Jan. 21, 1941. C. W. HANSELL 2,229,078
RADIO RELAYING SYSTEM
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Fig. 1

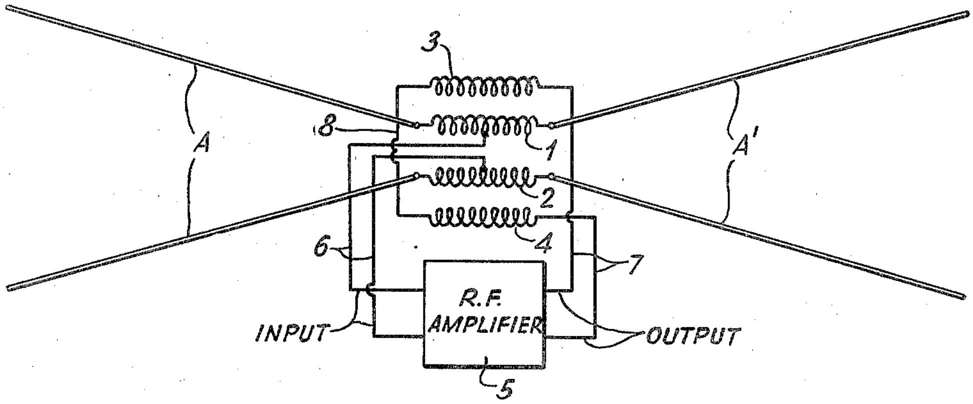

Fig. 2

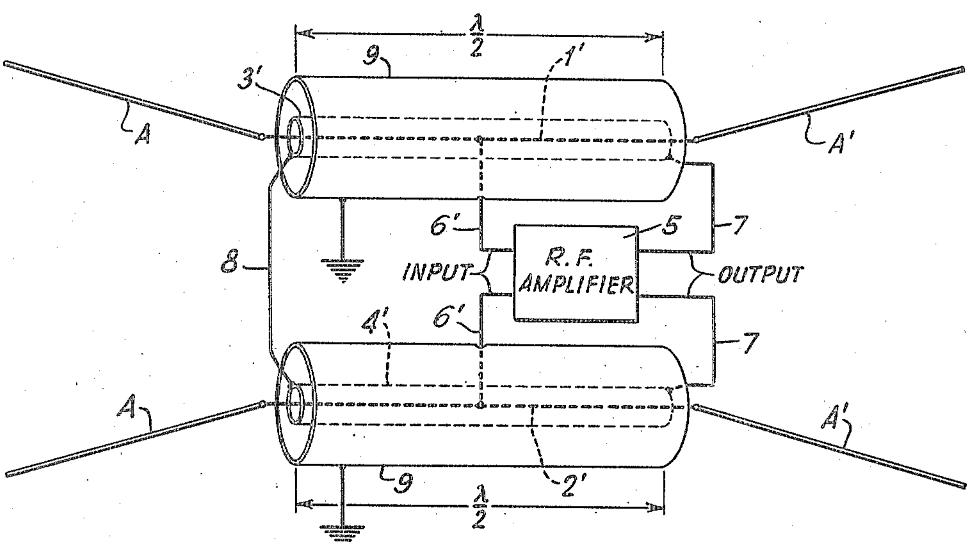

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Fig. 3

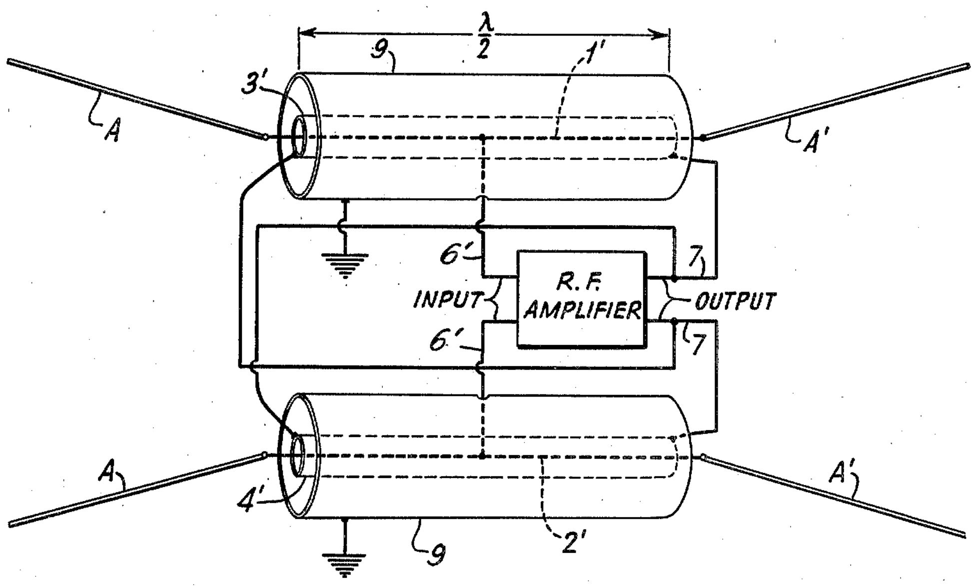

Fig. 4

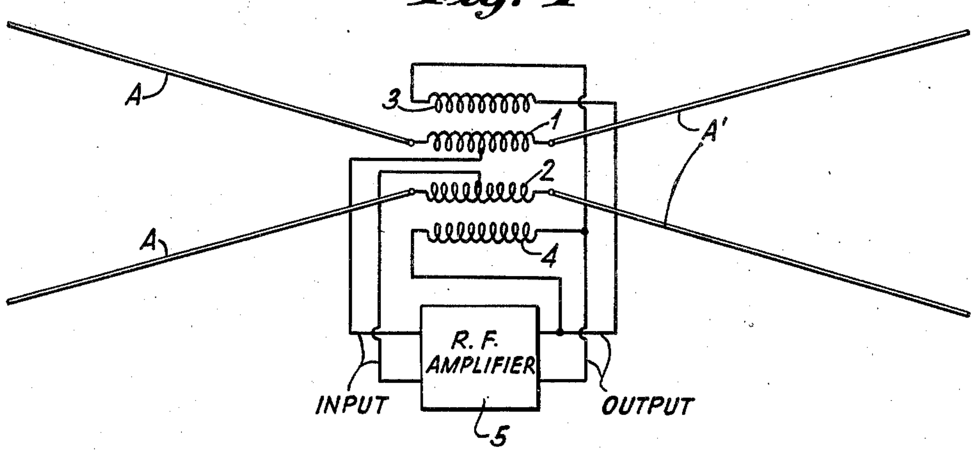

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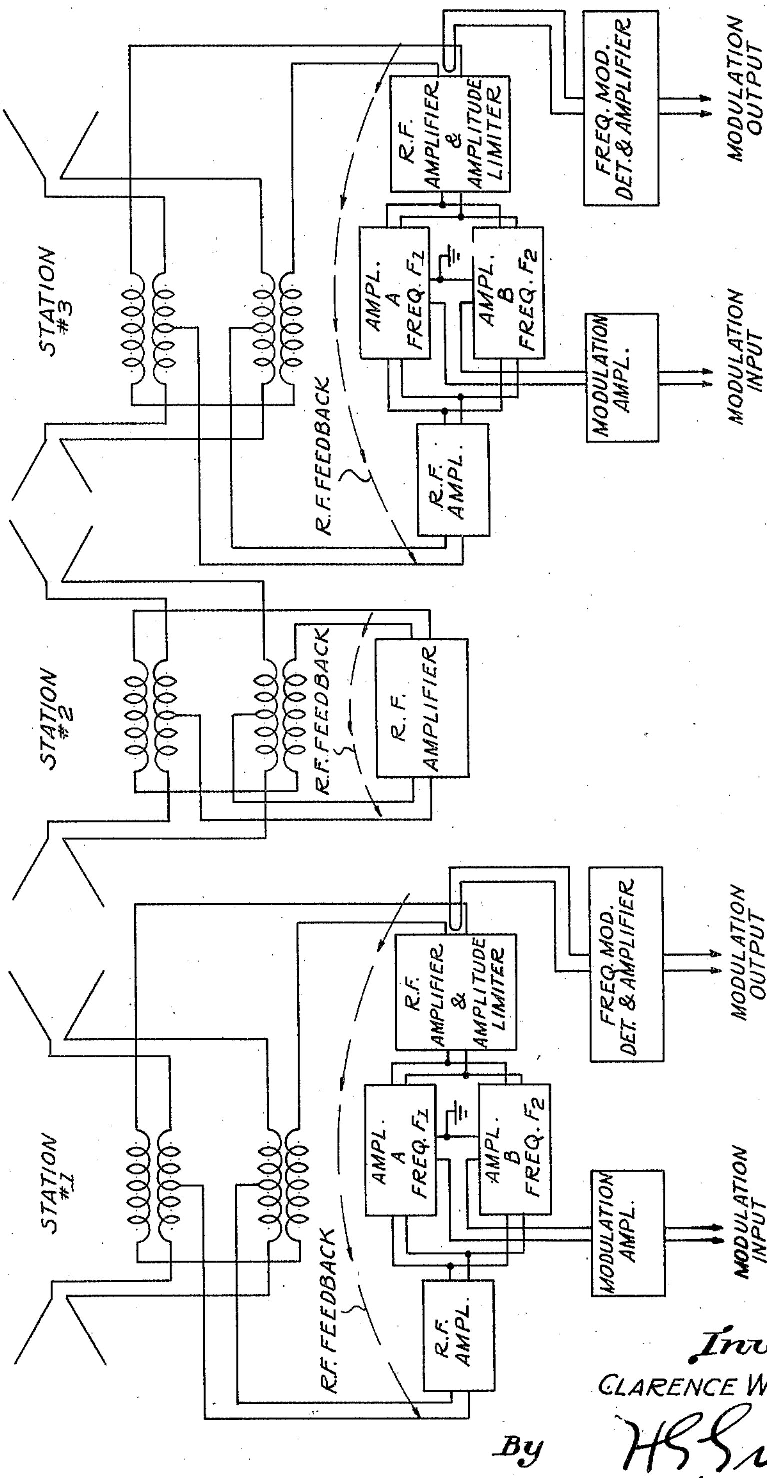
Fig. 5



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UNITED STATES PATENT OFFICE

2,229,078

RADIO RELAYING SYSTEM

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Application April 1, 1938, Serial No. 199,421

18 Claims. (Cl. 250—15)

This invention relates to improvements in radio relaying systems, and particularly to short wave radio relaying systems.

One of the objects of the present invention is to enable the relaying of radio signals simultaneously in two directions with little or no coupling between the input and output circuits of the amplifier at the repeating station.

Another object is to provide a simple and efficient type of radio relaying system employing a circuit balancing arrangement for reducing coupling between input and output circuits.

Another object is to provide a system of radio or wire line relaying by means of frequency modulation, over a chain of repeaters, in which all of the relays operate synchronously on a common carrier frequency and in which modulation introduced at any repeater is reproduced throughout the whole chain.

A further object is to provide a radio relaying system employing a circuit balancing arrangement whose elements have uniformly distributed inductance and capacitance.

Briefly stated, the present invention provides a two-way radio relaying station having a circuit balancing arrangement directly connected between two antennas which are conditioned to transmit to and receive short wave signals from different directions. The present system finds particular application in the relaying of signals transmitted with radio wavelengths below 100 meters. The system may be used for the relaying of signals by means of any type of modulated high frequency waves but is peculiarly adapted to the relaying of signals sent by modulating the phase or frequency of a high frequency carrier wave.

A feature of the invention lies in the use of a single amplifier in a radio relaying system for producing the relaying of signals in two directions simultaneously.

