Sept. 7, 1926. 1,598,663

J. S. STONE

MULTIPLEX RADIO TELEGRAPHY AND TELEPHONY

Filed Nov. 30, 1920 3 Sheets-Sheet 1

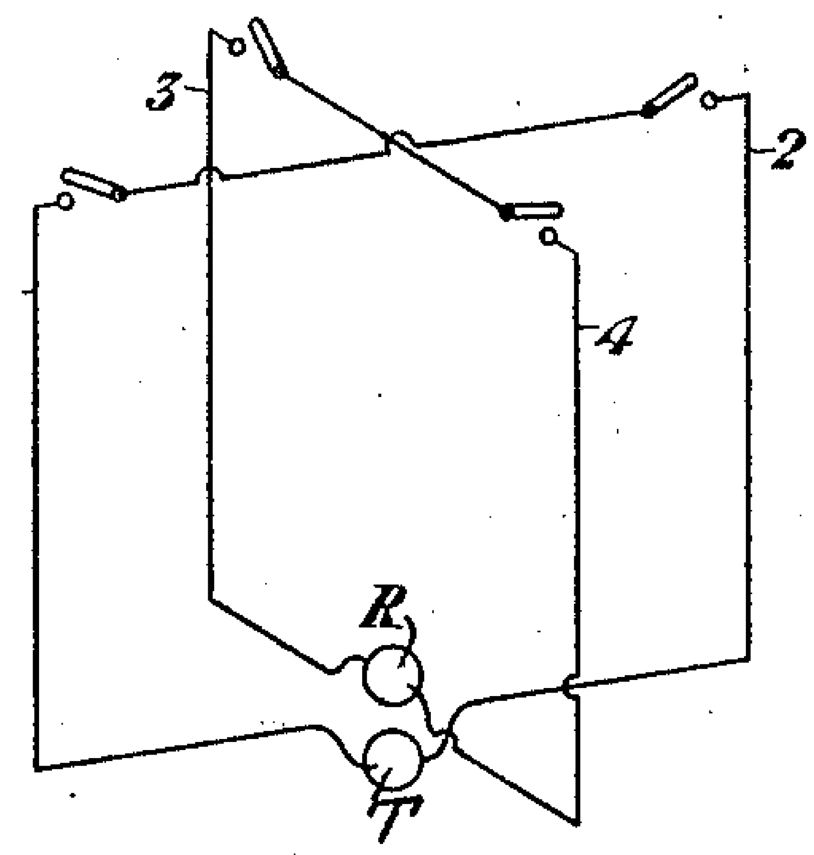

Fig. 1

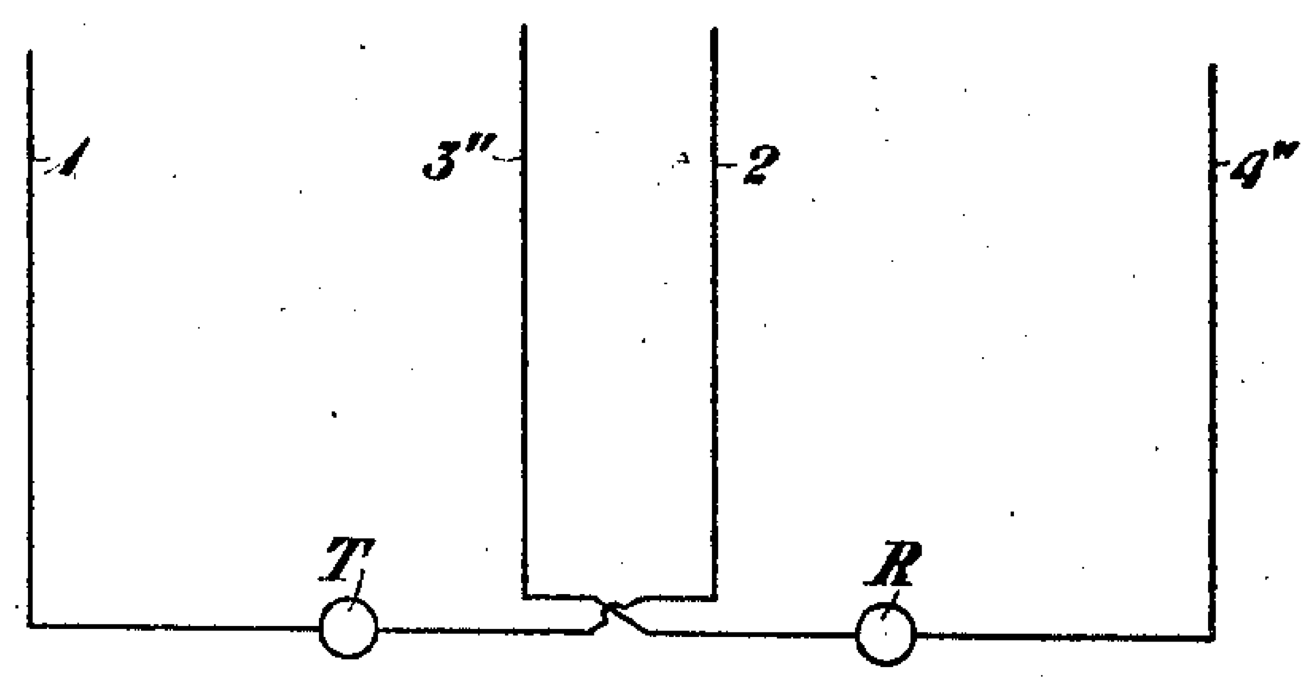

Fig. 3

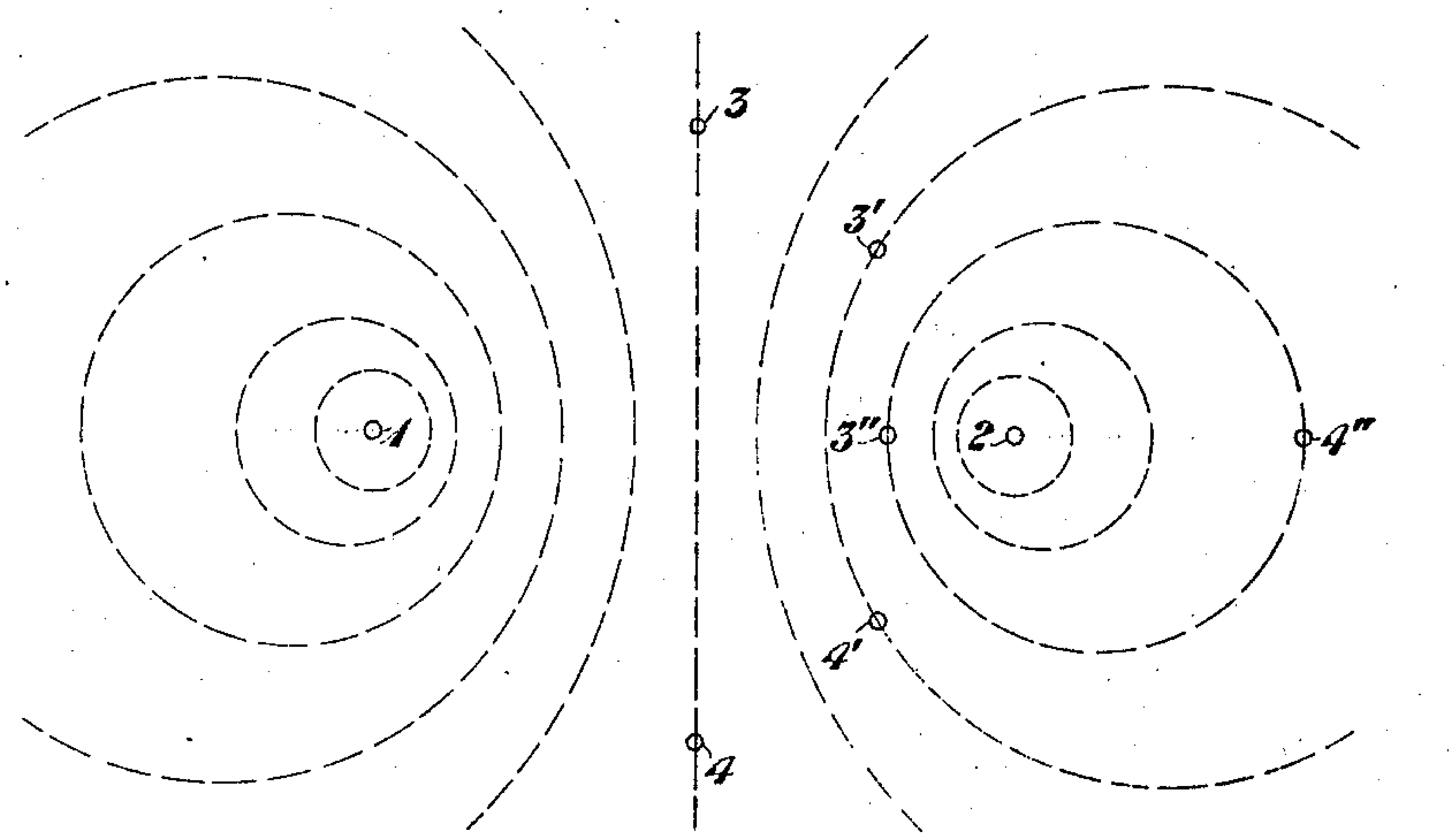

Fig. 2

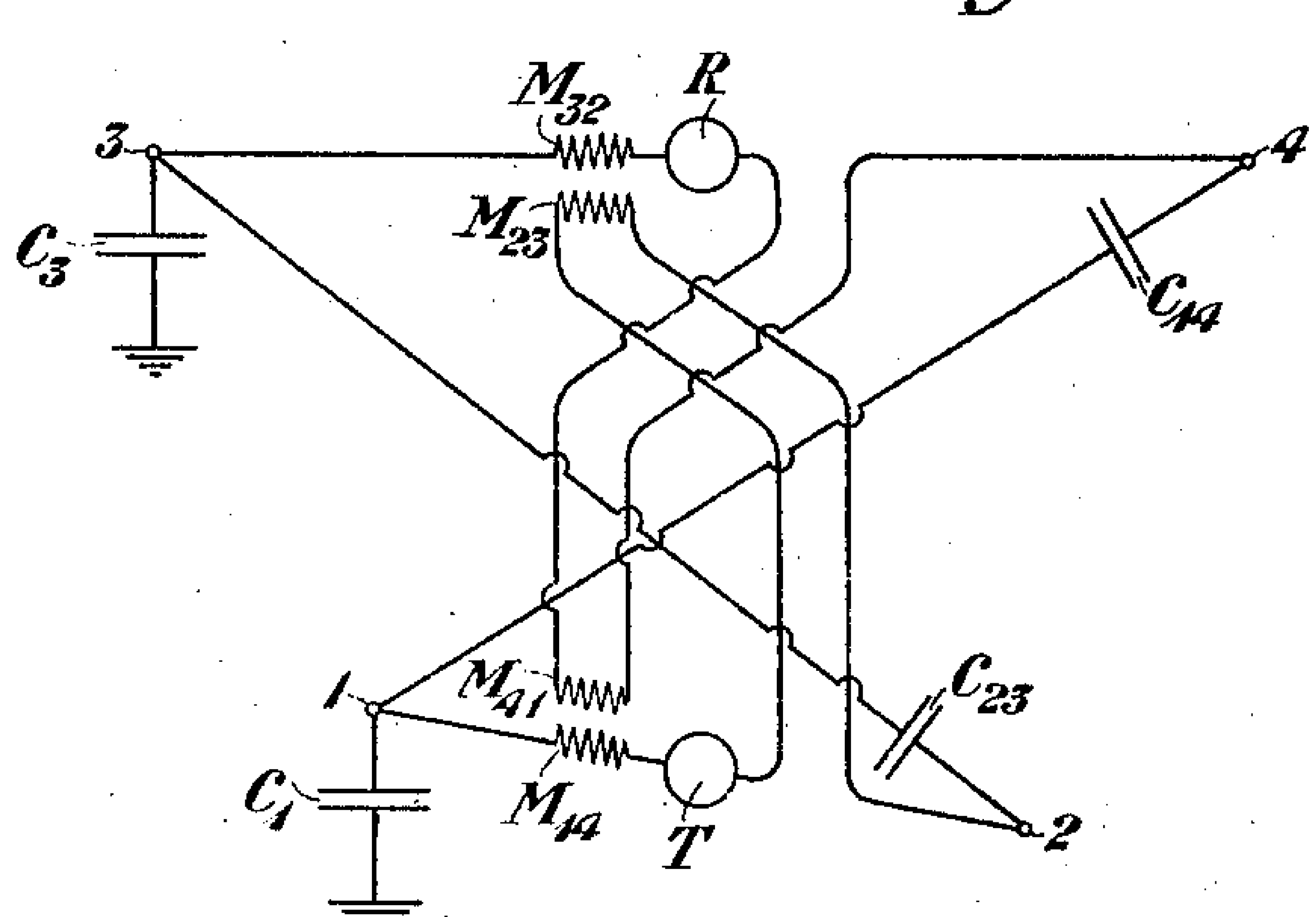

Fig. 4

INVENTOR
John Stone Stone
BY G. E. Folk
ATTORNEY

Sept. 7, 1926. | 1,598,663

J. S. STONE

MULTIPLEX RADIO TELEGRAPHY AND TELEPHONY

Filed Nov. 30, 1920 | 3 Sheets-Sheet 2

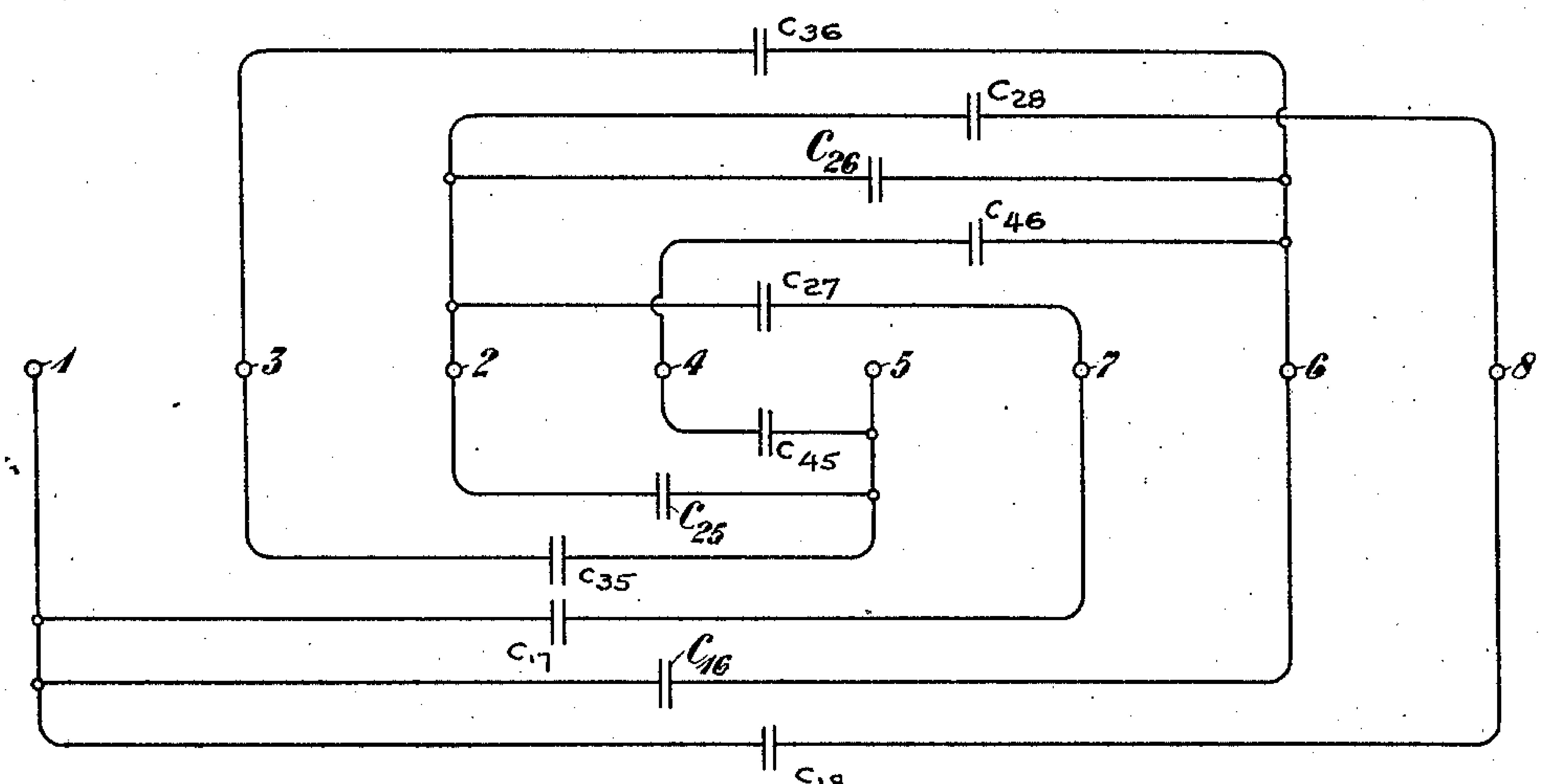

