ORIGINAL

INTEGRATED CIRCULATORS SHARING A CONTINUOUS CIRCUIT

ABSTRACT

[00100] The present invention is directed to a circuit assembly that includes an integrated circulator assembly. The circuit assembly has a first substrate, which contains a continuous circuit trace that includes a circulator component from the circulator assembly and at least one electrical component from the circuit assembly. A second substrate is disposed beneath the first substrate and includes a cladding on one surface. The second substrate contains an aperture that accepts a ferrite element, which is axially aligned with the circulator component of the circuit trace. A conductive material is placed across the ferrite element so that it forms a continuous ground plane with the cladding, which is common to the entire circuit trace. The circulator assembly also contains a magnet bonded to the ferrite element. The circulator assembly may also include a yoke disposed below the magnet to shield the circulator from external magnetic fields.

CLAIMS

We claim:

1. A device comprising:

a first substrate; and

a continuous circuit trace printed on the first substrate, the continuous circuit trace comprising a first circulator pattern and a first external component;

wherein the circulator pattern comprises a central conductor element and three or more connection ports.

2. The device of Claim 1, wherein the circulator pattern further comprises a discontinuous ring disposed around the central conductor element to improve circulator loading.

3. The device of Claim 1, wherein the central conductor element comprises one or more slots, one or more tabs, or both to improve circulator loading.

4. The device of Claim 1, wherein the first external component comprises an RF electronic component.

5. The device of Claim 4, wherein the RF electronic component comprises one of a second circulator pattern, a filter, an antenna, a power divider, and a power combiner.

6. The device of Claim 1, wherein the thickness of the first substrate is between approximately .001 and .010 inches.

7. The device of Claim 1, further comprising a second external component in a continuous circuit trace with the first circulator pattern and the first external component.

8. The device of Claim 1, further comprising:

a second substrate disposed beneath the first substrate, comprising:

a cladding on a first side;

an aperture; and

a ferrite element inserted into the aperture and proximately aligned with the central conductor element;

a conductive material disposed over the ferrite element and in electrical contact with the cladding to form a continuous ground plane; and

a first magnet disposed below the ferrite element.

9. A device comprising:

a first substrate;

a first continuous circuit trace printed on the first side of the first substrate, the first continuous circuit trace comprising a first circulator pattern and a first external component;

a second continuous circuit trace printed on the second side of the first substrate, the second continuous circuit trace comprising at least a second circulator pattern;

wherein the first and second circulators each comprise a central conductor element and three or more connection ports.

10. The device of claim 9, wherein the first circulator and the second circulator are connected with conductive vias in the first substrate.

11. The device of Claim 9, wherein the thickness of the first substrate is between approximately .001 and .010 inches.

12. The device of Claim 9, wherein the second continuous circuit trace printed on the second side of the first substrate comprises the second circulator pattern and a second external component.

13. The device of claim 9, further comprising:

a second substrate disposed beneath the first substrate, comprising:

a cladding on a first side;

a first aperture; and

a first ferrite element inserted into the first aperture and proximately aligned with the central conductor elements;

a conductive material disposed over the first ferrite element and in electrical contact with the cladding on the first side of the second substrate to form a continuous ground plane; and

a first magnet disposed below the first ferrite element.

14. The device of Claim 13, wherein the thickness of the second substrate is between approximately .01 and .07 inches.

15. The device of Claim 13, wherein the conductive material comprises a conductive thin film adhesive.

16. The device of Claim 13, further comprising:

a third substrate disposed above the first substrate, comprising:

a cladding on a first side;

a second aperture; and

a second ferrite element inserted into the second aperture and proximately aligned with the central conductor elements;

a conductive material disposed over the second ferrite element and in electrical contact with the cladding on the first side of the third substrate to form a continuous ground plane; and

a second magnet disposed above the second ferrite element.

17. A method for creating an integrated circuit comprising:

providing a first substrate;

printing a continuous circuit on the first side of the first substrate comprising a first circulator pattern and a first external component.

18. The method of Claim 17, further comprising:

providing a second substrate comprising a metalized layer on at least one side;

creating a first aperture in the second substrate sized and shaped to accept a first ferrite disk;

inserting the first ferrite disk into the aperture;

placing a conductive material over the first ferrite disk such that the conductive material is in electrical contact with the first ferrite disk and the metalized layer on the second substrate to form a continuous ground plane;

placing a first magnet below the first ferrite disk; and

bonding the second substrate to the bottom of the first substrate.

