

Composite Structure For An Electronic Circuit

FIELD OF INVENTION

5 The present invention relates broadly to a composite structure for an electronic circuit, to a method of fabricating a composite structure for an electronic circuit, and to a method of noise suppression utilising a composite structure for an electronic circuit.

10 BACKGROUND

 Suppression of electromagnetic noise in electronic devices is an ongoing challenge in the electronics field. For example, the increasing adoption of mixed-signal (analog and digital) systems in electronic applications typically involves
15 analog/digital (A/D) and digital/analog (D/A) conversion for signal processing, phase-lock loop (PLL) based high-speed signal input/output (I/O), or radio frequency (RF) front-end with a digital core, giving rise to a strong need for noise decoupling between nodes in such mixed-signal systems. For electronic circuits including system-in-package (SiP) technology, such as low temperature co-fired ceramic
20 (LTCC) – based system-in-package, or printed circuit boards (PCBs), various approaches to reduce the switching noise in the parallel plate power plane/ground plane configuration have been developed. Examples of such approaches include a method for suppressing resonances generated in a cavity between the two plates, for example by attenuating RF signals using absorbent or loss components, such as
25 ferrit beads, or discrete decoupling capacitors. In another approach, e.g. the plate for the power plane is divided into segments, for noise suppression.

 However, those previous approaches are effective only for suppression of an electromagnetic wave having a band of a few hundred megahertz (MHz) and having
30 a limited directionality. Furthermore, the suppression is typically confined within a restricted region, i.e. it does not extend along substantially the entire SiP or PCB.

In another approach, an electromagnetic band gap (EBG) structure has been proposed to suppress a surface current generated in an RF analog device. In this approach, the EBG structure is inserted between the power plane and the ground plane, and operates as an RF band stop filter. The EBG can be incorporated substantially along the entire SiP or PCB, i.e. it can be incorporated during the built-up of the planar structures for the SiP or PCB together with the power plane and the ground plane as an EBG plane. The EBG structure has been found to be very effective for suppression of an electromagnetic wave having a band of the order of gigahertz (GHz) and planar omni directional characteristics, and the suppression extends along substantially the entire SiP. Furthermore, the EBG structure can be cost-effectively implemented into the fabrication process.

However, with existing EBG structure designs, there remains the problem of achieving large bandwidth of suppression, and with a low starting frequency. In existing designs, the challenge is that in order to achieve those desired characteristics, i.e. a large bandwidth of suppression and a low starting frequency, the dimensioning of the EBG structure becomes practically too big to incorporation into SiPs or PCBs for applications where overall minimization in size has become the major design consideration. As such, with current EBG structure designs, there is a compromise between the suppression performance and physical size of the resulting structures, which is often assessed with reference to a Figure of Merit Index (FMI) for the suppression performance versus the dimensions of the relevant structures.

A need therefore exist to provide an EBG structure for noise suppression in SiPs or PCBs that seeks to address at least one of the above mentioned problems.

SUMMARY

In accordance with a first aspect of the present invention there is provided a composite structure for an electronic circuit, the composite structure comprising a power plane; a ground plane; an EBG structure including one or more first EBG planes each electrically connected via one or more stubs to one of the power or ground planes; and one or more magnetic dielectric layers formed between the said

one of the power or ground planes and the first EBG planes for selective inductive loading of the EBG structure.

5 The magnetic dielectric layers may be patterned such that the EBG structure exhibits different inductive loading in different areas of the composite structure.

Each EBG plane may comprise a plurality of EBG electrodes, and a distribution of the EBG electrodes is chosen to accommodate via transitions between EBG electrodes.

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Each EBG plane may comprise a plurality of EBG electrodes, and a distribution of the EBG electrodes is chosen to provide different suppression characteristics for different areas of the composite structure.

15 The different areas may comprise respective areas for analog and digital signal processing.

The composite structure may further comprise one or more Hi-K dielectric layers formed between the other one of the power or ground planes and the first EBG planes for selective capacitive loading of the EBG structure.

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The the EBG structure may include one or more second EBG planes each electrically connected via one or more stubs to the other one of the power or ground planes.

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The composite structure may further comprise one or more further magnetic dielectric layers formed between the said other one of the power or ground planes and the second EBG planes for selective inductive loading of the EBG structure.

30 The composite structure may further comprise a lossy material for contributing to inductive or capacitive loading of the EBG structure.

