



Estimates of Coupling to Fixed Satellite Services

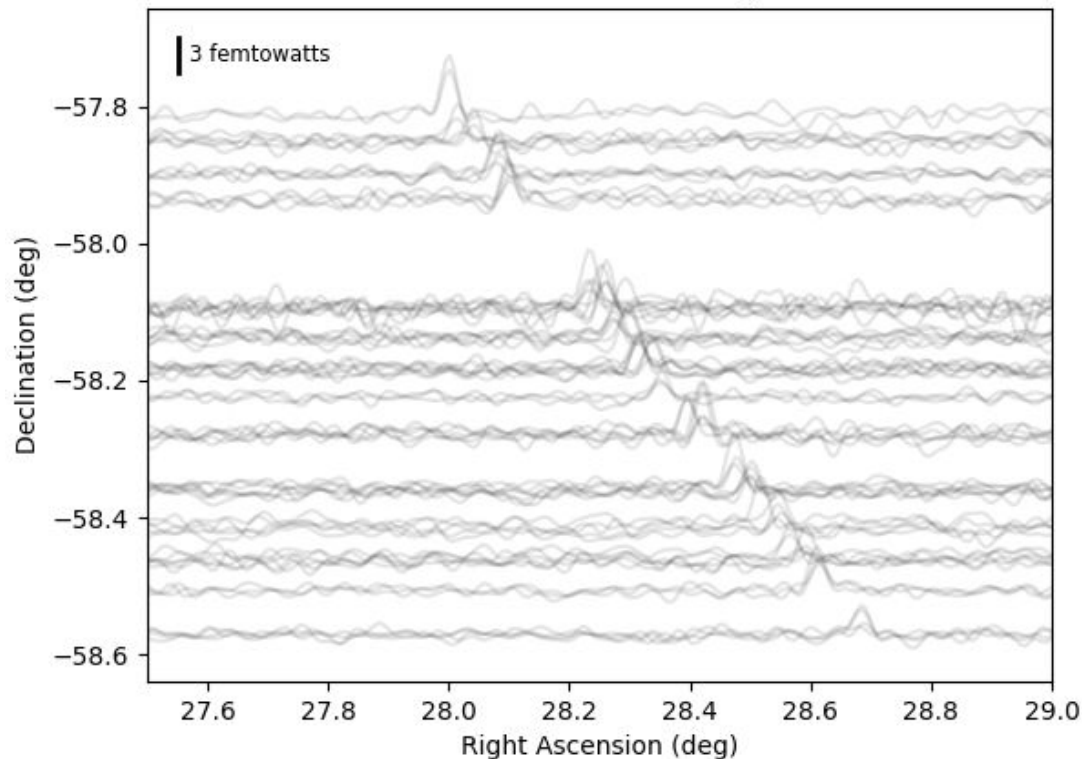
CMB-S4 Spring 2022 Meeting

Ian Birdwell for the CMB-S4 RFI Working Group

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SPT-3G GRACE-FO observation

Bolometer timestreams offset by declination



Detection of GRACE-FO 2
in SPT-3G data

SNR ~ 5 in single bolometer
timestreams at 150 GHz

Crossing time ~ 1.5 s

Consistent with 6th order harmonics
from G-FO2 K-Band antenna

Back-of-the-envelope power works out,
but large uncertainties

For details, see this [presentation](#) by
Sam Guns

Scope and Methods

- In as broad terms as possible, determine the possible coupling of RFI from fixed satellite services on CMB-S4 (without addressing the frequency of such events)
- Sensitivity to emission depends on the coupling conditions:
 - Coupling through main beam, or through satellite/instrument sidelobes
 - Whether satellite emission is in the designated band vs. a harmonic
 - Narrowband emission vs. broadband thermal emission
- The categories for potential coupling strength:
 - Strong coupling - $S/N \gg 1$
 - Borderline coupling - $S/N \sim 1$
 - Negligible coupling - $S/N \ll 1$
- Integration time is based on a satellite velocity of 0.5 deg/s
- All cases are assessed using regulatory limits.

