

Hagler et al.

[45] Oct. 24, 1972

- [56]
- References Cited**

UNITED STATES PATENTS

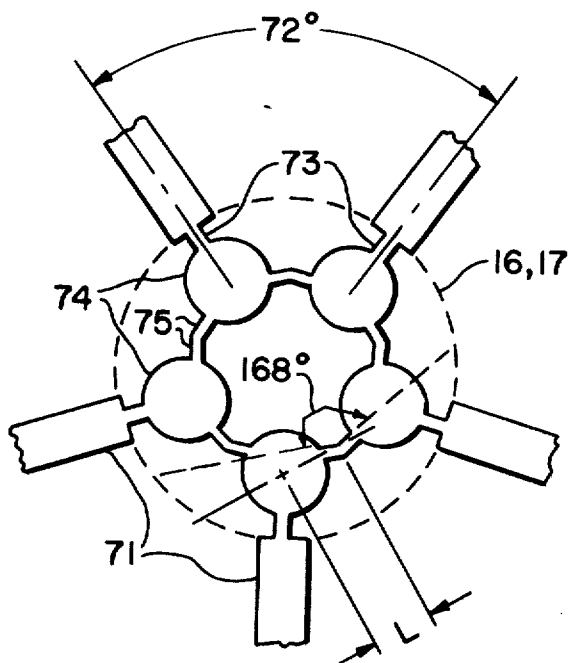
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[57] **ABSTRACT**

This invention relates to an impedance matching structure and technique that is particularly useful in junction circulators. The improved impedance match between the circulator junction and a strip transmission line, for example, is accomplished by abruptly reducing the size of the transmission line that is under the conventional ferrite puck or disk structure by a factor of approximately four. A broadband impedance match structure is obtained by this structure and technique, and the impedance plot can be shifted reactively or resistively by: (1) varying the strip width of the transmission line under the puck, or (2) varying the amount that the ferrite puck overlaps the full-width portion of the transmission line, or (3) varying the length of the reduced width transmission line.

