

March 4, 1952

A. F. BREWER

2,587,590

ULTRAHIGH-FREQUENCY APPARATUS

Filed July 26, 1946

FIG. 1

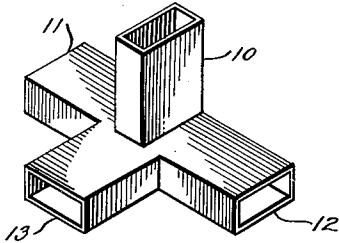


FIG. 2

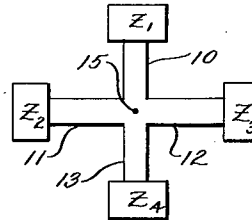


FIG. 3

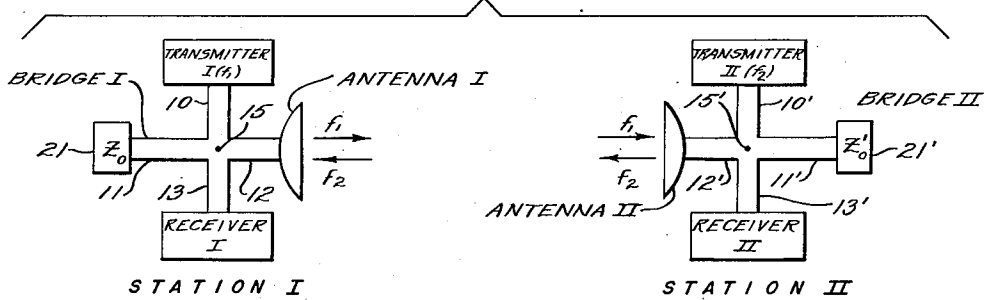
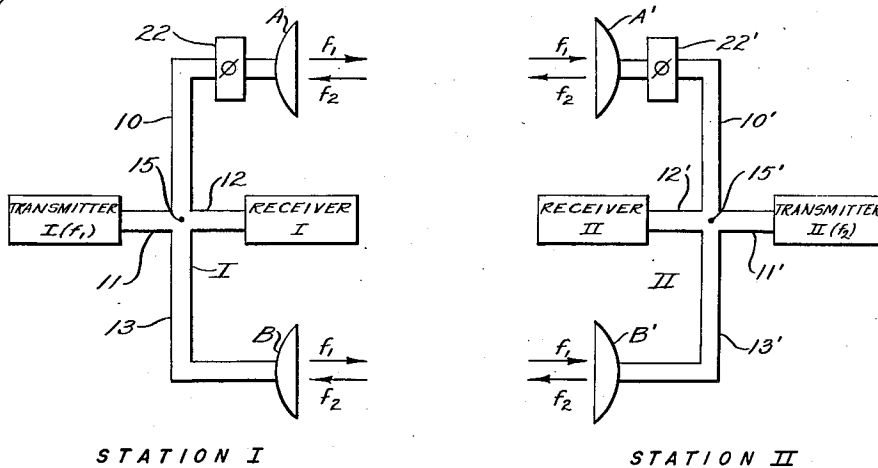


FIG. 4



INVENTOR
ALEXANDER F. BREWER
BY *Paul B. Hunter*
ATTORNEY

UNITED STATES PATENT OFFICE

2,587,590

ULTRAHIGH-FREQUENCY APPARATUS

Alexander F. Brewer, Lynbrook, N. Y., assignor to
The Sperry Corporation, a corporation of Delaware

Application July 26, 1946, Serial No. 686,304

2 Claims. (Cl. 250—6)

1

This invention relates to ultra-high-frequency apparatus and more particularly to ultra-high-frequency bridge circuits and their applications in ultra-high-frequency communication systems.

An object of this invention is to provide an improved microwave communication system in which a single oscillator serves as a transmitter and as the local oscillator for the microwave superheterodyne receiver.

A further object of this invention is to provide an improved microwave communication system in which the transmitter and receiver are connected to a single antenna in such a manner that the transmitted power does not harm the receiver which is in a continuously operative condition.

Another object of this invention is to provide an improved communication system having a single antenna in which the receiver is in an operative condition at all times, thus eliminating the necessity of a push-to-talk switching system.

Still another object of the present invention is to provide an improved microwave communication system using two antennas and utilizing the maximum amount of power available in the system.

Another object of the present invention is to provide an improved microwave diversity-type communication system.

