Oct. 26, 1926. 1,604,610

J. C. SCHELLENG

MODULATION INDICATOR

Filed Feb. 28, 1923

Fig. 1.

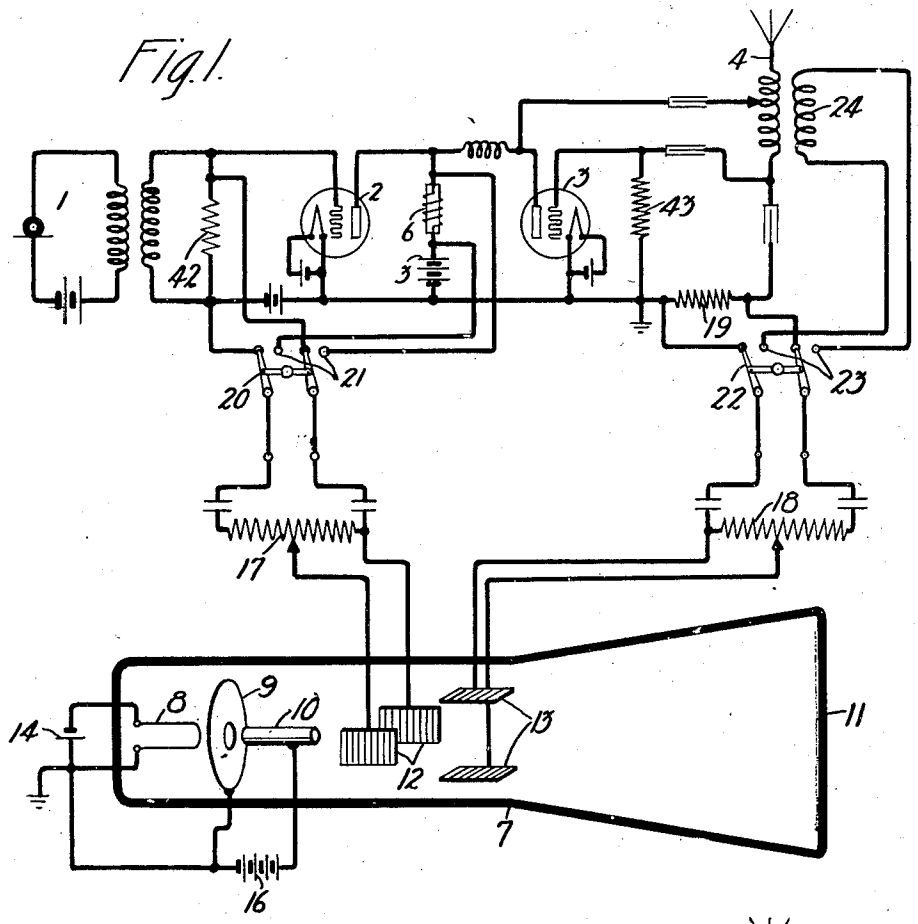


Fig. 2.

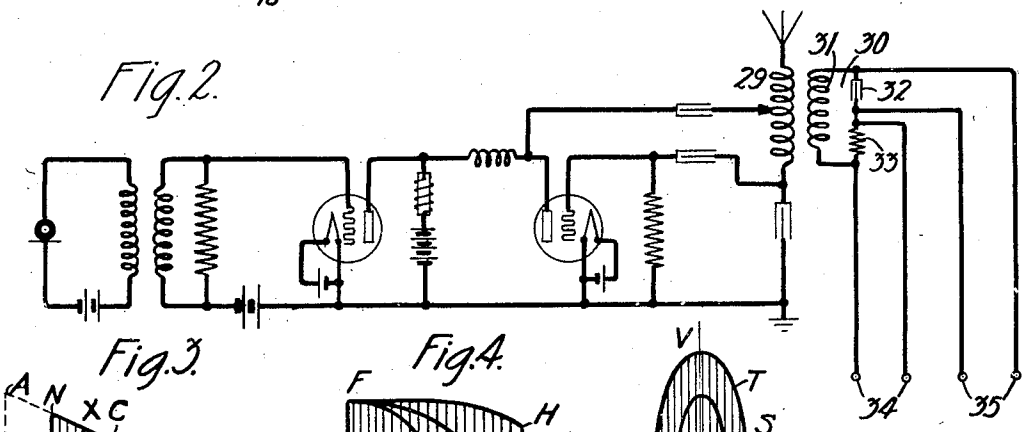


Fig. 3.

