[CLAIMS]

[Claim 1]

A bandwidth extension method for producing a full bandwidth signal from a low frequency bandwidth signal, said method comprising:

a first transform step of transforming the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a pitch shift step of generating pitch-shifted signals by applying different shifting factors on the low frequency bandwidth signal;

a high frequency generation step of generating a high frequency QMF spectrum by time-stretching the pitch-shifted signals in a QMF domain;

a spectrum modification step of modifying the high frequency QMF spectrum to satisfy high frequency energy and tonality conditions; and

a full bandwidth generation step of generating the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 2]

The bandwidth extension method according to Claim 1,

wherein said high frequency generation step includes:

a second transform step of transforming the pitch shifted signals into a QMF domain to generate QMF spectra;

a harmonic patch generation step of stretching the QMF spectra along a temporal dimension with different stretching factors to generate harmonic patches;

an alignment step of time-aligning the harmonic patches; and

a sum-up step of summing up the time-aligned harmonic patches.

[Claim 3]

The bandwidth extension method according to Claim 2,

wherein said harmonic patch generations step includes:

a calculation step of calculating the amplitude and phase of a QMF spectrum among the QMF spectra;

a phase manipulation step of manipulating the phase to produce a new phase; and

a QMF coefficient generation step of combining the amplitude with the new phase to generate a new set of QMF coefficients.

[Claim 4]

The bandwidth extension method according to Claim 3,

wherein in said phase manipulation step, the new phase is produced on the basis of an original phase of a whole set of QMF coefficients.

[Claim 5]

The bandwidth extension method according to one of Claims 3 and 4,

wherein in said phase manipulation step, manipulation is performed repeatedly for sets of QMF coefficients, and

in said QMF coefficient generation step, new sets of QMF coefficients are generated.

[Claim 6]

The bandwidth extension method according to any one of Claims 3, 4 and 5,

wherein in said phase manipulation step, a different manipulation is performed depending on a QMF subband index.

[Claim 7]

The bandwidth extension method according to Claim 5,

wherein in said QMF coefficient generation step, the new sets of QMF coefficients are overlap-added to generate the QMF coefficients corresponding to a temporally-extended audio signal.

[Claim 8]

A bandwidth extension method for producing a full bandwidth

signal from a low frequency bandwidth signal, said method comprising:

a first transform step of transforming the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a low order harmonic patch generation step of generating a low order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation step of (i) generating signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generating a high frequency QMF spectrum from the signals;

a spectrum modification step of modifying the high frequency QMF spectrum to satisfy high frequency energy and tonality conditions; and

a full bandwidth generation step of generating the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 9]

The bandwidth extension method according to Claim 8

wherein said low order harmonic patch generation step includes:

a second transform step of transforming the low frequency bandwidth signal into a second low frequency QMF spectrum;

a bandpass step of bandpassing the second low frequency QMF spectrum; and

a stretching step of stretching the bandpassed second low frequency QMF spectrum along a temporal dimension.

[Claim 10]

The bandwidth extension method according to Claim 9,

wherein the second low frequency QMF spectrum has finer frequency resolution than the first low frequency QMF spectrum.

[Claim 11]

The bandwidth extension method according to any one of Claims 8, 9, and 10,

wherein said high frequency generation step includes:

a patch generation step of bandpassing the low order harmonic patch to generate bandpassed patches;

a high order generation step of mapping each of the bandpassed patches into high frequency to generate high order harmonic patches; and

a sum-up step of summing up the high order harmonic patches with the low order harmonic patch.

[Claim 12]

The bandwidth extension method according to Claim 11,

wherein said high order generation step includes:

a splitting step of splitting each QMF subband in each of the bandpassed patches into multiple sub-subbands;

a mapping step of mapping the sub-subbands to high frequency QMF subbands; and

a combining step of combining results of the sub-subband mapping.

[Claim 13]

The bandwidth extension method according to Claim 12,

wherein said mapping step includes:

a division step of dividing the sub-subbands of each of the QMF subbands into a stop band part and a pass band part;

a frequency computation step of computing transposed center frequencies of the sub-subbands on the pass band part with patch order dependent factor;

a first mapping step of mapping the sub-subbands on the pass band part into high frequency QMF subbands according to the center frequencies; and

a second mapping step of mapping the sub-subbands on the stop band part into high frequency QMF subbands according to the

sub-subbands of the pass band part.

