Microwave Four-Mirror Ring Resonator

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

***Abstract*—Experiments on an X-band four-mirror ring resonator are described. Measured frequency spacing and quality factor values are given. Clockwise and counterclockwise circulating modes are excited with different amplitudes. Fundamental mode patterns are shown across the circulating beam and across a mirror. They indicate that such modes are similar to those of a two-mirror Fabry–Perot (FP) resonator.**

Ring resonators constituted by multiple mirrors or by ring-shaped reflectors have been investigated [1]–[6] in view of their applications as gyroscopes and sensitive interferometers or as microwave circuit elements [7]–[9]. Another possible application could be in the field of high-power lasers as an alternative to the multifolded resonator.

The present short paper is concerned with some experimental tests performed on an X-band ring resonator consisting of four plane mirrors placed at the vertices of a square, normally to the square diagonals (Fig. 1).

A standard X-band chain feeds the resonator through a dielectric endfire antenna protruding from the center of one mirror and parallel to the mirror itself, so to excite modes circulating in one direction (say counterclockwise). Obviously, the backward radiation of the antenna also excites clockwise modes, but of much lower amplitude. The resonance curves of the modes observed in reaction are displayed on a CRO.

The resonator mirrors are aluminum machined square plates having sizes $2a \times 2a = 50\lambda \times 50\lambda$ and a distance between the centers of two adjacent mirrors $d = 100\lambda$ (Fig. 2). The angles between any two adjacent mirrors were adjusted at right angles within $\pm 5'$.

The measured spacing between the fundamental modes (24.98 MHz) is in good agreement with the value one gets by means of the approximate relation used by Schawlow and Townes [10] ($\sim c/4d$). It is to be observed that due to the high ratio between the forward and backward radiation, the coupling of the two circulating modes (clockwise and counterclockwise) is so low that the resonance curve is not split as one could expect. The measured value of the unloaded Q($\sim$30 000) for the lowest order mode gives a fractional energy loss per round trip of $\sim$0.085, which is about four times that of a Fabry–Perot (FP) resonator having vertical mirror aperture $2a$, horizontal mirror aperture $2a' = 2a \cos \pi/4$, and mirror spacing d.

Figs. 3 and 4 show typical patterns of the fundamental mode measured across a mirror and across the beam, respectively, by means of a well-known perturbation method [11]. Comparisons are given with the same patterns obtained by means of a numerical procedure [12]. Dotted–dashed line in Fig. 4 corresponds to the mode pattern of an FP with mirror aperture $2a'$ and spacing d.

The measured field distributions are disturbed by the interference between the resonating mode and other (nonresonant) modes constituting the primary wave from the feeder. To eliminate this disturbance an averaging procedure is necessary which, however, leads to smoothing some details on the mode pattern. Such a disturbance can be less easily eliminated in the measurements across the mirrors because in this case the interference pattern is asymmetric. This circumstance could be responsible for the larger discrepancies between the computed and measured patterns across the mirror.

However, other interference phenomena occur in the resonator, independently of the feeding system. First of all, the impinging and reflected waves from a mirror give rise to fringes parallel to the mirror in the region of superposition of the two beams. Such fringes were not observed because the pattern is recorded parallel to the mirror. Secondly, if clockwise and counterclockwise modes are present simultaneously, a standing-wave system exists along the beam. The fringes are not visible when recording the field pattern across the beam but, on the contrary, they are clearly observable when recording across a mirror. The curve shown in Fig. 3 does not

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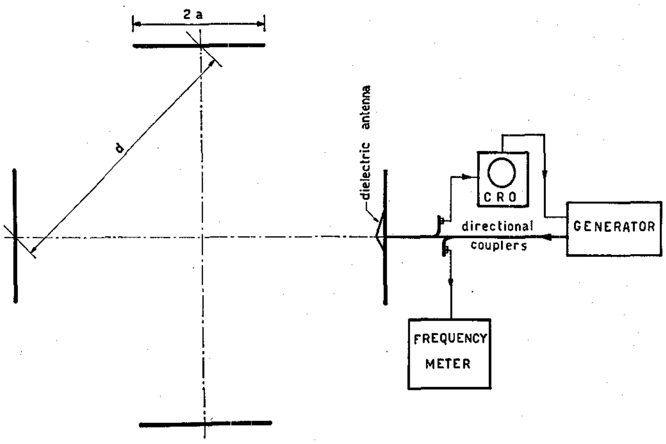

Fig. 1. Block diagram of the apparatus.

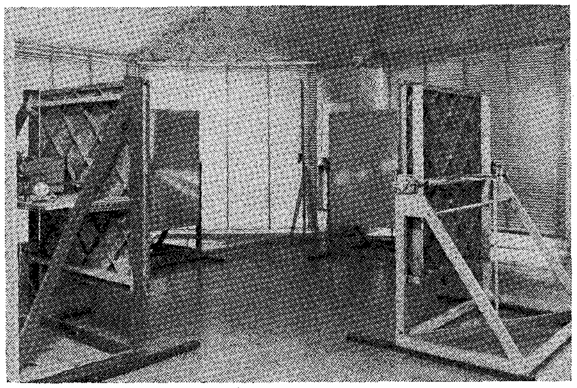

Fig. 2. The four-mirror ring resonator.

