

Sept. 30, 1941.

J. E. SMITH ET AL

2,257,282

FREQUENCY MODULATION OF SIGNALS

Filed April 27, 1939

4 Sheets-Sheet 1

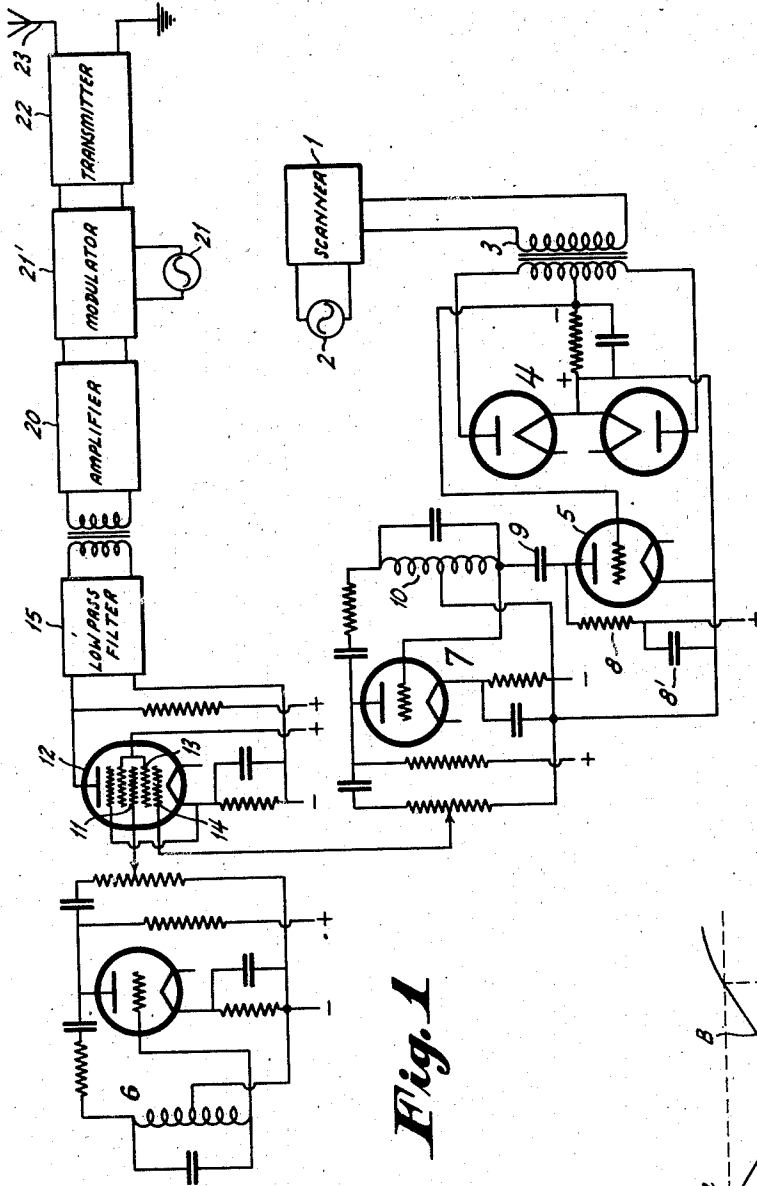


Fig. 1

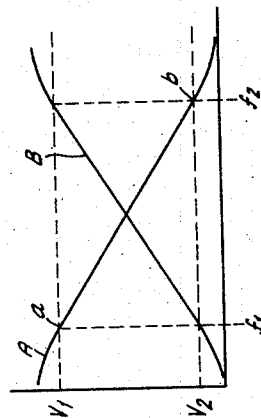


Fig. 6

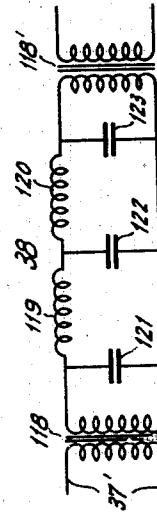


Fig. 7

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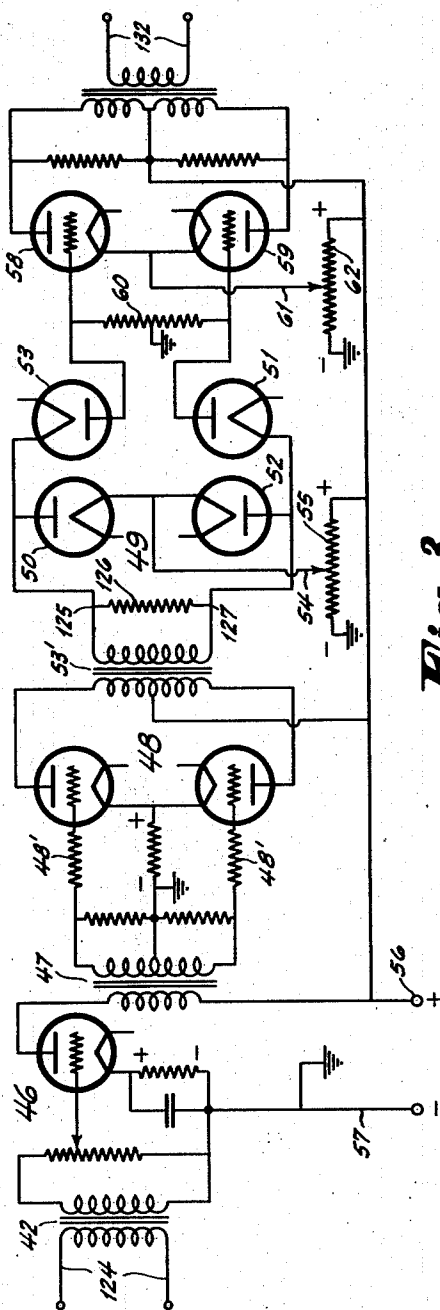
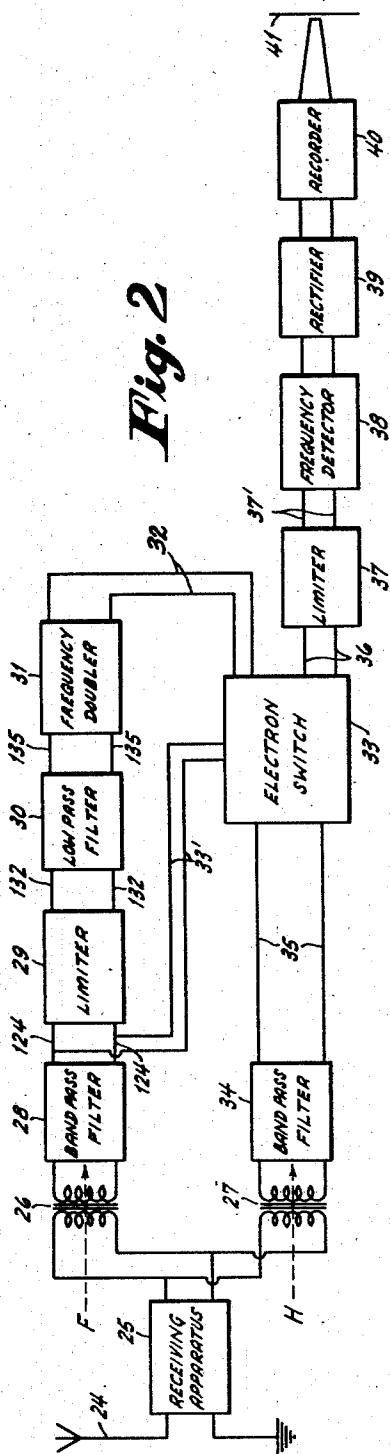
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FREQUENCY MODULATION OF SIGNALS