The composite structure is in the form of an SiP or a PCB.

In accordance with a second aspect of the present invention there is provided a method of fabricating a composite structure for an electronic circuit, the method comprising the steps of forming a power plane; forming a ground plane; forming an EBG structure including one or more first EBG planes each electrically connected
5 via one or more stubs to one of the power or ground planes; and forming one or more magnetic dielectric layers formed between the said one of the power or ground planes and the first EBG planes for selective inductive loading of the EBG structure.

The method may further comprise patterning the magnetic dielectric layers
10 such that the EBG structure exhibits different inductive loading in different areas of the method.

Each EBG plane may comprise a plurality of EBG electrodes, and the method further comprises choosing a distribution of the EBG electrodes to
15 accommodate via transitions between EBG electrodes.

Each EBG plane may comprise a plurality of EBG electrodes, and the method further comprises choosing a distribution of the EBG electrodes to provide different suppression characteristics for different areas of the method.
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The different areas may comprise respective areas for analog and digital signal processing.

The method may further comprise forming one or more Hi-K dielectric layers
25 between the other one of the power or ground planes and the first EBG planes for selective capacitive loading of the EBG structure.

Forming the EBG structure may include forming one or more second EBG planes each electrically connected via one or more stubs to the other one of the
30 power or ground planes.

The method may further comprise forming one or more further magnetic dielectric layers between the said other one of the power or ground planes and the second EBG planes for selective inductive loading of the EBG structure.

The method may further comprise providing a lossy material for contributing to inductive or capacitive loading of the EBG structure.

5 The composite structure may be in the form of an SiP or a PCB.

In accordance with a third aspect of the present invention there is provided a method of noise suppression utilising a composite structure for an electronic circuit, the method comprising providing selective inductive loading of an EBG structure
10 formed in the composite structure.

The method may further comprise providing different inductive loading in different areas of the composite structure.

15 The method may further comprise choosing a distribution of EBG electrodes to accommodate via transitions between EBG electrodes.

The method may further comprise choosing a distribution of EBG electrodes to provide different suppression characteristics for different areas of the method.
20

The different areas may comprise respective areas for analog and digital signal processing.

The method may further comprise providing selective capacitive loading of
25 the EBG structure.

The EBG structure may include a stacked EBG structure.

The composite structure may be in the form of an SiP or a PCB.
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BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

5 Figure 1 is a schematic cross-sectional view of a composite structure in an example embodiment.

 Figure 2 is a schematic cross-sectional view of a composite structure in an example embodiment.

10 Figure 3 is a schematic cross-sectional view of a composite structure in an example embodiment.

 Figure 4 is a schematic cross-sectional view of a composite structure in an example embodiment.

 Figure 5 is a schematic cross-sectional view of a composite structure in an example embodiment.

15 Figure 6 is a schematic cross-sectional view of a composite structure in an example embodiment.

 Figure 7 shows a frequency response of a composite test structure according to an example embodiment.

20 Figure 8 is a schematic cross-sectional view of a composite structure in an example embodiment.

 Figure 9 shows a flowchart 900 illustrating a method of fabricating a composite structure for an electronic circuit according to an example embodiment.

DETAILED DESCRIPTION

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 Figure 1 shows a schematic cross-sectional view of an LTCC based SiP composite structure in one example embodiment. The structure 100 comprises a parallel plate power plane 102/ground plane 104 configuration. One or more EBG planes 106 are provided between the power plane 102 and ground plane 104. In
30 this example, the EBG plane 106 comprises a plurality of patch electrodes 108, 110, electrically connected to the power plane 102 via vertical stubs 112, 114 respectively.

The composite structure 100 further comprises one or more magnetic dielectric layers 116, formed between the power plane 102 and ground plane 104, and directly adjacent the power plane 102 in this example embodiment. Furthermore, the composite structure 100 comprises one or more high permittivity (Hi-K) dielectric layers 118, formed between the power plane 102 and the ground plane 104, and directly adjacent the ground plane 104 in this example embodiment. In this example embodiment, the Hi-K dielectric layer 118 extends through the entire vertical region between the EBG patch electrodes 108, 110, and the ground plane 104.

