

Jan. 13, 1942.

R. E. MATHES

2,269,594

MODULATION OF WIRE AND RADIO TRANSMISSION BY FREQUENCY VARIATION

Filed March 18, 1939

4 Sheets-Sheet 1

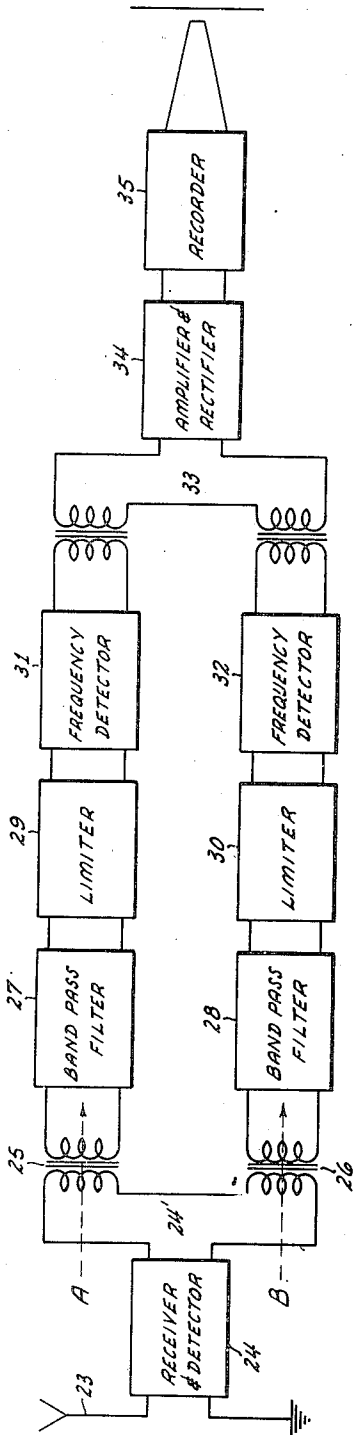


Fig. 2

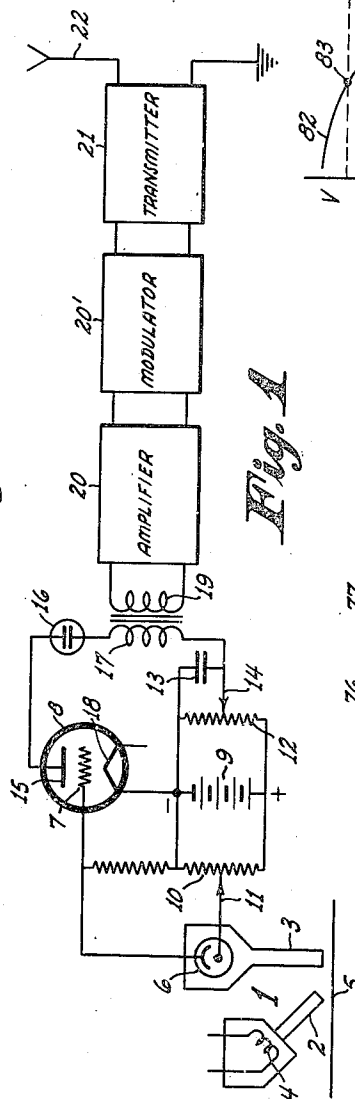


Fig. 1

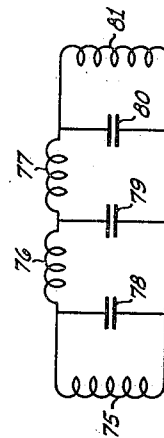


Fig. 6

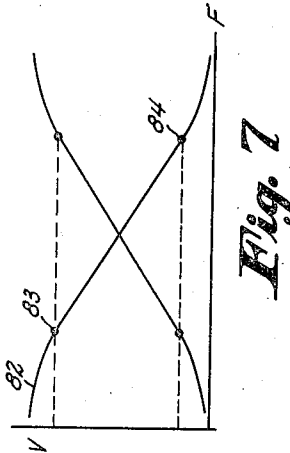


Fig. 7

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4 Sheets-Sheet 2

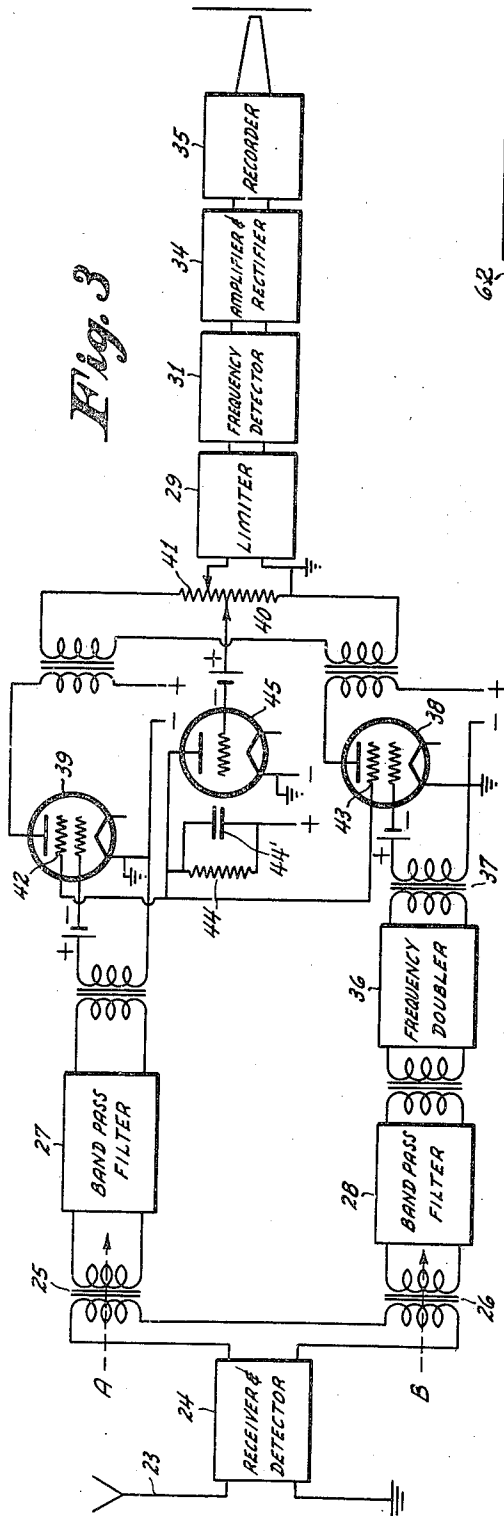


Fig. 3

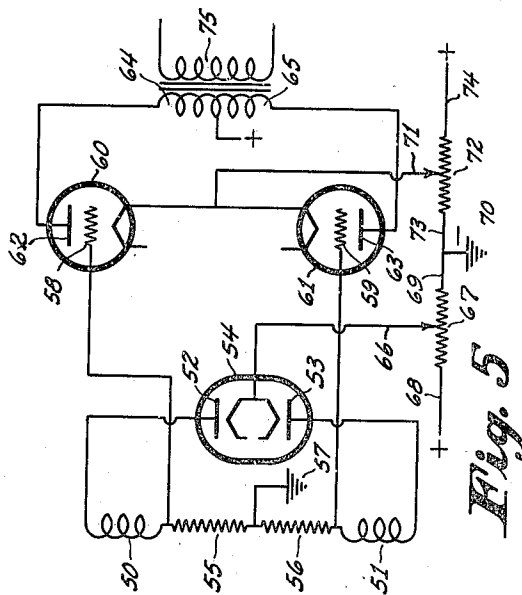


Fig. 5

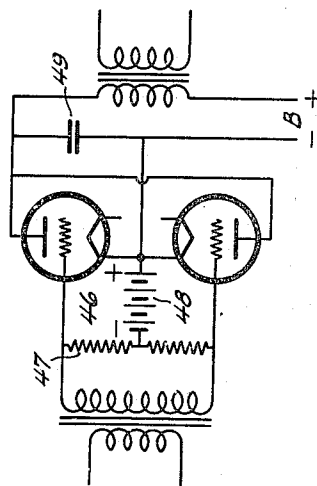


Fig. 4

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4 Sheets-Sheet 3

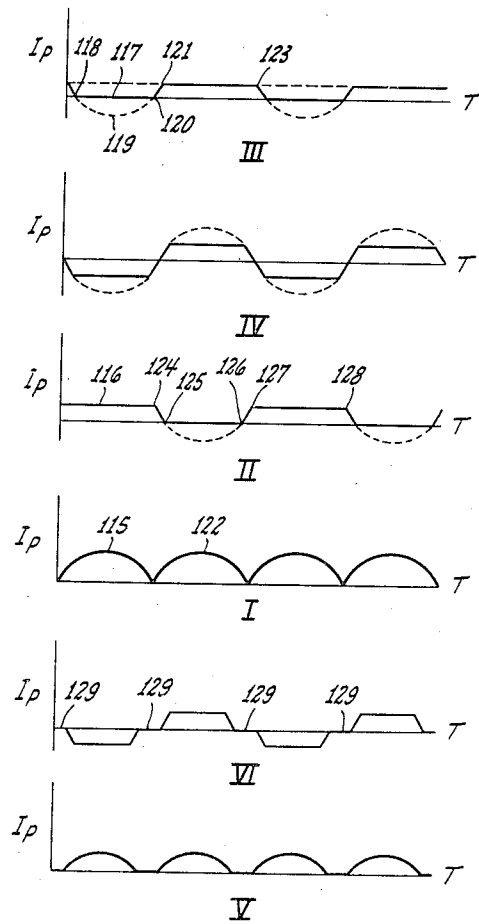


Fig. 8

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4 Sheets-Sheet 4

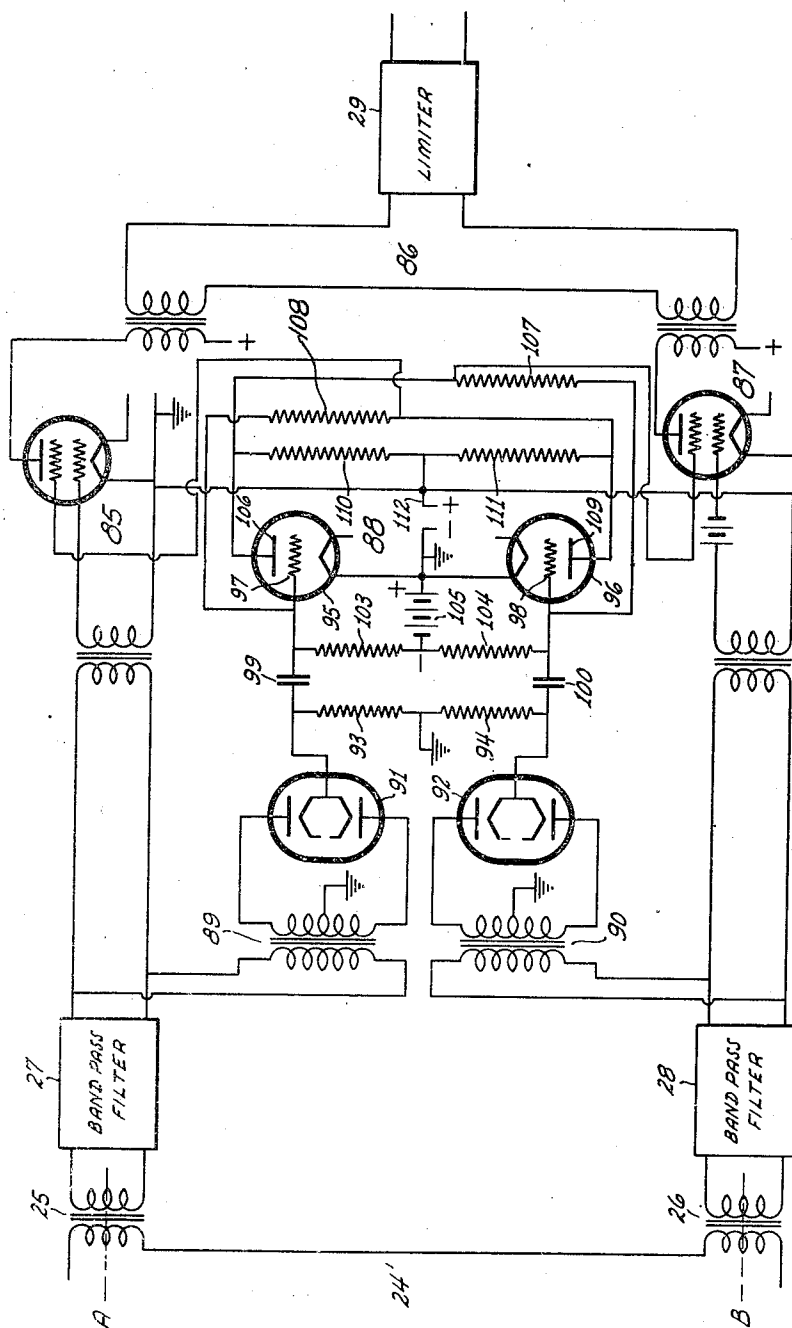


Fig. 9

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UNITED STATES PATENT OFFICE

2,269,594

MODULATION OF WIRE AND RADIO TRANSMISSION BY FREQUENCY VARIATION

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Application March 18, 1939, Serial No. 262,664

30 Claims. (Cl. 250—6)

This invention relates to frequency modulation of wire and radio transmission and more particularly to photo-radio transmission.

As is now well known, changes in the condition and height of the ionosphere produce fading effects in radio transmission. This is a difficulty in all forms of radio transmission but it is particularly objectionable in photo radio transmission. To overcome the effects of fading it has been proposed to modulate the carrier wave by changing the frequency rather than the amplitude of the wave. Since fading produces amplitude variations of the signal frequency modulation, this enables one to discriminate between the signal modulation and fading modulation. By using frequency modulation at the transmitter and a voltage or current limiter 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 to Wright and Smith, No. 1,964,375, June 26, 1934.

