

Oct. 25, 1938.

A. ALFORD

2,134,278

HIGH FREQUENCY RADIO REPEATER

Filed June 15, 1937

2 Sheets-Sheet 1

FIG. 1.

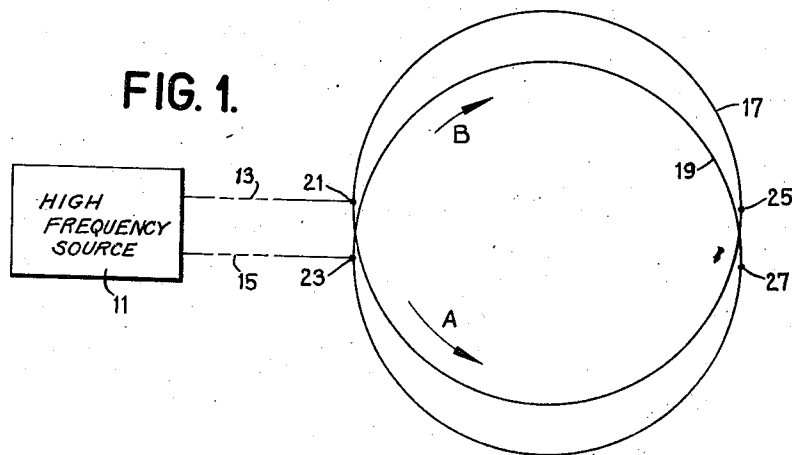


FIG. 2.

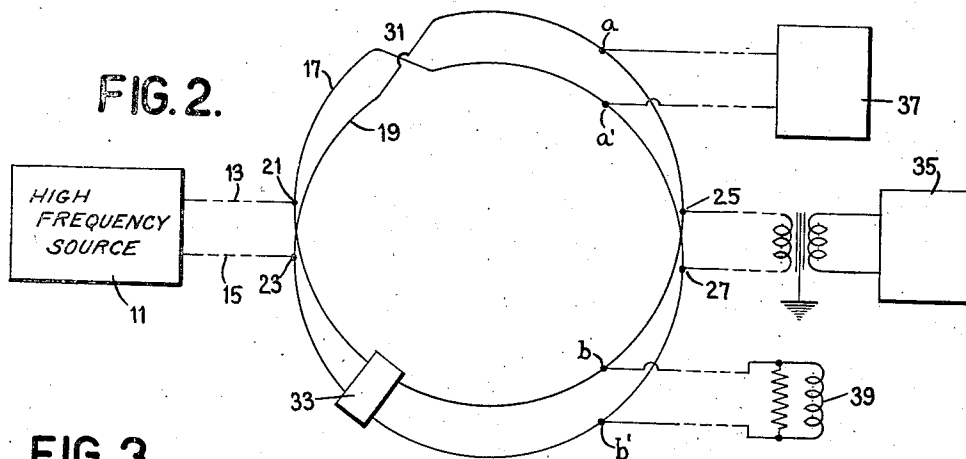
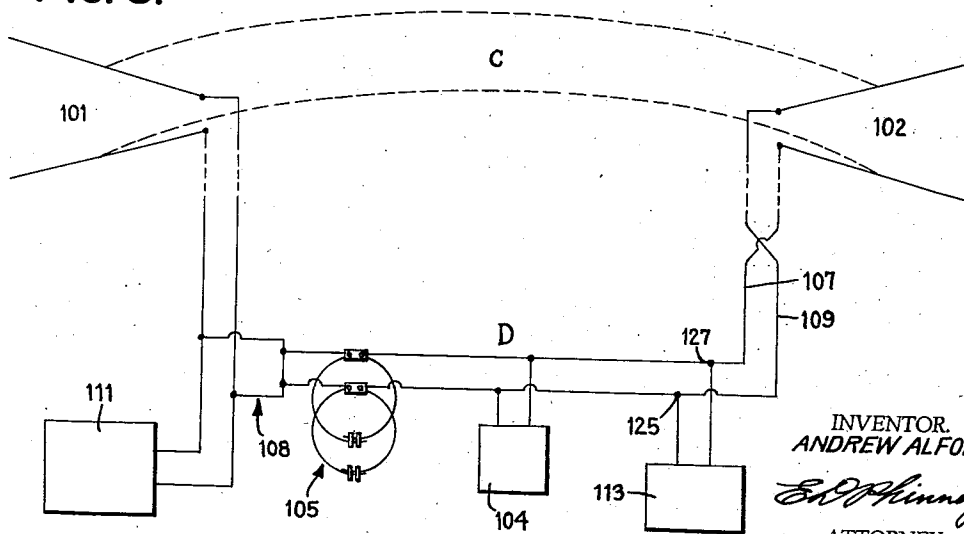


FIG. 3.



