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# Rain Rate Retrieval from Millimeter-wave Propagation Measurements in China

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Communication at millimeter-wave frequencies represents the most recent game-changing development for wireless systems. Provided the significant increase in bandwidth and new capabilities offered by millimeter wave frequencies, the base station-to-device links, as well as backhaul links between base stations, will be able to handle much greater capacity than today's cellular networks in populated areas. Governments around the world have allowed operations in the millimeter bands for backhaul, often as little or no licensing fee. In addition to 6 – 42 GHz, 50 GHz, 60 GHz bands, and recently, the E-bands at 71-76, 81-86, and 92-95 GHz in the USA have become popular, as the spectrum is made available at very little cost to carriers.

Millimeter-wave technology has also been considered as challenging. The main limitation of millimeter-wave is range. Mainly, this is due to the channel characteristics of mm-wave spectrum, i.e. large path loss, impact of atmospheric absorption CO2, O2 and attenuation due to water vapor, rain, fog and snow. On the other hand, the disadvantage of large attenuation of electromagnetic signal in the millimeter-wave range due to changing of atmospheric condition has been proven to be useful for weather estimation. This work will study the potential of using millimeter-wave links to retrieve atmospheric parameters including rainfall and water vapor in Beijing, China.

High resolution, continuous and accurate monitoring of ground level atmospheric parameters such as rainfall and water vapor are of great importance to meteorology, hydrology, agriculture, and weather forecasting. Current methods of obtaining measurements include mainly surface rain gauges, weather radars and satellite systems. However, the deployed observational equipments are still limited in number. All measurement techniques can not yield global data sets of these parameters to meet the needs in weather monitoring and numerical weather model studies. Previous studies show this situation can potentially be counteracted by using the received signal level data from the enormous number of backhaul links used worldwide in commercial cellular communication networks. There has been trial measurements carried out in Israel, Netherlands, Germany, Japan and West Africa [1]. This method is a passive weather monitoring approach by analyzing the electromagnetic signals propagation and degradation.

We have built a millimeter-wave measurement link at our research institute in central Beijing, China and carried out long term measurements during rainy season. We have monitored transmit and receive signal level variations in sunny time and rainy time. In this paper, we will present our trial measurements results. The results show that the millimeter-wave signals are weakened by weather conditions, especially rain. As the rain intensity increases to 120 mm/hr, the signal attenuation due to rain becomes more significant, causing deep fades in received signal strength. We used the average received signal level in sunny time as a reference level, The rain induced signal attenuation is calculated by using the reference received level to subtract the received signal strength in rainy time. We retrieved rain rate from the attenuated signal due to rain and compared with the measurements from rain gauge and distrometer. It is also found that the accuracy of the rain rate estimation can be improved with a better estimation of the reference level by understanding the propagation characteristics of the measurements.

Similar to 4G and previous generation of wireless networks, 5G networks which will heavily use millimeter frequency range spectrum are expected to be widely deployed. The results in this study show that the millimeter-wave based wireless networks can potentially be considered as a highly densed, and high-time and -space resolution ground level atmospheric observation network, operating in real time with low cost.

[1] Gosset, M., Kunstmann, H., Zougmore, F., Cazenave, F., Leijnse, H., Uijlenhoet, R., Chwala, C., Keis, F., Doumounia, A., Boubacar, B. and Kacou, M., Alpert, P., Messer, H., Rieckermann, J., Hoedjes, J., "Improving Rainfall Measurement in gauge poor regions thanks to mobile telecommunication networks." Bulletin of the American Meteorological Society 97.3 (2016): ES49-ES51.