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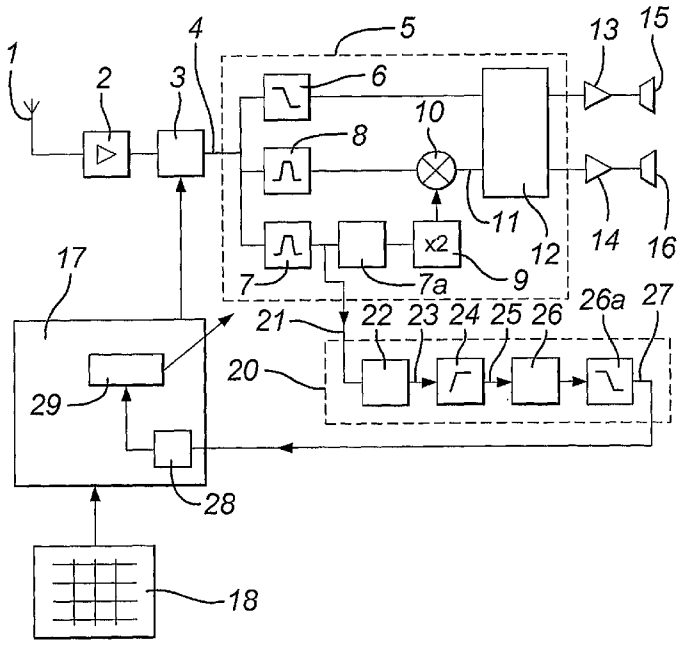
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(54) **Title:** FM SIGNAL QUALITY MEASUREMENT



(57) **Abstract:** A signal quality estimator for estimating the quality of signal reception in a signal receiver, the signal quality estimator comprising: a first filter for filtering a signal received by the receiver to isolate a frequency band therein; and a signal analyser for forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time, to serve as an estimate of the quality of signal reception in the receiver.

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FM SIGNAL QUALITY MEASUREMENT

This invention relates to measuring the quality of received FM (frequency modulation) signals.

Conventional FM broadcast radio signals are transmitted according to a standardised scheme. Mono FM broadcast signals are modulated by an audio signal with 15 kHz bandwidth. This is known as the M signal. The modulating signal of stereo FM broadcasts additionally contains a pilot signal at 19 kHz and a second signal representing the difference between the left and right stereo channels which is transmitted as a double-sideband suppressed carrier (DSBSC) signal in the range from 23 kHz to 53 kHz. This second signal is known as the S signal. In generating stereo signals for transmission, the M, S and pilot signals are combined producing a signal known as the stereo multiplex, and then frequency modulated. Signals carrying other information, such as RDS, RBDS, ARI and subsidiary communications may also be added to a stereo multiplex. For mono reception only the M signal needs to be received. For stereo reception the left and right stereo channels are recovered by combining the M and S signals. The pilot signal aids the receiver to perform separation of the stereo multiplex components.

When an FM signal is to be received and decoded for reproduction, it is frequency demodulated to yield the stereo multiplex signal. If the FM signal is transmitted as a stereo signal then the stereo multiplex contains the M, S and pilot signals. If the FM signal is transmitted as a mono signal then the stereo multiplex contains the M signal but it does not contain the S and pilot signals. Nowadays most FM radio stations transmit stereo broadcasts. The structure of the stereo multiplex for a stereo FM broadcast signal is illustrated in figure 1.

For various reasons it might be desirable for the receiver to have a measure of the quality of the received signal. For example, when a single radio station is broadcast on two FM channels it may be useful for the receiver to switch automatically to the channel that can be received with better quality. To achieve this, the receiver must be able to compare the receive quality of those two channels. Another use for a quality measure is to provide the input to a quality meter for providing an indication of receive quality to a user of the receiver.

A conventional way to assess received FM signal quality is by taking received signal strength as a measure of received signal quality. However, this approach can not detect signal impairments that do not affect the signal's strength, such as interference and distortion.

There is therefore a need for an improved method for estimating the signal quality of received FM radio signals.

According to the present invention from one aspect there is provided a signal quality estimator for estimating the quality of signal reception in a signal receiver, the signal quality estimator comprising: a first filter for filtering a signal received by the receiver to isolate a frequency band therein; and a signal analyser for forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time, to serve as an estimate of the quality of signal reception in the receiver.

