Jan. 19, 1937. H. A. AFFEL ET AL 2,068,309

TRANSMISSION MEASURING SYSTEM

Filed Aug. 18, 1933 2 Sheets-Sheet 1

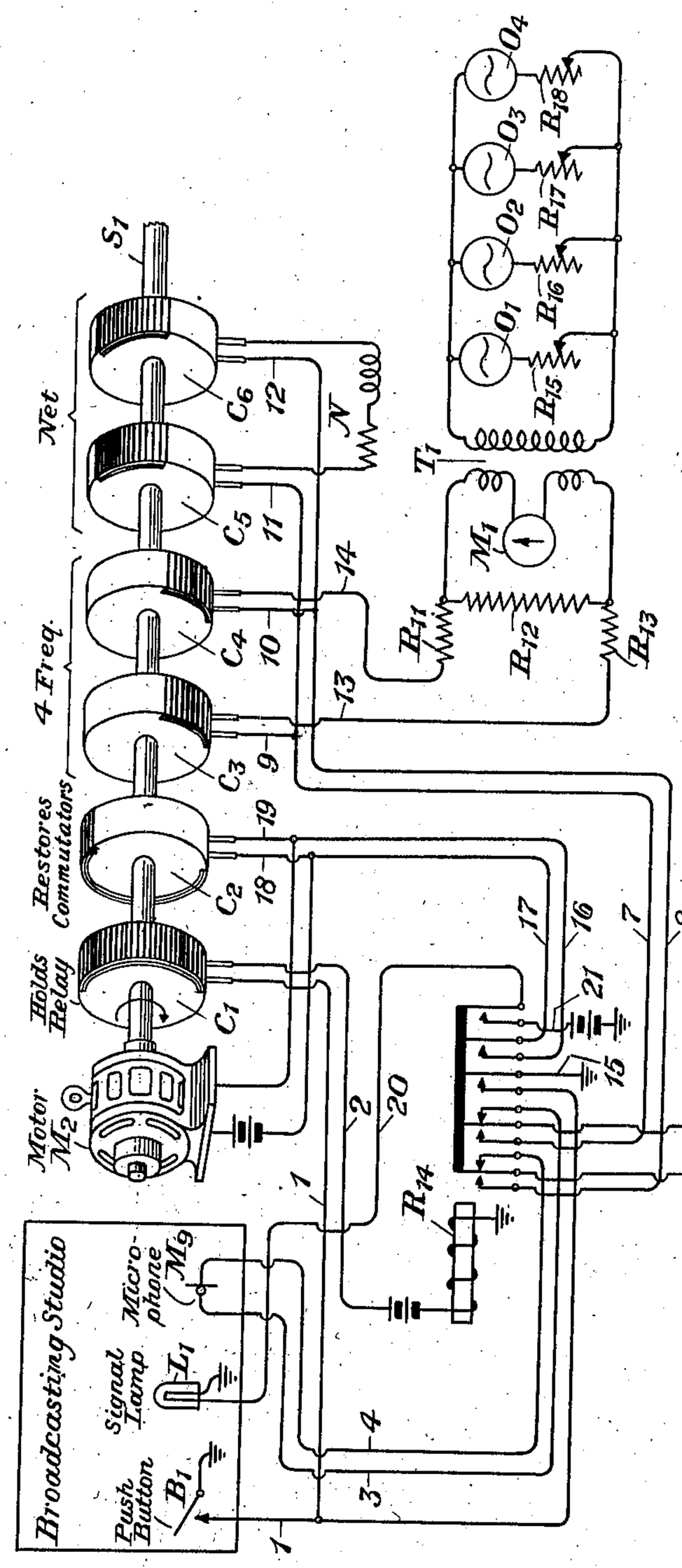


