[6] D. Marcuse and R. M. Derosier, "Mode conversion caused by diameter changes of a round dielectric waveguide," *B.S.T.J.*, pp. 3216–3233, Dec. 1969.
[7] E. Topuz, "Periodic boundary perturbations on cylindrical dielectric waveguides," Diss. I.T.U., Istanbul, 1975.

A Tunable Bandpass Ring Filter for Rectangular Dielectric Waveguide Integrated Circuits

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***Abstract*—Dielectric waveguide structures have received renewed interest in recent years for application at millimeter wavelengths. A number of passive and active microwave devices in the dielectric waveguide technologies have been recently developed. This short paper describes a method for providing continuous mechanical tuning of a resonant dielectric ring filter for use with rectangular dielectric waveguide integrated circuits. Results obtained with an experimental device operating at *K* band are also given.**

I. Introduction

A bandpass filter can be constructed using a dielectric ring of rectangular cross section that is proximity-coupled to two dielectric image waveguides which form the input and output lines of this four-port device. The ring is a multiple resonant bandpass device which will provide a maximum transfer of microwave energy from one line to the other at center frequencies where the mean circumference of the ring is approximately $n\lambda g$ ($n = 1,2,3,\cdots$). The basic analytical approach and some practical applications of these types of filters can be found in [1]–[4].

The resonant condition for the ring of $n\lambda g$ was stated to be only approximate because the propagation characteristics of the uncoupled portion of the loop are different, in general, from that of the coupled sections. The propagation characteristics are therefore a function of various physical parameters such as overall dimensions and loading. The basic ring configuration provides fixed-frequency responses with the center frequencies primarily determined by the ring filter dimensions. Consequently, a great deal of tolerance must be achieved in machining the rings in order to obtain filters with the desired resonant frequencies. This limitation led to the development of the tunable filter described in this short paper. The tuning characteristic is achieved by controlling or changing the effective guide wavelenth around the ring.

It is known that the dispersion characteristics of insulated image guide are a function of the thickness of the low-permittivity dielectric layer used to suspend the high dielectric constant waveguide off the metal ground plane. Theoretical curves demonstrating this dependence for straight sections of insulated image guide can be found in [4]. These curves demonstrate that there can be significant variation in the guide dispersion characteristics as the low-permittivity layer thickness approaches zero. It is this dependence of guide wavelength on the thickness of the substrate layer for a fixed waveguide structure that is proposed to be used in tuning the ring filter.

II. An Experimental Tunable Bandpass Filter

An experimental tunable bandpass filter was constructed for *K*-band operations. The tunable filter consists of a dielectric ring

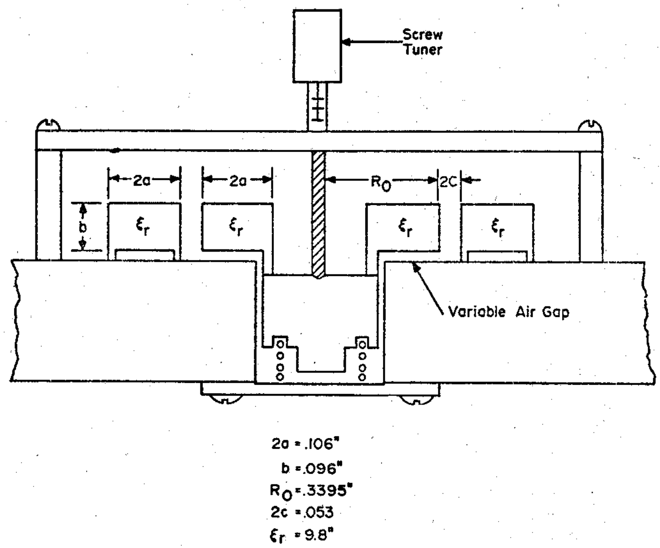

Fig. 1. A cross section of a tunable MILIC bandpass filter.

