Subterahertz 2 Gbit/s wireless channel with frequency-driven beam steering

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Abstract. In this work, we report on a subterahertz wireless channel with frequency-driven beam steering in reflected light as a blockage mitigation tool, which is in demand by the next-generation wireless networks with user mobility support. Blockage-preventing switching between user devices via frequency-selective reflecting surface is demonstrated for 2 Gbit/s indoor channel with carrier frequencies in the spectral band 134-158 GHz.

Субтерагерцовый беспроводной канал 2 Гбит/с с частотно-управляемой разверткой пучка

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Аннотация. В этой работе мы сообщаем о субтерагерцовом беспроводном канале с частотно-управляемой разверткой пучка в отраженном свете как о средстве смягчения эффекта блокировок, востребованном в сетях связи нового поколения с поддержкой мобильности пользователя. Нами продемонстрирована возможность коммутации между пользовательскими устройствами с предотвращением блокировок с помощью частотно-селективной отражающей поверхности для внутреннего канала со скоростью 2 Гбит/с и несущими частотами в спектральном диапазоне 158–134 ГГц.

Introduction

Next generation wireless communication networks are expected to utilize spectra of the sub-terahertz (sub-THz) band (100−300 GHz) to increase data transfer rate and reduce latency. Standardization of spectral bands for sub-THz and even terahertz (THz) communications is already underway [1]. However, sub-THz and THz waves are subjects to significant atmospheric absorption [2], making them nearly impractical to use in outdoor cellular network deployments. But indoors, where distances are short and typically do not exceed a few tens of meters, deployment of such networks seems quite feasible utilizing highly directional channels. Their use results in the appearance of line-of-sight blockage and user micromobility issues [3, 4], making wireless connection essentially less stable. The issues can be fixed in the reflection-aided channels equipped with intelligent reflecting surfaces (IRSs). Generally speaking, IRS enables creation of virtual line-of-sight path and, depending on deployment condition and application scenario, can be used for dynamic beam steering or static beamforming through non-specular reflections of carrier signals. In this work, we report on the use of our previously designed and fabricated frequency-selective IRS [5] for real-time beam steering as a blockage mitigation tool in a sub-THz indoor high-speed channel. IRS is presented array of the 36×36 log-periodic spiral antennas with static phase-configured via three different unit cells repeated in each row. IRS exhibit in-reflection phase shifts within 0−350° at the operational angles of incidence up to 75° with beamwidth, side lobe and cross-polarization levels of 4°, −13 dB and −26 dB, respectively. Details of our experimental studies are provided below. Details of our experimental studies are provided below.

Materials and Methods

Referring to Fig. 1, the core of the experimental setup is the transmitter (Tx) module, which can generate modulated signals with carrier frequencies from 134 GHz to 158 GHz and output powers of up to 20 dBm. The modulation type is adjustable. Either quadrature amplitude modulation with 16 states or amplitude shift keying with 4 states (ASK-4) can be implemented by controlling in-phase (I) and quadrature (Q) inputs of IQ mixer incorporated in the Tx module. Baud rates of up to 3 GHz are supported by both the IQ mixer and the digital-to-analog converter (DAC) controlling its I and Q states. Due to the limitations on the receiver (Rx) module side, we fix the modulation to ASK-4 and the baud rate to 1 GHz in our experiments. The limitations of the Rx module are caused by the lack of a suitable sub-THz heterodyne source at our disposal. At the same time, on the Tx module side, the modulation frequency and the number of amplitude states are basically limited by the capabilities of the DAC operated in a stand-alone test mode.

