PERFORMANCE OF A CIRCULAR WAVEGUIDE FEED WITH A CONE-SHAPED FLANGED TERMINATION

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ABSTRACT: An experimental study showns that an open-ended circular waveguide with a very sharp cone-shaped flanged termination is a practical realization for obtaining results similar to the exact solution of Weinstein for a waveguide with infinitely thin walls.

INTRODUCTION: The performance of a circular waveguide feed is influenced by the metal flange that surrounds the aperture. In corrugated feeds it is required that the flange force its tangential fields to zero. Thus its surface should be corrugated [1] or a computational simulation should be developed in order to find a width for optimal feed performance [2]. In a non corrugated feed the finite thickness of the truncated waveguide may also be regarded as a flange, changing its characteristics [3,4] particulary for waveguides with a small diameter. In this case the presence of the flange is responsible for an effect resulting from the superposition of a direct aperture wave and a wave being scattered at the outer edge of the flange that is one wall-thickness away from the inner edge [2]. The use of an open-ended circular waveguide with a cone-shaped flanged termination [5] was considered as a means of avoiding the influence of the outer edge. As a result, such a radiator could be a strong candidate to confirm and to be a practical realization for the infinitesimal wall thickness circular waveguide considered in the Weinstein theory [6]. The results obtained for a radiator of this type are next shown.

ANTENNA DESCRIPTION: A cross section view of the open-ended circular waveguide with a cone-shaped flanged termination is shown in Figure 1. The antenna was built with a standard 2.5 inches internal diameter brass tube having an 1/8 inch wall thickness. A very sharp cone-shaped flanged termination with an angle α = 0.78 degrees was designed and constructed by milling and polishing. The final variation of diameter excentricity was $\pm$ 0.01 mm for an average inner diameter 2a = 63.53 mm. The other antenna dimensions were chosen as 2b = 69.85 mm, ℓ_1 = 210 mm and ℓ_2 = 232 mm.

THEORETICAL AND EXPERIMENTAL RESULTS: The theoretical results presented here were obtained for an open-ended circular waveguide with an infinitesimal wall thickness using Weinstein theory [6,7]. The experimental results were obtained with the antenna shown in Figure 1 located inside an anechoic chamber (Ranteck of 50 dB) with dimension 5.4m x 5.4m x 11.8m and with the Antenna Data Collection 2030 from Scientific Atlanta. The E-plane amplitude co-polar radiation patterns as a function of the product, ka, of the free space wave number, $k = \omega\sqrt{\mu\varepsilon}$, with the waveguide inner radius, a, for various values of the elevation angle, θ , are shown in Figure 2 (left). Agreement between theoretical and experimental results can be observed. Similar patterns for the H-plane are shown in Figure 2 (right) and agreement between theory and experiment is again observed. The phase patters have also been obtained and were discussed in another paper [8].

The 12-dB off-set angle, θ_{12dB}, and the maximum cross polarization for the cone-shaped flanged termination shown in Fig. 1, for (b/a) = 1.10, were obtained for various values of ka. These results were compared with those calculated for an infinitesimal wall thickness open-ended circular waveguide and those obtained by James and Greene [4] from a finite wall thickness open-ended circular waveguide with (b/a) = 1.08. Some of the values of interest are shown in Table I. In this Table, "Cone" is used to refer to the waveguide with the cone-shaped flanged termination while "Cyl." is used to refer to the antenna reported by James and Greene [4]. The values calculated using Weinstein theory are those denoted by "Th.". As expected the 12 dB off-set angles either in the E-or H-planes measured for the waveguide with the cone-shaped flanged termination approached those calculated for the infinitesimal wall thickness open-ended circular waveguide. The results obtained for the finite wall thickness waveguide [4] show a stronger deviation from this tendency, particularly in the E-plane where there is a stronger effect of flange difraction.

Table I also shows results for maximum crosspolarization levels either at the illuminated region, $|\theta| < \theta_{12dB}$, or at the frontal region, $|\theta| < 90^{\circ}$. Again the results for the conical antenna are slightly closer to the theoretical ones than those obtained for the finite wall thickness waveguide [4] for values ka < 2.75. However the low theoretical values calculated for waveguide diameters approaching one wavelength, ka $\cong \pi$, were not observed in practice.

CONCLUSION: The performance of an open-ended circular waveguide with a very sharp cone-shaped flanged termination has been measured. It has been shown that this type of conical flange approaches the results obtained with the experimental model with those calculated for a semiinfinite open-ended circular waveguide with infinitesimal wall thickness. The theoretical and experimental results have shown an excellent agreement except for cross polarization values below -32 dB.