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4 Sheets-Sheet 2



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FREQUENCY MODULATION OF SIGNALS

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4 Sheets-Sheet 3.

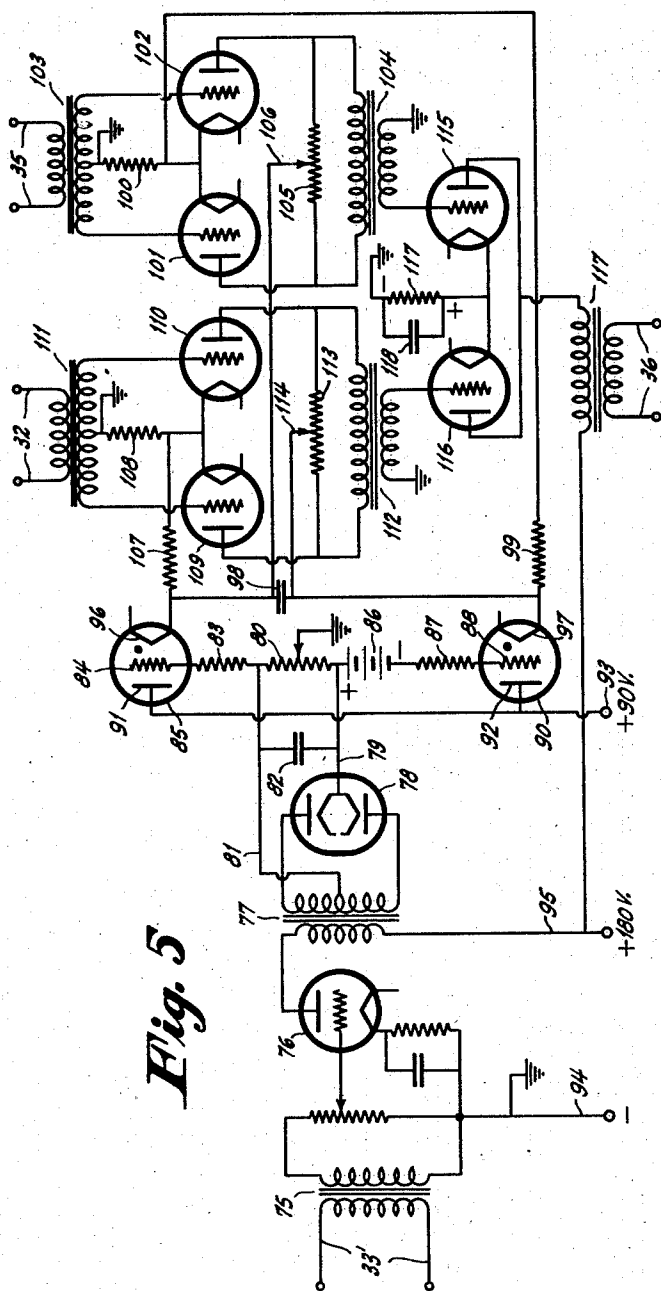


Fig. 5

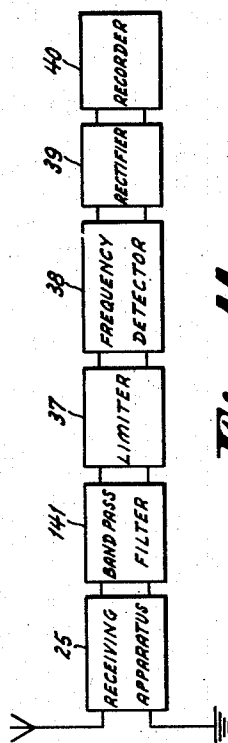


Fig. 4

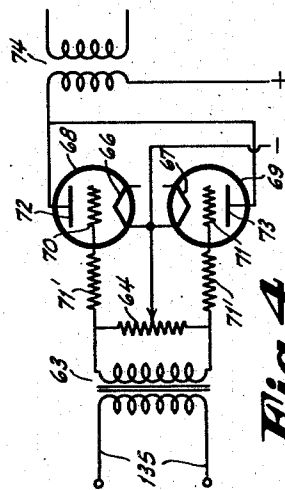


Fig. 4

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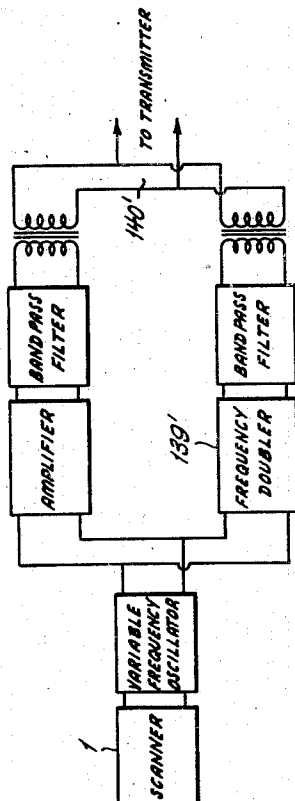
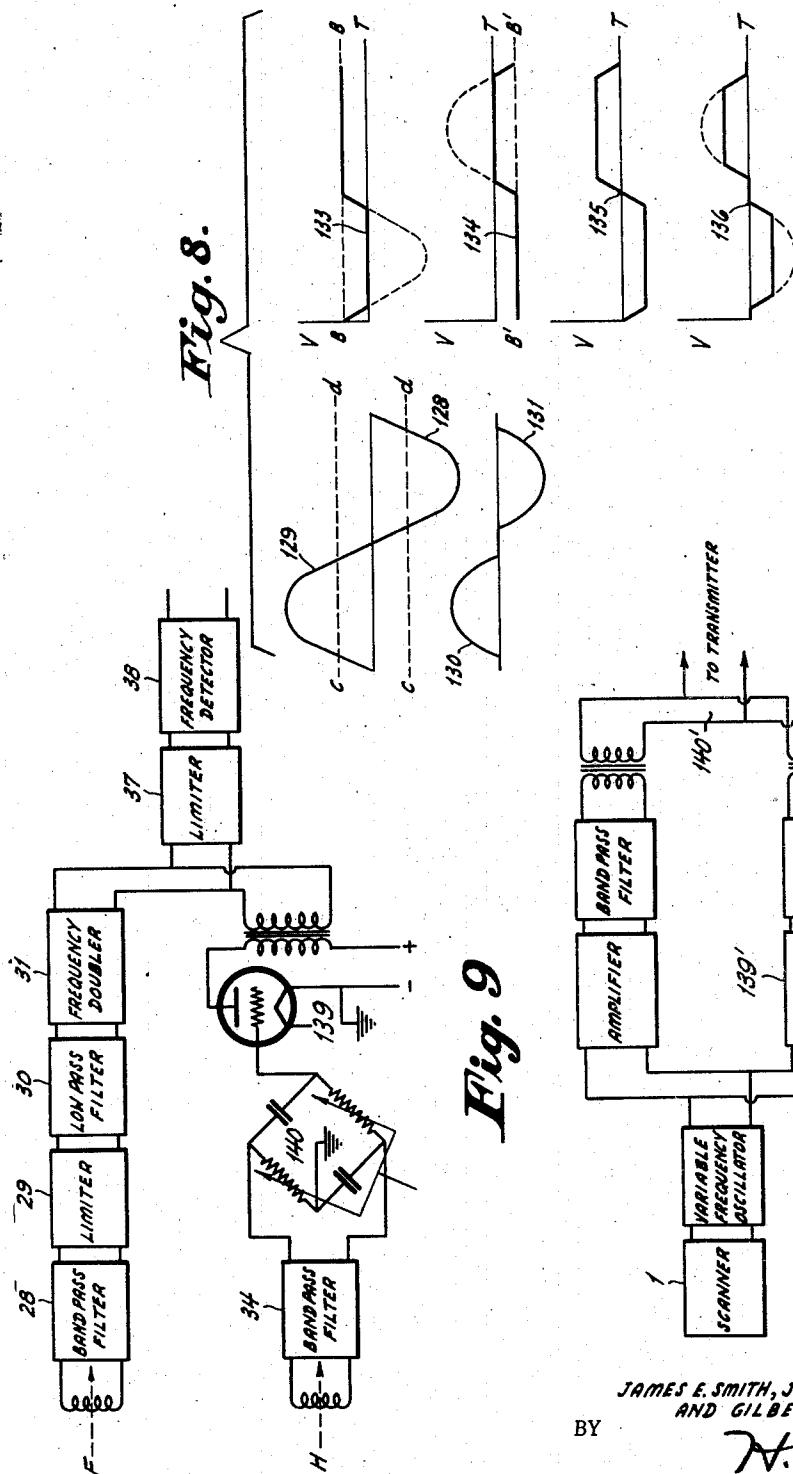
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FREQUENCY MODULATION OF SIGNALS

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4 Sheets--Sheet 4



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UNITED STATES PATENT OFFICE

2,257,282

FREQUENCY MODULATION OF SIGNALS

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Application April 27, 1939, Serial No. 270,332

21 Claims. (Cl. 250—20)

This invention relates to the variation of carrier waves by change in frequency, instead of amplitude, and is particularly useful in photo radio transmission although it is capable of various other uses.

As is now well known, changes in the condition and height of the ionosphere produce fading effects in radio transmission. These changes may at times affect all frequencies within a wide range and at other times affect only a particular frequency or frequencies within a quite narrow range. The first is usually referred to as general fading and the second as selective fading. These two effects may be produced at different times or they may occur simultaneously.

