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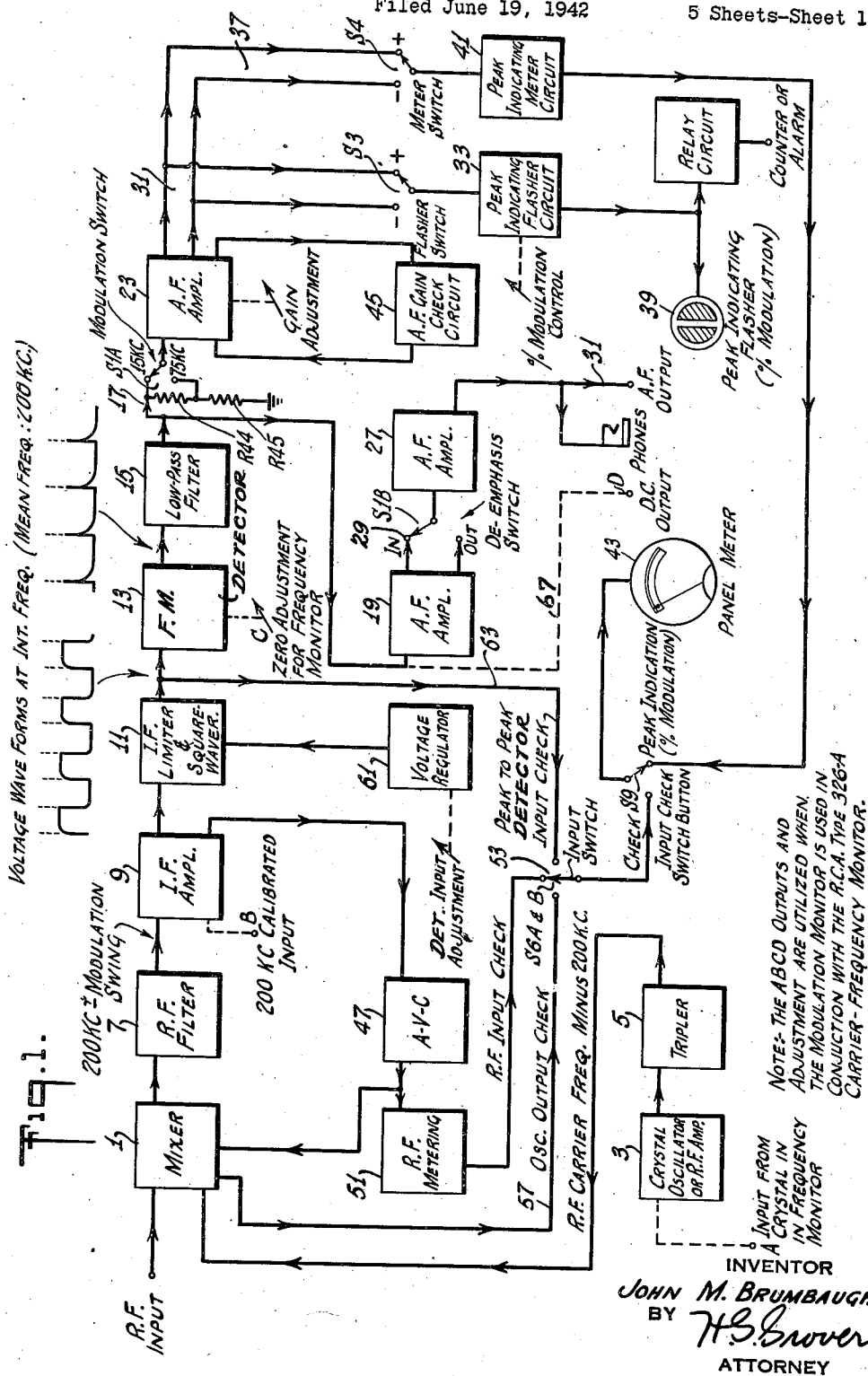
J. M. BRUMBAUGH

2,415,456

FREQUENCY MODULATION MONITOR

Filed June 19, 1942

5 Sheets-Sheet 1



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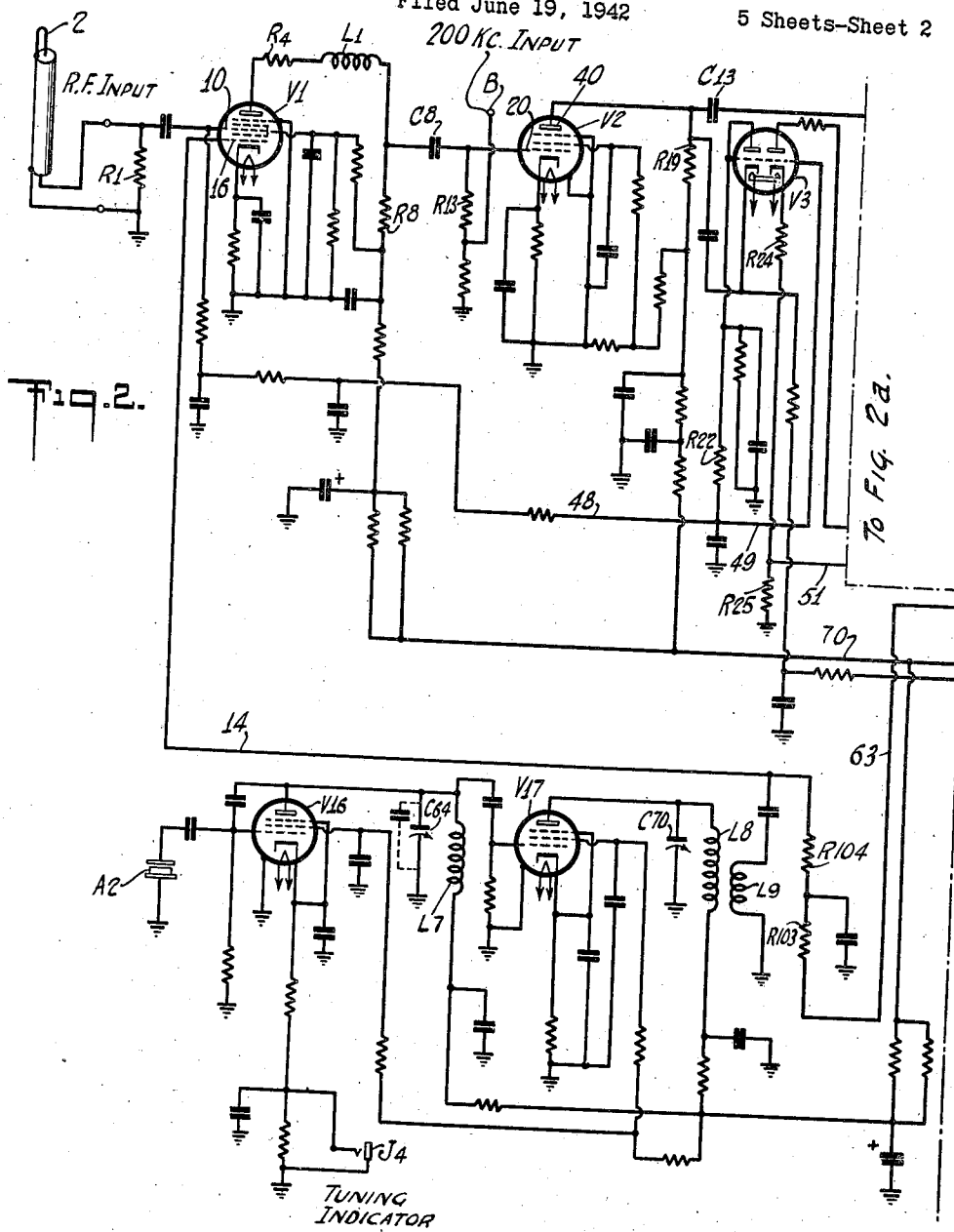
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FREQUENCY MODULATION MONITOR

