BROWN

Supplemental Statement of Brown University

FCC Experimental License File 0859-EX-CN-2021

October 8, 2021

This application is for facilities intended to be used by Prof. Daniel Mittleman[1] of the School of Engineering, for propagation measurement experiments on the Brown University campus in Providence RI. Prof. Mittleman is a qualified researcher in this field who has written extensively on the subject of terahertz propagation.[2] The purpose of the experiment is to gather measurement data in a complex environment at frequencies of approximately 100 GHz.

The research using this license would be used in furthering the research goals of NSF Award Number 1954780, Scaling WLANs to TB/sec: THz Spectrum, Architectures, and Control. The abstract of that award is attached in the Appendix. NSF POC is Dr. Alexander Sprintson, asprints@nsf.gov, (703) 292-8950.

The application is **not** filed pursuant to the recent Subpart I of the Part 5 of the Commission's Rules on Spectrum Horizons Experimental Radio Licenses, rather is a traditional experimental license. But we note that under Subpart I a 10 year license term is possible for multiple locations and we seek only a 3 year terms at a single location under essentially the same restrictions as a Subpart I license.

This application for a new license specifies the same operating parameters now authorized under an STA File 0313-EX-ST-2021, and invokes the provisions of § 5.61(c) for extending that license while this application is pending.

Previous licenses for our university this frequency have been limited to 6 months and we seek herein a 3 year license. As discussed below, such licenses are subject to the strict terms of §5.83 and can be immediately revoked in case of interference or changed circumstances such a new passive users of the same band. Our research program is a long term program that needs intermittent access to this spectrum for experiments. We are willing to take whatever steps are necessary to prevent interference to present or future allocated uses of this spectrum and have proposed several protection alternatives below. We see no reasons in the public interest to require renewals every 6 months - wasting both our resources, funded in part by NSF, and those of FCC and NTIA.

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[1] https://www.brown.edu/research/labs/mittleman/http%3A/www.brown.edu/research/labs/mittleman/people/daniel-m-mittleman

[2] https://scholar.google.com/citations?hl=en&user=O3T1F7cAAAAJ&view_op=list_works

We believe that the technology being tested here is "new technology in the context of 47 U.S.C. 157 and that the results from this experiment will help to further other use by others of spectrum above 95 GHz that now lacks any FCC rules for regular licensing. Therefore, the applicant asks that this application be treated under the provisions of Section 7, particularly with respect to the burden test of § 157(a):

> Any person or party (other than the Commission) who opposes a new technology or service proposed to be permitted under this chapter shall have the burden to demonstrate that such proposal is inconsistent with the public interest. (Emphasis added)

Some of the spectrum covered in the application overlaps with passive allocations. Thus, the applicant acknowledges that following provisions of §5.85(a)(2) apply to this application:

> (2) Applications to use any frequency or frequency band exclusively allocated to the passive services (including the radio astronomy service) must include an explicit justification of why nearby bands that have non-passive allocations are not adequate for the experiment. Such applications must also state that the applicant acknowledges that long term or multiple location use of passive bands is not possible and that the applicant intends to transition any long-term use to a band with appropriate allocations.

This application overlaps spectrum with primary passive allocations in the bands 100-102 GHz, per US Allocation Table Footnote US246. The applicant recognizes the primary nature of the passive allocations in these bands and that its use of these bands must not cause harmful interference. Pursuant to § 5.111(a) applicant will "use every precaution to ensure that it will not cause harmful interference to the services carried on by stations operating in accordance with the Table of Frequency Allocations of (P)art 2".[3]

The updated Resolution 731 adopted at the 2019 ITU World Radio Conference[4] states that

> "in the past, technological developments have led to viable communication systems operating at increasingly higher frequencies, and that this can be expected to continue so as to make communication technology available in the future in the frequency bands above 71 GHz;"

The resolution further invites ITU-R

> "to continue its studies to determine if and under what conditions sharing is possible between active and passive services in the bands above 71 GHz, such as, but not limited to, 100-102 GHz, 116-122.25 GHz, 148.5-151.5 GHz, 174.8-191.8 GHz, 226-231.5 GHz and 235-238 GHz"

These experiments include research requested by WRC-19 in Resolution 731 and the results will be available to ITU-R.

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[3] 47 C.F.R. § 5.111(a)

[4] ITU, *World Radiocommunication Conference 2019 (WRC-19) – Provisional Final Acts* (https://www.itu.int/en/ITU-R/conferences/wrc/2019/Documents/PFA-WRC19-E.pdf) at p.334

Statements required by § 5.85(a)(2)

Justification of why nearby bands that have non-passive allocations are not adequate for the experiment. The basic purpose of this experiment is propagation measurement in a complex outdoor environment. At these frequencies atmospheric absorption is a key issue and varies with frequency.[5] In many cases multipath is also important and varies with frequency. A wide variety of frequencies is needed to fully characterize the nature of propagation at the regions being studied.

Transmitters above 100 GHz are not in general production and are usually quite expensive. Brown has identified and purchased an off the shelf signal source that has the ability to transmit near each of the following frequencies: 100 GHz, 200 GHz, 300 GHz, and 400 GHz including the frequency range specified in the application and was available at a realistic price for this research. The transmitter uses a frequency multiplication technique and is not completely frequency agile.