Another feature of the invention resides in the use of transformers in the form of hollow metallic tubes having substantially uniformly distributed constants.

Other objects and features will appear from a reading of the following description which is accompanied by drawings, wherein:

Fig. 1 illustrates one relaying embodiment of the invention employing conventional transformers of lumped constants in a circuit balancing arrangement;

Fig. 2 illustrates another embodiment of the invention which is electrically equivalent to that of Fig. 1 but whose transformers have uniformly distributed constants;

Fig. 3 shows an arrangement somewhat similar to that of Fig. 2, but differing therefrom in having the outer elements of the balancing arrangement connected in parallel;

Fig. 4 illustrates an arrangement which is electrically equivalent to that of Fig. 3, but whose transformer elements are of the conventional coil type; and

Fig. 5 illustrates, by way of example only, a series of spaced repeater stations in a relaying system embodying the principles of the invention.

In the drawings, like parts are represented by like reference characters.

Referring to Fig. 1 in more detail, there is shown a radio relaying station comprising a circuit balancing and coupling arrangement 1, 2, 3, 4, also known as a hybrid coil or bridge transformer system, directly connected between V antennas A and A′ positioned in opposite directions, in combination with a radio frequency amplifier 5. The V antenna A is positioned to receive signals from and transmit signals to the left. The V antenna A′ is positioned to receive signals from and transmit signals to the right. The circuit balancing and coupling arrangement is composed of four transformer coils, two of which (1 and 3) are wound in one direction and coupled together, while the other two coils (2 and 4) are wound in the opposite direction and coupled together. The left hand terminals of coils 1 and 2 are connected to antenna A directly or through a two-conductor transmission line, while the right hand terminals of these same coils are similarly connected to antenna A′. The radio frequency amplifier 5 has its input circuit connected to the mid-points of coils 1 and 2 through leads 6, 6, and its output circuit connected to the right hand terminals of coils 3 and 4 through leads 7, 7. Coils 3 and 4 are respectively symmetrically positioned with respect to coils 1 and 2, and are electrically connected in series relation by lead 8 connecting the left hand terminals of these coils together.

Although I have not shown them in the drawings, I may associate two series connected condensers, one at each end of each of the coils 1, 2, 3 and 4, for the purpose of tuning or balancing out the self inductance of the coils at the operating frequency. I may also employ electric field shielding between coils to prevent electric energy transfer of energy from one coil to the other in a manner to cause unbalanced couplings. In the system shown, I prefer to transfer energy from one coil to another principally by magnetic coupling.

Although antennas A and A′ are shown as being of the V type, reference being made to United States Patent No. 1,974,387, granted to Philip S. Carter September 18, 1934, for a more detailed description thereof, it should be understood that other types of antennas may also be used.

Also, it is to be understood that the antennas and space circuits between relaying stations could be replaced by wire line connections for providing a two way communication circuit by means of frequency modulation applied to a single carrier wave.

The operation of the relay or repeater arrangement of Fig. 1 is as follows: Signals arriving from the left are collected by antenna A and half of the collected energy is impressed on leads **6**, **6** extending to the input of amplifier **5**. The received signals are amplified by the radio frequency amplifier and sent out over output leads **7**, **7** to coils **3**, **4**, which impress the amplified signals on coils **1** and **2**, in turn passing the amplified signals onto antennas A, A′ which simultaneously radiate the signals in opposite directions. Due to the symmetrical coupling of coils **3** and **4** with respect to coils **1** and **2**, respectively, of the hybrid coil or transformer system, and the input leads, half of the amplified energy is sent out over one antenna, while the remaining half of the amplified energy is sent out over the other antenna. Consequently, there will be little or no feed back of the amplified energy into the input leads **6**, **6**. Putting it another way, we can say that coils **3** and **4** are balanced with respect to the input circuit of the amplifier.

The operation of the relay system is the same as described above for signals arriving from the right which are collected by antenna A′. Half of the energy of the collected signals from A′ is impressed on input leads **6**, **6**, and the amplified signals are sent out over both antennas A and A′ with equal energy.

