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Radio receiver including a frequency-locked loop and a muting circuit

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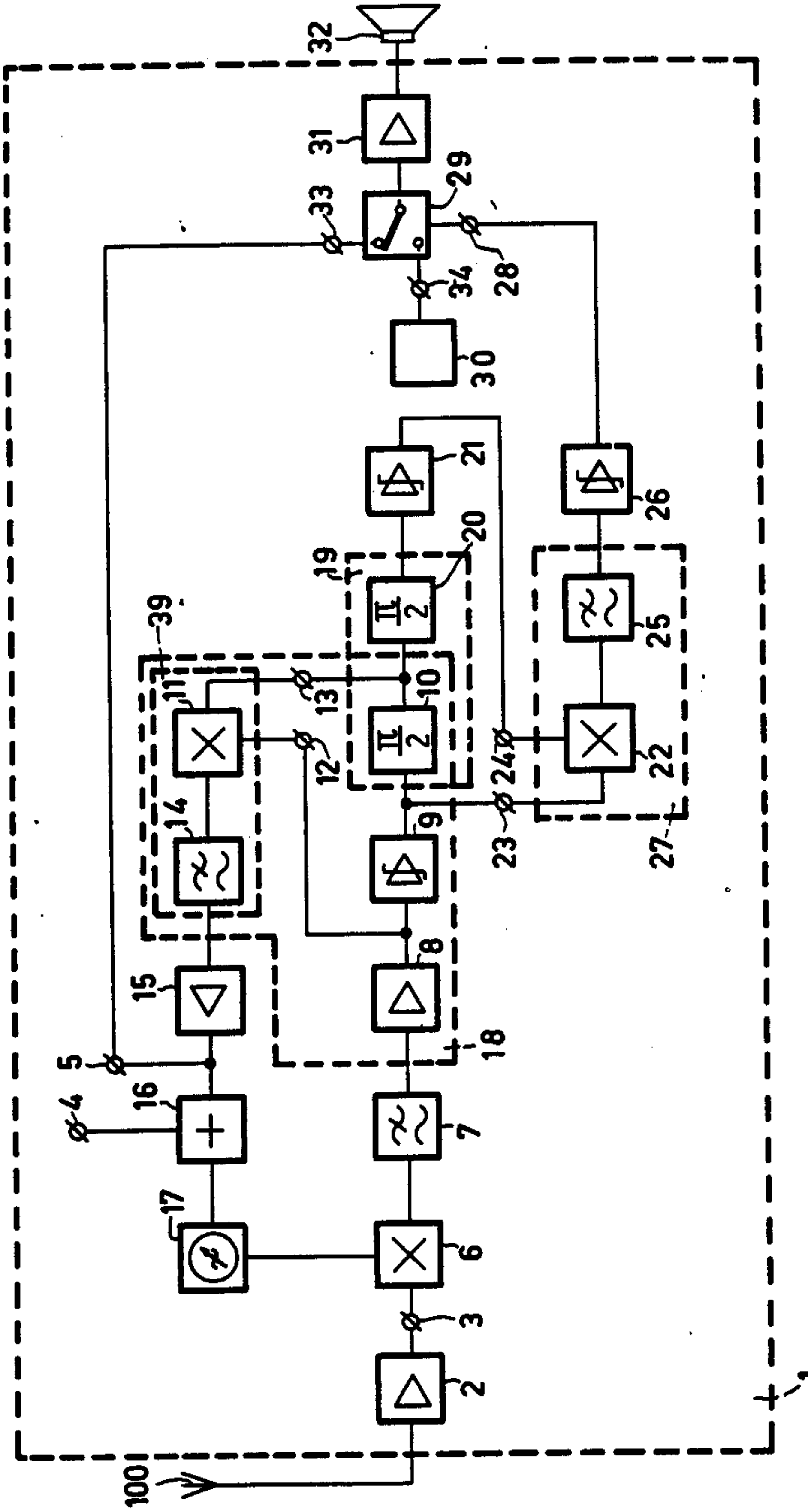

