Dec. 16, 1941. H. HOOVER, JR 2,266,041

GEOPHYSICAL PROSPECTING RECEPTOR CIRCUITS

Filed April 18, 1938 2 Sheets-Sheet 1

Fig. 1

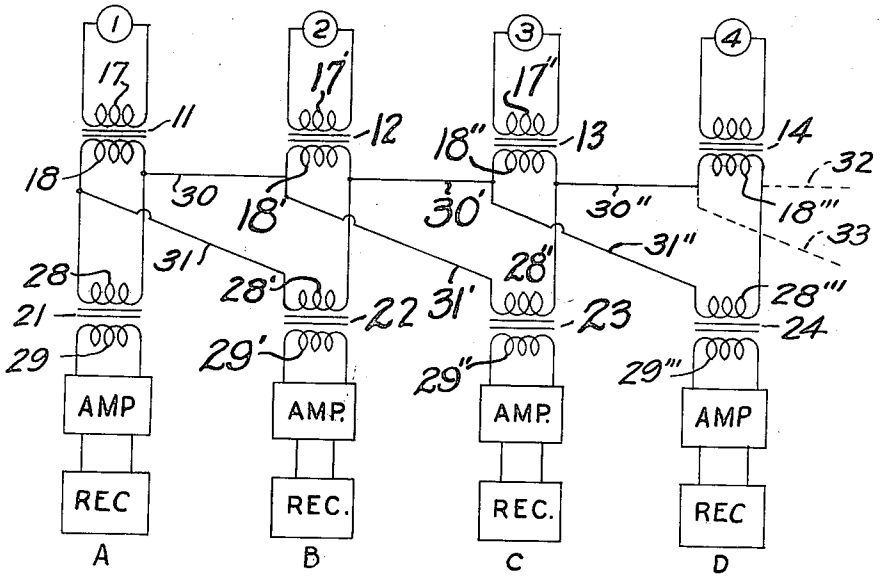
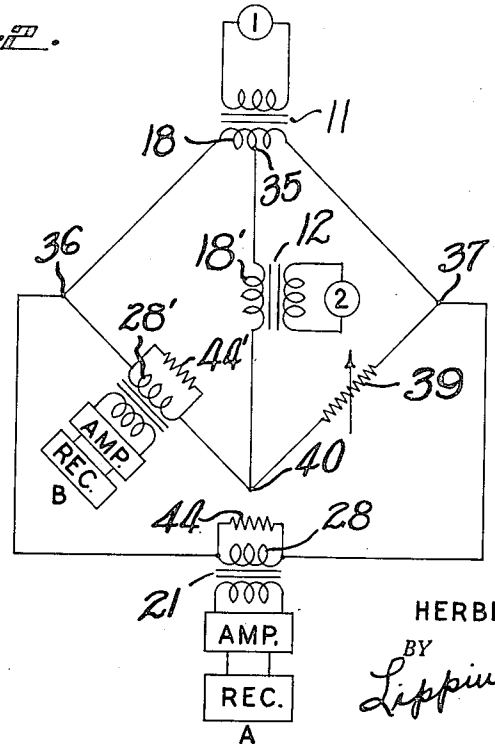


Fig. 2.



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Filed April 18, 1938 2 Sheets-Sheet 2

Fig. 3.

