Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	WT Docket No. 24-243
	)	
Lower 37 GHz Band	)	
	)	
	)	
Use of Spectrum Bands Above 24 GHz for Mobile Radio Services	)	GN Docket No. 14-177
	)	

**COMMENTS OF THE
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES**

The National Academy of Sciences, through its Committee on Radio Frequencies (hereinafter, CORF), hereby submits its Comments in response to the Commission's Further Notice of Proposed Rulemaking (FNPRM; FCC 25-24, released April 29, 2025), seeking comment on whether to revise the emissions limits for Upper Microwave Flexible Use Service (UMFUS) operations above 37 GHz to protect critical passive sensors in the adjacent 36-37 GHz band. In these comments, CORF outlines the importance of the 36.0-37.0 GHz Earth Exploration Satellite Service (EESS) band and reiterates and expands upon its earlier comments[1] assessing that the out-of-band emission (OOBE) limits defined in Part 30.203 are inadequate to protect this passive services band and urging adoption of the more stringent limits proposed in Resolution 243 (WRC-19).

[1] CORF Comments in Docket 24-243, filed September 27, 2024 ("CORF Sept. 2024 Comments").

I. Introduction: Earth Exploration Satellite Service / Earth Remote Sensing in the 36-37 GHz band and the Vulnerability of Passive Services.

Spaceborne microwave and millimeter wave remote sensing of the state of Earth's atmosphere and surface provides information that is essential for accurate weather forecasting and climate monitoring. Consequently, the data collected by these instruments has enormous impact on public safety, health, and the U.S. economy. The 36-37 GHz EESS (passive) band is one of the key passive remote sensing bands across the microwave and millimeter wave spectrum that enable spaceborne sensors to analyze the state of Earth's atmosphere and surface. The 36-37 GHz band, together with other EESS (passive) bands such as those near 22 GHz and 60 GHz, provides the Earth observing system with sensitivity to many critical variables. For example, bands near the 22 GHz rotational emission line of the H_2O molecule are particularly sensitive to atmospheric water vapor, while multiple bands strategically placed within the 60 GHz spin-rotation band of the O_2 molecule are particularly valuable for using thermal emission from atmospheric oxygen to probe the atmospheric temperature profile. The 36-37 GHz band, lying between the water vapor and oxygen bands, is sensitive to a host of other phenomena, as described below.

It is important to recognize that although a particular band might measure emissions associated with a particular physical process or molecular species, correct interpretation of this emission signal requires that data from many bands be analyzed together. As a simplified example, water vapor line emission at 22 GHz depends on both temperature and integrated line-of-sight water vapor, which can only be disentangled with the aid of additional measurements made in other bands. In practice, the integrated

Earth observing system uses both multiple channels in the wings of spectral lines to obtain vertical profile information encoded in pressure broadening, and "window channels" relatively free from line wing emission. These window channels observe sources of broadband continuum emission and absorption with more gradual spectral dependence, such as clouds, precipitation, and surface properties. No individual channel is wholly selective for any given atmospheric or surface property. Instead, these properties are found from a collective analysis of measurements across the spectrum, constrained by physical and statistical prior information.

The 36-37 GHz band at issue here is an extensively used passive microwave window channel between the 22 GHz water vapor line and the 60 GHz oxygen line complex, with a record stretching back to the 1970s. This band is essential because it provides unmatched radiometric sensitivity to key Earth system variables, including precipitation and cloud liquid water; surface freeze-thaw conditions and snow cover; and sea-ice concentration and ocean vector winds. Moreover, in numerical weather prediction, the 37 GHz frequency is used in "all-sky" satellite radiance data assimilation to estimate observation errors in the presence of clouds and precipitation. This band is utilized by a number of instruments from multiple operators. (See Table 1 in Section III.) To be useful for weather forecasting, remote sensing observations must be made over the entire Earth and with the highest practicable temporal resolution. For this reason, information from these instruments is customarily shared in near real time among their respective operators.