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FIG.1

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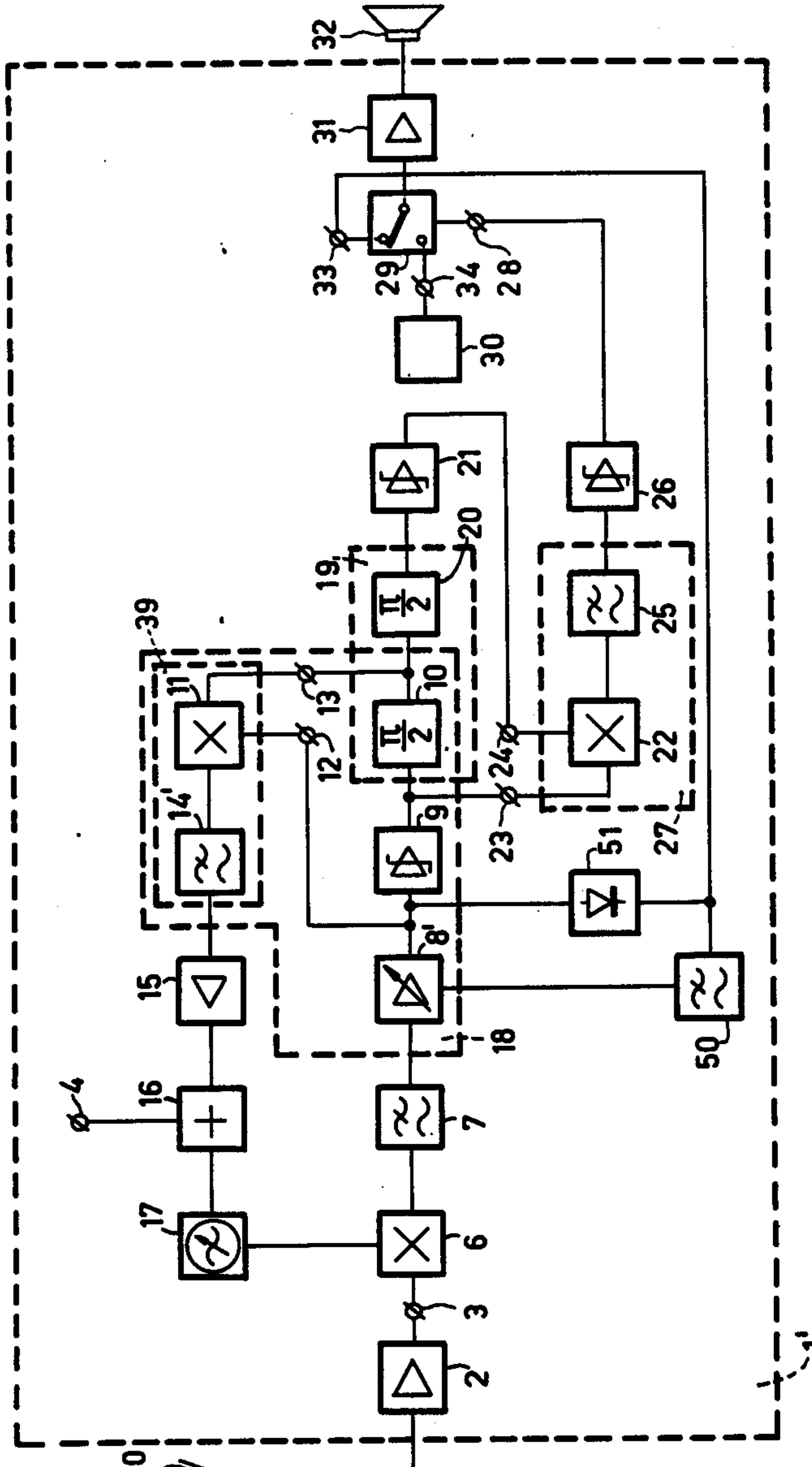

