulated by subcarrier waves which are at different frequencies. The transmitting equipment includes an oscillator which can be directly modulated such as klystron and magnetron oscillators which are available and are suitable for this purpose. The oscillator is modulated by one or more subcarrier waves which are individually modulated by the signals to be transmitted. The oscillator is connected to a suitable antenna which radiates the modulated carrier wave produced thereby. A receiving system is provided which may be connected to the same antenna as the oscillator, or to a separate antenna. The receiving system includes a demodulator for deriving the modulation from the received carrier wave. The carrier wave to be received is modulated by one or more subcarrier waves, the frequency of which is different from the frequency of the subcarrier waves being transmitted. The oscillator is connected through suitable attenuating means to the demodulator for providing local oscillations required thereby for demodulating the received wave. When a single antenna is used for transmitting and receiving, a filter is provided between the antenna and the receiver for eliminating the transmitted waves. The system described above can be used for relay operation with the subcarriers received from one link of the relay system being applied to the oscillator for the next link, and so on.

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Referring now to the drawings, in Fig. 1 there is illustrated a radio communication system providing simultaneous two way operation in which the same oscillator provides transmission at one frequency and acts as a local oscillator for reception at a different frequency. A modulating signal derived from any source **10** is applied to subcarrier generator **11** and is used to modulate the subcarrier wave at frequency f_{10} produced thereby. The output of the subcarrier generator **11** is applied to the oscillator **12** so that the oscillator produces a wave of microwave frequency F_1 which is modulated by the subcarrier wave f_{10}. Frequency modulation of the subcarrier waves by the modulating signal and frequency modulation of the microwaves by the combined subcarrier waves may be used. A klystron or a magnetron oscillator is suitable for providing the modulated microwave. The system disclosed, however, is not limited to use with frequency modulation. The modulated carrier wave from the oscillator **12** is applied to antenna **13** and is radiated thereby.

For receiving signals at the terminal station described, a second antenna **14** is provided. The received signals will be a microwave frequency carrier wave F_2 modulated by a subcarrier wave f_{11}. The signals from the antenna **14** are applied to the demodulator **15**, and the oscillator **12** is connected through attenuator **16** to the demodulator **15** to provide local oscillations therefor. The demodulator **15** is of the superheterodyne type, and it is obvious that the carrier waves F_1 and F_2 must be separated by the intermediate frequency of the demodulator **15**. During simultaneous transmission and reception, the oscillator **12** will be modulated by the wave f_{10} from the subcarrier generator **11** as previously described. The output of the oscillator therefore will include this modulation and when used to demodulate the received signal, the subcarrier wave f_{10} produced by subcarrier generator **11** will be present. That is, the intermediate frequency wave produced by the converter in the demodulator will include both the received subcarrier wave f_{11} and the transmitted subcarrier wave f_{10}. The detector of the demodulator will also provide both the subcarrier waves f_{11} and f_{10}. The output of the demodulator **15** is applied to the subcarrier receiver **17** which is highly selective so that only the received subcarrier wave f_{11} will be received thereby and the transmitted subcarrier is thereby eliminated. The subcarrier receiver recovers the original modulating signal from the received subcarrier wave.

The terminal station just described may communicate with another station which is identical therewith, as illustrated in Fig. 1. The second station includes a modulating signal source **20**, subcarrier generator **21** operating at frequency f_{11}, oscillator **22** operating at frequency F_2, transmitting antenna **23**, receiving antenna **24**, demodulator **25**, attenuator **26** and subcarrier receiver **27**. The demodulator **25** is arranged to receive the frequency F_1 transmitted by the antenna **13**, while the oscillator **22** will produce a carrier wave of the frequency F_2 being received by the demodulator **15**. The oscillator **22** provides oscillations to the demodulator **25** in the manner fully described above.

In Fig. 2 there is disclosed a microwave radio communication system which is generally similar to that of Fig. 1. In this system a plurality of modulating sources **30** are provided which individually modulate the subcarrier generators **31**. The oscillator **32** is modulated by the waves f_{10} and f_{11} from the subcarrier generators and applies the modulated carrier wave F_1 to the antenna **33**. A single antenna **33** is used for transmission and reception and is connected to the demodulator **34** of the receiver through filter **35** which passes the received frequency F_2. The filter may be of the cavity type and prevents the relatively strong transmitted signal F_1 from being applied to the receiving system. Oscillations are applied from the oscillator **32** to the demodulator **34** through the attenuator **36**. Sufficient signals may be transmitted through the filter **35** so that the path through the attenuator may be eliminated. Connected to the output of the demodulator are a plurality of subcarrier receivers which may be selective to derive the subcarrier frequencies f_{12} and f_{13} being received. The subcarrier receivers **37** provide the separate modulating signals from the subcarrier waves.

