Use of the Loop Antennae near Large Radiators

Typically, field strength measurements below 30 MHz are performed using a loop antenna. Inherently, a loop antenna measures the strength H of the magnetic field. Subsequently, the strength E of the electric field can be computed from H using the far field relation between those two quantities:

$$E = \eta \cdot H, \quad \eta = 377\,\Omega$$
$$E[dB\mu V/m] = H[dB\mu A/m] + 51.42 \qquad \text{(B1)}$$

This equation (B1), however, may yield an unacceptable error when the measurements are performed close to large radiators such as power lines. Due to the presence of reactive fields near the radiator, the electric and magnetic fields do not obey the simple relation given by (B1).

To demonstrate this theoretical argument, AEC simulated four spans of a two conductor power line using the NEC software. The line parameters are shown in Figure B-1.

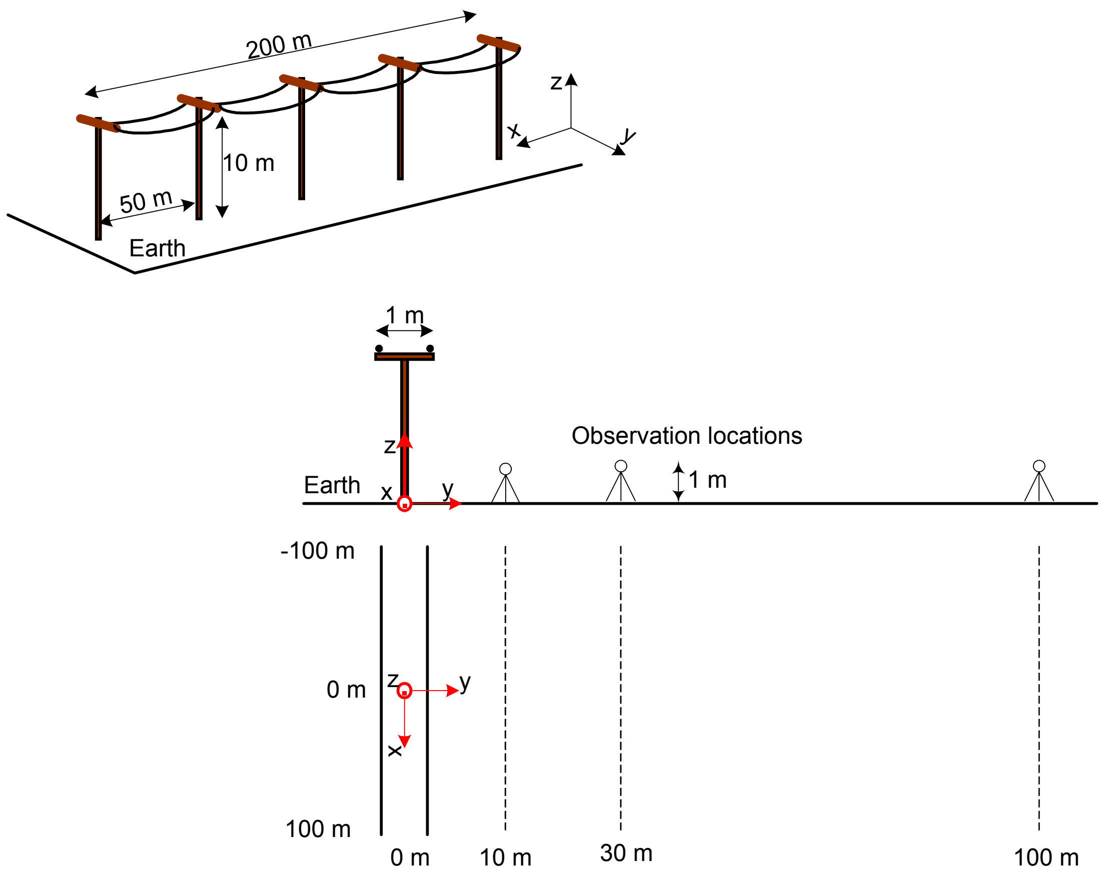

Fig. B-1. Simulated line, and field observation locations.

