Recovery of non-stationary free field based on pressure and acceleration measurements in a noisy environment

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ABSTRACT

In order to remove the non-stationary incoming field from the back side of the measurement plane and the scattered field caused by the incoming wave falling on the surface of the target source, a recovery method of the non-stationary free field with the pressure and particle acceleration measurements is proposed. First, the mixed time-evolving pressure and particle acceleration calculated by the finite difference technique on one measurement plane are obtained. Then, two physical relations are employed to deduce a forward complete recovery formulation of the target source in the noisy environment. One relation contains two impulse response functions relating the time-wavenumber pressure spectrum to particle acceleration and pressure spectrums, respectively, and the other is the surface reflection coefficient of the target source relating the scattered field to the incoming field. Finally, the time-evolving pressure radiated by the target source in free-field is recovered. A circular piston fixed on an infinite rigid baffle and two monopole sources are designed in a numerical simulation to test the performance of the proposed method. The simulation results attest that the proposed method not only can recover the time-evolving pressure radiated by the target source in free-field at any space points, but also recover the space distribution of the non-stationary sound field of the target source in free-field at different time instants effectively.

Keywords: Pressure and particle acceleration measurements, non-stationary free field, Recovery
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1. INTRODUCTION

Near-field acoustic holography (NAH) [1,2] is an effective tool for the visualization and reconstruction of sound sources. However, in a noisy environment, the measured sound field cannot be directly used as the input of NAH for investigating the characteristics of the vibration and sound radiation of a target source accurately. The reason is that the measured sound field not only contains the sound field radiated by the target source in free-field, but also includes the incoming field from the back side of the measurement plane and the scattered field caused by the incoming wave falling on the surface of the target source.

For removing the influence of the incoming field, different sound field separation methods (FSM), such as the spatial Fourier transform method [3,4], the statistically optimized near field acoustic holography [5,6], the spherical wave expansion method [7,8], the boundary element method [9,10] and the equivalent source method [11,12], have been developed to realize the separation of the sound fields from both sides of the measurement surface. Some FSMs [3-5,7,9,11] are based on double-layer pressure measurements, and the separation accuracy depends on the distance between the measurement surfaces. To improve the separation accuracy, the pressure and particle velocity on one measurement surface are employed as the inputs of FSMs to achieve the separation, and the particle velocity can be measured directly by a p-u probe [13] or obtained indirectly by the finite difference technique [6,13,8,10,12]. Due to the cost of the p-u probe, the indirect measurement is more economic for the engineering application. However, FSM can only remove the incoming field and is useless to eliminate the influence of the scattered field. Because the propagation direction of the radiated wave of the target source is contrary to that of the incoming wave, while it is the same as that of the scattered wave. To remove the scattered field, Hald *et al.* [14] first used the statistically optimized near-field acoustic holography (SONAH) with double-layer pressure measurements to separate the outgoing and incoming fields. Second, the surface absorption coefficient of the source was used as the intermediate quantity to indirectly establish the relationship between the scattered field and the incoming field. Last, the scattered field is subtracted from the outgoing field, and the sound field radiated by the target source in free-field is recovered. Hu *et al.* [15] employed the plane wave reflection coefficient on the surface of the source to extend the spatial Fourier transform-based NAH for deducing a complete recovery formulation, and realized the identification of the sources in a noise environment. These two works are suitable for planar sources. For dealing with spherical sources, the spherical wave superposition method (SWSM) with a hemispheric array [16] was applied by Braikia *et al.* to calculate the scattered field and accurately identify the source in a small and non-anechoic space. To surmount the assumption of the rigid boundary condition in Braikia's method, Bi *et al.* [17] introduced the surface admittance into the SWSM and proposed a recovery method of free field. Besides, in order to be suitable for arbitrarily-shaped sources, Langrenne *et al.* [18] extended the boundary element method (BEM) into the recovery process and removed the scattered field for further obtaining the radiated sound field of the target source in free-field. As an alternative approach, the equivalent source method is applied to establish the recovery model of free-field and realize the recovery of the sound field in a noisy environment [19]. However, all the above recovery methods depend on the double-layer pressure measurements, which lead to a problem that the accuracy of the recovered results depends on the distance between two measurement surfaces. To avoid the problem associated with double-layer measurements, Fernandez-Grande *et al.* [20] combined the SONAH and the single-layer pressure and particle velocity measurements to develop a recovery method of free field, and further removed the scattered field. The single-layer pressure and particle velocity measurements were also introduced by Braikia *et al.* [18] into the SWSM for realizing the identification of the source in a small and non-anechoic space, and both particle velocities measured directly by the p-u probe and obtained indirectly by the finite difference were employed. For dealing with the arbitrarily-shaped source in an enclosed space, the BEM with the pressure and velocity measurements is performed for recovering the pressure field radiated by the target source in free space [21].

