United States Patent [19]

Nishiyama

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[54] **WIDE-BAND CIRCULATOR**

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[21] Appl. No.: **200,529**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 17,528, March 9, 1970, abandoned.

[30] **Foreign Application Priority Data**

Mar. 29, 1969 Japan 44/27590

[52] **U.S. Cl.** **333/1.1,** 333/34

[51] **Int. Cl.** **H01p 1/32,** H01p 5/12

[58] **Field of Search** 333/1.1

[56] **References Cited**

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[57] **ABSTRACT**

A wide-band circulator employing a Y-shaped stripline conductor having a generally circular center section and a plurality of symmetrically spaced, generally sector-shaped arms extending radially from the center section, in a preferred embodiment each sector-shaped arm subtending an angle 2θ where θ can vary between 17.5° and 27.5°. The circulator futher includes a disk-shaped ferrite plate on each side of the stripline conductor and an outer conductor covering each ferrite plate.

3 Claims, 5 Drawing Figures

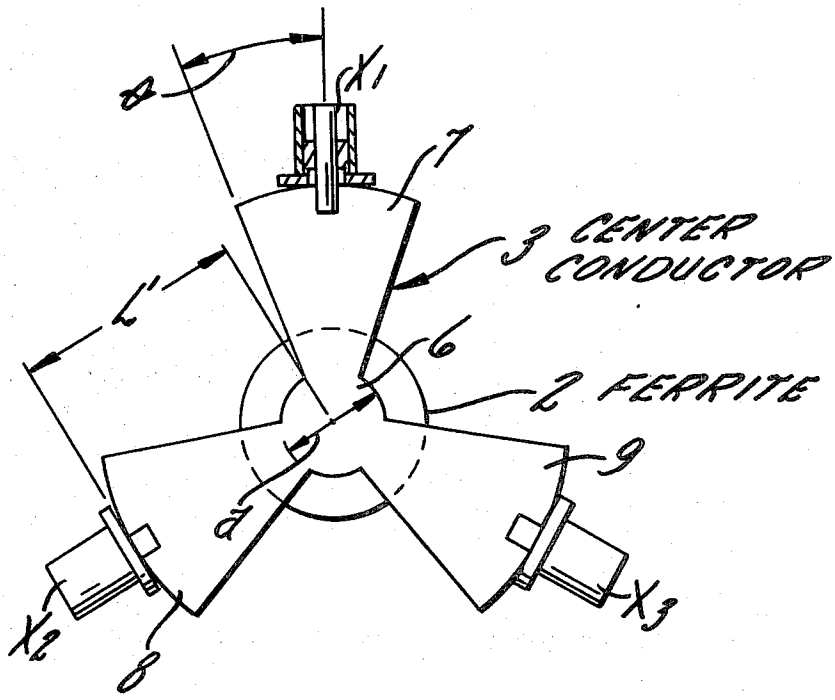


Fig. 1.

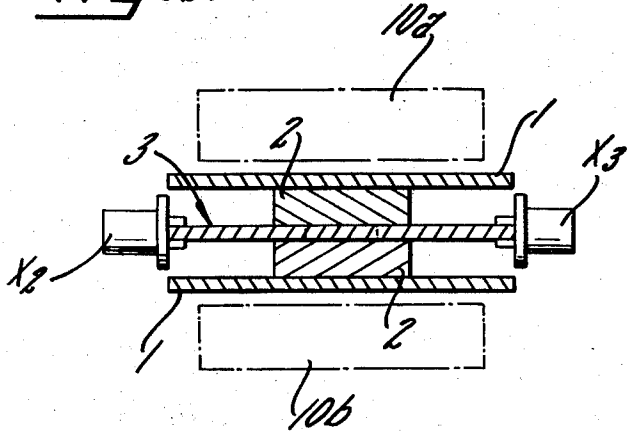


Fig. 2.
(PRIOR ART)

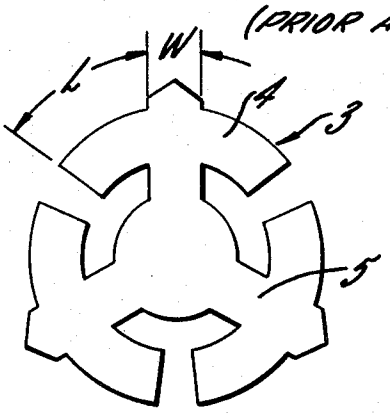


Fig. 3.

