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(54) RADIO BROADCASTING SYSTEM WITH CODE SIGNALING /

(71) We, N.V. PHILIPS' GLOEI-LAMPENFABRIEKEN, a limited liability Company, organised and established under the laws of the Kingdom of the Netherlands, of Emmasingel 29, Eindhoven, the Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a radio broadcasting system of a type with a code signalling wherein at the transmitter side a multiplex signal which is frequently modulated on a main carrier is transmitted, said multiplex signal comprising: an audio frequency information signal, a stereo pilot whose frequency is located between the frequency spectrum of the audio frequency information signal and which serves for spectrum envisaged for the transmission of a suppressed sub-carrier modulated stereo information signal and which serves for demodulating such stereo information signal, as well as a binary code signal modulated on a further sub-carrier located outside said frequency spectra and having an amplitude which causes the main carrier to deviate for not more than 1 KHz. In addition the invention relates to a transmitter for transmitting signals in accordance with a system of the above type as well as to a receiver for receiving such signals.

When tuning the present FM-radio receivers the user often experiences great difficulties because the tuning scale only mentions frequencies and/or channel numbers and not the names of the stations, in addition, one given program is often transmitted by several transmitters so that the user may not know if he has tuned to the strongest transmitter.

In order to provide the user with an easily

recognizable identification of the FM transmitters and/or of the nature of the program transmitted by the transmitter, a radio broadcasting system with code signalling of the type referred to has already been suggested at the CCIR Comité Consultatif International des Radiocommunications). In this system the code signal is transmitted by means of a suitable sub-carrier above the frequency spectrum for the stereo information signal. This sub-carrier is frequency-modulated with the binary code signal which, by means of a digital code, contains information on, for example, the name of the program, the location of the transmitter, the nature of the program and the channel number, so that, for example, the following information, consisting of 16 characters, is received:

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The receivers for such a system are provided with a decoder which decodes the binary code signal from the signal received and uses it, for example, for wholly or partly optically displaying the information thus transmitted, so that the user can immediately see to which transmitter his receiver is tuned. Alternatively, it is possible to arrange the receiver in such a way that at a preset code a portion of the receiver or of a tape recorder or reproducing apparatus is switched on or off. In particular, if the code contains a special code which is transmitted for traffic reports, the code can be used to switch on the reproducing section of a car radio receiver or to stop a tape reproducing device which is in operation.

The above-mentioned prior art broadcasting system with code signalling has been tested in practice with the following values:

The sub-carrier frequency was 66 KHz and the frequency sweep 1 KHz so that owing to the binary information the frequency was switched between 65 KHz and 67 KHz.

The code used was the 6-bit ASCII-code having 16 characters per information.

The amplitude of the modulated code signal was chosen such that 1 KHz, i.e. 1.33% of the total frequency sweep of 75 KHz available for the FM modulation of the main carrier, was occupied by the code signal. The comparatively small amplitude (1 KHz) of this signal is opted for because experiments proved that a greater amplitude may cause interference noise in some FM receivers.

It appeared, however, that the necessarily small amplitude of the modulated code signal and the comparatively high frequency thereof (66 KHz) resulted in a poor signal-to-noise ratio. In order to recover the code signal flawlessly, the receiver requires a high-grade filter having a good quality factor and a good temperature stability. In addition, it appeared that in spite of the use of such a high-grade and expensive filter, decoding of the code signal no longer occurs flawlessly at aerial voltages below 10 μ V (at 60 Ohm) whereas the average FM receivers still furnish an acceptable mono-reception at such aerial voltages.

It is an object of the invention to provide a radio broadcasting system with code signalling which enables a substantially flawless decoding of the code signal at received aerial voltages where an acceptable mono-reception is not hardly possible, whereas the signal reception in existing receivers is not or hardly disturbed and whereas, furthermore, high-grade and, consequently, expensive filtering means in the receiver for the system according to the invention can be dispensed with.

According to the invention a radio broadcasting system of the type referred to is characterized in that said further sub-carrier is a harmonic of a sub-harmonic of the stereo pilot not coinciding with a harmonic of the stereo pilot, and is derived at the transmitter side from the same frequency source as the stereo pilot and in that the code signal is binary phase modulated on this sub-carrier.

The expression binary phase modulation must here, as customary, be understood to mean a phase modulation in which the phase of the sub-carrier is shifted 180° by the binary code signal. This furnishes a modulated signal with a fully suppressed carrier.

Using phase modulation of the sub-carrier with the binary code signal (phase shift keying) instead of frequency

modulation (frequency shift keying) results in an improvement of the signal-to-noise ratio. In contrast to the demodulation of the frequency-modulated sub-carrier the demodulation of the phase-modulated sub-carrier requires, however, an unmodulated ("clean") sub-carrier. This sub-carrier is not present in the binary phase-modulated code signal because the sub-carrier itself is suppressed and sidebands only are transmitted. Generating this sub-carrier at the receiving side can, however, be effected by squaring the incoming binary phase-modulated signal which results in a carrier having double the frequency, by thereafter filtering this carrier with double frequency, and subsequently having the carrier of the original frequency recovered from the carrier of double this frequency by means of a frequency divide-by-two divider.

With this method, in the case of poor signal-to-noise ratios, the carrier of double the frequency must be obtained from a signal having a high degree of noise. If, for example, a so-called phase locked loop is used for this purpose, then this can indeed be effected by using a low-pass filter having a low cut-off frequency in this loop in such a way that the phase of the voltage-controlled oscillator of the phase loop is not modulated too much by noise. On the other hand such a low-pass filter having a low cut-off frequency reduces the pulling-in range of the phase locked loop to such an extent that a voltage-controlled oscillator having a very stable free-running frequency is now required. In practice this can only be obtained with a crystal-controlled oscillator.

With the present invention wherein binary phase modulation of the sub-carrier for the code signal is used in combination with a frequency relationship between the stereo pilot and said sub-carrier, which relationship is fixed at the transmitter side, a system is obtained which can be decoded without high-grade means and which is comparatively insensitive to poor signal-to-noise conditions.

The sub-carrier for the transmitter identification signal can now be recovered with much simpler means because the stereo pilot is modulated with a much greater frequency sweep (10% of the total 75 KHz frequency sweep) on the main carrier than the transmitter identification signal itself (1.33% of the total frequency sweep of 75 KHz). In a receiver for a system according to the invention phase errors may be produced owing to different delay times for the modulated code signal and for the stereo pilot in the tuner and in the intermediate frequency section of the receiver. Also phase multiplicities are

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produced because sub-carrier frequency (ω_k) of the modulated code signal is chosen equal to a "fractional" harmonic of the stereo pilot (ω); this expression means that

$$\omega_k = \frac{n}{m} \omega,$$

where m and n are integers but n is not divisible by m . The frequency division required thereby in the transmitter and in the receiver may produce these phase multiplicities.

