US009479871B2

(12) **United States Patent**
Kim et al.

(10) **Patent No.: US 9,479,871 B2**
(45) **Date of Patent: *Oct. 25, 2016**

(54) **METHOD, MEDIUM, AND SYSTEM SYNTHESIZING A STEREO SIGNAL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 347 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/134,508**

(22) Filed: **Dec. 19, 2013**

(65) **Prior Publication Data**

US 2014/0105404 A1 Apr. 17, 2014

Related U.S. Application Data

(63) Continuation of application No. 11/707,990, filed on Feb. 20, 2007, now Pat. No. 8,620,011.

(60) Provisional application No. 60/778,932, filed on Mar. 6, 2006.

(30) **Foreign Application Priority Data**

May 30, 2006 (KR) 10-2006-0049036
Nov. 7, 2006 (KR) 10-2006-0109523

(51) **Int. Cl.**
H04R 5/00 (2006.01)
H04R 5/02 (2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***H04R 5/02*** (2013.01); ***G10L 19/008*** (2013.01); ***H04S 1/002*** (2013.01); ***H04S 3/002*** (2013.01); ***H04S 3/02*** (2013.01); *H04R 5/033* (2013.01); *H04S 3/00* (2013.01); *H04S 2420/01* (2013.01); *H04S 2420/07* (2013.01)

(58) **Field of Classification Search**
CPC H04S 1/00; H04S 1/002; H04S 1/005; H04S 3/00; H04S 5/033; H04S 5/04; H04S 2400/01; H04S 2420/01; H04S 2420/07; H04S 5/00; H04R 5/027; H04R 5/04; H04R 5/00; H04R 5/033
USPC 381/1, 17–23, 309, 310, 74, 26
See application file for complete search history.

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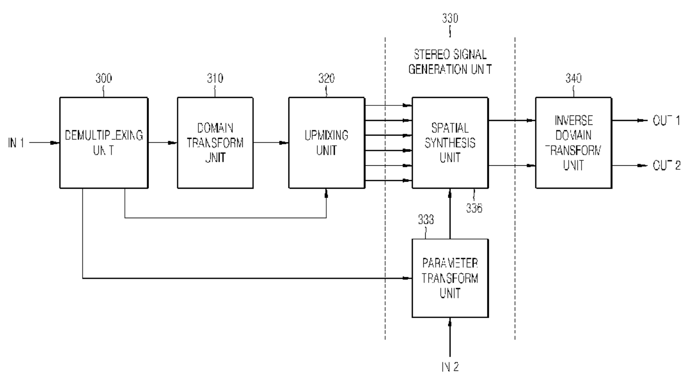
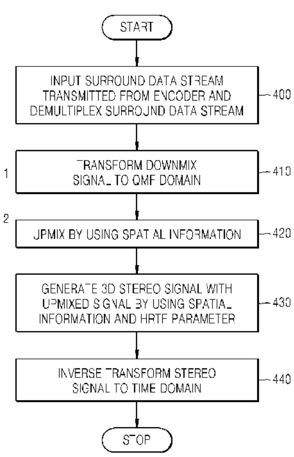
(57) **ABSTRACT**

A method, medium, and system generating a 3-dimensional (3D) stereo signal in a decoder by using a surround data stream. According to such a method, medium, and system, a head related transfer function (HRTF) is applied in a quadrature mirror filter (QMF) domain, thereby generating a 3D stereo signal by using a surround data stream.

4 Claims, 7 Drawing Sheets





(51) **Int. Cl.**

G10L 19/008	(2013.01)
H04S 1/00	(2006.01)
H04S 3/02	(2006.01)
H04R 5/033	(2006.01)
H04S 3/00	(2006.01)

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FIG. 1 (PRIOR ART)

