

"FM stereo receiver"

The invention relates to a FM stereo receiver including a mixer stage for mixing an input signal with the signal of a first oscillator having an electrically controllable frequency, an FM demodulator for demodulating the input signal converted into the intermediate frequency range and a circuit for recovering the pilot signal contained in the input signal.

Generally, receivers of such a type have an intermediate frequency of 10.7 MHz. There are, however, also FM receivers having a very low intermediate frequency (for example 80 kHz), which is of the order of magnitude of the frequency of the pilot signal. An advantage of a receiver having such a low intermediate frequency is the possibility to realize the overall receiver to a very large extent by one single integrated circuit. The low intermediate frequency has, however, the disadvantage that interferences in the reception occur when such a circuit is implemented as a stereo receiver and stereo signals are to be received thereby.

The present invention has for its object to provide a circuit arrangement of the type defined in the opening paragraph having such a structure that such interferences in the reception are suppressed to a very large extent, also when a low intermediate frequency is used.

According to the invention, this object is accomplished by means of the measures described in the characterizing part of Claim 1.

Investigations which resulted in the invention have shown, that at the output of an FM receiver of the type defined in the opening paragraph, noise components occur whose spacing from the intermediate frequency and also from twice the intermediate frequency corresponds to an integral multiple of the pilot signal frequency, the amplitude of the noise component being lower according as the above-mentioned frequency spacing is larger. With FM stereo receivers having a higher intermediate frequency these components are located very far outside the useful low frequency signal range and consequently do not interfere. In contradistinction thereto, with intermediate frequencies of, for example, 80 kHz, these side bands extend into the useful signal range, that is to say into the

range of the differential signal modulated on the sub-carrier (38 kHz). In this case the noise components become noticeable in an annoying manner during reproduction.

According to the invention, these noise components are now reduced because of the fact that a loop having a negative loop gain for the frequency of the pilot signal is formed. As a result thereof the oscillator produces an output signal which - as also the input signal applied to the mixer stage - is frequency-modulated by the pilot signal. For a negative loop gain the frequency modulation comprised in the input signal and originating from the pilot signal is partially compensated for by the frequency modulation contained in the oscillator output signal, thus significantly reducing the interferences.

The invention is not only suitable for use with FM stereo receivers having a low intermediate frequency, but basically with all types of FM receivers in which the pilot signal produces interferences.

DE-PS 20 52 098, for example, discloses a noise canceller circuit in which the signal path incorporates a noise detector-controllable switch which is opened in the event of an interference, the instantaneous value of the signal immediately prior to the interference being stored in a capacitor coupled to the switch. When such a noise canceller circuit is used, the pilot signal produces the same interferences which, in the prior art circuit must be eliminated, by means of a parallel resonant circuit. When the invention is used such a parallel resonant circuit is superfluous.

DE-OS 27 39 668 also discloses a receiver in which the reception is disturbed by the pilot signal and which consequently comprises a circuit for filtering or compensating for, respectively, the pilot signal. Also this compensation or filter circuit is not required when, in accordance with the invention, the pilot signal is already reduced before the FM demodulator.

The invention will now be described in greater detail by way of example with reference to the accompanying drawing, in which:

Fig. 1 shows a block circuit diagram of a receiver according to the invention and

Fig. 2 shows the frequency spectrum which would be produced

in such a receiver when the invention were not used.

Fig. 1 shows the essential portion of an FM-stereo receiver comprising a receiver section 1, a circuit 2 for recovering the pilot signal and a circuit portion for reducing the pilot signal in the received signal. The receiving section 1 is known per se, for example from the publication Technischen Information TI 840217 "Die integrierte Empfängerschaltung TDA 7000", published by Messrs. Valvo, or EP-A-0088467, respectively. Therein an input signal is applied from an aerial 3 to a mixer stage 4 and mixed therein with the output signal of a first oscillator 5 having an electronically controllable frequency. The output signal of the mixer stage 4 is applied via an IF-amplifier 6 to a limiting amplifier 7 which, in a wide input voltage range, produces a constant-amplitude IF-voltage and suppresses to a very large extent any noise amplitude-modulation contained in the IF signal. The output signal of the limiting amplifier is demodulated in an FM-demodulator which is constituted by a quadrature demodulator, and comprises a frequency-dependent phase shifter 8 and a multiplier stage 9. The output signal of the limiting amplifier is applied on the one hand directly and on the other hand via the frequency-dependent phase shifter 8 which is of such a structure that it produces a 90° phase shift at the intermediate frequency of, for example, 80 kHz to the multiplier stage 9. The output signal of the mixer stage is applied to the control output of the first oscillator 5 via a low-pass filter 10 having a cut-off frequency of only a few kHz and a further limiting amplifier 11.

