

Referee's report on the paper

"Coded Continuous wave meteor radar" by Vierinen et al.

Summary: The paper is worth publication but requires considerable changes. Greater respect needs to be shown to those who already presented similar ideas over 60 years ago.

Specific comments.

Please change the title to reflect the fact that this idea is 60 years old! This paper begins its abstract by saying "*The concept of coded continuous wave meteor radar is introduced.*"

This is quite ironic - I would very much like the authors to look at this paper

Elford, W., and D. Robertson, Measurements of winds in the upper atmosphere by means of drifting meteor trails II, J. Atmos. Terr. Phys., 4, 271-284, 1953.

In this paper, early meteor measurements were made (prior to 1953!) *using a CW mode with coding*. In that case the coding comprised a pulse overlaying the CW signal, which may not be as sophisticated as the newer codes, but *it is* nonetheless a coded CW system.

Quoting from the paper by Elford and Robertson:

"To determine the position of the trail in space, both the direction of arrival of the sky wave and the slant range of the reflection point must be measured. The latter is determined by pulse-modulating the transmitted signal above the CW"

The paper also refers to a companion paper with more details about the method (ROBERTSON, LIDDY and ELFORD).

The paper also refers to an even earlier paper by

MANNING, VILLARD and PETERSON (1950) who described *a C. W. doppler system on 23 mc.*

So for these current authors to claim to INTRODUCE coded CW techniques is very misleading. They *are re-introducing* a 60 year-old technique, at best.

I would very much like to ask the authors to remove the introductory statement of the abstract, and give better recognition to those who have gone (long) before. A change to the title to remove the implication that this is all new would also be respectful. The actual coding that is used is different - true. But the concept is not. The authors should focus on what is new, not try to pretend they have invented the idea.

In addition, in the first paragraph of the introduction, the authors refer to some "early works" by McKinley, Sugar etc. These papers were about 10 years after the first meteor studies - the first were by Manning e.g.

Manning, L., The theory of the radio detection of meteors, J. Applied Phys., 19 , 689-699, 1948.
Manning, L., O. Villard, and A. Peterson, Meteoric Echo Study of Upper Atmosphere Winds, Proc.Inst. Radio Engrs, 38 , 877-883, 1950.

and then followed by the papers by Elford and Roberston.

Please modify the paper to be more historically accurate and more respectful of those who developed their ideas so long ago.

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I shall now get to a more detailed assessment of the paper.

There are many typographical errors which are addressed at the end of the comments.

Page 7881, line 16 - "meteor trails are typically point-like in range" - this is wrong. The meteor trails can be 5 - 10 km long in range. The specularly reflecting point is potentially point-like (though it is usually considered to cover a Fresnel zone) but the trail is NOT!

Page 7881, line 11 - not sure why Holdsworth is referenced here for winds - there were many papers before this one - at the least, say (Holdsworth et al., 2004, AND REFERENCES THERE-IN)

Page 7883 line 22 - the equation " $N = c(d)...$ etc" - the origin of this is unclear. Is it supposed to be obvious? Or is there a reference? How/when were typical values of $c(d)$ found? What is d ? Is it supposed to be distance?

Page 7884 section 3 - the authors mention both frequency domain and time domain analysis - but then say little about the frequency domain. A link to a paper that does use long coded pulses and does the analysis in the frequency domain might be useful to some readers e.g. Hocking et al., "Windprofiler optimization using digital deconvolution procedures", JASTP, 118(A), 45-54, <http://dx.doi.org/10.1016/j.jastp.2013.08.025>, 2014, uses this strategy to obtain ~50m resolution with a 1 km pulse. Might also be a useful reference at the bottom of p. 7881 and top of p.7882.

Page 7885, equation (1). This is not well described. It says "our measurement equation is.." Measurement of what? What is m ? Is it complex amplitudes? I assume so, but it is not stated. In addition, on lines 5-6, it says ".. target backscatter coefficient at a given range gate and coherence time i .." - is the "given range gate" represented by " r "? I assume so, but it is not specified.

Page 7886, equation (7) - maybe I missed it, but Σ does not seem to be defined. And the authors talk about the "standard formula for complex linear least-squares problems". Standard or not, a reference would still be a good idea.

Figs. 4, 5 and 6 are very hard to read.. the layout could be a lot better. I suppose the idea is that since the paper is to be shown on the web, the reader can zoom in, but for someone who prefers to read a paper version, they are very hard to read. In addition, the labels seems funny - the ordinate reads "Counts x 30 mins" - which I suppose means "Counts at 30 min intervals" (maybe "Counts @ 30 min" might be better?)

Page 993, line 22 - the authors mention the range-Doppler ambiguity problem with pulsed systems. Yet I would expect the coded systems might start breaking down if the velocities get very large - which the authors agree is true at a later stage when they discuss measurement of head echoes (p. 7894, lines 17-18). I did not get a clear idea of the velocities needed before this problem sets in, but it does seem to be something that is worth discussing. The authors are clearly intent on "selling" their system, and take every opportunity to show the advantages of the CW system over the pulsed system, but not much is discussed the other way around - - some better level of "balance" would be worth thinking about.

Some extra things to think about and (hopefully) discuss in the text.

I could not see where the authors have discussed the height resolution of the CW system.

Because they mainly use low elevation signals, due to the large distances between transmitter and receiver, the height resolution becomes critically dependent on the accuracy of

determination of phase differences on the receiver antennas, and at elevations below 20 degrees (and maybe even 30 degrees) errors in phases lead to uncertainty in angular positions of the meteors, which manifests itself as uncertainties in height (e.g. see , Hocking, “Radar meteor decay rate variability and atmospheric consequences”, *Annales Geophysicae*, 22, 3805-3814, 2004.) An interesting test of this would be to see the plots of inverse decay time vs height - these should be presented. It is noticeable in other systems that the plots of inverse decay time vs height are much more tightly clustered for systems with higher gain antennas, which obtain a higher percentage of meteors closer to overhead (and so which have better height resolution).

Another point of note is that because the new design relies more critically on low elevations, (or at least I assume it does) then it is also potentially more susceptible to ground-level interference. I am not sure if this is important, but some discussion might be warranted.

I did not see much detail about the specifics concerning the codes used - not even a table of codes. The discussion of codes is kept as an overview - more specific details should be given. The only detail is in fig. 2, and it is very generic. How long were the bauds? Were the code pseudo-random? etc. It is hard to assess the paper without such details.

Typographical and Grammatical Errors.

p 7880, line 21 -- "atmosphere were early on recognized important"

would be better as "atmosphere were recognized early on as important"

p 7881, lines 6 to 10 - long sentence - break it up -- or at the very least put "< 1 kW average transmit power meteor radar" in brackets.

p. 7882 line 26 "allowing observing" --> "allowing observation of"

p. 7884 line 12 "in frequency domain" --> 'in THE frequency domain.

p 7884, line 13 - "in time domain" --> "in the time domain'

p 7887, line 6 -- "is additive noise" --> "are additive noise" (signals is plural)

p 7889, line 4 -- "for as" --> "as"

p 7890, line 8 - full-stop needed at end of sentence.

p 7890, line 13 "sent waveform" --> "transmitted waveform"?

p 7891 line 12 - insert "system" after "CW"

p 7893 line 1 - "more fair" --> "fairer"

p. 7894 line 15 - "seldomly" --> infrequently.

p 7895, lines 19 and 20 - "However, with careful planning and surveying, these issues are not prohibitive". This is not proven and is speculation - which is not advisable in a scientific paper.

p 7895, line 25 - put "the" in front of "vicinity"
