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AN ULTRA-WIDEBAND ANTENNA

by

I.T. Ivanov

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Procurement Executive, Ministry of Defence
Farnborough, Hants

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AN ULTRA-WIDEBAND ANTENNA

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Translator
J. Palmer

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G.A. Wilkinson

EDITOR'S SUMMARY

A size-reduced ultra-wideband three-element antenna is described. Each resonator element is a half-wave dipole, tuned to long, medium and short wave points in the frequency band, respectively. Size reduction of the dipoles is effected by employing a slow-wave helical structure wound coaxially on an insulated tube. The helices are short-circuited at their outer ends to achieve broadbanding. The reported match of this antenna over 4-5 octaves is 1.5 VSWR.

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Fig 1 shows a size-reduced ultra-wideband triple dipole antenna. The geometry of the antenna is as follows (all dimensions are normalised by dividing by λ_{max}): $\ell_1 \approx 0.25$, $\ell_2 = 0.22$, $\ell_3 = 0.2$; $h = 0.22$, $H = 0.056$; $d = 0.33$; $s = 0.0114$; $2\rho_1 = 0.0125$; $2\rho_1 = 0.005$; $a = 0.011$, $b = 0.04$.

The dipoles are of different lengths and are tuned to long, medium and short-wave sections of the operating frequency band. In order to reduce the linear dimensions the dipoles are made in the form of slow-wave structures from coaxial helices. In order to extend the wide-band properties of the antenna the helical strips at the ends of the dipoles are terminated electrically by a thin strip.

In the proposed design, a metal tube 1 is used as a former for each half-dipole. One end of this tube is welded to the parallel circuit 2, while the other has a shorting strap 3. Expanded polystyrene foam sleeves 4 are put on the metal tubes 1, helices of thin metal strip 5 being then wound on the insulating sleeve. One end of the helical strip is connected to the parallel closed circuit 2, and the other is connected to the shorting strap 3.

Thanks to this design the linear dimensions of the antenna dipoles are reduced by a factor of almost two compared with the well-known resonant dipole antenna, as a result of velocity reduction in the slow-wave coaxial helical structure.

The inverse velocity ratio m of the wave on the dipole, and, as a consequence, the length of the antenna dipole in an individual section of the operating frequency band, may be calculated according to formula [1]:

$$m = \frac{c}{v_\phi} = \frac{\lambda}{\Lambda} = \sqrt{\varepsilon(q \cot^2 \Psi + 1}\ ; \qquad \lambda = \frac{2\pi\rho_1}{\chi}\sqrt{\varepsilon q}\cot \Psi \tag{1}$$

where

$$q = \frac{\dfrac{I_1(\chi\theta)K_0(\chi) + I_0(\chi)K_1(\chi\theta)}{I_0(\chi\theta)K_0(\chi) - I_0(\chi)K_0(\chi\theta)} + \dfrac{1}{\sqrt{\varepsilon}}\dfrac{K_1(\chi\nu)}{K_0(\chi\nu)}}{\dfrac{I_0(\chi\theta)K_1(\chi) + I_1(\chi)K_0(\chi\theta)}{I_1(\chi\theta)K_1(\chi) - I_1(\chi)K_1(\chi\theta)} + \dfrac{1}{\sqrt{\varepsilon}}\dfrac{K_0(\chi\nu)}{K_1(\chi\nu)}};$$

$$\theta = \frac{\rho_2}{\rho_1}\ ; \qquad \chi = \gamma_1\rho_1\ ; \qquad \gamma_1^2 = \left(\frac{\omega}{\omega_\phi}\right)^2 - \varepsilon\beta_0^2\ ; \qquad \nu = \frac{\theta}{\sqrt{\varepsilon}}\ ;$$

$\beta_0 = \frac{\omega}{c}$; $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ is the velocity of light in free space; ρ_1 and ρ_2 are the radii of the central conducting tube and of the helix respectively; I_0; K_0; I_1; K_1 are modified Bessel functions; $\psi = \arctan(S/2\pi\rho_3)$ is the winding angle of the helix; S is the pitch of the helix.

The active resistance, which is approximately equal to the radiation resistance of the antenna, may be found from the well-known expression

$$R_A^2 = \rho_{cir}\rho_v \tag{2}$$

where $\rho_{cir} = 120 \ln\{d/2\rho_1 + [(d/2\rho_1)2 - 1]^{\frac{1}{2}}\}$ is the wave impedance of the parallel circuit; $\rho_v = 120m \ln(\rho_2/\rho_1)$ is the wave impedance of the dipole in the form of a slow-wave coaxial helix; $m = c/v_\phi$ is the inverse velocity ratio of the wave on the helical structure.