INVENTOR.
ANDREW ALFORD

E. P. Hinney
ATTORNEY.

Oct. 25, 1938.

A. ALFORD

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FIG. 3A.

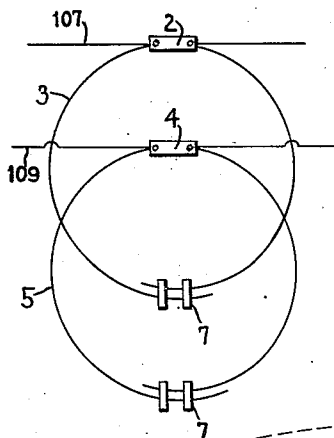


FIG. 3B.

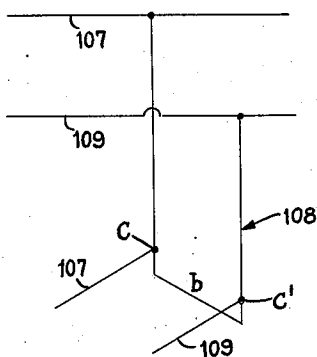


FIG. 3C.

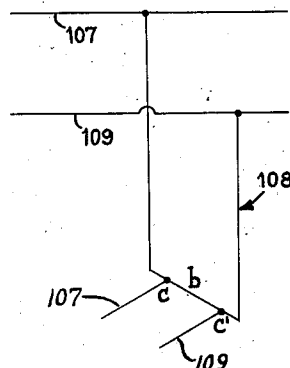


FIG. 4.

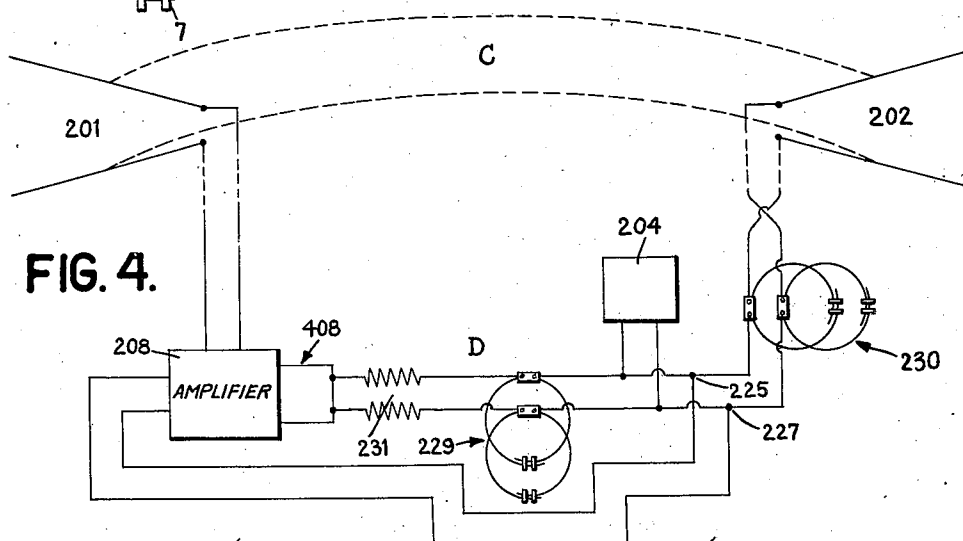
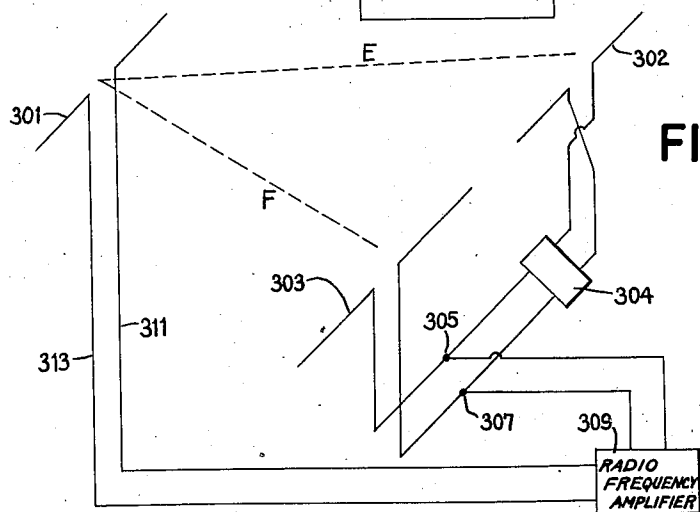


