

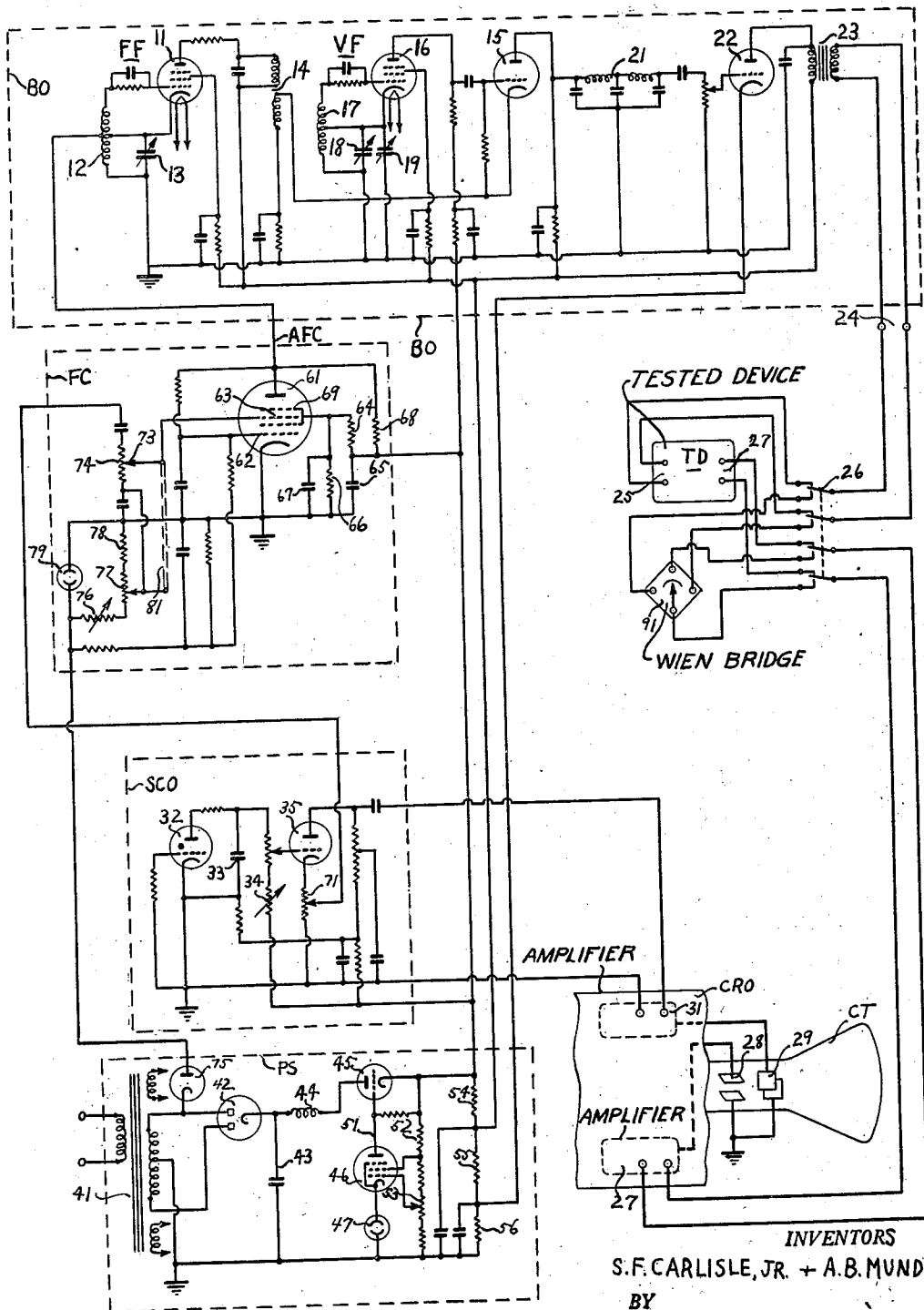
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FREQUENCY RESPONSE TESTING SYSTEM

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FREQUENCY RESPONSE TESTING SYSTEM

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This invention relates to frequency response testing systems, and has among its objects a simplified improved frequency response measuring system which requires in addition to the standard equipment of a regular commercial cathode ray oscillograph and a regular commercial beat-frequency oscillator, only a simple electronic frequency control circuit for enabling continuous observation of the frequency response characteristics of the device to be tested on the usual screen of a standard cathode ray tube.