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

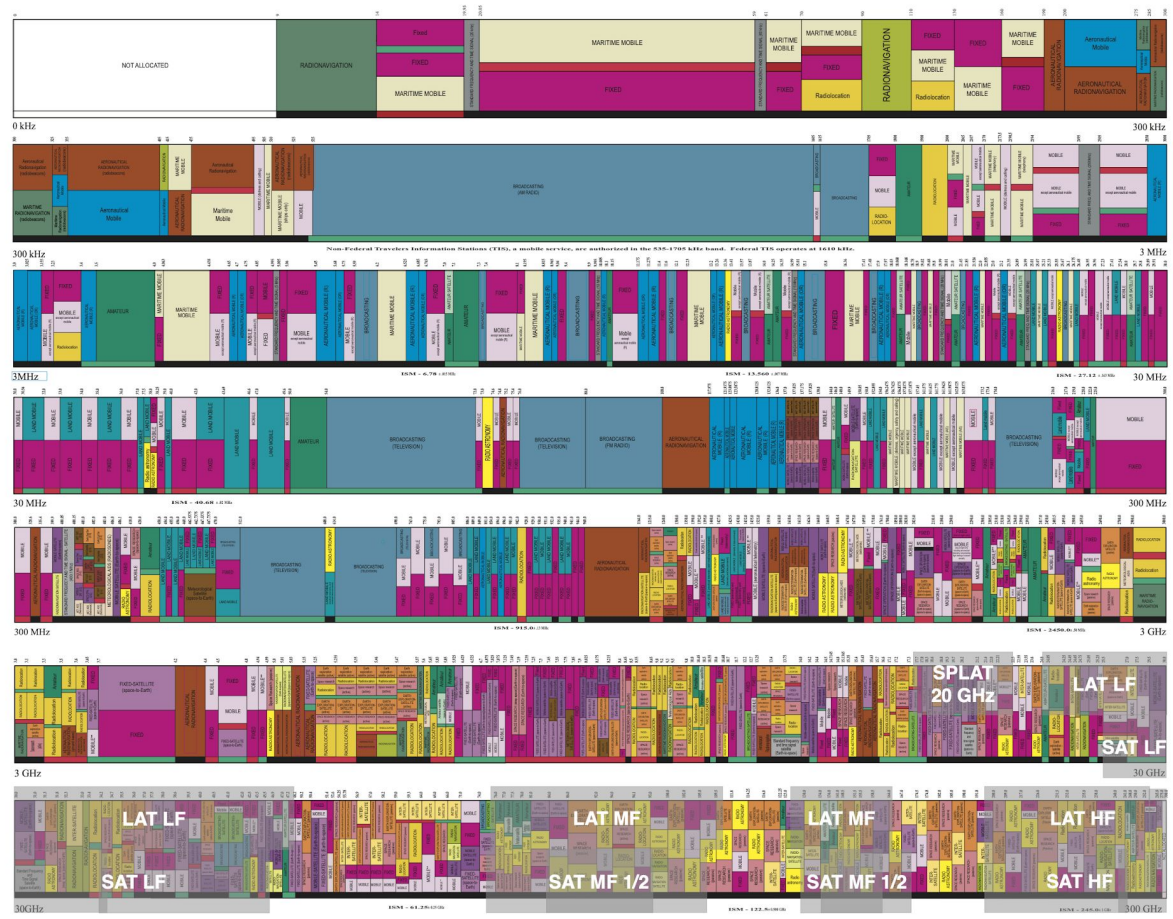


SERVICE	EXAMPLE	DESCRIPTION
Primary	Fixed	Signal Center
Secondary	Mobile	As Capital with lower user limits

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U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management