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5 Sheets-Sheet 2



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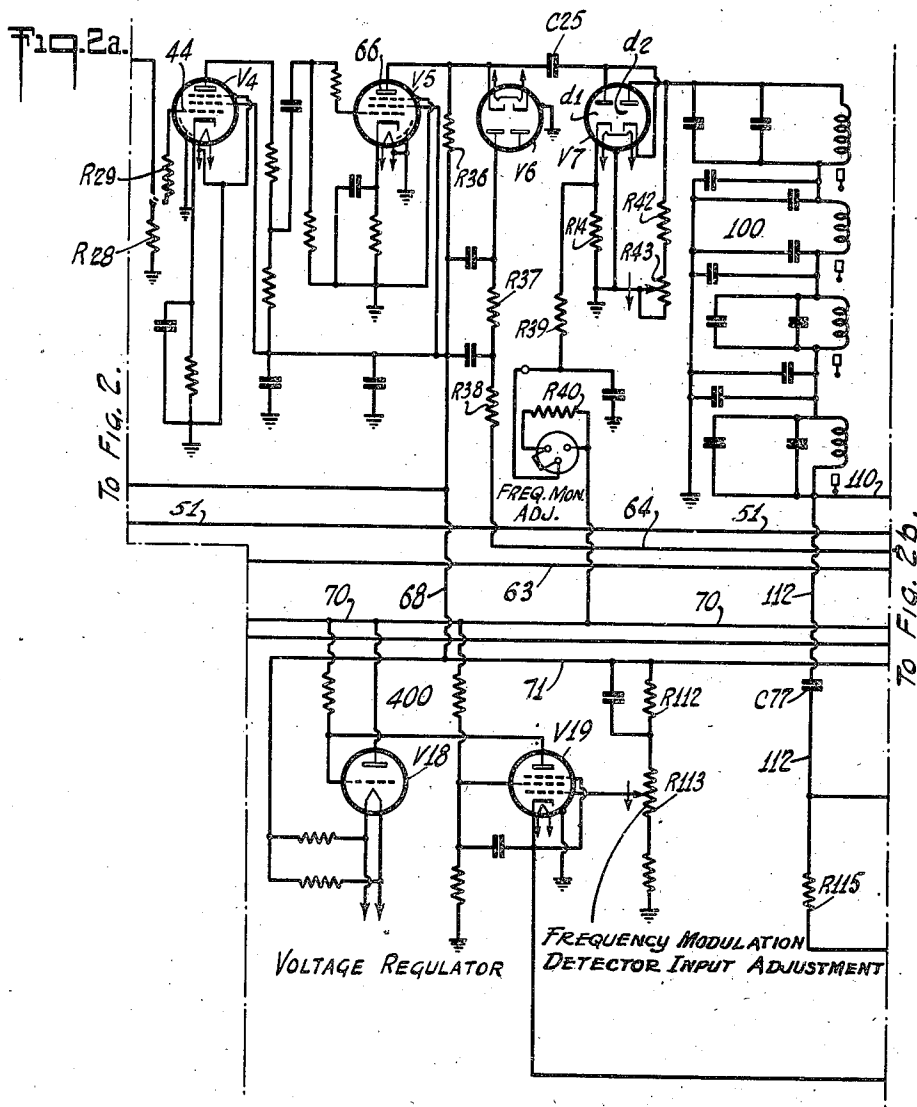
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FREQUENCY MODULATION MONITOR

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5 Sheets-Sheet 3



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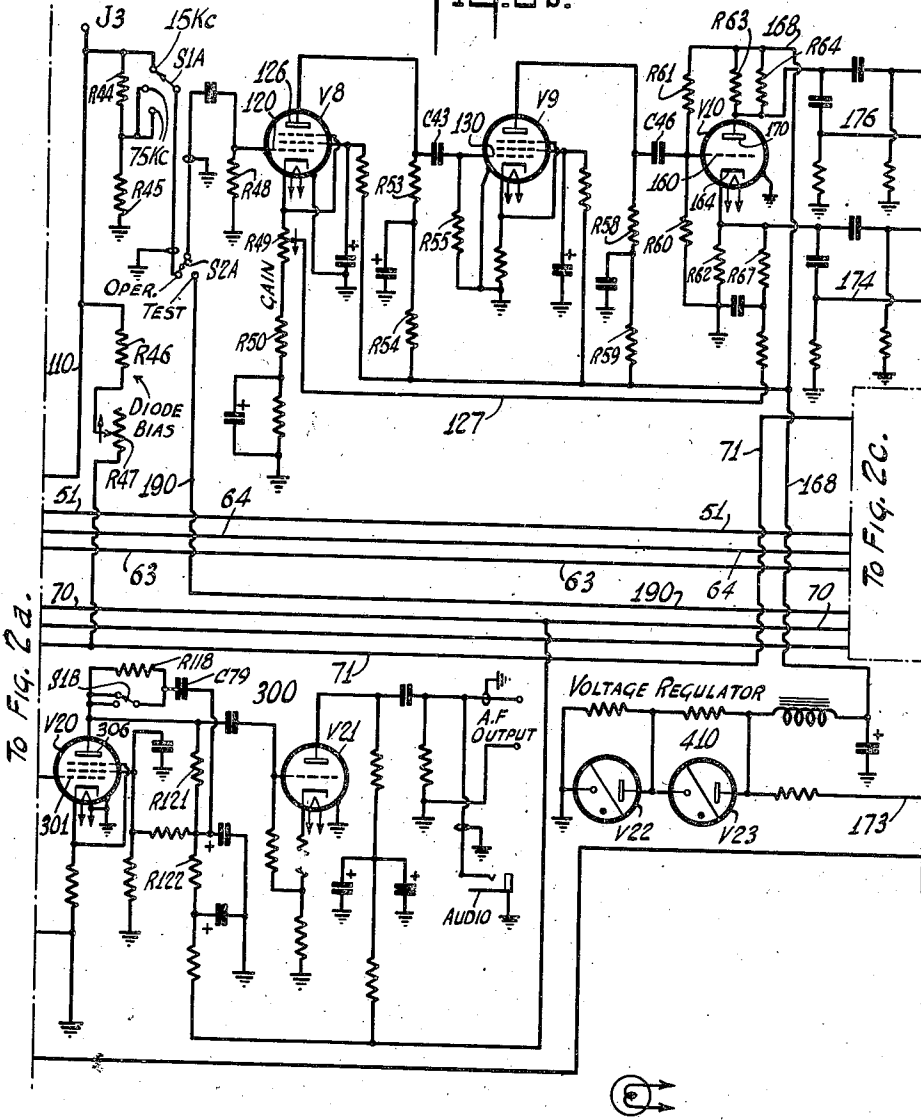
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FREQUENCY MODULATION MONITOR