The foregoing and other objects of the invention will be best understood from the following description of a frequency response testing system exemplifying one form of the invention and illustrated in the single figure of the accompanying drawing.

The principal parts of the system are formed by a beat-frequency oscillator BO which serves as the source of test oscillations which supplies oscillations of constant frequency to the tested device TD, such as a hearing aid amplifier; a testing device in the form of a cathode ray oscillograph CRO having a cathode ray tube on the screen of which the response characteristics of the tested device are traced; an electronic frequency control circuit FC through the operation of which the frequency of the oscillations supplied by the beat frequency oscillator BO is automatically determined; and a source of control oscillations formed by control oscillator SCO which serves to control the frequency sweep of the oscillations supplied to the tested device and to actuate one deflecting electrode set of the cathode ray tube to produce a cathode ray trace in one direction.

The beat-frequency oscillator BO, shown, is the standard a. c. operated beat-frequency oscillator manufactured by the RCA Manufacturing Company and described in its instruction booklet IB-26411. This beat-frequency oscillator BO has its standard fixed frequency (R. F.) oscillation stage FF comprising a self-biased 6J7 tube 11 and its associated circuit elements, including the frequency determining inductance 12 and condenser 13. The second and third grids of the tube operate as the oscillator plate and this oscillator portion of the tube is electronically coupled to the work-plate circuit which feeds into the primary winding of the intermediate frequency (I. F.) transformer 14.

The secondary winding of this I. F. transformer is connected in series with the cathode of the self-biased detector stage tube 15 which provides detector-cathode modulation at the frequency of

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the fixed oscillator. The variable frequency oscillator stage VF of the beat-frequency oscillator BO utilizes a circuit similar to that of the fixed oscillator stage FF, including a 6J7 oscillator tube 16 and the frequency controlling circuit elements formed by the tank circuit inductance 17 and the condensers 18, 19, the condensers being variable and permitting variations of the capacitance to change the frequency below that of the fixed oscillator, thereby determining the frequency of the beat oscillations. The electron-coupled work plate of the tube 16 of this stage is resistance-capacitance coupled to the grid of the detector tube 15 so as to provide detector-grid modulation at the frequency of the variable oscillator.

The two R. F. oscillator signals entering the detector tube 15, one at the cathode circuit and the other at the grid circuit, are combined to produce the desired beat frequency of the type required for testing acoustic devices. The beat-frequency detector oscillation output is fed through a two-stage radio frequency filter 21 to a fixed bias amplifier tube 22, so as to allow only the detected audio-frequency beat oscillation voltage to be applied to the grid of the amplifier tube 22, the output of which is fed to an output transformer 23.

The secondary winding of the oscillator output transformer 23 is connected to two oscillator output terminals 24, to which two input terminals 25 of the tested device are shown connected by the two upper contacts of a multi-blade switch 26, the switch 26 having also two lower blades through which the output terminals 27 of the tested device are connected to the vertical amplifier of the cathode ray oscillograph CRO, the voltage of which is impressed on a set of deflecting electrodes 28 of the cathode ray tube CT, which has the usual second set of deflecting electrodes 29 controlling the horizontal trace on the cathode screen of the tube.

The cathode ray oscillograph CRO shown is the standard Du Mont oscillograph, type 164, and includes, in addition, a horizontal sweep amplifier 31 which amplifies a horizontal sweep voltage supplied by the standard saw-tooth sweep control oscillator SCO, which usually forms a part of such oscillograph. The sweep control or saw-tooth oscillator SCO has a saw-tooth oscillation stage comprising a gas discharge tube 32, type 885, for instance, and its usual associated circuit elements including a condenser 33 connected across the plate circuit and a variable rheostat 34 connected in series with the plate for determining the rate at which the condenser 33 is charged and there-

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through the frequency of the saw-tooth oscillations. The output of the saw-tooth oscillation stage associated with tube 32 is impressed on the grid of an amplifier stage tube 35 of the SC5 type, the output of which is impressed on the horizontal sweep amplifier 31 of the cathode ray oscillograph.

