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ELECTRICAL TESTING SYSTEM

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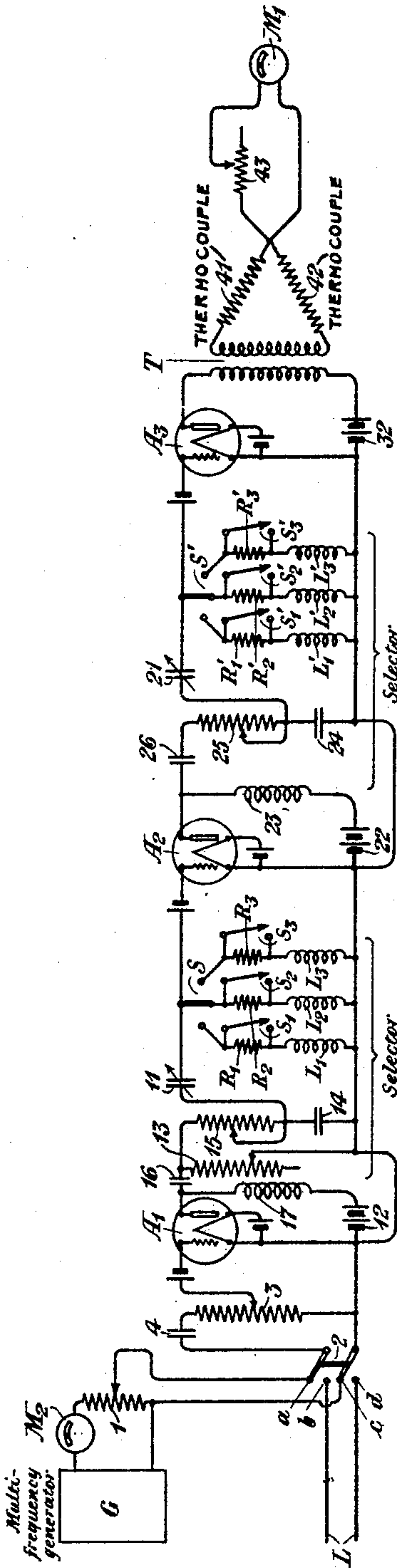


Fig. 1

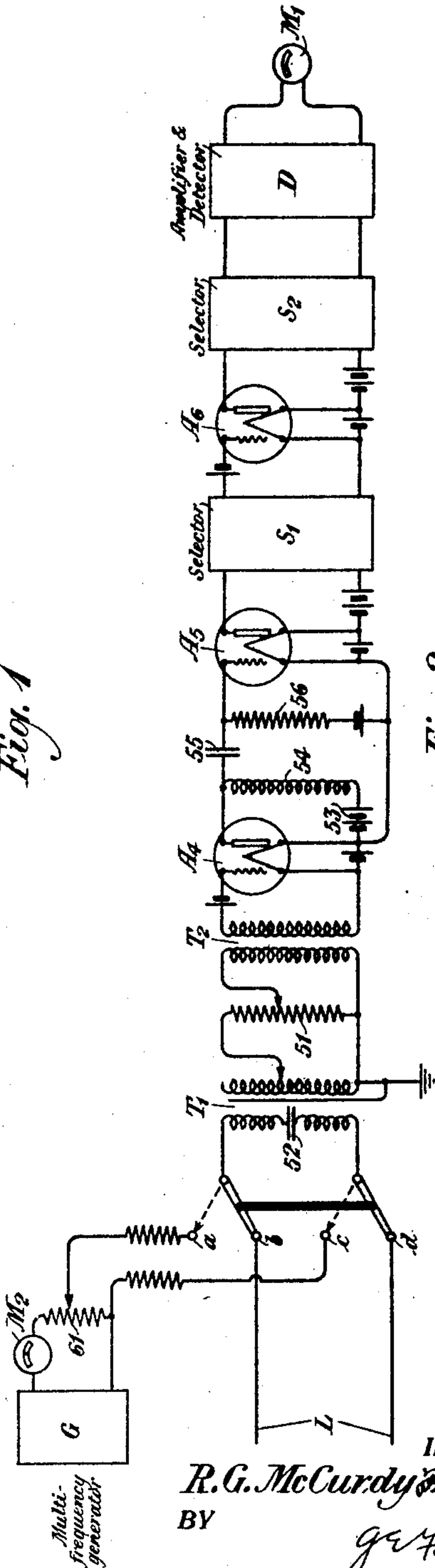


Fig. 2

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ELECTRICAL TESTING SYSTEM.