In accordance with a further aspect of the invention an automatic phase corrector is used in a receiver according to the invention which can adjust the phase unmodulated wave required for detecting the modulated code signal relative to the modulated code signal itself. This phase corrector is controlled from a phase detector which compares the phase of the modulated code signal to the phase of the unmodulated wave obtained from the stereo pilot and depending on the result of this comparison, the phase corrector corrects any phase errors. As the carrier itself is missing in the binary modulated code signal, this, however, cannot be done without further measures.

A first method to solve this difficulty is the use of frequency doubling of the modulated code signal which provides an unmodulated carrier of twice the sub-carrier frequency. This carrier of twice the sub-carrier frequency is applied to one input of the phase detector, a wave of likewise twice the sub-carrier frequency, which is obtained by means of frequency multiplication and/or division of the stereo pilot being applied to the other input.

A second method consists in the use of a phase inverter in one of the input leads or in the output of the phase detector, which phase inverter is controlled by the demodulated output signal of the synchronous detector. It appears that this results in both cases in a phase duplicity at the detection of the code signal. This phase duplicity is not disturbing if a code is used which is insensitive to such a duplicity, for example a so-called differential code; this is a code with which the two binary states are not transmitted by two phase conditions of the sub-carrier but by the occurrence or non-occurrence, respectively, of a phase transition from the one phase to the other or vice versa.

The frequency of the sub-carrier can, for example, be chosen between the third and the fifth harmonic of the stereo pilot. Choosing it below the third harmonic brings the sub-carrier too closely to the spectrum of the stereo information signal

and choosing it above the fifth harmonic increases the chance for disturbances owing to adjacent transmitters.

Furthermore, interference may occur in a number of stereo receivers between the sub-carrier for the transmitter identification and the second harmonic of the 38 KHz signal required for stereo detection, which corresponds to the fourth harmonic of the pilot. For this reason the sub-carrier for the code signalling should not be located too near this fourth harmonic.

Owing to the non-linear phase characteristic of the intermediate frequency section of the receiver an interference product having a frequency equal to the difference frequency between the sub-carrier and the stereo pilot occurs in the multiplex signal. This interference product may, after detection with the 38 KHz wave, cause audible noise if the sub-carrier is located too near the third harmonic of the stereo pilot.

The above-mentioned non-linear phase characteristic furthermore causes noise in the region of the whole harmonics of the stereo pilot. All these considerations lead to the choice that the sub-carrier for the code signal should not coincide with a full harmonic of the stereo pilot. Consequently, it should be preferred to choose a "fractional" harmonic of the stereo pilot for the sub-carrier of the code signal and to remove the phase multiplicity then occurring in the receiver in the manner described above.

On the bases of the above consideration preference should be given to a position of the sub-carrier half-way between two harmonics of the stereo pilot, for example at $7/2$ or $9/2$ times the stereo pilot. The invention has been tested with a sub-carrier frequency of $7/2$ times the pilot frequency; for clearness' sake an embodiment for a sub-carrier frequency of $16/5$ times a pilot frequency is given.

A further improvement of a radio broadcasting system with code signalling in which, while maintaining a reliable transmission of the code information, a reduced chance of disturbing existing receivers is possible, is characterized in that the further sub-carrier with the modulated code signal is located in at least one of the two halves of the frequency range, divided in two by the stereo pilot, between the upper limit of the frequency spectrum of the audio frequency information signal and the lower limit of the frequency spectrum of the modulated stereo information signal and in that the modulated code signal has an amplitude which causes the main carrier to deviate less than 1 KHz, preferably 0.25 KHz.

This measure has the following effects

1. Because the sub-carrier for the code signalling is now remote from the higher harmonics of the 38 KHz stereo detection signal, these higher harmonics cannot produce audible noise in existing receivers.

2. Because the sub-carrier for the code signalling is now located much lower in the frequency spectrum of the multiplex signal, the signal-to-noise ratio is considerably more favourable. Consequently, the modulated code signal can have a still smaller amplitude than was the case for a sub-carrier of, for example, 66.5 KHz. For comparison it should be noted that with the present preferred embodiment, for obtaining a reliable code signalling, the modulated code signal need only occupy approximately 0.25 KHz of the maximum frequency sweep of 75 KHz. This requires approximately 1 KHz in case of a 66.5 KHz sub-carrier. Of course the much smaller sub-carrier amplitude considerably reduces the chance for interference noise caused by other components of the multiplex signal.

A still further reduction of the chance for noise in existing receivers, particular in the case of monoreception, can be achieved in accordance with a further characteristic of the invention when a sub-carrier, binary phase modulated by the code signal, is located in each of the two halves of the frequency range divided into two parts by the stereo pilot. The two sub-carriers modulated by the code signal can have equal amplitudes and such a phase relative to the stereo pilot that together with the stereo pilot they form a signal produced by quadrature modulation of the stereo pilot by a sub-carrier derived from the stereo pilot, this sub-carrier being binary phase modulated by the code signal.

With such a signal each of the binary phase modulated sub-carrier signals may be considered to be a sideband of a double-sideband signal having the stereo pilot as the carrier. The stereo pilot is quadrature modulated by a modulation signal which itself is binary phase modulated by the code signal. The modulation signal has a frequency equal to the difference between the frequency of the stereo pilot and of a sub-carrier. A system according to this further feature of the invention, and tested in practice has, next to the stereo pilot with a frequency f_p of 19 KHz, a first sub-carrier of 16.625 KHz ($7/8 f_p$), whose phase is binary modulated by the code signal and a second sub-carrier of 21.375 KHz ($9/8 f_p$) whose phase is binary modulated by the code signal. In the case of equal amplitudes of the two sub-carriers and a relative proper phase relation between the sub-carriers and the stereo pilot, the three signals together constitute a stereo pilot which is quadrature

modulated by a sub-carrier signal of $1/8 f_p$ which itself is binary phase modulated by the code signal. To this end the phase of one sub-carrier must lead the stereo pilot, shifted over 90° , for the same amount as the other sub-carrier lags this 90° -shifted stereo pilot, in other words the resultant of the two modulated sub-carriers has a 90° phase shift relative to the stereo pilot.

The sum of the stereo pilot and the two sub-carriers forms a pilot signal the amplitude of which is substantially constant. As especially the amplitude variations of the pilot give rise to distortion products owing to the non-linear phase characteristic of the intermediate frequency section of the receivers the above-described measure offers an additional distortion reduction.

Within the framework of the invention it is alternatively possible to give the sub-carrier modulated by the code signals such a phase that the resultants always coincide (0° or 180°) with the stereo pilot. The two sub-carriers functioning as sideband for the stereo pilot then cause an amplitude modulation of the stereo pilot by a carrier signal which itself is binary phase-modulated by the code signal.

