Atmos. Meas. Tech. Discuss., 7, C1402–C1409, 2014
www.atmos-meas-tech-discuss.net/7/C1402/2014/

Atmospheric Measurement Techniques Discussions

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

Anonymous Referee #2

Received and published: 25 June 2014

General comments:

The paper points out a potential problem for future GPS radio occultation (RO) measurements using the GPS L5 frequency. The problem is that a number of DME/TACAN ground stations (which are used for aviation) in the United States and in Europe operate sufficiently close to the GPS L5 frequency. This may particularly be a problem for a RO receiver in a Low Earth Orbit looking at the Earth's limb over these areas. The authors claim that the interference from too many DME/TACAN stations can result in receiver saturation, and that it will prevent the retrieval of atmospheric parameters from RO measurements. However, the technical problem is not adequately described, and receiver saturation for a RO receiver is not really quantified. Simulations using a Systems Tool Kit is carried out in an effort to quantify the number of stations transmitting a

strong enough signal that a RO receiver will see, but it is not clear if such a scenario is realistic (comments below regarding receiving antenna pattern and number of stations operating at the same time). There is no firm conclusion that a certain number of stations (or received power) would lead to receiver saturation. For these reasons, I am not fully convinced that it is a real problem, but I am willing to give the authors the benefit of the doubt. If it is a real problem, it would be very critical for future RO missions relying on the Galileo and GPS E5/L5 frequencies. Therefore, the paper is potentially very important, but major revision is necessary before I can recommend publication in AMT.

A weak point of the paper is that there are many references to non peer-reviewed publications. Not all of them are readily accessible. If references could be made to peer-reviewed publications it would be better and increase reliability. Please make an effort towards this and replace non peer-reviewed references with peer-reviewed ones where possible.

Generally, it should be possible for anyone reading the paper to reproduce the results. In some places there is not enough information so that this can be done. Some of my comments below are related to this.

My expertise is in the RO technique, but not receiver technology. Some of my comments below may reveal my limited knowledge about RO receiver technology.

Specific comments and technical corrections:

Page 4530, line 7: "...a means" -> "...a source". "A means" implies that it is something one wants to achieve. I don't suppose that is what is meant here.

Page 4530, line 8: Suggestion to reformulate: "This study presents results from a Systems Tools Kit (STK) simulation..."

Page 4531, line 16: "This resulting ..." could be reformulated to "The post correlation C/N0 is a popular metric ..." with a reference at the end of the sentence. But perhaps even better just to skip (or move somewhere else) everything from "This resulting ..."

to "...can be witnessed". It would make a better connection to the previous sentence.

Last paragraph of the Introduction: A reference such as "(see next section for more information on GPS RO)" or "As described in the next section..." would be appropriate when explaining about GPS RO already here.

Page 4532, line 8: I don't think it is correct to say that "GPS has stimulated an evolution in weather forecasting technology". The technology has not changed because of GPS, but GPS RO has contributed to the advance of weather forecasts. Maybe this could be written differently.

Page 4532, line 9: "RO technique leverage ..." I'm not sure what 'leverage' means in this context.

Page 4532, line 17: "refraction of the signal causes a delay...". Delay refers to time; when talking about the phase it would be more accurate to call it "excess phase".

Page 4532, line 19: Maybe replace "into desired values for" with "the vertical distribution of". Refraction depends on these variables, but in humid regions of the atmosphere they cannot be derived individually from the observed refraction alone.

Page 4532, line 22: To be consistent, first letter in "ratio" should be capitalized.

Page 4532, line 23: "(SN(R+I))" seems odd. R does not stand for Noise, it stands for Ratio. But is the abbreviation necessary? It is not used later. I don't understand how "reduced Signal..." would allow for lower atmosphere soundings. Shouldn't it be "increased Signal...".?

