SYNTHETIC APERTURE APPROACH TO MULTI-BEAM SCANNING

ACOUSTICAL IMAGING

Kazuhiko Nitadori
Oki Electric Industry Co., Ltd.
Hachioji, Japan 193

An acoustical imaging method is described which realizes high resolution imaging with relatively small number of transmitters and receivers on the basis of a synthetic aperture technique, but does not require a severe phase stability. It uses a sparse planar transmitting array for generating narrow transmitting multi-beams and a dense planar receiving array for resolving the transmitted multi-beams into independent pencil beams and scans the transmitting multi-beams electronically to obtain the whole picture elements of an image. It differs from the usual synthetic aperture method only in that the transmitters are used for beamforming instead for sequential scanning. Under ideal circumstances, both methods are almost equivalent. But, under practical circumstances, the present method has many advantages over the usual method as the following: i) unstability of a transmitter/receiver platform and a medium causes less influences on resolution and image dynamic range, ii) no speckle noise occurs, iii) memory capacity and processing time required for signal processing can be saved, and iv) higher acoustic power can be transmitted under the cavitation limited environment.

INTRODUCTION

In a holographic acoustical imaging method, the number of picture elements of a reconstructed image coincides approximately with the number of receivers arranged within a receiving aperture,\(^1\) so that a large number of receivers must be used to obtain high resolution images. In order to
reduce the amount of the receivers without degrading resolution, the synthetic aperture technique is used\(^{(2),(3)}\) in which the transmitting signals are radiated successively from each transmitter in a transmitting array, the reflected echoes from an object are received with a receiving array, and the received signals are stored during the whole scanning period, then synthesized to obtain a large effective receiving aperture. By the technique we can obtain as many picture elements as the product of the number of transmitters times the number of receivers. In order for this to be possible, however, a transmitter/receiver platform, a transmission medium, and an object must be stationary during the whole transmitter scanning period, which may be restricting the applications of this technique.

As a method for overcoming the fault of the usual synthetic aperture method, which we refer as a transmitter scanning method or TS method, for simplicity, we propose here a multi-beam scanning method or MBS method, which uses the same transmitting and receiving array as the TS method, but uses the transmitting array for beamforming instead using the transmitters individually and sequentially. Under ideal circumstances, the present method is almost equivalent to the TS method. But, under practical circumstances, it has many advantages over the TS method.

SYNTHETIC APERTURE TECHNIQUE

We first introduce the theory of synthetic aperture technique for a fixed transmitting and receiving array preparatory to deriving the MBS imaging method. Suppose transmitters and receivers are arranged on the same plane (T/R plane) and an object is placed on the object plane that is parallel to and at a distance \( z \) from the T/R plane, as shown in Fig. 1. Each of the transmitters and the receivers are assumed to have the identical pupil functions \( g_{t}(x,y) \) and \( g_{r}(x,y) \), respectively, and to be centered at \( (u_{t},v_{t}) \) and \( (u_{r},v_{r}) \) on the T/R plane, respectively. Let \( S_{t}(u_{t},v_{t}) \) denote the complex amplitude of the driving signal for the transmitter at coordinates \( (u_{t},v_{t}) \) and \( S_{r}(u_{r},v_{r};u_{t},v_{t}) \) denote the complex amplitude of the corresponding received signal by the receiver at coordinates \( (u_{r},v_{r}) \).

When the transmitting signal \( S_{t}(u_{t},v_{t}) \) is radiated, the complex field of the sound at a point \( (x_{0},y_{0}) \) on the object