Fig. 1

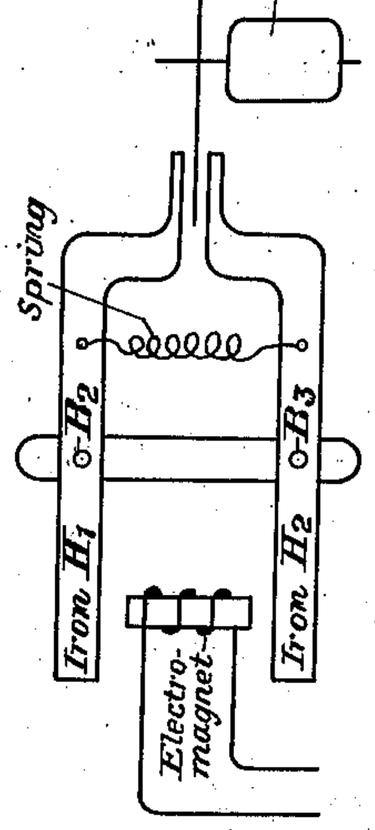


Fig. 3

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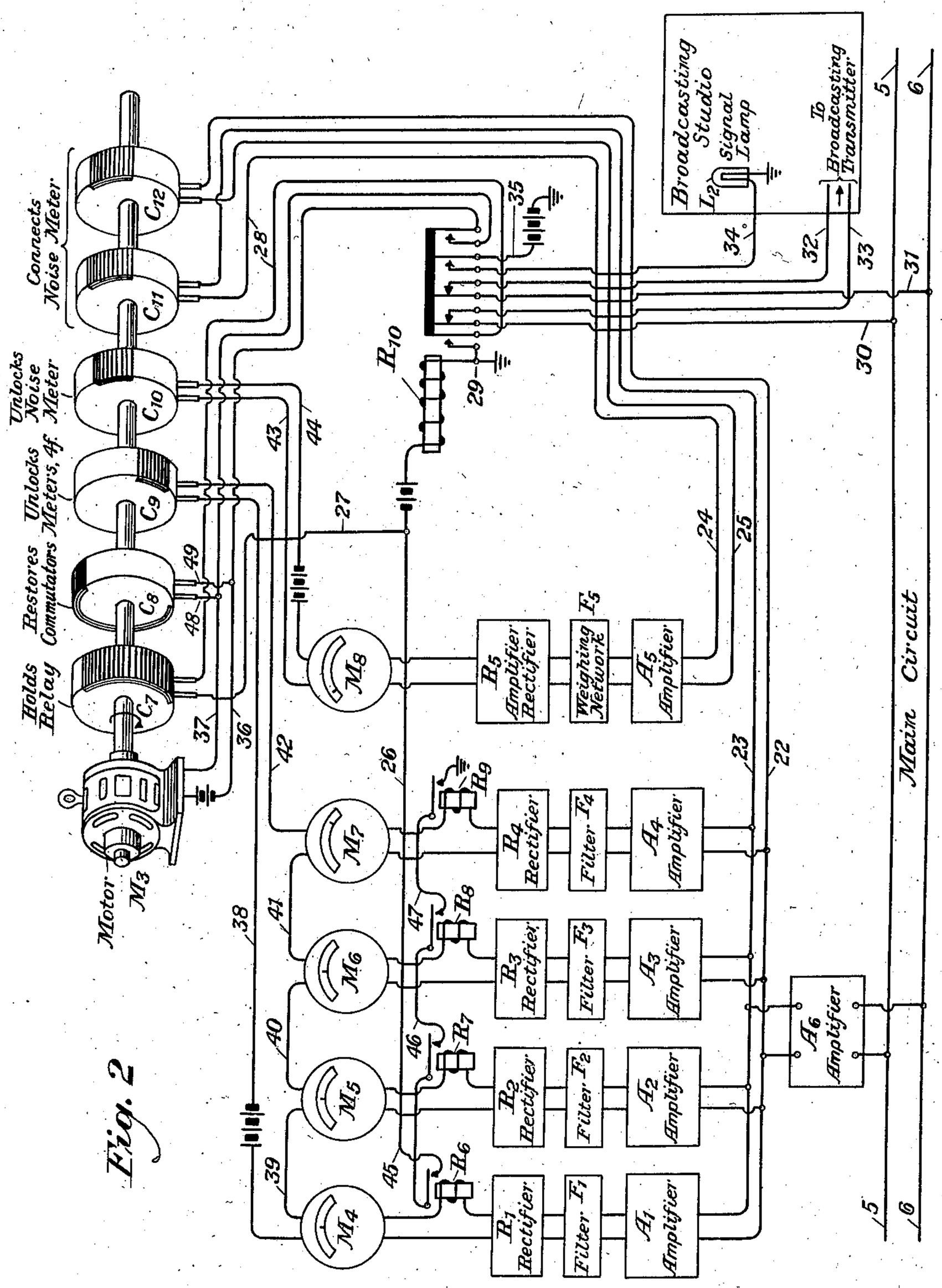


