

Dec. 29, 1942.

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2,306,687

MEANS FOR IMPROVING RECEPTION DURING SELECTIVE FADING

Filed Oct. 21, 1941

3 Sheets-Sheet 1

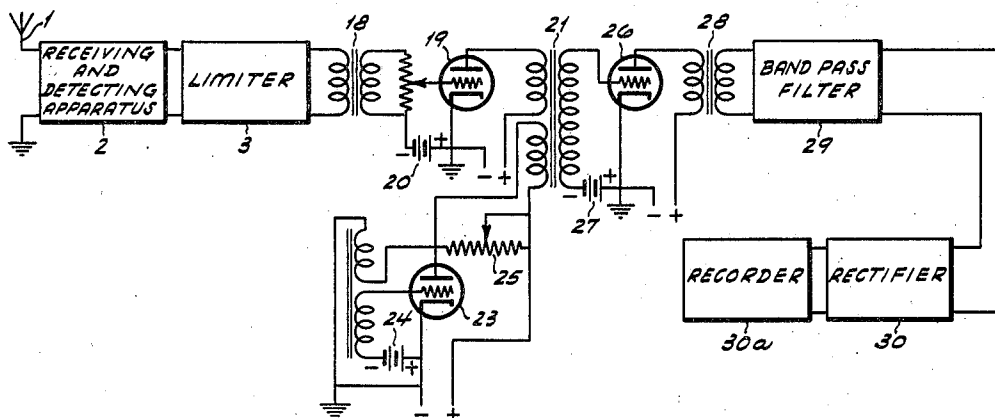


Fig. 1

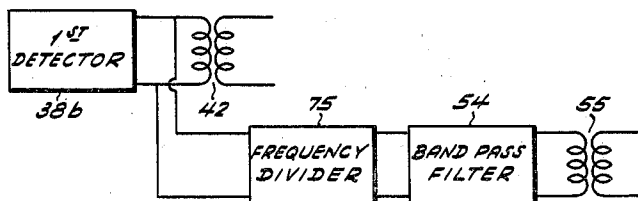


Fig. 3

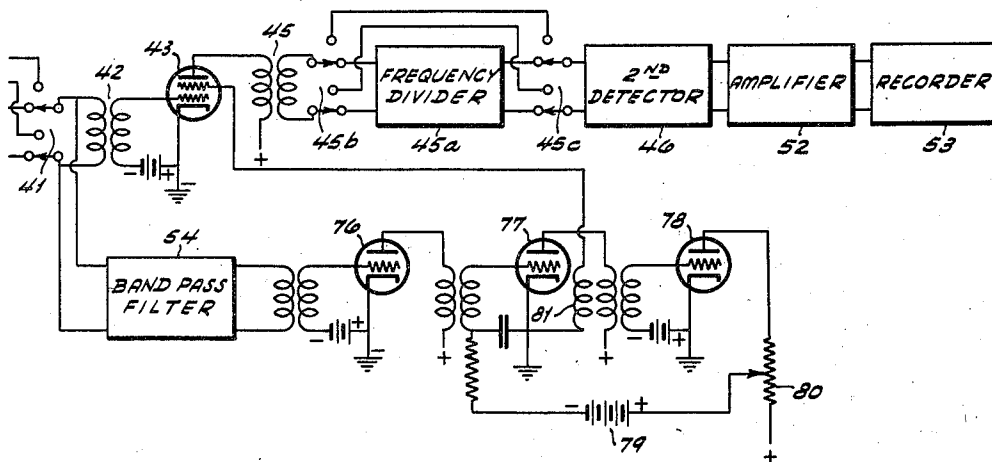


Fig. 4

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3 Sheets-Sheet 2

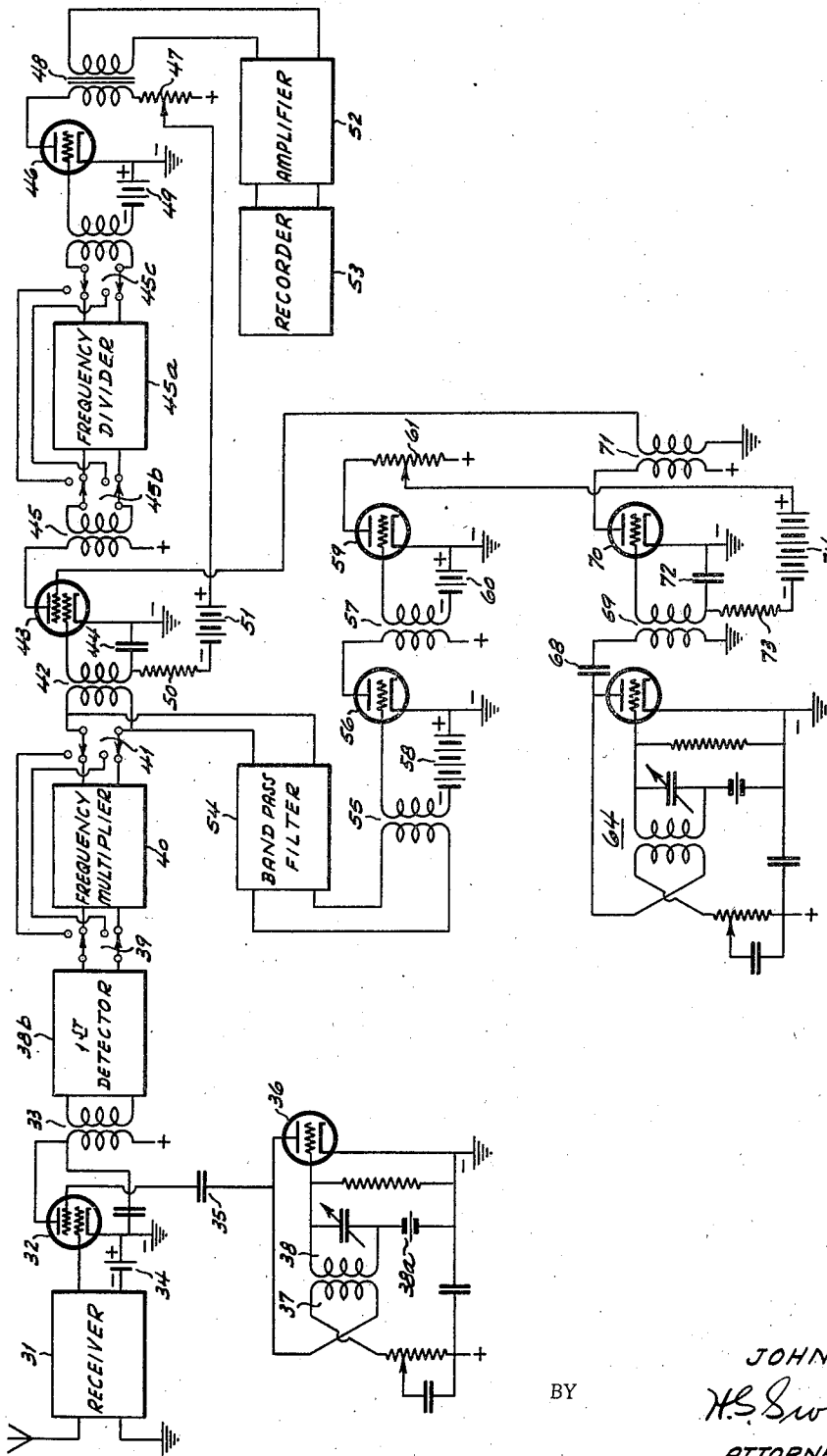


Fig. 2

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3 Sheets-Sheet 3

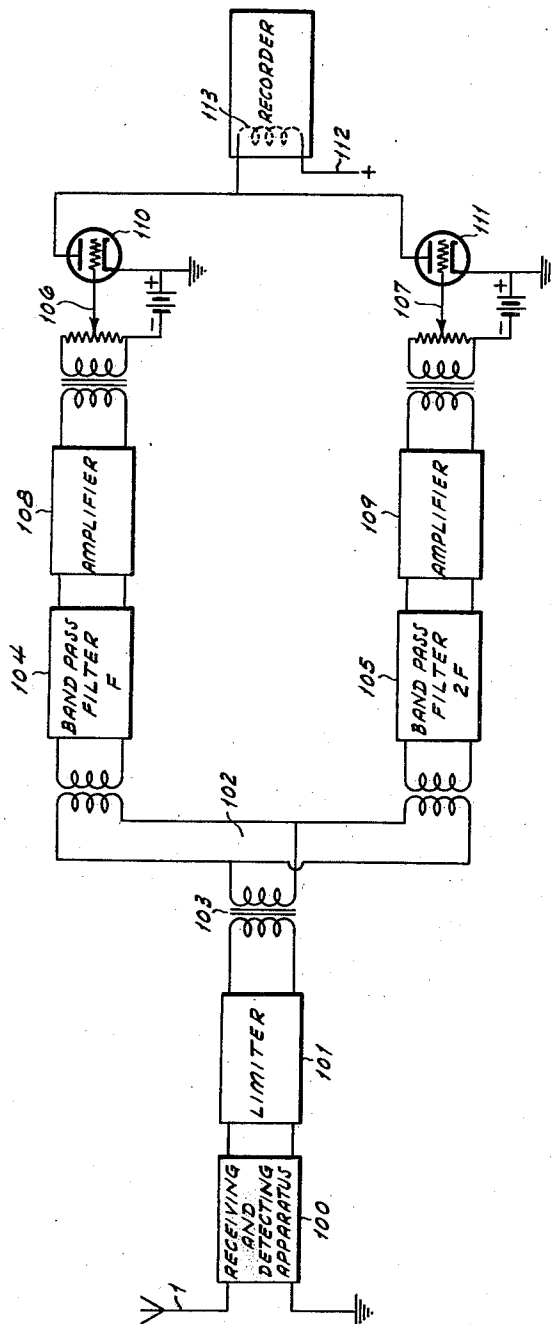


Fig. 5

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MEANS FOR IMPROVING RECEPTION DURING SELECTIVE FADING

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Application October 21, 1941, Serial No. 415,871

9 Claims. (Cl. 250—20)

This invention relates to radio telegraphy.

In radio telegraph signals transmitted so as to contain a sub-carrier component, the fading of the radio carrier wave produces or increases the strength of the harmonics of the sub-carrier signals and reduces or entirely removes that of the fundamental, depending upon the degree of fading. Such sub-carrier components in telegraph signals may be utilized in various ways; for example, they may be in the form of interruptions of the radio carrier wave, as described in my co-pending application filed June 6, 1939, Serial No. 277,607, or they may be amplitude modulations of the radio frequency wave by a frequency-modulated sub-carrier wave, such as disclosed in my co-pending application filed April 20, 1939, Serial No. 268,873.