FIG.1A

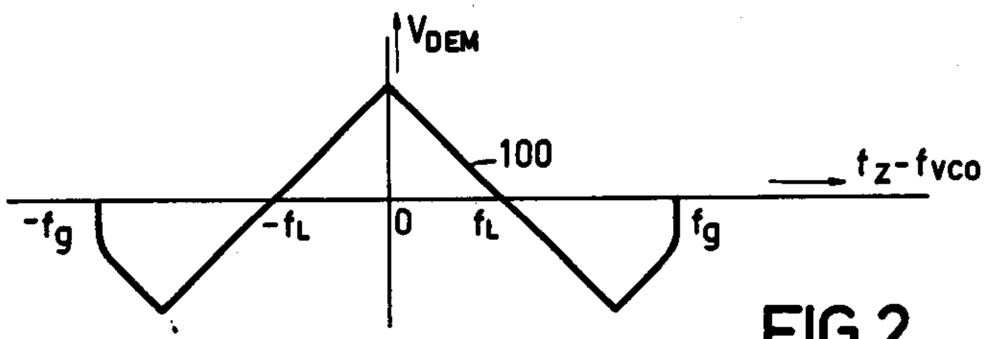

FIG.2

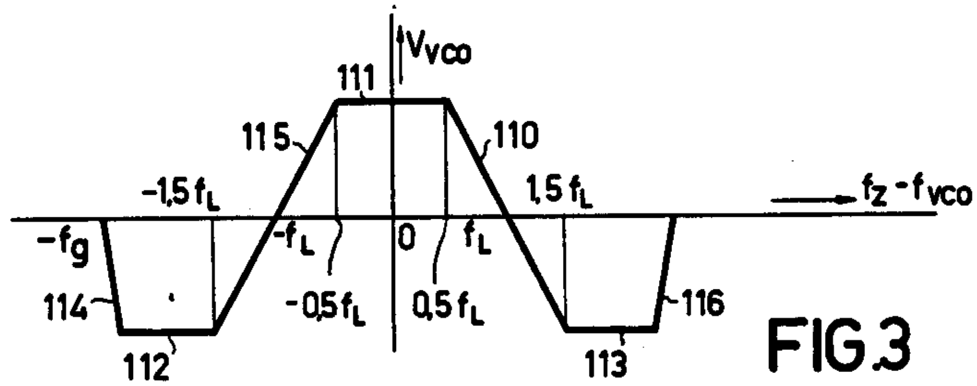

FIG.3

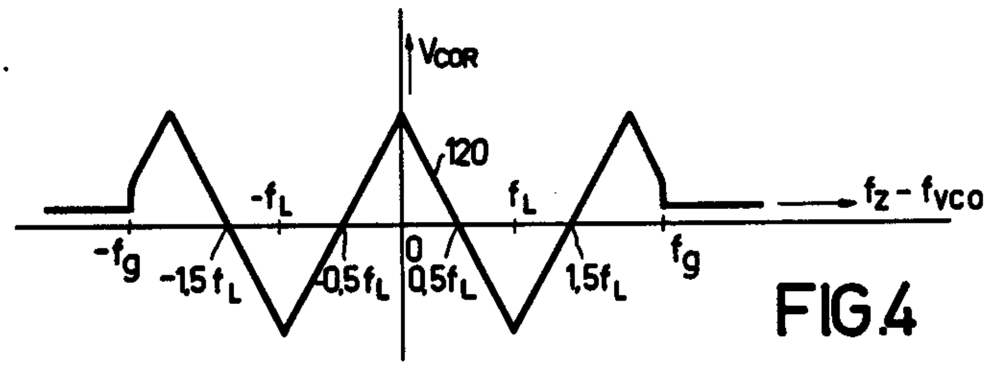

FIG.4

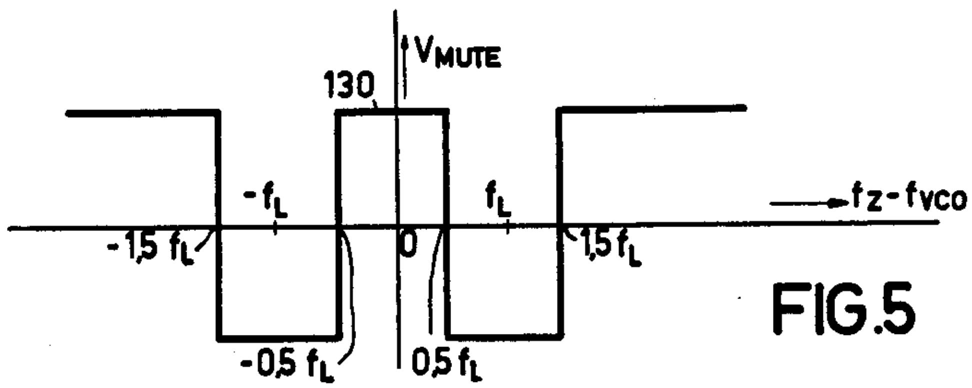

FIG.5

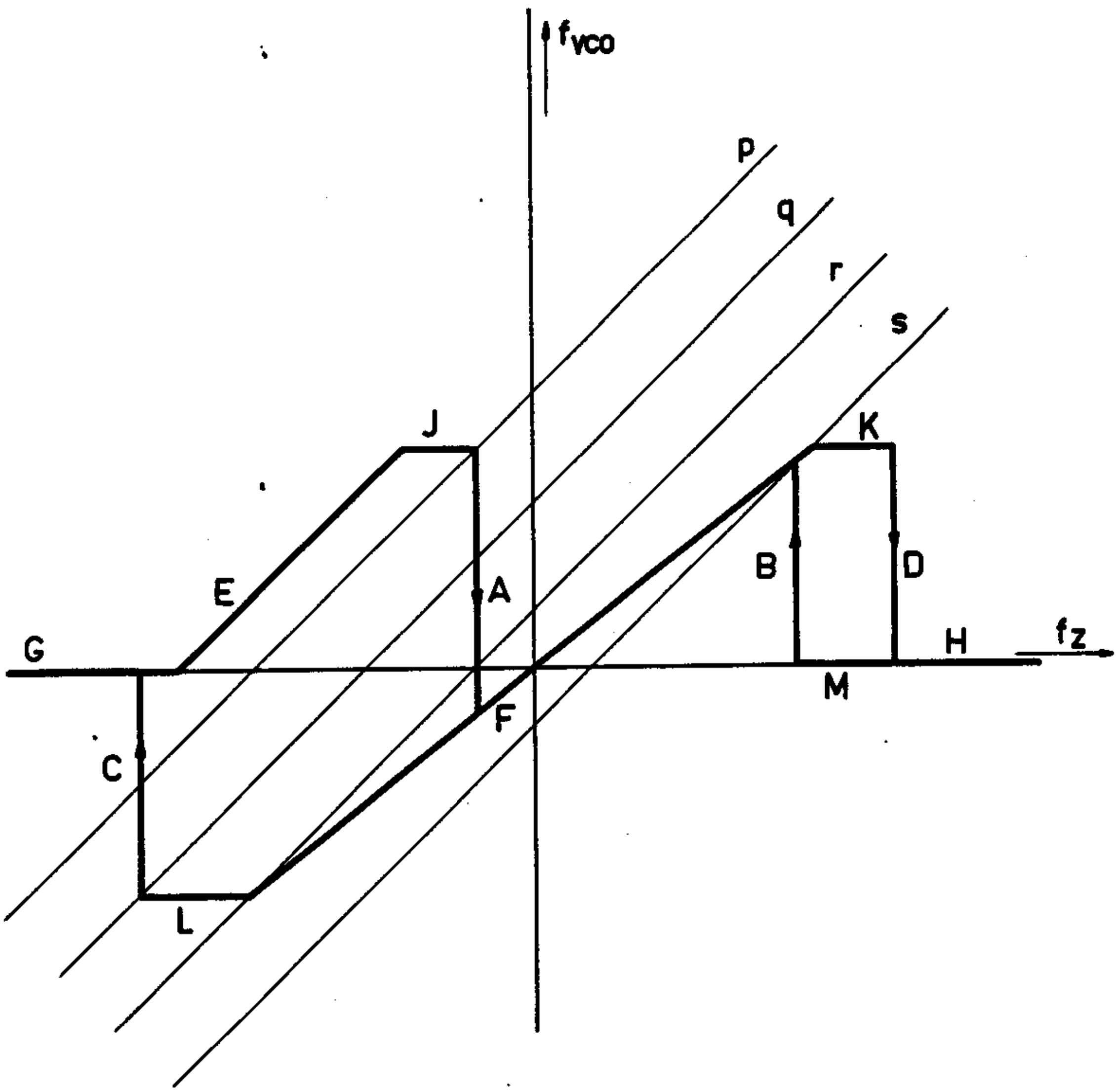

FIG.6

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"RADIO RECEIVER INCLUDING A FREQUENCY-LOCKED LOOP AND A MUTING CIRCUIT"

The invention relates to a radio receiver including a tuning circuit which comprises a frequency-locked loop, which loop includes, in succession, a voltage-controlled oscillator to a frequency control input of which is coupled an input for a tuning voltage, a mixer stage to which is coupled an aerial input, a filtering element, and a frequency-to-voltage converter an output of which is coupled to a control input of the voltage-controlled oscillator.

A known such receiver is described in the article "Ein neues Empfangsprinzip für FM-Empfänger mit integrierter Schaltung", by G.G. Gassmann, published in "Radio Mentor" no. 6, 1966, pages 512-518.

The invention provides a radio receiver including a tuning circuit which comprises a frequency-locked loop, which loop includes, in succession, a voltage-controlled oscillator to a frequency control input of which is coupled an input for a tuning voltage, a mixer stage to which is coupled an aerial input, a filtering element, and a frequency-to-voltage converter an output of which is coupled to a control input of the voltage-controlled oscillator, said receiver also including (a) a muting circuit for blocking transmission through an audio signal channel of said receiver unless the receiver is substantially correctly tuned to a broadcast transmission and (b) an amplifier-limiter included in the coupling from the output of the frequency-to-voltage converter to the control input of the voltage-controlled oscillator.

The provision of such an amplifier/limiter enables the loop gain and the size of the effective range of action of the automatic frequency control function performed by the loop to be suitably matched to the tuning range over which the muting circuit is in the inoperative condition, by means of a suitable choice for the limiting amplitude of the amplifier/limiter. Moreover, when the receiver is tuned to one end of the correct tuning range then, if the receiver is an FM receiver the audio output of which is derived from the amplifier/limiter, the at least partially limiting action of the amplifier/limiter then occurring will result in distortion of the sound signal, which can be an indication to the user that the tuning could be improved.

