L. DE FOREST.

SYSTEM OF DUPLEX WIRELESS TRANSMISSION.

APPLICATION FILED OCT. 5, 1908.

1,042,205.

Patented Oct. 22, 1912.

2 SHEETS—SHEET 1.

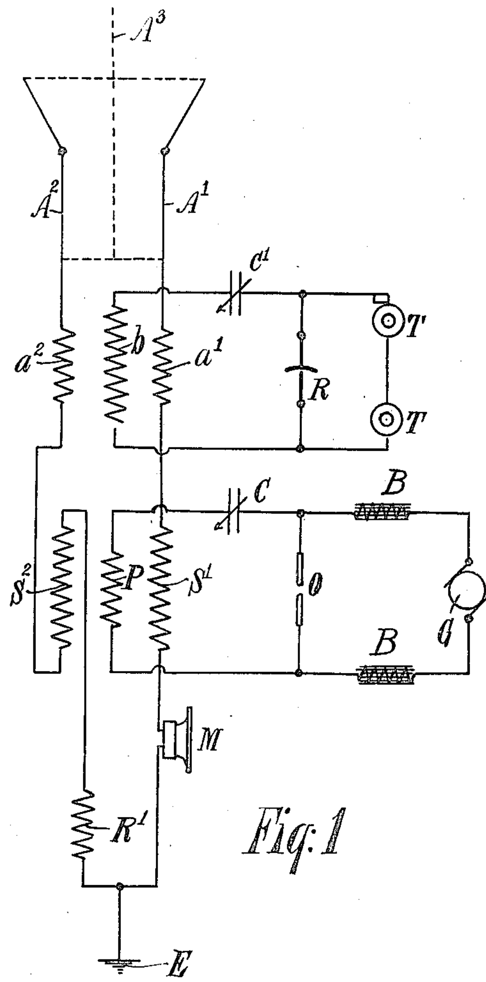

Fig:1

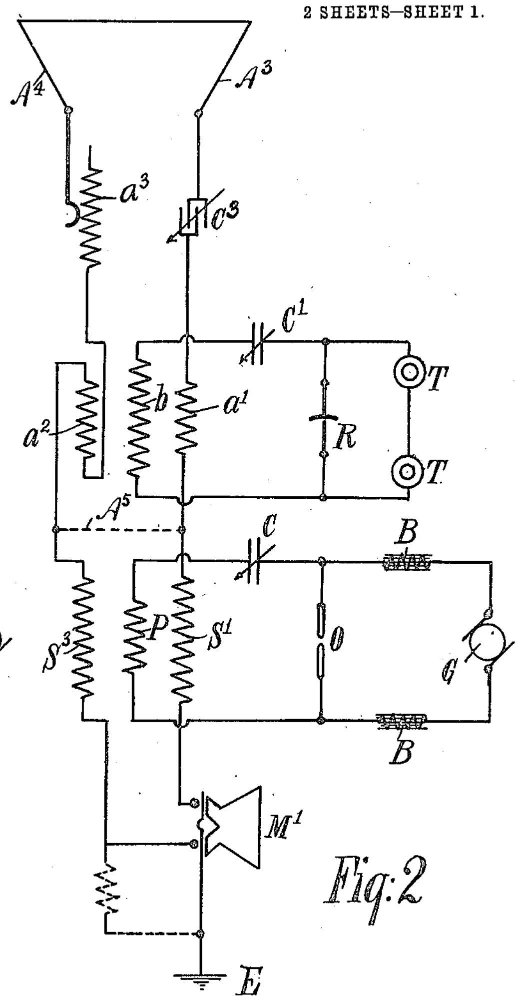

Fig:2

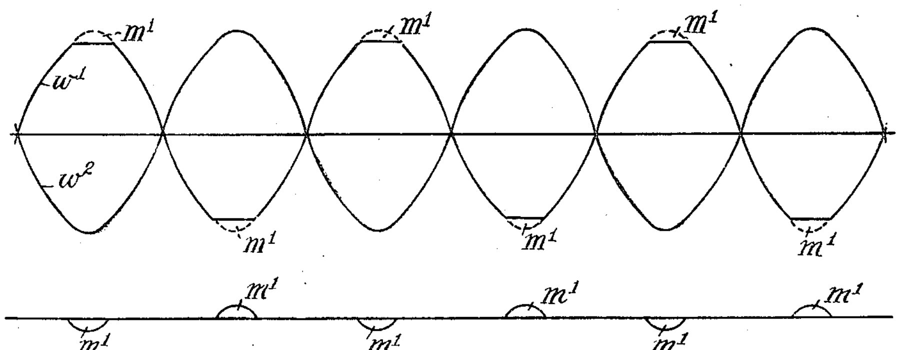