To assure utmost stability, the D. C. operating voltage for the various electronic circuit parts of the system is derived from a standard regulated D. C. power supply circuit PS which assures that irrespective of variations of the A. C. power supply, the D. C. voltage delivered by it is constant. The voltage regulated D. C. power supply circuit PS is likewise of a well-known standard type, having been described, for instance, in the printed application notes published by the RCA Manufacturing Company in diagram 92C-4943 of July 20, 1938, entitled "Circuit of D-C voltage regulator."

The power supply circuit PS shown comprises the usual A. C. power supply transformer 41, the secondary winding of which delivers a rectified output through a rectifier 42 to a filter circuit including a shunt condenser 43 and a series choke 44 across which the voltage regulator circuit is connected. The voltage regulator shown has a regulator tube 45, a control tube 46 and a gas glow tube 47, the three tubes being of a standard known type. These tubes are interconnected with the resistor network shown so that the D. C. voltage is obtained from the cathode of the regulator tube 45.

In the normal operation of the regulator, the rectified current supplied through the rectifier filter circuit 42, 43, 44 flows through the regulator tube 45 to its cathode, where it divides into three branches, namely, one branch leading through tubes 46, 47 to ground, a second branch leading through resistances 52, 53 to ground, and a third branch being formed by the external load represented by the resistance elements 54, 55, 56 connected to the ground. The gaseous tube 47 is of the type which forms a non-linear resistance, the voltage drop across which is substantially independent of the current through it over a wide range of current values.

The various circuit elements of the regulator circuit formed by the tubes 45, 46, 47 and their associated resistor elements 51, 52, 53 are so chosen and correlated that, taking into consideration the fact that the voltage across the glow tube 47 remains constant, the regulator tube 45 serves as a variable voltage take-up device, compensating for any variations of the voltage across the load represented by the resistors 54, 55, 56, the magnitude of the voltage taken up across the regulator tube 45 being controlled by the action of the control tube 46, the bias of which is varied through the connection of its control grid to the tap of rheostat 53 by any change in the voltage across the load; a change in the bias of the control tube 46 producing a corresponding change in the current through its plate circuit including the resistor 52, which, in turn, produces a change in the bias voltage applied to the regulator tube 45 to produce a corresponding change in its conductance and the amount of voltage absorbed by it, so as to compensate for the change in the voltage impressed across the load. The regulated D. C. operating voltage, suitably proportioned by the three resistance elements 54, 55, 56 connected across the load circuit, is interconnected to the various circuit parts of the system described above, the electrodes of the various tubes being

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interconnected with the associated circuit elements so as to apply to them their appropriate operating voltages.

All of the elements of the system thus far described are well known and form standard parts of equipment used in laboratories and in production set-ups, and their arrangement and operation require no further explanation. In order to serve as a part of the frequency response measuring system of the invention, they are combined in a novel manner with the electronic frequency control circuit FC, which will now be described.

The electronic frequency control circuit FC utilizes as a control tube 61 a standard multi-grid electron-space discharge tube, which may be a 6L7 tube, the electron space discharge of which is coupled to the oscillating or tank circuit 12, 13 of the fixed frequency oscillator stage FF, so as to automatically change its frequency, and therethrough the frequency of the supplied beat oscillations, over a selected range, in a manner analogous to that used in the automatic frequency control of superheterodyne receivers.

The plate circuit of the control tube 61 is shown connected in parallel with the oscillator inductance 12 of the fixed frequency oscillator FF and its effective inductance is changed by altering the dynamic characteristics of the control tube 61 through variation of the bias of one of its control grids 62, 63. The control tube 61 has connected in its plate circuit a phase-changing network including resistor and condenser elements 64, 65, 66, 67, 68 correlated so that the control tube 61 is able to produce out-of-phase plate currents.

In other words, the frequency control tube 61 is arranged to be so interconnected with the tank circuit of the fixed oscillator stage FF of the beat oscillator that the modifications of the impedance of the space discharge path of the control tube are reflected into the frequency controlling network of the fixed frequency oscillator FF as an effective reactance determining in conjunction with the other reactive elements of the tank network of the fixed frequency oscillator its operating R. F. frequency. The control impedance of the control tube is controlled by variations in the voltage across the sweep control or saw-tooth oscillator stage SCO. The range of the frequency change affected by the control tube 61 may be controlled by applying a variable bias either to the first control grid 62 or to the second control grid 63. The instantaneous frequency is determined by the out of phase signal fed back from the oscillator tank circuit 12, 13 through its shift network to the third or screen grid 69.

