

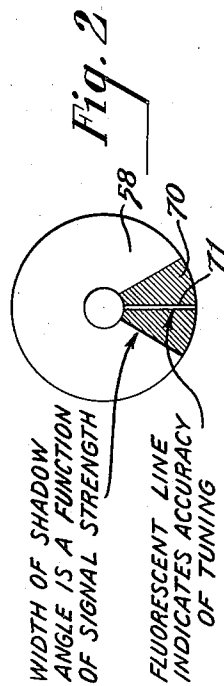
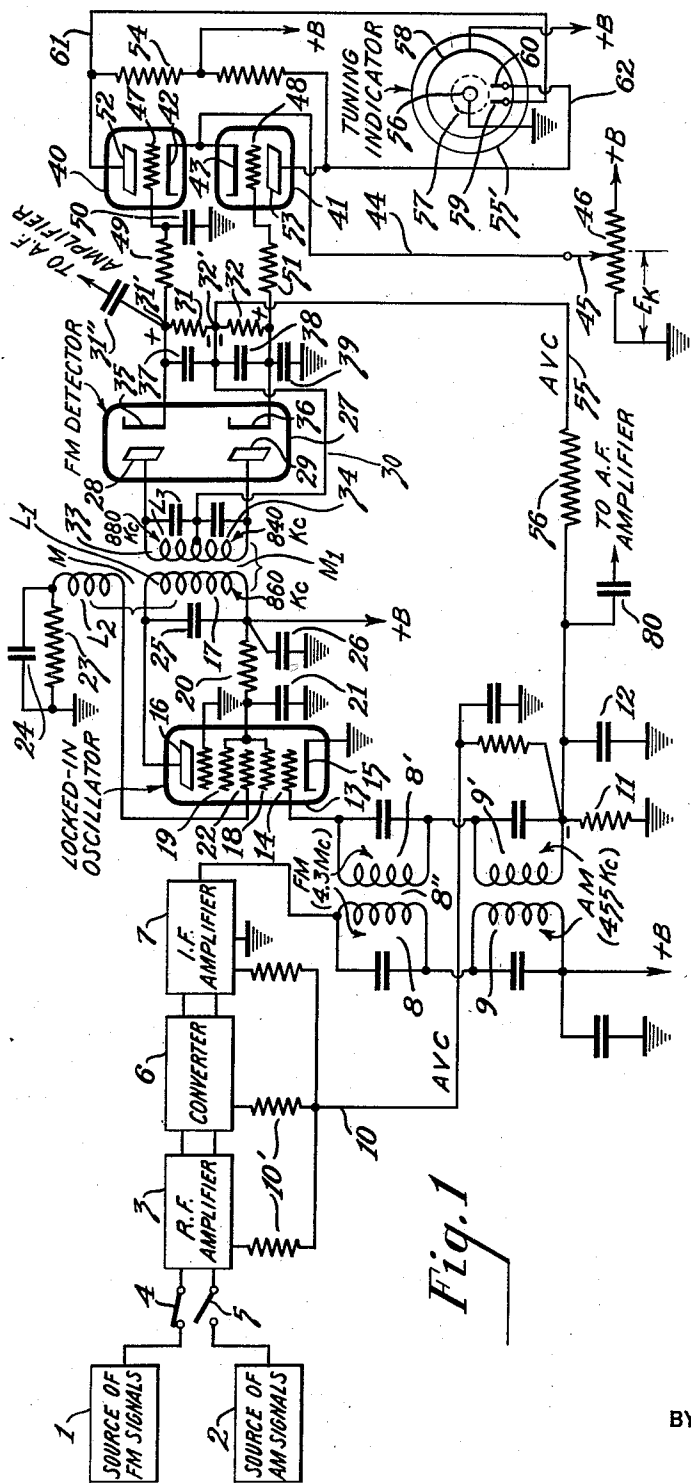
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SIGNAL RECEIVER TUNING INDICATOR

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SIGNAL RECEIVER TUNING INDICATOR

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My present invention relates to improved tuning indicator devices for radio signal receivers, and more particularly to an improved visual tuning indicator system for a combined frequency modulation FM and amplitude modulation AM receiver.

In U. S. Patent No. 2,366,320 granted January 2, 1945 to George F. Elston, there has been disclosed an improved voltage indicator for visually comparing two voltages in one viewing area. More specifically, the voltage indicator disclosed in the aforesaid patent is adapted for indicating the resonance condition of an FM receiver. In general, the indicator comprises an electron discharge device having a fluorescent anode or target responsive to electron bombardment for visually indicating voltages. The electron discharge device is constructed so as to provide a fluorescent line on a shadow, or non-illuminated, area of the fluorescent target, and the position of the line indicates the resonance condition of the FM receiver.

It is desirable to provide a differentiation between a "no-signal" and "in-tune" condition while using such an indicator device. A special problem is presented in providing such differentiation where the FM receiver is of the type employing a frequency divider of the locked-in oscillator type, as disclosed by George L. Beers in U. S. Patent No. 2,356,201 granted August 22, 1944. In such an FM receiver the locked-in oscillator continuously feeds oscillations into the FM detector circuit, and thus makes it difficult to distinguish by means of a tuning indicator between the resonance condition with respect to a received signal and the condition of no signal. In addition, it is highly desirable to avoid utilizing a separate indicator device should the FM receiver include an AM receiving band, which is expected to be the usual case.