However, the object in the aforementioned methods is the stationary source, and the separated and recovered processes are given in the frequency domain. Most sources have a non-stationary behavior, in which the acoustic characteristics of the sound sources vary with time. For analyzing this kind of the non-stationary source in a noisy environment, the non-stationary incoming or scattered field at different time instants should be removed and the free-field radiated characteristics of the target source related to time need to be recovered. With the aid of measuring the time-evolving pressures on two closely spaced measurement planes, Zhang *et al.* [22] developed a non-stationary sound field separation method (NS-FSM) to separate the non-stationary sources located at both sides of the measurement planes, and the separation process was carried out in the time-wavenumber domain. Nevertheless, the deconvolution process in the NS-FSM is a complex iterative calculation, in which the time-wavenumber pressure spectrums generated by the target source solved at all the previous time steps are the necessary inputs of the solving formulation at the present time step. In addition, since the deconvolution process is an ill-posed inverse problem, the standard Tikhonov regularization and the singular value decomposition need to be applied for obtaining an appropriate solution, which leads to a large computational workload. To avoid the solving inverse process of the deconvolution in the NS-FSM, a time-domain sound field separation method (TD-FSM) with the single-layer time-evolving pressure and particle velocity measurements is presented [23], and it provides a simple forward separation formulation. In the TD-FSM, the time-evolving pressure generated by the target source alone at any time instant can be separated by a simple superposition of the measured mixed pressure at this time instant and the convolution between the mixed particle velocity measured by the p-u probe and the corresponding impulse response function. However, the p-u probe used in the TD-FSM is expensive, and the array of the p-u probe will cause a higher cost of measurement. Consequently, a real-time sound field separation method (RT-FSM) [24] based on the pressure and particle acceleration measurements is developed by the finite difference approximation of the time-evolving pressures on the double-layer planes, and it performs a simple forward separation formulation with lower measurement cost.

It is noted that NS-FSM, TD-FSM and RT-FSM can only remove the non-stationary incoming field from the back side of the measurement plane, and the separated field is different from the non-stationary radiated field of the target source in free-field since the separated field still contains the scattered field. Therefore, the purpose of this paper is to propose a recovery method of non-stationary free-field based on the time-evolving pressure and particle acceleration measurements. In the proposed method, a simple forward recovery formulation is deduced in the time-wavenumber domain, which removes the influences of the non-stationary incoming and scattered fields simultaneously. Here, the time-evolving particle acceleration is obtained by the finite difference approximation. Simulation is carried out to demonstrate the recovery ability of the proposed method, and its superiority is to be proven by comparing with the RT-FSM.

2. THEORY

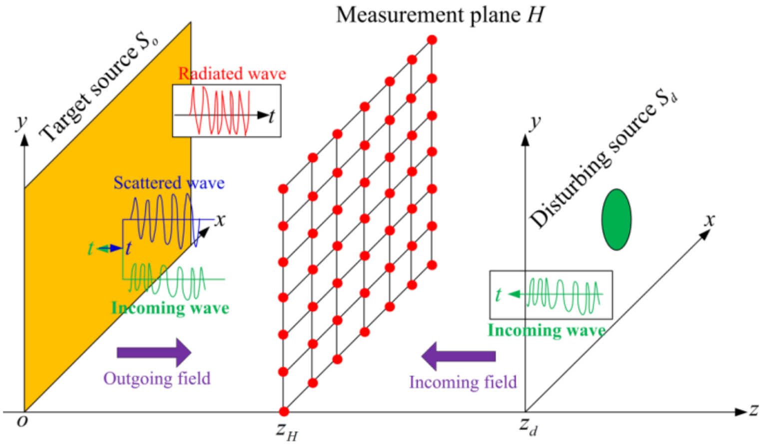

Fig. 1. Position relations of the target source S_o, the disturbing source S_d and the measurement plane H in the Cartesian coordinate system $o(x, y, z)$.