In order to prevent undesirable interactions between the sweep control oscillator SCO and the intercoupling of the control tube 61 with the fixed frequency oscillator FF, a pentagrid tube is used as a control tube so that its two control electrodes 62, 63 may be maintained effectively decoupled from each other by the screen grid 69.

With this arrangement, if the control tube 61 is biased to a condition of infinite impedance or to cutoff, it has no effect and causes no change in the inductance of the tank circuit 12, 13. By reducing the bias of the control grid of the control tube 61, its mutual conductance is increased, thereby shunting the inductance of the tank circuit coil 12 with an apparent inductance and raising the frequency of the fixed oscillator FF.

It is usually desirable to have a logarithmic

spread of the frequency spectrum on the cathode ray screen. In accordance with the invention, this may be accomplished by varying the bias of the control tube in a linear saw-tooth manner and using a control tube having a mutual conductance which changes substantially logarithmically with the grid bias. Since the audio output of the beat frequency oscillator is approximately a straight line function of the mutual conductance of the control tube 61, the frequency of the beat oscillations will vary logarithmically if the mutual conductance of the control tube changes logarithmically with a linear change of the grid bias. In this manner it is possible to use the standard saw-tooth wave of a standard saw-tooth oscillator to produce one trace sweep of the cathode ray tube as well as for varying the mutual conductance of the control tube 61 to obtain a logarithmic change in the frequency of the generated audio oscillations.

In the arrangement shown, the generated beat oscillations are automatically controlled to rise from a low frequency to a higher frequency by biasing the control grid 63 of the control tube 61 to a cutoff value and also applying to this control grid 63 a component of the sweep voltage of such character as to cause the bias of the control grid 63 to rise from the chosen negative cutoff value to a predetermined more positive value. The beat frequency oscillator used in the system has a tank circuit, the frequency of which can be widely varied with only a small change in inductance, and represents a type which is particularly desirable for use in a system of the type described.

As shown in the drawing, a component of the saw-tooth oscillator voltage picked up from a tap of the self-biasing cathode resistor 71 of its amplifier tube 35, is applied through an adjustable tap 73 of a potentiometer rheostat 74 to control grid 63 of the control tube 61. This control grid 63 is arranged to have also impressed thereon a correlated D. C. bias voltage derived from a D. C. supply circuit, formed by a rectifier tube 75 connected through the secondary of the power supply transformer to a voltage dividing circuit including an adjustable tap rheostat 77 and series resistors 76, 78, a neon glow tube or similar constant voltage device 79 being connected across the circuit of the resistance elements 76, 77, 78 so as to maintain thereacross a constant D. C. voltage irrespective of changes in the A. C. supply voltage.

The series resistor 76 serves only to initially set the magnitude of an adjustable D. C. voltage supplied to the two series connected resistance elements 77, 78 through which the D. C. biasing voltage is applied to the control grid 63 by adjusting the tap of the rheostat 77. Rheostat tap 77 is further connected to the electrically grounded end of the adjustable rheostat 74 through which the component of the sweep oscillator control voltage is applied to the same control grid 63.

The various rheostat elements 74, 77, 78 are so adjusted and correlated to the other parameters of the circuit that the saw-tooth voltage derived from the sweep frequency oscillator SCO and applied to the grid 63 of the control tube 61 shall have a form going positive and negative about a biasing value equal to half of its sweep value subtracted from its cutoff bias voltage which represents in this case the maximum negative bias voltage. It is for this reason that the two rheostats 77, 78 are made equal to twice

the rheostat element 74 so that when the taps of the rheostat elements 74, 77, which are moved by a common control grip 81, are brought to a cutoff position, in which the impedance of the control tube 61 is infinite, an appropriate D. C. biasing cutoff voltage is applied through the rheostat 77 to the control grid 63.

In other words, the various circuit elements are so arranged that the saw-tooth wave voltage applied to the control grid 61 of the control tube 61 goes positive and negative about a biasing value of the saw-tooth voltage equal to half the peak value subtracted from the cutoff-bias voltage, and this D. C. biasing potential is varied in order to keep the minimum frequency of the fixed oscillator FF constant and occurring simultaneously with the peak of the saw-tooth wave. Furthermore, the multiple potentiometer including the rheostat element 74, the rheostat element 77 and series resistor 78 is being so arranged that the bias of the control grid is varied in suitable proportion to the magnitude of the saw-tooth potential applied to the control grid.

