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CHARACTERISTICS OF A HORIZONTAL LOOP ANTENNA OVER A DISSIPATIVE HALF-SPACE

David C. Chang
Department of Electrical Engineering
University of Colorado, Boulder, Colo. 80302 U.S.A.

The loop antenna to be analyzed consists of a circular ring of perfectly-conducting wire, and is located in free-space over a homogeneous, non-magnetic dissiptative half-space. When the antenna is electrically small, current is known to be predominantly due to that of a uniform-mode, and the antenna is analogue to a magnetic Hertzian diopole. When the antenna length is comparable to the free-space wavelength (λ), the dipole-mode current, becomes dominant and the analogy is no longer valid. Since the broadside radiation of an isolated antenna is known to be enhanced by the dipole-mode, the change in antenna characteristics due to the presence of the half-space is expected to be more pronounced.

In formulating the problem, it is assumed that the antenna is driven by a delta-function voltage generator of amplitude V_o at $\phi = 0$. The radius of the loop is b, and that of the wire a. The center of the loop is located along the z-axis of coordinate system (ρ,ϕ,z), at a distance $z = d$ above a dissipative half-space, having a conductivity σ, relative dielectric constant ε_r and refractive index $n=\varepsilon_r+i\sigma/\omega\varepsilon_o$. A suppressed time-factor, $\exp(-i\omega t)$, and a thin-wire approximation $a\ll\lambda$ and $a^2\ll b^2$ are assumed. By matching the electric field E_ϕ on the antenna surface, an integral equation for the current distribution I_ϕ, is obtained. This equation is then solved by the Fourier-series expansion.

$$I_\phi(\phi) = \sum_{m=0}^{\infty}\varepsilon_m I_m \cos m\phi$$

$$I_m = iV_o/\{\pi\zeta_o(a_m^p+a_m^s)\}$$

where $\varepsilon_m=1$ for m=0, and 2, otherwise. For a thin-wire loop, analytical expression for a_m^p is given by King[1], while a_m^s can be shown as

$$a_m^s = 0.5(kb)^2\{(\Omega_{m+1,2}+\Omega_{m-1,2})\}$$
$$-m^2\{\Omega_{m,1}/n^2-(1-1/n^2)\Omega_{m,3}\},$$

$$\Omega_{m,j} = i\int_0^1 T_j'(\{1-s^2\}^{\frac{1}{2}})\exp(i2kzs)ds$$
$$+\int_0^\infty T_j'(\{1+s^2\}^{\frac{1}{2}})\exp(-2kzs)ds$$

for m=1,2,3,... and j=1,2,3 and

$$T_j'(w) = T_j(w)J_m^2(kbw),$$

$$T_1(w) = (n^2t-t_n)/(n^2t-t_n),$$

$$T_2(w) = (t-t_n)/(t+t_n),\quad T_3(w)=1;$$

where $t=(w^2-1)^{\frac{1}{2}} = -i(1-w^2)^{\frac{1}{2}}$, and $t_n = (w^2-n^2)^{\frac{1}{2}} = -i(n^2-w^2)^{\frac{1}{2}}$. J_m is the Bessel function of order m. Thus, the associated admittance of the loop, $Y=Y^p+Y^s$, is simply given by I_ϕ/V_o at $\phi=0$. If the infinite sum is replaced by a finite one, say m=20, then the approximate formula, thus obtained, gives a good measure of the admittance for use with a physically realizable voltage source, provided that a proper terminal-zone is included. For a half-space corresponding to a typical earth ($\varepsilon_r=10$, $\sigma=10^{-2}$mho/m), the refractive index is 3.17+i0.28 at