Fig. 5

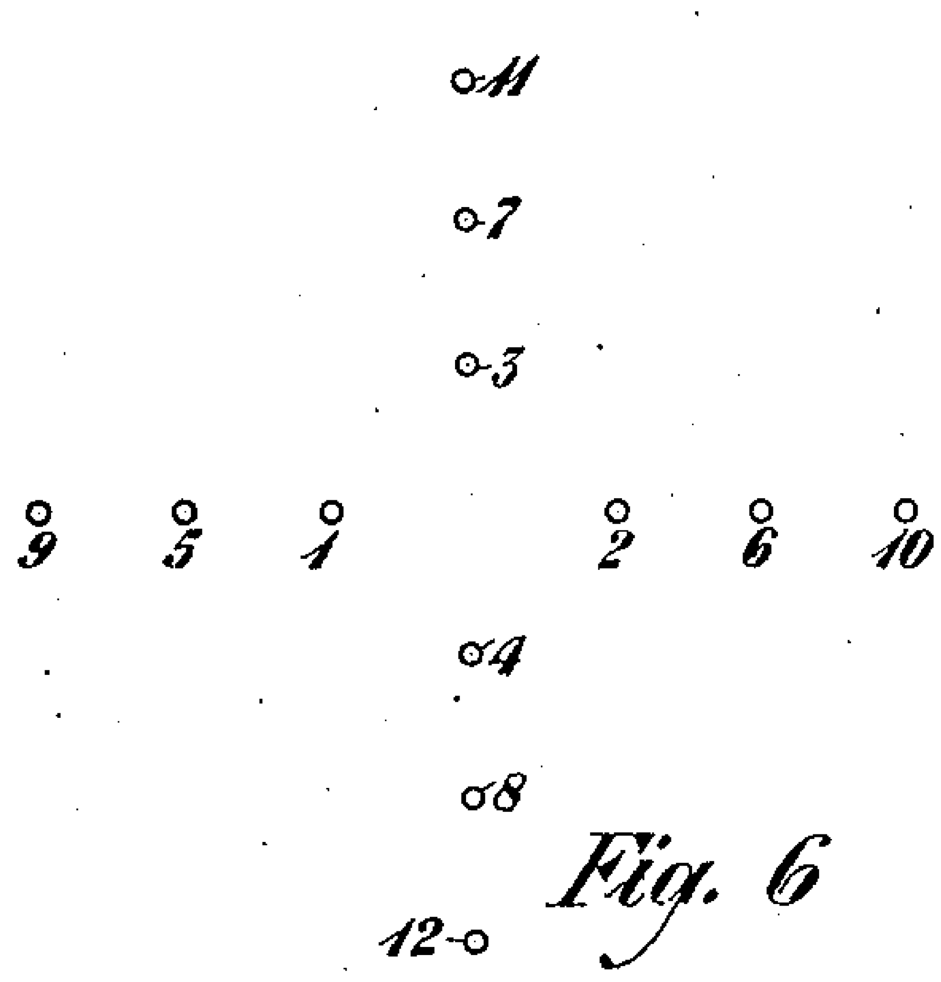

Fig. 6

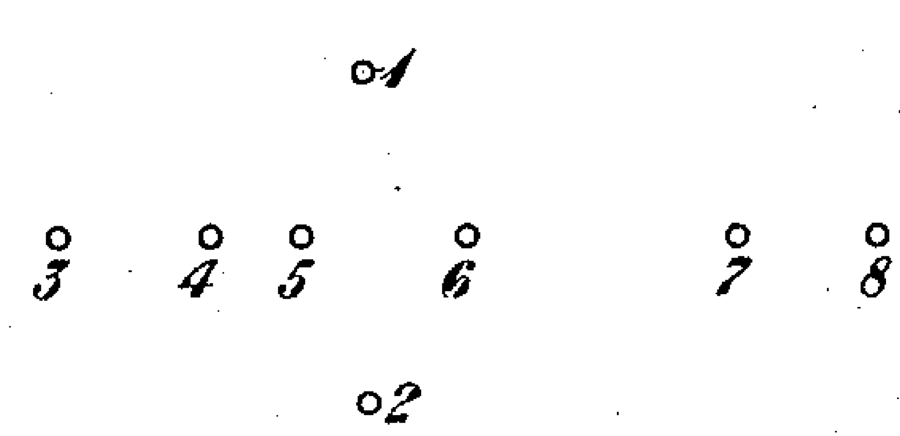

Fig. 7

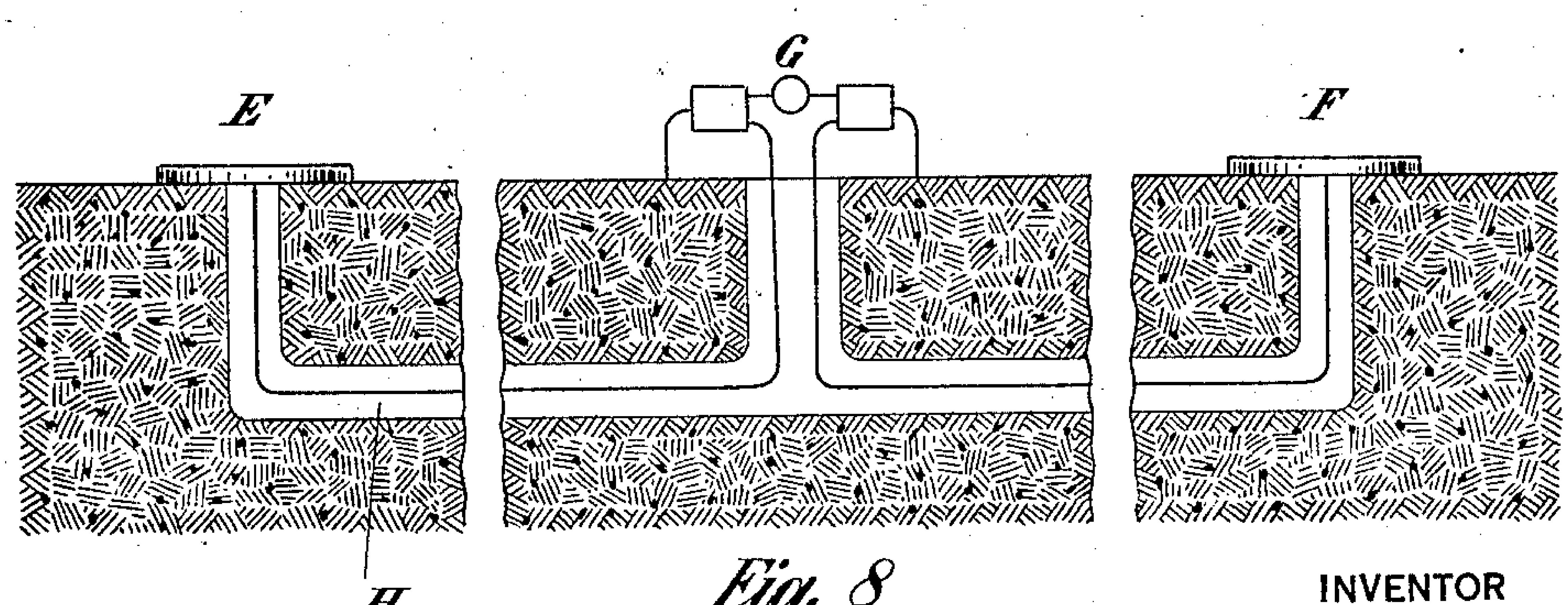

Fig. 8

INVENTOR
John Stone Stone
BY G. E. Folk
ATTORNEY

Sept. 7, 1926. **1,598,663**

J. S. STONE

MULTIPLEX RADIO TELEGRAPHY AND TELEPHONY

Filed Nov. 30, 1920 3 Sheets-Sheet 3

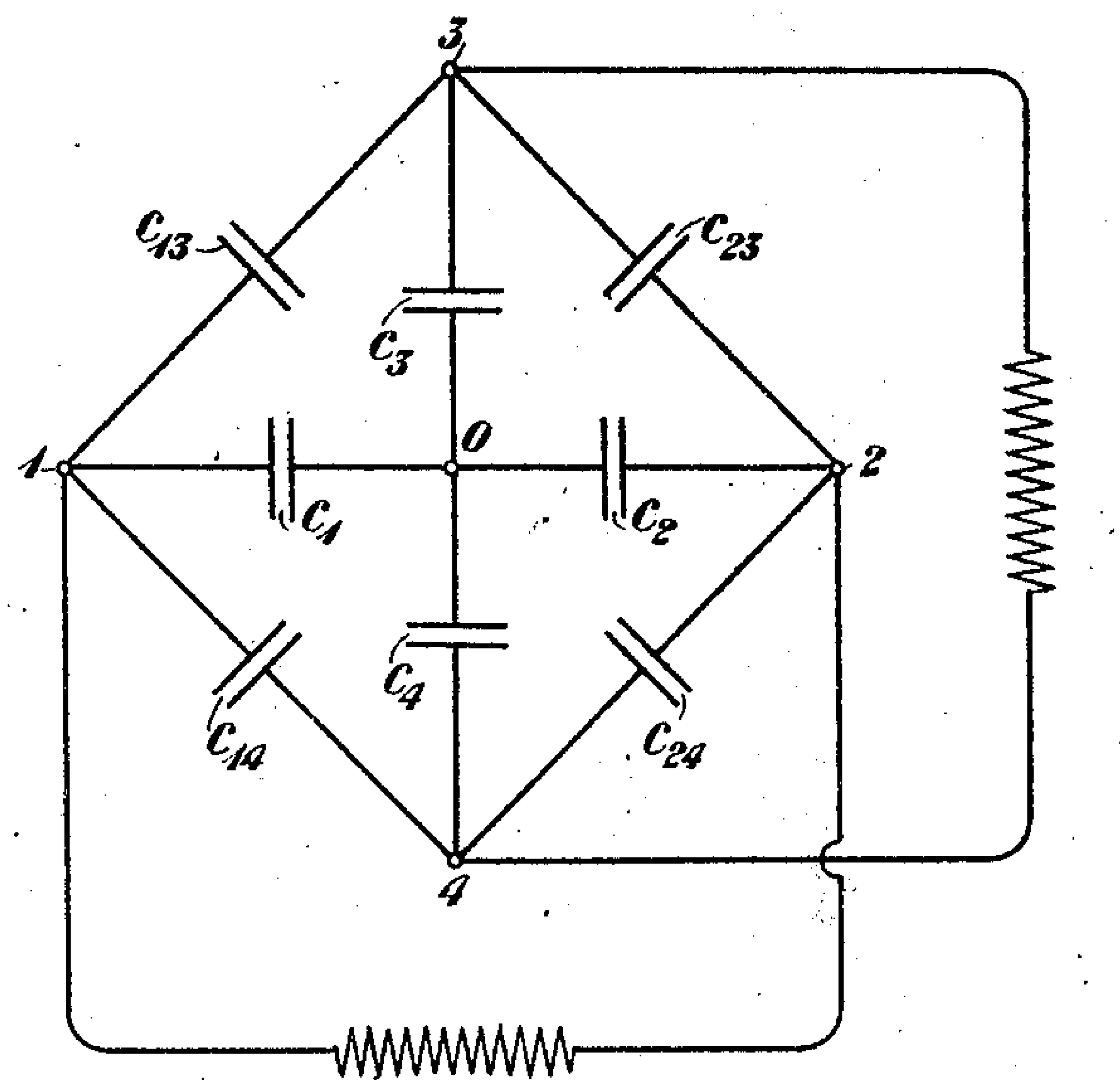

Fig. 9

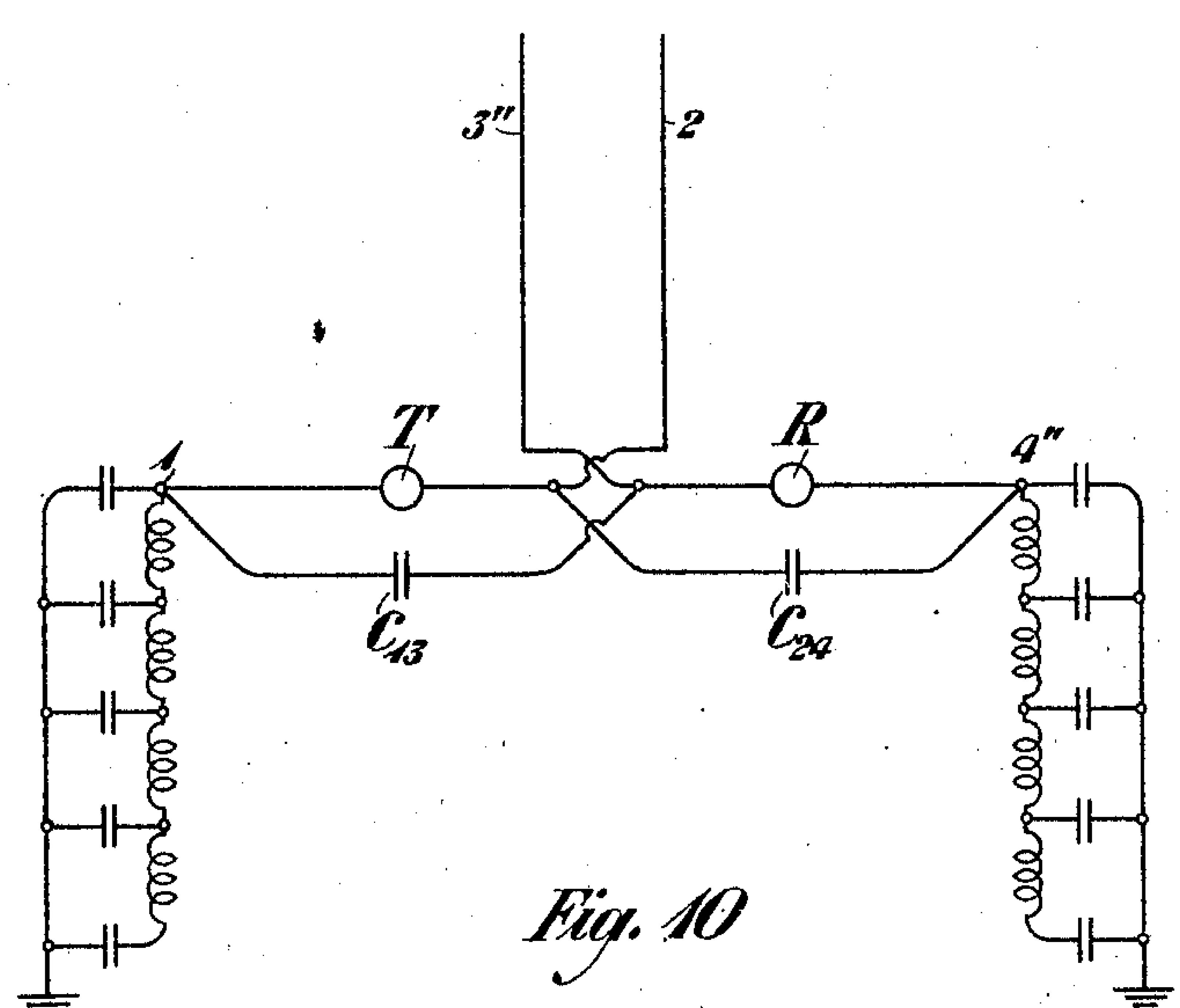

Fig. 10

Inventor
John Stone Stone

By Attorney G. E. Folk

Patented Sept. 7, 1926. **1,598,663**

