

Receiver circuit.

The invention relates to a receiver circuit as claimed in the introductory part of the main Claim. Such a receiver circuit is disclosed in DE-A 30 32 701.

Such a receiver circuit is intended in the first place to receive frequency-modulated signals, though it can in principle also receive amplitude-modulated signals. The oscillator, the mixer and the frequency-voltage converter form a loop whose loop gain in a useful tuning range is negative and whose value is greater than unity (for example 4). As a result thereof the frequency deviation of the intermediate-frequency signal is significantly reduced with respect to the frequency deviation of the aerial signal (at a negative loop gain of 4, by a factor of 5). It is then possible to choose a low value (for example 70 kHz) for the intermediate frequency signal which is in essence determined by the design of the frequency-voltage converter, such that a simple RC-low-pass filter is sufficient for selecting the intermediate frequency signal. Consequently, circuits of this type are particularly suitable for manufacture in an integrated circuit technique.

In a circuit of this type there are two stable tuning ranges, namely on the one hand the (wanted) useful tuning range around the target mean frequency and on the other hand an (unwanted) tuning range on a side band in the region of the image frequency. With the prior art circuit the tuning on this unwanted tuning range is suppressed with the aid of a muting circuit which is controlled by the control circuit and is arranged in the signal path of the demodulated wanted signal.

A disadvantage of the prior art circuit is that it has an unusual tuning behaviour. More specifically, the

tuning is highly asymmetrical, that is to say the extent of the tuning range and its position relative to the target mean frequency greatly depend on the fact whether a higher or a lower frequency is taken as the initial point during tuning. A further unusual fact is that at the reception of FM-signals tuning positions are possible in which no output signal and substantially no noise are present. This may be confusing for an unskilled user of such a receiver, as he does not know this behaviour from conventional receivers.

It is an object of the present invention to provide a receiver circuit of the type described in the opening paragraph such that a highly symmetrical tuning behaviour is obtained in spite of a low intermediate frequency.

According to the invention, this object is accomplished by the measures as described in the characterizing part of the main Claim.

When tuning is effected to the wanted tuning range around the target mean frequency, the loop gain remains unchanged so that the frequency deviation compression and the further advantageous properties of the circuit in this range are maintained. In the case of greater detunings the loop gain is however reduced, so that a symmetrical tuning behaviour is obtained. The reduction is however less than the maximum value of the gain.

In this respect it is to be noted that US-A-3,851,263 discloses an FM receiver with an automatic frequency control, which comprises an oscillator whose frequency is controllable by means of a DC control voltage at a control input, a mixer stage mixing the oscillator signal with an aerial signal and forming an IF signal therefrom, and a frequency-voltage converter to which the IF signal is applied and from whose output signal the DC control voltage for the control input of the oscillator is derived. Arranged between the frequency-voltage converter and the mixer stage is a limiter which, dependent on the output signal of the frequency-voltage converter, is control-

led in such a way that the limiter level is maximum when the IF signal corresponds to the centre of the frequency characteristic of the frequency-voltage converter and that the limiter level decreases with an increasing detuning.

5 Additionally provided is a detector to which the input signal of the limiter is applied and which sets the limiter level at zero when the amplitude of the IF signal exceeds a given value. As a result, a muting circuit should be used in the case of a large mistuning.

10 The problems of the invention (non-symmetrical tuning behaviour) do not occur in the known circuit and the solutions described are not suitable for solving these problems.

In accordance with a further embodiment of the
15 invention the control circuit is in the form of a correlator, the correlation period corresponding to half a period of the target mean value of the intermediate frequency. As is known, a correlator is a circuit in which the momentary means value of the product of an oscillation signal
20 and the oscillation signal being delayed by the correlation period is formed, in this case the correlation period corresponding to half a cycle of the target mean frequency, that is to say that at the target mean frequency the signals to be multiplied have a phase shift of 180° precisely.