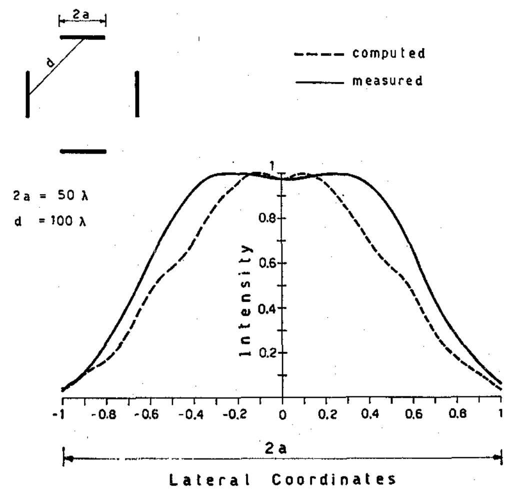

Fig. 3. Measured and computed fundamental-mode intensity patterns across the mirror.

present this fringe pattern due to the used averaging procedure. The computed curve reported in Fig. 4 represents the envelope of an interference pattern between the two modes of equal amplitudes circulating in opposite directions.

These measurements have shown that in a polygonal FP resonator it is possible to excite modes circulating in opposite directions in a very simple way and with a prescribed amplitude ratio. The measured envelope of the fringe pattern of the two modes has a shape similar to that of the two-plane mirror FP resonator, and the

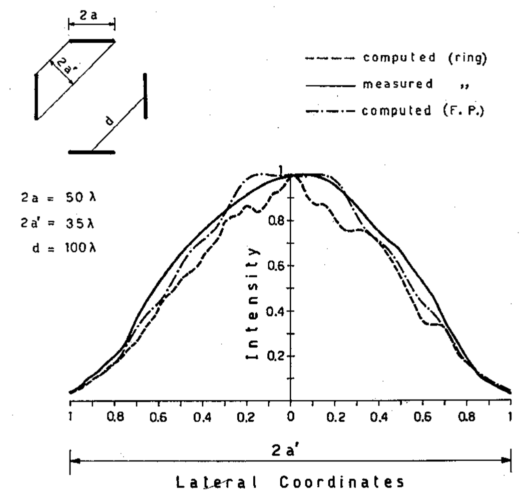

Fig. 4. Measured and computed fundamental-mode intensity patterns across the beam compared with the computed one for a FP resonator.

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].

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Beam Waveguides with Minimized Dielectric Structures

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***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

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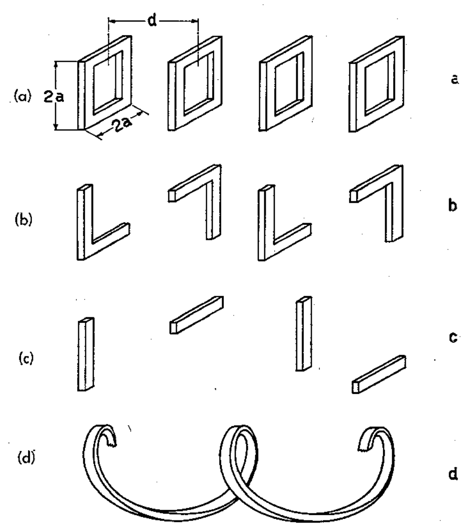

Fig. 1. Dielectric beam waveguides of different shapes.

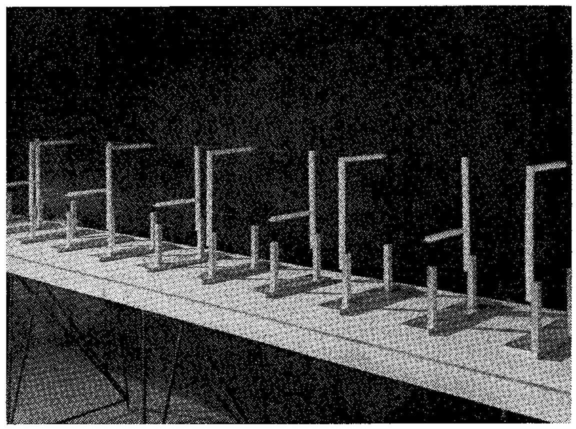

Fig. 2. Prototype of an incomplete-frame beam waveguide.

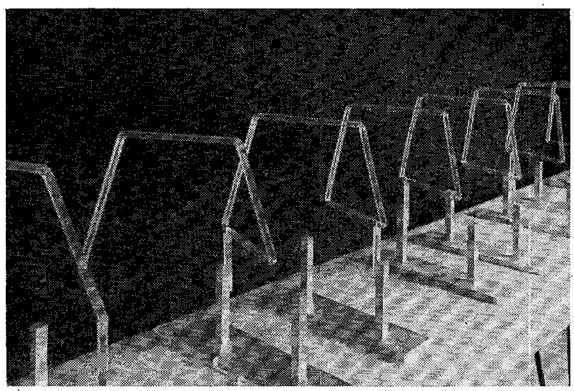

Fig. 3. Prototype of the helix waveguide.

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.