At this time, it should be observed that only half of the energy of the signals collected on an antenna is impressed on the input leads. The remaining collected energy which is passed on through coils **1** and **2** to the other antenna is radiated therefrom but can be neglected, since the amplified energy from the output of the amplifier is so much greater than the received energy. The ratio of output energy from the amplifier **5** to the received energy impressed on the input leads to the amplifier may be of the order of 10,000 to 1 or 100,000 to 1 in power, or even more.

The balancing or bridge transformer arrangement described above has the advantage of reducing coupling between output and input terminals of the amplifier **5**, thus reducing the amount of received energy required to control the frequency of the output of the amplifier. Of course, an oscillator may also be used instead of or in combination with amplifier **5**. When it is desired to repeat frequency modulated waves, it is only necessary that the received energy be capable of controlling the frequency of output from the amplifier **5**. Therefore, the amplifier may be normally in an oscillating condition.

Of course the relaying system may be employed for other purposes than the transmission of signals by means of modulation of the carrier wave. For example, the system may be used to synchronize clocks, radio stations, facsimile systems etc. by using the carrier frequency as a means of transferring exact timing. Likewise, when modulation of the carrier wave is used this modulation may be utilized for synchronizing or other purposes rather than for ordinary telephone, telegraph or other type of signalling.

Where ultra short waves are used, it is of particular advantage to employ a circuit as shown in Fig. 2 which uses electrically half wavelength tubes as the electrical equivalent of the transformer coils of Fig. 1. In Fig. 2 the elements which are the same as in Fig. 1 are designated by the same reference characters, while the electrically equivalent elements have been given a prime designation. The tubes **3′** and **4′** are respectively coupled inductively to wires **1′** and **2′** located within the tubes. Because these tubes and wires are each equal, electrically, to half the length of the operating wave and coupled as shown, they form, in effect, a transformer with a single turn primary and a single turn secondary, and with the leakage reactance tuned out. Both tubes **3′** and **4′**, and both wires **1′** and **2′** have uniformly distributed inductance and capacitance. Grounded shields **9**, **9** surround the tubes **3′**, **4′**. The input leads **6′**, **6′**, are connected through holes in the shields **9**, **9** and tubes **3′**, **4′** to the mid points of wires **1′**, **2′**, and are made to be symmetrical and of equal length.

In practice, the shields **9**, **9** may, of course, be an integral part of the shielding for the amplifier **5**. Also, there may be transmission lines of any desired length between the antennas and the coupling arrangement.

The relay arrangements shown in Figs. 3 and 4 are respectively similar to the arrangements shown in Figs. 2 and 1, except that the tubes **3′** and **4′** of Fig. 3 and coils **3** and **4** of Fig. 4 are electrically connected in parallel relation but in reverse polarity, as shown, so as to provide push-pull voltages on the antennas. It will be noted that the corresponding elements in Figs. 1 and 2 are electrically in series relation.

In one method of using the arrangements shown in the figures, I may set up a number of these repeater stations at a distance apart, and couple them together through the radio space circuit and the antennas in such a manner that, when a radio frequency current is set up in any one amplifier, then a synchronous radio frequency current will exist in all of the amplifiers. Then, if we modulate the frequency of the currents in any one of the amplifiers, a corresponding modulation will exist in the currents in all the other amplifiers. The frequency modulation of currents in the whole system may be complex in nature, made up of any number of modulation frequency compounds introduced at any of the repeater points. We may take a portion of the frequency modulated energy at any one repeater point, demodulate it, amplify the demodulated current and utilize the resultant modulating frequency currents in any way we wish. Then, by employing different modulation frequencies for each channel, we may communicate from any repeater point in the system to any other point.

In the operation of such a system, all the repeaters should preferably be operated at maximum output amplitude, with limiting of amplitude, and one amplifier, or at least the system as a whole should be self-oscillating.

