

RADIO FREQUENCY (RF) ENERGY TRANSMISSION LINE TRANSITION STRUCTURE

TECHNICAL FIELD

5 This disclosure relates generally to radio frequency (RF) energy transmission line structures and more particularly to RF energy transmission line structures having a transition for coupling RF energy between a pair of RF transmission lines disposed in different elevations.

BACKGROUND OF THE INVENTION

10 As is known in the art, RF transitions are used to connect one RF transmission line to another RF transmission line. One technique uses wire bonding wires. The length of the wire bonds however adds inductance which may adversely affect the performance of the transition. As is also known in the art there is a trend to use additive manufacturing techniques (3D printing) to facilitate in the formation of RF transmission line structures.

SUMMARY OF THE INVENTION

15 In accordance with the present disclosure, a radio frequency (RF) energy transmission line transition is provided for coupling RF energy between a pair of RF transmission lines disposed at different elevations. The transition is coupled between the pair of transmission lines and includes a pair of RF transmission line sections disposed on intersecting surfaces of a corresponding one of a pair of conductive members, a first one
20 of the pair of conductive members having a wall with a jog therein for receiving an end portion of a second one of the pair of conductive members, the end portion of an electrically conductive strip of the first one of the pair of radio frequency transmission line sections being disposed on, and electrically connected to, an electrically conductive strip of a second one of the pair of radio frequency transmission line sections.

25 In one embodiment the jog has orthogonal walls.

In one embodiment, the transition comprises: (a) A first one of the pair of radio frequency transmission line sections disposed on a first one of the pair of surfaces, comprising: a first electrically conductive member; a first dielectric disposed on the first electrically conductive member; and a first electrically conductive strip disposed on the
30 first dielectric; (b) A second one of the pair of radio frequency transmission line sections disposed on a second one of the pair of surfaces, comprising: a second electrically conductive member having a first surface portion disposed on the first one of the pair of

surfaces and a second surface portion disposed on a second one of the pair surfaces; a second dielectric disposed on the first surface portion and the second surface portion of the second electrically conductive member; a second electrically conductive strip having an end portion disposed on both: the first surface portion of the second dielectric and on the second surface portion of the second dielectric; and (c) wherein the end portion of the second electrically conductive strip disposed on the first surface of the second dielectric is disposed on and electrically connected to the first electrically conductive strip conductor.

In one embodiment, the second electrically conductive member comprises a block of conductive material, such block having a wall with a jog herein for receiving a front portion of the second one of the pair of radio frequency transmission line sections, a wall of the jog having the end portion of the second electrically conductive strip disposed on the first surface of the second dielectric is disposed on and electrically connected to the first electrically conductive strip conductor.

In one embodiment, a radio frequency transmission line transition is provided, comprising: (a) A first radio frequency transmission line section, comprising: a first electrically conductive member having a horizontal surface; a first dielectric disposed on the horizontal surface; and a first electrically conductive strip disposed on the horizontal surface of the dielectric; (b) A second radio frequency transmission line section, comprising: a second electrically conductive member having a vertical surface portion and a horizontal surface portion; a second dielectric disposed on the vertical surface portion and the horizontal surface portion of the second electrically conductive member; a second electrically conductive strip disposed on the vertical surface portion of and the horizontal portion of the second dielectric; and (c) a transition region wherein the end portion of the second electrically conductive strip disposed on the horizontal surface of the second dielectric is electrically connected to the first electrically conductive strip conductor.

The details of one or more embodiments of the disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a radio frequency transmission transition, bonded to a heat sink, for coupling an upper microwave transmission line section to a lower microwave transmission line section according to the disclosure;

5 FIG. 1A is a perspective view of an enlarged portion of the transition of FIG. 1, such enlarged portion being encircled by the arrow 1A-1A in FIG. 1;

FIG. 2 is a cross-section view of the transition of FIG. 1 according to the disclosure;

10 FIG. 2A is a cross section of an enlarged portion of the transition of FIG. 2, such enlarged portion being encircled by the arrow 2A-2A in FIG. 2;

FIG. 3 is an exploded, perspective view of a radio frequency transmission transition, of FIG. 1 according to the disclosure;

FIG. 4A is cross sectional view of the transition of FIG. 1, such cross section being taken along line 4A-4A of FIG. 1;

15 FIG. 4B is cross sectional view of the transition of FIG. 1, such cross section being taken along line 4B-4B of FIG. 1;

