Computer Networks 203 (2022) 108628

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

Data article

Data signals for Terahertz communications research

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ARTICLE INFO

Keywords:
Terahertz communication
Ultrabroadband networks
6G

ABSTRACT

The Terahertz (THz) band (0.1–10 THz) is a key asset to unlock the next generation of wireless communication systems. With larger available bandwidths, THz systems would allow for faster data rates to interconnect many more users than traditional communication systems in the microwave and millimeter wave frequency ranges. While the hardware for THz communications is quickly emerging, the wireless research community lacks access to THz signals. In addition to hardware solutions, much is left to explore on the signal processing side for THz communications. Thus, in this paper, an extensive data set consisting of 260 frames of information-carrying ultrabroadband signals transmitted and received at 120–140 GHz, 210–240 GHz, and 1–1.05 THz is presented. This data set will enable the wireless community to experimentally explore solutions relating to ultrabroadband time, frequency and phase synchronization, channel estimation and equalization, and modulation, to name a few.

Specifications table

Subject	Wireless communications
Specific subject area	Terahertz communication for 6G networks
Type of data	Modulated time-domain signals
How data were acquired	All waveforms were acquired using the TeraNova Testbed described in [1], [2], [3], and [4].
Data format	Raw digitized data signals collected after down conversion to an intermediate frequency. Each signal contains two files: (i) a binary file of recorded digital samples and (ii) a metafile with information describing each dataset in plain-text JSON format. This binary and meta format is an extension of and compatible with NTIA's SigMF specifications as listed here https://github.com/NTIA/sigmf-ns-ntia.
Parameters for data collection	The signals are modulated using M-PSK modulation schemes of various (i) modulation orders, (ii) symbol rates, (iii) transmission distances, and (iv) carrier frequencies. The exact specifications for each waveform are provided in the meta data.
Description of data collection	The signals were generated in baseband using MATLAB before being converted to analog signals by an arbitrary waveform generator and modulated to the target RF frequency using a custom-made transmitter front end. The corresponding receiver front end down-converted the signals, after which they were captured by a digital storage oscilloscope. More details on the data collection process can be found in [1], [2], [3], and [4].
Data source location	Institution: Northeastern University City: Boston, MA Country: United States
Data accessibility	Repository name: Northeastern University Digital Repository Service (DRS) Follow the *Red (2021)* link provided from the data set's web page to access the data files.
Related research article	P. Sen, V. Ariyarathna, A. Madanayake, J. M. Jornet, A versatile experimental testbed for ultrabroadband communication networks above 100 GHz, Computer Networks, 193 (2021).https://doi.org/10.1016/j.comnet.2021.108092

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https://doi.org/10.1016/j.comnet.2021.108628
Received 9 September 2021; Accepted 11 November 2021
Available online 14 December 2021

(continued...)

Subject	Wireless communications
Related projects	Project name: CNS-2011411 Funding body: National Science Foundation (NSF) Project duration: 5 years Project name: CNS-1955004 Funding body: National Science Foundation (NSF) Project duration: 5 years Project name: CNS-1801857 Funding body: National Science Foundation (NSF) Project duration: 4 years Project name: FA8750-20-1-0200 Funding body: Air Force Research Laboratory (AFRL) Project duration: 3 years

1. Value of the data

- **Why is this data useful?** Still only a few hardware systems can operate at true THz frequencies. As a result, little to no data is available for experimental research in the THz band. This work releases such data to the community. With 260 frames of modulated M-PSK data signals transmitted at three different frequencies above 100 GHz, this data set is the first of its kind to be accessible to the community.
- **Who can benefit from these data?** Wireless communication researchers working on THz communications or ultrabroadband signal processing techniques will benefit from this data, especially given the range of frequencies (120 GHz - 1.04 THz) and data rates from 1 to 10 Gigasymbols per second included in this data set. Researchers without access to THz hardware will benefit from access to this data.
- **How these data might be used for further insights or development of experiments?** The wide variety of signals provided in this data set allow for the researchers to use this data for various purposes. Synchronization, channel estimation, equalization, and demodulation techniques (to name a few) can be tested using this data set.
- **What is the additional value of this data set?** This data set contains of 260 frames transmitted at three different frequency ranges (120–140 GHz, 210–240 GHz, and 1–1.05 THz) all above 100 GHz with data rates ranging from 1 to 10 Gsps and transmission distances from 5 cm to 35 m. The comprehensiveness of this data set enables its use for a myriad of purposes to continue pushing wireless communications research forward.

