Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	ET Docket No. 21-186
	)	GN Docket No. 14-177
Emission Limits in the 24.25-27.5 GHz Band	)	
	)	
	)	

REPLY COMMENTS OF THE AMERICAN GEOPHYSICAL UNION, AMERICAN METEOROLOGICAL SOCIETY and NATIONAL WEATHER ASSOCIATION

Lexi Shultz
VP, Science Policy & Government Relations
American Geophysical Union

Keith Seitter
Executive Director
American Meteorological Society

Janice Bunting
Chief Executive Officer
National Weather Association

July 26, 2021

The American Geophysical Union (AGU), the American Meteorological Society (AMS) and the National Weather Association (NWA) appreciate the opportunity to provide reply comments in this proceeding of this docket seeking input on Part 2 and Part 30 of the Commission's rules for out-of-band emission (OOBE) limits into the 23.6-24.0 GHz passive spectrum. The membership of AGU, AMS and NWA include the world's preeminent atmospheric, oceanic, hydrological and other physical scientists as well as operational practitioners of environmental modeling and forecasting. These scientists and practitioners depend heavily on technology that is reliant on passive bands for their forecasts, models and research to better understand the Earth's atmosphere, oceans and land to predict natural hazards that impact lives, property and economies in the U.S. and across the world.

The following is a summary of the key points of this reply comment:[1]

[1] References throughout this text to the other comments and reply comments in this proceeding are available here: https://www.fcc.gov/ecfs/search/filings?proceedings_name=14-177&sort=date_disseminated,DESC

1. At a minimum, the Commission should align its rules with the WRC-19 limits on emissions from active operations in the 24.25-25.25 GHz band into passive sensing in the 23.6-24.0 GHz band.

2. The Commission is encouraged to implement more stringent rules that expedite limits on emissions to 2024, consistent with European regulators, given continued concerns from the Earth science community about major interference to weather modeling that will ensue before 2027 under WRC-19 rules.

3. The Commission should require licensees to use only Total Radiated Power (TRP) to measure compliance with these emission limits to aid the Earth science community in estimating impacts to passive band sensing measurements.

4. To minimize future conflicts related to passive bands, it is recommended that the Commission develop processes for further and continued dialogue with the science community to develop Service Rules and out-of-band (OOB) emission levels for passive bands.

I. At a minimum, the Commission should align its rules with the WRC-19 limits on emissions from active operations in the 24.25-25.25 GHz band into passive sensing in the 23.6-24.0 GHz band.

A. The Science Behind 23.8 GHz Passive Measurements

Experts from AGU, AMS and NWA are concerned about contamination of passive measurements at 23.8 GHz and other key passive bands of critical importance in the generation of accurate and timely meteorological forecasts particularly through numerical weather prediction. The 24 GHz passive band is a unique spectral feature of very high importance to operational services.

Recent extreme events in many places (North American heatwaves, large wildfires in multiple states, severe and widespread drought, and historic flooding in Europe and China)[2] demonstrate the importance of advance warning for critical weather events. Sensing at 23.8 GHz is important to quantify the amount of water vapor in the Earth's atmosphere. Water vapor is transient; understanding where water vapor is changing is essential for improving weather forecast skill, including track and intensity forecasts of major storm systems. Because satellites provide global coverage in their orbits around the Earth, they are the most comprehensive source of atmospheric water vapor estimates. The term 'estimates' is used because satellites do not directly measure water vapor like instrumentation on the ground, weather balloons, and aircraft. The satellite estimates are reliable due to the maturity of the science of radiative transfer, however, and the best estimates usually require a multi-spectral approach (i.e., the use of multiple satellite sensing bands around and beyond 24 GHz).[3]

Water vapor is most often quantified in terms of total precipitable water, or TPW. This quantity is measured in inches as if water molecules in an imaginary column of the atmosphere are condensed into rain and fall into a rain gauge. There is usually more water vapor near the surface, where 23.8

[2] Source: Extreme Events | National Centers for Environmental Information (NCEI) formerly known as National Climatic Data Center (NCDC) (noaa.gov) (https://www.ncdc.noaa.gov/climate-information/extreme-events)
[3] Source: Remote Sensing Systems (remss.com) (https://remss.com/measurements/atmospheric-water-vapor/#:~:text=Microwave%20Measurement%20of%20Atmospheric%20Water%20Vapor%20Because%20of,to%20the%20high%20signal-to-noise%20ratio%20for%20this%20measurement.)