UNITED STATES PATENT OFFICE.

JOHN STONE STONE, OF SAN DIEGO, CALIFORNIA, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MULTIPLEX RADIO TELEGRAPHY AND TELEPHONY.

Application filed November 30, 1920. Serial No. 427,391.

The principle object of my invention is to provide new and improved apparatus by which a number of messages may be transmitted or received simultaneously at a single station by radio telegraphy or telephony. Another object of my invention is to provide a plurality of pairs of balanced antennæ or equivalent structures at a station, so positioned and adjusted that each pair may be conjugate to certain other pairs, and thus facilitate the simultaneous transmission and reception of messages. These and various other objects of my invention will become apparent upon consideration of the following disclosure. The invention is defined in the appended claims, and a few specific embodiments are described in the following specification.

Referring to the drawings, Figure 1 is a perspective diagram showing two conjugate pairs of antennæ, one for transmitting, the other for receiving. Fig. 2 is a plan diagram that will be referred to in explaining Fig. 1 and other figures. Fig. 3 is an elevation showing another arrangement of two pairs of antennæ. Fig. 4 is a plan diagram showing two pairs of antennæ that are made conjugate by adjusting with coils and condensers. Fig. 5 is a plan diagram showing how a plurality of pairs of transmitting antennæ and pairs of receiving antennæ may be made conjugate by adjustment with condensers. Fig. 6 is a plan diagram showing a space arrangement of more than two pairs of antennæ to secure the desired conjugate relationship. Fig. 7 is a plan diagram showing a space arrangement that makes one pair of transmitting antennæ conjugate to each of a plurality of pairs of receiving antennæ. Fig. 8 illustrates an earth conduction system that may be employed instead of a pair of aerial structures. Fig. 9 is a diagram that will be referred in explaining the theory of one form of my invention and Fig. 10 illustrates a modification to which reference will be made.