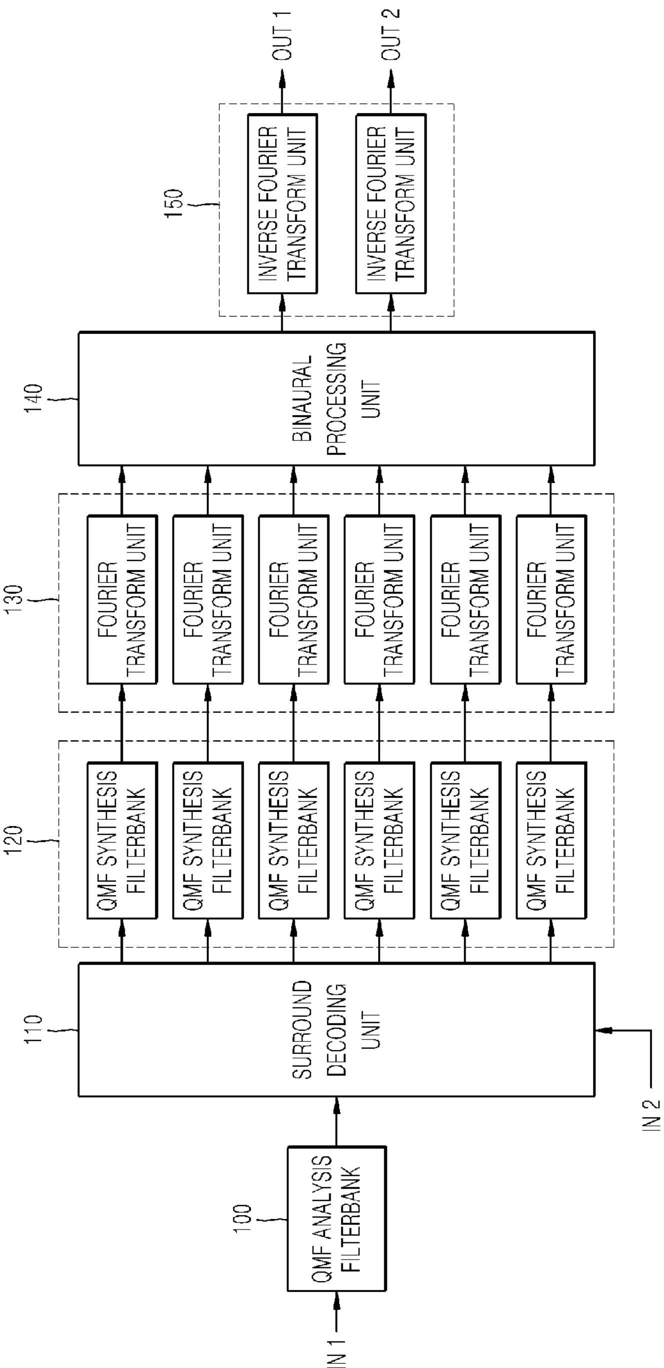


FIG. 2

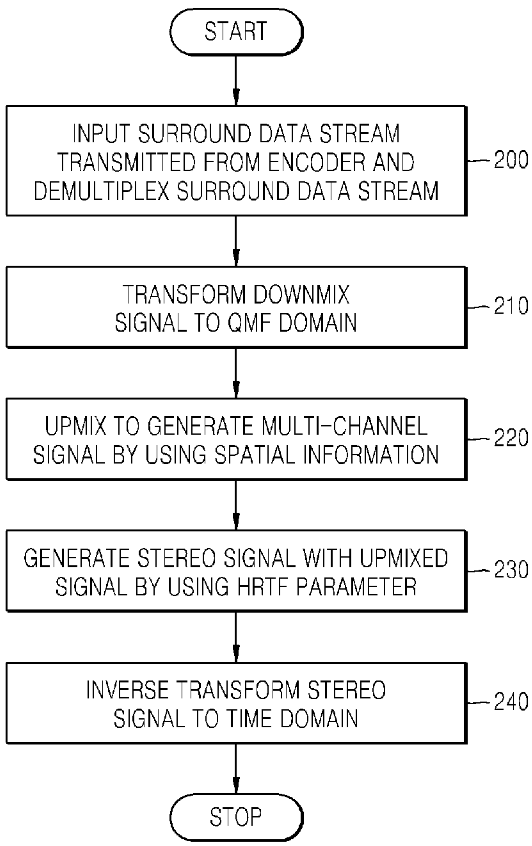

START
INPUT SURROUND DATA STREAM TRANSMITTED FROM ENCODER AND DEMULTIPLEX SURROUND DATA STREAM
200
TRANSFORM DOWNMIX SIGNAL TO QMF DOMAIN
210
UPMIX TO GENERATE MULTI-CHANNEL SIGNAL BY USING SPATIAL INFORMATION
220
GENERATE STEREO SIGNAL WITH UPMIXED SIGNAL BY USING HRTF PARAMETER
230
INVERSE TRANSFORM STEREO SIGNAL TO TIME DOMAIN
240
STOP

FIG. 3

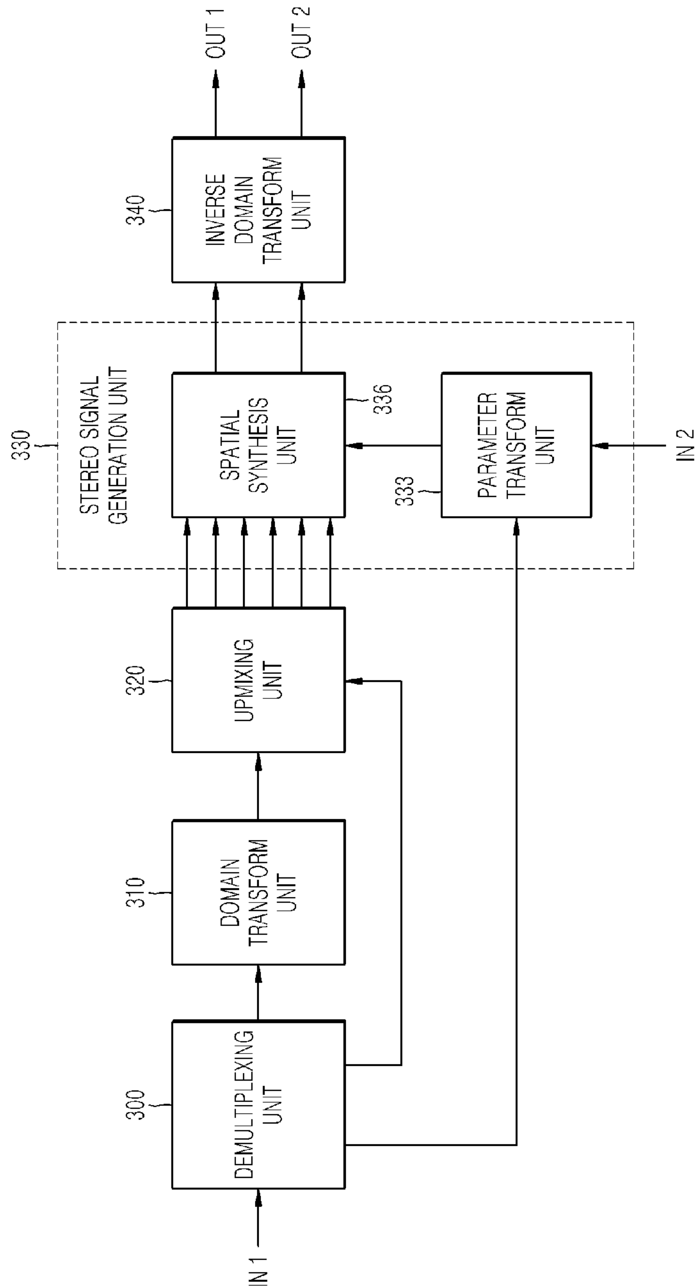

OUT 1
OUT 2
340
INVERSE DOMAIN TRANSFORM UNIT
330
STEREO SIGNAL GENERATION UNIT
SPATIAL SYNTHESIS UNIT
336
333
PARAMETER TRANSFORM UNIT
IN 2
320
UPMIXING UNIT
310
DOMAIN TRANSFORM UNIT
300
DEMULTIPLEXING UNIT
IN 1

FIG. 4

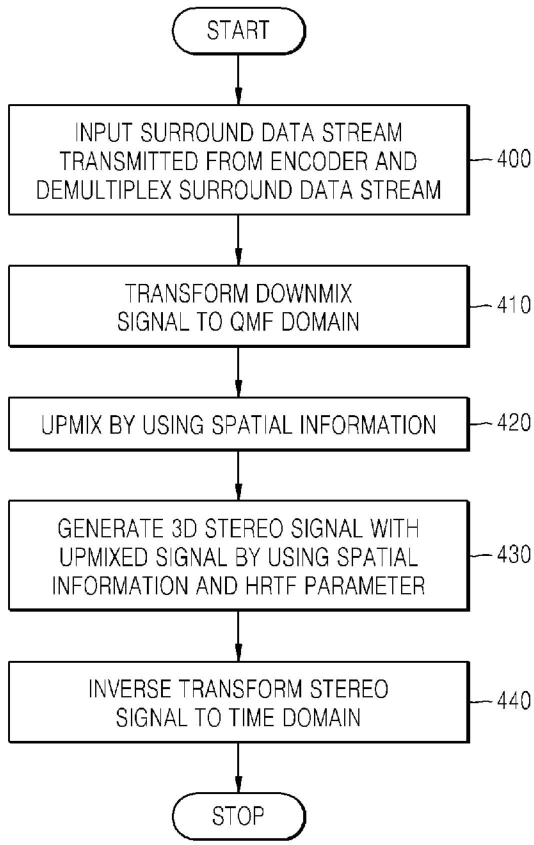

START
INPUT SURROUND DATA STREAM TRANSMITTED FROM ENCODER AND DEMULTIPLEX SURROUND DATA STREAM
400
TRANSFORM DOWNMIX SIGNAL TO QMF DOMAIN
410
UPMIX BY USING SPATIAL INFORMATION
420
GENERATE 3D STEREO SIGNAL WITH UPMIXED SIGNAL BY USING SPATIAL INFORMATION AND HRTF PARAMETER
430
INVERSE TRANSFORM STEREO SIGNAL TO TIME DOMAIN
440
STOP