To overcome the effects of fading it has been proposed to modulate the carrier wave by changing the frequency rather than the amplitude, since fading produces amplitude variations of the signal. Frequency modulation would thus enable one to discriminate between the signal modulation and that produced by fading. By using frequency modulation at the transmitter and rigidly limiting the voltage or current at the receiving station, the amplitude modulations produced by fading can be eliminated. For a disclosure of this general method of reducing fading, reference is made to the patent of Wright and Smith, No. 1,964,375, June 26, 1934.

Also, in producing frequency variation it has been found advantageous to vary the frequency of a sub-carrier and then amplitude modulate the radio frequency carrier by this frequency modulated sub-carrier. While the improvements produce an improvement in the transmission of pictures as compared to systems using amplitude modulations, selective fading effects are still noticeable. Most objectionable is the selective fading of the radio frequency carrier. Whenever this occurs the received signal appears to be over modulated by the side bands thus producing spurious components in the detected output consisting of the side band separation frequency and harmonics thereof. The main spurious component is the second harmonic of the sub-carrier caused by this beating together of the two side bands. Other even harmonics may be produced but to a less extent.

It is one object of our invention to overcome the effects of selective fading by selectively receiving the subcarrier and its second harmonic and utilizing the latter when the former fades.

Another object of the invention is to provide an improved switch of instantaneous action for automatically selecting either the sub-carrier or

the second harmonic thereof, depending upon selective fading conditions.

Another object is to provide an arrangement that automatically switches a desired harmonic frequency of the signal in or out of circuit upon the fundamental frequency of the signal falling below a predetermined intensity.

