A Second Trip Echo Suppression Method using Two Different Code Sequences

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1. Background / Objective

In pulse radars, appearance of the strong scatterers such as storms, mountains, and so on beyond the unambiguous range of radars, second trip echoes sometimes contaminate desired signals i.e. first trip echoes. The phase coding scheme, which separate overlaid echoes in the frequency domain, alters the spectra of the overlaid signals and enables one to estimate the spectral moments of each component. However, as mentioned above, there are many cases where the second trip echoes are much stronger than the first trip echoes. In that case, the first trip echoes are buried in the second trip echoes, which lead poor accuracy of detecting the first trip echo.

2. Second Trip Echo Suppression Using Two Code Sequence

The proposed method utilizes two different code sequences; one (code #1) is an arbitrary code sequence such as random phase code, while the other sequence (code #2) is produced by multiplying the previous sequence by positive integer k (k > 1).

code #1 : $e^{j\psi_m} = exp\left(-j\sum_{l=0}^{m}\frac{2\pi(l^3+l)}{M}\right)$ ... (1) code #2 : $e^{jk\psi_m} = exp\left(-j\sum_{l=0}^{m}\frac{2k\pi(l^3+l)}{M}\right)$ ... (2)

received signals by code #1 : $V_m = V_{m1}e^{j\psi_m} + V_{m2}e^{j\psi_{m-1}}$ ... (3)

received signals by code #2 : $Z_m = V_{m1}e^{jk\psi_m} + V_{m2}e^{jk\psi_{m-1}}$ ... (4)

M : number of hit
m : 0, 1, . . . , $M-1$
V_{m1} :1st trip echo signal
V_{m2} :2nd trip echo signal

When phase correction to the second trip echoes is achieved for the two received signals modulated by each code sequence, the second trip echoes become identical, while the first trip echoes are different from each other.

$$V_m e^{-j\psi_{m-1}} = V_{m1}e^{j(\psi_m-\psi_{m-1})} + V_{m2} \quad ... (5)$$

$$Z_m e^{-jk\psi_{m-1}} = V_{m1}e^{jk(\psi_m-\psi_{m-1})} + V_{m2} \quad ... (6)$$

So by subtracting the one signal from the other, only the first trip echoes remain, which enables high accuracy of the detection.

$$V_m e^{-j\psi_{m-1}} - Z_m e^{-jk\psi_{m-1}} = V_{m1}\left(e^{j(\psi_m-\psi_{m-1})} - e^{jk(\psi_m-\psi_{m-1})}\right) \quad ... (7)$$

$$V_{m1} = \frac{V_m e^{-j\psi_{m-1}} - Z_m e^{-jk\psi_{m-1}}}{\left(e^{j(\psi_m-\psi_{m-1})} - e^{jk(\psi_m-\psi_{m-1})}\right)} \quad ... (8)$$

