Modified Hyperbolic Summation for Through-the-Wall Radar Imaging using FDTD simulation

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***Abstract* – A modified focusing image technique based on a hyperbolic summation algorithm for through-the-wall radar system is introduced in this paper. The unavoidable ghost image of the hyperbolic summation can be suppressed using this modified algorithm. The 3-dimensional finite-difference time-domain (FDTD) method is performed to realize problem situation. The conventional hyperbolic summation blurs its raw image in the front area of a target, which may violate a causality principle. The final correction image satisfying the causality principle shows remarkable decrease of ghost image in comparison with the conventional hyperbolic image.**

***Index Terms* — Hyperbolic Summation, Synthetic aperture radar, Through-the-wall radar, Finite-difference time-domain (FDTD).**

I. INTRODUCTION

Through-the-wall radar using electromagnetic wave is highly useful instrument to extract the target behind the wall in a wide range of applications including military, police and rescue. Transmitting and receiving antennas radiated and received electromagnetic signal with moving along the wall. The signals of the certain region are corrected with the directivity of the antennas. The received signals on the through-the-wall radar focus the image on the one point using post processing. The focusing is realized by performing migration of the received signal at the certain position. Until now, there are many researches of the focusing methods such as the hyperbolic summation, the Kirchhoff, the phase shift, the frequency wavenumber and the back projection based migration [1]. The hyperbolic summation method is the frequently used algorithm due to conceptually simple, easy to implement and very intuitive. However, the image reconstructed by the hyperbolic summation algorithm suffers from some ghost image tails in the front area of its original target. This phenomenon occurs when the tails of a hyperbolic template pass over some true image locations for the pixels that are located in front region. If the target located in the same range position, the ghost image tails according to the each target may be added and emphasized at the wrong location.

In this paper, we introduce the modified hyperbolic summation for the through-the-wall radar imaging that may suppress the unnecessary ghost image. The 3-dimensional finite-difference time-domain (FDTD) method is performed to realize such a problem situation.

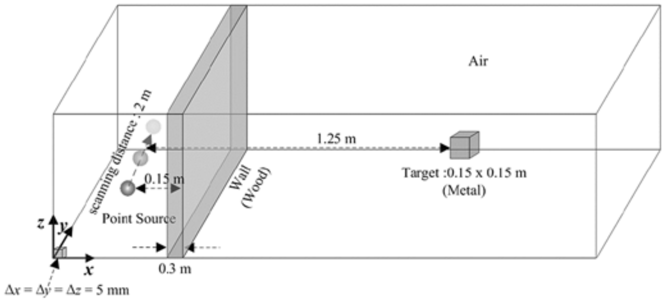
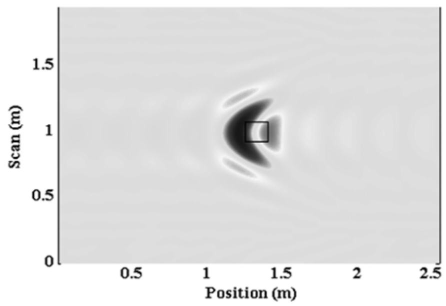


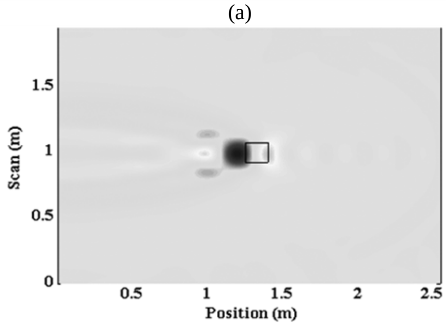
Fig. 1. the geometry of the FDTD simulation.

II. PROBLEM SITUATION

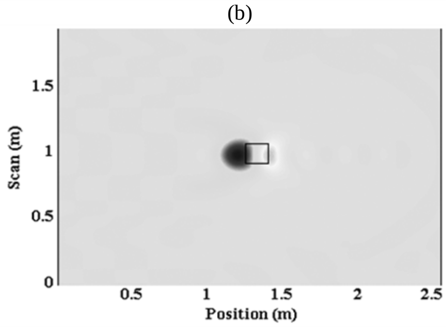
We use linear frequency modulated (LFM) chirping signal that the frequency range of S-band, 2.7 to 3.3 GHz. The chirping rate is 15 us. Figure 1 depicts the geometry of our FDTD simulation. We ignore the ground reflection effect. The gap between the transmitting and receiving points is 10 cm. The metal target of which shape is 15 cm regular hexagon is 1.25 m apart from the point source. The wood wall with width 30 cm is placed between the point source and the target. We use Tesla Kepler K20 with memory size of 5 GB and CUDA core of 2496. The spatial resolution ($\Delta x = \Delta y = \Delta z$) is uniformly taken by 0.005 m by considering the electrical property of wood wall and the maximum frequency. The total simulation dimension is 48 Mcells. The scanning distance is 2 m with 40 points of 0.05 m step. The LFM chirping signal transmits and receives back due to the reflection of obstacles. The frequency difference between the chirping and receiving signal means the round trip time which reflect back from the obstacles. The round trip times between the source and the wall are constant at each scan location since the point source moves along the wall. In contrast, at each scan location, the round trip times are consistently changed according to the straight-line distance. In typical scan image, the target within image region manifest as a hyperbolic shape. In the hyperbolic summation algorithm, the hyperbolic templates at all pixels are constructed and added [2]. If we apply the hyperbolic summation algorithm where the target is not present, the