The second terminal of the system in Fig. 2 may be identical in all respects to the terminal just described with the demodulator **40** responding to the frequency F_1 of the oscillator **32** and the subcarrier receivers **41** being individually responsive to the frequencies f_{10} and f_{11} of the subcarrier generators **31**. Similarly the oscillator **42** will produce the frequency F_2 to which the demodulator **34** is responsive and the subcarrier generators **43** will individually provide the subcarrier frequencies f_{12} and f_{13} to which the subcarrier receivers **37** are responsive.

In Fig. 3, a relay system is illustrated in which the terminal equipment is generally similar to that illustrated in Fig. 2. To simplify reference thereto, the terminal stations are indicated A and B and the relay station is indicated as C. The terminal stations A and B may be identical to the terminal stations illustrated in Fig. 2 and therefore will not be described in detail. The components illustrated are designated by the same reference numbers used in Fig. 2. At the terminal station A, the oscillator **32** provides a carrier wave F_1 modulated by subcarrier f_{10} which is transmitted by the antenna **33**. The wave F_4 received by the antenna **33** is applied through filter **35** to the demodulator **34** to which local oscillations are applied from oscillator **32** through attenuator **36**. Similarly the terminal station B includes oscillator **42** for applying carrier wave F_2 modulated by subcarrier wave f_{11} to the antenna **45**, and demodulator **41** for processing the received signal from the antenna **45**.

The distance of communication between terminals A and B can be increased by the provision of one or more relay stations therebetween. Relay station C illustrates this arrangement but it is to be pointed out that a plurality of stations such as C can be used instead of a single relay station. The relay station C includes an antenna **50** to receive signals transmitted by antenna **33** and to transmit signals to the antenna **33**. The relay station C also includes a second antenna **51** for communicating with the antenna **45** of terminal station B. Signals received by the antenna **50** from terminal A are applied through filter **52** to demodulator **53** wherein the subcarrier wave f_{10} is derived from the carrier wave F_1 and applied to the oscillator **54**. The oscillator **54** is modulated by the subcarrier waves to produce a new carrier wave F_3 which is radiated by the antenna **51**.

Similarly, signals received by the antenna **51** from station B are applied through filter **55** to demodulator **56** in which the subcarrier wave f_{11} is derived from the carrier wave F_2 and applied to the oscillator **57** for modulating the same so that a modulated carrier wave F_4 is radiated by the antenna **50**. The carrier waves, F_1 and F_2, received by the antennas **50** and **51** and the waves, F_3 and F_4, transmitted thereby are preferably all at different frequencies although some duplication of frequencies may be possible. In the relay station C the oscillators **54** and **57** provide local oscillators for the demodulators **56** and **53** respectively, as in the terminal stations described above. Connection is made to the demodulators **56** and **53** through attenuators **58** and **59** which reduce the level of the oscillations. It is apparent from the above description that continuous simultaneous transmissions may be made from station A to station B, and from station B to station A, with the relay station C relaying the signals in both directions at the same time.

In Fig. 4 a modified relay station is illustrated including terminal stations A and B and relay station C_1. The terminal stations A and B are identical with the terminal stations A and B of Fig. 3. The relay station C_1, however, has a somewhat different system. Considering now the relay of signals from station A to station B through relay station C_1, signals received by antenna **50** are passed through filter **60** to demodulator **61**. The subcarrier wave f_{10} is derived from the carrier wave F_1 in the demodulator **61** and applied through filter **62** to heterodyne converter **63** which changes the frequency of the subcarrier wave to provide a new subcarrier wave f_{12} of a different frequency. The output of the converter **63** is applied to filter **64** which allows the new subcarrier wave f_{12} to pass but blocks the original subcarrier wave f_{10}. The new subcarrier wave is then applied to the oscillator **65** and modulates the carrier wave F_3 produced thereby. The modulated carrier wave produced by the oscillator **65** is applied to the antenna **51** and radiated thereby. The output of the oscillator **65** is also applied through attenuator **66** to the demodulator **61** and thereby provides the local oscillations for demodulating the received wave as in the modifications described above. It will be apparent that when a single oscillator is used in a relay station as the transmitter and for providing local oscillations in the receiver, the transmitted and received wave must be modulated by different subcarrier waves. The filter **62** which passes the subcarrier wave f_{10} but rejects the wave f_{12}, and filter **64** which passes the subcarrier wave f_{12} but rejects f_{10} prevent regenerative action because of energy which is passed through the attenuator **66**.