Fig. 2

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2,068,309

## TRANSMISSION MEASURING SYSTEM

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17 Claims. (Cl. 179—175.3)

This invention relates to transmission measuring systems and particularly to means for rapidly recording the transmission equivalent of a circuit at a plurality of frequencies.

Various systems have been proposed and used heretofore to determine the transmission equivalent of a circuit at one or several frequencies and to measure the interfering effect of noise currents on a circuit. Such systems have been designed to give accurate results and are sufficiently fast in operation for maintenance tests on message telephone circuits where a circuit may be spared for several minutes for testing purposes.

In radio broadcasting it is common practice to broadcast a single program simultaneously from a large number of broadcasting stations, the program being transmitted from the studio over a network of wire circuits which may cover a large section of the country and contain several thousand miles of circuit. It is also common practice to have a program continuously transmitted over this net work for long periods such as 12 or 14 hours without interruption except at 15-minute intervals when station announcements are made and programs are changed. During the long period it is impossible to determine the transmission characteristics of the circuit with measuring systems heretofore used as the time required by these systems is too great. As a result changes in the transmission condition of the circuit are not easily determined and corrected. The object of this invention is to provide a system which will record the transmission condition at numerous points on a network of circuits a few seconds after the operation of a push-button switch at the broadcasting studio, this interval being so short that it can be spared from the silent interval devoted to station announcements and change of programs. Operation of the system is accomplished without special signaling or control circuits between the testing points.

Other objects of this invention will be apparent from the following description when read in connection with the attached drawings in which Figure 1 shows the arrangements at the broadcasting studio and the main circuit terminal associated with it; Fig. 2 shows the arrangements at a junction between the main circuit and a circuit to one of the network broadcasting stations; Fig. 3 shows a form of meter which can be used to record the transmission condition of the circuit.

When it is desired to make a set of measurements, a push-button in the broadcasting studio is operated. This disconnects the microphone from the network of circuits and sends out a multi-frequency testing current. When this current is received at points along the network at which it is desired to make measurements, an automatic device at each point disconnects the broadcasting station at that point and starts in operation an automatic transmission measuring device which registers the transmission condition of the circuit between the studio and that point. When this has been done the testing current is removed from the network of circuits, noise measuring devices are substituted for the transmission measuring devices at the various testing points and the noise on the circuit is then recorded. When this has been done the entire network is returned to its normal condition for broadcasting. The detailed operation of the testing arrangement is as follows:

In Fig. 1 current from the microphone $M_9$ or other translating device at the broadcasting studio is transmitted to the main circuit terminal over conductors **3** and **4** and through the contacts of relay $R_{14}$ to conductors **5** and **6** of the main circuit. This is the condition for normal operation of the program circuit network, the broadcasting stations being bridged on this main circuit. When it is desired to measure the transmission condition of the circuit, push-button $B_1$ at the broadcasting studio is operated momentarily, putting a ground on conductor **1**. This operation causes relay $R_{14}$ to operate, the operating circuit of the relay being through conductor **1**, commutator $C_1$, conductor **2**, battery and ground. When $R_{14}$ operates it is locked in position by the circuit through contact **15** of relay $R_{14}$ which also grounds conductor **1** so that the relay stays operated after the push-button $B_1$ is released. The operation of relay $R_{14}$ disconnects conductors **5** and **6** of the main circuit from the microphone circuit and connects them to conductors **7** and **8** whih are the conductors used for testing. At the same time the signal lamp $L_1$ at the studio is lighted by the closing of contact **21** which completes the circuit of the grounded battery through conductor **20** and through the lamp to ground. This indicates to the studio attendants that the microphone circuit is disconnected and that the main circuit has been taken for tesing.

