Power Lines as Antennas From 100 kHz to 50 MHz

Author: Ed Hare, ARRL Laboratory Manager[1]
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1. Electrical transmission lines were designed to conduct 50- or 60-Hz power from point to point. At those frequencies, power lines are excellent transmission lines and little of that 50- or 60-Hz power is radiated. The electric-utility industry also uses those lines at frequencies below 490 kHz to transmit Power Line Carrier signals to control utility equipment. Those lines, however, were not designed to carry radio-frequency energy. As the frequency of carrier-current signals conducted on power lines is raised, the amount of signal radiated from the line increases rapidly.

2. ARRL used a well-known antenna-modeling program, EZNEC PRO[2] 3.0 with the NEC-2 calculation engine[3] to model a simple medium-voltage (MV)[4] neighborhood- distribution power line. The frequency of the signal was varied from 0.1 to 50 MHz. The number of segments per line was increased as necessary as the frequency was increased.

3. Table 1 shows the calculated gain of the power-line antenna model at different frequencies. Figure 1 is a graph of part of the data in Table 1. Figure 2 shows the antenna pattern of the model at various frequencies. The antenna patterns at selected frequencies are shown in Figure 1 and a graph showing the variation in gain vs frequency is shown in Figure 2. Above 1 MHz, the gain continued to increase, although the complexity of the radiated patterns also increased, with significant directivity and peaks and nulls. Examples of this are seen in the patterns of Figures 3 through 5.

4. For a given signal level, the radiated emissions from power lines will increase by tens of dB as the frequency is increased from LF through HF. At HF, power line wiring makes a fair to excellent antenna, similar in gain and pattern to the antennas used by licensed radio services.

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[1] ARRL, Ed Hare, Laboratory Manager, 225 Main St., Newington, CT 06111, Tel: 860-594-0318, Email: w1rfi@arrl.org, Web: http://www.arrl.org/
[2] EZNEC software is available from Roy Lewallen, P.E., PO Box 6658, Beaverton, OR 97007, Tel: 503-646-2885, Email: w7el@eznec.com, Web: http://www.eznec.com
[3] NEC-2 is a freely distributed software available from the Lawrence Livermore National Laboratories, http://www.llnl.gov/.
[4] The FCC NOI refers to the power-line distribution lines as “medium-voltage” lines. The power-line industry usually categorizes lines as distribution equal to or less than 13 kV, sub-transmission less than 69 kV and transmission equal to or greater than 69 kV. In this paper, the term medium-voltage refers to lines that are typically 13 kV or less.

Table 1		
Frequency	Power-line model antenna gain	File
0.1 MHz	-71.0 dBi[5]	DIPR1.EZ
0.2 MHz	-52.1 dBi[3]	DIPR2.EZ
0.3 MHz	-33.9 dBi	DIPR3.EZ
0.5 MHz	-18.3 dBi	DIPR5.EZ
0.8 MHz	-9.9 dBi	DIPR8.EZ
1 MHz	-7.5 dBi	DIP1.EZ
1.8 MHz	-3.4 dBi	DIP1R8.EZ
2 MHz	-2.2 dBi	DIP2.EZ
3.5 MHz	1.6 dBi	DIP3R5.EZ
5.3 MHz	1.2 dBi	DIP5R3.EZ
7 MHz	6.5 dBi	DIP7.EZ
10.1 MHz	7.4 dBi	DIP10R1.EZ
14.0 MHz	7.7 dBi	DIP14.EZ
18.1 MHz	7.6 dBi	DIP18R1.EZ
21.0 MHz	7.8 dBi	DIP21.EZ
24.9 MHz	10.6 dBi	DIP24R9.EZ
28.0 MHz	7.9 dBi	DIP28.EZ
50.0 MHz	9.2 dBi	DIP50.EZ