FIG. 5.



INVENTOR.
ANDREW ALFORD

E. L. Finney
ATTORNEY.

UNITED STATES PATENT OFFICE

2,134,278

HIGH FREQUENCY RADIO REPEATER

Andrew Alford, New York, N. Y., assignor to
Mackay Radio and Telegraph Company, New
York, N. Y., a corporation of Delaware

Application June 15, 1937, Serial No. 148,292

8 Claims. (Cl. 250—15)

My invention relates to high frequency repeaters, and more particularly to high frequency repeaters using a balanced network or impedance bridge circuit such as disclosed in my application

Serial No. 140,594, filed May 4, 1937.

My invention makes use of reentrant loop circuits of the general type disclosed in my above identified application, in which the bridge loop may comprise one or more open radiation or mutual impedance paths between radio antennae.

It is an object of my invention to provide a high frequency radio repeater, in which the amplifier is coupled to the circuit by means of a reentrant loop bridge circuit.

It is a further object of my invention to provide an amplifying radio repeater which is easily constructed and adjusted to perform the desired amplified repetition of signals over a range of frequencies.

Other objects and uses of my invention will be suggested by the particular description made in connection with the accompanying drawings, in which

Figs. 1 and 2 illustrate a simple form of the network particularly for explaining the theory thereof; Fig. 3 illustrates an embodiment of the loop bridge circuit in which a portion of the loop circuit comprises a radiation path; Figs. 3A, 3B and 3C illustrate details of elements illustrated in Fig. 3; Fig. 4 illustrates a system for adapting the bridge circuit of Fig. 3 to a radio repeater; Fig. 5 illustrates a repeater in which the reentrant loop includes radiation or mutual impedance, in both arms.

Referring more particularly to Fig. 1, reference numeral 11 represents a source of radio frequency energy connected by transmission lines 13, 15 with reentrant loops 17, 19 at junction points 21, 23. Points 25, 27 represent points along loops 17, 19, respectively, which are separated equal electrical distances from the corresponding junction points 21, 23. In the loop circuits 17, 19 there then exist two traveling waves, each of which starts forwardly from junction points 21, 23 as indicated by arrows A and B, and which after passing each other at 25 and 27 become back waves. The two halves of loops 17, 19 are assumed to be identical in all respects, including attenuation. Since these traveling waves travel equal distances to junction points 25, 27, and are of equal amplitude at the starting points 21, 23, they are in phase and still of equal amplitude at points 25, 27. Since the voltages are of equal amplitude and are in phase at points 25, 27, they add, forming a voltage loop, but the currents are

in phase but in opposite directions and consequently cancel, producing an absolute current node. It can thus be seen that this circuit provides a very readily constructed means for obtaining an absolute current node.

Fig. 2 is substantially the same as Fig. 1, with the exception that the loops are transposed at points 31. As a consequence of this transposition the currents in this circuit add at points 25, 27 and the voltages cancel, producing an absolute voltage node. Since the transmission lines in Fig. 2 are assumed to be equal in all respects, as stated in connection with Fig. 1, the voltage across the line at 25, 27 would be precisely zero if there were no reflection at the point of transposition 31. However, since there always exists a certain amount of reflection due to any irregularity in a transmission line, and since a transposition results in such an irregularity, there will be a small residual voltage at 25, 27 unless some compensating means is used to correct for this irregularity. Accordingly, some such compensating means is indicated at 33 which may comprise merely a capacity connected across the line. This compensating means together with a slight increase in the length of the arms completely compensates for the transposition. It should be further noted that any irregularity in the attenuation in the two arms of the bridge circuit may be compensated by means of suitable attenuators added to the line circuit.