Embodiments of the invention will be described, by way of example, with reference to the accompanying diagrammatic drawings in which

Figure 1 is a block diagram of a first embodiment;

Figure 1A is a block diagram of a second embodiment;

Figures 2 to 5 illustrate the idealized operation of various components of the embodiments of Figs. 1 and 1A, and

Figure 6 shows the tuning behaviour of the embodiments of Figs. 1 and 1A.

Figure 1 shows an FM-receiver 1 an input of which is connected to an aerial device 100 and the output of which is connected to a loudspeaker 32. The FM- receiver 1 comprises a frequency-locked loop 6 to 18 inclusive having a signal input 3 to which is coupled the aerial device 100 via an input amplifier 2, and a muting control circuit 19 to 27 inclusive, which is fed from the frequency-locked loop 6 to 18 in a manner to be described hereinafter and the output of which is coupled to a control input 28 of a muting circuit 29. The muting circuit 29 has first and second inputs 33 and 34, the first input 33 being fed from an audio signal output 5 of the frequency-locked loop 6 to 18, and the second input being fed from a noise source 30. An output of the muting circuit 29 is coupled to the loudspeaker 32 through an audio signal processing section 31. When the muting circuit 29 is in the quiescent or inactive state, the first input 33 thereof is connected to its output, and when the muting circuit is in the active or muting state the second input 34 thereof is connected to its output. The frequency-locked loop 6 to 18 comprises, in succession, a mixer stage 6 to which is connected the signal input 3, a low-pass filter 7, a frequency-to-voltage converter 18, a first amplifier/limiter 15, an adder circuit 16 and a voltage controlled oscillator 17 the output of which is connected to the mixer stage 6. The junction point between the first amplifier/limiter 15 and the adder circuit 16 is connected to the signal output 5 of the frequency-locked loop 6 to 18. The adder circuit 16 also has a tuning voltage input 4 and adds a tuning voltage applied thereto to the output voltage of the first amplifier/limiter 15. The frequency-to-voltage converter 18 comprises a second amplifier/limiter 8, which is fed from the low-pass filter 7 and an output of which is coupled to a first input 12 of a phase detector 39 directly and also to a second input 13 of the phase detector 39 by way of a cascade arrangement of a limiter 9 and a first 90° phase shifter 10. The phase detector 39 comprises a cascade arrangement of a mixer stage 11, fed from the inputs 12 and 13, and a low-pass filter 14 the output of which is connected to the first amplifier/limiter 15.

