SC1 WiFi Power Flux Density Discussion

The SC1 spacecraft WiFi payload subsystem will test the connection stability of the Wi-Fi to communicate between modules within the spacecraft. The WPEA-352ACNRBI Wi-Fi module on the payload computer will communicate with the Raspberry Pi Pico W Wi-Fi module, in the 2.4GHz band.

This analysis shows that the emissions from these modules will be below the minimum levels that would require coordination.

The following analysis evaluates PFD levels at Earth surface, and at GSO, resulting from emissions from the Wifi modules.

Conclusion:

The PFD is lower than the published limits by 29 dB or more, in all cases. So no coordination is required.

Calculations:

Power Flux Density Analysis SC1 Satellite Wifi		
Parameter	**Unit**	**Value**
Constants		
Speed of Light	m/s	2.998E+08
Earth Radius	km	6378
Orbit Altitude	km	510
GEO Altitude	km	35,786
Transmitter Emission		
Wifi Frequency	GHz	2.412 - 2.484
Wifi Max Tx Power	dBW	-10.84
Antenna Gain (Max.)	dBi	0.0
Bandwidth	Hz	20,000,000
Bandwidth	dBHz	73.01
Power Flux Max Density at Transmitter	dBW/Hz	-83.9
Ref. Freq. Range	Hz	4000
Ref. Freq. Range	dBHz	**36.0**
Power Flux Max Density at Transmitter	dBW/4kHz	**-47.8**

Earth Surface PFD Discussion:

Calculation of PFD at Earth Surface			
Elevation Angle	degrees	**5.0**	**90.0**
Slant Range	km	**2103.9**	**510.0**
Orbit Altitude	km	510	510
Spreading Loss	dB	**137.5**	**125.1**
PFD Earth Surface	dB(W/m^2-4kHz)	**-185.3**	**-173.0**
PFD Limit	dB(W/m^2-4kHz)	-154	-144
Margin	dB(W/m^2-4kHz)	**31.3**	**29.0**

Requirement from ITU-R SF.358-5:

TABLE 1

Limits of power flux-density*

Frequency range (GHz)	Limit of power flux-density (dB(W/m^2))			
	$\theta \leq 5°$ (1)	$5° < \theta \leq 25°$	$25° < \theta \leq 90°$	Reference bandwidth
1.7-2.5 (2)	–154	$-154 + 0.5(\theta - 5)$	–144	in any 4 MHz band
2.50-2.69	–152	$-152 + 0.75(\theta - 5)$	–137	
3-8	–152	$-152 + 0.5(\theta - 5)$	–142	
8-11.7	–150	$-150 + 0.5(\theta - 5)$	–140	
11.7-15.4	–148	$-148 + 0.5(\theta - 5)$	–138	
15.4-27.5	–115	$-115 + 0.5(\theta - 5)$	–105	in any 1 MHz band

* According to RR No. S21.16.4, the power flux-density limits in bands between 17.7 and 27.5 GHz shall apply until such time as modified by a competent world radiocommunication conference.

(1) θ : the angle of arrival of the wave (degrees above the horizontal).

(2) No frequency bands are at present allocated in the RR to the FSS between 1.7 and 2.5 GHz.

Conclusion:

The requirements provide separate limits for 5 degrees elevation and 90 degrees elevation.

5 degrees elevation: From the calculations, based on a Power Flux Max Density at Transmitter of -47.8 dBW/4kHz, the maximum possible PFD at Earth surface, is -185.3 dB(W/m^2-4kHz) at 5 degrees. This exceeds the limit of -154 dB(W/m^2-4kHz), by a margin of 31.3 dB.

90 degrees elevation: From the calculations, based on a Power Flux Max Density at Transmitter of -47.8 dBW/4kHz, the maximum possible PFD at Earth surface, is -173 dB(W/m^2-4kHz) at 90 degrees. This exceeds the limit of -144 dB(W/m^2-4kHz), by a margin of 29 dB.

GSO PFD Discussion:

Calculation of PFD at GSO			
Spreading Loss	dB	**161.9**	
PFD GEO, maximum	dB(W/m^2-4kHz)	**-209.8**	
PFD Limit, minimum	dB(W/m^2-4kHz)	**-144**	
Margin	dB(W/m^2-4kHz)	**65.8**	

Requirement from 47 CFR § 25.208:

(v) In the band 2496-2500 MHz, the power flux-density at the Earth's surface produced by emissions from non-geostationary space stations for all conditions and all methods of modulation shall not exceed the following values (these values are obtained under assumed free-space propagation conditions):

(1) −144 dB (W/m^2) in 4 kHz for all angles of arrival between 0 and 5 degrees above the horizontal plane; −144 dB (W/m^2) + 0.65(δ −5) in 4 kHz for all angles of arrival between 5 and 25 degrees above the horizontal plane; and

−131 dB (W/m^2) in 4 kHz and for all angles of arrival between 25 and 90 degrees above the horizontal plane.

(2) −126 dB (W/m^2) in 1 MHz for all angles of arrival between 0 and 5 degrees above the horizontal plane; −126 dB (W/m^2) + 0.65(δ −5) in 1 MHz for all angles of arrival between 5 and 25 degrees above the horizontal plane; and

−113 dB (W/m^2) in 1 MHz and for all angles of arrival between 25 and 90 degrees above the horizontal plane.

Conclusion:

From the calculations, based on a Power Flux Max Density at Transmitter of -47.8 dBW/4kHz, the maximum possible PFD at GSO, is -209.8 dB(W/m^2-4kHz). This exceeds the limit of -144 dB(W/m^2-4kHz), by a margin of 65.8 dB.