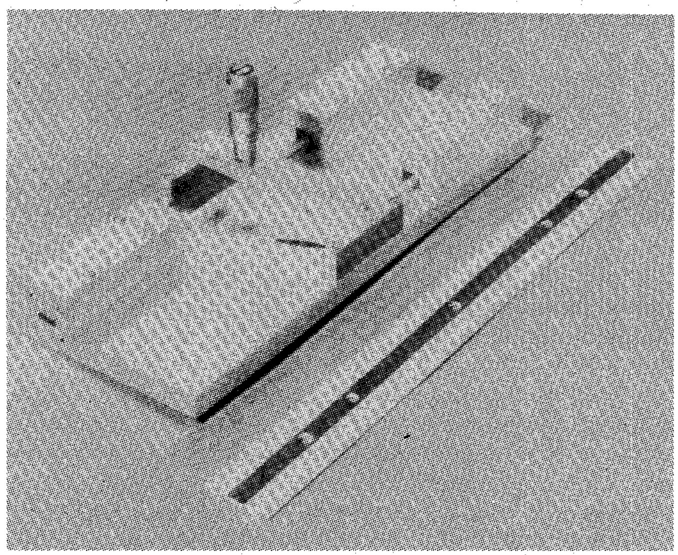

Fig. 2. A *K*-band tunable MILIC bandpass filter.

mounted in a bandpass configuration between two sections of dielectric waveguide which form the input and output feed lines. The ring structure rides on a piston which is spring-loaded and mounted in the metal base plate. A tuning screw is mounted above the ring, which is used to control the piston movement and, in turn, the gap between the ring and baseplate. A cross-sectional sketch of the device is shown in Fig. 1. The experimental device utilizes a variable air gap ($\varepsilon_r = 1.0$) beneath the ring instead of a dielectric material layer.

Fig. 2 is a photograph of the experimental *K*-band filter mounted on a test plate. The dielectric ring can be seen in the center of the test plate with the micrometer tuning screw mounted above. Three of the output ports of the device are fed into standard metal-waveguide-to-dielectric-image-guide launchers for the connection of test equipment. The fourth port is terminated with a ferrite load.

The material used for the dielectric guides and ring structure was Custom Materials High-K 707L with a dielectric constant of $\varepsilon_r = 9.8$. This plastic material has a higher loss tangent than alumina ceramic, but it is much easier to machine and work with for laboratory prototypes.

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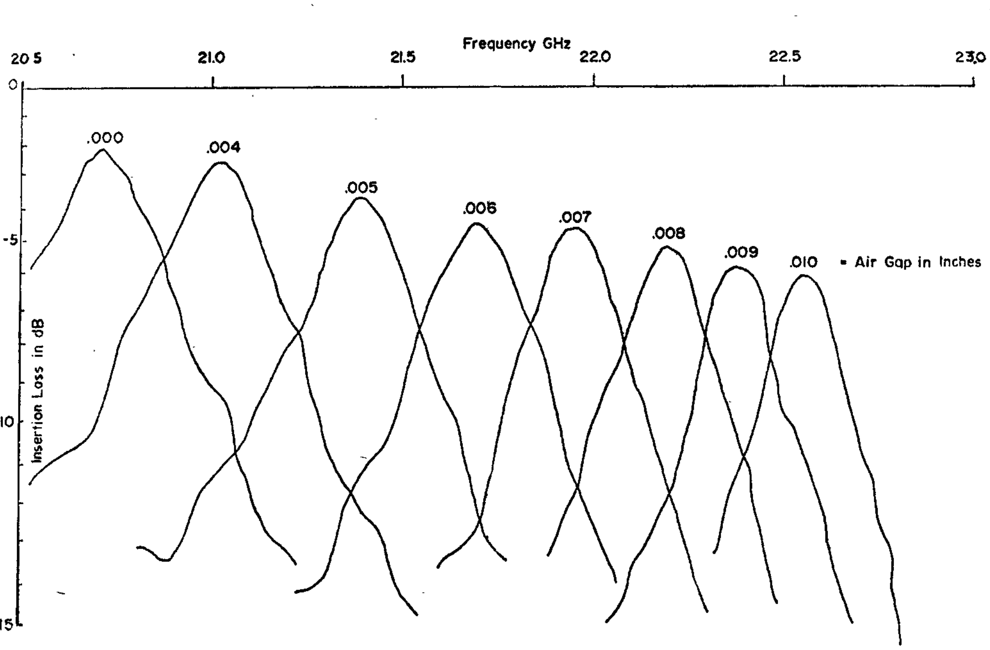

Fig. 3. Insertion loss and tuning characteristics of an experimental MILIC filter.

