

Circuit arrangement for an FM-receiver.

The invention relates to a circuit arrangement as claimed in the pre-characterizing part of the main Claim. Such a circuit arrangement is disclosed in DE-A-3032701. Herein the total FM-demodulator output-
5 signal - so not only its DC-component - is employed to control the oscillator frequency. So also in the case of being tuned to a transmitter, the oscillator frequency changes continuously in accordance with the LF-output signal and more specifically in such a way that the
10 frequency swing of the frequency-modulated input signal is reduced. It is therewith possible to choose an intermediate frequency whose magnitude is equal or even smaller than that of the frequency swing. For FM-receivers whose input signal has, as shown, a frequency
15 swing of 75 kHz an intermediate frequency of, for example 70 kHz may be chosen. This has the advantage that filtering can be effected in the intermediate-frequency range by means of a simple RC low-pass filter which does not require adjustment.

20 This prior art FM-receiver has the drawback that the amplitude of the output signal and the transmission bandwidth are highly dependent on the tuning frequency of the oscillator when the oscillator frequency is controlled by the FM-demodulator in known manner by
25 means of a capacity diode.

Moreover, it is known from DE-A-2706662 to provide a DC-controlled resonant circuit capacitance for the oscillator in an FM demodulator, the DC bias of the resonant circuit capacitance being determined
30 in dependence upon the adjusted carrier frequency. A constant frequency swing of the modulated carrier should thereby be achieved in the overall frequency range.

The invention has for its object to provide a circuit arrangement of the above-mentioned type of such a construction that the amplitude of the output signal and the transmission bandwidth are substantially independent of the tuning frequency of the oscillator.

According to the invention, this is accomplished in that the oscillator circuit can be detuned by a reactance circuit comprised in the loop whose reactance is controlled by the FM-demodulator output signal has the same dependence on the tuning frequency of the oscillator circuit as the quotient of an inductance or capacitance change, respectively and the oscillator frequency change being effected by said inductance or capacitance change in the oscillator circuit.

Here, a reactance circuit is defined as a circuit comprising active elements whose susceptance is controllable proportionally to the signal at the control input.

The invention is based on the recognition that the dependence of the amplitude of the output signal and the transmission bandwidth on the tuning frequency is a result of the frequency-dependence of the loop gain. If now the susceptance depends in the manner described on the tuning frequency, a tuning-frequency independent fine tuning slope (i.e. the quotient of the change of the oscillator frequency and the change of the instantaneous value of the FM-demodulator output signal) is obtained. This results in a frequency-independent loop gain or a frequency-independent amplitude of the output signal and a frequency-independent transmission bandwidth, respectively.

The required frequency dependence of the reactance depends on the construction of the oscillator circuit and more specifically on the fact how this circuit is tuned. When, for example the oscillator circuit is inductively tuned and a capacitive retuning or detuning, respectively, is used for the instantaneous

change of the oscillator frequency in dependence on the demodulator output signal, the capacitance generated by the reactance circuit must be inversely proportional to the tuning frequency. In oscillator circuits which
5 are capacitively tuned, however, it is provided in accordance with a further embodiment of the invention that the reactance circuit is of such a construction that a capacitance which is proportional to the inverse value of the third power of the tuning frequency is
10 operative at its output. The conductance of the reactance circuit must then be as small as possible and be independent of the oscillator frequency.

A capacitively operative reactance circuit having such a frequency dependence is characterized
15 in that the reactance circuit comprises a higher order low-pass or band-pass network to which the oscillator signal is applied, in that the filtered signal is multiplied in a multiplying stage by the FM-demodulator output signal, in that the product signal is fed back
20 as an impressed current to the oscillator circuit so that a capacitive susceptance is produced in parallel with the oscillator circuit and in that the upper cutoff frequency of the low-pass or band-pass network is chosen such that the maximum of the product of the
25 susceptance and the square of the frequency is located in the tuning frequency range or in the vicinity thereof. In a preferred embodiment the reactance circuit comprises a low-pass network having two low-pass filters. The low-pass filters may be decoupled relative to each
30 other, that is to say, circuit elements are provided between the low-pass filters in such a way that the transfer function of each of the two low-pass filters is not affected by the other low-pass filter, so that the total transfer function corresponds to the product
35 of the transfer functions of the individual low-pass filters.