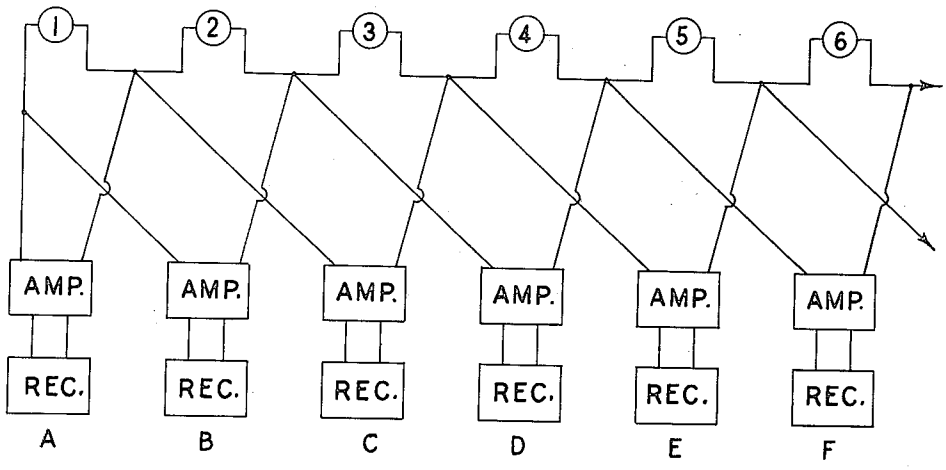
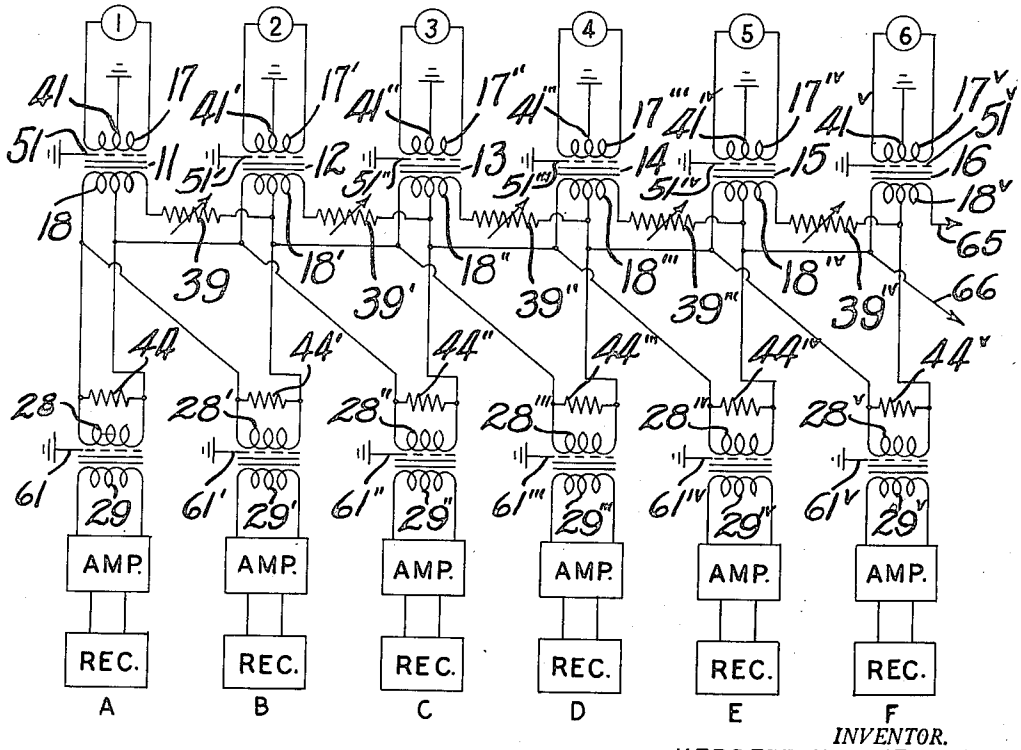


Fig. 4.



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UNITED STATES PATENT OFFICE

2,266,041

GEOPHYSICAL PROSPECTING RECEPTOR CIRCUITS

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Application April 18, 1938, Serial No. 202,752

19 Claims. (Cl. 177—352)

My invention relates to geophysical prospecting, and particularly to circuits having improved means for minimizing unwanted cross-feed when a plurality of pickup and amplifying circuits are used.

Among the objects of my invention are:

To provide geophysical prospecting receptor circuits in which a plurality of receptor units may be interconnected without undesired cross-feed due to such interconnection.

To provide receptor circuits which may be cross-connected, and in which cross-feed may be controlled exactly.

To provide means for utilizing a plurality of pickup and amplifying units simultaneously and permitting a controlled amount of cross-feed therebetween.

To provide receptor circuits into which signal components from several separate seismometers may be introduced in desired proportions.

To provide such circuits in which the different signal components may be controlled as to both phase and amplitude.

To provide means for introducing to each of a number of amplifier units signal components, controlled as to both phase and amplitude, from separate seismometers, and at the same time eliminating stray pickup and unwanted cross-feed.

To provide means for controlling cross-feed between several amplifiers used in conjunction with a number of seismometer units.

To provide means for controlling cross-feed between a plurality of seismometer and amplifier circuits with respect to phase and amplitude.

To provide balanced circuits of the Wheatstone's bridge type for such use.

To provide balanced bridge circuits in which undesired circuits components may oppose and cancel each other.

To provide such receptor circuits in a form having a high degree of flexibility.

My invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing my novel method. It is therefore to be understood that my method is applicable to other apparatus, and that I do not limit myself, in any way, to the apparatus of the present application, as I may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

The way in which these objects may be attained may be better understood with the aid of the drawings, wherein

Fig. 1 shows a simple method of cross-connecting two seismometer and amplifier units.

Fig. 2 shows schematically one form of my bridge circuit arrangement.

Fig. 3 illustrates a method of interconnecting a plurality of seismometer and amplifying units.

