

Claims

1. An apparatus for generating one or more audio output channel signals depending on two or more audio input channel signals, wherein each of the two or more audio input channel signals comprises direct signal portions and ambient signal portions, wherein the apparatus comprises:

a filter determination unit (110) for determining a filter by estimating first power spectral density information and by estimating second power spectral density information, and

a signal processor (120) for generating the one or more audio output channel signals by applying the filter on the two or more audio input channel signals,

wherein the first power spectral density information indicates power spectral density information on the two or more audio input channel signals, and the second power spectral density information indicates power spectral density information on the ambient signal portions of the two or more audio input channel signals, wherein the signal processor (120) is configured to calculate the first power spectral density information so that the first power spectral density information indicates a first covariance matrix of the two or more audio input channel signals, and wherein the signal processor (120) is configured to calculate the second power spectral density information so that the second power spectral density information indicates a second covariance matrix of the ambient signal portions of the two or more audio input channel signals, or

wherein the first power spectral density information indicates the power spectral density information on the two or more audio input channel signals, and the second power spectral density information indicates power spectral density information on the direct signal portions of the two or more audio input channel signals, wherein the signal processor (120) is configured to calculate the first power spectral density information so that the first power spectral density information indicates the first covariance matrix of the two or more audio input channel signals, and wherein the signal processor (120) is configured to calculate the second power spectral density information so that the second power spectral density information indicates a third covariance matrix of the direct signal portions of the two or more audio input channel signals, or

wherein the first power spectral density information indicates the power spectral density information on the direct signal portions of the two or more audio input channel signals, and the second power spectral density information indicates the power spectral density information on the ambient signal portions of the two or more audio input channel signals, wherein the signal processor (120) is configured to calculate the first power spectral density information so that the first power spectral density information indicates the third covariance matrix of the direct signal portions of the two or more audio input channel signals, and wherein the signal processor (120) is configured to calculate the second power spectral density information so that the second power spectral density information indicates the second covariance matrix of the ambient signal portions of the two or more audio input channel signals.

2. An apparatus according to claim 1,

wherein the apparatus furthermore comprises an analysis filterbank (605) for transforming the two or more audio input channel signals from a time domain to a time-frequency domain,

wherein the filter determination unit (110) is configured to determine the filter by estimating the first power spectral density information and the second power spectral density information depending on the audio input channel signals, being represented in the time-frequency domain,

wherein the signal processor (120) is configured to generate the one or more audio output channel signals, being represented in a time-frequency domain, by applying the filter on the two or more audio input channel signals, being represented in the time-frequency domain, and

wherein the apparatus furthermore comprises a synthesis filterbank (625) for transforming the one or more audio output channel signals, being represented in a time-frequency domain, from the time-frequency domain to the time domain.

3. An apparatus according to claim 1 or 2, wherein the filter determination unit (110) is configured to determine the filter by estimating the first power spectral density information, by estimating the second power spectral density information, and by determining parameter information (β_i, β_j) depending on at least one of the two or more audio input channel signals.

4. An apparatus according to claim 3, wherein the filter determination unit (110) is configured to determine the parameter information (β_i, β_j) depending on whether a transient is present in at least one of the two or more audio input channel signals.

5. An apparatus according to claim 3 or 4, wherein the filter determination unit (110) is configured to determine the parameter information (β_i, β_j) depending on a presence of additive noise in at least one signal channel through which one of the two or more audio input channel signals is transmitted.

6. An apparatus according to one of claims 3 to 5,

wherein the filter determination unit (110) is configured to determine the power spectral density information on the two or more audio input channel signals depending on a first matrix (Φ_y), the first matrix (Φ_y) comprising an estimation of the power spectral density for each channel signal of the two or more audio input channel signals on the main diagonal of the first matrix (Φ_y), and is configured to determine the power spectral density information on the ambient signal portions of the two or more audio input channel signals depending on a second matrix (Φ_a) or depending on an inverse matrix (Φ_a^{-1}) of the second matrix (Φ_a), the second matrix (Φ_a) comprising an estimation of the power spectral density for the ambient signal portions of each channel signal of the two or more audio input channel signals on the main diagonal of the second matrix (Φ_a), or

