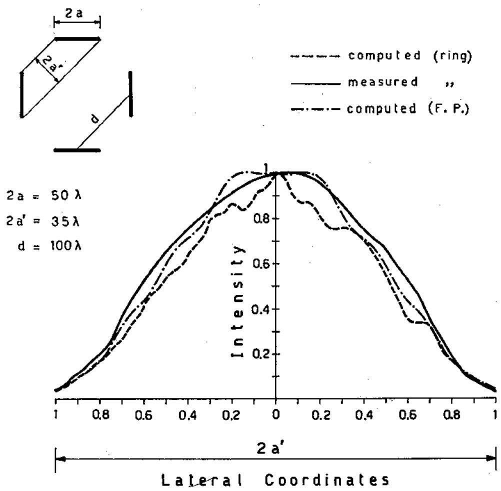


Fig. 4. Measured and computed fundamental-mode intensity patterns across the beam compared with the computed one for a FP resonator.

measured power loss is very close to four times that of an FP having mirrors with apertures reduced by a factor cos ($\pi/4$) and spacing equal to that between two consecutive mirrors. Hence one can say that the modes of a polygonal ring resonator are essentially of the same type as those of the FP resonator, and this is also in agreement with the theoretical predictions of other authors [9].

Acknowledgment

The authors wish to thank F. Cosi for his helpful collaboration in performing the experimental tests.

References

[1] P. O. Clark, "Multireflector optical resonators," *Proc. IEEE* (Corresp.), vol. 51, pp. 949–950, June 1963.
[2] S. A. Collins, Jr., "Analysis of optical resonators involving focusing elements," *Appl. Opt.*, vol. 3, p. 1263, 1964.
[3] S. A. Collins, Jr., and D. T. M. Davis, Jr., "Modes in triangular ring optical resonator," *Appl. Opt.*, vol. 3, p. 1314, 1964.
[4] W. W. Rigrod, "The optical ring resonator," *Bell Syst. Tech. J.*, vol. 44, p. 9, 1965.
[5] G. Goubau and F. Schwering, "Modes in radial wave beam resonators," *IEEE Trans. Microwave Theory Tech.* (*1965 Symposium Issue*), vol. MTT-13, pp. 749–755, Nov. 1965.
[6] J. Janse, "Theoretical and numerical investigations of modes in ring-shaped resonators," *Alta Freq.* (*Special Issue*), vol. 37, nos. 6–7, p. 300, 1968; also presented at the Int. Scientific Radio Union Symp. Electromagnetic Waves, Stresa, 1968.
[7] W. M. Macek and D. T. M. Davis, Jr., "Rotation rate sensing with travelling wave ring lasers," *Appl. Phys. Lett.*, vol. 2, p. 67, 1963.
[8] P. V. Cheo and C. V. Heer, "Beat frequency between two travelling waves in a Fabry-Perot square cavity," *Bull. Amer. Phys. Soc.*, vol. 9, p. 501, 1964.
[9] G. Schulten, "Microwave optical ring resonator, "*IEEE Trans. Microwave Theory Tech.* (Corresp.), vol. MTT-15, pp. 54–55, Jan. 1967.
[10] A. L. Schawlow and C. H. Townes, *Phys. Rev.*, vol. 112, p. 194, 1958.
[11] R. W. Zimmerer, "Spherical mirror Fabry-Perot resonators," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-11, pp. 371–379, Sept. 1963.
[12] P. F. Checcacci, R. Falciai, and A. M. Scheggi, "Modes and losses of a flat-mirror ring resonator," presented at the Optical Soc. Amer. 1972. Annu. Meeting, San Francisco, Calif., Oct. 17–20, 1972.

