CLAIMS

What is claimed is:

1. A processing module comprising:

a spatial processor to spatially process surround-left and surround-right channel signals and front-left and front-right channel signals;

circuitry to generate signals for first and second drivers of a center speaker by removal of crosstalk from the spatially processed signals; and

front-virtualization control circuitry to cause the spatial processor to selectively refrain from spatially processing at least one of either the front-left and front-right channel signals.

2. The processing module of claim 1 wherein the first and second drivers provide virtualized surround-right and surround-left audio,

wherein the first and second drivers optionally provide virtualized front-right and front-left audio,

wherein the front-virtualization control circuitry causes the spatial processor to selectively refrain from spatially processing at least one of the front-left and front-right channel signals when the processing module is coupled to at least one of front-left and front-right speakers to inhibit the first and second drivers from providing the virtualized at least one of front-right and front-left audio.

3. The processing module of claim 2 wherein the spatial processor comprises:

surround-channel spatial-processing circuitry to spatially process the surround-left and surround-right channel signals;

front-channel spatial-processing circuitry to spatially process the front-left and front-right channel signals; and

signal combining circuitry to combine outputs from both the surround-channel spatial-processing circuitry and the front-channel spatial-processing circuitry to generate first and second spatially-processed combined signals, and

wherein the circuitry to generate signals for the first and second drivers of the center speaker adds a center-channel signal to the spatially processed signals.

4. The processing module of claim 3 further comprising a front-left speaker port and a front-right speaker port,

wherein the front-virtualization control circuitry is configured to disable operation of at least a portion of the front-channel spatial-processing circuitry when at least one of the front-left and front-right speakers are connected to the ports.

5. The processing module of claim 4 wherein front-virtualization control circuitry includes at least one of:

load-sensing circuitry to determine when at least one of the front-left and front-right speakers is connected to the ports; of

a switch selectable by a user to cause the front-virtualization control circuitry to either enable or disable operation of at least a portion of the front-channel spatial-processing circuitry.

6. The processing module of claim 3 wherein the spatially-processed surround channel signals are generated to simulate a perception that a surround-left sound source is located behind and to the left of a listener location and to simulate a perception that a surround-right sound source is located respectively behind and to the right of the listener location when transmitted as audio signals by the first and second drivers after crosstalk cancellation, and

wherein the spatially-processed front channel signals are generated to simulate a perception that a front-left sound source is located in front of and to the left of the listener location and to simulate a perception that a front-right sound

source is located in front of and to the right of the listener location when transmitted as audio signals by the first and second drivers after crosstalk cancellation.

7. The processing module of claim 3 wherein the circuitry to generate signals for the first and second drivers comprises:

crosstalk cancellation circuitry to substantially remove crosstalk from the first and second spatially-processed combined signals for a predetermined listener location; and

center-channel signal combining circuitry to add a center-channel signal to the first and second spatially-processed combined signals to generate signals for the drivers of the center speaker,

wherein the processing module is configured to receive a multichannel input comprising at least the surround-left and surround-right channel signals, the front-left and front-right channel signals, and the center-channel signal.

8. The processing module of claim 7 wherein a decoder generates the multichannel input from an encoded audio signal.

9. The processing module of claim 3 wherein the surround-channel spatial-processing circuitry comprises:

a left ipsilateral head-related transfer function (HRTF) filter and a left contralateral HRTF filter to operate on the surround-left channel signal;

a right contralateral HRTF filter and a right ipsilateral HRTF filter to operate on the surround-right channel signal;

a right-channel interaural time-delay (ITD) element to delay an output of the right contralateral HRTF filter; and

a left-channel ITD element to delay an output of the left contralateral HRTF filter, and

wherein the front-channel spatial-processing circuitry comprises:

a left ipsilateral head-related transfer function (HRTF) filter and a left contralateral HRTF filter to operate on the front-left channel signal;

a right contralateral HRTF filter and a right ipsilateral HRTF filter to operate on the front-right channel signal;

a right-channel interaural time-delay (ITD) element to delay an output of the right contralateral HRTF filter; and

a left-channel ITD element to delay an output of the left contralateral HRTF filter.

