Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2018-287-AC1, 2018

Atmospheric Measurement Techniques Discussions

Interactive comment on "Novel specular meteor radar systems using coherent MIMO techniques to study the mesosphere and lower thermosphere" *by* Jorge Luis Chau et al.

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Received and published: 23 November 2018

We thank the referee for her/his careful review and suggestions. We will wait for the comments from the other referees before submitting a revised version and the corresponding reply point by point. Here we comment on some of the major concerns and suggestions:

1) MIMO increasing counts. It was not our main point to claim that MIMO, under most parameters and considerations the same, will increase the number of detections. However, we do want to stress that using MIMO approaches allows an alternative and, based on our experience, easier to implement way to increase the number of detec-

tions using multi-static links. To make a fair comparison between a single link MIMO and SIMO, one would need to use similar analysis and software. We will make appropriate changes in the revised version to clarify this aspect. 2) Signal processing. We will add additional description about the signal processing. Namely, we are using a compressing sensing approach that, using more common radar terminology, combines a matched filter and an inverse filter approach. Inverse filter is used to detect the strong echoes, which are then remove from the complex voltages. After this initial cleaning, a matched filter approach is applied to go after the remaining weaker echoes. In both cases, the time and range location of the echoes is obtained, and a minimum mean least square error estimator is used to estimate the complex voltages of the meteor echoes. 3) Increase counts with different variations. By combining all transmitters (5) and all receivers (5), one obtains effectively complex signals from 25 virtual eceivers. Therefore, when compare to a MISO approach (5 txs and 1 rx), by just comparing the average power, in the case of MIMO, the noise uncertainty is reduced, allowing more detections in the MIMO variants when compared to MISO. As we pointed out in the paper, we are yet not exploring the full power of MIMO, i.e., combining the signals of all 25 rxs in a unified way, i.e., focusing from the tx site and the rx site simultaneously (stereoscopy). Instead we are using the MIMO information either to get SIMO (with respect to the rx) or MISO (with respect to the tx) information. We will clarify the main text accordingly. 4) MIMO implementation. Implementing MIMO with time diversity is a good idea, and indeed we have done that in other applications (at Jicamarca and at MAARSY to get radar images of Equatorial electrojet echoes and polar mesospheric summer echoes, respectively). In our previous implementations we have applied time diversity from pulse to pulse (i.e., with time separations governed by usual pulse repetition frequencies, i.e., a few milliseconds), which will not be convenient for specular meteor radars (poor duty cycle, poor time sampling, etc.). However, the suggestion of the referee, i.e., using staggered pulses with a few tens of microsecond separation, is worth considering. They might be possible by commercial systems. However, additional transmitters and antennas on transmission would be needed. In our case, we

do not have the multiple pulsed transmitters to test the idea. We will modify the text accordingly, and make some kind of “invitation” to test such implementation by other groups, possibly with commercial systems, and also stressing why we have chosen code diversity.

Although we agree that the implementation might be simple, the processing might require some special treatment, since for example, each echo would have many representations in range (in the case of 5 txs, 5 representations), they might not be easy to identify using standard detection software in the presence of other echoes (e.g., airplanes, ground clutter, other meteor echoes, other atmospheric echoes).

The proposed implementation with staggered pulses, could be considered as a particular case a phase-coded CW implementation, where the code has three symbols (0, +1, -1). The main difference with the conventional code CW would be the cross-talk between codes. In the case of time-staggered the cross-talk would be higher given that the symbol “0” does not carry any additional information and we might miss weak echoes near to strong ones. The application of time-staggered will be also limited by the number of transmitters (as in the conventional CW) given that (number of transmitters) times (code length) defines the area of interference. If this area is large, the probability of missing weak echoes is high.

Example:

Time-staggered:

TX1: +1 -1 -1 +1 -1 +1 0 0 0 0 0 0 0 0 . . .

TX2: 0 0 0 0 0 0 +1 -1 -1 +1 -1 +1 0 0 . . .

Coded CW:

TX1: +1 -1 -1 +1 -1 +1 +1 -1 -1 +1 -1 +1 +1 -1 ...

TX2: -1 -1 +1 -1 +1 +1 -1 +1 -1 +1 +1 -1 -1 +1 ...

5) Count rates of Jruh SIMO vs MIMO approaches. Again, it was not our intention to focus on the increase number of counts. Besides the differences pointed out by the referee, there are also differences on the detection and identification processing used, in Jruh we are using a commercial system (and software), while in the MIMO links we are using our own software. The idea of using Jruh SIMO results is to provide the reader with an idea of what is expected for the time of experiment, winds, diffusion vs altitude, approximate counts, etc.

6) Angle of departure (AOD). This is an excellent suggestion. We apologize for the oxymoron. We abuse the use of AOA respect to the tx, trying to simplify the explanation and using it as an analogy. Using AOD is definitely more appropriate, and we will make the changes accordingly.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2018-287, 2018.