1 Claim, 13 Drawing Figures



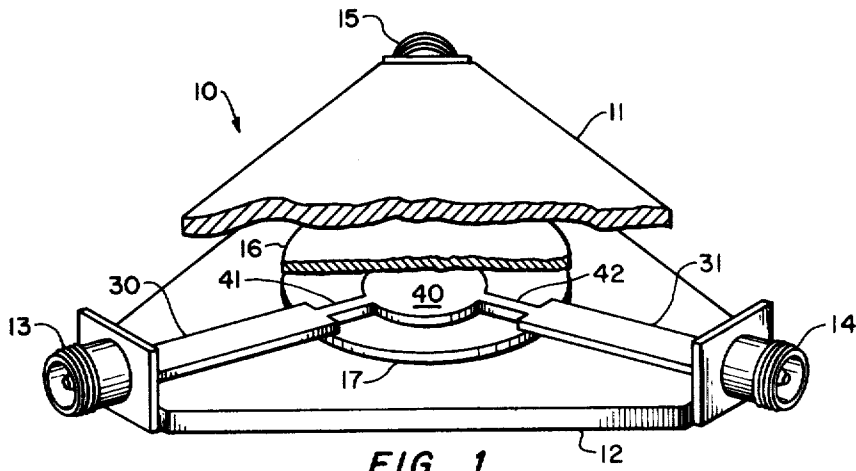


FIG. 1

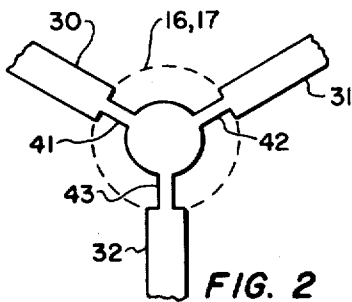


FIG. 2

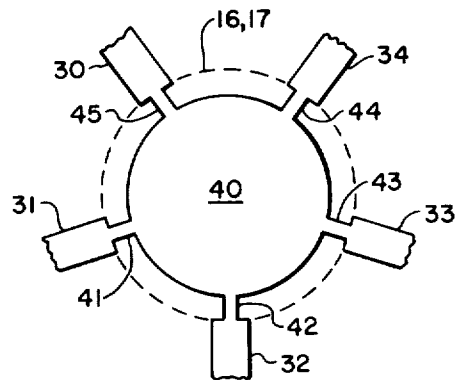


FIG. 4

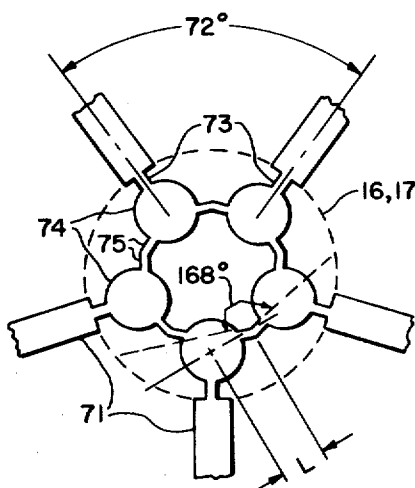


FIG. 7

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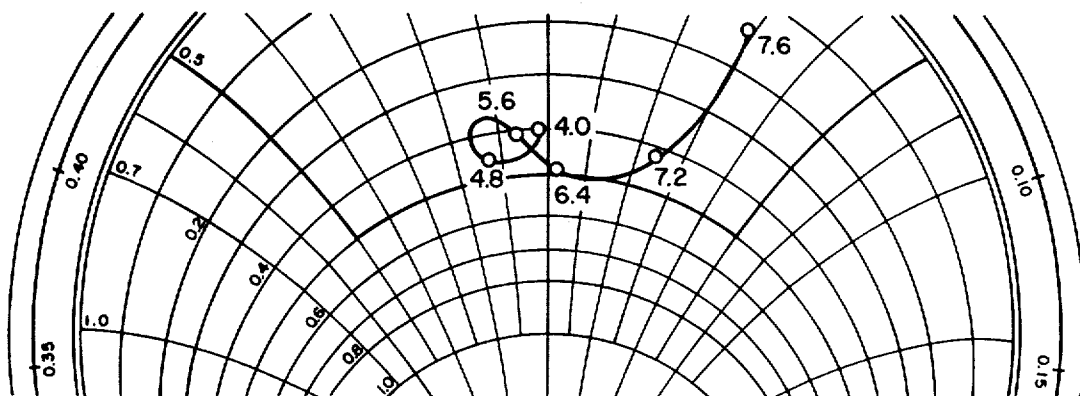