In producing frequency variation it has been found advantageous to vary the frequency of a sub-carrier in photo radio uses and then modulate the radio frequency carrier by this frequency modulated sub-carrier. While this will produce a marked improvement over the transmission of pictures by amplitude modulation, there are still times when the modulation completely disappears. This seems to be due to selective fading of the radio frequency carrier and causes equivalent over-modulation by the side bands when the carrier fades. This produces a spurious component in the detected output consisting of harmonics of the side band frequencies. The main component is the second harmonic of the sub-carrier frequency but other harmonics may be produced though to a less extent.

It is one object of my invention to overcome the effects of selective fading by providing arrangements for selectively receiving the sub-carrier and its second harmonic.

Another object of the invention is to provide an automatic switch for selecting either the sub-carrier or its second harmonic, depending upon selective fading conditions.

Another object is to selectively receive the sub-carrier and its second harmonic and then double the frequency of the sub-carrier so that either one or both can be effectively handled by identical devices such as filters and frequency detectors.

Other objects will appear in the following de-

scription, reference being had to the drawings, in which:

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

Fig. 2 is a part diagrammatic and part block illustration of one form of the receiving system.

Fig. 3 is an illustration of another form of receiving system.

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

Fig. 5 is a diagrammatic illustration of the voltage limiter.

Fig. 6 is a diagrammatic illustration of the frequency detector or converter.

Fig. 7 illustrates the voltage-frequency curves of the frequency detector.

Fig. 8 is a series of graphs.

Fig. 9 is a diagrammatic illustration of another form of automatic switch for selecting the stronger of the two components of the signal.

Referring to Fig. 1, the scanning apparatus 1 consists of an illuminating unit 2 and a photo electric cell unit 3. In the illuminating unit any form of lamp 4 may be used for projecting light onto the object 5, the picture of which is to be transmitted. The light reflected from the object 5 passes into the photo cell unit 3 having photo cell 6 with the cathode connected to the grid 7 of vacuum tube 8. The anode of the photo cell is connected to a source of potential such as battery 9 having potentiometer resistance 10. Adjustable contact 11 permits one to adjust the potential that is applied to the anode of the photo cell. The battery 9 has another potentiometer 12 connected around it and a condenser 13 connected across a selected portion of it. The potential applied to the condenser may be adjusted by movable contact 14.