Fig:3

Witnesses
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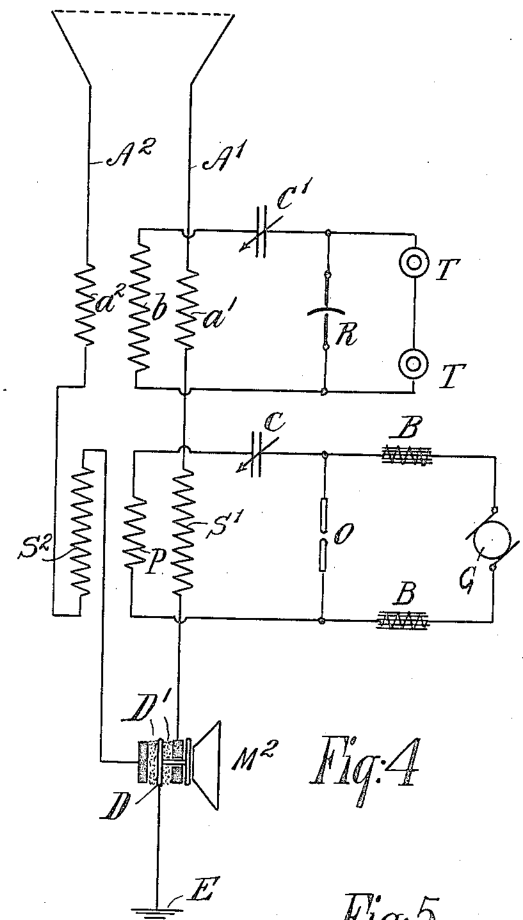


Fig:4

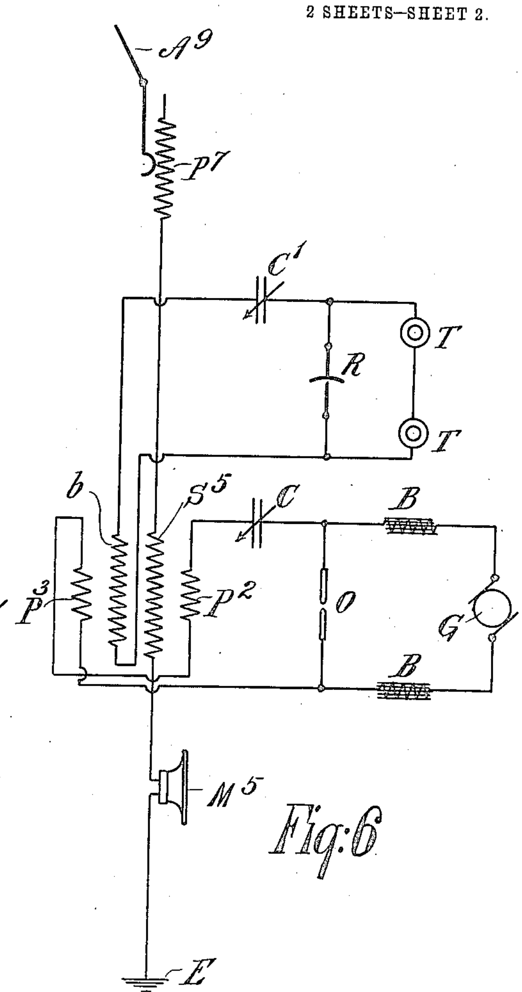


Fig:6

Fig:5

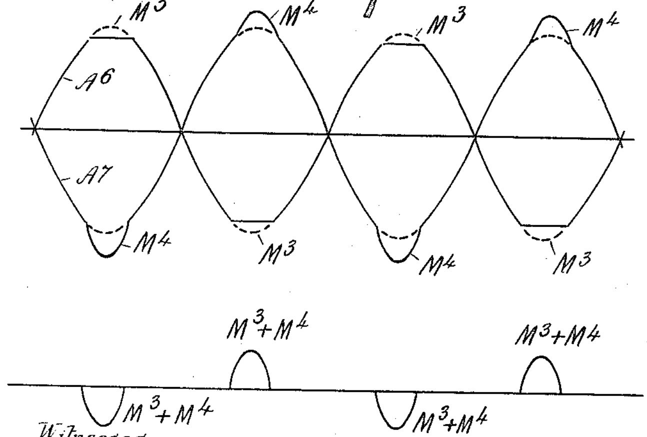
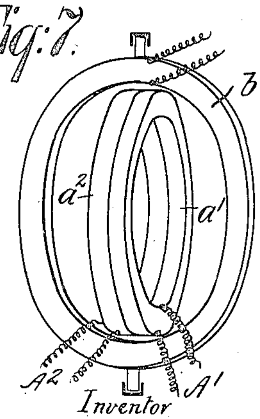


Fig:7.