As discussed quantitatively below, the natural thermal emissions measured by microwave and millimeter wave remote sensing instruments are exceedingly weak, and consequently interference thresholds are much lower than those for active communications systems. Active systems operate at signal-to-noise ratios well in excess of unity, typically utilizing receivers with noise figures of a few decibels (i.e., system noise temperatures significantly greater than 290 K). However, remote sensing receivers need to measure *changes* in noise temperature of 0.1 K or less over a wide range of scene temperatures up to about 300 K, with system temperature often dominated by scene temperature, and with absolute radiometric calibration. This is accomplished using state-of-the-art low-noise receivers combined with integration times that are orders of magnitude greater than the inverse measurement bandwidth. This operating regime is dramatically different from communications systems that operate at symbol rates comparable to the channel or subchannel bandwidth.

Additionally, Earth remote sensing systems use total power radiometers that have no way of distinguishing between natural thermal emissions and in-band interference from artificial transmitters, unless the artificial signals rise to a recognizably unnatural emission level. Measurements corrupted by such recognizable interference can be flagged as unusable at the cost of data loss, but lower-level “insidious interference” introduces unknown measurement bias into remote sensing data, skewing the results. The thresholds defined in Recommendation ITU-R RS.2017, discussed below, are intended to establish interference levels at which the consequences of this bias are at a tolerable level.

CORF has noted previously that the present discussion of OOBE rules for the lower 37 GHz band recalls the earlier 24 GHz proceeding (ET Docket 21-186) in which OOBE limits initially adopted domestically were found to be too high. The subsequent harmonization with international rules may yet prove to be insufficiently protective depending on actual deployment levels, as some contamination of 23.6-24 GHz remote sensing data has already been observed.[2] With this in mind, CORF emphasizes that it is critical to adopt appropriate regulations before extensive deployments occur. Indeed, despite lower 37 GHz commercial deployments having only occurred thus far under experimental licensing, already some commenters in this proceeding have argued that adopting new rules would impose an onerous cost to refit existing equipment.

II. Current and Proposed Out-of-Band Emission Limits in the 36-37 GHz Band.

In its FNPRM, the Commission seeks comment on emissions into the passive band below 37 GHz. Specifically, the Commission asks whether the current OOBE limit under 47 CFR § 30.203, which is -13 dBm/MHz (equivalent to −43 dBW/MHz, or −13 dBW/GHz), should be replaced by the more stringent limit defined in Resolution 243 (WRC-19), which is likewise −43 dBW/MHz, but further subject to a band-averaged limit of −23 dBW/GHz across the full 36-37 GHz passive band. Under this additional constraint, the permitted spectral density of OOBE averaged across the entire 36-37 GHz passive band would be an order of magnitude below the spectral density permitted at the band edge.

Such a “two-pronged” OOBE limit, with a stricter limit applied to the band-averaged emission across the entire passive band, is a sensible approach to protecting EESS sensors with wide measurement bandwidth. The Commission asks (FNPRM at para. 60) for comment on the alternative of applying this stricter limit only to nonfederal

[2] *See* CORF Comments in ET Docket 21-186, filed February 27, 2024.

operations in the 37.0-37.2 GHz band. As a practical matter, CORF finds this would be unnecessary, since equipment at higher frequency would be operating with at least a 200 MHz guard band relative to the upper edge of the passive band. Such equipment, already required to meet the OOBE requirements of 47 CFR § 30.203 in a directly adjacent band, should readily meet the more stringent requirement specific to the 36-37 GHz band with this large minimum guard band.

In the context of setting OOBE limits, the question arises whether conductive or radiated emissions measurements should be used for assessing compliance with these limits. CORF argued in its prior comments (CORF Sept. 2024 Comments at 7) that radiated measurements are most appropriate given that many hardware implementations lack clean access to an antenna port. CORF notes that the National Spectrum Strategy 37 GHz Spectrum Sharing Report[3] concurs with this conclusion.

III. Protectiveness of Part 30.203 and Resolution 243 (WRC-19) OOBE Limits.

A critical question is the degree of protection offered to an EESS (passive) sensor by current Part 30.203 OOBE limits and by the 36-37 GHz broadband OOBE limit proposed in Resolution 243 (WRC-19). As discussed in CORF's prior filing in this proceeding, for point-to-point links and wireless broadband systems with horizontally directed transmission, a key factor is the fraction of ground-directed radiation that scatters towards the sky versus being absorbed. Indeed, the Commission asks (FNPRM at para. 59), "What kind of propagation and scattering models should be used to determine the impact, if any, of OOBE from terrestrial transmitters on satellite sensors?"