The composite structure 100 further comprises one or more dielectric layers 120 of normal permittivity, i.e. as compared to the Hi-K dielectric layer 118. It will be appreciated by a person skilled in the art that Hi-K materials typically have a dielectric constant in excess of 10, whereas dielectric layers 120, similar to the top and bottom dielectric layers 121, 122, have a dielectric constant of about 2.5 to about 10 in example implementations. The normal permittivity layer 120 may comprise polymer, organic or glass ceramics in example implementations. The Hi-K dielectric layer 118 can comprise ceramic loaded polymer or ferroelectric ceramics in example implementations. The magnetic dielectric layer 116 can comprise ferrite loaded polymer or ferromagnetic ceramics in example implementations.

In the composite structure 100 shown in Figure 1, the EBG bandwidth is determined by the vertical stubs' 112, 114 inductance, and the patch electrodes' 108, 110 capacitance, i.e. the capacitance between the EBG patch electrodes 108, 110 and the ground plane 104. The magnetic dielectric layer 116 advantageously provides independent control or tuning of the vertical stubs' 112, 114 inductance. Furthermore, the control or tuning can be further enhanced by selection of the shape, dimensions, or both of the vertical stubs 112, 114.

On the other hand, the Hi-K dielectric layer 118 advantageously provides independent control or tuning of the EBG patch electrodes 108, 110 capacitance. Again, this control or tuning can be further enhanced by selection of the shape, dimensions, or both of the EBG patch electrodes 108, 110.

The dielectric layer 120 having a dielectric constant typically in the range between about 2.5 and 10 functions as a conventional medium for signal transmission in the composite structure 100 of the example embodiment.

5 Lossy magnetic or lossy Hi-K dielectric materials, or both, may be used in the layers 116, 118 to enhance the EBG attenuation factor and hence the signal suppression effectiveness.

10 Figure 2 shows a schematic cross-sectional view of a LTCC SiP based composite structure 200 according to another embodiment. The structure 200 comprises a parallel plate power plane 202 / ground plane 204 configuration. One or more EBG planes 206 are provided between the power plane 202 and ground plane 204. In this example, the EBG plane 206 comprises a plurality of patch electrodes 208, 210, electrically connected to the power plane 202 via vertical stubs
15 212, 214 respectively.

 The composite structure 200 further comprises one or more magnetic dielectric layers 216, formed between the power plane 202 and ground plane 204, and directly adjacent the power plane 202 in this example embodiment.
20 Furthermore, the composite structure 200 comprises one or more Hi-K dielectric layers 218, formed between the power plane 202 and the ground plane 204, and directly adjacent the ground plane 204 in this example embodiment. In this example embodiment, the Hi-K dielectric layer 218 extends through the entire vertical region between the EBG patch electrodes 208, 210, and the ground plane 204.

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 The composite structure 200 further comprises one or more dielectric layers 220 of normal permittivity, i.e. as compared to the Hi-K dielectric layer 218.

30 In the composite structure 200 shown in Figure 2, the EBG bandwidth is determined by the vertical stubs' 212, 214 inductance, and the patch electrodes' 208, 210 capacitance, i.e. the capacitance between the EBG patch electrodes 208, 210 and the ground plane 204. The magnetic dielectric layer 216 advantageously provides independent control or tuning of the vertical stubs' 212, 214 inductance.

Furthermore, the control or tuning can be further enhanced by selection of the shape, dimensions, or both of the vertical stubs 212, 214.

On the other hand, the Hi-K dielectric layer 218 advantageously provides
5 independent control or tuning of the EBG patch electrodes 208, 210 capacitance. Again, this control or tuning can be further enhanced by selection of the shape, dimensions, or both of the EBG patch electrodes 208, 210.

The dielectric layer 220 having a dielectric constant typically in the range
10 between about 2.5 and 10 functions as a conventional medium for signal transmission in the composites structure 200 of the example embodiment.

In the composite structure 200 of the example embodiment, the selective
distribution of the EBG patch electrodes 208, 210 is advantageously used to enable
15 via transitions 222, 224 conveniently. Furthermore, lossy magnetic or lossy Hi-K dielectric materials, or both, may be used in layers 216, 218 to enhance the EBG attenuation factor and hence the signal suppression effectiveness.