25 The attenuator can be controlled by the control signal of the control circuit in the switched mode (with sudden transients) but alternatively in the analog mode (continuously). The attenuator itself can be directly included in the loop so that the loop is closed through
30 the attenuator, whose gain or attenuation, respectively is then controlled by the control circuit. However, in contrast therewith in accordance with a preferred embodiment of the invention, the frequency-voltage converter comprises a multiplying circuit when gain is controlled by
35 the control circuit. In this case the attenuator is consequently not included directly in the loop, but only influences the gain of a circuit comprised in the loop. This

structure results in particularly low additional costs.

The complexity may be reduced in accordance with a further embodiment of the invention, when a muting circuit is provided for fully or partially suppressing the reproduction of the useful signal derived from the aerial signal, and that the control circuit controls the muting circuit outside the attenuator such that the muting circuit is activated when the intermediate frequency deviates from the target mean frequency by a predetermined amount. The muting circuit and the control circuit controlling it are also comprised already in the prior art receiver circuit. Thus as an additional component, only the attenuator is essentially added in the case of the invention.

The invention will now be further described with reference to the drawing in which

Fig. 1 shows a block diagram of the prior art receiver circuit,

Figs. 2a to 2e show different diagrams, which illustrate the tuning behaviour of the circuit shown in Fig. 1,

Fig. 3 shows a block diagram of the circuit according to the invention,

Fig. 4 shows different diagrams which illustrate the tuning behaviour of the circuit shown in Fig. 3,

Fig. 5 shows a particularly simple embodiment of an attenuator in combination with a frequency-voltage converter,

Fig. 6a shows an embodiment of a control circuit, and

Figs. 6b and 6c show the resultant voltage variations.

Fig. 1 shows the block diagram of a prior art FM-receiver. Reference numeral 1 denotes an aerial whose signal is applied to a mixer 2 in which it is mixed with the signal from an oscillator 3, whose frequency is linearly controllable by a voltage and which can be tuned in usual manner, for example by means of a variable capacitor.

The intermediate-frequency signal produced by the mixer 2 is applied to a low-pass filter 4 whose cut-off frequency is approximately 100 kHz, so that it suppresses signals from adjacent transmitters and especially mixing products having the sum frequency of the aerial and the oscillator signal. The output of the low-pass filter 4 is connected to a limiter-amplifier 5, whose output signal is applied to a frequency demodulator 6 which functions as a frequency-voltage converter. The frequency-voltage converter is designed for an intermediate mean frequency f_{zo} of, for example, 70 kHz, that is to say the demodulator output signal has zero value for this frequency and changes approximately linearly with the deviation of the intermediate frequency from this (target mean) value. The output signal of the FM-demodulator 6 is applied to a low-pass filter 7, which is used to stabilize the loop and whose cut-off frequency is lower than that of the useful signal. The output of the low-pass filter 7 is connected to the input of a limiter-amplifier 8 from whose output the signal is taken and which is simultaneously connected to the control input of the voltage-controlled oscillator, so that the oscillator frequency changes dependent on the amplitude deviations of the audio signal. The audio signal is applied to a reproducing unit 10, for example a loudspeaker, via a muting circuit 9 and optionally via an amplifier, not shown further. The muting circuit 9 is controlled by a control circuit 11 having a relatively large time constant via a suitable converter stage 12, for example an amplifier having a very high gain, and this in such a way that the reproduction is attenuated or suppressed, respectively, when the intermediate frequency deviates from the value f_{zo} by a predetermined amount. The control circuit 11 may be of the same construction as the correlator in the circuit disclosed in DE-A 30 32 701. More specifically the demodulator 6 and the control circuit 11 - as is also the case in the prior art receiver - may have a portion of the phase shifter in common.