19. The method of Claim 18, further comprising:

providing a third substrate comprising a metalized layer on at least one side;

creating a second aperture in the third substrate sized and shaped to accept a second ferrite disk;

inserting the second ferrite disk into the aperture;

placing a conductive material over the ferrite disk such that the conductive material is in electrical contact with the first ferrite disk and the metalized layer on the third substrate to form a continuous ground plane;

placing a second magnet above the second ferrite disk; and

bonding the third substrate to the top of the first substrate.

20. The method of Claim 17, further comprising printing a second continuous circuit trace on a second side of the first substrate comprising at least a second circulator.

Dated this 10/02/2012

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REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. Patent Application No. 11/314,160 of the same title filed 19 December 2005, which claims priority to U.S. Provisional Patent Application Serial No. 60/636,945, filed on December 17, 2004. Both Applications are incorporated herein by reference as if fully set forth below.

BACKGROUND

1. Field of the Invention

[0002] Embodiments of the present invention relate to a device, system, and method for providing continuous circuit traces, and specifically to a device, system, and method for providing continuous circuit traces comprising circulators and other electronic components in a continuous circuit trace, obviating the need for manual interconnects and impedance matching.

2. Description of the Related Art

[0003] The use of circulators to isolate and transmit electronic signals is well known. Circulators are multi-port devices, which receive a radio frequency (RF) signals on one port and route them to an adjacent port while isolating or decoupling the RF signal from the remaining ports. Currently, circulators are used for applications that operate at very high frequencies. For example, circulators are commonly used in microwave circuits and microwave transmit and receive (T/R) modules for both RADAR and communications systems. Conventional circulator designs may include a y-shaped RF conductor with three port connectors that are positioned between a pair of ferrite substrates. Magnets are placed above and below the ferrite substrates to produce a DC-biasing magnetic field in the ferrite elements to provide non-reciprocal operation of the transmission paths between the three port connectors. A thin metal plate, or cladding, is placed on the outer surface of each ferrite substrate below each magnet to provide ground planes for the circulator and provide shielding from spurious RF radiation. The components are then placed within a steel case or housing to hold provided a return path for the magnetic fields generated by the magnets, while at the same time shielding the components from extraneous magnetic fields.

[0004] Although circulators are extremely efficient devices, conventional circulators have several drawbacks. First, installation of conventional circulators on a circuit board requires that an aperture, which is slightly larger than the circulator package is cut into the circuit board where the circulator is to be installed. The circulator is then placed within the aperture and the port connectors are attached to the external circuit trace on the circuit board using manual interconnection, such as solder, ribbon cables, and the like.

[0005] As shown in FIG. 1A, from U.S. Patent No. 4,761,621 to Kane ("*Kane*"), printed circuit circulators are known in the art. Conventionally, however, even those circulators manufactured as printed circuit components have nonetheless been connected to other external electronic components (e.g., resistors, filters, additional circulators) using traditional methods. In other words, the external components are surface mounted or through hole mounted and then soldered to the printed circuit board ("PCB"). As a result, since the port leads **313, 401, 403** of the circulator are normally made from different materials and have different impendence values from the external components **407, 409, 413**, and because these components **407, 409, 413** are soldered to the board, there is an impedance mismatch at the interconnects, which results in a degradation of the electrical performance of the circulator.

[0006] The impedance mismatch must be corrected using ribbon connectors, or other known methods to match the impedance the port connectors with the circuit trace. As shown in Fig. 1B, from U.S. Patent No. 3,334,317 to Andre ("*Andre*"), attempts to correct this impedance mismatch include using multiple stepped impedance matching sections **10b, 10c** to perform a conventional impedance transformation. This adds complexity to the manufacturing process and requires tuning based on the operational frequency range of the circulator. In other words, two resonators operating at two different frequencies require impedance matching sections **10b, 10c** that are different sizes (i.e., widths) based on their frequency.

[0007] Additionally, discontinuities between the circulator and the circuit trace exist at the connection ports. The manual interconnects also lead to insertion losses at the port connectors, an increase in the interference from unwanted RF signals, and high performance variability of