Accordingly, it may be stated that it is one of the main objects of my present invention to provide an FM receiver utilizing a resonance indication device of the type shown in the aforesaid Elston patent, but improved in its operation in that variations in the received FM signal intensity are automatically employed to vary the width of the shadow, or non-illuminated, area of the fluorescent target of the indicator device thereby to provide a supplemental indication as to whether or not FM signals are being received.

Another important object of this invention is to provide in an FM receiver of the type utilizing a locked-in oscillator form of frequency divider, a tuning indicator arrangement of the fluorescent

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target type, and a control voltage being derived from the signal grid circuit of the locked-in oscillator to control the shadow area on the target.

A further object of my invention is to provide a tuning indicator arrangement that can be used in a radio receiver having both AM and FM channels, and particularly one that will differentiate between "no-signal" and "in-tune" conditions in the case of an FM channel employing a locked-in oscillator form of frequency divider.

A more specific object of the present invention is to utilize the signal grid input circuit of a frequency divider of the locked-in oscillator type as a demodulator circuit for an AM channel, and the rectified voltage in such case being employed to provide an indication on a common resonance indicator device of the carrier intensity of a received AM signal.

Still other objects of my invention are to improve generally the efficiency and reliability of FM tuning indicators, and more especially to provide an economical and compact form of tuning indicator device for an FM-AM receiver.

Other features of my invention will best be understood by reference to the following description, taken in connection with the drawing, in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows that portion of an FM-AM receiver employing my invention; and

Fig. 2 shows the operative appearance of the indicating face of the resonance indicator tube.

Referring now to Fig. 1 of the accompanying drawing, there is shown an illustrative FM-AM receiving system of the superheterodyne type. The FM signals, reduced to a suitable intermediate frequency (I. F.), are subjected to frequency division by a locked-in oscillator, and the frequency divided signals are demodulated concurrently with production of operating voltage for the tuning indicator tube. For AM reception the input circuit of the locked-in oscillator tube is employed as a detector, and a common tuning indicator tube is employed to indicate resonance conditions. These various functions are performed by the system of Fig. 1. The receiver circuits employed prior to the locked-in oscillator tube are not shown in detail, since they are well-known to those skilled in the art of radio communication. The following general description of such prior circuits is believed adequate, and the prior circuits are schematically represented.

Those skilled in the art of radio reception are

well acquainted with the nature of the circuits customarily employed in multi-band receivers. While my invention is readily adapted for FM and AM reception on respective bands of 42 to 50 megacycles (mc.) and 550 to 1700 kilocycles (kc.), it is to be clearly understood that the invention is not limited to such frequency bands. The 42 to 50 mc. band is presented by way of illustration, since it is the FM broadcast band presently assigned by F. C. C. to such transmission. The band of 88 to 102 mc. has been assigned for this service in the future. The 550 to 1700 kc. band is the present AM broadcast band assigned to transmission of AM signals. It will further be understood that in the following description and claims the generic expression "angle modulated" is intended to include frequency modulation, phase modulation, or hybrid modulations thereof possessing characteristics common to both forms of modulation.

The numerals 1 and 2 in Fig. 1 denote respectively different sources of modulated carrier waves. Source 1 may be any suitable signal collector, such as a dipole, employed for collecting FM waves. The FM waves are transmitted from FM transmitters at a mean, center or carrier frequency assigned to the particular transmitter. In the presently assumed FM band of 42 to 50 mc. the radiated carrier wave would have a frequency in that frequency range, and would be a wave of variable frequency and substantially uniform amplitude. As is well known, the frequency modulation of the carrier wave would be in accordance with the modulation signals at the transmitter. The extent of frequency deviation of the carrier frequency is a function of the modulation signal amplitude, while the rate of frequency deviation is dependent upon the modulation signal frequencies per se. The permissible extreme frequency deviation in the present FM band of 42 to 50 mc. is ± 75 kc. to either side of the carrier frequency; the allotted FM station channels are 200 kc. wide. These values are purely illustrative.

Source 2 may be the customary grounded antenna circuit employed in AM broadcast reception. The allotted station channels are 10 kc. wide in this band. In AM transmission the carrier wave is modulated in amplitude in accordance with the modulation signals. The carrier frequency is maintained constant in value at the transmitter. The numeral 3 designates a tunable radio frequency amplifier having suitable signal selector circuits for FM or AM reception. Switching devices 4 and 5 are provided for separate connection of the sources 1 and 2 to respective selector circuits of amplifier 3. It will be understood that when switch 4 is in closed position, collected FM signal energy will be applied to selector circuits of amplifier 3 capable of selectively amplifying the FM signals over a band at least 150 kc. wide. Upon closing of switch 5 and opening of switch 4 the same amplifier 3 will have the FM selector circuits thereof operatively replaced by AM selector circuits. These latter circuits will select the collected AM signals, and permit amplifier 3 to amplify the same over a 10 kc. band. Multi-band selector circuits and switching devices for suitable change-over are well known to those skilled in the art of radio communication.

Assuming the receiver system is of the superheterodyne type, as is the usual practice at present, the converter 6 and intermediate frequency (I. F.) amplifier 7 will, also, be provided with suitable FM and AM signal selector circuits. At the

converter 6 the FM signals will have the mean or center frequency thereof reduced to a value which may be chosen from a range of 1 to 20 mc., as for example 4.3 mc. The AM signals are reduced to an I. F. of 455 kc., as an illustrative frequency value, the latter value being a commonly employed frequency in AM broadcast receivers of the superheterodyne type. The I. F. amplifier 7, which may consist of one or more separate stages of amplification, will have an ultimate output circuit from which may be derived at separate points thereof the amplified FM signals or AM signals.