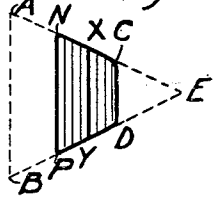
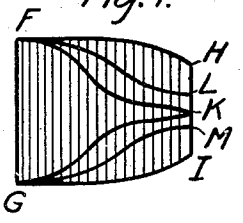


Fig. 4.



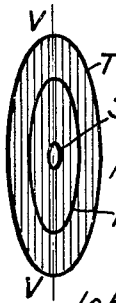


Fig. 5.

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by W. Griggs Atty.

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UNITED STATES PATENT OFFICE.

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MODULATION INDICATOR.

Application filed February 28, 1923. Serial No. 621,702.

This invention relates to a method of and means for indicating the quality reproduction characteristics of a modulator and more particularly to a method for graphically indicating the percentage modulation of a modulated carrier wave.

According to one arrangement embodying the present invention, the modulating current produces a control field in one plane and the modulated carrier wave produces a control field in a second plane at right angles to the first. The resultant field obtained may be used to deflect an electron stream or cathode ray to trace a pattern upon the receiving screen of a Braun tube. The physical characteristics of the pattern show the degree or percentage of modulation effected by the modulator, indicate whether there is any undesirable distortion present and also the cause of such distortion.

In the case where there is no phase displacement between the modulating current and the carrier envelope, the carrier wave before modulation is a pure sinusoidal wave, and in the modulating process the carrier wave is completely modulated, as defined by H. J. Van der Bijl in his treatise on the thermionic vacuum tube at page 321, the form of the pattern produced upon the receiving screen of a Braun tube will be an isosceles triangle. If the carrier wave is incompletely modulated, the pattern will be an isosceles trapezoid. Should the potentials supplied to the modulator and oscillator be such that either of these devices cause distortion, certain of the boundary lines of the pattern will be curved.

According to a second arrangement for practicing this invention only the modulated carrier wave is used to produce the deflecting field for the cathode ray or pencil of the Braun tube to trace a pattern upon its receiving screen. The physical characteristics of the pattern or diagram serves to indicate the degree or percentage of modulation. In this case, the pattern will be circular or elliptical.

The primary object of this invention is to provide a method for indicating the quality reproduction characteristic of a modulator.

Another object is the provision of a means whereby the percentage modulation effected by a modulating apparatus may be graphically indicated.

The present invention will be best understood by referring to the accompanying drawing in which Fig. 1 shows an arrangement of apparatus for obtaining the desired result. Fig. 2 illustrates a different arrangement for deriving the voltages adapted to be impressed upon the respective pairs of deflecting plates of the Braun tube. Figs. 3 and 4 illustrate different forms of the pattern traced upon the receiving screen under varying operating conditions of the modulator when using the arrangement shown in Fig. 1, and Fig. 5 represents the diagram obtained when the connection shown in Fig. 2 is employed.

Referring to Fig. 1, there is shown a modulating source 1 herein illustrated by way of example as a microphone and its associated battery. A modulator 2, the output circuit of which is connected with the plate circuit of the oscillator 3 effects modulation of the carrier frequency waves generated by the oscillator in the circuit 4, herein shown as an antenna circuit. The antenna circuit shown is but one example of the load circuit to which the modulated carrier wave may be supplied. It should be noted that the coil 24, inductively associated with the inductance coil in the antenna circuit, may be connected to a line for supplying modulated carrier waves for transmission to a distant station.

The modulating device 2 is preferably a space discharge device, comprising an evacuated vessel enclosing a heated cathode, an anode and a control element or grid, and the oscillator 3 is a space discharge tube which includes a heated cathode, an anode and a grid and associated input and output circuits which are coupled in feed-back relation to produce sustained carrier oscillations. The frequency of the oscillations generated is largely determined by the antenna circuit.

Space current for the modulator 2 and oscillator 3 is supplied from a common source 5 through a choke coil 6, so that, as explained in U. S. Patent No. 1,442,147, January 16, 1923 to Heising, the source 5

and coil 6 constitute a substantially constant current source for the plate circuits of the modulator and oscillator.

The low frequent voltages impressed upon the input circuit of the modulator 2 cause the resistance of the output circuit to vary through a correspondingly wide range, thereby causing variations in the power supplied to the generator so as to produce, in the load circuit, carrier frequency waves modulated in amplitude in accordance with the low frequency waves supplied by the source 1. For a detailed description of the operation of this modulating arrangement, reference may be made to the above mentioned U. S. patent.