10. The processing module of claim 1 wherein the center speaker comprises a stereo-dipole speaker,

wherein the first and second drivers are adjacent to each other and separated by a distance, and

wherein the first and second drivers are to be directed in a forward direction to better achieve crosstalk cancellation and virtualization of at least the surround-left and surround-right channel signals.

11. The processing module of claim 1 further comprising an amplifier to reduce a signal level of the center-channel signal prior to the addition to the spatially processed signals.

12. A method comprising:

spatially processing surround-left and surround-right channel signals and front-left and front-right channel signals;

removing crosstalk from the spatially-processed signals and combining the spatially-processed signals with a center-channel signal to generate signals for first and second drivers of a center speaker; and

refraining from spatially processing at least one of the front-left and front-right channel signals in response to coupling of at least one of front-left and front-right speakers.

13. The method of claim 12 wherein the first and second drivers provide virtualized surround-right and surround-left audio,

wherein the first and second drivers optionally provide virtualized front-right and front-left audio, and

wherein the refraining from spatially processing at least one of the front-left and front-right channel signals is performed when at least one of the front-left and front-right speakers are coupled to inhibit at least one of the first and second drivers from providing at least one of the virtualized front-right and front-left audio.

14. The method of claim 13 further comprising either:

determining when at least one of the front-left and front-right speakers are connected by sensing a load of at least one of the front-left and front-right speakers; or

enabling or disabling at least a portion of front-channel spatial processing in response to an input from a user.

15. The method of claim 12 wherein the spatially-processed surround channel signals are generated to simulate a perception that a surround-left sound source is located behind and to the left of a listener location and to simulate a perception that a surround-right sound source is located respectively behind and to the right of the listener location when transmitted as audio signals by the first and second drivers speaker after crosstalk cancellation.

16. The method of claim 12 wherein the spatially-processed front channel signals are generated to simulate a perception that a front-left sound source is located in front of and to the left of the listener location and to simulate a perception that a front-right sound source is located in front of and to the right of the listener location when transmitted as audio signals by the first and second drivers after crosstalk cancellation.

17. The method of claim 13 further comprising enabling the spatially processing of the front-left and front-right channel signals in response to de-coupling of at least one of the front-left and front-right speakers.

18. The method of claim 13 further comprising reducing a signal level of the center-channel signal prior to the combining with the spatially processed signals.

19. A processing module comprising:

spatial processor to spatially process surround channel signals; and

signal combining circuitry to add the spatially-processed surround channel signals to a center-channel signal for an array of two or more drivers of a center speaker, the array of drivers together to provide both virtualized surround-left and virtualized surround right audio signals,

wherein front-left and front-right channel signals are provided unprocessed to front-left and front-right speakers respectively.

20. The processing module of claim 19 wherein the center speaker comprises a stereo-dipole speaker,

wherein the first and the second speakers drivers are adjacent to each other and separated by a distance, and

wherein the first and the second speakers drivers are to be directed in a forward direction to better achieve crosstalk cancellation and virtualization of the surround-left and surround-right channel signals.

21. The processing module of claim 19 further comprising an amplifier to reduce a signal level of the center-channel signal and to provide the center-channel signal with the reduced signal level to the signal combining circuitry for adding to both the spatially-processed surround channel signals.

22. The processing module of claim 19 wherein the spatial processor comprises:

head-related transfer function (HRTF) filtering circuitry to perform HRTF filtering on the surround-left and surround-right channel signals to generate spatially-processed surround channel signals that simulate a perception that a sound source is behind a predetermined listener location; and

crosstalk cancellation circuitry selected to substantially reduce crosstalk for the predetermined listener location.

23. The processing module of claim 22 wherein the HRTF filtering circuitry comprises:

a left ipsilateral HRTF filter having a transfer function selected to simulate a perception that a sound source is at a left-rear perceived location that is behind and to the left of the predetermined listener location;

a left contralateral HRTF filter having a transfer function selected to simulate a perception that a sound source is at the left-rear perceived location;

a right contralateral HRTF filter having a transfer function selected to simulate a perception that a sound source is at a right-rear perceived location that is behind and to the right of the predetermined listener location;

a right ipsilateral HRTF filter having a transfer function selected to simulate a perception that a sound source is at the right-rear perceived location;

a left channel combining element to combine signal outputs from the left ipsilateral HRTF filter and the right contralateral HRTF filter to generate the spatially-processed surround channel signal; and

a right channel combining element to combine signal outputs from the left contralateral HRTF filter and the right ipsilateral HRTF filter to generate the spatially-processed surround channel signal.