To explain the operation of the circuit shown in Fig. 1, reference is made to Figs. 2a to 2e. In Fig. 2a the output voltage U of the limiter-amplifier 8 is shown as a function of the difference between the transmitter frequency f_s and the oscillator frequency f_o , with the loop being assumed to be opened before the control input of the oscillator. This characteristic is symmetrical around the point $f_s = f_o$ ($f_s - f_o = 0$). In the outer regions, that is to say for difference frequencies exceeding a predetermined amount, the curve has horizontally extending regions d and e in which the output voltage U of the limiter-amplifier is independent of the difference between transmitter and oscillator frequencies. The position of these regions, that is to say their frequency distance is determined by the design of the low-pass filter 4 (Fig. 1): the higher the cut-off frequency, the larger the distance between these two curve sections. Therebetween, that is to say at lower difference frequencies, there are still further horizontally extending curve sections, namely the sections a, b and c. These sections are produced by the limiter 8. As in these regions the change in the difference between the transmitter and oscillator frequencies do not influence the output voltage and consequently do not influence the frequency of the oscillator 3, the closed loop gain is here zero (in the case of a closed loop). If in addition thereto a frequency-modulated signal is received in the regions a, b or c, the noise is suppressed thereby and no signal is audible at the loudspeaker 10, whilst the frequency modulation, that is to say the change in the instantaneous value of the transmitter frequency in correspondence with the instantaneous value of the signal has no influence on the output voltage.

In addition, the curve has two regions with a negative slope, in which therefore the output voltage U decreases versus an increasing intermediate frequency. These regions are the region s and the region around the target mean frequency f_{zo} in which the transmitter frequency ex-

ceeds the oscillator frequency. Let it be assumed that the (closed) loop is designed such that a negative loop gain is obtained at this negative slope, namely such that the loop gain around the frequency f_{zo} is less than -1, for example -4. This then implies that each change in the instantaneous value of the transmitter frequency, that is to say any frequency modulation, results in a change in the limiter-output voltage U and consequently in the oscillator frequency f_o such that the difference between the instantaneous value of the transmitter frequency and the instantaneous value of the oscillator frequency is reduced, which is similar to the situation in which the frequency deviation of the intermediate frequency signal at the output of the mixer 2 is less than the frequency deviation of the transmitter signal. So with a loop gain of -4 the frequency deviation is reduced by a factor of 5. For this reason it is possible to receive with such a circuit in which the intermediate frequency has a nominal value f_{zo} of only 70 kHz, an FM signal whose frequency deviation is, as is known, 75 kHz, without non-linear distortions being produced because of the band limitation.

As the output voltage U varies symmetrically around the straight line $f_s = f_o$ as a function of the difference $f_s - f_o$, the curve also has two regions with positive slopes. The region in which the transmitter frequency is less than the oscillator frequency by the value f_{zo} then has in the assumed example (in the case of a closed loop) a loop gain of +4. This means that tuning to one of these regions having a positive loop gain which is greater than 1 is not possible, as the loop is here unstable, so that these regions are skipped during tuning as will be described hereinafter.

Figs. 2b to 2d show the closed loop behaviour of the receiver as a function of the transmitter frequency f_s , for the sake of simplicity with the assumption that when tuning is effected to the regions d and e the oscillator frequency f_o has the constant value f_{oo} and that only the

unmodulated carrier frequency f_s of the transmitter is modulated. From Figure 2b which shows the dependence of the oscillator frequency f_o on f_s it will then be obvious that in the region d in which the transmitter frequency is adequately far below the oscillator frequency f_{oo} an increase of the transmitter frequency does not influence the oscillator frequency. Fig. 2c, which illustrates the dependence of the intermediate frequency on the transmitter frequency, shows that consequently the intermediate frequency always decreases by the same amount by which the transmitter frequency increases, so that in this region a straight line, shown by means of a broken line, having a slope angle of -45° is obtained. Fig. 2d, which characterizes the type of useful signal at the input of the muting circuit 9 as a function of the transmitter frequency f_s at an increasing transmitter frequency, shows that only noise can be received in this region d.