Briefly, the present invention is characterized by the use of a microwave bridge adjusted to operate in an unconventional manner. Microwave bridges are known which consist of four adjustable elements or arms arranged in a symmetrical fashion, similar in function to the low frequency bridges. One such bridge using wave guide arms has been termed a "magic Tee" and is described below. In the present system, one such arm or element of this type of bridge is designated as the input arm and is adapted to receive electromagnetic energy which distributes itself among the other arms of the bridge in amounts dependent upon the adjustment of the remaining arms. The arm which is symmetrically opposite the input arm is for convenience called the output arm, while the remaining arms symmetrically positioned between the input and output arms are designated as the balancing arms. The fundamental property of such bridge circuits is that the energy which enters the bridge through the input arm separates at the junction of the arms into three parts, each of which is transmitted down one of the remaining arms. However, under certain conditions of impedance balance, it is possible to cause the input energy to split into

2

but two parts, each of which travels down the balancing arms adjacent to the input arm. With such an impedance balance no portion of the input energy appears at the output arm. The amount of energy which appears at the output arm is dependent upon the degree of impedance unbalance that exists between the balancing arms.

A further property of such a bridge circuit is that for any degree of impedance unbalance between the two balance arms, the input and output arms of the bridge may be interchanged without changing the operation of the system, i. e., the ratio of output energy to input energy remains constant.

When such a bridge circuit is used in a microwave system, the various arms may be shifted functionally so that the arm which is designated as the input arm for one function may become a balancing arm when the bridge is used in a different manner. The arm through which energy is being supplied to the bridge during any particular function of the system is called, at that time, the input arm, the two adjacent arms being designated as balancing arms, and the arm which is symmetrically opposite the input arm is then called the output arm.

By using a microwave bridge in an unbalanced condition, such as described above, it is possible to construct a microwave communication system in which a single oscillator serves as the microwave transmitter and at the same time provides a local oscillator wave for the superheterodyne receiver. In such a system the oscillator is connected to the input arm of the bridge. The antenna is connected to one of the balancing arms, the second balancing arm being terminated preferably in its characteristic impedance, and the mixer of the superheterodyne receiver is connected to the output arm. In operation, the frequency of the oscillator is adjusted so as to differ from the frequency of the received signal by an amount equal to the intermediate frequency of the receiver. Any impedance unbalance that exists between the second balancing arm (preferably terminated in its characteristic impedance) and the antenna arm causes a fraction of the oscillator power which is fed into the input arm to appear at the output arm to which the mixer for the receiver is attached. By proper adjustment, this fraction is kept at a sufficiently small value to prevent overloading the mixer.

The received signal which enters the system through the antenna divides at the junction point

of the microwave bridge so that a portion of it appears in the mixer arm. Since the frequency of the received signal differs from the frequency of the local oscillator by an amount equal to the intermediate frequency of the receiver, the mixer is excited by these two ultra-high-frequency signals and produces a resultant intermediate frequency output which is amplified and detected by the remainder of the receiver.

The invention in another of its aspects relates to novel features of the instrumentalities described herein for achieving the principal objects of the invention and to novel principles employed in those instrumentalities, whether or not these features and principles are used for the said principal objects or in the said field.

A further object of the invention is to provide improved apparatus and instrumentalities embodying novel features and principles, adapted for use in realizing the above objects and also adapted for use in other fields.

For a better understanding of the invention, in this and other embodiments, reference is had to the following description taken in connection with the accompanying drawings in which:

Fig. 1 is a perspective view of a wave guide type of ultra-high-frequency "magic Tee" bridge useful in explaining the present invention;

Fig. 2 is a general schematic representation of an ultra-high-frequency bridge circuit utilizing the bridge shown in Fig. 1;

Fig. 3 is a simplified schematic circuit diagram of an embodiment of the present invention used in an ultra-high-frequency communication system having but one antenna; and

Fig. 4 is a simplified schematic circuit diagram of a further embodiment of the present invention used in an ultra-high-frequency communication system using two antennas.

Referring now more particularly to Fig. 1, there is shown a perspective view of a wave guide type of ultra-high-frequency bridge having four arms 10, 11, 12 and 13. According to conventional notation, arm 10 is said to be in series with arms 11 and 12 and is said to form a "series" or "E-plane" Tee. Arm 13 is said to be in shunt with arms 11 and 12 and is said to form a "shunt" or "H-plane" Tee. That is, arm 10 is coupled to the electric field in arms 11 and 12 and arm 13 is coupled to the magnetic field in arms 11 and 12.