The selective circuits 8 and 9 are to be understood as being arranged in series in the plate circuit of the last I. F. amplifier tube. Each of circuits 8 and 9 is resonated to its respective operating I. F. value for FM or AM reception. Thus, circuit 8 is tuned to 4.3 mc., while circuit 9 is tuned to 455 kc. There will be developed across tuned circuit 8 the FM signals at the 4.3 mc. mean frequency when switch 4 is closed, and all FM selector circuits of amplifier 3, converter 6 and I. F. amplifier 7 are in operative electrical connection. Conversely, when switch 5 is closed, and switch 4 is open, and all AM selector circuits are in operative electrical connection, there will be developed across circuit 9 the AM signals at the I. F. value of 455 kc. The impedance of circuit 9 is negligible at 4.3 mc. Therefore, the insertion of circuit 9 in series with circuit 8 will not affect the development of FM signal voltage across circuit 8. Similarly, the impedance of circuit 8 is negligible at 455 kc., and circuit 8 will not affect development of AM signal voltage across circuit 9.

The series-arranged primary circuits 8 and 9 are respectively magnetically coupled to resonant secondary circuits 8' and 9'. Each of the latter resonant secondary circuits 8' and 9' is tuned to 4.3 mc. and 455 kc. respectively. The resistor 11 is connected from the low potential side of circuit 9' to ground, and is shunted by the I. F. bypass condenser 12. An automatic volume control AVC lead 10 is connected from the ungrounded, or negative, end of resistor 11 to the several gain control electrodes, for example the signal grids, of the controlled tubes of stages 3, 6, and 7. Suitable filter resistors 10' are included in the AVC connections to the controlled tubes. The high potential side of circuit 8' is connected to the signal input electrode of the locked-in oscillator tube. The locked-in oscillator circuit shown, in general, is of the type disclosed by George L. Beers in his U. S. Patent No. 2,356,201 granted August 22, 1944.

The locked-in oscillator circuit comprises a tube 13 which may be of the pentagrid type. Between the input grid 14 and cathode 15 there is impressed the FM signal energy. The plate 16 has connected in circuit therewith a resonant output circuit 17 which is tuned to a subharmonic of the input energy mean frequency. By way of illustration, the fifth subharmonic may be employed. The plate 16 is established at a positive potential +B with respect to the grounded cathode. The second and fourth grids 18 and 19 of the tube are connected in common to the source of positive potential +B through a voltage reducing resistor 20 whose upper end is bypassed to ground by a suitable condenser 21. These positive grids function as a positive screen grid for the intermediate grid 22.

The grid 22 is regeneratively coupled, as at M, to the plate circuit 17. The fifth grid of tube 1 is connected back to the grounded cathode, and functions as a suppressor electrode. The cath-

ode 15, grid 22 and plate or anode 16 provide the oscillator section of the circuit. This oscillator section continuously produces oscillations at the subharmonic frequency of 860 kc., even in the absence of FM signal energy at grid 14. The FM oscillations developed across circuit 17 are transferred through magnetic coupling M_1 to the FM detector network. As indicated in Fig. 1, the utilization network is the FM discriminator-rectifier of the frequency modulation receiver.

The oscillator coupling transformer M consists of primary winding L_1 and a secondary winding L_2 . The winding L_2 has one end connected to grid 22, while the opposite end thereof is connected to ground through the resistor 23. The resistor 23 is bypassed for high frequency currents by condenser 24. The resistor 23 functions to provide self-bias for grid 22. During positive swings of the oscillatory voltage on the grid 22 current flows through resistor 23. Before explaining the electrical actions which occur in the oscillator tube circuit, it will be assumed that the latter acts as a frequency-dividing network in a receiver of the type disclosed in the aforementioned Beers patent. As more fully explained in the said patent, the locked-in oscillator functions concurrently to reduce or divide the mean frequency of applied FM signal waves, and proportionately to reduce the range of frequency deviation of the waves.

In other words, the I. F. energy is the original selected FM wave whose means frequency has been reduced to a much lower frequency, but whose frequency deviation is unchanged. After amplification in one or more separate stages of I. F. amplifiers, the I. F. energy is applied to the locked-in oscillator for concurrent frequency division and frequency deviation reduction. The I. F. transformer 8'', which may be of the iron core type, preferably has a response curve whose mean frequency is located at 4.3 mc., whereas the passband is substantially in excess of 150 kc. This signifies that the I. F. network up to grid 2 is capable of efficiently transmitting the entire frequency swings of the FM wave whose mean frequency has been reduced to the operating I. F. value. The function of the network 11, 12 is to provide voltage across its resistor element 11 in response to grid current flow through the input grid circuit of tube 13. Such grid voltage developed across the resistor 11 is used for AVC voltage, and is employed automatically to bias the gain control grids of preceding controlled amplifier tubes in a manner well-known to those skilled in the art. As shown later, this is also true for AM reception.

