A THIN FILM LUMPED ELEMENT CIRCULATOR

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The lumped element circulator has been treated analytically [1)2)] and several lumped element circulators have been described [3)4)].

Recent advances in thin film technology such as the thin film crossover as developed by J. P. Sitarik (BTL) who used photo-resist as the insulating layer at the crossover point and more recently the air crossover by Martin P. Lepselter (BTL) offer new design possibilities for lumped element circulators which decrease their size, increase the possibility of integration and extend the range of feasibility from L-band up into the higher regions of the microwave spectrum.

These new lumped element circulator designs could be used in many applications where stripline and conventional lumped element circulators are now used with the following advantages:

1. Minimum size - The thin film lumped elements circulator exclusive of connectors would be about half an order of magnitude smaller in diameter than a fully alumina loaded stripline circulator. Figure 1 shows an L-band stripline circulator for comparison.
2. Low Cost - The small quantities of material required and the use of batch photolithographic processing should result in significantly lower device or integrated circuit cost.
3. Reproducibility - The high degree of reproducibility inherent in the photolithographic process would eliminate many of the elements contributing to variations in device performance.

NOTES

Some specific features of the design not readily obtainable except by thin film techniques are:

1. A complete planar circuit using either all ferrite or a composite alumina-ferrite substrate.
2. Complete symmetry of the junction inductors obtained by interweaving them.
3. Symmetrically configured and grounded, interdigital junction capacitors.
4. Lumped capacitors and inductors for microwave frequencies above L-band.

Figure 2 is a close up of the lumped element circulator of Figure 1. In this figure, the nature of the junction inductors and the shunt resonating capacitors is readily apparent. The interdigital capacitors lie within a circle of 0.5 inches diameter. The performance of this circulator at L-band is shown in Figure 3. The insertion loss is less than 1 dB, the maximum isolation is greater than 30 dB and the 20 dB bandwidth is currently 2%. The device has not been optimized with respect to bandwidth and insertion loss so that further development can be expected to improve upon this performance.

To this junction one could add photo etched series resonant circuits for broadbanding the device. The series circuit could conceivably consist of a gap capacitor and either a short piece of high impedance transmission line, a meander line, or a spiral type inductor, with dielectric or air crossovers.

The device is designed to operate at fields below the field for gyromagnetic resonance and the saturation magnetization is chosen to be low enough to avoid low field losses.

In this way, all of the circulator elements as well as connecting circuitry may be generated on the ferrite as a substrate without the necessity of magnetizing the entire substrate. Alternatively the circulator elements alone could be generated on the ferrite and the circulator could be bonded into a microwave integrated circuit. With this approach operation above or below resonance would be acceptable, and both have been found to be feasible.

The circulator design is adaptable to:

1. Suspended substrate stripline.
2. Microstrip.
3. Fully loaded stripline.

In each case it should be possible to design with or without a top ferrite disc.

As indicated above, the nature of the approach suggests the application of the lumped element circulator in the higher microwave spectrum. Figure 4 shows, as an example, a lumped element circulator designed for operation at approximately 4 GHz. Preliminary results are most encouraging.

REFERENCES

[1] J. Deutsch and B. Wieser, IEEE Transactions on Magnetics, vol. Mag. 2, No. 3, September 1966, pp. 278-282.

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[3] E. Pivit, "Zirkulatoren aus konzentrierten Schaltelementen", Telefunken-Z., vol. 38, PP. 206, 1965.

[4] V. E. Dunn and R. W. Roberts, "New Design Techniques for Miniature VHF Circulators", 1965 G-MTT Symposium, Clearwater, Florida, May 1965.

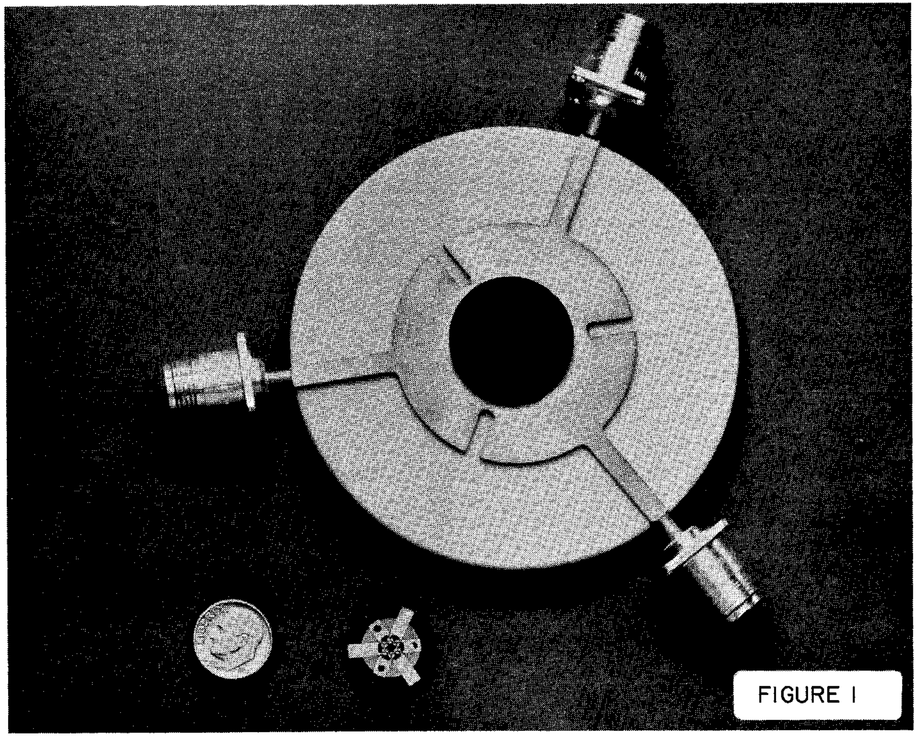


FIGURE I

L-BAND LUMPED ELEMENT CIRCULATOR AS COMPARED TO A CONVENTIONAL STRIPLINE CIRCULATOR.

