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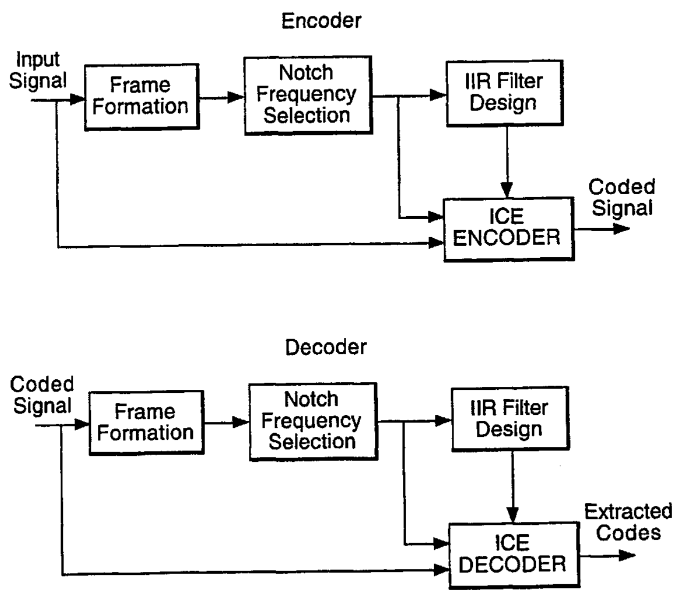

(57) Abstract: A system for labelling and subsequently identifying a multi-frequency signal, includes means for inserting a code signal into a multi-frequency signal, signal distribution means, signal receiving means, code extractions means, and monitoring means to determine which parts of the frequency spectrum will at least partly mask the code signal at a given time using predetermined criteria. The means for inserting a code signal includes means for eliminating one or more frequency ranges being located in a part of the frequency spectrum that will at least partly mask the code signal, the location of the frequency ranges being eliminated from said multi-frequency signal varies with the frequency content of said multi-frequency signal.

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A METHOD OF LABELLING A MULTI-FREQUENCY SIGNAL

This invention relates to a method of labelling a multi-frequency signal, and particularly, though not exclusively, to a method of labelling an audio or video signal prior to broadcast or distribution to provide an audit trail. It also relates to a system for labelling such a signal and a system for controlling replay of such a signal.

A known method of labelling or watermarking a plural channel audio signal is disclosed in WO96/21290. Although the technology was initially targeted at the broadcast monitoring field, there are a number of other application areas where it can be employed. These include: digital television systems, streaming audio over the Internet, and digital audio distribution. The system provides a method of labelling an audio signal by embedding an identifying code inaudibly within the signal. The code can be used for identifying copyright ownership, fingerprinting and access control to digital audio data. Two notches are inserted in the audio band to provide frequencies at which the code may be inserted. The code signal is inserted as a series of pulses at the centre frequencies of the notches, and insertion is initiated when the program content provides sufficient masking conditions for the code to be inserted inaudibly. A masking filter is employed to determine the masking level of the incoming signal at the chosen code frequencies. The level of unwanted signal breakthrough in the notch frequencies is also monitored as it can prevent correct extraction of the code. Whilst this process is in progress, if either level falls below a pre-determined value the code generation is abandoned. Thus, the codes are inserted as often as the input signal conditions allow.

The technique can be applied to both mono and stereophonic signals. The code is inserted in both channels simultaneously in a way that gives monophonic compatibility for coded stereo signals. The system, however, has a potential security problem as an attacker can filter out the code by the use of narrow notch filters operating at the same frequencies as used at the original encoding process. To enhance the security of the system, US 5,113,437 discloses implementing frequency hopping, by allowing the encoder to switch randomly between three predetermined notch frequency pairs. In order to decode the signal it is necessary to provide three decoders connected in parallel, each decoder being responsive to one of the three notch frequency pairs. Another method of inserting a code in one or more frequency components of an audio signal is disclosed in US 5,450,490.

According to a first aspect of the invention there is provided a method as specified in claims 1 – 10.

According to a second aspect of the invention there is provided a system as specified in claim 11,

According to a third aspect of the invention there is provided a system as specified in claim 12.