	a_0^P	a_1^P	a_2^P
	1.488 + i0.136	-0.154 + i0.224	-3.500 + i0.039
h/λ	a_0^S	a_1^S	a_2^S
0.1	$(-96.21 - i12.73)\times10^{-3}$	$(98.74 - i42.17)\times10^{-3}$	$(65.42 + i17.63)\times10^{-3}$
0.2	$(-10.80 - i32.68)\times10^{-3}$	$(78.00 + i15.71)\times10^{-3}$	$(10.26 - i15.37)\times10^{-3}$
0.3	$(12.82 - i10.81)\times10^{-3}$	$(21.33 + i57.76)\times10^{-3}$	$(5.992 + i1.686)\times10^{-3}$
0.5	$(-1.118 + i6.269)\times10^{-3}$	$(-36.76 - i14.61)\times10^{-3}$	$(-1.879 + i2.161)\times10^{-3}$
0.8	$(1.757 + i1.835)\times10^{-3}$	$(16.08 + i19.81)\times10^{-3}$	$(1.087 - i0.563)\times10^{-3}$
1.25	$(0.115 - i1.044)\times10^{-3}$	$(16.24 + i3.109)\times10^{-3}$	$(0.162 - i0.493)\times10^{-3}$

100 MHz. The table gives the change in model currents (a_m^S), from an isolated antenna (i.e. a_m^P), as a function of height for the first three modes. The antenna is assumed to have a radius kb=1 and Λ=2 ln2 b/a=12. Thus, it appears that only the dipole-mode (m=1) is greatly affected by the presence of the earth. The admittance is plotted as a function of height in Fig. 1. As expected, both the conductance and susceptance are oscillatory with a decaying envelope. On the other hand, the change in admittance of the same antenna at height z = 0.1λ is plotted in Fig. 2, as a function of the earth parameters. The value of admittance changes from 17.2+i1.2mhos for the case of sea-water to 5.18-i4.2mhos. In this regard, the resonant loop is useful in probing the electrical property of an unknown earth. Comparison between the characteristics of the loop, in the presence of a homogeneous earth, with that of a layered earth will also be discussed.

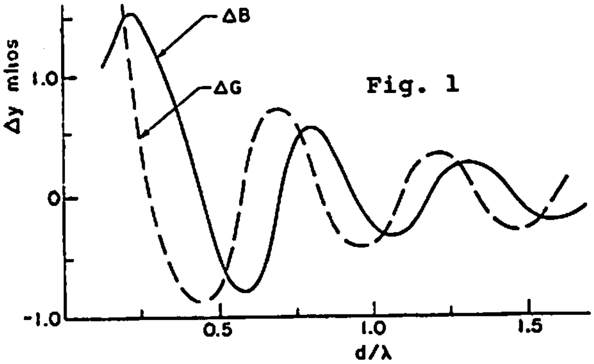

Fig. 1

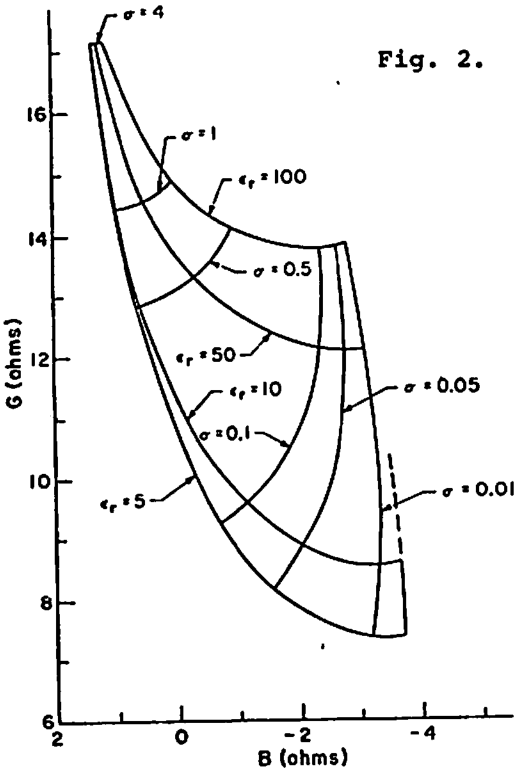

Fig. 2.

[1] Antenna Theory, pt. I, (ed. Collin and Zucker), p. 463, McGraw-Hill, New York, 1969.