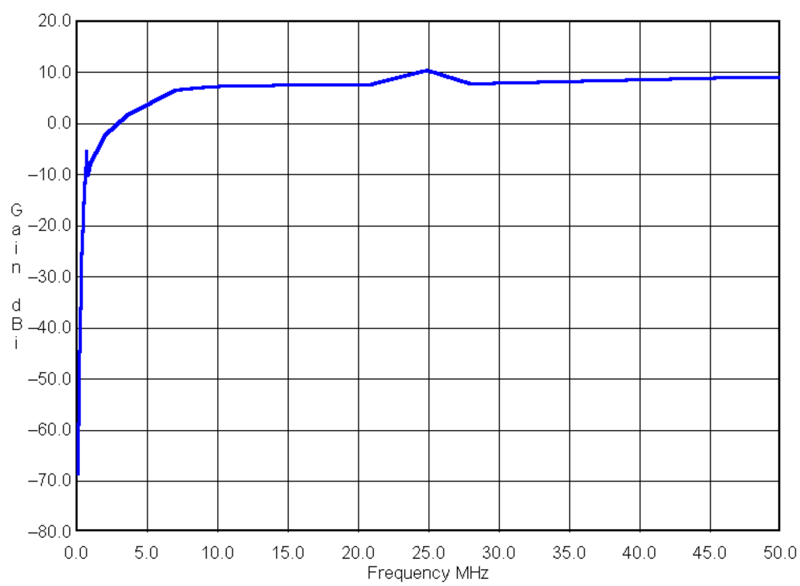

Figure 1: The gain of the power-line as a radiator increases rapidly with frequency. A radiating conductor with relatively low emissions at 0.1 MHz can have emissions tens of dB higher at HF.

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[5] At this frequency, the number of segments in the model had to be significantly reduced, stretching the model to the limits. The actual gain is probably somewhat higher than what is indicated in this table.

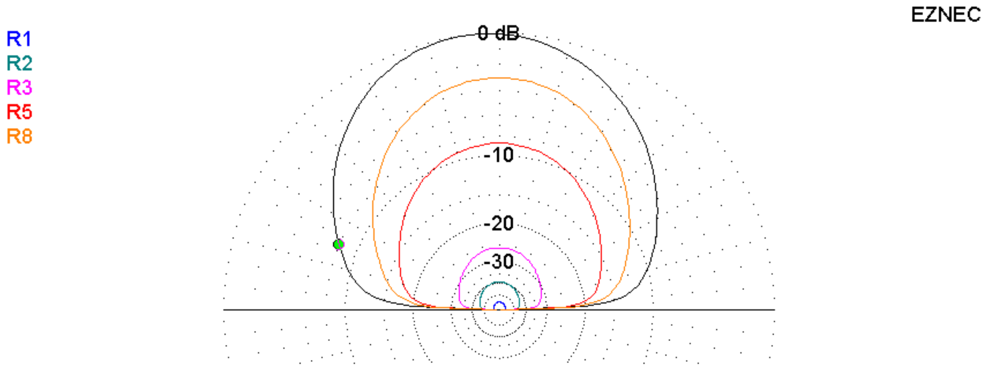

Figure 2:

Trace R1 = 0.1 MHz.
Trace R2= 0.2 MHz.
Trace R3 = 0.3 MHz.
Trace R5 = 0.5 MHz.
Trace R8 = 0.8 MHz.
Outer trace = 1 MHz.
Inner ring = -70 dBi.
Outer ring = -7.5 dBi.
(File: pwrline10.ez)