FIG. 5

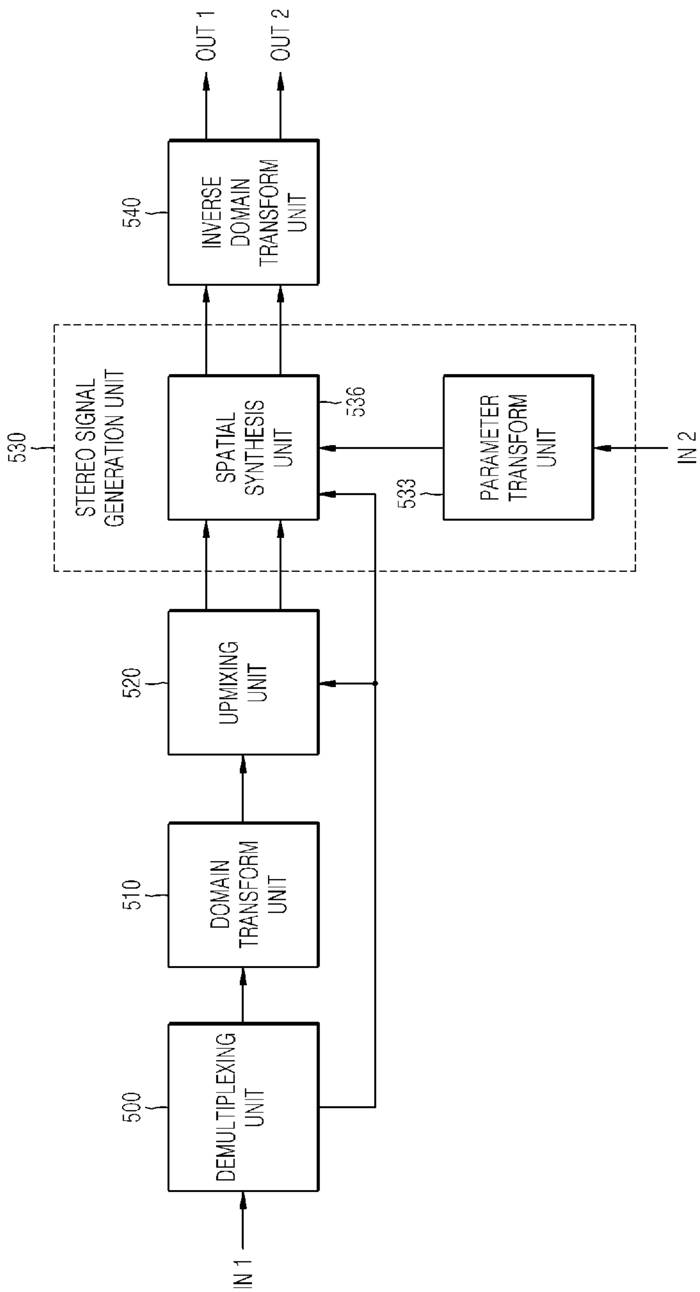

IN 1
500
DEMULTIPLEXING UNIT
510
DOMAIN TRANSFORM UNIT
520
UPMIXING UNIT
530
STEREO SIGNAL GENERATION UNIT
533
PARAMETER TRANSFORM UNIT
IN 2
536
SPATIAL SYNTHESIS UNIT
540
INVERSE DOMAIN TRANSFORM UNIT
OUT 1
OUT 2

FIG. 6

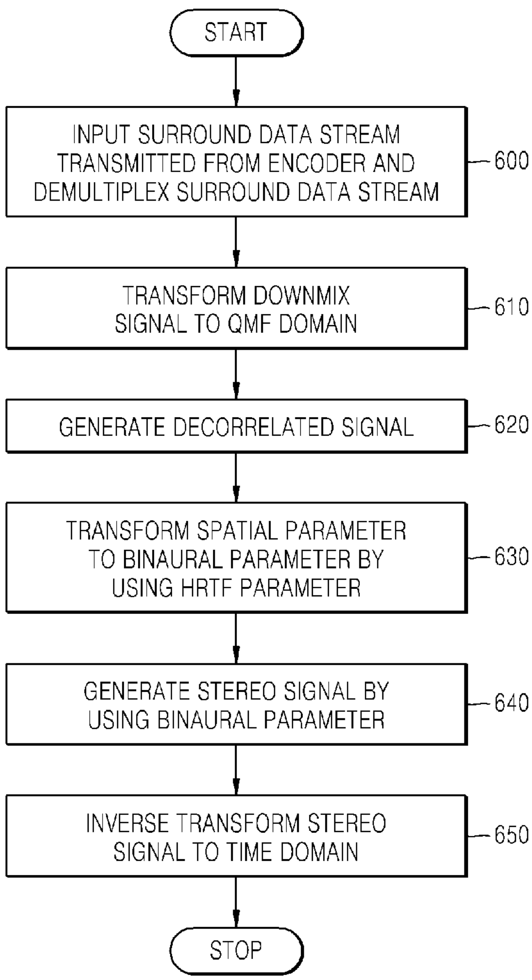
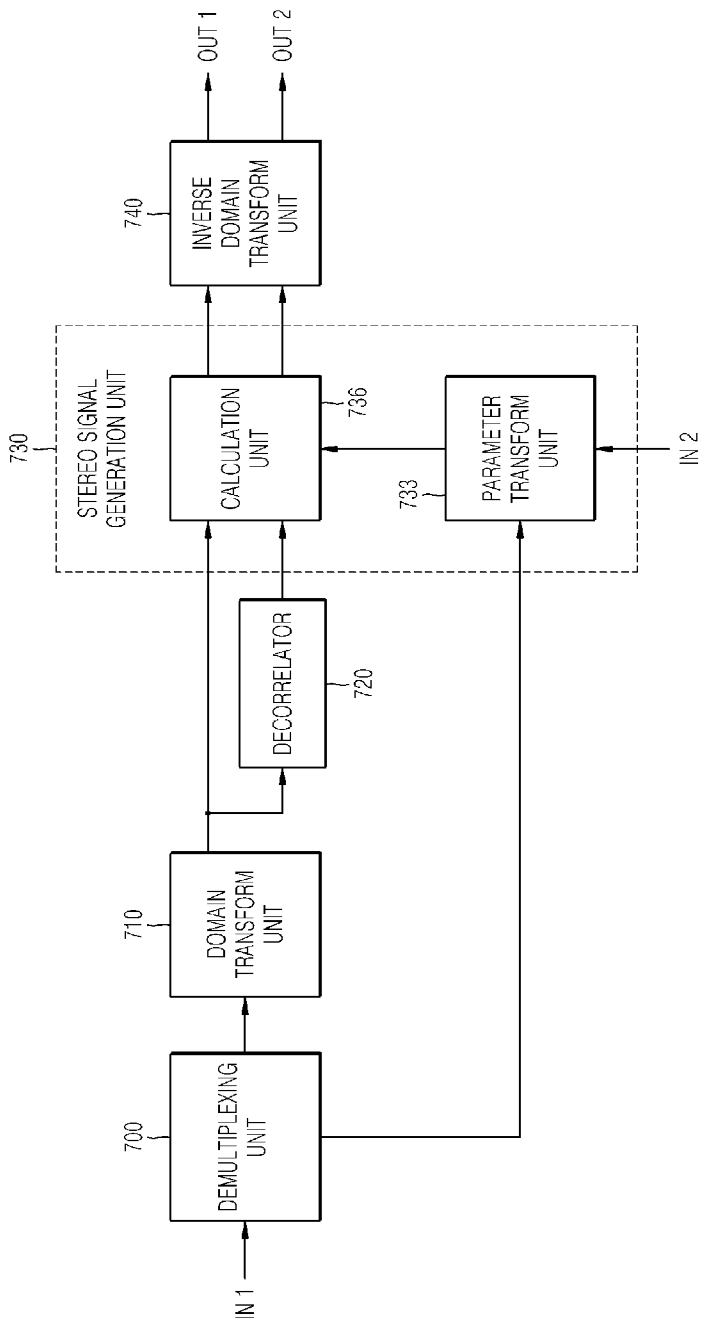