In the composite structure 200, the two signals vias 222, 224 transitions are each
20 surrounded by dielectric material of normal permittivity compared to the Hi-K dielectric material of layer 218, along the portion of the signal vias 222, 224 transitions from the power plane 202 to the ground plane 204. Surrounding the vias 222, 224 with dielectric material of normal permittivity in this example embodiment advantageously avoids or minimizes signal degradation that may otherwise be experienced if the vias 222, 224
25 were surrounded with the magnetic dielectric or Hi-K dielectric materials of layers 216, 218, or both.

In different example embodiments, selective inductive, capacitive, or both, loading may be applied to the EBG patch electrodes, as an alternative, or additionally to
30 the selective distribution of the EBG patch electrodes. Figures 3 and 4 show modified composite structures 300, 400 respectively. In the composite structures 300, 400, the magnetic dielectric layers 302, 402, and the Hi-K dielectric layers 304, 404 are patterned, so as to achieve a desired selective inductive, capacitive, or both loading in different areas of the composite structures 300, 400.

Figure 5 shows a cross-sectional view of an LTCC SiP based composite structure 500 incorporating a stacked EBG structure according to another embodiment. The structure 500 comprises a parallel plate power plane 502 / ground plane 504 configuration. One or more EBG planes 506 are provided between the power plane 502 and ground plane 504. In this example, the EBG plane 506 comprises a plurality of patch electrodes 508, 510, electrically connected to the power plane 502 via vertical stubs 512, 514 respectively.

The composite structure 500 further comprises one or more magnetic dielectric layers 516, formed between the power plane 502 and ground plane 504, and directly adjacent the power plane 502 in this example embodiment. Furthermore, the composite structure 500 comprises one or more Hi-K dielectric layers 518, formed between the power plane 502 and the ground plane 504, and directly adjacent the ground plane 504 in this example embodiment. In this example embodiment, the Hi-K dielectric layer 518 extends through the entire vertical region between the EBG patch electrodes 508, 510, and the ground plane 504.

The composite structure 500 further comprises one or more dielectric layers 520 of normal permittivity, i.e. as compared to the Hi-K dielectric layer 518.

In the composite structure 500 shown in Figure 5, the EBG bandwidth is determined by the vertical stubs' 512, 514 inductance, and the patch electrodes' 508, 510 capacitance, i.e. the capacitance between the EBG patch electrodes 508, 510 and the ground plane 504. The magnetic dielectric layer 516 advantageously provides independent control or tuning of the vertical stubs' 512, 514 inductance. Furthermore, the control or tuning can be further enhanced by selection of the shape, dimensions, or both of the vertical stubs 512, 514.

On the other hand, the Hi-K dielectric layer 518 advantageously provides independent control or tuning of the EBG patch electrodes 508, 510 capacitance. Again, this control or tuning can be further enhanced by selection of the shaped, dimensions, or both of the EBG patch electrodes 508, 510.

The dielectric layer 520 having a dielectric constant typically in the range between about 2.5 and 10 functions as a conventional medium for signal transmission in the composites structure 500 of the example embodiment.

5 In the composite structure 500 of the example embodiment, the selective distribution of the EBG patch electrodes 508, 510 is advantageously used to enable via transitions 522, 524 conveniently. Furthermore, lossy magnetic or Hi-K dielectric materials, or both, may be used in layers 516, 518 to enhance the EBG attenuation factor and hence the signal suppression effectiveness.

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 In this embodiment, one or more additional EBG planes 530 connected to the ground plane 504 are provided as a stacked EBG structure. The EBG plane 530 comprises a plurality of EBG patch electrodes 532. In this embodiment, the EBG patch electrode 532 comprises through-holes 534, 536 for the stubs 514, 516 of the
15 EBG patch electrodes 508, 510, with the overall dimension of the EBG patch electrode 532 being larger than the EBG patch electrodes 508, 510. The EBG patch electrode 532 is electrically connected to the ground plane 504 through vertical stub e.g. 538. Stubs 540, 542 not terminating on the actual patch electrode 532 are also incorporated in this example embodiment, and can further enhance the
20 controllability or tuneability of the suppression characteristics of the composite structure 500.

 Compared with the EBG plane 506, the EBG layer 530 has a "typical" inductive and capacitive loading. It will be appreciated by a person skilled in the art
25 that even though for the EBG layer 530 magnetic dielectric layer 516 may have some influence on the capacitance of the patch electrode 532, the increase in the magnetic coefficient of such a material is typically associated with only a minor increase in the dielectric constant. For example, for a typical magnetic dielectric material having a 50 to 100 times higher magnetic permeability, than a normal
30 dielectric material, the associated increase in the dielectric constant may only be by a factor of about 2 to 5. The magnetic dielectric material may comprise LTCC co-sintering tape with magnetic powder dispersed in an organic matrix in an example implementation.

