# Terahertz communication based on high order digital modulation

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***Abstract*—We have developed a 0.14THz wireless link with 10Gbit/s data rate. Terahertz signal is generated and detected by Schottky diode superheterodyne transmitter and receiver. 16QAM high order digital modulation/demodulation has been successfully applied in IF signal processing, which works with non real time software method and could improve the spectrum efficiency and carrier noise rate (CNR). The system has successfully transmitted 10Gbit/s data rate signal over 0.5km with bit error rate (BER)<$10^{-6}$, CNR>35dB. The maximum transmission distance is estimated to be about 1.5km。**

## I. Introduction And Background

Terahertz communication has larger bandwidth compared with millimeter-wave lower than 0.1THz , and it is more robust under environment variation compared with Free space optical communication[1]. Utilizing the broadband characteristic of terahertz wave to achieve high data rate communication is an attractive research aspect.

Current terahertz communication systems mainly work with analog [2][3] or low order digital modulation[4] ,such as ASK and BPSK. Analog modulation limits the transmission bandwidth to tens of kHz. Low order digital modulation can be used in ultra fast data communication. Hirata et al. in Japan had developed a 120GHz wireless link with 10Gbit/s data rate[5]. But atmosphere transmission windows in 0.14Hz is only about 35GHz [6], 10Gbit/s ASK signal occupies bandwidth up to 17GHz. As the low spectrum efficiency, low order modulation has limited the maximum transmission ability of Terahertz communication.

We are working on utilizing the high order digital modulation to greatly improve the spectrum efficiency. Dyadyuk et al. had reported a 85GHz 6Gbit/s point to point link in 2007 [7], which had only taken up 2.5GHz bandwidth under 8PSK modulation. We have developed a 0.14THz link up to 10Gbit/s., which works with 16QAM modulation and takes up 3.6GHz bandwidth.

## II. System Configuration

Configuration of the 0.14THz communication system is shown in Fig.1. The 0.14THz transmitter and receiver are used to realize frequency conversion between IF and Terahertz signal, which are based on Schottky diode superheterodyne techniques. 10Gbit/s data stream is modulated on the IF signal with center frequency 6GHz, bandwidth 3.6GHz. Then, the IF signal is up converted to RF band (133.8GHz~137.4GHz) by Schottky diode Sub-harmonic mixer, whose up convert loss is about 7dB, down convert loss is about 13dB,.3dB IF bandwidth is about DC~10GHz. The 0.14THz band pass filter is used to achieve sideband frequency rejection. The sideband rejection rate is better than 40dB. The RF signal is amplified by solid state 0.14THz amplifier. Finally, the RF signal is radiated to free space by 51dBi Gain paraboloidal antenna.

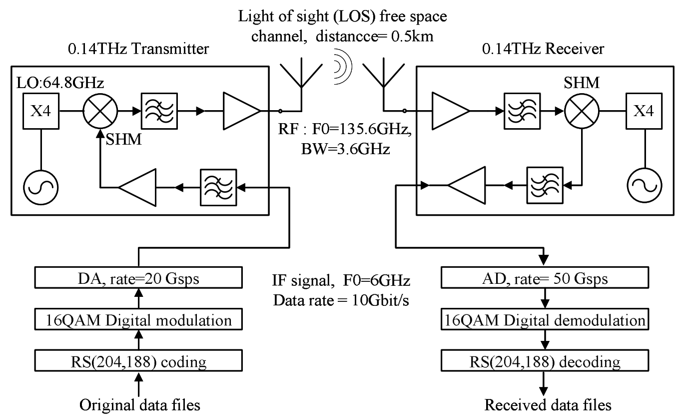


Fig.1 Configuration of 0.14THz communication system

The 0.14THz receiver is similar with the transmitter. Sub harmonic mixer converts the RF signal to IF band. It used the IF amplifier and filter chain to get suitable IF power spectrum for Analog to Digital conversion(AD). In the 0.14THz Transmitter and receiver, LO signal frequency is 64.8GHz, which is half of the RF frequency. LO signal is generated by cascading 16.2GHz Phase lock loop (PLL) frequency source locked by 100MHz crystal oscillator and the 4X multiplier chain.

16QAM high order digital modulation/demodulation are successfully realized in IF signal processing. Experiment data indicates that the phase and amplitude distortion of free space channel and frequency conversion channel can seriously affect the performance of 16QAM signal. So, self-adaptive digital equalization and Reed-Solomon coding (RS(204,188)) are indispensable for bit error rate reducing. The arithmetic of them have been validated in practical system.

Considering the time consumption, we have realized the IF signal processing system on software workstation first, it will be constructed as real time high speed hardware processing in the further research. In current system, original data files are modulated and coded though software computation, then it is converted to IF signal by 20 Gsps Digital to Analog conversion (DA). In the receiving system, 50 Gsps Analog to Digital conversion (AD) will be used to get sampled waveform data from IF signal for software digital demodulation. Limited by the memory size of AD&DA, the size of a original data file is no more than 2Mbit. It has been repeated in 5kHz rate to achieve 10 Gbit/s.