(a)

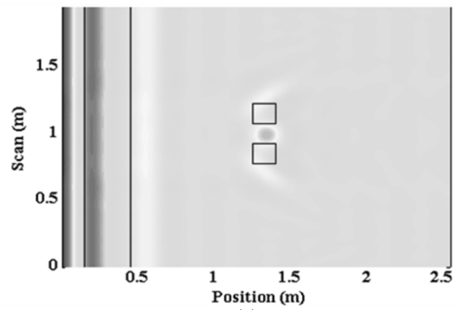


(b)

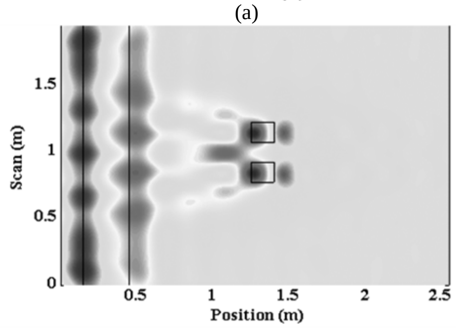


(c)

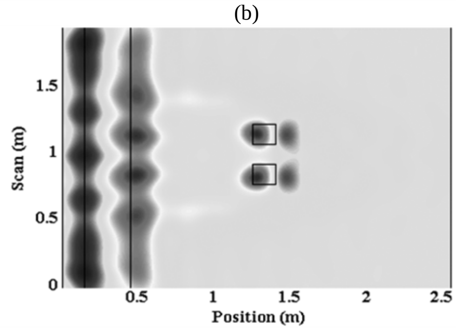
Fig. 2. The results that the single target without wall, (a) raw image, (b) conventional hyperbolic summation (c) modified algorithm.



(a)



(b)



(c)

Fig. 3. The results that the multiple target behind the wall, (a) raw image, (b) conventional hyperbolic summation (c) modified algorithm.

random noise is added. On the other hand, the signal is emphasized at the location of the target.

III. Results

Fig. 2 shows the simulation results when a single target locates apart from the source of 1.25 m without wall. The horizontal and vertical axes mean range and spatial distance, respectively. Fig. 2(a) depicts the normalized raw image without any post processing. The solid square box means the original target region. The signal according to the target shows the hyperbolic shape as expected. The applying hyperbolic summation algorithm to Fig. 2(a) shows Fig. 2(b). The image focuses at the location of the target. However, the ghost image appears in the front area of the target. The modified hyperbolic summation algorithm is based on such a causality principle that any real target cannot exist in the front area of its raw image. Fig. 2(c) shows the modified image satisfying the causality principle.

Fig. 3(a) shows the raw image in case of the two same targets behind the wall. After conventional migration, the ghost image occurs at the front pixels, as shown in Fig. 3(b). The causality principle also remarkably improves the ghost image of the conventional hyperbolic summation, as shown in Fig. 3(c).

IV. Conclusion

The 3-D FDTD simulation was performed for the through-the-wall imaging. To suppress the ghost image generated by the conventional migration algorithm, a modified hyperbolic summation algorithm was implemented by introducing a causality principle. The modified image assured the validity of the presented modification especially where the pixels overlap the ghost image.

Acknowledgment

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References

[1] C. Ozdemir, S. Demirci and E. Yigit, “A Review on the Migration Methods in B-scan Ground Penetrating Radar Imaging,” *in Proc. Progress in Electromagnetics Research Symposium (PIERS),* 2012, Kuala Lumpur, Malaysia, pp. 789-793.

[2] C. Ozdemir, S. Demirci, E. Yigit and A. Kavak, “hyperbolic summation method to focus B-scan ground penetrating radar images: An experimental study with a stepped frequency system,” *Microwave Opt. Technol. Lett.*, vol. 49, pp. 671-676, 2007.