The system for relaying signals transmitted from station B to station A is identical to that described above with signals transmitted by antenna **45** being picked up by antenna **51** and applied through filter **67** to the demodulator **68**. The subcarrier wave f_{11} is derived from the carrier wave F_2 by the demodulator **68** and passed through filter **69** to heterodyne converter **70** wherein it is converted to a subcarrier wave f_{13} of different frequency. The new subcarrier wave f_{13} is applied through filter **71** to the oscillator **72** which produces a modulated carrier wave F_4 which is radiated by the antenna **50**. A portion of the output of the oscillator **72** is applied through attenuator **73** to the demodulator **68** providing local oscillations for demodulating the received wave.

In Fig. 5 there is illustrated still a further radio relay system with the terminal stations A and B being generally identical to the terminal stations of Figs. 3 and 4, but with the relay station C_2 being of different construction than the relay stations C of Fig. 3 and C_1 of Fig. 4. The principal characteristic of the relay station C_2 is that a single oscillator is provided for transmitting in both directions and for providing local osclations for the receiving systems which receive from both directions. Referring to the drawings the oscillator **32** of the terminal station A provides a carrier wave at a frequency F_1 modulated by a subcarrier wave f_{10}. This carrier wave is transmitted by antenna **33** and picked up by antenna **50** at the relay station C_2. The received wave is applied through filter **75** to demodulator **76** wherein the subcarrier wave f_{10} is derived from the carrier wave F_1. The subcarrier wave f_{10} is passed through a filter **77** and is converted to a subcarrier wave f_{11} at a different frequency in the heterodyne converter **78**. The output of the converter **77** is passed through filter **79** which passes the new subcarrier wave f_{11} but rejects the subcarrier wave f_{10}. The subcarrier wave f_{11} is then applied to the oscillator **80** which operates at a frequency F_2. The output of the oscillator **80** is applied to the antenna **51** from which it is transmitted to the next relay or terminal station. Local oscillations are applied to the demodulator **76** from the oscillator **80** through attenuator **81**. As the oscillator is modulated by subcarrier frequencies the demodulator **76** will provide these subcarriers as well as the subcarrier f_{10} but all of the subcarriers will be eliminated by the filter **77** except the subcarrier f_{10}. The filters **77** and **79** must not have overlapping frequency ranges or singing might take place at a frequency which would pass through both.

The relay station C_2 operates in a similar manner to relay signals received by antenna **51** and transmitted by antenna **50**. The oscillator **42** at terminal B provides a carrier wave F_3 which is modulated by a subcarrier wave f_{12}. This carrier wave is radiated at antenna **45** and received by antenna **51**. The received wave is passed through filter **82** to demodulator **83** which derives the subcarrier wave f_{12} therefrom. The subcarrier wave f_{12} is passed by filter **84** and converted to a subcarrier wave f_{13} of a different frequency in heterodyne converter **85**. The newly derived subcarrier wave f_{13} is selected in the filter **86** and applied to the oscillator **80** for modulating the same. The oscillator **80** therefor produces a carrier wave F_2 modulated by subcarrier wave f_{13} which is applied to the antenna **50** and received by antenna **33** at the station A. Local oscillations are applied to demodulator **83** from oscillator **80** through attenuator **87**.

It will be apparent from the foregoing that the oscillator **80** is modulated by both subcarrier waves f_{11} and f_{13} so that the carrier wave F_2 transmitted in both directions by antennas **50** and **51** is modulated by the subcarrier waves which are to be transmitted in the two directions. However, this causes no difficulty as the receivers at the terminals A and B are selective only to the subcarrier wave which are to be received and the undesired subcarrier wave will be rejected. That is, the subcarrier receiver **36** at terminal A will receive only the subcarrier wave f_{13} and the subcarrier receiver **41** at terminal B will receive only the subcarrier wave f_{11}. In this system, the frequency of the carrier waves F_1 and F_3 must necessarily differ from the frequency of the carrier wave F_2 by the intermediate frequencies of the demodulators **76** and **83**. It is desirable for the purposes of standardization to have the intermediate frequencies of these demodulators the same although this is not necessary. The waves F_1 and F_3 may be at different frequencies if one of the waves (F_1) is equal to the frequency of the wave F_2 plus the intermediate frequency, and the other (F_3) is equal to the frequency of wave F_2 minus the intermediate frequency. The same carrier wave F_2 may be transmitted in both directions by the antennas **50** and **51** without causing difficulty.