With the circuit constructed as described above and the compensating means 33 properly adjusted, the voltage across points 25, 27 is extremely small compared to the voltages across points a, a' , b, b' , which are spaced a distance equal to a fraction of a wavelength from points 25, 27. It is this phenomenon which renders this circuit particularly useful as a bridge.

If a sensitive meter such as, for example, a vacuum tube volt meter, is connected across points 25, 27, through a suitable balancing transformer, the voltage indicated by meter 35 will be very small, substantially zero. However, if a load such as 37, having an impedance Z , is connected across the line at points a, a' spaced from the points 25, 27, the balance of the bridge will be upset due to reflections along the arm 27, a' , 21. Accordingly, meter 35 will show a material increase in reading. However, if a second load 39 is connected across the line at points b, b' , equally spaced on the opposite side of the points 25, 27, from that of points a, a' , said second load having an impedance Z_2 equal in every respect to impedance Z_1 , then symmetry of the circuit

will be restored and the voltage nodes again established at points 25 and 27 and the meter will again indicate a minimum reading. For this to be the case, the load Z_2 must be equal in every way to the load Z_1 in reactance and resistance. Thus it will be seen that the reentrant loop circuits shown behave in much the same manner as the ordinary impedance bridge.

If the impedance Z_1 of load 37 is high, the load should be connected at a point distant a substantial fraction of a quarter wavelength from the voltage nodal points 25, 27. In fact, it may be noted that as the distance between the voltage nodal points 25, 27 and points a , a' is gradually increased from zero with a corresponding and opposite increase of distance between the voltage nodal points 25, 27 and b , b' , the voltage across the line at points a , a' gradually increases. Since points 25, 27 represent a voltage node, the voltage across a point a small distance from this node will be small and consequently a very small amount of current can be diverted into the high impedance load 37. As the distance is increased the voltage across the line at points a , a' increase and consequently the current diverted into the load also increases with the result that a larger meter reading is noted at 35 with a given amount of unbalance. The loop circuit 17, 19, however, is not most sensitive with respect to unbalance when the distance between the load and the voltage nodal points 25, 27 is equal to a quarter wavelength. The reason for this is that when the load is located at a quarter wavelength from the voltage nodal points, such a large amount of current is diverted into the load, that only a small fraction is able to penetrate as far as the points 25, 27, across which the meter 35 is connected. For this reason there is a certain distance for every value of impedance Z_1 of the load 37 at which the loop circuit will be most sensitive. The larger the impedance Z_1 of the load 37 the greater is the distance for maximum sensitivity. Only in cases in which the load impedance Z_1 is of very large value, is the maximum sensitivity obtained when the spacing is nearly a quarter of a wavelength. The actual distance at which the given impedance should be connected to obtain maximum sensitivity of the loop is not very critical, however, so that exact location of the load with respect to the bridge voltage node is not necessary.

It has already been explained in connection with Fig. 2, that each arm of the loop may have a considerable amount of attenuation and that still the voltage node attained across the line at points 27, 25 may be a complete null. This attenuation may be due to dissipation, or to reflection, or any other cause.

In Fig. 3 is illustrated a loop bridge circuit in which there is a considerable amount of attenuation in both arms of the loop designated C and D for convenience in description. In this figure is shown a loop circuit in which one arm C is completed through the mutual impedance between two antennae 101 and 102. This mutual impedance path is denoted by the dotted lines between the antennae. The other arm of the loop D is made up of a length of transmission line 107, 109 and an adjustable attenuator 108. The voltage nodal point is indicated at 125, 127 at which point voltmeter 113 is connected. An adjustable loop 105 is provided for the purpose of adjusting the electrical length of the line 107, 109.

The structural details of the loop 105 and the

attenuator 108 are shown in more detail in Figs. 3A, 3B and 3C.