A plurality of commutators $C_1$ to $C_6$, inclusive, are mounted on shaft $S_1$ which can be turned slowly by means of motor $M_2$. These commutators consist of conducting segments, shown as

shaded areas in Fig. 1, mounted on insulating segments. In contact with each commutator are two brushes so arranged that the circuit is completed through them when they both rest on the conducting segment. At the beginning of a test the commutators are in the relative positions shown in Fig. 1, the brushes of commutators $C_1$, $C_3$ and $C_4$ being connected through the conducting segments. The operation of relay $R_{14}$ starts the motor by connecting conductors **16** and **17** through the relay contacts, completing the battery circuit of the motor. The motor is geared to turn the shaft $S_1$ at a slow speed so that one revolution of the shaft is accomplished in, say, 10 seconds. During the first part of the revolution of shaft $S_1$ conductors **7** and **8**, which, as stated, are now connected to the main circuit **5**, **6** through the contacts of relay $R_{14}$, are also connected through the commutators $C_3$ and $C_4$ to conductors **13** and **14**, which latter conductors constitute the circuit over which testing power is supplied to the main circuit for transmission measurements.

The testing power is generated by several oscillators shown by $O_1$ to $O_4$ inclusive, but it is to be understood that any number of oscillators may be used. Rheostats $R_{15}$ to $R_{18}$ regulate the output power of the oscillators which are connected in parallel to transformer $T_1$. Meter $M_1$ measures the power supplied by each oscillator or by all oscillators to the network of resistances $R_{11}$, $R_{12}$ and $R_{13}$ and to the main circuit when it is connected through commutators $C_3$ and $C_4$. These resistances are proportioned so that the impedance from conductors **13** and **14** toward the resistance network is approximately that of the main circuit, this being the usual arrangement for transmission testing. The current through meter $M_1$ is adjusted until the power supplied to the main circuit is a suitable value, say, 1 milliwatt. This testing power is supplied through commutators $C_3$ and $C_4$ for several seconds until the indicating meters at various points on the network have indicated the transmission condition of the circuit at each of the frequencies of testing current supplied to the main circuit.

Fig. 2 shows the arrangement at any point on the main circuit at which a broadcasting station is connected, or at which it is desired to test, just prior to the operation of the push-button $B_1$ at the broadcasting studio. The broadcasting transmitter is connected to the main circuit through the contacts of relay $R_{10}$, conductors **30** and **31**, a bridge on the main circuit being connected through the relay contacts to conductors **32** and **33** which supply the program to the broadcasting transmitter.

Also bridged on the main circuit is amplifier $A_6$, the impedance of which is high relative to that of the main circuit so that it causes no disturbance to the program. To the output of amplifier $A_6$ are connected a plurality of amplifiers $A_1$ to $A_4$, inclusive, each amplifier having in its output circuit a filter $F_1$ to $F_4$, inclusive, each filter being arranged to pass a different one of the several frequencies used in testing. At the output terminals of each filter is a rectifier $R_1$ to $R_4$ inclusive, which converts the alternating current to direct current. The output of each rectifier is connected to a D. C. indicating milliammeter through the relays $R_6$ to $R_9$ inclusive. The indicating pointer of each meter is locked by an electromechanical device so that it cannot move until released by the closing of an electrical circuit.

The contacts of relays $R_6$ to $R_9$, inclusive, are open when no current is on the main circuit. When a program of music or speech is being transmitted, one or more of the relays may operate momentarily due to the presence on the circuit of the frequency to which a filter is tuned. With a plurality of frequencies and with narrowly selective filters, music and speech will not operate all relays simultaneously so that conductor **26** will not be connected to ground through conductors **45**, **46** and **47**. As long as all relays do not operate simultaneously, relay $R_{10}$ cannot operate and the main circuit remains connected to the broadcasting transmitter.