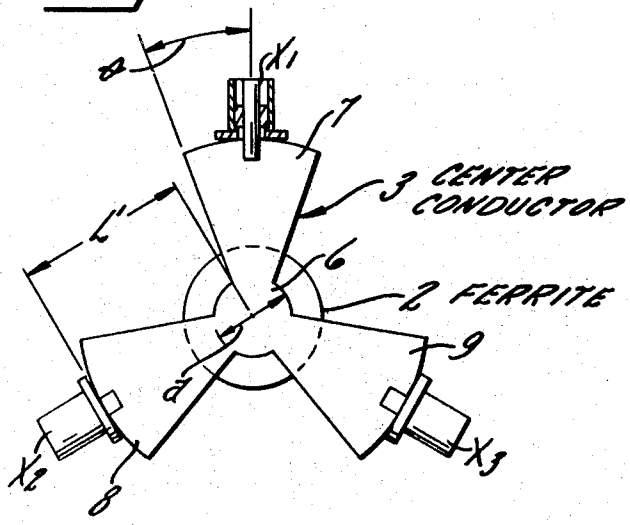
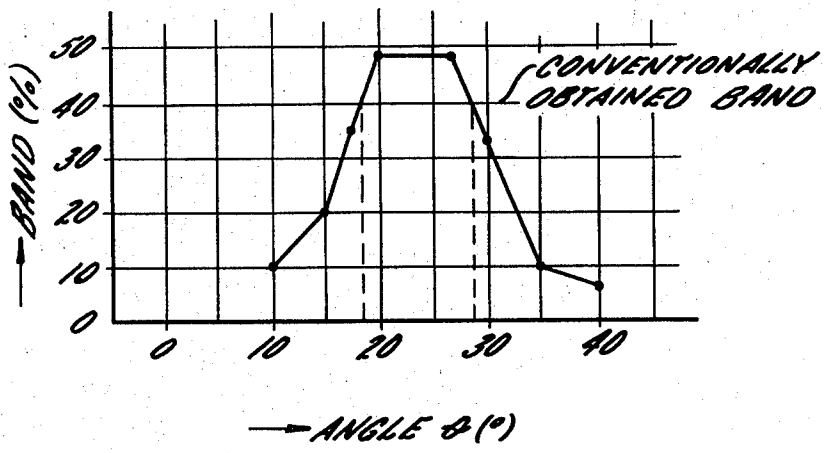


Fig. 5.