In addition to the repeaters and the modulating or demodulating arrangements at repeaters or terminal stations, I contemplate any number of subsidiary receiving and demodulating systems for receiving a portion of the power in the system and making it available for use. I may, for example, be repeating aural or visual entertainment through the system, which can be made available to a large number of persons enroute, if they have suitable receivers.

Fig. 5 is an illustration of a portion of a radio relaying system in accordance with my invention. It shows three radio repeater stations which may be employed as part of a system of any desired number of repeaters, all linked together through radio space circuits.

In the illustration, two of the repeaters, namely stations **1** and **3**, are shown equipped for introducing useful signal modulations into the relaying system and also for deriving useful signal modulations from the system. The other repeater, station **2**, is illustrated as one at which there is no need for introducing signals nor for deriving signals from the system. However, in practice, this repeater will usually be identical with the others except for omission of unused parts. These omitted parts may be supplied by means of portable components temporarily connected with the repeater, when servicing of the repeater is done.

Referring to each of the repeaters equipped for introducing and taking out signals, I have shown two antennas for receiving and transmitting radio frequency power in two desired directions, toward other repeaters in the chain. These antennas are connected through transmission lines and balancing and coupling circuits of the type shown in Fig. 1 to both the input and output terminals of repeater amplifier equipment. As previously explained in connection with the other figures, these coupling and balancing circuits reduce feedback coupling from output to input terminals of the repeater amplifier to a very low value. However, the feedback, in practice, can never be reduced to zero and, if the repeater amplifier power gain is made great enough the repeater may be self-oscillating. I prefer to make each repeater with sufficient gain so that self oscillations always take place even though the percentage of output power fed back to the input circuits is made very small. The power fed back is preferably of the same order of magnitude or less than the power received from other distant repeaters by way of the antennas and coupling circuits. The received power then can control the frequency of oscillations in the repeater over a substantial range of frequencies. Then, by means of the space circuits, all repeaters in the chain will be coupled together and all will operate on the same frequency. At each repeater of Fig. 5 the received power and fed back power are amplified to a much higher power level and returned to the antennas through the transmission lines and coupling and balancing circuits where it is radiated toward the distant repeaters which operate in synchronism with it.

As shown in Fig. 5, at some point in the repeater amplifier system the radio frequency current is divided into two paths and passed through two parallel amplifier stages, after which the current is combined into one path again for further amplification.

The two parallel amplifier stages, designated as amplifier A and amplifier B in Fig. 5, are provided with tuned circuits tuned to different frequencies F_1 and F_2 which are respectively above and below the highest and lowest frequencies of the modulated radio frequency currents used in the system.

The gain of the two amplifiers A and B is variable and is varied differentially by modulation input currents from a modulation amplifier as shown. In consequence the frequency of the currents in the whole relay system is varied up and down toward and away from frequencies F_1 and F_2 of the amplifier circuits in amplifiers A and B.

Other repeaters in the radio relaying system have similar modulation input arrangements through which modulations of the frequency of the radio frequency currents of the whole system may be introduced. The resultant system frequency at any instant will be determined by the resultant of all the modulation input currents and will be substantially similar to the condition which would exist if all the modulation input currents to the system were combined and introduced at a single point. To derive modulation frequency currents from the frequency modulated radio frequency currents it is only necessary to couple a frequency modulation detector, as shown, to the repeater output circuits. In the output of the detector there will be currents corresponding to all the modulations present in the system. By means of the frequency modulation detectors modulations introduced at any repeater station in the system may be taken out and utilized at any repeater station in the system.

What is claimed is:

1. A radio relaying station comprising two antennas positioned to be effective in different directions, a balancing and coupling circuit comprising a symmetrical transformer arrangement connected between said antennas, and a radio frequency amplifier having input and output leads connected to said balancing circuit in such manner that signals received by either antenna are amplified by said amplifier and simultaneously radiated by both antennas, there being substantially no feed-back of energy from the output of said amplifier to the input thereof by virtue of the symmetrical arrangement of the elements of said transformer arrangement.

