

[54] **WIDEBAND MICROWAVE POWER DIVIDER**

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[58] Field of Search **333/10, 9, 11, 84, 84 M, 21 R**

[56] **References Cited**

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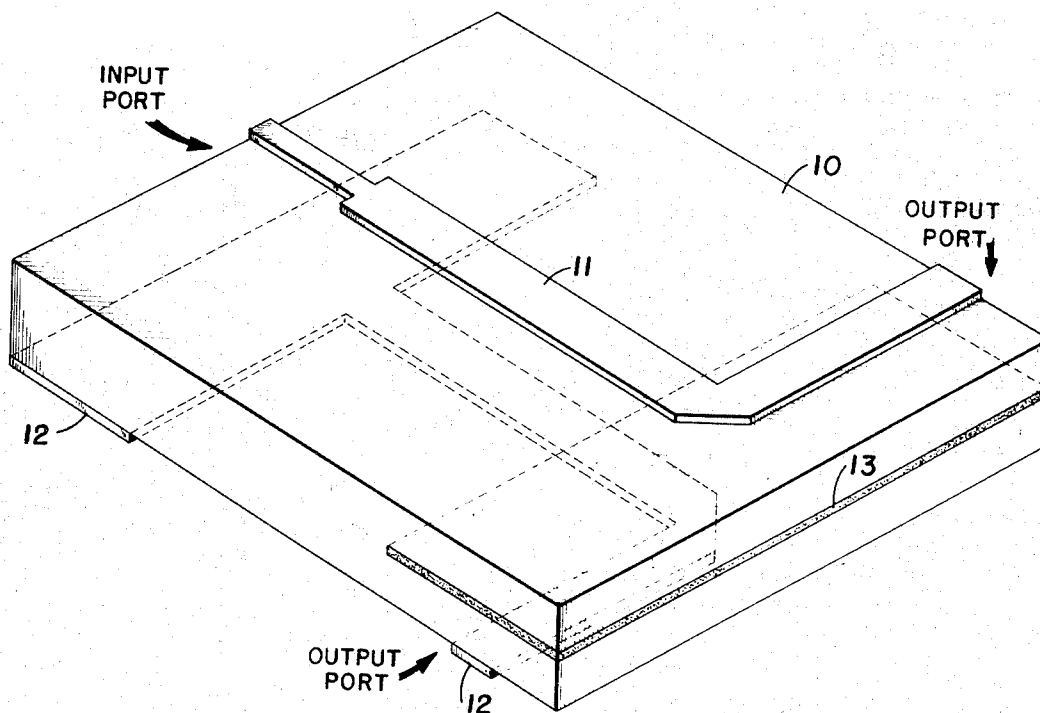
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[57] **ABSTRACT**

A microwave structure comprising a parallel transmission line that is bisected by a conducting septum to form two independent microstrip circuits that are in anti-phase; i.e., the conducting septum becomes a common ground plane for a pair of equal amplitude microstrip circuits that are in anti-phase relative to the common ground at points equidistant from the point of bisection of the parallel transmission line. In one embodiment, the proposed microwave structure is utilized as a power divider with input power being supplied to a conventional microstrip circuit formed of a pair of spaced parallel conductor strip members which also form the parallel transmission line and the anti-phase microstrip circuits, and whose widths are varied to form a reflectionless transition from the input microstrip circuit to the parallel transmission line and subsequently to the pair of output microstrip circuits, each of which receives half of the input power supplied to the device.