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This invention relates to electrical measuring systems, and particularly to means for and methods of determining the characteristics of any complex source of alternating currents.

One object of the invention is to provide a method and means for determining the characteristics of any complex source of alternating currents.

Another object of the invention is to provide means for indicating the relation existing between the characteristics of a component of a complex source of alternating currents and a component of known characteristics.

A further object of the invention is to provide a method and means for determining the various frequencies present in any complex source of alternating currents.

While the nature of the invention will be pointed out with particularity in the appended claims, the invention itself, both as to its objects and features, will be better understood from the detailed description hereinafter following when read in connection with the accompanying drawing, in which Figure 1 represents one embodiment of the invention suitable for analyzing a complex source of alternating currents, and Fig. 2 shows schematically another embodiment of the invention.

Referring to Fig. 1, there are shown a plurality of amplifiers A_1 , A_2 and A_3 , which are of the vacuum tube type. These amplifiers may, however, be of any well-known type, preferably of the vacuum tube type, as shown. Two interstage resonant circuits, known as selectors, interconnect the three stages of amplification. The selector placed between the amplifiers A_1 and A_2 comprises three inductances L_1 , L_2 and L_3 in series with three padding resistances R_1 , R_2 and R_3 , respectively, and a switch S for connecting whichever inductance and resistance may be found desirable. A variable condenser 11 is employed for tuning the particular inductance connected by switch S to any desirable frequency.

The selector placed between the amplifiers A_2 and A_3 comprises three inductances L_1' , L_2' and L_3' in series with three padding resistances R_1' , R_2' and R_3' , respectively, and a switch S' for connecting whichever inductance and resistance may be found desirable. It will be understood, however, that a plu-

rality of inductances may be included in series with a plurality of resistances within the scope of this invention. A variable condenser 21 is also associated with the selector for tuning whichever inductance is connected by the switch S' to any desirable frequency. The range of condensers 11 and 21 is limited on the one hand by their physical size and weight, and, on the other hand, by their impedance which should be low enough to avoid trouble due to leakage across their terminals.

The anodes of the amplifiers A_1 and A_2 are supplied with potential from batteries 12 and 22 through choke coils 17 and 23, respectively. The potential for the anode of the amplifier A_3 is supplied by a battery 32 through the primary winding of a transformer T . Two variable resistances 13 and 15 are included between amplifiers A_1 and A_2 and a variable resistance 25 is included between amplifiers A_2 and A_3 , these variable resistances compensating for variations in amplification when different inductances and padding resistances are included in the selectors.

A thermocouple is coupled to the amplifier A_3 through the transformer T . This thermocouple comprises two different metallic elements or resistances 41 and 42. This thermocouple is employed for producing direct current from the current amplified by the amplifier A_3 , and it transmits the rectified current to an indicating meter M_1 through a rheostat 43. It will be understood, however, that the thermocouple may be replaced by any other device capable of detecting alternating currents.

The reference character G represents a multi-frequency generator, or an adjustable frequency oscillator, suitable for transmitting any one of a plurality of frequencies. This multi-frequency generator may be of any well-known type, preferably a vacuum tube multi-frequency generator. The output of the multi-frequency generator G is connected in series with an indicating meter M_2 and a potentiometer 1. The magnitude of the potential set up across potentiometer 1 may be determined from the current amplitude as measured by the current indicating meter M_2 and the resistance of the potentiometer 1.

The line L represents a telephone line, a power line or any other source of complex current. This line L may be connected by a

switch 2, which closes contacts *b* and *d*, to the terminals of another potentiometer 3, a condenser 4 having a low capacity being included in the path to the potentiometer 3 for blocking direct and very low frequency currents. The switch 2, by closing contacts *a* and *c*, may also connect the output of the multi-frequency generator G with the terminals of the potentiometer 3, the potential of the generated wave being varied by the movable arm associated with the potentiometer 1.