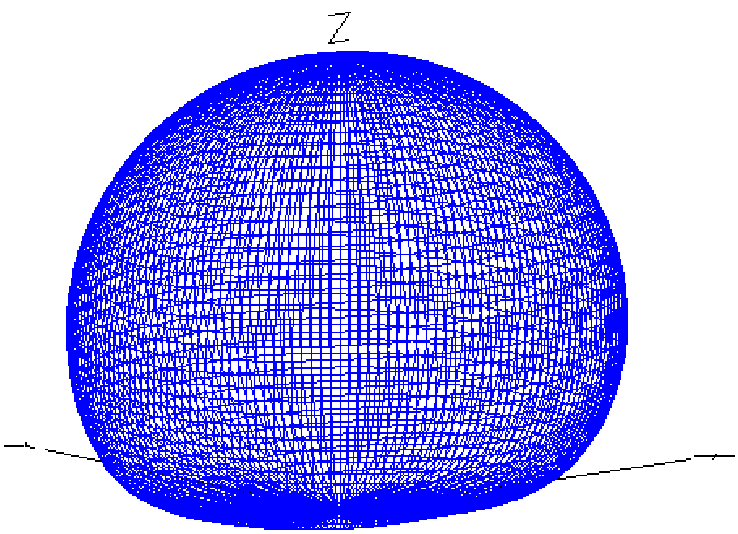

Figure 3:

This 3-D pattern of the power-line model at 1 MHz is close to omnidirectional. The gain on 1 MHz is –7.5 dBi. (File: pwrline10.ez)

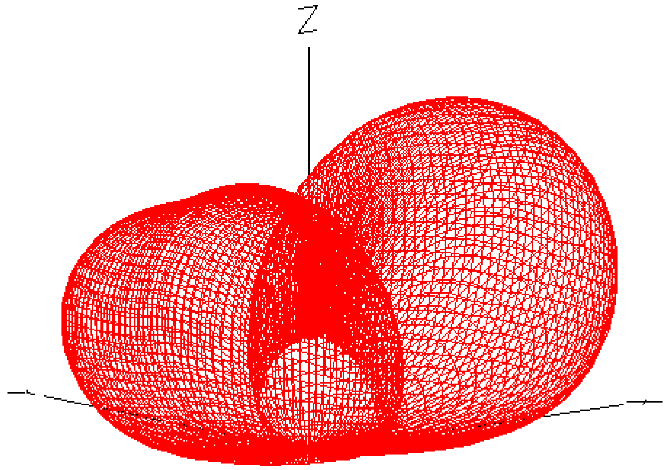

Figure 4:

On 2 MHz, the pattern is already starting to show directivity. The gain in this model is -2.2 dBi. (file: pl2mhz.ez)

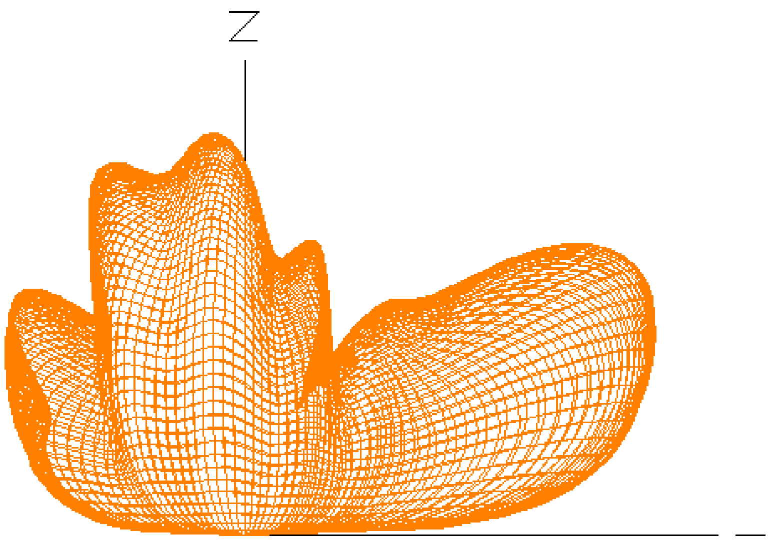

Figure 5:

At 5 MHz, the power-line model is showing considerable gain and directivity. At +1.3 dBi, this is no longer just a transmission line; it has become an effective antenna. Its gain generally increases with frequency. (DIP5.EZ)