CHAPTER V

MATCHING TECHNIQUES IN THE AND 4-PORT STRIP-LINE CIRCULATORS

Much work has been carried out on 3-port Y-junction circulators till now, but comparatively little on the 4-port devices. The 4-port devices (105, 123, 120, 148, 191) can be formed by cascading internally the two tri-plate strip-line junctions and so have the advantage of greater compactness.

After making successful experimental studies on matching techniques in Y-junction ferrite strip-line circulators for their broad-band operation in S- and C-bands of the microwave spectrum, it is also aimed to use and test the above techniques in 3-port T-type and 4-port ferrite strip-line circulators, so as to get broad-band operation in the above bands.

V.1. T-JUNCTION STRIP-LINE CIRCULATORS

The S-band strip-line circulator designed and fabricated for T-configuration is shown in the fig. V.4, in which the two of the three tri-plate strip-line arms in fig. V.3b are given a curved bend without affecting their 50-ohm characteristics impedance, to form into a T-shape at the periphery of the cavity enclosure.

The \( \lambda/4 \)-linear/exponential taper matching elements tested previously are inserted in the strip-line junction in the magnetic region and the external d.c. magnetic field is oriented perpendicular to the plane of the ferrite junction. Also the wide-band co-axial to strip-line slot-transitions designed are essentially employed to sustain good symmetry
Fig. V.4. T-STRIP-LINE CIRCULATOR

(Dimensions in inches)
at each port which will only ensure to cross check against any possible deviation from that of the Y-junction circulator, in its performance characteristics.

The T-circulator designed above is tested and its performance is shown in fig. V.1, is compared with that of the Y-circulator as shown in fig. IV.3, in the S-band of the microwave spectrum. It is interesting to note that their performance characteristics are found to be close.

Also when the λ/4-step matching elements are tested in I-type strip-line circulator, their matching characteristics and the resulted broad-band circulation observed to be consistence, with those of the Y-junction circulator in both the bands.

V.2. 4-PORT STRIP-LINE CIRCULATORS

The 4-port strip-line circulators designed, are formed, by cascading internally either by two Tees or Y-stripline junctions as in fig. V.3a. In the 4-port device, two types of configurations result by the way the external d.c. magnetic field is oriented. Zero (0) configuration in r.f. power circulation as in fig. V.7b is obtained when the external d.c. fields applied in the same direction at two ferrite loaded junctions and the infinity (∞) configuration as in fig. V.7a is obtained, when the two junctions are biased in opposite directions.

The 4-port strip-line circulators in two configurations are designed and tested with built-in λ/4-taper matching elements in the junction region are shown in the
IMPEDANCE OR ADMITTANCE COORDINATES

S. KESAVULU
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a. Strip-line for 4-port Circulator

b. Strip-line for T- Circulator

Fig.V.3. TEE and 4-PORT STRIP LINES
figs. V.5 and V.6 and their admittance characteristics are presented in the fig. V.2. It can be examined from the plots that the two types of 4-port devices have exhibited very close admittance characteristics.

V.3. PERFORMANCE CHARACTERISTICS

The performance characteristics of S-band T-circulators are given below (as measured),

- Frequency range (GHz): 2.6 to 4.0
- Minimum isolation (dB): 20
- Maximum V.S.W.R: 1.25
- Maximum insertion loss (dB): 0.30

The performance characteristics of the 4-port strip-line circulator for S-band in infinity (\( \infty \)) configuration is given below (as measured):

<table>
<thead>
<tr>
<th>Isolation</th>
<th>Frequency range (GHz)</th>
<th>Isolation</th>
<th>Insertion loss</th>
<th>V.S.W.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 ( \rightarrow ) 1</td>
<td>2.50 to 3.50</td>
<td>3 ( \rightarrow ) 2</td>
<td>0.30 dB Max.</td>
<td></td>
</tr>
<tr>
<td>3 ( \rightarrow ) 2</td>
<td>: 20 dB Mini.</td>
<td>4 ( \rightarrow ) 1</td>
<td>: 0.60 dB Max.</td>
<td></td>
</tr>
<tr>
<td>1 ( \rightarrow ) 3</td>
<td>: 30 dB typical</td>
<td>2 ( \rightarrow ) 3</td>
<td>: less than 1.22 : 1</td>
<td></td>
</tr>
<tr>
<td>3 ( \rightarrow ) 4</td>
<td>: 40 dB Mini.</td>
<td>4 ( \rightarrow ) 1</td>
<td>: less than 1.16 : 1</td>
<td></td>
</tr>
<tr>
<td>1 ( \rightarrow ) 1</td>
<td>: 50 dB typical</td>
<td>2 ( \rightarrow ) 4</td>
<td>: less than 1.18 : 1</td>
<td></td>
</tr>
<tr>
<td>3 ( \rightarrow ) 3</td>
<td></td>
<td>3 ( \rightarrow ) 3</td>
<td>: less than 1.18 : 1</td>
<td></td>
</tr>
<tr>
<td>4 ( \rightarrow ) 4</td>
<td></td>
<td>4 ( \rightarrow ) 4</td>
<td>: less than 1.18 : 1</td>
<td></td>
</tr>
</tbody>
</table>
a. Plan-Top ground plane removed