Witnesses.

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UNITED STATES PATENT OFFICE.

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SYSTEM OF DUPLEX WIRELESS TRANSMISSION.

1,042,205. Specification of Letters Patent. Patented Oct. 22, 1912.

Application filed October 5, 1908. Serial No. 456,226.

To all whom it may concern:

Be it known that I, LEE DE FOREST, a citizen of the United States, residing at New York, in the county of New York and State of New York, have made a certain new and useful Invention in System of Duplex Wireless Transmission, of which the following is a specification.

This invention relates to systems of duplex wireless transmission.

The object of the invention is to provide a system of wireless transmission, whether telegraphic or telephonic, which is simple and efficient, and wherein messages may be received and transmitted simultaneously.

A further object of the invention is to provide a balanced system of wireless transmission wherein the effect of irregularities due to the action of the oscillator are eliminated.

A further object of the invention is to provide a differentially balanced system of wireless transmission with the attendant advantages of simultaneous reception and transmission of electro-magnetic wave signals.

Other objects of the invention will appear more fully hereinafter.

The invention consists substantially in the construction, combination, location and relation of parts, all as will be more fully hereinafter set forth, as shown in the accompanying drawings, and finally pointed out in the appended claims.

Referring to the accompanying drawings, and to the various views and reference signs appearing thereon: Figure 1 is a view in diagram illustrating one form of arrangement embodying the principles of my invention. Fig. 2 is a similar view illustrating modified arrangements embraced within the scope of my invention. Fig. 3 are wave diagrams illustrating the action of the arrangements shown in Figs. 1 and 2. Fig. 4 is a view similar to Figs. 1 and 2, showing another form of transmitter and arranged in accordance with the principles of my invention. Fig. 5 are wave diagrams illustrating the action of the arrangement shown in Fig. 4. Fig. 6 is a diagram similar to Figs. 1, 2 and 4, showing still another arrangement embraced within the broad scope of my invention. Fig. 7 is a detail view showing means which are simple and efficient for simultaneously, and to the same or reciprocal degree, varying the mutual inductance of certain of the parts in attaining a balanced condition and relation of circuits in accordance with the principles of my invention.

The same part is designated by the same reference sign wherever it occurs throughout the several views.

Various systems for simultaneously receiving and transmitting electro-magnetic wave signals have heretofore been proposed, but none, so far as I am aware, have proven successful in practical operation on account of latent defects in the systems or other causes. For instance, it has been proposed to base such a system on a definite relation and physical separation through a definite distance of the receiving and transmitting antennæ, the receiving antenna being located in a plane midway between and in the planes of two transmitting antennæ. Such an arrangement is commercially impractical, however, since its utility is confined to the receipt of signals transmitted from a fixed point, and, moreover, require a distance of separation of the order of one half a wave length, which is very seldom possible.

Again, in wireless systems generally, more or less irregularities due to the action of the oscillator are encountered, which disturb the signals transmitted and impair the efficiency of the receiver. This is especially true in the case of the wireless or radio telephone, the noises and other sounds produced by the arc or other form of oscillator, impressing their effect and influence on the transmitted electro-magnetic waves, and being reproduced at the distant receiving station, they more or less seriously interfere with the receipt of the message.

It is among the special purposes of my present invention to provide a system of wireless transmission and reception of electro-magnetic waves in which the above and other objections and difficulties are avoided and eliminated; wherein signals may be simultaneously transmitted and received without the necessity of employing switches to vary the circuit connections; wherein a differential balance of circuits is maintained; wherein the antenna and the transmitting and receiving systems are preferably coupled up in series, the antenna serving as the connecting link between the transmitter and receiver; wherein any special relation or physical separation of the antenna is unnecessary; and wherein other features of improvement are embodied, and other advantageous results are obtained.