The position relations of the target source S_o, the disturbing source S_d and the measurement plane H in the Cartesian coordinate system $o(x, y, z)$ are shown in Fig. 1. The measured sound field on the measurement plane H not only contains the non-stationary sound field radiated by the target source S_o in free-field, but also includes the non-stationary incoming field from the other side of the measurement plane and the non-stationary scattered field caused by the incoming wave falling on the surface of the target source S_o. The measurement plane H is divided into M discrete space points. According to the superposition principle of the sound waves, the mixed time-evolving pressure $p(x, y, z_H, t)$ and particle acceleration $a(x, y, z_H, t)$ at any point (x, y, z_H) on the measurement plane H at the time t can be expressed, respectively, as

$$p(x,y,z_H,t) = p_f(x,y,z_H,t) + p_s(x,y,z_H,t) + p_{in}(x,y,z_H,t)\,, \tag{1}$$

$$a(x,y,z_H,t) = a_f(x,y,z_H,t) + a_s(x,y,z_H,t) - a_{in}(x,y,z_H,t)\,, \tag{2}$$

where $p_{in}(x, y, z_H, t)$ and $a_{in}(x, y, z_H, t)$ denote the time-evolving pressure and particle acceleration of the incoming field on the measurement plane H, respectively, $p_f(x, y, z_H, t)$ and $a_f(x, y, z_H, t)$ denote the time-evolving pressure and particle acceleration radiated by the target source S_o in free-field, respectively, and $p_s(x, y, z_H, t)$ and $a_s(x, y, z_H, t)$ are the time-evolving scattered pressure and particle acceleration caused by the incoming wave falling on the surface of the target source, respectively.

By applying a two-dimensional Fourier transform with respect to x and y to Equations (1) and (2), the relationships of the corresponding time-wavenumber spectrums can be obtained

$$P(k_x,k_y,z_H,t) = P_f(k_x,k_y,z_H,t) + P_s(k_x,k_y,z_H,t) + P_{in}(k_x,k_y,z_H,t)\,, \tag{3}$$

$$A(k_x,k_y,z_H,t) = A_f(k_x,k_y,z_H,t) + A_s(k_x,k_y,z_H,t) - A_{in}(k_x,k_y,z_H,t)\,, \tag{4}$$

where k_x and k_y represent the wavenumber components in x and y directions, respectively.

The relationships between the pressure and particle acceleration spectrums $P_f(k_x, k_y, z_H, t)$ and $A_f(k_x, k_y, z_H, t)$, $P_s(k_x, k_y, z_H, t)$ and $A_s(k_x, k_y, z_H, t)$, $P_{in}(k_x, k_y, z_H, t)$ and $A_{in}(k_x, k_y, z_H, t)$ can be written as, respectively,

$$P_f(k_x,k_y,z_H,t) = A_f(k_x,k_y,z_H,t) * G_{pa}(k_x,k_y,0,t)\,, \tag{5}$$

$$P_s(k_x,k_y,z_H,t)=A_s(k_x,k_y,z_H,t)*G_{pa}(k_x,k_y,0,t), \tag{6}$$

$$P_{in}(k_x,k_y,z_H,t)=A_{in}(k_x,k_y,z_H,t)*G_{pa}(k_x,k_y,0,t), \tag{7}$$

where the asterisk represents the convolution of two time functions, and $G_{pa}(k_x,k_y,0,t)$ is the impulse response function relating the pressure spectrum to particle acceleration spectrum on the measurement plane H, which is given in Ref. 24.

