have ranged from about 10 kHz to about 3500 Hz. U.S. Patents 5,583,962; 5,633,981, 5,727,119, 5,909,664, and 6,021,386 include teachings that relate to the combining of multiple audio channels into a composite channel and auxiliary or sidechain information and the recovery therefrom of an approximation to the original multiple channels. Each of said patents is hereby incorporated by reference in its entirety.

Methods according to the pre-characterizing portion of claims 1 and 12 are known from the document WO 03/090208 A1 that describes encoding of N input audio channels to a monophonic audio signal and a set of spatial parameters including a parameter representing a measure of similarity of waveforms of the N input audio channels, namely interchannel level difference and a selected one of interchannel time difference and interchannel phase difference. The monophonic audio signal is derived from the N input audio channels by summing the N input audio channels after a phase correction in accordance with interchannel time difference. The corresponding decoding method disclosed in this document synthesizes replica of the N input audio channels from the monophonic audio signal and the spatial parameters.

Disclosure of the Invention

Aspects of the present invention may be viewed as improvements upon the "coupling" techniques of the AC-3 encoding and decoding system and also upon other techniques in which multiple channels of audio are combined either to a monophonic composite signal or to multiple channels of audio along with related auxiliary information and from which multiple channels of audio are reconstructed. Aspects of the present invention also may be viewed as improvements upon techniques for downmixing multiple audio channels to a monophonic audio signal or to multiple audio channels and for decorrelating multiple audio channels derived from a monophonic audio channel or from multiple audio channels.

In a first aspect, the present disclosure provides a method performed in an audio decoder for reconstructing N audio channels from an audio signal having M audio channels, the method comprising: receiving a bitstream containing the M audio channels and a set of spatial parameters, wherein the set of spatial parameters includes an amplitude parameter and a correlation parameter, wherein the amplitude parameter is differentially encoded across time; decoding the M encoded audio channels, wherein each audio channel is divided into a plurality of frequency bands, and each frequency band includes one or more spectral components; extracting the set of spatial parameters from the bitstream; applying a differential decoding process across

time to the differentially encoded amplitude parameter to obtain a differentially decoded amplitude parameter; analyzing the M audio channels to detect a location of a transient; decorrelating the M audio channels to obtain a decorrelated version of the M audio channels, wherein a first decorrelation technique is applied to a first subset of the plurality of frequency bands of each audio channel and a second decorrelation technique is applied to a second subset of the plurality of frequency bands of each audio channel; deriving N audio channels from the M audio channels, the decorrelated version of the M audio channels, and the set of spatial parameters, wherein N is two or more, M is one or more, and M is less than N; and synthesizing, by an audio reproduction device, the N audio channels as an output audio signal, wherein both the analyzing and the decorrelating are performed in a frequency domain, the first decorrelation technique represents a first mode of operation of a decorrelator, the second decorrelation technique represents a second mode of operation of the decorrelator, and the audio decoder is implemented at least in part in hardware.

In a second aspect, the present disclosure provides a non-transitory computer readable medium containing instructions that when executed by a processor perform the method according to the first aspect.

In a third aspect, the present disclosure provides an audio decoder for decoding M encoded audio channels representing N audio channels, the audio decoder comprising: an input interface for receiving a bitstream containing the M encoded audio channels and a set of spatial parameters, wherein the set of spatial parameters includes an amplitude parameter and a correlation parameter, wherein the amplitude parameter is differentially encoded across time; an audio decoder for decoding the M encoded audio channels, wherein each audio channel is divided into a plurality of frequency bands, and each frequency band includes one or more spectral components; a demultiplexer for extracting the set of spatial parameters from the bitstream; a processor for applying a differential decoding process across time to the differentially encoded amplitude parameter to obtain a differentially decoded amplitude parameter, and analyzing the M audio channels to detect a location of a transient; a decorrelator for decorrelating the M audio channels, wherein a first decorrelation technique is applied to a first subset of the plurality of frequency bands of each audio channel and a second decorrelation technique is applied to a second subset of the plurality of frequency bands of each audio channel; a reconstructor for deriving N audio channels from the M audio channels and the set of spatial parameters, wherein N is two or more, M is one or more, and M is less than N; and an audio reproduction device that

synthesizes the N audio channels as an output audio signal, wherein both the analyzing and the decorrelating are performed in a frequency domain, the first decorrelation technique represents a first mode of operation of a decorrelator, and the second decorrelation technique represents a second mode of operation of the decorrelator.

Aspects of the invention may be employed in an N:l :N spatial audio coding technique (where "N" is the number of audio channels) or an M: 1 :N spatial audio coding technique (where "M" is the number of encoded audio channels and "N" is the number of decoded audio channels) that improve on channel coupling, by providing, among other things, improved phase compensation, decorrelation mechanisms, and signal-dependent variable time-constants. Aspects of the present invention may also be employed in N:x:N and M:x:N spatial audio coding techniques wherein "x" may be 1 or greater than 1. Goals include the

CLAIMS

1. A method for decoding multi-channel spatially encoded audio, comprising:

receiving, using a decoding device, a bitstream including audio information and side information relating to the audio information and useful in decoding the bitstream; and

spatially decoding the audio information using the decoding device, including upmixing the audio information to provide multiple channels and decorrelating the multiple channels within the audio information using multiple decorrelators, each having a filter characteristic; wherein the audio information is upmixed prior to the decorrelating and the decorrelating includes reshaping the audio channels in accordance with at least some of the side information.

2. The method according to Claim 1, wherein decoding the audio information includes dematrixing.

3. The method according to Claim 1, wherein the side information has a granularity and a temporal resolution limited by the bitrate of the side information.