The signal analyser may comprise: an amplitude estimator for forming an estimate of the time-variance of the amplitude of the signal in the frequency band; and a signal estimator for forming the said indication in dependence on the magnitude of the estimate formed by the amplitude estimator.

The amplitude estimator may comprise: an amplitude detector for detecting the time-variant amplitude of the signal in the frequency band; and a second filter for

filtering time-constant components from the output of the amplitude detector so as to form the estimate of the time-variance of the amplitude of the signal in the frequency band.

The amplitude detector may operate periodically to set the value of its output to be representative of the maximum amplitude of the signal in the frequency band during a preceding period.

The amplitude detector may be a peak detector.

The second filter may be a high-pass filter.

The signal estimator may be arranged to form the said indication in dependence on the average magnitude of the estimate formed by the amplitude estimator.

The signal estimator may be or comprise a rectifier followed by a low-pass filter.

The said frequency band preferably includes 19 kHz. The first filter preferably has a 3 dB bandwidth of less than 100 Hz, and more preferably less than 50 or 20 Hz.

According to the present invention from a second aspect there is provided a signal receiver comprising a signal quality estimator for estimating the quality of signal reception in the receiver, the signal quality estimator comprising: a first filter for filtering a signal received by the receiver to isolate a frequency band therein; and a signal analyser for forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time, to serve as an estimate of the quality of signal reception in the receiver.

The receiver may comprise: a frequency demodulator for frequency demodulating a received signal to form a demodulated signal, and wherein the first filter takes the demodulated signal as its input.

The signal receiver may comprise a signal recovery unit for recovering a traffic signal from the demodulated signal, the signal recovery unit being arranged to recover the traffic signal by means of a pilot signal passed in the said frequency band.

The signal receiver may be an FM broadcast radio receiver.

According to a third aspect of the present invention there is provided a method for estimating the quality of signal reception in a signal receiver, the method comprising: filtering a signal received by the receiver to isolate a frequency band therein; and forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time, to serve as an estimate of the quality of signal reception in the receiver.

The step of forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time may comprise: forming an estimate of the time-variance of the amplitude of the signal in the frequency band; and forming the said indication in dependence on the magnitude of the estimate formed by the amplitude estimator.

The step of forming an estimate of the time-variance of the amplitude of the signal in the frequency band may comprise: detecting the time-variant amplitude of the signal in the frequency band; and filtering time-constant components from the output of the amplitude detection step so as to form the estimate of the time-variance of the amplitude of the signal in the frequency band.

The step of detecting the time-variant amplitude of the signal in the frequency band may comprise periodically setting the value the output of the amplitude detection step to be representative of the maximum amplitude of the signal in the frequency band during a preceding period.

The method may comprise forming the said indication in dependence on the average magnitude of the estimate formed by the amplitude estimator.

The present invention will now be described by way of example with reference to the accompanying drawing.

In the drawing:

Figure 1 shows the structure of the stereo multiplex for conventional FM broadcast signals; and

Figure 2 is a schematic diagram of an example of an FM receiver.

The quality measure described herein is a function of the amount of amplitude variation of the signal present in a relatively narrow band centred on 19 kHz in the stereo multiplex signal. Preferably the quality measure is proportional to that amount as measured according to a suitable mechanism, examples of which are described below.

Figure 2 illustrates a receiver for FM broadcast signals. The signals are received at an antenna 1, amplified by amplifier 2 and then FM demodulated by demodulator 3. The signal at point 4, at the output of the demodulator, is the stereo multiplex signal, which contains the M signal and for a stereo broadcast the S and pilot signals, as illustrated in figure 1.