Fig. 4 shows means for controlling cross-feed in a circuit of the type of Fig. 3.

The most important geophysical prospecting method, as is well known in the art, consists in exploding dynamite at or near the surface of the ground and recording the vibration set up thereby in the earth. The waves received include some passing directly from the explosion point to the receiving apparatus, and some which have been reflected back toward the surface from various strata therebeneath. By proper interpretation of the record, it is possible to map the underlying formations with great accuracy, and derive very important information as to the location of valuable deposits. Particular success has been achieved by these means in connection with very deep oil fields.

In mapping a field by the seismic method, a number of seismometers are placed at strategic points on the earth's surface, a charge is exploded, and prior to recording, the signals picked up by the seismometers are strengthened by vacuum tube amplifiers of conventional type. The original method was to have one seismometer individually connected to each amplifier. Each amplifier in turn actuated a galvanometer element or other recording device. The final record, therefore, was a separate reproduction of each seismometer individually.

An improvement was outlined in Taylor Patent No. 1,799,398 where two or more seismometers were used on each amplifier and galvanometer. Each galvanometer, according to this patent, recorded the algebraic sum of the voltages generated by all the seismomoters attached to that particular amplifier.

Still another improvement was outlined in North Patent No. 2,059,018. One common method of using this patent in actual practice is to connect part or all of seismometers in series. The inputs to the individual amplifiers are taken off across groups of the seismometers, in such a way that one or more seismometers may be common to two or more amplifiers. One example of the almost infinite number of possible circuits is shown in Figure 3. This is generally termed "over-lapping" or "mixing."

The systems such as shown in Figure 3 are subject to considerable unwanted cross-feed and stray pickup, which may be reduced by inserting isolation transformers in the circuits, as disclosed in my co-pending application for United States Letters Patent, Serial No. 164,100, filed September 16, 1937, and entitled "Geophysical prospecting receptor circuits."

The elementary circuits involved may be seen in simplified form in Figure 1. In this connection it should be understood that any desired number of additional seismometer and amplifying units may be added, each connected to its predecessor as indicated by the dotted lines.

In Figure 1, 1, 2, 3, and 4 are seismometer units, A, B, C, and D being the amplifying and recording units pertinent thereto. The amplifying and recording units A, B, C and D have impedance-matching transformers 21, 22, 23 and 24 connected to their respective inputs. The amplifying and recording unit A is inductively linked to the corresponding seismometer 1 through an isolation transformer 11 and an impedance matching transformer 21. The isolation transformer 11 has a primary 17 and a secondary 18. The impedance matching transformer 21 has a primary 28, and a secondary 29.

Seismometer 1 is connected to isolation transformer primary 17, isolation transformer secondary 18 is connected to impedance matching transformer primary 28, and the impedance matching transformer secondary 29 is connected to the amplifying and recording unit A.

Similarly, the seismometers 2, 3 and 4 are connected to the corresponding amplifying and recording units B, C and D through corresponding isolation transformers 12, 13 and 14. The secondary 18' is connected to the primary of the impedance matching transformer 22 in series with the secondary of isolation transformer 11 through leads 30 and 31. The secondary 18'' of transformer 13 is connected with the primary of impedance matching transformer 23 in series with the secondary 18' of isolation transformer 12 through leads 30' and 31'. The secondary 18''' of transformer 14 is connected to the primary of impedance matching transformer 24 in series with the secondary 18'' of isolation transformer 13 through leads 30'' and 31''. If another pickup and recording group is desired, connection would be made as indicated by the dotted lines 32 and 33, corresponding to leads 30 and 31, etc., shown, the method being capable of indefinite expansion. It is also sometimes desirable to ground the midpoint of the isolation transformer primaries, and to use an electrostatic shield in both the isolation transformers and matching transformers, the shield being grounded. These additions are omitted from Figure 1 for clarity, and are shown and discussed further in connection with Figure 4 later.

It is apparent that in Figure 3, it is intended that amplifier and recorder A shall receive only the output of seismometer 1; that B shall receive substantially equal outputs from 1 and 2; that C shall receive substantially equal outputs from 2 and 3; that D shall receive substantially equal outputs from 3 and 4; and so on for other channels similarly connected to the foregoing.

Several advantageous effects are claimed for this and similar arrangements, namely that each seismometer is in effect used more than once, and that therefore more efficient use is obtained from a given number of them; that some out-of-phase cancellation (as outlined in the Taylor patent) of unwanted surface waves is obtained; and that incoming reflections tend to line up better due to the fact that each recorded trace represents an overlapped average of one or more adjacent traces. Briefly stated, the effect is to introduce a definite and controlled amount of cross-feed.