GHz sensing is particularly valuable and unique, and less at greater altitude. Meteorologists use TPW as an indicator for precipitation predictions and particularly whether flooding might be anticipated from thunderstorms.

Without the use of an Earth sensing band at 23.8 GHz, satellite-based estimates of TPW over the contiguous United States may degrade more than 15%.[4] Explained differently, 23.8 GHz is responsible for refining estimates of TPW to more than a quarter of an inch on humid summer days, which could alter forecasts for the eventual coverage and intensity of afternoon thunderstorms, which is crucial to the transportation industry (especially aviation).

Simultaneous use of an Earth sensing band with expanding wireless operations is likely to be increasingly unsustainable to preserve the quality TPW estimates based on 23.8 GHz. Because satellite radiometers are sensing the background energy from the atmosphere instead of a particular signal, it will be difficult to determine whether terrestrial radio signals have contaminated the signal unless it is overwhelming. Even if the probability of contamination could be ascertained, it is impossible to separate the atmospheric emissions from any radiometric sensing of terrestrial radio signals. In short, the prospect of contamination may decrease the use of 23.8 GHz observations (since when there is a possibility that measurements are contaminated, the information must be omitted from models), which could make forecasts from numerical weather prediction less precise, reverting our predictive capability, rather than improving it.

Therefore, protecting Earth sensing at 23.8 GHz necessitates the most restrictive thresholds for adjacent band interference from non-atmospheric signals. With loss in the confidence of 23.8 GHz TPW estimates from satellite, the quality of weather predictions, reliant on those estimates, is likely to decrease, especially if such contamination becomes evident or suspected in large geographic portions of the United States.

As stated in written testimony for a hearing of the U.S. House Committee on Science, Space and Technology on July 20, 2021,

"There is no mitigation for such contamination of weather sensors – the best one can do is identify that contamination and avoid propagating that data into supercomputers and the weather models."[5]

It is essential that the Commission get these limits right. The ramifications of contamination of any of the passive bands would be significant and impact many weather-sensitive segments of the American economy and the public.

B. ITU WRC-19 Limits and Passive Use to Support Operational Meteorology

We would like to support the comment of the National Academies of Sciences' Committee on Radio Frequencies (CORF) in appreciating the Commission's recognition in the *Public Notice* on the critical importance of protecting the 23.6 – 24.0 GHz band [23.8 GHz passive band], which is

[4] Liu, Quanhua; Cao, Changyong; Grassotti, Christopher; Lee, Yong-Keun. 2021. "How Can Microwave Observations at 23.8 GHz Help in Acquiring Water Vapor in the Atmosphere over Land?" *Remote Sens.* 13, no. 3: 489. https://doi.org/10.3390/rs13030489

[5] "Spectrum Needs for Observations in Earth and Space Science", Committee on Science, Space and Technology, U.S. House of Representatives, July 20, 2021. Written Testimony of David G. Lubar.

reserved for scientific use and per 47 CFR §2.106 footnote 5.340 where, "All emissions are prohibited."

Following study by numerous ITU member states and regional organizations, Resolution 750, as contained in the 2020 Radio Regulations, based upon decisions at the 2019 World Radiocommunications Conference (WRC-19), established a split schema requirement for emissions from IMT[6] (International Mobile Telephony) stations operating in the 24.25-24.45 GHz or 24.75-25.25 GHz bands.[7]

As noted in the National Telecommunication and Information Administration's (NTIA) comment, the Commission should update section 30.203 of its rules to conform with Table 1 of the Public Notice and provide that, for IMT stations operating in the 24.25-24.45 GHz or 24.75-25.25 GHz bands, the total radiated power of emissions in any 200 MHz of the 23.6-24.0 GHz passive band shall not exceed the following limits:

- -33 dBW for base stations brought into operation on or prior to September 1, 2027;
- -39 dBW for base stations brought into operation after September 1, 2027;
- -29 dBW for user equipment brought into operation on or prior to September 1, 2027; and
- -35 dBW for user equipment brought into operation after September 1, 2027.

AGU, AMS and NWA see adopting these rules based on the decisions at the WRC-19 as a minimum step to protect passive microwave satellite observations that contribute significantly to weather forecasting. However, we believe that quicker implementation of the more stringent levels is required before 2027 to protect weather forecasting capabilities and their impact on U.S. lives, property and livelihoods.