This region ends when the transmitter frequency has increased to such an extent that the (negative) difference between the transmitter frequency and the oscillator frequency f_{oo} has decreased to such an extent that the resulting difference frequency is transmitted by the low-pass filter 4. The tuning then arrives in the region s in which the oscillator frequency f_o increases versus the transmitter frequency (Fig. 2b), but because of the finite loop gain not to the same extent as the transmitter frequency f_s . As a result thereof there now results a further - but smaller - decrease in the intermediate frequency (Fig. 2c). In this region, in which tuning is effected to an edge of the low-pass filter, a demodulation of the input signal is obtained, but poorer signal-to-noise ratios.

When the oscillator frequency reaches the value at which the voltage U , which controls the oscillator frequency, corresponds to the level a, the oscillator frequency at first no longer increases with an increasing transmitter frequency (Fig. 2b) so that the intermediate frequency again decreases by the same amount with which the

transmitter frequency increases (Fig. 2c). As explained in the foregoing, no output signal is however obtained in this region, not even then when the transmitter signal is frequency-modulated.

5 When this region has been passed through, there follows the region having a positive loop gain which, as mentioned, is not stable. As a result thereof the oscillator signal changes here suddenly versus the transmitter frequency (Fig. 2b jump A) and also the intermediate frequency (Fig. 2c). Then not only the total region with a positive
10 loop gain is skipped, but also the region c and even a portion of the useful tuning region n around the frequency at which the transmitter frequency is equal to the sum of the constant oscillator frequency f_{oo} and the target mean
15 value of the intermediate frequency f_{zo} . This jump A increases when the loop gain is increased. At a higher loop gain the ideal transmitter tuning ($f_s = f_{oo} + f_{zo}$) may even be skipped. After this jump, by which the region n with the negative loop gain is reached, the oscillator
20 frequency f_o changes again versus the transmitter frequency, but because of the finite loop gain to a lesser extent than this transmitter frequency, the oscillator frequency again reaching the value f_{oo} at the transmitter frequency $f_s = f_{oo} + f_{zo}$ and thereafter increasing further in an
25 essentially linear way. In this useful tuning range any change in the transmitter frequency is converted into a change in the output voltage of the limiter-amplifier 8, that is to say a frequency-modulated signal is demodulated.

 This region ends when the transmitter frequency
30 has become so much higher than the oscillator frequency that the region b is reached. In this region the oscillator frequency does not change anymore (Fig. 2b), the intermediate frequency f_z increases to the same extent as the transmitter frequency f_s (Fig. 2c), and no signal is re-
35 ceived at the input of the muting circuit (Fig. 2d). This region is followed by a region of a positive loop gain, in which the oscillator frequency f_o or the intermediate

frequency f_z , respectively, suddenly already at a very small change in the transmitter frequency (or - when the assumption that the transmitter frequency f_s changes and the initial tuning f_{oo} remains constant is left - at a very small decrease of the initial tuning f_{oo}), skips a portion of the horizontally extending region e again until the initial tuning is reached. With a still further increasing transmitter frequency the oscillator frequency changes no more and a noise signal is produced at the input of the muting circuit 9.

If instead thereof the transmitter frequency is decreased, starting from higher values, a quite different tuning behaviour is obtained. In the first place the region e is again passed through - to its very end - the oscillator frequency remaining constant (f_{oo}), whilst the intermediate frequency decreases versus the transmitter frequency. A noise signal appears at the input of the muting circuit 9 (Fig. 2e). This region ends when the region of the positive loop gain is reached, which region is determined by the edges of the low-pass filter 4. Then a jump C of the oscillator frequency or the intermediate frequency, respectively occurs, the region B (Fig. 2a) being skipped entirely and also a small portion of the useful tuning range n . From there the oscillator frequency f_o follows the transmitter frequency on the line n (Fig. 2b), the intermediate frequency decreasing slightly (Fig. 2c), until the overall tuning range n is passed through and the portion c follows in which the oscillator frequency changes no more (Fig. 2b), whilst the intermediate frequency decreases to the same extent as the transmitter frequency, subsequently increases again in the opposite sense during which no signal appears at the input of the muting circuit (Fig. 2e) until finally the beginning of the curve portion with a positive loop gain is reached.