The operation of this system for determining the characteristics of the components in the complex source connected to the leads L may be determined in the following manner: The movable arm associated with the potentiometer 3 is moved to its upper contact. Then the switch 2 is moved so as to close contacts *a* and *c* in order to connect the output of the multi-frequency generator G, which is a wave of pure sinusoidal form free from harmonics, across the grid and cathode of the amplifier A_1 . The selector between the amplifiers A_1 and A_2 is then adjusted for resonance at the frequency transmitted by the multi-frequency generator G by moving the variable condenser 11 and the switch S. The selector between the amplifiers A_2 and A_3 is also adjusted for resonance at the same frequency by moving the variable condenser 21 and the switch S'. This effects a deflection of the pointer of the indicating meter M_1 . The pointer of this indicating meter is then brought back to its mid-scale position by manipulation of the movable arm associated with the rheostat 43. This rheostat thus corrects for any variations in the amplification by amplifiers A_1 , A_2 or A_3 .

Then the switch 2 is moved to close contacts *b* and *d* so as to connect the complex source of alternating currents across the terminals of the potentiometer 3. The selectors between the amplifier stages A_1 , A_2 and A_3 select from the complex source of current a wave having the same frequency as that transmitted by the multi-frequency generator G, this component being freely transmitted while all other components are substantially suppressed. This causes another deflection of the pointer of the indicating meter M_1 , which is now brought back to its mid-scale position by manipulation of the movable arm associated with the potentiometer 3.

The potentiometer 3 is therefore used for comparing the voltage of the component of the complex source connected to the leads L with the voltage of the wave of the same frequency transmitted by the multi-frequency generator G. The voltage across the terminals of the potentiometer 3 may be determined from the current flowing through the indicating meter M_2 , the total resistance of the potentiometer 1 and the setting of the movable arm associated therewith. The volt-

age of the component in the complex source having the same frequency is a fraction of the voltage across the terminals of the potentiometer 3, which fraction is equal to the ratio that the resistance below the movable arm bears to the total resistance of the potentiometer 3.

The multi-frequency generator is then set so as to transmit another frequency, and the selectors are then adjusted so as to transmit that frequency, and the needle of the pointer of the indicating meter M_1 is again moved to its mid-scale position by the manipulation of the arm of the rheostat 43. The switch 2 is then moved to connect the complex source connected to the leads L to the terminals of the potentiometer 3. The component in the complex source having the same frequency as the one transmitted by the multi-frequency generator G is selected by the selectors and freely transmitted thereby to the exclusion of all other components; and the arm of the potentiometer 3 is then manipulated to bring the pointer of the indicating meter M_1 to its mid-scale position.

Thus, the selectors are progressively adjusted over the entire frequency range, and the characteristics of the components in the complex source of current connected to the leads L are progressively selected by these selectors so that the characteristics of these components may be compared with the known characteristics of waves transmitted by the multi-frequency generator G.

As an alternative, the components of the complex source of alternating current may be determined even though at different frequencies from those transmitted by the multi-frequency generator if a frequency calibration curve for the apparatus is used, which curve shows the response (as might be measured by a meter, such as M_1) plotted against frequency.

The employment of more than one selector for frequency selection, each between different stages of amplification, gives a very high degree of selectivity; that is, it has the advantage of diminishing the response for frequencies different from those for which the tuned circuits are adjusted. By employing more than one selector, the response curve becomes parabolic, being relatively flat in the immediate vicinity of the tuned frequency, and falling off extremely rapidly at frequencies differing substantially from the tuned frequency. This also permits the testing at low energy levels without the interference from other frequencies present in the circuit when the testing frequency is held within very narrow limits of variation. The selectivity obtainable by the use of more than one selector is so great that in order that the normal fluctuations in the frequency of the components in the complex source of current might not prevent accurate measurements,

175.31

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3

the padding resistances are provided, which may be switched into the tuned circuits to degrade the selectivity wherever necessary. The padding resistances R_1 , R_2 and R_3 in the selector between the amplifiers A_1 and A_2 may be shunted by the switches S_1 , S_2 and S_3 , respectively, and the padding resistances R_1' , R_2' and R_3' in the selector between the amplifiers A_2 and A_3 may be shunted by the switches S_1' , S_2' and S_3' , respectively. Should a further lessening of the selectivity be desired, the condenser 11 associated with the selector between the amplifiers A_1 and A_2 may be short-circuited, thus making only one of the selectors effective.