The plate circuit 17, which consists of the primary winding L_1 and the shunt condenser 25, is in the present application of the invention resonated to a frequency of 860 kc. Suitable resistance may be connected in shunt with the resonant circuit 17 to provide an appropriate and suitable degree of damping for the circuit. The numeral 26 designates a bypass condenser connected to ground from the low potential side of resonant circuit 17. Assuming a frequency division by a factor of 5, there will be developed across the plate circuit 17 FM signal energy whose mean frequency is divided by a factor of 5 with respect to the mean frequency of 4.3 mc. In other words the response curve at the output circuit 17 will ideally have a passband width in excess of 30 kc. with a mean frequency of 860 kc. This follows by virtue of the action of the locked-in oscillator network, which is to divide

the mean frequency of the FM wave energy and the overall frequency deviation range by the same factor. The locked-in oscillator produces an output of substantially uniform amplitude thus tending to eliminate any amplitude modulation effects which may have been created on the FM wave energy in the transmission through space, or during the passage of the signal energy through the receiver networks.

The frequency-divided signal energy may be applied to any desired form of discriminator-rectifier network for the purpose of abstracting the modulation signal voltage which will be amplified and ultimately reproduced. Those skilled in the art of radio communication are well acquainted with discriminator-rectifier circuits. For example, there may be used the circuit shown by Conrad in U. S. Patent No. 2,057,640, granted October 13, 1936, or the circuit disclosed by S. W. Seeley in U. S. Patent No. 2,121,103 granted June 21, 1938. The discriminator-rectifier circuit shown in the aforesaid Beers patent may be employed, if desired. That type of discriminator-rectifier is disclosed by J. D. Reid in U. S. Patent No. 2,341,240, patented February 8, 1944.

The action of the locked-in oscillator may generally be explained as follows. Harmonics of 860 kc are impressed on the oscillator grid 22 due to the considerable non-linearity of the characteristic relating grid voltage of grid 22 and current through the plate circuit 17. These harmonics include the fourth and sixth harmonics of the 860 kc. The presence of the fourth and sixth harmonics of the 860 kc. frequency serves greatly to extend the oscillator lock-in range.

The applied FM signals, assumed to be of a frequency of 4300 kc. in the present case, will beat with the aforementioned fourth and sixth harmonics to provide a difference frequency whose value is the same as the desired fundamental frequency of 860 kc. (the fifth subharmonic of 4300 kc.). This new component (termed "harmonic difference component" to differentiate it from the normal oscillator current of 860 kc.) will not, in general, have the same phase as the normal oscillator current. It is, thus, equivalent to injecting into the plate circuit an out-of-phase current. The oscillator tube acts in the manner of the well-known reactance tube by virtue of this phenomenon. If the oscillator frequency is not exactly one-fifth of the applied signal, the natural frequency of circuit 17 is "pulled over" until the frequency of oscillations is exactly one-fifth. In this condition the oscillator section is said to be "locked in" with the applied FM signals.

The maximum amount the natural frequency of the oscillator can be pulled over or adjusted, and still be locked-in, occurs when the harmonic difference current injected into the oscillator plate circuit is in quadrature (90 degrees out of phase) with respect to the normal oscillator current. This is true because in this quadrature state there exists maximum reactive current. When the injected current (the harmonic difference current) is leading the normal oscillator current in phase, the frequency of oscillations will be pulled to one side of its natural frequency (860 kc.). When the injected current lags, the oscillatory frequency will be pulled to the other side of its natural frequency. It is evident, therefore, that there is developed in the plate circuit a frequency modulated current which is "locked-in" with the applied FM signals. This follows from the fact that the applied FM energy has a frequency which changes from instant to in-

stant with respect to the mean or center frequency F_c thereof.

The FM detector comprises a pair of opposed diodes whose electrodes are located in a common tube envelope 27. The tube is of the 6HG type, although there may be used separate diode tubes. The anodes 28 and 29 of the diodes are connected to opposite ends of secondary coil L_2 of transformer M_1 . The midpoint of coil L_2 is connected by lead 30 to the junction of diode load resistors 31 and 32. Each half of coil L_2 is shunted by a respective condenser thereby to provide a pair of resonant diode input circuits 33 and 34. The cathodes 35 and 36 are respectively connected to the upper and lower ends of load resistors 31 and 32, and each of the load resistors is shunted by a respective I. F. bypass condenser 37 and 38. Condenser 39 bypasses the cathode end of resistor 32 to ground for I. F. currents; the audio ground is at the low end of resistor 32.

The input circuits 33 and 34 of respective diodes 28, 35 and 29, 36 are oppositely and equally mistuned relative to 860 kc. Thus, circuit 33 may be tuned to a frequency of 880 kc., while circuit 34 is resonated to a frequency of 840 kc. The peak frequencies are, therefore, in excess of the maximum swing of the FM signals at circuit 17. It will be recognized that the discriminator network 17, 33, 34 is similar to that shown in the Conrad Patent No. 2,057,640. The action of the discriminator is well known to those skilled in the art of FM signalling.

In general, the rectified voltages across resistors 31 and 32 will be of equal magnitude when the FM signal at circuit 17 has an instantaneous frequency equal to 860 kc. This follows from the fact that at that frequency both input circuits 33 and 34 will have equal amounts of signal energy applied thereto. Hence, each of the respective load resistors 31 and 32 will have developed thereacross equal rectified voltages. However, the polarities of these rectified voltages are opposed, since the junction of resistors 31 and 32 is connected by lead 30 to the anode of each of the opposed diodes. As the frequency of the FM signals at circuit 17 deviates from 860 kc., the rectified voltages across resistors 31 and 32 will vary in relative magnitudes depending upon the sense and degree of frequency deviation of the energy at circuit 17.