By combining Equations (3)-(7), it yields

$$P_f(k_x,k_y,z_H,t)+P_s(k_x,k_y,z_H,t)=\frac{1}{2}[P(k_x,k_y,z_H,t)+A(k_x,k_y,z_H,t)*G_{pa}(k_x,k_y,0,t)], \tag{8}$$

$$P_{in}(k_x,k_y,z_H,t)=\frac{1}{2}[P(k_x,k_y,z_H,t)-A(k_x,k_y,z_H,t)*G_{pa}(k_x,k_y,0,t)]. \tag{9}$$

According to the propagation principle of sound waves, the relationships between the pressure spectrums $P_{in}(k_x,k_y,z_H,t)$ and $P_{in}(k_x,k_y,z_0,t)$, $P_s(k_x,k_y,z_H,t)$ and $P_s(k_x,k_y,z_0,t)$ can be written as, respectively,

$$P_{in}(k_x,k_y,z_0,t)=P_{in}(k_x,k_y,z_H,t)*G_{pp}(k_x,k_y,\Delta z_{H0},t), \tag{10}$$

$$P_s(k_x,k_y,z_H,t)=P_s(k_x,k_y,z_0,t)*G_{pp}(k_x,k_y,\Delta z_{H0},t), \tag{11}$$

where $P_{in}(k_x,k_y,z_0,t)$ and $P_s(k_x,k_y,z_0,t)$ denote the time-wavenumber spectrums of the incoming and the scattered pressures on the target source plane z_0, respectively, $\Delta z_{H0}=z_H-z_0$, and $G_{pp}(k_x,k_y,\Delta z_{H0},t)$ is the impulse response function relating the pressure spectrum to pressure spectrum, which is given in Ref. 24.

Because the non-stationary scattered field is caused by the incoming wave falling on the surface of the target source S_o, the relationship between the pressure spectrums $P_s(k_x,k_y,z_0,t)$ and $P_{in}(k_x,k_y,z_0,t)$ can be established by using the surface reflection coefficient of the target source S_o, which is given by

$$P_s(k_x,k_y,z_0,t)=P_{in}(k_x,k_y,z_0,t)*R(k_x,k_y,t), \tag{12}$$

where $R(k_x,k_y,t)$ denotes the time-wavenumber spectrum of the surface reflection coefficient of the target source S_o.

The substitution of Equation (12) into Equation (11) yields

$$P_s(k_x,k_y,z_H,t)=P_{in}(k_x,k_y,z_0,t)*R(k_x,k_y,t)*G_{pp}(k_x,k_y,\Delta z_{H0},t). \tag{13}$$

Equation (10) is substituted into Equation (13), it yields

$$P_s(k_x,k_y,z_H,t)=P_{in}(k_x,k_y,z_H,t)*G_{pp}(k_x,k_y,\Delta z_{H0},t)*R(k_x,k_y,t)*G_{pp}(k_x,k_y,\Delta z_{H0},t). \tag{14}$$

By combining Equations (8), (9) and (14), the recovery formulation of the time-wavenumber pressure spectrum $P_f(k_x,k_y,z_{H1},t)$ radiated by the target source S_o in free-field on the measurement plane H is obtained

$$P_f(k_x,k_y,z_H,t)=\frac{1}{2}\left[P(k_x,k_y,z_H,t)*T_1(k_x,k_y,t)+A(k_x,k_y,z_H,t)*T_2(k_x,k_y,t)\right], \tag{15}$$

where

$$T_1(k_x,k_y,t)=\delta(t)-G_{pp}(k_x,k_y,\Delta z_{H0},t)*R(k_x,k_y,t)*G_{pp}(k_x,k_y,\Delta z_{H0},t), \tag{16}$$

$$T_2(k_x,k_y,t)=G_{pa}(k_x,k_y,0,t)*[\delta(t)+G_{pp}(k_x,k_y,\Delta z_{H0},t)*R(k_x,k_y,t)*G_{pp}(k_x,k_y,\Delta z_{H0},t)]. \tag{17}$$

Equation (15) is a forward complete recovery formulation, which removes the influences of the non-stationary incoming and scattered fields simultaneously. With the aid of the known $T_1(k_x,k_y,t)$ and $T_2(k_x,k_y,t)$, and the mixed time-evolving pressure and particle acceleration, the time-wavenumber pressure spectrum $P_f(k_x, k_y, z_H, t)$ radiated by the target source S_o in free-field on the measurement plane H can be recovered

Suppose that the time t is discretized as $t_i = (i-1)\Delta t$ ($i = 1, 2, \ldots, I$), where Δt denotes the time step and I is the total number of time steps. Accordingly, the convolution calculation of Equation (15) can be expressed in a discrete form as

$$P_f(k_x, k_y, z_H, t_i) = \frac{1}{2}\sum_{q=1}^{i}[P(k_x, k_y, z_H, t_q) * T_1(k_x, k_y, t_{i\text{-}q+1}) + A(k_x, k_y, z_H, t_q) * T_2(k_x, k_y, t_{i\text{-}q+1})]. \quad (18)$$