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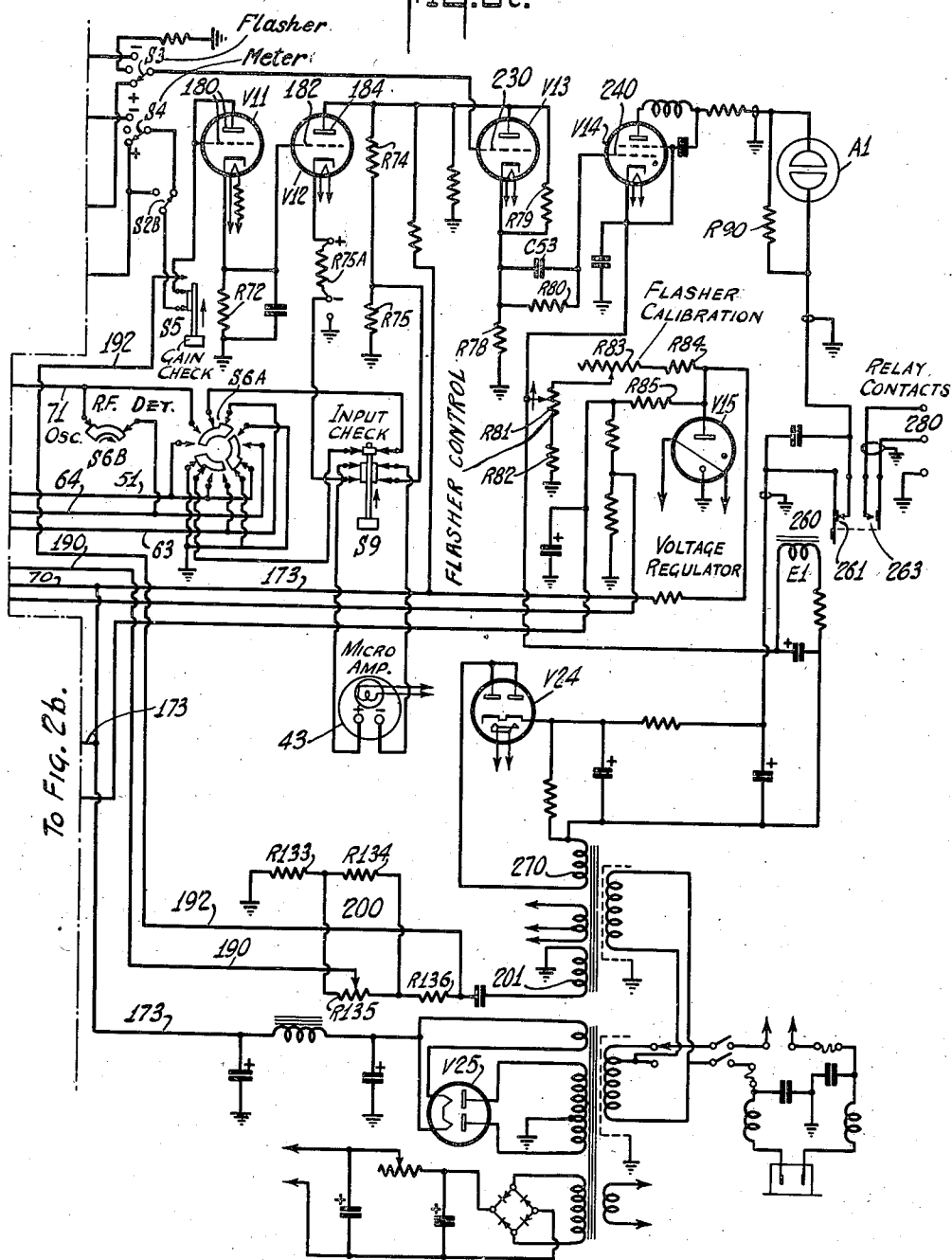
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FREQUENCY MODULATION MONITOR

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Fig. 2c.



To FIG. 2b.

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UNITED STATES PATENT OFFICE

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FREQUENCY MODULATION MONITOR

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Application June 19, 1942, Serial No. 447,629

15 Claims. (Cl. 179-171.5)

1

This application concerns a new and improved modulation analyzer or monitor which provides continuous visual indication of the modulation level.

An object of my invention is to provide a practical instrument for demodulation of frequency modulation signals with relatively little distortion and for measurement of modulation per cent of a frequency modulation signal and to provide a direct current voltage component proportional to deviation of the mean carrier frequency.

In my monitor a panel meter indicates modulation level peaks in accordance with the standard time constant set up by the Federal Communications Commission and a flasher lamp indicates audio peaks which exceed a pre-determined level. By means of a novel audio amplifier including a phase inverter, the flasher lamp is caused to indicate negative and positive audio peaks. The audio amplitude is proportional to the deviation of the carrier. The flasher circuit also operates a relay which may control the operation of an external alarm or a peak counter. An external meter may be connected from a control desk or other remote location to the instrument for modulation indication. The system includes a demodulator having a low distortion characteristic which may be used for distortion measurements on the transmitted wave or on the overall transmitting system.

My modulation monitor also serves as a frequency modulation demodulator of high quality having low distortion characteristic and it may be used for distortion measurements on the transmitter or the over-all transmitting system.

Provision is made for the attachment to my system of a carrier frequency monitor or meter. Attachment of this frequency monitor or meter and application to the modulation monitor of the additional circuits and energy to operate the carrier frequency monitor in no way affects the operation of the system as a modulation monitor.

My system has many advantages over monitors known in the art today and is, as a matter of fact, as far as I know, the only complete modulation monitor of this type satisfying the requirements of the Federal Communications Commission and including a distortionless modulation demodulator and amplifier known in the art today.

In describing my invention reference will be made to the attached drawings wherein Figure 1 shows schematically by block diagram in simplified form my modulation monitor; while Figures

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2 to 2c inclusive illustrate in considerable detail the circuit connections of a modulation monitor arranged in accordance with my invention. The monitor input is in Figure 2 and the circuits progress to the right through Figures 2, 2a, 2b and 2c.

Referring to Figure 1, the frequency modulated wave is supplied to a connection marked R. F. Input and thence to a heterodyning or mixing stage in a unit included in rectangle 1. In this mixer stage the modulated energy is heterodyned against oscillations of substantially constant frequency supplied by a crystal controlled oscillator in unit 3 after multiplication in a frequency multiplier 5 here shown as a frequency tripler. For purposes of example, the oscillations out of 5 are assumed to differ from the radio frequency carrier by minus 200 kc. The difference frequency is supplied from the output of mixer 1 to a radio frequency filter in unit 7, and in the example given, this output intermediate frequency is of 200 kc. plus and minus the modulation swing. After filtering in unit 7, the modulated I.-F. is supplied to an I.-F. amplifier in unit 9 and therein additionally filtered and amplified. The frequency modulated wave out of unit 9 may vary in amplitude because of the effect thereon of the pass characteristics of filters 7 and 9 or for other reasons. Amplified intermediate frequency modulated energy is supplied from 9 to an intermediate frequency amplitude limiter and square wave former in unit 11 and thence to a cycle counter or demodulator in unit 13. The frequency modulated wave herein as applied to the frequency modulated wave detector is caused to have the form shown above unit 11. The amplifier in 9 limits or clips the wave to remove therefrom the amplitude variations.