START
INPUT SURROUND DATA STREAM TRANSMITTED FROM ENCODER AND DEMULTIPLEX SURROUND DATA STREAM
600
TRANSFORM DOWNMIX SIGNAL TO QMF DOMAIN
610
GENERATE DECORRELATED SIGNAL
620
TRANSFORM SPATIAL PARAMETER TO BINAURAL PARAMETER BY USING HRTF PARAMETER
630
GENERATE STEREO SIGNAL BY USING BINAURAL PARAMETER
640
INVERSE TRANSFORM STEREO SIGNAL TO TIME DOMAIN
650
STOP

FIG. 7


IN 1
DEMULTIPLEXING UNIT
700
DOMAIN TRANSFORM UNIT
710
DECORRELATOR
720
STEREO SIGNAL GENERATION UNIT
730
CALCULATION UNIT
736
PARAMETER TRANSFORM UNIT
733
IN 2
INVERSE DOMAIN TRANSFORM UNIT
740
OUT 1
OUT 2

METHOD, MEDIUM, AND SYSTEM SYNTHESIZING A STEREO SIGNAL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 11/707,990, filed on Feb. 20, 2007, which is currently pending, and which claims the benefit of U.S. Provisional Patent Application No. 60/778,932, filed on Mar. 6, 2006, in the U.S. Patent trademark Office, and of Korean Patent Application No. 10-2006-0049036, filed on May 30, 2006 and Korean Patent Application No. 10-2006-0109523, filed on Nov. 7, 2006. in the Korean Intellectual Property Office, the disclosures of which are incorporated herein in their entirety by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

One or more embodiments of the present invention relate to audio coding, and more particularly, to a method, medium, and system generating a 3-dimensional (3D) signal in a decoder by using a surround data stream.

2. Description of the Related Art

FIG. **1** illustrates a conventional apparatus for generating a stereo signal. Here, a quadrature mirror filter (QMF) analysis filterbank **100** receives an input of a downmixed signal and transforms the time domain signal to the QMF domain. The downmixed signal is a signal that previous to encoding included one or more additional signals/channels, but which now represents all of the signals/channels with less signals/channels. An upmixing would be the conversion or expanding the downmixed signals/channels into a multi-channel signal, e.g., similar to its original channel form previous to encoding. Thus, after transforming of the time domain signal to the QMF domain, a surround decoding unit **110** decodes the downmixed signal, to thereby upmix the signal. A QMF synthesis filterbank **120** then inverse transforms the resultant multi-channel signal in the QMF domain to the time domain. A Fourier transform unit **130** further applies a faster Fourier transform (FFT) to this resultant time domain multi-channel signal. A binaural processing unit **140** then downmixes the resultant frequency domain multi-channel signal, transformed to the frequency domain in the Fourier transform unit **130**, by applying a head related transfer function (HRTF) to the signal, to generate a corresponding stereo signal with only two channels based on the multi-channel signal. Thereafter, an inverse Fourier transform unit **150** inverse transforms the frequency domain stereo signal to the time domain.

Again, surround decoding unit **110** processes an input signal in the QMF domain, while the HRTF function is generally applied in the frequency domain in the binaural processing unit **140**. Since the surround decoding unit **110** and the binaural processing unit **140** operate in different respective domains, the input downmix signal must be transformed to the QMF domain and processed in the surround decoding unit **110**, and then, the signal must be inverse transformed to the time domain, and then, again transformed to the frequency domain. Only then, is an HRFT applied to the signal in the binaural processing unit, followed by the inverse transforming of the signal to the time domain. Accordingly, since transform and inverse transform are separately performed with respect to each of the QMF domain and the frequency domain, when decoding is performed in a decoder, the complexity increases. With

such complexity, such an arrangement may not be suitable for a mobile environment, for example. In addition to the complexity, sound quality is also degraded in the processes of transforming or inverse transforming a domain representation, such as transforming a QMF domain representation to a time domain representation, transforming a time domain representation to a frequency domain representation, and inverse transforming a frequency domain representation to a time domain representation.

SUMMARY

Accordingly, one or embodiments of the present invention provide a method, medium, and system for applying a head related transfer function (HRTF) within the quadrature mirror filter (QMF) domain, thereby generating a simplified 3-dimensional (3D) signal by using a surround data stream.

Additional aspects and/or advantages of the invention will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the invention.

According to an aspect of the present invention, an embodiment of the present invention includes a method of generating an upmixed signal from a downmixed signal, including transforming the downmixed signal into a sub-band filter domain, and generating and outputting the upmixed signal from the transformed signal based on spatial information for the downmixed signal and a head related transfer function (HRTF) parameter in the sub-band filter domain.

According to another aspect of the present invention, an embodiment of the present invention includes a method of generating an upmixed signal from a downmixed signal, including transforming the downmixed signal into a sub-band filter domain, generating the upmixed signal from the transformed signal based on spatial information for the downmixed signal and a head related transfer function (HRTF) parameter, inverse transforming the upmixed signal from the sub-band filter domain to a time domain, and outputting the inverse transformed upmixed signal.

According to another aspect of the present invention, an embodiment of the present invention includes a method of generating an upmixed signal from a downmixed signal, including transforming the downmixed signal into a sub-band filter domain, generating a decorrelated signal from the transformed signal by using spatial information, generating the upmixed signal from the transformed signal and the generated decorrelated signal by using the spatial information and an HRTF parameter, inverse transforming the upmixed signal from the sub-band filter domain to a time domain, and outputting the inverse transformed upmixed signal.

According to another aspect of the present invention, an embodiment of the present invention includes a method of generating an upmixed signal from a downmixed signal, including transforming the downmixed signal to a sub-band filter domain, transforming a non-sub-band filter domain HRTF parameter into a sub-band filter domain HRTF parameter, generating the upmixed signal from the transformed signal based on spatial information and the sub-band filter domain HRTF parameter, and outputting the upmixed signal.

According to another aspect of the present invention, an embodiment of the present invention includes a method of generating an upmixed signal from a downmixed signal, including transforming the downmixed signal to a sub-band filter domain, transforming a non-sub-band filter domain

HRTF parameter into a sub-band filter domain HRTF parameter, generating a decorrelated signal from the transformed signal by using spatial information, generating the upmixed signal from the transformed signal and the generated decorrelated signal by using the spatial information and the sub-band HRTF parameter, and outputting the upmixed signal.

According to another aspect of the present invention, an embodiment of the present invention includes a least one medium including computer readable code to control at least one processing element to implement at least an embodiment of the present invention.

According to another aspect of the present invention, an embodiment of the present invention includes a system generating an upmixed signal from a downmixed signal, including a domain transform unit to transform the downmixed signal to a sub-band filter domain, and a signal generation unit to generate the upmixed signal from the transformed signal based on spatial information and an HRTF parameter in the sub-band filter domain.