The arrangement described above, for producing a modulated wave is but typical of a satisfactory arrangement for the purpose and is, therefore, not an essential feature of the present invention. Any other modulating system may be employed.

As typical of a Braun tube which may be used, there is shown in Fig. 1 a device comprising an elongated evacuated glass tube 7 which is supplied with mercury vapor at a pressure of one or two microns. The tube encloses an electron emitting cathode 8 consisting of a heated filament; a perforated plate electrode 9; an anode 10 having a small aperture; a receiving screen 11 comprising, for example, a coating of fluorescent material deposited on the end of the glass tube, and two pairs of deflecting plates or grids 12 and 13 of conducting material symmetrically disposed relatively to the longitudinal axis of the tube. The plates 12 and 13 are mounted between the anode 10 and the receiving screen 11. The plates 12 are disposed on opposite sides of the electron stream path and the plates 13 are similarly positioned relatively to the stream path. The center lines of the two pairs of plates 12 and 13, respectively, lie in the same transverse plane on diametral lines at right angles to each other.

In the preferred arrangement of this type of Braun tube, a source 14 supplies heating current to the filament 8, and a source 16 is employed to supply the desired positive potential difference between the anode 10 and the cathode 8, while the pairs of plates 12 and 13 are connected to the circuit to be tested. As is well known in the art, a narrow beam of cathode rays will pass through the anode 10 when a sufficient voltage is impressed between the hot cathode and the anode, and will produce a luminous spot on the receiving screen 11 at the opposite end of the vessel.

The plates 12 are connected through a potentiometer resistance 17 across the high resistance 42 included in the input circuit of the modulator 2. The resistance 42 is adapted to aid in reducing distortion. In one instance, where a step up input transformer of 50 ohms to 700,000 ohms was used, the value of resistance 42 was 750,000 ohms. The plates 13 are connected through a potentiometer 18 across a resistance 19 in the antenna circuit 4. 43 is a resistance leak path, connecting the cathode and grid of the oscillator 3 and for a VT_2 tube may be of the order of 10,000 ohms.

In Fig. 1 there are shown alternative arrangements for deriving the modulating voltage impressed upon the potentiometer 17. By throwing the switch 20 to the right into engagement with the contacts 21, the potentiometer 17 will be connected across the choke coil 6, the potential drop across which varies in accordance with the speech frequency voltages controlling the space current of the modulator 2. Again by moving the switch 22 into engagement with the contacts 23, the coil 24 inductively associated with the inductance coil in the antenna will supply modulated carrier waves to the potentiometer 18. The drop of potential across the potentiometer 18 is impressed upon the deflecting plates 13. The resultant field being a combination of the field between the plates 12 and that between the plates 13 causes the cathode ray to trace a pattern upon the receiving screen 11 as described above.

The operation of this apparatus is as follows: If no modulating current is supplied by the source 1, an electrostatic field will be set up between the plates 13 which causes the cathode ray of the Braun tube to be deflected along a straight line, such as XY of Fig. 3, the length of which will be proportional to the voltage of the carrier frequency wave produced by the oscillator, and hence an illuminated straight line will appear on the receiving screen of the tube. With modulating current impressed upon the input circuit of the device 2, an electrostatic field, proportional at any given instant to the instantaneous value of the potential drop across the potentiometer 17 will be produced between the plates 12 and will cause the cathode ray of the tube to be deflected in a plane at right angles to the field of the plates 13. The joint action of these two fields causes the cathode ray to trace a luminous pattern upon the receiving screen of the tube, the configuration of which, as stated above, depends upon the percentage of modulation effected. The shape of the pattern also depends upon whether there is any phase displacement between the modulating current and the carrier frequency envelope, and whether the carrier output wave itself is distorted by the oscillating tube. Thus, the coordinates, that is the ordinates of the pattern in one direction and its ordinates in the other direction are respectively proportional to the instan

taneous value of the modulating voltage and the instantaneous value of the voltage of the modulated wave.