In Fig. 3A the transmission lines 107—109 are broken at a point and insulators 2 and 4, respectively, are inserted therein; each portion of the line is then formed in a loop 3, 5 which is adjustable in size by reason of a slide connection 7. To adjust the electrical length of the line, the loops 3, 5 may be adjusted through the slide connection until the desired length is obtained.

In Fig. 3B the attenuator loop 108 is shown connected across transmission line 107, 109 which delivers energy to antenna 101. When the initial impedance between two antennae is small so that the attenuation in arm C of the loop circuit, including this impedance is high, then the attenuator 108 should also have a correspondingly high attenuation. In this case, the length of the attenuator loop 108 is made approximately one-quarter wavelength long at the operating frequency to which is connected the transmission line 107, 109 at points c , c' near the voltage node along the section. In fact, when the mutual impedance between the antennae is very small, the point of connection c , c' to the impedance section may fall across the shorting bar d , as shown in Fig. 3C.

Turning again to Fig. 3, in order that the position of the nodal point on the loop 125, 127 may not depend too critically on the frequency, it is well to make the electrical length of both arms of the loop substantially equal or at least not greatly different from each other. While it is of course possible to obtain a voltage null point at 125, 127 even when the two electrical paths of the loop circuit differ by a great number of complete wavelengths plus a transposition or its equivalent, the nodal point 125, 127 will be substantially independent of frequency only when the electrical lengths of the two arms are equal, except for a 180° phase shift which is substantially independent of frequency at least over a small range of frequencies. However, when the two arms differ by a number of wavelengths plus a transposition, a slight variation in the frequency in the circuit will displace the nodal point.

The phenomena noted above, of displacement of the nodal point with frequency enables the selection of the proper length for arm D in cases where the electrical length of arm C is somewhat in doubt. In this case, when the circuit is first connected as shown in Fig. 3 the first variable to be adjusted is the attenuator 104. This adjustment may be made as follows: First, the standing waves on arm D are investigated by means of some suitable instrument. Second, the attenuation is varied by adjusting the position of the points c , c' along the section 108 shown in Figs. 3B and 3C until the voltage or current minimum along arm D becomes complete at points 125, 127.

When this has been accomplished the length of arm D may be adjusted so that the nodal point 125, 127 which has been selected, may be stable with variations in frequency. This adjustment may be made by varying the frequency of the oscillator 111 by a small amount. If the electrical length of arm D is too short, an increase in the frequency of the oscillator will shift the nodal point 125, 127 to the right away from the junction point of arms C and D. If the frequency is decreased the nodal point will move toward the junction. Thus by observing which way the

nodal point moves when the frequency of the oscillator is varied, it is possible to infer whether arm D should be lengthened or shortened in order that the two arms of the loop may be of equal electrical length, and the position of the nodal point substantially independent of frequency at least over a narrow range of frequencies.

This result in adjustment is of particular value when the loop circuit such as shown in Fig. 3 is applied to a high frequency radio repeating station such as shown in Fig. 4. In the circuit shown in Fig. 4 the voltmeter connected at the nodal point shown in Fig. 3 has been replaced by the amplifier 208. The last stage of the amplifier 208 replaces the oscillator 111 in Fig. 3. After the loop circuit has been adjusted by means of a local oscillator and voltmeter as has been explained in connection with Fig. 3, the circuit of Fig. 4 is ready to function as a radio repeating station. The waves received by antenna 202 will be amplified by amplifier 208 and radiated by antenna 201. The amplifier 208 is prevented from singing because the signals from the output of the amplifier will reach the input of the amplifier after having traversed over two arms of the loop circuit, and meeting at point 225, 227. There will be a voltage node established at this point as has already been explained in connection with the other figures. This voltage nodal relation also prevents reradiation of the energy from antenna 202, since cancellation occurs at the voltage nodal point. If the position of this voltage nodal point is made nearly independent of frequency over the range of frequencies which will be amplified by the amplifier 208, in a manner such as fully explained in connection with Fig. 3, then the amplifier will not sing. On the other hand, if the nodal point 225, 227 is one of the subsidiary nodal points which shift with frequency the amplifier may find a frequency at which it can amplify and which is sufficient for cumulative regeneration, and accordingly will produce singing in the amplifier.