For recovery of the audio components of the signal, the M, S and pilot signals pass to an audio recovery section 5. At the input of the audio recovery section, the M, S and pilot signals are isolated from the stereo multiplex by means of filters 6, 8 and 7. Filter 6 is a low-pass filter having a cut-off frequency at 15 kHz, which passes only the M signal. Filter 7 is a band-pass filter centred on 19 kHz, which passes only the pilot signal. Filter 8 is a band-pass filter that passes only the 23 to 53 kHz S signal. The recovered pilot signal passes to a frequency doubler 9. The frequency doubler generates a 38 kHz signal which is mixed with the S signal in mixer 10 to shift the S signal to baseband, forming a signal at 11 that represents the difference between the left and right stereo channels. The M signal and the signal at 11 pass to unit 12 which generates the left and right stereo channels by combining the M signal and the signal at 11. These can be output to amplifiers 13, 14 and loudspeakers 15, 16.

In some implementations filter 7 may incorporate an optional phase locked loop 7a (as shown in figure 2), in order to improve the quality of the recovered pilot signal. Further, filter 8 may be located at the output of the mixer 10 and implemented as a low-pass filter similar to filter 6.

The receiver has a control unit 17 which controls its operation. For example, control unit 17 is responsive to a keypad 18 by which a user can indicate the channel that is to be received. In dependence on that input the control unit sets the FM demodulator 3 accordingly.

Section 20 is intended for assessing the quality of the received signal.

Section 20 takes as its input the isolated pilot signal as output from filter 7. For this purpose the filter 7 is preferably selected to be relatively narrow, and centred on the frequency of the pilot signal. In the case of conventional broadcast FM signals the filter 7 could be centred on 19 kHz and could have a 3 dB bandwidth

of around 10 Hz and a stop-band attenuation of 60 dB at frequencies more than 3 kHz away from 19 kHz.

The isolated pilot signal at 21 is input to an amplitude detector 22. This produces an output signal at 23 that represents the amplitude of the signal at 21. The amplitude detector may periodically measure the amplitude of the signal at 21, over sample periods of t_{samp}. This is particularly convenient in a digital processing implementation. t_{samp} is preferably selected such that the sampling frequency, $1/t_{samp}$, is less than the frequency of the pilot signal. The output of the amplitude detector is preferably an analogue signal whose value during any sample period is representative of the maximum amplitude of the signal at 21 during the previous sample period. It could be representative of other functions of the amplitude during that period, such as the average amplitude. Most preferably the output of the amplitude detector is equal to or proportional to the maximum amplitude of the signal at 21 during the immediately previous sample period. Other methods of estimating the amplitude of the signal at 21 could be used: for example the signal at 23 could be formed so as to have a level that follows the level of the signal at 21 as the latter increases above the level of the signal at 23, but that otherwise decays over time. The estimate of the amplitude of the signal at 21 could be formed digitally if required.

The signal at 23 that is output from the amplitude detector is input to a high-pass filter 24 which rejects the DC component of the signal at 23 to form an output at 25. In a digital processing implementation, the z transform of filter 24 may, for example, be $H(z) = 1 - 1/z$. The effect of the filter 24 is to make the signal at 25 independent of the magnitude of any constant amplitude tone that may be present in the signal at 21. An example of such a constant amplitude tone is – in normal reception conditions – the pilot tone itself, so the filter 24 has the effect of removing the influence of the pilot tone itself from the signal at 25. Again, this step may be performed digitally if that is preferred.

The quality measure is taken to be dependent on the average power of the signal at 25. The higher the average power of the signal at 25, the lower the signal quality is. The dependency may take any suitable form, but most preferably the dependency is such that the quality measure is representative of the RMS (root mean square) of the power of the signal at 25. This may be determined in a number of ways. One convenient mechanism is to pass the signal at 25 through a rectifier 26 followed by a low-pass filter 26a so as to generate at 27 an approximation of the RMS value of the signal at 25. Other mechanisms could be used, such as digitally sampling the signal at 25 and performing a digital RMS estimation on it.

The signal at 27 can then be passed to the control unit 17 where it can be used in controlling the operation of the receiver. The control unit may operate largely in the digital domain, in which case it may be convenient to digitise the signal at 27 by means of an analog-to-digital converter 28 before using it further. This is not necessary if section 20 is implemented using digital processing.