Another object is to provide an arrangement in which a utilization device is automatically connected to receive the fundamental frequency when it rises above a predetermined intensity and to receive a desired harmonic thereof when the fundamental falls below a predetermined intensity.

Another object is to produce an automatic switch that will operate at greater speed than the rate of change in selective fading.

Other objects will appear in the following description, reference being had to the drawings in which:

Fig. 1 is a part diagrammatic and part block illustration of a transmitter.

Fig. 2 is a block diagram of the receiving circuits.

Fig. 3 is a diagrammatic illustration of the voltage limiter of Fig. 2.

Fig. 4 is a diagrammatic illustration of the frequency doubler of Fig. 2.

Fig. 5 is a diagrammatic illustration of the electron switch of Fig. 2.

Fig. 6 gives the voltage-frequency graphs of the frequency detector.

Fig. 7 is a diagrammatic illustration of the band pass frequency detector of Fig. 2.

Fig. 8 gives a series of graphs illustrating the operating characteristics of the limiter.

Fig. 9 is a modified form of receiver.

Fig. 10 is a modified form of transmitter.

Fig. 11 is a receiving system for the transmitter of Fig. 10.

Referring to Fig. 1, the picture scanner may be of any desired kind as indicated at 1, but it preferably has a tone output by control of a source 2 of audio oscillations. The tone output at 3 varies the frequency of a sub-carrier oscillator which in turn modulates a radio frequency carrier. Various sub-carrier oscillators may be used but we have illustrated one of the heterodyne type. The tone output 3 of the scanner feeds into double rectifier 4 and the rectified output is applied so that it acts as a negative bias on tube 5 that varies with the scanner output. Two high frequency oscillators 6 and 7 are adjusted to oscillate at frequencies differing by a low frequency beat, for example, 800 cycles. Os-

oscillator 6 maintains a constant frequency but oscillator 7 has its frequency varied by the vacuum tube stage 5. Tube 5 has its plate-cathode circuit in shunt with the high resistance 8 and condenser 9 which is in series with the condenser 9 to one side of coil 10. The series-parallel circuit of condenser 9 and tube 5 and high resistance 8 and condenser 9 is thus in parallel with half the input coil 10 of oscillator 7.

The output of oscillator 6 is adjustably connected to control grid 11 of tube 12 which is surrounded by screen grid 13. The voltage on this screen is preferably lower than that on the plate of the tube. The output of oscillator 7 is adjustably connected to another control grid 14 of tube 12. The output of tube 12 is passed through a low pass filter 15 to filter out all frequencies but the varying beat frequency. This varying beat frequency which is the sub-carrier frequency previously referred to, is amplified at 20 and modulates a high frequency carrier 21 at 21' in any way. Transmitter 22 radiates the signal by means of antenna 23. The modulator 21' may be of any type desired.

In Fig. 2 the receiving antenna 24 is connected to an appropriate receiving apparatus 25 which may consist of radio frequency amplifiers, a detector and audio frequency amplifiers and any other desired devices for converting the signals into audio frequencies of the desired intensity. The output of the amplifier 25 contains two primaries 26, 27, providing two paths for the signal, one for the fundamental sub-carrier, and the other for the second harmonic of the sub-carrier. The path for the fundamental consists of a band pass filter 28, voltage limiter 29, low pass filter 30, and frequency doubler 31. The output lines 32 of the frequency doubler are connected to electron switch 33. Filter 28 is also connected to the switch 33 by lines 33' for a purpose explained later herein.

The path for the second harmonic consists of a band pass filter 34, the output lines 35 of which are connected to the electron switch 33. The output lines 36 of the electron switch are connected to the voltage limiter 37 and the circuit is continued from conductors 37' through frequency detector 38, rectifier 39 to recorder 40, which records a picture of the object on the surface 41. This recording may be carried out by the photographic process, visual process, or by any other method as our invention is independent of the particular type of the recorder. The details of the voltage limiter, frequency doubler, electron switch and frequency detector are shown in Figs. 3, 4, 5 and 7, respectively. The details of the other devices in Figs. 1 and 2 indicated in block diagrams are old and well known in the art and are not illustrated.

In Fig. 3 which illustrates the voltage limiter, input coil 42 feeds into the input of amplifier 43. The output 44 feeds into push pull amplifier 45 having resistors 46 to aid in the limiting action. The output of the amplifier feeds into the rectifying device indicated generally at 49. This consists of four rectifiers 50, 51, 52 and 53, so arranged that the rectified current for each half wave passes through two rectifiers in series and both half waves are produced by the same coil 53'. The cathodes of rectifiers 50, 52, are connected by adjustable tap 54 to potentiometer resistance 55, one end of this resistance being connected to the positive terminal 56 of a source of supply, the other terminal 57 of this source being

grounded. It is preferable to use this resistance but it can be omitted when desired.

The anode of rectifier 50 is connected to the cathode of rectifier 53 and the anode of rectifier 52 is connected to the cathode of rectifier 51. The anodes of rectifiers 51 and 53 are connected to the grids of tubes 58 and 59 and resistance 60 is connected across these grids, the center of the resistance being grounded. The cathodes of tubes 58 and 59 are connected by adjustable tap 61 to potentiometer resistance 62, one end of which is connected to the positive terminal 56 and the other one of which is connected to negative terminal 57 through ground. This resistance is a source of negative bias for tubes 58 and 59. The anodes of tubes 58 and 59 are connected in push pull fashion and fed by the source 56 in the usual way as is clearly indicated in the drawing.

Referring to Fig. 4 which illustrates the frequency doubler, the input coil 63 is connected across resistance 64, the adjustable tap of which is connected directly to the cathodes 66 and 67 of tubes 68 and 69 and to the negative supply. The grids 70 and 71 of these tubes are connected to opposite ends of resistance 64 through resistances 71'. It will be recognized that the input of tubes 68 and 69 are connected in the well known push pull fashion. The anodes 72 and 73, however, are connected in parallel to the output primary 74. This is a well known form of frequency doubler having a double frequency output voltage that is substantially a sine wave.