When applying the stereo pilot, double-sideband quadrature or amplitude-modulated by the two sub-carriers or the stereo pilot single-sideband phase and amplitude-modulated by one sub carrier, to the stereo decoder of radio receivers, the sub-carrier amplitudes which are already small, are suppressed so much by the stereo pilot filter provided in such receivers, relative to the stereo pilot itself that disturbing the stereo detector does substantially not occur. Such a disturbance would be much greater in the case of direct phase or amplitude modulation of the stereo pilot by the code signal.

This disturbance is, of course, also greater according as the sub-carriers are located nearer the stereo pilot (for example at $11/12 f_p$ and/or $13/12 f_p$). On the other hand, in case of an excessive sub-carrier stereo pilot distance the sub-carrier becomes located too near the frequency spectrum of the audio information signal or of the modulated stereo information signal. On the basis of these considerations a spacing of $1/8 f_p$ between sub-carrier (sub-carriers respectively) and the stereo pilot should be preferred.

As with the system according to the present embodiment the sub-carrier frequency is relatively near that of the stereo pilot it is preferred in the receiver arranged for receiving such signals to convert the modulated sub-carrier ($7/8 f_p$ and/or $9/8 f_p$) first with the stereo pilot to an intermediate frequency ($1/8 f_p$) which is

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harmonically related to the stereo pilot and which is equal to the difference between the sub-carrier frequency and stereo pilot frequency. The synchronous detection of the code signal can then be effected as this lower frequency in a corresponding manner as described above.

The invention will now be further explained with reference to the Figures in the accompanying drawings. Herein:

Figure 1 is a block diagram of an embodiment of a transmitter for a first implementation of the system according to the invention,

Figure 2 shows the frequency spectrum of the multiplex signal generated in the first embodiment of the system according to the invention at the transmitter side and obtained at the receiver side after FM demodulation,

Figure 3 is a block diagram of a first embodiment of a receiver according to the invention,

Figure 4 is a block diagram of a second embodiment of a receiver according to the invention,

Figure 5 and Figure 5a, respectively, are block diagrams of a transmitter for a second embodiment of the system according to the invention,

Figure 6 shows the frequency spectrum of the multiplex signal generated at the transmitter side and obtained at the receiver side after FM-modulation according to the second embodiment of the system,

Figure 7 is a block diagram of an embodiment of a receiver for receiving a signal as shown in Figure 6, and

Figure 8 is a block diagram of a second embodiment of a receiver for receiving a signal as shown in Figure 6.

The transmitter of Fig. 1 comprises a source of left-hand audio signals 1 and a source of right-hand audio signals 2. Each of the left-hand and right-hand audio signals is applied *via* a pre-emphasis network 3 and 4, respectively, and *via* a low-pass filter 5 and 6, respectively, having a cut-off frequency of 15 KHz, to an adder circuit 7 and to a subtractor circuit 8. thereafter the sum signal L+R derived from the adder circuit is applied to an input 9 of a multiplexer 10. The difference signal L-R of the subtractor circuit 8 is modulated in a balanced modulator 11 on a stereo sub-carrier of for example, 38 KHz and the modulated stereo information signal thus obtained, which consists of two sidebands with suppressed stereo sub-carrier, is applied *via* a bandpass filter 12 to a second input 13 of the multiplexer 10.

In addition, the transmitter of Fig. 1 comprises a stable oscillator 14, for example a crystal oscillator supplying a

wave of, in general, 19 KHz which is used as a stereo pilot. This stereo pilot is applied to a third input 15 of the multiplexer 10.

The stereo pilot of the oscillator 14 is also applied to a so-called phase locked loop 16 which includes a phase detector 16a, a low-pass filter 16b, a voltage-controlled oscillator 16c and a frequency-divide-by-two divider 16d. The phase locked loop 16 is used for producing a sub-carrier whose frequency (38 KHz) is equal to twice the frequency of the stereo pilot and which is locked to the stereo pilot. The operation of such a phase locked loop is known; the 38 KHz output signal of the oscillator 16c is converted in the divide-by-two divider 16d into a 19 KHz signal which is compared in the phase detector 16a with the 19 KHz pilot of the oscillator 14. The output voltage of the phase detector 16a is filtered in low-pass filter 16b and applied as a control voltage to the oscillator 16c.

Via a phase shifter 17 the 38 KHz output signal of the phase locked loop 16 is applied as stereo sub-carrier to the modulator 11 for modulating the L-R signal. The phase shifter 17 is used to give the sub-carrier the internationally prescribed phase relative to the 19 KHz stereo pilot.

A second phase locked loop 18, connected to the 19 KHz oscillator, comprises a phase detector 18a, a lowpass filter 18b, a voltage-controlled oscillator 18c and a 16-scaler 18d. The phase locked loop 18 operates in a similar manner as the phase locked loop 16 and supplies an output signal (which is locked to the stereo pilot) of 304 KHz, i.e. 16 times the pilot frequency. Thereafter the 304 KHz signal of the phase locked loop 18 is reduced in a divide-by-5 divider 19 to 60.8 KHz and the latter signal is applied as sub-carrier of the transmitter identification signal to the carrier input of a balanced modulator 20. The modulation input of this modulator is connected to a schematically shown arrangement 21 for generating a suitable binary code which includes the transmitter identification information, for example a code as defined in the preamble.

The modulator 20 may, for example, be a ring modulator or a dual long-tail circuit or any other known modulator which, under the influence of the bits derived from the arrangement 21, shifts the phase of the 60.8 KHz signal from the divide-by-5 divider 19 over 180°. The 60.8 KHz signal, phase modulated in this way, is applied *via* a bandpass filter 22 having a bandwidth of approximately 4 KHz to a fourth input 23 of the multiplexer 10. The multiplexer combines the signals at the inputs 9, 13, 15 and 23 and supplies them combined to a FM-transmitter, not shown in the drawing.

For further explanation, Figure 2 shows

the frequency spectrum of the signal obtained at the output of the multiplexer. Between 0 and 15 KHz there is the sum signal L+R supplied via the input 9, at 19 KHz there is the stereo pilot supplied via the input 15, between 23 and 53 KHz there is the L-R signal which is modulated at 38 KHz and which is supplied via the input 13 and at 60.8 KHz there is the approximately 4 KHz wide transmitter identification signal which is supplied via the input 23. It should be noted that the relative amplitude ratios generally deviate more from one another than is indicated for clearness' sake. In general the stereo pilot is approximately 9x smaller than the L+R and L-R components and the amplitude of the transmitter identification signal is preferably chosen to be approximately 10x smaller than that of the stereo pilot.

The receiver of Fig. 3 comprises a tuner 24, an intermediate frequency amplifier 25 and an FM-detector 26. The multiplex signal which is composed of the components shown in Fig. 2 is available at the output of this FM detector. For a stereo receiver this multiplex signal is applied to a stereo decoder 27 which supplies the left-hand and right-hand audio signals which are supplied via audio amplifiers 28 and 29 to a left-hand and a right-hand loudspeaker 30 and 31.