Equation (25) indicates that once the mixed time-wavenumber pressure and particle acceleration spectrums from the time instant t_1 to the time instant t_i are obtained, the pressure spectrum $P_f(k_x, k_y, z_H, t_i)$ radiated by the target source S_o in free-field on the measurement plane H at the time instant t_i can be recovered. After all the calculation processes from the time instant t_1 to the time instant t_i, the pressure spectrum $P_f(k_x, k_y, z_H, t)$ radiated by the target source S_o in free-field on the measurement plane H at all time instants can be acquired. Finally, the inverse two-dimensional Fourier transform with respect to k_x and k_y is applied to the recovered pressure spectrum $P_f(k_x, k_y, z_H, t)$ for obtaining the time-evolving pressure $P_f(x, y, z_H, t)$ radiated by the target source S_o in free-field on the measurement plane H.

In the recovery formulation, the mixed time-evolving pressure and particle acceleration are the necessary inputs. The former can be measured by the microphone array directly, while the latter is difficult to be measured directly. Here, with the aid of the mixed time-evolving pressure on a auxiliary measurement plane, the mixed time-evolving particle acceleration can be obtained by a finite difference technology.

3. NUMERICAL SIMULATION

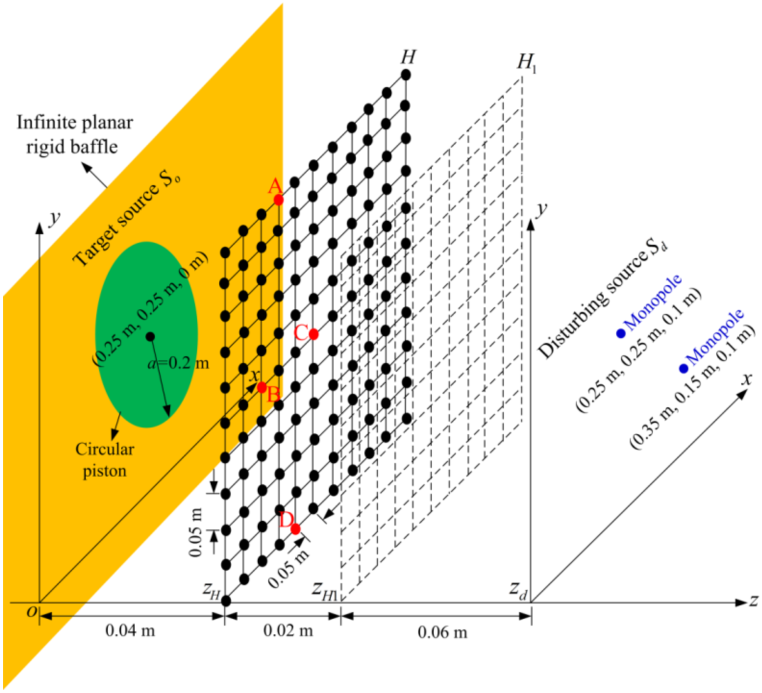

Fig. 2. Simulation set-ups: positions of the target source S_o, the disturbing source S_d, the measurement plane H and the auxiliary measurement plane H_1 in the Cartesian

coordinate system $o(x, y, z)$. Four space points A, B, C and D are chosen and marked with red point.

For investigating the recovery ability of the proposed method, a circular piston mounted in an infinite rigid baffle and two monopole sources are employed to design a numerical simulation. In this simulation, the former is situated at one side of the measurement plane as the target source S_o and the latter is located at the other side of the measurement plane as the disturbing source S_d. The purpose is to use the proposed method to recover the non-stationary sound field radiated by the target source S_o in free-field. In the simulation, the positions of the target source S_o, the disturbing source S_d, the measurement plane *H* and the auxiliary measurement plane H_1 in the Cartesian coordinate system $o(x, y, z)$ are depicted in Fig. 2.