A critical analysis of the circuits, however, will show that, for instance, channel D will not only receive energy from seismometers 3 and 4 (the desired condition), but in practice will receive appreciable energy from seismometers considerably removed from those to which the effect should be confined. This shows up as apparent unwanted cross-feed between channels. The effect is particularly serious because the unwanted cross-feed is often 180° out-of-phase with the desired cross-feed.

To demonstrate this point, assume that an impulse is received on seismometer 3 in the circuit of Figure 1. The impulse will appear in the secondary 18'' of the corresponding isolation transformer and from there find its way to the primaries of the matching transformers associated with recording units C and D; thence being amplified and recorded by channels C and D in substantially equal strength. This is the desired condition, and represents what is generally called "50% overlap."

A further analysis of the circuit, however, shows that the impulse will also find its way into some, or all, of the other channels in varying amounts. Though usually this unwanted cross-feed signal to other traces is substantially less than to the desired traces, nevertheless it is often of such magnitude and relative phase as to seriously interfere with the desired results.

Take the above example of an impulse from seismometer 3. The impulse appears in the secondary of the associated isolation transformer. In order to get to the primary of the matching transformer 23 and thence to the amplifier C, it is necessary that it also pass through the secondary 18' of the isolation transformer 12, the primary of which is connected to seismometer 3. This means that the impulse is common to the circuit including the secondaries of the isolation transformers associated with seismometers 1 and 2 and the primary of the matching transformer associated with unit B and will therefore appear in amplifier B and be recorded by that trace.

The amplitude appearing in B will be somewhat less than in C and D, but nevertheless will be appreciable. It is also important to note that while the phase of the signal in C and D will be the same, and the recordings will appear to be similar, that nevertheless the unwanted cross-feed in channel 2 will be 180° out-of-phase, and will appear upside down on the recording, and may seriously interfere with any impulses received by seismometer 3 and transmitted to channel B at approximately the same time.

By similar analysis it can be shown that appreciable (although diminished) unwanted cross-feed will appear in channel A, and that it also will be 180° out-of-phase with the impulses recorded in C and D. By carrying the analysis even further, it can be shown that unwanted cross-feed, in constantly diminishing amounts, will be experienced in channels at a considerable distance on each side, and that the phase is reversed by essentially 180° each time that it passes from one circuit to the next.

One method of reducing the above type of cross-feed has been to make the input impedances of the amplifiers, represented in Figure 1 by the

primaries 28—28', etc., of transformers 21, 22, etc., as high as possible, either for the direct purpose of eliminating cross-feed, or incidental to other purposes such as control of volume. In the examples cited above where the impulse was introduced through seismometer 3, this would reduce the amount of voltage drop across the secondaries of the adjacent isolation transformers, and thus reduce the amount of unwanted cross-feed starting into the adjacent channels. It is often not convenient to carry this practice beyond a certain point, however, because of the difficulties in getting an efficient voltage transfer into the amplifiers, and for other reasons, such as the stray coupling of high impedance windings, connecting leads, etc.

Another specific method previously used is to employ transformers having high impedance secondaries suitable for working directly into the grid of an amplifier tube. The mixing or overlapping may then be affected directly in series with the grid circuit of the amplifier, and because of the high load impedance reflected by the grid, very little cross-feed will result. Still other methods use separate tubes in the amplifier for each circuit to be mixed, the plates of these tubes being connected substantially in parallel. Most of these systems, however, are relatively inflexible, and flexible switch arrangements are difficult to obtain from them.

The method proposed here is to make each of the circuits a Wheatstone bridge type network. In Figure 1, neglecting now the dotted lines 32 and 33, there is overlap introduced between the two channels according to conventional practice. Assume it is desired to have channel A respond only to seismometer 1, and channel B respond to both seismometers 1 and 2. As shown in the previous analysis, some unwanted cross-feed from seismometer 2 will be recorded on channel A, and it will be 180° out-of-phase with that recorded on channel B. The desirable condition is to eliminate unwanted cross-feed altogether, or under some conditions possibly to deliberately introduce some cross-feed in phase. For this purpose, I have developed a modification of a Wheatstone bridge circuit. There are several configurations able to give the desired results, one of which is shown schematically in Figure 2, which derives from Figure 1.

In Figure 2, the secondary 18 of isolation transformer 11 has a center tap 35, and end terminals 36 and 37 to which is joined the primary 28 of matching transformer 21.