FIG. 3A

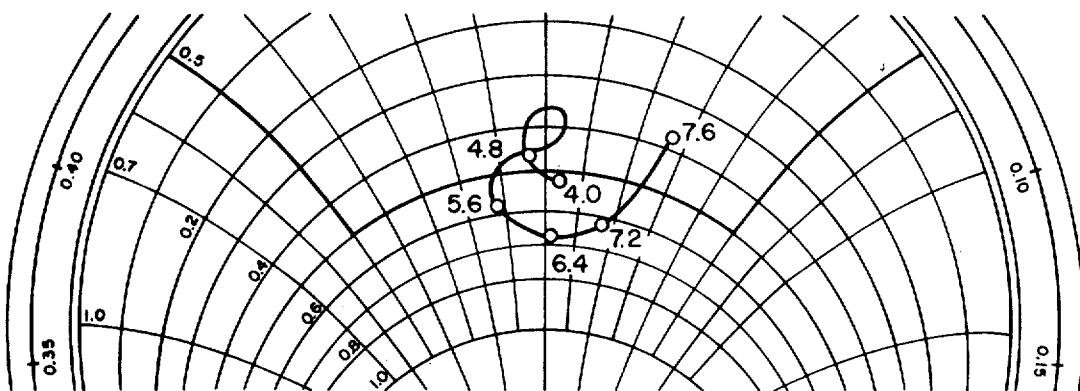


FIG. 3B

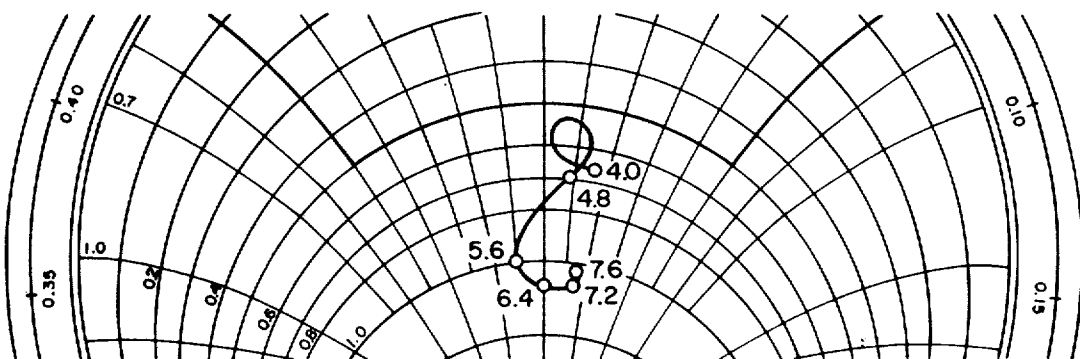


FIG. 3C

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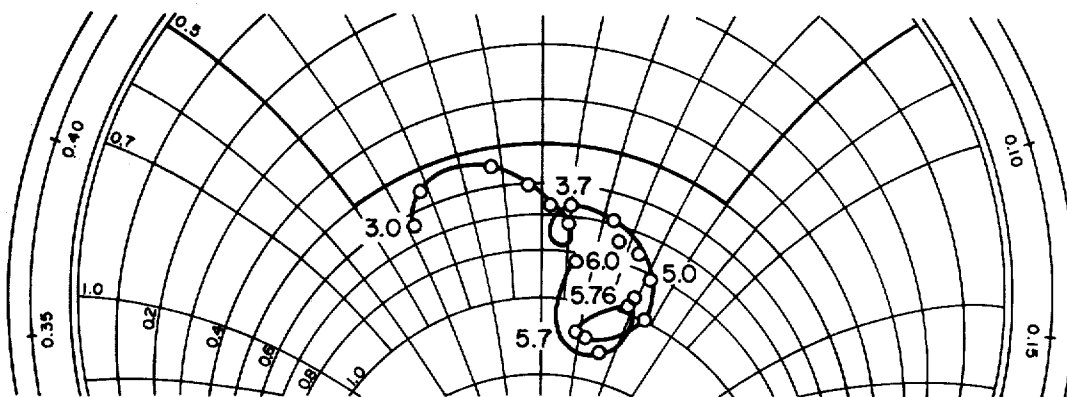