The tuned circuit comprising the condenser 11 and any one of the inductances L_1 , L_2 and L_3 is loosely coupled to the plate circuit of the amplifier A_1 by means of a condenser 14 which is in series with a resistance 15. The voltage across the condenser 14 is impressed across the tuned circuit, and consequently the voltage set up across the inductance portion of the tuned circuit is then applied to the grid of the amplifier A_2 . In the selector between the amplifiers A_2 and A_3 , the potential across the condenser 24 is similarly applied to the grid of the amplifier A_3 . In either case the tuned circuit of the selector is loosely coupled to the output circuit of the previous amplifier in order to diminish as much as possible the effect of one circuit on the other.

Figure 2 shows a more schematic arrangement of the invention, in which the testing circuit is isolated from the circuits connected to the multi-frequency generator G and the complex source of current connected to the leads L . This isolation is effected by the transformers T_1 and T_2 , the secondary of the transformer T_1 being connected to the primary of the transformer T_2 through a potentiometer 51. The secondary of the transformer T_1 is made adjustable by a movable arm connected with it so that the impedance facing the testing circuit can be made equal to the impedance of the circuit under test connected to the leads L . A condenser 52 is included in the primary winding of the transformer T_1 so as to prevent direct current from passing therethrough. The amplifiers A_4 and A_5 are coupled in a well-known manner, the potential for the anode of the amplifier A_4 being supplied from the battery 53 through a choke coil 54, and the condenser 55 being included in the path connecting the anode of the amplifier A_4 and the grid of the amplifier A_5 so as to prevent the potential of the battery 53 from being applied to the grid of the amplifier A_5 . The manner in which the characteristics of the components in the complex source of current are determined is similar to that already described.

Although the measurement of the voltage characteristics of the components of the com-

plex source of currents has been particularly described herein, it is to be distinctly understood that the testing apparatus of this invention is equally suitable for the measurement of the other characteristics of the components of the complex source.

Although the arrangements of this invention have been prepared for the analysis of a complex current wave, similar arrangements may also be applied to the measurement of attenuation, cross-talk and other like measurements.

The invention is not limited to the circuits herein shown and described, and it is obvious that various modifications may be made without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. The method of studying the characteristics of a complex source of current with apparatus including a plurality of tuned circuits, which consists in impressing the complex source of currents on the plurality of tuned circuits each of which may be adjusted from one frequency to a different frequency, amplifying each different frequency, progressively noting the characteristics of each different frequency, and comparing these characteristics with the predetermined characteristics of currents from a known source.

2. A system for studying the characteristics of a complex source of alternating currents, comprising a complex source of alternating currents, a plurality of tuned circuits upon which the complex source of alternating currents is impressed, said tuned circuits being progressively resonated at one frequency and then at a different frequency corresponding to the different frequencies in the complex source of alternating currents, and means for progressively indicating and comparing the characteristics of each of the different frequencies of the complex source of alternating currents with the predetermined characteristics of known currents.

3. In a testing circuit, in combination, a multi-frequency generator suitable for transmitting any one of a plurality of predetermined frequencies, a complex source of current, a plurality of selectors each selecting from the complex source of current a frequency equal to one of the predetermined frequencies transmitted by the multi-frequency generator and transmitting that frequency to the exclusion of all other frequencies, and means for comparing the characteristics of the selected and transmitted frequency with the characteristics of the predetermined frequency transmitted by the multi-frequency generator.

4. In a testing circuit, an oscillator generating a wave of known characteristics, a complex source of current, means comprising a plurality of selectors for selecting from the complex source of current a wave substan-

tially equal in frequency to the frequency of the wave generated by the oscillator, means for freely transmitting the selected wave and for substantially suppressing all other waves, and means for comparing the characteristics of the selected and transmitted wave with the characteristics of the wave generated by the oscillator.

5. In a testing circuit, a generator suitable for generating any one of a plurality of waves of known characteristics, a complex source of current of unknown characteristics, a plurality of amplifiers, a plurality of selectors, one selector being located between any two amplifiers, each selector being so related to the complex source of current as to transmit a predetermined frequency equal to one of the frequencies of the generator to the exclusion of all other frequencies, a thermocouple, and a measuring device, said thermocouple and said measuring device being arranged to compare the voltage and amperage characteristics of the selected wave with those of the generated wave of the same frequency.