AEC excited one end of the line by a 14 MHz source (differential injection) and connected a 50 Ω load on the other end. Subsequently, AEC calculated the fields along the x (longitudinal) direction 1 m above the ground at three different distances from the center of the line (please, refer to Figure B-1.) The results are presented in the figures below.

Figure B-2 shows the fields calculated along the longitudinal (x) direction at a distance y=10 m from the line center. The line in magenta shows the magnetic field; the blue line, the electric field. The red line shows the estimated electric field using a loop antenna (obtained from H and equation (B1)). As can be seen from Figure B-2, the estimated value of the E-field using the loop antenna is considerably off from its actual value. The error in estimation reaches as high as 10 dBuV/m according to the figure (either overestimating or underestimating the actual field value).

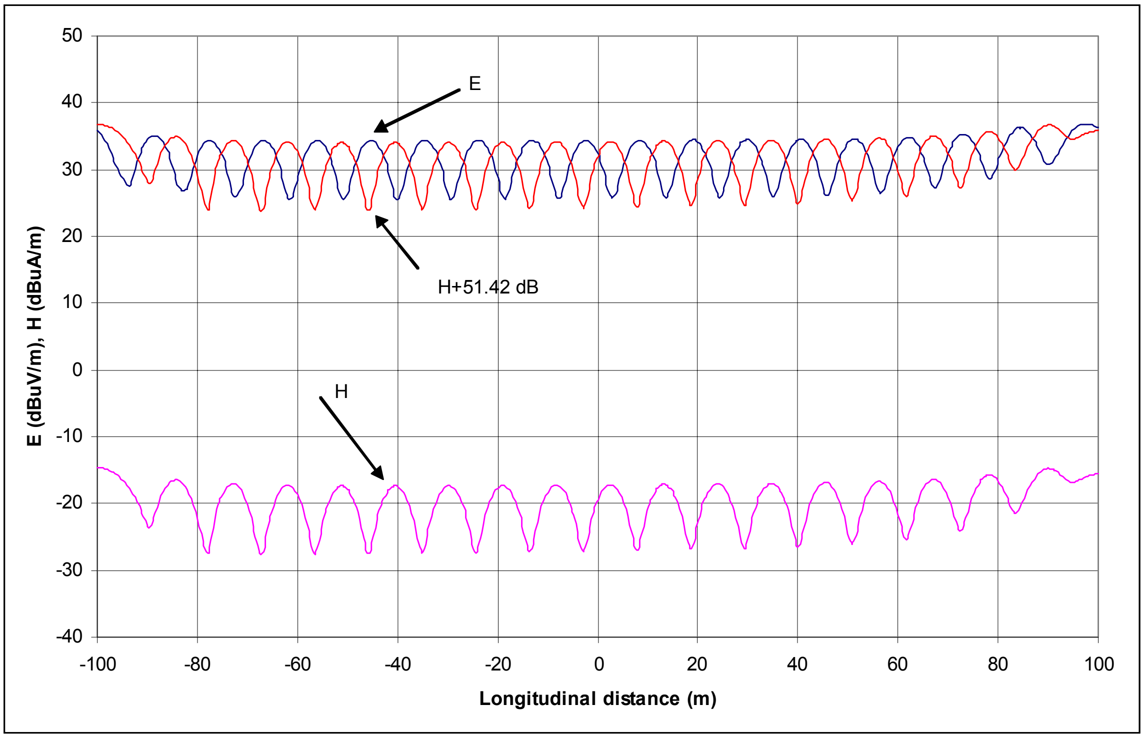

Fig. B-2. Calculated fields along the longitudinal direction (x) at 14 MHz; y=10m, z=1m.

Figures B-3 and B-4 show the same fields at a 30 and a 100 m distance from the line center, respectively. The estimation error of the electric field using the loop antenna is unacceptably high in both of those figures.