In this unit 13 by new and improved means the modulations on the carrier are detected and the output is supplied through a low pass filter in unit 15. The input 15 provided by the counter circuit is a uni-directional pulse of pre-set coulomb content for each I.-F. cycle. The cycle counter includes a condenser charged by the square wave and its charge is built up in increments which are superposed on the uni-directional current. The low pass filter smooths out this direct current so that the pulses are averaged in the low pass filter in 15 to produce at point 17 a steady direct current (no modulation) or a smoothed audio frequency wave form corresponding to the modulation of the carrier impressed on the mixer in unit 1 and also the modulations on the I.-F. in say the filter and ampli-

fier in unit 9. The low pass filter also removes the intermediate frequency components. This steady direct current or smoothed audio frequency wave form is fed from the output of 15 to a high-class audio amplifier in unit 19 and also by way of a modulation range switch S1A to an audio amplifier in unit 23.

The audio amplifier in unit 19 may be coupled by a switch S1B to an additional amplifier 27 and thence to an audio frequency output including, if desired, locally connected phones and, if desired, a line 31 to a remote point. The amplifier 19 also includes a de-emphasis network to be cut in by moving switch S1B to the contact 29 when pre-emphasis is used at the transmitter.

The amplitude of the smoothed audio on the direct current output at 17 represents the percentage modulation of the carrier and the modulation on the carrier and this output is supplied by switch S1A to the amplifier 23. The amplifier 23 includes a novel phase reverser by means of which potentials proportional to negative and positive modulation peaks are supplied by leads 31 to a peak current indicating flasher circuit including an isolator stage and flasher current amplifier in unit 33. The stage 33, as shown, may be connected by switch S3 to a point in the output of the phase reverser 23 at which a voltage which measures the positive peaks or a voltage which measures the negative peaks appears. Thus, by manipulating switch S3, one may produce in the flasher 39 negative and positive peak modulation indications, that is, percentage modulation. The output of the flasher voltage amplifier in 33 may also actuate a relay circuit to control a remotely located counter alarm. The peak indicating flasher circuit in unit 33 includes also percent modulation control circuits in the form of a resistive network in the cathode bias circuit of an amplifier in unit 33 to regulate the gain thereof. This network cooperates with a voltage regulated source of supply current.

The output of the amplifier including the phase reverser in 23 is also supplied by lines 37 and switch S4 to a peak indicating meter circuit 41, including current amplifying tubes, one of which has a meter in its cathode return circuit. The output of the circuits in 41 may be also supplied to a peak indication of percent modulation meter 43.

The amplifier in 23 also includes an audio frequency gain adjustment circuit in the form of an adjustable feed-back network for the initial amplifier tube by means of which the audio gain is standardized. By this means the gain of the amplifier may be readjusted at any time. This is for the purpose of relating the amplifier system gain with the strength of the modulated wave derived from the mixer as recorded by the meter.

The meter 43 may also be connected by switch S9 and switch S6B to check up on the strength of the mixer stage (unit 1) output and the output of the crystal source in unit 5 as supplied to the mixer.

The output of amplifier 9 is also supplied to a rectifier in unit 47 to derive automatic gain control potentials for the tubes in unit 1. This AVC current may also be supplied, after amplification, through a radio frequency metering circuit in unit 51 and thence by switches S6A and S6B and S9 to the panel meter 43. The oscillator output, that is, the output of the circuits in 5, can be checked by passing the direct current supplied to the final stage therein by lead 57 through

switches S6A and S6B and S9 to this panel meter 43.

A voltage regulator for the wave former stages in unit 11 is included in unit 61, which also includes means for adjusting the amplitude of the input to the frequency modulation detector or counter circuits in unit 13. Other refinements, such as a voltage regulator for the amplifier in unit 23, are used throughout the circuits as will appear more in detail hereinafter.

The peak-to-peak input of the discriminator is checked by connecting the output of 11 through lead 63 and switches S6A and S6B and S9 to the panel meter 43.

Referring to Figure 2, the frequency modulated energy to be analyzed is picked up on loop 2, by induction or by coupling the same to a line passing frequency modulated waves, and fed to a control electrode 10 of a converter tube V1. A conventional crystal control oscillation generator, including tube V16, crystal A2 and anode tank circuit L7, and C64 supplies oscillations of constant frequency to a tripler stage including tube V17 and tuned tank circuit C70—L8. The mixer stage including V1 is included in rectangle 1 of Figure 1, while the generator and frequency multipliers including tubes V16 and V17 are included in units 3 and 5 of Figure 1. This oscillation generator and tripler are coupled capacitively rather than by transformer, and since the operation thereof will be obvious from the showing thereof, they will not be described in detail herein. It will be noted, however, that a tuning indicator may be connected to jack J4 for tuning and other adjustment purposes, so that at the output tank circuit C70—L8 oscillations of the proper frequency and amplitude are supplied by inductance L9 and lead 14 to the control grid 16 of tube V1 to heterodyne therein with the received wave.

The intermediate frequency is supplied by a filter circuit comprising resistive and inductive couplings R4—L1, resistor R8 and coupling condenser C8 to the control grid 20 of an intermediate frequency amplifier stage V2. This filter is included in the unit 7 of Figure 1. The amplified intermediate frequency is supplied from the anode 40 of V2 by way of a coupling condenser C13 and resistance R19 to the grid 44 of a tube V4, (Figure 2a), which comprises the first stage of an amplitude limiter and square wave former including tubes V4 and V5. These tubes are included in rectangle 11 of Figure 1, along with, if desired, the peak-to-peak meter tube V6.

The output of tube V2 is also supplied to a double purpose tube V3 wherein the I-F. is rectified in the diode section to derive between the resistance R22 and ground and on lead 48 automatic volume control potentials which are supplied back to the grid 10 of tube V1 for gain control purposes. This gain control circuit is included in unit 47 of Figure 1. The feed-back potential is also supplied by line 49 to the grid of a triode in V3 wherein it is amplified and taken from the cathode resistance R25 and passed over line 51 and switches S6A and B to the meter 43 for radio frequency input readings.

The radio frequency wave as received may be of varying amplitude and/or the same may be modulated in amplitude while passing through the stage including tubes V1 and V2 due to the bandpass characteristics of the circuits. This undesired amplitude modulation is removed substantially completely so that a frequency varying wave of flat topped form is fed to the cycle

counter (unit 13, Figure 1). To so modify the wave the stages V4 and V5 are coupled in cascade as shown and biased and operated to clip off the rounded portions of the wave to thereby limit the amplitude of the I.-F. signal and cut off the peaks thereof to produce an output signal at resistor R35, which is substantially of square wave form. The tubes V4 and V5 or one thereof may be considered biased to a gain such that saturation output is attained for all usable input voltages. The anode 66 of V5 is supplied by direct current through R36 and lead 68. The amplitude of the square wave (as applied to the frequency modulation detector or cycle counter) may be adjusted, by means of resistor R113 which controls the output voltage of the voltage regulator tube V19 cooperating with the tube V18 and connected by lead 70 and 173 (Figure 2b) with the B supply including tube V25 (Figure 2c), to a certain calibrated value, which is indicated on the panel meter 43 (Figure 2c) when it is properly connected to the anode 66 of tube V5 through the tube V6 by means of lead 64 and the input and input check switches S6A and S6B and S9. This circuit through tube V6 and the meter 43 is as follows: Switch S6A as shown is the oscillator check position. This switch is moved clockwise two positions. The path from the top of resistance R36 is through tube V6, R37, R38, lead 64 (see Figures 2b and 2c) switch S6A, S6B and line 71 to voltage regulator tubes V18 and V19. Now if switch S9 is pushed up, the meter 43 is included in this series circuit.

