

PAN-1 EMC Analysis

Introduction:

This exhibit provides an assessment of potential for interference from the PAN-1 mission mRobotics SiK radios. The mission comprises two spacecraft, PAN-1A and PAN-1B, launched together. The maximum separation distance they are expected to operate is 1 km. The two spacecraft communicate with one another via the SiK radios, a low power, low gain link, with the following characteristics:

Center Frequency: 50 channels, from 915 MHz to 928 MHz.

Bandwidth: 250 kHz per Channel

Radio Power: 0.025 W, equal to -16.02 dBW

Antenna Maximum Net Gain: -4 dBi

Modulation: GFSK

Altitude: 500 km

Summary of Findings:

This study calculates the power spectral density at Earth surface, at the nadir point directly under the spacecraft as it orbits. This value, 1.27×10^{-19} W/m²-Hz or -189 dBW/m²-Hz, appears to be below the threshold of concern for interference, and to be below the noise floor for receivers in this frequency range. It is expected that no Earth based receiver will be configured to receive a signal of this weak power. Further, by the FCC recommended process for determination of protected field strength, Tables 1 and 2 show that the protected field strength for relevant station classes is not exceeded in any case.

Therefore, no interference is expected.

Consideration of Spread Spectrum Transmission:

The SiK radio uses spread spectrum frequency hopping, over the frequency range given. The channel changes every 0.4 seconds, hopping among the 50 channels in a pseudorandom sequence. This means that a given channel is only in use for 0.4 seconds, once every 20 seconds. For a 5 minute pass, this would mean a total exposure on a given channel, of 6 seconds, for 0.4 seconds at a time, during the 5 minute pass.

Earth Surface Maximum Power Density and Power Spectral Density:

Power density is calculated using the formula

Power Density = $(P + G)/(4 * \pi * D^2)$, where

P = Output Power

G = Gain

D = Distance

From the values given in the Introduction, the formula yields the following for maximum power density at Earth surface:

Power Density = $3.18 \text{ e-}14 \text{ W/m}^2$, or -135 dBW.

Bandwidth is 250 kHz, so spectral power density at the transmitter is $0.025/250000 = 1\text{e-}7 \text{ W/Hz}$. With a gain of -4 dBi, and at a distance of 500km,

Power Spectral Density at Earth Surface = $1.27\text{e-}19 \text{ W/m}^2\text{-Hz}$ or -189 dBW/m²-Hz.

Based on this, we believe that the emissions of the PAN inter satellite radios are below the noise floor of any ground systems operating on this frequency.

Normalizing the power density produced by the space station to meet the bandwidth of the victim receiver, we get power spectral density at Earth's surface for a 200kHz bandwidth and a 5MHz bandwidth.

Power Spectral Density at Earth Surface at 200kHz Bandwidth = $1.59\text{e-}19 \text{ W/m}^2\text{-Hz}$ or -188 dBW/m²-Hz.

Power Spectral Density at Earth Surface at 5MHz Bandwidth = $6.36\text{e-}21 \text{ W/m}^2\text{-Hz}$ or -202 dBW/m²-Hz.

Using an online field strength calculator (<https://www.compeng.com.au/field-strength-calculator/>) the PAN radio emission field strength at Earth's surface is found.

Field Strength at Earth Surface = $10.79 \text{ dB}\mu\text{V/m}$

Calculating the protected field strength for each class of station:

$$E = -37 + F - G_r(\theta) + L_F + 10 \log (B_r) + 20 \log (f) + I/N \text{ (Recommendation ITU-R [M.1767](#))}$$

where:

- F : receiving station noise figure (dB)
 $G_r(\theta)$: receiver antenna gain (dBi) at the elevation angle of θ
 L_F : receiving station antenna cable feeder loss (dB)
 B_r : receiving bandwidth (MHz)
 f : center frequency of the receiving station (MHz)
 I/N : interference to noise ratio (dB)

Table 1: Field Strength to be Protected for Land Mobile Service Systems

System to be protected	Class of station	Frequency (MHz)	Noise Figure (dB)	Feeder Loss (dB)	Receiving antenna gain (dBi) at 90°	Field strength to be protected (dBμV/m)			Receiving antenna height (m)
						200 kHz GSM-R	200 kHz GSM	5 MHz LTE	
GSM or LTE system	Receiving base station	880-915	5	3	-1.5* ($G_{\max} = 15$)	16	19	33	30
	Receiving mobile station	925-960	9	0	0 (GSM-R and GSM) -3 (LTE)	15	18	35	1.5

* -1.5 dB of omnidirectional vertical antenna gain at the elevation angle of 90 degree as the worst case is used for calculation. (See *recommends* 2.2 of Recommendation ITU-R [F.1336-4](#)).

Table 2: PAN Spacecraft Field Strength Interference Analysis Results

Parameters of NGSO space station notified to the BR						Field Strength at Earth's Surface <i>dBμV/m</i>		Excess of Interference (dB)				
BR ID	freq_min (MHz)	freq_max (MHz)	Min_dist (km)	Bandwidth (MHz)	EIRP (dBW)	200kHz	5MHz	GSM-RMS	GSM-BS	GSM-MS	LTE-BS	LTE-MS
	915	928	490	0.25	-16.02	10.79	10.79	N	N	N	N	N