As a general rule, the voltage at the nodal point 225, 227 will not remain zero over a wide range of frequencies because the attenuation in arm C of the loop does not remain independent of frequency. The mutual impedance between the antennae, however, may be made to vary only slowly with frequency by proper choice of antennae so that over the small frequency range which is to be amplified by the amplifier 208 the attenuation in arm C varies slightly. This construction results in a substantially complete cancellation of the voltage at points 225, 227 to which the input of the amplifier is coupled.

When the structure is such that the mutual impedance varies with frequency to an extent such that the amount of amplification which is possible without singing is undesirably limited, there may be added to the arm D of the loop an additional attenuator in which the attenuation varies with frequency in approximately the same sense as the attenuation in the arm C.

The irregularity in the arm D of the loop caused by the attenuator 408 may create reflection in the line which will cause disturbances at points 225, 227 unless the distance 408—225 is properly chosen. These disturbances may be eliminated by introducing equal changes in the length of both arms of the loop by means of adjustable loops 229, 230, so that the reflected energy as well as the directly introduced energy will produce a voltage node at points 225, 227.

If the additional lengths inserted at 229 and 230 are equal, the balance of the loop bridge will be maintained since they will introduce equal lengths in both arms of the bridge. In addition to loops 229, 230 or in place thereof absorbing resistors 231 may be inserted in the line to partially absorb the reflected energy and reduce the adverse effect caused thereby.

The repeating station described in Fig. 4 should preferably have at least one of the antennae 201 or 202 directional. If both the antennae are non-directional any change in the surrounding medium such as the introduction of a foreign body or a moving object in the field may cause a distortion of the field and a consequent unbalance of the loop circuit and thus destroy the balance of the amplifier 208 and will produce undesired oscillation. It has been found, however, that if either of the antennae is made directional, this difficulty is largely eliminated.

In Figs. 3 and 4 the antennae 102 and 202 correspond to the load indicated as 37 in Fig. 2. The impedance of these loads may be balanced in the other arm of the bridge circuit by constructing the line so as to provide the proper impedance balance. However, it is preferable to include a balancing attenuator such as indicated at 104 and 204, respectively, in order to provide for a more ready balance of the impedances.

In Fig. 5 is illustrated a system for repeating radio signals, in which both of the arms E and F corresponding generally to C and D of Fig. 4 include as part of their circuit the mutual impedance between two antennae. In this figure, 301 indicates the transmitting antenna and 302, 303 receiving antennae. The receiving antennae are spaced the proper distance apart and an attenuator such as indicated at 304 may be included in the circuit so as to produce a voltage nodal point at 305, 307 for the loop circuit. This circuit consists of the radiation path E, including the mutual impedance between the antennae 301 and 302, and the connecting leads of antenna 302, and the arm F including the mutual impedance between antennae 301 and 303, and the connecting leads of antenna 303. Although the two receiving antennae 302 and 303 are in spaced relation and accordingly would have a certain directional effect for signals coming from a distant point due to their arrangement as an array, there will be no detrimental effect regarding the energy radiated from antenna 301 since this antenna is spaced in such relation with respect to the antennae 302 and 303 that the path from 301 to 305—307 through either 302 or 303 is of the same electrical length plus 180° phase shift, and as a result the voltage waves cancel at point 305. This is true since the waves are in 180° phase opposition either because of a difference in the lengths of the paths or because of a transposition and the amplitudes thereof are made equal by means of attenuation adjuster 304.

It is then necessary merely to position the two antennae 302 and 303 at the proper angle to receive the signal which it is desired to relay, in such manner that the said signal produces an operative potential difference at 305—307, while at the same time maintaining the correct angle of antenna 301 with respect to 302, 303, so that cancellation of waves from 301, results at 305—307. The three antennae 301, 302 and 303 need not be parallel to one another as shown but may assume irregular positions provided the conditions above outlined are assured.