Figure B-5 demonstrates the same problem by calculating the fields 1 m above the ground along the lateral distance from the line center (with reference to Figure B-1, that is along the y coordinate with x remaining at 0). Notice that errors of 20 dBuV/m are possible. It should be mentioned that the line antenna-gain is very small in the same direction. Consequently, the estimation error does not converge to zero when moving away from the line. That is, the radiated field in that direction is very small compared to the reactive field.

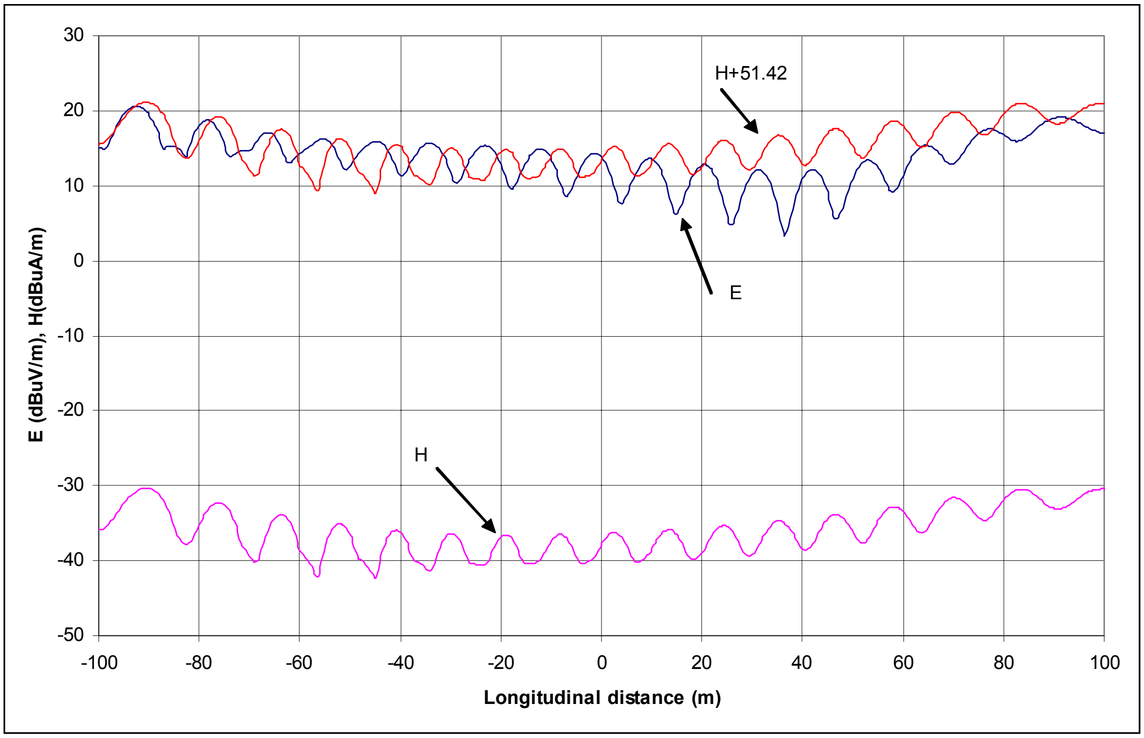

Fig. B-3. Calculated fields along the longitudinal direction (x) at 14 MHz; y=30m, z=1m.