On complete fading of the radio frequency carrier wave, the fundamental of the abstracted sub-carrier signals at the receiver completely disappears and the energy appears in the harmonics, particularly in the second harmonic.

If the audio circuit at the receiver is arranged to discriminate in favor of the fundamental, as by band-pass filters, audio tuning, or otherwise, there is a complete drop-out of the signal when the radio carrier fades completely and a partial drop-out when a partial fade occurs.

To overcome the effects of selective fading, filters have been used to separately select the fundamental and its second harmonic and reinforce the waning fundamental signal with the waxing second harmonic. This is successful to a considerable extent, but for best results it has been found that automatic switching means are required to switch the indicator from one component to the other as selective fading occurs. These automatic switching devices also have their disadvantages and I have provided improvements that make it unnecessary to employ them.

One object of my invention is to provide a circuit that utilizes the same signal component regardless of fading conditions.

Another object of my invention is to provide a circuit that will always produce a second harmonic component or alternately the fundamental for utilization both with and without fading of the radio frequency carrier wave.

Another object of my invention is to provide circuits for producing a local radio frequency carrier wave at the receiver, or its equivalent frequency, when selective fading of the transmitted wave occurs.

Another object is to provide an oscillator at

the receiver to form a beat with the fundamental equal to the second harmonic, so that the latter is received both with and without selective fading of the carrier.

Another object is to heterodyne the received wave and produce a converted carrier at the receiver equal to the carrier beat frequency which is introduced into the circuit when the transmitted carrier fades.

Another object is to provide for selection of the components of the signal frequency in frequency modulation of the radio carrier wave.

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

Figure 1 is an illustration of a circuit at the receiver for beating an oscillator with the fundamental signal frequency to produce the harmonic, or vice versa.

Figure 2 is a receiving circuit for restoring, in effect, the carrier when it is eliminated by selective fading.

Figure 3 is a modification of Figure 2.

Figure 4 is an additional modification of Figure 2.

Figure 5 is a receiving circuit for a frequency modulated wave.

