An Estimation Method of Target Location and Scattered Waveforms for UWB Pulse Radar Systems

Takuya Sakamoto Toru Sato
Dept. of Communications and Computer Eng., Kyoto University, Kyoto, 606-8501 JAPAN
Facsimile: +81-75-753-3342 E-mail: t-sakamo@aso.cce.i.kyoto-u.ac.jp

1 Background and Objectives

Environment measurement is an important issue for various applications including household robots. Radars utilizing ultra-wide-band (UWB) pulses, for which FCC has recently set a standard, is a promising candidate in a near future.

Noise reduction is essential for a precise locationing, but accurate noise reduction with Wiener filter requires information of the scattered waveform. On the other hand, target location estimation is indispensable to the waveform estimation. Here, we propose a method which simultaneously estimates target location and scattered waveforms, and examine its performance.

2 System Model

We deal with a 2-dimensional problem. We assume an 11-element linear sensor array with intervals of half-wavelength, and one point target located within its near field. We assume that we have no information of scattered waveforms, which we model as the differential of the transmitted waveform. We define the received signal for the m-th sensor as $s'_m(t)$. We also define $s(x,y)$ as $s((m-(M-1)/2)d/\lambda, ct/\lambda) \equiv s'_m(t)$, where c is speed of the light, λ is the center wavelength, $M = 11$, $d = \lambda/2$. We define the estimated target location for i-th iteration as $\boldsymbol{T}_i = (x_i, y_i)$.

3 The Proposed Method

We define Hyperbolic Coherent Transform (HCT) as

$$H(\beta, \boldsymbol{T}_i) \equiv \int\int_{-\infty}^{\infty} s(x,y) \frac{\mathrm{e}^{\mathrm{j}\beta[u(x,\boldsymbol{T}_i)-y]}}{\sqrt{u(x,\boldsymbol{T}_i)}} \mathrm{d}x\mathrm{d}y, \quad (1)$$

where we define $u(x, \boldsymbol{T}_i) \equiv |\boldsymbol{T}_i| + \sqrt{(x-x_i)^2 + y_i^2}$, and initial value $H(\beta, \boldsymbol{T}_0)$ as the Fourier transform of the transmitted waveform. HCT is an approximate of the Fourier transform of a scattered waveform $F(\beta)$. We describe the target location estimation methods as

$$\mathrm{maximize}_{\boldsymbol{T}_{i+1}} \left| \int_{-\infty}^{\infty} \frac{H(\beta, \boldsymbol{T}_{i+1}) P_i^*(\beta)}{1-\eta+\eta|P_i(\beta)|^2} \mathrm{d}\beta \right|^2, \quad (2)$$

where $P_i(\beta)$ is estimated dominant-frequency waveforms after denoising. We set $P_i(\beta)$ for each method as in Table 1, where we also define IHCTW (IHCT Without waveform estimation) which is a conventional method, and IHCTK (IHCT with Known scattered waveform) which needs ideal assumptions.

4 Performance Evaluation

Figure 1 illustrates the center-frequency waveforms estimated at the 1st, 5th and 10th iteration of IHCT. Figure 2 shows the performance of each method compared to Cramer-Rao Lower Bound (CRLB). IHCTK achieves CRLB for S/N > 11dB. IHCTW has a floor of estimation error caused by biases due to the fixed reference waveforms. On the other hand, the performance of IHCT is near to CRLB. The precision of IHCT is 140 times better then that of IHCTW. Moreover IHCT achieves an accuracy of $10^{-3}\lambda$ for S/N > 34dB.

Consequently, we clarified that our proposed method has a remarkable performance, which is close to the theoretical limit.

Table 1: HCT $P_i(\beta)$ for each method.

IHCT	$(H(\beta, T_i) * \mathrm{sinc}(t_0\beta))\,|H(\beta, T_{i-1})|$
IHCTW	$H(\beta, T_0)$ (Transmitted waveform)
IHCTK	$F(\beta)$ (Unknown in actual cases)

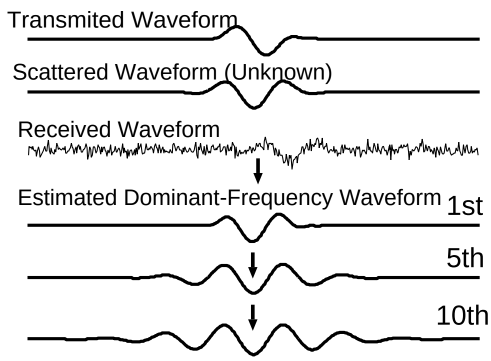

Figure 1: Estimated dominant-frequency waveforms.

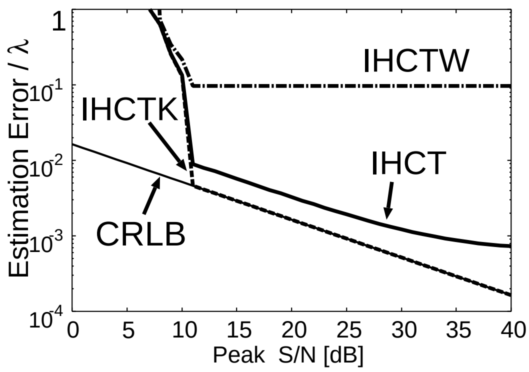

Figure 2: Estimation error of the target location.