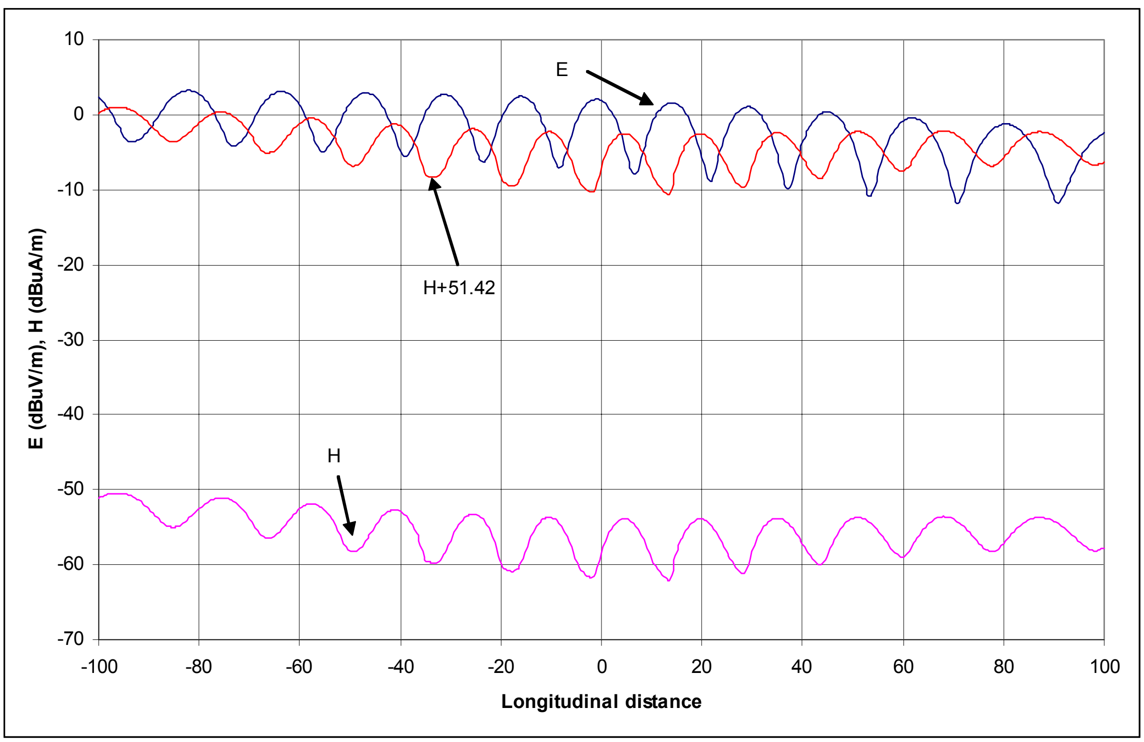

Fig. B-4. Calculated fields along the longitudinal direction (x) at 14 MHz; y=100m, z=1m.