FIGS. 5A, 5B and 5C, show sequential steps used to process a block used in the transition of FIG. 1 according to the disclosure; and

20 FIGS. 6A, 6B and 6C, show sequential steps used to process another block used in the transition of FIG. 1 according to the disclosure.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

Referring now to FIGS. 1, 1A, 2, 2A, 3, a radio frequency transmission transition 10 is shown disposed on and bonded to an electrically conductive, baseplate or mounting medium, here for example a heat sink 11. The transition 10 couples an first, upper microwave transmission line section 14, here for example a microstrip transmission line, disposed in the X-Y (horizontal) plane at one elevation along a Z-axis to a second, lower microwave transmission line section 16, here for example a microstrip transmission line, disposed in the X-Y (horizontal) plane at different, here lower elevation along the Z-axis through a transition region, or section 18.

More particularly, the radio frequency transmission transition 10 includes a pair of electrically conductive blocks 13 and 15, which may also be thermally conductive. Block

13 has a vertical wall 17 with a jog 19 therein to receive a forward end of block 15, as shown. More particularly, the second radio frequency transmission line section 16, here for example, is a microstrip transmission line having: a first, horizontal, electrically conductive member, here the block 15, serving as a ground plane conductor for the second microstrip transmission line section 16, and having a horizontal surface 21 (disposed in the X-Y plane); a first dielectric 20, here a dielectric stripe, disposed on the horizontal surface 21 of block 15; and a first electrically conductive strip 22 disposed on a horizontal surface of the first dielectric 20, the first electrically conductive strip 22 serving as a signal conductor microstrip transmission line section 16.

It is noted that the transition section 18 (FIGS. 1, 1A, 2 and 2A) includes: the forward end 15F (FIG. 3) of block 15 disposed in jog 19 which is an extension of a ground plane conductor of the lower microstrip transmission line 16, the forward portion of dielectric 20 disposed in jog 19 which is an extension of a dielectric of the lower microstrip transmission line 16; and the forward portion of the electrically conductive strip conductor 22 which is an extension of the signal strip conductor of the lower microstrip transmission line, 16, as shown more clearly in FIGS. 2, 2A and 3).

The transition 10 includes a reverse facing (in FIG. 2) L-shaped, second radio frequency transmission line section 24, here for example, a microstrip transmission line having: a second electrically conductive member 26, here block 13, shown more clearly in FIGS. 2 and 2A), serving as a ground plane for the microstrip transmission line section 24, as well as serving as a ground plane conductor for the upper microstrip transmission line 14, having a vertical surface portion 26V (disposed in the X-Z plane), and a horizontal surface portion 26H disposed in the X-Y plane; a second dielectric 30, here a dielectric stripe, disposed on the vertical surface portion 26V and the horizontal surface portion 26H of the second electrically conductive member 26; and a second electrically conductive strip 32 disposed on a vertical surface portion 30V and the horizontal portion 30H of the second dielectric 30; serving as a signal conductor microstrip transmission line section 24. It is noted, as shown more clearly in FIGS. 1A and 2A, the transition 10 couples RF energy between the pair of RF transmission line sections 16, 24, such transmission line sections 16, 24 being disposed in intersecting planes, here for example, orthogonal planes. Thus the transition 10 is here a 90 degree transition.

The transition section or region 18, shown more clearly in FIGS. 1A and 2A, includes the end portion 24F of the reverse facing (in FIG. 2) L-shaped, second radio

frequency transmission line section 24 and the forward end 15F (FIG. 3) of block 15. The bottom portion of the horizontal portion 32H of strip conductor 32 is disposed on, and electrically connected to, the end portion 22F of the strip conductor 22 with here an electrically conductive bonding material 40 (FIG. 3), or a conductive ink when using additive manufacturing (3D printing) to fabricate the transition 10, as shown more clearly in FIGS. 1A, 3, 3A, 3B, 4A and 4B. It is also noted that a dielectrics attachment material 42 is also deposited on, or 3D printed on the dielectric 20, as shown more clearly in FIGS. 3, 4A and 4B. It is noted that the ends of the horizontal portion 32H of the strip conductor 32 and the front portion 22F of strip conductor 22 are spaced from the rear wall 15B of the block 15 and hence spaced from the vertical, jog portion 19 of wall 17 as shown in FIGS. 2, 2A and 3 to prevent them from contacting, and thereby electrically short circuiting, to the bottom, narrower portion of wall 17. It should be understood that other method are arrangements may be used to prevent them from contacting and thereby electrically short circuiting to the bottom, narrower portion (region 17B) of wall 17.