The anode 15 of vacuum tube 8 is connected to neon tube 16, primary 17 and the adjustable contact 14. The filament 18 of the vacuum tube 8 is connected to the negative side of the battery 9. The output of the vacuum tube 8 is fed into secondary 19 which is connected to a suitable amplifier 20 and modulator 20' which may be of any sort, for example, such as is used in amplitude modulation. The modulator is connected to transmitter apparatus 21 for radiating the modulated signal by antenna 22.

In Fig. 2 the receiving antenna 23 is connected to appropriate receiving apparatus 24 which may consist of the usual radio frequency amplifier, detector and audio frequency amplifier. The output 24' of the receiver extends through two paths, one, path A, being through

transformer 25 and the other, path B, through transformer 26. Band pass filter 27 passes the second harmonic of the sub-carrier but blocks the fundamental while band pass filter 28 passes the fundamental and blocks the harmonic and also any low frequency noise. The fundamental frequency, and therefore its harmonic, when formed by atmospheric conditions, is varied by the scanner and the filters are designed to pass the resulting bands while excluding higher and lower frequencies. The signal in each of the two paths after passing the filters extends through limiters 29, 30, and frequency detectors 31, 32. The detail construction of each limiter and frequency detector is shown in Figs. 5 and 6, and will be referred to later herein. The voltages in the two paths are combined in circuit 33 connected to an appropriate amplifier and rectifier indicated generally at 34, and thence to the recorder 35 for recording the picture, though, of course, rectification may equally well be had before combining the outputs of the two paths. The detail construction of the receiving apparatus 24, the fundamental and the harmonic band-pass filters 27 and 28, the amplifier-rectifier 34 and recorder 35 are old and well known in the art and need not be described in detail.