Signals received on the antennae 302, 303 will

be conducted through their respective transmission lines to points 305, 307 and from there through amplifier 309, and leads 311, 313 to antenna 301 to be radiated at increased power. The energy radiated from 301 and picked up by antennae 302 and 303, has traversed the two equal impedance paths E and F, which paths are also of equal electrical lengths plus 180° phase shift, and accordingly arrive at points 305, 307 in opposite phase and with equal amplitudes, therefore creating a voltage null and consequently producing no feedback through the amplifier 309. Since the radiation portions of the paths E and F are of substantially equal lengths, the attenuation in these paths will be substantially equal and accordingly very little attenuation correction to equalize them is necessary. However, any necessary correction may be made by the attenuator 304 to obtain a balance at the voltage nodal points 305, 307.

In the diagram of Fig. 5, the various antennae are shown as doublets and as being of substantially equal size, but various changes in the particular form of antennae used, as well as in their relative sizes and angular relations may be made without any alteration in the general principles of my invention as outlined above. If desired, the receiving antennae elements 302, 303 may be properly arranged to produce a sharply directive reception lobe in some particular direction and also transmitting antenna 301 may be made strongly directional in a selected direction. If desired, antenna 303 which is used to complete the reentrant loop arrangement may be relatively small so as to be effected primarily by radiation from antenna 301 for the balancing of the paths without being large enough in dimension to be affected to any great extent by the reception of the signals from the distant point. In an arrangement such as this the antenna 302 will then receive signals and produce effective potentials of point 305—307 dependent substantially only upon its own characteristics.

A repeating station such as disclosed in Figs. 4 and 5 may be used as a unit of a high frequency transmitting system which connects two points that are separated by a great distance so that the high frequency signals transmitted therebetween would be so highly attenuated as to make direct communication impractical. However, by the use of one or more repeater stations such as described above between the said widely spaced stations the signals may be relayed between the stations without too great an attenuation.

While I have described particular embodiments of my invention for purposes of illustration it should be understood that various modifications and adaptations thereof may be made within the spirit of my invention as set forth in the appended claims.

I claim:

1. A conjugate bridge circuit comprising a reentrant loop circuit including in part a radiation path, means coupled to said loop at a first point, other means coupled to said loop circuit at a

second point, the circuit path from said first point to said second point around one side of said loop including said radiation path, and the circuit path from said first point to said second point around the other side of said loop differing in electrical length from said circuit path first mentioned, by 180°, and substantially equal impedance means coupled to said loop on opposite sides of said second named point and at equal distances therefrom.

2. A high frequency bridge circuit comprising high frequency radio apparatus, a reentrant loop circuit coupled to said apparatus and comprising two transmission paths each having electrical length, at least one of said paths being constituted at least in part by the mutual impedance path between two radiators, means to establish a voltage nodal point in said loop circuit comprising means for effecting 180° phase shift in one side of said loop, and means coupled to said loop circuit at said voltage nodal point.

3. A high frequency circuit in accordance with claim 2, in which said high frequency radio apparatus comprises the output of an amplifier, and said means coupled to the voltage nodal point comprises the input of said amplifier, and in which said radiators comprise a receiving antenna and a transmitting antenna, respectively.

4. A radio repeater comprising a receiving antenna, a transmitting antenna, a reentrant loop circuit comprising in part the mutual impedance path between said antennae and in part transmission lines coupling together said antennae, an amplifier coupled between conjugate points on said reentrant loop circuit, said conjugate points dividing the loop circuit into two arms, one of which includes said impedance path, and an attenuator connected in said other arm to compensate for the attenuation in said impedance path.

5. A repeater according to claim 4, in which means are included in said reentrant loop circuit to compensate for reflections at points of irregularity therein.

6. A repeater according to claim 4, in which at least one of said antennae is directional.

7. A high frequency system comprising high frequency apparatus, a transmitting antenna and a receiving antenna coupled to said apparatus, a reentrant loop circuit coupled to said antennae and comprising two transmission paths each having electrical length, at least one of said paths being constituted at least in part by the mutual impedance between said antennae, means for establishing a voltage nodal point in said loop circuit comprising means for effecting a 180° phase shift in one side of said loop, and means coupled to said loop at said voltage nodal point.

8. A high frequency system according to claim 1, in which said means coupled at said voltage nodal point comprises an amplifier, for amplifying receiving high frequency signals, and said high frequency apparatus comprises the output of said amplifier.

ANDREW ALFORD.