b. Cross-Sectional End-view (B-B)

c. Cross Sectional Front Elevation

(A-A) Fig. V.5 4-PORT CIRCULATOR (Y-JUNCTION 85 CASCADED)

Magnets

D-Diameter
H-Height

1/16" 1/16"
3/64" 5/16"
1/32 0.063" = 1/16"
C.20" C.20"
Fig. V.6. 4-PORT CIRCULATOR (T-JUNCTIONS CASCADED) (Dimensions in inches)

a. Plan - top plate removed

b. Sectional elevation, connectors removed

A - A
# TABLE V.1

THE PERFORMANCE CHARACTERISTICS OF 3-PORT S-BAND STRIPLINE CIRCULATOR

<table>
<thead>
<tr>
<th>1. Manufacturers:</th>
<th>RAYTHEON</th>
<th>FERRANTI</th>
<th>HOGGINS</th>
<th>MELABS</th>
<th>SPERRY</th>
<th>WESTERN MICROWAVE</th>
<th>MARCONI</th>
<th>PRESENT INVESTIGATOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Frequency-range (GHz):</td>
<td>2.4-4.0</td>
<td>2.4-4.0</td>
<td>2.4-4.0</td>
<td>2.4-4.0</td>
<td>2.4-4.0</td>
<td>2.4-4.0</td>
<td>2.4-4.0</td>
<td>2.4-4.0</td>
</tr>
<tr>
<td>5. Max.V.S.W.R:</td>
<td>1.27</td>
<td>1.30</td>
<td>1.25</td>
<td>1.25</td>
<td>1.12</td>
<td>1.25</td>
<td>1.24</td>
<td>1.25</td>
</tr>
<tr>
<td>6. Max.Insertion loss (dB):</td>
<td>0.50</td>
<td>0.50</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>7. Connectors:</td>
<td>N-type</td>
<td>N-type</td>
<td>N-type</td>
<td>N-type</td>
<td>N-type</td>
<td>N-type</td>
<td>N-type</td>
<td>N-type</td>
</tr>
<tr>
<td>8. Size:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>diameter (inch):</td>
<td>2.10</td>
<td>2.50</td>
<td>-</td>
<td>2.65</td>
<td>-</td>
<td>2.75</td>
<td>-</td>
<td>2.45</td>
</tr>
<tr>
<td>height (inch):</td>
<td>1.14</td>
<td>1.50</td>
<td>-</td>
<td>1.25</td>
<td>-</td>
<td>1.25</td>
<td>-</td>
<td>1.58</td>
</tr>
<tr>
<td>9. Weight (oz):</td>
<td>8.12</td>
<td>14.20</td>
<td>12.00</td>
<td>-</td>
<td>22.3</td>
<td>-</td>
<td>-</td>
<td>16.80</td>
</tr>
<tr>
<td>10. Price:</td>
<td>$360.00</td>
<td>-</td>
<td>$275.00</td>
<td>$185.00</td>
<td>$185.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Fig. V.C. FINAL VERSION OF 4-HOERT CIRCUITATON
C-Configuration
Fig. V.9. S-BAND 4-PORT CIRCULATOR

Fig. V.10. C-BAND 4-PORT CIRCULATOR
V.4. REPEATABILITY AND STANDARDIZATION

(i) Repeatability is secured as long as the co-axial to strip-line slot-transition in each arm is symmetrically maintained, and this has been achieved in 3-port and 4-port strip-line circulators for both S- and C-bands as shown in impedance and admittance plots. Repeatability is also achieved in the case of 4-port circulators in both α- and β-configurations.

(ii) The circulators are perfectly shielded with conatic or natic-shielding material and they are sealed in aluminium circular cavities of 0.0312 inch thickness by means of Araldite-adhesives and then the components are brought under the following tests,

(a) vibration test
(b) temperature test, -50 to +80°C

Then the performance of the component is checked after the tests. The components repeat their performance. Then they are engraved, painted and their performance is compared with standard foreign components as detailed in the Table V.1 to standardize the present devices.

The final standardized versions of 3- and 4-port circulators for S- and C-bands, at below resonance operation and with built-in matching techniques, are shown in the figs. V.8 to V.10.