II. The Commission is encouraged to implement more stringent rules that expedite limits on emissions to 2024, consistent with European regulators, given continued concerns from the Earth science community about major interference to weather modeling that will ensue before 2027 under WRC-19 rules.

A. Interim Protection Level of -33 dBW and Contributors to OOB Emissions

AGU, AMS and NWA experts believe that base stations at the -33 dBW OOBE level will impact passive remote sensing measurements currently received from satellites from the U.S. (JPSS, DMSP follow-on systems in development, as well as Coriolis and Aqua), Europe (Metop and the Copernicus CIMR mission, Sentinel-series), India (Megatropiques), Japan (GCOM), France (SARAL) as well as China and Russia.[8] The protection limit effectiveness will be determined by the:

a) density of installation of terrestrial broadband systems,
b) timeframe when such systems are deployed, and

[6] We recognize that IMT is ITU terminology that is not utilized by the Commission. In this context, mobile services in the millimeter wave bands above 24 GHz, such as regulated in Part 30 at Upper Microwave Flexible Use Service (UMFUS) and popularly referred to as "5G high-band" are what we are discussing in the reply comment.

[7] RR-2020-00013-Vol.III-EA5.pdf (itu.int) page 519.

[8] JPSS – Joint Polar Satellite System, DMSP – Defense Meteorological Satellite Program, Metop (Meteorological Operation) satellites are Europe's contribution to the Initial Joint Polar System shared with NOAA, CIMR – Copernicus Imaging Microwave Radiometer, GCOM is the Global Change Observation Mission operated by the Japanese Aerospace Exploration Agency (JAXA) and joint India/France mission SARAL – Satellite with Argos and AltiKa. A more complete satellite list is shown in Table 1 of the CORF filing in this proceeding.

c) amount of energy from these systems that is directed at the sensitive radiometers on the satellite systems noted above. Though base stations may be pointed with a downward tilt, those signals can bounce off the ground, off buildings, and off terrain to move energy in a direction that can be detected by the sensitive satellite-based radiometers that perform passive measurements essential for operational meteorology and environmental applications.

We support the following NTIA statement: "*In developing the two-step approach for the OOBE limits, experts at the ITU considered that there would be gradual deployment of 5G systems in the bands at issue. They recognized that, because the number of 5G systems deployed prior to September 1, 2027, could not be predicted with certainty, it is possible the interim OOBE limits could become ineffective if 5G deployment exceeds expectations. For purposes of calculating the ultimate values for the post-2027 OOBE limits, the* [spectrum] *experts at the ITU based their assessment on the presumption that all 5G systems in operation would be compliant with the more stringent* [-39 dBW] *limits. The reality could be a bit different …*"

B. Timing and Compliance Considerations

We also support NTIA in its statement urging the Commission to have licensees comply with the -39 dBW limit as soon as practical and not wait until the ITU prescribed September 1, 2027: *"[NTIA] … we further ask that the Commission urge licensees to comply with the ultimate, post-September 2027 OOBE as soon as reasonably possible. We also ask that the Commission consider adopting measures that would incentivize licensees to deploy systems that comply with the more stringent, post-September 2027 OOBE limit even before 2027. NTIA is concerned that systems deployed before September 2027 under less stringent limits could result in harmful interference to passive weather satellite sensors, especially where such deployments are densified."*

NTIA goes on further to say, *"As such, encouraging manufacturers, suppliers, innovators, entrepreneurs, standards bodies, and service providers to meet the -39 dBW/200 MHz OOBE limit as soon as possible is critical to ensuring U.S. leadership in 5G and protecting vital weather and earth observation data obtained from satellite-based passive sensors."*

Our three scientific organizations would like to support the call to clarify the Commission rules to remove ambiguity to clarify in Part 30 that base stations and user equipment modified or replaced after September 1, 2027, must comply with the post-2027 (e.g., -39 dBW) OOBE levels. We would like to further recommend that **all heritage equipment installed prior to 2027 that does not meet the more stringent limits be given a sunset date of September 1, 2028, for retrofit or replacement** to comply with the more stringent -39 dBW OOBE limit.