Referring to Fig. 1 of the drawings, antenna 1 is connected to the receiving apparatus 2 and the output of the latter is connected to a limiter 3 to eliminate amplitude modulation produced in the other path or otherwise. The receiving apparatus consists of well-known devices such as radio frequency amplifiers, a detector, heterodyne or other circuit and audio frequency amplifiers. These are well known and need no description, hence they have been indicated in block diagram. The limiter 3 is likewise well known and has also been shown in block diagram. The output of the limiter is fed through transformer 18 into the input circuit of coupling tube 19, the input voltage being adjustable and a negative bias being indicated at 20. The positive terminal of the supply connects through one primary of transformer 21 to the anode of tube 19 and the cathode is connected to the negative terminal of the supply, which is grounded.

An oscillator 23 has its plate circuit coupled to its grid circuit with a negative bias 24 on the grid, if desired. The cathode of this tube is connected to the negative terminal, which is grounded. The positive terminal of the supply is connected through the other primary of transformer 21 to the anode of the oscillator tube. The primary may be shunted by an adjustable resist-

ance 25 to control the amount of current therein. The oscillator produces a beat frequency with the incoming sub-carrier, or signal, frequency equal to the second harmonic of the incoming signal frequency.

The secondary of transformer 21 is connected to the input of amplifier 26, having negative bias 27. The anode supply of tube 26 is connected through the primary of transformer 28 to the anode of the amplifier 26. The grounded negative terminal is connected to the cathode. The secondary of transformer 28 is connected to narrow band-pass filter 29, which is adjusted to pass the harmonic of the modulation frequency but not the fundamental. The output of the band-pass filter 29 is connected to rectifier 30 and the latter is connected to recorder 30a, which may be of any type.

The operation of Fig. 1 is as follows:

The incoming signal is received at 1 and the audio component extracted at 2, after which it is limited at 3. The signal frequency output is applied to the coupling tube 19 and it beats in the plate circuit of this tube with the output of oscillator 23. If there has been no fading, the signal component introduced into transformer 21 will be the fundamental, say 425 cycles. The beat oscillator, in this case, would then have a frequency of 1275 cycles and the beats formed would be 850 cycles and 1700 cycles. There therefore would be, in the secondary of transformer 21, frequencies of 425, 850, 1275 and 1700 cycles and these would be amplified by the amplifier 26 and introduced through transformer 28 into the band-pass filter 29. The second harmonic of 850 cycles, however, is the only frequency that will pass this filter and hence this frequency is recorded by recorder 30a.

If a selective fade occurs and the radio frequency carrier is eliminated, the second harmonic frequency of 850 cycles will be formed and this will beat with the oscillator frequency. The output of transformer 21 will then contain the harmonic frequency of 850 cycles, the oscillator frequency of 1275 cycles and the two beat frequencies of 425 cycles and 2125 cycles. However, only the harmonic frequency of 850 cycles caused by the fading will pass the filter and be recorded by recorder 30a. Thus, the second harmonic of the fundamental frequency of the signal is the only one that is recorded, regardless of the fading of the radio frequency carrier. However, different filters and oscillators may be used so as to utilize instead the fundamental or any other desired component.

In Fig. 2 a modification is shown. In this modification the receiving apparatus 31 will contain the usual apparatus for producing the requisite output of radio frequency, such as radio frequency amplifiers, and the radio frequency output is fed into the input circuit of mixer tube 32, which in the form shown has two grids, though this is an example only. The positive supply passes through the primary of transformer 33 to the anode or plate of the tube 32. The grounded negative terminal of the supply is connected to the cathode. The input circuit may have a suitable negative bias 34. The extra grid of tube 32 is connected through a coupling condenser 35 to the plate of oscillator tube 36. The positive terminal of the source of supply is connected to the anode through coil 37 coupled to grid tank circuit 38 and the grounded negative terminal is connected to the cathode. The tank circuit 38, coil 37 and tube 36 constitute a well-

known form of oscillator, disclosed in "Proceedings of the Institute of Radio Engineers," June, 1934, page 732. The crystal control typified by 38a is used to keep the frequency constant. Any desired oscillator and frequency control may be used in the place of the one shown.

The secondary of transformer 33 is connected to a detector or other means 38b for extracting the beat frequency produced by the interaction of the radio frequency carrier wave with the oscillator wave. This extracting means is shown in block diagram, as such devices are old and well known. The output of the first detector 38b is connected through switch 39 to frequency multiplier 40. This frequency multiplier is well known in the art and hence it has been shown in block diagram.

