Comments on egusphere 2025-1015

Title: Analysis of Lightning-Induced Currents in Supply Cable Shields and Their Impact on LLS Sensor Site Errors

Author(s): Hannes Kohlmann et al.

Reviewer: Kenneth Cummins

General Comments

This work is a quantitative, detailed effort to explain the physical mechanisms contributing to site errors in magnetic direction finders used to locate lightning. The authors provide a clear, logical, and well-organized presentation of the physical "steps" leading to the unwanted magnetic field seen by a near-ground sensor that is produced by buried cables associated with the sensor. Briefly, these steps include propagation of the lightning-produced EM signal over lossy ground, coupling of the resulting field onto the buried cables producing current in the cables, and the resulting magnetic field produced by this cable current and sensed by the instrument. This all leads to angle-dependent errors in both the magnitude and inferred direction of the observed lightning magnetic field wavefront.

The authors model all the steps in this process and evaluate their behavior in terms of the physical properties that influence site errors. The cable properties include cable length, depth, diameter, electrical properties, and grounding methods. Ground electrical conductivity is separately parameterized for the propagation path from the lightning discharge to the sensor, and for the local conditions at the site. The geometrical relationship between the conductors (assumed to terminate at the sensor) and the sensing loops of the sensor is parameterized in terms of separation distance and conductor depth in the ground. All-in-all, this is the first in-depth exploration of cable-caused site errors that this reviewer has seen, and it is a clear and poignant scientific and technical contribution for those who strive to understand or improve the performance of lightning locating systems employing magnetic direction finding.

I have no major concerns/issues with the approach taken in this work or with the findings, but I do have some questions, comments and "issues" that I would like to convey to the authors. I also have a number of minor and editorial comments and suggestions. These are enumerated in separate sections below. I have seen the comments by the other reviewer (Martin Murphy), so I do not include issues that he identified.

Scientific/Technical Questions/Comments/Issues

1. One over-arching issue for this reviewer is the number of analyses that were carried-out before providing results for a simple "bare wire" case in Fig. 14. It is my understanding that that it is common practice to place a bare wire 20-30 cm directly above the insulated power and communications cables, to serve as lightning protection for these cables. Given the clear benefit of this for also reducing site errors, it was surprising that the analyses for field-to-cable coupling and scattered field values did not include this condition. The authors may have reasons for this.

2. A question for the authors: do you know if the case of a bare wire above the insulated cables will produce the same coupling behaviors as a bare wire by itself? I am not sure about this.

3. The stimulating content in this study has caused me to think about unusual geometries for the underground cables to the sensors. What about a long cable coming towards the sensor, but offset laterally by about 6-8m. Then, at the appropriate distance, the cables could make a ~90-degree turn to go to the sensor? The long cable would be far enough away to produce an minimal site error (see your Fig. 16), and then the short cable near the sensor would have much less coupled current and its site-error would be out-of-phase with the long cable's contribution. Comments?

4. Frequent use of 0.001 and 0.0001 S/m conductivity may not align well with typical LLS locations. Starting with Fig. 7, many of the simulations employ this very-low local near-surface electrical conductivity. It would be appropriate to justify this early in the manuscript. In my experience, this value only exists for dry or non-porous rock.

5. The simulations typically used a fixed propagation distance and then varied the path electrical conductivity. It might be helpful to state that for a path with fairly uniform electrical conductivity, shortening the path length by some percentage is approximately the same as decreasing the electrical conductivity in the same proportion. SO – nearby lightning will have more high-frequency content than distant lightning. This should therefore change the site error magnitude as a function of distance, given the right mix of conditions. Might this be wort stating?

6. I am confused about Fig. 11, although I may have figured out some of the issues. In both panels in Fig. 11, the legends say “L = nnn”, but I think that it should be “x = nnn”. If these are really positions along the line, then it should be stated in the caption or the body of the manuscript. Also, the text states that the peak current at the line end in Fig. 11(a) is 82 mA, but it looks like 100 mA. For both Fig. 11 a &b, I am unable to reconcile the 15-20 microsecond periodicity in the current waveforms. Why does this periodicity exist for the cable grounded at both ends (11a)? This period also seems quite long, given that the round-trip time to one end and back, at the speed of light, is about 3 microseconds. A discussion of this would be helpful.

7. It seems that there is a difference between the insulted wire current waveforms for L=100 in Fig. 12 (red waveform) and Fig. 14a (blue waveform). The amplitudes, fall time, and subtitles in the shape all differ.

8. Figures 17 &18 are very nice illustrations, but the parameter domains may not be ideal. The “short” risetime associated with 0.001 S/m does not provide the likely subsequent stroke risetimes seen at 100-200 km, and the “long” risetime case seems unrealistic. Also, inclusion of 0.00001 S/m in the domain for the local conductivity is probably unnecessary, and produces unstable behaviors.

Minor/Editorial Comments/Suggestions

9. Line 29: suggest changing “are network of sensors” to “include a network of sensors”, since an LLS is more than just sensors.
10. Line 33: misspelling of “Cooray”
11. Line 35: (picky point) - I note that Vaisala’s IMPACT LLS’s use the absolute time of arrival, relative to the estimated discharge time, rather than time-differences between sensors.
12. Line 48: suggest adding “additive” after “spurious”
13. Lines 49-50: suggest eliminating “at the sampling instants”, since the spurious fields superimpose on the whole waveform.
14. Line 54: suggest adding “nearby” before “ground”
15. Line 69: suggest changing “serves as an estimator for” to “is used to produce the estimated”
16. Line 72: The second half of this line, starting with “respectively”, does not seem to fit here.

17. Line 105: suggest changing “shield currents” to “cable currents” or something like this, since a bare wire is one of the conditions.
18. Line 108: suggest changing “MDF techniques to locate lightning.” to “magnetic fields to locate lightning and/or estimate peak current.”
19. Line 112: suggest adding “cable grounding method” to the list
20. Line 249: suggest changing “introduces an error to” to “adds a spurious term beyond”, or something like this, since it does not change the true incident field.
21. Line 326: unnecessary line break after “shows”
22. Line 329: should this be “line end”, and not “cable end” ?
23. Line 330: Should the percentage be 60%, rather than 75%?
24. Lines 336-7: suggest changing “local conductivity on the site reduces” to “local conductivity is lower”
25. Line 351: suggest changing “distance of the MDF to” to ”vertical separation between the MDF antennae and”
26. Fig. 15: I cannot find the cable length that was used for this study
27. (suggestions beyond Line 351 have not been transcribed /refined yet)
28.