The radiation resistance of the antenna may also be calculated by another method.

$$2R_\Sigma \approx 2R_A = R_{\Sigma 1} + R_{\Sigma 2} + R_{\Sigma 3} \, . \tag{3}$$

The radiation resistance of the ith dipole of the antenna $R_{\Sigma i}$ is determined by

$$R_{\Sigma i} = 60 \left[\frac{\left(\frac{\pi D}{\lambda_0}\right)^4}{\left(\frac{2S}{\lambda_0}\right)^2} + 1 \right] \left(\xi \, \mathrm{Si}(\xi) + \frac{\sin \xi}{\xi} + \cos \xi - 2 \right) , \tag{4}$$

where

$$\xi = \frac{S/\lambda_0}{D/\lambda_0} \, ; \qquad D = 2\rho_2 \, ; \qquad \frac{D}{\lambda_0} = 0.0125 \frac{\lambda_{max}}{\lambda_0} \, ; \qquad \frac{S}{\lambda_0} = 0.0114 \frac{\lambda_{max}}{\lambda_0} \, .$$

The active component of the input resistance of the antenna (Fig 1), calculated for $\ell_1/\lambda = 1$, from (1), (2), (3) and (4) amounts to approximately 200 ohm and differs to a negligible extent from the experimental value of $R_A = 250$ ohm. Therefore in order to match the antenna to the feed cable which has an impedance of 75 ohm, the quarter-wave matching transformer 6 of 150 ohm impedance was used (a length of cable type RK50).

$$\rho_{tr} = \sqrt{R_A r_k} = \sqrt{250 \times 75} = 138 \text{ ohm.}$$

After a series of experiments had been performed, the optimal characteristics were derived for matching the antenna (Fig 2) over a frequency range of 25:1, with travelling wave ratio $\geqslant 0.3$. The geometry of the optimal antenna is shown in Fig 1.

The radiation patterns of the antenna, plotted in the horizontal plane for horizontal polarisation of the signal, are shown in Fig 3, and in the short-wave part of the band have a tendency towards splitting of the main lobe. The radiation patterns retain their shape over nearly a seven-fold frequency range.

REFERENCE

Ivanov, I.T. Slow-wave structure in the form of a coaxial helix. *Voprosy Radioelektroniki*, 12, No.16 (1966)

Figs 1,2&3

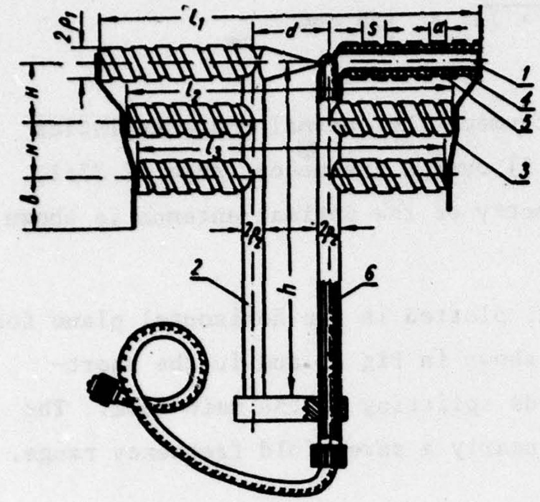

Fig 1

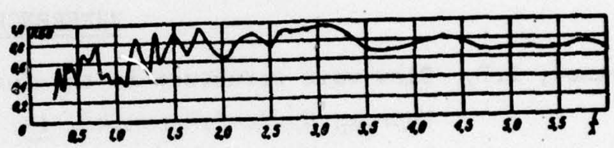

Fig 2

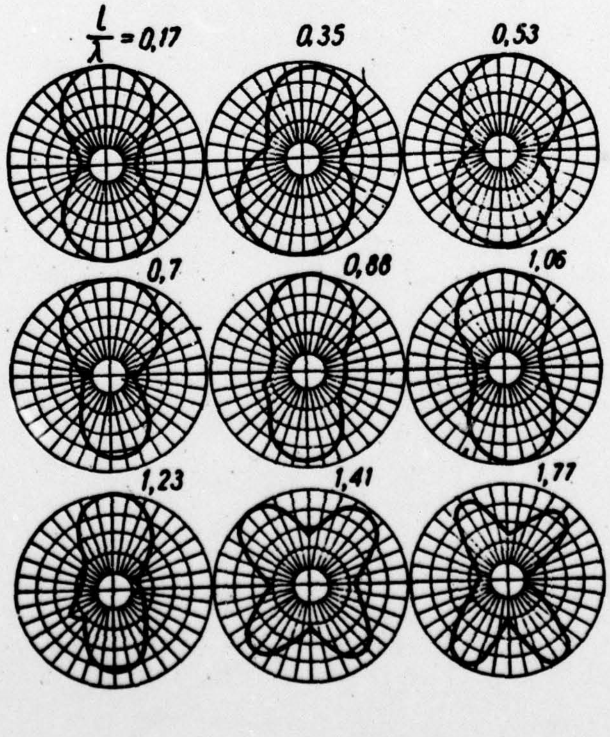

Fig 3

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