8 Claims, 2 Drawing Figures



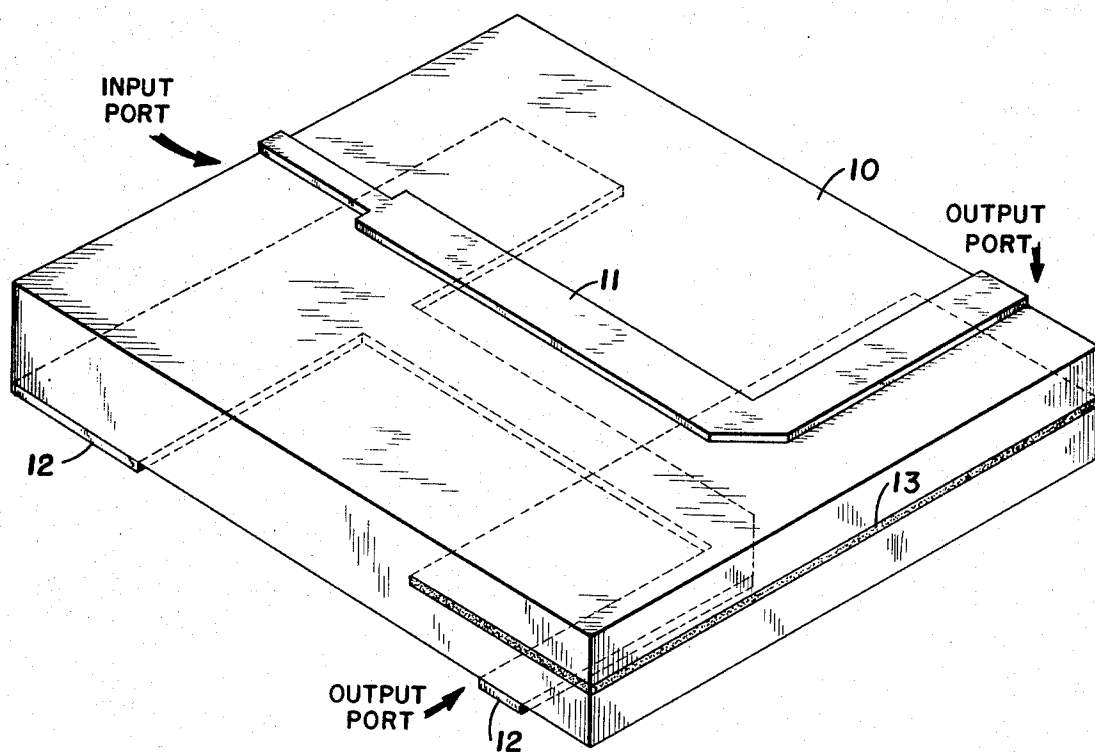


FIG. 1

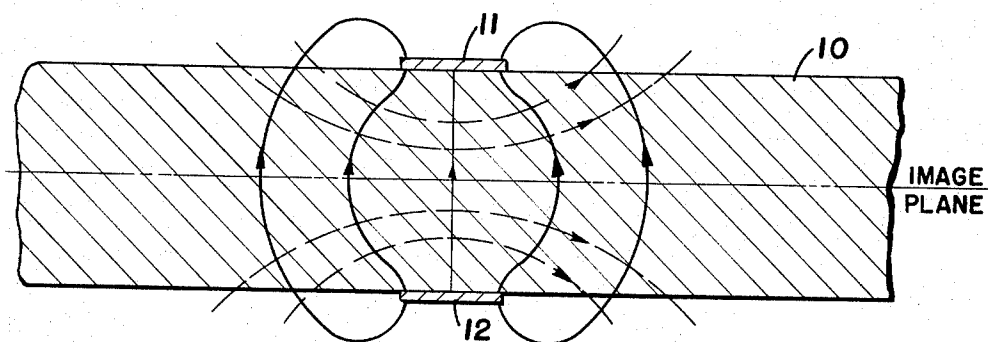


FIG. 2

WIDEBAND MICROWAVE POWER DIVIDER

BACKGROUND OF THE INVENTION

In recent years, the relatively bulky and cumbersome hollow waveguide and circular coaxial transmission line have been replaced by so-called planar transmission line structures, one class of which is the so-called microstrip circuit wherein electromagnetic waves propagate along a narrow flat strip conductor element dielectrically separated from a wider conductive element or ground plane. In certain applications of these so-called microstrip circuits or transmission lines; e.g., for use in microwave mixers or antenna difference channels, it is often desirable to employ a power divider structure wherein the input power is divided equally between two output ports in equal amplitude but with voltages that are 180° out-of-phase. In the past, in order to accomplish this with the so-called microstrip transmission line, it was necessary to utilize half wavelength line lengths to achieve the 180° out-of-phase outputs. Unfortunately, such a device is frequency dependent in that the anti-phase relationship is attained only at a very select frequency; i.e., the prior art microstrip power divider was very narrow banded.

DESCRIPTION OF THE INVENTION

In accordance with the present invention, it is proposed to provide a microwave structure suitable for use as a power divider which is independent of half or quarter wavelengths lines and therefore inherently wideband in operation. Moreover, the proposed device provides naturally or inherently for reflectionless transmission over the entire operating bandwidth where the output characteristic impedance for each output is equal to one-half the input characteristic impedance of the device, and the device can also be designed so that it is impedance matched to a common impedance value (e.g. 50 ohms) at all ports. The proposed device is also amenable to miniaturization for microwave integrated circuit applications.

Basically, the proposed microwave structure of the present invention comprises a transmission line of parallel and equal width strips that is bisected by a thin septum of electrically conductive material to form two independent microstrip circuits that are in anti-phase. More particularly, it is well-known to those skilled in the art that the electric and magnetic fields of a parallel transmission line conductor pair of equal width mounted one above the other on an intervening dielectric substrate are mirror images about a plane midway between the lines.

