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Interactive Comment

Interactive comment on "Potential radio frequency interference with the GPS L5 band for radio occultation measurements" *by* A. M. Wolff et al.

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Dear Dr. Young,

I appreciate your comments and expertise on this matter. The process of responding to your comments has strengthened the integrity of this paper and furthered my understanding of the material. Further investigation is ongoing concerning certain parts of this research including the EIRP from the stations encountered atop Pikes Peak. Below are my responses to your specific comments.

Sincerely,

-Alex

Referee comments include page numbers

Author response noted by **

Specific comments

Page/line

4530/12 One should qualify the statement that RTK “results confirmed”. The link calculation portion seems to be confirmed by its comparison to a published result for RFI to an aircraft. This would be stronger if the assumptions used for both calculations (power, ant gains, range, etc) were described.

**Referee #1 had a similar comment. The values are as follows: range: d = 246 NM, DME radiated peak power: P_e = 40 dBW, wavelength: lambda = 25.5 cm, receiver antenna gain: G = 0 dB. These values will be noted in the text after the first revision. The same parameters were used in the STK simulation.

4532/22 Change to S(N+I)R, and make use of this ratio instead of the I/S ratio. As mentioned in General Comments above, I believe the RFI should be discussed in relation to the noise, not the signal. This equation can be used to compare the loss of SNR from interference (I) which is the ratio S/(N+I) to S/N, which is a factor of N/(N+I). So, when the pulse is active, the loss of SNR is 10*Log(N/(N+I)). Notice the signal power is not in the equation.

**This quantity was not used initially within the paper but will be a point of further development as the research progresses. The challenge of adding Noise + Interference arises due to the nature of each signal. The noise is assumed to be white Gaussian noise whereas the interference behaves as a pulsed sinusoid. Future analysis will look into how to add these two signals together in order to provide a S(N+I)R parameter.

4534/19 change “the directive orientation of the receiver antenna pattern aboard a RO satellite with respect to a DME station increases the received power level from a DME station as well as increases the total number of DME stations effectively witnessed

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by the receiver." to "the high-gain RO antenna toward a DME station increases the received power level from a station in its beam but decreases the total number of DME stations received." Why: Basic antenna property is the gain and beam solid angle are inversely proportional. High-Gain means a smaller solid angle is within the beam.

**This statement was initially misworded. It has been changed and will be shown correctly in the revision.

4534/4 What is the peak gain of the DME antenna? What is its 3 dB beamwidth in elevation? [I think +9 dBi linear and >6 deg per manufacturer specs]

**The specifications that you suggested were correct. These values will be included in the revision.

Fig 2: Gain of helical antenna is? [I'd guess +9 dBic for a 2-turn helix]

**The gain according to the specification sheet is +10 dBi. This specification as well as a reference to the manufacturer, Steatite, will be included in the revision.

Estimated noise floor at L5 is ___ K, (or dBm/Hz)? Hump in noise is due to filter shape, or?? Vertical scale is ___ dBm/MHz Resolution BW is? Is this averaged over many pulses or is it taken from a short dwell while the pulse is ON? Can you estimate the EIRP from each station?

**The estimated noise floor is -131 dBW assuming 290 K and 20 MHz bandwidth. It is correct that the hump in noise is due to the filter shape. For this measurement, the pulses were averaged over the 10 ms of data captured. The EIRP can be estimated and that is an ongoing topic of research. An STK link budget simulation will be compared to the direct measurements from Pikes Peak. This study aims to provide insight into the EIRP from these stations.

Fig 4 and 5: Please describe what is plotted. For example, is it the voltage of the signal + noise + interference after some amount of amplification?

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**You are correct. It is the voltage after signal processing. This explanation will be included in the figure's caption.

4535/22 What is the estimated noise floor? What are the respective gains (approximate) of the choke ring and helix toward Denver?

**The estimated noise floor is -131 dBW assuming 290 K and 20 MHz bandwidth. The approximate gains for the choke ring and helix are -3dBi and +9dBi respectively.

4535/24 Change from "high gain directive antenna that's energy is focused on the limb of the earth" to "high gain directive antenna whose gain is focused on the limb of the earth" Why change: RO antenna is receiving, not transmitting.