If the modulating voltage used is so chosen that when impressed upon the grid of the modulator in the negative sense under correct operating conditions, it just reduces the amplitude of a carrier frequency output wave to zero, and when applied in the opposite sense, it causes the amplitude of the output carrier wave to increase to twice its unmodulated value, and there is no distortion, the luminous pattern produced upon the receiving screen 11 will correspond to the isosceles triangle ABE, Fig. 3. With incomplete undistorted modulations, a luminous diagram of trapezoidal form, represented by the diagram NPDC, will appear upon the receiving screen of the tube. In the latter case, if the length of the longer side NP of the trapezoid is represented by a, and the length of the shorter side CD of the trapezoid is represented by b, the percentage of modulation M will be equal to

$$\frac{a-b}{a+b}\times 100.$$

If there is any distortion of the modulating wave between the grid of the modulator and the output circuit of the oscillator, the converging boundary lines of the luminous pattern, which appears upon the receiving screen of the tube will be non-linear. As shown in Fig. 4, the diagram FGHI shows that the initial negative voltage impressed upon the grid of the modulator is too great. This is indicated by the fact that for increasing negative grid potentials, which in the proper adjustment should give increasing high frequency voltages, as is indicated by the difference in the ordinates XY and AB in Fig. 3, no increase is obtained. This is because the modulator grid is initially so negative that little or no current is flowing when there is no modulation and hence increasing the grid voltage of the modulator negatively during modulation is without the desired effect in increasing the oscillator plate current.

Diagram FGK shows a bad case of over modulation. In this case, the amplitude of the alternating energy supplied to the input circuit of the modulator is so great that when the negative portion of the wave is supplied to the modulator input circuit, the cut-off value of the voltage impressed upon the grid of the modulator is exceeded and when the positive portion of the wave is supplied to the input circuit, the grid voltage exceeds the value necessary to make the modulator resistance small compared to that of its load; i. e., the equivalent audio frequency resistance of the oscillating tube and its circuit.

A curve such as FGLM will be obtained if the oscillator is adjusted to take a plate current which is larger than that for which the modulating tube is designed. For example, if the current capacity of the modulator is insufficient to completely modulate the oscillations generated by the oscillator, and the input energy supplied to the modulator is increased so as to cause the modulating tube to operate on the non-linear portion of its input voltage output current characteristic curve, a diagram such as FGLM would be obtained.

Should there be a change in the phase of the modulating current between the grid of the modulator and the output circuit of the oscillator, the pattern upon the receiving screen will consist of two loops. In practice, this type of pattern usually does not occur unless some phase shift occurs in the audio frequency circuits or the capacity reactance of the deflecting grids of the Braun tube, upon which the modulating voltage is impressed and the leads connected thereto, is comparable to the resistance of the potentiometer.

In order that this apparatus may be operated without distortion, there should be no stray magnetic or electrostatic fields in the vicinity of the apparatus, and the capacity reactance of the lead wires to the modulating frequency deflecting plates 12 should be large, relative to the resistance of the potentiometer 17 shunting them.

A second arrangement for indicating the percentage of modulation effected, is illustrated in Fig. 2. In this case, only the carrier frequency wave is utilized to control the deflection of the cathode ray pencil of the Braun tube.

Referring to Fig. 2, there is shown a circuit 30, including a coil 31 inductively associated with the inductance coil 29. By means of the inductive coupling between the coils 29 and 31, modulated carrier waves will be supplied to the circuit 30. Connected across the terminals of the coil 31 are two impedances, herein illustrated as a condenser 32 and a resistance 33. Any combination of two impedances having different characteristics could be used, for example, a resistance and inductance or a condenser and an inductance could be connected across the coil 31.

Either potentiometer 17 or 18 may be connected across the condenser and the other across the resistance. For illustrative purposes it is assumed that the potentiometer 17 is connected to the terminals 35 and hence across the condenser 32, whereby the potential drop across this element is impressed upon the deflecting plates 12 of the Braun tube. Potentiometer 18 is assumed to be connected to the terminals 34 and hence across the resistance 33, so that

the difference of potential between its terminals is impressed upon the deflecting plates 13 of the tube 7.

Because of the difference in the impedance characteristics of the condenser 32 and resistance 33, the high frequency voltages across these two impedances will be out of phase and as a result the potentials across the corresponding pairs of deflecting grids will also be out of phase. Thus, the potentials impressed upon the respective pairs of plates 12 and 13 will be out of phase with the result that the combined control field for the cathode pencil of the Braun tube will cause the luminous pattern, produced upon its receiving screen, to be circular or elliptical.

As shown in Fig. 5, when the carrier wave is unmodulated a pattern of circular or elliptical form represented by the line R will be traced upon the receiving screen 11 of the tube. When a modulated carrier wave is supplied to the circuit 30, an illuminated figure bounded by the lines S and T will be produced upon the receiving screen 11.