With this arrangement, the sweep of the generated beat oscillations supplied to the tested device may be varied from very low values to a very high value, for instance, from a low voltage of a few cycles to a high voltage of 1500 cycles per second.

With an arrangement of the foregoing type and using a standard saw-tooth oscillator SCO having a frequency of 30 cycles per second, a very good response curve is obtained on a standard medium persistence screen of a standard cathode ray tube, and with such tube, the lowest usable limit of the instrument is about 100 cycles per second, a frequency sufficient for testing most acoustic devices. If tests are to be made in a range below 100 cycles, a cathode ray tube with a long persistence cathode screen should be used and the saw-tooth oscillator adjusted to a suitable lower frequency.

The calibration of the instrument can be accomplished by the use of a Wien bridge 91 connected between the output of the beat frequency oscillator and the vertical deflecting plates 28 of the cathode ray tube CT. The multi-blade switch 26 makes it possible to interconnect either the tested device TD or the Wien bridge 91 in the circuit. The Wien bridge 91 can be calibrated at fixed frequencies and when it is placed in the output circuit will show a sharp narrow V notch point at the frequency points to be determined.

In a practical system of the foregoing type with the range control set to sweep from zero to 10,000 cycles per second, the mid-point of the trace was found to be 1000 cycles per second, indicating a very close approximation to a logarithmic frequency scale. By varying the setting of the variable frequency oscillator, the range of the frequency change produced by the operation of the control tube 61 may be shifted to different parts of the frequency range.

Summarizing, the testing system of the invention comprises a cathode ray tube having a first deflecting electrode for deflecting the cathode ray to produce a trace in one direction, and a second deflecting electrode for deflecting the cathode ray to produce a trace in a direction generally transverse thereto; a sweep oscillation source producing sweep oscillations of an amplitude increasing gradually over the major part of the oscillation cycle and decreasing abruptly to its minimum value; circuit means for im-

pressing a voltage corresponding to said sweep oscillations on one of said deflecting electrodes; test oscillation means formed by a beat oscillation source supply test oscillations of constant intensity to said tested device, for producing a response voltage in accordance with the response characteristics of said device and for applying said response voltage to the other of said deflecting electrodes. The beat oscillation source comprises a first oscillator producing oscillations of a settable frequency and a second frequency modifying oscillator producing oscillations of a predetermined controllable frequency range and interlinked with said first oscillator so as to impress on the tested device resultant beat oscillations of a controllable frequency range by varying the oscillation frequency of the modifying oscillator relatively to the oscillation frequency of the other settable oscillator. The modifying oscillator includes a frequency-determining reactive network which determines the frequency of its oscillations and serves to automatically cause periodic variations of the frequency of said beat oscillations over a predetermined variable beat frequency range. Frequency control means including an electron space-discharge control tube have output electrodes interconnected with the frequency determining reactive network of the modifying oscillator so that modifications of the impedance of the space discharge path of the control tube are reflected into the frequency determining network as an effective reactance for determining in conjunction with the reactive elements of said network the operating frequency of the frequency modifying oscillator. The operation of the control tube is controlled by biasing means including an adjustable bias circuit element connected to apply to its space discharge path an adjustable biasing potential for adjustably setting the operating characteristics of said tube. The operation of the control tube is also controlled by an adjustable control circuit element interconnected to the source of control oscillations to apply to the space discharge path of the control tube an adjustable control potential corresponding in a predetermined manner to said control oscillations for producing corresponding variations in the reactance effect reflected by said space discharge path into the frequency-determining network and thereby correspondingly varying the frequency of the oscillations of the modifying oscillator over a predetermined frequency range. The adjustable control circuit elements have interlinked adjusting means arranged so that in each adjustment thereof the bias potential and control potential applied to the discharge path of the control tube are correlated to each other in a predetermined manner so that the frequency modifying oscillator oscillates with the lowest frequency when the amplitude of the control oscillations is a maximum and the applied bias potential causes the reflected impedance of the path to be substantially infinite or a maximum when the applied amplitude of the control potential is zero, and that when the applied amplitude of the control potential is increased the applied bias potential has a value at which the negative peak of the control potential causes the impedance of the path to be substantially infinite or a maximum.