In the electron switch shown in detail in Fig. 5 the control lines 33' (see also Fig. 2) introduce the fundamental of the signal into the input 75 of the amplifier tube 76. The circuit of this amplifier is of the usual kind and will be understood from the drawings without further detailed description. The output circuit 77 introduces the signal into double rectifier 78 which also may be two separate tubes. The positive terminal 79 of this rectifier is connected to one end of resistance 80 and the negative terminal 81 is connected to the other end of this resistance. A filter condenser 82 is connected across these terminals and an adjustable tap on 80 is grounded. The negative end of resistance 80 is connected through an appropriate resistance 83 to the grid 84 of a gas triode 85. The positive end of resistance 80 is connected through a negative grid bias 86 and appropriate resistance 87 to grid 88 of a similar gas triode 89. These gas triodes are variously known as "Thyratrons" and "Grid glow" tubes and usually have an internal drop of about 15 volts across the anode and cathode. The anodes 91 and 92 of the gas triodes are joined together and connected to the positive terminal 93 of a source of which the negative terminal is indicated at 94. The terminal 93, may, for example, have 90 volts and a still higher voltage terminal 95 may have 180 volts. This latter is connected to the plate of amplifier tube 76 and to other electrodes to be referred to later. The cathodes 96 and 97 of the gas triodes are connected together through commutating condenser 98. Cathode 97 is also connected through resistance 99 to one end of resistance 100, which end is also connected to the cathodes of push pull amplifier tubes 101 and 102. The other end of resistance 100 is grounded and is connected to the center of the secondary of transformer 103 which is fed by input connection 35 (see also Fig. 2). The opposite ends of this transformer secondary are connected to the grids of tubes 101 and 102.

The anodes of tubes 101, 102, are connected to

output coil 104 across which is connected resistance 105. The center of this resistance has an adjustable connection 106 extending from cathode 96 of the gas triode 85. Cathode 96 is connected through resistance 107 to resistance 108 and also to the cathodes of push pull amplifier tubes 109 and 110. The opposite end of resistance 108 is connected to ground and to the center of the secondary of transformer 111 which is fed by the input lines 32. The opposite ends of the secondary of transformer 111 are connected to the grids of tubes 109 and 110. The anodes of these tubes are connected to the primary of transformer 112 across which is tapped resistance 113. An adjustable connection 114 is made between the central portion of this resistance and cathode 97.

The secondary of transformer 104 is connected between ground and the grid of amplifier tube 115. The secondary of transformer 112 is connected between ground and the grid of amplifier tube 116. The anodes of tubes 115, 116, are connected in parallel to output transformer 117 which is connected to positive terminal 95. The cathode of tubes 115, 116, are likewise connected in parallel through grid bias resistor 117' to ground. Across this resistor may be placed a filter condenser 118. The secondary of transformer 117 is connected to lines 36 which feed the limiter 37 of Fig. 2.

In the frequency detector 38 of Fig. 2 shown in detail in Fig. 7, the input lines 37' introduce the signal into a low pass filter through transformer 118. The low pass filter consists of series inductances 119, 120, and shunt capacities 121, 122 and 123, arranged in the usual way. These inductances and capacities are of such number and value that the characteristic curve A shown in Fig. 6 will have a substantially straight portion *a*, *b*, between the frequencies f_1 and f_2 . The frequencies f_1 and f_2 may have various values but in practice we have found it satisfactory to use a sub-carrier frequency varying between 800 and 1000 cycles per second which when doubled by the frequency doubler would have a value of 1600 to 2000 cycles per second. The lower frequency f_1 would therefore have a value of substantially 1600 cycles per second and the higher frequency f_2 a value of substantially 2000 cycles per second. As an alternative form the filter may have series condensers and shunt inductances, if desired, and then the characteristic will be like curb B in Fig. 6.

The operation will now be described. The tone output of scanner 1 is rectified by double rectifier 4 and varies the plate-cathode impedance of tube 5 and thus varies the tuning effect of condenser 9 in oscillator 7. Oscillator 6 is set to oscillate at some suitable frequency, for example, 75 kilocycles and oscillator 7 will oscillate under control of the scanner at a frequency that varies above or below the frequency of oscillator 6 a sufficient amount to produce a beat, the latter varying from about 800 to 1000 cycles. This beat or sub-carrier frequency is produced in the output of tube 12 by connecting the output of oscillator 6 and 7 to control grids 11 and 14 respectively. Low pass filter 15 permits the varying sub-carrier frequency to pass and the higher frequencies are filtered out.

The sub-carrier frequency is amplified at 20 and the modulator 21' modulates the radio frequency carrier 21. The modulated carrier is then radiated by transmitter 22 through antenna 23.

The antenna thus radiates a radio carrier frequency modulated by the variable sub-carrier frequency, the variations being produced by the scanning apparatus.

The sub-carrier frequency-modulated radio frequency carrier will be received by antenna 24 and receiving apparatus 25 of Fig. 2. It will be amplified, detected and amplified at audio frequency in the usual way and the output will consist of the varying frequencies of the sub-carrier. These frequencies may not, and in most cases will not, be of constant amplitude because of the fading effects previously referred to. When the selective fading is such as to cause the fading of the radio frequency carrier the two side bands of the sub-carrier beat together and form even harmonics, chiefly the second harmonic frequency.

It will be noted from Fig. 2 that the audio output of the radio receiver 25 is fed to the recording apparatus through two paths, one F for the varying fundamental of the sub-carrier, and another H, for its correspondingly varying harmonic. If the fundamental of the sub-carrier has not been materially affected by fading of the radio frequency carrier the main signal energy will pass through band pass filter 28 which has been designed to have sufficient breadth to pass the sub-carrier fundamental and its variations produced by the scanning apparatus. The fundamental then passes through the limiter 29 which is so designed as to provide an output of substantially constant amplitude for wide variation in input amplitude. The output of the limiter is fed through low pass filter 30 to eliminate harmonics caused by the action of limiter 29. The fundamental frequency is then doubled by doubler 31 so that it is the same as the frequencies in the other path. The limiter 29 is inserted so as to give a constant input to the frequency doubler 31. If it were not for this, the limiter 37, to be later described, would suffice.

The limiter 29 need not be of a particular type, but the limiter shown in Fig. 3 is preferred. As the signals pass into limiter 29 through input conductors 124 the signals are amplified by the single stage 46 (Fig. 3) and pass into the input of the push-push stage 48. The purpose of resistors 48' is to aid in the limiting of the modulations. The output of the stage 48 is then rectified and the rectified signal fed through the push-pull limiter tubes 58, 59. When the signal is introduced into the input of rectifiers 49 with slider 54 moved to the ground terminal of resistance 55 and with terminal 125 positive, current will pass from the anode of tube 58 to the cathode, through adjustable contact 54 to ground and from ground to the lower part of resistance 60 to the anode of tube 51 and thence to the cathode and end 127 of the resistance 126.