Avoiding the passive bands that overlap with the tuning range would either require a much more expensive custom-made signal source or would result in less data collected on this area of the spectrum where little measurement data is available for complex paths.

Applicant acknowledgements: The applicant has no intention of long term use of these frequencies and understands that their use in multiple locations may not be possible. The sole purpose of this experiment is to generate propagation data and propagation models that characterize terrestrial propagation in the region above the 95 GHz which was until recently the upper limit of FCC radio service rules

Technical Issues in Application

The application asks for mobile use as the transmitter will be moved around the university campus in making the tests. Unlike most mobile use, the experiments will use a high gain antenna which will be directed in different azimuth during the tests. The antenna system cannot be readily indicated in the format of FCC Form 442 so we are taking this opportunity to clarify our intentions.

The antenna to be used in this project is listed below with key parameters:

Virginia Diodes Model Number	Frequency Range in Experiment (GHz)	Beam Width (Degrees)	Gain (dBi)
WR 8.0 CH	97.5-103	13	21

The application form submitted uses the 13-degree maximum beamwidth in all bands for simplification.

[5] FCC, "Millimeter Wave Propagation: Spectrum Management Implications", OET Bulletin No. 70, July 1997, https://www.fcc.gov/bureaus/oet/info/documents/bulletins/oet70/oet70a.pdf

The applicant will demonstrate below why it believes that this proposed experiment is not an interference threat to passive users consistent with FCC and international allocations. Brown believes that this explanation of non-interference meets the requirements of the "necessary showing" in § 5.702 to permit the uses authorized under Subpart I, which permits uses broader than what is requested herein.

The basic reason that the applicant believes there will be no interference is that there is no documented passive satellite use of the 100-102 GHz band, as discussed below.

Appendix B of the Docket 18-21 *Notice of Proposed Rulemaking* contained a "list of current and proposed passive satellite operations above 95 GHz was provided by the National Aeronautics and Space Administration." This list does not indicate any present or proposed passive satellite operations in either of the bands requested in this application during the anticipated license term. The World Meteorological Organization's Observing Systems Capability Analysis and Review Tool (WMO/OSCAR)[6] also indicates no present or proposed passive satellites operating during the anticipated license term.

Finally, we note that in a response from NASA to a FOIA request from Brown on satellite-based receivers in the 100-120 GHz, NASA stated

> In accordance with NASA's FOIA regulations (14 CFR §1206.307), a diligent search was conducted by the program office for the records you requested, and no responsive records were located. The search included an internal database and Government Master File.
>
> According to the program office, NASA does not have any information to definitively confirm whether or not there are any non-NASA domestic or foreign radio frequency (RF) passive sensors operating in the 100-102 GHz and 200-209 GHz bands.[7]

Brown would be willing to participate in any reasonable coordination activities with passive interests that the Commission find necessarily in order to comply with the letter and spirit of both §5.85(a)(2).

If there are operational passive satellites during the proposed license term in bands that might be adversely affected by transmissions proposed herein, the applicant proposes to prevent interference by ceasing all transmission during periods when such satellites are visible from the Brown University campus in the matter specified in the October 15, 2019 license it received in File Number 1756-EX-ST-2019.

Alternatively, Brown University is willing to submit requests for experiment time to FCC or an agency designated by FCC for coordination at least 30 days before any experimental operation, along with a stated amount of experimental time need in the requested period. Under this option, Brown will only conduct experiments in the passive bands during time that are explicitly approved by FCC or the agency designated for coordination. The applicant is open to alternative scheduling arrangements that will allow this experiment with reasonable advanced notification to

[6] https://www.wmo-sat.info/oscar/satellitefrequencies
[7] NASA Office of Communications, FOIA: 20-HQ-F-00154, December 19, 2019

the approving agency of experimental time needed and reasonable notification to Brown of approved time periods.

The closest radio astronomy facility with known capability at these frequencies is the MIT Haystack Observatory in Westford MA[8] which is 88 km away but without a line of sight path. The azimuth from Brown to Haystack is 355°. Out of an abundance of caution, Brown will avoid all transmissions in azimuths from 340° to 370°.

All transmissions will be at a zero degree or less elevation angle, which should contribute to the protection of any passive satellite sensors in these bands in both GSO and NGSO orbit. Atmospheric absorption is also a key factor that facilitates sharing in this range.

The April 10, 2020 Special Temporary Authority issued to Brown in File No. 0313-EX-ST-2021 contained a condition, which are discussed below.

> "Condition 5: All operations are limited to propagation measurement experiments, and Brown University shall be aware that long term or multiple location use of passive only allocations may not be possible. Brown University shall have no expectations that future requests for operational use of this frequency band will be approved. It is recommended Brown University ensure that future operational use of this equipment be conducted in appropriately allocated frequency bands."