Beam Waveguides with Minimized Dielectric Structures

P. F. CHECCACCI, R. FALCIAI, AND A. M. SCHEGGI

***Abstract*—An experimental study of dielectric beam waveguides with minimized dielectric structures is presented. Such structures are derived from the square-frame beam waveguide described elsewhere. The experimental results show that even very much reduced structures maintain guiding properties. In particular, the helix structure results are competitive with the complete-frame beam waveguide.**

In a preceding paper [1] we described the experimental tests performed on a new type of beam waveguide previously proposed [2] as a by-product of an investigation on rimmed Fabry–Perot resonators [3]. This waveguide, which is constituted of a series of equispaced dielectric frames, turns out to be low loss, compact, and lightweight. However, one could think of further reducing the guiding structures so as to get a minimum hardware but still practically usable waveguide. For this purpose, experimental tests were performed on waveguides constituted of incomplete frames. Such incomplete frames are obtained by removing some sides of each square frame so that the complete beam reconstruction process takes place after a certain number of frames [Fig. 1 (a), (b), (c)]. A helical structure was also conceived and tested [Fig. 1(d)] which is a continuous open structure along which the beam reconstruction is performed point by point around the beam, and not at periodic intervals as it occurs in the other types of beam waveguides.

Manuscript received September 11, 1972; revised December 7, 1972.
The authors are with the Consiglio Nazionale delle Ricerche, Istituto di Ricerca sulle Onde Elettromagnetiche, Firenze, Italy.

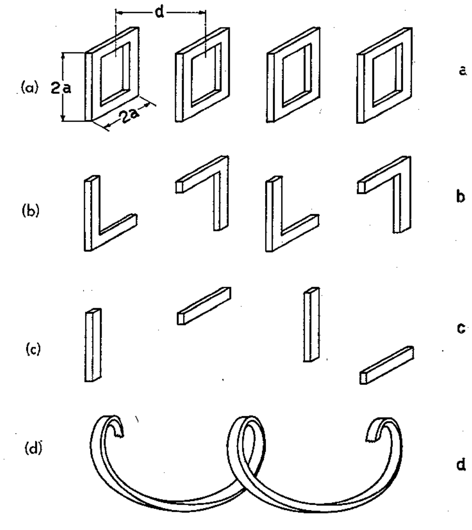


Fig. 1. Dielectric beam waveguides of different shapes.

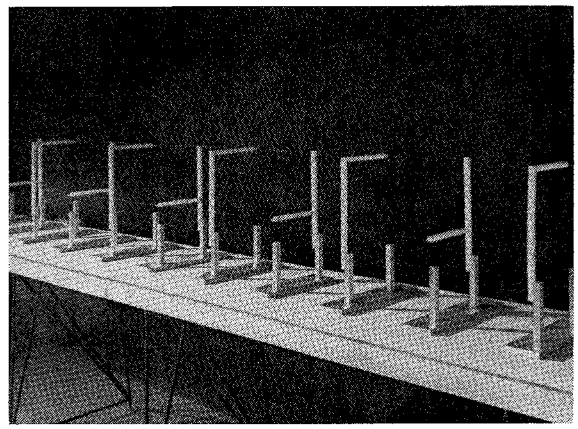


Fig. 2. Prototype of an incomplete-frame beam waveguide.

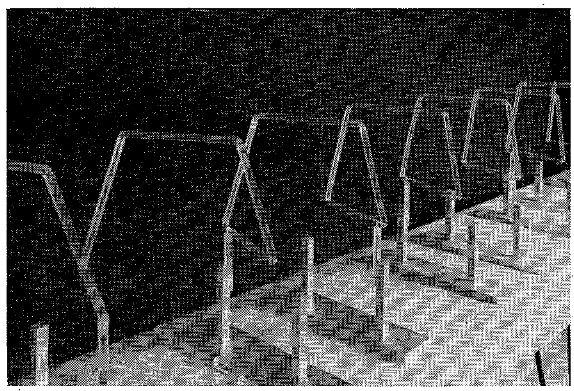
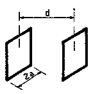
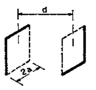
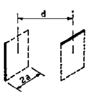
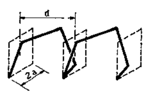


Fig. 3. Prototype of the helix waveguide.