When terminal 127 is positive current will pass from the anode to the cathode of tube 52 and thence through contact 54 to ground and through the upper part of resistance 60 and from the anode to the cathode of tube 53 to opposite end 125. In Fig. 8, 128 represents the drop in the lower half of resistance 60 and 129 the drop in the upper half. That is, an oscillograph placed across the whole of resistance 60 would produce the graph 128, 129. By sliding the contact 54 towards the positive side of resistance 55, a counter E. M. F. is introduced and the part of the wave extending from the zero axis to the lines *c*, *d*, will be eliminated. The portion beyond these lines will be all that is passed. The form

of the wave with this adjustment of slider 54 will be as indicated at 130, 131, in Fig. 8. The amount of threshold action can be made any desired value by adjusting the contact 54. The potential applied across the grid and cathode of tube 59 is like either 128 or 130, depending upon the adjustment of slider 54 for regulating counter E. M. F. The shape of the waves appearing in the primary of the output of the push pull stage depends on the adjustment of contact 61 which places a negative bias on the grids.

Assuming for purpose of explanation that an appropriate negative bias has been placed on the grids of tubes 58 and 59 from resistance 62, the steady electron flow in tube 59 may be of the value indicated by line B, B', and that of tube 58 by line B', B', one being reversed in reference to the other because of the push pull connection of the plate coils. With slider 55 on the ground end of resistance 55, the current flow through the plate circuit of tube 59 in one complete cycle of the signal will be indicated by graph 133 of Fig. 8. The first half of the cycle is the reduced electron flow produced by the half wave 128 applied as a negative voltage to the grid of that tube and the last half of the cycle is the electron flow with no signal voltage applied to the grid.

During the same complete cycle the current flow in the plate circuit of tube 58 is indicated by graph 134, the sign being reversed because of the opposing relation in the push pull plate connection. In both of the graphs 133 and 134 the signal drives the grids to negative cut-off, the parts of the wave cut off being indicated by the dotted lines. It will be apparent that the current, or voltage, in the output circuit 132 will be as indicated by graph 135 or 136, depending upon the adjusting of slider 54 on resistance 55. The output of the limiter 29 passes through the low pass filter 30 (Fig. 2) to eliminate any harmonics existing therein and thence to the doubler 31.

The frequency doubler 31 produces in output lines 32, a signal of the same frequency as the second harmonic appearing in lines 35 of the other channel, this harmonic being produced by the beating together of the radio frequency side bands when the radio frequency carrier selectively fades. The second harmonic when thus formed passes through the band pass filter 34 which excludes the fundamental.

The signal in the two channels thus are passed to the electron switch 33. In order to switch either the signal of input 35 or that of input 32 to the recorder or other utilization device, it is desirable to use a switching device of the electron type such as illustrated in Fig. 5. In this figure the second harmonic, when formed by selective fading of the sub-carrier enters at 35 and the second harmonic formed from the fundamental by the frequency doubler enters at 32. In order to control the operation of the electron switch, a control voltage is introduced at 33', shown at the left of Fig. 5 and indicated generally in Fig. 2. This voltage is amplified by the vacuum tube 76. The output of this amplifier is rectified by double rectifier 78 and the output of the rectifier is passed through resistance 80, an intermediate part of which is grounded. As shown by the drawing, this places a positive voltage on the grid 88 and a negative voltage on grid 84 of the thyatron tubes 90 and 85, respectively. Grid bias 86 places a sufficient negative bias on tube 90, in absence of signal voltage, to block this tube, but when the positive signal voltage is placed on the grid of tube 90 this tube will strike and cur-

rent will flow from plate 92 through resistances 99 and 100 to ground. When no signal voltage exists in resistance 80 thyatron tube 85 conducts current but when thyatron tube 92 strikes it raises the potential at the terminals of the condenser 98 by the amount of the drop therein. The potential of cathode 96 is therefore momentarily raised above the potential of the anode 91. The current through tube 85 is thus interrupted. The time constant of the condenser is such that it cannot discharge fast enough to lower the cathode to its operating voltage before deionization occurs in tube 85 and its grid 84 resumes control. Since the grid 84 is now made negative by the signal drop in resistance 80 tube 85 cannot restrike at this time when the positive ions diffuse.

Condenser 98 thereafter discharges through resistances 107 and 108 to ground and thence through the power supply and thyatron tube 96. The condenser then charges in the opposite direction.

When tube 92 struck and tube 85 was extinguished plate voltage was removed from amplifier tubes 101, 102, and was applied to amplifier tubes 109, 110. Blocking bias was simultaneously removed from tubes 109, 100, 101, 102. Therefore the doubled fundamental at 32 is amplified by tubes 109, 100 and tube 116 and is passed onto the limiter 37, which is the same as limiter 29 already explained. The output of the limiter is passed to the frequency detector 36 and is changed from frequency modulation to amplitude modulation. Various frequency detectors may be used but a satisfactory one is shown in Fig. 7. By referring to graph A of Fig. 6, it will be seen that the highest frequency f_2 has the lowest amplitude V_2 , while the lowest frequency f_1 has the highest amplitude V_1 . Consequently, the current flowing from the frequency detector varies in amplitude oppositely to the varying frequencies of the modulation. If inductances 118 and 120 in the frequency detector are removed and capacities substituted, and inductances substituted for capacities 121, 122 and 123, the curve would be as indicated in graph B. Either type of filters will produce the desired result.

The fundamental circuits to the recorder will remain closed and the harmonic circuit open, as long as the fundamental voltage in control lines 33' is above a predetermined value which may be made anything desired.

When the fundamental drops below the predetermined value the negative bias in resistance 80 is insufficient to prevent thyatron tube 85 from striking and it immediately strikes. This at once stops thyatron tube 90 from passing current by action of the commuting condenser 98, as already explained. Blocking bias is simultaneously applied to tubes 109, 110, and is removed from tubes 101, 102. Plate voltage also is applied to tubes 101, 102, and removed from tubes 109, 110. The harmonic caused by selective fading now passes through amplifier 101, 102 and 116, to the limiter 37 where the amplitude variations produced by fading are removed without affecting the frequency modulation of the signal. The output of the limiter is then passed to the frequency converter where the frequency modulations are converted into amplitude modulations and recorded as previously referred to.