The target source S_o is a circular piston mounted in an infinite rigid baffle. The center of the circular piston is located at (0.25 m, 0.25 m, 0 m), and the piston generates a Gaussian modulation sine pulse signal, which is given as

$$v(t) = 0.015\sin(2\pi f_1 t)e^{-[5.26(\frac{1}{6}ct-0.3)]^2}, \tag{20}$$

where the frequency $f_1 = 1000$ Hz, the sound velocity *c*=344 m/s. Assume that the velocity on the surface of the piston is a simply supported distribution

$$v_0 = 1-(r/a)^2, \tag{21}$$

where the radius a of the circular piston is 0.2 m, and r is the distance between any space point on the piston and its center. According to the method in Ref. 25, the theoretical time-evolving pressures generated by the target S_o at any measurement points can be calculated. The disturbing source S_d contains two monopole sources, and their centers are located at (0.25 m, 0.25 m, 0.1 m) and (0.35 m, 0.15 m, 0.1 m), respectively. These two monopole sources generate the same time-domain signal, which is defined by

$$s(t) = 0.3\sin(2\pi f_2 t)e^{-50t}, \tag{22}$$

where the frequency $f_2 = 800$ Hz. The theoretical time-evolving pressures radiated by one monopole source at any measurement points can be calculated by the following equation

$$p(R,t) = \frac{s(t-R/c)}{4\pi R}, \tag{23}$$

where *R* is the distance between the measurement point and the monopole source.

As shown in Fig. 2, the measurement plane *H* is located at $z_H = 0.04$ m, and the discretized point number and the grid spacing on the plane *H* are 11×11 and 0.05 m, respectively. To obtain the time-evolving particle acceleration on the measurement plane *H*, the auxiliary measurement plane H_1 located 0.02 m away from the measurement plane *H* is set, and its discretized point number and grid spacing are the same as those of the plane *H*. The sampling frequency and time are set as 25.6 kHz and 10 ms, separately. For simulating the practical measurement environment, a Gaussian white noise with a signal-to-noise ratio of 30 dB is added. Since the surface of the target source S_o is acoustically rigid, with the mirror image theory, the theoretical time-evolving scattered pressure on the planes *H* and H_1 can be calculated. Due to the rigid boundary condition, the time-wavenumber spectrum $R(k_x, k_y, t)$ of the surface reflection coefficient of the target source S_o is $\delta(t)$. To lessen the errors due to the finite aperture, the 11×11 pressure and particle acceleration matrices on the measurement plane H are extended to 31×31 matrices by zero-padding.