In Fig. 1 the two transmitting antennæ 1 and 2 are balanced against each other, that is, the transmitter T excites them equally and in opposite phase relation. In the equatorial plane of the transmitting antennæ 1 and 2 stand the two receiving antennæ 3 and 4 balanced against each other through the receiver R. The dotted lines in Fig. 2 represent equipotential surfaces around the respective transmitting antennæ 1 and 2. At different times a particular line may represent different potentials, positive or negative; but any two points on the same line will always be at the same potential, whatever that may be. If 1 and 2 are transmitting antennæ excited equally and in opposite phase relation, and if two other antennæ, 3 and 4, are placed on the mid-normal to the line joining 1 and 2 and balanced against each other, no current will be excited in them by the transmission from the antennæ 1 and 2. This is the case shown in perspective diagram in Fig. 1.

But it is not necessary that the receiving antennæ shall be limited to the equatorial plane; for, if they are balanced against each other, they may stand in other convenient relations as 3′ and 4′ or, for example all four antennæ 1, 2, 3″, 4″ may stand in the same vertical plane, and this special case is shown in elevation in Fig. 3. The necessary conditions to be satisfied will be stated presently.

In Figs. 1 and 3, I have shown the antennæ open at their upper ends; but they may be closed across to form loops if desired, as indicated, for example in Fig. 1, where the switches may be thrown down to complete the loops.

As a convenient notation for the discussion that follows, I shall let the lower case letters c and m refer to the resultant capacities and inductances of the aerials whether or not supplemented or modified by added coils and condensers; and I shall use upper case letters C and M for condensers and coils added to the system for purposes of adjustment. Thus the c's and m's include the C's and M's. The positions given the antennæ in Fig. 1 are such that $c_{13}=c_{23}=c_{14}=c_{24}$; where c_{13} represents the capacity between the two aerials 1 and 3 measured against each other, and similarly for the other c's. Also these arrangements satisfy the conditions $m_{13}=m_{23}=m_{14}=m_{24}$ where the m's represent mutual inductances between the respective antennæ indicated by the associated sub-scripts. Furthermore, it is assumed in Fig. 1 that the four antennæ are physically alike and equal, so that the conditions $c_1=c_2$ and $c_3=c_4$ will be satisfied, where these c's represent the respective capacities of the aerials to ground.

When the aerial conductors are openended, the balancing of the mutual capacities of the transmitter and receiver systems is the most important, but when they are in the form of closed loops, as will be the case when the switches are closed in Fig. 1, the balancing of the mutual inductances of these systems becomes the most important.

In Fig. 4 I have represented a pair of balanced transmitting antennæ, 1 and 2, and a pair of balanced receiving antennæ, 3 and 4. These are assumed to be positioned so that neither pair will be found standing on a normal to the line joining the other pair; hence an adjustment or correction by means of condensers or coils, or both, will be necessary to secure the proper balance and conjugate relation. Moreover, it may be assumed in Fig. 4 that the antennæ are not physically alike. One may be taller than another, or have a different overhead structure from another; and such differences will require adjustment with condensers or coils, or both, to secure the proper balance and conjugate relation. If the antennæ of Fig. 4 were all equal, and if the conjugate relation were secured by positioning them, the equations among the c's and m's previously written out would be satisfied; but since in the system of Fig. 4 these conditions are assumed not to exist, the discrepancies must be compensated for, and the balance and conjugate relationship secured by the addition of suitable condensers and coils, as indicated in the diagram.

It is assumed, to make the illustration definite, that aerials 1 and 3 have somewhat less capacities to ground than 2 and 4, and therefore suitable correction is made by adding the condensers C_1 and C_3 so as to make $c_1=c_2$ and $c_3=c_4$ where as previously explained, the lower case c's are resultant values. The capacities of the two condensers C_{14} and C_{23} are made such as to compensate for the greater proximity of conductors 1 to 3 and 2 to 4, compared to that of conductors 1 to 4 and 2 to 3, respectively. Similarly, the mutual inductances of the two transformers M_{14}, M_{41} and M_{23}, M_{32} are made such as to compensate for the greater proximity of the conductors 1 to 3 and 2 to 4, respectively, compared to that of 1 to 4 and 2 to 3.

From the foregoing discussion of Fig. 4, it will be seen that the balancing of the transmitter and receiver systems, as well as the establishment of the conjugate relation between them, may be secured by the proper addition of coils and condensers, and that this may be done in general, no matter what are the constants of the aerial conductors, and no matter what is the space relation between them. Fig. 9 is a diagram illustrating another form of connection for the 4 aerials which constitute the aerial system. The branches 12 and 34 may be most conveniently made conjugate by the relation we have already given of $c_{13}=c_{23}=c_{14}=c_{24}$ when $c_1=c_2$ and $c_3=c_4$. But when it is only necessary to prevent currents developed in the branch 12 from affecting the branch 34, then it suffices to establish the relations $c_{13}=c_{23}$ and $c_{14}=c_{24}$. The case of Fig. 3 is now seen to be a special case under Fig. 4.

Thus far I have considered only two conjugate systems, a transmitting pair and a receiving pair, but I will now proceed to show how a larger number of pairs of antennæ may be balanced and rendered conjugate for multiplex transmission and receiving of messages.