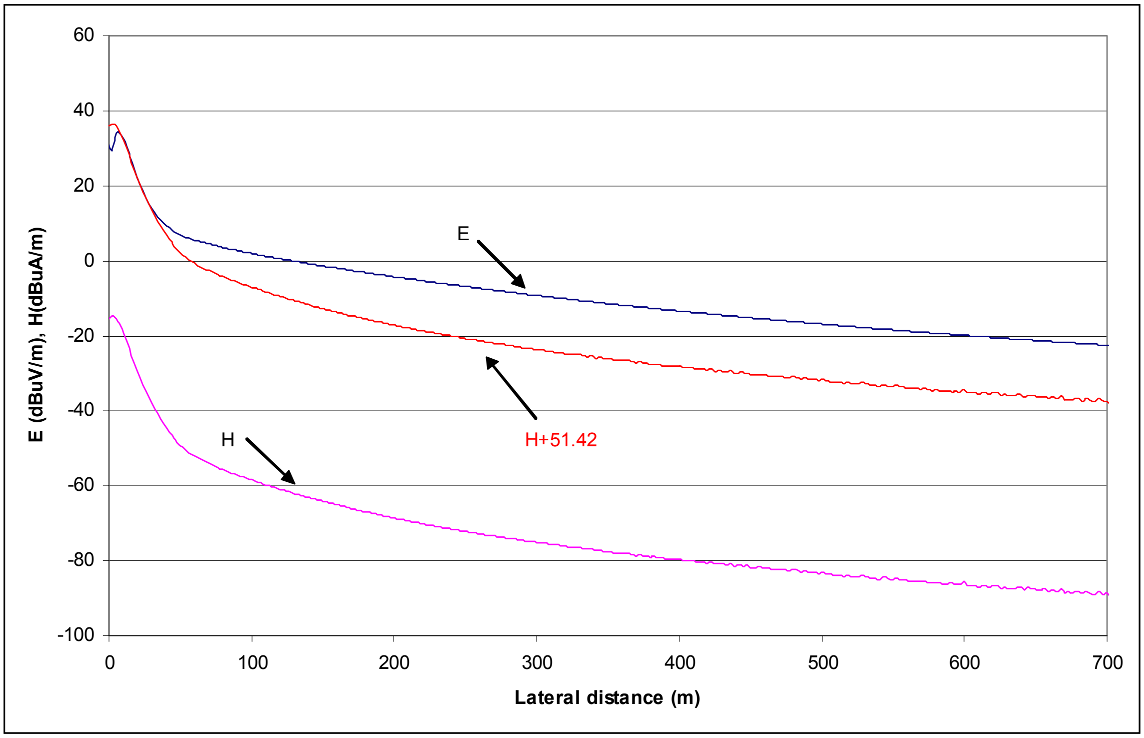

Fig. B-5. Calculated fields along the lateral direction (y) at 14 MHz; x=0m, z=1m.

Repeating the previous study at 30 MHz, AEC derived the same conclusions. Figure B-6 shows the longitudinal variation of the field 100 m from the line center. The estimation error using a loop antenna could exceed 10 dBuV/m.

Finally, Figure B-6 shows the effect of the direction of measurement to the estimation error. This figure shows the fields calculated in the direction of maximum antenna-gain (occurring at an elevation of 12 deg and azimuth of 0 deg). In this case, because the radiated fields are stronger, the estimation error is smaller (the highest value is 5 dBuV/m). The same figure also shows this error vanishing as it approaches the far field region (justifying measurement with a loop antenna 300 m or more away from the line).

