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STUDY AND INVESTIGATION OF A UHF-VHF ANTENNA

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ABSTRACT

An improved ferrite material has been ordered from Motorola-Phoenix.

Further work on the ferrite-loaded biconical antenna has been initiated, with the object of evaluating the impedance, beam pattern, and efficiency,

The problem of a ferrite-loaded, rectangular-cavity slot antenna has been formulated, and the variational procedure is being carried out to evaluate the impedance, radiation pattern, and the efficiency.

The radiation patterns of the ferrite-loaded, rectangular-cavity slot antenna have been measured and compared with the theoretical predictions of simple-aperture diffraction theory.

Agreement with theory is good for the H-plane patterns and poor for the E-plane patterns. The effect of a flange is greater than expected.

1. REPORTS, TRAVEL, AND VISITORS

During this period no reports were issued, project personnel made no trips, and no one visited the project.

2. FACTUAL DATA

2.1 Ferrite Material

Three experimental ferrite compositions have been prepared and evaluated by Motorola-Phoenix for Cooley Electronics Laboratory. One of these compositions has been selected, and ferrite material in solid and powdered forms has been ordered from Motorola in sufficient quantity to meet the projected needs of the contract. The characteristics of this material at 200 Mc have been guaranteed within ±10%. Characteristics are as shown in Table I.

Complex Permeability	at 100 Mc	$u' - ju'' = 6.62 - j\,.063$ $\tan \delta m = 0.00953$ $Qm = 105$
	at 200 Mc	$u' - ju'' = 6.80 - j\,.18$ $\tan \delta m = 0.0265$ $Qm = 37.8$
Curie Temperature		$Tc = 447^{\circ}C$
Bulk Density		$\rho_b = 3.89$ grams/cm^3
Saturation Magnetization		$\sigma_s = 39.96$ emu $4\pi M_s = 4\pi \cdot \rho b \cdot \sigma_s = 1950$ gauss
Complex Permittivity	at 20 Mc	$e' - je'' = 11.77 - j\,.0223$ $\tan \delta e = 0.0019$ $Qe = 527$

Table I. Ferrite material characteristics.

2.2 Biconical Antenna

The work of this project on spherical geometry has shown that in the biconical antenna and the infinitesimal dipole that resonances in radiation resistance occur which are associated with the resonances of the spherical dielectric medium. It is possible that these resonances may bring about improved efficiency in small antennas at the expense of some bandwidth. A program is now in progress which will calculate the efficiency, radiation resistance, and beam pattern for the dielectric-loaded, thin, biconial antenna, having as parameters permeability, permittivity, radius, and frequency.

The efficiency will be calculated for an aluminum radiator, although it will be quite simple to extend this to any good conductor. The losses over the surface of the conductor will be calculated by a perturbation method, which assumes that the fields exterior to the conductor are not changed significantly from those of a conductor with infinite conductivity, if the conductivity is still quite high. The surface currents induced at the boundary will then provide a heat loss in the conductor as they flow. The total loss will then be compared with the power fed into the antenna terminals to obtain the resulting efficiency. The assumption will also be made that the skin depth is small compared to the radius of curvature of the cone. This will be valid except at the vertex of the cones. However, the efficiency will be related to that of the same size antenna in air, and a small region at the vertex will be avoided in both cases.

The beam pattern will be calculated by finding the coefficients of the various associated Legendre functions and adding them together. An inspection of the equations shows that patterns will be obtained which are normally associated with antennas physically much larger.

The radiation resistance calculation will be a repetition of Polk's work (Ref. 1) for other choices of permittivity and permeability than his.

Previous results regarding the increased energy density around a dielectric sphere will be correlated with these results, and general conclusions concerning loaded antennas will be delineated.

2.3 Rectangular-Cavity Slot Radiator

This problem has been formulated. A stationary expression for the input impedance has been derived and shown to be stationary. The approximation procedure is being carried out. The formulation and the results will be presented in the next quarterly report.