In accordance with the present invention, it is proposed that a conducting septum be inserted along a plane midway between the parallel transmission line conductors without disturbing the magnetic or electric field configurations. As a result, the power contained above the image plane (conducting septum) is equal to the power below the image plane, and relative to the image plane or conducting septum the electric fields above and below this plane are in anti-phase. Because the field configurations are not altered by the presence of the conducting septum, the parallel transmission line appears continuous. On the other hand, once the conducting septum is inserted, as proposed in accordance with the present invention, the upper and lower conductors are no longer required to lie one directly above

the other as is the case with the parallel transmission line; i.e., the conductors can be taken in separate directions in their respective plane and the field configurations above the image plane (septum) will be preserved relative to the upper conductor and the field configurations below the image plane (septum) will be preserved with regard to the lower conductor.

As will be described in more detail hereinafter, the field configurations associated with the upper and lower conductor elements are those of a microstrip line, and relative to the conducting septum the voltages of the upper and lower conductors are in anti-phase at points equidistant from the point of insertion of conducting septum. Moreover, the power propagated by upper conductor above the conducting septum is equal to the power propagated by the lower conductor below conducting septum. The conducting septum, therefore, becomes common ground plane for a pair of equal amplitude microstrip circuits that are in anti-phase relative to the common ground plane.

In view of the foregoing, one object of the present invention is to provide a microwave structure for converting a parallel transmission line into a pair of anti-phase microstrip circuits.

Another object of the present invention is to provide a microwave structure capable of being utilized to perform broadband, equal power division of input microwave power.

Another object of the present invention is to provide a microwave structure having application as a reflectionless power divider whose outputs are in anti-phase relative to a common ground conductor and which is inherently broadband, compact, of very simple construction, and amenable to microminiaturization.

Other objects, purposes and characteristic features of the present invention will in part be pointed out as the description of the present invention progresses and in part be obvious from the accompanying drawings, wherein:

FIG. 1 is an isometric view of a power divider structure constituting one embodiment of the present invention; and

FIG. 2 is an enlarged partial cross-sectional view of the central parallel transmission line portion of the power divider structure of FIG. 1.

In the power divider embodiment shown in FIG. 1 of the drawings, a suitable dielectric member formed of alumina ($\epsilon_r \approx 9$) or like material and designated at 10 supports a pair of electrical conductor members 11 and 12 formed of flat copper strips, for example. These conductor strips 11 and 12 have substantially L-shaped configurations at the respective right-hand ends thereof, as viewed in FIG. 1. Also carried in the dielectric 10, midway between the spaced-apart conductor strip members 11 and 12, is a suitable thin sheet or septum 13 formed of suitable electrically conductive material such as, for example, 0.003 inch aluminum foil.

The left-hand end of the upper conductor strip 11 is slightly narrower than the midportion of this member and, together with the enlarged left-hand end portion of the lower conductor strip member 12 forms an input microstrip circuit for the power divider structure of FIG. 1. By way of example, in one practical embodiment of the proposed power divider structure (utilizing

0.050 inch alumina as the dielectric block 10) for a 50 ohm transmission line, the width of the left-hand end portion of the upper conductor strip 11 was 0.050 inch; whereas, the enlarged end portion of the lower conductor strip 12 (which ideally would be infinitely wide) was found to function successfully with a 2 inch width.

On the other hand, the midportions of the upper and lower conductor strips 11 and 12 are the same width and form a parallel transmission line pair. By way of example, a strip width of 0.080 inch was found to be acceptable for this midportion of the strips 11 and 12, during fabrication of the practical 50 ohm line embodiment mentioned above. The right-hand or output microstrip end portions of both the upper and lower conductor strips also have a width equal to that of the center portions of the conductor strips 11 and 12. It should be noted here that the variation in width between the left-hand end and center portion of the upper conductor strip 11 is for the purpose of attaining a constant characteristic impedance transition when proceeding from the left-hand or microstrip input end of the structure into the central or parallel transmission line portion. On the other hand, by making the right-hand or output ends of conductors 11 and 12 of a width equal to the central portions, the characteristic impedance of each of the output microstrip circuits is one-half that of the parallel transmission line, in order to also achieve reflectionless transmission therebetween.

Referring now to the cross-sectional view of FIG. 2 taken, as mentioned previously, at the parallel transmission line portion of the illustrated device, the electric and magnetic fields of such a parallel transmission line with an intervening dielectric substrate are mirror images about a plane midway between the line conductors 11 and 12, as shown. In FIG. 2 the electric field lines are shown in solid line form and the magnetic field lines are shown as dashed lines. Relative to the designated image plane which is midway between conductors 11 and 12, the electric fields above and below the image plane are in anti-phase and the microwave power contained above the illustrated image plane is equal to the power below the image plane. Accordingly, the conducting septum 13 can be inserted along this image plane, as shown in FIG. 1, without disturbing the field configurations and therefore the parallel line appears continuous. Once the septum 13 is inserted, however, the upper and lower conductor strips 11 and 12 are no longer required to lie one directly above the other, as in the parallel transmission line portion. Thus, the extending right-hand ends of the conductors 11 and 12 can now be taken in separate directions in their respective planes; e.g., taken perpendicular to the direction of the parallel transmission line portions as shown in FIG. 1, and the field configurations above the image plane (septum 13) will still be preserved with regard to the upper conductor strip 11 and the field configurations below the image plane (septum 13) will be preserved with regard to the lower conductor strip 12. As a result, the voltages of the upper and lower conductors 11 and 12 relative to the conducting septum 13 are in anti-phase at points equidistant from the plane of insertion of the conducting septum 13. The septum 13 thus becomes a common ground plane for a pair of equal amplitude microstrip