[3] Department of Defense and the National Telecommunications and Information Administration, 2024, National Spectrum Strategy 37 GHz Spectrum Sharing Report, November 29, at page 21.

In CORF's prior comments, 37 GHz surface emissivity data were used to derive equivalent surface reflectance. CORF finds this is a reasonable approach to arriving at a quantitative estimate of upward scattered radiation. The link budget analysis below follows this approach, considering a realistic range of surface emissivity. This is then used to evaluate how protective the Part 30.203 and Resolution 243 (WRC-19) 36-37 GHz OOBE limits are in the context of different environments and likely transmitter deployment density.

Invoking the same physical model as in CORF's prior filing, it is useful to note that, just as the grazing beam of light from a flashlight placed on the ground is partly absorbed and partly scattered upwards, the lower half of the main beam from both fixed and mobile UMFUS transmitters will eventually be incident upon land features or clutter, and likewise partly absorbed and partly scattered upwards.[4] (The upper half of the main beam will escape to space at low elevation angles less likely to cause interference to an EESS (passive) sensor.) This upward scattered radiation, while of little consequence for communications links with transmit and receive antenna directivity concentrated near the horizon, is indistinguishable from upwelling thermal emission from the point of view of an EESS (passive) sensor. Here, it is also important to recognize that antenna down-tilt, by increasing the fraction of the beam which eventually strikes the ground, will actually <u>increase</u> the fraction of the beam scattered into angles potentially in the field of view of an EESS sensor. Nevertheless, down-tilt will be neglected in the following analysis.

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[4] Relative to wavelength, terrain and clutter on the 1-10 meter scale at 37 GHz corresponds in scale to soil or sand particles at optical wavelengths.

To quantitatively assess the coupling of this scattered radiation into an EESS (passive) sensor, what is needed is an estimate of the fraction of total transmitter power that is scattered upwards. That is, how black is the ground at 37 GHz, and how rough or specular does it appear? It is reasonable to assume that most 37 GHz UMFUS deployments will be in areas dominated by land surfaces and built environments that are optically rough at the corresponding wavelength λ = 8 mm. This means that even surfaces illuminated by the dominant, near-horizontal main beam radiation will present a wide range of incidence angles, resulting in a roughly isotropic range of scattering directions for the reflected fraction of the incident radiation. At 37 GHz, emissivity e for a variety of natural surfaces and polarizations at a mid-range incidence angle of 50 degrees varies widely, from about e = 0.65 to e = 0.995.[5] Typically, emissivity is higher for vegetation than for mineral surfaces or snow, and higher for vertical polarization than for horizontal. Similarly, soil moisture and soil types and seasons also have an impact on surface emissivity. The corresponding range of reflection loss $1 - e$, expressed in decibels, is 4.5 dB, to 23 dB. Comparable data for built environments is harder to obtain but can be expected to lie within this range. Adding an additional 3 dB factor to account for half of the transmitted radiation that does not interact with the

[5] *See,* C. Mätzler, ed., 2006, "Surface Emissivity Data from Microwave Experiments at the University of Bern," Appendix A in *Thermal Microwave Radiation: Applications for Remote Sensing*, The Institution of Engineering and Technology ; T.R.H. Holmes, R.A.M. De Jeu, M. Owe, and A.J. Dolman, 2009, "Land Surface Temperature from Ka Band (37 GHz) Passive Microwave Observations," *Journal of Geophysical Research: Atmospheres* 114:D4; L. Jiang, J. Shi, S. Tjuatja, J. Dozier, K.-S. Chen, and L. Zhang, 2007, "A Parameterized Multiple-Scattering Model for Microwave Emission from Dry Snow," *Remote Sensing of Environment* 111:357-366, doi:10.1016/j.rse.2007.02.034; B. Yan, F. Weng, and H. Meng, 2008, "Retrieval of Snow Surface Microwave Emissivity from the Advanced Microwave Sounding Unit," Journal of Geophysical Research 113:D19206, doi:10.1029/2007JD009559; and C. Prigent, W.B. Rossow, and E. Matthews, 1997, "Microwave Land Surface Emissivities Estimated from SSM/I Observations," Journal of Geophysical Research 102(D18):21867-21890, doi:10.1029/97JD01360.

ground, the effective isotropic “gain factor” for upward scattered radiation ranges from $G_t = -7.5$ dB to $G_t = -26$ dB.

