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

In the Matter of	)	
	)	
Sharing in the Lower 37 GHz Band	)	WT Docket No. 24-243
	)	

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 Public Notice DA 24-789 (released August 9, 2024) seeking information on sharing in the lower 37 GHz band in connection with the National Spectrum Strategy implementation plan.[1,2] In these comments, CORF outlines the importance of the adjacent 36.0-37.0 GHz Earth Exploration Satellite Service ("EESS") band and responds to the Commission's request for input on "whether additional measures are needed to protect spaceborne remote passive sensors" in this band.

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[1] *Information Sought on Sharing the Lower 37 GHz Band in Connection With the National Spectrum Strategy Implementation Plan*, Public Notice, FCC WT Docket No. 24-243, DA 24-789 (released August 9, 2024). https://www.federalregister.gov/documents/2024/08/27/2024-19081/information-sought-on-sharing-the-lower-37-ghz-band-in-connection-with-the-national-spectrum

[2] CORF hereby seeks leave to file these Comments later than the stated due date. The public interest will be served by the acceptance of these Comments, as CORF provides significant information from a unique perspective on passive use of the spectrum, a core issue in this proceeding. No party will be harmed by the timing of this filing, since there is no official opportunity to respond to Comments in this proceeding. Nevertheless, other parties will have an opportunity to respond to these Comments in *ex parte* filings, if they so choose.

II. 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 the Earth's atmosphere and surface provides information that is essential for accurate weather forecasting and climate monitoring. Consequently, the data collected by these instruments have enormous impact on safety, health, and the economy. The 36-37 GHz EESS (passive) primary band is one of a set of such bands across the microwave and millimeter wave spectrum that enable spaceborne sensors to assemble a complete picture of the state of the Earth's atmosphere and surface. These bands are designed to provide the total Earth observing system with sensitivity to multiple 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.

It is important to recognize that although a certain 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 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 that afford sensitivity to sources of broadband continuum emission and absorption with more gradual spectral dependence, including 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 continuous program of record stretching back to the 1970s. It provides unmatched radiometric sensitivity to key Earth system variables, including precipitation and cloud liquid water, surface freeze-thaw conditions and snow cover, 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 the assigned observation errors in the presence of clouds and precipitation. This band is utilized by several instruments operated by multiple administrations, listed below in Table I. To be useful for forecasting and climate studies, remote sensing observations must be made over the entire Earth and with the highest practicable temporal resolution. For this reason, production data from these instruments is customarily shared in near real time between administrations.

As CORF discusses 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. This is readily understood by considering that while active systems operate at signal-to-noise ratios well in excess of unity, typically

Table 1 Current and Planned* 37 GHz Remote Sensing Missions

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

* 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 Agency (USA)
NSOAS	National Satellite Ocean Application Service (China)
RosHydroMet	Federal Service for Hydrometeorology and Environmental Monitoring (Russia)

utilizing receivers with noise figures greater than 0 dB (i.e., noise temperatures greater than 290 K), remote sensing receivers need to measure *changes* in noise temperature of 0.1 K or less, with absolute radiometric calibration. This is accomplished through the use of state-of-the-art low-noise receivers combined with integration times orders of magnitude greater than the inverse measurement bandwidth, a dramatically different operating regime compared with communications systems that operate at symbol rates comparable to the channel or subchannel bandwidth.

Additionally, because Earth remote sensing systems are total power radiometers, they have no way of distinguishing between the natural thermal emissions these systems are designed to detect and in-band interference from artificial transmitters, unless the artificial signals rise to a level that causes a statistically or physically recognizable unnatural emission level. Such recognizable interference can be flagged out at the cost of data loss, but lower-level “insidious interference” introduces unknown measurement bias into remote sensing data. The thresholds defined in Recommendation ITU-R RS.2017, discussed further below, are intended to establish interference levels at which the consequences of this bias are at a tolerable level.