wherein the filter determination unit (110) is configured to determine the power spectral density information on the two or more audio input channel signals depending on the first matrix (Φ_y), and is configured to determine the power spectral density information on the direct signal portions of the two or more audio input channel signals depending on a third matrix (Φ_d) or depending on an inverse matrix (Φ_d^{-1}) of the third matrix (Φ_d), the third matrix (Φ_d) comprising an estimation of the power spectral density for the direct signal portions of each channel signal of the two or more audio input channel signals on the main diagonal of the third matrix (Φ_d), or

wherein the filter determination unit (110) is configured to determine the power spectral density information on the ambient signal portions of the two or more audio input channel signals depending on the second matrix (Φ_a) or depending on

an inverse matrix (Φ_a^{-1}) of the second matrix (Φ_a), and is configured to determine the power spectral density information on the direct signal portions of the two or more audio input channel signals depending on the third matrix (Φ_d) or depending on an inverse matrix (Φ_d^{-1}) of the third matrix (Φ_d).

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7. An apparatus according to claim 6,

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wherein the filter determination unit (110) is configured to determine the first matrix (Φ_y) to determine the power spectral density information on the two or more audio input channel signals, and is configured to determine the second matrix (Φ_a) or an inverse matrix (Φ_a^{-1}) of the second matrix (Φ_a) to determine the power spectral density information on the ambient signal portions of the two or more audio input channel signals, or

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wherein the filter determination unit (110) is configured to determine the first matrix (Φ_y) to determine the power spectral density information on the two or more audio input channel signals, and is configured to determine the third matrix (Φ_d) or an inverse matrix (Φ_d^{-1}) of the third matrix (Φ_d) to determine the power spectral density information on the direct signal portions of the two or more audio input channel signals, or

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wherein the filter determination unit (110) is configured to determine the second matrix (Φ_a) or an inverse matrix (Φ_a^{-1}) of the second matrix (Φ_a) to determine the power spectral density information on the ambient signal portions of the two or more audio input channel signals, and is configured to determine the third matrix (Φ_d) or an inverse matrix (Φ_d^{-1}) of the third matrix (Φ_d) to determine the power spectral density information on the ambient signal portions of the two or more audio input channel signals.

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8. An apparatus according to claim 6 or 7,

wherein the filter determination unit (110) is configured to determine the filter $H_D(\beta_i)$ depending on the formula

$$\mathbf{H}_D(\beta_i) = \frac{\Phi_a^{-1} \Phi_y - \mathbf{I}_{N \times N}}{\beta_i + \lambda}$$

or depending on the formula

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$$\mathbf{H}_D(\beta_i) = \frac{(\Phi_y - \Phi_d)^{-1} \Phi_y - \mathbf{I}_{N \times N}}{\beta_i + \lambda}$$

or depending on the formula

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$$\mathbf{H}_D(\beta_i) = \frac{\Phi_a^{-1} (\Phi_d + \Phi_a) - \mathbf{I}_{N \times N}}{\beta_i + \lambda}, \text{ or}$$

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wherein the filter determination unit (110) is configured to determine the filter $\mathbf{H}_A(\beta_i)$ depending on the formula

$$\mathbf{H}_A(\beta_i) = \mathbf{I}_{N \times N} - \frac{\Phi_a^{-1} \Phi_y - \mathbf{I}_{N \times N}}{\beta_i + \lambda}$$

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or depending on the formula

$$\mathbf{H}_A(\beta_i) = \mathbf{I}_{N \times N} - \frac{(\Phi_y - \Phi_d)^{-1} \Phi_y - \mathbf{I}_{N \times N}}{\beta_i + \lambda}$$

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or depending on the formula

$$\mathbf{H}_A(\beta_i) = \mathbf{I}_{N \times N} - \frac{\Phi_a^{-1} (\Phi_d + \Phi_a) - \mathbf{I}_{N \times N}}{\beta_i + \lambda},$$

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wherein Φ_y is the first matrix,

wherein Φ_a is the second matrix,

5 wherein Φ_a^{-1} is the inverse matrix of the second matrix,

wherein Φ_d is the third matrix,

wherein $\mathbf{I}_{N \times N}$ is a unit matrix of size $N \times N$,

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wherein N indicates the number of the audio input channel signals,

wherein β_i is the trade-off information being a number, and

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wherein $\lambda = \text{tr}\{\Phi_a^{-1}\Phi_d\}$,

wherein tr is the trace operator.