The combination of the enhanced inductive and capacitive loading EBG layer 506 with the EBG layer 530 can advantageously provide an ultra wide bandgap performance.

5 Figure 6 shows a cross-sectional view of an LTCC SiP based composite structure 600 incorporating a stacked EBG structure according to another embodiment. The structure 600 comprises a parallel plate power plane 602 / ground plane 604 configuration. One or more EBG planes 606 are provided between the power plane 602 and ground plane 604. In this example, the EBG plane 606 comprises a
10 plurality of patch electrodes 608, 610, electrically connected to the power plane 602 via vertical stubs 612, 614 respectively.

The composite structure 600 further comprises one or more magnetic dielectric layers 616, formed between the power plane 602 and ground plane 604,
15 and directly adjacent the power plane 602 in this example embodiment. Furthermore, the composite structure 600 comprises one or more magnetic dielectric layers 618, formed between the power plane 602 and the ground plane 604, and directly adjacent the ground plane 604 in this example embodiment. In this example embodiment, the magnetic dielectric layer 618 extends through the entire
20 vertical region between the EBG patch electrodes 608, 610, and the ground plane 604.

The composite structure 600 further comprises one or more dielectric layers 620 of normal permittivity.

25 In the composite structure 600 shown in Figure 6, the EBG bandwidth is determined by the vertical stubs' 612, 614 inductance, and the patch electrodes' 608, 610 capacitance, i.e. the capacitance between the EBG patch electrodes 608, 610 and the ground plane 604. The magnetic dielectric layer 616 advantageously
30 provides independent control or tuning of the vertical stubs' 612, 614 inductance. Furthermore, the control or tuning can be further enhanced by selection of the shape, dimensions, or both of the vertical stubs 612, 614.

The EBG layer 606 has a "typical" capacitive loading. It will be appreciated by a person skilled in the art that even though for the EBG layer 606 magnetic dielectric layer 618 may have some influence on the capacitance of the patch electrode 606, the increase in the magnetic coefficient of such a material is typically associated with only a minor increase in the dielectric constant. For example, for a typical magnetic dielectric material having a 50 to 100 times higher magnetic permeability, than a normal dielectric material, the associated increase in the dielectric constant may only be by a factor of about 2 to 5. The magnetic dielectric material may comprise LTCC co-sintering tape with magnetic powder dispersed in an organic matrix in an example implementation.

The dielectric layer 620 having a dielectric constant typically in the range between about 2.5 and 10 functions as a conventional medium for signal transmission in the composites structure 600 of the example embodiment.

In the composite structure 600 of the example embodiment, the selective distribution of the EBG patch electrodes 608, 610 is advantageously used to enable via transitions 622, 624 conveniently. Furthermore, lossy magnetic or Hi-K dielectric materials, or both, may be used in layers 616, 618 to enhance the EBG attenuation factor and hence the signal suppression effectiveness.

In this embodiment, one or more additional EBG planes 630 connected to the ground plane 604 are provided as a stacked EBG structure. The EBG plane 630 comprises a plurality of EBG patch electrodes 632. In this embodiment, the EBG patch electrode 632 comprises through-holes 634, 636 for the stubs 614, 616 of the EBG patch electrodes 608, 610, with the overall dimension of the EBG patch electrode 632 being larger than the EBG patch electrodes 608, 610. The EBG patch electrode 632 is electrically connected to the ground plane 604 through vertical stub e.g. 638. Stubs 640, 642 not terminating on the actual patch electrode 632 are also incorporated in this example embodiment, and can further enhance the controllability or tuneability of the suppression characteristics of the composite structure 600.

In the composite structure 600 shown in Figure 6, the EBG bandwidth is further determined by the vertical stubs' 638, 640, 642 inductance, and the patch electrode's 632 capacitance, i.e. the capacitance between the EBG patch electrode 632 and the ground plane 604. The magnetic dielectric layer 618 advantageously provides independent control or tuning of the vertical stubs' 638, 640, 642 inductance. Furthermore, the control or tuning can be further enhanced by selection of the shape, dimensions, or both of the vertical stubs 638, 640, 642.