Differential resultant voltage of the rectified voltages across resistors 31 and 32 may be utilized, and such differential voltage would then represent the modulation signal originally applied to the carrier at the FM transmitter. The modulation signal voltage is taken off from the cathode end of resistor 31. The direct current voltage components of the rectified voltages across resistors 31 and 32 are utilized for actuating the tuning indicator tube. This is accomplished by utilizing the direct current voltages to drive a pair of direct current amplifiers in push-pull relation. The audio output from the FM detector is taken from the point 31', effectively from cathode 35 to ground. The low side of resistor 32 is grounded through capacitor 39. The condenser 31'' couples the audio output point 31' to any suitable audio amplifier. The electrical midpoint 32' of the load resistors 31 and 32 is at ground for direct currents.

While a pair of triodes 40 and 41 are shown in Fig. 1, it is to be understood that the electrodes thereof may be mounted in a single tube envelope if desired, as in a twin triode type tube. The cathodes 42 and 43 are connected in common by

lead 44 and slider 45 to a voltage supply resistor 46 having one end grounded, while its opposite end is connected to the +B terminal of the direct current supply network. The slider 45 is adjusted to a point on resistor 46 such that the voltage between the slider and ground represents the initial, or no-signal, bias applied to the grids 47 and 48 of triodes 40 and 41 respectively. Grid 47 is connected to the cathode, or positive, end of resistor 31 through filter resistor 49, the condenser 50 bypassing grid 47 to ground for all alternating current voltage components. The grid 48 is connected by filter resistor 51 to the cathode, or positive, end of resistor 32. Condenser 39 cooperates with resistor 51 to filter all alternating voltage components from the voltage applied to grid 48.

The plates 52 and 53 are connected to the opposite ends of the output resistor 54, whose midpoint is connected to the +B terminal of the direct current source. The junction of resistors 31 and 32 is connected by an AVC lead 55, including filter resistor 56, to the ungrounded end of resistor 11. The resistor 56 is of a high resistance, and avoids loading the lower half of the discriminator circuit.

The direct current voltages across each of load resistors 31 and 32 are applied in push-pull to the respective grids 47 and 48 of the direct current voltage amplifiers 40 and 41. The respective amplified direct current voltages appear across each half of the common output load resistor 54. These amplified direct current voltages are utilized to control the potential of the pair of control electrodes of the tuning indicator tube. The latter is a dual ray-control tuning indicator tube of the type disclosed in U. S. Patent No. 2,366,320 granted to G. F. Elston on January 2, 1945. In Fig. 1 I have shown a schematic representation of the tuning indicator tube, particular reference being made to the aforesaid Elston patent for the construction details thereof. It is to be understood that the tuning indicator tube is viewed in plan view in Fig. 1.

In general, this type of indicator tube is a modification of the well-known variable shadow angle indicator tube which employs a flared fluorescent target having the shape of an inverted frustum of a cone. The numeral 55' denotes the usual tube envelope. The electron emitter, or cathode, 56 is established at ground potential, while the grid 57 is at cathode potential. The flared target is denoted by numeral 58, and the latter is connected to the +B terminal of the direct current supply network. In Fig. 1 the target is viewed from its flared end, which is the indicating end. The inner face of target 58 is provided with a fluorescent coating, and the cathode 56 is axially located relative to the target 58. The ray control electrodes are designated by numerals 59 and 60. Electrode 59 is connected by lead 61 to plate 52, while electrode 60 is connected to plate 53 by lead 62.

The electron deflection electrodes 59 and 60 are a pair of rods, or ribbons, of metal between which a narrow flat beam of electrons may pass to the target 58 to create a line or pencil of light extending radially across the sector shadow area on the positive target. In Fig. 2 I have shown the shaded and illuminated areas of the viewing surface of the indicator tube. Target 58 is shown provided with sector shadow area 70. The line or pencil of light 71 is indicated on shadow area 70. In accordance with my present invention, the width of shadow, or non-illuminated, area 70

varies as a function of signal strength, being a maximum in the absence of received signals or in the extreme off-tune condition. Further, the angular position of line 71 varies relative to its central position in accordance with the sense and degree of mistuning of the receiver relative to a desired in-tune condition.

These functions are accomplished in the following manner. Assume that no signals are being received, and that switch 5 is closed and switch 4 is opened thereby to condition the system for AM signal reception. There will be no signal energy at circuit 9', and, hence, there will be zero voltage across resistor 11. The grids 47 and 48 will, therefore, have biases determined by the voltage drop E_k across the lower portion of resistor 46 between slider 45 and ground. This voltage E_k is the compensation voltage for the high positive bias developed at the cathode ends of resistors 31 and 32. That is, the voltage E_k is normally sufficiently negative to provide an initial negative bias for the grids 47 and 48. Since the locked-in oscillator is continuously oscillating at 360 kc., there will be produced rectified voltages across each of resistors 31 and 32. Were it not for negative voltage E_k , these no-signal voltages would drive grids 47 and 48 highly positive.