## III. TRANSMISSION EXPERIMENT

Transmission experiment has been done between two buildings, 0.5 km away from each other. Fig.2 shows the receiving part of 0.14THz communication system. 51 dBi High Gain paraboloidal antenna, RF receiver, IF amplifier and high speed AD are integrated in a operational platform. The paraboloidal antenna main lobe beam width is about 0.4 degree. So, optical aiming and single tone adjusting method are used to minimize the antenna transmission loss.

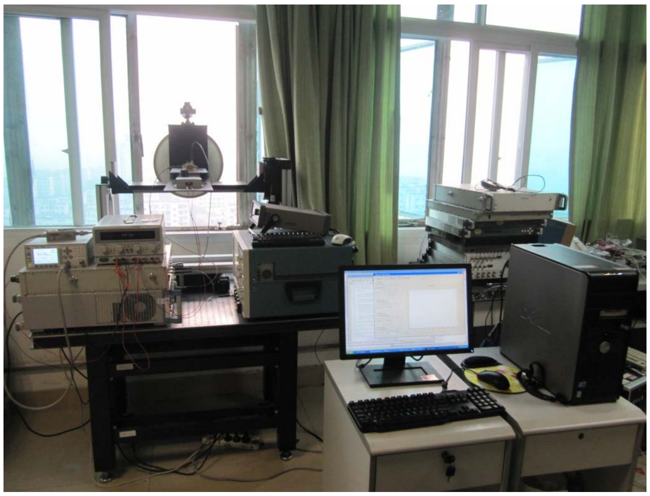

Fig.2 0.14THz receiving system

Measured data indicates the output power of transmitter could achieve 0dBm. But in the experiment, it was reduced to -3dBm to enhance system linearity. The receiving gain of 0.14THz receiver is -2dB , noise temperature is about 2200K. The free space transmission loss is about -129dB. The measured receiving IF power from the 0.14THz sub-harmonic mixer is -35dBm, which is coincide well with the result of wireless link computation (-34dBm).

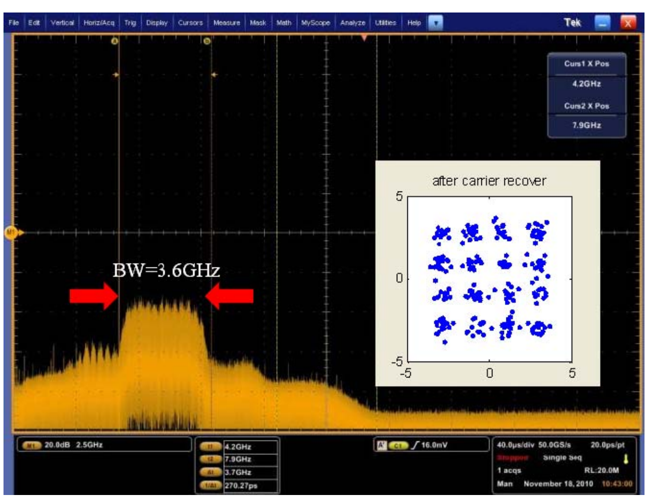


Fig.3 IF Spectrum and demodulated constellation

After IF amplifying, the IF signal power in front of high speed AD is 0dBm. Fig.3 shows the IF spectrum and the demodulated constellation of 0.14THz communication system. The measured IF band width is 3.6GHz, and CNR >35dB.It is necessary to indicate that wide band modulation and high speed DA had introduced more noise than the RF transmitter and receiver. So, it looks like the CNR is only better than 20dB in Fig.3, but the real value is better than 35dB.

We have transmitted pictures (data size: 2Mbit) over 0.14THz channel in the experiment. The demodulated constellation indicates the bit error rate is 1.2e-3 over 0.5km distance. RS(204,188) coding can reduce the bit error rate lower than 1e-6. No bit error is found in the final data files. The maximum transmission distance of current system is estimated to be 1.5km, with CNR >25dB.

## IV. RESULTS

In this paper, we had developed a 10Gbit/s transmission link in 0.14THz band. Schottky diode superheterodyne transmitter and receiver are used to generate and detect Terahertz signal. The IF signal frequency is 3.2~7.8GHz, which is up converted to 133.8GHz~137.4GHz (bandwidth=3.6GHz). non real time software processing based 16QAM modulation/demodulation, digital equalization and Reed-Solomon coding (RS(204,188)) are applied to IF signal. In the transmission experiment, the RF radiation power is -3dBm, transmission distance is 0.5km. The transmission bit error rate (BER) is less than $10^{-6}$, and carrier noise rate (CNR) > 35dB.

Though this research, the feasibility of Terahertz communication based on solid state RF components and high order digital modulation is verified. High order digital modulation can greatly improve the spectrum efficiency. The terahertz electron vacuum components as traveling wave tube only have bandwidth less than 5GHz, which is matching with the current system and could improve the output power of terahertz signal to tens of watts. High speed communication between satellites and earth can be realized in future.

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