For demodulating the transmitter identification signal the multiplex signal is applied to a 19 KHz band-pass filter 32 for the stereo pilot and a 60.8 KHz band-pass filter 33 for the transmitter identification signal. The stereo pilot filtered out by means of the filter 32 is additionally filtered and its frequency multiplied by a phase locked loop 34 which includes a phase detector 34a, a low-pass filter 34b, a voltage-controlled oscillator 34c and a 1:32 frequency divider 34d. Its operation is similar to that of the phase locked loops 16 and 18 of Fig. 1.

The output wave of the phase locked loop 34, which has a frequency of $32 \times 19 = 608$ KHz, is thereafter reduced to 121.6 KHz in a divide-by-five divider 35, thereafter passed through a controllable phase shifter 36, whose function will be explained in the course of this description, thereafter divided in a divide-by-two divider 37 to 60.8 KHz and, finally, applied to a first input 38 of a synchronous demodulator 39.

The 60.8 KHz phase modulated transmitter identification signal originating from the bandpass filter 33 is applied via a 45° phase shifter 40 to a second input 41 of the synchronous demodulator 39. The synchronous detection of the 60.8 KHz phase modulated transmitter identification signal at the input 41 by means of the unmodulated 60.8 KHz wave at the input 38

furnishes, at the output of the synchronous demodulator 39, the demodulated binary transmitter identification signal. This binary code signal is passed through a low-pass filter 42, and thereafter it is formed into square pulses in a pulse shaper 43 and applied to a decoder 44. This decoder converts the binary transmitter identification signal into signals suitable for driving a "display" 45.

For a proper synchronous detection in the demodulator 39, the unmodulated wave at the input 38 must have the proper phase relation relative to the modulated signal applied to the input 41. In general this proper phase relation is not guaranteed owing to the following causes:

1. Owing to the insufficient linear phase characteristic of the intermediate frequency amplifier 25 the 19 KHz stereo pilot and the 60.8 KHz transmitter identification signal may be subjected to mutually different delay times.

2. The input filters 32 and 33 may effect unwanted phase shifts.

3. Owing to the frequency division by the divider 19 in the transmitter the phase of the transmitted 60.8 KHz transmitter identification signal is no longer unambiguously determined relative to the transmitted stereo pilot. A similar phase multiplicity is caused by the frequency divider 35 in the receiver.

In order to obviate all these phase problems the circuit of Fig. 3 comprises the adjustable phase shifter 36 mentioned above. This shifter is controlled via a low-pass filter 46 from a phase detector 47. The phase detector 47 has two inputs 48 and 49, the input 48 being connected to the output wave of the phase shifter 36, the input 49 being connected to the output of a device 50 which produces a modulated wave of double the frequency (namely 121.6 KHz) from the phase-modulated signal of the filter 33. To this end the device 50 has a non-linear characteristic with even-power term, for example a squaring circuit or a full-wave rectifier.

Because the phase locked loop 34 multiplies the stereo pilot by a factor of 2 more than necessary for the synchronous detection, the frequency of the wave which is applied to the input 48 of the phase detector is equal to double the carrier frequency. So measuring the phase by means of the phase detector 47 is effected at double the carrier frequency and the result of the measurement is used to compensate for the above-mentioned unwanted phase shifts in the controllable phase shifter 36. It should be noted that the frequencies of the two signals which are connected to the phase detector 47 are always equal to one another so that no

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pulling-in problems can arise. The phase errors which are corrected therewith vary only slowly and the low-pass filter 46 can, consequently, have a very low cut-off frequency (for example 10 Hz). Owing to this low cut-off frequency, rapid phase variations which might be produced owing to the noise in the transmission path 33—40—41 of the transmitter identification signal can be effectively suppressed. By means of the specified measures it is possible to obtain for the synchronous detector 39 and unmodulated wave of the proper frequency and the proper phase and which is noise-free to a sufficient degree. As, owing to the phase control by means of 36, 46, 47 the phase is compensated at double the carrier frequency, the phase relation at the inputs of the synchronous detector 39 is still not unambiguous (180° phase duplicity). When using a (differential) code which is insensitive thereto a proper transmission of the code signal can, however, yet be guaranteed.

In practice, the automatic phase control by means of the phase controller 36 always operates so that the two input signals of the phase detector 47 are shifted 90° in phase relative to one another. Moreover it is desirable that the mutual phase relation between the input signals of the synchronous detector is 0° or 180°. If the divide-by-two divider 37 is so constructed that the zero-crossings of its output wave coincide with zero-crossings of its input wave and if the frequency doubler 50 is implemented as a squaring circuit in which the tops of the input wave coincide with tops of the output wave, then this preferred phase relation is achieved automatically. In other cases an additional phase correction may be necessary in one of the input leads of the detectors 47 and 39, for example a 90° correction for the double carrier frequency or a 45° correction for the carrier frequency itself. The 45° phase shifter 40 is used for this purpose. It should be noted that several variants of the circuit of Fig. 3 are possible. It is, for example, possible to replace the divide-by-two divider 37 by a frequency doubler in the input lead 48 of phase detector 47. The frequency multiplication factor of the phase locked loop 34 should then be a factor of 2 smaller. Alternatively it is, for example, possible to include the phase controller 36 in the output lead of the filter 33.

If, instead of 16/5 times the stereo pilot, 7/2 times this pilot would, for example, be chosen for the carrier frequency of the transmitter identification signal, the divisor of the divider 34d might be equal to 14 and that of the divider 35 might be equal to 2. It is then, of course, simpler to choose the

divisor of 34d to be equal to 7 so that the divider 35 can be dispensed with.

In the embodiment of Fig. 4 the units corresponding to the functional units of Fig. 3 have been given the same reference numerals.

Whereas in the embodiment of Fig. 3 the phase comparison for the control of the phase corrector 36 is effected at double the carrier frequency, it is effected for the embodiment of Fig. 4 at the carrier frequency itself. To this end the frequency doubling circuit 50 and the frequency divide-by-two divider 37 are omitted and the divisor of the frequency 34d is reduced to 16.

Via the phase shifter 36 the divider 35 now supplies an unmodulated carrier of the carrier frequency (60.8 KHz) to the input 48 of the phase detector 47.

A phase inverter 51 (balanced modulated) is included in the input lead to the input 49 of the phase detector 47. The phase inverter 51 is controlled by the output signal of the synchronous detector 39 or by, alternatively, the output signal of the pulse shaper 43. Each time the phase of the transmitter identification signal is changed 180° owing to the code signal, this causes a transient in the output signal of the pulse shaper 43 which effects a phase reversal by the phase inverter 51 so that, at the input 49, the original phase reversal is cancelled. So the input 49 of the phase detector 47 is supplied with the 60.8 KHz transmitter identification carrier from which the original phase modulation was removed. In phase detector 47 the phase of this unmodulated carrier is compared relative to the wave at input 48 and any phase errors are compensated again by the phase shifter 36 via low-pass filter 46.