In the case of a further increase the tuning then skips this region, the subsequent region a and a large portion of the next region having a negative loop gain, whereafter only the small remaining portion of the tuning

range s determined by the filter edges is still passed through, which range follows after the range d in which the initial tuning f_{00} is reached, whereafter no further change in the oscillator frequency f_0 occurs (Fig. 2b) and only a noise signal is still applied to the muting circuit 9 (Fig. 2e).

A comparison between the Figs. 2d and 2e shows that the tuning behaviour depends in principle on the fact in which direction the tuning range is passed through. It will be obvious that the useful tuning range n in Fig. 2d is located highly asymmetrically relative to the correct tuning frequency $f_s = f_{00} + f_{z0}$. The muting ranges a , b and c are confusing for the user. The muting circuit 9 controlled by the control circuit 11 can only partly suppress the above-described effects and does not influence the asymmetrical tuning behaviour.

The circuit according to the invention shown in Fig. 3 differs from the prior art circuit in that an attenuator 13 is arranged between the output of the low-pass filter 7, which follows the FM demodulator, and the input of the limiter-amplifier 8 which controls the frequency of the oscillator 3, which attenuator is controlled by the control circuit 11 via an amplifier 14. For the rest the circuit comprises the same components, for which reason the same reference numerals are used. If the initial attenuation or initial gain of the attenuator 13 which can be reduced by the control circuit 11 or the amplifier 14, respectively, differs from the value 1, the transfer factor of the other components can be dimensioned such that approximately the same loop gain is obtained as in the circuit shown in Fig. 1.

As a result thereof, in open loop condition, the output signal U varies with the difference between the transmitter frequency and the oscillator frequency in the same way as in Fig. 2a when the attenuator 13 is inoperative or operative only at its initial attenuation or gain - cf. Fig. 4a, curve x . When however the attenuator 13 is operative and

its attenuation is at a maximum, its gain is reduced to such a low value that no limitation occurs anymore - compare Fig. 4a, curve y . The increase in the attenuation or the reduction in the gain must however be limited to such a value that the loop gain in the useful tuning range n and in the mirror-inverted range must remain higher than 1, as then only the possibility is excluded that tuning can be effected to a region having a positive loop gain.

Fig. 4b shows the variation of the output voltage U_1 of the control circuit 11 as a function of the difference between the transmitter frequency f_s and the oscillator frequency f_o . The control circuit may be, as is also the prior art circuit, a correlator comprising a low-pass filter which integrates the output voltage of a multiplier to an average value, one input of which being directly supplied with the intermediate frequency signal from the output of the limiter-amplifier 5 and the other input thereof being supplied by this signal being phase-shifted with a phase shift which depends linearly on the frequency, the phase shift being 180° at the target mean value f_{zo} of the intermediate frequency. A curve is then obtained which is symmetrical to the point $f_s = f_o$ and which has its minimum values when the difference frequency equalizes to the amount of f_{zo} . The output voltage U_1 is amplified by the amplifier 14 and compared to the voltage at its reference input 15, and the difference is amplified in a region about the target mean value whose magnitude depends on the choice of the voltage U_2 (cf. Fig. 4b broken line and solid line) at the reference input 15 of the amplifier, resulting in a control voltage which maintains the loop gain at its initial value, whilst in the outside regions of the intermediate frequency it is reduced. This effects an essential change in the tuning behaviour of the circuit as will be obvious from the Figures 4c to 4e.