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9. An apparatus according to one of claims 3 to 8, wherein the filter determination unit (110) is configured to determine a trade-off parameter (β_i, β_j) for each of two or more audio input channel signals as the trade-off information (β_i, β_j) , wherein the trade-off parameter (β_i, β_j) of each of the audio input channel signals depends on said audio input channel signal.

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10. An apparatus according to claim 8,

wherein the filter determination unit (110) is configured to determine a trade-off parameter (β_i, β_j) for each of two or more audio input channel signals as the trade-off information (β_i, β_j) , so that for each pair of a first audio input channel signal of the audio input channel signals and another second audio input channel signal of the audio input channel signals

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$$\mathbf{h}_{A,i}^H(\beta_i)\Phi_a\mathbf{h}_{A,i}(\beta_i) - \mathbf{h}_{A,j}^H(\beta_j)\Phi_a\mathbf{h}_{A,j}(\beta_j)$$

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is true,

wherein β_i is the trade-off parameter of said first audio input channel signal,

wherein β_j is the trade-off parameter of said second audio input channel signal,

wherein

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$$\mathbf{h}_{A,i}(\beta_i) = [\beta_i \Phi_d + \Phi_a]^{-1} \Phi_a \mathbf{u}_i,$$

wherein $\mathbf{h}_{A,i}^H(\beta_i)$ is the conjugate transpose matrix of $\mathbf{h}_{A,i}(\beta_i)$, and

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wherein $\mathbf{u}_i$ is a null vector of length N with 1 at the i -th position.

11. An apparatus according to claim 8 or 10,

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wherein the filter determination unit (110) is configured to determine the second matrix Φ_a according to the formula

$$\Phi_a = \hat{\phi}_A \mathbf{I}_{N \times N}; \quad \text{or}$$

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wherein the filter determination unit (110) is configured to determine the third matrix Φ_d according to the formula

$$\Phi_d = \Phi_y - \hat{\phi}_A \mathbf{I}_{N \times N},$$

wherein $\hat{\phi}_A$ is a number.

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12. An apparatus according to claim 11, wherein the filter determination unit (110) is configured to determine $\hat{\phi}_A$ depending on the two or more audio input channel signals.

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13. An apparatus according to one of claims 1 to 7,

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wherein the filter determination unit (110) is configured to determine a filter matrix $\mathbf{H}_D$ for computing an estimate of the direct signal portions ($\hat{\mathbf{d}}(m, k)$) by estimating first power spectral density information and by estimating second power spectral density information, and

wherein the filter determination unit (110) is configured to determine the filter $\tilde{\mathbf{H}}_D$ depending on the filter matrix $\mathbf{H}_D$ according to the formula

$$\tilde{\mathbf{H}}_D = \mathbf{I} - \mathbf{G} + \mathbf{G}\mathbf{H}_D,$$

wherein $\mathbf{I}$ is a unit matrix, and

wherein $\mathbf{G}$ is a diagonal matrix,

wherein the signal processor (120) is configured to generate the one or more audio output channel signals by applying the filter $\tilde{\mathbf{H}}_D$ on the two or more audio input channel signals.