In order to better explain the theory of operation of the present invention as well as to discuss the operation of such a wave guide type of bridge shown in Fig. 1, reference is made to Fig. 2 which is a general schematic representation of an ultra-high-frequency bridge circuit. In Fig. 2 load impedances Z_1 , Z_2 , Z_3 and Z_4 are coupled to the arms of the wave guide Tee shown in Fig. 1. Arm 10 is considered to be in series with arms 11 and 12, whereas arm 13 is considered to be in shunt with arms 11 and 12. If arm 10 is considered as the input arm, that is, if an input voltage is made to appear across impedance Z_1 , the input electromagnetic wave will travel down the input arm 10 and will divide at junction point 15 in a manner which is dependent upon the relative magnitudes of the impedances Z_2 and Z_3 which terminate the balancing arms 11 and 12 adjacent to the input arm 10. If these two impedances Z_2 and Z_3 are equal when viewed from the junction point 15, the input electromagnetic wave will divide into two equal portions, one portion travelling down arm 11 and the remaining portion travelling down arm 12. There will be

no part of the input wave introduced into arm 10 which travels down output arm 13, to output circuit element Z_4 .

However, a slight unbalance in the value of impedances Z_2 and Z_3 (as transformed to junction point 15) will cause shunt output arm 13 to be excited, and a fraction of the energy introduced into input arm 10 will then travel along output arm 13. The magnitude of this fraction will be determined by the degree of impedance unbalance between Z_2 and Z_3 .

If the functions of arms 11 and 12 are reversed the same result will be observed. In this case the electromagnetic energy which enters shunt arm 13 divides at the junction point 15 of the bridge. If the impedances Z_2 and Z_3 are equal when viewed from the junction point 15, the input electromagnetic wave will divide into two equal portions, one portion travelling down arm 11 and the remaining portion travelling down arm 12. As before, an unbalance of impedances Z_2 and Z_3 will cause a fraction of the energy introduced into shunt arm 13 to enter series arm 10, the magnitude of the fraction being dependent upon the amount of impedance unbalance.

The electromagnetic waves which travel down the arms 11 and 12 when series arm 10 is the input arm are exactly opposite in phase at points equi-distance from the plane of symmetry of the arms 11 and 12. On the other hand, if electromagnetic energy is introduced through shunt arm 13, the arms 11 and 12 are excited by respective waves which are coincident in phase at points equi-distance from the plane of symmetry of the arms 11 and 12.

Either or both arms 11 and 12 may be used as input arms as well as arms 10 and 13. However, if arm 11 or arm 12 is to be used as the input arm, both the series arm 10 and shunt arm 13 should be matched to the bridge circuit so that when looking down either arms 11 or 12 their characteristic impedance Z_0 is seen. If arm 11 is used as the input arm, the energy which travels down it will divide, in the same manner as described above, into two or three portions depending upon the impedance relation of the two adjacent arms. Similarly, energy which is introduced through arm 12 will divide in a manner dependent upon the impedance balance between the two adjacent arms.

It should be noted at this point that the present invention is in no way limited to ultra-high-frequency bridges composed entirely of wave guides. Instead, the invention is completely general and is adaptable to ultra-high-frequency bridges composed completely of coaxial elements, or combinations of coaxial and wave guide elements, or of other types of elements such as the conventional two-wire transmission line elements used at lower frequencies.

From the above discussion it is seen that, by adjusting the relationship of the terminating impedances of the two opposite arms of the bridge circuit, it is possible to cause a predetermined fraction of the input energy to appear at the symmetrically opposite output arm. This fraction can be made zero merely by making the terminating impedances of the balancing arms equal to each other, so that the bridge circuit is said to be balanced. The results obtained by operating such a bridge circuit in a slightly unbalanced condition are very useful in many ultra-high-frequency applications.

Fig. 3 is a simplified schematic circuit diagram of an ultra-high-frequency communication sys-

tem having two stations I and II, each employing a bridge circuit used in an unbalanced state as above-described. Station I has a transmitter I connected to the input arm 10 of a bridge I. The mixer of a superheterodyne receiver I is connected to the output arm 13 of bridge I. An antenna I is connected to arm 12 of bridge I, and its arm 11 is terminated in its characteristic impedance Z_0 by a suitable circuit element 21 having that impedance value. The input impedance of antenna I is adjusted to be slightly different from the characteristic impedance of arm 12 to which it is connected. By so doing, a slight impedance unbalance is obtained between arms 11 and 12 when viewed from junction point 15, so that a small fraction of the energy which is introduced into the bridge I from transmitter arm 10 will be introduced into mixer arm 13, as discussed above. Care must be taken to make the impedance unbalance sufficiently small so that the amount of energy which enters mixer arm 13 does not damage the mixer of receiver I which is connected to this arm. The impedances of arms 10 and 13, when viewed from junction point 15, are usually kept equal so that the energy which enters arm 12 from antenna I during reception will divide into but two portions, one portion entering transmitter arm 10 and the remaining portion entering mixer arm 13, with none of the energy being introduced into terminated arm 11.