As long as the fundamental remains below a predetermined point the thyatron 85 will cause the harmonic circuit to be closed to the recorder

and the fundamental to be open because thyatron tube 90 cannot restrike due to insufficient positive signal voltage to overcome the negative bias 86. Whenever the fundamental voltage in control lines 33' reaches the predetermined point tube 90 will restrike and commute tube 85. The fundamental will then be switched in circuit and the harmonics switched out.

A limiter and filter could be placed between the harmonic filter 34 and the switch 33, if desired, but we have found that limiter 37 is sufficient. This limiter 37 would also suffice for the fundamental but as previously explained the limiter 29 is preferably used so as to prevent a constant input to the frequency doubler.

In Fig. 9 we have shown a modified form of receiving system. In this figure devices and parts that are similar to those previously described are given the same reference characters. It will be noted that no automatic switch is used in this modification. To compensate for phase shift between the two channels we employ a phase shifting stage 139. By adjusting the resistance in the bridge 140 the input into the vacuum tube stage 139 will have the phase shifted any desired angle in a way that will be apparent. This will take care of difference in phase between the two channels where the phase shift is of a slow character.

In Fig. 10 we have shown a modified form of transmitting system in which the frequency modulated sub-carrier is passed through two channels, in one of which a frequency doubler 139' is used to produce a frequency having the value of the second harmonic of the sub-carrier. The fundamental and the second harmonic are combined at 140' after being filtered and the two frequencies are used to modulate the transmitter as in Fig. 1.

The receiver for this system of transmission is shown in Fig. 11. The receiving, rectifying and amplifying apparatus 25 will be of the usual type. The band pass filter 141 will be designed to pass the harmonic frequency sent out at the transmitter of Fig. 10. The other devices in this Fig. 11 will be similar to those in Fig. 2 having the same reference characters.

When there is no fading the harmonic frequency will be received and recorded in Fig. 11. When the radio frequency carrier selectively fades the transmitted harmonic frequency will be doubled and it will not pass through the filter 141. The fundamental of the sub-carrier will simultaneously be doubled and it will be passed by the filter 141 and will pass to the recorder in a way that will be understood from the previous description of Fig. 2.

The conversion of the frequency modulation into amplitude modulations can obviously be accomplished by means other than low or high pass filters as other devices are known in the art.

The foregoing description has been given as an example of the devices that will produce desired results but the invention is not limited thereto. Appropriate low and high pass or band pass filters may be connected in various parts of the circuits to exclude undesired frequencies. These are well known in the art and to illustrate them or other well known devices in every conceivable place in the circuit would unduly complicate the disclosure. While it is preferable to use band pass filters in the places indicated, it is permissible to use low and high pass filters instead.

A simple double rectifier may be substituted for the bridge rectifier shown in the limiter of

Fig. 3 but the latter is preferable because it utilizes the entire input transformer for each half of the wave and the input impedance of the rectifiers is therefore identical. Various other modifications may be made without departing from the spirit of our invention.

Having described our invention, what we claim is:

1. In reception of a radio carrier wave containing a modulating frequency, a receiver for said radio carrier wave, a frequency doubler, a filter for passing the fundamental of the modulation frequency to said frequency doubler, a second filter for passing a harmonic of the modulation frequency formed by fading of the radio carrier wave, a gas tube having a cathode, an anode and a control electrode, a second gas tube having a cathode, an anode and a control electrode, means for firing one gas tube and for extinguishing the other when the fundamental frequency rises to a predetermined value, a signal indicator and means for forming a closed circuit between the frequency doubler and the indicator, and an open circuit between the second filter and the indicator when the one gas tube is fired and the other is extinguished.

2. In reception of a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, a frequency doubler, a filter for passing the fundamental of the modulation frequency to said frequency doubler, a second filter for passing a harmonic of the modulation frequency formed by fading of the radio carrier wave, a gas tube having a cathode, an anode and a control electrode, a second gas tube having a cathode, an anode and a control electrode, means for firing the one gas tube and for extinguishing the other when the fundamental frequency falls to a predetermined value, a signal indicator and means for forming a closed circuit between the second filter and the indicator, and an open circuit between the frequency doubler and the indicator when the one gas tube is fired and the other is extinguished.

3. In reception of a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, a filter for passing the fundamental of the modulation frequency, a frequency doubler connected to said filter, a second filter for passing the fundamental modulation frequency formed by fading of the radio carrier wave, an amplifier tube connected to the frequency doubler having a cathode, an anode and a control electrode, a second amplifier tube connected to the second filter having a cathode, an anode and a control electrode, a gas tube having a cathode, an anode and a control electrode, a second gas tube having a cathode, an anode and a control electrode, a source of voltage normally biasing the control electrode below firing value in the second gas tube, means for applying anode voltage to the first amplifier tube when anode current flows in the second gas tube, means for applying anode voltage to the second amplifier tube when anode current flows in the first gas tube, and means for raising the control electrode voltage above firing value in the second gas tube when the fundamental frequency passing the first filter rises above a predetermined value.

4. In reception of a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, a filter for passing the fundamental of the modulation frequency, a frequency doubler connected to said filter, a second filter for passing the fundamental modulation frequency

7. In reception of a radio carrier wave containing a modulated frequency, a receiver for said radio carrier wave, a filter for passing the fundamental of the modulation frequency, a frequency doubler connected to said filter, a second filter

9. In reception of a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, a filter for passing the fundamental of the modulation frequency, a frequency doubler connected to said filter, a second filter for passing the fundamental modulation frequency formed by fading of the radio carrier wave, an amplifier tube connected to the frequency doubler having a cathode, an anode and a control electrode, a second amplifier tube connected to the second filter having a cathode, an anode and a control electrode, a gas tube having a cathode, an anode and a control electrode, a second gas tube having a cathode, an anode and a control electrode, a source of voltage normally biasing the control electrode below firing value in the second gas tube, means for applying anode voltage to the first amplifier tube when anode current flows in the second gas tube, means for applying anode voltage in the second amplifier tube when anode current flows in the first gas tube, means for raising the control electrode voltage above firing value in the second gas tube when the fundamental frequency passing the

an anode and a control electrode, a gas tube having a cathode, an anode and a control electrode, a second gas tube having a cathode, an anode and a control electrode, a source of voltage normally biasing the control electrode below firing value in the second gas tube, means for blocking the control electrode of the first amplifier tube when anode current flows in the first gas tube, means for blocking the control electrode of the second amplifier tube when anode current flows in the second gas tube, means for raising the control electrode voltage above firing value in the first gas tube when the fundamental frequency passing the first filter falls below a predetermined value, and a commutating condenser connected from a point in the anode circuit of one gas tube to a point in the anode circuit of the other gas tube for extinguishing one tube when the other one fires.