The muting control circuit 19 to 27 comprises a 180° phase shifter 19 which, by way of a limiter 21, is coupled to an input 24 of a phase cetector 27. The other input 23 of the phase detector 27 is fed from an output of the limiter 9 included in the frequency-to-voltage converter 18. An output of the phase detector 27 is connected to the control input 28 of the muting circuit 29 by way of a limiter 26.

The 180° phase shifter 19 includes a second 90° phase shifter 20, which is connected between the first 90° phase shifter 10 of the frequency-to-voltage converter 18 and the limiter 21. The two cascaded 90° phase shifters 10 and 20 jointly operate as a 180° phase shifter, thereby effecting an economy in components compared with the alternative possibility of constructing the phase shifters 10 and 19 completely separately. The phase detector 27 comprises a cascade arrangement of a mixer stage 22, fed from the two inputs 23 and 24, and a low-pass filter 25, connected between the mixer stage 22 and the limiter 26.

The input amplifier 2 amplifies the aerial signal, which it will be assumed has a carrier frequency f_z, and applies it to the mixer stage 6. In the mixer stage 6 this aerial signal is multiplied by the output signal of the voltage-controlled oscillator 17, which it will be assumed has a frequency f_{vco}, whereafter the desired mixed product having the frequency $f_z - f_{vco}$ is selected by means of the low-pass filter 7. Unwanted mixed products, for example caused by neighbouring-frequency transmissions, are suppressed by the low-pass filter 7. In a practical embodiment the 3 db-point of the response of the low-pass filter 7 was at 100 kHz.

The second amplifier/limiter 8 amplifies weak input signals (for example noise signals or signals which are not fully suppressed because their frequencies lie on the edge of the response of the low-pass filter 7) linearly and acts as a limiter for strong input signals which pass the low-pass filter unattenuated. The output signal of the second amplifier/limiter 8 is applied to the first input 12 of the mixer stage 11 and also to the limiter 9, where the amplitude of this output signal is limited. In the subsequent first 90^{o} phase shifter 10 a frequency-dependent phase shift is effected, signals having a frequency f_L, being submitted to a 90^{o} phase shift. The frequency f_L, being the characteristic frequency of the 90^{o} phase shifter 10, was chosen equal to 60 kHz in a practical embodiment.

In the mixer stage 11, the output signals of the 90^{o} phase shifter 10 are multiplied by the output signals of the second amplifier/limiter 8. The mixed products thus obtained have an amplitude which depends on the phase difference between the signals applied to the two inputs 12 and 13 of the mixer stage 11, as well as on the amplitude thereof. Due to the presence of the limiter 9 the noise behaviour of the frequency-to-voltage converter 18 is more advantageous than that which would be obtained if a conventional FM square-law demodulator, (in which both signals to be multiplied together are limited to the same degree) were used therein. Such a conventional FM square-law demodulator would operate in a square-law manner for noise signals and use thereof would consequently result in noise components located in the pass band of the low-pass filter 7 providing a significant signal at the converter output.

The low-pass filter 14 selects the audio-frequency mixed product from the complete mixed product obtained at the output of the mixer stage 11. The low-pass characteristic of this low-pass filter 14 determines the slope and the cut-off frequency of the loop gain characteristic and consequently the frequency range within which feedback may occur in the loop. The 3dB point of the response of this low-pass filter 14 (the loop filter) was at 15 kHz in a practical embodiment.

For a detailed description of the operation of the frequency-to-voltage converter 18 reference is made to Figure 2 in which the curve 100 shows the idealized variation of the output voltage V_{DEM} of this frequency-to-voltage converter 18 as a function of the relative tuning frequency, i.e. the frequency of a received transmission relative to the output frequency of the voltage-controlled oscillator 17, in other words the difference $f_z - f_{vco}$ between the frequency of the aerial signal and the output frequency of the oscillator 17, assuming that the aerial signal has a given amplitude and is unmodulated.

The curve 100 is symmetrical with respect to the point at which $f_z = f_{vco}$ as a result of the conversion, carried out in the mixer stage 6, of the aerial signal to a low base-band. Furthermore, at the values f_L and $-f_L$ of the relative tuning frequency $f_z - f_{vco}$ a 90^o phase shift is obtained between the signals at the two inputs 12 and 13 of the second phase detector 39. V_{DEM} is then equal to zero. If the frequency at which a signal having the amplitude of the said aerial signal and translated to the base-band is suppressed almost completely in the low-pass filter 7 is denoted by f_g then V_{DEM} is equal to zero also when the relative tuning frequency $f_z - f_{vco}$ lies within the frequency range above f_g or below $-f_g$.

For values of the relative tuning frequency $f_z - f_{vco}$ at which partial suppression of the translated aerial signal occurs due to its lying on the edge of the characteristic of the low-pass filter 7, the translated aerial signal, thus suppressed to a considerable extent, may be smaller than the noise signal generated by the mixer stage 6 and present in the pass-band of the low-pass filter 7. Because of the linear law demodulation of the noise in the limiter 9, the mean voltage V_{DEM} is unaffected by such noise, i.e. the average noise level after demodulation in the frequency-to-voltage converter 18 will coincide with the average level of the demodulator output obtained when the relative tuning frequency is f_L. The result of this is that weak aerial signals which are occasionally drowned in noise do not give rise to annoying interference pulses, as sudden voltage transients between the noise level and the signal level (as seen at the demodulator output) do not occur.