With this range of effective gain factors in hand, a link budget can be used to estimate the interference power P_r coupled to a representative EESS (passive) sensor from a transmitter emitting OOBE power P_t into the sensor band. Recommendation ITU-R RS.1861 provides characteristics for generically designated EESS (passive) sensors derived from various deployed or planned instruments. The analysis below will consider Sensor H7, which is typical of current instruments and their likely successors and corresponds closely to the 36-37 GHz channel of the Global Precipitation Measurement (GPM) Microwave Imager instrument carried by the GPM Core Observatory listed in Table 1. The pertinent characteristics of this sensor are as follows:

- Altitude 407 km
- Bandwidth 1 GHz centered on 36.5 GHz
- 53 degrees angle of incidence at ground
- Antenna gain $G_r = 50.3$ dBi
- Instantaneous field of view 12 × 7.3 km

Table 1: Current and Planned* 36-37 GHz Remote Sensing Missions

Center Frequency	Agency†	Satellite	Sensor	Bandwidth	Impact	Upper Limit
36.42 GHz						
	JAXA	*GOSAT-GW*	*AMSR-3*	*840 MHz*	*Unlikely*	36.84
36.5 GHz						
	JAXA	GCOM-W	AMSR2	1000 MHz	**Certain**	37.0
	NASA	GPM Core Observatory	GMI	1000 MHz	**Certain**	37.0
	CNES	SARAL	Altika	200 MHz	Unlikely	36.6
	CMA	FY-3C	MWRI-1	400 MHz	Unlikely	36.7
	CMA	FY-3D	MWRI-1	400 MHz	Unlikely	36.7
	CMA	FY-3F	MWRI-2	400 MHz	Unlikely	36.7
	CMA	FY-3G	MWRI-RM	400 MHz	Unlikely	36.7
	ESA	Sentinel-3A	MWR	1000 MHz	**Certain**	37.0
	ESA	Sentinel-3B	MWR	1000 MHz	**Certain**	37.0
	CMA	*FY-3H*	*MWRI-2*	*400 MHz*	*Unlikely*	36.7
	CMA	*FY-3I*	*MWRI-RM*	*900 MHz*	*Likely*	36.95
	ESA	*Sentinel-3C*	*MWR*	*1000 MHz*	***Certain***	37.0
	ESA	*Sentinel-3D*	*MWR*	*1000 MHz*	***Certain***	37.0
	ESA	*CIMR-A*	*CIMR*	*300 MHz*	*Unlikely*	36.65
	ESA	*CIMR-B*	*CIMR*	*300 MHz*	*Unlikely*	36.65
36.7 GHz						
	RosHydroMet	Meteor-M N2-3	MTVZA-GY	400 MHz	Likely	36.9
	RosHydroMet	Meteor-M N2-4	MTVZA-GY	400 MHz	Likely	36.9
	RosHydroMet	*Meteor-M N2-5*	*MTVZA-GY*	*400 MHz*	*Likely*	36.9
	RosHydroMet	*Meteor-MP N1*	*MTVZA-GY-MP*	*400 MHz*	*Likely*	36.9
	RosHydroMet	*Meteor-MP N2*	*MTVZA-GY-MP*	*400 MHz*	*Likely*	36.9
	RosHydroMet	*Meteor-M N2-6*	*MTVZA-GY*	*400 MHz*	*Likely*	36.9
36.75 GHz						
	DoD	WSF-M1	MWI	500 MHz	**Certain**	37.0
	DoD	*WSF-M2*	*MWI*	*500 MHz*	***Certain***	37.0
37 GHz						
	NSOAS	HY-2B	MWI	1000 MHz	**Certain**	>37.0
	DoD	DMSP-F16	SSMIS	1580 MHz	**Certain**	>37.0
	DoD	DMSP-F17	SSMIS	1580 MHz	**Certain**	>37.0
	DoD	DMSP-F18	SSMIS	1580 MHz	**Certain**	>37.0
37.3 GHz						
	DoD	WSF-M1	MWI	2500 MHz	**Certain**	>37.0
	DoD	*WSF-M2*	*MWI*	*2500 MHz*	***Certain***	*>37.0*

SOURCE: Columns 1-5 from World Meteorological Organization, "Oscar | Satellite Frequencies for Earth Observation, Data Transfer, and Platform Communications and Control," https://space.oscar.wmo.int/satellitefrequencies, accessed May 11, 2025; Columns 6 and 7 are committee generated.