The grids 47 and 48 are biased towards the upper end of their grid voltage versus plate current (E_g-I_p) characteristics, but have sufficient range above this point to handle the unbalance of voltages across resistors 31 and 32 during FM reception. The electron deflection electrodes 59 and 60, being connected to the anode ends of resistor 54, will be less positive than target 58, since the voltage drop across each half of resistor 54 is a maximum in the absence of voltage across resistor 11. Hence, the electrodes 59 and 60 repel or deflect the electrons normally traveling in all radial directions from the cathode 56. This produces the non-illuminated, or enlarged shadow, area 70 on the positive fluorescent target, or anode, 58. The maximum shadow width may be nearly 90° by assigning suitable values to resistor 54 and voltage E_k . As long as the voltages of deflection electrodes 59 and 60 are equal and less positive than the target the narrow flat beam of electrons passing between the electrodes produces the central illuminated line 71 on the shadow angle 70. In other words, the shadow angle is bisected by fluorescent line 71.

If, now, AM signals are received, and AM signal voltage of 455 kc. is developed across circuit 9', rectified voltage will be produced across resistor 11. The existence of I. F. voltage at circuit 9' has no effect on circuit 8', and, therefore, the signal grid 14 is energized solely in response to the I. F. energy at 455 kc. The grid 14 functions as the anode relative to cathode 15, and, hence, provides a demodulator device for AM signals.

The modulation signal component of rectified voltage is taken off from the ungrounded end of resistor 11 by audio coupling condenser 80, and an audio frequency network may be fed with the modulation signals. The AVC line 55 applies solely the direct current voltage to grids 47 and 48, and the voltage will be directly proportional to the received AM carrier strength. The ungrounded end of resistor 11 will become increasingly negative relative to ground as the AM signal strength increases. Therefore, the grids 47 and 48 will be biased increasingly more negative than normal, and the voltage drop across both halves of resistor 54 decreases. As a result the voltages

of electrodes 59 and 60 will approach the potential of target 58. The width of shadow angle 70 will, therefore, decrease since the deflection of electrons becomes less. Ultimately, when the potentials of electrodes 59 and 60 are equal to, or near, the target voltage no shadow is cast by the deflection electrodes. The correct, or in-tune, indication for AM signal reception is the tuning adjustment which in the presence of that signal results in minimum shadow angle. During all this time the voltages of electrodes 59 and 60 are equal.

Assume, now, that switch 4 is closed and switch 5 is opened (as in Fig. 1) for FM reception. The FM signals appear across circuit 8', as previously explained. Should the receiver be tuned between FM channels, or no FM signals be received, there will be solely constant frequency energy of 360 kc. developed at circuit 17. No voltage appears across resistor 11, since no FM signals are applied to grid 14. Hence the grids 47 and 48 have normal negative biases E_k applied thereto. The shadow area 70 will be of maximum size, as previously explained. The fluorescent line 71 will be at the central position on shadow sector 70, since the potentials of electrodes 59 and 60 are equal. Were it not for the wide shadow angle 70, it is easily seen that the set operator would be confused into thinking that the receiver was correctly tuned to the center frequency of an FM station. The maximum width of the shadow informs the operator that he is either between stations or is getting no useful FM signal.

Upon tuning the receiver into an FM channel from one limiting frequency to the opposite limiting frequency, there will be two changes indicated on the target 58. First, the FM signals applied in increasing intensity to grid 14 will cause grid current to flow through resistor 11. The grid current produces a voltage drop across resistor 11 thereby supplying AVC voltage for increasing the parallel mean biasing of grids 47 and 48. The shadow angle of area 70 is caused to decrease, and thereby acts as an indicator of the FM signal carrier amplitude. The shadow area 70 becoming smaller indicates the presence of FM signal. If the receiver is accurately tuned to the center frequency of a desired FM station, the voltages across resistors 31 and 32 will, of course, be equal and balanced. Hence, the fluorescent line 71 will be "centered" as shown in Fig. 2. Hence, the discriminator balance, or in-tune condition, is indicated as in a zero center meter.

Should the receiver be tuned to one or the other side of center frequency, the rectified voltages across load resistors 31 and 32 would become unequal to an extent and in a sense dependent respectively on the magnitude and direction of receiver mistuning. The effect of unbalance of the rectified voltages across resistors 31 and 32 is to make one of grids 47 and 48 less negative, and the second grid more negative. The E_g-I_p characteristics of triodes 40 and 41 preferably should be of the remote cut-off type, as this would provide sufficient range above the normal bias points of grids 47 and 48 to handle unbalance voltages due to mistuning. The application of the unbalance voltages to grids 47 and 48 results in corresponding inequality of the potentials of deflection electrodes 59 and 60. The angular position of line 71 changes either to one side or the other side of the central position shown in Fig. 2.

The reduction in shadow angle size with the

amplitude of the applied signal is determined mainly by the shape of the characteristic ($E_g - I_p$) of the amplifier tubes 40 and 41. Tubes designed for this service should preferably have a remote cut-off characteristic so that the shadow angle does not reduce to zero until the signal develops about 35 volts. The triode amplifier used in the conventional electronic indicator tube requires about 20 volts for zero shadow angle. The more remote cut-off is employed in this case in order to maintain a larger shadow angle on which to center the fluorescent line 71. In the conventional AM receiver tuning indicator arrangement the design is such that the shadow angle reduces to zero under maximum signal conditions. With this present arrangement it is desirable, of course, to have some shadow angle left under maximum signal conditions on which to center the fluorescent line. In general, therefore, the shadow angle will vary from maximum to about one fourth of maximum depending on the signal strength.