When the multi-frequency testing generators $O_1$ to $O_4$, inclusive, shown in Fig. 1, are connected to the main circuit by the operation of push-button $B_1$, relays $R_6$ to $R_9$ operate simultaneously since each filter is tuned to one of these frequencies. Relay **10** then operates, the circuit to ground being completed through conductors **26**, **45**, **46** and **47** and the contacts of relays $R_6$ to $R_9$ inclusive. The operation of relay $R_{10}$ disconnects conductors **32** and **33** from the main circuit, and thereby effectively removes the broadcasting station from the main circuit. The testing current which produces the aforesaid result is heard by those listening to the radio program only during the brief interval necessary to cause relay $R_{10}$ to operate. A signal lamp $L_2$ at the broadcasting station is simultaneously lighted by the operation of relay contacts which complete the signal lamp circuit through conductors **34** and **35** and the battery through ground. This indicates that the main circuit has been disconnected from the broadcasting transmitter. When relay $R_{10}$ operates it is held up by the circuit through contact **29**, conductor **28**, commutator $C_7$ and conductor **27** which form a circuit in parallel with the circuit through conductors **26**, **45**, **46**, **47** and the contacts of relays $R_6$ to $R_9$ inclusive.

A plurality of commutators $C_7$ to $C_{12}$, inclusive, are mounted on shaft $S_2$ which is turned by motor $M_3$ at a slow rate, the commutators and motor being similar to those shown in Fig. 1. Before the operation of relay $R_{10}$, the conducting segment in commutator $C_7$ is underneath the two brushes associated therewith. The circuits of the brushes of the other commutators are open. As soon as relay $R_{10}$ operates, its contacts connect conductors **36** and **37**, completing the battery circuit of the motor $M_3$ which turns the shaft $S_2$ and almost immediately causes the brushes of commutator $C_9$ to be connected together, closing the circuit which unlocks the moving system of meters $M_4$ to $M_7$ inclusive, through conductor **38**, battery, conductors **39**, **40**, **41** and **42**, causing current to flow through the electromagnetic unlocking devices of the meters, allowing the pointers to swing free and indicate the received current at each of the several testing frequencies, this being an indication of the transmission condition of the circuit.

Fig. 3 shows a schematic arrangement of the electromagnetically unlocking meters. The meter is of the conventional type employing a permanent magnet and a moving coil with a pointer connected to it, the moving coil being normally locked so that it cannot move by the two iron arms $H_1$ and $H_2$ which are pivoted on bearings $B_2$ and $B_3$ so that the spring causes them to clamp the pointer of the moving system. When

the electromagnet is energized by a direct current, it attracts arms $H_1$ and $H_2$ overcoming the tension of the spring and causing the arms to release the pointer allowing it to swing freely.

The conducting segment of commutator $C_9$ is sufficiently large to give the pointers of meters $M_4$ to $M_7$ inclusive, a sufficient time to come to rest, whereupon the circuit through commutator $C_9$ is opened, causing the locking devices to operate and clamp the pointers so that they will continue indefinitely to indicate the transmission condition of the circuit at the time the locking device operated.

During the time meters $M_4$ to $M_7$, inclusive, are unlocked, testing power is being supplied through commutators $C_3$ and $C_4$ of Fig. 1. Shortly after the meters have been locked in position, the commutators $C_3$ and $C_4$ open the circuit between conductors **9** and **13** and **10** and **14** so that the testing power is removed from the main circuit, the transmission test having been completed.