JANUARY 2016



Instrument Parameters

Type	Freq.s (GHz)	NEPs (aW/rtHz)	Beamwidth (arcmin)
ULF LAT	17.5 - 22.5	3.3	11.4
LF SAT	21.5 - 30.0 30.0 - 47.5	10.57 30.0	72.8 72.8
LF LAT	21.5 - 30.0 30.0 - 47.5	3.9 18.0	7.4 5.1
MF SAT (MF1 + MF2)	74.8 - 95.2 129.1 - 161.0 83.6 - 106.4 138.0 - 172.1	37.7 51.3 37.1 53.7	25.5 25.5 22.7 22.7
MF LAT	77.0 - 106.0 128.0 - 169.0	19.0 45.4	2.2 1.4

From PBD: <https://docs.google.com/spreadsheets/d/1sovTfZ5gIYq-l3cMMtEBDWT7YbfzB64SPp4bbShLpk4/edit?usp=sharing>
Using CHILAT values where applicable. Saturation not considered.

Case 1: Main beam - Main beam

Inst. Type	Total Power	SNR	Status
ULF LAT	12 pW	1e6	Strong Coupling
LF SAT	10 pW	1e5 - 1e6	Strong Coupling
LF LAT	10 pW	1e5 - 1e6	Strong Coupling
MF1 SAT	24 aW	~0.6	Borderline Coupling
MF LAT MF2 SAT	0	0	Negligible Coupling

Case 2: Instrument Sidelobes (In-Band)

Note: SNR now calculated to account for a larger signal time (240s, approx.)

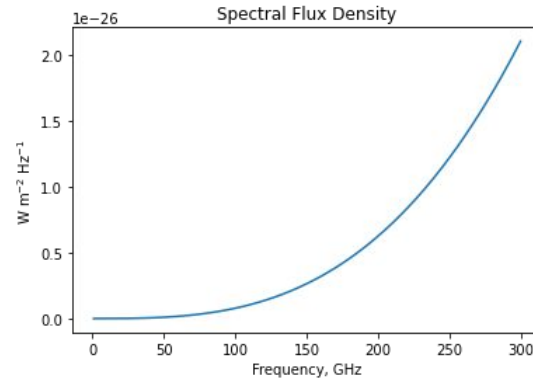
Inst. Type	Sidelobe Atten.	Total Power	SNR	Status
ULF LAT	-20dBi	120 fW	~410000	Strong Coupling
LF SAT	-35dBi	3.2 fW	~725	Strong Coupling
LF LAT	-20dBi	100 fW	~41000	Strong Coupling
MF SAT	-35dBi	8e-22 W	~1e-4	Negligible Coupling
MF LAT	-20dBi	0	0	Negligible Coupling

Case 3: Satellite Sidelobes (In-Band)

Inst. Type	Attenuation	Total Power	SNR	Status
ULF LAT	-30 dB	12 fW	2.2e3	Strong Coupling
LF SAT	-30 dB	10 fW	1e2 - 1e3	Strong Coupling
LF LAT	-30 dB	10 fW	1e2 - 1e3	Strong Coupling
MF SAT	-30 dB	24e-21	6e-4	Negligible Coupling
MF LAT	-30 dB	0	0	Negligible Coupling

Thermal

- Here, we figure out whether the broad thermal emission from a low Earth orbit satellite could couple significantly.
- Assuming 70 deg. C temperature, 550 km orbit, 4m diameter:
 - **Negligible coupling** (on the order of 1-10 ppm SNR)



Conclusions

- Ultimately, these are estimates which will hopefully inform observations and simulations.
- These are based on regulatory limits, and not on actual in-sky observations.
- Future directions:
 - Develop more complex computational models which assess the frequency of these various events
 - Integrate regulatory limits on harmonics (a more complex, but very necessary case to investigate)

Bonus Slides

Thermal

TYPE	Power (W)	SNR	Status
LF SAT	6e-23	3e-6	Negligible Coupling
MF1 SAT	5e-22	1e-5	Negligible Coupling
MF2 SAT	6e-22	3e-5	Negligible Coupling
HF SAT	2e-21	3e-5	Negligible Coupling
ULF LAT	7e-24	2e-6	Negligible Coupling
LF LAT	6e-23	6e-6	Negligible Coupling
MF LAT	6e-22	2e-5	Negligible Coupling
HF LAT	2e-21	3e-5	Negligible Coupling