13. In reception of a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, a filter for passing the fundamental of the modulation frequency, a frequency doubler connected to said filter, a second filter for passing the fundamental modulation frequency formed by fading of the radio carrier wave, an amplifier tube connected to the frequency doubler having a cathode, an anode and a control electrode, a second amplifier tube connected to the second filter having a cathode, an anode and a control electrode, a gas tube having a cathode, an anode and a control electrode, a second gas tube having a cathode, an anode and a control electrode, a source of voltage normally biasing the control electrode below firing value in the second gas tube, means for applying anode voltage to the first amplifier tube and for blocking the control electrode of the second amplifier tube when anode current flows in the second gas tube, means for applying anode voltage to the second amplifier tube and for blocking the control electrode of the first amplifier tube when anode current flows in the first gas tube, means for raising the control electrode voltage above firing value in the second gas tube when the fundamental frequency passing the first filter rises above a predetermined value, and a commutating condenser connected from a point in the anode circuit of one gas tube to a point in the anode circuit of the other gas tube for extinguishing one tube when the other one fires.

14. In reception of a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, a filter for passing the fundamental of the modulation frequency, a frequency doubler connected to said filter, a second filter for passing the fundamental modulation frequency formed by fading of the radio carrier wave, an amplifier tube connected to the frequency doubler having a cathode, an anode and a control electrode, a second amplifier tube connected to the second filter having a cathode, an anode and a control electrode, a gas tube having a cathode, an anode and a control electrode, a second gas tube having a cathode, an anode and a control electrode, a source of voltage normally biasing the control electrode below firing value in the second gas tube, means for applying anode voltage to the first amplifier tube and for blocking the control electrode of the second amplifier tube when anode current flows in the second gas tube, means for applying anode voltage to the second amplifier tube and for blocking the control electrode of the first amplifier tube when

12. In reception of a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, a filter for passing the fundamental of the modulation frequency, a frequency doubler connected to said filter, a second filter for passing the fundamental modulation frequency formed by fading of the radio carrier wave, an amplifier tube connected to the frequency doubler having a cathode, an anode and a control electrode, a second amplifier tube connected to the second filter having a cathode,

anode current flows in the first gas tube, means for raising the control electrode voltage above firing value in the first gas tube when the fundamental frequency passing the first filter falls below a predetermined value, and a commutating condenser connected from a point in the anode circuit of one gas tube to a point in the anode circuit of the other gas tube for extinguishing one tube when the other one fires.

15. In a signal system employing a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, means for separating the fundamental component of the modulation frequency from a harmonic component thereof, a signal indicator, and means for effectively switching the indicator from one component to the other responsive to a change in the amplitude of one of said components to a predetermined value due to reduction of selective fading of the received carrier wave.

16. In a signal system employing a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, means for separating the fundamental component of the modulation frequency from a harmonic component thereof, a signal indicator, and means for effectively switching the indicator from said fundamental frequency to the harmonic frequency responsive to a reduction in the amplitude of the fundamental frequency to a predetermined value due to selective fading of the received carrier wave and for switching the indicator from the harmonic frequency to the fundamental frequency responsive to an increase in amplitude of the fundamental frequency to a predetermined value due to reduction in said selective fading.

17. In a signal system employing a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, means for separating the fundamental of the modulation frequency from a harmonic thereof, means for increasing said fundamental frequency to equal said harmonic frequency, a signal indicator, and means for effectively switching the indicator from said increased frequency to said harmonic frequency responsive to a reduction in the amplitude of the fundamental frequency to a predetermined value due to selective fading of the received carrier wave.

18. In a signal system employing a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, means for separating the fundamental of the modulation frequency from a harmonic thereof, means for increasing said fundamental frequency to equal said harmonic frequency, a signal indicator, and means for effectively switching the indicator

from said harmonic frequency to said increased frequency responsive to an increase in amplitude of the fundamental frequency to a predetermined value due to the decrease in selective fading of the received carrier wave.

19. In a signal system employing a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, means for separating the fundamental of the modulation frequency from a harmonic thereof, means for increasing said fundamental frequency to equal said harmonic frequency, a limiter, a signal indicator connected to said limiter, and means for effectively switching the limiter from said increased frequency to said harmonic frequency responsive to a reduction in the amplitude of the fundamental frequency to a predetermined value due to selective fading of the received carrier wave.

20. In a signal system employing a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, means for separating the fundamental of the modulation frequency from a harmonic thereof, means for increasing said fundamental frequency to equal said harmonic frequency, a signal indicator, and means for effectively switching the indicator from said increased frequency to the harmonic frequency responsive to a reduction in the amplitude of the fundamental frequency to a predetermined value due to selective fading of the received carrier wave and for switching the indicator from the harmonic frequency to the increased frequency responsive to an increase in amplitude of the fundamental frequency to a predetermined value due to the decrease in selective fading of the received carrier wave.

21. In a signal system employing a radio carrier wave containing a modulation frequency, a receiver for said radio carrier wave, means for separating the fundamental of the modulation frequency from a harmonic thereof, means for increasing said fundamental frequency to equal said harmonic frequency, a limiter, a signal indicator connected to said limiter, and means for effectively switching the limiter from said increased frequency to the harmonic frequency responsive to a reduction in the amplitude of the fundamental frequency to a predetermined value due to selective fading of the received carrier wave and for switching the limiter from the harmonic frequency to the increased frequency responsive to an increase in amplitude of the fundamental frequency to a predetermined value due to the decrease in selective fading of the received carrier wave.

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