Referring to the drawings, and particularly to Fig. 1, reference sign A^1, and A^2 designate antennæ or aerial conductors, which, as is common in the art, may consist of one or several wires. These may be independent of each other, or, and as indicated by the dotted line A^3, they may be different legs of the same loop antenna. These conductors are both grounded, as, for instance, at E.

Associated with both aerial conductors by any suitable method of coupling is an oscillating circuit for the generation of electromagnetic waves. In practice, and as shown, though in this respect my invention, as broadly defined in the claims, is not to be limited or restricted, the oscillating circuit includes one or other form of oscillator, O, a condenser C, and an inductance coil P. The oscillator may be of any desired form such as is employed in this art for the purpose. I have found an arc oscillator to be best adapted for the purpose, the arc being supplied with current from any suitable source, preferably a source of direct current, as, for instance, a direct current generator indicated at G. This arrangement which I have selected to illustrate the principles of my invention results in the production of a practically continuous train of electro-magnetic waves, and I have found such a system best adapted for my purposes. The leads of the current source may contain choke coils B, in the usual way. The inductance coil P, in the oscillating circuit, in accordance with the principles of my invention as embodied in the arrangement shown in Fig. 1, is coupled inductively with coils S^1, S^2, oppositely wound with respect to each other, and respectively arranged in the aerial conductor systems A^1, A^2. The coils S^1, S^2 and P should be so relatively proportioned, wound and arranged, as to enable the same inductive effect to be created in each of the coils S^1, S^2, by coil P, but in opposite phase relation. By this arrangement the oscillations of the oscillating circuit produce exactly equal electro-magnetic vibrations in each of the aerial conductor systems, but of opposite phase, or phases of one hundred and eighty degrees apart. Also associated with both aerial conductors by any suitable method of coupling is a receiving circuit. In practice, and as shown, though in this respect my invention, as broadly defined in the claims, is not to be limited or restricted, the receiving circuit includes an inductance coil b, a variable condenser C^1, and a receiver, which, in the exemplification I have selected for illustration purposes, comprises an ordinary head telephone T. And connected across this circuit is a detector R, which may be of any suitable or well known type, such as an audion, a perikon, or other construction well known in the art. The coil b is, in this form of my invention, associated inductively with coils a^1, a^2, and in such relation as to be influenced in exactly the manner and to the same degree by both of said coils, a^1, a^2. When the aerial conductors A^1, A^2, are arranged in parallel, that is, to act in unison, then the received oscillations, to be detected in the receiving circuit, cause the coils a^1, a^2, to act additively, as contradistinguished from differentially, upon the coil b, that is, the received oscillations act in the same phase relation, provided the aerial conductors are not too widely separated, and hence an amplified effect is produced in the receiving circuit.

The transmitting device may be of any suitable form such as is common in wireless systems. In the particular arrangement shown, to which, however, my invention as defined in the claims is not to be limited, I employ a microphone transmitter indicated at M for wireless telephoning. The transmitter is preferably arranged in series in one of the aerial conductor systems, as, for instance, the aerial conductor A^1, and preferably in the earth connection thereof. In the other aerial conductor system I place a resistance R^1, adjusted to approximately the average resistance of the microphone or other transmitter M.

From the foregoing description it will be seen that I provide an exceedingly simple system of wireless communication wherein a differentially balanced circuit relation is maintained, thereby enabling electro-magnetic wave signals to be simultaneously transmitted and received at the same station and without the employment of switches to cut in or out either the transmitting or receiving apparatus according to whether messages are being sent or received.

In Fig. 3 I have graphically illustrated the action of the system. In transmitting, for instance, telephonically, the emitted magnetic waves radiating from the aerial conductor system A^1, A^2, are illustrated by the curves w^1 and w^2 respectively. It will be observed that these curves are exactly alike in amplitude and period, but are in opposite phase relation, and hence, in ordinary circumstances, when no signal is being sent out, they neutralize each other. If, now, the transmitter is operated, as, in the case of telephoning, by speaking into the microphone M, the oscillations generated in the aerial conductor system A^1 are modified by the microphone in accordance with the sonorous vibrations accompanying the sounds to be transmitted, and these modifications are impressed upon the electro-magnetic waves radiated from the conductor A^1, while those radiated from conductor A^2, remain unaffected by the transmitter. The modifications thus impressed upon the waves radiated from conductor A^1 are in the nature of amplifying or cutting off of the peaks of the waves as indicated at m^1, m^1, Fig. 3, and since at all other points the two radiated wave trains neutralize each other, only these amplified or cut off portions of the peaks of one set of waves have any effect or influence on the distant receiving apparatus, but since these portions correspond to and are produced by the sound waves, the effect of these portions in the distant receiving apparatus is to produce exactly such sound waves.