Such a reactance circuit can be used advantageously not only in circuits for receivers of the above-mentioned type, but alternatively also in different receivers for automatic fine-tuning.

5 The capacitance generated by this reactance circuit is not accurately proportional to the inverse value of the third power of the tuning frequency, but the deviations from the exact value are slight when the cutoff frequencies of the low-pass filters are chosen
10 such that the maximum of the product of the susceptance and the frequency is within the tuning frequency range of the oscillator circuit. If the maximum is located at, for example, approximately 98 MHz, then for the overall FM-range (88 - 108 MHz) deviations of only some 0/00
15 are produced. When the tuning frequencies are very high, for example in the ultra-short wave range, the low-pass filters can be realized by RC-components having such a short time constant that they can be produced in integrated circuit technique.

20 The invention will be further described with reference to the accompanying drawing. Herein:

Fig. 1 is a block diagram of a receiver in accordance with the invention,

Fig. 2 is a block diagram of a reactance
25 circuit in accordance with the invention,

Fig. 3 shows the concrete construction of the reactance circuit.

The block diagram of an FM-receiver shown in Fig. 1, comprises a mixing stage 2, which mixes the
30 input signal supplied by an input amplifier 1 which amplifies the aerial signal, with the oscillator signal produced by an oscillator 3. The difference between the frequency of the input signal and the frequency of the oscillator signal is comparatively small, - 70 kHz,
35 so that the required selection in the intermediate-frequency range can be effected by means of a low-pass filter 4 of a simple construction. The low-pass filter

- 4 is followed by an FM-demodulator 5, which is of such a construction that the amplitude of its output signal is proportional to the frequency deviation between the input signal and the intermediate frequency (70 kHz).
- 5 The output signal of the FM-demodulator 5 is applied via a suitable filter which is used for the purpose of stabilisation and which may be a simple low-pass filter in the case of mono-receivers whose cutoff frequency is lower than that of the lowpass filter 4, which is,
- 10 however, dimensioned in such a way that the low-frequency output signal of the demodulator 5 is not subjected to a frequency-dependent attenuation, and via an isolating capacitor 7 which removes the direct current component from the demodulator output signal, to an amplifier 8
- 15 having a de-emphasis element, not further shown, which amplifier supplies a loudspeaker 9.

- The output signal of the filter 6, that is to say its LF and DC component, respectively is also applied to a control input 10 of a reactance circuit 11.
- 20 This reactance circuit functions at the output 12 as a capacitance which varies proportionally with the signal at its control input 10. This capacitance is in parallel with the capacitively tunable oscillator circuit 31 of the oscillator 3, this oscillator circuit being
- 25 in the form of a parallel resonant circuit, the detuning of the oscillator circuit 31 produced in response to the change in reactance remaining so small compared to the tuning frequency as to be disregarded. The change in the oscillator frequency produced by the reactance
- 30 circuit 11 is effected such that the difference between the frequencies of the input signal and the frequency of the oscillator signal is reduced. Depending on the magnitude of the (negative) loop gain in the loop formed by the components 2 ... 6, 11 the frequency swing of
- 35 the input signal is compressed to a greater or lesser extent thereby. A practical value of this compression is at approximately 5, so that at ultra-short wave reception only a frequency swing of 15 kHz is produced

behind the mixing stage, so that the intermediate frequency may be lower than the frequency swing of the input signal, without a resultant negative effect on the transmission quality.

5 A problem with such a circuit is that the change in the tuning frequency in response to a given capacitance change of the reactance circuit 11 depends on the magnitude of this tuning frequency, and varies more specifically to the third power thereof. The
10 frequency change related to the capacitance change is therefore almost twice as large at the upper limit (108 MHz) of the ultra-short wave range than at the lower limit (88 MHz). As a result thereof, also the loop gain changes by the third power of the tuning
15 frequency and, consequently, also the amplitude of the LF-output signal and also the LF-transmission bandwidth. As the reactance circuit 11 is of such an implementation that its capacitance changes with the inverse value of the third power of the tuning frequency and also
20 proportionally to the amplitude of the signal at the control input 10, a constant loop gain is obtained and the above-described disadvantages of a frequency-dependent loop gain are eliminated.

