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Cezanne et al.

(54) **ADAPTIVE MICROPHONE ARRAY**

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H04R 1/40 (2006.01)

(52) **U.S. Cl.** **381/92**; 381/94.7

(58) **Field of Classification Search** .... None
See application file for complete search history.

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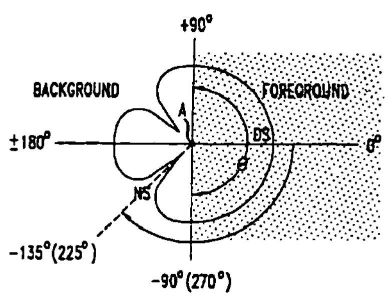
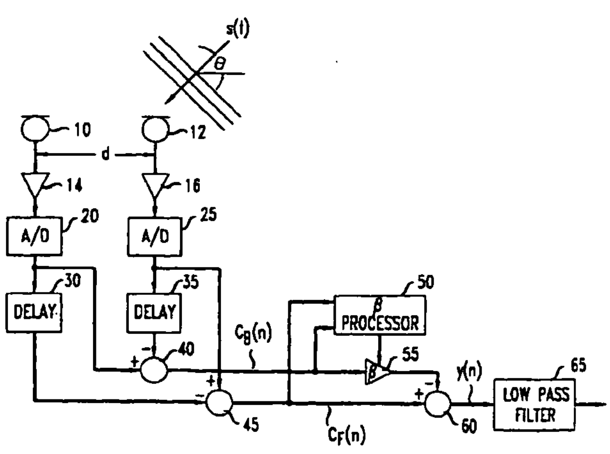
(57) **ABSTRACT**

The present invention is directed to a method [of] *and* apparatus of enhancing the signal-to-noise ratio of a microphone array. The array includes a plurality of microphones and has a directivity pattern which is adjustable based on one or more parameters. The parameters are evaluated so as to realize an angular orientation of a directivity pattern null. This angular orientation of the directivity pattern null reduces microphone array output signal level. Parameter evaluation is performed under a constraint that the null be located within a predetermined region of space. Advantageously, the predetermined region of space is a region from which undesired acoustic energy is expected to impinge upon the array, and the angular orientation of a directivity pattern null substantially aligns with the angular orientation of undesired acoustic energy. Output signals of the array microphones are modified based on one or more evaluated paramaters. An array output signal is formed based on modified and unmodified microphone output signals. The evaluation of parameters, the modification of output signals, and the formation of an array output signal may be performed a plurality of times to obtain an adaptive army response. Embodiments of the invention include those having a plurality of directivity patterns corresponding to a plurality of frequency subbands. Illustratively, the array may comprise a plurality of cardioid sensors.





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EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

ONLY THOSE PARAGRAPHS OF THE SPECIFICATION AFFECTED BY AMENDMENT ARE PRINTED HEREIN.

Column 3, lines 5–20:

FIG. **1** presents three representations of illustrative backgound and foreground configurations in two dimensions. In FIG. **1**(a), the foreground is defined by the shaded angular region –45°>Θ>45°. The letter "A" indicates the position of the array (i.e., at the origin), the [letter "x" indicates] *letters "DS" indicate* the position of the desired source, and [letter "y" indicates] *the letters "NS" indicate* the position of the undesired noise source. In FIG. **1**(b), the foregound is defined by the angular region –90>Θ>90°. In FIG. **1**(c), the foreground is defined by the angular region –160°>Θ>120°. The foregound/background combination of FIG. **1**(b) is used with the illustrative embodiments discussed below. As such, the embodiments are sensitive to desired sound from the angular region –90°>Θ°90°(foreground) and can adaptively place nulls within the region –90°>Θ>270°to mitigate the effects of noise from this region (background).

Column 3, lines 21–41:

FIG. **2** presents an illustrative directivity pattern of an array shown in two-dimensions in accordance with the present invention. The sensitivity pattern is superimposed on the foreground/background configuration of FIG. [**2**(b)] *1(b)*. As shown in FIG. **2**, array A has a substantially uniform sensitivity (as a function of Θ) in the foreground region to the desired source of sound DS. In the background region, however, the sensitivity pattern exhibits a null at approximately 180°±45°, which is substantially coincident with the two-dimensional angular position of the noise source NS. Because of this substantial coincidence, the noise source NS contributes less to the array output relative to other sources not aligned with the null. The illustrative embodiments of the present invention automatically adjust their directivity patterns to locate pattern nulls in angular orientations to mitigate the effect of noise on array output. This adjustment is made under the constraint that the nulls be limited to the background region of space adjacent to the array. This constraint prevents the nulls from migrating into the foreground and substantially affecting the response of the array to the desired sound.

Column 4, lines 56–63:

Delay lines **30**, [**25**] *35* introduce signal delays needed to form the cardioid sensors of the embodiment. Subtraction circuit **40** forms the back cardioid output signal, [C_B(t)] $C_B(n)$, by subtracting a delayed output of microphone **12** from an undelayed output of microphone **10**. Subtraction circuit **45** forms the front cardioid output signal [C_F(t)] $C_F(n)$, by subtracting a delayed output of microphone **10** from an undelayed output of microphone **12**.

Column 5, lines 6–11:

The output signals from the subtraction circuits **40**, **45** are provided to β processor **50**. β processor **50** computes a gain β for application to signal [C_B (t)] $C_B(n)$ by amplifier **55**. The scaled signal [βC_B(t)] $\beta C_B(n)$, is then subtracted from front cardioid output signal [C_F(t)] $C_F(n)$, by subtraction circuit **60** to form array output signal [y(t)] *y(n)*.

Column 5, lines 12–15:

Output signal [y(t)] *y(n)* is then filtered by lowpass filter **65**. Lowpass filter **65** has a 5 kHz cutoff frequency. Lowpass filter **65** is used to attenuate signals that are above the highest design frequency for the array.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims **1**–**23** is confirmed.

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