Quantum Electron., vol. 9, no. 1, pp. 33–42, 1977.
[3] S. Kawakami and S. Nishida, "Characteristics of a doubly clad optical fiber with a low-index inner cladding," *IEEE J. Quantum Electron.* vol. QE-10, pp. 879–887, 1974.
[4] J. Sakai, "Transmission characteristics of single-mode fiber with large-core," *Paper of the Tech. Group on Opt. & Quantum Electron.*, IECE of Japan, OQE 76-45, pp. 55–62, 1976.
[5] T. Nakahara, M. Hoshikawa, M. Yoshida, and S. Suzuki, "Transmission properties of ring-type optical fibers," in *Proc. of Second European Conf. Optical Fiber Communication*, 1976, pp. 149–155.
[6] J. Sakai and T. Kimura, "Large-core broadband optical fiber," *Opt. Lett.*, vol. 1, no. 5, pp. 169–171, 1977.
[7] K. Kitayama, M. Ikeda, and Y. Kato, unpublished.
[8] D. Gloge, "Weakly guiding fibers," *Appl. Opt.*, vol. 10, no. 10, pp. 2252–2258, 1971.
[9] K. Okamoto and T. Okoshi, "Analysis of wave propagation in optical fibers having core with α-power refractive index distribution and uniform cladding," *IEEE Trans. Microwave Theory Tech.* vol. MTT-24, pp. 416–421, 1976.
[10] R. Olshansky and D. B. Keck, "Pulse broadening in graded-index optical fibers," *Appl. Opt.*, vol. 15, no. 2, pp. 483–491, 1976.
[11] S. Kobayashi, S. Shibata, N. Shibata, and T. Izawa, "Refractive-index dispersion of doped fused silica," in *Tech. Digest of* Int. Conf. *Integrated Optics and Optical Fiber Communication*, 1977, pp. 309–312.
[12] N. Shibata, S. Shibata, S. Kobayashi, and T. Izawa, private communication.
[13] H. M. Presby and I. P. Kaminow, "Binary silica optical fibers: Refractive index and profile dispersion measurements," *Appl. Opt.*, vol. 15, no. 12, pp. 3029–3036, 1976.
[14] D. Gloge, "Dispersion in weakly guiding fibers," *Appl. Opt.*, vol. 10, no. 11, pp. 2442–2445, 1971.
[15] D. C. Chang and E. F. Kuester, "Radiation and propagation of a surface-wave mode on a curved open waveguide of arbitrary cross section," *Radio Sci.*, vol. 11, no. 5, pp. 449–457, 1976.
[16] J. Sakai and T. Kimura, "Bending loss of propagation modes in arbitrary index profile optical fibers," *Appl. Opt.*, vol. 17, no. 10, pp. 1499–1506, 1978.

A Compact Light-Weight Gaussian-Beam Launcher for Microwave Exposure Studies

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***Abstract*—A new type of compact light-weight Gaussian-beam launcher for producing a focused-microwave exposure field in biological experiments is described. This launcher is identical to the structure described by the authors elsewhere [1], except that a simple circular waveguide aperture, instead of a corrugated pipe, is used to illuminate a dielectric sphere lens with the result that a considerable weight and size reduction of the launcher is achieved. The proposed structure consists of a simple cylindrical waveguide excited with a balanced mixture of complementary modes and the diffracted field due to this waveguide aperture is made to illuminate a dielectric sphere (lens). It is shown that a near-circular Gaussian beam is then produced in the image space of the sphere with a high focusing factor. Design details, theoretical calculations, and experimental results concerning a practical launcher are presented. Suitability of this compact structure for diathermy applications at a frequency of 2450 MHz is mentioned.**

I. Introduction

RECENTLY, the authors [1], [2] described a practical method of launching a microwave Gaussian beam which is used to produce a focused exposure field in biological experiments for partial-body irradiation. This launcher consists of a dielectric spherical lens, illuminated by a scalar horn; the resulting EM field in the image zone of the lens is a near-circular Gaussian beam. The simplicity and compactness of this structure with its ability to focus microwave energy in a very small region indicate its practical utility in the areas of biological researches and medical applications of microwaves. For example, one of the authors has successfully employed this launcher in a noninvasive beam wave reflectometric instrumentation for measuring complex permittivity of biological materials at microwave frequencies [3].

While the launcher described in [1] is a more practical source of microwave Gaussian beam than the plane-wave irradiated dielectric spherical lens system due to Ho *et al.* [4], yet the sphere-illuminating scalar horn of this launcher is rather a heavy structure, and, therefore, for low-frequency applications (such as for 2450 MHz), there is a need to develop a low-weight launcher system. Hence, presently, a new type of launching device is proposed wherein the heavy scalar horn of [1] is replaced by a suitable low-weight waveguide aperture antenna.

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II. Description of the Proposed Structure

Fig. 1 illustrates the launcher structure presently proposed. It consists of an open-ended circular waveguide with a modified aperture end. The open end has a shorted

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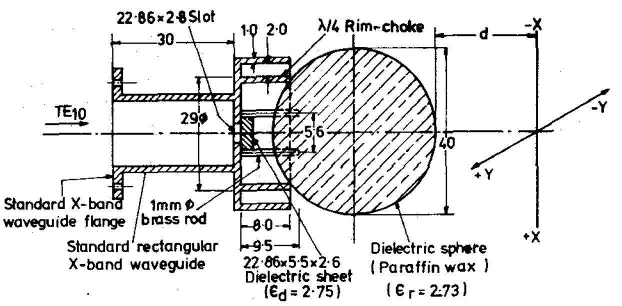


Fig. 1. X-band Gaussian-beam launcher (dimensions are in mm).