FIG. 5A

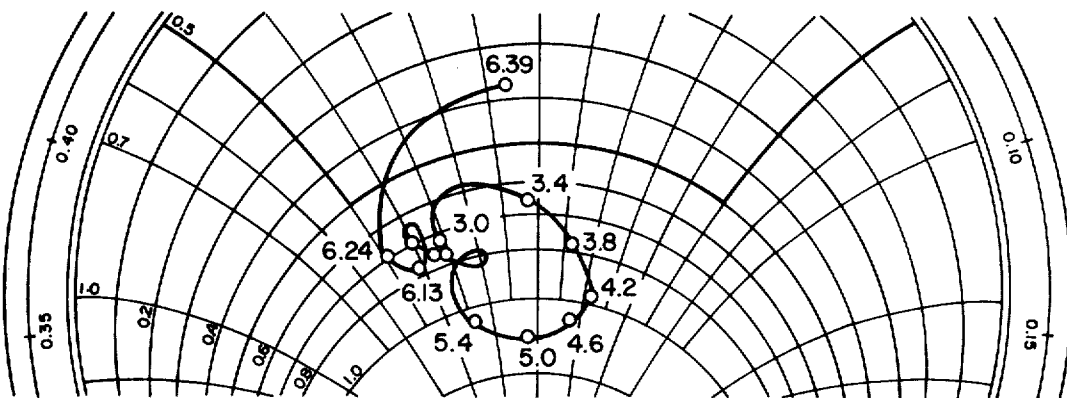


FIG. 5B

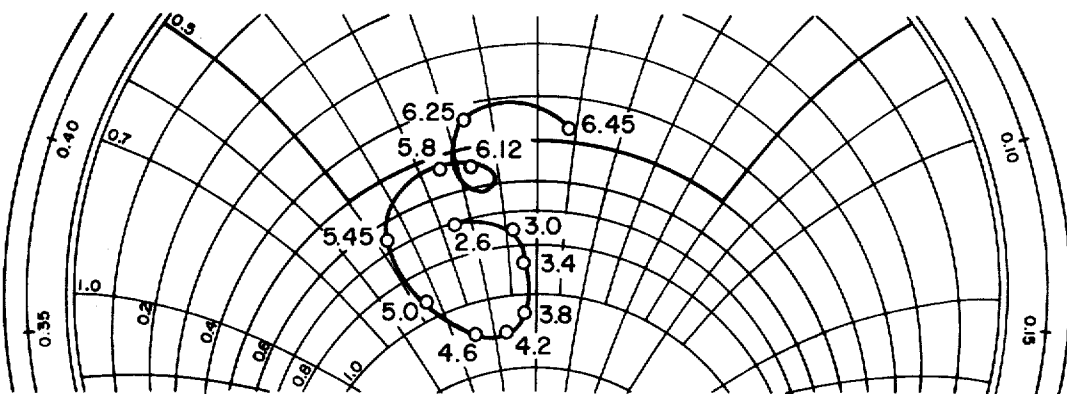


FIG. 5C

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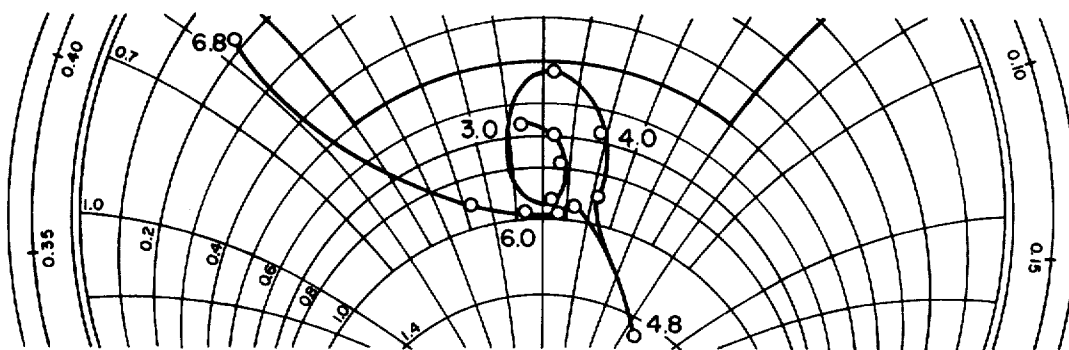