The tunable filter shown in Fig. 2. proved to be continuously tunable over a 3-GHz range as the air gap was increased from 0.0 to 0.022 in. The gap of 0.0 in is only approximate since the tuning mechanism did not provide for the complete elimination of all the air gap beneath the ring. Although the response could be easily tuned over the 3-GHz range, the useful tuning range due to increased insertion loss at larger gaps was about 2 GHz. This increase in insertion loss is attributed to the fact that as the gap is increased there is a decoupling of the ring from the fringe fields of the feed line. The tuning characteristic of a single resonant response for the experimental filter of Fig. 2 is presented in Fig. 3. From Fig. 3 the continuous tuning of the filter can be seen as the gap is varied from 0.0 to 0.010 in. As the air gap is increased, the resonant response is seen to tune upward in frequency as would be expected from the theoretical results [4].

III. Conclusions

The ability to mechanically tune a bandpass ring filter by varying the air gap beneath the structure provides for a continuously tunable filter for use with dielectric waveguide integrated circuits. This device could be used as a tunable preselector filter for the front end of a microwave receiver. It also provides a method for controlling the dependence of the filter response on the gap effect by providing a fine-tuning mechanism when fixed-frequency operation is desired.

Further experimental and theoretical work is necessary in order to improve the performance of the filter, particularly to decrease the insertion loss. This could be accomplished by improving the matching of the filter to the feed lines and by using a lower loss material such as alumina.

References

[1] F. S. Coale, "A traveling-wave directional filter," *IRE Trans. Microwave Theory Tech.*, vol. MTT-4, pp. 256–260, Oct. 1956.
[2] B. J. Levin and J. E. Kietzer, "Hybrid millimeter-wave integrated circuits," U.S. Army Electronics Command, Rep. ECOM-74-0577-F, Contract DAAB07-74-C-0577, Final Rep., Oct. 1975.
[3] E. A. Marcatilli, "Bends in optical dielectric guides," *Bell System Tech. J.*, vol. 48, pp. 2103–2132, Sept. 1969.
[4] P. P. Toulios and R. M. Knox, "Image line integrated circuits for system applications at millimeter wavelengths," U.S. Army Electronics Command, Rep. ECOM-73-0217-F, Contract DAAB07-73-C-0217, Final Rep., July 1974.

A New Form of Ferrite Device for Millimeter-Wave Integrated Circuits

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***Abstract*—A new form for ferrite devices has been developed which finds extensive applications in the integrated circuits from *Ku* band to millimeter wavelengths. The new configuration is compatible with the emerging technology of millimeter-wave image line integrated circuits (MILIC's) which use dielectric image line as the guiding structure. Development of a MILIC isolator is discussed in detail to spotlight the salient points of the new approach. The design approach permits flexibility in layout and mechanical dimensions, and it results in low fabrication costs for MILIC ferrite devices at component and subsystem levels.**

I. Introduction

Dielectric image line [1] is emerging as an important vehicle for realizing integrated-circuit systems at millimeter waves. It is essentially a single-mode refractive waveguide which guides energy in the dielectric medium using a high-permittivity low-loss guide material laid on a metal plane. A theoretical model [2] for dielectric image guide has been developed which predicts the dispersion characteristics needed for design information of the components. The feasibility of this approach has been demonstrated by developing several passive distributed circuit components and signal processing devices. Recently, a 60-GHz communication system has been developed by IITRI for ECOM using this technology. The system description, including that for various devices, is presented by Kietzer *et al.* [3], Kaurs [4], and Shiau [5].

The use of gyromagnetic media in the dielectric image guide circuits has not been investigated so far. Since ferrite devices constitute an important building block in many RF systems, the scope of the present effort is to explore this important requirement of ferrite devices in the millimeter-wave integrated circuits. This short paper describes a few configurations of ferrite devices

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