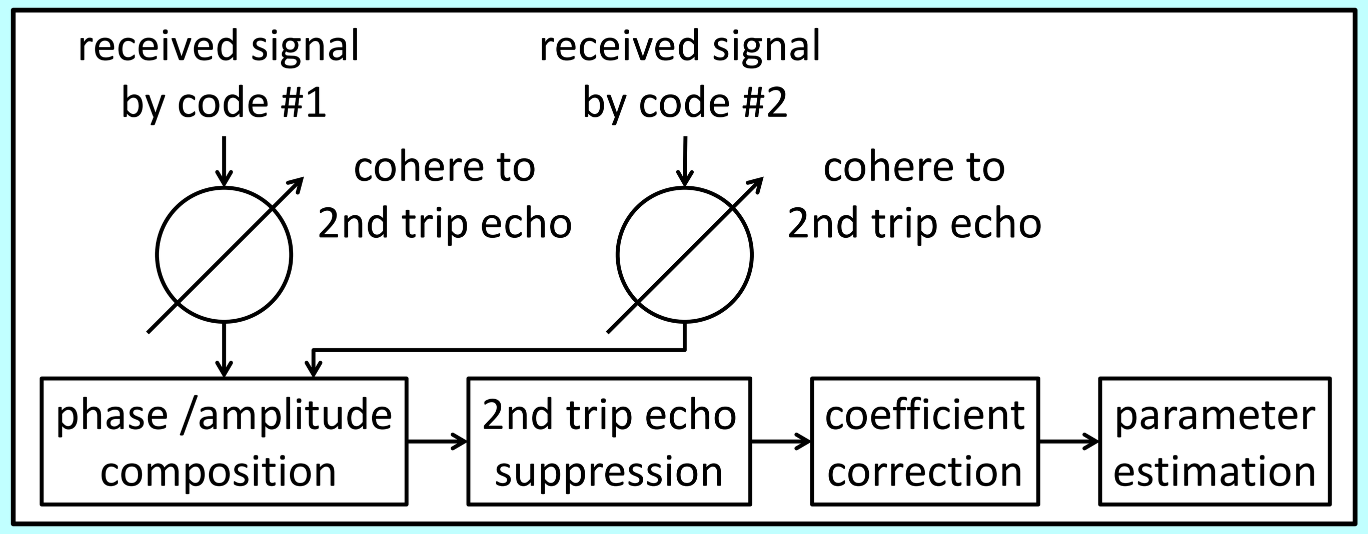

Figure1. Diagram of the proposed method

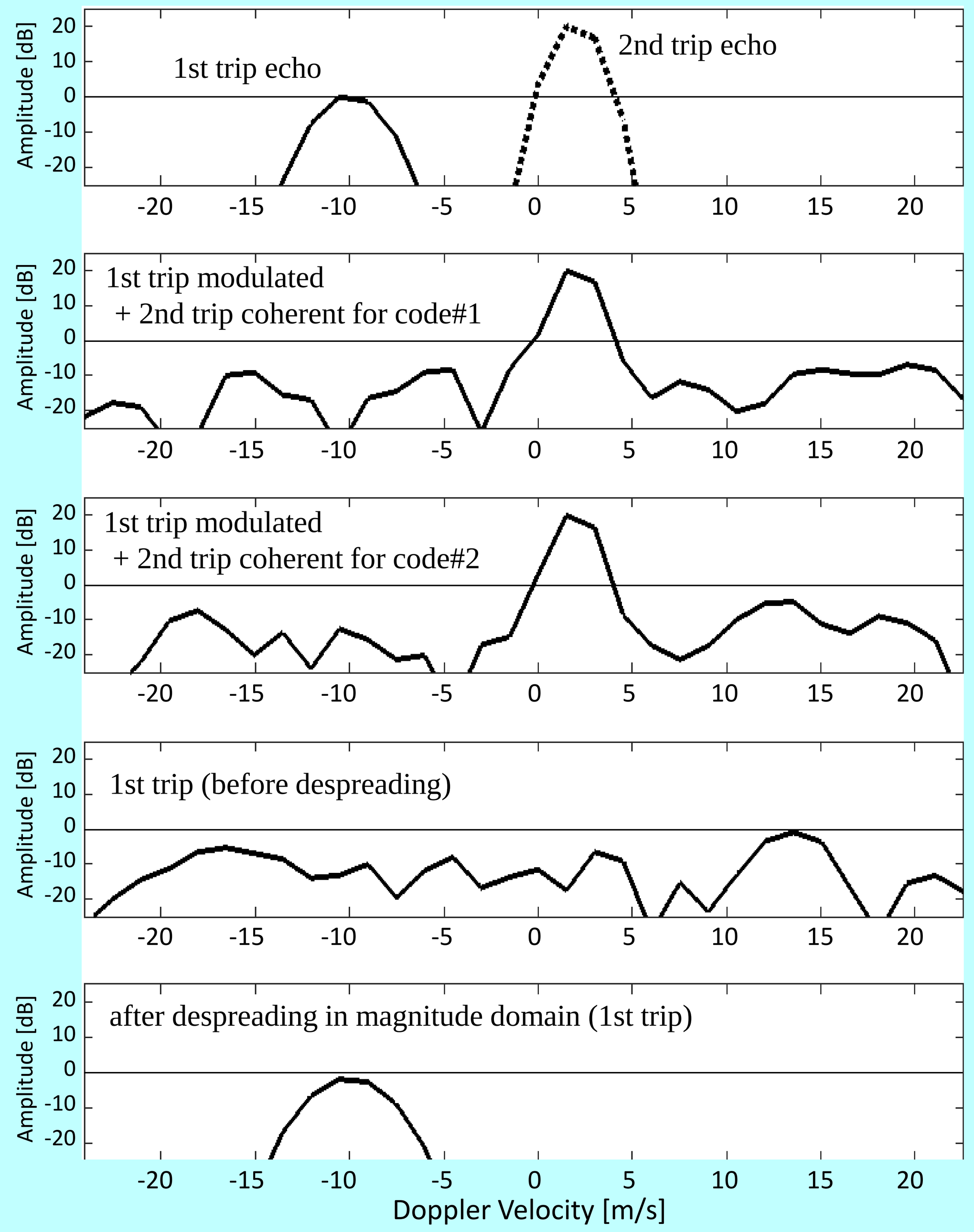

Figure2. The second trip echo suppression process of the proposed method

3. Simulation

We performed the simulation and confirmed the effectiveness of the proposed method.

Table1. Comparison of the suppression performance between the conventional method and the proposed method