The quality measure can be used in a number of ways. One notable use is in assisting the control unit to automatically vary operational parameters of the receiver with the aim of achieving a desired receive quality. The control unit may include an optimisation unit 29 which adjusts operational parameters of the receiver. After an adjustment it compares the quality measure with its value prior to the adjustment, and if the quality measure indicates an improvement the adjustment is retained. Otherwise the adjustment is reversed. More sophisticated algorithms for automatic adjustment of the operating parameters could also be used. Examples of the operational parameters that could be adjusted with the aim of maximising or at least increasing the quality measure, or with the aim of maintaining the quality measure within a desired range, are as follows:

- The demodulator 3 will typically include a local oscillator which generates a signal that is mixed in the demodulator 3 with the amplified received

signal to mix the received signal down to an intermediate frequency. The intermediate frequency or frequencies used in the down-conversion process can be adjusted as one or more of the said parameters.

- The current consumption of receiver components, for example that of
    - the low noise amplifier 2
    - any local oscillator(s) used in the down-conversion process that forms part of the demodulator 3
    - receiver analogue and digital filters, where higher selectivity requires higher current consumption
    - receiver analogue to digital converters
- The mono/stereo blending processing of the received audio signal, performed in unit 12. Mono reception audio quality typically resists receive signal impairments better than stereo reception. It a known approach for receivers to reduce the amount of audio stereo separation as signal quality decreases. The amount of audio stereo separation can be one of the said parameters.
- A degree of attenuation of the received audio signal, which may be applied in unit 12. When receiving very poor quality signals, even mono reception produces noisy audio. It is a known approach for receivers to attenuate the received audio as signal quality decreases, in order to limit the audio noise heard by the user.

The signal quality measure discussed above has a number of advantages over conventional techniques. First, it is simple to implement. The circuit 20 can be formed from two filters (24, 26a), a rectifier (26) and a peak detect circuit for amplitude detector (22). Second, it provides a relatively accurate indication of received signal quality as opposed to simply received signal strength. As indicated above, it is particularly useful in a configurable FM receiver, where parameters may be tuned with the goal of maximising signal quality. The present signal quality measure also has the advantage that it works irrespective of

whether the signal that is being received by the receiver is a mono or a stereo signal – i.e. irrespective of whether the pilot tone is present in the received signal.

The method described above is conveniently applicable to conventional broadcast FM signals. It is also applicable to other signals, especially those containing a pilot tone at a frequency such that the quality of reception of the pilot tone is representative of the quality of reception of signals at data frequencies of the protocol in question. It is conveniently applicable to systems in which the pilot tone is conventionally isolated by means of a band-pass filter from other components of the received signal, since the filter that is used to isolate the pilot signal (filter 7 in figure 2) can provide an output for use in the signal recovery process as well as for use by the signal quality estimator (20 in figure 2).

The receiver as illustrated in figure 2 (excluding the antenna 1 if desired) can conveniently be implemented on a single integrated circuit.

The quality measure could be used in other ways. For example, it can provide an indication allowing the receiver to decide which of two channels to receive on or to provide the input to a quality meter for providing an indication of receive quality to a user of the receiver.

The applicant hereby discloses in isolation each individual feature described herein and any combination of two or more such features, to the extent that such features or combinations are capable of being carried out based on the present specification as a whole in the light of the common general knowledge of a person skilled in the art, irrespective of whether such features or combinations of features solve any problems disclosed herein, and without limitation to the scope of the claims. The applicant indicates that aspects of the present invention may consist of any such individual feature or combination of features. In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention.

CLAIMS

1. A signal quality estimator for estimating the quality of signal reception in a signal receiver, the signal quality estimator comprising:

a first filter for filtering a signal received by the receiver to isolate a frequency band therein; and

a signal analyser for forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time, to serve as an estimate of the quality of signal reception in the receiver.

2. A signal quality estimator as claimed in claim 1, wherein the signal analyser comprises:

an amplitude estimator for forming an estimate of the time-variance of the amplitude of the signal in the frequency band; and

a signal estimator for forming the said indication in dependence on the magnitude of the estimate formed by the amplitude estimator.

3. A signal quality estimator as claimed in claim 2, wherein the amplitude estimator comprises:

an amplitude detector for detecting the time-variant amplitude of the signal in the frequency band; and

a second filter for filtering time-constant components from the output of the amplitude detector so as to form the estimate of the time-variance of the amplitude of the signal in the frequency band.

