IV. A SHORT CONICAL LOGARITHMIC SPIRAL

To establish a criterion against which to assess spirals of our own design, a “standard conical spiral” was built based on Dyson’s results. This was a self-complementary spiral with two sheet-brass arms 75-µm thick, formed on a cardboard cone. Its parameters (see Fig. 1) were \( \theta_0 = 20^\circ, \alpha = 80^\circ, \beta = 90^\circ, \) \( H = 1.70 \lambda, h = 1.53 \lambda, \) and \( D = 0.6 \lambda. \) Dyson’s “infinite balun feed” was used, as it was in all spirals tested. Our measurements agreed well with Dyson’s results regarding HPBW (70° ± 4° depending on azimuth) and also AR (1.09, 1.06, and 1.75 at \( \theta = 0^\circ, 30^\circ, \) and \( 60^\circ, \) respectively).

Height reduction by truncation was studied first. A test spiral was used which was initially identical to the standard spiral, except that the sheet-brass arms were each replaced by a single RG-59/U coaxial cable. The results of these tests were disappointing. As the height \( h \) was reduced from 1.53 \( \lambda \) to 0.75 \( \lambda, \) the HPBW changed little, but the AR at zenith deteriorated from 1.1 to 1.4. Further truncation caused more deterioration in AR and HPBW, as did disconnecting the ends of the arms from the ground screen. The latter effect was in accord with the findings of Dietrich and Long, and had been explained by them as being due to reflections, at the ends of the primary wave. Truncation was abandoned in favor of cone-angle widening, the method used by Dietrich and Long.

Size reduction by cone-angle widening entails retaining a base diameter of at least \( \lambda/\pi \) for good efficiency while increasing \( \theta_0; \) attendant beam-broadening can be avoided by increasing the pitch angle \( \alpha, \) especially near the base. Such a spiral was built, using RG-174/U miniature coaxial cable on a cardboard form, with \( 2\theta_0 = 70^\circ. \) The pitch angle \( \alpha \) was 85°, except for the bottom four turns, in which the cable was wrapped as tightly as its diameter would allow.

The performance of this spiral was also disappointing, since its AR even near the zenith was very high (e.g., 3.2 at \( \theta = 20^\circ. \) However, tests involving replacement of the ground screen below the spiral by a pad of absorbing material revealed the existence of a strong back lobe. Closer examination of Dietrich and Long’s paper suggested that the back lobe could be removed if the angle of wrap \( \alpha \) were increased slightly. Accordingly, \( \alpha \) was increased by \( 2^\circ, \) and the spiral was tested again.

Fig. 3 shows the measured values of AR and relative power response, as functions of \( \theta, \) for the modified wide-cone-angle log spiral. The results (which pertain to the single test frequency of 960 MHz, necessarily) may be summarized as follows: HPBW = 65°, AR = 1.25 from the zenith out to \( \theta \approx 50^\circ, \) no strong sidelobes present, and pattern circularly symmetrical. Parameters used in constructing the antenna were \( 2\theta_0 = 70^\circ, \alpha = 87^\circ \) (though tighter at the base, as mentioned), \( H = 0.27 \lambda, \) and \( D = 0.38 \lambda; \) the height \( h \) was only 0.16 \( \lambda. \) This antenna therefore exhibited all the characteristics desired, and the results were viewed as being very promising. Further testing is still required to ascertain the effects of minor parameter variations such as may be incurred during construction of the full-scale riometer antennas. In particular, sensitivity of the AR and pattern to variations in pitch angle \( \alpha \) must be studied.

REFERENCES


Further Comments on “Measured Field of a Directional Antenna Submerged in a Lake”

PETER R. BANNISTER, MEMBER, IEEE

The reason for the major discrepancy in Fig. 4 in the above communication between the numerical integration results and those based upon Banos’ formulas [1] is that Shen et al. 1 have employed Banos’ formulas directly instead of replacing \( \sigma \) by \( \sigma + j\omega. \) Clearly, for the case under consideration (\( \sigma/\omega = 0.094, \) \( \sigma \) should be replaced by \( \sigma + j\omega. \) Since the horizontal electric dipole \( E_\theta \) component varies inversely as \( \sigma + j\omega, \) the Banos’ curves presented in Fig. 41 should be reduced by 20 logl0 (\( \omega/\sigma \)) = 20.5 dB. Once this is done, Banos’ intermediate field and asymptotic field curves will be in much better agreement with the numerical integration results.