Fig. 2 shows a detailed block diagram of the experimental setup. Generated sub-THz ASK-4 signal is emitted into a free space in the form of an 8 deg wide Gaussian beam. The beam is further incident on an IRS panel, whose frequency-selective reflective properties are used to fed signals with carrier frequencies of 135.6 GHz and 152.4 GHz into two distanced Rx modules based on our previously designed and fabricated the Schottky diode detectors [6]. Switching of the carrier frequencies is maintained at Tx automatically if blockage of a currently active Tx-IRS-Rx path occurs. The employed threshold algorithm with an Rx signal strength as input parameter enables real-time feedback functioning. Time series of the Rx signal strength are logged by a digital oscilloscope with a 1 GHz analog bandwidth.
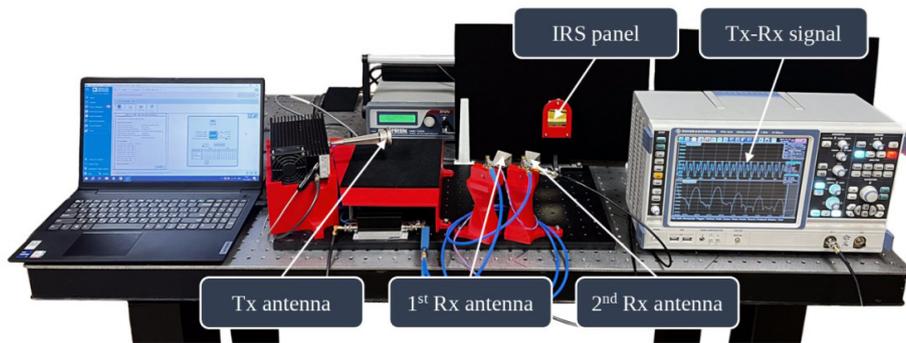
Fig. 1. Photograph of a sub-THz wireless channel with frequency-driven beam steering
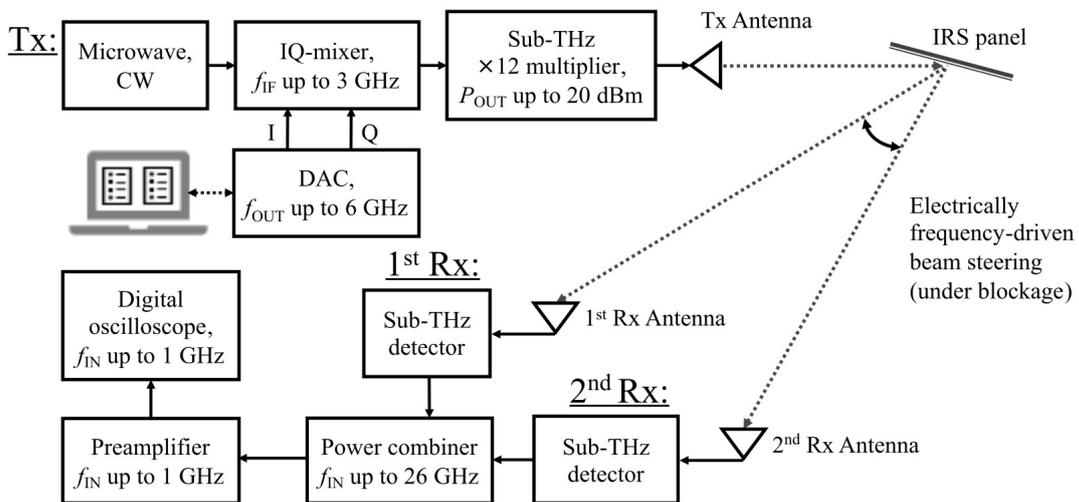

Fig. 2. Block diagram of a sub-THz wireless channel with frequency-driven beam steering

Results and discussion

Fig. 3 shows the oscillograms of the received signal on the first Rx module at a frequency of 135.6 GHz and on the second Rx module at a frequency of 152.4 GHz, the data rate is 2 Gbit/s using only one IQ mixer input, with the potential to reach 4 Gbit/s using both IQ mixer inputs. It is possible to achieve a data rate of 12 Gbit/s if the DAC is handled through a Firepower Management Center (FMC) hardware interface by an external field-programmable gate array (FPGA) introduced additionally into the developed setup. The time series of the first and second Rx modules exhibit the same data transfer rate but have different waveforms. This is due to the fact that on the Tx side of the module, the DAC component has difficulty generating
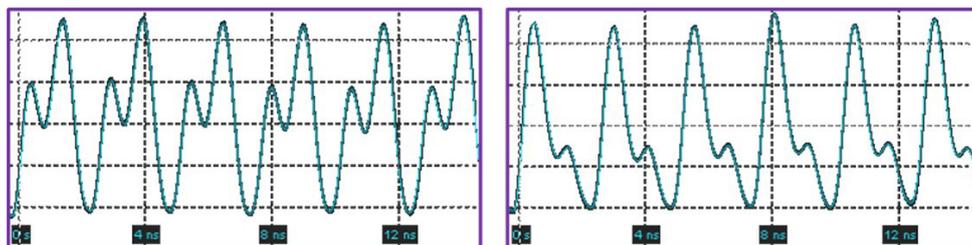

Fig. 3. Oscillograms of the received signal on the first (*a*) and second Rx modules (*b*) via frequency-driven beam steering at 135.6 GHz and 152.4 GHz respectively

time series that determine the signal modulation, since it requires a high-performance FPGA for efficient operation. Timely recognition of blockage in the sub-THz channel between the IRS and one Rx, achieved by the threshold algorithm, allows for fast switching to the second sub-THz channel between the IRS and another Rx, which demonstrates the implementation of blockage-preventing detection.

Conclusion

We implement the IRS panel and the detector diodes of the Rx modules in accordance with our recently reported designs. All electronic and optical components are assessed individually and as a part of the Tx-IRS-Rx assembly. In the end, our experiments successfully demonstrate block-age-preventing switching between user devices in real time via frequency-driven beam steering in a 2 Gbit/s indoor channel with carrier frequencies in the spectral band 134-158 GHz.

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