As was noted in a July 20, 2021, hearing of the U.S. House Committee on Science, Space and Technology, this should not be treated as a "we versus them" scenario by the Commission. Despite the importance of maintaining the accuracy of weather forecasts, the weather enterprise is not a competitor of the telecommunications industry, and no one should characterize this issue as one of "us versus them". The telecommunications industry is an essential partner in delivering urgent weather messages to cell phones and establishing communications immediately after a disaster to assist in the response.

If the telecommunications industry and the Commission could develop a better understanding of how the satellite sensors (radiometers) are measuring energy for the determination of weather information and how those observations improve weather forecasts it would assist the Commission in decisions regarding the protection of passive spectrum. We believe that industry partners and

regulators can work with the scientific and operational weather community to deploy equipment in proximity to pre-existing spectrum for Earth sensing without contamination of this irreplicable data.

C. Characterizing Passive Band Contamination

We do not know if passive band contamination at 23.8 GHz is already occurring. As described by the Geoscience and Remote Sensing Society of the Institute of Electrical and Electronics Engineers (IEEE GRSS) submission in this proceeding, "*There are three levels of contamination to passive measurements … Obvious, Insidious, and Undetectable.*" **Undetectable** is below the measurement threshold of passive sensors, while **Obvious** is high enough to indicate a non-natural source and is discarded, leaving that location as unmeasured. The real problem is in the middle range with **Insidious** contamination.

Insidious contamination refers to when the corrupting signal is small enough to realistically look like desired natural emissions, but large enough to affect the data. We are concerned that quality checks of data in the satellite data assimilation process would not reject this data as invalid, as would happen with obvious contamination, which would mean the data may be inserted into numerical weather predictions, corrupting the accuracy of environmental model outputs.

The IEEE GRSS comment in this proceeding describes why these measurements are important. *"Measurements are required worldwide (throughout the volume of the atmosphere) to obtain initial conditions for the global numerical weather prediction models necessary for weather forecasting. Passive microwave observations contribute around 40% of the overall improvement of short-range weather forecast accuracy, plus a further 10% from active microwave."*[9]

Without space-based measurements, and the implementation of the appropriate detection algorithms, in add-on capabilities to operational weather satellites making passive measurements, the determination of when contamination occurs for a given area is nearly impossible. Performing RF surveys from space or airborne platforms would establish a baseline and could be used to eliminate data from space sensors for further use, but that is a less precise method that would result in impact to a much larger amount of data, which would deprive its use in forecasting models.

Again, it's important that the Commission get this out-of-band-emission value right and require compliance within an appropriate timeframe.

D. Wireless Equipment Manufacturer Comments

We also note comments in this proceeding from both Nokia and Ericsson regarding the potential to comply with these limits by the 2027 date.

Both manufacturers of base station equipment indicated they could meet the timeline for the -33 dBW/200 MHz with Ericsson indicating they have initial products planned for Q2/Q3 of 2021.

Ericsson suggests it is not clear how the actual equipment will perform for the more stringent limit and that it is working to improve when it achieves the more stringent value, but an accelerated timeline is not guaranteed. Nokia also indicated they are working toward a goal to ensure compliance

[9] Final report of the Radio Frequency Interference (RFI) Workshop, European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, UK, September 13-14, 2018.

with the more stringent limit by September 1, 2027. Their statements don't guarantee they will make that date.

However, Nokia (of Finland) and Ericsson (of Sweden) are also the predominant suppliers for this equipment in Europe. The European Union decided to implement the ITU two-step OOBE limits on a quicker timescale.

In the European Union's Commission Implementing Decision, they require compliance with the -39 dBW limit by January 1, 2024, which is a full 44 months before the ITU limit being considered in the U.S. [10] We note both manufacturers were silent on how they would develop and field -39 dBW compliant equipment in Europe over three years earlier.

Considering that a global numerical weather prediction model covers the entire volume of the atmosphere for the entire planet, having equipment in one region with more stringent protection limits and the rest of the world still overflying terrestrial infrastructure that is subject to a less stringent limit (that may be causing data contamination), will require different handling for data being assimilated from each region. And considering that all the major agencies share data with each other, this drives different data assimilation both with and without 23.8 GHz, for all countries that perform modeling, which will likely degrade forecasting results.

III. The Commission should require licensees to use only Total Radiated Power (TRP) to measure compliance with these emission limits to aid the Earth science community in estimating impacts to passive band sensing measurements.

A. Measurements and Limit Applicability

We note the Commission asked what measurement technique or techniques should be allowed for licensees to prove compliance. We agree with NTIA that total radiated power (TRP) should be used.