2.4 Experimental Results on the Rectangular-Cavity Slot Antenna

2.4.1 Theoretical Data. This antenna has previously been analyzed, using an approximate analysis assuming dominant-mode aperture fields and neglecting the effect of surface currents. Results were reported in Quarterly Progress Report No. 5 (pp. 26-34). The data in QPR No. 5 were plotted for $\lambda/\lambda_c = 0.80$. In order to provide a more thorough comparison with experimental data, the computer program was rerun for three sets of values of material constants ($\mu_r = \epsilon_r = 1$, $\mu_r = \epsilon_r = 3$, $\mu_r = \epsilon_r = 10$), expanding the program to calculate patterns for six values of λ/λ_c running from 0.60 to 0.85. These data are shown in Figs. 3, 4, and 5. Tables II, III, and IV summarize the half-power beam width and gain data from the computer results. The gain was calculated using the formula $G = 41{,}253/\phi_1{}^{\circ}\theta_1{}^{\circ}$ (Ref. 2, p. 25). This formula is not very accurate for our large beam widths, but it provides a basis for comparison. The theoretical data predict that, using a material with $\epsilon_r = \mu_r = 3$, both the E-plane and H-plane patterns will be broadened, the E-plane by 14%, the H-plane by 40%, and that the average gain will be reduced from 4.04 to 2.52, or by a factor of 0.625.

2.4.2 Experimental Data.

2.4.2.1 General Discussion. Experimental beam pattern data on the rectangular cavity slot antenna are shown in Figs. 3 and 4. Tables II and III summarize the data on beamwidths and gain. The beam patterns were taken on the outdoor range on the roof of the Automotive Laboratory. Patterns were taken with and without ferrite loading. The loaded patterns were taken with (Fig. 2) and without (Fig. 1) a flange.

The flange is three-feet square, or approximately one wavelength square at center frequency with ferrite loading. Cutoff data on the loaded rectangular-cavity slot antenna indicate that $\sqrt{\mu_r \epsilon_r}$ is approximately 2.5 instead of 3.0 as measured. Accordingly, 2.5 has been used as the basis for comparison for the rectangular-cavity slot antenna. Certain asymmetries were noted in the patterns. These could be caused by (1) slight asymmetries in the rotator mounting structure and (2) asymmetry in the feed structure. In order to partially eliminate this additional variable, the average of the ordinates at $+\theta$ and $-\theta$ was plotted. This does not affect the gain and gives us a better comparison of theoretical and experimental data. In general, these asymmetries were slight, with the exception of the E-plane, unflanged, loaded patterns. With the addition of the flange, these asymmetries were eliminated.

2.4.2.2 Unloaded Case. The beam patterns for the unloaded case are shown in Fig. 3. There is not detailed agreement between the theoretical and experimental patterns, but there is general agreement for average characteristics. Beam widths decrease with increasing frequency in both cases. Side-lobe levels are higher on the experimental curves. The average gain figures agree within 5%, and the higher side lobes of the experimental curves would tend to make the agreement even better.

The effect of the flange is as predicted by Butson and Thompson (Ref. 3), with relatively small effect on the H-plane patterns and double and triple major lobes on the E-plane patterns.

Silver (Ref. 4, p. 345) has plotted experimental and theoretical data for a single case. He also shows higher side lobes and a slightly narrower H-plane beam on the experimental patterns than on the theoretical patterns. He shows approximately the same beam width on the E-plane experimental and theoretical patterns, whereas we show, on an average, slightly greater beam width on the experimental patterns.

2.4.2.3 Loaded Case. The theoretical and experimental patterns for the loaded case are plotted in Fig. 4.

Several interesting effects may be noted here. The unflanged H-plane patterns bear approximately the same relationship to the theoretical patterns as they did in the unloaded case. The average experimental beam width is slightly narrower than the theoretical one, as in the unloaded case, but the side lobe level has increased considerably. The unflanged E-plane patterns are practically omnidirectional. The gain of the unflanged case is considerably lower than that predicted by theory. However, with the addition of the flange, the patterns change radically. The change in the patterns is considerably greater than that which would be expected by a flange of similar size, in terms of wavelength, on an air-filled guide, judging by the data of Thompson and Butson. In fact, Thompson and Butson's data would indicate almost no change for a flange of this size. With the addition of the flange, the gain increases to 5.05, approximately twice the theoretical value. In addition, all side lobes drop down, and the asymmetries in the patterns are eliminated. It is possible that this same effect could be obtained with a much smaller flange. This possibility will be investigated.