According to another aspect of the present invention, an embodiment of the present invention includes a system generating an upmixed signal from a downmixed signal, including a domain transform unit to transform the downmixed signal to a sub-band filter domain, and a signal generation unit to generate the upmixed signal from the transformed signal based on spatial information and an HRTF parameter, and a domain inverse transform unit to inverse transform the upmixed signal from the sub-band filter domain to a time domain.

According to another aspect of the present invention, an embodiment of the present invention includes a system generating an upmixed signal from a downmixed signal, including a domain transform unit to transform the downmixed signal to a sub-band filter domain, a decorrelator to generate a decorrelated signal from the transformed signal by using spatial information, a signal generation unit to generate the upmixed signal from the transformed signal and the generated decorrelated signal by using the spatial information and an HRTF parameter, and a domain inverse transform unit to inverse transform the upmixed signal from the sub-band filter domain to a time domain.

According to another aspect of the present invention, an embodiment of the present invention includes a system generating an upmixed signal from a downmixed signal, including a domain transform unit to transform the downmixed signal to a sub-band filter domain, an HRTF parameter transform unit to transform a non-sub-band filter domain HRTF parameter into a sub-band filter domain HRTF parameter, and a signal generation unit to generate the upmixed signal from the transformed signal based on spatial information and the sub-band filter domain HRTF parameter.

According to another aspect of the present invention, an embodiment of the present invention includes a system generating an upmixed signal from a downmixed signal, including a domain transform unit to transform the downmixed signal to a sub-band filter domain, an HRTF parameter transform unit to transform a non-sub-band filter domain HRTF parameter into a sub-band filter domain HRTF parameter, a decorrelator to generate a decorrelated signal from the transformed signal by using spatial information, and a signal generation unit to generate the upmixed signal from the transformed signal and the generated decorrelated signal by using the spatial information and the sub-band filter domain HRTF parameter.

BRIEF DESCRIPTION OF THE DRAWINGS

These and/or other aspects and advantages of the invention will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings of which:

FIG. **1** illustrates a conventional apparatus for generating a stereo signal;

FIG. **2** illustrates a method of generating a stereo signal, according to an embodiment of the present invention;

FIG. **3** illustrates a system for generating a stereo signal, according to an embodiment of the present invention;

FIG. **4** illustrates a method of generating a stereo signal, according to another embodiment of the present invention;

FIG. **5** illustrates a system for generating a stereo signal, according to another embodiment of the present invention;

FIG. **6** illustrates a method of generating a stereo signal, according to another embodiment of the present invention; and

FIG. **7** illustrates a system for generating a stereo signal, according to another embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. Embodiments are described below to explain the present invention by referring to the figures.

FIG. **2** illustrates a method of generating a stereo signal, according to an embodiment of the present invention.

A surround data stream including a downmix signal and spatial parameters (spatial cues) may be received and demultiplexed, in operation **200**. Here, as noted above, the downmix signal can be a mono or stereo signal that was previously compressed/downmixed from a mulit-channel signal.

The demultiplexed downmix signal may then be transformed from the time domain to the quadrature mirror filter (QMF) domain, in operation **210**.

The QMF domain downmix signal may then be decoded, thereby upmixing the QMF domain signal to a multi-channel signal by using the provided spatial information, in operation **220**. For example, in the case of a pre-encoded 5.1 multi-channel signal, the corresponding downmixed signal can be upmixed to back into the corresponding decoded 5.1 multi-channel signal of 6 channels, including a front left (FL) channel, a front right (FR) channel, a back left (BL) channel, a back right (BR) channel, a center (C) channel, and a low frequency enhancement (LFE) channel, in operation **220**.

Thereafter, the upmixed multi-channel signal may be used to generate a 3-dimnesional (3D) stereo signal, in operation **230**, by using a head related transfer function (HRTF) that has been transformed for application in the QMF domain. At this time the transformed QMF domain HRTF may also be preset for use with the upmixed multi-channel signal. Thus, here, in operation **230**, rather than using an HRTF parameter that is generally expressed in the time domain, an HRTF parameter that has been transformed for application in the QMF domain is used. Here, the time-domain HRTF parameter/transfer function can be transformed into the QMF domain by transforming the time response of an HRTF to the QMF domain, and, for example, by calculating an impulse response in each sub-band. Such a transforming of the time-domain HRTF parameter may be also referred to as an HRTF parameterizing in the QMF domain, or as filter morphing of the time-domain HRTF filters, for example. Similarly, the QMF domain can be considered as falling within a class of sub-band filters, since sub bands are being filtered. Thus, such application of the HRTF parameter in the QMF domain permits for selective upmixing, with such HRTF filtering, of different levels of QMF domain sub-band filtering, e.g., one, some, or all sub-bands depending on the available of processing/battery power, for example. In some embodiments, in order to reduce complexity, the LFE channel may not be used in operation **230**. Regardless, such a 3D stereo signal corresponding to the QMF domain can be generated using the below equation 1, for example.

$$\begin{pmatrix} x\_left[sb][timeslot] \\ x\_right[sb][timeslot] \end{pmatrix} = \begin{pmatrix} a11 & a12 & a13 & a14 & a15 & a16 \\ a21 & a22 & a23 & a24 & a25 & a26 \end{pmatrix} \cdot \begin{pmatrix} x\_FL[sb][timeslot] \otimes HRTF1[sb][timeslot] \\ x\_FR[sb][timeslot] \otimes HRTF2[sb][timeslot] \\ x\_BL[sb][timeslot] \otimes HRTF3[sb][timeslot] \\ x\_BR[sb][timeslot] \otimes HRTF4[sb][timeslot] \\ x\_C[sb][timeslot] \otimes HRTF5[sb][timeslot] \\ x\_LFE[sb][timeslot] \otimes HRTF6[sb][timeslot] \end{pmatrix} \quad \text{Equation 1}$$

Here, x_left[sb][timeslot] is the L channel signal expressed in the QMF domain, x_right[sb][timeslot] is the R channel signal expressed in the QMF domain, a11, a12, a13, a14, a15, a16, a21, a22, a23, a24, a25, and a26 may be constants, x_FL[sb][timeslot] is the FL channel signal expressed in the QMF domain, x_FR[sb][timeslot] is the FR channel signal expressed in the QMF domain, x_BL[sb][timeslot] is the BL channel signal expressed in the QMF domain, x_C[sb][timeslot] is the C channel signal expressed in the QMF domain, x_LFE[sb][timeslot] is the LFE channel signal expressed in the QMF domain, HRTF1[sb][timeslot] is the HRTF parameter with respect to the FL channel expressed in the QMF domain, HRTF2[sb][timeslot] is the HRTF parameter with respect to the FR channel expressed in the QMF domain, HRTF3[sb][timeslot] is the HRTF parameter with respect to the BL channel expressed in the QMF domain, HRTF4[sb][timeslot] is the HRTF parameter with respect to the BR channel expressed in the QMF domain, HRTF5[sb][timeslot] is the HRTF parameter with respect to the C channel expressed in the QMF domain, and HRTF6[sb][timeslot] is the HRTF parameter with respect to the LFE channel expressed in the QMF domain,

In operation **230**, although an embodiment where a HRTF parameter that has been transformed for application in the QMF domain has been used, in other embodiments, a separate operation for transforming a time domain, for example, HRTF parameter to the QMF domain may also be performed.