Referring now to FIGS. 5A, 5B and 5C, the sequential steps used to process block 13 are shown, and referring to FIGS. 6A, 6B and 6C, the sequential steps used to process block 15 are shown. Thus, referring to FIG. 5A the block 13 has the dielectric 3D printed as shown in FIG. 5B and the strip conductor 3D printed on the dielectric as shown in FIG. 5C. Thus, referring to FIG. 6A the block 15 has the dielectric 3D printed as shown in FIG. 6B and the strip conductor printed on the dielectric as shown in FIG. 6C. It is noted that the blocks 13, 15 may be created using Additive Manufacturing to create two pieces that can be overlapped/ fit together to form a true 90 degree angle transition 10.

It should now be appreciated according to the disclosure, a radio frequency (RF) energy transmission line transition for coupling RF energy includes a pair of RF transmission line sections disposed on intersecting surfaces of a corresponding one of a pair of conductive members, a first one of the pair of conductive members having a wall with a jog therein for receiving an end portion of a second one of the pair of conductive members, the end portion of an electrically conductive strip of the first one of the pair of radio frequency transmission line sections being disposed on, and electrically connected to, an electrically conductive strip of a second one of the pair of radio frequency transmission line sections. The radio frequency (RF) energy transmission line transition may include the feature wherein the jog has orthogonal walls.

It should now also be appreciated according to the disclosure, a radio frequency (RF) energy transmission line transition for coupling RF energy between a pair of RF transmission line sections disposed on intersecting surfaces, includes: (a) a first one of the pair of radio frequency transmission line sections disposed on a first one of the pair of surfaces, comprising: a first electrically conductive member; a first dielectric disposed on the first electrically conductive member; and a first electrically conductive strip disposed on the first dielectric; (b) a second one of the pair of radio frequency transmission line sections disposed on a second one of the pair of surfaces, comprising: a second electrically conductive member having a first surface portion disposed on the first one of the pair of surfaces and a second surface portion disposed on a second one of the pair surfaces; a second dielectric disposed on the first surface portion and the second surface portion of the second electrically conductive member; a second electrically conductive strip having an end portion disposed on both: the first surface portion of the second dielectric and on the second surface portion of the second dielectric; and (c) wherein the end portion of the second electrically conductive strip disposed on the first surface of the second dielectric is disposed on and electrically connected to the first electrically conductive strip conductor. The radio frequency (RF) energy transmission line transition may include one or more of the following features, either individually or in combination to include: wherein the intersecting surfaces are orthogonal surfaces; or wherein the second electrically conductive member comprises a block of conductive material, such block having a wall with a jog therein for receiving a front portion of the second one of the pair of radio frequency transmission line sections, a wall of the jog having the end portion of the second electrically conductive strip disposed on the first surface of the second dielectric is disposed on and electrically connected to the first electrically conductive strip conductor.

It should now also be appreciated according to the disclosure, a radio frequency transmission line structure, includes: (a) A first radio frequency transmission line section, comprising: a first electrically conductive member having a horizontal surface; a first dielectric disposed on the horizontal surface; and a first electrically conductive strip disposed on the horizontal surface of the dielectric; (b) A second radio frequency transmission line section, comprising: a second electrically conductive member having a vertical surface portion and a horizontal surface portion; a second dielectric disposed on the vertical surface portion and the horizontal surface portion of the second electrically conductive member; a second electrically conductive strip disposed on the vertical surface

portion of and the horizontal portion of the second dielectric; and (c) a transition region wherein the end portion of the second electrically conductive strip disposed on the horizontal surface of the second dielectric is electrically connected to the first electrically conductive strip conductor.

5 A number of embodiments of the disclosure have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. For example, the upper and lower may be connected to electrical components such as Monolithic Microwave Integrated Circuits (MMICs) or may be used in other 3D structures such as described in Patent U. S. Application Publication
10 No.2019/0313522 A, entitled, "CIRCUIT SUPPORT AND COOLING STRUCTURE", Published October 10, 2019, inventors Trulli et al, assigned to the same assignee as the present patent application. Further, other angles than 90 degrees may be used. Accordingly, other embodiments are within the scope of the following claims.