The data suggest that the assumptions of the simple analysis undertaken are not entirely justified for small antennas. Evidently, the surface currents are more important for this type of antenna, giving rise to an increased sensitivity to physical irregularities and asymmetries. The unloaded E-plane patterns exhibit small irregularities and asymmetries, probably due to the feed apparatus. These irregularities and asymmetries are greatly increased in the loaded case.

The data obtained to date suggest a significant effect of the size of ground plane on a ferrite-loaded slot radiator. This effect may have significant effect upon the ultimate applications of these antennas. In future work, this effect will be investigated and analyzed further.

It has been shown that, as predicted, the effect of ferrite loading is to broaden the beam patterns somewhat. The broadening effect on an unflanged radiator is greater than that predicted, while the effect on a flanged radiator is less. Theoretical results predict only slightly further broadening for $\mu_r = \epsilon_r = 10$ (Fig. 5).

3. ACTIVITIES FOR THE NEXT PERIOD

During the next period beam pattern data will be taken for the other ferrite-loaded models, including the ridged-cavity slot antenna and the spiral. Efficiency measurements will be made on one of the loaded models and compared with the unloaded efficiency. Preparations will be made for the arrival of the improved ferrite material, including redesign and construction of models.

Theoretical work for the next period on the ferrite-loaded biconical antenna will include completion of the formulation and preparation of a computer program to evaluate efficiency. Further work will also be done on the variational solution of the ferrite-loaded, rectangular-cavity slot antenna.

4. SUMMARY

An improved ferrite material has been ordered from Motorola-Phoenix. Further work on the ferrite-loaded biconical antenna has been initiated, with the object of evaluating the impedance, beam pattern, and efficiency. The impedance and beam pattern will be evaluated using classical analysis, and the efficiency will be evaluated using a perturbation technique. The variational solution of the ferrite-loaded, rectangular-slot antenna has been formulated, and the approximation technique is being carried out.

The radiation patterns of the ferrite-loaded, rectangular-cavity slot antenna have been measured and compared with theoretical predictions of simple-aperture diffraction theory.

This theory neglects the effect of surface currents, and this approximation appears to be considerably less valid for the loaded antenna than it was for the unloaded antenna. Agreement with theory is good for the H-plane patterns but poor for the E-plane patterns. The effect of the flange is considerably greater than expected and produces a pattern with gain twice as large as that predicted theoretically for this particular antenna and three or four times as large as that of the unflanged antenna. In future tests this effect will be analyzed more thoroughly.

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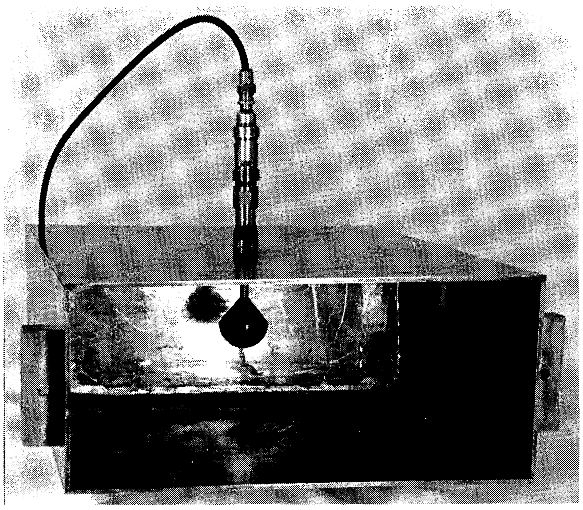
3. P. C. Butson and G. T. Thompson, The Effects of Flanges on the Radiation Patterns of Waveguides and Sectoral Horns, IEE, July 1959, pp. 422-426.
4. S. Silver, Microwave Antenna Theory and Design, McGraw-Hill, 1959.

Fig. 1. Rectangular-cavity slot antenna without flange.