The percentage of modulation may be determined from this diagram by using the sum and difference of the lengths of the diameters or axes of the lines S and T in any single plane at right angles to the plane of the screen. Thus, on the section line V—V, if a equals the length of the diameter or axis of T and b equals the length of the diameter or axis of S, the percentage of modulation M will be equal to

$$\frac{a-b}{a+b}\times 100.$$

Should the carrier frequency be a multiple of the modulating frequency and the ratio of the two frequencies be of the order of less than 10, the pattern which is traced on the receiving screen of the Braun tube will be a complicated one, consisting of two spirals and hence the problem of determining the percentage of modulation by this method will be rather cumbersome and unsatisfactory. However, for a system in which the two frequencies are not multiples of each other or in which their ratios are greater than 10, this arrangement may be satisfactorily employed.

An arrangement similar to Fig. 2 in which a condenser 32 only is connected across the coil 31 may be employed to indicate the degree of modulation effected. The deflecting plates 12 and 13 are connected through the respective potentiometers 17 and 18 across the terminals of the condenser 32. The deflection will be a straight line. It has been found that with incomplete modulation two bright spots appear on this line and the distance between them represents the minimum amplitude of the modulated wave. Hence, as described above, if a equals the length of the illuminated line and b the distance between the bright spots, the percentage of modulation M will be equal to

$$\frac{a-b}{a+b}\times 100.$$

Obviously the arrangements described above may be used at a carrier wave receiving system. In this case it will be necessary to amplify the incoming modulated carrier.

From the preceding description, it will be apparent that this invention provides a very simple method for studying the reproduction characteristics of a modulating apparatus, since it is adapted to graphically indicate the degree of modulation effected by the apparatus, if an undistorted modulated wave is being produced and, in case distortion is present, the first arrangement described also serves to indicate the cause of the distortion.

As described above, certain arrangements and specific details have been set forth for the purpose of clearly and completely disclosing the principles of the present invention. However, this invention is independent of the arrangements and details hereinbefore specified, and may be used at either a carrier transmitting or a carrier receiving station, whether used for radio transmission or in a system in which the carrier wave is guided by wires connecting the communicating station. This method is independent of the modulating scheme employed. Moreover, any well-known type of amplifier modulator or carrier frequency source as well as any well-known type of Braun tube may be used.

It is to be understood that, aside from the limitation referred to in the preceding paragraph, this invention is of general application and is, therefore, limited only by the scope of the appended claims.

What is claimed is:

1. A method of studying the characteristics of a carrier wave modulated in accordance with a signal current, which comprises producing a pencil of cathode rays, deriving a composite field from the modulated wave, controlling by said field the pencil of rays to trace a pattern, the characteristics of which serve to indicate the percentage of modulation effected.

2. A method of indicating the characteristics of a modulated wave which comprises producing a luminous pattern, the coordinates of which in two directions are proportional to the voltage of the modulating current and the modulated carrier wave, respectively, the configuration of said pattern serving to indicate whether the modulated wave is undistorted or distorted.

3. A method of indicating the character

istics of a modulated wave which comprises producing a luminous pattern, the coordinates of which in two directions are proportional to the voltage of the modulating wave and the modulated carrier wave, respectively, the configuration of said pattern serving to indicate whether the modulated wave is undistorted or distorted, and if distorted the cause of the distortion.

4. A method of indicating the reproduction characteristics of a modulating apparatus which comprises producing a diagram, the coordinates of which in one direction are proportional to the amplitude of the modulating current and the coordinates in another direction are proportional to the amplitude of the modulated wave.

5. A method of indicating the reproduction characteristics of a modulating apparatus which comprises producing a diagram, the coordinates of which in one direction are proportional to the amplitude of the modulating current, and the coordinates in another direction are proportional to the voltage of the modulated wave.

6. A method of indicating the reproduction characteristics of a modulating apparatus which comprises producing a pencil of cathode rays displacing said pencil of rays in one direction proportional to the voltage of the modulating current, and displacing said pencil in another direction proportional to the voltage of the modulated wave.

7. A method of indicating the reproduction characteristics of a modulating apparatus which comprises producing a pencil of cathode rays, displacing said pencil of rays in one direction proportional to the voltage of the modulating current, and displacing said pencil, in a direction at right angles to the first, proportional to the voltage of the modulated wave.