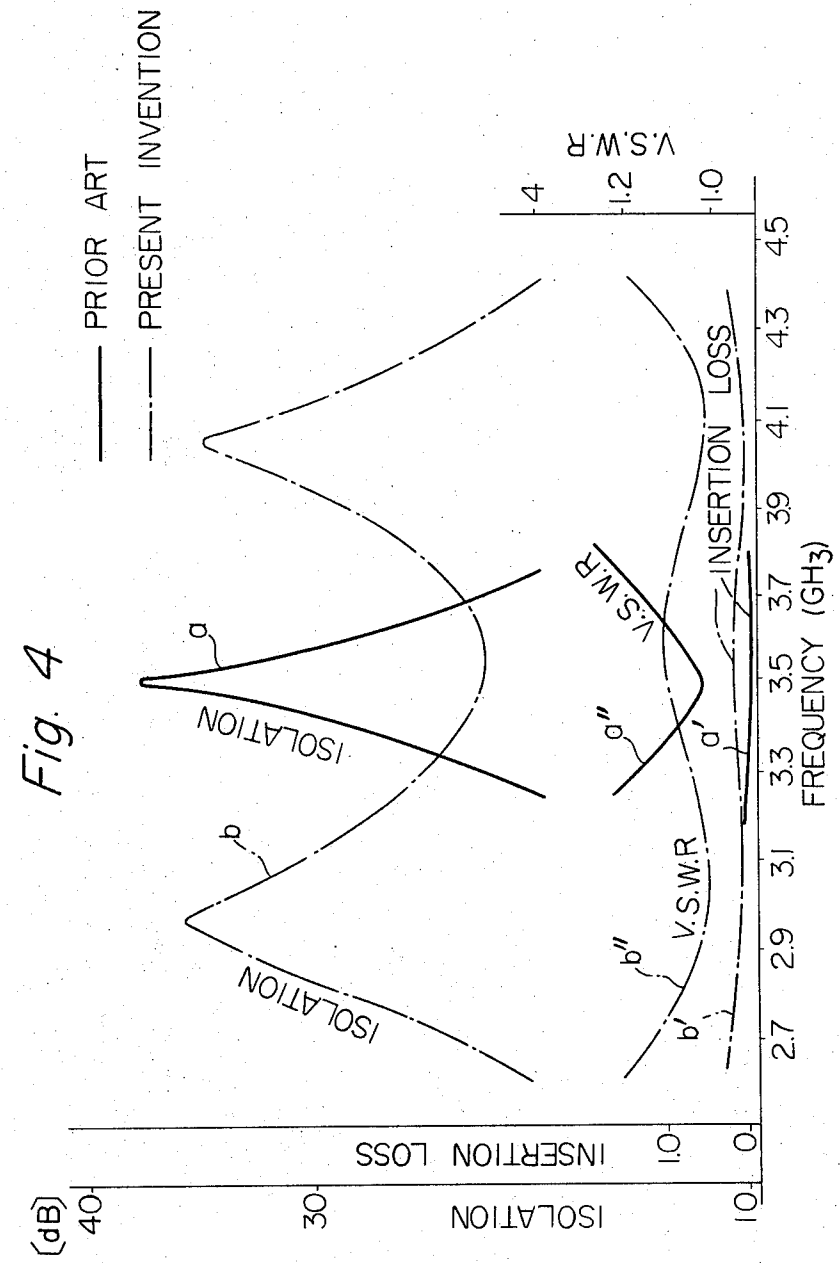


Fig. 4

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WIDE-BAND CIRCULATOR

The present application is a continuation-in-part of Nishiyama application Ser. No. 17,528, filed Mar. 9, 1970, for Wide-Band Circulator, which is now abandoned.

Wide-band circulators are commonly used in microwave circuits for, as an example, VHF and UHF operation. Though various types of circulators are available, such as wave guide circulators, coaxial circulators, lumped element circulators, and the like, it is highly desirable that all circulators be operable over a wide frequency bandwidth at optimum operating characteristics. Among the operating characteristics which determine the optimum operation of a circulator are the insertion loss, the isolation, and the voltage standing wave ratio (V.S.W.R.).

It is an important object of this invention to provide an improved wide-band circulator with a Y-shaped stripline having optimum operating characteristics over a large frequency bandwidth.

A further object of the present invention is to provide a wide-band circulator which is operative over a large frequency bandwidth with particularly improved forward and backard losses.

Other objects of the invention will become apparent upon reading the attached detailed description and upon reference to the drawings in which:

FIG. 1 is a wide-band circulator in a fragmented section employing the present invention;

FIG. 2 is a prior art center conductor for use in a conventional circulator;

FIG. 3 is a Y-shaped stripline, constructed according to the present invention for use as a center conductor in a wide-band circulator;

FIG. 4 is a graphic comparison of the operating characteristics of a conventional prior art circulator and of a wide-band circulator constructed according to the present invention; and

FIG. 5 is a graph showing the variation in the operative frequency bandwidth of a wide-band circulator constructed according to the present invention with variation in the shape of the Y-shaped stripline.

While the invention has been described in connection with certain preferred embodiments, it will be understood that I do not intend to be limited to the particular embodiments shown but intend, on the contrary, to cover the various alternative and equivalent constructions included within the spirit and scope of the appended claims.

Turning now to the construction shown in FIG. 1, the wide-band circulator includes two outer conductor plates 1 between which are sandwiched ferrite plates 2. A center conductor 3 is mounted between the ferrite plates in a conventional manner. Exterior to the circulator are magnets 10a and 10b which are effective to bias the circulator with a D.C. magnetic field.

