THE E-FIELD SENSOR

How It Works

A considerable amount of misunderstanding and mystery has in the past surrounded the basic functioning of the broadband electric-field integrated-circuit sensing antenna in the minds of most users. The purpose of this article is to dispel the mystery, and explain how these instruments work. We shall be talking about electrically-small receiving antennas.

Most antenna design engineers are trained to think in terms of passive broadband impedance matching to extract the maximum response from an atenna over a given operating band. This is fine as far as it goes, but such techniques are virtually useless for RFI and Tempest applications, toward which our thoughts here are directed. Bandwidths of several decades of frequency are required. In these applications, the distance from the source is usually very short, hence the antenna must be relatively short physically to be able accurately to sample the field. A monopole of one-meter height is about as tall as one feels comfortable in using at close range. When frequencies are of the range of 1 KHz to 50 MHz, a one-meter whip is considered electrically short because it is much shorter than its first natural resonance. At kilohertz frequencies, the wavelength is so long that the element is little more than an infinitesimal field probe. The relations between electrical size, bandwidth and efficiency for passively-matched (tuned) electrically-small antennas dictate that the bandwidth will either be very narrow, or the system will be very inefficient, or both.

Assume for the moment that the short whip could be matched to a 50-ohm receiver over an extremely broad band by means of a dissipationless transformer of some kind. The absolute gain would be 3.0, independent of the frequency, to within a negligible amount as long as the whip remains electrically short. The response (or inverse antenna factor[1]) V_o/E_i of any antenna is related to the absolute gain G by the wavelength λ according to the expression,

$$V_o/E_i = \lambda(GR/480\pi^2)^{1/2}, \qquad (1)$$

where V_o is the output voltage across the load R. E_i is the incident field strength in volts per meter, and G is the absolute gain relative to R. With gain being constant, and frequency being inversely proportional to wavelength, it is evident that the response would vary inversely as the frequency, or at the rate of 20 dB per decade of frequency. Obviously this is not a desirable result, even if it were attainable, for what is desired is as nearly constant a response as possible.

The only possible way to realize a constant response with an electrically short whip antenna is to make use of its effective height h_e, which is frequency independent. The effective height of a short whip is essentially one-half its physical height measured in meters. The open-circuit voltage V_{01} at the base of the whip is

$$V_{01} = h_e E_i. \qquad (2)$$

Suppose a short whip, although its internal impedance is high, be connected directly to the input of a FET source follower. Since the input impedance of the source follower is substantially an open circuit compared to the internal impedance of the whip, over a very wide range of frequencies, practically no voltage drop occurs when the whip is connected to the source follower.

With the proper choice of FET and circuit design, the source follower will have an output impedance of 50 ohms resistance and a frequency independent output voltage V_{02} of about 0.9 times the voltage V_1 applied to its input. Thus the open-circuit output voltage of the combination is

$$\begin{aligned} V_{02} &= 0.9\, V_1 && (3)\\ &= 0.9\, V_{01} && (4)\\ &= 0.9\, h_e E_i. && (5) \end{aligned}$$