Between terminals 36 and 37 there is also a current path through the primary 28' of matching transformer 22 and a variable resistor 39 connected in series therewith between the said terminals. Across center tap 35 on secondary 18 of transformer 11 and a point 40 common to resistor 39 and primary 28', I connect the secondary 18' of isolation transformer 12. There are also connected in the circuit two fixed resistors, 44, across the primary 28 of matching transformer 21, and 44' across the primary 28' of matching transformer 22.

It will be seen that the circuit of Figure 2 is of the Wheatstone's bridge type, with the segment of transformer secondary 18 lying between terminals 35 and 36, together with matching transformer primary 28' and its shunt resistance 44', forming one branch, and the transformer segment lying between terminals 35 and 37 forming, together with variable resistor 39, the opposed branch.

The conjugate arms are formed between terminals 35 and 40 by secondary 18', and between terminals 36 and 37 by primary 28 and its shunt resistor 44.

It will be obvious to those skilled in the art that proper variation of the resistor 39 will so balance the bridge that the component received by the amplifying and recording unit A from seismometer 2 is substantially zero, inasmuch as the voltage drop between terminals 35 and 40 is the same through either terminal 36 or 37.

Although resistor 39 may be pure resistance, the transformer windings 28 and 28' have considerable reactance, and it is to render this reactance component less effective that resistors 44 and 44' are used. It is to be understood, of course, that resistor 39 may be any other type of impedance such as an inductance or other balancing impedance. Thus a more nearly perfect impedance balance may be obtained.

By adjustment of resistor 39, it is also possible to unbalance the bridge so that a desired and controlled amount of cross-feed is obtained from seismometer 2 to recorder A, and by properly proportioning the fixed shunts 44 and 44' it is possible to exercise phase control as well, so that signals from a number of seismometer units may be introduced in phase or phase opposition as desired, and the component from each which enters a particular recorder may be exactly predetermined.

In Fig. 2 a current due to seismometer 2 produced in secondary 18' of transformer 12 flows upward to center tap 35 of secondary 18 where it is divided into two substantially equal parts, one flowing to the left and one to the right. Each of these branch currents produces equal and opposite magnetic fields in the core of transformer 11 and due to the mutual inductance of the two halves of secondary 18 the resultant potential across each half of secondary 18 is substantially zero. Transformer 11 is substantially non-inductive so far as currents from transformer 12 are concerned. This is especially true if the transformer is of the closed core type.

So far as currents from seismometer 2 are concerned the effective impedance between the midpoint 35 and either terminal of transformer 11 is therefore very small, being due almost entirely to the copper loss in the winding. The potential drop, therefore, between the midpoint 35 and either outside terminal of the secondary 18 due to waves arriving at seismometer 2 is very small compared to the potential drop across impedance 39 or the substantially equal potential drop across the parallel network comprising resistor 44' and primary 28'.

If, therefore, recorder A is disconnected from terminal 37, and this same lead from recorder A is connected to any other point of the secondary 18, such as the midpoint 35, very little current from secondary 18' will actuate recorder A. Such a shift of connection is seen in Fig. 4. This phenomenon may be regarded several ways: first of all, the potential drop from secondary 18' across any portion of the secondary 18 is very small; secondly the effective impedance of winding 18 as viewed from winding 18' practically short circuits the primary of the transformer 21; looked at still a third way, the potential that would ordinarily exist between points 35 and either 36 or 37 due to currents from secondary 18' are counteracted by appropriate induced voltages or "bucking voltages."

The derived bridge type circuit hereinabove de-

scribed has been used in Fig. 4 to provide controlled coupling and crossfeed between various receptor circuits.

In Figure 4, I have shown the Wheatstone type bridge circuit derived from Figure 2 applied to a plurality of channels, six being shown; others can be added in similar fashion. This circuit performs the same function as the circuits of Figures 1 and 3, plus the control features of Figure 2.

To each of the seismometer units 1—6, I connect the primary 17—17^{V} of an isolation transformer 11—16, and preferably ground the midpoints, 41—41^{V}. Between the primary windings 17—17^{V} and secondaries 18—18^{V}, electrostatic shields 51—51^{V} are interposed, and also grounded.

Variable balancing resistors 39—39^{IV} are provided for the control of each channel, and connected to the proper centertapped isolation transformer secondary 18—18^{V}, which is also connected to the corresponding matching transformer primary 28—28^{V}. Across each of primaries 28—28^{V} is shunted a resistor 44—44^{V}, and each of the matching transformers has a grounded electrostatic field 61—61^{V} disposed between the windings. Matching transformer secondaries 29—29^{V} are connected to their respective amplifying and recording units A—F. Additional channels may be added by connecting to leads 65 and 66 attached to secondary 18^{V} in similar fashion to those connections made to secondaries 18—18^{IV}. In case no further channels are added, the right half of transformer secondary 18^{V} to which the lead 65 is connected may be omitted. Or if desired for symmetry an impedance equal to resistance 39^{IV} plus another recorder may be connected in series across leads 65 and 66.