Instead of having been included in the lead to the input 49 the phase inverter 51 may also be included in the supply lead to the input 48 of the phase detector 47. The 60.8 KHz carrier supplied via the phase shifter 36 is then phase-modulated by the binary code signal in the same manner as the transmitter identification signal itself has been modulated. Then the phase detector 47 supplies again an output voltage which can be used for the phase correction.

A third possibility is to include the phase inverter in the output lead of the phase detector 47, either before or after the filter 46. The phase detector 47 itself then supplies the binary code signal but as the phase inverter changes state of each signal transient of this signal, the output signal of the phase inverter becomes a d.c. voltage which can be used for the phase correction.

A 90° phase shifter 52 in the input lead 38 of the synchronous detector has a similar function as the 45° phase shifter 40 of Fig.

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2. Alternatively, the phase shifter 52 may be included in the input lead 41 of the synchronous detector 39 or in one of the input leads of the phase detector.

5 A further analysis of the circuit of Fig. 4 shows that the entire phase correction system has two stable control conditions wherein the phase difference of the signal at the input 49 relative to the signal at the input 48 of the phase detector can be $+90^\circ$ or -90° . The detection of the binary code signal by means of the synchronous detector 39 has, consequently, the same ambiguity as in the receiver of Fig. 3.

10 The circuits shown in Figs. 3 and 4 do not require resonant circuits which satisfy high selectivity requirements, because a large part of the required selectivity can be realized at low frequency, that is to say by low-pass filters (34b, 46, 42). Consequently, the bandpass filters 32 and 33 need have moderate quality factors (approximately 20) only. Recent tests have shown that the stereo pilot filter 32 may even be dispensed with completely. In some cases it is also possible to obtain from the stereo decoder 27 a stereo pilot which has already been filtered. The input of the phase locked loop 34 is then connected to a suitable point in the stereo decoder 27.

15 The functional units shown in the Figs. 1, 3 and 4 are all known *per se*, and, consequently, require no further explanation. The transmitter of Fig. 5 comprises a stereo multiplex encoder 101 to which sources 102 and 103 of left-hand and right-hand audio signals, respectively, are connected and a 19 KHz oscillator 104 which generates a stereo pilot f_p . The encoder 101 composes in a similar manner as described with reference to Fig. 1 the standard multiplex signal from the applied signals, said standard multiplex signal comprising the audio frequency sum signal $L+R$, the $L-R$ stereo information signal modulated on a suppressed carrier of twice the pilot frequency, as well as the stereo pilot f_p itself. It should be assumed that the stereo pilot derived from the oscillator 104 has the same phase as the pilot in the multiplex signal.

20 The stereo pilot is applied directly to a second contact *b* and, in addition, via a 90° phase shifter 105 to a first contact *a* of a switch 106. The master contact *c* of the switch 106 is connected to a first input 107 of a linear modulator 108. Therefore, switch 106 being in the position shown in the drawing, a stereo pilot shifted 90° relative to the stereo pilot in the multiplex signal is applied to this input. In the other position of the switch the input 107 of the modulator 108 receives the stereo pilot in phase with that in the multiplex signal.

25 Furthermore, the stereo pilot is applied

via a pulse shaper 109 to a frequency divider 110 which furnishes a square wave of $1/8 \times$ the stereo pilot frequency (2.375 KHz). A band filter 111, tuned to this frequency, filters the fundamental frequency so that a sinusoidal wave of $1/8 \times$ the pilot frequency is available at the second input 112 of the modulator 108.

The modulator 108 is a linear balanced modulator which produces the sum and the difference frequencies ($f_p - f_p/8$ and $f_p + f_p/8$) from the two applied sinusoidal signals, while the frequencies (f_p and $f_p/8$) originally applied, are missing from the output signal.

The output signal of the modulator 108 is thereafter directly applied to a first contact *a* of a three-position switch 113, and also, via a bandpass filter 114, tuned to 16.625 KHz ($7/8 f_p$) to a second contact *b* and via a bandpass filter 115, tuned to 21.375 KHz ($9/8 f_p$) to a third contact *c* of the three-position switch 113. The master contact *d* of the three-position switch 113 is connected to a first input 116 of a linear balanced modulator 117. A device 120 which supplies the binary code signal comprising the transmitter identification information is connected via a trapezoidal wave-shaper 119 to the second input 118 of this modulator 117. The trapezoidal wave-shaper 119 reduces the higher frequency component's contents, so that the code signal applied to the modulator comprises a limited frequency range (up to approximately 600 Hz).

In the third position (*c*) of switch 113 the $9/8 f_p$ sub-carrier passed by the filter 115 is binary phase-modulated in the modulator 117 with the code signal of the device 120. In the second position (*b*) of switch 113 the $7/8 f_p$ sub-carrier passed by filter 114 is binary phase-modulated by the code signal. In the first position (*a*) of switch 113 the two sub-carriers ($7/8 f_p$ and $9/8 f_p$), originating from modulator 108, are both binary phase-modulated by the code signal. Finally, the output signal of the modulator 117 is added to the stereo multiplex signal of the encoder 101 in an adder stage 121, all this in such a way that the amplitude of the added sub-carrier or sub-carriers, respectively, is considerably (for example 30 times) smaller than the amplitude of the stereo pilot comprised in the multiplex signal. Finally, the output signal of the adder stage 121 is applied to a FM-transmitter, not shown.

In position (*a*) of the two switches 106 and 113 the whole, transmitted, signal comprises next to the stereo pilot f_p the sub-carriers $f_p + 1/8 f_p$ and $f_p - 1/8 f_p$, which are both binary phase-modulated by the code signal. The resultant of the two sub-carriers is always shifted over 90° relative to the stereo pilot so that the stereo pilot with the two sub-carriers as sidebands form a signal

which is quadrature modulated, so that the stereo pilot is amplitude-modulated to a very limited extent only. The modulating signal itself is a sub-carrier of $1/8 f_p$, which is binary phase-modulated by the code signal. In the second position (b) of the switch 106 the resultant of the two sub-carriers is in-phase or (180° out of phase) with the stereo pilot so that the stereo pilot with the two sub-carriers as sidebands forms a signal which is amplitude-modulated, but not phase-modulated with the modulated $1/8 f_p$ signal.

In the second or third position, respectively, of the switch 113 only the lower or upper sideband, respectively, is added to the stereo pilot of the multiplex signal. Switching over of switch 106 results indeed in a 90° phase shift of the single sideband relative to the stereo pilot but this of little practical importance.