circuits that are in anti-phase relative to the common ground at points equidistant from the plane of bisection of the parallel transmission line pair.

As shown in the power divider embodiment of FIG. 1, input microwave power to the divider structure is applied to a microstrip circuit formed by the left-hand ends of the upper and lower conductor strip members 11 and 12. In particular, the enlarged left-hand end of the lower conductor strip 12 functions as the ground plane for the input microstrip circuit and the width of the upper conductor strip 11 determines the characteristic impedance of this input microstrip circuit. On the other hand and as mentioned hereinabove, the widths of the parallel line conductors; e.g., the midportions of the conductor strips 11 and 12, are equal to one another and to the width of the output microstrip conductors but different from that of the input microstrip in order to achieve reflectionless transmission throughout the structure. Moreover, the fact that the field configurations are not disturbed by the presence of the conducting septum 13 also facilitates the reflectionless transmission of power section to the parallel line section to the two output microstrip circuits. The resulting three dimensional microstrip circuit is thus a reflectionless power divider whose outputs are in anti-phase relative to the common ground plane 13; it is inherently broadband, compact, very simply constructed and amenable to microminiaturization; and, requires only that the two output microstrip arm segments be of equal length. The characteristic impedance of each of these two output microstrip circuits is equal to one-half that of the central of parallel transmission line portion of the device. It should be understood at this time that the illustrated microstrip input to the transmission line pair of the proposed structure is only one manner of applying input microwave energy to the transmission line pair. By way of example, this input microstrip circuit might be replaced by a coaxial-to-parallel transmission line pair transition structure, etc.

Suitable coaxial-to-microstrip transitions on either side of the substrate 10 can provide a pair of coaxial outputs from the proposed device which are in anti-phase relative to their outer conductors, or imaginative transitions could be used for a pair of anti-phase planar microstrip or strip line outputs. If the input port and the two output ports of the proposed power divider are to have the same impedance, tapers or quarter-wavelength impedance matching transformers can, if desired, be incorporated into the divider. Tapers would be the better choice here since they tend to have ultra broad-band characteristics above a cutoff frequency determined by the length of the taper. Moreover, the taper could be designed into each microstrip arm or the whole divider could be formed as one continuous taper.

Various other modifications, adaptations and alterations are of course possible in light of the above teachings. It should therefore be understood at this time that within the scope of the appended claims the invention may be practiced otherwise than as specifically described hereinabove.

What is claimed is:

1. A microwave structure comprising,
 - a parallel line transmission line formed of a pair of electrically conductive line members separated by a dielectric material and disposed in spaced parallel planes, and

a septum member formed of electrically conductive material disposed in a plane bisecting the distance between the spaced parallel planes of said pair of transmission line members and cooperating with equal lengths of each of said transmission members for converting said parallel line transmission line to a pair of equal amplitude, anti-phase microstrip circuits.

2. The microwave structure specified in claim 1 wherein said parallel line members are in the form of a pair substantially thin flat strip members having portions disposed one above the other and extending in the same direction to form the line members of a parallel line transmission line.

3. The microwave structure specified in claim 2 wherein said pair of strip members include respective second portions which are of equal length and which extend in different directions relative to one another and relative to said same direction and cooperate with said septum member to form a pair of microstrip circuits with spaced apart output ports.

4. The microwave structure specified in claim 3 wherein said second portion of each of said strip members extend in opposite directions perpendicular to said

same direction.

5. The microwave structure specified in claim 1 further including a pair of spaced elements separated from one another by said dielectric material and forming a microstrip input operably connected to said parallel line transmission line elements.

6. The microwave structure specified in claim 3 wherein said electrically conductive strip members have third portions configured to form an input microstrip circuit operably connected adjacent those portions of said strip members forming said parallel line transmission line.

7. The microwave structure specified in claim 6 wherein said third portions include a portion of each of said strip members forming respectively a conductor and ground plane element for said microstrip input circuit.

8. The microwave structure specified in claim 7 wherein the respective widths of said electrically conductive strip members is varied to maintain a constant characteristic impedance between the input to said input microstrip circuit and the output ports formed by said strip members and said conductive septum.

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