Fig. 4c shows the variation of the oscillator frequency f_o as a function of the transmitter frequency f_s , again assuming that the initial tuning f_{oo} of the oscillator

is maintained constant, whilst the transmitter frequency f_s is changed. At relatively low transmitter frequencies the initial tuning is at first not changed, until the region s is reached. In this region or in a portion of this region - depending on the value of the reference voltage U_2 - the output voltage U_1 of the control circuit 11 exceeds the reference value U_2 so that the attenuator is made operative and the loop gain is reduced. As a result thereof the oscillator frequency here indeed follows the transmitter frequency (Fig. 4c), but not to the same extent as in the circuit shown in Fig. 1 (cf. Fig. 2c), until a lower value is reached which corresponds to the minimum of the curve y (Fig. 4a).

This is already followed by the region having a positive loop gain, which results in a frequency jump A ending in the useful tuning range n , as the loop gain is greater than unity also when the attenuator is operative. Although in this useful tuning range the output voltage U_1 of the control circuit 11 should be below the reference voltage U_2 , which would result in the attenuator being inoperative so that the full loop gain would be attained, the attenuator is at first still operative, as the voltage U_1 changes only comparatively slowly because of the relatively large time constants of the control circuit 11 (0.1 sec. or longer). This means that the loop gain becomes gradually greater, which results in a further increase of the oscillator frequency without a change in the transmitter frequency until finally the attenuator is not operative and the full loop gain is attained. The tuning range n is then passed through at whose end the oscillator frequency again changes suddenly (jump B), until the value f_{oo} is reached. Thereafter the oscillator frequency is independent of the transmitter frequency.

The behaviour of the signal at the input of the muting circuit 9 as a function of the transmitter frequency is illustrated by Fig. 4e. This Figure shows that the useful range n is located approximately symmetrically

to the transmitter frequency, at which the correct tuning is attained.

If instead thereof the tuning range is passed through, starting from higher transmitter frequencies f_s , the attenuation is at first fully operative so that the curve y determines the behaviour of the circuit. When the transmitter frequency is so low that the resulting intermediate frequency signal passes, at least partly, the low-pass filter and consequently a portion with a positive loop gain is reached, a jump C occurs again in the useful tuning range n , the attenuation however still being operative. Not until the transmitter frequency is decreased to such a low value that the signal U_1 falls short of the signal U_2 (Fig. 4b) does the full loop gain become operative and a new frequency jump C' is effected. Thereafter the remaining portion of the tuning range is passed through again until the difference between the transmitter frequency and the oscillator frequency has become so great that the voltage U_1 again exceeds the reference voltage U_2 and the attenuation of the attenuator is effective again. Then a jump D (Figs. 4a and 4c) is effected, until the region s is reached whereafter the oscillator frequency gradually decreases again to the initial value f_{oo} . The resulting tuning behaviour as a function of the transmitter frequency is shown in Fig. 4f. It will be obvious that the region c (cf. Fig. 2e), in which no signal is applied to the muting circuit 9 is omitted, as are also the regions a and b (cf. Fig. 2d and Fig. 4e).

So it has proved to be successful to improve the tuning behaviour of the circuit to a considerable extent by controlling the loop gain in dependence on the intermediate frequency. The residual disturbances (frequency jumps A, ... D, fringe tuning s and noise d , e) can be suppressed by the muting circuit, in correspondence with the prior art circuit disclosed in DE-A-30 32 701. It is not necessary for the muting circuit to completely suppress the signal, but it is sufficient when the signal is attenua-

ted to a considerable extent. As is also the case in the prior art circuit, a switch to an artificial noise generator can be made, when the intermediate frequency deviates from its target mean value f_{z0} by a predetermined amount.

5 It is not absolutely necessary for the attenuator to be arranged between the limiter-amplifier 8 and the low-pass filter 7. It must only be arranged such that the loop gain can be influenced thereby. It is also not necessary for the signal in the loop to pass the attenuator. 10 It is on the contrary sufficient when the gain of one of the circuits, for example, the FM demodulator 6, is controlled by the attenuator in such manner that the loop gain is changed. Fig. 5 shows an example of such an FM-demodulator.