Measurement of noise on the circuit is then made. The first step in a noise measurement is to terminate the main circuit in a network of resistance and inductance or capacitance which has approximately the same impedance as the circuit. Such a network N is connected to conductors **11** and **12** through the conducting segments of commutators $C_5$ and $C_6$, conductors **11** and **12** being connected to the main circuit through conductors **7** and **8** and the contacts of relay $R_{14}$. By the time this has been done the continued operation of shaft $S_2$ in Fig. 2 causes conductors **24** and **25** to be connected through commutators $C_{11}$ and $C_{12}$ to conductors **22** and **23** which are the output conductors of amplifier $A_6$ so that amplifier $A_5$ receives current from the main circuit. Conductors **24** and **25** are the input terminals to amplifier $A_5$ which together with weighting network $F_5$, amplifier-rectifier $R_5$ and meter $M_8$ comprise a noise meter which indicates on the meter the interfering effect of the noise currents at the input terminals of $A_5$. Weighting network $F^5$ attenuates the different frequencies of the noise currents so that their effect on the meter reading is in proportion to their interfering effect on the program. Amplifier-rectifier $R_5$ amplifies this current and converts it to direct current, which is indicated by the pointer of meter $M_8$. This meter is equipped with an electromagnetically operated device similar to meters $M_4$ to $M_7$, inclusive, which is operated when commutator $C_{10}$ closes the circuit of the electromagnet through conductors **43**, **44** and battery. After network N of Fig. 1 has been connected to the main circuit through commutators $C_5$ and $C_6$, commutator $C_{10}$ of Fig. 2 closes the circuit of conductors **43**, **44**, battery, and the electromagnetic unlocking device of meter $M_8$, allowing the pointer to swing free. After a short interval commutator $C_{10}$ opens the circuit through the electromagnetic unlocking device causing the pointer of meter $M_8$ to be clamped into position, indicating the noise on the circuit at the time the meter was clamped. Shortly after meter $M_8$ is clamped, commutators $C_{11}$ and $C_{12}$ disconnect conductors **24** and **25** from conductors **23** and **22**, removing the noise meter from the main amplifier $A_6$. At approximately this same time commutators $C_5$ and $C_6$ of Fig. 1 remove the network N from the main circuit.

The cycle of tests is now completed and it is necessary to restore the main circuit and the connections to the broadcasting studio and broadcasting stations to their normal condition. This is accomplished in Fig. 1 by commutator $C_1$ which opens the circuit through relay $R_{14}$ by disconnecting conductors **1** and **2**, causing relay $R_{14}$ to release and connecting the microphone circuit **3**, **4** to the main circuit **5**, **6**. The broadcasting station in Fig. 2 is connected to the main circuit as a result of the movement of commutator $C_7$ which opens the circuit through relay $R_{10}$ by disconnecting conductors **27** and **28**, causing relay $R_{10}$ to release. The signal lamps at the broadcasting studio and broadcasting station go out, indicating that the circuit has been restored to use.

It is necessary for motor $M_2$ in Fig. 1 and $M_3$ in Fig. 2 to continue to rotate shafts $S_1$ in Fig. 1 and $S_2$ in Fig. 2 until the commutators are all in the position occupied at the start of the test just prior to the operation of push-button $B_1$ in Fig. 1. This is accomplished in Fig. 1 by commutator $C_2$ which completes the circuit through conductors **18** and **19** just before the test is completed and causes the motor to continue its operation until the shaft $S_1$ has reached the desired position whereupon it opens the circuit and stops the motor. Shaft $S_2$ in Fig. 2 is similarly restored to the desired position by commutator $C_8$ which closes the circuit of conductors **48** and **49** just before the completion of the test and opens the circuit when the desired position of shaft $S_2$ has been reached.

While the invention has been disclosed as embodied in a particular form, it is to be understood that it is capable of embodiment in other forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a system for automatically determining the characteristics of an electrical transmission system, the combination with a source of power comprising a plurality of frequencies of a main transmission circuit whose electrical properties are to be determined by the transmission of the said power thereover, a branch circuit containing a translating device normally connected to said main circuit, a switching device to connect the said source of power to said circuit, the said device comprising means to limit the period of application of power to said circuit and also means to hold the said branch circuit disconnected from said main circuit during said period of application of power.

2. In a system for automatically determining the characteristics of an electrical transmission system, the combination with a main transmission circuit whose electrical properties are to be determined by the transmission of power thereover, a plurality of branch circuits normally effectively connected to said main circuit at different points upon said latter circuit, a source of power, switching means to effectively connect said source to said main circuit and to disconnect therefrom one of said branch circuits, means to measure the said power and another switching means to effectively connect said measuring means to said main circuit and to disconnect therefrom the other of said branch circuits.