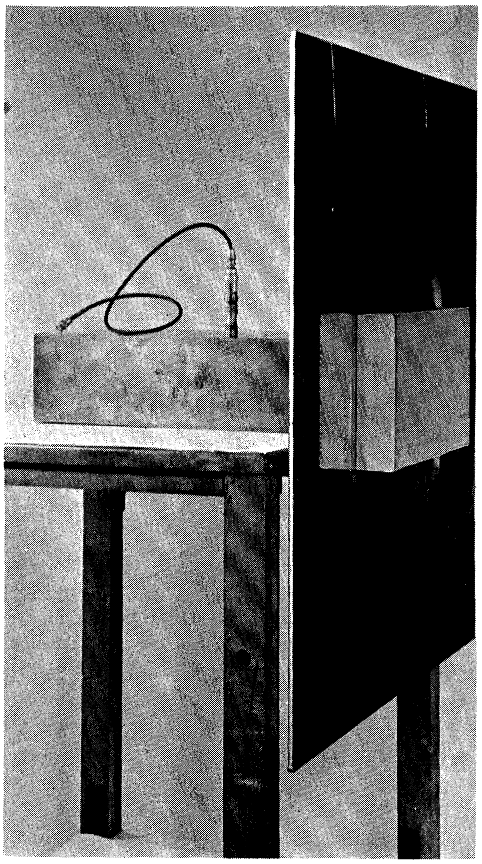


Fig. 2. Rectangular-cavity slot antenna with flange.