Fig. 2 shows the block diagram of a reactance
25 circuit* having such a frequency dependence. The circuit comprises a first amplifier 13 having a highly resistive input which does not substantially load the oscillator circuit 31. This amplifier is followed by a low-pass filter 14 having the transfer function $1/(1+j\omega T_1)$,
30 wherein ω is the frequency of the signal at point 12 and T_1 is a time constant which depends on the dimensioning of the low-pass filter. This low-pass filter is followed by a second amplifier 15, which decouples the low-pass filter 14 from a further low-pass filter 16 connected
35 to the output of the amplifier 15 and having the transfer function $1/(1+j\omega T_2)$, wherein T_2 is a time constant which depends on the dimensioning of the low-pass filter 16, so that the transfer function of each of the two

low-pass filters is not affected by the input or output, respectively of the other low-pass filter. The output signal of the low-pass filter 16 is applied to an input of a multiplying circuit 17, a further input 10 of which is the control input of the reactance circuit and to which the output signal of the FM-demodulator 5 is applied. A signal which is inter alia proportional to the product of the transfer functions of the low-pass filters 14 and 16 and also to the amplitude of the signal at the control input 10 is produced at the output of the multiplying circuit 17.

The multiplying circuit 17 has a highly resistive output and consequently supplies an impressed current which is supplied to the output terminal 12 and to the input of the decoupling amplifier 13. The susceptance value then obtained is proportional to the imaginary portion of the product of the transfer functions of the two low-pass filters and capacitive when the elements 13, 15, 17 produce an overall phase shift of 180° .

This product or this susceptance, respectively, corresponds, however, in only a limited frequency range to a capacitance which is proportional to the inverse value of the third power of the frequency. The range in which this condition is satisfied, is characterized in that the product of the susceptance and the square of the tuning frequency is constant, which is the case in the range of the maximum of this product. As this maximum is usually flat, this condition is also satisfied in a fairly large frequency range.

When the two low-pass filters 14 and 16 have, for example, the same frequency characteristics, the maximum of the last-mentioned product is substantially a factor $\sqrt{3}$ higher than the 3 dB cutoff frequency of the two low-pass filters. When the maximum is located in the tuning range of the oscillator 3, the reactance circuit forms a capacitance which varies approximately

inversely proportional to the third power of the tuning frequency. The deviations are smaller as said tuning range is smaller, compared to the central frequency of this range. With ultra-short wave reception it has, for example, been found that the deviation from the ideal value within the overall tuning range is less than 0.5%, when the 3 dB cutoff frequency is located at approximately 56.3 MHz.

The time constants T_1 and T_2 of the two low-pass filters need, however, not be equal to each other. Equally satisfactory results are obtained when, for example, the 3 dB cutoff frequencies of the two low-pass filters and the inverse value of the time constants, respectively evidence a ratio of $3/4 : 4/3$ and the higher cutoff frequency is approximately 26% below the tuning range or when the ratio between the two cutoff frequencies is $1 : 4$ and the tuning frequency or the centre of the tuning frequency range, respectively is 10% above the higher 3 dB cutoff frequency. The larger the distance between the two cutoff frequencies, the smaller the distance between the higher of the two cutoff frequencies and the superjacent centre frequency of the tuning range must be.

A preferred embodiment of the reactance circuit shown in the block diagram of Fig. 2 is shown in Fig. 3. The decoupling stage 13 is here provided by an emitter-follower having the npn transistor 131 and the emitter-current source 132. The base of the transistor 131 is connected via the terminal 12 and the inductance of the oscillator circuit 31 to the same voltage U_B to which also the collector of this transistor is connected. A 750 Ohm resistor 141 which together with a 1.8 pF capacitor 142 forms the first low-pass filter 14 is connected to the emitter. The subsequent decoupling stage 15 is also here provided by an emitter follower having the transistor 151 and the current source 152 (the two current sources 132 and 152 produce a 100 μ A impressed

direct current), the emitter of the transistor 151 being connected to a 750 Ohm resistor 161 which together with a capacitor 162, whose other end is connected to the supply voltage U_B forms the low-pass filter 16.

