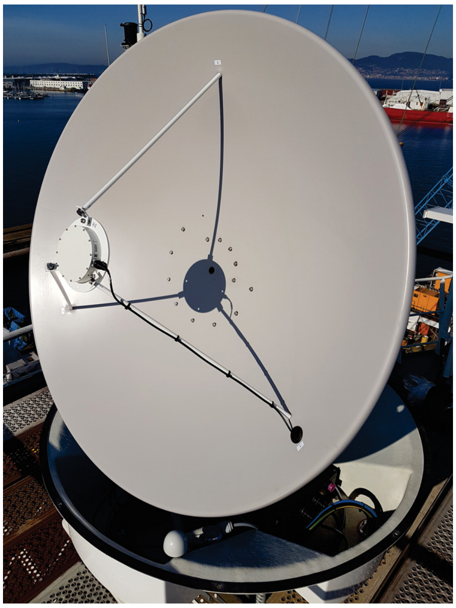

Meteor-M2, a Russian weather satellite launched in 2014, orbits the Earth at an altitude of 820 km. It weights about 2800 kg and once deployed, the solar panels span a width of 14 m. As a weather observation satellite monitoring optical wavelengths from 500 nm (visible) to 12 μm (thermal), two radiofrequency signals are beamed back to Earth from this satellite, carrying the Low Resolution Transmission Protocol Transmission (LRPT) and the Advanced High Resolution Transmission Protocol Transmission (AHRPT). The former is sent on a carrier around 137 MHz, the latter around 1700 MHz.

1. Considering that low cost R820T2-based software defined radio receivers exhibit a detection limit of -112 dBm [1] at 138 MHz for a 10 dB signal to noise ratio, and that the effective radiated power from the satellite is about +6 dBW, is a dipole antenna sufficient on the ground to receive the LRPT signal ? Justify quantitatively with a link budget analysis.
2. Is an antenna with the same geometry sufficient to receive AHRPT ? Justify quantitatively.
3. `www.dartcom.co.uk/products/hrpt-ahrpt-system/marine-antenna` (see figure) sells a stabilized 1.5 m diameter parabolic antenna operating in the AHRPT band. What is the impact of this antenna on the link budget ? how could it change the conclusion from the previous question ?
4. Despite the updated antenna feed, is the R820T2 receiver able to receive AHRPT ? If yes justify. If not, what external component, which might (or might not) be introduced on the advertisement web page, may help improving reception ?
5. How does the frequency shift induced by the satellite motion impact the 120 kHz bandwidth LRPT ? Justify quantitatively the answer.

---

[1] `http://jmfriedt.free.fr/sdr2.pdf`

Answers

1. $FSPL = 20\log_{10}(f)+20\log_{10}(d)-147.55 = 20\log_{10}(137\cdot 10^6)+20\log_{10}(820\cdot 10^3)-147.55 = 133$ dB $\Rightarrow P_R = P_E - 133$ dB with P_E the emitted power given in watts and which must be converted to milliwatts to be consistent with the sensitivity specifications. 6 dBW=36 dBm and the received power is -97 dBm, well above the detection limit of -112 dBm.

2. the same calculation at $f = 1700$ MHz hints at a Free Space Propagation Loss of 155 dB or a received power of -119 dBm, insufficient for decoding the high frequency signal with a simple dipole antenna connected to the receiver.

3. The parabola will provide additional receiving gain. The $D = 1.5$ m diameter parabola provides $G = 10\log + 10\left(\pi\frac{D^2}{\lambda^2}\right)$ at $\lambda = 300/1700 = 0.18$ m wavelength so that the received power is focused and raised by 23 dB. This additional gain raises the received power to -96 dBm, above the detection limit.

4. 1700 MHz is at the limit of the frequency range of the R820T2 frontend, advertised to operate up to 1766 MHz. The receiver performance can be expected to be much worse at its upper limit: mixing with a local oscillator for frequency transposition to a lower frequency band is advisable. Indeed the antenna website provides an "Integrated feed/downconverter" whose specifications claim that it allows for reaching an output intermediate frequency around 130 MHz where the receiver operates best.

5. The motion of the satellite introduces a Doppler shift observed as an offset of the received frequency to the nominal frequency. The satellite at an altitude of 820 km orbits the Earth every $\sqrt{\frac{(6400+820)^3}{(6400+36000)^3}} = 0.07$ days=1.69 h=101 minutes or a velocity of $v = 26900$ km/h= 7472 m/s. The Doppler shift as the satellite rises over the horizon or sets is $df = f_0 \cdot \frac{v}{c} \cdot \frac{6400}{6400+820}$ with c the speed of light and $f_0 = 137$ MHz the carrier frequency: here $df \in [\pm 3]$ kHz matching the observation (slide 29) of a 6 kHz frequency variation during a satellite pass. This frequency variation is much less than the modulation bandwidth and will be cancelled during the demodulation step.