The EBG layer 630 has a "typical" capacitive loading. It will be appreciated by a person skilled in the art that even though for the EBG layer 630 magnetic dielectric layer 616 may have some influence on the capacitance of the patch electrode 632, the increase in the magnetic coefficient of such a material is typically associated with only a minor increase in the dielectric constant. For example, for a typical magnetic dielectric material having a 50 to 100 times higher magnetic coefficient, than a normal dielectric material, the associated increase in the dielectric constant may only be by a factor of about 2 to 5. The magnetic dielectric material may comprise LTCC co-sintering tape including magnetic powder dispersed in an organic matrix in an example implementation.

The combination of the enhanced inductive loading EBG layer 606 with the enhanced inductive loading EBG layer 630 can also advantageously provide an ultra wide bandgap performance.

Figure 7 shows the frequency response of an LTCC SiP composite test structure according to an embodiment as schematically shown and described above with reference to Figure 6. The frequency response was measured across respective via interconnections at opposing ends of the SiP structure (compare via transitions 322, 324 in Figure 3). As can be seen from Figure 7, for a 30dB suppression, the bandwidth is exceeding about 20 GHz. At the same time, the low frequency suppression indicates the superior suppression characteristics compared with existing EBG structures, where typically a penalty has to be paid in terms of increased dimensions of the structure to achieve low start frequency, large bandwidth suppression characteristics. The measurement shown in Figure 4 was taken from a SiP structure of about 20x20mm, and 25 large patches of 4x4 mm² as

an EBG layer connected to the ground plane, and 50 small patches of $2 \times 2 \text{ mm}^2$ as an EBG layer connected to the power plane. The magnetic dielectric material used was LTCC co-sintering tape with magnetic powder dispersed in an organic matrix. The typical thickness of each dielectric layer was around 80 to 90 μm .

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The described example embodiments can be implemented for mixed-signal (analog and digital) applications. Figure 8 shows a composite structure 800 for mixed-signal applications. In the composite structure 800, neighbouring portions 802, 804 underneath an analog component 806, and a digital component 808 respectively, are designed with different inductive, capacitive, or both, loading for the EBG structure. More particular, in this example implementation, a magnetic dielectric layer 810 and a Hi-K dielectric layer 812 are patterned such that the inductive and capacitive loading is different between the portions 802 and 804 of the composite structure 800. It will be appreciated that in different embodiments, numerous combination of inductive, capacitive, or both, loading of the EBG structure in different areas can be implemented.

The described embodiments may be fabricated using existing LTCC technology manufacturing as an example of implementation. In such LTCC technology manufacturing, multiple tape layers are laminated to form the composite structure including the EBG structures. Via holes can be formed by punching or drilling in e.g. a ceramic tape and forming the pattern for the relevant EBG layer on one surface of the ceramic tape and, if applicable, around the drill holes by printing or other known techniques. Stencil filling is then used to fill the holes, thereby forming the filled vias. Similarly, blind vias can be readily achieved using existing LTCC technology manufacturing.

Furthermore, it will be appreciated that the described example embodiments can also be implemented as PCB's using e.g. existing organic polymer circuit board fabrication technology manufacturing.

Figure 9 shows a flowchart 900 illustrating a method of fabricating a composite structure for an electronic circuit according to an example embodiment. At step 902, a power plane is formed. At step 904, a ground plane is formed. At step

906, an EBG structure including one or more first EBG planes each electrically connected via one or more stubs to one of the power or ground planes is formed. At step 908, one or more magnetic dielectric layers are formed between the said one of the power or ground planes and the first EBG planes for selective inductive loading
5 of the EBG structure.

A method of noise suppression using a composite structure for an electronic circuit in an example embodiment uses selective inductive loading of an EBG structure formed in the composite structure.

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The described example embodiments can suppress the propagation of the switching noise by providing a stop band having a wide frequency range, and with a low starting frequency. In existing designs for analog and digital applications, typically the physical separation of the digital and analog circuit components has to
15 be kept large due to the high power associated with the digital switching noise, to accommodate e.g. existing large EBG structure for suppression. The digital switching noise energy is typically about ten times higher than for analog signals, and thus the component density in existing designs for mixed-signal applications has typically been low. With the described example embodiments, by providing an
20 improved suppression characteristic, i.e. large suppression bandwidth and low starting frequency, with reduced dimensions, a higher component density can be realized.

