VERTICALLY POLARIZED FLAT ANTENNA WITH OMNIDIRECTIONAL RADIATION

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INTRODUCTION. Numerous ideas for developing low cost ground vehicle antennas for applications with future Land Mobile Satellite Service Systems are currently being investigated in the world (ex: [1]). Both medium gain and low gain antennas with omnidirectional radiation are under research and development. A recent paper [2] was related to the study and the conception of a very flat antenna with a circularly or elliptically polarized directional radiation in a large conical angular sector and a linearly omnidirectional radiation in the horizontal plane. It can be advantageously used for communications between mobile stations. With two such antennas, and when their size is taken into account, it should be possible to practise diversity and avoid fading. The antenna was composed of four short-circuited half dipoles acting at a quarter wavelength resonance and fed in phase quadrature. The purpose of the present article is to study and describe an antenna which is vertically polarized and must have a full azimuthal coverage of 360° and an elevation coverage from 30° to 70° above the horizon. Furthermore, an antenna used on a ground vehicle for land mobile satellite service must be very flat.

CONFIGURATION. Fig. 1a shows the configuration and the co-ordinate system of the antenna which is composed of four half flat short-circuited dipoles acting at a quarter wavelength resonance and fed in phase. As the substrate reduces the bandwidth of each half dipole for a given height H, the air medium is chosen. To match the radiation resistance of each half dipole, a right feed-point location along the symmetrical axis is found and soldered to the central conductor of a coaxial line [3] and fig. 1b. So the short-circuited dipole is considered as a resonator acting at quasi TEM mode. The four coaxial lines are fed in parallel by means of a standard divider not shown in fig. 1.

THEORY. Without approximation upon the characteristic resistance $R_c$ of the transmission line equivalent to the flat half dipole we obtain [4], for the bandwidth expressed as a percentage and given in terms of the maximum allowable voltage-standing-wave-ratio (VSWR):

$$B = \frac{100(VSWR-1)}{\sqrt{VSWR}} \cdot \frac{64\pi^2}{3} \cdot \frac{R_c}{R_0} \left( \frac{W}{\lambda_0} \right)^2 \left[ \frac{1}{4} - \frac{H}{\lambda_0} \right]$$

(1)

with $R_0 = (\mu_0/\varepsilon_0)^{1/2}$, $\lambda_0^{-1} = \sqrt{\mu_0 \varepsilon_0}$.

This bandwidth is centered around the resonance frequency given by the approximate formula:

$$f_r = 4 \mu_0^{1/2} \varepsilon_0^{1/2} \left[ h/H0.72 \right] (W/H + 0.81)^{-1}$$

(2)

The elevation pattern or "E plane" (ϕ = 0 or π/2) is given by the expression:

$$\Gamma(\theta) = \frac{\sin[k_0(h+\ell)\sin\theta] - \cos(k_0h)\sin(k_0\ell\sin\theta)}{\sin(k_0h)} + \frac{\sin[\pi(W/\lambda_0)\sin\theta]}{\pi W/\lambda_0}$$

(3)

When diffraction upon the two reflector plane edges is taken into account we obtain in "E plane" the far-field radiation:
if \( \theta = \frac{\pi}{2} \): 
\[
E_\theta = \frac{E_0 \exp(-jk_0 r)}{r} \left\{ \phi \left( \frac{\pi}{2} - \theta \right) F(\phi) \right. \left. + \frac{(1+i)}{\sqrt{2\pi}} \left[ C_1 \sqrt{k_0 d}(1+\sin\theta) - jS_1 \sqrt{k_0 d}(1+\sin\theta) \right] \right. \\
\left. + \text{sign}(\theta - \frac{\pi}{2}) \frac{(1+i)}{\sqrt{2\pi}} F(\phi) \left[ C_1 \sqrt{k_0 d}(1-\sin\theta) - jS_1 \sqrt{k_0 d}(1-\sin\theta) \right] \right\} 
\]

\[ C_1(x) = \int_x^\infty \cos(\tau^2) d\tau \quad \text{and} \quad S_1(x) = \int_x^\infty \sin(\tau^2) d\tau \]

\( \gamma \) is the Heaviside function.

The azimuthal pattern \( (\theta = \frac{\pi}{2}, \phi \) variable) is given by the formula:

\[ G(\phi) = \cos(k_0 \alpha \sin\phi) \frac{\sin[\pi(W/\lambda_0) \sin\phi]}{(\pi W/\lambda_0) \sin\phi} + \cos(k_0 \alpha \sin\phi) \frac{\sin[\pi(W/\lambda_0) \cos\phi]}{(\pi W/\lambda_0) \cos\phi} \]

NUMERICAL AND EXPERIMENTAL RESULTS.

A model was calculated and tested with the following parameters:

\[ \varepsilon_r = 1 \quad \ell = 40.5 \text{ mm}, \quad W = 52 \text{ mm}, \quad H = 2.6 \text{ mm} \]
\[ h = 34.5 \text{ mm} \quad 2d = 400 \text{ mm}. \]

The measured resonance frequency was found to be \( 1.90 \text{ GHz} \) while the theoretical one given by (2) is equal to \( 1.93 \text{ GHz} \). The measured bandwidth for a VSWR below than 2 is equal to \( 4.7 \% \). The theoretical bandwidth (1) with \( R_C = R_0, H/W = 18.85 \text{ ohms} \) is equal to \( 4.62 \% \) (fig. 2).

Fig. 3 shows the measured "E plane" directivity patterns (dB) copolar and cross polarization, and the theoretical one without diffraction correction according to (3) and with diffraction corrections according to (4) and (5). Maximum isotropic linear directivity of \( 6.45 \text{ dB} \) appears for \( \theta = 37^\circ \). The measured maximum gain of the antenna with its divider is equal to \( 5.8 \text{ dB} \).

For a constant angle \( \theta \) around the antenna, the measured radiated far field is practically constant as indicated in table I.

<table>
<thead>
<tr>
<th>( \theta ) (degrees)</th>
<th>20</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured omnidirectional errors (dB)</td>
<td>( \pm 0.35 )</td>
<td>( \pm 0.40 )</td>
<td>( \pm 0.85 )</td>
<td>( \pm 1.0 )</td>
<td>( \pm 1.0 )</td>
<td>( \pm 0.90 )</td>
</tr>
</tbody>
</table>

The theoretical omnidirectional error according to (6) for \( \theta = 90^\circ \) is equal to \( \pm 0.2 \text{ dB} \).

CONCLUSION.

Theoretical and experimental results are in good agreement. The theory, with its literal formulas (1) to (6), may be used to change the elevation coverage when adjusting the \( \ell \) parameter. On the other hand the bandwidth can be improved when the height \( H \) is increased.

Our model is especially thin since \( H/\lambda_0 \) is equal to \( 0.017 \) for a bandwidth equal to \( 4.7 \% \).
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REFERENCES.


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Fig. 2

RADIATION IMPEDANCE OF EVERY SHORT-CIRCUEITED HALF DIPOLE RELATED TO THE FEED POINT LOCATION.

(Frequencies in GHz)