15 This demodulator is what is commonly referred to as a quadrature demodulator, which comprises four transistors 21 ... 24 arranged as a cross-coupled differential amplifier, so in which each transistor has one electrode - and only this one electrode - in common with the three 20 other transistors. The input voltage, that is to say the intermediate frequency signal is applied to this circuit between the interconnected bases of the transistors 21 and 24 on the one hand and the transistors 22 and 23 on the other hand via the terminals 25. The emitter currents 25 for the transistors 21 and 22 and also 23 and 24 are supplied by a transistor 26 and 27, respectively whose emitters are also interconnected and to whose base electrodes, which are connected to the second input 35 also the intermediate frequency signal is applied - however with a phase shift 30 which depends linearly on the intermediate frequency, the phase shift being 90° at the target mean value f_{z0} of the intermediate frequency. A direct current source 28 is included in the common emitter lead of the transistors 26 and 27. The input voltages applied to the input terminals 35 25 and 35 are modulated by the circuit formed by the transistors 21 ... 27 and the direct current source 28, so that at the interconnected collectors of the tran-

sistors 22 and 24 a collector-signal current occurs which is proportional to the product of the intermediate-frequency input signals. The collector-signal current produces at a resistor 29 which is arranged between the said collectors and a positive supply voltage terminal a signal voltage which can be taken off from output 30. A capacitor 31 which is arranged in parallel with the resistor 29 operates together with this resistor as a low-pass filter, so that a separate low-pass filter 7 is not required, provided the time constant of the RC-network 29, 31 is adequately dimensioned.

For this demodulator the amplitude of the output signal also depends on the direct current from the direct current source 28, and more specifically, the amplitude is the greater the greater this direct current is. The gain of such a demodulator can therefore be reduced by shunting a portion of the direct current. The two transistors 32 and 33 whose emitter terminals are interconnected and connected to the emitter terminals of the transistors 26 and 27 via a resistor 34 are used for this purpose. A control voltage U_3 which may be derived from the output voltage of the control circuit 11 or the amplifier 14, respectively is applied to the interconnected base electrodes of the transistors 32 and 33. If the voltage U_3 is positive compared with the voltage at the input of the transistors 35, a portion of the direct current produced by the direct current source 28 is shunted via the resistor 34 and the two transistors, the direct current portion being equally divided over the two transistors. This results in a lower gain of the demodulator and therewith in a reduced loop gain. If in contrast therewith the voltage U_3 is lower than the d.c. voltage at the base terminals of the transistors 26 and 27, substantially no direct current is shunted and a higher demodulator gain and therewith a higher loop gain, is obtained.

In principle, one single transistor would be sufficient to vary the demodulator gain. However, the d.c.

voltage at the output 30 would then vary, which would result in an unwanted shift of the operating point in the loop. This shift is obviated in that the one half of the shunted direct current of the direct current source 28

5 is applied to the output of the FM demodulator via the transistor 33 whose collector is connected via the output 30 to the resistor 29, whereas the other half of the shunted direct current passes the collector of the transistor 32, which is connected to the positive supply voltage, so that
10 this portion of the current is ineffective for the operating point. That half of the shunted direct current taken off from the direct current input of the demodulator and passing the transistor 33 and the resistor 29 accurately compensates for the reduction in the collector-direct current
15 of the transistors 22 and 24 which passes the resistor 29, because the direct current supplied by the direct current source 28 via the transistors 26 and 27 is uniformly distributed over the four transistors 21 ... 24. In other words, when the demodulator gain is reduced, the current
20 passing through the transistor 33 is increased by the same amount by which the sum of the collector direct currents of the transistors 22 and 24 is reduced, so that the d.c. voltage at the output 30 is independent of the demodulator gain.