To understand how limited crossfeed between channels is obtained when the bridge type circuits are in balance, consider receptor number 2. When earth waves are received, voltage is generated across the secondary 18' of transformer 12.

In the preferred application of my invention resistor 39' has approximately the same impedance value as the parallel network 28''—44'' so that the common point between them connected to the center tap of secondary 18'' is at substantially the same potential as the mid-point of the secondary 18'. Since the secondary 18'' of transformer 13 is connected to the two aforementioned equi-potential points, no appreciable part of the voltages appearing across the secondary 18' of transformer 12 can affect other circuits connected to transformer 13. Therefore, the waves received at seismometer number 2 do not affect recorders D, E, or F in any appreciable amount.

It will now be shown that the waves arriving at seismometer number 2 affects recorder B but not recorder A. Current is generated in the left half section of the secondary 18' of the transformer 12. Here the current is divided into two substantially equal parts, one going to the left and returning to the midpoint of secondary 18' through the resistor 44' and primary 28' and the other going to the right and returning to the midpoint of secondary 18' through the resistor 39. Waves received by receptor number 2 therefore actuate record B. Since secondary 18 virtually acts as a short circuit across primary 28 so far as currents from transformer 12 are concerned, as hereinabove explained in connection with Fig. 2, only a negligible current from seismometer 2 actuates recorder A.

It should be observed that a signal from seismometer 2 would reach recorder A were it not for the bucking voltage introduced into the left half of winding 18 by currents flowing in the right half of winding 18. It is obvious that such bucking voltage may be introduced by other methods, but the use of the auto-transformer connections of secondary 18 are considered preferable.

It is interesting to note that regardless of the currents flowing in any of the circuits the voltages across the two halves of each secondary 18—18^{V} are always substantially equal, due to the auto-transformer effects of these windings.

By a similar analysis of the other circuits of Fig. 4, it is readily seen that in the balanced condition each seismometer actuates no more than two recorders. Recorder A, of course, is actuated by only the single receptor 1.

The effectiveness of the network of Fig. 4 in reducing the amplitude of unwanted crossfeed is in part due to the modified Wheatstone bridge principle and partly due to the application of a system of inductive bucking voltages. In this network I have used a sequence of modified Wheatstone bridges each within another and taken advantage of these bucking voltages.

In a sense the Wheatstone bridge type circuits, too, utilize a set of bucking voltages for preventing undesired crossfeed. Thus, for example, signals arriving at receptor 1 generate voltages across the input of amplifier B and secondary 18'. Were it not for a substantially equal and opposite bucking voltage across resistor 39 and secondary 18', signals from receptor 1 would produce currents in secondary 18' and thereby affect recorder C. Similar reasoning applies, of course, to the other receptor circuits and reproducers.

Looked at broadly, therefore, my invention utilizes circuits which produce desired crossfeed but simultaneously prevent undesired crossfeed by the introduction of bucking voltages.

Recorders A and B are associated with seismometer 1, B and C with 2, C and D with 3, etc. When the bridge type circuits are balanced, signals from each seismometer reach only the recorders associated therewith. The cross-feed between channels associated with seismometers 1 and 2 is controlled by resistor 39, that between channels associated with seismometers 1 and 3 by resistors 39 and 39', and so on.

The method and circuit here shown is not the only means of obtaining the desired result, as the mixing and controlling may be done at other points in the system, for example, in the output circuit between the amplifiers and recorders, using a similar arrangement, or neutralizing by means of "bucking out" the unwanted signals may be had.

Applying the reciprocatory theorem and the principle of superposition to the circuits of Figs. 2 and 4, modifications of my invention will readily appear to those skilled in the art. To see this in connection with Fig. 4 consider a case in which there are no connections to leads 65 and 66 so that there are six receptors and six recorders. If the ground connections 41, 41' . . . 41^{V}, are shifted from the coils 17 . . . 17^{V} to coils 29 . . . 29^{V}, and receptors 1 . . . 6 are interchanged with recorders F . . . A and the associated amplifiers respectively, then the relation between the group of traces appearing on the recorders A . . . F and the waves reaching receptors 1 . . . 6, will be the same as in the circuit of Fig. 4. For example, if the bridge type circuits are balanced, recorder A will reproduce signals from receptor 1 alone, recorder B will reproduce signals from both receptors 1 and 2, etc., as in Fig. 4.