Further to operation **230**, the generated 3D stereo signal can be inverse transformed from the QMF domain to the time domain, in operation **240**.

Here, by transforming the downmix signal by using a QMF analysis filterbank in operation **210**, and by inverse transforming the stereo signal generated in operation **230** by using a QMF synthesis filterbank in operation **240**, this QMF domain method embodiment may equally be available as operating in a hybrid sub-band domain or other sub-band filtering domains known in the art, according to an embodiment of the present invention.

FIG. **3** illustrates a system for generating a stereo signal, according to an embodiment of the present invention. The system may include a demultiplexing unit **300**, a domain transform unit **310**, an upmixing unit **320**, a stereo signal generation unit **330**, and a domain inverse transform unit **340**, for example.

The demultiplexing unit **300** may receive, e.g., through an input terminal IN **1**, a surround data stream including a downmix signal and a spatial parameter, e.g., as transmitted by an encoder, and demultiplex and output the surround data stream.

The domain transform unit **310** may then transform the demultiplexed downmix signal from the time domain to the QMF domain.

The upmixing unit **320** may, thus, receive a QMF domain downmix signal, decode the signal, and upmix the signal into a multi-channel signal. For example, in the case of a 5.1-channel signal, the upmixing unit upmixes the QMF domain downmix signal to a multi-channel signal of 6 channels, including FL, FR, BL, BR, C, and LFE channels.

The stereo signal generation unit **330** may thereafter generate a 3D stereo signal, in the QMF domain, with the upmixed multi-channel signal. In the generation of the stereo signal, the stereo signal generation unit **330** may thus use a QMF applied HRTF parameter, e.g., received through an input terminal IN **2**. Here, the stereo generation unit **330** may further include a parameter transform unit **333** and a calculation unit **336**, for example.

In one embodiment, the parameter transform unit **333** may receive a time-domain HRTF parameter, e.g., through the input terminal IN **2**, and transform the time-domain HRTF parameter for application in the QMF domain. In one embodiment, for example, the parameter transform unit **333** may transform the time response of the HRTF to the QMF domain and, for example, calculate an impulse response with respect to each sub-band, thereby transforming the time-domain HRTF parameter to the QMF domain.

In another embodiment, a preset QMF domain HRTF parameter may be previously stored and read out when needed. Here it is noted that alternative embodiments for providing a QMF domain HRTF parameter may equally be implemented

Referring to FIG. **3**, the spatial synthesis unit **336** may generate a 3D stereo signal with the upmixed multi-channel signal, by applying the QMF domain HRTF parameter or by applying the above mentioned preset stored QMF domain HRTF parameter, for example. As noted above, in one embodiment, the spatial synthesis unit **336** may not use the LFE channel in order to reduce complexity. Regardless, the spatial synthesis unit **336** may generate a 3D stereo signal corresponding in the QMF domain by using the below Equation 2, for example.

$$\begin{pmatrix} x\_left[sb][timeslot] \\ x\_right[sb][timeslot] \end{pmatrix} = \begin{pmatrix} a11 & a12 & a13 & a14 & a15 & a16 \\ a21 & a22 & a23 & a24 & a25 & a26 \end{pmatrix} \cdot \begin{pmatrix} x\_FL[sb][timeslot] \otimes HRTF1[sb][timeslot] \\ x\_FR[sb][timeslot] \otimes HRTF2[sb][timeslot] \\ x\_BL[sb][timeslot] \otimes HRTF3[sb][timeslot] \\ x\_BR[sb][timeslot] \otimes HRTF4[sb][timeslot] \\ x\_C[sb][timeslot] \otimes HRTF5[sb][timeslot] \\ x\_LFE[sb][timeslot] \otimes HRTF6[sb][timeslot] \end{pmatrix} \quad \text{Equation 2}$$

Here, x_left[sb][timeslot] is the L channel signal expressed in the QMF domain, x_right[sb][timeslot] is the R channel signal expressed in the QMF domain, a11, a12, a13, a14, a15, a16, a21, a22, a23, a24, a25, and a26 may be constants, x_FL[sb][timeslot] is the FL channel signal expressed in the QMF domain, x_FR[sb][timeslot] is the FR channel signal expressed in the QMF domain, x_BL[sb][timeslot] is the BL channel signal expressed in the QMF domain, x_C[sb][timeslot] is the C channel signal expressed in the QMF domain, x_LFE[sb][timeslot] is the LFE channel signal expressed in the QMF domain, HRTF1[sb][timeslot] is the HRTF parameter with respect to the FL channel expressed in the QMF domain, HRTF2[sb][timeslot] is the HRTF parameter with respect to the FR channel expressed in the QMF domain, HRTF3[sb][timeslot] is the HRTF parameter with respect to the BL channel expressed in the QMF domain, HRTF4[sb][timeslot] is the HRTF parameter with respect to the BR channel expressed in the QMF domain, HRTF5[sb][timeslot] is the HRTF parameter with respect to the C channel expressed in the QMF domain, and HRTF6[sb][timeslot] is the HRTF parameter with respect to the LFE channel expressed in the QMF domain.

The domain inverse transform unit **340** may thereafter inverse transforms the QMF domain 3D stereo signal into the time domain, and may, for example, output the L and R channel signals through output terminals OUT **1** and OUT **2**, respectively.

Here, by transforming a demultiplexed downmix signal by the domain transform unit **310** by using a QMF analysis filterbank, and by inverse transforming the QMF domain 3D stereo signal generated in the spatial synthesis unit **336** by using a QMF synthesis filterbank, the domain transform unit **310** may equally be available to operate in a hybrid sub-band domain as know in the art, according to an embodiment of the present invention.

FIG. **4** illustrates a method of generating a stereo signal, according to another embodiment of the present invention.

A surround data stream, including a downmix signal and spatial parameters (spatial cues), may be received and demultiplexed, in operation **400**. Here, as noted above, the downmix signal can be a mono or stereo signal that was previously compressed/downmixed from a multi-channel signal.

The demultiplexed downmix signal output may then be transformed from the time domain to the QMF domain, in operation **410**.

The QMF domain downmix signal may then be decoded, thereby upmixing the QMF domain signal to a number of channel signals by using the provided spatial information, in operation **420**. Unlike the above embodiment where all available channels of the multi-channel signal may be upmixed, in operation **420**, all available channels may not be upmixed. For example, in the case of 5.1 channels, only 2 channels among the 6 available multi-channels may be output, and as another example, in the case of 7.1 channels, only 2 channels among the available 8 multi-channels may be output, noting that embodiments of the present invention are not limited to the selection of only 2 channels or the selection of any two particular channels. More particularly, in this 5.1 channels signal example, only FL and FR channel signals may be output among the available 6 multi-channel signals of FL, RF, BL, BR, C, and LFE channel signals.