FIG. 8

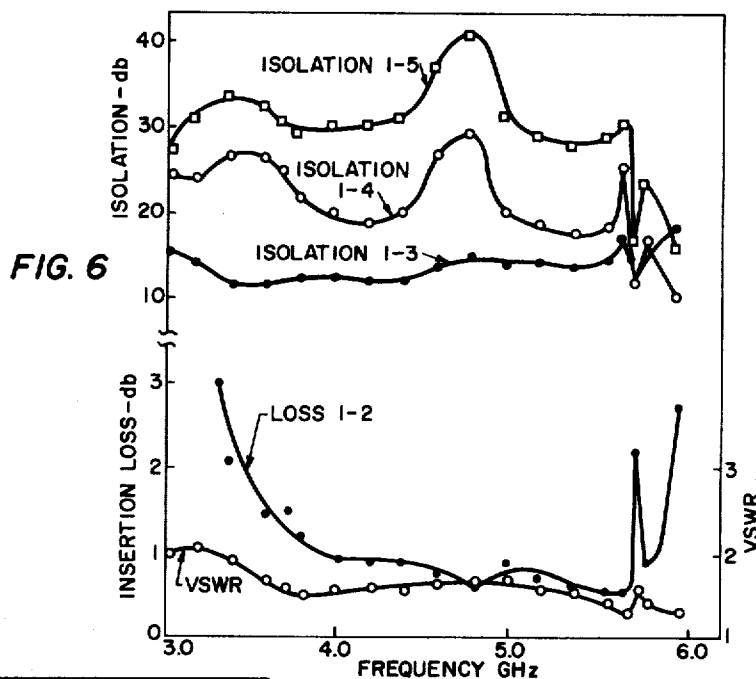


FIG. 6

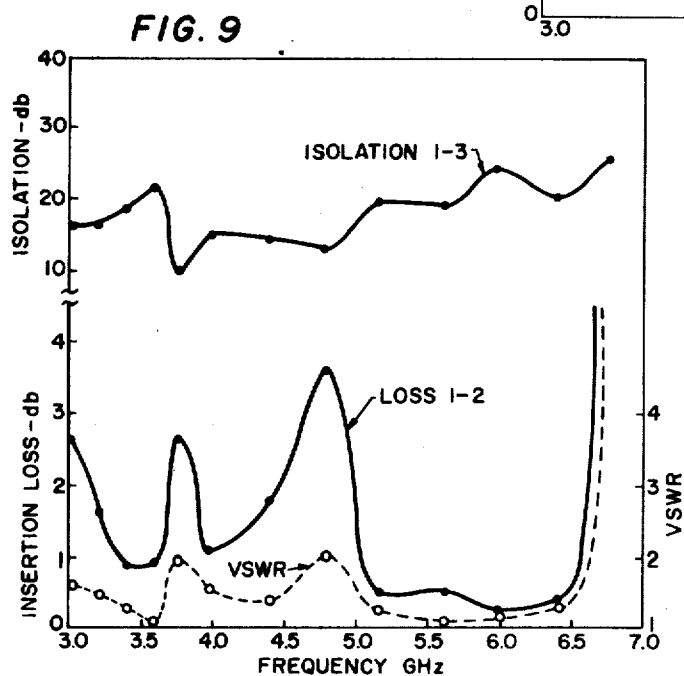


FIG. 9

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IMPEDANCE MATCHING STRUCTURE HAVING REDUCED PORTIONS OF TRANSMISSION LINES CONNECTED TO OFFSET STRIPLINE CENTER CONDUCTORS WITH STRIP GUIDES CONNECTING SAID CENTER CONDUCTORS

BACKGROUND OF THE INVENTION

This invention relates to multi-port junction circulators of the type having TEM mode transmission lines and is generally concerned with providing an improved technique and structure permitting an improved broadband impedance match between the external 50-ohm transmission line and the circulator junction. Multi-port circulators have found wide utility in the past in such devices as duplexers, isolators and other non-reciprocal devices. Such devices generally employ a pair of ferrite disks on either side of the transmission line junction and then a ground plane or other structure on either side of the ferrite pucks thereby enclosing the junction. Suitable connectors are employed.

Such circulator junctions heretofore constructed generally employ one of a number of impedance matching techniques that have been more or less effective. Some of the various techniques employ components external to the junction formed by the transmission line and the ferrite pucks and include tuning screws, dielectric ring transformers encircling the pucks and certain size and configuration changes to the transmission line, likewise external to the aforementioned junction. Of recent development is the technique of reducing the width of the transmission lines under the ferrite pucks to improve the impedance match, and it is to this recent development that this invention is directed.

SUMMARY OF THE INVENTION

This invention broadly relates to an improved impedance matching technique and structure. More particularly, it relates to an improved impedance match between a circulator junction and an external transmission line. A stripline center conductor junction of the instant invention is sandwiched between ferrite disks and the device is then enclosed by ground planes on two sides thereby forming a circulator junction. The width of the portion of stripline that is under the disk is abruptly reduced thereby giving an improved impedance match between the circulator junction and the external transmission line.

The improved impedance match of the instant invention eliminates the need for impedance matching structures external to the pucks thereby effecting a reduction in size, weight, cost, and number of parts utilized in the junction circulator. Stripline material is likewise conserved by utilizing striplines of reduced width. Since the circulator junction of the instant invention utilizes no matching structures external to the ferrite disks, smaller circulator structures can be obtained.

A broadband impedance match is obtained by the instant invention, and the impedance plot can be shifted resistively or reactively by varying the length and width of the stripline that is under the ferrite disks or by varying the amount that the ferrite disks overlap the full-width portions of the stripline, as will be more fully developed hereafter.

BRIEF DESCRIPTION OF THE DRAWING

The exact nature of this invention will be readily apparent from consideration of the following specification relating to the annexed drawing in which:

FIG. 1 illustrates a perspective view in partial section of a C Band 3-Port circulator of the instant invention.

FIG. 2 more clearly illustrates the stripline junction of a 3-Port circulator shown in FIG. 1.

FIGS. 3A, 3B and 3C show the impedance plot of the 3-Port circulator as illustrated in FIGS. 1 and 2.

FIG. 4 illustrates a stripline junction of a 5-Port C band circulator.

FIGS. 5A, 5B, and 5C show the impedance plot of the circulator illustrated by FIG. 4.

FIG. 6 is a plot of the isolation, insertion loss, and VSWR of the C Band 5-Port circulator of FIG. 4.

FIG. 7 illustrates a 5-Port C Band circulator having a different junction configuration.