The output signal V_{DEM} of the frequency-to-voltage converter 18 is applied to the amplifier/limiter 15, in which a linear amplification of the output signal V_{DEM} is effected for values of the signal V_{DEM} up to a predetermined maximum. It is arranged that this maximum signal level is reached <u>inter alia</u> when the relative tuning frequency $f_z - f_{vco}$ is $0.5\ f_L$ and $1.5\ f_L$ (assuming that the aerial signal has sufficient amplitude to result in limiting occurring in the second amplifier/limiter 8). If the value of signal V_{DEM} is above this maximum it is limited.

For a detailed description of the operation of the limiter 15 reference is made to Figure 3. In this Figure 3 the curve comprising the curve portions 110 to 116 inclusive shows the idealized variation of the output voltage V_{VCO} of the amplifier/limiter 15 as a function of the relative tuning frequency $f_z - f_{vco}$, when the aerial signal has an adequate amplitude.

The amplifier/limiter 15 is in the limiting mode when the relative tuning frequency $f_z - f_{vco}$ lies within the ranges covered by the curve portions 111 to 113 inclusive. Within these ranges, which will be termed "holding ranges" hereinafter, the condition of the loop is indeed controlled by the aerial signal, but V_{VCO} and, consequently, the oscillator frequency f_{vco} is independent of the actual value of the relative tuning frequency. A linear amplification of V_{DEM} is carried out when the relative tuning frequency lies within the ranges covered by the curve portions 110 and 114 to 116 inclusive. Positive feedback occurs in the frequency-locked loop 6 to 18 when the relative tuning frequency lies within the ranges covered by the curve portions 115 and 116. When the relative tuning frequency lies within these frequency ranges the oscillator frequency will vary suddenly.

Negative feedback occurs in the loop when the relative tuning frequency lies within the ranges covered by the curve portions 114 and 110. When the relative tuning frequency lies within these ranges stable tuning is effected, that is to say locking of the frequency-locked loop to the frequency of the aerial signal occurs. The stable (secondary) tuning which occurs when the relative tuning frequency lies within the range covered by the curve portion 114 is incorrect (c.f. Fig. 2) and it is arranged that the muting circuit 29 is active when such tuning occurs, as will be described hereinafter. The curve portion 110 corresponds to the correct tuning range or the correct lock-in range of the voltage-controlled oscillator 17.

A control voltage for the muting circuit is obtained by means of the control circuit 19 to 27 shown in Figure 1 and comprising the 180° phase shifting network 19, the limiter 21, the phase detector 27 and the limiter 26.

To explain the operation of this control circuit 19 to 27 reference is made to Figures 4 and 5 which show the output voltage V_{COR} of the phase detector 27 and the control voltage V_{MUTE} at the output of the limiter 26 respectively as a function of the relative tuning frequency $f_z - f_{vco}$.

The variation of V_{COR} shown in Figure 4 by means of curve 120 is obtained as a result of the fact that the two signals applied to the inputs 23 and 24 of the mixer stage 22 have both been limited and have a mutual phase difference which has been produced in the 180° phase shifting network.

The characteristic frequency of the second 90° phase shifter 20 is chosen equal to that of the first 90° phase shifter 10 (f_L = 60 kHz), so that for values of the relative tuning frequency $f_z - f_{vco}$ equal to 0; 0.5 f_L; f_L; 1.5 f_L; -0.5 f_L; $-f_L$ and -1.5 f_L phase shifts of 0; 90°; 180°; 270°; -90°; - 180° and -270°, respectively, are obtained. The bandwidth of the low-pass filter 25 should not be chosen too large, because if it were the muting circuit would be continuously switched between the operative and non-operative states in an audio frequency rhythm when the aerial signal is audio-frequency modulated and the receiver tuning is such that the relative tuning frequency $f_z - f_{vco}$ is in the region of 0.5 f_L or 1.5 f_L. On the other hand, this bandwidth should not be chosen too small, because if it were the muting circuit might be switched to the inoperative state too slowly when the receiver is tuned, which might cause transmissions to be missed. A practical value for this bandwidth is 1 Hz.

The idealized variation of V_{MUTE} shown in Figure 5 by means of curve 130 is obtained on the assumption that the gain in the limiter 26 for the signal V_{COR} when limiter 26 is out of limiting is infinite. The output voltage V_{MUTE} of the limiter 26, that is to say the control voltage for the muting circuit 29, always takes one of two discrete values. Change-overs are effected at the values -1.5 f_L; -0.5 f_L; 0.5 f_L and 1.5 f_L of the relative tuning frequency $f_z - f_{vco}$.

The muting circuit 29 is constructed so that it is in the operative state when V_{MUTE} is positive and is switched to the inoperative or quiescent condition when V_{MUTE} is negative, so that the signal output 5 of the frequency-locked loop is decoupled from the signal processing section 31 and the noise source 30 is coupled to this signal processing section 31 when the relative tuning frequency $f_z - f_{vco}$ is below -1.5 f_L, between -0.5 f_L and 0.5 f_L and above 1.5 f_L. The loudspeaker 32 consequently furnishes the user, when the receiver is not tuned to a station, with an acoustic indication of the fact that the FM-receiver is in operation. Moreover, the receiver is also muted should secondary tuning occur, i.e. tuning which results in the output of amplifier/limiter 15 lying on the curve portion 114 in Figure 3. The thermal noise across a resistor, amplified by an amplifier, may be used as the noise source.