By using the spatial information and the QMF domain HRTF, a 3D stereo signal may be generated from the selected 2 channel signals, in operation **430**. In operation **430**, the QMF domain HRTF parameter may be preset and applied to the select channel signals. As noted above, the QMF domain HRTF parameter may be obtained by transforming the time response of the HRTF to the QMF domain, and calculating an impulse response in each sub-band. In one embodiment, in operation **430**, in order to reduce complexity, the LFE channel may not be used. Regardless, in an embodiment in which the FR and FR channel signals are the select two channels signals, by using the spatial information and the QMF domain HRTF parameter, a 3D stereo signal may be generated using the below equation 3, for example.

$$\begin{pmatrix} \text{x\_left}[sb][timeslot] \\ \text{x\_right}[sb][timeslot] \end{pmatrix} = \begin{pmatrix} a11 & a12 & a13 & a14 & a15 & a16 \\ a21 & a22 & a23 & a24 & a25 & a26 \end{pmatrix}. \quad \text{Equation 3}$$

$$\begin{pmatrix} \text{x\_FL}[sb][timeslot] \otimes HRTF1[sb][timeslot] \\ \text{x\_FR}[sb][timeslot] \otimes HRTF2[sb][timeslot] \\ \text{x\_FL}[sb][timeslot]CLD3[sb][timeslot] \otimes \\ HRTF3[sb][timeslot] \\ \text{x\_FR}[sb][timeslot]CLD4[sb][timeslot] \otimes \\ HRTF4[sb][timeslot] \\ CLD3[sb][timeslot](\text{x\_FL}[sb][timeslot]CLD3 \\ [sb][timeslot] \otimes HRTF5[sb][timeslot] + \\ \text{x\_FR}[sb][timeslot] \otimes HRTF6[sb][timeslot]) \\ \text{x\_LFE}[sb][timeslot]CLD5[sb][timeslot] \otimes \\ HRTF7[sb][timeslot] \end{pmatrix}$$

Here, x_left[sb][timeslot] is the L channel signal expressed in the QMF domain, x_right[sb][timeslot] is the R channel signal expressed in the QMF domain, a11, a12, a13, a14, a15, a16, a21, a22, a23, a24, a25, and a26 may be constants, x_FL[sb][timeslot] is the FL channel signal expressed in the QMF domain,

In addition, the described CLD 3, CLD 4 and CLD 5 are channel level differences specified in an MPEG surround specification, HRTF1[sb][timeslot] is the HRTF parameter with respect to the FL channel expressed in the QMF domain, HRTF2[sb][timeslot] is the HRTF parameter with respect to the FR channel expressed in the QMF domain, HRTF3[sb][timeslot] is the HRTF parameter with respect to the BL channel expressed in the QMF domain, HRTF4[sb][timeslot] is the HRTF parameter with respect to the BR channel expressed in the QMF domain, HRTF5[sb][timeslot] is the HRTF parameter with respect to the C channel expressed in the QMF domain, and HRTF6[sb][timeslot] is the HRTF parameter with respect to the LFE channel expressed in the QMF domain.

Thereafter, the generated 3D stereo signal generated may be inverse transformed from the QMF domain to the time domain, in operation **440**.

Here, by transforming the downmix signal by using a QMF analysis filterbank in operation **410**, and by inverse transforming the stereo signal generated in operation **430** by using a QMF synthesis filterbank in operation **440**, this QMF domain method embodiment may equally be available as operating in a hybrid sub-band domain as known in the art, for example, according to an embodiment of the present invention.

FIG. **5** illustrates a system for generating a stereo signal, according to another embodiment of the present invention. The system may include a demultiplexing unit **500**, a domain transform unit **510**, an upmixing unit **520**, a stereo signal generation unit **530**, and a domain inverse transform unit **540**, for example.

The demultiplexing unit **500** may receive, e.g., through an input terminal IN **1**, a surround data stream including a downmix signal and spatial parameters, e.g., as transmitted by an encoder, and demultiplex and output the surround data stream.

The domain transform unit **510** may then transform the demultiplexed downmix signal from the time domain to the QMF domain.

The upmixing unit **520** may receive a QMF domain downmix signal, decode the signal, and by using spatial information, upmix the signal to select channels, which does not have to include all available channels that could have been upmixed into a multi-channels signal. Thus, here, unlike the aforementioned embodiment, the upmixing unit **520** may output only 2 select channels among the 6 available channels in the case of 5.1 channels, and may output only 2 select channels among 8 available channels in the case of 7.1 channels. in one example, in the case of 5.1 multi-channel signals, the upmixing unit **520** may output only select FL and FR channel signals among the 6 available multi-channel signals, including FL, RF, BL, BR, C, and LFE channel signals, again noting that embodiments of the present invention are not limited to these particular example select channels or only two select channels.

Thereafter, stereo signal generation unit **530** may generate a QMF 3D stereo signal with the 2 select channel signals, e.g., output from the upmixing unit **520**. In the generation of the QMF 3D stereo signal, the stereo signal generation unit **530** may use the spatial information output, e.g., from the demultiplexing unit **500**, and a time-domain HRTF parameter, e.g., received through an input terminal IN **2**. Here, the stereo generation unit **530** may include a parameter transform unit **533** and a calculation unit **536**, for example.

The parameter transform unit **533** may receive the time-domain HRTF parameter, and transform the time-domain HRTF parameter for application in the QMF domain. Thus, the parameter transform unit **533** may transform the time-domain HRTF parameter by transforming the time response of the HRTF into a hybrid sub-band domain, for example, and then calculate an impulse response in each sub-band.

However, similar the above, a preset QMF domain HRTF parameter may be previously stored and read out when needed. Here, it is again noted that alternative embodiments for providing a QMF domain HRTF parameter may equally be implemented.

Referring to FIG. **5**, the spatial synthesis unit **536** may generate a 3D stereo signal with the 2 select channel signals output from the upmixing unit **520**, by using the spatial information and the QMF domain HRTF parameter.

In one embodiment in which a FL channel signal and a FR channel signal from the upmixing unit **520** may be received by the spatial synthesis unit **536**, for example, and a QMF 3D stereo signal may be generated by using the spatial information and the QMF domain HRTF parameter using the below Equation 4, for example.

$$\begin{pmatrix} \text{x\_left}[sb][timeslot] \\ \text{x\_right}[sb][timeslot] \end{pmatrix} = \begin{pmatrix} a11 & a12 & a13 & a14 & a15 & a16 \\ a21 & a22 & a23 & a24 & a25 & a26 \end{pmatrix}.$$

-continued

$$\begin{pmatrix} \text{x\_FL}[sb][timeslot] \otimes HRTF1[sb][timeslot] \\ \text{x\_FR}[sb][timeslot] \otimes HRTF2[sb][timeslot] \\ \text{x\_FL}[sb][timeslot]CLD3[sb][timeslot] \otimes HRTF3[sb][timeslot] \\ \text{x\_FR}[sb][timeslot]CLD4[sb][timeslot] \otimes HRTF4[sb][timeslot] \\ CLD3[sb][timeslot](\text{x\_FL}[sb][timeslot] CLD3[sb][timeslot] \otimes HRTF5[sb][timeslot] + \text{x\_FR}[sb][timeslot] \otimes HRTF6[sb][timeslot]) \\ \text{x\_LFE}[sb][timeslot]CLD5[sb][timeslot] \otimes HRTF7[sb][timeslot] \end{pmatrix}$$