The output of the multiplier 40 is connected through a switch 41 to the primary of transformer 42. By throwing switches 39 and 41 upward, as shown in the drawing, the multiplier may be disconnected, in case its use is not desired. The secondary of transformer 42 is connected to the input of amplifier tube 43, which may have a suitable by-pass condenser 44. This tube, as shown, has two grids. The positive terminal of the supply passes through the primary of transformer 45 to the anode of tube 43 and the grounded negative terminal of the supply is connected to the cathode.

The secondary of transformer 45 is connected to a frequency divider 45a and the output of this divider is connected to the input of second detector tube 46. The frequency divider 45a restores the signal to its original frequency before multiplication by multiplier 40. When separation can be satisfactorily obtained without multiplication at 40, the frequency multiplier and divider 45a can be cut out of circuit by the switches 45b and 45c. Frequency dividers, like frequency multipliers, are well known in the art and hence divider 45a has been indicated by block diagram only.

The positive terminal of the source of supply for detector tube 46 is connected through a resistance 47 and the primary of transformer 48 is connected to the anode of this tube. The grounded negative terminal of the source of supply is connected to the cathode. The input circuit may have a suitable negative bias 49. The secondary of transformer 42 is connected through a suitable resistance 50 and negative bias 51 to a slider on resistance 47 to furnish automatic volume control.

The secondary of transformer 48 is connected to suitable amplifiers 52 and the output of the amplifiers is connected to any desired recorder 53.

The primary of transformer 42 is connected through band-pass filter 54 or other frequency selecting device to the primary of transformer 55. The secondary of this transformer is connected to the input of vacuum tube amplifier 56. The positive source of supply is connected through the primary of transformer 57 to the anode of this tube and the grounded negative terminal is connected to the cathode. Negative bias source 58 is connected to the secondary of transformer 55 and the cathode.

The secondary of transformer 57 is connected to the input terminals of rectifier 59. A suitable negative bias 60 may be incorporated in the input circuit to furnish rectification. The positive terminal of the source of supply is connected through resistance 61 to the anode of this

tube and the grounded negative terminal of the supply is connected to the cathode.

A second oscillator 64, similar in design to 36, 38, is coupled through condenser 68 to the primary of transformer 69. The positive terminal of the source of supply is connected to the anode and the grounded negative terminal of the supply is connected to the cathode. The plate of oscillator 64 is connected through coupling condenser 68 and the primary of transformer 69 to ground. The secondary of transformer 69 is connected to amplifier tube 70. The positive terminal of the source of supply is connected through the primary of transformer 71 to the anode of this tube and the grounded negative terminal of the supply is connected to the cathode. The low potential side of the secondary of transformer 69 may be connected to the cathode of the tube by a suitable by-pass condenser 72 and to the slider on resistance 31 through a suitable resistance 73 and negative bias 74. The secondary of transformer 71 has one terminal grounded and the other one connected to the second grid in tube 43.

The operation of the embodiment shown in Fig. 2 is as follows:

The incoming radio wave is intercepted by the antenna and suitably amplified by the receiving set 31 and the radio frequency output is fed into mixer tube 32. The frequency of oscillator 36 may be anything desired, but by way of example it may be assumed to be such as to produce a beat of 50 kilocycles with the incoming radio wave and this 50 kilocycle component is extracted by the first detector 38b. If we assume that the signal or modulation frequency is 100 cycles, the two side bands introduced into the frequency multiplier would be 50.1 and 49.9 kilocycles. There will also be present in the input to the frequency multiplier the 50 kilocycles, which is the converted carrier for the two side bands mentioned. The frequency multiplier may increase the frequencies any desired amount, but in the example given it would be sufficient to increase them six times, which will make sufficient difference between the frequencies to provide for the filtering of the converted carrier of 300 kilocycles from the two side bands in filter 54, as will later be referred to. The converted carrier and the two side bands from the multiplier will be introduced into the amplifier 43, thence into frequency divider 45a and finally into the second detector 46. The audio output from this detector then passes into the amplifiers and finally into the recorder, so that the signal may be recorded.

The output of the intermediate frequency amplifier 43 may be maintained within any desired degree of constancy by means of the automatic volume control shown.