FIG. 8 shows the impedance characteristic of the junction illustrated in FIG. 7.

FIG. 9 shows the isolation, insertion loss and VSWR characteristics of the 5-Port circulator of FIG. 7.

DESCRIPTION OF THE PREFERRED EMBODIMENT

There is shown in FIG. 1 a perspective view in partial section of the junction circulator 10 of the instant invention having triangular shaped ground planes 11 and 12. Connector flanges 13, 14, and 15 are provided for attaching suitable transmission lines, for example, a 50 ohm air filled line. Connector flanges 13, 14, and 15 are spaced essentially 120° apart and are connected to striplines 30, 31, and 32 (not shown) respectively. The width of striplines 30, 31, and 32 is preserved from the flanges 13, 14, and 15 to the edge of ferrite disks 16 and 17 at which point the width is abruptly changed thereby forming reduced width portions 41, 42, and 43 (not shown) that are joined at center conductor 40. FIG. 2 more clearly shows the 3-Port stripline junction.

A broadband impedance match is obtained from this reduced width stripline technique, and the impedance plot can be shifted resistively, as shown in FIGS. 3A, 3B, and 3C, by varying the width of portions 41, 42, and 43, with the smaller width corresponding to greater resistance. In each of the noted FIGS., 3A, 3B, and 3C, the striplines 30, 31, and 32 have a width of 0.258 inches, while a material thickness of 0.025 inches is maintained throughout for the noted striplines and for reduced portions 41, 42, and 43 as well as for center conductor 40. The ferrite disks 16 and 17 are 0.500 inches. Although disks 16 and 17 were constructed of 5% Al_2O_3 ; 51.62% MgO ; 5.68% MnO ; 37.7% Fe_2O_3 , having a saturation magnetization of approximately 1,300 Gauss, other suitable ferrimagnetic materials may be employed. The reference for the plots in FIGS. 3A, 3B, and 3C was the face of puck 16. In FIG. 3A, the width of striplines 30, 31, and 32 is maintained at 0.258 inches until it joins the center conductor 40, that is, both the striplines 30, 31, and 32 and reduced portions 41, 42, and 43 have a width of 0.258 inches. Center conductor 40 has an effective diameter hereof approximately 0.287 inches. In FIG. 3B, reduced portions 41, 42, and 43 are approximately 0.126 inches wide while the center conductor 40 is approximately

0.275 inches in diameter. In FIG. 3C, reduced portions 41, 42, and 43 are approximately 0.056 inches in width while the center conductor 40 is approximately 0.287 inches in diameter.

A reactive shift in the impedance plot is produced by changing the amount the ferrite disks 16 and 17 overlap the full-width portion of striplines 30, 31, and 32 with more overlap corresponding to greater capacitance.

There is shown in FIG. 4 a stripline junction of a 5-Port C band circulator having striplines 30, 31, 32, 33, and 34 with reduced portions 41, 42, 43, 44, and 45 joined at center conductor 40. Ferrite pucks 16, 17 are positioned on either side of center conductor 40 and the arrangement is then sandwiched between ground planes in a fashion similar to FIG. 1. A reactive shift similar to that described above can be obtained by varying the lengths of reduced portions 41, 42, 43, 44, and 45 but with the advantage that the impedance grouping remains more compact than when the shift is obtained by varying the amount the ferrite pucks 16, 17 overlap the full width portions of striplines 30, 31, 32, 33, and 34. Varying the lengths of reduced portions 41, 42, 43, 44, and 45 was effectively accomplished by varying the diameter of center conductor 40, as more fully described below.

FIGS. 5A, 5B, and 5C show the impedance characteristics of the circulator illustrated by FIG. 4 and show that the plots may be shifted reactively by varying the effective length of reduced portions 41, 42, 43, 44, and 45. For each of the Figures, striplines 30, 31, 32, 33, and 34 are 0.258 inches wide, portions 41, 42, 43, 44, and 45 are 0.056 inches wide, and 0.025 inches thick throughout. Ferrite pucks 16, 17 are fabricated of $3(Y_2O_3) \cdot 5(Fe \ 1.925 \ O_3)$ having a saturation magnetization of approximately 1,780 Gauss, a diameter of 1.860 inches and a thickness of approximately 0.100 inches. In FIG. 5A the center conductor 40 diameter is 1.582 inches while in FIG. 5B it is 1.480 inches and in FIG. 5C it is 1.380 inches. Best centering of the impedance characteristic occurs with a center conductor 40 diameter of 1.480 inches as illustrated in FIG. 5B.