3. In a radio broadcast network, the combination with a main circuit of a studio branch circuit, a broadcasting station branch circuit and means to automatically determine the transmission characteristics of said main circuit, said means including switching means to

disconnect said studio branch circuit from said main circuit and to connect to the latter a source of power, switching means controlled by the power transmitted over said main circuit to disconnect the broadcasting station branch circuit from said main circuit and to connect to the latter a measuring device, means to maintain the said source and said measuring device connected throughout a predetermined interval, and to disconnect said source and said device therefrom at the end of said interval.

4. In a transmission measuring system, the combination with a main circuit of branch circuits normally effectively connected thereto, testing apparatus, switching means controllable at will to automatically disconnect one of the branch circuits from said main circuit and to connect to the latter certain testing apparatus, and other switching means controlled by said first switching means to automatically disconnect other branch circuits from said main circuit and to connect to the latter other testing apparatus and means automatically operable at the end of a predetermined interval to disconnect said apparatus from said main circuit and to restore the connection of the said branch circuits thereto.

5. In a system for determining the transmission characteristics of the main circuit of a radio broadcasting network having a plurality of stations connected thereto, the combination with a main circuit of a plurality of branch circuits normally effectively connected thereto, a source of power and an artificial line at one of said stations, a sequence switch to which said source and artificial line are connected, switching means to disconnect one of said branch circuits from said main circuit and to connect the said sequence switch to the latter circuit, means at another of said stations to effectively disconnect the other branch circuit, means to measure the transmission efficiency of said main circuit for currents transmitted thereover from said source at the first mentioned station, means also at said other station to measure the noise level upon said main circuit and a switch to control the sequence of the said latter measurements.

6. In a system for determining the transmission characteristics of the main circuit of a radio broadcasting network having a plurality of stations connected thereto, the combination with a main circuit of a plurality of branch circuits normally effectively connected thereto, a source of power and an artificial line at one of said stations, a sequence switch to which said source and artificial line are connected, switching means to disconnect one of said branch circuits from said main circuit and to connect the said sequence switch to the latter circuit, means at another of said stations to effectively disconnect the other branch circuit, means to measure the transmission efficiency of said main circuit for currents transmitted thereover from said source at the first mentioned station, means also at said other station to measure the noise level upon said main circuit and a switch to control the sequence of the said latter measurements, and means to lock the said measuring instruments at said other station to preserve the readings thereon.

7. In an electrical testing system the combination with a circuit to be tested of a source of current comprising a group of frequencies arranged for connection to said circuit, a plurality of measuring devices normally disconnected from said circuit, and means to effectively connect said devices to said circuit only when all frequencies of said group are present in said circuit.

8. In an electrical testing system the combination with a circuit whose transmission qualities are to be determined of a source of current comprising a plurality of frequencies, certain of which are known, adapted to be connected to said circuit, and a translating device normally disconnected from said circuit and capable of connection to said circuit only when all the said known frequencies are present in said circuit.

9. In an electrical testing system the combination with a circuit, a source of current containing a group of known frequencies, adapted for connection to said circuit, means connected to the said circuit to select the said known frequencies, a translating device and means to operate said device only when the said group of known frequencies is present in said circuit.

10. In an electrical testing system the combination with a circuit, a source of current containing a group of known frequencies, adapted for connection to said circuit but normally disconnected therefrom, means connected to said circuit to select each of the frequencies of the said group, a plurality of measuring devices, one for each frequency, and means responsive only to the said group of frequencies for connecting said measuring devices to said circuit to measure its transmission qualities for the frequencies of said group.

11. In a radio broadcast network including a broadcast studio having a microphone thereat, a broadcasting station having means to broadcast the program picked up by said microphone, and a circuit connecting said studio and station, the method of determining the transmission characteristics of the connecting circuit, which consists in automatically disconnecting from the said circuit the microphone at the said studio and applying testing power to the said circuit, automatically disconnecting by means of the said power the broadcasting apparatus from said connecting circuit, connecting thereto means to measure the power transmitted by the said connecting circuit, and automatically stopping the application of the said power at the end of a predetermined interval.