Page 4533, line 3: Like the current COSMIC mission, COSMIC-2 is also a joint Taiwan/US mission, and that should perhaps be mentioned here. To be correct it should be referred to as Formosat-7/COSMIC-2. Also the Metop-SG satellites to be launched several years from now will carry RO receivers relying on E5/L5 signals. The situation is potentially more critical for Metop-SG, since they will not in addition track the GPS L2C signal (as COSMIC-2 will). Also it could be noted that future RO with Galileo

is relying on E5a (which is at the same carrier frequency as GPS L5, but the signal structure is different).

Page 4533, line 7 (also in other places in the paper): As a matter of style, starting a sentence with an acronym should be avoided.

Page 4533, line 14-16: Is "interference" correct/sufficient terminology (by which I understand the superposition of two or more waves resulting in a new wave pattern). Wikipedia gives several definitions of interference, one of which is called "adjacent-channel interference", another one "co-channel interference". Would any of those describe it better? As I understand (and I admit that my understanding is limited here), it may not be the interference itself that is the problem, but the large input power at the RF front-end. Is that correct?

Page 4534, line 11: Could the statement that "In the United States alone there are approximately 203 DME or TACAN ground stations ..." be supported by a reference?

Page 4534, line 15: Please discuss briefly why RO receivers have bandwidths of +/-10 MHz or wider, and relate it to the fact that a RO receiver sampling rate of about 50-100 Hz is sufficient for data collection. See Sokolovskiy (Radio Science, vol. 36, 483-498, 2001) and Bonnedal et al. (GPS Solutions, vol. 14, 109-120, 2010) and cite as appropriate. There is also a recent paper on interference from terrestrial sources and it's impact on RO measurements from the Metop-A satellite (Isoz et al., Radio Science, vol. 49, doi:10.1002/2013RS005243, 2014). What is the impact of interference in such a wide bandwidth (+/-10 MHz) when the GPS signal is subsequently filtered in the receiver with a bandwidth of only 100 Hz around the carrier (plus shift from Doppler model in the receiver)? Is the subsequent filtering relevant for the possibility (or avoidance) of receiver saturation? The Doppler model in the receiver takes into account the shift due to the atmosphere and the satellite velocities (see Sokolovkiy, 2001). The Doppler shift from satellite velocities could shift the received L5 signal by about 10-30 kHz, depending on the geometry. Would/could DME/TACAN stations transmit within

10-30 kHz of the L5 frequency? Would this be relevant for the possibility of receiver saturation, or is the problem merely that the incoming power in the +/-10 MHz bandwidth around the carrier from DME/TACAN stations is larger than a RO receiver can cope with?

Page 4534, line 17: Please explain a bit more what 'receiver saturation' means. Is this design dependent? Can it be quantified and put into context with the simulations later on in the paper? The provided reference (ITU, 1998) gives some explanation, but it is unclear if the numbers there can be directly applied to a RO receiver system.

Page 4534, line 18: "Furthermore, the directive orientation of the receiver antenna pattern ... increases the total number of DME stations". I'm not sure I understand this. I agree that the directional pattern of the RO antenna adds to the concern, because the gain is then the largest possible, but why would it lead to an effective increase in the total number of DME stations seen by the receiver? Wouldn't it decrease the total number seen, exactly because the antenna patterns are highly directional.

Page 4535, line 5: 38 deg in azimuth relative to what? To North? What was the azimuths to the DME/TACAN stations?

Page 4536, line 5: "The author of" could be skipped, just starting the sentence "Roturier (2001) ...".

Equation 1 (besides the correction pointed out by R. Notarpietro in the on-line discussion): In the text, please give the values for P_e, G, lambda, and d that were used to obtain P_1 = -107 dBW. Is 'effective radiated peak power' the same as 'DME radiated peak power'? If it is, use only one term; if not, explain the difference.

Page 4537, line 1-3: Please make clear that Formosat-3/COSMIC is a constellation of 6 satellites. I suppose only one of them was used in the simulations. Which one?