6. In a testing circuit, in combination, an alternating current wave of known frequency and known characteristics, a source of alternating current waves of unknown frequencies and unknown characteristics, an amplifier for amplifying said waves, a plurality of selectors for selecting from the source of alternating current waves of unknown frequencies one wave having the same frequency as the wave of known frequency, said selectors transmitting this selected wave to the exclusion of all other waves, and means for comparing the characteristics of the selected wave with the characteristics of the known wave.

7. In a testing circuit, in combination, an alternating current wave of known frequency and known characteristics, a source of alternating current waves of unknown frequencies and unknown characteristics, a plurality of selectors each selectively transmitting from the source of alternating current waves of unknown frequencies a wave having the same frequency as the wave of known frequency, and means for comparing the characteristics of the selectively transmitted frequency with the characteristics of the known frequency.

8. In a testing circuit, in combination, a multi-frequency oscillator suitable for generating any one of a plurality of known frequencies, a complex source of current having a plurality of unknown frequencies, a device for selectively transmitting any one of the known frequencies to the exclusion of all other frequencies, an amplifier for amplifying the transmitted wave, another device for assuring further selectivity of the transmitted wave with respect to the other frequencies after amplification by the amplifier, means for measuring the characteristics of the selected wave, and means for comparing

these characteristics with those of a wave having the frequency generated by the multi-frequency oscillator.

9. In an electrical testing circuit, in combination, a generator for generating known currents of any one of a plurality of frequencies, a telephone line, and a testing circuit for determining the characteristics of the currents flowing in the telephone line, said testing circuit comprising a plurality of amplifiers, a plurality of selectors, one selector being located between each pair of amplifiers, a detector, a measuring device, and means for matching the impedance of the testing circuit with the impedance of the telephone line, each of said selectors comprising a plurality of tuned circuits each of which selectively transmits one of the currents having the frequency of resonance of that tuned circuit to the exclusion of all other frequencies, said measuring device comparing the characteristics of the selectively transmitted frequency and the known characteristics of the current of the generator of the same frequency after detection.

10. The method of determining the characteristics of a complex source of current with the aid of a plurality of tuned circuits connected to a source of known characteristics, which consists in adjusting each of the tuned circuits to the point of resonance and of maximum response at the frequency of the known source, measuring the characteristics of the frequency of the known source on a calibrated device, connecting the plurality of tuned circuits across the complex source of current, and comparing the characteristics of the frequency of the known source with the characteristics of the same frequency in the complex source of current.

11. The method of determining the characteristics of a complex source of current with apparatus comprising a plurality of tuned circuits connected to a complex source of current, which consists in adjusting each of the tuned circuits to a point of resonance and of maximum response at one of the frequencies in the complex source of current, measuring on a calibrated device the characteristics of the particular frequency of the complex source of current at which the tuned circuits give a maximum response, connecting the plurality of tuned circuits across a source of current of known characteristics having the same frequency as the tuned circuits for a maximum response, and comparing the characteristics of the frequency of the complex source of current with the known characteristics of the source.

12. The method of determining the characteristics of a complex source of current which is connected to a plurality of selectors separated by amplifiers, each selector comprising an adjustable tuned circuit, which consists in progressively adjusting each of

175.31

1,694,425

5

the selectors so as to freely transmit a component of the complex source to the exclusion of all other components, progressively detecting each of the components, and progressively comparing the characteristics of these components after detection with the characteristics of known currents.

13. In a testing system, a complex source of current, a plurality of selectors, a plurality of amplifiers, each selector being placed between any two amplifiers, each selector comprising an adjustable tuned circuit, means for adjusting the tuned circuit of the selector so as to progressively transmit one of the components of the complex source to the exclusion of all other components, means for progressively detecting each of these components, and means for comparing the characteristics of these components after detection with the characteristics of known currents.

14. A testing system suitable for meas-

uring currents of different frequencies with a sensitivity independent of frequency, comprising a plurality of tubes arranged in tandem, each tube including plate, filament and grid electrodes, an output circuit for each tube to be connected between its plate and filament electrodes, each output circuit including a capacity exhibiting a low impedance, and a resonant circuit for each tube composed of an inductance and a capacity, said resonant circuit being capacitatively coupled to each output circuit, the natural period of each resonant circuit being variable as desired, the inductance of each resonant circuit being connected between the grid and filament electrodes of the succeeding tube.

In testimony whereof, we have signed our names to this specification this 26th day of February, 1926.

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