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Link Budget Estimation for 6G Fixed Wireless Systems under Windy Condition with Optimized Antenna Gain Design

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Millimeter-waves (mmWaves) and terahertz (THz) waves are considered and standardized for the fixed wireless systems (FWSs) in the 6th generation (6G) technology for establishing the ubiquitous network connection. Due to the considerable atmospheric attenuations of either mmWave or THz waves, the antenna sites of such bands need to be established as ultra-dense and small cell as possible. In this scenario, the increasing number of small cells adds the challenges and constructing cost on connecting all the remote nodes. Besides, owing to the cost issue and place limitation in the metropolitan areas, some antenna sites cannot be fixed on walls or buildings but on cost-effective hollow metal poles at outdoor environments. In this circumstance, the robustness and performance of such mmWave/THz antenna sites become important issue because the devices inevitably suffer from vibrations, misalignments, and severe weather conditions such as wind or rain effects [1]. For the weather issue to such mmWave/THz links, previous literatures have comprehensively discussed rain-induced attenuations, whereas few put the spotlight on windy conditions. On the other hand, for the link performance issue to fit the 6G standard, a high gain antenna with high-frequency bandwidth is an available way to enhance the data capacity in the FWS. However, if designing the mmWave/THz antenna as high gain, the radiation pattern will become sharp and narrow, which considerably increases the difficulty on installation and alignment. Moreover, when the inevitable vibration or slight misalignment occur to such high gain antenna set, the link will directly become invalid. As a result, the trade-off between robustness and high capacity needs to be considered carefully, especially for mmWave/THz antennas [2]. Finally, to verify the effectiveness of such adjustments for fitting the 6G standard, the link budget of mmWave/THz FWS needs to be estimated and evaluated, especially taking wind effect into account.

In this presentation, we present the link budget estimation for mmWave/THz FWSs under windy condition with optimized antenna gain designs. For the selection of employed bands, the E-band mmWave radio (71–76 and 81–86 GHz) and 0.3-THz band are chosen for the possible usage of 6G standard. The numerical estimation of the antenna effective gain in the mmWave/THz FWS is firstly conducted. During the calculation, a hollow core metal cylinder pole is selected as the model for estimating the inclination angle under windy conditions, which could be derived from the basic mechanics of materials. Later, we use the international telecommunication union radiocommunication sector (ITU-R) recommendations for calculating the radiation patterns of the mmWave/THz antennas. During the calculation, the effective gains of such antennas can be affected by inclination angles which are mainly from misalignments and windy effect at outdoor environments. By combining the ITU-R and material mechanics models, the trade-off between mmWave/THz antenna maximum gain and the FWS robustness can be verified. It can be concluded that the maximum gains of the mmWave/THz antennas should be designed within specific values for supporting the robustness of the FWSs. In other words, with the optimized antenna gain designs, the mmWave/THz FWSs can provide promising robustness and adequate performance for fitting the 6G standard even under windy conditions. Finally, the link budget evaluation based on the aforementioned modeling are demonstrated, which provides the information of the least guaranteed link performances of the mmWave/THz FWSs. The results of this work can be a clear guideline for designing the mmWave/THz FWSs under windy conditions in the 6G wireless network.

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1. Z.-K. Weng *et al.*, "Millimeter-Wave and Terahertz Fixed Wireless Link Budget Evaluation for Extreme Weather Conditions" *IEEE Access*, **9**, December 2021, pp. 163476-163491, doi: 10.1109/ACCESS.2021.3132097.

2. Z.-K. Weng *et al.*, "Antenna Effective Gain Estimation under Windy Condition in Terahertz Fixed Wireless Systems" in *2023 IEEE Conference on Antenna Measurements and Applications (CAMA)*, November 2023, pp. 271-272, doi: 10.1109/CAMA57522.2023.10352721.