2. Data description

The signals are saved as sigMF data files using the format detailed by the National Telecommunications and Information Administration (NTIA). Each signal has a meta data file accompanying it. The data is organized into folders by the carrier frequency ranges. As shown in Fig. 1, inside the frequency folder there are folders for each test scenario. Each scenario was repeated several times, so there will be multiple captured frames inside the folders for each scenario. Specific instructions on how to read and decode the data can be found in a ReadMe file uploaded with the data files.

3. Experimental design, materials and methods

These signals were collected using (i) three different carrier frequencies above 100 GHz, (ii) various transmission distances, (iii) bandwidths ranging from 2 to 20 GHz, and (iv) different modulation schemes. For a more comprehensive explanation of the methods and experimental set up, refer to its website.

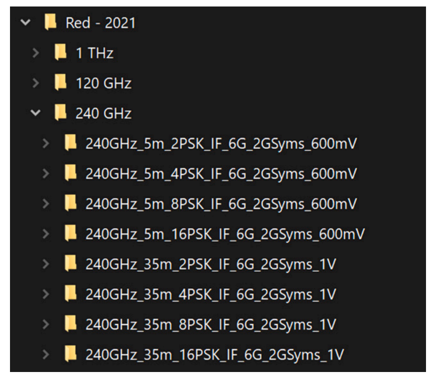

Fig. 1. File Organization for Red (2021).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work is supported by the National Science Foundation (NSF), USA under grants CNS-2011411, CNS-1955004, CNS-1801857 as well as the United States' Air Force Research Labs (AFRL) under award number FA8750-20-1-0200.

References

[1] P. Sen, V. Ariyarathna, A. Madanayake, J.M. Jornet, A versatile experimental testbed for ultrabroadband communication networks above 100 GHz, Comput. Netw. 193 (2021) 108092.

[2] P. Sen, D.A. Pados, S.N. Batalama, E. Einarsson, J.P. Bird, J.M. Jornet, The TeraNova platform: An integrated testbed for ultra-broadband wireless communications at true terahertz frequencies, Comput. Netw. 179 (2020) 107370, http://dx.doi.org/10.1016/j.comnet.2020.107370.

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[4] P. Sen, V. Ariyarathna, A. Madanayake, J.M. Jornet, Experimental wireless testbed for ultrabroadband terahertz networks, in: Proceedings of the 14th International Workshop on Wireless Network Testbeds, Experimental Evaluation & Characterization, 2020, pp. 48–55.

Duschia Bodet In 2021 received her B.S. and M.S. in Electrical Engineering with a concentration in Communications, Controls, and Signal Processing. During her undergraduate years, she spent six months co-oping at Raytheon in radar systems, and another six months as a research assistant for the Air Force Research Labs with the Griffiss Institute. For her master's thesis she investigated new modulation solutions for Terahertz communications under the guidance of Dr. Josep M. Jornet. She is continuing her research with Dr. Jornet as a Ph.D. student focusing on modulation schemes and physical layer solutions for THz communications.

Jacob Hall In Spring 2020, Jacob Hall received his BS in Electrical and Computer Engineering from SUNY Polytechnic Institute in Utica, NY. He joined Northeastern University in Fall 2020 as an MS student in the ECE department. His attendance at Northeastern is being sponsored by the Science, Mathematics, and Research for Transformation (SMART) Scholarship Program, a DoD funded Scholarship-for-Service program, in connection with the Air Force Research Laboratory (AFRL) Information Directorate in Rome, NY.