The outer boundaries of shadow area 70 move but little with variations over a considerable range in the voltages of the deflection electrodes, whereas the position of the line 71 is sensitive to unbalance voltages of the deflection electrodes. The shadow boundaries will change to some extent with the application of unbalance voltage to the two grids 47 and 48. The unbalance voltage has a much greater effect on the position of the fluorescent line 71 since the latter position is determined by the relative potentials of the two ray control electrodes which initially are at the same potential, and which change in potential in opposite polarity directions. In other words, the effect on the edges of the shadow angle depends on the difference in the potentials of the target and ray control electrodes, one of which (the target) is essentially fixed so that the relative variation is more gradual. If the two electrodes 59 and 60 are unequal in voltage, as in response to the receiver being detuned to either side of resonance with a given FM station, the line 71 will be swung or shifted to a corresponding side of center. Thus, if the voltage across resistor 31 exceeds that across resistor 32, due the FM signals having a mean frequency closer to 880 kc., then the grid 47 is biased less negative than grid 48. This results in more plate current flowing through the upper half of resistor 54, and electrode 59 assumes a potential less positive than electrode 60. Hence, the beam of electrons passing between electrodes 59 and 60 is swung or shifted towards electrode 60, the more positive of the pair. The line 71, therefore, is shifted along the shadow area 70 in a direction towards electrode 60. The line 71 will shift in the direction towards electrode 59 in response to the rectified voltage across the lower half of resistor 54 exceeding the voltage across the upper half. The line 71 simulates an illuminated needle moving over the shadow area 70 as the receiver is tuned from one limit of the desired station channel to the opposite limit.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention.

What I claim is:

1. In a system for receiving radio signals, a resonance indicator of the fluorescent target type

provided with a pair of electron deflection electrodes between which passes a beam of electrons to form a fluorescent line on the target, means normally applying equal voltages to said electrodes which are less positive than the target potential thereby to provide a relatively wide shadow sector on the target, said line being located at the center of the sector, and means responsive to received signal carrier amplitude variation for controlling said applying means to vary the magnitudes of said voltages equally whereby the width of the shadow sector is varied to indicate said carrier amplitude variation.

2. In a system for receiving radio signals, a resonance indicator of the fluorescent target type provided with a pair of electron deflection electrodes between which passes a beam of electrons to form a fluorescent line on the target, means normally applying equal voltages to said electrodes which are less positive than the target potential thereby to provide a relatively wide shadow sector on the target, said line being located at the center of the sector, and rectifier means responsive to received signal carrier amplitude variation for controlling said applying means to vary the magnitudes of said voltages equally whereby the width of the shadow sector is varied to indicate said carrier amplitude variation, and means for deriving modulation signals from the rectifier means.

3. In a system for receiving radio signals, a resonance indicator of the fluorescent target type provided with a pair of electron deflection electrodes between which passes a beam of electrons to form a fluorescent line on the target, means for normally applying equal voltages to said electrodes which are less positive than the target potential thereby to provide a relatively wide shadow sector on the target, said line being located at the center of the sector, means responsive to received signal carrier amplitude variation for controlling said applying means to vary the magnitudes of said voltages equally whereby the width of the shadow sector is varied to indicate said carrier amplitude variation, a locked-in oscillator tube provided with a cathode, signal input grid, oscillator grid and anode, said signal responsive means comprising a signal input circuit in series with a resistor between said signal grid and cathode, means applying to the said input circuit frequency modulated radio signals, a tank circuit, tuned to a subharmonic of the mean frequency of said frequency modulated signals, coupling said anode and oscillator grid continuously to provide oscillations of said subharmonic frequency but whose frequency deviations are locked-in with those of the input signals, and means responsive to departures in center frequency of the oscillations relative to said subharmonic frequency for controlling said applying means to render said voltages unequal thereby to shift the position of the fluorescent line.

4. In combination in a system of the type including a locked-in oscillator circuit having a pair of signal input electrodes and an oscillator section, a pair of signal input circuits connected in series between the input electrodes, the input circuits being tuned to widely spaced signal frequencies, means for selectively applying frequency-variable signals to one of the input circuits and amplitude-variable signals to the second input circuit, an output circuit tuned to a subharmonic of the frequency-variable signals and coupled to the oscillator section, means cou-

pled to said output circuit for producing a pair of direct current voltages whose relative polarity and magnitude depend respectively on the sense and extent of departure of the mean frequency of the output oscillations from said subharmonic frequency, means responsive to said pair of voltages providing a visual indication of said departure, resistor means in circuit with said signal input circuits for providing voltage whose magnitude is proportional to the intensity of said frequency-variable signals, and means responsive to said last voltage for controlling the visual indication means thereby to provide a supplemental indication of said intensity.

5. In combination in a system of the type including a locked-in oscillator circuit having a pair of signal input electrodes and an oscillator section, a pair of signal input circuits connected in series between the input electrodes, the input circuits being tuned to widely spaced signal frequencies, means for selectively applying frequency-variable signals to one of the input circuits and amplitude-variable signals to the second input circuit, an output circuit, tuned to a subharmonic of the frequency-variable signals, coupled to the oscillator section, means coupled to said output circuit for producing a pair of direct current voltages whose relative polarity and magnitude depend respectively on the sense and extent of departure of the mean frequency of the output oscillations from said subharmonic frequency, means responsive to said pair of voltages providing a visual indication of said departure, resistor means in circuit with said signal input circuits for providing a voltage whose magnitude is proportional to the intensity of said frequency-variable signals, means responsive to said last voltage for controlling the visual indication means thereby to provide a supplemental indication of said intensity, and said resistor means also providing said voltage in response to selective application of amplitude-variable signals to said second input circuit.