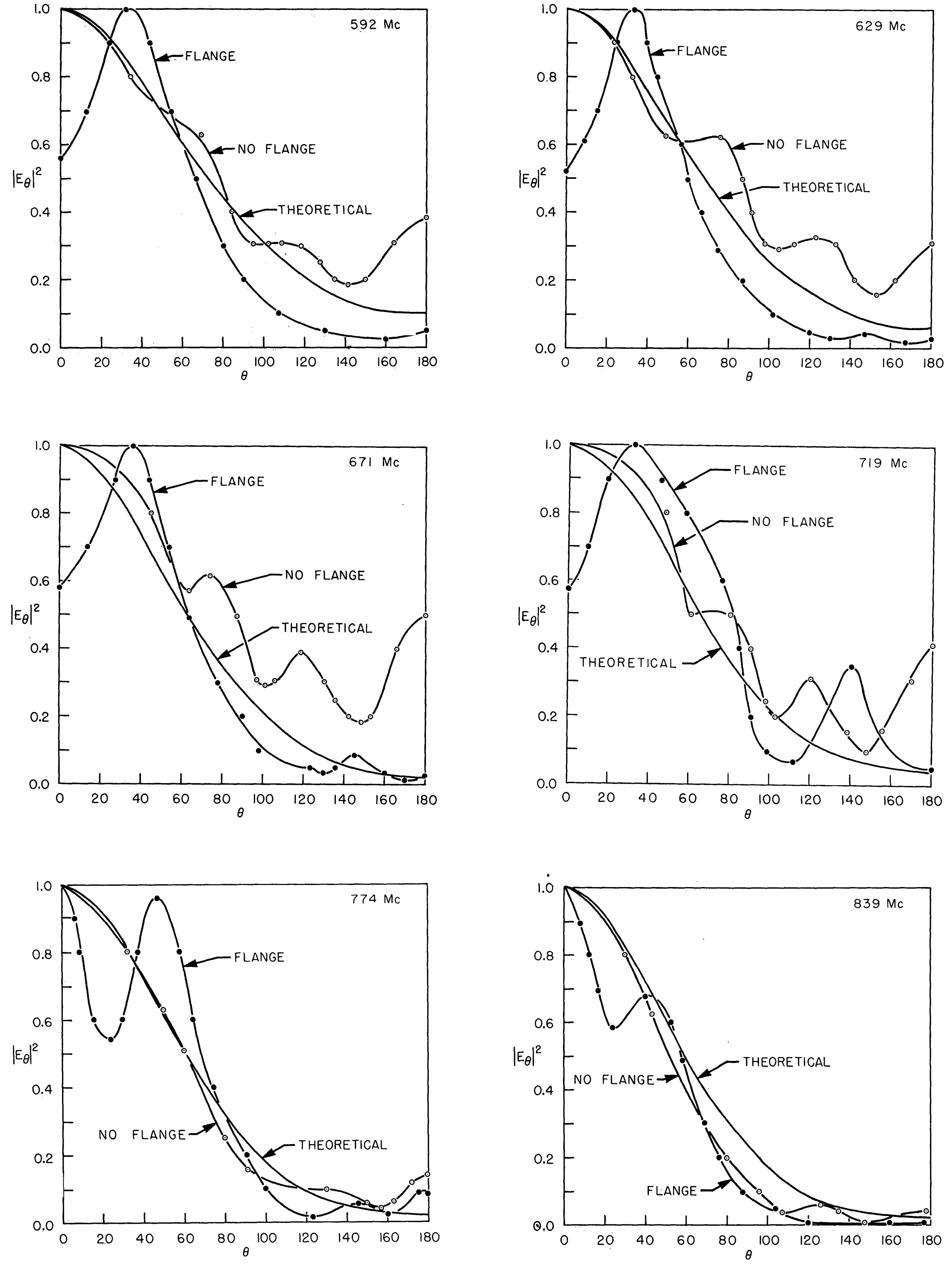


Fig. 3(a). Unloaded rectangular-cavity slot antenna; theoretical and experimental results. E-plane patterns.

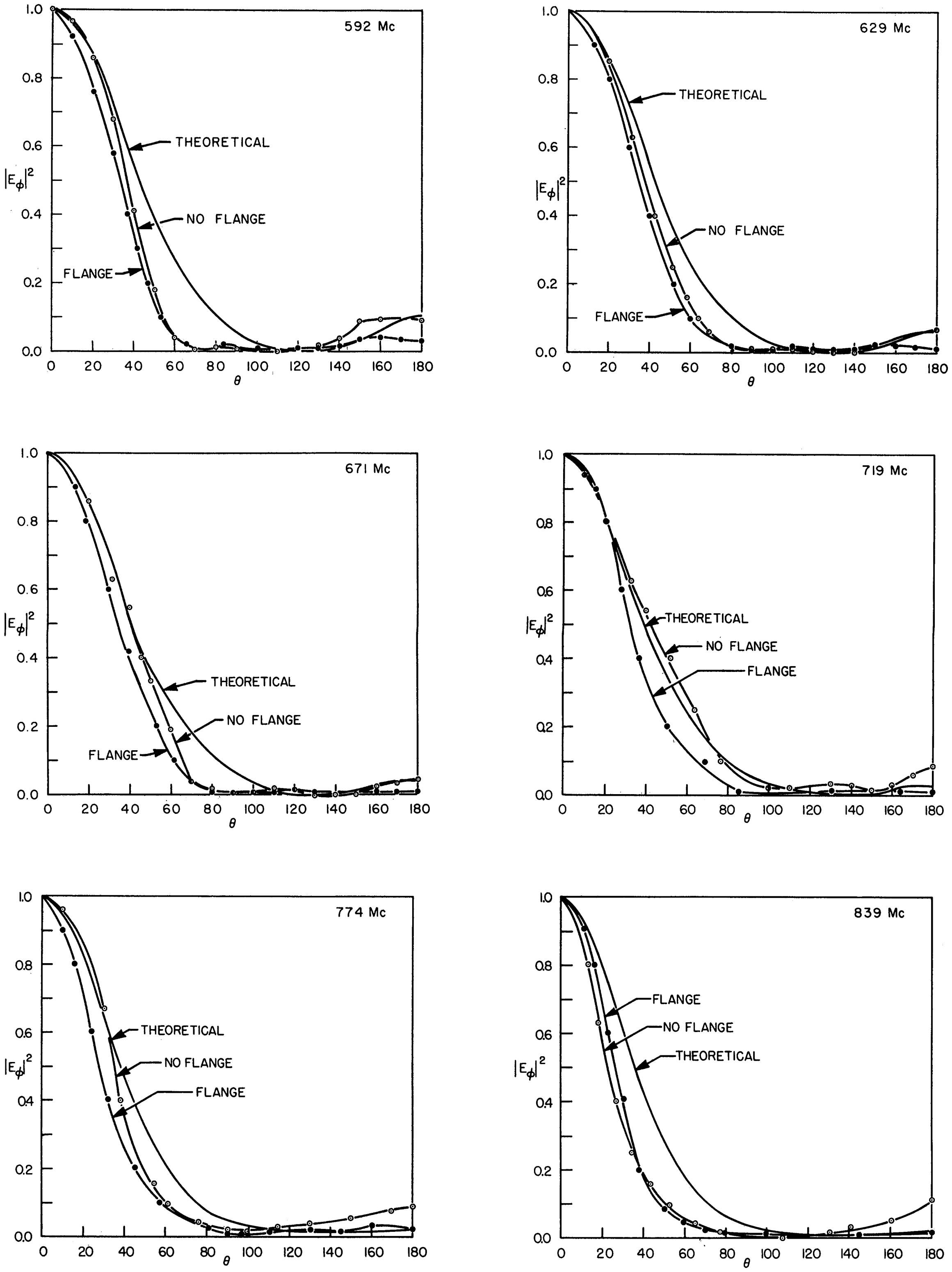


Fig. 3(b). Unloaded rectangular-cavity slot antenna; theoretical and experimental results. H-plane patterns.