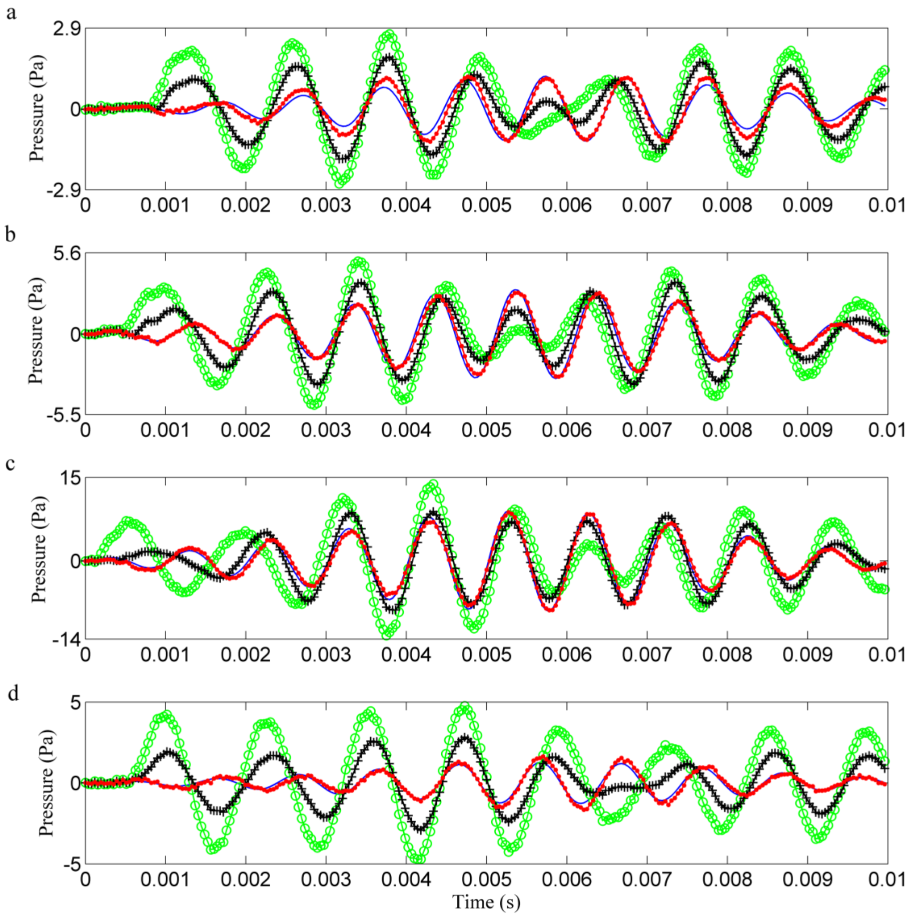

Fig. 3. Comparisons of the time-domain pressure waveforms among the theoretical pressure radiated by the target source S_o in free-field (solid line), the mixed pressure (line with circle sign), the separated pressure by the RT-FSM (line with plus sign) and the recovered pressure by the proposed method (dotted line) at four points: (a) A(0.15 m, 0.5 m, 0.04 m), (b) B(0.1 m, 0.25 m, 0.04 m), (c) C(0.25 m, 0.25 m, 0.04 m) and (d) D(0.2 m, 0 m, 0.04 m).

For displaying the recovered results in the time domain, four space points A(0.15 m, 0.5 m, 0.04 m), B(0.1 m, 0.25 m, 0.04 m), C(0.25 m, 0.25 m, 0.04 m) and D(0.2 m, 0 m, 0.04 m) on the measurement plane H are chosen. Figure 3 shows the comparisons of the time-domain pressure waveforms at these four points. In Fig. 3, the solid lines and the lines with circle sign denote the theoretical pressures radiated by the target source S_o in free-field and the mixed pressures generated by the outgoing and incoming fields together at these four points, respectively, and their differences in both phase and amplitude illustrate that the theoretical pressure radiated by the target source S_o in free-field has been changed greatly because of the influence of the disturbing source S_d. After using the RT-FSM, the separated pressures at these four points are represented by the lines with plus sign shown in Fig. 3. Although the separated pressures by the RT-FSM are different from the mixed pressures and are a little similar to the theoretical pressure at some time instants, there are still many differences between the separated pressures and the theoretical pressures, especially in Fig. 3(d), the values of the separated pressure are almost twice the values of the theoretical pressure. The reason is that the RT-FSM is effective to remove the non-stationary incoming field but is ineffective for the scattered field. For removing the influence of the scattered field, the proposed method must be performed, and the recovered pressures at these four points are marked with the dotted lines shown in Fig. 3. After comparing the dotted lines and the solid lines, it can be found that the recovered pressures at these four points are in good agree with their theoretical ones, which proves that the proposed method are effective in recovering the non-stationary sound field radiated by the target source S_o in free-field.