It will be apparent to those versed in the art

that the balancing and cross-feed controlling system here presented may be combined with the switching arrangement disclosed in my pending application, cited supra, to form an extremely flexible and perfectly controlled prospecting device.

By the circuits and methods outlined above, I have provided means for taking advantage of the connection together of a number of seismometer units, applying their output cumulatively or in opposition as desired to recording units, with means for eliminating cross-feed entirely when desired, or permitting a controlled amount wherever useful, and also controlling the phase relations between different channels.

The term receptor as herein used shall be deemed to include devices known as seismometers, detectors, or pickup instruments, and also to include any and all devices or means to convert earth vibrations into energy suitable for use in making a record of the changes in the earth's condition due to an explosion or other vibration producing impact. The term receptor also includes any device whatever used for receiving electrical waves or other impulses used in geophysical exploration.

I claim:

1. In a geophysical prospecting system, a plurality of receptors, a corresponding plurality of receptor lines, a corresponding plurality of amplifier and recorder units operable in accordance with electric signals arriving over said lines, an impedance matching device between each of said lines and the corresponding amplifying and recording unit, an isolation transformer between each of said lines and the corresponding impedance matching device, and means including impedances interconnecting isolation transformer secondaries and linking portions of connected transformers in series relationship so that portions of adjacent connected transformers are parts of a common current carrying circuit, said circuit also including a connecting impedance, all said impedances and said secondaries being so connected and arranged that a controlled amount of crossfeed is introduced between at least one of said secondaries and only a fraction of the remaining interconnected secondaries.

2. In a geophysical prospecting system having a plurality of receptors and a corresponding number of receptor lines, a plurality of amplifier and recorder units operable in response to signals received on said lines, an impedance matching device between each of said lines and the corresponding amplifier and recorder unit, an isolation transformer between each of said lines and the corresponding impedance matching device, said impedance matching device comprising a matching transformer having a primary connected to said isolation transformer, and means for introducing a desired cross-feed component between certain of said isolation transformers, including a bridge circuit formed between isolation transformer secondaries, impedance matching transformer primaries, and a variable resistor.

3. In a geophysical prospecting system, a plurality of receptors, a corresponding plurality of receptor lines, a corresponding plurality of amplifier and recorder units operable in accordance with electric signals arriving over said lines, an impedance matching device between each of said lines and the corresponding amplifying and recording unit, an isolation transformer between each of said lines and the corresponding impedance matching device, said means comprising a bridge circuit having half of two opposed arms formed by an isolation transformer secondary, having the remaining half of one opposed arm formed by an impedance matching transformer primary, and having the remaining half of a second opposed arm formed by a variable resistor, having one conjugate arm formed by the secondary of a second isolation transformer and having a second conjugate arm formed by the primary of a second matching transformer.

4. A geophysical prospecting circuit substantially as described in claim 3, wherein the midpoint of each isolation transformer primary is grounded.

5. A geophysical prospecting circuit substantially as described in claim 3, wherein the midpoint of each isolation transformer primary is grounded and wherein a grounded shield is provided between the primary and secondary windings of each of said isolation transformers.

6. A geophysical prospecting circuit substantially as described in claim 3, wherein the midpoint of each isolation transformer primary is grounded and wherein a grounded shield is provided between the primary and secondary windings of each of said isolation transformers, and wherein grounded electrostatic shields are positioned between the primary and secondary windings of each of said impedance matching transformers.

7. In a geophysical prospecting circuit substantially as described in claim 3, fixed resistors shunted across the primary of each of said impedance matching transformers.

8. Geophysical prospecting circuits substantially as described in claim 3 having a plurality of associated units, connected to form a plurality of bridge circuits between adjacent units.

9. A geophysical prospecting system, comprising a plurality of receptor circuits, each of said circuits including at least one receptor, a corresponding plurality of recorders, mixing means providing channels intermediate said receptor circuits and said recorders; for introducing signals from the receptor circuits to the respective corresponding recorders, and auxiliary circuits connected to introduce desired crossfeed, between certain receptor circuits and certain non-corresponding recorders, said auxiliary circuits including inductive means for preventing undesired crossfeed between said certain receptor circuits and other non-corresponding recorders.

10. In a geophysical prospecting system, a plurality of signal transmission lines, each of said lines being connected to at least one receptor, a plurality of reproducers operable in accordance with signals received by said receptors, and mixing circuits intermediate said lines and said reproducers; said mixing circuits comprising means for introducing desired crossfeed from certain lines to certain reproducers, and inductive means interconnecting mixing circuits to introduce bucking voltages from some of said lines to some of said mixing circuits to prevent undesired crossfeed between said certain lines and other mixing circuits.