In Fig. 3 much of the apparatus is the same as in Fig. 2 and similar devices have been given the same reference characters. In this figure the fundamental after being selected by band pass filter 28 has its frequency doubled by doubler 36 shown in detail in Fig. 4. The output 37 of this doubler is connected to amplifier 38. The output of filter 27 is connected to amplifier 39. The outputs of these amplifiers are connected to mixing circuit 40 having load resistance 41. The output of limiter 29 is connected as in Fig. 2. In this modification, provision is made for favoring a relatively strong signal in one path over a weak signal in the other by control of the amplifier tubes 38, 39. The screen grids 42, 43, of these tubes are connected to the negative end of resistance 44 in the plate circuit of control tube 45, the control grid of which is adjustably connected to resistance 41.

In Fig. 5 an improved form of limiter is shown. In prior art constructions it is usual to rely on blocking of a tube by a negative grid bias for the negative half wave and electron saturation, or grid energy consumption for the positive half wave. The negative and positive parts of the wave passed through the prior art limiters are dissimilar and give rise to harmonics which in many cases are objectionable. I overcome this by the limiter in Fig. 5. In this figure the input may consist of two coils 50, 51, connected to the anodes 52 and 53 of the double rectifier 54 which, of course, can be two separate rectifiers. The two coils 50, 51, are connected together by resistances 55 and 56. The conductor joining these two resistances is grounded at 57. The ungrounded ends of resistances 55, 56, are connected to grids 58, 59, of vacuum tubes 60, 61, respectively. The anodes 62 and 63 of these tubes are connected in push pull fashion by transformer primaries 64, 65. The cathodes of the double rectifier 54 are connected by adjustable contact 66 to resistance 67, one terminal 68 of which is connected to a positive potential and the other terminal 69 of which is grounded at 70. The cathodes of vacuum tubes 60, 61, are connected by adjustable contact 71 with resistance 72, one terminal 73 being connected to

ground, and the other terminal 74 being connected to a positive source of potential.

The output of transformer primaries 64, 65, passes into the input of frequency detector 31, or 32, which is shown in detail in Fig. 6. This detector may have one or more inductances 76, 77, and condensers 78, 79 and 80. This frequency detector is virtually a low pass filter passing current values into its output coil 81 in accordance with curves such as shown at 82 in Fig. 7. The substantially straight portion of the curve between points 83 and 84 covers the band of the modulation frequencies which may be, for example, from 1600 to 2000 cycles when the frequency doubler is used. When the doubler is not used as in Fig. 2, filter 28 would be designed to pass 800 to 1000 cycles and filter 27, 1600 to 2000. By substituting capacity for the inductances 76 and 77 and inductances for the capacities 78, 79 and 80, a similar frequency conversion will be accomplished but the action will be reversed, that is, the high frequencies passed will have the lowest intensity and the lowest frequency, the highest. With the circuit otherwise unchanged one form of filter would produce a positive and the other a negative at the recorder.

In Fig. 4 the frequency doubler 46 is shown. This is essentially two vacuum type tubes with their inputs connected in push-pull and their anodes connected in parallel. Across the grids of this frequency doubler is connected a resistance 47 and to the mid portion of this resistance is connected the negative terminal of biasing battery 48, the positive terminal being connected to the filaments. The value of this negative grid bias is such that the tubes are blocked for the negative cycle and for a considerable part of the positive cycle, giving a pulsating form of output which produces harmonics of the frequency introduced into the grid circuit. The arrangement shown is particularly efficient in producing the second harmonic, but of course other doublers may be used. The output circuit of this doubler may be tuned to the double frequency by an appropriate condenser 49.

In Fig. 9 I have shown another form of automatic selection of the preferred signal of the two paths. In this figure the output of the band pass filter 27 is shown connected to the input of amplifier 85 shown by way of example as a screen grid stage but of course other forms may be used. The output of this amplifier is connected to a circuit 86 feeding into limiter 29. The output of band pass filter 28 is connected to the input of a similar amplifier 87, the output of which is connected to the circuit 86. The differential switch generally designated by 88 passes the signal of either one path or of the other to the limiter 29 and thence to the recorder, as shown in Fig. 3. This differential switch is connected to band pass filter 27 by transformer 89 and to band pass filter 27 by transformer 90. Transformers 89, 90, are connected to rectifiers 91, 92, having load resistances 93, 94, connected through ground to the center of the respective transformers. Two vacuum tubes 95, 96, have their grids 97, 98, connected respectively to load resistances 93 and 94 through coupling condensers 99, 100.

Grids 97, 98, are connected together by resistances 103, 104. Negative bias 105 is connected between these two resistances and the cathodes of tubes 95 and 96. The grid 98 of one tube is connected to the plate 106 of the other tube

through a suitable resistance 107. The grid 97 is connected through resistance 108 to the plate 109. The plates 106, 109, are connected respectively through resistances 110, 111, to the positive terminal 112. Resistances 110, 111, are connected respectively to the screen grids of the amplifiers 87, 88, and their respective cathodes.

The operation will now be described.

At the transmitter of Fig. 1 the scanning device 1 will scan the object 5, a picture of which is to be transmitted, and the varying light from the object focussed on the cathode of the photo electric cell 6 varies the potential between the grid 7 and the cathode 18. The battery 9 charges the condenser 13 and the charging voltage applied to this condenser is placed across the neon tube 16 through transformer 17 and the internal plate cathode circuit of the tube 8. After a certain time, depending upon the value of the resistance in the charging circuit, which of course is very short, the condenser will be sufficiently charged to cause the neon tube 16 to strike. This discharges the condenser and it commences to charge again. If the internal impedance of the plate circuit of tube 8 were constant the condenser 13 and its associate circuit would produce oscillations of constant frequency and these would pass into the amplifier through transformer secondary 19. The modulation will produce a band of frequencies, for example, between 800 and 1000 cycles.