I have mentioned that the coils a^1, a^2, should have such arrangement and relation as to exert exactly the same influence on the coil b of the receiving circuit. In Fig. 7 I have shown a simple arrangement for varying the mutual inductance between the coil b and the two coils a^1 and a^2 simultaneously, but always to like degree. This is accomplished by winding the coils b and a^1 and a^2 into ring form, one of the rings containing both coils a^1 and a^2, and pivotally mounting one of the said rings within the other for relative rotative movement. In this manner, by simply adjusting the relative angular positions of the ring coils I am enabled to vary simultaneously and to always the same degree the mutual inductance between the coil b and the coils a^1, a^2.

Any suitable, well known or convenient means, familiar to those skilled in the art, may be employed to prevent the proximity of the transmitting apparatus to the receiving apparatus at the same station therewith from unduly influencing or affecting said receiving apparatus, through inductive action.

In Fig. 2 I have shown a slightly different arrangement embodying the principles of my invention, and wherein a loop receiving antenna is employed, the two legs A^3, A^4 thereof being spaced far apart, but close together as compared with a quarter wave length. In this arrangement the receiving circuit including the coil b, variable condenser C^1, detector R and receiver T, remain the same as above described. The coils a^1, a^2 of the aerial conductor system A^3, A^4, however, which are associated inductively with the coil b, are wound in opposite directions with respect to each other, instead of being wound in the same direction as in Fig. 1, thereby establishing a differential relation. The transmitting system including the coil P, condenser C, oscillator O, choke coils B, and generator or other source of current G, remains the same as in the arrangement of Fig. 1, while the coils S^1 and S^2 which are inductively associated with the coil P, are wound in the same direction with respect to each other and with respect to coil P, instead of in reverse directions with respect to each other as shown in Fig. 1. Instead of arranging the microphone in the circuit of one of the aerials and a fixed resistance in the other, as in Fig. 1, I may employ in the arrangement of Fig. 2 a double or multiple microphone M^1, arranged to impress equal effects or modifications upon the generated or radiated waves in both the conductor systems A^3 A^4.

In receiving signals from a distant station with the arrangement shown in Fig. 2, the coils a^1, a^2 would act differentially upon the receiving coil b. In order to avoid this I change or vary the phase relation of the oscillations set up in the two legs of the loop antenna circuit. This result may be attained by arranging an adjustable inductance a^3 in one or the other of the aerial conductor systems A^3, A^4, or a variable condenser, indicated at C^3, may be inserted in one or the other of said conductor systems or an inductance may be inserted in one and a condenser in the other, or other suitable expedient may be employed. If desired, the conductor A^4 may be connected in series with the coil S^1, as indicated in dotted lines at A^5.

In the arrangements shown in Fig. 2, the irregularities due to the action of the oscillator will not be eliminated in the effects produced thereby in the distant receiving station. The same action as above described with reference to Fig. 1 and as graphically illustrated in Fig. 3, takes place in the arrangement illustrated in Fig. 2.

In Fig. 4 is shown the same relation and arrangement of circuits and systems as in Fig. 1, but instead of employing a transmitting microphone in one aerial system and a fixed resistance in the other, I employ a transmitter so constructed and arranged as to increase the resistance in the one aerial system, while at the same time decreasing the resistance in the other aerial system. As one embodiment of this idea, I have shown a microphone M^2, for impressing variations upon the oscillations in one aerial system and means actuated by the microphone for simultaneously varying inversely the resistance of the other aerial system. This is accomplished by connecting a disk or plate D to the diaphragm of the microphone, and arranging the same to compress or to release the carbon or other conducting particles indicated at D^1, and which are included in the circuit of aerial system A^2. Thus the increase of resistance in the antenna system A^1, due to the action of the microphone diaphragm under the influence of sound vibrations, is accompanied by a corresponding decrease of resistance in the antenna system A^2. The result is that the waves emitted or radiated by the elevated conductors A^1, A^2, are alike in amplitude and frequency, but are in opposite phase relation, as in the case of the arrangement shown in Figs. 1 and 2, and the peaks of the radiated waves of one conductor are cut off, while the correspondingly opposite peaks of the waves radiated by the other conductor are increased or amplified, thereby magnifying or amplifying in the resulting transmitted waves the effects of the modifications impressed by the sonorous vibrations in the microphone. This action is indicated graphically in Fig. 5, wherein the curves A^6, A^7 represent respectively the radiated waves of the conductor system A^1, A^2, and M^3, M^4 designate respectively the decreased or cut off peaks of one wave, and M^4 the amplified or increased peaks of the other wave, the resultant effect being a combined or amplified wave indicated at M^3, M^4.