6. In a system for receiving radio signals utilizing either frequency modulation or amplitude modulation, a tuning indicator of the fluorescent target type provided with two ray control electrodes so arranged as to provide a substantial shadow sector when operated at the proper potential and at the same time focus a beam of electrons on the approximate center of said shadow sector when substantially no difference of potential exists between the two ray control electrodes, said beam of electrons resulting in a fluorescent line on the shadow sector, means providing a direct current voltage whose amplitude varies proportionally with the strength of the received carrier and which in the case of the frequency modulation channel is separate from the frequency modulation detector output circuit, means for applying the effect of said last voltage in parallel relationship to the two ray control electrodes so as to cause the size of the shadow sector to change with variation in the amplitude of the received carrier, means for simultaneously applying in push-pull relationship to the two ray control electrodes the effect of the direct current voltages developed across the two halves of the frequency modulation detector output circuit so that the condition of equal voltages developed across the two halves of said circuit is indicated by the centering of the fluorescent line on the shadow sector whose size is made to change with variation in the amplitude of the received carrier.

7. In combination in a system of the type in-

cluding a locked-in oscillator circuit having a pair of signal input electrodes and an oscillator section, a pair of signal input circuits connected in series between the input electrodes, the input circuits being tuned to widely spaced signal frequencies, means for selectively applying frequency-variable signals to one of the input circuits and amplitude-variable signals to the second input circuit, an output circuit, tuned to a subharmonic of the frequency-variable signals, coupled to the oscillator section, means coupled to said output circuit for producing a pair of direct current voltages whose relative polarity and magnitude depend respectively on the sense and extent of departure of the mean frequency of the output oscillations from said subharmonic frequency, means responsive to said pair of voltages providing a visual indication of said departure, and resistor means in circuit with said signal input circuits providing a voltage in response to selective application of amplitude variable signals to said second input circuit.

8. In a system for receiving radio signals, a resonance indicator of the fluorescent target type provided with a pair of electron deflection electrodes between which passes a beam of electrons to form a fluorescent line on the target, means normally applying equal voltages to said electrodes which are less positive than the target potential thereby to provide a shadow sector on the target, said line being located at an intermediate point of the sector, and means responsive to received signal carrier amplitude variation for controlling said applying means to vary the magnitudes of said voltages in such a manner as to cause the width of the shadow sector to vary so as to indicate said carrier amplitude variation.

9. In a system for receiving radio signals, a resonance indicator of the fluorescent target type provided with a pair of electron deflection electrodes between which passes a beam of electrons to form a fluorescent line on the target, means normally applying voltages to said electrodes such as to provide a shadow sector on the target, said line being located at the center of the sector, means responsive to received signal carrier amplitude variation for controlling said applying means to vary the magnitudes of said voltages whereby the width of the shadow sector is varied to indicate said carrier amplitude variation, and means for deriving modulation signals from the responsive means.

10. In a system for receiving radio signals, a resonance indicator of the fluorescent target type provided with a pair of electron deflection electrodes between which passes a beam of electrons to form a fluorescent line on the target, means for applying voltages to said electrodes such as to provide a shadow sector on the target, said line being located at the center of the sector, means responsive to received signal carrier amplitude variation for controlling said applying means to vary the magnitudes of said voltages whereby the width of the shadow sector is varied to indicate said carrier amplitude variation, a locked-in oscillator tube provided with a cathode, signal input grid, oscillator grid and anode, said signal responsive means comprising a signal input circuit in series with a resistor between said signal grid and cathode, means applying to said input circuit frequency modulated radio signals, a tank circuit coupling said anode and oscillator grid continuously to provide oscillations whose frequency deviations are locked in with those of the

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input signals, and means responsive to departures in center frequency of the oscillations for controlling said applying means so as to shift the position of the fluorescent line.

11. In combination, in a system of the type including a locked-in oscillator circuit having a pair of signal input electrodes and an oscillator section, a pair of signal input circuits connected in series between the input electrodes, the input circuits being tuned to widely spaced signal frequencies, means for selectively applying frequency-variable signals to one of the input circuits and amplitude-variable signals to the second input circuit, an output circuit, tuned to a sub-harmonic of the frequency-variable signals, coupled to the oscillator section, a detector coupled to the output circuit, resistor means in circuit with said signal input circuits, said resistor means providing a rectified voltage in response to selective application of amplitude-variable signals to said second input circuit.

12. In a system for receiving radio signals, a tuning indicator of the fluorescent target type provided with two ray control electrodes so arranged as to provide a substantial shadow sector when operated at the proper potential and at the same time focus a beam of electrons on the

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approximate center of said shadow sector when substantially no difference of potential exists between the two ray control electrodes, said beam of electrons resulting in a fluorescent line on the shadow sector, a frequency variation detector provided with a pair of output loads, means for applying in push-pull relationship to the two ray control electrodes the effect of direct current voltages developed across the two loads of the frequency variation detector output circuit so that the condition of equal voltages developed across the two loads of said circuit is indicated by the centering of the fluorescent line on the shadow sector.

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