The components 4 to 11 form a loop which has a negative loop gain of the order of magnitude of 4 or 5 in a frequency range which depends on the upper cut-off frequency of the low-pass 10. Consequently, a dynamic negative feedback is obtained which is compressed by the frequency swing of the input signal, so that on the one hand the low intermediate frequency of 80 kHz does not result in clipping of the transmission band and on the other hand a static negative feedback is effected, in response to which the average oscillator frequency assumes such a value that the temporal mean value of the frequency of the output signal of the mixer stage 4 corresponds to that frequency at which a phase shift of approximately 90° is produced by the phase shifter 8. The low

frequency output signal is taken from the output of the low-pass filter 10 and applied to an output terminal 12.

The output signal of a multiplier stage 9 which forms part of the FM quadrature demodulator is applied to the input of the circuit 2 for recovering the pilot signal; it is fundamentally however possible to use the output signal of the low-pass filter 10 for this purpose. The circuit 2 includes a mixer or a multiplier stage 13, respectively, in which the output signal of stage 9 is mixed with a 19 kHz square-wave signal. A low-pass filter 14 arranged subsequent to the mixer stage 13 suppresses the mixed products resulting from the mixing or multiplying procedure on the sum frequency and only products having a differential frequency are passed through, which are applied to the control input of a second electronically frequency-controllable oscillator 15, which produces an output signal having a frequency of 76 kHz. The frequency of this output signal is divided and shaped in a circuit 16. The circuit 16 produces at a first output 17 a first 19 kHz square-wave signal, at a second output 18 a second 19 kHz square-wave signal phase-shifted through 90° , and at a third output 19 a 38 kHz signal whose positive edges coincide with the zero crossings of the 19 kHz square-wave signal at the first output 17, and is used for decoding the stereo signal. The second 19 kHz signal at the output 18 is applied to a second input of the mixer stage 13 and, as described in the foregoing, is mixed therein with the output signal of the multiplier circuit 9. As the low-pass filter 14 subsequent to the mixer stage 13 is dimensioned such that only those mixed products are allowed to pass which are obtained from mixing the 19 kHz signal with the pilot signal contained in the output signal of the multiplier stage 9, the output signal of the oscillator 15 only depends on the phase difference between the pilot signal and the signal at the output 18. In the steady state it adjusts itself such that a phase difference of accurately 90° consists between the said two signals, the output signal of the low-pass filter 14 being zero.

Processing the differential signal modulated on the sub-carrier is not shown in greater detail in the drawing. This operation may be effected in the manner described in EP-A-0088467.

Fig. 2 shows the frequency spectrum which would be obtained at

output 12 when the aerial input signal were only modulated with the pilot signal, and the circuit according to the invention still further to be described were not available. A series of noise components are shown. A more accurate analysis shows, that there is a first group of noise components whose frequency spacing of twice the value of the intermediate frequency f_{IF} corresponds to an integral multiple of the frequency f_p of the pilot signal. This group of interferences is basically determined by the quadrature demodulator. In addition, there is a second group of noise components whose frequency spacing from the intermediate frequency f_{IF} always corresponds to an integral multiple of the frequency f_p of the pilot signal and are determined by the finite IF-suppression of the IF-demodulator.

As will be obvious from the diagram, the noise components extend into the frequency range around the sub-carrier f_H , in which the side bands of what is commonly referred to as the differential signal are located. During decoding of the stereo signal some of these components become consequently audible in an annoying manner. These components are suppressed, at least partially, by the invention.

The circuit for suppressing the noise components includes a multiplier stage 20, which may be of the same structure as the stages 4, 9 and 13. One input of the multiplier stage 20 is connected to the output 17 of the circuit 16 and the other input to the output of the FM-demodulator 8, 9, i.e. also to the input of the PLL-circuit 20. The input signals applied to the two inputs of the multiplier stage 20 consequently have either the same or the opposite phase positions, so that the output signal of this stage contains a d.c. component and an a.c. component of twice the frequency of the pilot signal, which is suppressed by means of a low-pass filter 21.

The low-pass filter 21 connects the output of the multiplier stage 20 to an input of a further multiplier stage 22. Therefore, the d.c. component which is produced by the stage 20 and is proportional to the amplitude of the pilot signal at the output of the FM demodulator 8, 9 is present at this input. The other input of the further multiplier stage 22 is connected to the output 17 of the circuit 16, at which output there is a 19 kHz signal which has the same phase as

the pilot signal at the output of the FM demodulator 8, 9. Consequently, a 19 kHz signal, whose amplitude is proportional to the d.c. component at the output of the low-pass filter 21, i.e. the amplitude of the pilot signal at the output of the FM demodulator 8, 9 appears at the output of the multiplier stage 22.