4. A signal quality estimator as claimed in claim 3, wherein the amplitude detector operates periodically to set the value of its output to be representative of the maximum amplitude of the signal in the frequency band during a preceding period.

5. A signal quality estimator as claimed in claim 3, wherein the amplitude detector is a peak detector.

6. A signal quality estimator as claimed in claim 3 or 4, wherein the second filter is a high-pass filter.

7. A signal quality estimator as claimed in any of claims 2 to 5, wherein the signal estimator is arranged to form the said indication in dependence on the average magnitude of the estimate formed by the amplitude estimator.

8. A signal quality estimator as claimed in any of claims 2 to 6, wherein the signal estimator comprises a rectifier followed by a low-pass filter.

9. A signal quality estimator as claimed in any preceding claim, wherein the frequency band includes 19 kHz.

10. A signal quality estimator as claimed in any preceding claim, wherein the first filter has a 3 dB bandwidth of less than 100 Hz.

11. A signal receiver comprising a signal quality estimator for estimating the quality of signal reception in the receiver, the signal quality estimator comprising:

a first filter for filtering a signal received by the receiver to isolate a frequency band therein; and

a signal analyser for forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time, to serve as an estimate of the quality of signal reception in the receiver.

12. A signal receiver as claimed in claim 11, wherein the receiver comprises:

a frequency demodulator for frequency demodulating a received signal to form a demodulated signal,

and wherein the first filter takes the demodulated signal as its input.

13. A signal receiver as claimed in claim 12, comprising a signal recovery unit for recovering a traffic signal from the demodulated signal, the signal recovery unit being arranged to recover the traffic signal by means of a pilot signal passed in the said frequency band.

14. A signal receiver as claimed in any of claims 11 to 13, wherein the signal receiver is an FM broadcast radio receiver.

15. A method for estimating the quality of signal reception in a signal receiver, the method comprising:

filtering a signal received by the receiver to isolate a frequency band therein; and

forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time, to serve as an estimate of the quality of signal reception in the receiver.

16. A method as claimed in claim 15, wherein the step of forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time comprises:

forming an estimate of the time-variance of the amplitude of the signal in the frequency band; and

forming the said indication in dependence on the magnitude of the estimate formed by the amplitude estimator.

17. A method as claimed in claim 16, wherein the step of forming an estimate of the time-variance of the amplitude of the signal in the frequency band comprises:

detecting the time-variant amplitude of the signal in the frequency band; and

filtering time-constant components from the output of the amplitude detection step so as to form the estimate of the time-variance of the amplitude of the signal in the frequency band.

18. A signal quality estimator as claimed in claim 17, wherein the step of detecting the time-variant amplitude of the signal in the frequency band comprises periodically setting the value the output of the amplitude detection step to be representative of the maximum amplitude of the signal in the frequency band during a preceding period.

19. A method as claimed in any of claims 16 to 18, comprising forming the said indication in dependence on the average magnitude of the estimate formed by the amplitude estimator.

20. A signal quality estimator substantially as herein described with reference to the accompanying drawings.

AMENDED CLAIMS
received by the International Bureau on 12 May 2008 (12.05.2008)

1. A signal quality estimator for estimating the quality of signal reception in a signal receiver, the signal quality estimator comprising:

a first filter arranged to filter a signal received by the receiver to isolate a frequency band that includes a pilot signal; and

a signal analyser configured to form an indication of the degree to which the amplitude of the signal in that frequency band varies over time, said indication serving as an estimate of the quality of signal reception in the receiver.

2. A signal quality estimator as claimed in claim 1, wherein the signal analyser comprises:

an amplitude estimator for forming an estimate of the time-variance of the amplitude of the signal in the frequency band; and

a signal estimator for forming the said indication in dependence on the magnitude of the estimate formed by the amplitude estimator.

3. A signal quality estimator as claimed in claim 2, wherein the amplitude estimator comprises:

an amplitude detector for detecting the time-variant amplitude of the signal in the frequency band; and

a second filter for filtering time-constant components from the output of the amplitude detector so as to form the estimate of the time-variance of the amplitude of the signal in the frequency band.

4. A signal quality estimator as claimed in claim 3, wherein the amplitude detector operates periodically to set the value of its output to be representative of the maximum amplitude of the signal in the frequency band during a preceding period.