Here, x_left[sb][timeslot] is the L channel signal expressed in the QMF domain, x_right[sb][timeslot] is the R channel signal expressed in the QMF domain, a11, a12, a13, a14, a15, a16, a21, a22, a23, a24, a25, and a26 may be constants, x_FL[sb][timeslot] is the FL channel signal expressed in the QMF domain,

In addition, the described CLD 3, CLD 4 and CLD 5 are channel level differences specified in an MPEG surround specification, HRTF1[sb][timeslot] is the HRTF parameter with respect to the FL channel expressed in the QMF domain, HRTF2[sb][timeslot] is the HRTF parameter with respect to the FR channel expressed in the QMF domain, HRTF3[sb][timeslot] is the HRTF parameter with respect to the BL channel expressed in the QMF domain, HRTF4[sb][timeslot] is the HRTF parameter with respect to the BR channel expressed in the QMF domain, HRTF5[sb][timeslot] is the HRTF parameter with respect to the C channel expressed in the QMF domain, and HRTF6[sb][timeslot] is the HRTF parameter with respect to the LFE channel expressed in the QMF domain,

The domain inverse transform unit **540** may further inverse transform the QMF domain 3D stereo signal to the time domain, and, in one embodiment, output the L channel signal and the R channel signal through output terminals OUT **1** and OUT **2**, respectively, for example.

Here, by disposing a QMF analysis filterbank as the domain transform unit **510** and a QMF synthesis filterbank as the domain inverse transform unit **540**, the current embodiment may equally be available to operate in a hybrid sub-band domain as known in the art, for example, according to an embodiment of the present invention.

FIG. **6** illustrates a method of generating a stereo signal, according to another embodiment of the present invention.

A surround data stream, including a downmix signal and spatial parameters (spatial cues), may be received and demultiplexed, in operation **600**. Here, as noted above, the downmix signal can be a mono signal, for example, that was previously compressed/downmixed from a multi-channel signal.

The demultiplexed mono downmix signal may be transformed from the time domain to the QMF domain, in operation **610**.

Thereafter, a decorrelated signal may be generated by applying the spatial information to the QMF domain mono downmix signal, and in operation **620**.

By using an HRTF parameter, the spatial information may be transformed to a binaural 3D parameter, in operation **630**. Here, the binaural 3D parameter is expressed in QMF domain, and is used in a process in which the mono downmix signal and the decorrelated signal are input and calculation is performed in order to generate a 3D stereo signal.

Then, a 3D stereo signal may be generated by applying the binaural 3D parameter to the mono downmix signal and the decorrelated signal, in operation **640**.

The generated 3D stereo signal may then be inverse transformed from the QMF domain to the time domain, in operation **650**.

Here, by transforming the downmix signal by using a QMF analysis filterbank in operation **610**, and by inverse transforming the 3D stereo signal generated in operation **640** by using a QMF synthesis filterbank in operation **650**, this QMF domain method embodiment may equally be available as operating in a hybrid sub-band domain as known in the art, for example, according to an embodiment of the present invention.

FIG. **7** illustrates a system for generating a stereo signal, according to another embodiment of the present invention. The system may include a demultiplexing unit **700**, a domain transform unit **710**, a decorrelator **720**, a stereo signal generation unit **730**, and a domain inverse transform unit **740**, for example.

The demultiplexing unit **700** may receive, e.g., through an input terminal IN **1**, a surround data stream including a downmix signal and spatial parameters, e.g., as transmitted by an encoder, and demultiplex the surround data stream. As noted above, the downmix signal may be a mono signal, for example.

The domain transform unit **710** may then transform the mono downmix signal from the time domain to the QMF domain.

The decorrelator **720** may then generate a decorrelated signal by applying the spatial information and the QMF domain mono downmix signal.

The stereo signal generation unit **730** may further generate a QMF domain 3D stereo signal from the QMF domain mono downmix signal decorrelated signal. In the generation of the 3D stereo signal, the stereo signal generation unit **730** may use the spatial information and an HRTF parameter, e.g., as received through an input terminal IN **2**. Here, the stereo generation unit **730** may include a parameter transform unit **733** and a calculation unit **736**.

The parameter transform unit **733** transforms the spatial information to a binaural 3D parameter by using the HRTF parameter. Here, the binaural 3D parameter is expressed in QMF domain, and is used in a process in which the mono downmix signal and the decorrelated signal are input and calculation is performed in order to generate a 3D stereo signal.

Thus, the calculation unit **736** receives the QMF domain mono downmix signal and the decorrelated signal, and through calculation by applying the QMF domain binaural 3D parameter, generates a 3D stereo signal.

Thereafter, the domain inverse transform unit **740** may inverse transform the QMF domain 3D stereo signal to the time domain, and output the L channel signal and the R channel signal through output terminals OUT **1** and OUT **2**, respectively, for example.

Here, by disposing a QMF analysis filterbank as the domain transform unit **710** and a QMF synthesis filterbank as the domain inverse transform unit **740**, the current embodiment may equally be available to operate in a hybrid sub-band domain as known in the art, for example, according to an embodiment of the present invention.

Accordingly, one or more embodiments of the present invention include a method, medium, and system generating a stereo signal by applying a QMF domain HRTF to generate a 3D stereo signal.

In this way, a compressed/downmixed multi-channel signal can be upmixed through application of an HRTF without requiring repetitive transforming or inverse transforming for application of the HRTF, thereby reducing the complexity and increasing and the quality of the implemented system.

In addition to the above described embodiments, embodiments of the present invention can also be implemented through computer readable code/instructions in/on a medium, e.g., a computer readable medium, to control at least one processing element to implement any above described embodiment. The medium can correspond to any medium/media permitting the storing and/or transmission of the computer readable code.

The computer readable code can be recorded/transferred on a medium in a variety of ways, with examples of the medium including magnetic storage media (e.g., ROM, floppy disks, hard disks, etc.), optical recording media (e.g., CD-ROMs, or DVDs), and storage/transmission media such as carrier waves, as well as through the Internet, for example. Here, the medium may further be a signal, such as a resultant signal or bitstream, according to embodiments of the present invention. The media may also be a distributed network, so that the computer readable code is stored/transferred and executed in a distributed fashion. Still further, as only an example, the processing element could include a processor or a computer processor, and processing elements may be distributed and/or included in a single device.

Although a few embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.

What is claimed is:

1. An apparatus for generating a stereo signal, comprising:

a transform unit to transform a mono downmixed signal to a quadrature mirror filter (QMF) domain signal;

a decorrelator to generate a decorrelated signal from the QMF domain signal;

a signal generating unit to convert spatial information to a binaural 3D parameter in the QMF domain by using a head related transfer function (HRTF) parameter, and to generate a binaural output signal from the QMF domain signal and the generated decorrelated signal by using the converted binaural 3D parameter in the QMF domain; and

an inverse transform unit to inverse transform the generated binaural output signal from the QMF domain to a time domain to generate the stereo signal.

2. The apparatus of claim **1**, wherein the QMF domain is a hybrid sub-band domain.

3. The apparatus of claim **1** further comprising a domain transform unit to transform a corresponding HRTF parameter into the QMF domain.

4. The apparatus of claim **1**, wherein the HRTF parameter is transformed into the QMF domain by transforming a time response of a corresponding HRTF into the QMF domain and calculating an impulse response with respect to each sub-band.

* * * * *