The condenser C25, diode d1 and diode d2 of V7 and resistor R14 provides a frequency modulation detector or counter circuit which counts the intermediate frequency cycles to provide an output proportional to the frequency of the intermediate frequency energy.

When a square wave voltage is applied to the input of tube V5, on negative swings the plate potential at anode 66 reaches its peak value at the same time C25 is charged by R36 through the diode d1 to a peak value with the end of condenser C25 adjacent d1 negative. Now when the input to tube V5 swings positive, the plate potential at 66 and on R36 goes to its minimum value and C25 discharges through diode d2 in series with its load R42 and R43 at a rate determined by resistors R42 and R43. The time constants are made such that the diode coupling capacitor C25 is completely charged or discharged during each half cycle of the square wave. As long as the voltage of square wave form remains substantially of constant amplitude, the total quantity of electricity which flows through R42 in each cycle of the I.-F. is constant. Thus, an increase in the repetition rate or I.-F. frequency increases the number of current pulses per unit of time and, therefore, increases the average value of current through R42. The advantage of this is that its response to the frequency deviations or changes is linear and is unaffected by large changes in the "rise time" and roundness of corners of the "square wave"; that is, the wave front per se has no effect on the linearity of the output of this detector, provided that the time constants are made such that the diode coupling capacitor C25 is completely charged or discharged during each half cycle of the I.-F. square wave.

The direct current with superposed audio output in R42 results from intermittent excitation of the condenser C25 by the square wave I.-F. and, as a consequence, has superposed thereon sharp pulses. To smooth out these sharp pulses, 75

I pass the output from resistor R42 through a low pass filter designated generally at 100. In this filter circuit 100, the sharp peaks are filtered off along with other higher frequency components leaving only the audio carrying direct current, which represents and is proportional to the signal. A single condenser in shunt to R42 would not be satisfactory because it would add capacity to the network including C25 and cause distortion by not properly counting the cycles. The network or filter characteristic impedance is high, so that it does not set up a diode bias preventing complete discharge of C25.

The detector circuit associated with the tube V7 is of the counter type which is inherently linear over its operating range since its linearity does not depend upon the alignment of tuned circuits. The circuit time constants are such that the capacitor C25 charges and discharges during one-half of an I.-F. wave cycle and, therefore, a definite quantity of electricity flows in the resistor R42 in the form of a relative sharp pulse during each I.-F. wave cycle as shown by the curves on the block diagram in Figure 1. The average values of current flowing through this resistor follow the corresponding values of modulation level of the I.-F. carrier. The sharp I.-F. pulses are filtered out by the low pass filter 100 following the diode V7 and the voltage appears through line 110 and across resistances R44 and R45 of a wave form similar to that of the modulating audio voltage at the transmitter. This voltage constitutes the audio signal. The diodes V7 are included in unit 13 of Figure 1 and the low pass filter 100 is included in unit 15 of Figure 1.

The smoothed current produces a voltage which is fed to R44 and R45, Figure 2b, and thence to the range switch S1A which is set for a large or small frequency deviation of the frequency modulated carrier being monitored.

This voltage is fed by switch S2A to the grid 120 of the amplifier tube V8 and from the anode 126 to the grid 130 of the tube V9 wherein it is amplified and then fed to the control grid 160 of a phase reverser tube V10. Note that the couplings between tubes comprise resistances and condensers.

This phase reverser tube V10 has its control grid 160 coupled by resistance R60 and resistance R62 to its cathode 164, while its control grid 160 is also coupled by a relatively high resistor R61 to lead 168 connected with the positive potential source, which also supplies the anode of the tube V10. The potential supplied to the anode 170 and grid 160 of the phase inverting tube V10 is derived by lead 168 from the main source including rectifier tube V25 (Figure 2c) the cathode of which is connected by filters and lead 173 and voltage regulator tubes V22 and V23 to lead 168. Thus, the grid 160 is in effect connected to a resistance potentiometer across the plate supply source.

The applied modulation voltage is reversed in phase by the tube action so that the voltage on the anode 170 is reversed with respect to the voltage applied to the grid 160. The voltage in R62, however, is in phase with the grid voltage. Thus, if I take the output from the anode resistances, R63 and R64, it is a measure of peak deviations of the applied frequency modulated wave in one direction. If I take the output from the cathode resistance R62, it is a measure of peak deviation of the wave in the other direction. By noting the phase reversals between the

input of the system and the contacts at the output of tube V10, the flasher switch S3 and the meter switch S4 contacts can be appropriately marked as shown with a + or - indicating that the frequency of the wave is above and below respectively the mean or carrier frequency.

The phase reversed outputs are taken across resistance R52 and from R63 and supplied by leads including coupling and direct current blocking networks 174 and 176 to the flasher switch S3 and meter switch S4 (Figure 2c). The purpose of this reverser tube V10 is to permit negative as well as positive peaks of the modulation to be analyzed. In this reverser arrangement, as shown, the full cathode bias resistor R62 drop is supplied to the control grid 160 and then to compensate this high negative potential, some positive potential is supplied to the control grid by resistor R61. Thus, the signal of reversed phase is obtained from balanced resistors R62 and R63 in the plate and cathode of the same tube, and the voltages must be identically equal in magnitude since they are produced by the same current flowing in matched resistors. Thus, the voltage balance is independent of tube gain. In arrangements known heretofore the bias has been obtained by means of a tap on the cathode resistor and this gives full cathode degeneration only if the grid is driven from an impedance which is quite low compared to the grid resistor. The bleeder bias method of the present invention gives full degeneration with a high impedance source. It also tends to maintain a more stable operating point on the tube characteristic. As is well known, many phase inverters of the prior art use two tubes and, as a consequence, are subject to changes of currents due to changes in the two tube characteristics. Here a fundamental requirement is that the impressed voltages give phase reversed voltages identically equal in magnitude and the arrangement shown meets this requirement.

The phase reversed signals are then supplied by switch S4 to a meter rectifier diode V11 and from diode load R72 to amplifier tube V12 and appear in the cathode load R75 and R75A. If desired, a meter may replace the resistor R75A, this meter being on a remote panel and similar in nature to meter 43.

These meters then indicate the signal peak maximums, both positive and negative when the switch S4 is moved and indicate the variations of the peak maximums. This assumes that S9 is the position shown to put R75A, or the remote meter replacing the same, meter 43 and R75 all in the cathode circuit of tube V12. Note that the diode V11 is of the cathode follower type, the output therefrom being supplied from resistance R72 to the grid 182 of tube V12, the anode 184 of which is connected by a resistance potentiometer R74 and R75 to ground and by switch S9 through the meter 43 to the cathode resistance R75A. The plate 184 is connected to the main supply source including tube V25.