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in connection with specific exam-

plications thereof will suggest various other modifications and applications of the same.

We claim:

1. In a testing system for determining the frequency response characteristics of a tested device by means of a testing device, such as a cathode ray tube, and including a control oscillation source for supplying to the testing device and to a frequency modifying oscillator control oscillations of an amplitude increasing gradually over a major part of the predetermined control cycle and decreasing abruptly to its minimum value so that said modifying oscillator may controllably modify the frequency of a test oscillator supplying test oscillations to the tested device; said modifying oscillator including a reactive network which determines the frequency of its oscillations for automatically causing periodic variations of the frequency of the test oscillation over a predetermined variable beat frequency range; frequency control means including an electron space discharge tube having output electrodes interconnected with said reactive network so that modifications of the impedance of the space discharge path of said tube are reflected into said network as an effective reactance determining in conjunction with the reactive elements of said network the operating frequency of the modifying oscillator; biasing means including an adjustable bias circuit element connected to apply to the space discharge path of said tube an adjustable biasing potential for adjustably setting the operating characteristics of said tube; said first oscillator including adjusting means for selectively adjusting the frequency of its oscillation and thereby selectively shifting said variable beat frequency range to a selected part of the frequency spectrum; control means including an adjustable control circuit element interconnected to said source of control oscillations so as to apply to the space discharge path of said tube an adjustable control potential corresponding in a predetermined manner to said control oscillations for producing corresponding variations in the reactance effect reflected by said space discharge path into said reactive network and thereby correspondingly varying the frequency of the oscillations impressed on said device over a predetermined frequency range; said adjustable circuit elements having interlinked adjusting means arranged so that in each adjustment thereof the bias potential and control potential applied to said discharge path are correlated to each other in a predetermined manner; the elements of the biasing means and the elements of the control means being so arranged and correlated that the modifying oscillator oscillates with the lowest frequency when the amplitude of the control oscillations is a maximum and that the applied bias potential causes the reflected impedance of the path to be above a predetermined maximum when the applied amplitude of the control potential is zero, and that when the applied amplitude of the control potential is increased the applied bias potential has a value at which the negative peak of the control potential causes the reflected impedance of the path to have the same predetermined minimum.

2. In a testing system for determining the frequency response characteristics of a tested device by means of a testing device, such as a cathode ray tube, and including a control oscillation source for supplying to the testing device and to a frequency modifying oscillator control oscillations of an amplitude increasing gradually over

a major part of the predetermined control cycle and decreasing abruptly to its minimum value so that said modifying oscillator may controllably modify the frequency of a test oscillator supplying test oscillations to the tested device; said modifying oscillator including a reactive network which determines the frequency of its oscillations for automatically causing periodic variations of the frequency of the test oscillation over a predetermined variable beat frequency range; frequency control means including an electron space discharge tube having output electrodes interconnected with said reactive network so that modifications of the impedance of the space discharge path of said tube are reflected into said network as an effective reactance determining in conjunction with the reactive elements of said network the operating frequency of the modifying oscillator; biasing means including an adjustable bias circuit element connected to apply to the space discharge path of said tube an adjustable biasing potential for adjustably setting the operating characteristics of said tube; said first oscillator including adjusting means for selectively adjusting the frequency of its oscillation and thereby selectively shifting said variable beat frequency range to a selected part of the frequency spectrum; control means including an adjustable control circuit element interconnected to said source of control oscillations so as to apply to the space discharge path of said tube an adjustable control potential corresponding in a predetermined manner to said control oscillations for producing corresponding variations in the reactance effect reflected by said space discharge path into said reactive network and thereby correspondingly varying the frequency of the oscillations impressed on said device over a predetermined frequency range; said adjustable circuit elements having interlinked adjusting means arranged so that in each adjustment thereof the bias potential and control potential applied to said discharge path are correlated to each other in a predetermined manner; the elements of said biasing means and the elements of the control means being so arranged and correlated that the modifying oscillator oscillates with the lowest frequency when the amplitude of the control oscillations is a maximum and that the applied bias potential causes the reflected impedance of the path to be substantially infinite when the applied amplitude of the control potential is zero, and that when the applied amplitude of the control potential is increased the applied bias potential has a value at which the negative peak of the control potential causes the impedance of the path to be substantially infinite.