* Planned missions are denoted in italics.

† Agency key:

CMA	China Meteorological Administration
CNES	Centre national d'études spatiales (France)
DoD	Department of Defense (USA)
ESA	European Space Agency
JAXA	Japan Aerospace Exploration Agency
NASA	National Aeronautics and Space Administration (USA)
NSOAS	National Satellite Ocean Application Service (China)
RosHydroMet	Federal Service for Hydrometeorology and Environmental Monitoring (Russia)

From this, the line-of-sight distance from the sensor to ground is d = 644 km, with corresponding free-space propagation loss $L_{fs} = 20 \log (4\pi d/\lambda)$ = 179.8 dB. Loss along this path due to atmospheric absorption is relatively negligible, approximately L_{atm} = 0.5 dB assuming a U.S. standard atmosphere and 50 percent relative humidity throughout the troposphere.[6] The total link budget is

$$P_r = P_t + G_r + G_t - L_{fs} - L_{atm},$$

from which $P_r = P_t + G_t - 130$ dB. Considering different scattered radiation scenarios noted above from different land surface types, the result is a range of $P_r = P_t - 137.5$ dB to $P_r = P_t - 156$ dB. Next, compare these values with the harmful interference threshold for this band, defined in Recommendation ITU-R RS.2017, which is −166 dBW in a reference bandwidth of 100 MHz, to be exceeded no more than 0.1 percent of the time. Converting to a 1 GHz reference bandwidth, the result is an allowable $P_{r,\, max}$ = −156 dBW. Deriving P_t that results in maximum allowable received power leads to a range of allowable transmit powers P_t = 0 dBW to −18 dBW. The current OOBE limit under Part 30.203 quoted above sets $P_{t,\, max}$ = −13 dBW, which is higher than the minimum allowable transmit power depending on the surface type. This is more clearly illustrated in Figure 1, where the red-dashed curve represents the allowable maximum received power at the EESS sensor, and the blue curve shows how the ITU-R RS.2017 limit can easily be violated due to scattered power for a transmitter operating under the current Part 30 rules.

[6] Path geometry and loss computed using the Smithsonian Astrophysical Observatory (SAO) *am* code (see S. Paine, 2023, "The *am* Atmospheric Model," Version 13.0, Zenodo, https://doi.org/10.5281/zenodo.8161272). The line-of-sight path length here (644 km) corrects a transcription error (608 km) in CORF's prior comments using this example.