When the relative tuning frequency $f_z - f_{vco}$ lies between $-1.5\ f_L$ and $-0.5\ f_L$ and between $0.5\ f_L$ and $1.5\ f_L$ the signal output 5 of the frequency-locked loop is connected to the signal processing section 31 and reproduction of audio frequency signals is effected by means of the loudspeaker 32. As mentioned hereinbefore positive feedback occurs in the loop when the relative tuning frequency lies in the range between $-0.5\ f_L$ and $-1.5\ f_L$, so that the relative tuning frequency is immediately driven out of this range, stable tuning with the muting circuit 29 in the non-operative condition being possible only when the tuning is in the correct range, i.e. such as to give a relative tuning frequency between $0.5\ f_L$ and $1.5\ f_L$.

Figure 6 shows the tuning behaviour of the FM-receiver of Fig. 1. For simplicity, the frequency f_{vco} of the voltage-controlled oscillator 17 is shown as a function of the frequency f_z of a constant-amplitude unmodulated aerial signal when the frequency f_z is varied in a continuous manner.

The lines p, q, r and s are lines of constant relative tuning frequency $f_z - f_{vco}$, corresponding to values of this frequency equal to $-1.5\ f_L$, $-0.5\ f_L$, $0.5\ f_L$ and $1.5\ f_L$, respectively. The muting circuit 29 is in the quiescent or inoperative condition when the relative tuning frequency $f_z - f_{vco}$ corresponds to a point between the lines p and q, and to a point between the lines r and s. Otherwise the muting circuit 29 is operative.

In the range where $f_z - f_{vco}$ is more negative than $-1.5\ f_L$, trajectory G is first passed through as f_z increases. The frequency-locked loop is not locked here and the voltage-controlled oscillator 17 runs free. Thereafter, when $f_z - f_{vco}$ becomes equal to $-1.5\ f_L$ trajectory E is reached. When trajectory E is subsequently passed through the frequency-locked loop is locked and the frequency f_{vco} of the voltage-controlled oscillator 17 is pulled-in by the aerial signal of frequency f_z. The trajectory E corresponds to the aforementioned stable secondary tuning, corresponding to curve portion 114 in Figure 3.

Trajectory J is then passed through as f_z increases further. While this is taking place limiter 15 is performing its limiting action and the frequency f_{vco} remains at a constant value in spite of the increasing f_z. The trajectory J corresponds to the holding range corresponding to the curve portion 112 in Figure 3. As the muting circuit is active, i.e. performs its muting function, when the trajectories G, E and J are passed through, the receiver is mute when it is tuned by the application of a tuning signal to input 4 so that its tuning effectively passes through this frequency range, only the noise from the noise source 30, which serves as an acoustic indication for the tuning process, being reproduced.

The trajectory J is followed, when f_z increases still further, by trajectory A where positive feedback occurs in the frequency-locked loop. This causes the frequency f_{vco} to decrease suddenly until the frequency-locked loop becomes locked again. During this sudden decrease of f_{vco} the trajectory passes between the lines p and q. As the muting circuit 29 is rendered inoperative only after a certain time lag arising because of the narrow bandwidth of the low-pass filter 25, the muting circuit remains operative, i.e. continues to perform its muting function, while this part of trajectory A is passed through, so that the frequency jump does not result in any audible effect.

The said locking of the frequency-locked loop is maintained when f_z is increased further so that the right-hand portion of trajectory F is passed through. Trajectory F corresponds to the correct tuning range or pull-in range, and corresponds to curve portion 110 in Figure 3. Within this range, which is quite wide, the oscillator frequency f_{vco} follows the aerial signal frequency f_z. If, therefore, the receiver tuning is such that the relative tuning frequency $f_z - f_{vco}$ lies within this range the loop will perform a demodulating function (if the aerial signal is in fact frequency-modulated) in addition to an automatic frequency control function.

One end of the pull-in range is defined by the line s; when this line is reached the limiter 15 starts its limiting function and the oscillator frequency f_{vco} remains constant as the aerial signal frequency f_z increases further. When this occurs the muting circuit 29 is activated once again. Trajectory K is then passed through. This trajectory K corresponds to the curve portion 113 in Figure 3.

As the aerial signal frequency f_z increases still further the limiting action of the limiter 15 stops and positive feedback cccurs in the frequency-locked loop (see curve portion 116 in Figure 3). As a result thereof the oscillator frequency f_{vco} suddenly decreases, the loop comes out of its locked state, and the oscillator runs completely freely once again. While this occurs trajectory D is passed through.

When the aerial signal frequency f_z increases still further the frequency-locked loop remains in the non-locked state and trajectory H is passed through. If the receiver is tuned so that the trajectories K, D and H are effectively passed through, the muting circuit is active while this occurs and only the noise from the noise source 30, which is used as an acoustic tuning indication, is audible. In a practical embodiment the pull-in range (corresponding to trajectory F) was found to be approximately 350 kHz.