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TABLE I - COMPARISON OF RESULTS FROM AN OPEN-ENDED CYLINDRICAL ANTENNA WITH (b/a) = 1.08 [4] (Cyl.) WITH THESE FROM A CONE-SHAPED FLANGED TERMINATION WITH (b/a) = 1.10 (Cone) AND FROM WEINSTEIN THEORY WITH (b/a) = 1.0 (Th.)

		ka	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75
12 dB off set angle: θ_{12dB},degrees	E PLANE	Cyl	108°	86°	72°	-	59°	-	-	-
		Cone	-	94°	80°	73°	66°	60°	57°	53°
		Th.	124.9°	94.3°	81.6°	72.7°	65.9°	60.4°	55.9°	52.0°
	H PLANE	Cyl	78°	76°	69°	-	62°	-	-	-
		Cone	-	78°	72°	69°	64°	61°	60°	
		Th.	84.7o	79.5°	74.9°	70.2°	66.3°	62.7°	59.4°	56.5°
MAX. CROSS - POL,dB	$\|\theta\| < \theta_{12dB}$	Cone	-	-26	-31	-32	-33	-33	-33	-31
		Th.	-21.3	-26.7	-31.4	-38.0	-47.2	-39.2	-34.5	-31.0
	$\|\theta\| < 90^{o}$	Cyl	-25	-26	-28	-	-			
		Cone		-27	-29	-31	-32	-32	-32	-31
		Th.	-25.0	-27.4	-30.0	-33.0	-36.8	-39.2	-34.6	-31.3

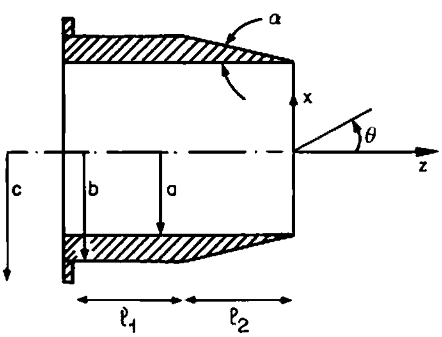

Fig. 1 - Cross section view of the circular waveguide feed with a cone-shaped flanged termination

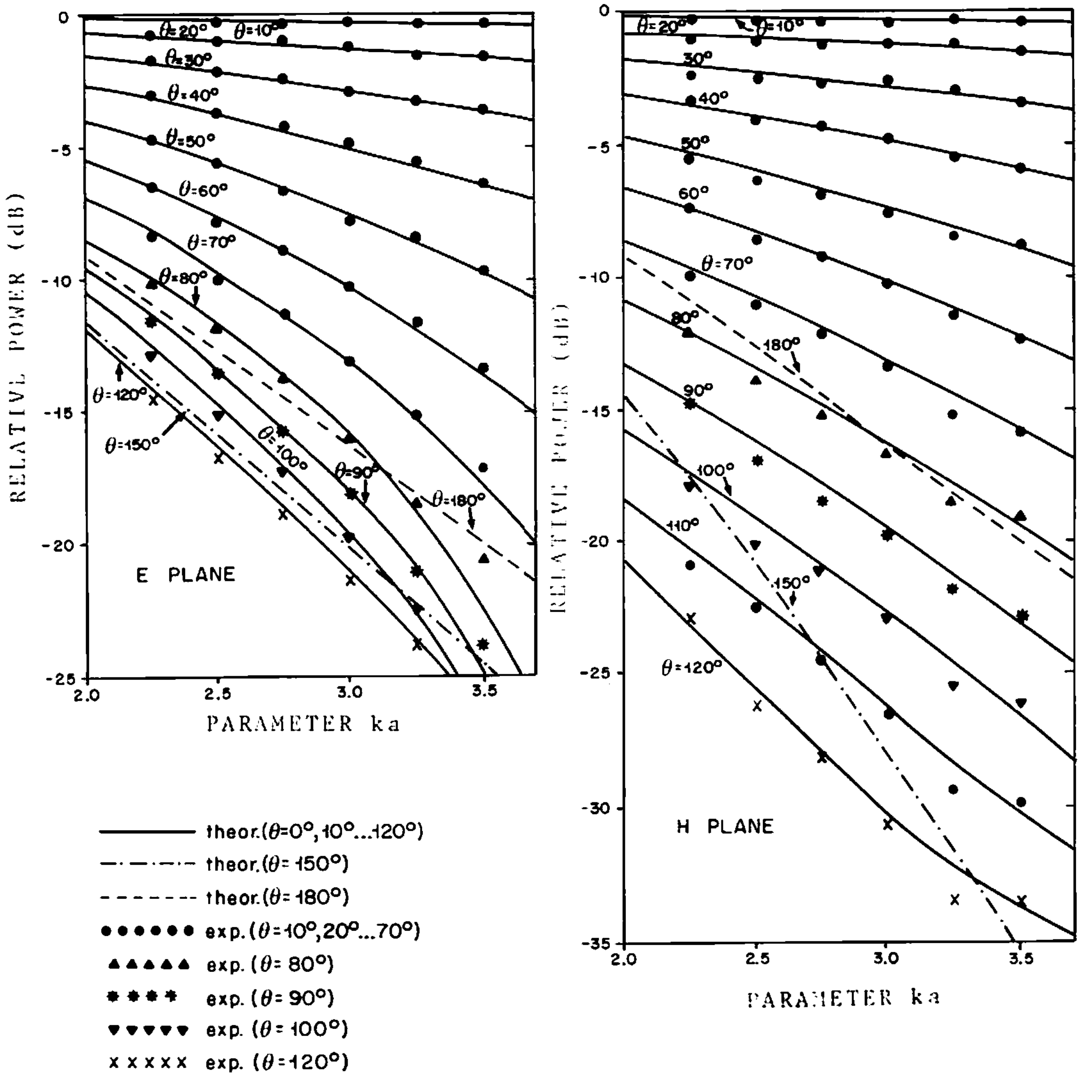

Fig. 2 - Theoretical (continuous and discontinuous lines) and experimental (dots) amplitude radiation patterns for the antenna in Fig. 1,at the E-plane (left) and H-plane (right) as a function of ka and with the elevation angle θ as a parameter.