Finally, although the focus of this Public Notice is on protection of the 36-37 GHz EESS (passive) primary band, under RR 5.149, administrations are urged to take all practicable steps to protect the Radio Astronomy Service from harmful interference within a narrow window mid-band at 36.43-36.5 GHz. This window covers astronomically observed molecular emission lines of carbonyl sulfide (OCS) and cyanoacetylene (HC_3N). Appropriate regulation of out-of-band emissions (OOBEs) from 37 GHz Upper Microwave Flexible Use Service (UMFUS) devices to protect EESS (passive) has the additional benefit of facilitating protection of radio astronomy under RR 5.149.

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

In the Public Notice, the Commission comments on the evolving state of OOBE limits and seeks input on additional measures that may be needed to protect EESS (passive), writing:

> *Adjacent Band Protection.* In the *2016 R&O* [Report and Order], the Commission adopted an out-of-band emission limit that it concluded would "keep emissions from an UMFUS device into the 36-37 GHz band well below the -10 dBW level specified by footnote US550A," noting that the -10 dBW power limit "was adopted to protect passive sensors in the 36-37 GHz band in accordance with ITU Resolution 752 (WRC- 07)."[14] Under FCC Part 30.203, operations are limited to -13 dBm/MHz, which expands to -13 dBW/GHz. Subsequently, Resolution 243 (WRC-19), Table 1, established a -23 dBW/GHz unwanted emission mean power for IMT stations within the frequency band 36-37 GHz.15 In light of these developments, we seek input on whether additional measures are needed to protect spaceborne remote passive sensors in the 36-37 GHz band. [*Public Notice* at page 3]

That is, in establishing technical rules for 37 GHz UMFUS devices, the Commission followed limits set forth in 2007 in Resolution 752 (WRC-07).[3] However, the more recent Resolution 243 (WRC-19) proposes OOBE limits that are 13 dB lower (i.e., more stringent). CORF appreciates the Commission's interest in considering additional measures to protect EESS (passive) from OOBE. Indeed, as discussed below, CORF assesses that even the more stringent Resolution 243 (WRC-19) limits are insufficient to ensure protection from interference when considering scattering from terrain and ground clutter, and when accounting for the aggregate emission from many devices within the footprint of an EESS (passive) sensor. The situation is analogous to the earlier 24 GHz

[3] *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services,* GN Docket No. 14-177, Report and Order and Further Notice of Proposed Rulemaking, 31 FCC Rcd 8014, 8073 (2016) (*2016 R&O*), https://www.federalregister.gov/documents/2019/05/13/2019-09426/use-of-spectrum-bands-above-24-ghz-for-mobile-radio-services.

proceeding (ET Docket 21-186), in which the OOBE limits initially adopted domestically were found to be too high, leading to subsequent harmonization with international rules that may yet prove to be insufficiently protective depending on actual deployment levels and under which some contamination of remote sensing data has already been observed.[4]

A second consideration that arises in setting OOBE standards is the use of conductive or radiated emission measurements to establish compliance, and whether to apply a spectral emission mask. In the 2016 R&O, the Commission cites multiple commenters advocating for different approaches.[5] CORF believes that radiated emission testing is appropriate, particularly for portable devices employing adaptive antennas with multiple individually driven elements that do not provide clean antenna port access. Moreover, in view of its assessment of the importance of scattered main beam power below, CORF additionally believes that total radiated power is the appropriate metric. Finally, since several of the sensors in Table 1 use the entire 36-37 GHz bandwidth to achieve required sensitivity, CORF believes that total unwanted emission into the 1 GHz bandwidth is the appropriate spectral metric. These recommended spatial and spectral metrics, i.e., total radiated power in all directions and averaged over the 36-37 GHz band, are the same as those adopted in Resolution 243 (WRC-19).

III. Understanding the Need for Strict OOBE Limits: A Quantitative Example.

In evaluating OOBE limits needed to protect EESS (passive), it is important to carefully consider whether transmitter directivity can be invoked as a mitigating factor.

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[4] *See* CORF Comments in ET Docket 21-186, filed February 27, 2024.
[5] 31 FCC Rcd at 8117-8121.