[Claim 14]

A bandwidth extension apparatus that produces a full bandwidth signal from a low frequency bandwidth signal, said bandwidth extension apparatus comprising:

a first transform unit configured to transform the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a pitch-shifting unit configured to generate pitch-shifted signals by applying different shifting factors on the low frequency bandwidth signal;

a high frequency generation unit configured to generate a high frequency QMF spectrum by time-stretching the pitch-shifted signals in a QMF domain;

a spectrum modification unit configured to modify the high frequency QMF spectrum to satisfy high frequency energy and tonality conditions; and

a full bandwidth generation unit configured to generate the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum

[Claim 15]

A bandwidth extension apparatus that produces a full bandwidth signal from a low frequency bandwidth signal, said bandwidth extension apparatus comprising:

a first transform unit configured to transform the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a low order harmonic patch generation unit configured to generate a low order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation unit configured to (i) generate signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generate a high frequency QMF

spectrum from the signals;

a spectrum modification unit configured to modify the high frequency QMF spectrum to satisfy high frequency energy and tonality conditions; and

a full bandwidth generation unit configured to generate the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 16]

A program for producing a full bandwidth signal from a low frequency bandwidth signal, said program causing a computer to execute:

a first transform step of transforming the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a pitch shift step of generating pitch-shifted signals by applying different shifting factors on the low frequency bandwidth signal;

a high frequency generation step of generating a high frequency QMF spectrum by time-stretching the pitch-shifted signals in a QMF domain;

a spectrum modification step of modifying the high frequency QMF spectrum to satisfy high frequency energy and tonality conditions; and

a full bandwidth generation step of generating the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 17]

A program for producing a full bandwidth signal from a low frequency bandwidth signal, said program causing a computer to execute:

a first transform step of transforming the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a low order harmonic patch generation step of generating a low

order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation step of (i) generating signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generating a high frequency QMF spectrum from the signals;

a spectrum modification step of modifying the high frequency QMF spectrum to satisfy high frequency energy and tonality conditions; and

a full bandwidth generation step of generating the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 18]

An integrated circuit that produces a full bandwidth signal from a low frequency bandwidth signal, said bandwidth extension apparatus comprising:

a first transform unit configured to transform the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a pitch-shifting unit configured to generate pitch-shifted signals by applying different shifting factors on the low frequency bandwidth signal;

a high frequency generation unit configured to generate a high frequency QMF spectrum by time-stretching the pitch-shifted signals in a QMF domain;

a spectrum modification unit configured to modify the high frequency QMF spectrum to satisfy high frequency energy and tonality conditions; and

a full bandwidth generation unit configured to generate the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum

[Claim 19]

An integrated circuit that produces a full bandwidth signal from

a low frequency bandwidth signal, said bandwidth extension apparatus comprising:

a first transform unit configured to transform the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a low order harmonic patch generation unit configured to generate a low order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation unit configured to (i) generate signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generate a high frequency QMF spectrum from the signals;

a spectrum modification unit configured to modify the high frequency QMF spectrum to satisfy high frequency energy and tonality conditions; and

a full bandwidth generation unit configured to generate the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 20]

An audio decoding apparatus comprising:

a separation unit configured to separate a coded low frequency bandwidth signal from coded information;

a decoding unit configured to decode the coded low frequency bandwidth signal;

a transform unit configured to transform the low frequency bandwidth signal generated through the decoding by said decoding unit, into a quadrature mirror filter bank (QMF) domain to generate a low frequency QMF spectrum; a pitch-shifting unit configured to generate pitch-shifted signals by applying different shifting factors on the generated low frequency bandwidth signal;

a high frequency generation unit configured to generate a high frequency QMF spectrum by time-stretching the pitch-shifted signals in a QMF domain;

a spectrum modification unit configured to modify the high

frequency QMF spectrum to satisfy high frequency energy and tonality conditions;

a full bandwidth generation unit configured to generate the full bandwidth signal by combining the modified high frequency QMF spectrum with the low frequency QMF spectrum; and

an inverse transform unit configured to transform the full bandwidth signal, from a quadrature mirror filter bank (QMF) domain signal to a time domain signal.

[Claim 21]

An audio decoding apparatus comprising:

a separation unit configured to separate a coded low frequency bandwidth signal from coded information;

a decoding unit configured to decode the coded low frequency bandwidth signal;

a transform unit configured to transform the low frequency bandwidth signal generated through the decoding by said decoding unit, into a quadrature mirror filter bank (QMF) domain to generate a low frequency QMF spectrum;

a low order harmonic patch generation unit configured to generate a low order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation unit configured to (i) generate signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generate a high frequency QMF spectrum from the signals;

a spectrum modification unit configured to modify the high frequency QMF spectrum to satisfy high frequency energy and tonality conditions;

a full bandwidth generation unit configured to generate the full bandwidth signal by combining the modified high frequency QMF spectrum with the low frequency QMF spectrum; and

an inverse transform unit configured to transform the full bandwidth signal, from a quadrature mirror filter bank (QMF) domain signal to a time domain signal.