The system of Fig. 5 may be simplified somewhat by properly selecting the subcarrier frequencies f_{10} and f_{12} which are received at the relay station C_2. By using adjacent frequencies for these subcarriers, the filters **77** and **84** may be replaced by a single filter which will pass both subcarrier frequencies. A single converter may then be used in place of converters **78** and **85** and a single filter in place of filters **79** and **86**. A single attenuator may also be used to replace attenuators **81** and **87**.

Although the systems of Figs. 3, 4 and 5 have been described as transmitting a single subcarrier wave, it is obvious that a plurality of subcarrier waves can be simultaneously transmitted by these systems to provide a larger number of communication channels. In the systems of Figs. 4 and 5 a plurality of subcarrier waves can be converted in the same converters and passed through the same filters. In such arrangements the frequencies of the subcarrier waves must be selected so that subcarriers on adjacent frequencies are transmitted together and can be passed by the same filters. As previously stated, the filters before and after the converters must not both pass any one frequency or regeneration around the loop circuit may take place.

It is seen from the above that simultaneous two way microwave communication systems have been provided in which a single oscillator provides the waves to be transmitted and local oscillations for demodulating the received wave. This is made possible by providing transmission and reception simultaneously at different frequencies and by the use of subcarrier waves of different frequencies or the transmitted and received waves so that the received waves can be selected. This arrangement simplifies radio communication systems operating in the microwave ranges and particularly simplifies relay systems as the large number of oscillators normally

required is reduced by half. Since oscillators suitable for operation in the very high frequency and microwave ranges are very expensive and delicate, this is a very worthwhile saving.

Although certain embodiments of the invention which are illustrative thereof have been described, it is obvious that various changes and modifications can be made therein without departing from the intended scope of the invention as defined in the appended claims.

I claim:

1. A radio relay communication system for providing simultaneous two way communication on frequencies in the microwave frequency range including in combination, a pair of terminal stations and at least one intermediate relay station, said relay station including a pair of antenna means each of which is positioned to communicate with one of said other stations, a relay circuit interconnecting said antennas for providing transfer of signal in both directions therebetween, said relay circuit including transmitting means connected to both antenna means for providing a modulated carrier wave for transmission thereby, said transmitting means including means for producing subcarrier waves and a single oscillator for providing a carrier wave modulated by said subcarrier waves, a pair of receiving means individually connected to said antenna means for receiving carrier waves modulated by subcarrier waves of different frequencies than said transmitted subcarrier waves, and means for applying said modulated wave produced by said oscillator to both of said receiving means for converting the carrier waves received thereby to waves of lower frequencies.

2. A radio relay communication system for providing simultaneous two way communication on frequencies in the microwave frequency range including in combination, a pair of terminal stations and at least one intermediate relay station, said relay station including a pair of antenna means each of which is positioned to communicate with one of said other stations, a relay circuit interconnecting said antennas for providing transfer of signal in both directions therebetween, said relay circuit including transmitting means connected to both antenna means for providing a modulated carrier wave for transmission thereby, said transmitting means including means for producing subcarrier waves and a single oscillator for providing a carrier wave modulated by said subcarrier waves, a pair of receiving means individually connected to said antenna means for receiving carrier waves modulated by subcarrier waves of different frequencies from said transmitted subcarrier waves, means for applying said modulated wave produced by said oscillator to both of said receiving means for converting the carrier waves received thereby to waves of lower frequencies, said receiving means deriving said received subcarrier waves from said received carrier waves, means for converting said received subcarrier waves to waves of different frequencies, and means for applying said subcarrier waves so produced to said oscillator for modulating the wave produced thereby.

3. In a radio relay communication system for providing simultaneous two way communication on frequencies in the microwave frequency range and which includes a pair of terminal stations and at least one intermediate relay station, a radio relay station including in combination, a pair of antenna means each of which is positioned to communicate with another station, a relay circuit interconnecting said antenna means for providing transfer of signals in both directions therebetween, said relay circuit including transmitting means connected to both antenna means for providing a modulated carrier wave for transmission thereby, said transmitting means including single oscillator means for providing a carrier wave modulated by at least one signal wave, a pair of receiving means individually connected to said antenna means for receiving carrier waves of frequencies different from that of the transmitted carrier wave, which received carrier waves are modulated by signal waves of frequencies different from the frequencies of the signal waves modulating said transmitted carrier wave, and means for applying said modulated carrier wave produced by said oscillator means to said pair of receiving means for converting the carrier waves received thereby to waves of lower frequencies.

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