2. A radio relaying station as defined in claim 1, characterized in this that said balancing circuit comprises four inductance coils constituting two transformers, one winding of each transformer having its terminals connected to said antennas, the other windings of said transformers being conductively connected to each other and to said amplifier.

3. A radio relaying station as defined in claim 1, characterized in this that said balancing circuit comprises two concentric lines, each of which constitutes, in effect, a transformer which is electrically equal to half the length of the operating wave, the inner conductor of each concentric line having its terminals connected to said antennas, the outer conductors of said concentric lines being conductively connected to each other and to said amplifier.

4. A radio relaying station comprising two antennas positioned to be effective in different directions, a balancing and coupling circuit comprising two pairs of coils, the coils of each pair being inductively coupled to each other symmetrically, a radio frequency amplifier, connections from opposite terminals of a coil in one pair to terminals of said two antennas, connections from opposite terminals of a coil in said other pair to different terminals of said two antennas, connections from the mid points of said last two coils to

the input of said amplifiers, a connection from one terminal of each of the other coils of said pairs to the output of said amplifier, and a connection coupling said other coils in series relation, whereby said amplifier amplifies the signals received over either antenna and impresses amplified signals on both antennas simultaneously.

5. A relay station in accordance with claim 4, characterized in this that said antennas are of the V type.

6. A radio relaying station comprising two antennas positioned to be effective in different directions, a balancing and coupling circuit comprising two pairs of coils, the coils of each pair being inductively coupled to each other symmetrically, a radio frequency amplifier, connections from opposite terminals of a coil in one pair to terminals of said two antennas, connections from opposite terminals of a coil in said other pair to different terminals of said two antennas, connections from the mid points of said last two coils to the input of said amplifier, connections from the terminals of the other coils of said pairs to the output of said amplifier, said last coils being coupled in parallel relation but in reverse polarity with respect to said output.

7. A radio relaying station comprising two antennas positioned to be effective in different directions, each of said antennas having two arms, a circuit connected between said two antennas, said circuit being constituted by two concentric lines each having an inner and an outer conductor, a connection from one end of the inner conductor of one line to an arm of one antenna, a connection from the other end of said same inner conductor to an arm of the other antenna, similar connections from the inner conductor of the other line to the other arms of said antennas, a radio frequency amplifier having an input and an output, connections from the mid points of said inner conductors to the input of said amplifier, and connections for coupling said outer conductors of said concentric lines electrically in parallel relation to said output, whereby signals received over either antenna are amplified by said amplifier and impressed on both antennas simultaneously.

8. A radio relaying station comprising two antennas positioned to be effective in different directions, each of said antennas having two arms, a circuit connected between said two antennas, said circuit being constituted by two half wavelength concentric lines each having an inner and an outer conductor, a connection from one end of the inner conductor of one line to an arm of one antenna, a connection from the other end of said same inner conductor to an arm of the other antenna, similar connections from the inner conductor of the other line to the other arms of said antennas, a radio frequency amplifier having an input and an output, connections from the mid points of said inner conductors to the input of said amplifier, and connections from the output of said amplifier to the ends of said outer conductors of said concentric lines such that said outer conductors are in parallel relation to said output but coupled thereto in reverse sense.

9. A radio relaying station comprising two antennas positioned to be effective in different directions, each of said antennas having two arms, a circuit connected between said two antennas, said circuit being constituted by two half wavelength concentric lines each having an inner and an outer conductor, a connection from one end of the inner conductor of one line to an arm of one antenna, a connection from the other end of said same inner conductor to an arm of the other antenna, similar connections from the inner conductor of the other line to the other arms of said antennas, a radio frequency amplifier having an input and an output, connections from the midpoints of said inner conductors to the input of said amplifier, and means for coupling the ends of said outer conductors of said concentric lines electrically in series relation to the output of said amplifier.

10. A radio relaying station in accordance with claim 9, including a grounded shield surrounding each outer conductor of said concentric lines.