8. A method of indicating the reproduction characteristics of a modulating apparatus which comprises producing a pencil of cathode rays and displacing said pencil of rays by a composite field, the strength of which in one direction is proportional to to the modulating voltage, and the strength of which in another direction is proportional to the voltage of the modulated wave.

9. A method of indicating the reproduction characteristics of a modulating apparatus which comprises controlling by the modulated wave the production of a pattern having characteristics which indicate the percentage modulation effected and also whether an undistorted modulated wave is produced.

10. A method of indicating the reproduction characteristics of a modulating apparatus which comprises producing a pencil of cathode rays, deflecting said pencil of rays in two directions by the modulated wave to produce a pattern having characteristics which indicate the degree of modulation effected and also whether the modulated wave is undistorted or distorted.

11. A method of indicating the reproduction characteristics of a modulating apparatus which comprises producing a pencil of cathode rays and deflecting by the modulated wave said pencil of rays in two directions at right angles to each other whereby the character of the modulation effected is indicated.

12. A method of studying the quality reproduction characteristics of a modulating apparatus which comprises producing a pattern, the coordinates of which in one direction are proportional to the voltage of modulating current and the coordinates of which in another direction are proportional to the voltage of the modulating wave, whereby a distorted condition of the modulated wave and the cause of such distortion will be indicated by the configuration of the pattern.

13. A method of studying the quality reproduction characteristics of a modulating apparatus which comprises producing a pencil of cathode rays, producing an electrostatic field in one direction proportional to the voltage of the modulating current, producing an electrostatic field in a direction at right angles to the first mentioned field, and controlling the deflection of said pencil of rays by the joint action of said electrostatic fields to produce an enclosed pattern, the length of certain of the boundary lines of which serve to determine the degree of modulation effected.

14. A method of studying the quality production characteristics of a modulating apparatus which comprises producing a pencil of cathode rays, producing an electrostatic field in one direction proportional to the voltage of the modulating current, producing an electrostatic field in a direction at right angles to the first mentioned field, and controlling the deflection of said pencil of rays by the joint action of said electrostatic fields to produce an enclosed pattern, the length of certain of the boundary lines of which serve to determine the degree of modulation effected, and the character of the other boundary lines of the pattern serve to indicate whether the modulated wave is undistorted or distorted.

15. A method of studying the quality production characteristics of a modulating apparatus which comprises producing a pencil of cathode rays, producing an electrostatic field in one direction proportional to the voltage of the modulating current, producing an electrostatic field in a direction at right angles to the first mentioned field, and controlling the deflection of said pencil of rays by the joint action of said electrostatic

fields to produce an enclosed pattern, the length of certain of the boundary lines of which serve to determine the degree of modulation effected, and the other boundary lines indicate the cause of distortion of a distorted modulated wave.

16. An apparatus for studying the characteristics of a carrier wave modulated in accordance with a signal current, comprising means for producing a pencil of cathode rays, means utilizing the modulated wave to displace said pencil of rays to trace a pattern, the configuration of which indicates the character of the modulation effected.

17. An apparatus for studying the characteristics of a carrier wave modulated in accordance with a signal current, comprising means for producing a sharply defined cathode ray stream, means for producing a composite field from the modulated wave, means employing said field for displacing said cathode ray stream to trace a pattern, features of which serve to indicate the percentage of modulation effected.

18. An apparatus for studying the characteristics of a carrier wave modulated in accordance with a signal current, comprising means for producing a pencil of cathode rays, means for producing from the modulated wave current components which are out of phase, means deflecting said cathode rays under the control of said out of phase currents to trace a pattern, certain dimensions of which serve to indicate the percentage of modulation effected.

19. An apparatus for studying the characteristics of a carrier wave modulated in accordance with a signal current, comprising means for producing a pencil of cathode rays, means for displacing said pencil in one direction by the modulating current, and means for deflecting said pencil of cathode rays in another direction by the modulated wave to trace a pattern, the configuration of which indicates the character of the modulation effected.

20. An apparatus for indicating the percentage modulation of a carrier wave modulated in accordance with signaling currents which comprises means for producing a pencil of cathode rays, means for deflecting said pencil of rays in one direction under control of the modulating currents and for deflecting said pencil of rays at right angles thereto under control of the modulated waves to trace a pattern, the ordinates of which at right angles to one another serve to indicate the percentage of modulation effected, and the shape of which serves to indicate the cause of distortion if present.

In witness whereof, I hereunto subscribe my name this 27th day of February A. D., 1923.

JOHN C. SCHELLENG.