If the aerial signal frequency is reduced from the value now reached, trajectory H is passed through in the opposite direction, followed by the trajectory M, the non-locked state of the frequency-locked loop being maintained in trajectory M. As the frequency f_z decreases still further the relative tuning frequency $f_z - f_{vco}$ decreases until the value f_g (see previously) is reached and positive feedback occurs in the loop (curve portion 116 of Figure 3). At that moment the oscillator frequency f_{vco} increases suddenly until the frequency-locked loop becomes locked. This frequency jump, shown as trajectory B, does not result in an audible effect, as the muting circuit 29 is active when the relative tuning frequency $f_z - f_{vco}$ lies within this range.

When the frequency f_z decreases further the frequency-locked loop remains in the locked state and trajectory F, corresponding to the correct tuning or pull-in range in which demodulation of the aerial signal if it be frequency-modulated, together with an automatic frequency control function will be performed. The muting circuit 29 is in the quiescent state while trajectory F is traversed. As the frequency f_z is decreased further, the other end of the pull-in range, defined by the line r, is encountered. When this line is reached the relative tuning frequency $f_z - f_{vco}$ has a value $0.5\ f_L$. The limiter 15 is actuated and trajectory L, corresponding to curve portion 111 in Figure 3, is passed through. The muting circuit 29 is now active once again.

As the frequency f_z decreases still further positive feedback occurs in the frequency-locked loop when the line q is reached, in response to which the oscillator frequency f_{vco} suddenly increases. The loop enters the fully non-locked state and the voltage-controlled oscillator 17 runs completely freely. Trajectory C is passed through while this occurs. As was also the case for trajectory A, the frequency jump along the trajectory C passes between the lines p and q. Owing to the narrow bandwidth of the low-pass filter 25, the muting circuit 29 is switched to the inactive state only after a certain delay, so that it remains active during the passage between the lines p and q, resulting in no audible effects while this is occurring. As the frequency f_z decreases still further the frequency-locked loop remains in the non-locked state and the voltage-controlled oscillator 17 runs completely freely (trajectory G).

It should be noted that it is alternatively possible to construct the amplifier/limiter 15 and/or the control circuit 19 to 27 in such manner that limitation of V_{VCO} occurs before the muting circuit 29 is activated. If this is so the audible sound distortion by which this additional limitation will be accompanied will be an indication for the user that the receiver is tuned to one end of the correct tuning range.

Figure 1A shows an AM-receiver 1' in which circuits which have the same function as the circuits of the FM-receiver 1 of Figure 1 have been given the same reference numerals. The AM-receiver 1' differs from the FM-receiver 1 in that the demodulation function is not performed in the frequency-to-voltage converter 18 but rather in an amplitude detector 51, which is fed from the low-pass filter 7 by way of an automatic gain controlled amplifier 8'. An output of the amplitude detector 51 is connected to a control input of the amplifier 8' by way of an AGC-filter 50 and also to the input 33 of the muting circuit 29. The time constant of the AGC-filter 50 is approximately 0.1 second.

Because the frequency-to-voltage converter 18 of Fig. 1A functions only as an automatic frequency control signal generating circuit, the audio frequency low-pass filter 14 of the FM-receiver 1 is replaced by an automatic frequency control filter 14' having a time constant of approximately 1 second.

The idealised variations of the output voltage of the frequency-to-voltage converter 18, the first amplifier/limiter 15, the phase detector 27 and the limiter 26 of this AM-receiver 1' as a function of the difference between the frequency of a standard-level, unmodulated, aerial signal and the output frequency of the oscillator 17, as well as its tuning behaviour for unmodulated aerial signals, will not of course deviate from those of the FM-receiver 1 as shown in Figures 2 to 6.

This application describes matter for which protection is sought in copending patent application 8028384 and in copending patent application 8312990.

CLAIMS:-

1. A radio receiver including a tuning circuit which comprises a frequency-locked loop, which loop includes, in succession, a voltage-controlled oscillator to a frequency control input of which is coupled an input for a tuning voltage, a mixer stage to which is coupled an aerial input, a filtering element, and a frequency-to-voltage converter an output of which is coupled to a control input of the voltage-controlled oscillator, said receiver also including (a) a muting circuit for blocking transmission through an audio signal channel of said receiver unless the receiver is substantially correctly tuned to a broadcast transmission and (b) an amplifier-limiter included in the coupling from the output of the frequency-to-voltage converter to the control input of the voltage-controlled oscillator.

2. A receiver as claimed in Claim 1, wherein the frequency-to-voltage converter includes a low-pass filter in the output circuit thereof, which low-pass filter has a bandwidth in the order of the magnitude of the audible frequency range.

3. A receiver as claimed in Claim 2, wherein the frequency-to-voltage converter includes a multiplying stage an output of which is coupled to said low-pass filter, the frequency-to-voltage converter also including a further amplifier/limiter coupling said filtering element to a first input of said multiplying stage, a phase shifter having its output coupled to a second input of said multiplying stage, and a limiter coupling the output of the further amplifier/limiter to the input of said phase shifter, said phase shifter being constructed to shift the phase of signals passing therethrough by 90^{o} when their frequency has a predetermined value.

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Radio receiver including a frequency-locked loop and a muting circuit

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