11. A radio relaying system comprising a series of spaced repeating amplifier stations, each of said stations having an antenna positioned to receive signals from and to transmit signals to the nearest preceding station and another antenna positioned to transmit signals to and to receive signals from the nearest succeeding station, circuit means at each station including an electron discharge device amplifier coupled to both antennas for amplifying the signals received by it and for impressing the amplified signals on both of its antennas, whereby the amplified signals are radiated toward both adjacent spaced amplifier stations simultaneously, the electron discharge device amplifier circuit at one of said stations being self-oscillating, whereby all of said amplifier stations operate with a common output frequency.

12. A radio relaying system comprising a series of spaced repeating amplifier stations, each of said stations having an antenna positioned to receive signals from and to transmit signals to the nearest preceding station and another antenna positioned to transmit signals to and to receive signals from the nearest succeeding station, circuit means at each station including an electron discharge device amplifier coupled to both antennas for amplifying the signals received by it and for impressing the amplified signals on both of its antennas, whereby the amplified signals are radiated toward both adjacent spaced amplifier stations simultaneously, the electron discharge device amplifier circuit at one of said stations being self-oscillating, whereby all of said amplifier stations operate with a common output frequency, and means at one of said stations for frequency modulating said common output frequency.

13. A radio relaying system comprising a series of spaced repeating amplifier stations, each of said stations having an antenna positioned to receive signals from and to transmit signals to the nearest preceding station and another antenna positioned to transmit signals to and to receive signals from the nearest succeeding station, circuit means at each station including an electron discharge device amplifier coupled to both antennas for amplifying the signals received by it and for impressing the amplified signals on both of its antennas, whereby the amplified signals are radiated toward both adjacent spaced amplifier stations simultaneously, the electron discharge device amplifier circuit at one of said stations being self-oscillating, whereby all of said amplifier stations operate with a common output frequency, and means at each station for limiting the amplitude of the signal waves impressed on said antennas, whereby the output power is substantially independent of the input power.

14. A system in accordance with claim 13,

characterized in this that means are provided at at least one station for modulating the common carrier frequency.

15. A system in accordance with claim 13, characterized in this that means are provided at least one station for modulating the common carrier frequency, and means are also provided at one or more stations for demodulating the common carrier frequency.

16. A radio relaying station comprising two antennas positioned to be effective in different directions, each of said antennas having two arms, a circuit connected between said two antennas, said circuit being constituted by two half wavelength concentric lines each having an inner and an outer conductor, a connection from one end of the inner conductor of one line to an arm of one antenna, a connection from the other end of said same inner conductor to an arm of the other antenna, similar connections from the inner conductor of the other line to the other arms of said antennas, a radio frequency amplifier having an input and an output, connections from the midpoints of said inner conductors to the input of said amplifiers, and means for coupling the ends of said outer conductors of said concentric lines to the output of said amplifier.

17. A radio relaying station comprising two antennas positioned to be effective in different directions, each of said antennas having two arms, a balancing transformer circuit arrangement connected between said two antennas, said balancing circuit being constituted by two transformers each having a primary and a secondary, a connection from one end of the primary of one transformer to an arm of one antenna, a connection from the other end of said same primary to an arm of the other antenna, similar connections from the other primary to the other arms of said antennas, a radio frequency amplifier having an input and an output, connections from points intermediate the ends of said primaries to the input of said amplifier, and means for coupling the ends of said secondaries to the output of said amplifier.

18. A radio relaying station comprising two antennas one effective in one direction only and the other in a different direction only, a balancing and coupling circuit comprising a symmetrical transformer arrangement connected between said antennas, and a radio frequency amplifier having input and output leads connected to said balancing circuit in such manner that signals received by either antenna are amplified by said amplifier and simultaneously radiated by both antennas, there being substantially no feed-back of energy from the output of said amplifier to the input thereof by virtue of the symmetrical arrangement of the elements of said transformer arrangement.

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