**This change will be reflected in the revision.

4535/24 "Therefore, it is consistent that GPS RO receiver will witness interference comparable to that seen by the helical test" This remains to be shown. One could say it is possible, if the higher gain of the RO antenna and the fact there are more DME/TACAN transmitters in view compensate for the additional range from the RO geometry. (The typical range from LEO to the earth limb is 3,000 km while the range from Pikes Peak to the Denver airport is 118 km, a difference of -28 dB. The gain of the COSMIC RO antenna is similar to a 2-turn helix, and the worst-case (all 76 stations transmitting at the same times) factor with 76 DME stations in the beam at the same time is +19 dB. I'd guess the COSMIC RO case would show, worst case, about 9 dB lower RFI from DME.)

**Your sentiments are absolutely correct. My word choice did not accurately portray the actual meaning. I will end that section with the following: "Similarly, a GPS L5 receiver used for RO applications utilizes a high gain directive antenna that's energy is focused on the limb of the earth (Wu et al., 2005). Further analysis was conducted in order to detail the interference that a GPS RO satellite may encounter due to DME pulses."

Section 4: The assumptions used for the STK and reference calculations are not described in this text, and so the similar result from the toolkit is not convincing. If the toolkit link calculation needs verification, that can be done by numerical calculation in a few lines. Otherwise please describe the range, gains, etc. used to calculate the link. The parentheses are missing a square in formula 1.

**The values are as follows: range: d = 246 NM, DME radiated peak power: P_e = 40 dBW, wavelength: lambda = 25.5 cm, receiver antenna gain: G = 0 dB. These values will be noted in the text after the first revision. The same parameters were used in the STK simulation.

**The missing square was noted in a peer review comment and will be changed for the revision.

4536/7 Mention the gain of the DME transmit antenna is +9dBi with vertical linear polarization. (also, vertical FWHM is >= 6 degrees) Both taken from the manufacturer's website. What is the gain of the aircraft antenna toward the boresight of a ground antenna aimed at +4 degrees elevation? What range was used?

**These parameters (+9dBi and 6 degrees) are both correct and will be included in the revision. The aircract antenna gain is 0 dB and the range is 246 NM.

4537/19 What satellite height and RO gain were used? At 4 deg el, Satellite at 800 km altitude, Pt = 1000W, Gt = +9 dBil, I get R = 2878 km, and Pr at L5 with a +10 dBic RO antenna [The COSMIC antenna was about +10 dBic, but was L1 + L2] to be -117 dBW. [That is close enough to the STK -123 dBW value.]

**The same input parameters as the ones you noted were used for the STK simulation. The difference between our values may be attributed to modeled antenna gain patterns STK as compared with a hand link budget calculation with peak gains. Due to the individual orientations of each antenna, the peak gain of the receiver might not coincide with the peak gain of the transmitter. I am still unsure if this is the cause but I believe it is a reasonable explanation.

4538/2 Why -125 dBW? Perhaps a somewhat arbitrary dividing line, which is fine.

**I needed to employ a constraint in order to simplify the results. This is an arbitrary value.

4538/8 Must specify which code and the receive antenna gain for if you give a typical received GPS signal power. Also, the ratio of RFI power to signal power is not the best comparison. One should compare RFI to the noise floor. (See comment 4532/22)

**After reviewing this sentence, I feel it is best to omit it. The section reads with more fluidity and the information given is unnecessary.

4538/10-16 I suggest this be re-written. Even if all DME pulses occur simultaneously, the received power is < -123 dBW + 10*log(76) = -104 dBW. A typical receiver saturation level is well above that.

**This section is inaccurate and will be revised in the revision.

Does the result shown in Fig. 8 assume random pulse timing among DME sites? Is this timing known to be random or is it coordinated among sites?

**Figure 8 only shows the number of accesses witnessed by the orbiting receiver which does not take into account the pulsed nature. Figure 9 assumes random timing and uses probability to calculate the percentage of time at least one DME station is interfering with the receiver. Using the figures in conjunction with one another would provide the best understanding of the situation.

4538/23 I think you mean “experiment” instead of “simulation”.

4538/23 Change “Specific antenna patterns. . .” to “Uncertainties in specific antenna patterns. . .” By the way, these parameters are known for the COSMIC-2 mission, which has L5-capable receiver hardware. The parameters can be obtained from UCAR or JPL.

4538/24 Why is the transmitter noise figure of interest? Is “receiver noise figure”

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meant?

4539/5 Change “at any point in time” to “at some point in time”.

**The previous four comments will be reflected in the revision.

Interactive comment on Atmos. Meas. Tech. Discuss., 7, 4529, 2014.