We also recognize the support for TRP that Ericsson indicated in their comments,
"Ericsson supports the decision to measure these unwanted emission limits in terms of Total Radiated Power (TRP). Mobile terrestrial systems are increasingly relying on large arrays of active antenna elements in their design."

The scientific community requires a method to take the measurement data from licensees and determine if those levels may be detrimental to passive sensing measurements. The calculation process is not straightforward, and the use of multiple methods by the industry would only contribute to the difficulty. We recommend only one measurement method be utilized by equipment providers and licensees, TRP.

[10] Official Journal of the European Union, L 127/13, "Commission Implementing Decision (EU) 2019/784 of 14 May 2019 on harmonization of the 24.25 – 27.5 GHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services in the Union" consolidated with Official Journal of the European Union, L 138/29, "Commission Implementing Decision (EU) 2020.590 of 24 April 2020 amending Decision (EU) 2019/784 as regards an update of relevant technical conditions applicable to the 24.25-27.5 GHz frequency band," https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02019D0784-20200430&from=EN

IV. To minimize future conflicts related to passive bands, it is recommended that the Commission develop processes for further and continued dialogue with the science community to develop Service Rules and out-of-band (OOB) emission levels for passive bands.

A. Broader Use of Passive Measurements and Future Impacts

Although the Commission is focused upon OOBE limits for 24 GHz in this proceeding, we would like to note that the data derived from the 23.8 GHz passive band is an important ingredient in numerical weather prediction and that it is utilized in concert with passive measurements in other bands.

As stated in the final report of a Radio Frequency Interference Workshop held with numerical weather prediction and spectrum management experts in September 2018:

"All spectral bands [1.4 – 1.427, 6.425-7.25, 10.6-10.68, 10.68-10.7, 18.6-18.8, 23.6-24, 31.3-31.5, 31.5-31.8, 36-37, 50.2-50.4, 52.6-54.25, 54.25-59.3, 59.3-59.5, 60.40-61.15, 63-63.5, 86-92, 100-102, 109.5-111.8, 114.25-116, 116-122, 148-151.5, 155.5-158.5, 164-167, 174.8-182.0, 182.0-185.0, 185.0-190.0, 190.0-191.8 GHz] contribute to the overall forecast impact achieved with passive microwave satellite data. They do so through the varied and complementary information they provide on the Earth system. …"[11]

The report continues,
"The impact of a given channel is often reliant on the presence of other channels, and therefore the attribution of the impact to a single channel of a multi-channel instrument would be inappropriate."

It is important to note the main microwave passive sensor on operational U.S. satellites, the Advanced Technology Microwave Sensor (ATMS) on the Joint Polar Satellite System (JPSS), has 22 passive band sensing channels.

The 24 GHz band is used in conjunction with data gathered at 31 GHz and with temperature soundings in the 50 – 60 GHz region.

"The 50-60 GHz temperature-sounding band provides the largest impact on tropospheric and stratospheric forecast skill for all [numerical weather prediction] centres. Successful use of the data relies on the availability of measurement data from the channels around 23.8 and 31.4 GHz to identify contributions from clouds. Thus, the impact on the channels around 23.8 and 31.4 GHz is equally important and indispensable to exploit the 50-60 GHz temperature-sounding bands."[12]

Although the Commission is examining the Part 2 and Part 30 rules applicable to the 24 GHz band in this proceeding, our scientific organizations would like to emphasize that contamination of the 50.2-50.4 GHz passive band from services adjacent both below and above this spectrum are also of great concern. As the Commission has already provided for these services in the Table of Allocations, **we highly recommend scientific input and advice before the creation of service rules and the OOBE limits for 50.4-52.6 GHz, and any other actions associated with 48.2-50.2 GHz OOBE**.