- 5 The junction of the resistor 161 and the capacitor 162, that is to say the output of this low-pass filter is connected to the base of an npn-transistor 171, whose emitter is connected to the emitter of a transistor 172. The base of the transistor 172 is connected to the
- 10 positive supply voltage via two diodes which are arranged in series in the forward direction and through which a direct current (100 μ A) produced by a direct source 175 flows, so that the base d.c. voltages of the transistors 171 and 172 are substantially equal to each
- 15 other. For signals having frequencies located in the ultra-short wave range a capacitor 176 forms substantially a short circuit for the diodes. A controllable current source 177, which produces a current proportionally to the instantaneous value of the signal at the control
- 20 input 10 is included in the common emitter lead of the transistors 171, 172. This current is divided substantially equally over the two transmitters 171 and 172, the current from the transistor 172 flowing to the supply source and the current from the transistor 171 being
- 25 feedback to the base of the transistor 131 and to the output terminal 12, respectively.

The reactance circuit described with reference to Fig. 3 is suitable for use in FM-receivers. The 3 dB cutoff frequency (the inverse value of the product

30 of the 750 Ohm resistor and the 1.8 pF capacitor) is considerably higher than shown in Fig. 2. However, when the input capacitances of the transistors 151 and 171 in parallel with the capacitors 142 and 162 are taken into account, it will be obvious that the required

35 transfer functions of the low-pass filters can then be obtained. Since the capacitances of the capacitors 142, 162 and 176 are all extremely small, the whole reactance

circuit can be produced in a simple way with integrated circuit technique.

The reactance circuit shown in Fig. 2 and Fig. 3, respectively has a negative conductance when the phase shift of the components 13, 15 and 17 amounts to 180° , as a result of which the oscillator 3 is undamped to an additional extent. This oscillator must be dimensioned such that it nevertheless continues to oscillate correctly.

The conductance of the reactance circuit increases proportionally to the current of the current source, that is to say proportionally to the output signal of the FM-demodulator and also the extent to which the oscillator is undamped changes accordingly. In certain circumstances this may result in an unwanted amplitude modulation of the oscillator signal and of the IF signal. This can be prevented by controlling the oscillator in dependence on the LF-output signal such that the dependence of the oscillator amplitude on the LF output signal is at least approximately compensated for.

In addition, the conductance also depends on the oscillator frequency, which is, however, not very disturbing, at least when used in the ultra-short wave range.

Instead of being connected to the collector of the transistor 171 the terminal 12 may alternatively be connected to the collector of transistor 172. The admittance between the terminals 12 and ground then inverts its sign. A negative capacitance is then obtained instead of a (positive) capacitance - that is to say the capacitance of the oscillator circuit is reduced by the parallel-arranged reactance circuit - but also this negative capacitance has the required frequency dependence. The conductance of the reactance circuit is then positive, that is to say the oscillator is undamped, which must be taken into account when dimensioning the

oscillator. The dependence of this conductance on the signal at the control input 10 may, however, be compensated for in a corresponding manner as described above.

The reactance circuit operates satisfactorily, even when the decoupling stage 15 and 151, 152, respectively is omitted, so that the low-pass filters 14 and 16 are directly arranged in cascade. The desired frequency dependence of the susceptance is then, however, only obtained when the low-pass filters are dimensioned differently. If, for example, the low-pass filters are identical, their 3 dB cutoff frequency, that is to say the inverse value of their time constant, must be at approximately 36.8% of the centre frequency of the tuning range of the oscillator. Instead of both low-pass filters 14 and 16 networks are applicable, whose susceptance varies at least proportionally to the square of the frequency within the tuning range. The frequency range in which such a variation occurs is largest around or in the vicinity of the maximum of the product of the susceptance and the square of the frequency, which means that this maximum should occur in the tuning range or in the vicinity thereof. Such networks may be second or higher-order networks and may have a low-pass or a bandpass characteristic with a given upper cutoff frequency defining the said frequency range.

