Terahertz Wireless Systems: Analysis With Transceiver Fluctuations

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Abstract

Terahertz (THz) wireless communication is increasingly recognized as a key enabler for high-speed, ultra-broadband, and low-latency data transmission. The efficiency of THz communication systems is significantly influenced by various channel and system parameters, including molecular absorption, free-space path loss, fading, and pointing error. Existing literature often models the THz transmission links using $\alpha - \mu$ fading model combined with a pointing error model, which is primarily applicable for optical communication systems or a specific type of THz antennas. A new pointing error model designed for THz antennas has recently been proposed and the recently proposed fluctuating two-ray (FTR) fading model emerges as a very suitable choice for THz transmission, as it considers the line-of-sight components and their random phase distributions, in addition to the multipath and non-linearity of the propagation medium. The newly proposed pointing error model for THz communication is especially proposed for point-to-point communication between two $N \times N$ conventional antenna arrays, one positioned at the fluctuating transmitter and one at the fluctuating receiver (the transmitter and receiver account for the fluctuating nature of drone-to-drone communication scenarios, particularly, hovering drones fluctuating in yaw, roll, and pitch directions). Furthermore, a flying drone can be equipped with an RF component to enable secure and stable ground-to-drone and drone-to-ground data transmission, enhancing the capacity, coverage, energy efficiency, and reliability of heterogeneous cellular networks.

In this thesis, we model a THz transmission link considering FTR short-term fading, channel path loss, and the recently proposed pointing error model, with two standard uniform $N \times N$ THz antenna arrays, one mounted at the fluctuating transmitter and one at the fluctuating receiver (the fluctuating nature of drone-to-drone communication scenarios, mainly accounts hovering drones fluctuating uniformly in yaw and pitch directions with negligible fluctuations in the roll direction). Novel exact analytical closed-form expressions for the probability density function (PDF), the cumulative distribution function (CDF), the moment generating function (MGF), and the nth moment of the received instantaneous signal-to-noise ratio (SNR) are derived for the aforementioned system using standard mathematical functions. Next, closed-form expressions for performance metrics, namely, the outage probability (OP), the average bit error rate (ABER), the average channel capacity (ACC), and the diversity order (DO) are derived. The effects of various channel and system parameters on the system performance are studied, and

the accuracy of the derived analytical expressions is confirmed by simulation results. Furthermore, we quantify and evaluate the performance of a unique system model that offers end-to-end (E2E) connectivity from a stable source to flying drones. Specifically, we examine a relay-assisted double-hop hybrid radio frequency (RF)-THz uplink wireless communication system utilizing both the $\alpha-\mu$ fading model and the FTR fading model to characterize the THz link. Next, we extend our analysis to quantify and evaluate the performance of a relay-assisted double-hop hybrid THz-RF wireless communication system utilizing $\alpha-\mu$ fading to characterize the THz link. For both the THz-RF and RF-THz systems, we derive closed-form expressions for the PDF, CDF, MGF, and nth moment of the E2E SNR. These expressions are obtained in terms of the univariate Fox's H-function (UFH). Utilizing these expressions, novel closed-form expressions for the performance metrics such as OP, ABER, and ACC are obtained in terms of the UFH. In addition to this, to gain better insights into system performance, asymptotic expressions for both the OP and the ABER are provided, and the DO of the system is determined. Finally, the accuracy of the derived expressions is verified through simulations, the impact of different design parameters on the system performance is investigated, and critical insights are drawn.