11. In a geophysical prospecting system, a plurality of signal transmission lines, each of said lines being connected to at least one receptor, a plurality of reproducing circuits operable in accordance with signals received by said receptors, and mixing circuits intermediate said lines and

said reproducing circuits, said mixing circuits comprising current transfer means directly connected to produce desired crossfeed between certain lines and certain reproducing circuits and inductive means for simultaneously introducing bucking voltages from some lines to some reproducing circuits to prevent undesired crossfeed.

12. In a geophysical prospecting system a plurality of signal transmission lines, each of said lines being connected to at least one receptor, a plurality of reproducers operable in accordance with signals received by said receptors, and mixing means connected intermediate said lines and said reproducers, said mixing means comprising input elements connected to said lines, balancing impedances, and overlapping bridge type circuits interconnecting said balancing impedances, said reproducers, and said input elements.

13. A geophysical prospecting system comprising receptors, recorders, and amplifiers, if necessary; a sequence of first transformer windings each having first and second end taps, and center taps; a conductive connection from the center tap of each of said transformer windings, except the last, to the first end tap of the next transformer winding following in sequence; a balancing impedance connecting the center tap of each transformer winding, except the first, with the second end tap of the next of said transformer windings prior in sequence; a corresponding sequence of second transformer windings; conductive connections from end terminals of each of said second transformer windings to first end taps of two alternate non-adjacent first transformer windings; means coupling said receptors to one of said sequence of transformer windings, means coupling said recorders to the other of said sequence of transformer windings.

14. A geophysical prospecting circuit as in claim 13 in which said balancing impedances are substantially equal to the impedances looking into the terminals of said second transformer windings.

15. A geophysical prospecting system as in claim 13 in which the receptors and reproducers are inductively coupled to the respective transformer windings.

16. A geophysical prospecting system, comprising receptors and reproducers; a sequence of first transformer windings each of said transformer windings having a center tap and a first and second end taps; a conductive connection from the center tap of each of said transformer windings, except the last, to the first end tap of the next transformer winding following in sequence; an impedance connecting the center tap of each transformer windings, except the first, with the second end tap of the next of said transformer winding prior in sequence; a corresponding sequence of second transformer windings, having first and second terminals; a conductive connection from each of said first end taps to the first terminal of the next adjacent second transformer winding following in sequence; a conductive connection from each center tap for the second terminal of the corresponding second transformer winding; a set of transformer windings associated with the sequence of first transformer windings and another set of transformer windings associated with said sequence of second transformer windings; means connecting said receptors to one of said sets of transformer windings; and means connecting said reproducers to the other of said sets of transformer windings.

17. In a geophysical prospecting system utilizing a bridge type circuit, a first pair of coupling devices comprising self-inductances, a second pair of coupling devices, means connecting one of said second coupling devices and a balancing impedance in series with one of said first coupling devices, means connecting the other of said first coupling devices between the mid-point of said first coupling device and the common connecting point between said second coupling device and said balancing impedance, means connecting the other of said second coupling devices across a portion of said one of said first coupling devices, at least one receptor connected to each of one pair of coupling devices and a reproducing unit connected to each of the other of said pairs of coupling devices.

18. In a geophysical prospecting system, the combination which comprises at least three receptor circuits, a corresponding plurality of recorders, intermediate current-carrying circuits coupling each said receptor circuit with the said corresponding recorder, means including electrical impedance elements coupling each of said intermediate circuits to at least one other of said intermediate circuits, said impedances and intermediate circuits being so connected and arranged as to introduce a controlled amount of crossfeed from one intermediate circuit to another intermediate circuit through one of said impedance elements and also connected and arranged to introduce no cross feed between two of said intermediate circuits that are non-adjacent, whereby some of said recorders receive signals from more than one receptor circuit and none of said recorders receive signals from all of said receptor circuits.

19. In a geophysical prospecting system, the combination which comprises at least three receptor circuits, a corresponding plurality of recorders, common current-carrying circuits coupling each of said recorders with each of the corresponding receptor circuits, signal mixing means including impedances coupling adjacent current-carrying circuits, and means connected in said adjacent current carrying circuits for preventing cross feed from passing from one of said current carrying circuits to another of said current carrying circuits that is non-adjacent thereto.

HERBERT HOOVER, JR.

CERTIFICATE OF CORRECTION.

Patent No. 2,266,041. December 16, 1941.

HERBERT HOOVER, JR.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 62, for "Figure 3" read --Figure 1--; page 4, second column, line 56, for "reciprocatory" read --reciprocity--; page 5, second column, line 46, claim 9, strike out the semi-colon after "recorders"; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 19th day of May, A. D. 1942.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

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