An example of a typical prior art center conductor 3 is illustrated in FIG. 2. In order to regulate the ratio between forward and backward losses, or insertion loss and isolation, the length L of the wings 4 and the width W of the arms 5 on the prior art center conductor are varied to obtain a desired ratio.

The operating characteristics of circulators using such prior art center conductors are illustrated in FIG. 4 by the solid-line curves a, a', and a''. An inspection of these three curves shows that the "isolation" curve is above 20 db, the "V.S.W.R." curve is below 1.2 and the "insertion loss" curve is below 0.3 db, which are accepted limits on the optimum operating characteristics of a circulator, for a bandwidth which is only approximately 2 percent of the center frequency f_o. Outside of this small bandwidth the operating characteristics of the prior art circulator of FIG. 2 are outside the limits of optimum operation. There are other prior art circulators which are operable within these desirable limits of the operating characteristics, but the maximum bandwidths for such optimum operation by these circulators do not exceed 40 percent of their center frequencies.

Referring now to FIG. 3, there is illustrated a center conductor 3 constructed in accordance with the teachings of the present invention to provide a circulator which is operable within the above-noted operating characteristic limits over a bandwidth which significantly exceeds 40 percent of its center frequency. This center conductor or Y-shaped stripline 3 comprises a plate, preferably a copper plate, which has a generally circular-shaped center section 6 and three generally sector-shaped arms 7, 8 and 9 which extend radially from and are located symmetrically about the periphery of the circular center section. One of the ferrite disks 2 is shown positioned below the Y-shaped stripline as it would be in the wideband circulator. To operatively connect the stropline, and thus the circulator, to lead wires to the transmission medium, connectors X_1, X_2 and X_3 are mounted respectively on the extremities of arms 7, 8 and 9.

This particular structure of the Y-shaped stripline results in improved operation of the circulator over a much wider bandwidth than is presently attainable in prior art circulators using conventional center conducturs. An important feature of the invention resides in the angle transcribed by the sector-shaped arms of the stripline; through large variations in the angle θ, which is one-half the angle transcribed by a sector-shaped arm, the circulator will operate within the limits of optimum operation and, in particular, will operate with isolation above 20 db. Further it has been found that by setting θ equal to 25° optimum operation is obtained.

Using a center conductor constructed according to the present invention having a circular center section with a diameter a= 5 mm and sector-shaped arms each with an angle θ= 25° and a length L'= 14mm and having a center frequency f_o= 3.5 GHZ, the curves b, b', and b'' in FIG. 4 were derived indicating respectively the variation of "isolation," "insertion loss," and "V.S.W.R." as the operating frequency varied. It can be seen from these curves that the circulator functions within the limits of optimum operation over a bandwidth of approximately 1.7 GHZ which is almost 50 percent of the center frequency. Referring to FIG. 5, the variation in the bandwidth within which the circulator constructed in accordance with the invention functions within the limits of optimum operation as a function of θ, one-half the angle transcribed by each sector-shaped arm of the stripline, is shown with the bandwidth represented by its percentage of the center frequency. It is easily appreciated that for $17.5° \leq \theta \leq 27.5°$ the present circulator operates within a bandwidth that exceeds 40 percent of the center frequency which is the highest percentage attainable in known prior art circulators.

Thus, in accordance with the invention there has been provided a wide-band circulator that is operative within generally accepted limits of optimum operation within a bandwidth that approaches 50 percent of the center frequency of the circulator.

I claim as my invention:

1. In a wide-band circulator adapted to be biased by a magnetic field, the combination comprising

two outer conductor plates;

two ferrite plates sandwiched between said outer conductor plates; and

an inner conductor plate held between said ferrite plates, said inner conductor plate having a generally circular-shaped center section and a plurality of symmetrically spaced, sector-shaped arms extending radially from said center section.

2. In a wide-band circulator adapted to be biased by a magnetic field, the combination as defined in claim **1** wherein

each of said sector-shaped arms subtends an angle 2θ where θ is within a range of approximately 17.5° to approximately 27.5°.

3. In a wide-band circulator adapted to be biased by a magnetic field, the combination as defined in claim **2** wherein θ equals 25°.

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