	power[dB]	velocity[m/s]	velocity width[m/s]
ideal value	0.00	-10.00	2.12
the conventional method	-4.26	-11.37	3.69
the proposed method	-1.19	-10.54	2.26

number of trials: 40
SNR: 20dB

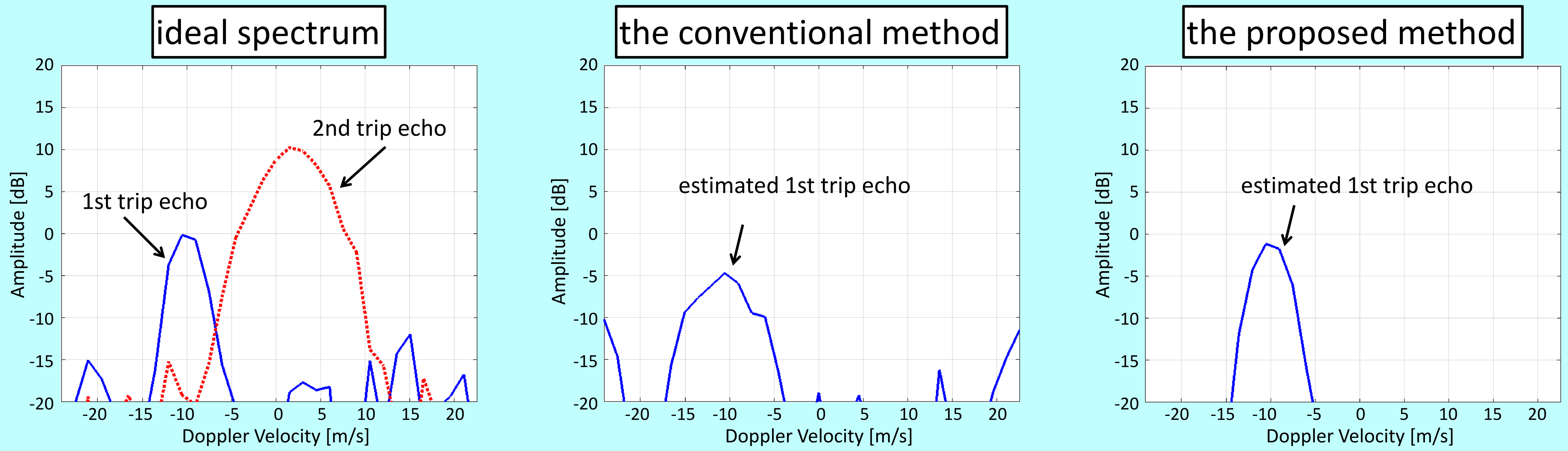

Figure3. Ideal spectrum and each spectrum after the second trip echo suppression processing

p: mean power
v: mean velocity
w: mean spectrum width
subscript 1: the 1st trip
subscript 2: the 2nd trip