The output of the phase reverser tube V10 is also connected by switch S3 to a flasher contact and thence to the grid 230 of a triode amplifier V13, this amplifier also being of the cathode follower type and having its cathode load R78 coupled by an over load protecting resistor R80 and bypass condenser C53 to the controlling electrode 240 of a flasher gas tube V14. The tube V13 serves as a coupling and isolating amplifier for the flasher and relay tube V14 to prevent it

from reacting on the meter circuits and tube V12. The bias of tube V14 is adjusted by the graduated flasher control including resistor R81 and the resistor network comprising R82, R84, R85, etc. coupled with the voltage regulator tube V15 and by lead 173 to the main supply source. This bias as controlled by the tap on resistor R81 determines the peak audio voltage and thus the percentage modulation at which the flasher A1 connected with the anode of tube V14 and the relay 260 will operate.

The glow tube A1 is connected to the positive side of rectifier V24, the negative side of which is connected to the cathode of tube V14. The tube A1 is also shunted by R90 so that the gas tube V14 is in a series circuit across the output of rectifier tube V24. This circuit all floats above ground as R81 is varied. The bias on grid 240 swings and adjustment on peaks is such that tube V14 conducts and the voltage across V14 drops while the voltage across A1 raises and A1 discharges or flashes.

The winding E1 of relay 260 is in series with the cathode direct current circuit of the tube V14 and with the independent power supply source including rectifier V24 and high voltage winding 270.

When the flasher tube A1 breaks down winding 260 opens normally closed contact 261 and closes contact 263 to close at 280 a circuit connected to any remotely located alarm or calling circuit or signal light arrangement. In the presence of sustained over-modulation the audio keeps tending to break down tube V14. However, winding 260 opens contact 261 and the relay is de-energized to let contact 261 close and the cycle is repeated. This gives an intermittent indication of over-modulation by ringing the bell or flashing a light on and off at the remote point connected to the output of 280.

The flasher A1 gives individual indications of peaks following each other by not less than .12 second, which is the time required for recuperation of the flasher circuits. On sustained high modulation levels the flasher A1 and relay 260 operate intermittently at the rate of about 8 cycles per second.

The potential drop at the cathode end of resistance R52 in the phase reverser stage tube V10 is also supplied through a network including resistance R57 to lead 127 and thence to a movable point on gain control resistance R49. The purpose of this automatic gain control will be described later.

The output of tube V7 appearing across resistors R42 and R43 is also supplied by lead 112 (Figure 2a) through coupling condenser C77 to the grid 301 of a tube V20 (Figure 2b) of a low distortion amplifier circuit designated generally at 300. This amplifier circuit comprises two tubes, V20 and V21, coupled in cascade by resistances and condensers to amplify linearly the smooth audio frequency supplied to the grid 301 of the first tube V20 by coupling condenser C77. The output of this amplifier, which corresponds to units 19 and 27 in Figure 1, may be taken from the leads marked A. F. Output. The amplifier may include in the coupling between stages a de-emphasizing circuit including condenser C79 and resistor R121 connected in parallel between the anode 306 of tube V20 and the upper terminal of the resistor R122 in the plate supply circuit. By cutting in resistance R118 to include C77 in shunt to R121, the voltages fed from

the anode 306 to the grid of tube V2 follow linearly the voltages supplied on the grid 301.

By placing the short circuit across resistance R113 by means of switch S1B (in the position shown), C79 is directly in shunt to R121 to de-emphasize the modulation potentials as their frequency increases. The purpose of R113 is to maintain the average potential drop across R121 on C79 and prevent key shocks when switch S1B is moved. The switch S1B corresponds to the switch S1B and contact 29 of Figure 1, while the stage V21 is the audio amplifier of unit 27 of Figure 1.

In order to maintain insofar as possible constant potentials on the stages in the oscillation generator and in the mixer and intermediate frequency amplifier stages, I provide at 400 (Figure 2a) a voltage regulator. This voltage regulator is not being claimed herein and a detailed description thereof is believed undesirable at this point.

A voltage regulator is also shown at 410 (Figure 2b) for supplying potential to the modulation amplifier stage comprising tubes V8, V9 and V10, substantially constant anode and screen electrode potentials. The main power supply comprising rectifier V25 supplies plate and screen electrode potentials directly or after regulation in the voltage regulators 400 and 410.

If the voltage across resistors R44 and R45, Figure 2b, that is, at the output of the demodulator or counter circuit varies as the intermediate frequency varies and the gain of the following audio frequency amplifier including tubes V9 and V9 is standardized, the peak audio frequency voltages appearing at the anode 180 of tube V11 and, therefore, indicated on the panel meter 43 connected to R75A will be a direct indication of the peak modulation. The monitor is adjusted to fulfill these conditions during production test by adjustment of the bias resistor R43 for diode d2 and potentiometer resistance R135 in the audio frequency gain standardizer indicated generally at 200.

This gain standardizer includes a source of audio in the form of a secondary winding 201 shunted by a resistance network. A point on resistance R135 of this network is connected by lead 199 to a contact of switch S2A, Figure 2b, and thence to the grid 120 of the amplifier tube V8. A second point on this network at resistance R136 is connected by lead 192 to switch S5 and then to the anode 180 of diode tube V11. As will appear more in detail hereinafter, the audio current is fed to the meter 43 through amplifiers V8, V9, tubes V10, V11 and V12, or through tubes V11 and V12 by changing the position of switch S5.

Assume that the system has been all set up in good working order including proper adjustment of the feedback, in the amplifiers V8, V9 and tube V10, over line 127 and adjustable gain control potentiometer R49 in the cathode circuit of tube V8.

Say the adjustment is complete and in the presence of an input wave which has a total 150 kc. deviation, we have out of V7 or into V8 an alternating current or audio signal of fixed intensity which represents this swing and is proper to operate the flasher circuits and meter circuits, and I do not want this current to become more or less in the presence of a wave of the above nature. If this current should vary due to ageing of tubes or for some other reason, the flasher tube A1 might not flash on peaks and

the meter 43 would not be driven to 100% by a 150 kc. input signal deviation.

The amplifiers V8 have had or now have their gain adjusted by regenerative feedback lead 127 and potentiometer resistance R49 until 100% modulation is indicated in the meter 43 with 150 kc. input signal deviation, and the flasher A1 operates when R81 is properly set. Next we close switch S2A on the contact marked "Test" and put in audio from the network 200 (Figure 2c) and flip the switch S5 back and forth so the meter is fed alternately by audio potentials from line 190 amplified by tubes V8 to V12 or by audio potentials from line 192 supplied to the meter through tubes V11 and V12 only. Now adjust the ratio of the two supplies over lines 190 and 192 until the meter 43 reading is the same in both positions of switch S5. This ratio is adjusted by the movable point on resistance R135 of standardization network 200, and may be, say 1 to 74, so the gain in tubes V8, V9, V10 and V11 is 75.

Now if in the future we want to check up on the gain of amplifiers V8, V9, etc., we put audio from 200 on V3 and manipulate the gain check switch S5. If the meter 43 readings are different in the two switch positions, the feedback adjustment at potentiometer R49 is changed until the meter readings are the same in both switch positions. Thus we know that if the monitor up to the counter circuit is responding properly, the flasher tube A1 and meter 43 will give correct indications of the modulation peaks and percentage modulation. If they do not, we can check the gain of the amplifier by the gain standardizer circuit 200 and adjust its gain to a proper amount.