---

[11] Final report of the Radio Frequency Interference (RFI) Workshop, European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, UK, September 13-14, 2018.
[12] *Ibid.*

Our organizations appreciated the comments of Acting FCC Chairwoman Jessica Rosenworcel on July 16, 2020, when she reflected on U.S. reliance on millimeter wave terrestrial broadband: *"I think that the FCC made a mistake a few years ago when it focused all of its energy in the early 5G days on spectrum called 'millimeter wave'. Those are airwaves that are really high up there with lots of capacity, but their signals don't travel very far, but that means you have to have lots of ground-based facilities to make those signals viable and that's a really costly thing to do. And so, if we just relied on millimeter wave spectrum, you would actually grow the digital divide with 5G. The good news is that in the last year and the last several months we really recognized that we had to pivot from millimeter wave spectrum to mid-band spectrum. That's the sweet spot to deploy 5G across the country, because it has a mix of capacity and propagation that is really ideal for this technology."* [13]

AGU, AMS and NWA also note two statements by David Lubar from The Aerospace Corporation from the July 20, 2021, hearing of the U.S. House Committee on Science, Space and Technology that accurately reflect our organizations' views on the nuances of these 24 GHz considerations and related passive bands:

"Communications receivers, such as those in our smartphones or in ground stations, rely on an active transmitted signal originating from an antenna to carry our voice or videos. But space- based passive sensors are very different technologies that do not have the same functionality or protection requirements. Unlike communications receivers, these satellite microwave radiometers are extremely sensitive power measurement devices for detecting energy emissions. One analogy about the sensitivity of space-based passive measurements: it is like trying to hear a whisper in San Francisco while standing 500 miles away in San Diego."

"… A traditional communications device is designed to detect and maximize the signal content while discarding the noise, but a radiometer is designed to detect the small changes in that noise level caused by properties in the atmosphere. This critical difference between radiometers and traditional communications devices may not be understood by communications engineers who have not worked with these sensitive instruments. And it may also not be understood that these space-based radiometer measurements are crucial to weather forecasting."[14]

Perhaps a more measured approach to future decisions associated with potential impacts to passive bands is needed. We urge direct scientific input into future FCC proceedings in this area, engaging science experts who understand the impacts to weather sensors in these passive bands, to arrive at an appropriate protection mechanism, with timing accounting for appropriate peer review. The FCC should strongly consider engaging outside scientific experts, bringing in external resources to properly advise the Commission on these devices, to avoid repeating the issues that have plagued this proceeding. To minimize future conflicts related to passive bands, the Commission should develop processes for further and continued dialogue with the science community to develop Service Rules for passive bands.

[13] "Watch: A conversation on America's digital connectivity." Axios Events. https://www.axios.com/axios-event-5g-future-fcc-chair-302fecf5-f6af-4f8f-99a7-4d9ce0fa37e9.html

[14] "Spectrum Needs for Observations in Earth and Space Science", Committee on Science, Space and Technology, U.S. House of Representatives, July 20, 2021. Written Testimony of David G. Lubar.

V. Additional Comments

A. Comparison of Limits for point-to-point microwave service and Part 30 OOBE

In their comment on this proceeding, Qualcomm indicates they believe the FCC's current -13 dBm/MHz unwanted emissions limit that applies below the lower 24.25 GHz edge of the Upper Microwave Flexible Use Service (UMFUS) band should be "maintained for mobile operations …" because that limit provides adequate interference protection of the "… EESS passive systems in the 23.6-24.0 GHz band." Qualcomm continues in a footnote citing that "commercial and federal users have deployed 40,000 point-to-point microwave links directly adjacent to the 23.6-24.0 GHz band … and notably, there has been no indication that any of these links have caused harmful interference to passive sensors in the 23.6 – 24.0 GHz band."

Qualcomm uses this logic to defend the use of -13 dBm/MHz, a value that is mathematically identical to -20 dBW/200 MHz, to protect mobile services.

We disagree with their reasoning. Point-to-point microwave systems are operated on the face of the Earth, fixed pointed from a transmit to a receive antenna. Although the signal from the transmitter may spread to radiate beyond the diameter of the receive antenna, its geometry is not as likely to be detected by passive radiometer instruments in space. This is analogous to a well -focused flashlight beam mounted parallel to the surface of the Earth. That light beam will spread as it travels away from the source, but if the light is held steady, little energy should reflect upward. And the density of point-to-point microwave systems will not match the potential high-density installation of terrestrial broadband systems as they communicate with user equipment. The overall energy from such microwave systems might factor into the overall apportionment of energy that leaks into the passive frequency range, but there is no comparison between the potential for contamination from the example cited by Qualcomm and a terrestrial broadband system.