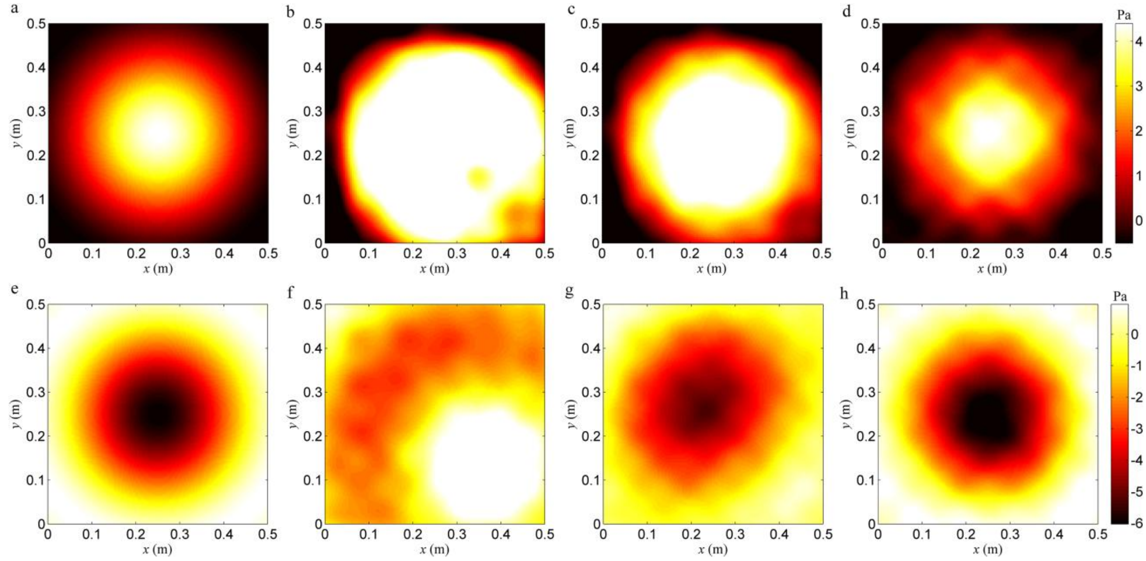

Fig. 4. Spatial distributions of the theoretical pressure fields radiated by the target source S_o in free-field at (a) 3.40 ms and (e) 6.88 ms, the mixed pressure fields at (b) 3.40 ms and (f) 6.88 ms, the separated pressure fields by the RT-FSM at (c) 3.40 ms and (g) 6.88 ms, and the recovered pressure fields by the proposed method at (d) 3.40 ms and (h) 6.88 ms.

The comparisons of the time-evolving pressure waveforms at different points have been shown clearly to demonstrate the recovered ability of the proposed method in the time domain. Besides, the recovered ability of the proposed method in the space domain also should be examined. Consequently, two time instants 3.40 ms and 6.88 ms are chosen to provide the recovered results of the spatial distribution of the pressure field. The theoretical pressure fields radiated by the target source S_o in free-field at these two time instants are depicted in Fig. 4(a) and (e), respectively, and the mixed pressure fields including the outgoing and incoming fields are shown in Fig. 4(b) and (f), respectively. It can be seen that the pressure modes and the color distributions in Fig. 4(b) and (f) are very different from those in Fig. 4(a) and (e). The reason is that the influence of the disturbing source S_d has changed the spatial distribution of the theoretical pressure field radiated by the target source S_o in free-field. After using the RT-FSM, although the separated pressure fields shown in Fig. 4(c) and (g) at several space regions are a little similar to those in Fig. 4(a) and (e), there still exist many differences between them. The reason is that the separated pressure field still contains the scattered pressure field caused by the incoming wave falling on the surface of the target source S_o. Consequently, the proposed method is employed for removing the scattered field, and the recovered pressure fields at these two time instants are shown in Fig. 4(d) and (h). Comparing with Fig. 4(a) and (e), the spatial distributions of the recovered pressure fields in Fig. 4(d) and (h) are almost the same as those of the theoretical pressure fields. All the comparison results indicate that the proposed method can remove the incoming and the scattered fields simultaneously, and recover the pressure field radiated by the target source S_o in free-field.

4. CONCLUSIONS

A recovery method of non-stationary free-field with the time-evolving pressure and particle acceleration measurements is proposed to recover the pressure of the non-stationary planar source in a noisy environment. In the proposed method, the mixed time-evolving pressure and particle acceleration on the measurement plane are first obtained, and the corresponding time-wavenumber spectrums are obtained by a two-dimensional Fourier transform. Then, two impulse response functions and the surface reflection coefficient of the target source are used to deduce a forward complete recovery formulation in the time-wavenumber domain. Finally, the inverse two-dimensional Fourier transform is applied to acquire the time-evolving pressure radiated by the target source in free-field. To prove the feasibility of the proposed method, a numerical simulation with a circular piston mounted in an infinite rigid baffle and two monopole sources has been employed. The simulation results demonstrate that the proposed method can effectively remove the non-stationary incoming field from the back side of the measurement plane and the non-stationary scattered field caused by the incoming wave falling on the surface of the target source. In other word, the proposed method can recover the time-evolving pressure radiated by the target source in free-field effectively. Subsequently, an experiment of a planar steel plate with two speakers as the target source and a speaker as the disturbing source has been carried out in a semi-anechoic chamber. Furthermore, the recovered time-evolving pressure by the proposed method could be used as the input of the non-stationary nearfield acoustic holography for studying the acoustic and vibration characteristics of the target source in the time domain.

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