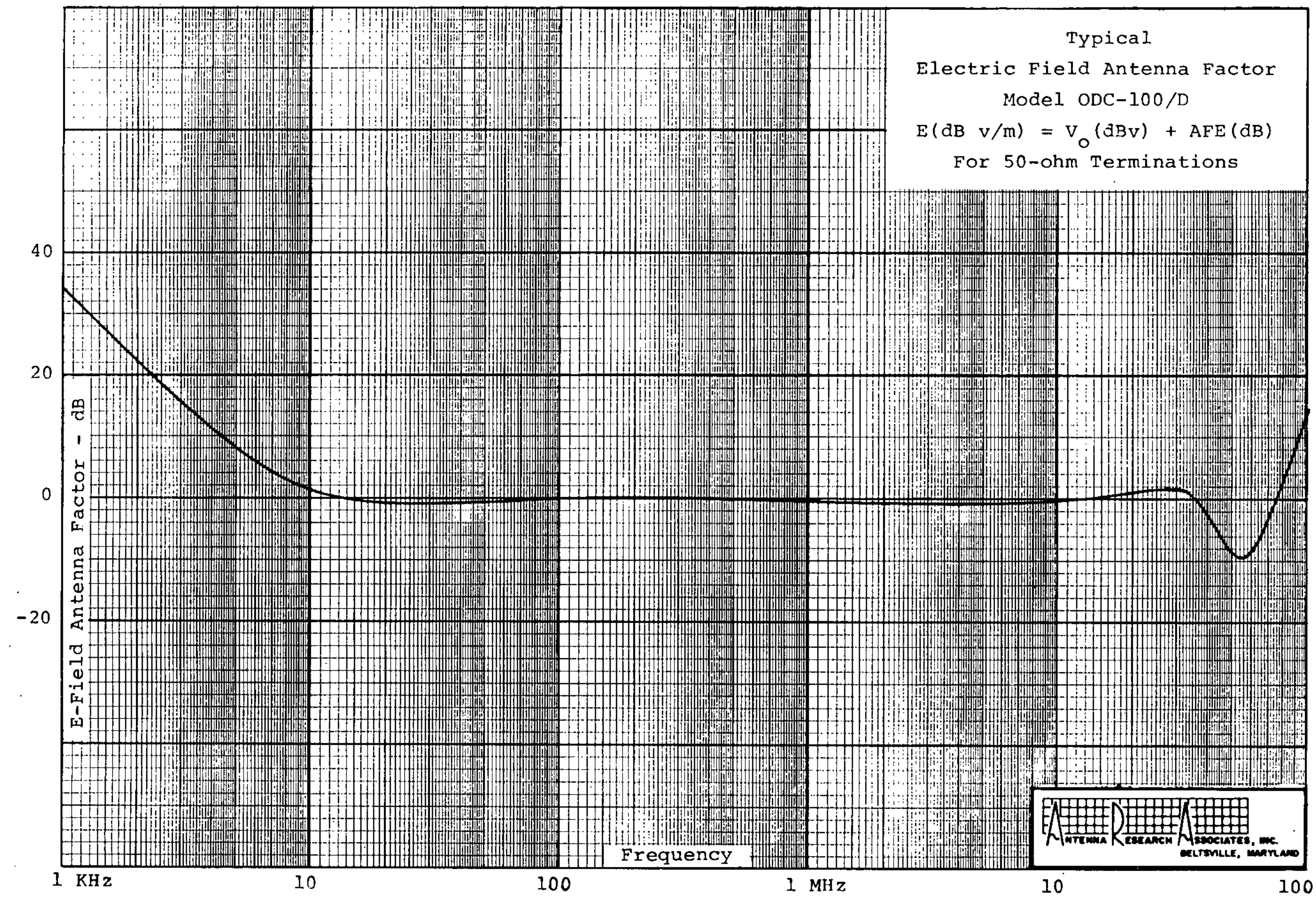
This response of this system is not very great, so it is desirable to introduce some amplification by means of a 50-ohm second stage, such as a negative-feedback common-emitter amplifier using a bipolar transistor. This adds very little noise to the already low-noise first stage, and it raises the overall response to a level where the full sensitivity of the antenna can be realized with most receivers used for field-intensity measuring purposes. A loaded gain of 10 dB is easily attainable in the second stage.

With the 50-ohm preamplifier connected to the output terminals of the source follower, the voltage V_2 delivered to the preamplifier is only one-half V_{02}. That is, from (5),

$$\begin{aligned} V_2 &= 0.5\, V_{02} && (6)\\ &= 0.45\, h_e E_i. && (7) \end{aligned}$$

Applying an assumed preamplifier loaded gain of 10 dB, or 3.16 times volts, the output voltage V_3 to a 50-ohm receiver becomes

$$V_3 = 1.42\, h_e E_i. \qquad (8)$$



One of the whip antennas offered by Antenna Research Associates is the ODC-100/D, whose physical height is about 62 inches, and whose effective whip height is about 0.79 meters. Its preamplifier has a gain of approximately 10 dB. Substituting in (8) for h_e, one obtains a response of

$$V_3/E_i = 1.12, \tag{9}$$

or an electric-field antenna factor AFE, which is the reciprocal of (9), of

$$AFE = E_i/V_3 = 0.89 \tag{10}$$

and

$$AFE\,(db) = -1.0\ dB. \tag{11}$$

The accompanying figure presents the E-field antenna factor in decibels as a function of frequency for the ODC-100/D antenna. The preamplifier has been emphasized at the low-frequency end of the band to compensate partially for the loss of voltage due to the rising self impedance of the whip. Eventually the response must roll off (antenna factor increases) as the frequency decreases. Nevertheless, the antenna factor is practically flat over a frequency range of more than three decades, which is the desired kind of characteristic, and it is useable over a range of five decades. Over the flat part of the operating band, the voltage output of the antenna across a 50-ohm load is essentially equal to the incident field in volts/meter.

In conclusion, the source follower, plus its preamplifier, function very much the same as a high impedance voltmeter head. Analysis of the system is very easy on a voltage basis, but very difficult on an impedance mismatch and power-transfer basis. One is lost at the outset in the latter approach because neither the internal impedance of the whip nor the input impedance of the source follower are known well enough to be able to calculate accurately the reflection loss.

REFERENCES

1. Masters, R.W. "Antenna Factor" pp. 168-170, ITEM 1978.

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