As the scanner 1 proceeds over the object 5 the varying voltages between the grid and cathode of tube 8 will correspondingly vary the internal plate-cathode impedance of the tube and this will retard or enhance the discharge of condenser 13 and thus decrease or increase the frequency of the oscillations. It will thus be seen that the sub-carrier frequency is increased or decreased in proportion to the light values of the object 5. As the circuit is shown connected in Fig. 1, the lightest spots on the object 5 will produce the highest frequency in the condenser-neon tube oscillator and the darkest spots the lowest frequency. With this arrangement the picture being transmitted modulates by changing the frequency instead of by changing the amplitude. This varying sub-carrier frequency is amplified and used to modulate the radio transmitter by any form of modulator such as prior art amplitude modulators either of the constant current type or of the balanced modulator type.

The signals radiated by the antenna 2 are received at the receiving station by antenna 23 and after detection appear in the common circuit 24'. These signals will at certain times be subject to selective fading of the radio frequency carrier and when this happens the absence of part or all of the carrier wave often causes the two side bands of the sub-carrier modulation frequencies to beat together and produce second harmonics of the sub-carrier frequencies. This produces a spurious component, as previously referred to. The selective fading of the radio frequency carrier usually occurs at a quite rapid rate though the frequency of the fading changes may vary widely from time to time. At the moment that no fading occurs the fundamental sub-carrier frequencies will pass through path B because these frequencies cannot pass filter 27 in path A. They will be limited by the limiter 30 and converted into amplitude modulation by the frequency detector 32. The latter modulations then pass through the amplifier and rectifier to the recorder 35 and the picture is recorded in any way de-

sired. At the moment that selective fading occurs, the harmonics caused by beating of the side bands will pass through path A and through a similar limiting device and frequency detector to the recorder.

The limiting device 29 or 30 may be of various designs but I prefer that shown in Fig. 5 because the two halves of the waves are equally acted upon. When the currents of either path A or path B leave the respective filters they enter the limiter through the two coils 50 and 51, say, by transformer action, the secondary of the transformer only being shown. The current in these coils is rectified by the double rectifier 54 and direct current potential is applied to load resistances 55 and 56. The negative ends of this resistance are connected to the grids of the push pull tubes. Let it be supposed that the upper end of coil 50 as shown in the drawings is for the instant made positive by the incoming signal. This means that the lower end of coil 51 is negative. It also means that the lower end of coil 50 is negative in respect to the upper end and that the upper end of coil 51 is positive in respect to the lower end of that coil.

With the assumption made, current will flow from the upper end of coil 50 to plate 52 of the rectifier to the cathode, to ground 70, ground 57 and resistance 55 to the grid 53. It will first be assumed that the adjustable tap 66 is connected to the ground end of resistance 67. This will make grid 53 negative by the amount of the drop in load resistance 55. The shape of the wave passing through rectifier 54 is indicated for the purposes of illustration by 115 of graph I in Fig. 8. No current from the lower coil 51 can pass through the rectifier 54 because the negative end is connected to the anode 53. Therefore no signal potential will be applied to grid 59. For the half wave of the signal under discussion the plate current I_p of 61 will be a steady current, as indicated at 116 of graph II in Fig. 8. During this same half cycle the current I_p through the plate circuit of tube 60 is decreased by the negative potential applied to its grid by resistance 55, and therefore the graph of plate current in this tube is given by 117 of graph III. It will be seen that the current in this graph reaches the cut-off point 118 and no current flows through the tube. The dotted line 119 indicates the wave shape if there had been no cut-off of the current by the negative grid potential.

When the negative potential on the grid 53 decreases sufficiently current starts to flow at point 120 in the plate circuit of tube 60. It reaches its maximum value 121 at which point the other half wave of the signal reverses the polarity in coils 50 and 51. For this half cycle the current through the rectifier 54 will be as shown at 122 which, of course, is the same shape as the other half wave given at 115. No signal potential is applied to the grid of tube 60 at this time because of this reversal of polarity and its curve of plate current will be given by the straight portion between points 121 and 123. At this time a negative signal potential is applied to the grid of tube 61 and from the very beginning of the half cycle indicated at point 124 the negative potential increases and the plate current decreases until the cut-off point 125 is reached (graph II).

No current will flow in the plate circuit of tube 61 until the negative potential on grid 59 de-

creases to the cut-off point indicated by 126. As the negative potential continues to decrease until the half cycle is ended the plate current in this tube will increase till it reaches full value at point 127 and for the next half cycle the plate current through this tube will be given by the straight line between points 127 and 128. In this way the plate current is limited and the modulation due to fading is eliminated.

Since the tubes 60 and 61 are arranged in push pull fashion it is obvious that graphs II and III will have a combined output indicated by graph IV of Fig. 8. This curve also indicates in general the induced electromotive force in output coil 75.

If we assume that the resistance tap 66 is adjusted to place a positive voltage on the cathodes of rectifier 54, no current can flow through the rectifiers until the signal voltage reaches a threshold value in excess of this countervoltage. The shape of the rectified current in this case would be indicated generally by graph V of Fig. 8, where at the beginning and ending of each half wave no current flow is indicated. This will be the shape of the negative potential applied alternately to tubes 60 and 61 instead of the shape given in graph I. It will be seen that the shape of the current flow, or induced E. M. F., as the case may be, will be like the graph VI which is similar to graph IV except that there are appreciable lengths of time when current does not flow in the output circuit as indicated at 129. The cut-off value in the rectifier 54 and the push pull limiter tubes 60, 61, can be varied singly or jointly within any desired limits by adjustment of the resistance taps 66 and 71, respectively.