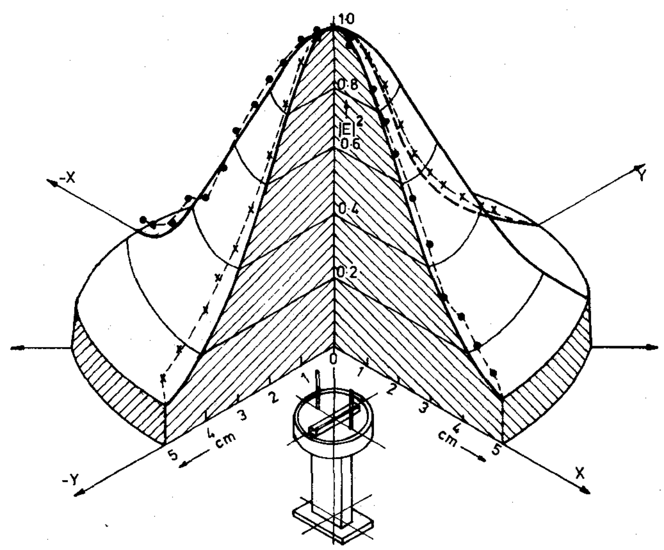


Fig. 2. Normalized three-dimensional pattern (electric field squared at $d=5.0$ cm).

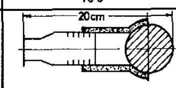
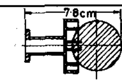
cup approximately quarter-wavelength high excited with two complementary propagating modes (TE_{11} and TM_{11}) by means of a slot in the shorting plane and by two vertical wires symmetrically disposed on either sides of the slot [5]. A rim choke is provided circumferential to the cup to suppress the back radiation and side lobes due to edge diffraction. The slot in the shorting plane is loaded with a dielectric piece in order to eliminate any possible excitation of spurious slot modes.

This dual-mode excited waveguide aperture, produces a symmetrical tapered field [5] similar to the scalar horn of [1], which is used to illuminate the dielectric spherical lens. The expressions for the field components in the two principal planes in the image zone of the lens are given by [1, (5)].

III. Results and Discussion

A test launcher of the dimensions shown in Fig. 1 was fabricated and near-field measurements were carried out at a frequency of 9.370 GHz with a dielectric sphere

TABLE I

Sl. No.		Sphere dia. in cm	Launcher system of [4] Frequency: 10 GHz; d=6·0 cm Polyethylene ϵ_r=2·26	Launcher system of [4] Polyfoam ϵ_r=1·89	Launcher system of [1] Frequency: 10 GHz Sphere off-set = 3·0 cm d = 6·0 cm; $1 \le \epsilon_r \le 4$	Present method Frequency: 9·37 GHz d = 5·0 cm ϵ_r = 2·73 (Paraffin wax)
1	Focusing factor in db	5·1	0·792	4·914	13·6	12·7
		10·2	5·051	4·914	14·7	15·5 [For sphere dia. of 4 cm, focusing factor = 8·5 db]
		15·2	7·994	11·038	15·4	17·1
		20·3	12·175	16·021	16·6	18·4
		25·4	15·763	18·529	17·0	19·4
		30·5	18·182	20·145	17·7	20·0
		35·6	20·149	21·691	18·3	21·5
		40·6	21·945	23·730	18·5	21·9
2	Over-all dimensions	–			 20cm	 7·8cm
					SIZE REDUCTION RATIO : 1 : 2·5	
3	Net weight	–			1500 gms	200 gms
					WEIGHT REDUCTION RATIO: 1 : 7·5	

having a relative permittivity of $\epsilon_r=2.73$ (paraffin wax) and of a diameter equal to 4.0 cm. The measured and calculated patterns at $d=5$ cm in the image space of the lens of the test launcher are presented in Fig. 2. From the results presented here, the following inferences can be made: 1) similar to the Gaussian-beam launcher of [1], the present structure also produces a near-circular Gaussian beam, in the proximity of the sphere; 2) Table I provides results on the focusing factors of the three systems, namely, the planewave illuminated lens [4], dielectric sphere illuminated by the scalar horn [1], and the presently described system; and 3) for a relative comparison, the overall sizes and weights of the two types of launchers are also given in Table I which indicate the considerable reduction in size and weight of the proposed launcher.

The performance characteristics of the launcher described and the relevant design considerations, follow closely those applicable to the structure of [1]. Research efforts are being made to design and fabricate a launcher at the microwave diathermy frequency of 2450 MHz.

References

[1] P. S. Neelakantaswamy, K. K. Gupta, and D. K. Banerjee, "A gaussian-beam launcher for microwave exposure studies," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-25, pp. 426–428, May 1977.

[2] P. S. Neelakantaswamy, D. K. Banerjee, and K. K. Gupta, "Near-field characteristics of a scalar horn-fed dielectric spherical radiator," *Arch. Elek. Übertragungstechnik*, vol. 31, pp. 173–175, Apr. 1977.

[3] P. S. Neelakantaswamy, "Non-invasive beam-wave reflectometric instrumentation for measuring complex permittivity of dielectric materials at microwave frequencies," *Rev. Sci. Instr.* (to be published).

[4] H. S. Ho, G. J. Hager, and M. R. Foster, "Microwave irradiation design using dielectric lenses," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-23, pp. 1058–1061, Dec. 1975.

[5] A. Clavin, "A multimode antenna having equal E- and H-planes," *IEEE Trans. Antennas Propag.*, vol. AP-23, pp. 735–737, Sept. 1975.