Operating calibrations are checked thereafter in terms of the panel meter 43 indications and adjustment made by operation of the feedback adjustment R49 for the audio amplifier V8 and V9 and by adjustment of the gain of tubes V4 and V5 by use of R113 (Figure 2a) associated with the voltage regulator 400 to supply out of the cycle counter the proper steady direct current when the incoming wave deviates through a given range.

The accuracy of these check circuits is dependent upon primarily the stability of precision resistors and of the meter circuit. The overall accuracy of indication is thus dependent upon the stability of capacitor C25 and resistor R42 in the anode circuit of diode V7 and the check circuit mentioned above.

The instrument is calibrated, in manufacture, according to the following procedure:

(a) The usual type of mechanical and electrical inspections are made; including circuit continuity checks, voltage measurements, tuning, distortion and frequency response checks, etc.

(b) Calibrated 200 kc. signal is introduced at B in the grid circuit of V2, sufficient to give normal "R. F." indication in the AVC metering circuit. This metering circuit, as stated above, comprises the triode section of V3 excited by the drop through resistance R22 resistance R25, line 51, switches S6A, S6B and S9 and meter 43. A 50,000 ohm rheostat is substituted for R40 in the cathode circuit of V7, and this 50,000 ohm resistor and R47 in the input circuit of tube V8 (Figure 2b) are varied to give: (a) zero potential on the direct current output of the cycle counter V7 (Figure 2a) and (b) minimum shift in this potential when the power line voltage is varied. R47 is then left at this setting, and substitution

is made for R40 only when the instrument is used with a frequency monitor, in which case this control is used for zero calibration of the mean-carrier deviation scale.

(c) Calibrated intermediate frequency signals of 100, 200 and 300 kc. are supplied at the same input point, B. and R43 adjusted to give 1.02 volt change in direct current potential at "direct current output" jack, J3, Figure 2b and D in Figure 1, or 0.765 volt peak to peak for 150 kc. swing. During this operation, the detector input (peak to peak square wave voltage) is kept at its proper value, as shown by the meter indication on "Discr." input. As stated above tube V6, Figure 2a, and its circuits including R38, line 64, switches S6A and S9 complete a square wave peak to peak indicating circuit through meter 43, Figure 2c. The linearity of response of demodulator is checked.

(d) With the "Gain" control, R49, Figure 2b, set to give 100% meter indication when 0.2707 volt R. M. S. (0.765 volt peak to peak) of audio signal is applied to J3, the "Gain" switch S2A at the "Test position" on contact labeled "Test," and S1A set at "75 kc." position, R135 of the gain standardizer network, Figure 2c, is so adjusted that the meter indication does not change when S5 is alternately pressed and released.

(e) R83 and the knob on R81, Figure 2c, are set so that the flasher lamp A1, Figure 2c, 39 Figure 1, lights when the meter indication is equal to the setting of the "Flasher" control (R81) on its per cent modulation scale.

(f) Checks for elimination of effects of amplitude modulation on signal, hum and noise level, operation of flasher relay, etc.

After proper calibration, as outlined above, the normal operating procedure is as follows:

(a) A crystal is selected such that its tripled frequency will be 200 kc. below the transmitter mean-carrier frequency. Oscillator V16 and tripler V17 are tuned to give proper meter indication for the "Osc. check" operation. The "Input" switch, S6B (Figure 2c), is turned to "OSC." and "Check" button, S9, is pressed. The meter circuit is from the grid 16 of tube V1, lead 14, R104, R103, lead 63, Figures 2, 2a, 2b, switches S6A, S6B, S9 and meter 43.

(b) Sufficient transmitter signal, about 1 volt, is applied to the "R. F. Input" at resistor R1, Figure 2, to produce proper meter indication on the "R. F. Check" operation.

(c) The "Demodulator" input control, R113, is set to its proper position, as indicated on the meter by the "Demodulator Check" operation.

(d) The audio frequency "Gain" switch, S2A, Figure 2b, is turned to "Test" and the "Gain" control, R49, is set so that the meter deflection remains unchanged when the gain check button, S5, is pressed and released.

(e) The "Kilocycle swing" switch, S1A, Figure 2b, is set to the desired condition of sensitivity and de-emphasis, the "Flasher" control, Figure 2c, at the desired warning level, and the "Gain" switch S2A on the contact as shown, that is, the operating contact, to "Oper." The meter will now indicate per cent modulation on the transmitter signal, of the polarity indicated by the "Meter" and "Flasher" switches, S4 and S3.

It should be noted that the proper settings of the audio frequency, "Gain" and "Demodulator" input controls are not entirely independent of supply-line voltage, and they should be checked when a modulation reading of high accuracy is desired. However, under normal operating con-

ditions, the adjustment controls will require very little re-setting.

The instrument also serves as a de-modulator of very low inherent distortion and may be used for system distortion checks, noise checks, etc.

Since many programs, particularly of speech, are quite unsymmetrical as to peak amplitudes, checks should be made at the beginning of programs for the presence and direction of such unbalanced peaks. The "Meter" switch is turned quickly from plus to minus and vice versa during modulation peaks, and is finally left on the polarity which shows the larger peaks. The "Flasher" should be set on the same polarity and the level control at the desired warning level.

Normal operating procedure should include daily checks of the various panel adjustments after a normal warm-up period.

When my system is to be used with a carrier frequency monitor, a constant frequency calibrated source supplies input to the intermediate frequency amplifier by connections to the dotted contact B. The crystal in unit 3 is removed and the tubes therein are used as amplifiers and frequency multipliers. The crystal in the frequency monitor is connected through dotted line labeled "A" to the stages in 5. A very stable oscillator is required in wave metering and the monitor has such an oscillator. The radio frequency input to mixer 1 is interrupted and the demodulator in 13 is adjusted for a known output at 200 kc., this frequency being derived by the calibrated input at B. This output is fed to a line 67, Figure 1, and thence to a sensitive meter connected to D. A direct current which bucks this output is supplied in line 67 from the monitor and adjusted to buck out or compensate the output of the discriminator until a zero center reading is had in the meter connected to D. The radio frequency input is now applied and, if correct, the demodulator output will be a mean average such as to compensate the current supplied at 67 and cause in the meter a zero reading indicating that the mean carrier is of a frequency differing from the frequency in the output of 5 by exactly 200 kilocycles. Deviations from this proper mean frequency will result in changes in the direct current output in line 67, which will cause the meter hand to deviate from zero in a direction depending on whether the mean carrier is too high or too low.

In order to minimize distortion at the higher audio frequencies, and to keep the cross modulation of high A.-F. wave components at a low value, it is necessary that phase delay in the I.-F. system be kept nearly constant over the I.-F. range. Otherwise distortion is introduced by superimposed phase modulation. The use of resistance-coupling in the mixer circuit and throughout the I.-F. circuits of the monitor reduces this type of distortion to a minimum. In order to indicate peak modulation accurately, it is necessary to preserve the exact wave form of the audio signal as it comes from the demodulator. This requires not only low distortion in the A.-F. amplifier, but also negligible phase shift of various components of the audio wave with respect to each other. In this instrument, the audio phase delay is such that any α -f wave component is not shifted in phase (with respect to a 1000 cycle component) by more than 8 per cent of its own wave length.