In the modification of Fig. 3 the action will be the same as in Fig. 2, except that tube 45 in effect blocks out the weaker signal while the stronger signal passes to the limiter. The tube 45 rectifies a portion of the signal output in circuit 40 and applies this to the screen grids 42 and 43. The resistance 44 and capacity 44' smooths out this rectified portion. If the harmonic frequency is stronger than the fundamental, the lowered voltage applied to the screen grid 43 will not block out the harmonic signal because of its strength, but it will substantially block out the weak fundamental as it is below cut-off or on a less favorable part of the characteristic curve. The action is the reverse when the fundamental is stronger than the harmonic. This use of the signal as a common volume control of two or more circuits is akin to that used in the well-known diversity telephone receiver and the operation will be understood without further amplification.

In Fig. 9 I have shown another form of differential switch which may be substituted for the differential switch of Fig. 3, or it may be incorporated in Fig. 2. With the latter substitution, filters 27 and 28 will have a portion of their outputs rectified by rectifiers 91 and 92. The rectified voltages will be applied to grids 97 and 98 of a locking circuit described in the patent to J. L. Finch, No. 1,844,950, February 16, 1932. Condensers 99 and 100 in the grid circuits receive charges from the rectified potentials and the grids 97 and 98 are made positive to the extent of the drop in the resistances 103, 104, respectively, by current charging these condensers.

The grid of one tube in this locking circuit is connected to the plate of the other tube so that they are in a very unstable condition and it is impossible for both tubes to pass current at the

same time because as soon as one tube starts to conduct, the plate current of that tube immediately places such a strong negative potential on the grid of the other tube through either resistance 107 or 108 as to block that tube.

Let it be supposed that there is substantially no selective fading of the radio frequency carrier, and the signal will consist substantially entirely of the fundamental sub-carrier frequencies entering through path B. There will then be substantially no current in output transformer 88 and there will be full potential in transformer 90. Condenser 100 will charge while condenser 99 will receive substantially no charge at all. The positive charge on grid 98 will unblock tube 96 and permit tube 96 to conduct, if we assume that tube 95 has previously been conducting and tube 96 blocked. It will be noted that absence of voltage drop in resistance 110 in the plate circuit of tube 95 places a strong positive potential on the screen grid of amplifier 88 in path B causing the signal of that path to pass. The plate current flowing in tube 95 produces such a large drop in resistance 110 as to reduce the voltage on the screen grid of amplifier tube 85 to the point where the electron flow practically ceases. The signal in path A therefore does not pass to any appreciable extent.

When the radio frequency carrier selectively fades and the side bands beat together to produce second harmonics of the sub-carrier frequency of considerable magnitude, current through path B will decrease or reach zero, depending upon the extent of the fading while current through path A will correspondingly increase. This will supply a strong negative potential on the grid of tube 95 in the locking circuit and remove it from tube 96. This will instantly cause tube 95 to block and tube 96 to conduct current. Vacuum tube amplifier 85 will now pass the second harmonics of path A. Tube 96 will produce such a heavy drop in resistance 111 that amplifier 87 will not pass signal to the recorder. In this way the stronger signal in the two paths A and B will alone be passed through to the recorder. The action of the locking circuit is practically instantaneous and is faster than the selective fading changes so that instantaneous switching is secured.

While the combining arrangement of Fig. 2 will in general produce satisfactory results some difficulty may be encountered at times because the phase of the currents in path A may differ more or less from the phase of the currents in path B. With the differential switch arrangement in Figs. 3 and 8 the weaker signal is suppressed and the stronger signal passed to the recorder so that differences in phase are of no consequence.

While I have disclosed my invention in connection with facsimile and photo radio uses, it is not limited to these particular fields of use as it also can be used with improved results in radio telephony and telegraphy.

It will be apparent that the stronger signal of the two paths need not be the one passed at all times, since the selection may be made in other ways.

The foregoing description has been given as an example of the devices that will produce the desired result but the invention is not to be limited thereto. Appropriate filters may be connected in various parts of the circuits to exclude undesired frequencies, for example, after the limiters 29 and 30. While it is preferable to use band pass

filters, satisfactory results can be obtained with high and low pass filters.

Selective fading effects can also be minimized in amplitude modulated signals by receiving only the stronger of the two side bands. In such case Fig. 9 can be used to receive the intermediate frequency of the well known super heterodyne (not shown) from input 24'. Filter 27 would then be tuned to one side band and filter 28 to the other. From the description of Fig. 9 it will be obvious that the stronger of the two side bands would alone be received. In this case the limiter would be dispensed with and the usual amplitude detector would be substituted for the frequency detector.

Various other modifications may be made without departing from the spirit of the invention.

Having described my invention, what I claim is:

1. In a signaling system for reducing selective fading effects, an oscillator for producing a sub-carrier, means for varying the frequency of said sub-carrier in accordance with a signal, a high frequency oscillator for producing a radio frequency carrier, means for modulating the radio frequency carrier by the varying sub-carrier, means for receiving the modulated radio frequency carrier wave and its side bands, two separate circuits connected to said receiving means, one adapted to pass the fundamentals of the varying sub-carrier frequency and reject the harmonics thereof and the other adapted to pass the harmonics and reject the fundamentals, a limiter in each circuit, means connected to the limiters for converting the frequency variations into amplitude variations, and means for translating the amplitude variations into signal indications.

2. In a signaling system for reducing selective fading effects, an oscillator for producing a sub-carrier, means for varying the frequency of said sub-carrier in accordance with a signal, a high frequency oscillator for producing a radio frequency carrier, means for modulating the radio frequency carrier by the varying sub-carrier, means for receiving the modulated radio frequency carrier wave and its side bands, two separate circuits connected to said receiving means, one adapted to pass the fundamentals of the varying sub-carrier frequency and reject the second harmonics thereof, and the other adapted to pass the second harmonics and reject the fundamentals, means for limiting the amplitude variations of the components, means connected to the limiting means for converting the frequency variations into amplitude variations, and means for translating the amplitude variations into signal indications.