4. A non-transitory computer-readable storage medium encoded with a computer program, for causing a computer to perform the method according to Claim 1.

5. Apparatus for decoding multi-channel spatially encoded audio, comprising:

means for receiving, using a decoding device, a bitstream including audio information and side information relating to the audio information and useful in decoding the bitstream; and

means for spatially decoding the audio information using the decoding device, including means for upmixing the audio information to provide multiple channels and means for decorrelating the multiple channels within the audio information using multiple decorrelators, each having a filter characteristic; wherein the audio information is upmixed prior to the decorrelating and said means for decorrelating reshapes the audio channels in accordance with at least some of the side information.

6. The apparatus according to Claim 5, wherein said means for decoding the audio information includes means for dematrixing.

7. The apparatus according to Claim 5, wherein the side information has a granularity and a temporal resolution limited by the bitrate of the side information.

8. A non-transitory computer-readable storage medium encoded with a computer program, for causing a computer to control the apparatus according to Claim 5.

9. Apparatus for decoding multi-channel spatially encoded audio, comprising:

a decoding processor receiving a bitstream including audio information and side information relating to the audio information and useful in decoding the bitstream, the decoding processor upmixing the audio information to provide multiple channels, spatially decoding the audio information, including decorrelating multiple channels within the audio information using multiple decorrelators, each having a filter characteristic, wherein the audio information is upmixed prior to the decorrelating and the decorrelating includes reshaping the audio channels in accordance with at least some of the side information.

10. The apparatus according to Claim 9, wherein decoding the audio information includes dematrixing.

11. The apparatus according to Claim 9, wherein the side information has a granularity and a temporal resolution limited by the bitrate of the side information.

12. A non-transitory computer-readable storage medium encoded with a computer program, for causing a computer to control the apparatus according to Claim 9.

CLAIMS

1. A method performed in an audio decoder for reconstructing N audio channels from an audio signal having M audio channels, the method comprising:

receiving a bitstream containing the M audio channels and a set of spatial parameters, wherein the set of spatial parameters includes an amplitude parameter and a correlation parameter, wherein the amplitude parameter is differentially encoded across time;

decoding the M encoded audio channels, wherein each audio channel is divided into a plurality of frequency bands, and each frequency band includes one or more spectral components;

extracting the set of spatial parameters from the bitstream;

applying a differential decoding process across time to the differentially encoded amplitude parameter to obtain a differentially decoded amplitude parameter;

analyzing the M audio channels to detect a location of a transient;

decorrelating the M audio channels to obtain a decorrelated version of the M audio channels, wherein a first decorrelation technique is applied to a first subset of the plurality of frequency bands of each audio channel and a second decorrelation technique is applied to a second subset of the plurality of frequency bands of each audio channel;

deriving N audio channels from the M audio channels, the decorrelated version of the M audio channels, and the set of spatial parameters, wherein N is two or more, M is one or more, and M is less than N; and

synthesizing, by an audio reproduction device, the N audio channels as an output audio signal,

wherein both the analyzing and the decorrelating are performed in a frequency domain, the first decorrelation technique represents a first mode of operation of a decorrelator, the second decorrelation technique represents a second mode of operation of the decorrelator, and the audio decoder is implemented at least in part in hardware.

2. The method of claim 1 wherein the first mode of operation uses an all-pass filter and the second mode of operation uses a fixed delay.

3. The method of claim 1 wherein the analyzing occurs after the extracting and the deriving occurs after the decorrelating.

4. The method of claim 1 wherein the first subset of the plurality of frequency bands is at a higher frequency than the second subset of the plurality of frequency bands.

5. The method of claim 1 wherein the M audio channels are a sum of the N audio channels.

6. The method of claim 1 wherein the location of the transient is used in the decorrelating to process bands with a transient differently than bands without a transient.

7. The method of claim 6 wherein the N audio channels represent a stereo audio signal where N is two and M is one.

8. The method of claim 1 wherein the N audio channels represent a stereo audio signal where N is two and M is one.

9. The method of claim 1 wherein the first subset of the plurality of frequency bands is non-overlapping but contiguous with the second subset of the plurality of frequency bands.

10. A non-transitory computer readable medium containing instructions that when executed by a processor perform the method of claim 1.

11. An audio decoder for decoding M encoded audio channels representing N audio channels, the audio decoder comprising:

an input interface for receiving a bitstream containing the M encoded audio channels and a set of spatial parameters, wherein the set of spatial parameters includes an amplitude parameter and a correlation parameter, wherein the amplitude parameter is differentially encoded across time;

an audio decoder for decoding the M encoded audio channels, wherein each audio channel is divided into a plurality of frequency bands, and each frequency band includes one or more spectral components;

a demultiplexer for extracting the set of spatial parameters from the bitstream;

a processor for applying a differential decoding process across time to the differentially encoded amplitude parameter to obtain a differentially decoded amplitude parameter, and analyzing the M audio channels to detect a location of a transient;

a decorrelator for decorrelating the M audio channels, wherein a first decorrelation technique is applied to a first subset of the plurality of frequency bands of each audio channel and a second decorrelation technique is applied to a second subset of the plurality of frequency bands of each audio channel;

a reconstructor for deriving N audio channels from the M audio channels and the set of spatial parameters, wherein N is two or more, M is one or more, and M is less than N; and

an audio reproduction device that synthesizes the N audio channels as an output audio signal,

wherein both the analyzing and the decorrelating are performed in a frequency domain, the first decorrelation technique represents a first mode of operation of a decorrelator, and the second decorrelation technique represents a second mode of operation of the decorrelator.