14. A method for generating one or more audio output channel signals depending on two or more audio input channel signals, wherein each of the two or more audio input channel signals comprises direct signal portions and ambient signal portions, wherein the method comprises:

determining a filter by estimating first power spectral density information and by estimating second power spectral density information, and

generating the one or more audio output channel signals by applying the filter on the two or more audio input channel signals,

wherein the first power spectral density information indicates power spectral density information on the two or more audio input channel signals, and the second power spectral density information indicates power spectral density information on the ambient signal portions of the two or more audio input channel signals, wherein calculating the first power spectral density information is conducted so that the first power spectral density information indicates a first covariance matrix of the two or more audio input channel signals, and wherein calculating the second power spectral density information is conducted so that the second power spectral density information indicates a second covariance matrix of the ambient signal portions of the two or more audio input channel signals, or

wherein the first power spectral density information indicates the power spectral density information on the two or more audio input channel signals, and the

second power spectral density information indicates power spectral density information on the direct signal portions of the two or more audio input channel signals, wherein calculating the first power spectral density information is conducted so that the first power spectral density information indicates the first covariance matrix of the two or more audio input channel signals, and wherein calculating the second power spectral density information is conducted so that the second power spectral density information indicates a third covariance matrix of the direct signal portions of the two or more audio input channel signals, or

wherein the first power spectral density information indicates the power spectral density information on the direct signal portions of the two or more audio input channel signals, and the second power spectral density information indicates the power spectral density information on the ambient signal portions of the two or more audio input channel signals, wherein calculating the first power spectral density information is conducted so that the first power spectral density information indicates the third covariance matrix of the direct signal portions of the two or more audio input channel signals, and calculating the second power spectral density information is conducted so that the second power spectral density information indicates the second covariance matrix of the ambient signal portions of the two or more audio input channel signals.

15. A computer program for implementing the method of claim 14 when being executed on a computer or processor.

Claims

1. An apparatus for generating one or more audio output channel signals depending on two or more audio input channel signals, wherein each of the two or more audio input channel signals comprises direct signal portions and ambient signal portions, wherein the apparatus comprises:

a filter determination unit for determining a filter by estimating first power spectral density information and by estimating second power spectral density information, and

a signal processor for generating the one or more audio output channel signals by applying the filter on the two or more audio input channel signals,

wherein the first power spectral density information indicates power spectral density information on the two or more audio input channel signals, and the second power spectral density information indicates power spectral density information on the ambient signal portions of the two or more audio input channel signals, or

wherein the first power spectral density information indicates the power spectral density information on the two or more audio input channel signals, and the second power spectral density information indicates power spectral density information on the direct signal portions of the two or more audio input channel signals, or

wherein the first power spectral density information indicates the power spectral density information on the direct signal portions of the two or more audio input channel signals, and the second power spectral density information indicates the power spectral density information on the ambient signal portions of the two or more audio input channel signals.

2. An apparatus according to claim 1,

wherein the apparatus furthermore comprises an analysis filterbank for transforming the two or more audio input channel signals from a time domain to a time-frequency domain,

wherein the filter determination unit is configured to determine the filter by estimating the first power spectral density information and the second power spectral density information depending on the audio input channel signals, being represented in the time-frequency domain,

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wherein the signal processor is configured to generate the one or more audio output channel signals, being represented in a time-frequency domain, by applying the filter on the two or more audio input channel signals, being represented in the time-frequency domain, and

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wherein the apparatus furthermore comprises a synthesis filterbank for transforming the one or more audio output channel signals, being represented in a time-frequency domain, from the time-frequency domain to the time domain.

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3. An apparatus according to claim 1 or 2, wherein the filter determination unit is configured to determine the filter by estimating the first power spectral density information, by estimating the second power spectral density information, and by determining trade-off information depending on at least one of the two or more audio input channel signals.

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4. An apparatus according to claim 3, wherein the filter determination unit is configured to determine the trade-off information depending on whether a transient is present in at least one of the two or more audio input channel signals.

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5. An apparatus according to claim 3 or 4, wherein the filter determination unit is configured to determine the trade-off information depending on a presence of additive noise in at least one signal channel through which one of the two or more audio input channel signals is transmitted.

