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FDTD Analysis of Doppler Shift Caused by Moving Antennas Above Rough Surface

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Beyond 5G (B5G) technology requires high speed and reliability [1]. Due to its high reliability, the use of B5G technology in advanced traffic control systems is being considered. In the advanced traffic control systems, vehicle to vehicle (V2V) communication is one of the key technique. On the other hand, part of the radio wave is reflected from the road surface of the ground and is consequently affected by Doppler shift. This Doppler shift may affect clarity of communication, therefore, a quantitative estimation of the Doppler shift is required. The FDTD method is one of the major numerical technique. The FDTD has wide capability in terms of modeling. Furthermore, Calculation speed improving techniques is also proposed[3], therefore, in this research FDTD method is use. In this research, FDTD analysis of Doppler shift caused by moving antennas above rough surface is shown.

The Doppler shift can be estimated by the following equation.

$$f_R = f_c + f_{DMAX}\left(\cos\theta_{TX} - \cos\theta_{RX}\right) \quad (1)$$

where

$$f_{Dmax} = \frac{f_c \times v}{c_0}$$

and, θ_{TX} and θ_{RX} are incident angle, receiving angle to the antenna respectively. Furthermore, the the Bragg resonance is occurring on the road surface due to periodicity of the roughness. Spectrum shift f_D due to the Bragg resonance is estimated as

$$f_D = f_{Dmax}\frac{n\lambda}{\lambda_W} \quad (2)$$

where n is integer, λ_W is wavelength of road surface, λ is wavelength of transmitted radio wave.

Table 1: Calculation Conditions

Center Freq.	27.9GHz
TX signal	CW
TX and RX ant.	Dipole Ant.
Ant. Height	0.15m
D	0.25m
speed	30km/h
Road Surface Gap	0.02m
Road surface wave length	0.043m

Next, calculated Doppler shift by the FDTD method is shown. The analysis model is that the antennas are located above the road surface. The analysis conditions are summarized in Table 1. The results are shown in Figs.1 and 2. The road surface model is sinusoidal wave to investigate validity of the proposed method. The wavelength and height of the sinusoidal wave is 0.043m. The vertical dipole antennas are used as transmitting and receiving antenna. The antenna height is 0.15 m. Doppler spectrum was analyzed for vehicle speeds were 30 km/h (8.3 m/s) and 60 km/h (16.6 m/s). This speed is relatively slow. The results are shown in Figs. 1 and 2. The theoretical values of the Doppler shift are $f_D = 538n$ (30km/h) and $f_D = 1706n$ (60km/h) according to eq.(2). The results are good agreement with theoretical values. Therefore, the effectiveness of the proposed method was confirmed. The actual models such as random surface or horn antenna case will be analyzed.

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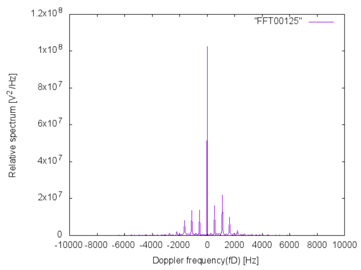

Figure 1: Doppler spectrum (30 km/h)

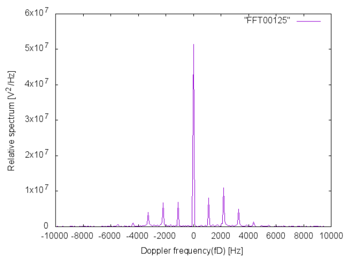

Figure 2: Doppler spectrum (60 km/h)

References

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[3] K. Asahi, T. Arima, A. Uematsu, T. Nishibori and T. Uno, "Space-Time Adaptive Processing Concept for Calculation Speed Improvement in Multi-Region/FDTD Method," in IEEE Journal on Multiscale and Multiphysics Computational Techniques, vol. 6, pp. 92-99, 2021