The two types of phase-delay effects just cited are particularly important in modulation measurements on F-M transmitters, due to the large

amount of pre-emphasis used at high audio frequencies.

The "Flasher" and "Meter" switches (S3 and S4, respectively) permit the monitoring of modulation peaks in either the "high" (+) or "low" (-) direction, which is equivalent to indicating audio signal peaks of opposite polarity at the amplifier output. This feature is provided because the audio wave peaks of some types of programs are quite unsymmetrical. Orchestral music will, in general, produce wave forms having peaks approximately equal in magnitude on both "sides" of the reference line. Some speakers, vocalists, and solo instruments may produce quite unsymmetrical wave forms, and the resultant "direction" of maximum modulation (+ or -) will depend upon the microphone polarity and all line connections to the transmitter. Two people in dialogue may produce maximum peaks in opposite directions if they are on opposite sides of certain microphones. It is desirable to monitor the "side" of the audio signal producing the greater number of maximum peaks.

I claim:

1. In apparatus for analyzing a wave length modulated wave, a wave amplitude limiter excited by said modulated wave, a wave frequency detector coupled to said wave limiter and excited by said amplitude limited wave length modulated wave for deriving a potential substantially proportional to the wave frequency, a tube system coupled to said detector and excited by said derived potential, said tube system having two outputs at which substantially identical potentials corresponding to said first potential but of opposed phase appear, a normally extinguished glow tube, and connections for coupling said glow tube to either of said outputs.
2. In a system for monitoring wave length modulated wave energy, a current amplitude limiter having an input excited by said wave length modulated wave energy, said amplitude limiter having an output, a wave cycle counter circuit having an input coupled to the output of said current amplitude limiter, said wave cycle counter having an output wherein a potential proportional to the wave frequency appears, a flasher tube, two paths arranged to alternatively couple said flasher tube to the output of said cycle counter, and a potential polarity reverser in one of said paths.
3. In a system for analyzing a wave length modulated wave, a wave length detector having an input excited by said wave length modulated wave, said wave length detector having an output, an electron discharge tube having an input coupled to the output of said detector and having an output impedance connected to its anode and an output impedance connected to its cathode, a peak potential indicator and a current meter and a switch for coupling said meter and said indicator to either of said output impedances.
4. In a system for analyzing a wave length modulated wave, a wave length detector having an input excited by said wave length modulated wave, said wave length detector having an output, a low pass filter having an input coupled to the output of said detector, said low pass filter having an output, an electron discharge tube having an input coupled to the output of said low pass filter and having an output impedance connected to its anode and an output impedance connected to its cathode, a peak potential indicator and a current meter and switching means

for coupling said meter and said indicator to either of said output impedances.

5. In a system for analyzing a wave length modulated wave, a current amplitude limiter excited by said modulated wave, a wave length detector having an input coupled to said current amplitude limiter, said wave length detector having an output, a low pass filter having an input coupled to the output of said detector, an electron discharge tube having an input coupled to the output of said low pass filter and having an output impedance connected to its anode and an output impedance connected to its cathode, a peak potential indicator and a current meter and switches for coupling said meter and said indicator to either of said output impedances.

6. In apparatus for producing indications of peaks of recurring potentials, a glow tube, an electron discharge device having a cathode, an electron receiving electrode and a control grid, a relay having a winding and normally closed contacts arranged to be opened by current flow through said winding, a source of potential, a relay operating circuit including in series said glow tube, contacts of said relay, said source of potential, the winding of said relay and the impedance between the cathode and electron receiving electrode of said device, and connections for applying said recurring potentials to the control grid of said discharge device to alter the conductivity thereof in the presence of peaks of said recurring potentials.

7. In a frequency modulated wave monitor, a wave frequency detector for deriving, from a modulated wave, potentials proportional to the frequency thereof, a potential peak indicator, an electron discharge device having output electrodes and a control grid, a source of potential and a relay having contacts and a winding for controlling the position thereof, a circuit including said potential peak indicator, the contacts of said relay, said source of potential, the winding of said relay and the output electrodes of said device, and a coupling between said detector and the control grid of said device for controlling the conductivity thereof in accordance with the derived potentials.

8. In a frequency modulated wave monitor, a wave frequency detector for deriving, from a modulated wave potentials proportional to the frequency thereof, a glow tube having an energizing circuit including the contacts of a relay, a source of potential, the winding of said relay and the impedance of a grid controlled gas tube in series, and a coupling between said detector and the control grid of said gas tube for controlling the conductivity thereof in accordance with the derived potentials.

9. In a system for monitoring wave length modulated wave energy, a current amplitude limiter having an input excited by said wave length modulated wave energy, said amplitude limiter having an output, a wave cycle counter circuit having an input coupled to the output of said current amplitude limiter, said wave cycle counter having an output wherein a potential proportional to the wave frequency appears, a current meter, two paths arranged to alternatively couple said current meter to the output of said cycle counter, and a potential polarity reverser in one of said paths.

10. In a system for analyzing a wave length modulated wave, a wave length detector having an input excited by said wave length modulated wave, said wave length detector having an out-

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put, an electron discharge tube having an input coupled to the output of said detector and having an output impedance connected to its anode, and an output impedance connected to its cathode, a peak potential indicator and a switch for coupling said indicator to either of said output impedances.

11. In a system for analyzing a wave length modulated wave, a wave length detector having an input excited by said wave length modulated wave, said wave length detector having an output, a variable gain amplifier having an input coupled to said detector output, said variable gain amplifier having an output, a potential peak indicator, two paths arranged to alternatively couple said variable gain amplifier output to said peak indicator, and a potential phase reverser in one of said paths.

12. In a system for analyzing a wave length modulated wave, a wave length detector having an input excited by said wave length modulated wave, said wave length detector having an output, a variable gain amplifier coupled to said detector output, said variable gain amplifier having an output, a current meter and a potential peak indicator, two paths arranged to alternatively couple said variable gain amplifier to said meter and to said peak indicator, and a potential phase reverser in one of said paths.

13. In a frequency modulated wave monitor, a wave frequency detector for deriving from a modulated wave potentials proportional to the frequency thereof, an electron discharge device having output electrodes and a control grid, a source of potential and a relay having at least two pairs of contacts and a winding for controlling the said contacts, a circuit including a pair of said contacts of said relay, said source of potential, the winding of said relay and the output electrodes of said device, a coupling between said detector and a control grid of said device for controlling the conductivity therein in accordance

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with the derived potentials, and connections to the other pair of said contacts to which an alarm or warning device may be connected.

14. In apparatus for producing indications of peaks of recurring potentials, a glow tube, an electron discharge device having a cathode, an electron receiving electrode, and a control grid, a relay having a winding and contacts for completing at least two circuits, the said contacts being controlled by the current through said winding, a source of potential, a relay operating circuit including in series said glow tube, contacts of said relay, said source of potential, the winding of said relay and the impedance between the cathode and electron receiving electrode of said device, connections for applying said recurring potentials to the control grid of said device to alter the conductivity thereof in the presence of peaks of said recurring potentials, and means for coupling an alarm circuit to other contacts of said relay.

15. Apparatus as recited in claim 14, wherein a resistance is connected in shunt to said glow tube.

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