According to a further aspect of the invention there is provided a signal as specified in claim 13.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:-

Figure 1 shows a schematic diagram of an embodiment of the invention,

Figure 2 shows a flow diagram of an embodiment of the invention, and

Figure 3 shows a schematic diagram of a second embodiment of the invention.

The present invention includes a method for appropriately selecting the part of the frequency spectrum where each watermark code is inserted, providing improved audio quality and extra security in the form of frequency hopping. The method described may be been implemented in software.

The present invention differs from prior art systems in that the selection of the location of the notch or notches in the frequency spectrum of a signal (and hence the frequency of the embedded code) is chosen adaptively with regard to the frequency content of the signal (with the possible addition of a random offset). Moreover, in general it does not require the existence of a decoder array for all the possible notch frequency values in order to extract the codes, although use of such an array is not precluded.

The placement of the notch frequencies plays a significant role to the subjective quality of the coded signals. The codes are more perceptible if the notch frequencies coincide with the main frequency component of the signal. On the other hand, they have to be placed in a part of the spectrum with sufficient energy so that frequent masking conditions can be met. Therefore, a criterion that satisfies these requirements is needed for the selection of the code frequencies.

In one embodiment, the method comprises the following elements:

- Segmentation of the input signals into frames and transformation into the frequency domain (unless the input signal is already in this form).
- Selecting the appropriate notch frequency location for each frame according to a predetermined criterion.
- Adapting the encoder and decoder filter parameters to the selected notch frequencies.
- Adding a degree of randomness or unpredictability in determining the precise location of the notch frequencies.

The integration of these main elements of the invention to the encoder and decoder of WO96/21290 is illustrated in the block diagram of Figure 1.

The input signal is digitized and processed in frames. Once a frame of samples has been assembled, the notch frequency selection criterion is applied to determine the position of the notch frequencies. The function of the criterion is illustrated in Figure 2. A frequency analysis technique, e.g. FFT, is applied to generate a set of spectral coefficients. The spectral coefficients are grouped to form frequency bands of approximate width 0.6 - 0.7 kHz. The energy content of each band is calculated from the corresponding spectral coefficients. The band with the maximum energy content is found. This process up to here can use part of the psycho-acoustic modeling performed by an MPEG encoder. The notch frequencies are placed in one of the two neighbouring bands, as illustrated in the flow diagram of Figure 2. This Figure shows that when the band with maximum energy in it is determined (B_{max}, the code is either placed in the nearest neighbour band B_{max+1} if the energy peak is narrower than some threshold value, or placed in the second nearest neighbour band B_{max+2} if the energy peak is broad.

Changing the position of the notch frequencies during the encoding process involves the employment of a new filter set that will be responsive to the new frequency values. Since the set of possible values that the notch frequencies can take is large and depends upon the signal content, using a pre-computed set of filters for each possible notch frequency value is not practical and would increase significantly the memory requirements of the system. Therefore, it is more efficient to design the new filter set in real time every time the position of the notches is changed. The band-pass and band-stop filters are designed by applying a frequency transformation to a prototype low-pass filter, as described for example in the book "Introduction to Digital Signal Processing", by J. G. Proakis and D. G. Manolakis, Maxwell Macmillan International Editions (1989). By applying the appropriate frequency transformation to a 4^{th}-order IIR prototype low-pass filter 8^{th}-order band-pass and band-stop filters are generated. Thus, only one filter set corresponding to the current notch frequency values needs to be stored at any given time.

The notch frequency selection and filter design process are applied in an identical fashion during the decoding of a signal, as shown in Figure 1(b). The decoder is able to reproduce the same sequence of notch frequencies with the encoder and extract the codes from the signal, unless significant distortion has been introduced to the signal spectrum.

A second way to locate the best place to insert the notch filters will now be described. For each input block, a search is performed for the fundamental and harmonics of the input audio stream. Methods such as Fast Fourier Transform, Cepstrum, Correlogram or the Gold-Rabiner algorithm can be used to find both the fundamental and its harmonics. The notch filters can be inserted in the upper or lower edges of these harmonics (with the possible addition of a random offset).

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