Half Power Beam Width

Frequency (Mc)	λ/λ_c	Theoretical		Experimental			
				No Flange		Flange	
		E_θ	E_ϕ	E_θ	E_ϕ	E_θ	E_ϕ
592	.85	144°	86°	155°	72°	134°	66°
629	.80	136°	84°	174°	76°	120°	68°
671	.75	130°	82°	174°	80°	126°	67°
719	.70	124°	78°	120°	84°	164°	64°
774	.65	120°	76°	120°	68°	138°	56°
839	.60	116°	72°	104°	45°	116°	53°
Average BW		128°	80°	141°	69°	133°	62°
Average Gain		4.03		4.24		5.00	

E-Plane - E_θ

H-Plane - E_ϕ

Table II. Unloaded rectangular cavity antenna - theoretical and experimental results.

Half Power Beam Width

		Theoretical		Experimental			
				No Flange		Flange	
Frequency (Mc)	λ/λ_c	E_θ	E_ϕ	E_θ	E_ϕ	E_θ	E_ϕ
237	.85	160°	108°		154°	102°	84°
251	.80	152°	110°		92°	92°	78°
269	.75	146°	112°		96°	94°	84°
287	.70	146°	114°		90°	120°	102°
310	.65	138°	114°		78°	82°	78°
335	.60	136°	114°		68°	90°	78°
Average BW		146°	112°		96°	97°	84°
Average Gain		2.52		< 2		5.05	

E-Plane - E_θ
H-Plane - E_ϕ

Table III. Loaded rectangular cavity antenna theoretical ($\mu_r = \epsilon_r = 3$) and experimental ($\mu_r = \epsilon_r = 2.5$) results.

