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The Calculation Of the Signal from a Broadband Point Source Arbitrarily Moving in the Range-Dependent Ocean

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We shall consider the arbitrary sound source described only by its field of volume velocity $S(\mathbf{r},t)$. The effects of dipole components and components of higher orders may be considered in the same way. The field of the acoustic pressure p of such source in the arbitrary liquid medium has the form of the Green's integral as [1]

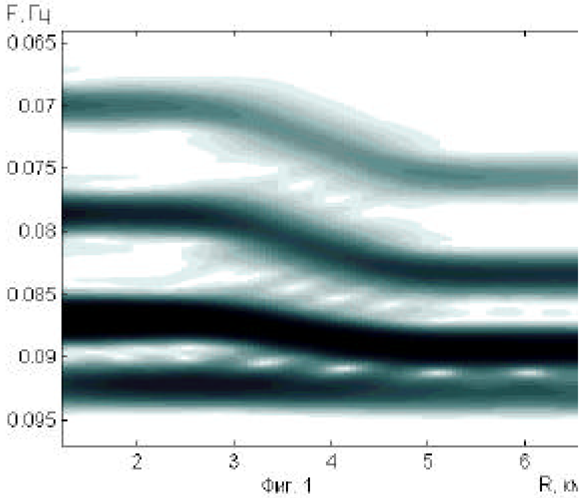
$$p(\mathbf{r}_r,t_r) = \int G(\mathbf{r}_r,\mathbf{r}_s,t_r-t_s)S(\mathbf{r}_s,t_s)\,d^3\mathbf{r}_s\,dt_s$$

Here G is the medium Green's function, indices r and s denote the coordinate of receever and source respectively. The translationally moving source is the source with the volume velocity distribution of the type $S(\mathbf{r}-\mathbf{r}_s(t),t)$, where $\mathbf{r}_s(t)$ is the coordinate of the fixed point of the source. The volume velocity distribution for the point source is the Dirac's delta-function so we get for the moving point source volume velocity distribution the expression $S(t)\,\delta(\mathbf{r}-\mathbf{r}_s(t))$. Its sound pressure field may be then calculated as

$$p(\mathbf{r}_r,t_r) = \int G(\mathbf{r}_r,\mathbf{r}_S(t_s),t_r-t_s)S(t_s)\,d\,t_s$$

Thus the availability of the medium Green's function enables the calculation of the signal from the point moving source by integrating along the trajectory of the source. The papers [2, 3] describe the calculation of the harmonic components of the Green's function for the ocean models whose properties depend arbitrary on depth and slowly on horizontal coordinates. Now this program package is generalized to compute the space-time Green's function and the signal from the point source moving in 2D inhomogeneous medium.

Figs 1 and 2 demonstrate two simple examples of the performance of this package. Fig. 1 shows the spectrogram of the source moving in the waveguide with range-dependent bottom and radiating the harmonic at



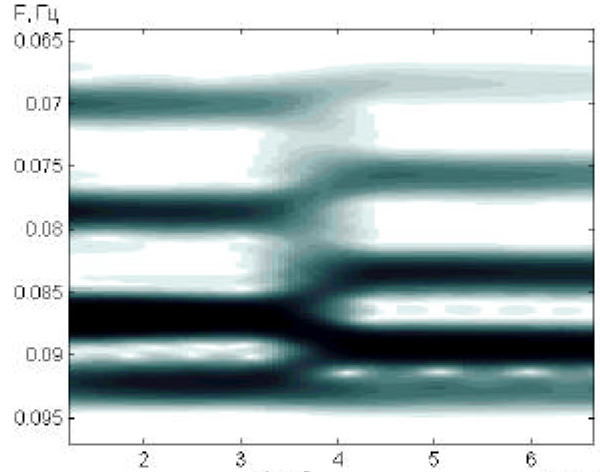
Фиг. 1

45 Hz. The source moves at the depth of 21 m away from the receiver residing at the depth of 70 m at 6 knots. The waveguide consists of three segments. The first segment has the constant depth 75 m and resides from 0 to 3 Km. The second segment residing from 3 to 5 Km serves as the transition from the first segment to the third one with constant depth of 95 m. The depth in the central segment varies linearly. The table shows the sound speed profile in this waveguide

z, m	0	12	14	21	31	54	75	95
?(z),m/s	1536.6	1536.8	1536.7	1520.3	1480.9	1479.4	1479.5	1479.6

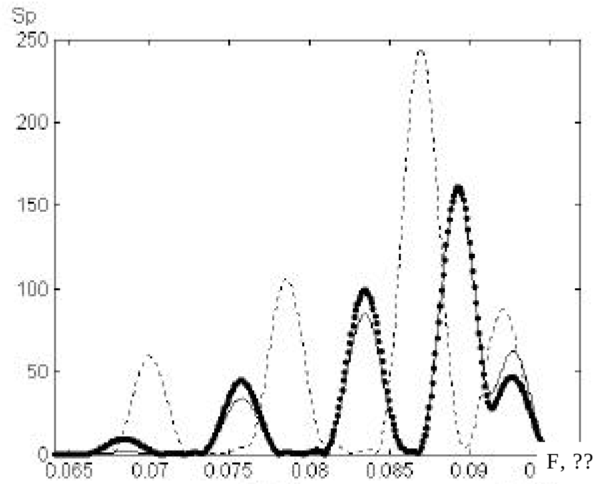
The bottom was taken as the liquid one and consisted of a layer of 20 m thickness, sound speed 1564-i*2.66 m/s and the density 1800 KG/m^3 lying on the halfspace with the sound speed 2300-i*6.98 m/s and the density 1995 KG/m^3. The spectrogram time window had the length of 800 s and the Hamming weighting function enabling the resolution of the four normal modes propagating in the waveguide. The first normal mode has the greatest Doppler's shift. As the waveguide depth near the source location grows one can see the increase in the Doppler's shifts corresponding to the increase in the phase velocities of the normal modes.

Fig. 2 shows the spectrogram of the moving source for the waveguide with the transition segment length 100 m. Due to the strong mode interaction this spectrogram displays the presence of the fifth mode after the transition segment and the valuable changes in amplitudes of normal modes.



Фиг. 2

Fig. 3 shows the frequency spectra in the left segment of the two sample waveguides with dashed line, in the right segment of the first waveguide with thin solid line and in the right segment of the second waveguide with bold dotted line. The growth in amplitude of higher order normal modes for the second waveguide is due to the normal mode interaction.



Фиг. 3

Fig. 4 shows the spectrogram of moving source emitting the noise in the band of 14-50 Hz. The waveguide is now a layered one with the depth 75 m and the sound speed profile from the table above. The source starts at 2 Km from the receivers and moves toward it with the speed of 6 knots. The nearest distance source receiver is 100m. The source moves from the receiver up to the distance of 2 Km. F on Fig. 4 is the absolute value of frequency. The time window for this spectrogram is 10 s. The periodic structure of this spectrogram is due to the interference of the normal modes. Only one normal mode exists at frequencies below 17 Hz and the spectrogram displays no interference for these frequencies. In the frequency interval 17 .. 34 Hz two normal modes account for the regular interference with one main period. For higher frequencies the higher number of normal modes leads to the more complicated interference structure.

These few examples confirm the possibility of calculation of the sound field from the moving broadband sources using the accessible computers such as Pentium 200 MHz one for the realistic models of the sea.

References

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