TABLE I

STRUCTURES	SIZES & MATERIALS	ATTENUATION		VOLUME OF MATERIAL
	2a=230mm=28λ d=324mm=40λ teflon rods:15mmx14mm	0.045/dB cell	0.14dB/m	557 cm^3/m
	2a=230mm=28λ d=324mm=40λ teflon rods:15mmx14mm	0.09 dB/cell	0.26dB/m	279 cm^3/m
	2a=230mm=28λ d=324mm=10λ teflon rods:15mmx14mm	016 dB/cell	0.50 dB/m	139 cm^3/m
	2a=230mm=28λ d=324mm=40λ plexiglass rods.10mmx10mm	0.067 dB/turn	0.2 dB/m	296 cm^3/m

Two prototypes of incomplete-frame waveguides were tested working at 37 GHz. In the first one, each frame was reduced to only two consecutive sides [Fig. 1(b)], while in the other one only one side per frame was retained [Fig. 1(c)]. Such prototypes were constituted by 53 Teflon elements having overall apertures of $2a \times 2a$, spacing d, and strip dimensions equal to those of the complete-frame waveguide described elsewhere [1]. For constructive convience the prototype of the helical waveguide was made of plexiglass, and with a square cross section. The aperture was still the same as above, while the pitch of the helix was chosen equal to the spacing between any two elements in the frame waveguide. The cross-section size of the plexiglass rods constituting the helix was chosen so as to obtain an optical path parallel to the beam axis like that of the frame waveguide.

Figs 2 and 3 show the prototypes of an incomplete dielectric frame and of a dielectric helical structure, respectively. Attenuation measurements and field pattern recording were performed using the same procedures as described in [1]. Table I shows the measured attenuation values for the tested structures compared with those of the complete-frame waveguide. Values are also given of the volume of material per meter. Fig. 4 shows some field configurations across the waveguide measured in two different positions along the guide axis for the complete and incomplete frames, as well as for the helical structure. The different amplitudes of the patterns in the vicinity of the launcher also depend on the different launching efficiency, as the same launcher (a Fabry–Perot resonator with a semitransparent mirror) was used. These data show that even a greatly reduced structure like the third one in Table I still maintains some guiding properties. The helical structure results competitive with respect to the complete frames having only slightly higher attenuation but reduced volume of material.

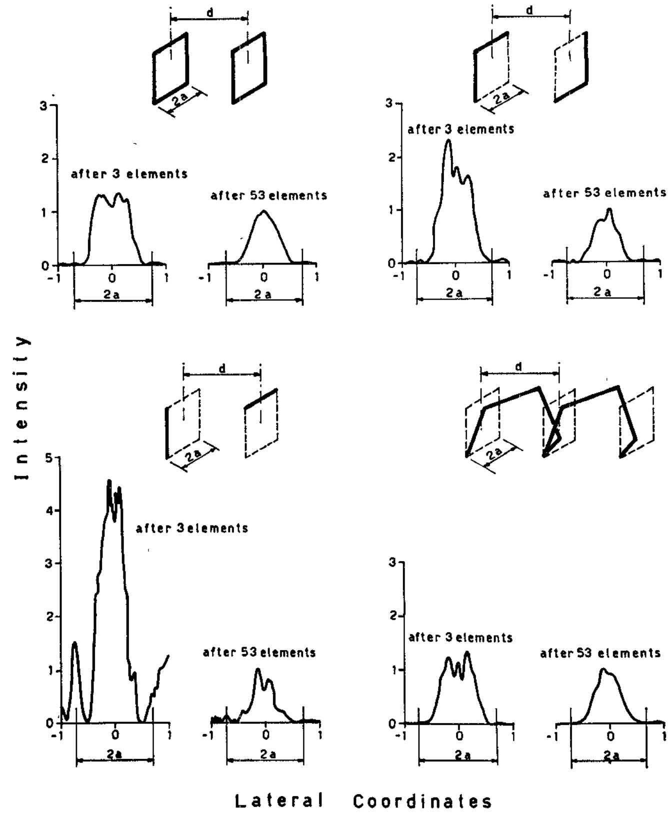


Fig. 4. Field patterns across the beam axis for the four tested dielectric beam waveguides.

Acknowledgment

The authors wish to thank F. Cecconi for his helpful collaboration in performing the experimental tests.

References

[1] P. F. Checcacci, R. Falciai, and A. M. Scheggi, "Phase step beam waveguide," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-20, pp. 608–613, Sept. 1972.
[2] P. F. Checcacci and A. M. Scheggi, "Dielectric frame beam waveguide," *Proc. IEEE* (Lett.), vol. 59, pp. 1024–1025, June 1971.
[3] P. F. Checcacci, A. Consortini, and A. M. Scheggi, "Effect of mirror rims on modes and losses of a planar Fabry-Perot resonator," *Appl. Opt.*, vol. 10, pp. 1363–1370, 1971.