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Fig. 4. Magnitude of radial component of electric field in Mystic Lake (corrected).

However, for most of the measurement distance in Fig. 4, the Sommerfeld numerical distance is neither very small nor very large. Since Banos' intermediate field and asymptotic field formulas are strictly valid only for very small and very large numerical distances, they will not correspond exactly to the numerical integration results of Fig. 4. Nevertheless, as Wait [2] has already pointed out, there are analytical results available which are in full agreement with the numerical integration curve in Fig. 4. These analytical results can be employed as long as the propagation constant in the air $\gamma_0$ is much greater than the propagation constant in the air $\gamma_1$, i.e., $|\gamma_1^2| > |\gamma_0^2|$. For the case under consideration, $|\gamma_1^2| > |\gamma_0^2| = 81$.

In summary, Shen et al.'s [2] statement that Banos' asymptotic formulas have no application to the 144-MHz Mystic Lake case is wrong. They are a fair approximation if $\sigma$ is replaced by $\sigma + j\omega$.

Reply by Liang C. Shen and Ronald W. P. King

In the evaluation of Banos' near-, intermediate-, and far-field formulas, the general expression for $k$, viz., $k = [\omega^2\mu + i\omega\sigma]^{1/2}$ was used, but due to a misunderstanding, $\sigma - i\omega e$ was not substituted for $\sigma$ in the denominators. Dr. Bannister is to be congratulated for discovering this. A corrected Fig. 4 is provided. It is seen that the intermediate and asymptotic formulas yield graphs that are much closer to the numerical evaluation of the exact formula. However, they are still poor approximations since they involve errors in amplitude between 26 percent and 88 percent and in phase between 120° and 147° in the range $r = 10$ to 100 m at $f = 144$ MHz for an antenna submerged in Mystic Lake water. This is not surprising since in deriving his approximate formulas Banos imposes the inequality $\sigma/\omega > 1$. On page 196 of [2] he states that in this case "we can neglect all exponentially attenuated integrals such as $G_{11}$, $G_{12}$, as well as $U(1)$, $V(1)$, and $W(1)."" On page 120 he is even more explicit in stating that "$k$ may be written as $|k|\ e^{-\sigma r/4}$." Since this is true only when $k = [i\omega\sigma]^{1/2}$ with $|\sigma/\omega| > 1$, it is evident that this inequality underlies all of Banos' approximate formulas. Many terms have been neglected under the assumption that it is satisfied, and these should be retained when it is not satisfied (as for lake water at 144 MHz). The procedure of neglecting terms because the condition $\sigma/\omega > 1$ is assumed to be satisfied and then forgetting this assumption in the resulting simplified formulas and using these with $\sigma/\omega$ as small as 0.094 has no justification. It is interesting that the errors are not much greater. Note, however, that when Banos' approximate formulas are properly used in the ranges prescribed by Banos, they agree with the numerical evaluation of the exact formulas up to at least three digits in both amplitude and phase.

REFERENCES


Rain-Induced Attenuation at 36 GHz and 110 GHz

K. L. HO, N. D. MAVROKOUKALIAS, AND R. S. COLE

Abstract—Results are presented of the ratios of the rainfall attenuation measured simultaneously along a common path at 36 GHz and 110 GHz. These ratios agree well with the theoretically derived ratios assuming the Laws-Parrson distribution.

INTRODUCTION

Attenuation due to rainfall can impose severe limitations on the use of millimeter waves for communication purposes, and in general, systems using these frequencies must be limited to distances of a few kilometers. The theoretical prediction of rainfall attenuation is therefore very desirable for the communications engineer, and numerous experiments have been carried out to verify the validity of the theoretical relationship between attenuation and rainfall rate, based on Mie scattering, at various frequencies. Recent measurements seem to confirm the theoretical predictions [1]–[3]. In particular, a dual frequency measurement at 18.5 and 30.9 GHz by Semplak [4] also shows good agreement with the theoretical computations based on the Laws-Parrson raindrop size distribution.

This communication describes dual frequency measurements of the rainfall attenuation made at 36 and 110 GHz for rainfall intensities up to 20 mm/h. The ratio of the attenuations measured simultaneously at the two wavelengths (8.3 mm and 2.73 mm) is compared with the theoretical value obtained assuming the Laws-Parrson raindrop size distribution [5].

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