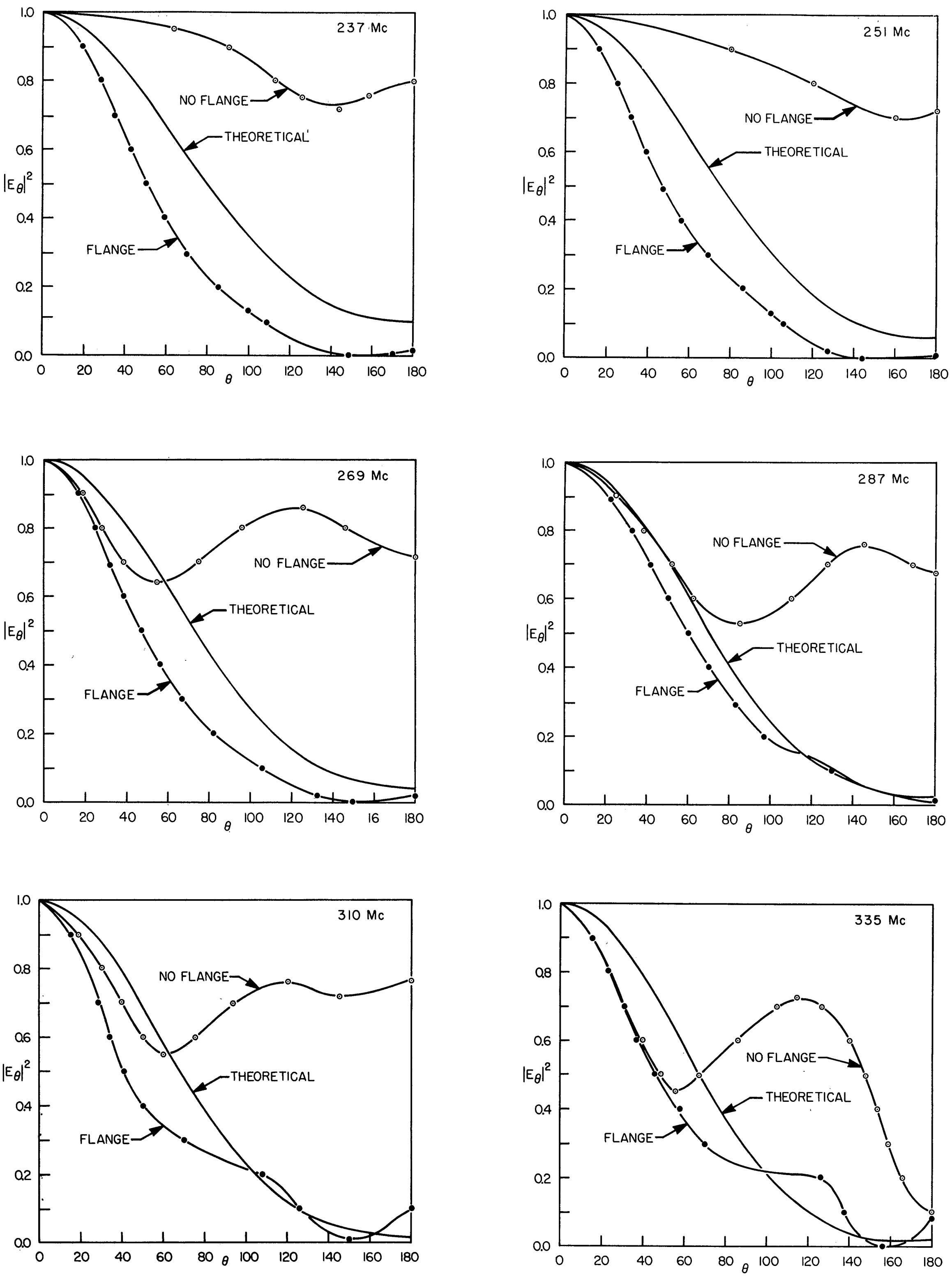


Fig. 4(a). Loaded rectangular-cavity slot antenna; theoretical and experimental results. E-plane patterns.