It will be obvious that the diagram of Figure 5 relates to an experimental transmitter suitable for testing which system will be most satisfactory in practice. In its definite version the transmitter needs only be suitable for one system and may, therefore, be of a simpler implementation. Thus, a transmitter wherein only one modulated sub-carrier of for example $7/8 f_p$ or $9/8 f_p$ is applied to the multiplex signal (see Fig. 5a) might comprise a phase locked loop 122 deriving a signal of $7 f_p$ or $9 f_p$ from the stereo pilot, furthermore an 8-scaler 123 for providing a pulse-shaped signal of $7/8 f_p$ or $9/8 f_p$, furthermore a band pass filter 124 for converting the pulse-shaped signal into a sinusoidal signal of $7/8 f_p$ or $9/8 f_p$, this sinusoidal signal being applied to the first input 116 of the modulator 117.

In a definitive transmitter for a system with two modulated sub-carriers the elements 106, 113, 114, 115 of Fig. 5 can be dispensed with. The oscillator 104 can then be connected directly of *via* the phase shifter 105 to the first input 107 of the modulator 108 and the output of 108 directly to the first input 106 of the modulator 117. Instead of first mixing the pilot f_p with the $f_p/8$ signal and by modulating the result thereafter by the code signal it is also possible to modulate the $f_p/8$ signal by the code signal and to mix it thereafter with the stereo pilot or to modulate the stereo pilot f_p by the code signal and to mix it thereafter with the $f_p/8$ signal.

Fig. 6 shows the frequency spectrum of the signal supplied by the adder stage 121. The Figure shows from 0—15 KHz the audio frequency information signal, at 19 KHz the stereo pilot, at 23 KHz up to 53 KHz (not visible) the stereo information signal modulated at 38 KHz, and at 16.625 and 21.375 KHz the two binary phase

modulated sub-carriers, each having a bandwidth of approximately 1200 Hz. It should be noted that the amplitudes of the signal components differ considerably more from one another shown in the Figure for clearness' sake. In practice the L+R and L-R signal components may be approximately 9 times greater than the stereo pilot, while the two sub-carrier signals may, for example, be 30 times smaller than the stereo pilot.

The receiver of Fig. 7 is especially suitable for a system in which only one binary phase modulated sub-carrier is transmitted at, for example $7/8 f_p$ (16.625 KHz). The customary receiver elements, such as high frequency, intermediate frequency and low frequency stages are not shown in Fig. 7. The multiplex signal derived from the frequency discriminator of the receiver is applied to a bandpass filter 125 tuned to the sub-carrier frequency of 16.625 KHz and may have an effective quality factor of, for example, 15. This filter passes the modulated sub-carrier frequency as well as the stereo pilot itself which, although coinciding with an edge of the filter is still considerably greater than the sub-carrier signal. After having been amplified in an amplifier 126 the two signals are applied to a first input 127 of a dual-function multiplier stage 128.

Firstly, stage 128 operates as a phase detector in a phase locked loop which comprises, in addition, a low-pass filter 129, a voltage-controlled 38 KHz oscillator 130 and a divide-by-two divider 131, the latter feeding a 19 KHz square wave back to a second input 132 of the multiplier stage 128. This phase locked loop locks into the received stereo pilot and consequently supplies, at the output of the divider 131 a 19 KHz square wave which is synchronized with the received stereo pilot. The lowpass filter 129 used for preventing the phase locked loop being influenced by other signal components than the stereo pilot may have a cut-off frequency of, for example, 300 Hz and a slope above this cut-off frequency of 6 db/octave.

Secondly, the multiplier stage 128 operates as a mixer stage for the modulated 16.625 KHz ($7/8 f_p$) sub-carrier. This sub-carrier is mixed with the 19 KHz (f_p) square wave at the input 132 which results in a binary phase modulated intermediate frequency signal of 2.375 KHz ($1/8 f_p$), which is passed on *via* a low-pass filter 133 having a cut-off frequency of, for example, 3 KHz and a high frequency slope of 20 db/octave.

Instead of a voltage-controlled 19 KHz oscillator a voltage-controlled 38 KHz oscillator 130 followed by a divide-by-two divider 131 is used because, in general, a

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divide-by-two divider supplies a more symmetrical square wave than a voltage-controlled oscillator. Consequently, stage 128 is controlled by a perfectly symmetrical square wave so that input signal components around the even harmonics of 19 KHz, in particular around 38 KHz, do not influence the output signal of the stage 128. The detection of signal components around 57 KHz by stage 128 is prevented to a sufficient degree by filter 125 which has an adequate attenuation for these signal components. Consequently, by means of the elements 128, 129, 130 and 131 a filtered stereo pilot is available at the output of the divide-by-two divider 131 and a converted binary modulated sub-carrier at the output of stage 128. However, it will be obvious that these functions can be performed by any other suitable filter and converter arrangement.

The 19 KHz square wave of the divide-by-two divider 131 is divided in a divide-by-eight divider 134 into a square wave having a frequency of 2.375 KHz ($1/8 f_s$). Therefore, a binary phase modulated 2.375 KHz carrier signal is available at the output of filter 133 and an unmodulated 2.375 KHz square wave, derived from the stereo pilot, at the output of the scaler 134. The modulated carrier signal can now be demodulated synchronously by means of the unmodulated wave and be processed in accordance with one of the methods described with reference to the Figures 3 and 4. The actual detection is effected in a synchronous detector 135 to a first input 136 whereof the modulated signal is applied via an amplifier 137, while the unmodulated wave is applied to a second input 138 via a controllable phase shifter 139. The detected code signals are filtered in a low-pass filter 140 having a cut-off frequency of, for example, 350 Hz and a 20 db/octave slope, thereafter converted into square pulses by means of a pulse shaper 141, thereafter applied to a decoder 142 which converts the binary transmitter identification signal thus obtained into signals suitable for application to a load 143. The load 143 can be different, depending on the information comprised in the code. In case the code comprises information about the transmitter received and/or the program received, the load 143 may comprise a display displaying this information, so that, for example, the customary tuning scale can be dispensed with. Alternatively the load 143 may comprise an automatic transmitter-search circuit so that the receiver only tunes to those stations broadcasting a given type of program, for example, classical music. If the code comprises time indication the

device 143 can, for example, switch a tape recorder connected to it on or off at a preset time. If the code is a semaphore signal the device 143 is formed by a semaphore receiver.

The phase shifter 139 serves for eliminating all phase errors which may be produced between the modulated 2.375 KHz signal and the unmodulated 2.375 KHz square wave. These phase errors can be produced at the divider 110 in the transmitter and the divider 134 in the receiver and by delay time differences in the various filters, for example in filter 125. For the benefit of this phase control the binary phase modulated 2.375 KHz signal is converted by means of a squaring device 144 and a pulse shaper 145 into a 4.75 KHz square wave. The unmodulated wave of the phase shifter 139 is converted into a 4.75 KHz square wave by means of a frequency multiplier 146. The two 4.75 KHz square waves are compared in a phase detector 147 which generates a control signal from these square waves which is applied, after filtering in a low-pass filter 148 and amplification in an amplifier 149, to the control input 150 of the controllable phase shifter 139. Thus, the phase shifter 139 ensures that the 2.375 KHz square wave and the 2.375 KHz signals applied to the synchronous detector have the same phase (or are 180° out of phase respectively). The phase duplicity then still occurring can again be offset by the use of a code insensitive thereto. The phase shifter 139 as well as the phase shifter 36 of Figs. 3 and 4 can, for example, consist of two cascade-arranged monostable circuits, the time constant of the first circuit being controlled by the control signal and that of the second circuit being equal to half a cycle of the signal to be delayed, the first circuit being started by the incoming signal and the second circuit by the trailing edge of the first circuit's output. Such a phase shifter is capable of shifting the phase of the signal over nearly 360°, which is more than sufficient since the signal should be shifted over 180°.