12. In a transmission measuring system for determining the electrical characteristics of a transmission line forming part of a broadcasting network, the combination with a line, the transmission characteristics of which are to be determined, of transmitting apparatus normally connected to said line but capable of disconnection therefrom, a signal lamp, a push button, a sequence switch having a plurality of commutators, a relay adapted to be energized upon the operation of the said push button and to remain operated as long as the brushes of one of said commutators remain upon the conducting segment thereof, the said relay being arranged to light said lamp whenever the said relay operates.

13. In a transmission measuring system for determining the electrical characteristics of a transmission line forming part of a broadcasting network, the combination with a line, the transmission characteristics of which are to be determined, of transmitting apparatus normally connected to said line but capable of disconnection therefrom, a signal lamp, a push button, a sequence switch having a plurality of commu-

tators, a relay adapted to be energized upon the operation of the said push button and to remain operated as long as the brushes of one of said commutators remain upon the conducting segment thereof, the said relay being arranged to disconnect said transmitting apparatus from said line and to light said lamp to indicate said disconnection.

14. In a transmission measuring system for determining the electrical characteristics of a transmission line forming part of a broadcasting network, the combination with a line, the transmission characteristics of which are to be determined, of transmitting apparatus normally connected to said line but capable of disconnection therefrom, a signal lamp, a push button, a sequence switch having a plurality of commutators, a source of power of a given frequency, an electrical network, a relay adapted to be energized upon the operation of the said push button and to remain operated as long as the brushes of one of said commutators remain on the conducting segment thereof, the said relay being arranged to disconnect said transmitting apparatus from said line and to connect thereto in sequence the said source and the said network, the sequence being determined by other commutators of the said sequence switch.

15. In a transmission measuring system for determining the electrical characteristics of a transmission line forming part of a broadcasting network, the combination with a line, of transmitting apparatus normally connected to the said line but capable of being disconnected therefrom, a sequence switch having a plurality of commutators, a source of power of a plurality of frequencies, a network, a relay capable of being operated at will and to remain operated throughout a prefixed interval of time, the said relay being capable of disconnecting the said transmitting apparatus from the said line and of connecting thereto in sequence the said source and the said network, the sequence being effected by commutators upon said sequence switch, a broadcast transmitter normally connected to said line at a distant point thereon, measuring apparatus, a second relay arranged to disconnect said transmitter from said line and to effectively connect said measuring apparatus to said line, and means to prevent the operation of said second relay unless all of said plurality of frequencies are present in said line.

16. In a transmission measuring system for determining the electrical characteristics of a transmission line forming part of a broadcasting network, the combination with a line of apparatus normally connected to said line but capable of disconnection therefrom, of a plurality of selecting circuits connected to the said line, each having means to select and to rectify one of a plurality of discrete frequencies transmitted by the said line, a relay arranged to disconnect said apparatus from said line, and controlling means connected to the output of each rectifier to effect the operation of the said relay, the said controlling means being so arranged that the relay is prevented from operating unless all frequencies for which the said circuits are selective are present therein.

17. In a transmission measuring system for determining the electrical characteristics of a transmission line forming part of a broadcasting network, the combination with a line of apparatus normally connected to said line but capable of disconnection therefrom, of a plurality of selecting circuits connected to the said line, each having means to select and to rectify one of a plurality of discrete frequencies transmitted by the said line, a meter connected to the output of each rectifier to indicate the magnitude of the current of each frequency, means connected to the said meters to effectively lock said meters and to maintain the indication thereof after the cessation of the rectified current, a relay arranged to disconnect from the said line the apparatus normally connected thereto, a sequence switch having a plurality of commutators, controlling means also connected to the output of the said rectifiers and arranged to operate said relay only when all of said frequencies are impressed upon said rectifiers, and means including one of said commutators to maintain said relay operated throughout a given interval.

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