3. In a signaling system for reducing selective fading effects, means for receiving and extracting a sub-carrier wave the frequency of which is modulated in accordance with a signal, means for passing the fundamentals of the modulation frequencies and rejecting the harmonics thereof, other means for passing said harmonics and rejecting said fundamentals, means for limiting the amplitude variations in the output of each of the last two mentioned means, and separate means connected to each limiting means for converting the frequency variations into amplitude variations, means for rectifying the output of the limiting means and means for translating the rectified output into signal indications.

4. A signaling system comprising means for receiving and extracting a sub-carrier wave the

frequency of which is modulated in accordance with a signal, two circuits connected to said means, one having means for passing the fundamentals of the modulation frequencies and rejecting the harmonics thereof and the other having means for passing the harmonics and rejecting the fundamentals, means for selecting one of said frequency components, and means for converting the frequency variations of the selected component into amplitude variations.

5. A signaling system comprising means for receiving and extracting a sub-carrier wave the frequency of which is modulated in accordance with a signal, two circuits connected to said means, one having means for passing the fundamentals of the modulation frequencies and rejecting the harmonics thereof and the other having means for passing the harmonics and rejecting the fundamentals, means for selecting one of the two frequency components and means for limiting the amplitude variations of the passed component, and means for converting the frequency variations of the selected component into amplitude variations.

6. In a signaling system for reducing selective fading effects, means for receiving and extracting a sub-carrier wave the frequency of which is modulated in accordance with a signal, means for passing the fundamentals of the modulation frequencies, means for passing the second harmonics, means for increasing the frequency of the fundamentals to equal that of the second harmonics, means for selecting one of the two harmonic frequencies, means for limiting the amplitude variations of the selected component, and means connected to the limiting means for converting the frequency variations into amplitude variations.

7. In a signaling system for reducing selective fading effects, means for receiving and extracting a sub-carrier wave the frequency of which is modulated in accordance with the signal, means for passing the fundamentals of the modulation frequencies, means for passing said harmonics, means for selecting one of the two components, means for limiting the amplitude variations of the selected component and means connected to the limiting means for converting the frequency variations into amplitude variations, and means for translating the rectified output into signal indications.

8. In a signaling system for reducing selective fading effects, means for receiving and extracting a sub-carrier wave the frequency of which is modulated in accordance with a signal, means for passing the fundamentals of the modulation frequencies, means for passing the second harmonics, means for doubling the fundamental frequencies, means for selecting one of the two harmonic frequencies, means for limiting the amplitude variations of the selected component and means connected to the limiting means for converting the frequency variations into amplitude variations.

9. In a signaling system for reducing selective fading effects, an oscillator for producing a sub-carrier frequency, means for varying the frequency of said sub-carrier frequency in accordance with a signal, a high frequency oscillator for producing a radio frequency carrier, means for modulating the radio frequency carrier by the varying sub-carrier frequency, means for receiving the modulated radio frequency carrier, two separate circuits connected to said receiving

means, one adapted to pass the fundamentals of the varying sub-carrier frequency and reject the harmonics thereof and the other adapted to pass the harmonics and reject the fundamentals, a limiter in each circuit and means connected to the limiters for converting the frequency variations into signal indications.

10. In a signaling system for reducing selective fading effects, an oscillator for producing a sub-carrier frequency, means for varying the frequency of said sub-carrier frequency in accordance with a signal, a high frequency oscillator for producing a radio frequency carrier, means for modulating the radio frequency carrier by the varying sub-carrier frequency, means for receiving the modulated radio frequency carrier, two separate circuits connected to said receiving means, one adapted to pass the fundamentals of the varying sub-carrier frequency and reject the second harmonics thereof and the other adapted to pass the second harmonics and reject the fundamentals, means for doubling the fundamentals, means for limiting the amplitude variations of both components, and means connected to the limiting means for converting the frequency variations into signal indications.

11. In a signaling system utilizing a radio frequency carrier modulated by a varying sub-carrier frequency, means for receiving the modulated radio frequency carrier, means connected to said receiving means for passing the fundamentals of the varying sub-carrier frequency and rejecting the second harmonics thereof, means connected to the receiving means for passing the second harmonics and rejecting the fundamentals, means for doubling the passed fundamentals, means for limiting the amplitude variations of both components, and means connected to the limiting means for converting the frequency variations of the sub-carrier frequency into signal indications.

12. In a signaling system utilizing a radio frequency carrier modulated by a varying sub-carrier frequency, means for receiving the modulated radio frequency carrier, two separate circuits connected to said receiving means, one adapted to pass the fundamentals of the varying sub-carrier frequency and reject the harmonics thereof and the other adapted to pass the harmonics and reject the fundamentals, a limiter in each circuit, and means connected to the limiters for converting the frequency variations of the sub-carrier frequency into signal indications.

13. In a signaling system utilizing a radio frequency carrier modulated by a varying sub-carrier frequency, means for receiving the modulated radio frequency carrier, two separate circuits connected to said receiving means, one adapted to pass the fundamentals of the varying sub-carrier frequency and reject the second harmonics thereof and the other adapted to pass the second harmonics and reject the fundamentals, means for doubling the fundamentals, means for limiting the amplitude variations of both components, and means connected to the limiting means for converting the frequency variations of the sub-carrier frequency into signal indications.

14. In a signaling system utilizing a radio frequency carrier modulated by a varying sub-carrier frequency, means for receiving the modulated radio frequency carrier, two separate circuits connected to said receiving means, one

adapted to pass the fundamentals of the varying sub-carrier frequency and reject the harmonics thereof and the other adapted to pass the harmonics and reject the fundamentals, a limiter in each circuit, means connected to the limiters for converting the frequency variations of the sub-carrier frequency into amplitude variations, and means for translating the amplitude variations into signal indications.