While the output of the frequency multiplier is passing along the path just traced to the recorder, the multiplied converted carrier of 300 kilocycles alone passes through filter 54 to the amplifier tube 56 and the output of this tube is passing into the additional second detector tube 59. The automatic volume control 73, 74 of vacuum tube 70 is so adjusted in connection with plate resistance 61 that when the converted carrier is being amplified and detected at 56 and 59, respectively, there is sufficient negative potential from source 74 on the grid of amplifier 70 to block the tube. The intermediate frequency of 300 kilocycles produced by oscillator 64 thus cannot get through to the second grid

of vacuum tube 43. Thus, when there is no fading, the second oscillator and its connected circuits has no effect on the recording.

If the radio frequency carrier wave selectively fades, there will be no converted carrier to pass through filter 54 and the anode current in rectifier tube 59 will be reduced to such an extent that the grid of tube 70 has sufficient potential to pass the 300 kilocycle frequency of the oscillator to the second control grid on vacuum tube 43. This will introduce the local carrier of 300 kilocycles into tube 43, where it can react with the multiplied side bands, after which the frequencies are restored to the original intermediate frequency value by frequency divider 45a and detection at 46 will produce the fundamental, which will be amplified at 52 and recorded at 53; that is, the fading of the radio frequency carrier wave will not produce second harmonics because of the introduction of a new carrier wave to take its place.

In case the modulation frequency is sufficiently high in relation to the beat oscillator frequency to provide for efficient separation of the converted carrier from the side bands in filter 54, the frequency multiplier 40 and divider 45a may be switched out of circuit and filter 54 would be changed to pass 50 kilocycles.

In Fig. 3 a modification of the invention of Fig. 2 is illustrated. This differs from Fig. 2 chiefly in using a frequency divider 75 in place of the frequency multiplier 40. The first detector 38b, transformer 42, frequency divider 75, band-pass filter 54 and transformer 55 only are illustrated in this figure, but the other parts and circuits of Fig. 2 would be used, except of course the frequency divider 45a would not be used and the oscillator 64 would have a frequency of 50 kilocycles to take the place of the fading converted carrier of the same frequency.

In this modification the 50 kilocycle beat produced by the first oscillator (see oscillator 36, 38 of Fig. 2) is amplified and detected at 38b and part of the energy is passed through transformer 42 to the recorder as in Fig. 2 and part through frequency divider 75. This frequency divider may be of any form, for example, a beat oscillator and detector or filter for producing with the 50 kilocycle converted carrier a beat of, say, 1000 cycles. Band-pass filter 54 will be made to pass this 1000 cycles only, which will be introduced by transformer 55 into the remaining circuit of Fig. 2 and the operation will be as already described in connection with the figure. The chief advantage in substituting the frequency divider 75 for the frequency multiplier 40 of Fig. 2 is that one can more readily construct a sharp filter that will filter the 1000 cycle frequency than the 50,000 cycle frequency.

In Fig. 4 the circuit is the same as in Fig. 2, except for the particular way the controlled beat carrier is utilized. The beat carrier of, say 50 kilocycles, after amplification and multiplication to, say, six times its original value, is passed into transformer 42 and amplified at 43. It is then detected at 46 and amplified at 52 and recorded at 53, as already described in connection with Fig. 2. The multiplied converted beat carrier of 300 kilocycles is passed through the sharp band-pass filter 54, which eliminates the other frequencies, as in Fig. 2, after which it is amplified to a much higher extent. This difference in amplification in the two paths is typified by illustrating one amplifier 43 in one path and two amplifiers 76 and 77 in the other path, though

of course this is indicative only and any number of amplifiers may be used so long as the filtered carrier is amplified more highly than the signals in the first path.

The highly amplified selected beat carrier of 300 kilocycles is rectified by tube 78. This tube has an AVC connection 79 between its plate resistance 80 and the input circuit of one or more of the amplifiers, the connection of tube 43 to amplifier 77 only being shown. The output voltage of tube 77 is applied through transformer coil 81 to the screen grid of tube 43 under control of the AVC connection.

The operation of the modification of Fig. 4 is, briefly, as follows:

When the converted carrier is above a predetermined value, the AVC control 79, 80 is so adjusted as to suppress the selected carrier passing through filter 54 and recording at recorder 53 proceeds without help from the screen grid in amplifier tube 43. When the converted carrier fades below this predetermined point, the AVC control permits the highly amplified converted carrier to pass through the second path to the screen grid and it is introduced into the first path to reinforce the fading component. In other words, in this modification special means has been provided to very highly amplify the converted carrier when it starts to fade.