A similar arrangement is provided at station II, with a transmitter II feeding energy into bridge II through its input arm 10', the mixer of a superheterodyne receiver II being connected to the bridge output arm 13', antenna II being connected to arm 12', and arm 11' being terminated in its characteristic impedance Z_0' by circuit element 21'. The same impedance relations are established at station II as at station I, with a slight impedance unbalance between arms 11' and 12', and impedance balance between 10' and 13'. The operating frequency of transmitter I is selected to differ from the operating frequency of transmitter II by an amount equal to the common intermediate frequency of the two microwave superheterodyne receivers I and II.

In operation, transmitter I is modulated in any conventional manner by the intelligence it is desired to transmit from station I to station II. The energy from transmitter I travels along the input arm 10 of bridge I and divides at the junction point 15. That portion of the modulated energy from transmitter I which enters antenna arm 12 will be radiated by antenna I. The modulated energy or signal thus radiated by antenna I is picked up by antenna II and is fed into antenna arm 12' of bridge II. This energy divides at junction point 15' with the useful portion entering arm 13'.

In the meantime, transmitter II is oscillating at a frequency which differs from that of transmitter I by an amount equal to the common intermediate frequency of the two microwave receivers. This carrier frequency energy from transmitter II will enter bridge II through transmitter arm 10' and will separate at junction point 15' with a small fraction of it entering mixer arm 13', along with the useful portion of the modulated or signal energy picked up by antenna II.

The carrier frequency wave from transmitter II which enters mixer arm 13' adds to that portion of the modulated wave from transmitter I picked up by antenna II reaching mixer arm

13', and these waves are mixed by the mixer of receiver II to produce an intermediate frequency wave. The resultant modulated intermediate frequency energy is amplified and detected by the other conventional stages of receiver II.

Communication in a reverse direction, from station II to station I, is accomplished simply by modulating transmitter II. The modulated energy from transmitter II which enters the bridge through transmitter arm 10' divides at a junction point 15'. That portion of the input modulated energy from transmitter II which enters antenna arm 12' is radiated by antenna II. This modulated signal is picked up by antenna I and enters bridge I through its antenna arm 12. The picked up signal energy separates at junction point 15 of bridge I, with the useful portion of it entering mixer arm 13.

The carrier energy of transmitter I (which is, of course, unmodulated during a reception) enters the bridge I through transmitter arm 10 and divides at junction point 15 in the same manner as before. That small fraction of the carrier energy from transmitter I which enters mixer arm 13 is mixed by the mixer of receiver I with the modulated signal energy from transmitter II which enters mixer arm 13, and the resultant modulated intermediate frequency signal which is produced is amplified and detected by receiver I.

Thus, it is seen that, by the use of a bridge circuit in a slightly unbalanced state caused by the intentional slight mismatch between the terminated arm 11 (or 11') and the antenna arm 12 (or 12'), a communication system has been devised using a single antenna for transmission as well as reception. Furthermore, by using a bridge circuit in such an unbalanced condition, a small fraction of the transmitter carrier wave is used to mix with the received wave thereby eliminating the need of a local oscillator for the superheterodyne microwave receiver.

Another desirable feature of the communication system just described is that, during transmission, the receiver of the transmitting station is in a fully operative condition, so that the speaker is able to hear his own voice in his own receiver if he so desires. This follows from the fact that during transmission part of the modulated radio frequency of the transmitter will enter the receiver at the transmitting station. At the same time the transmitter at the receiving station will provide an unmodulated carrier which, because of the frequency separation of the respective carriers, will act as a local oscillator for the receiving station. More specifically, referring to Fig. 3, let us assume that station I is transmitting a modulated carrier which emanates from transmitter 1. This energy passes down arm 10 and divides at the junction 15 into three parts, two of which travel down arms 11 and 12 to the terminating impedance and antenna, respectively. However, some energy, depending upon the impedance unbalance existing between the balancing arms 11 and 12, is introduced into receiver I by way of arm 13. At the same time station II, which arranged to receive energy from station I, has its transmitter II in an operative condition. As a result, this carrier frequency which emanates from antenna 2, is incident to antenna 1 and passes along line 12 to the junction point 15 and divides solely between arms 10 and 13 as a function of the respective impedance balance of these two arms. Inasmuch as the frequency separation of the two carrier waves is equal to the desired intermediate frequency, the two energies, which

are introduced into receiver I, are successfully mixed. Accordingly, station I, although it is set for transmission to station II, is capable of hearing its signal in its own receiver I.

