Correspondence

Comments on "Analysis of Lightning-Radiated Electromagnetic Fields in the Vicinity of Lossy Ground"

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1) In the above paper [1], an antenna-theory model of the lightning return stroke current was analyzed. It seems that distributed resistance R_D applied in [1] was 0.01 Ω/m rather than 0.1 Ω /m, as was erroneously stated by the authors in Section III-A. The results of comparative calculations of current waveforms are presented in Fig. 1 to prove this observation. The solid-line curves are obtained for $R_D = 0.01$ Ω/m, and they are the same as the curves presented in Fig. 6 in [1]. The dashed-line curves in Fig. 1 are obtained for $R_D = 0.1$ Ω/m.
2) The NEC2 computer program [2] is used with some modifications to the source code, which are necessary to introduce dielectric medium permittivity other than ε_0. All the numerical data are the same as specified in [1], except for the number of current spectrum samples.
3) The frequency band analyzed in [1] was 10 MHz. Therefore, the frequency domain calculations were carried out at 4096 frequencies, not 8192, because 2.44 kHz ×4096 ≈ 10 MHz. The same number of spectrum samples has been taken here to obtain the plots presented in Fig. 1.
4) The values of the ground conductivity analyzed in [1] were 0.4 S/m and 0.04 S/m. They are far from the numbers met in practice. It would be of more value if the authors presented results of computations for the conductivity of, e.g., 0.01 S/m for a typical ground and 0.001 S/m for a poorly conductive ground [3].

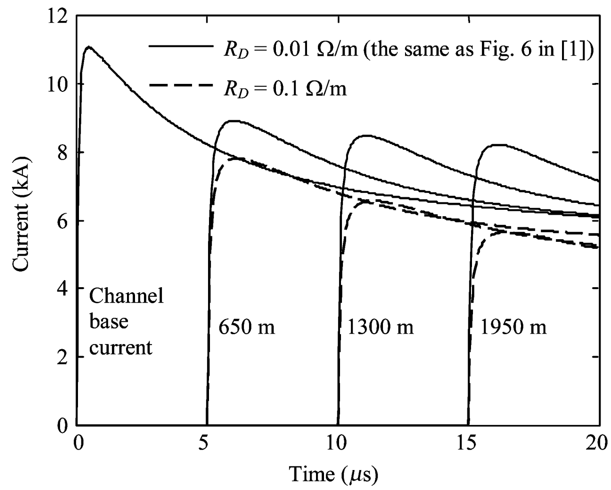

Fig. 1. Comparison of current waveforms for two values of distributed resistance R_D (0.01 Ω/m and 0.1 Ω/m) at three heights: 650, 1300, and 1950 m.

References

[1] A. Shoory, R. Moini, S. H. H. Sadeghi, and V. A. Rakov, "Analysis of lightning-radiated electromagnetic fields in the vicinity of lossy ground," *IEEE Trans. Electromagn. Compat.*, vol. 47, no. 1, pp. 131–144, Feb. 2005.

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Authors' Reply

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We thank K. Aniserowicz for his careful reading of our paper and offer the following item-by-item responses to his comments.

1) We confirm that the value of R_D used in our paper was 0.1 Ω/m, not 0.01 Ω/m as suggested by Aniserowicz [1]. The difference between our results (see Fig. 6 of Shoory *et al.* [2]) and those shown in Fig. 1 of Aniserowicz [1], both for $R_D = 0.1$ Ω/m, is apparently due to the use of different numerical procedures. It is interesting that the current profile predicted by NEC2 [3] for $R_D = 0.01$ Ω/m appears to be very similar to that predicted by our model for $R_D = 0.1$ Ω/m.
2) Aniserowicz [1] apparently refers to our statement on p. 137 that "frequency-domain calculations are carried out at 8192 frequencies up to 10 MHz with frequency intervals of 2.44 kHz. This corresponds to a sampling interval of 0.05 μs over a time window of 409.6 μs."

   This statement should be interpreted as follows: 8192 points in both the time and frequency domains were used for FFT and IFFT calculations. The time window from 0 to 409.6 μs was discretized to result in 8192 points with 0.05 μs intervals. The corresponding frequency window from −10 MHz to +10 MHz has 8192 points

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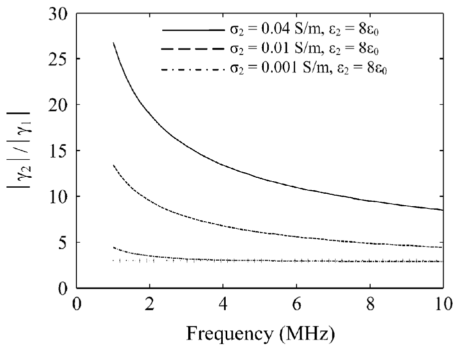

Fig. 1. $|\gamma_2|/|\gamma_1|$ as a function of frequency for ground permittivity $\varepsilon_2 = 8\varepsilon_0$ and three values of ground conductivity, $\sigma_2 = 0.04, 0.01$, and 0.001 S/m. Critical value of $|\gamma_2|/|\gamma_1| = 3$ is shown by horizontal line.

with 2.44 kHz intervals. Note that since the input (i.e., channel-base current) to the FFT is a real function of time, this input in the frequency domain is a complex conjugate function. Therefore, frequency domain calculations can be carried out only at positive frequencies of the frequency window. The values at negative frequency points are obtained by complex conjugation of the values at the corresponding positive frequency points.

3) The method proposed in [2] is valid if condition (28), $|\gamma_2|/|\gamma_1| \geq 3$, is satisfied (see p. 137). Fig. 1 shows $|\gamma_2|/|\gamma_1|$ as a function of frequency for ground permittivity $\varepsilon_2 = 8\varepsilon_0$ and three different values of ground conductivity, $\sigma_2 = 0.04, 0.01$, and 0.001S/m. It is clear from Fig. 1 that for $\sigma_2 = 0.04$ S/m (the lowest value considered in [2]) and $\sigma_2 = 0.01$ S/m (the highest value suggested in [1], which is not much different from the lowest value considered in [2]) the previously mentioned condition is satisfied, while for $\sigma_2 = 0.001$ S/m (the lowest value suggested in [1]) it is not satisfied. Thus, for $\sigma_2 = 0.001$ S/m, a different method needs to be utilized.

The values of ground's constitutive parameters used in [2] are taken from [4]. It is worth noting that values of conductivity for the same type of soil vary widely, depending on moisture content and other factors. For example, Weston [5] gives the range from 0.02 to 0.001 S/m for sand and gravel, and from 0.5 to 0.01 S/m for clay.

References

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