For example, the less stringent OOBE limits in Resolution 752 (WRC-07) were stated in the context of maximum incidence angle limits of 60 degrees for EESS (passive) sensors, and maximum elevation angles of 20 degrees for fixed service active links. In Resolution 752 (WRC-07), no limits were placed on mobile service links, but it is generally expected that base stations as well as user devices will employ highly directive adaptive antennas that will tend to keep main beam emissions at low elevation. In paragraph 301 of the 2016 R&O, the Commission concludes, “We believe these features of the mmW spectrum make the OOBE limit in the maximum EIRP direction less significant and a spatially averaged OOBE limit more appropriate.”

CORF disagrees. The concept of spatially averaging main beam OOBE is appropriate when considering interference with adjacent-channel active users located at low elevation, but it is not appropriate when considering coupling of OOBE into the beam of a spaceborne EESS (passive) sensor. This is because, 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. (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.

To assess the coupling of this scattered radiation into an EESS (passive) sensor, what is then 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. Tabulated 37 GHz emissivity e for a variety of natural surfaces at a mid-range incidence angle of 50 degrees ranges from about e = 0.7 to e = 0.95[6]. The corresponding range of reflection loss $1 - e$, expressed in dB, is 5 dB to 13 dB, indicating that 10 dB (i.e., 90% absorbed, 10% scattered isotropically upwards) is a reasonable reflection loss estimate. Comparable data for built environments is harder to come by, but here again 10 dB is a physically reasonable estimate. Adding an additional 3 dB factor to account for half of the transmitted radiation never interacting with the ground arrives at an effective isotropic "gain factor" for upward scattered radiation $G_t = -13$ dB.

With this effective gain factor in hand, a link budget can be assembled 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)

[6] "Surface emissivity data from microwave experiments at the University of Bern." Appendix A in C. Mätzler, Ed., "Thermal Microwave Radiation: Applications for Remote Sensing," The Institution of Engineering and Technology (IET), London, 2006, https://doi.org/10.1049/PBEW052E.

sensors derived from various deployed or planned instruments. This example will use Sensor H7, which 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
- Angle of incidence at ground: 53 degrees
- Antenna gain: G_r = 50.3 dBi
- Instantaneous field of view: 12 × 7.3 km

From this, the line-of-sight distance from the sensor to ground is d = 608 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 US standard atmosphere and 50% relative humidity throughout the troposphere.[7] The total link budget is

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

from which $P_r = P_t - 143$ dB. The harmful interference threshold for this band defined in Recommendation ITU-R RS.2017 is −166 dBW in a reference bandwidth of 100 MHz, to be exceeded no more than 0.1% of the time. For the 1 GHz reference bandwidth appropriate to this sensor, the equivalent interference threshold power is 10 dB higher,

[7] Path geometry and loss computed using the Smithsonian Astrophysical Observatory (SAO) *am* code: Paine, S. (2023). The *am* atmospheric model (13.0). Zenodo. https://doi.org/10.5281/zenodo.8161272

$P_{r\ max}$ = −156 dBW. Returning to the link budget, the corresponding maximum out-of-band transmitter power emitted into 36-37 GHz is $P_{t,\ max}$ = −13 dBW. This happens to be the same as the current OOBE limit under Part 30.203 as stated in the excerpt from the *Public Notice* quoted above.

However, this limit applies to a *single* transmitter in a point-to-point link, base station, or user device. To avoid harmful interference to an EESS (passive) sensor, the aggregate emission from all such devices within the instantaneous field of view of the sensor must be considered, which will depend on the product of their deployment density multiplied by their average duty cycle. As the Commission notes under *Potential Uses of the Lower 37 GHz Band* [*Public Notice* at page 2], the potential uses of the band have not yet been defined, so this information is not available. 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 10 active transmitters per 100 km^2, with downward revision or other restriction such as indoor operation required to maintain protection from any emerging application at higher product of density and duty cycle.

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 barely 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, should an application emerge for the lower 37 GHz UMFUS band that would involve an average number of active transmitters exceeding 10 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'
COMMITTEE ON RADIO FREQUENCIES

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