In Fig. 6 I have shown another arrangement embodying the principles of my invention, wherein the receiving circuit, including the coil *b*, variable condenser C^1, detector R, and receiver T, remains the same as in the arrangements above described. The oscillating system in addition to the condenser C, oscillator O, choke coils B, and generator or other source G, also includes coils P^2, P^3, both of which are in inductive relation with the receiving circuit coil *b*. The antenna system A^9 is connected with earth E, and includes a coil S^5, which is in inductive relation with coils P^2 of the oscillating system and also with coil *b* of the receiving system. These various couplings may be loose, that is, far apart and variable, that is, adjustable toward and from each other. The transmitter, here shown as a microphone M^5, is in the earth connection of the antenna. The receiving circuit, in this case, should be out of tune with the home transmitting station. To insure this relation, I insert an adjustable inductive coil P^7, in the antenna system. In this arrangement the coils P^2, P^3 are wound in opposite directions with respect to each other, and by suitably adjusting the distance between these various coils, is thereby established a differential balance which eliminates any effect upon the receiving coil *b*, by reason of irregularities of the oscillator, but such irregularities are impressed on the radiated waves, and hence are reproduced in the distant receiving system, because coil P^2 acts more strongly on coil S^5 than does P^3. The same method of winding and mounting of coils P, S^1, S^2 to adjustably regulate their mutual inductance as in the case of coils A^1, A^2, and as shown in Fig. 7 may also be employed.

My invention may be embodied in many other specifically different arrangements throughout a wide range of variations without departure from the spirit and scope of my invention as broadly defined in the claims. I do not desire therefore, in the broad scope of my invention to be limited or restricted to specific details of arrangement. But, having now set forth the objects and nature of my invention, and various arrangements embodying the principles thereof, and having set forth the purpose, function and mode of operation of such arrangements,

What I claim as new and useful and of my own invention and desire to secure by Letters Patent, is:

1. In a duplex system of wireless communication, an antenna system, a transmitting system and a receiving system associated therewith, means for normally balancing the effects of the transmitting system, and means for modifying the impressed oscillations of the transmitting system to disturb the balance.

2. In a duplex system of wireless communication, an antenna system, transmitting and receiving systems associated therewith, and differential balancing means for normally balancing the effects of the transmitting system, and a telephone transmitter for disturbing such balance.

3. In a system of wireless communication, an antenna system including two legs, a transmitting system including an inductance, inductances in each antenna leg with which the inductance of the transmitting system is associated, a receiving system including an inductance and inductances in each antenna leg with which the receiving inductance is associated.

4. In a system of wireless communication, an antenna system including two legs, a transmitting system including an inductance, inductances in each antenna leg with which said transmitting inductance is associated, a receiving system including an inductance, inductances in each antenna leg with which the receiving inductance is associated, said associated inductances being relatively adjustable.

5. In a system of wireless communication, an antenna system including two legs, each leg including two inductance coils, a transmitting system including an inductance coil associated with one of the coils in each antenna leg, a receiving system including an inductance coil, associated with the other coil in each antenna leg, the antenna coils arranged to exert equal influence on their associated receiving or transmitting coils, and one of the said antenna coils being wound in reverse relation with respect to its associated coil.

6. In a system of wireless communication, an antenna system, a transmitting and a receiving system coupled to the antenna system, said couplings being balanced, and one of the couplings being balanced in reverse direction with reference to the other.

7. In a system of wireless communication, an antenna system having separate

current paths, a transmitting system coupled to both paths to equally influence each, and a receiving system also coupled to both paths to be equally influenced by each.

8. In a system of wireless communication, an antenna system having separate current paths, a receiving system coupled to both paths, and a transmitting system also coupled to both paths.

9. In a system of wireless communication, an antenna system having separate current paths, a receiving system coupled to both paths, and a transmitting system also coupled to both paths, one of the coupling elements in one of the said couplings being in reverse direction to the other.

In witness whereof I have hereunto set my hand this 19th day of September, 1908, in the presence of the subscribing witnesses.

LEE DE FOREST.

Witnesses:
SAMUEL E. DARBY,
FREDERICK L. RAND.