CLAIMS:

1. A circuit arrangement for an FM-receiver having a loop whose loop gain is negative at least for the lower frequencies of the demodulated signal and comprising an FM-demodulator (5), an oscillator circuit (31) whose frequency is controlled by the output signal of the FM-demodulator (5) and which is tunable by means of a capacitance or inductance change, and a mixing stage (2), which mixes the oscillator signal with an input signal and its output being coupled to the input of the FM-demodulator (5), characterized in that the oscillator circuit (31) can be detuned by a reactance circuit (11) comprised in the loop whose reactance ~~is~~ controlled by the output signal of the FM-demodulator (5) has the same dependence on the tuning frequency of the oscillator circuit (31) as the quotient of an inductance or capacitance change, respectively and the change of the oscillator frequency caused thereby in the oscillator circuit.
2. A circuit arrangement as claimed in Claim 1, in which the oscillator circuit is tunable in accordance with a variable capacitance, characterized in that the reactance circuit (11) is of such a construction that a capacitance is active at its output, which capacitance is proportional to the inverse value of the third power of the tuning frequency.
3. A circuit arrangement for a receiver comprising a capacitively active reactance circuit controlled by an FM demodulator output signal, for influencing the frequency of an oscillator circuit, more specifically as claimed in Claim 2, characterized in that the reactance circuit comprises a higher-order low-pass or band-pass network to which the oscillator signal is applied,



in that the filtered signal is multiplied in a multiplying stage (17) by the FM-demodulator output signal, in that the product signal is fed back as an impressed current to the oscillator circuit (31) so that a

5 capacitive susceptance is produced in parallel with the oscillator circuit and in that the upper cutoff frequency of the low-pass or band-pass network is chosen such that the maximum of the product of the susceptance of the reactance circuit and the square of the frequency is
10 located in the tuning frequency range or in the vicinity thereof.

4. A circuit arrangement as claimed in Claim 3, characterized in that the reactance circuit comprises a low-pass network which includes two low-pass filters
15 (14, 16) between which a decoupling stage (15) is arranged.

5. A circuit arrangement as claimed in Claim 3, characterized in that the reactance circuit comprises a low-pass network which includes two low-pass filters (14, 16) which are directly arranged in cascade.

20 6. A circuit arrangement as claimed in Claim 4, characterized in that the cutoff frequencies of the two low-pass filters are equal to each other and are located at approximately 58% of the centre frequency of the tuning frequency range of the oscillator circuit (31).

25 7. A circuit arrangement as claimed in Claim 4, characterized in that the cutoff frequency of one low-pass filter is approximately four times larger than that of the other low-pass filter and approximately 10% below the centre frequency of one tuning range of the
30 oscillator circuit.

8. A circuit arrangement as claimed in Claim 4, characterized in that the cutoff frequency of one low-pass filter is approximately 78% larger than that of the other low-pass filter and approximately 26% lower
35 than the centre frequency of the tuning range of the oscillator circuit.

9. A circuit arrangement as claimed in Claim 5,



characterized in that the two low-pass filters are identical and that their cutoff frequencies are each located at approximately 36.8% of the centre frequency of the tuning frequency range of the oscillator circuit (31).

10. A circuit arrangement as claimed in any of the Claims 3 to 9, characterized in that the multiplying circuit (17) comprises two transistors (171, 172) whose common emitter lead includes a current source (177) which is controlled by the FM-demodulator output signal and whose current is linearly dependent on the FM-demodulator output signal, and in that the filtered signal is applied to the base of one of the transistors (171) and in that the collector current of one of the transistors (171) is applied to the oscillator circuit (31).

11. A circuit arrangement as claimed in Claim 4, characterized in that the reactance circuit comprises a first emitter-follower (131) whose output is connected to an RC-low-pass filter (14) which has a resistor (141) in the series branch and a capacitor (142) in the parallel branch, which is arranged in parallel for alternating current relative to the input of a second emitter follower (151) to the input of which a further low-pass filter is connected which has a resistor (161) in the series branch and a capacitor (162) in the parallel branch and in that the output of the further low-pass filter (161, 162) is connected to an input of the multiplying stage.