In Fig. 5 it is assumed that the transmitting pair 1, 2 and the receiving pair 3, 4 are respectively balanced and made conjugate, either by being suitably positioned or by a supplemental adjustment as indicated in the foregoing discussion. It is also assumed that the transmitting pair 5, 6 and the receiving pair 7, 8 are respectively balanced and made conjugate in the same way. It remains to discuss the relations that must be sustained between the elements 1, 2, 3 and 4 on the one hand and 5, 6, 7 and 8 on the other hand to get the necessary conjugate relationship for simultaneous operation.

In general, to render any one of the receivers immune from interference by any one of the transmitters requires the conditions to be established that

$$c_{pq}=c_{rq} \text{ and } c_{ps}=c_{rs} \quad (1)$$

where p and r represent the two aerials of a transmitting pair, q and s represent the two aerials of a receiving pair, and c_{pq} represents the capacity between the aerials p and q, and similarly for the other c's with their subscripts. Furthermore, to render any two pairs absolutely conjugate so that either may be used as transmitter while the other is used as receiver may be effected advantageously by making

$$c_{pq}=c_{rq}=c_{ps}=c_{rs} \quad (2)$$

Exemplifying the general equations (1) in connection with Fig. 5, we must make $c_{17}=c_{27}$ and $c_{18}=c_{28}$. This will make the receiver 7—8 immune to the transmitter 1—2. In order to make the reeciver 3—4 immune to the transmitter 5—6, the special cases of equations (1) must be satisfied as follows: $c_{35}=c_{45}$ and $c_{36}=c_{46}$. The condensers shown in Fig. 5 without reference characters are provided so that these four equations may be established by giving those condensers the proper capacity values.

In general, it will not be necessary to make the receiver systems (such as 3—4 and 7—8 in Fig. 5) conjugate with each other. They will be tuned differently and, therefore, they can receive simultaneously without interference. Neither will it always be necessary to make the transmitter systems conjugate with each other. But if it is deemed necessary, this can be accomplished by giving suitable values to the condensers designated C_{26}, C_{25} and C_{16} in Fig. 5. Whatever the capacity between aerials 1 and 5, which we represent as c_{15}, the condensers just mentioned can be given suitable values to satisfy the equations $c_{15}=c_{16}$ and $c_{25}=c_{26}$. Since it will usually be unnecessary to make the transmitter systems conjugate with each other, these last equations will not need to be satisfied except in special cases and the system of Fig. 5 will usually require only that the conditions indicated by equations (1) shall be satisfied.

Although I have explained in connection with Fig. 5 how suitable adjustment and correction may be made for a quadruplex system, it will be evident that by similar methods the capacity of the station can be increased for multiplex work of higher order. Thus another pair of transmitting aerials 9, 10 and another pair of receiving aerials 11, 12 might be added to the system of Fig. 5, in which case the conditions given in equations (1) and (2) would still be applicable.

As in the simpler cases given, it is not necessary in general to establish the conjugate relation between a transmitter and another transmitter, nor between a receiver and another receiver, it will generally only be necessary to establish the relations indicated by the equations (1). By extending this same method, any number of transmitters and receivers may be grouped at a given station.

In Fig. 5 I have shown how more than one transmitting pair and one receiving pair may be assembled at a station by the introduction of adjusting elements to establish a proper conjugate relationship. The same object can be attained by positioning the antennæ properly, as shown in the diagram of Fig. 6. Here the transmitters 1, 2; 5, 6; and 9, 10 are each in conjugate relationship with each of the receiving pairs 3, 4; 7, 8; 11, 12 by virtue of a space relation. In this case all the transmitters are disposed in one vertical plane having a common equatorial plane, and all the receivers are disposed in this common equatorial plane and vice versa, thus the desired conjugate relationship between any transmitter and any receiver is secured.

In Fig. 7 a single transmitting pair 1, 2 is shown with a plurality of receiving pairs 3, 4; 5, 6; 7, 8, all in the equatorial plane of the transmitter. Thus three messages might be received simultaneously by the three receivers without interference from the one transmitter.

In a set of antennæ such as here disclosed, it may be desirable and practicable to replace one or more of them by an artificial aerial or a plurality of such aerials. Fig. 10 illustrates a modification of Fig. 3, in which two of the four aerials of Fig. 3 have been replaced by artificial aerials.

By the term antenna in the following claims I include any equivalent structure. Thus a pair of aerials may be replaced by an earth conduction system as illustrated in Fig. 8, where E and F are two conductive plates connected by conductors laid in the subterranean conduit H. These conductors lead through the transmitting or receiving apparatus G.

What I claim is:—

1. A radio transmitting and receiving station having a plurality of pairs of balanced transmitting antennæ and a plurality of pairs of balanced receiving antennæ, each transmitting pair being conjugate with each receiving pair.

2. A radio transmitting and receiving station having a plurality of pairs of balanced transmitting antennæ and a plurality of pairs of balanced receiving antennæ, and current influencing elements interposed between the antennæ to secure adjustment thereof to make each transmitting pair conjugate to each receiving pair.

3. A radio transmitting and receiving station having a pair of balanced transmitting antennæ and a pair of balanced receiving antennæ, said antennæ being not all equal, nor equidistant from the members of the other pair, and connections from one pair to the other comprising coils and condensers to perfect the balance between them and to make each pair conjugate to the other pair.

4. A multiplex radio transmitting and receiving station having transmitting pairs of antennæ and receiving pairs spaced apart, and coils and condensers interconnecting certain members of the pairs, the members of each pair being balanced against each other, each transmitting pair being made conjugate with each receiving pair by means of said coils and condensers.

5. A multiplex radio transmitting and receiving station having transmitting pairs of antennæ and receiving pairs spaced apart, and coils and condensers interconnecting certain members of the pairs, the members of each pair being balanced against each other, each transmitting pair being made conjugate with each receiving pair by means of said coils and condensers and each transmitting pair being made conjugate to each other transmitting pair by means of said coils and condensers.

In testimony whereof, I have signed my name to this specification this 18th day of November 1920.

JOHN STONE STONE.