5. A signal quality estimator as claimed in claim 3, wherein the amplitude detector is a peak detector.

6. A signal quality estimator as claimed in claim 3 or 4, wherein the second filter is a high-pass filter.

7. A signal quality estimator as claimed in any of claims 2 to 5, wherein the signal estimator is arranged to form the said indication in dependence on the average magnitude of the estimate formed by the amplitude estimator.

8. A signal quality estimator as claimed in any of claims 2 to 6, wherein the signal estimator comprises a rectifier followed by a low-pass filter.

9. A signal quality estimator as claimed in any preceding claim, wherein the frequency band includes 19 kHz.

10. A signal quality estimator as claimed in any preceding claim, wherein the first filter has a 3 dB bandwidth of less than 100 Hz.

11. A signal receiver comprising a signal quality estimator as claimed in any preceding claim.

12. A signal receiver as claimed in claim 11, wherein the receiver comprises:

a frequency demodulator for frequency demodulating a received signal to form a demodulated signal,

and wherein the first filter takes the demodulated signal as its input.

13. A signal receiver as claimed in claim 12, comprising a signal recovery unit for recovering a traffic signal from the demodulated signal, the signal recovery unit being arranged to recover the traffic signal by means of a pilot signal passed in the said frequency band.

14. A signal receiver as claimed in any of claims 11 to 13, wherein the signal receiver is an FM broadcast radio receiver.

15. A method for estimating the quality of signal reception in a signal receiver, the method comprising:

filtering a signal received by the receiver to isolate a frequency band that includes a pilot signal; and

forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time;

using said indication as an estimate of the quality of signal reception in the receiver.

16. A method as claimed in claim 15, wherein the step of forming an indication of the degree to which the amplitude of the signal in that frequency band varies over time comprises:

forming an estimate of the time-variance of the amplitude of the signal in the frequency band; and

forming the said indication in dependence on the magnitude of the estimate formed by the amplitude estimator.

17. A method as claimed in claim 16, wherein the step of forming an estimate of the time-variance of the amplitude of the signal in the frequency band comprises:

detecting the time-variant amplitude of the signal in the frequency band; and

filtering time-constant components from the output of the amplitude detection step so as to form the estimate of the time-variance of the amplitude of the signal in the frequency band.

18. A method as claimed in claim 17, wherein the step of detecting the time-variant amplitude of the signal in the frequency band comprises periodically setting the value the output of the amplitude detection step to be representative of the maximum amplitude of the signal in the frequency band during a preceding period.

19. A method as claimed in any of claims 16 to 18, comprising forming the said indication in dependence on the average magnitude of the estimate formed by the amplitude estimator.