Of course, the highly amplified converted carrier need not be introduced into the first path by means of a screen grid connection. It could be introduced in many other ways and means could be provided for controlling it other than the AVC connection.

The oscillator of Fig. 1, of course, may be crystal controlled as shown in Fig. 2, or in any other desired way.

In Fig. 5 an embodiment is disclosed for receiving facsimile signals transmitted by frequency modulation of a sub-carrier used to amplitude modulate a radio frequency carrier wave, such as is disclosed in my said application 268,873. In this form the signals would be received, detected and amplified by the usual apparatus found in radio receiving stations, indicated by block diagram 100. The audio output, which would consist of the varying frequency of the sub-carrier, may then be limited at 101 by any well-known form of amplitude limiter and fed into the circuit 102 through transformer 103. If there has been no fading of the radio carrier wave, the fundamentals of the signal frequencies will pass through band-pass filter 104 and be excluded from band-pass filter 105. If the radio carrier wave selectively fades, the beating of the side bands of the signal frequencies, that is, the varying sub-carrier frequency, will produce the second harmonics of those frequencies and the fundamental frequencies will decrease. The second harmonics of the signal frequencies will then pass through band-pass filter 105.

Since the signal modulation is a frequency variation instead of an amplitude modulation, means must be used to convert the frequency variations into amplitude modulation for the usual recorder. To accomplish this I so design the band-pass filter 104 that the fundamental frequencies will pass through on the ascending, or descending, part of the characteristic curve of the filter. The varying sub-carrier frequency will pass through with a corresponding variation of amplitude; that is, the frequency variation will be converted into amplitude variation insofar as the fundamental frequencies are con-

cerned. This filter, however, will exclude the harmonic frequencies, as previously stated.

The band-pass filter 105 will be similarly constructed to pass the fundamentals of the varying sub-carrier so that the output voltages will vary with the variations in the frequency.

If a signal fades while the fundamental of a white portion of the picture or facsimile subject is being scanned, the production of the second harmonic must produce a signal of the same amplitude. Otherwise, there will be a change of shading in the recorded signal. To prevent this, band-pass filters 104 and 105 should either be designed so that the output voltage for each harmonic is the same as its fundamental, or other adjustments made such as the adjustments 106, 107 between the output of amplifiers 108, 109 and the input of rectifier tubes 110, 111. By making the characteristics of the fundamental and the harmonic band-pass filters similar in curvature, an adjustment at either 106 or 107 will produce substantially the same voltage input to the rectifier tubes for any fundamental frequency and its harmonic, if there should be any difference in the amplitude of the outputs of the filters. Thus, there will be no change of shading in the picture when selective fading increases the second harmonic and decreases the fundamental.

The triodes 110, 111 are made to serve as rectifiers by placing a blocking bias on their grids such that the negative half waves cannot pass, though of course any type of rectifiers may be used. The plate circuits of tubes 110 and 111 are connected in parallel to the source 112, so that the sums of their signal variations pass through the recorder coil 113, which may be of any type. The sum of the two currents will be substantially constant at any instant regardless of fading, for when one decreases the other proportionally increases.

It will thus be seen that in my circuit, facsimile and other photo radio signal transmitted by frequency variation may record either the fundamental or the second harmonic without change of shade in the picture or record when selective fading occurs.

Various other modifications may be made to secure the desired results and the claims are not to be limited to the ones disclosed.

While I have indicated band-pass filters in the figures of the drawings, it will be understood that low- and high-pass filters may be used instead without changing the theory of operation.

Having described my invention, what I claim is:

1. In the reception of a signal-modulated radio wave having a fundamental component of the signal frequency converted at times into a second harmonic component by selective fading of the radio carrier wave, a receiver for said modulated radio wave, a detector connected to the receiver for extracting the modulating signal components, an oscillator having such frequency as to produce with one of said components a beat having the frequency of the other component, means for combining the outputs of said oscillator and said detector, means for selecting said other component from the combined outputs and rejecting said one component and means connected to the selecting means for indicating the selected component.