[CLAIMS]

[Claim 1]

A bandwidth extension method for producing a full bandwidth signal from a low frequency bandwidth signal, said method comprising:

a first transform step of transforming the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a low order harmonic patch generation step of generating a low order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation step of (i) generating signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generating a high frequency QMF spectrum from the signals;

a spectrum modification step of modifying the high frequency QMF spectrum to satisfy high frequency energy conditions; and

a full bandwidth generation step of generating the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 2]

The bandwidth extension method according to Claim 1,

wherein said low order harmonic patch generation step includes a second transform step of transforming the low frequency bandwidth signal into a second low frequency QMF spectrum, and

the second low frequency QMF spectrum has finer frequency resolution than the first low frequency QMF spectrum.

[Claim 3]

The bandwidth extension method according to one of Claims 1 and 2,

wherein said high frequency generation step includes:

a patch generation step of bandpassing the low order harmonic patch to generate bandpassed patches;

a high order generation step of mapping each of the bandpassed patches into high frequency to generate high order harmonic patches;

and

a sum-up step of summing up the high order harmonic patches with the low order harmonic patch.

[Claim 4]

The bandwidth extension method according to Claim 3,

wherein said high order generation step includes:

a splitting step of splitting each QMF subband in each of the bandpassed patches into multiple sub-subbands;

a mapping step of mapping the sub-subbands to high frequency QMF subbands; and

a combining step of combining results of the sub-subband mapping.

[Claim 5]

The bandwidth extension method according to Claim 4,

wherein said mapping step includes:

a division step of dividing the sub-subbands of each of the QMF subbands into a stop band part and a pass band part;

a frequency computation step of computing transposed center frequencies of the sub-subbands on the pass band part with patch order dependent factor;

a first mapping step of mapping the sub-subbands on the pass band part into high frequency QMF subbands according to the center frequencies; and

a second mapping step of mapping the sub-subbands on the stop band part into high frequency QMF subbands according to the sub-subbands of the pass band part.

[Claim 6]

A bandwidth extension apparatus that produces a full bandwidth signal from a low frequency bandwidth signal, said bandwidth extension apparatus comprising:

a first transform unit configured to transform the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a low order harmonic patch generation unit configured to generate a low order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation unit configured to (i) generate signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generate a high frequency QMF spectrum from the signals;

a spectrum modification unit configured to modify the high frequency QMF spectrum to satisfy high frequency energy conditions; and

a full bandwidth generation unit configured to generate the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 7]

A program for producing a full bandwidth signal from a low frequency bandwidth signal, said program causing a computer to execute:

a first transform step of transforming the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a low order harmonic patch generation step of generating a low order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation step of (i) generating signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generating a high frequency QMF spectrum from the signals;

a spectrum modification step of modifying the high frequency QMF spectrum to satisfy high frequency energy conditions; and

a full bandwidth generation step of generating the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 8]

An integrated circuit that produces a full bandwidth signal from a

low frequency bandwidth signal, said integrated circuit comprising:

a first transform unit configured to transform the low frequency bandwidth signal into a quadrature mirror filter bank (QMF) domain to generate a first low frequency QMF spectrum;

a low order harmonic patch generation unit configured to generate a low order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation unit configured to (i) generate signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generate a high frequency QMF spectrum from the signals;

a spectrum modification unit configured to modify the high frequency QMF spectrum to satisfy high frequency energy conditions; and

a full bandwidth generation unit configured to generate the full bandwidth signal by combining the modified high frequency QMF spectrum with the first low frequency QMF spectrum.

[Claim 9]

An audio decoding apparatus comprising:

a separation unit configured to separate a coded low frequency bandwidth signal from coded information;

a decoding unit configured to decode the coded low frequency bandwidth signal;

a transform unit configured to transform the low frequency bandwidth signal generated through the decoding by said decoding unit, into a quadrature mirror filter bank (QMF) domain to generate a low frequency QMF spectrum;

a low order harmonic patch generation unit configured to generate a low order harmonic patch by time-stretching the low frequency bandwidth signal in a QMF domain;

a high frequency generation unit configured to (i) generate signals that are pitch shifted, by applying different shift coefficients to the low order harmonic patch, and (ii) generate a high frequency QMF spectrum from the signals;

a spectrum modification unit configured to modify the high

frequency QMF spectrum to satisfy high frequency energy conditions;

a full bandwidth generation unit configured to generate the full bandwidth signal by combining the modified high frequency QMF spectrum with the low frequency QMF spectrum; and

an inverse transform unit configured to transform the full bandwidth signal, from a quadrature mirror filter bank (QMF) domain signal to a time domain signal.