A preferred embodiment of a receiver for receiving signals comprising two binary phase modulated sub-carriers on either side of the stereo pilot, the stereo pilot being in quadrature to the resultant of the two sub-carriers, may be of the same shape as shown in Fig. 7, it being understood that the filter 125 is not tuned to one sub-carrier but to the stereo pilot, while the passband width of the filter must be sufficiently large to pass the two sub-carriers. On the other hand, the attenuation outside the passband, in particular for signals around 57 KHz, must be sufficiently high to prevent disturbances.

In a receiver for receiving signals having

a binary phase modulated sub-carrier on either side of the stereo pilot, the resultant of the two sub-carriers being in phase with the stereo pilot, it is not possible to use the phase detector (128) of the phase locked loop also for down-converting the signal, because the phase detector and the mixer stage must then be controlled with stereo pilots which are shifted 90° relative to one another. Fig. 8 shows a possible embodiment of such a receiver in which corresponding elements have been given the same reference numerals as in Fig. 7.

The output signal of the amplifier 126 is then applied to the phase detector 128 as well as to a second detector 151, which functions as a mixer stage. In this mixer stage the input signal is mixed with a 19 KHz square wave which is derived by means of frequency division by a divide-by-two divider 152 from the 38 KHz oscillator 130. The two dividers 131 and 152 are so energized that they supply 19 KHz waves whose phases are shifted 90° relative to one another.

WHAT WE CLAIM IS:—

1. A radio broadcasting system with code signalling wherein at the transmitter side a multiplex signal which is frequency-modulated on a main carrier is transmitted, said multiplex signal comprising: an audio frequency information signal, a stereo pilot whose frequency is located between the frequency spectrum of the audio frequency information signal and the frequency spectrum envisaged for the transmission of a suppressed sub-carrier modulated stereo information signal and which serves for demodulating such stereo information signal, as well as a binary code signal modulated on a further sub-carrier located outside said frequency spectra and having an amplitude which causes the main carrier to deviate for not more than 1 KHz, characterized in that said further sub-carrier is a harmonic of a sub-harmonic of the stereo pilot not coinciding with a harmonic of the stereo pilot, and is derived at the transmitter side from the same frequency source as the stereo pilot and in that the code signal is binary phase modulated on this sub-carrier.

2. A radio broadcasting system as claimed in Claim 1, characterized in that the frequency of said further sub-carrier is located in the middle between two harmonics of the stereo pilot.

3. A radio broadcasting system as claimed in Claim 1, characterized in that the further sub-carrier with the modulated code signal is located in at least one of the two halves of the frequency range, divided in two by the stereo pilot, between the upper limit of the frequency spectrum of

the audio frequency information signal and the lower limit of the frequency spectrum of the modulated stereo information signal and in that the modulated code signal has an amplitude which causes the main carrier to deviate by less than 1 KHz, preferably by 0.25 KHz.

4. A radio broadcasting system as claimed in Claim 3, characterized in that a sub-carrier, binary phase modulated by the code signal is located in each of the two halves of the frequency range divided into two by the stereo pilot.

5. A radio broadcasting system as claimed in Claim 4, characterized in that the two sub-carriers, modulated by the code signal, have equal amplitudes and such a phase relative to the stereo pilot that together with the stereo pilot they form a signal produced by quadrature modulation of the stereo pilot by a sub-carrier derived from the stereo pilot, this sub-carrier being binary phase modulated by the code signal.

6. A radio broadcasting system as claimed in Claim 3, characterized in that the sub-carrier modulated by the code signal is located from the stereo pilot at a distance equal to $1/8 \times$ the frequency of the stereo pilot.

7. A receiver for a radio broadcasting system with code signalling as claimed in any preceding Claim comprising a frequency discriminator for demodulating the received main carrier, characterized by a synchronous demodulator having first and second inputs and an output, a first transmission path coupled to the frequency discriminator for applying the binary phase modulated code signal to the first input of the synchronous demodulator, a second transmission path coupled to the frequency discriminator for applying an unmodulated wave synchronized by the stereo pilot to the second input of the synchronous demodulator and an output circuit coupled to the output of the synchronous demodulator for the demodulated binary code signal.

8. A receiver as claimed in Claim 7, characterized by a device, included between the two transmission paths, for generating a control signal in dependency on the relative phase between the carrier of the binary phase modulated signal applied to the first input of the synchronous demodulator and of the unmodulated wave applied to the second input of the synchronous demodulator and by an electronically controllable phase shifter, included in one of the two transmission paths and controlled by said control signal, for controlling said relative phase.

9. A receiver as claimed in Claim 8, characterized in that the device for generating a control signal comprises a



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a binary phase modulated sub-carrier on either side of the stereo pilot, the resultant of the two sub-carriers being in phase with the stereo pilot, it is not possible to use the phase detector (128) of the phase locked loop also for down-converting the signal, because the phase detector and the mixer stage must then be controlled with stereo pilots which are shifted 90° relative to one another. Fig. 8 shows a possible embodiment of such a receiver in which corresponding elements have been given the same reference numerals as in Fig. 7. The output signal of the amplifier 126 is then applied to the phase detector 128 as well as to a second detector 151, which functions as a mixer stage. In this mixer stage the input signal is mixed with a 19 KHz square wave which is derived by means of frequency division by a divide-by-two divider 152 from the 38 KHz oscillator 130. The two dividers 131 and 152 are so energized that they supply 19 KHz waves whose phases are shifted 90° relative to one another.