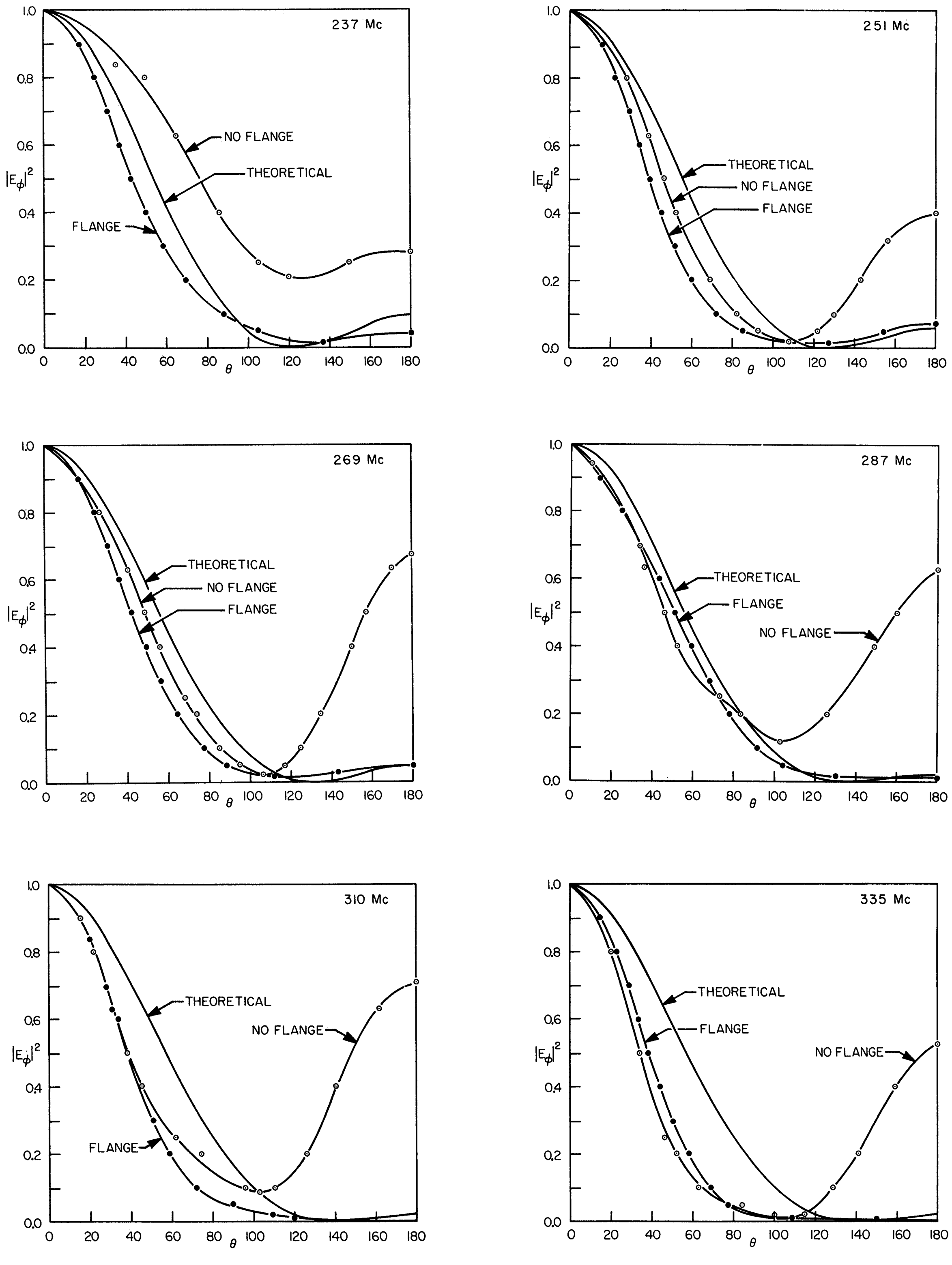
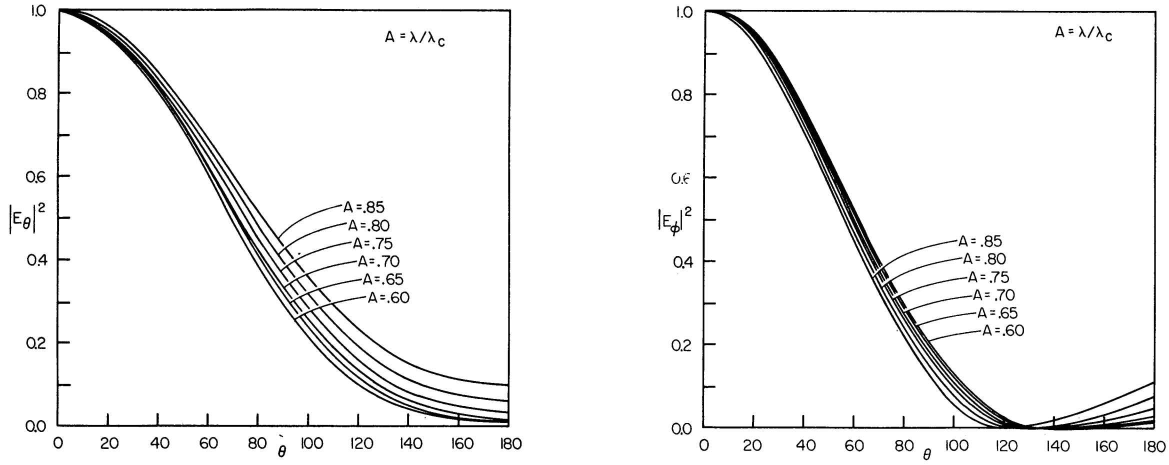


Fig. 4(b). Loaded rectangular-cavity slot antenna; theoretical and experimental results. H-plane patterns.



(a) E-plane patterns.

(b) H-plane patterns.

Fig. 5. Loaded rectangular-cavity slot antenna - theoretical results, ($\mu_r = \epsilon_r = 10$).

Half Power Beam Width

λ/λ_c	E_θ	E_ϕ
.85	162^o	112^o
.80	154^o	114^o
.75	148^o	116^o
.70	144^o	118^o
.65	142^o	120^o
.60	138^o	122^o
Average BW	148^o	117^o
Average Gain	2.38	

Table IV. Loaded rectangular cavity antenna theoretical results ($\mu_r = \epsilon_r = 10$).

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