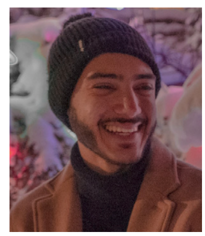
His interests lie at the crossroads of deep learning and THz communications, specifically in data-driven physical layer solutions.

Priyangshu Sen received the Bachelor of Technology degree from Biju Patnaik University of Technology, India, in 2012. He completed his Industrial training in Garden Reach Shipbuilders and Engineers Limited on the Communication system on naval board ship, in 2011. He started his career as a research engineer at the University of Calcutta in Radio-physics and Electronics in 2013. He received the Master of Technology degree in Radio-physics and Electronics from the University of Calcutta, India, in 2015. He is currently pursuing the Ph.D. degree in the Department of Electrical and Computer Engineering at Northeastern University, Boston, MA, USA, under the guidance of Professor Josep M. Jornet in UN Lab, MA, USA. He completed his summer training (2019) at Samsung Research America in the sub-Terahertz communication system and protocol design. His current research interests are in Experimental and statistical characterization of Terahertz communication channel and networks.

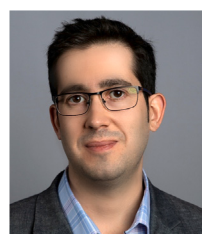
Rachel Johnson will complete her B.S. in Electrical and Computer Engineering from Northeastern University in May 2022 with minors in Math and Physics. She completed her first co-op during fall 2019 at Emphysys, Inc., her second co-op in fall 2020 at Commonwealth Fusion Systems, and her third co-op in fall 2021 at Apple. She is grateful for UN Lab for providing the opportunity to better her understanding of communication systems.

Isabelle Brandicourt will graduate with a BS in Electrical Engineering from Northeastern University in December, 2023. She aspires to learn about many various aspects of electrical engineering and enjoyed the opportunity to work with Terahertz communications and signal processing.

Xavier Cantos-Roman received the B.S. in Telecommunications Technologies and Services Engineering from the Universitat Politècnica de Catalunya, Barcelona, Spain, in 2019. He is a member of the Ultra-broadband Nanonetworking Laboratory at Northeastern University, Boston, MA, where he is currently a Ph.D. candidate under the guidance of Dr. Josep M. Jornet. His research interests include the modeling and simulation of THz plasmonic devices, the study of mmWave and THz signals propagation and the design and experimental demonstration of joint communication and sensing systems at sub-THz frequencies.



Omar Shoura will graduate with a BS in Computer Engineering and Computer Science in 2024 from Northeastern University. He plans on furthering his understanding of Communications in Electrical Engineering by assisting in the work done by the UN Lab, through contributing to applications of Machine Learning in the Terahertz band.



Josep Miquel Jornet received the B.S. in Telecommunication Engineering and the M.Sc. in Information and Communication Technologies from the Universitat Politècnica de Catalunya, Barcelona, Spain, in 2008. He received the Ph.D. degree in Electrical and Computer Engineering from the Georgia Institute of Technology (Georgia Tech), Atlanta, GA, in 2013. Between 2013 and 2019, he was a faculty with the Department of Electrical Engineering at the University at Buffalo (UB), The State University of New York. Since August 2019, he is an Associate Professor in the Department of Electrical and Computer Engineering, the Director of the Ultrabroadband Nanonetworking Laboratory (UNlab), and a faculty Member of the Institute for the Wireless Internet of Things and SMART at Northeastern University (NU), in Boston, MA. His research interests are in terahertz communications, wireless nano-bio communications and the Internet of Nano-Things. In these areas, he has co-authored more than 160 peer-reviewed scientific publications, 1 book, and has been granted 4 US patents. Since July 2016, he is the Editor-in-Chief of the Nano Communication Networks (Elsevier) Journal, and severs in the steering committee of the ACM Conference Series on Nanoscale Computing and Communications. He is serving as the lead PI on multiple grants from U.S. federal agencies, including the National Science Foundation, the Air Force Office of Scientific Research and the Air Force Research Laboratory. He is a recipient of the NSF CAREER award and of several other awards from IEEE, ACM, UB and NU.