number of trials: 40
SNR: 20dB

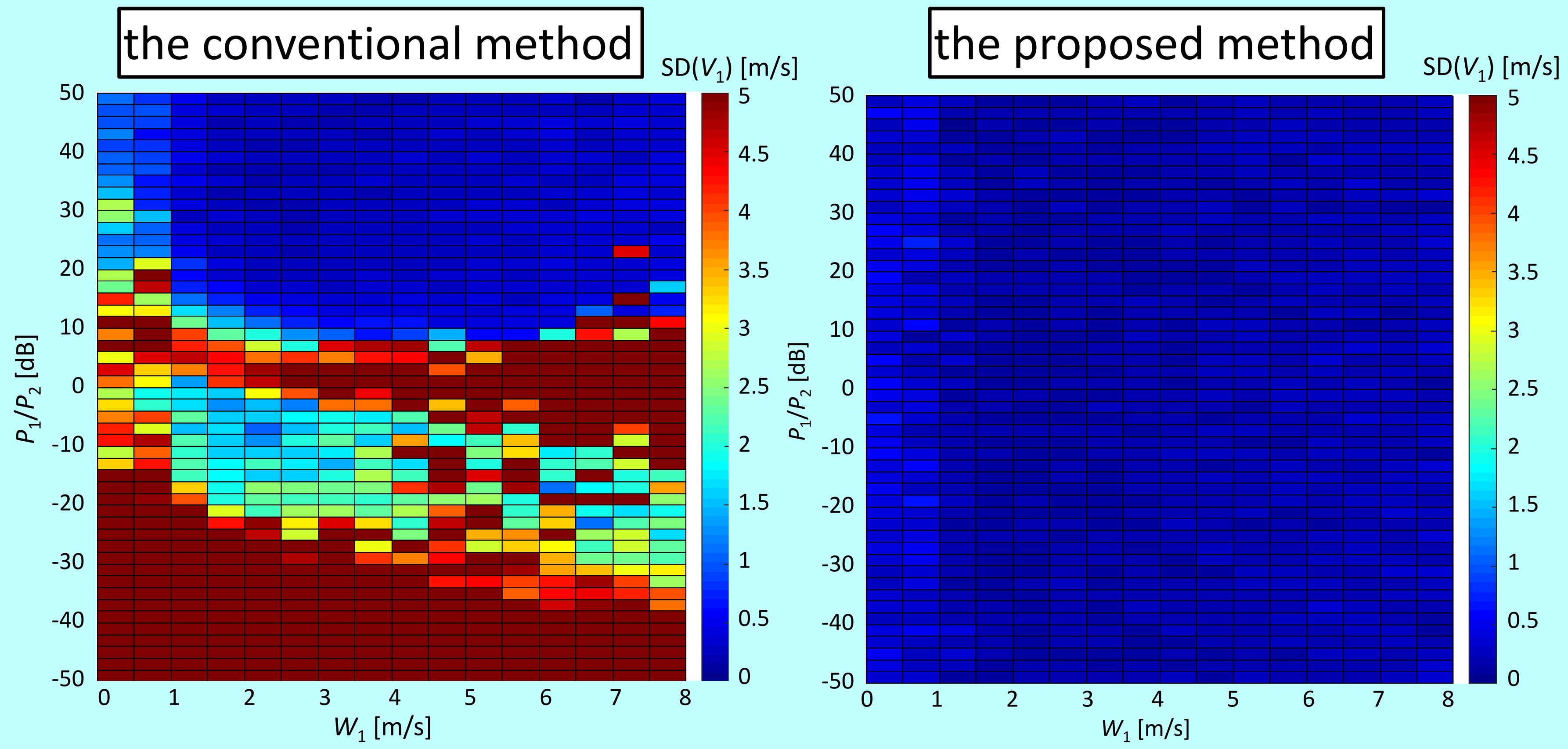

Figure4. Comparison plots of the SD($v1$) as a function of $p1/p2$ and $w1$, for conventional method and proposed method

These results suggest that the accuracy of estimated Doppler velocity is degraded as the second trip echo is getting strong in the conventional method. On the other hand, estimated Doppler velocity keeps accurate values regardless of power ratio p_1/p_2 in the proposed method.

4. Conclusions

In this paper, we proposed a new second trip echo suppression method using two kinds of code sequence. In the proposed method, only second trip echo component can be subtracted from received signal, therefore the first trip echo component can be estimated with high accuracy regardless of the power ratio between first and second trip echoes. The results of simulation indicate that the proposed method has a better performance of suppressing second trip echoes than the conventional method.