This 19 kHz square-wave signal is converted by a stage 23 into an at least substantially sinusoidal signal having the same frequency and phase. This stage which may alternatively be included in the connecting line between the multiplier stage 22 and the output 17, may, for example, contain appropriate filters which suppress the harmonics of the square-wave signal. The stage 23 may be omitted when the 19 kHz signal is produced by a circuit which synthesizes a substantially sinusoidal oscillation from several triangular signals, in the manner disclosed in the DE-OS 33 11 072. Fundamental for all these cases is only that a 19 kHz signal is available which is to a large extent free from harmonics and whose amplitude is proportional to the amplitude of the pilot signal at the output of the FM demodulator and that there is a fixed phase relationship between these two signals.

The output signal of the stage 23 is superposed in an adder stage 24 on the output signal of the limiting amplifier 11 and the sum signal is applied to the control input of the first frequency-controllable oscillator 5. When the signal applied to the adder stage 24 has such a phase position that a loop having a negative loop gain is obtained - in this case the output signal of the oscillator 5 is frequency-modulated by the 19 kHz signal in the same manner as the aerial signal is modulated by the pilot signal -, then at the output of the mixer stage an intermediate-frequency signal is produced, which, compared with the input signal, has a significantly reduced frequency modulation by the pilot signal. As consequently at the input of the FM demodulator 8, 9 a signal is available which is only frequency-modulated to a very small extent by the pilot signal, the noise-components produced thereby at the output 12 are significantly reduced.

The output signals of the PLL-circuit 2 are independent to a very large extent of the amplitude of the pilot signal contained in the aerial signal. If the output signal of this circuit were directly applied to the adder circuit 24, then the loop gain produced in the loop formed by the blocks 4, 6 ... 9, 2, 24, 5 were

not constant. This undesired effect is avoided by the use of the multiplier stage 22, in which the output signal of the circuit 2 is multiplied by a value proportional to the pilot signal amplitude at the output of the FM demodulator, so that the amplitude of the output signal of the multiplier stage 22 is proportional to the amplitude of the pilot signal and the loop gain for the pilot signal is constant.

The selective components in the loop, more specifically the intermediate-frequency filter 6, effect that the pilot signal at the output of the FM demodulator is phase-shifted relative to the pilot signal contained in the aerial input signal in the form of a modulation. This phase shift must then be compensated for again, to ensure that a negative loop gain is obtained. To that end, an appropriate phase shifting member may be provided in the loop, for example between the PLL-circuit 2 and the input of the multiplier stage 22. The desired phase shift is however also obtainable by applying to the input of the multiplier stage 22 in addition to the 19 kHz square-wave signal at the output 17 of the circuit 16, a portion of the 19 kHz square-wave signal located at output 18 which is shifted through 90° relative to the 19 kHz square-wave signal, as is illustrated by means of the broken line 25. It can namely be proved that from the weighted sum of two signals shifted through 90° relative to each other, and which are optionally also inverted, a super-position signal with any desired phase shift can be produced.

The noise components generated by the pilot signal are suppressed to a greater extent according as the loop gain is higher; with an infinite loop gain these components are fully suppressed. Because of production tolerances different delays occur in the individual receivers, which results in a finite loop gain in the relevant receiver, if an individual compensation were not effected. In practice, it is therefore more advantageous to choose a loop gain between 10 and 100, which can easily be adjusted independently of production tolerances and without an additional compensation. The noise components are then indeed not fully suppressed, but are at least reduced from 20 to 40 dB, which is sufficient for the majority of cases.

In the foregoing, the invention is described on the basis of a

receiver having a low intermediate frequency. The invention is, however, also useful for all those cases in which a pilot signal contained as a frequency modulation in the input signal produces interferences, for example in FM receivers in accordance with DE-PS 20 52 098 or EP-A-0088467, respectively, in which when the invention is used, the noise canceller circuit can be of a significantly simpler structure.

CLAIMS:

1. An FM stereo receiver including a mixer stage (4) for mixing an input signal with the signal of a first oscillator (5) having an electrically controllable frequency, an FM demodulator (8, 9) for demodulating the input signal converted into the intermediate frequency range and a circuit (2) for recovering the pilot signal contained in the input signal, characterized by a loop having a negative loop gain for the frequency of the pilot signal for at least partially suppressing interferences caused by the pilot signal, comprising the mixer stage (4), the FM-demodulator (8, 9), the circuit (2) for processing the pilot signal and the first oscillator.
2. An FM stereo receiver as claimed in Claim 1, characterized in that for recovering the pilot signal the circuit incorporates a second controllable oscillator (15) which is electrically controllable in frequency, from whose output signal a pilot signal is derived which is applied to the control input of the first oscillator (5) via a transfer element (22) having a transfer factor which is linearly controlled in dependence on the pilot signal amplitude.
3. An FM stereo receiver as claimed in one of the preceding Claims, characterized in that the circuit for recovering the pilot signal is connected to the control input of the first oscillator (5) via a circuit (23) for suppressing the harmonics.
4. An FM stereo receiver as claimed in any one of Claims 1 to 3, characterized in that the low-frequency output signal is also applied to the control input of the first oscillator (5).

