UNIVERSITÀ DEGLI STUDI DI TRIESTE

dipartimento di ingegneria e architettura

Parametric Loudspeaker

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Parametric loudspeaker

A new type of directional loudspeaker, known as the parametric loudspeaker, is able to project low-frequency sound with a small-size ultrasound emitters array. Parametric loudspeaker uses ultrasonic waves beyond the human hearing range as a unidirectional carrier to deliver audible sound to desired locations with precision.

The ultrasound emitters array can be built to different sizes to achieve different focal lengths that can be more readily deployed in many applications.

Small-volume, high-frequency ultrasonic transducers have been designed and fabricated by microelectromechanical technology, known as MEMS ultrasonic Transducers.

However, due to the current limitation in ultrasonic transducer technology, the parametric array is limited to speech-based applications such as public address systems and billboard advertisements.

Parametric loudspeaker

Fig. 1 Directional sound applications in a library and at a vending machine.

Parametric loudspeaker

The phenomenon of the parametric array was described by Westervelt in 1960 as: “two plane waves of differing frequencies generate, when traveling in the same direction, two new waves, one of which has a frequency equal to the sum of the original two frequencies and the other equal to the difference frequency.”

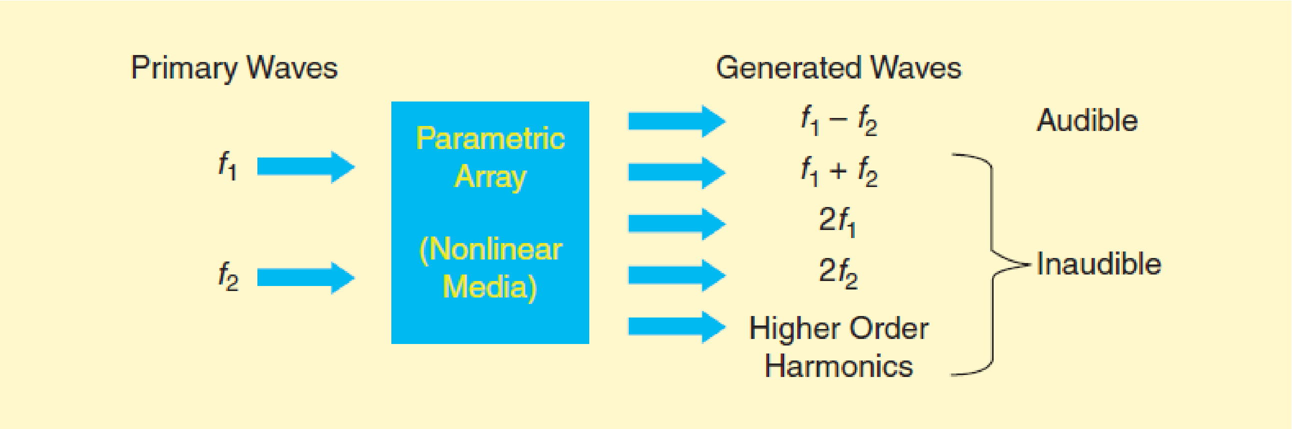

Fig. 2 Nonlinear interaction process in parametric array.

Parametric loudspeaker

After a short distance of propagation, only the audible waves in the sound beam remain sufficient amplitudes to be heard by humans.

There are two important distances to be considered in a parametric array, namely, ***Rayleigh distance*** and ***absorption length***.

Rayleigh distance

Rayleigh distance is defined as the distance from the array at which there is a transition from a near-field region to a farfield region.
Within Rayleigh distance, wavefronts are approximately planar.
After Rayleigh distance, the wavefront becomes more spherical and attenuates more rapidly at a rate of –6dB per double distance.

Absorption length

Absorption length is defined as the distance beyond which the nonlinear interaction no longer exists. The absorption length is also called the *effective array length*, determining the extent of the distance traveled by the ultrasonic carrier before it ceases to generate any more audible sound sources.
Intermodulation process inside the primary beam excites air molecules to oscillate at the audio frequency, and the oscillation is regarded as a virtual source.

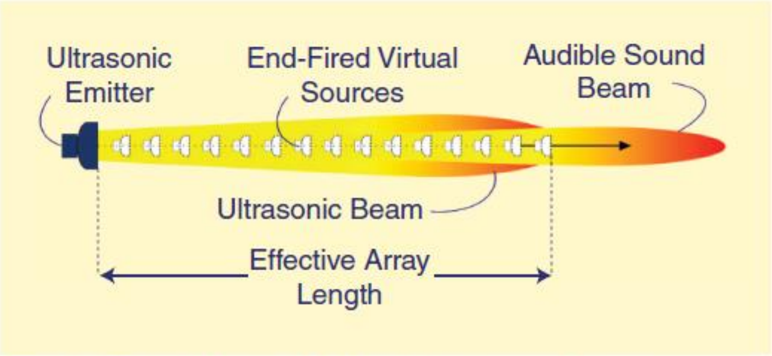

Fig. 3 Geometric model of the parametric array.

Models of nonlinear acoustics

Berktay provided a simple expression that can be used to predict the farfield array response on the propagating axis.
It is stated that the demodulated waveform along the axis of propagation is proportional to the second-time derivative of the square of the envelope of the primary signal:

$$p_2 = \frac{\beta P_0^2\, a^2}{16\rho c^4 z\delta} \frac{d^2}{d\tau^2} E^2(\tau),$$

a and P_0 are source radius and pressure amplitude at source, respectively. *z* is the coordinate along the beam propagation direction; $\tau = t - \frac{z}{c}$ is the retarded time, and *c* is the small signal sound speed. Furthermore, *p*, δ and β are the density, dissipation factor corresponding to thermoviscous absorption, and the nonlinearity coefficient of the medium.

Models of nonlinear acoustics

According to Berktay's equation, a 12-dB/octave slope in the frequency response of a parametric array is predicted.
Therefore, it is recommended that a lowpass filter with 12-dB/octave transition is used to equalize the frequency response before amplitude modulation.

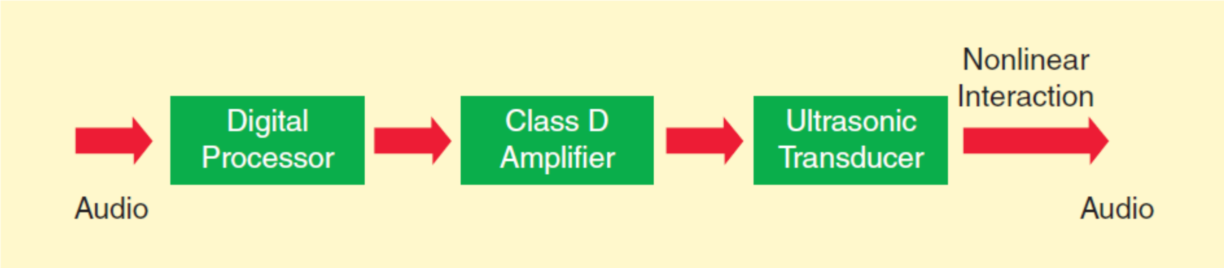

Fig. 5 Block diagram of ABS.

Fig. 6 ABS and its ultrasound emitters.

See

Shi, Chuang, and Woon-Seng Gan. "Development of parametric loudspeaker." *IEEE potentials* 29.6 (2010): 20-24.

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