There is shown in FIG. 6 a plot of the isolation, insertion loss and VSWR characteristics versus frequency for the circulator of FIG. 4. By adjusting the magnetic bias slightly above saturation the spikes are tuned above a desired frequency band of 3.7-5.7 GHz. The direction of circulation is in a left-handed rotational sense with respect to the direction of the applied magnetic field here as in the circulators heretofore and hereafter described. An operating bandwidth of 42.5 percent has been achieved in the 5-Port circulator employing the reduced stripwidth technique. In a typical circulator, maximum VSWR over this bandwidth is 1.5:1 and maximum insertion loss is 0.9 db. Minimum isolations obtained between port 1 and ports 3, 4, and 5 are approximately 10 db, 20 db, and 30 db respectively. Over a 21 percent bandwidth, maximum VSWR is 1.25:1 maximum insertion loss is 0.5 db and minimum isolations between port 1 and ports 3, 4, and 5 are approximately 15 db, 25 db, and 35 db respectively.

There is shown in FIG. 7 a different configuration of the junction of a 5-Port C band circulator with ferrite disks, 16, 17 being shown by dashed lines. Striplines 71 are positioned every 72° around the center of the junction.

Reduced portions 73 are formed under the disks 16, 17 and connect the striplines 71 with offset center conductors 74. The striplines 71, reduced portions 73, and offset center conductors 74 have a thickness of 0.025 inches throughout. The disks 16, 17 are constructed of the same material as the circulator disclosed with respect to FIG. 4, and are 1.860 inches in diameter and 0.100 inches thick. Reduced portions and connectors 75, hereinafter referred to as strip guides, are 0.056 inches in width and the offset center conductors 74 have a diameter of 0.380 inches. Dimension L, that is, the distance from the center of offset center conductor 74 to the junction of adjacent strip guides 75 is approximately 0.346 inches. Adjacent strip guides 75 form an angle of 168° where they join as shown in FIG. 7.

The resultant impedance characteristic is plotted in FIG. 8 while FIG. 9 shows isolation, insertion loss, and VSWR curves. Two pronounced insertion loss spikes occur in the frequency band of interest. The spikes are believed to be caused by higher order resonance of the ferrite disks 16, 17 and are tuned out at the operating frequency range by adjustment of the magnetic field.

The circulator of FIG. 7 might be utilized in the X-Band with the following dimensional changes: striplines 71, width 0.100 inches; reduced portions 73 and strip guides 75, width 0.025 inches; offset center conductors 74, 0.125 inch diameter; dimension L, 0.130 inch; and ferrite disks 16, 17, diameter of 0.700 inches on a thickness of 0.043 inches.

Multi-port circulators employing the technique disclosed herein may be employed in various frequency bands. Likewise various other ferrimagnetic materials may be employed in the construction of disks 16, 17. Best microwave performance of the 5-Port circulators has been obtained at approximately the magnetic bias field required for saturation of the ferrimagnetic material.

Other configurations incorporating the technique herein disclosed appear to be practical. One such configuration is the microstrip circulator using a single ferrite disk with a center conductor on one side and a ground plane and magnet on the opposite side.

It should be understood that the embodiments herein disclosed are not to be limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art.

What is claimed is:

1. A multi-port junction circulator having improved impedance matching characteristics when adapted to operate in a magnetic field and comprising:

five strip transmission lines having portions of reduced width;

five circularly-shaped offset stripline center conductors, each of said center conductors having a diameter substantially greater than the width of said portions of reduced width and formed at one end of each of said portions of reduced width;

strip guides joining said five offset center conductors in a generally circular arrangement to symmetrically position said transmission lines and said center conductors about a center of the generally circular arrangement;

ferrite pucks positioned concentric with respect to said center conductors and on each side thereof to

overlap said center conductors and said portions
of reduced width; and
ground plans positioned about said pucks and said
transmission lines thereby producing a five-port
junction circulator having improved impedance 5
matching characteristics.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,701,054 Dated 24 October 1972

Inventor(s) Thomas A. Hagler and William C. Heithaus

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Claim 1, line 61, "fine" should read --five--.

Signed and sealed this 2nd day of April 1974.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents