Angle Characterization Radiation Detection of Microstrip Antenna for Short Range Terahertz Communication System

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Abstract. Communication technologies are crucial components to develop smart city systems related to low latency and massive data transfer. The near field communication (NFC) technology has been becoming more popular for close-range data transmissions, such as multimedia data transfer and non-contact payment, and still increasing in term of capacity and data transfer. Increasing carrier frequencies is a solution to fulfill those demands. In wireless communication technology, an antenna is a crucial element to convert electrical signals into electromagnetic waves or vice versa. Theoretically, an antenna dimension is comparable to the considered wavelength. This condition indicates that higher working frequency systems have a smaller antenna size due to its wavelength shorten. Terahertz (THz) spectrum band is promising to apply higher carrier frequencies. However, the antenna design and fabrication are becoming issues because of the tiny size, electronic components availability, and practical complexities. We have designed a microstrip antenna for working frequency of 0.35 THz by combining ground modification to cover distance and data rates up to 10 cm and more than 20 Gbps, respectively. By considering the previous design, this paper discusses different distances and rotation angles to analyze the effectiveness of wave transmission by simulation using CST Microwave Studio. Analysis use received power parameters to identify accepted signals detection possibility. The results show that the received power exceeded the sensitivity boundary from -50° to 40°, which show that the angles also limit the allowable accepted power level. Therefore, THz NFC systems should consider the antenna placement for an optimum condition application.

Keywords: wireless, Terahertz, Near Field Communication (NFC), communication, antenna

1. Introduction
Communication technologies are crucial components to develop smart city infrastructure systems, especially related to the demand for low latency and massive data transfer. These requirements have been coming from new emerging human communication behaviors, such as video-on-demand services, video conferences, and cloud computing. Those technologies need wide bandwidth and high-speed data transfer to obtain high quality of service (QoS) for various both fix and mobile multimedia applications. They have been becoming more popular and have shifted previous telecommunication technologies usage and the way people communicate. The current technologies have been in a stage which should
find other alternatives to catch up the tremendously near future demands, such as the upcoming 5G standards.

Among various communication technology solutions, the Terahertz (THz) waves, which is lying in a frequency band between 0.1 - 10 THz, offers broad bandwidth for wireless communication systems. Even though the frequencies are not practical for long transmission, due to the atmospheric attenuation, it is promising for short distance, point to point communication, and high rate data transfer [1–3].

A Near Field Communication (NFC) system has been an attractive technology for near communication systems, which combines card, reader/writer, and peer-to-peer communication [4]. These three provide intuitive, simple, and safe connection. The example use of an NFC system embedded in a mobile phone device is to increase data exchange, fast and secure methods for payments [5]. Another example of NFC advanced application is a multimedia data exchange vending machine for purchasing multimedia data. It can work more efficiently by increasing data rates into far higher, such as the THz wave spectrum band [6,7].

In such very high frequencies, propagation is a challenging issue of THz NFC systems development affected by the high attenuation in the THz spectrum band. Various research groups have researched the THz waves challenge for communication system applications. A recent study has used the link budget and gain analysis for indoor communication analysis [2]. It shows a promising configuration to obtain high-speed data transfer. The Non-line-of-sight (NLOS) propagation phenomena have been analyzed and investigated in detail to observe more constraint in real applications [8–11]. Another research has shown the possibility of reaching a multi-gigabit THz communication channel using wireless data exchange at 300 GHz [12]. These researches indicate that the THz waves are coming to a possible stage for supporting the inevitable demand of a massive data transfer.

In a wireless communication system, including a THz wireless network, an interface between the propagation medium and electronic device mostly is an antenna as a transducer. In the THz waves spectrum band, design and fabrication of THz antennas have many challenging issues, such as the tiny antenna size in a few micrometer scales and high gain required to compensate high attenuation in the propagation. We have been researching antenna designs for THz wave radiation source and detection based on quasi-optical lens antenna and microstrip antenna [13–16]. A lens antenna is a solution to gain antenna radiation power density in an expected direction. However, the challenge is to tackle radiation efficiency affected by a boundary condition between a dielectric and free space medium [17]. Meanwhile, the use of a microstrip type antenna is because of its low-profile characteristics, robustness, and possibility to fabricate. A proper design of a microstrip THz antenna can provide wide bandwidth [18]. In our previous work, THz planar antenna design is to offer working frequencies of 0.35 THz for short wireless communication purposes [19]. In this research, we study wave propagation between transmitter and receiver antenna by varying angles for NFC applications. This research is conducted with electromagnetic simulation software of CST Microwave Studio. The receiver antenna is expected to detect a minimum level for the received signal, namely a sensitivity threshold. This present paper aims to study the impact of angle variations of a THz microstrip antenna for several short-range communication scenarios to understand the best configuration in a short-range THz communication.

2. Propagation simulation between two antennas

Figure 1 shows an angular scheme of a transmitting antenna (Tx) rotated horizontally and radiates THz waves. The receiving antenna (Rx) receives the radiated power as a function of the parameterized angles. We consider our previous microstrip antenna design with a modified ground antenna and the resonant frequency of 0.35 THz to simulate the scenario [13]. Propagation simulation between the transmitter and receiver antenna for NFC applications is conducted with electromagnetic simulation software of CST Microwave Studio. The power emitted by the transmitter antenna is 500 mW. The received power is compared with the sensitivity level, which is around -40 dBm, to find out angles whether the received power is enough for data transmission. The considered distances between the transmitter and the receiver are 0.1, 1, 5, and 10 cm, which are the possible ranges in a short-range NFC system. The rotation is conducted from 180o to -180o with 10o spacing angle.
3. Propagation simulation results

Figure 2 shows received power at a distance of 0.1 cm as a function of rotation angles. The line which has square marker shows the received power. The other line with a circle marker shows the sensitivity level of the receiver. Another shows the half-power beam width (HPBW). It shows that the entire received power is above the sensitivity level. These results indicate that the configuration can work well on the simulated angle variations.

Figure 3 and 4 show the received power at lengths of 1 cm and 2 cm, respectively. It shows that the received power is mostly above the sensitivity level except at the angle of -70°. This result is probably due to the spread of radiation that leads to another position so when there is a transmitting antenna shifting to an angle of -70°, the receiving antenna does not receive enough radiation to exceed the sensitivity limit.
Figure 3. Received power in a distance of 1 cm with angle variations

Figure 4. Received power in a distance of 5 cm with angle variations

Figure 5 shows the received power at a distance of 10 cm. It shows that the received power only exceeded the sensitivity level if the transmitting antenna directions are from angles of -50° to 40°. The received power for other scenarios does not exceed the sensitivity level. This condition is affected by the primary beam radiation direction, which is directive towards 0°. In the case of an NFC application, this scenario seems the last position for covering in the surrounding of the main beam direction except for correctly point to the point of zero degree condition. From the three scenarios, the covered area is decreasing at the given antenna input power. Higher antenna input power is necessary for more distances and covered area, which depends on the application requirements.

Figure 5. Received power in a range of 10 cm with angle variation
4. Conclusion
This paper has simulated and analyzed the THz wave propagation between a transmitting antenna and a receiving antenna in various near distances and rotation angles. By increasing the range, the received power levels do not exceed the sensitivity threshold. Received power in the furthest considered distance of 10 cm, exceeded the sensitivity boundary from -50° to 40°. Because the angles also limit the allowable accepted power level, therefore, NFC systems should consider the antenna placement.

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