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6. An apparatus according to one of claims 3 to 5,

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wherein the filter determination unit is configured to determine the power spectral density information on the two or more audio input channel signals depending on a first matrix, the first matrix comprising an estimation of the power spectral density for each channel signal of the two or more audio input channel signals on the main diagonal of the first matrix, and is configured to determine the power spectral density information on the ambient signal portions of the two or more audio input channel signals depending on a second matrix or depending on an inverse matrix

of the second matrix, the second matrix comprising an estimation of the power spectral density for the ambient signal portions of each channel signal of the two or more audio input channel signals on the main diagonal of the second matrix, or

5 wherein the filter determination unit is configured to determine the power spectral density information on the two or more audio input channel signals depending on the first matrix, and is configured to determine the power spectral density information on the direct signal portions of the two or more audio input channel signals depending on a third matrix or depending on an inverse matrix of the third matrix, the third matrix comprising an estimation of the power spectral density for the direct signal portions of each channel signal of the two or more audio input channel signals on the main diagonal of the third matrix, or

10 wherein the filter determination unit is configured to determine the power spectral density information on the ambient signal portions of the two or more audio input channel signals depending on the second matrix or depending on an inverse matrix of the second matrix, and is configured to determine the power spectral density information on the direct signal portions of the two or more audio input channel signals depending on the third matrix or depending on an inverse matrix of the third matrix.

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7. An apparatus according to claim 6,

25 wherein the filter determination unit is configured to determine the first matrix to determine the power spectral density information on the two or more audio input channel signals, and is configured to determine the second matrix or an inverse matrix of the second matrix to determine the power spectral density information on the ambient signal portions of the two or more audio input channel signals, or

30 wherein the filter determination unit is configured to determine the first matrix to determine the power spectral density information on the two or more audio input channel signals, and is configured to determine the third matrix or an inverse matrix of the third matrix to determine the power spectral density information on the direct signal portions of the two or more audio input channel signals, or

35 wherein the filter determination unit is configured to determine the second matrix or an inverse matrix of the second matrix to determine the power spectral density information on the ambient signal portions of the two or more audio input channel

signals, and is configured to determine the third matrix or an inverse matrix of the third matrix to determine the power spectral density information on the ambient signal portions of the two or more audio input channel signals.

- 5 8. An apparatus according to claim 6 or 7,

wherein the filter determination unit is configured to determine the filter $\mathbf{H}_D(\beta_i)$ depending on the formula

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$$\mathbf{H}_D(\beta_i) = \frac{\Phi_a^{-1} \Phi_y - \mathbf{I}_{N \times N}}{\beta_i + \lambda}$$

or depending on the formula

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$$\mathbf{H}_D(\beta_i) = \frac{(\Phi_y - \Phi_d)^{-1} \Phi_y - \mathbf{I}_{N \times N}}{\beta_i + \lambda}$$

or depending on the formula

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$$\mathbf{H}_D(\beta_i) = \frac{\Phi_a^{-1} (\Phi_d + \Phi_a) - \mathbf{I}_{N \times N}}{\beta_i + \lambda}, \text{ or}$$

wherein the filter determination unit is configured to determine the filter $\mathbf{H}_A(\beta_i)$ depending on the formula

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$$\mathbf{H}_A(\beta_i) = \mathbf{I}_{N \times N} - \frac{\Phi_a^{-1} \Phi_y - \mathbf{I}_{N \times N}}{\beta_i + \lambda}$$

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or depending on the formula

$$\mathbf{H}_A(\beta_i) = \mathbf{I}_{N \times N} - \frac{(\Phi_y - \Phi_d)^{-1} \Phi_y - \mathbf{I}_{N \times N}}{\beta_i + \lambda}$$

or depending on the formula

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$$\mathbf{H}_A(\beta_i) = \mathbf{I}_{N \times N} - \frac{\Phi_a^{-1}(\Phi_d + \Phi_a) - \mathbf{I}_{N \times N}}{\beta_i + \lambda},$$

wherein Φ_y is the first matrix,

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wherein Φ_a is the second matrix,

wherein Φ_a^{-1} is the inverse matrix of the second matrix,

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wherein Φ_d is the third matrix,

wherein $\mathbf{I}_{N \times N}$ is a unit matrix of size $N \times N$,

wherein N indicates the number of the audio input channel signals,

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wherein β_i is the trade-off information being a number, and

wherein $\lambda = \text{tr}\{\Phi_a^{-1} \Phi_d\}$,

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wherein tr is the trace operator.