From the discussion of the method of operation of this system, it is seen that this is an indication that both the transmitter at the receiving station (which is then being used as a local oscillator) and the distant transmitter are in operation. If the speaker fails to hear his own voice in the receiver, he immediately knows that there is a breakdown in the system. If the intelligence to be transmitted is other than voice, the receiver at the transmitting station may still be used as a monitor by giving either an aural or visual indication.

From the above discussion it is seen that a material portion of the ultra-high-frequency energy which is supplied to the input arm 10 of bridge I is introduced into terminated arm 11 where it is absorbed by the terminating impedance Z_0 . Also it is seen that only half the energy which is picked up by antenna I is utilized in mixer arm 13, with the half of the received energy which enters transmitter arm 10 being wasted. To overcome these losses and still provide many of the advantages of the communication system described above, a slightly different embodiment of the present invention is used as shown in Fig. 4, which is a general schematic representation of an ultra-high-frequency communication system employing a bridge circuit used in an unbalanced condition in combination with two antennas. Referring to Fig. 4, station I comprises a transmitter I which is here connected to the balancing or side arm 11 of bridge I; receiver I which is connected to the opposite side arm 12; and antennas A and B connected to series arm 10 and shunt arm 13 respectively.

The input impedances of antennas A and B are adjusted to be slightly different when viewed from bridge junction point 15. Because of this slight impedance unbalance, a small fraction of the input energy from transmitter I will enter receiver arm 12. On the other hand, the impedances seen from junction point 15, when looking down arms 11 and 12, are selected or adjusted to be balanced, so that energy which enters either series arm 10 or shunt arm 13 will divide into but two equal portions, with not energy entering the opposite arm.

Station II is arranged in the same manner as station I, with a transmitter II connected to side arm 11' of bridge II, a receiver II connected to side arm 12'; and antennas A' and B' connected to series and shunt arms 10' and 13' respectively. The same impedance relations are established at station II as at station I, with arms 11' and 12' being balanced and arms 10' and 13' having a slight impedance unbalance. As in the previous embodiment, superheterodyne receivers I and II have a common intermediate frequency, and the carrier frequencies of transmitters I and II differ in frequency by an amount equal to this intermediate frequency.

In operation, if it is desired to transmit signals from station I to station II, transmitter I is modulated in any conventional manner by the intelligence which it is desired to transmit. The modulated signal from transmitter I enters bridge I through side arm 11 and divides at the junction point 15, one portion of the input energy travelling along series arm 10 and a second portion travelling along shunt arm 13, with a very small fraction being introduced into receiver arm 12.

Those portions of the modulated energy which enter arms 10 and 13 are radiated by antennas A and B respectively. At station II, antennas A' and B' pick up the modulated energy from station I.

The modulated energy which is picked up by antenna A' enters series arm 10' and divides at the junction point 15', with a portion of it entering receiver arm 12' and a portion of it entering transmitter arm 11'. Since arm 10' is a series arm, the portions of energy which enter arms 12' and 11' are 180° out of phase at points equidistant from junction point 15'.

In the same manner, the energy which is picked up by antenna B' is fed through shunt arm 13' and divides equally at junction point 15', with a portion travelling along receiver arm 12' and another portion travelling along transmitter arm 11'. In this case the phases of the two portions at points equidistant from junction point 15' are the same, since the input energy is introduced through shunt arm 13'.

It can be seen, therefore, that, by adjusting the relative phases of the energy which travels down series arm 10' and shunt arm 13', it is possible, because of the phase relations described above, to have reinforcement or cancellation of energy in the side arms 11' and 12'. Since it is desired to feed the energy picked up by antennas A' and B' to the mixer of receiver II, while it is desirable that no energy go to transmitter II, a phase adjustment is made so that cancellation results in transmitter arm 11' and reinforcement results in receiver arm 12'. Such an adjustment could be made by shifting the physical location of one of the antennas A' and B' or by placing a conventional phase shifter in either arm 10' or 13'. Such phase shifters are indicated schematically at 22 and 22', connected to antennas A and A' respectively. Since the frequency of that portion of the unmodulated energy from transmitter II which reaches the mixer of receiver II, differs from the frequency of the modulated energy received from transmitter I, modulated energy of the difference or intermediate frequency is produced by the mixer of receiver II, which is then amplified and detected by the other stages of receiver II.