Page 4537: Was the true gain pattern for the COSMIC satellite antenna taken into account in the simulations (it is not mentioned)? In Figure 7, I would not expect much of a

signal when the receiver is right above the DME station, because the RO antenna does not point in that direction. The signal would also depend on the viewing azimuth angle from the receiver. Was this taken into account? I assume also that the gain pattern of the receiving antenna would depend on the frequency. If the true gain pattern was not taken into account, then please discuss the possible implications for the simulation results in the text, or make new simulations with a more realistic gain pattern. The gain pattern of the COSMIC satellites RO antennas are quite narrow in elevation and limited in the azimuth, but I'm not able to quantify this. Possibly scientists at UCAR/CDAAC can give more information. The person at UCAR to ask would be Bill Schreiner. Information might also be available at the COSMIC website (www.cosmic.ucar.edu).

Page 4537, line 24: "interfering" instead of "inferring".

Page 4537, line 25: "signal" instead of "station".

Page 4538, line 2: "the number of stations" instead of "a plot of the stations".

Page 4538, line 3: Please provide a table with relevant information on the 203 DME stations (at lest station name and coordinates). This would be necessary in order to reproduce the results if anyone wants to do that. Perhaps a reference to where such information is obtained would suffice.

Page 4538, line 3-7: Is the true gain pattern for the COSMIC satellite antenna taken into account here? If not, could this have influence on the conclusion that "receiver saturation remains as a possibility" (Page 4538, line 13)? How many interfering stations with a transmitting power of -125 dBW would it take for receiver saturation to occur? Is it realistic to think that all 203 stations are operating at the same time?

Page 4538, line 14-16: It is not clear if the results in Figure 9 comes out of the above described simulations, or if it is obtained separately. In Figure 8 the maximum number of stations is 76, in Figure 9 the curves extend (at least) to 90 stations. Please describe in some detail how the percentage of time was calculated (such that the results in

principle can be reproduced).

Page 4539, line 5: "...at any given point in time...". This is not consistent with Figure 8, which shows that there are more than 70 stations for only about one minute in the time interval around 6-7 minutes.

I suggest a bit more explanations in the Figure captions: Fig. 1: Is this a real measurement? What/when/where? What is the envelope curve? Fig. 2: Day and time of measurement? What is the 'Magnitude' the magnitude of? Fig. 3: What is the scale? What is the distance between stations? Fig. 4 and 5: Day and time of measurement (for Fig. 4 this would make it clear if it is the same measurement as in Fig. 2)? Antenna orientation? Fig. 6: Is it antenna gain? Write what the approximate values of the colors are if it is not possible to plot a color bar. Fig. 7: Is it the mean of the power over time? What is the location of the DME station? Fig. 8: Where is the satellite at time = 0? (North Dakota?). Where is it at time = 25 min? Please provide information that can identify the flyby (i.e., COSMIC satellite ID, date and time). Such information is important if someone wants to try to reproduce the simulation results. Figs. 7, 8, and 9: Write that it is simulated data. Generally, I'm not asking for discussion in the captions (discussions belong in the main text as it is), but information that relates directly to what is seen, such that the figures can be easily understood without too much reference to the text.

Fig. 4 and 5: 'Amplitude' is missing a unit.

Fig. 6: At the top of the figure it says with very small letters :'FOR UNFUNDED EDUCATIONAL USE ONLY'. Has it been checked if it is okay to use the figure in journal publications? Is there a legal issue that the AMT journal should be aware of here? Could the text be removed (if it is okay to remove it)?

References: Bastide et al.: Gps and e5a/e5b should perhaps be in capital letters. Griggs et al.: "...IROWG-2m". Why the "m"? Ostermeier, J.: Not able to locate it using Google scholar. Van Dierendonck: Journal information is given as "Proceedings of...".

Other references to papers in the same journal (Bastide et al.; Kim and Grabowski) does not include the respective proceedings volume, but just says "J. Inst. Navig.". I do not know which way AMT wants, but it should at least be consistent.

Generally the wording could be improved throughout the paper. I kindly urge the authors to run the paper by a person with excellent skill in the English language.

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