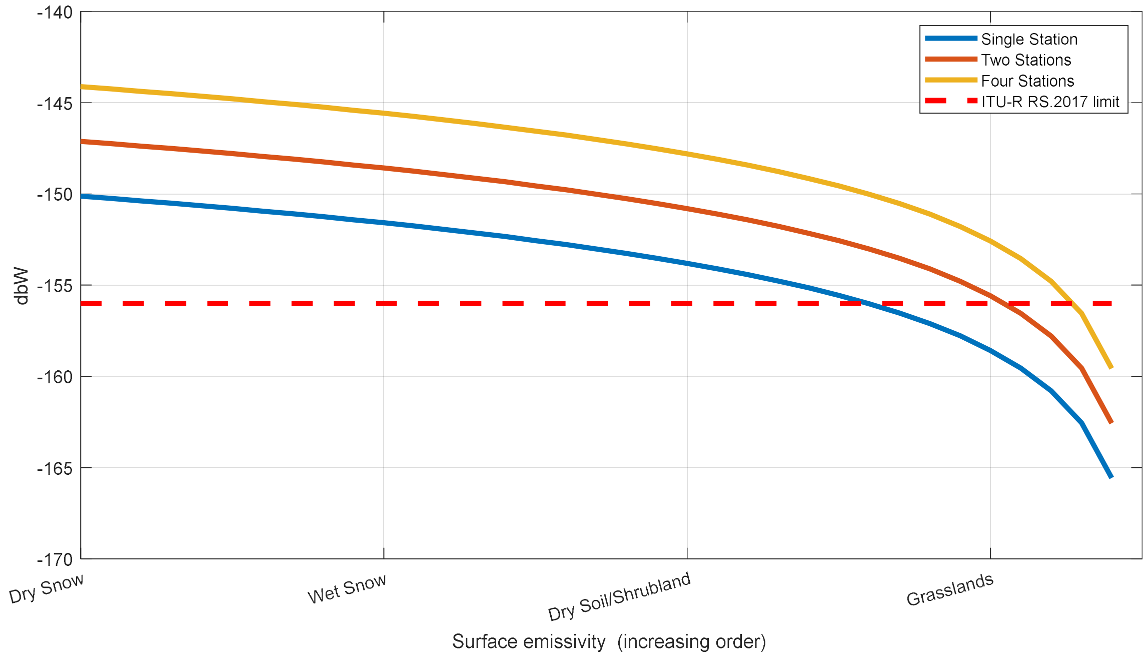

Figure 1: Distribution of P_t at 36-37 GHz from Upper Microwave Flexible Use Service over different land types. SOURCE: Committee generated.

Moreover, this limit applies to a *single* transmitter in a point-to-point link, base station, or user device. To avoid harmful interference with an EESS (passive) sensor, the aggregate emission from all such devices within the instantaneous field of view of the sensor must be considered, which depends on their deployment density and average duty cycle. The red and yellow curves in Figure 1 present reasonable scenarios in which there are multiple transmitter stations within a typical EESS sensor footprint. As the Commission noted previously,[7] the potential uses of the band have not yet been defined, so information on deployment density is not available.

[7] Federal Communications Commission, "Information Sought on Sharing in the Lower 37 GHz Band in Connection with the National Spectrum Sharing Implementation Plan," *Public Notice*, WT Docket No. 24-243, released August 9, 2024, at page 2.

Nevertheless, CORF assesses that a threshold just sufficient to protect EESS (passive) from a single transmitter is inadequate. The more stringent OOBE limit proposed in Resolution 243 (WRC-19) (−23 dBW in 36-37 GHz, considered in terms of total radiated power) offers a more realistic interim measure of protection for applications involving a product of density and duty cycle approaching four active transmitters per 100 km^2. A downward revision or other restriction, such as indoor operation, may be required to maintain protection from any emerging application involving a higher product of higher density and duty cycle. Any adjustment for average duty cycles less than 100 percent should consider that for typical passive sensors, integration time is around 5-20 ms. Bursts of communications traffic lasting longer than this will corrupt contemporaneous measurements at an effective duty cycle of 100 percent for the duration of the measurement. As noted above, the allowable fraction of corrupted measurements under ITU-R RS.2017 is 0.1 percent. Therefore, CORF assesses that any duty cycle derating should be applied with caution, if at all, when considering OOBE limits.

IV. Conclusion.

CORF appreciates the Commission's interest in evaluating current OOBE limits for lower 37 GHz UMFUS devices and the possible need for additional measures to protect EESS (passive) observations in the 36-37 GHz band. CORF assesses that the current OOBE limits defined in Part 30.203 are not sufficient to offer protection from a single 37 GHz transmitter within the entire footprint of a typical EESS (passive) sensor and urges immediate adoption of the more stringent limits proposed in Resolution 243

(WRC-19). Moreover, it should be emphasized that the above analysis is most relevant to sparsely deployed transmitters with horizontally focused emissions, such as those in point-to-point links or point-to-multipoint fixed wireless base stations. Applications such as handheld devices, automotive or autonomous vehicle connectivity, or wireless networking devices would likely be deployed at higher density and with less control of antenna directivity. Should applications emerge for the lower 37 GHz UMFUS band involving an average number of active transmitters exceeding four per 100 km^2, CORF urges the Commission to consider other measures, such as further reduced OOBE limits or restriction to indoor operation, to ensure continued protection of EESS (passive) observations in the 36-37 GHz band.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
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