Communication in the reverse direction, that is, from station II to station I, is accomplished simply by modulating transmitter II, the action being the same as described above.

It is to be noted further that in this system there is a greater utilization of transmitter energy than in the system shown in Fig. 3. In the latter system, a material fraction of the transmitter power is not used, by being dissipated in the terminating impedance Z_0 of arm 11. Also, half the energy picked up by antenna I is fed through arm 10 to transmitter I where it is useless. In the system shown in Fig. 4, practically all of the transmitter power is radiated, with only a small portion being utilized at the transmitting station as a local oscillator for the receiver. Also, all of the energy which is picked up by the two antennas is fed to the mixer of the receiver, and substantially none is fed into the transmitter arm to be there dissipated. For these reasons, in those cases where it is desired to maintain communication with the minimum amount of transmitter energy, this double-antenna system is more advantageous than the single-antenna system.

As in the previous embodiment, the speaker is able to hear his own voice in the background, as he modulates his transmitter. Again this is an

indication to him that the system is operating correctly. Failure to hear his voice in the background indicates to him that there is a breakdown in the communication link.

An added advantage of the embodiment shown in Fig. 4 is that the use of two antennas at both stations results in a diversity type system. In such a diversity system, the two antennas have directional characteristics but are oriented in slightly different directions so that signals are received, if possible, which travel over different space paths. The advantage of such a diversity system is that atmospheric effects of a local nature which may interfere with one signal path may have no effect on the second signal path, resulting in more reliable communication.

This system has all the advantages of that of Fig. 3, in that the transmitter is used as the local oscillator for a superheterodyne receiver. The receiver is in operative condition at all times and no additional attenuation is required to keep the relatively high transmitter power from damaging the input mixer of the receiver.

While the aforementioned embodiments serve to point out the advantages of the present invention, they are merely illustrative of the broad use to which a bridge circuit in an unbalanced state may be put. The invention in its broad aspects may be applied in other systems and it is not desired to limit the use of the invention only to the described communication systems.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In combination, a transmitter and a superheterodyne receiver which operate at frequencies which differ by an amount equal to the intermediate frequency of said receiver, a wave guide interconnecting the output of said transmitter and the input of said receiver, said transmitter providing the local oscillator for said receiver, first and second antennas, first and second wave transmission branches interconnecting said first and second antennas respectively to the electric and magnetic planes of said wave guide at a common junction, the impedances at said common

junction of the portion of said wave guide connected to said transmitter and the portion of said wave guide connected to said receiver being substantially equal and the impedances at said common junction of said first and second wave transmission branches being slightly unequal, and means for causing the wave-energy received by said antennas to differ in phase.

2. In combination, a bridge circuit having an input element and an output element and two balancing elements all interconnected through a common junction, separate antennas terminating each of said two balancing elements, the impedances of said balancing elements being unequal at said common junction, a transmitter having its output connected to said input element, and a superheterodyne receiver having its input connected to said output element, the operating frequency of said transmitter differing from the operating frequency of said receiver by an amount equal to the intermediate frequency of said superheterodyne receiver and the transmitter providing the local oscillator for said receiver.

ALEXANDER F. BREWER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
Re. 21,955	Chaffee	Nov. 25, 1941
2,333,719	Herold	Nov. 9, 1943
2,401,717	Wolff et al.	June 4, 1946
2,401,751	Friis	June 11, 1946
2,408,791	Magnuski	Oct. 8, 1946
2,412,935	Tashjian	Dec. 17, 1946
2,416,790	Barrow	Mar. 4, 1947
2,424,156	Espley	July 15, 1947
2,425,314	Hansell	Aug. 12, 1947
2,436,828	Ring	Mar. 2, 1948
2,445,895	Tyrell	July 27, 1948
2,445,896	Tyrell	July 27, 1948
2,447,392	Byrne	Aug. 17, 1948
2,475,127	Carlson	July 5, 1949
2,475,474	Bruck et al.	July 5, 1949

FOREIGN PATENTS

Number	Country	Date
466,014	Great Britain	May 20, 1937
551,472	Great Britain	Feb. 24, 1943