24. The processing module of claim 23 wherein the crosstalk cancellation circuitry comprises filters having transfer functions selected to:

cancel components from the spatially-processed surround channel signal that would arrive at a listener's left ear for the predetermined listener location; and

cancel components from the spatially-processed surround channel signal that would arrive at the listener's right ear for the predetermined listener location.

25. The processing module of claim 19 wherein a decoder generates a multichannel signal comprising the surround channel signals and the front-left and front-right channel signals from an encoded audio signal.

26. A method comprising:

spatial processing surround channel signals;

adding the spatially-processed surround channel signals to a center-channel signal for an array of two or more drivers of a center speaker, the array of drivers together providing both virtualized surround-left and virtualized surround right audio signals; and

providing front-left and front-right channel signals unprocessed to front-left and front-right speakers respectively.

27. The method of claim 26 wherein the center speaker comprises a stereo-dipole speaker,

wherein the first and the second speakers drivers are adjacent to each other and separated by a distance, and

wherein the first and the second speakers drivers are to be directed in a forward direction to better achieve crosstalk cancellation and virtualization of the surround-left and surround-right channel signals.

28. The method of claim 26 further comprising reducing a signal level of the center-channel signal and to provide the center-channel signal with the reduced signal level for adding to both the spatially-processed surround channel signals

29. The method of claim 26 wherein spatial processing comprises:

performing head-related transfer function (HRTF) filtering on the surround-left and surround-right channel signals to generate spatially-processed surround channel signals that simulate a perception that a sound source is behind a predetermined listener location; and

canceling crosstalk from the spatially-processed surround channel signals for the predetermined listener location.

CLAIMS:

1. A processing module comprising:

a spatial processor for spatially processing some or all of surround-left and surround-right channel signals and front-left and front-right channel signals;

circuitry to generate signals for first and second drivers of a centre speaker by removal of crosstalk from the spatially processed signals; and

front-virtualization control circuitry to cause the spatial processor to selectively refrain from spatially processing at least one of either the front-left and front-right channel signals.

2. The processing module of claim 1 wherein the first and second drivers provide virtualized surround-right and surround-left audio,

wherein the first and second drivers optionally provide virtualized front-right and front-left audio,

wherein the front-virtualization control circuitry causes the spatial processor to selectively refrain from spatially processing at least one of the front-left and front-right channel signals when the processing module is coupled to at least one of front-left and front-right speakers to inhibit the first and second drivers from providing the virtualized at least one of front-right and front-left audio.

3. The processing module of claim 1 or 2 wherein the spatial processor comprises:

surround-channel spatial-processing circuitry to spatially process the surround-left and surround-right channel signals;

front-channel spatial-processing circuitry to spatially process the front-left and front-right channel signals; and

signal combining circuitry to combine outputs from both the surround-channel spatial-processing circuitry and the front-channel spatial-processing circuitry to generate first and second spatially-processed combined signals, and

wherein the circuitry to generate signals for the first and second drivers of the centre speaker adds a centre-channel signal to the spatially processed signals.

4. The processing module of claim 2, or 3 when appended to claim 2 further comprising a front-left speaker port and a front-right speaker port,

wherein the front-virtualization control circuitry is configured to disable operation of at least a portion of the front-channel spatial-processing circuitry when at least one of the front-left and front-right speakers are connected to the ports.

5. The processing module of claim 4 wherein front-virtualization control circuitry includes at least one of:

load-sensing circuitry to determine when at least one of the front-left and front-right speakers is connected to the ports; of

a switch selectable by a user to cause the front-virtualization control circuitry to either enable or disable operation of at least a portion of the front-channel spatial-processing circuitry.

6. The processing module of any preceding claim wherein the spatially-processed surround channel signals are generated to simulate a perception that a surround-left sound source is located behind and to the left of a listener location and to simulate a perception that a surround-right sound source is located respectively behind and to the right of the listener location when transmitted as audio signals by the first and second drivers after crosstalk cancellation, and

wherein the spatially-processed front channel signals are generated to simulate a perception that a front-left sound source is located in front of and to the left of the listener location and to simulate a perception that a front-right sound source is located in front of and to the right of the listener location when transmitted as audio signals by the first and second drivers after crosstalk cancellation.