WHAT WE CLAIM IS:—

1. A radio broadcasting system with code signalling wherein at the transmitter side a multiplex signal which is frequency-modulated on a main carrier is transmitted, said multiplex signal comprising: an audio frequency information signal, a stereo pilot whose frequency is located between the frequency spectrum of the audio frequency information signal and the frequency spectrum envisaged for the transmission of a suppressed sub-carrier modulated stereo information signal and which serves for demodulating such stereo information signal, as well as a binary code signal modulated on a further sub-carrier located outside said frequency spectra and having an amplitude which causes the main carrier to deviate for not more than 1 KHz, characterized in that said further sub-carrier is a harmonic of a sub-harmonic of the stereo pilot not coinciding with a harmonic of the stereo pilot, and is derived at the transmitter side from the same frequency source as the stereo pilot and in that the code signal is binary phase modulated on this sub-carrier.
2. A radio broadcasting system as claimed in Claim 1, characterized in that the frequency of said further sub-carrier is located in the middle between two harmonics of the stereo pilot.
3. A radio broadcasting system as claimed in Claim 1, characterized in that the further sub-carrier with the modulated code signal is located in at least one of the two halves of the frequency range, divided in two by the stereo pilot, between the upper limit of the frequency spectrum of

the audio frequency information signal and the lower limit of the frequency spectrum of the modulated stereo information signal and in that the modulated code signal has an amplitude which causes the main carrier to deviate by less than 1 KHz, preferably by 0.25 KHz.

4. A radio broadcasting system as claimed in Claim 3, characterized in that a sub-carrier, binary phase modulated by the code signal is located in each of the two halves of the frequency range divided into two by the stereo pilot.

5. A radio broadcasting system as claimed in Claim 4, characterized in that the two sub-carriers, modulated by the code signal, have equal amplitudes and such a phase relative to the stereo pilot that together with the stereo pilot they form a signal produced by quadrature modulation of the stereo pilot by a sub-carrier derived from the stereo pilot, this sub-carrier being binary phase modulated by the code signal.

6. A radio broadcasting system as claimed in Claim 3, characterized in that the sub-carrier modulated by the code signal is located from the stereo pilot at a distance equal to $1/8 \times$ the frequency of the stereo pilot.

7. A receiver for a radio broadcasting system with code signalling as claimed in any preceding Claim comprising a frequency discriminator for demodulating the received main carrier, characterized by a synchronous demodulator having first and second inputs and an output, a first transmission path coupled to the frequency discriminator for applying the binary phase modulated code signal to the first input of the synchronous demodulator, a second transmission path coupled to the frequency discriminator for applying an unmodulated wave synchronized by the stereo pilot to the second input of the synchronous demodulator and an output circuit coupled to the output of the synchronous demodulator for the demodulated binary code signal.

8. A receiver as claimed in Claim 7, characterized by a device, included between the two transmission paths, for generating a control signal in dependency on the relative phase between the carrier of the binary phase modulated signal applied to the first input of the synchronous demodulator and of the unmodulated wave applied to the second input of the synchronous demodulator and by an electronically controllable phase shifter, included in one of the two transmission paths and controlled by said control signal, for controlling said relative phase.

9. A receiver as claimed in Claim 8, characterized in that the device for generating a control signal comprises a

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5 phase detector with first and second inputs and an output as well as a frequency doubling circuit coupled between a connection point of the first transmission path and the first input of the phase detector, in that a connecting point of the second input of the phase detector and in that the output of the phase detector controls the electronically controllable phase shifter.

10 10. A receiver as claimed in Claim 8, characterized in that the device for generating a control signal comprises a phase detector with first and second inputs and an output, the first input being connected via a first connection to a connection point of the first transmission path and the second input via a second connection to a connection point of the second transmission path, the output of the phase detector controlling the electronically controllable phase shifter via a third connection as well as a phase converter, included in one of said connections and being controlled by the output signal of the synchronous demodulator.

30 11. A receiver as claimed in Claim 9 or Claim 10, characterized in that the electronically controllable phase shifter is included in the second transmission path before said connection point of the second transmission path.

35 12. A receiver as claimed in Claim 7, characterized in that connected to the output of the frequency discriminator there is a filter and converter arrangement for filtering out the stereo pilot and of converting by means of the filtered stereo pilot the sub-carrier binary phase modulated by the code signal into an intermediate frequency carrier, binary phase modulated by the code signal and having a frequency equal to the frequency spacing between the sub-carrier and the stereo pilot, in that said first transmission path is connected to an output of the filter and converter arrangement for applying the binary phase modulated intermediate frequency carrier to the first input of the synchronous demodulator, and in that an output of the filter and converter arrangement for the filtered stereo pilot is connected to the second transmission path, comprising one or more frequency dividers, for generating an unmodulated intermediate frequency wave, synchronized by the filtered stereo pilot, and for applying this unmodulated intermediate frequency wave to the second input of the synchronous demodulator.

60 13. A receiver as claimed in Claim 12, characterized in that said filter and converter arrangement comprises a phase locked loop implemented with a voltage-

controlled oscillator, a filter and a phase detector, for filtering out the stereo pilot, the output signal of the frequency discriminator being applied to a first input of the phase detector and the filtered out stereo pilot derived from the voltage-controlled oscillator to a second input of the phase detector and in that the phase detector of the phase locked loop also functions as a converter for the modulated sub-carrier because said first transmission path is connected to the output of the phase detector.

14. a receiver as claimed in Claim 12, characterized in that a bandpass filter tuned to the sub-carrier modulated by the code signal is included between the output of the frequency discriminator and the input of the filter and converter arrangement, a slope of this bandpass filter passing the stereo pilot.

15. A transmitter for a radio broadcasting system with code signalling as claimed in any one of Claims 1 to 6 inclusive, comprising a device for generating an audio frequency information signal, an oscillator for generating a stereo pilot whose frequency is located between the frequency spectrum of the audio frequency information signal and the frequency spectrum for the transmission of a suppressed sub-carrier modulated stereo information signal, characterized by a source of binary code signals and a modulating signal generator, connected to this source and to the said oscillator, for generating a sub-carrier which is binary phase modulated by the code signal this sub-carrier being a harmonic of a sub-harmonic of the stereo pilot not coinciding with the harmonic of this pilot and being located outside said frequency spectra.

16. A transmitter as claimed in Claim 15, characterized in that the modulating signal generator generates a sub-carrier which is binary phase modulated by the code signal and is located in at least one of the two halves of the frequency range, divided into two by the stereo pilot, between the upper limit of the frequency spectrum of the audio frequency information signal and the lower limit of the frequency spectrum for the modulated stereo information signal.

17. A transmitter as claimed in Claim 15, characterized in that the modulating signal generator comprises a sub-carrier generator for generating said sub-carrier as well as a modulator, connected to the sub-carrier generator and the source of binary code signals, for binary phase modulating the sub-carrier by the code signals.

18. A transmitter as claimed in Claim 15, characterized in that the modulating signal generator comprises a frequency generator

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5 connected to the oscillator, for generating
an intermediate frequency carrier having a
frequency equal to the frequency spacing
between the sub-carrier and the stereo
pilot, as well as first and second modulators
each comprising first and second inputs and
an output, the output of the first modulator
being connected to the first input of the
10 second modulator, of the two inputs of the
first modulator and the second input of the
second modulator one input being
connected to the oscillator, a second input

to the frequency generator and a third input
to the binary code signal source.

19. A radio broadcasting system, 15
substantially as hereinbefore described with
reference to the accompanying drawings.

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