2. In the reception of a signal-modulated radio wave having the fundamental of the signal frequency converted at times into the second har-

monic by selective fading of the radio carrier wave, a receiver for said modulated radio wave, a detector connected to the receiver for extracting the modulating signals, an oscillator having such frequency as to produce with the fundamental of the signal frequency a beat having the frequency of the second harmonic thereof, means for combining the outputs of said oscillator and said detector to produce said beats, means for selecting the second harmonic frequency from the combined outputs and rejecting the fundamental and means connected to the selecting means for indicating the selected second harmonic frequency.

3. In the reception of a signal-modulated radio wave having the fundamental of the modulating signal frequency converted at times into the second harmonic by selective fading, a receiver for said modulated wave, means for producing a beat frequency from said wave containing the signal modulation, a local source of alternating electromotive force having the frequency of said signal-modulated beat frequency and means controlled by the selective fading of said radio wave for combining the outputs of said local source of alternating electromotive force and heat frequency means to prevent formation of said second harmonic.

4. In the reception of a signal-modulated radio wave having the fundamental of the modulating signal frequency converted at times into the second harmonic by selective fading, a receiver for said modulated wave, means for producing a beat frequency from said wave containing the signal modulation, a local source of alternating electromotive force having the frequency of said signal-modulated beat frequency and means controlled by the reduction of the volume of said beat frequency for combining therewith a sufficient amount of the energy of said local source of alternating electromotive force to supply the beat frequency energy eliminated by the fading of the radio wave.

5. In radio reception subject to selective fading, a receiver having means for producing a carrier wave containing the transmitted signal modulation frequency means for amplifying a part of the carrier energy with the side band components, means for filtering out a second part of the carrier energy from the side band components and amplifying it to a greater extent than the first mentioned part, means for combining the more highly amplified carrier energy with said less highly amplified part only when the carrier fades below a predetermined value and means for indicating the modulation frequency of the combined parts.

6. In reception of a signal-modulated radio wave having the fundamental of the modulating signal frequency converted at times into the second harmonic by selective fading, a receiver for said modulated wave, an oscillator, means for combining the output voltages of said receiver and said oscillator to produce a beat frequency containing the signal modulation frequency, means for extracting the beat frequency and its signal modulation frequency, means for filtering out a part of the beat frequency energy from its

modulation frequency, means for amplifying the filtered beat frequency energy when it fades below a predetermined value, means for combining the amplified beat frequency energy with the unfiltered part thereof and means for detecting and indicating the modulation frequency.

7. In reception of a signal-modulated radio wave having the fundamental of the modulating signal frequency converted at times into the second harmonic by selective fading, a receiver for said modulated wave, an oscillator, means for combining the output voltage of said receiver and said oscillator to produce a beat frequency containing the signal modulations, means for extracting the beat frequency and the signal modulations, means for multiplying said beat and signal frequencies, means for filtering a part of the multiplied beat frequency energy from its signal frequencies, amplifying means for the said filtered energy, means for combining the outputs of said amplifying means and the frequency multiplying means, an automatic volume control stage connected to said amplifying means and adapted to reduce its output to substantially zero when the carrier is above a predetermined value and to increase it when the carrier fades below said value, means for reducing the multiplied frequencies of the second combined outputs to the first-mentioned beat frequency with its signal modulation and means for extracting the last-mentioned signal modulation.

8. In the reception of a radio wave containing a frequency-modulated sub-carrier wave component and having the fundamental of the sub-carrier wave frequency converted at times into the second harmonic by selective fading of the radio carrier wave, a receiver for said modulated radio wave, means for deriving the fundamental frequency of said sub-carrier wave from the received radio wave, means for deriving therefrom the harmonic frequency of said sub-carrier wave when thus formed, means for converting the varying fundamental and harmonic frequencies into amplitude variations and means for combining the energy of said fundamental and harmonic frequencies in such ratio as to render the sum of their simultaneous amplitudes substantially constant under varying fading conditions.

9. In the reception of a radio wave containing a frequency-modulated sub-carrier wave component and having the fundamental of the sub-carrier frequency converted at times into the second harmonic by selective fading of the radio carrier wave, a receiver for said modulated radio wave, means for deriving the fundamental frequency of said sub-carrier wave from the received radio wave, means for deriving therefrom the harmonic frequency of said sub-carrier wave when thus formed, means for converting the varying fundamental and harmonic frequencies into amplitude variations, means for combining the energy of said fundamental and harmonic frequencies in such ratio as to render the sum of their simultaneous amplitudes substantially constant under varying fading conditions and means for indicating the signals contained in said combined frequencies.

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