3. In a testing system for determining the frequency response characteristics of a tested device by means of a testing device, such as a cathode ray tube, and including a control oscillation source for supplying to the testing device and to a frequency modifying oscillator control oscillations of an amplitude increasing gradually over a major part of the predetermined control cycle and decreasing abruptly to its minimum value so that said modifying oscillator may controllably modify the frequency of a test oscillator supplying test oscillations to the tested device; said modifying oscillator including a reactive network which determines the frequency of its oscillations for automatically causing periodic variations of the frequency of the test oscillation over a predetermined variable beat frequency range; frequency control means including an electron space

discharge tube having output electrodes interconnected with said reactive network so that modifications of the impedance of the space discharge path of said tube are reflected into said network as an effective reactance determining in conjunction with the reactive elements of said network the operating frequency of the modifying oscillator; biasing means including an adjustable bias circuit element connected to apply to the space discharge path of said tube an adjustable biasing potential for adjustably setting the operating characteristics of said tube; said first oscillator including adjusting means for selectively adjusting the frequency of its oscillation and thereby selectively shifting said variable beat frequency range to a selected part of the frequency spectrum; control means including an adjustable control circuit element interconnected to said source of control oscillations so as to apply to the space discharge path of said tube an adjustable control potential corresponding in a predetermined manner to said control oscillations for producing corresponding variations in the reactance effect reflected by said space discharge path into said reactive network and thereby correspondingly varying the frequency of the oscillations impressed on said device over a predetermined frequency range; said adjustable circuit elements having interlinked adjusting means arranged so that in each adjustment thereof the bias potential and control potential applied to said discharge path are correlated to each other in a predetermined manner; the elements of the biasing means and the elements of the control means being so arranged and correlated that the second oscillator oscillates with the lowest frequency when the amplitude of the control oscillations is a maximum and that the applied bias potential causes the reflected impedance of the path to be above a predetermined maximum when the applied amplitude of the control potential is zero, and that when the applied amplitude of the control potential is increased the applied bias potential has a value at which the negative peak of the control potential causes the reflected impedance of the path to have the same predetermined maximum.

4. In a testing system for determining the frequency response characteristics of a tested device by means of a testing device, such as a cathode ray tube, and including a control oscillation source for supplying to the testing device and to a frequency modifying oscillator control oscillations of an amplitude increasing gradually over a major part of the predetermined control cycle and decreasing abruptly to its minimum value so that said modifying oscillator may controllably modify the frequency of a test oscillator supplying test oscillations to the tested device; said modifying oscillator including a reactive network which determines the frequency of its oscillations for automatically causing periodic variations of the frequency of the test oscillation over a predetermined variable beat frequency range; frequency control means including an electron space discharge tube having output electrodes interconnected with said reactive network so that modifications of the impedance of the space discharge path of said tube are reflected into said network as an effective reactance determining in conjunction with the reactive elements of said network the operating frequency of the modifying oscillator; biasing means including an adjustable bias circuit element connected to apply to the space discharge path of said tube an adjustable biasing potential for adjustably setting the

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operating characteristics of said tube; said first oscillator including adjusting means for selectively adjusting the frequency of its oscillation and thereby selectively shifting said variable beat frequency range to a selected part of the frequency spectrum; control means including an adjustable control circuit element interconnected to said source of control oscillations so as to apply to the space discharge path of said tube an adjustable control potential corresponding in a predetermined manner to said control oscillations for producing corresponding variations in the reactance effect reflected by said space discharge path into said reactive network and thereby correspondingly varying the frequency of the oscillations impressed on said device over a predetermined frequency range; said adjustable circuit elements having interlinked adjusting means arranged so that in each adjustment thereof the

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bias potential and control potential applied to said discharge path are correlated to each other in a predetermined manner; the elements of said biasing means and the elements of the control means being so arranged and correlated that the second oscillator oscillates with the lowest frequency when the amplitude of the control oscillations is a maximum and that the applied bias potential causes the reflected impedance of the path to be substantially infinite when the applied amplitude of the control potential is zero, and that when the applied amplitude of the control potential is increased the applied bias potential has a value at which the negative peak of the control potential causes the impedance of the path to be substantially infinite.

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