A longstanding argument is that there are about 40,000 point-to-point microwave towers operating below the passive band at 21.2-23.6 GHz, and they are not creating interference to passive measurements at 23.8 GHz. Qualcomm is not the first to make this argument. These are significantly different systems, and a direct comparison between them is inaccurate and inappropriate. Getting exact number estimates for terrestrial broadband density is difficult, but we can estimate worst case values by both US population and land area: By population, one rule of thumb is that one base station site is needed for every 1,000 subscribers.[15] That would be on the order of 330 million base stations. By land area: According to the IEEE Communications Society (ComSoc), about 50 base stations are required per square km.[16] For nationwide coverage, if we apply these assumptions to the land area, that would be about 480 million base stations. Both values are a significantly larger number than 40,000 point-to-point microwave towers.

Further review of reply comments in this proceeding by Choyu Networks merit the Commission to examine any new standards and device capability that has the potential to increase emission levels beyond what was contemplated when OOBE limits were formulated. High transmission power (3GPP Class 1 devices) user equipment for Fixed Wireless Access and the introduction of outside-

[15] Source: operator watch.com "How many 5G Cell Towers and Base Stations Worldwide?" https://www.operatorwatch.com/search?q=How+many+5G+Cell+Towers+and+Base+Stations+Worldwide

[16] Source: IEEE Communications Society (ComSoc) https://techblog.comsoc.org/2020/08/07/5g-base-station-deployments-open-ran-competition-huge-5g-bs-power-problem

plant 5G repeaters that can be used for connectivity to both Fixed Wireless and Mobile User Equipment (UE) should both be evaluated before a final decision is made on adequacy of emission limits.

Choyu Networks states:
"…we find that new class 1 fixed-wireless UEs yield an increase in OOB emissions that could be 12dB or greater (depending on whether specific [fixed wireless access user equipment] *FWA UEs implement the 3GPP power control algorithm developed to extend the battery life of handheld UEs."*

Choyu Networks continues:
"Fixed-wireless deployments will thus contribute more OOB emissions in the 23.8GHz band than anticipated by the ITU when WRC-19 agreed to a limit of -29 dBW/200MHz-UE. "If these new network elements or capabilities invalidate the assumptions that were used to result in the WRC-19 limits, then the Commission should determine if the limits to be levied are adequate to protect the adjacent passive bands."

Summary
The use of passive microwave spectrum allocations for Earth exploration-satellite services is an essential component to the development of weather forecasts. Characteristics of terrestrial emissions, such as power levels, deployment schedule, and direction of emissions, will determine if contamination of adjacent passive bands alters the accuracy of weather forecasts that are an output from complex numerical weather prediction models. Improvements in numerical weather prediction performance over the past 20 years can be attributed to satellite observations, especially microwave sensing of water vapor, such as 23.8 GHz and other frequencies.[17]

To achieve global uniformity in the quality of passive microwave meteorological observations, the Commission should adopt the ITU limits from Resolution 750. The Commission should also adopt the more stringent limits in the two-step process sooner than the ITU Radio Regulations require. Finally, the Commission should apply the stringent limits to all transmitters after September 1, 2028, to enable consistent use of the 23.8 GHz sensing band and improve enforcement.

Testing techniques levied on licensees to validate the OOBE levels should be limited to Total Radiated Power, a single technique. Such a technique will improve the ability to relate those measured levels to the actual contamination levels in passively sensed weather observations. Despite arguments that existing point-to-point microwave towers operating in frequencies just below 23.8 GHz support looser power limits in the current proceeding, the number and proposed density of base stations operating in the 24 GHz band should dictate stricter power limits.

To minimize future conflicts related to passive bands, the Commission should develop processes for further and continued dialogue with the science community to develop Service Rules and OOBE levels for passive bands. Doing so would establish baseline expectations for allowable deployment strategies ahead of subsequent proceedings for frequencies adjacent to existing passive Earth sensing. Contamination from radio frequency interference will have wide ranging ramifications, leading to a degradation in weather forecasts important to several economic sectors, and/or a

[17] Geer, A. J., F. Baordo, N. Bormann, P. Chambon, S. J. English, M. Kazumori, H. Lawrence, P. Lean, K. Lonitz, and C. Lupu. "The Growing Impact of Satellite Observations Sensitive to Humidity, Cloud and Precipitation." Quarterly Journal of the Royal Meteorological Society 143, no. 709 (October 2017): 3189–3206. https://doi.org/10.1002/qj.3172.

reduction in the amount of warning lead time for dangerous weather events, especially if contamination occurs in multiple Earth exploration-satellite service bands.

We appreciate the opportunity to provide input into this proceeding.