25 In the circuit shown in Fig. 5, the attenuator is formed by the transistors 32 and 33 together with the resistor 34. Only a direct current flows through this attenuator so that the signal in the loop cannot be distorted by it. When the direct current level at the output
30 of the control circuit 11 and also the amplitude of the signal U_1 produced by it are chosen correctly, the transistors 32 and 33 may alternatively be controlled by the control circuit 11. In this case the additional cost compared to the prior art circuit of Fig. 1 is only formed by
35 the transistors 32 and 33 and the resistor 34. Then, when the intermediate frequency changes, the demodulator gain would not change suddenly, but more or less smoothly and

continuously. This however would not deteriorate the function of the circuit.

Sofar it has been assumed that the control circuit 11 was formed by a correlator - as is also the case
5 in the prior art circuit disclosed in DE-A-30 32 701. Fig. 6a shows another embodiment of such a control circuit. Therein the output voltage U_d of the demodulator whose variation as a function of the difference $f_s - f_o$ is illustrated in an idealized manner in Fig. 6b is applied to
10 the input of a circuit 40 for measuring the absolute signal amplitude, and at whose output the signal shown in Fig. 6c is consequently obtained. Such circuits for measuring the absolute signal amplitude of an FM demodulator output signal are known per se from DE-B-29 09 520. The output voltage
15 of the circuit 40 is applied through a low-pass filter 41, whose time constant is preferably significantly higher than the time constant of the low-pass filter 7, to the attenuator either directly or via the amplifier 14 (Fig. 3), for which the reference voltage U_2 at the input 15 is
20 chosen adequately.

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Claims:

1. A receiver circuit comprising an oscillator (3) whose frequency is controllable by a voltage applied to a control input, a mixer stage (2) which mixes the oscillator signal with an aerial signal and forms an intermediate frequency signal therefrom, a frequency-voltage converter (6) to which the intermediate frequency signal is applied and from whose output signal an audio-frequency signal having a d.c. component for the control input of the oscillator is derived, and a control circuit (11) for producing a control signal which depends on the deviation of the frequency of the intermediate-frequency signal from a target mean value (f_{zo}), characterized in that a controllable attenuator (13) for controlling the loop gain in the loop formed by the oscillator (3), the mixer (2) and the frequency-voltage converter (6) is provided and in that the attenuation of the attenuator is controlled by the control circuit in such manner that the loop gain is reduced to a lower value which is larger than unity when the intermediate frequency (f_z) deviates from the target mean frequency (f_{zo}) by more than a minimum value.

2. A receiver circuit as claimed in Claim 1, characterized in that the control circuit (11) is in the form of a correlator, the correlation period corresponding to half a period of the target mean value (f_{zo}) of the intermediate frequency.

3. A receiver circuit as claimed in any of the preceding Claims, characterized in that a muting circuit (9) for fully or partially suppressing the reproduction of the useful signal derived from the aerial signal is provided and in that other than the attenuator (13) the control circuit (11) controls the muting circuit (9) such that the muting circuit is activated when the intermediate fre-



quency (f_z) differs by a predetermined amount from the target mean value (f_{z0}).

4. A receiver circuit as claimed in any of the preceding Claims, characterized in that the output of the correlator (11) is coupled to an input of a comparator circuit to whose other input (15) a reference voltage (U_2) is applied, and in that the output of the comparator circuit is connected to the attenuator (13).

5. A receiver circuit as claimed in any of the preceding Claims, characterized in that the frequency-voltage converter (6) comprises a multiplying circuit (21 ..27) whose gain is controlled by the control circuit (11).

6. A receiver circuit as claimed in Claim 5, characterized in that the multiplying circuit (21, ... 27) is constructed such that its output signal varies in the same sense with a direct current applied thereto and in that the attenuator (32,33) is arranged and formed in such manner that it shunts a portion of the direct current.

7. A circuit arrangement as claimed in Claim 6, in which the direct current voltage level at the output of the multiplying circuit is determined by the direct current applied to the multiplying circuit, characterized in that the portion of the direct current shunted by the attenuator is applied at least partially to the output of the multiplying circuit.

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