20. A signal quality estimator substantially as herein described with reference to the accompanying drawings.

Fig. 1

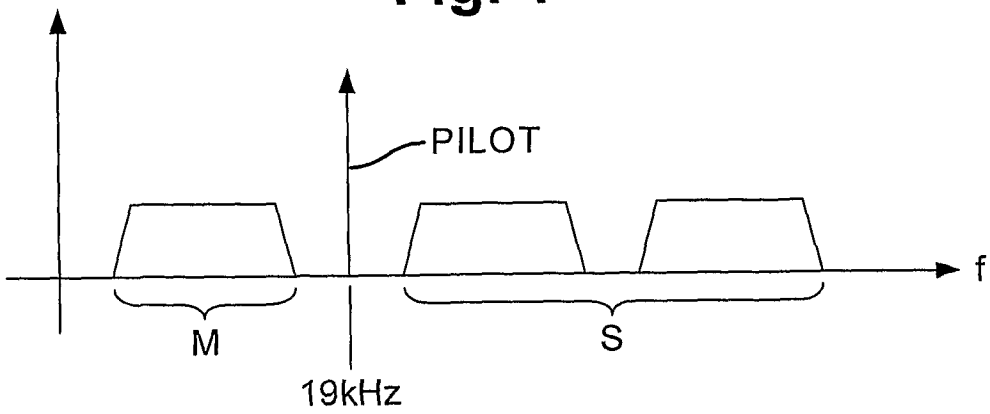
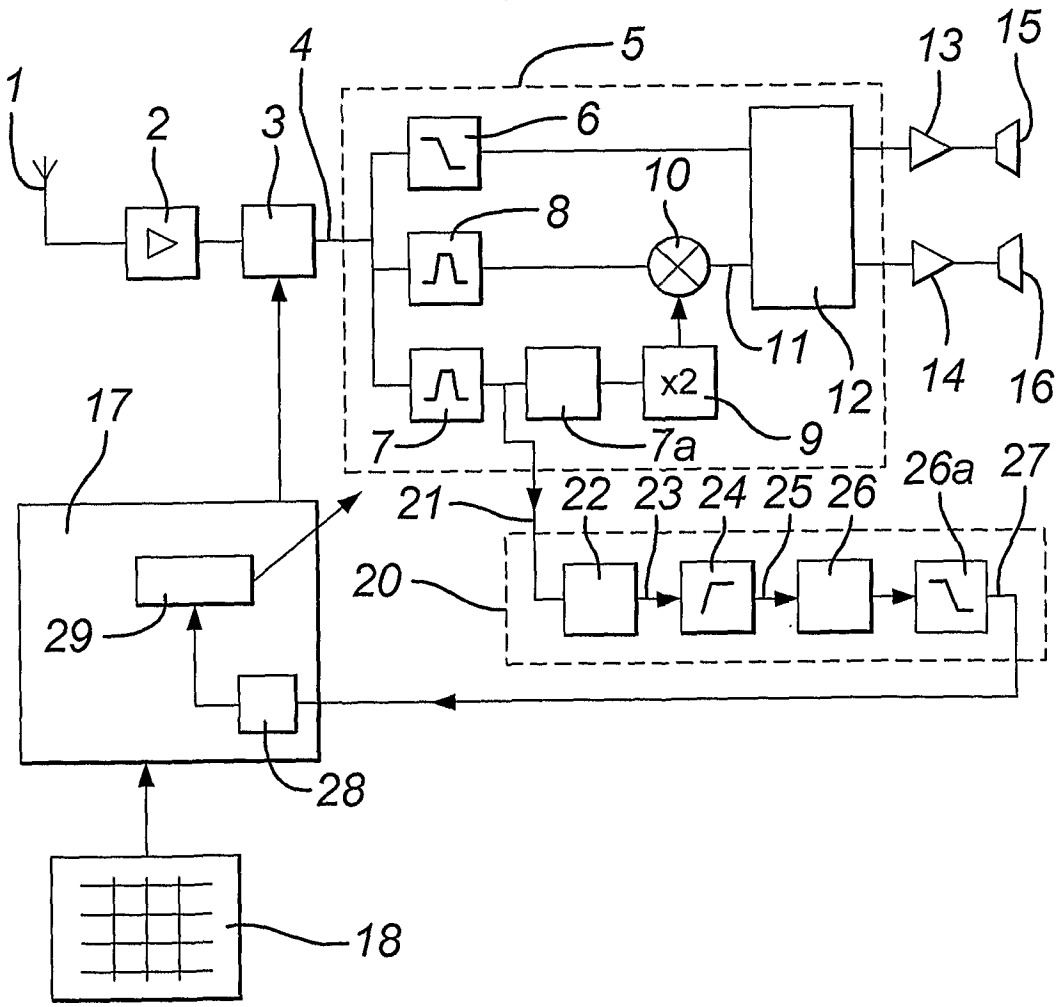

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Fig. 2


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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/004586

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B1/16 H04B17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 893 349 A (EASTMOND BRUCE C [US] ET AL) 9 January 1990 (1990-01-09) column 1, line 20 - line 28 figures 1,2 column 6, line 14 - line 35	1-3,6, 11,12, 15,16
X	US 5 416 843 A (HOPKINS HARLAND G [US]) 16 May 1995 (1995-05-16) column 1, line 50 - line 52 column 2, line 54 - column 3, line 6 column 3, line 42 - line 48 column 4, line 3 - line 14 figures 1,2	1,2,9, 11,12, 14-16

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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Date of the actual completion of the international search	Date of mailing of the international search report
29 February 2008	10/03/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	AVILES MARTINEZ, L

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/004586

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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