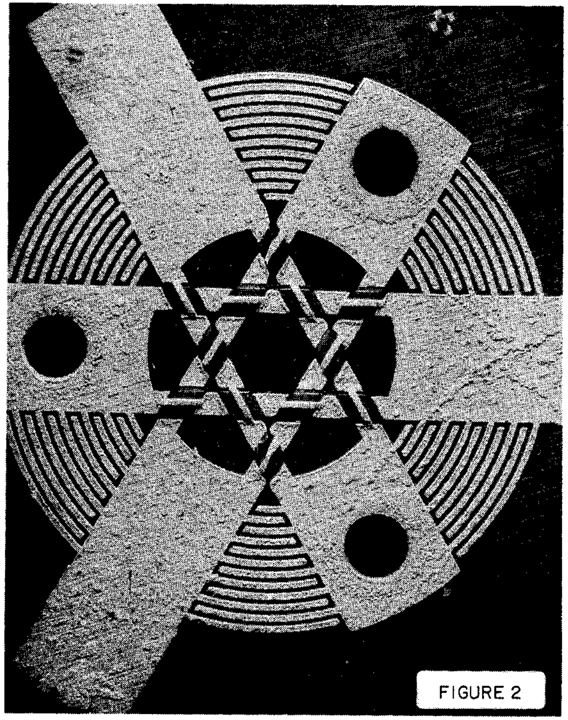


FIGURE 2

CLOSE-UP OF LUMPED ELEMENT CIRCULATOR OF FIGURE 1.

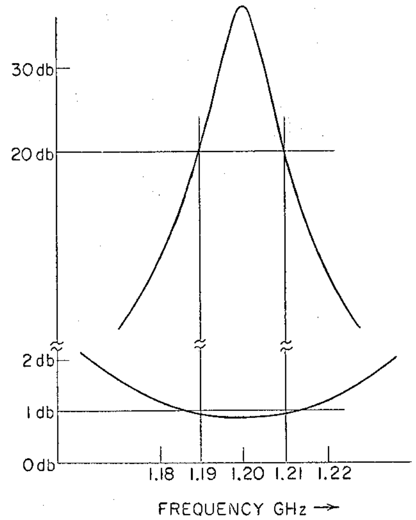
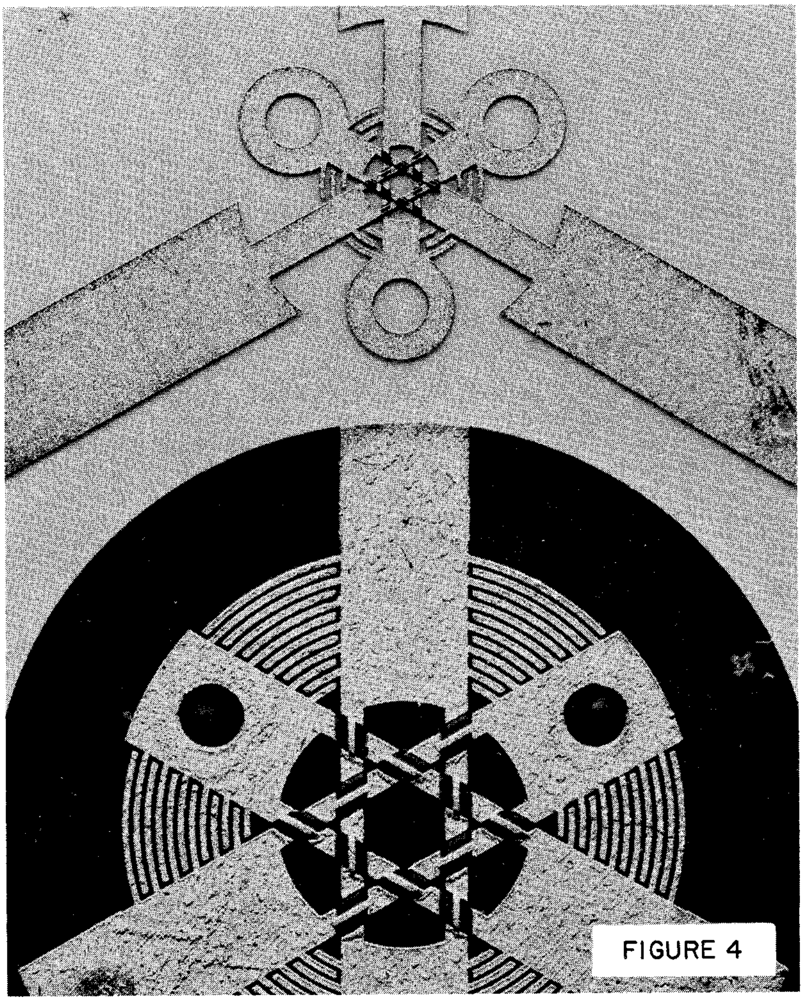


FIGURE 3

TYPICAL PERFORMANCE CHARACTERISTICS OF THE L-BAND CIRCULATOR OF FIGURE 2.



C-BAND LUMPED ELEMENT CIRCULATOR AS COMPARED TO THE L-BAND CIRCULATOR.