9. An apparatus according to one of claims 3 to 8, wherein the filter determination unit is configured to determine a trade-off parameter for each of two or more audio input channel signals as the trade-off information, wherein the trade-off parameter of each of the audio input channel signals depends on said audio input channel signal.

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10. An apparatus according to claim 8,

wherein the filter determination unit is configured to determine a trade-off parameter for each of two or more audio input channel signals as the trade-off information, so that for each pair of a first audio input channel signal of the audio input channel signals and another second audio input channel signal of the audio input channel signals

$$\mathbf{h}_{A,i}^H(\beta_i) \Phi_a \mathbf{h}_{A,i}(\beta_i) = \mathbf{h}_{A,j}^H(\beta_j) \Phi_a \mathbf{h}_{A,j}(\beta_j)$$

is true,

wherein β_i is the trade-off parameter of said first audio input channel signal,

wherein β_j is the trade-off parameter of said second audio input channel signal,

wherein

$$\mathbf{h}_{A,i}(\beta_i) = [\beta_i \Phi_d + \Phi_a]^{-1} \Phi_a \mathbf{u}_i,$$

wherein $\mathbf{h}_{A,i}^H(\beta_i)$ is the conjugate transpose matrix of $\mathbf{h}_{A,i}(\beta_i)$, and

wherein $\mathbf{u}_i$ is a null vector of length N with 1 at the i -th position.

11. An apparatus according to claim 8 or 10,

wherein the filter determination unit is configured to determine the second matrix Φ_a according to the formula

$$\Phi_a = \hat{\phi}_A \mathbf{I}_{N \times N}, \quad \text{or}$$

wherein the filter determination unit is configured to determine the third matrix Φ_d according to the formula

$$\Phi_d = \Phi_y - \hat{\phi}_A \mathbf{I}_{N \times N},$$

wherein $\hat{\phi}_A$ is a number.

12. An apparatus according to claim 11, wherein the filter determination unit is configured to determine $\hat{\phi}_A$ depending on the two or more audio input channel signals.

- 5 13. An apparatus according to one of claims 1 to 7,

wherein the filter determination unit is configured to determine an intermediate filter matrix $\mathbf{H}_D$ by estimating first power spectral density information and by estimating second power spectral density information, and

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wherein the filter determination unit is configured to determine the filter $\tilde{\mathbf{H}}_D$ depending on the intermediate filter matrix $\mathbf{H}_D$ according to the formula

$$\tilde{\mathbf{H}}_D = \mathbf{I} - \mathbf{G} + \mathbf{G}\mathbf{H}_D ,$$

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wherein $\mathbf{I}$ is a unit matrix, and

wherein $\mathbf{G}$ is a diagonal matrix,

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wherein the signal processor is configured to generate the one or more audio output channel signals by applying the filter $\tilde{\mathbf{H}}_D$ on the two or more audio input channel signals.

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14. A method for generating one or more audio output channel signals depending on two or more audio input channel signals, wherein each of the two or more audio input channel signals comprises direct signal portions and ambient signal portions, wherein the method comprises:

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determining a filter by estimating first power spectral density information and by estimating second power spectral density information, and

generating the one or more audio output channel signals by applying the filter on the two or more audio input channel signals,

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wherein the first power spectral density information indicates power spectral density information on the two or more audio input channel signals, and the second power spectral density information indicates power spectral density

information on the ambient signal portions of the two or more audio input channel signals, or

5 wherein the first power spectral density information indicates the power spectral density information on the two or more audio input channel signals, and the second power spectral density information indicates power spectral density information on the direct signal portions of the two or more audio input channel signals, or

10 wherein the first power spectral density information indicates the power spectral density information on the direct signal portions of the two or more audio input channel signals, and the second power spectral density information indicates the power spectral density information on the ambient signal portions of the two or more audio input channel signals.

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15. A computer program for implementing the method of claim 14 when being executed on a computer or processor.