have electrically conductive material on a further surface 260 (e.g., opposing a surface that is bonded to the surface 250 of the structure 300 of FIGS. 3A-3C). A portion 410 of the electrically conductive material may be milled away from the surface 260, as shown in FIG. 4B. In some embodiments, the surface 260 may not have electrically conductive material disposed thereon. A hole 420 may be drilled through the substrate 220 to provide access to the terminal pad 132 (and optional solder bump 134, see FIGS. 3A-3C), as shown in FIG. 4C. Various embodiments may involve milling, drilling, and bonding in differing orders than that described and result in the structure 400c or similar. For example, the hole 420 may be drilled prior to bonding the substrate 220 to the substrate 210. Accordingly, the order of operations may vary in various embodiments, and any suitable order may be used as a method in accord with aspects and embodiments herein, to fabricate various systems in accord with those herein.

FIGS. 5A1 and 5A2 illustrate a portion structure 500a of the electromagnetic circuit structure 100 in a stage of manufacture in accord with aspects and embodiments of the systems and methods described herein. The structure 500a includes the substrate 230 (see FIGS. 5A and 5C~~3A-3C~~) with a hole 510 drilled into the substrate 230 and a channel 520 milled into the substrate 230. The hole 510 accommodates an electrically conductive material, such as conductive ink or a wire, to be inserted in the hole 510, to form the receptor 120. Similarly, the channel 520 accommodates electrically conductive material, which may be conductive ink, to be inserted (e.g., by additive manufacturing technique) in the channel 520, to form at least a portion of the walls 140. In some embodiments, the substrate 230 may have electrically conductive material (e.g., copper electroplate) on a surface 270, and the channel 520 may be milled through the substrate 230 down to the electrically conductive material without piercing the electrically conductive material. Accordingly, filling the channel 520 with a conductive ink may form a continuous electrical structure (e.g., the walls 140) that may be electrically coupled to a ground plane upon the surface 270.

In various embodiments, the hole 510 may be drilled such that it does not reach the surface 270. In certain embodiments, the hole 510 may be drilled about 75% of the way through the substrate 230. Some embodiments may include the hole 510 drilled about 70-80% of the way through the substrate 230, but in various embodiments the

CLAIMS

1. A reactive beamformer, comprising:

a radiator disposed within a substrate and configured to radiate a received electromagnetic signal;

a plurality of receptors disposed within the substrate, each of the plurality of receptors configured to receive a portion of the radiated electromagnetic signal; and

a plurality of signal lines, each signal line of the plurality of signal lines being coupled to a respective receptor of the plurality of receptors to convey the portion of the radiated electromagnetic signal from the respective receptor and to provide the portion of the radiated electromagnetic signal to an output; and

an electrically and physically contiguous conductive wall disposed in the substrate around a perimeter of the plurality of receptors and configured to contain the radiated electromagnetic signal to a region within the conductive wall, the radiator and the plurality of receptors being disposed within the region.

2. The reactive beamformer of claim 1, wherein each receptor of the plurality of receptors is formed of an electrically conducting wire deposited into a milled hole in the substrate.

3. The reactive beamformer of claim 2, wherein the radiator is formed of an electrically conducting wire deposited into a milled hole in the substrate.

4. The reactive beamformer of claim 2, wherein each signal line of the plurality of signal lines is coupled to one receptor of the plurality of receptors by a solder joint formed at least in part by a solder reflow process.

5. The reactive beamformer of claim 1, wherein the plurality of receptors is physically arranged circumferentially around the radiator, each receptor of the plurality of receptors being substantially equidistant from the radiator and substantially equally spaced from each other.

~~6. The reactive beamformer of claim 1, further comprising an electrically and physically contiguous conductive wall disposed in the substrate around a perimeter of the plurality of receptors and configured to contain the radiated electromagnetic signal to a region within the conductive wall, the radiator and the plurality of receptors being disposed within the region.~~

67. The reactive beamformer of claim 1, further comprising a plurality of electrically conductive isolation walls disposed within the substrate and configured to isolate each receptor of the plurality of receptors from adjacent receptors of the plurality of receptors.

78. The reactive beamformer of claim 67, wherein each of the plurality of electrically conductive isolation walls is formed of a conductive ink deposited into a trench in the substrate.

89. The reactive beamformer of claim 67, further comprising an electrically and physically contiguous conductive outer wall disposed around a perimeter of the plurality of receptors, the conductive outer wall being electrically coupled to each isolation wall of the plurality of electrically conductive isolation walls.

910. The reactive beamformer of claim 89, further comprising a ground plane adjacent at least one surface of the substrate, the conductive outer wall and the conductive isolation walls being in electrically conductive communication with the ground plane.

1011. The reactive beamformer of claim 1, wherein the substrate is a first substrate and the plurality of signal traces is adjacent to a surface of a second substrate, the second substrate being bonded to the first substrate.

1112. The reactive beamformer of claim 1011, wherein the second substrate is indirectly bonded to the first substrate by one or more intermediate layers between the second substrate and the first substrate.

1213. The reactive beamformer of claim 1, wherein the reactive beamformer is configured to operate in millimeter-wave frequencies including 26.5 to 110 GHz.

14. A method of manufacturing a reactive beamformer, the method comprising:

milling a first substrate to form a first opening to accommodate a first electrical conductor;

milling the first substrate to form a plurality of second openings to accommodate a plurality of second electrical conductors;

milling the first substrate to form a continuous trench to accommodate a third electrical conductor;

depositing a first wire as the first electrical conductor in the first opening, the first wire forming an electromagnetic radiator;

depositing a plurality of second wires as the plurality of second electrical conductors in the plurality of second openings, each second wire of the plurality of second wires forming an electromagnetic receptor; and

filling the continuous trench with a conductive ink, the conductive ink forming a continuous electromagnetic boundary.

15. The method of claim 14, further comprising milling a conductive material disposed upon a second substrate to form a plurality of signal traces, each signal trace of the plurality of signal traces having a terminal end configured to have physical and electrical alignment with a respective one of the first electrical conductor or one of the plurality of second electrical conductors when the second substrate is aligned adjacent to the first substrate.

16. The method of claim 15, further comprising bonding the second substrate to the first substrate, directly or indirectly, the second substrate being positioned so each terminal end of the plurality of terminal ends make physical and electrical contact with one of the first electrical conductor or one of the plurality of second electrical conductors.

17. The method of claim 16, further comprising reflowing solder to bond each terminal end of the plurality of terminal ends with the respective one of the first electrical conductor or one of the plurality of second electrical conductors.

18. The method of claim 16, further comprising bonding a third substrate to the second substrate to substantially encapsulate the plurality of signal traces and terminal ends between the second substrate and the third substrate.

19. The method of claim 18, further comprising drilling through at least one of the second substrate and the third substrate to provide a plurality of access holes, each access hole of the plurality of access holes providing access to one of the plurality of terminal ends.

20. A method of forming an electromagnetic circuit, the method comprising:

milling away electrically conductive material disposed upon a surface of a substrate to form one or more circuit features;

milling one or more holes in the substrate;

filling the one or more holes with an electrical conductor;

milling one or more trenches in the substrate;

filling the one or more trenches with an electrical conductor;

applying solder to one or more of the circuit features or electrical conductors;

bonding a portion of the substrate, directly or indirectly, to another substrate; and

reflowing the solder.