7. The processing module of any preceding claim wherein the circuitry to generate signals for the first and second drivers comprises:

crosstalk cancellation circuitry to substantially remove crosstalk from the first and second spatially-processed combined signals for a predetermined listener location; and

centre-channel signal combining circuitry to add a centre-channel signal to the first and second spatially-processed combined signals to generate signals for the drivers of the centre speaker,

wherein the processing module is configured to receive a multichannel input comprising at least the surround-left and surround-right channel signals, the front-left and front-right channel signals, and the centre-channel signal.

8. The processing module of claim 7 wherein a decoder generates the multichannel input from an encoded audio signal.

9. The processing module of claim 3 or any one of claims 4 to 8 when appended directly or indirectly to claim 3 wherein the surround-channel spatial-processing circuitry comprises:

a left ipsilateral head-related transfer function (HRTF) filter and a left contralateral HRTF filter to operate on the surround-left channel signal;

a right contralateral HRTF filter and a right ipsilateral HRTF filter to operate on the surround-right channel signal;

a right-channel interaural time-delay (ITD) element to delay an output of the right contralateral HRTF filter; and

a left-channel ITD element to delay an output of the left contralateral HRTF filter, and

wherein the front-channel spatial-processing circuitry comprises:

a left ipsilateral head-related transfer function (HRTF) filter and a left contralateral HRTF filter to operate on the front-left channel signal;

a right contralateral HRTF filter and a right ipsilateral HRTF filter to operate on the front-right channel signal;

a right-channel interaural time-delay (ITD) element to delay an output of the right contralateral HRTF filter; and

a left-channel ITD element to delay an output of the left contralateral HRTF filter.

10. The processing module of any preceding claim wherein the centre speaker comprises a stereo-dipole speaker,

wherein the first and second drivers are adjacent to each other and separated by a distance, and

wherein the first and second drivers are to be directed in a forward direction to better achieve crosstalk cancellation and virtualization of at least the surround-left and surround-right channel signals.

11. The processing module of any preceding claim further comprising an amplifier to reduce a signal level of the centre-channel signal prior to the addition to the spatially processed signals.

12. A method comprising:

spatially processing some or all of surround-left and surround-right channel signals and front-left and front-right channel signals;

removing crosstalk from the spatially-processed signals and combining the spatially-processed signals with a centre-channel signal to generate signals for first and second drivers of a centre speaker; and

refraining from spatially processing at least one of the front-left and front-right channel signals in response to coupling of at least one of front-left and front-right speakers.

13. The method of claim 12 wherein the first and second drivers provide virtualized surround-right and surround-left audio,

wherein the first and second drivers optionally provide virtualized front-right and front-left audio, and

wherein the refraining from spatially processing at least one of the front-left and front-right channel signals is performed when at least one of the front-left and front-right speakers are coupled to inhibit at least one of the first and second drivers from providing at least one of the virtualized front-right and front-left audio.

14. The method of claim 12 or 13 further comprising either:

determining when at least one of the front-left and front-right speakers are connected by sensing a load of at least one of the front-left and front-right speakers; or enabling or disabling at least a portion of front-channel spatial processing in response to an input from a user.

15. The method of claim 12, 13 or 14 wherein the spatially-processed surround channel signals are generated to simulate a perception that a surround-left sound source is located behind and to the left of a listener location and to simulate a perception that a surround-right sound source is located respectively behind and to the right of the listener location when transmitted as audio signals by the first and second drivers speaker after crosstalk cancellation.

16. The method of any one of claims 12 to 15 wherein the spatially-processed front channel signals are generated to simulate a perception that a front-left sound source is located in front of and to the left of the listener location and to simulate a perception that a front-right sound source is located in front of and to the right of the listener

location when transmitted as audio signals by the first and second drivers after crosstalk cancellation.

17. The method of any one of claims 13 to 16 further comprising enabling the spatially processing of the front-left and front-right channel signals in response to de-coupling of at least one of the front-left and front-right speakers.

18. The method of any one of claims 13 to 17 further comprising reducing a signal level of the centre-channel signal prior to the combining with the spatially processed signals.