The applicant has no objection to continuing the terms of the first sentence in any subsequent license for 100-102 GHz. However, the applicant questions whether the second sentences statement of concurrence is consistent with statute, regulation, or precedent. This is a license application for intermittent use of this spectrum for valid experiments and we are willing to take any necessary steps to avoid interference to allocated uses of this band. We have never asked for nor do we intend any "operational use" of this band. Brown University is a research university and seeks to use this spectrum for intermittent research on a noninterfering basis to other allocations.

NTIA's concurrence is part of the process provided for in the FCC/NTIA Memorandum of Understanding of January 2003.[9] This MOU provides for FCC and NTIA to provide each other with "notice of all proposed actions that could potentially cause interference" to operations regulated by the other agency. It does not give NTIA veto power over FCC actions but rather states that "The FCC and NTIA will resolve technical, procedural, and policy difference by consensus whenever possible".

The NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management (Redbook) provides in Section 9.16.2 rules for interagency review of application including NTIA coordination of FCC license applications. These rules provide that

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[8] http://www.haystack.mit.edu/

[9] FCC and NTIA Memorandum of Understanding on Spectrum Coordination, January 31, 2003 (https://www.ntia.doc.gov/files/ntia/publications/fccntiamou_01312003.pdf)

> Agencies may only vote to table another agency's application if harmful interference is anticipated, there are technical errors in the application that affect the electromagnetic environment or the request violates NTIA radio spectrum policy. If an agency tables an application due to a violation of NTIA radio spectrum policy, the tabling agency must cite the specific policy violated

We urge FCC to remind NTIA of the applicability of these provisions and the requirement that the issue is whether actual "harmful interference is anticipated", not whether IRAC members agree with the present provisions of § 5.85 which were presumably coordinated with NTIA under the terms of the MOU.

We cite above the provisions of 47 U.S.C. § 7(a) which places a special burden on a "party (other than the Commission) who opposes a new technology or service proposed to be permitted under this chapter".

We also point out the codified terms of 47 C.F.R. § 5.85(a), which were recently updated, presumably with coordination with NTIA under the MOU, in August 2015.[10]

The applicant explicitly acknowledges that any Experimental Radio Service license is subject to the terms of § 5.83:

> **§5.83 Cancellation provisions.**
> The applicant for a station in the Experimental Radio Services accepts the license with the express understanding that:
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> (a) The authority to use the frequency or frequencies permitted by the license is granted upon an experimental basis only and does not confer any right to conduct an activity of a continuing nature; and
>
> (b) The grant is subject to change or cancellation by the Commission at any time without notice or hearing if in its discretion the need for such action arises. However, a petition for reconsideration or application for review may be filed to such Commission action.

Thus, any actual interference or even any *changed circumstances* resulting with an increased possibility of interference could result in immediate cancellation of the license that Brown is requesting, without any explanation required explanation by FCC (or NTIA).

The STOP BUZZER contact for this experiment is Dr. Mittleman who can be reached at (713) 992-4137, daniel_mittleman@brown.edu

Any questions about this application should be directed to Dr. Michael Marcus, consultant to Brown University, 301-229-7714, mjmarcus@marcus-spectrum.com

[10] 80 FR 52414, Aug. 31, 2015

APPENDIX

Abstract of NSF Award Number 1954780
Scaling WLANs to TB/sec: THz Spectrum, Architectures, and Control

(https://www.nsf.gov/awardsearch/showAward?AWD_ID=1954780)

Gigabit-per-second scale wireless transmission is already commercially available in wireless local area networks (WLANs). For example, the latest Wi-Fi standard at 60 gigahertz promises data rates up to 100 gigabits per second The objective of this project is to realize the next order of magnitude in data rate, spectrum access, directionality, and spatial multiplexing targeting terabit per second WLANs with a low-latency control plane that supports mobile clients. Namely, scaling spectrum access towards terahertz will provide a key ingredient to realize the sixth generation of wireless networks. Thus, this project will result in the design, implementation, and proof-of-concept demonstration of a WLAN architecture using spectrum from 100 gigahertz to 500 gigahertz with range exceeding 100 meters.

This project targets to scale multi-stream data rates to terabit per second for mobile clients via the following integrated research thrusts. The first project thrust provides two underlying building blocks for steerable and highly directional beams from 100 GHz to 500 GHz: (1) A first-of-its-kind pixelated metasurface waveguide will be developed to dynamically steer a THz beam via electrical switching of the meta-elements. (2) A THz leaky waveguide's unique property of coupling frequency and steering angle will be exploited for the first time to provide frequency-selective adaptive beam steering. The second project thrust targets scaling to high-density user populations. First, new smart reflecting surfaces will be developed that will enable engineered non-specular non-line-of-sight paths. This thrust will experimentally study the achievable network density under different architectural components, identifying empirical limits at THz scale of packing many simultaneous physical links into a limited spatial area. The third project thrust targets to provide uninterrupted Tb/sec scale communication even in the presence of user and environmental mobility. The project's methodology aims to scale the control plane to a large and dense mobile WLAN via a novel spectral signature for each transmission and reception angle. Namely, with a terahertz rainbow emitted from a leaky waveguide, a unique angular signature is derived for each path, whether line of sight, a specular reflection, or an engineered path.