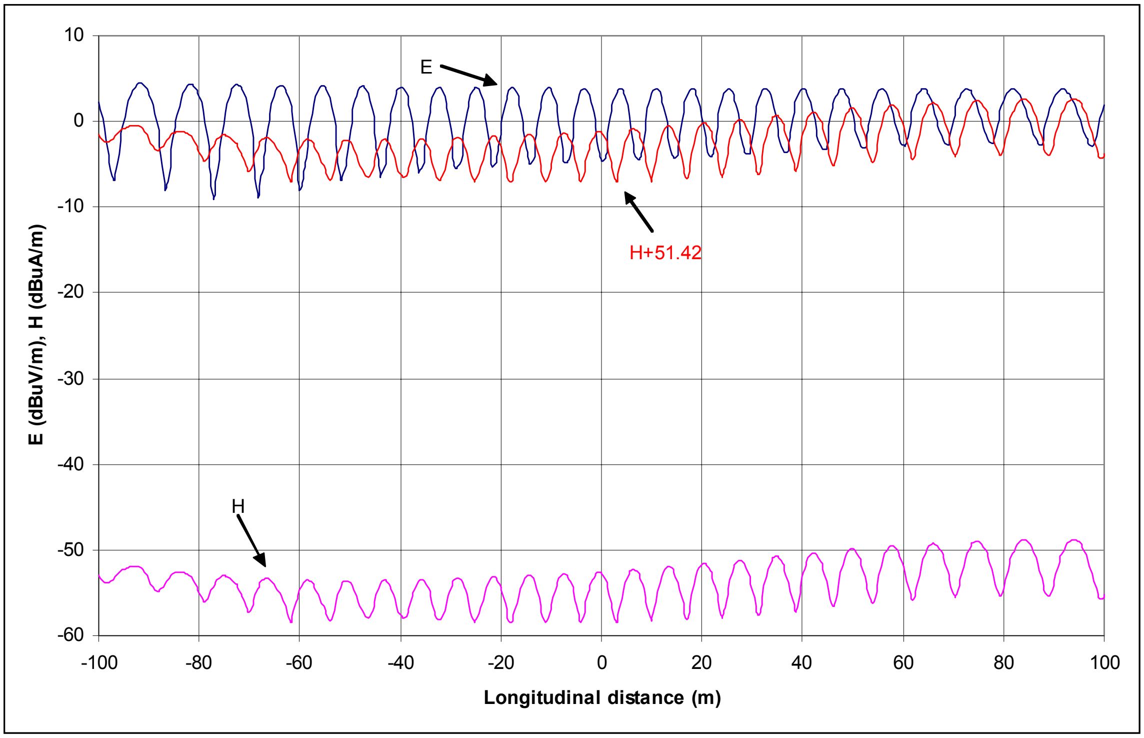

Fig. B-6. Calculated fields along the longitudinal direction (x) at 30 MHz; y=100m, z=1m.

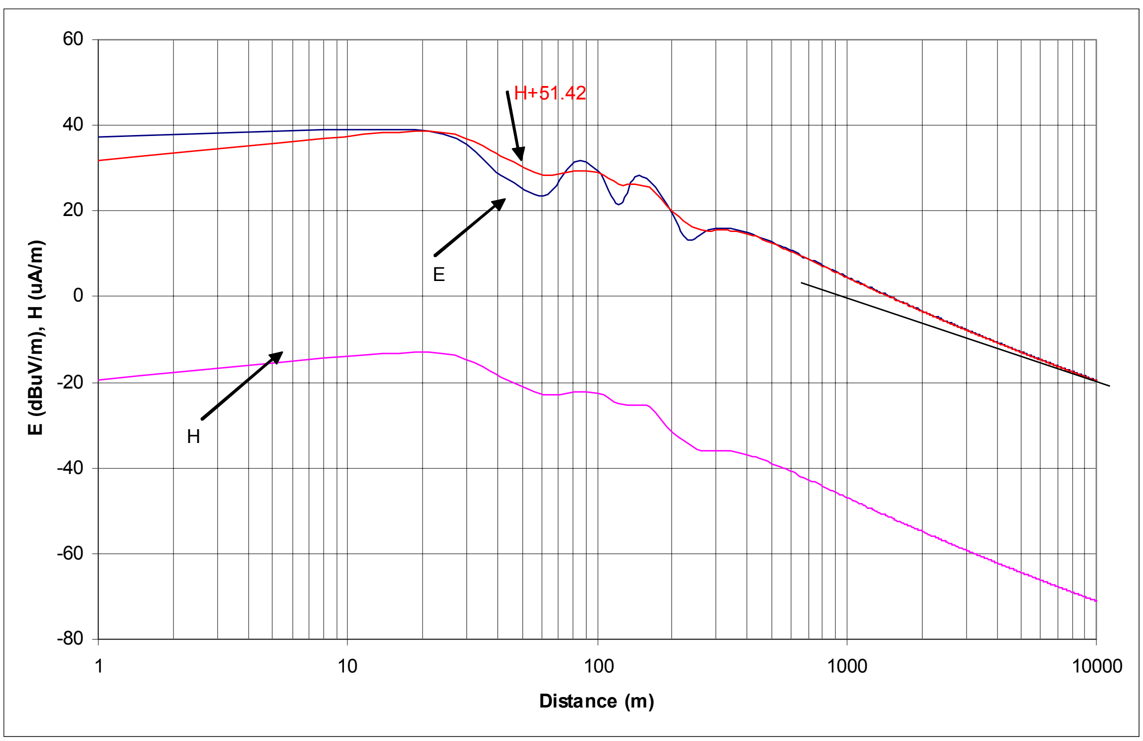

Fig. B-7. Fields calculated along the direction of maximum gain at 30 MHz; Elevation=12 deg; Azimuth=0.

In view of the efforts by the Commission and other interested entities to measure BPL emissions from power lines and houses, the Commission should review the procedures involving the use of the loop antenna for frequencies below 30 MHz. Based upon the analysis above, AEC believes that a loop antenna may introduce significant errors when measurements are made near a power line or a house (because the cumulative wiring of a house is also a large radiator). The use of a monopole antenna could mitigate this potential problem.