15. In a signaling system utilizing a radio frequency carrier modulated by a varying sub-carrier frequency, means for receiving the modulated radio frequency carrier, two separate circuits connected to said receiving means, one adapted to pass the fundamentals of the varying sub-carrier frequency and reject the second harmonics thereof and the other adapted to pass the second harmonics and reject the fundamentals, means for doubling the fundamentals, means for limiting the amplitude variations of both components, means connected to the limiting means for converting the frequency variations of the sub-carrier frequency into amplitude variations, and means for translating the amplitude variations into signal indications.

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 of the modulation frequency from a harmonic thereof, a signal indicator, and means for effectively switching the indicator from the weaker of said two frequency components to the stronger when selective fading of the radio carrier wave changes their relative strength.

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, a signal indicator, and means for effectively switching the indicator from said fundamental to the harmonic when selective fading of the radio carrier wave reduces the fundamental.

18. In a signal system employing a radio carrier wave containing a modulation frequency, a receiver containing a detecting circuit for said radio carrier wave, means for separating the fundamental component of the modulation frequency from its harmonic component produced in said detecting circuit by the beating of the side bands upon selective fading of the radio carrier wave, means for limiting the amplitude of said components, and means for indicating the stronger only of said limited components.

19. In a picture transmission system employing a radio carrier wave containing a sub-carrier wave of varying frequency, a receiver for said radio carrier wave, means for separating the fundamentals of the varying sub-carrier frequency from its harmonics, produced by beating of the side bands upon selective fading of the radio carrier wave, means for multiplying said fundamental frequencies to equal their harmonic frequencies, and means for indicating the multiplied fundamental and harmonic frequencies.

20. In a picture transmission system employing a radio carrier wave containing a sub-carrier wave of varying frequency, a receiver for said radio carrier wave, means for separating the fundamentals of the varying sub-carrier frequency from its harmonics, produced by beating of the side bands upon selective fading of the

radio carrier wave, means for multiplying said fundamental frequencies to equal their harmonic frequencies, means for converting the multiplied fundamentals and their harmonic frequencies into amplitude variations and means for recording the amplitude variations.

21. In a picture transmission system employing a radio carrier wave containing a sub-carrier wave of varying frequency, a receiver for said radio carrier wave, means for separating the fundamentals of the varying sub-carrier frequency from its harmonics, produced by beating of the side bands upon selective fading of the radio carrier wave, means for multiplying said fundamental frequencies to equal their harmonic frequencies, means for combining the multiplied and the harmonic frequencies, means for limiting said combined frequencies, means for converting the limited frequencies into amplitude variation and means for recording the amplitude variation.

22. In a signaling system employing a radio carrier wave modulated by a sub-carrier wave of varying frequency, means for receiving said radio carrier wave and extracting said sub-carrier wave, means for passing the fundamental components of the sub-carrier wave, means for passing the harmonic components of said fundamental components and means for selecting and indicating only the stronger of the two components.

23. In a signaling system employing a radio carrier wave modulated by a varying signal frequency, selective means for receiving said radio carrier wave and extracting said varying signal frequency, means for passing the fundamental components of said varying signal frequency, means for passing the second harmonic components of said fundamental components formed in said means upon fading of said radio carrier wave, means for changing the frequency of one of the components to equal that of the other and means for selecting and indicating the stronger of the two components.

24. In a signaling system employing a radio carrier wave modulated by a varying signal frequency, selective means for receiving said radio carrier wave and extracting said varying signal frequency, means for passing the fundamentals of said varying signal frequency, means for passing the second harmonics of said fundamentals formed in said means upon fading of said radio carrier wave, means for increasing the frequency of the fundamentals to equal that of the second harmonics and means for selecting and indicating the stronger of the two harmonic frequencies.

25. In a signaling system employing a radio carrier wave modulated by a varying signal frequency, means for receiving said radio carrier wave and extracting said varying signal frequency, means for passing the fundamental components of said varying signal frequency, means for passing the second harmonic components of said fundamental components formed in said means upon fading of

said radio carrier wave, means for increasing the frequency of the fundamental components to equal that of the second harmonic components and means for selecting and indicating the stronger of the two second harmonic frequencies.

26. In a picture transmission system employing a radio carrier wave modulated by a sub-carrier wave of varying frequency, a receiver for said radio carrier wave, means for extracting the fundamental of the varying sub-carrier frequency and a harmonic thereof, means for separating the fundamental and harmonic frequencies, means for changing the frequencies of one of the components to equal that of the other and means for recording the last-mentioned two equal frequencies.

27. In picture recording, the method which consists in receiving a radio carrier frequency modulated by a varying sub-carrier frequency, extracting the varying sub-carrier frequency and its harmonics produced by selective fading of the radio carrier frequency, separating the fundamental frequency and one of the harmonic frequencies, changing one of the last-mentioned frequencies to equal that of the other and utilizing the last-mentioned two frequencies in recording the picture.

28. In picture recording, the method which consists in receiving a radio carrier frequency modulated by a varying sub-carrier frequency, extracting the varying sub-carrier frequency and a second harmonic produced by selective fading of the radio carrier frequency, separating the varying fundamental frequency of the sub-carrier and one of the harmonic frequencies thereof, changing one of the last-mentioned varying frequencies to equal that of the other and utilizing the last-mentioned two frequencies in recording the picture.

29. In picture recording, the method which consists in receiving a radio carrier frequency modulated by a varying sub-carrier frequency, extracting the varying sub-carrier frequency and its harmonics produced by selective fading of the radio carrier frequency, separating the varying fundamental frequency of the sub-carrier and one of the harmonic frequencies thereof, changing one of the last-mentioned varying frequencies to equal that of the other, converting the last-mentioned two varying frequencies into amplitude variations and utilizing the amplitude variations in recording the picture.

30. In picture recording, the method which consists in receiving a radio carrier frequency modulated by a varying sub-carrier frequency, extracting the varying sub-carrier frequency and its harmonics produced by selective fading of the radio carrier frequency, separating the varying fundamental frequency and the second harmonic thereof, doubling the varying fundamental frequency, limiting the amplitude of the last-mentioned two varying frequencies, converting the limited frequencies to amplitude variations and recording the amplitude variations.

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