In the described example embodiments, the implementation of magnetic
25 dielectric material to increase the stop band significantly can increase the EBG inductances significantly without a) increasing the dielectric thickness, and, or b) reducing the stub diameter. The suppression bandwidth will be widened and the start frequency will also be reduced. By reducing the stub diameter, the inductance can also be increased but there is typically a finite limit constrained by manufacturing processes.

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In the described example embodiments, the EBG patches or electrode can be selectively capacitively, inductively, or both loaded in different areas of the SiP or PCB, allowing specific desired loadings around sensitive circuits, convenient signal via
35 transitions, or both.

In the described example embodiments which use an implementation of a Hi-K dielectric material and a magnetic dielectric material together, a significant increase in the stop band can be achieved.

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In the described example embodiments which implement lossy dielectric materials, for example lossy magnetic dielectric materials, lossy Hi-K dielectric materials, or both, the stop band can be significantly increased in particular the noise attenuation.

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Conventional EBG designs, as reported in the public literature, only achieve fairly narrow noise suppression bandwidth, typically below 7 GHz and the start frequency is typically above 3 GHz.

CLAIMS

1. A composite structure for an electronic circuit, the composite structure comprising:

- 5 a power plane;
 a ground plane;

an EBG structure including one or more first EBG planes each electrically connected via one or more stubs to one of the power or ground planes; and

- 10 one or more magnetic dielectric layers formed between the said one of the power or ground planes and the first EBG planes for selective inductive loading of the EBG structure.

1. The composite structure as claimed in claim 1, wherein the magnetic dielectric layers are patterned such that the EBG structure exhibits different inductive loading in different areas of the composite structure.

3. The composite structure as claimed in claims 1 or 2, wherein each EBG plane comprises a plurality of EBG electrodes, and a distribution of the EBG electrodes is chosen to accommodate via transitions between EBG electrodes.

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4. The composite structure as claimed in claim 1 or 2, wherein each EBG plane comprises a plurality of EBG electrodes, and a distribution of the EBG electrodes is chosen to provide different suppression characteristics for different areas of the composite structure.

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5. The composite structure as claimed in claims 2 or 4, wherein the different areas comprise respective areas for analog and digital signal processing.

6. The composite structure as claimed in any one of the preceding claims, further comprising one or more Hi-K dielectric layers formed between the other one of the power or ground planes and the first EBG planes for selective capacitive loading of the EBG structure.

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7. The composite structure as claimed in any one of the preceding claims, wherein the EBG structure includes one or more second EBG planes each electrically connected via one or more stubs to the other one of the power or ground planes.

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8. The composite structure as claimed in claim 7, further comprising one or more further magnetic dielectric layers formed between the said other one of the power or ground planes and the second EBG planes for selective inductive loading of the EBG structure.

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9. The composite structure as claimed in any one of the preceding claims, further comprising a lossy material for contributing to inductive or capacitive loading of the EBG structure.

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10. The composite structure as claimed in any one of the preceding claims, wherein the composite structure is in the form of an SiP or a PCB.

11. A method of fabricating a composite structure for an electronic circuit, the method comprising the steps of:

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forming a power plane;

forming a ground plane;

forming an EBG structure including one or more first EBG planes each electrically connected via one or more stubs to one of the power or ground planes; and

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forming one or more magnetic dielectric layers between the said one of the power or ground planes and the first EBG planes for selective inductive loading of the EBG structure.

12. The method as claimed in claim 11, further comprising patterning the magnetic dielectric layers such that the EBG structure exhibits different inductive loading in different areas of the method.

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13. The method as claimed in claims 11 or 12, wherein each EBG plane comprises a plurality of EBG electrodes, and the method further comprises choosing

a distribution of the EBG electrodes to accommodate via transitions between EBG electrodes.

14. The method as claimed in claim 11 or 12, wherein each EBG plane
5 comprises a plurality of EBG electrodes, and the method further comprises choosing a distribution of the EBG electrodes to provide different suppression characteristics for different areas of the method.

15. The method as claimed in claims 12 or 14, wherein the different areas
10 comprise respective areas for analog and digital signal processing.

16. The method as claimed in any one of claims 11 to 15, further
comprising forming one or more Hi-K dielectric layers between the other one of the power or ground planes and the first EBG planes for selective capacitive loading of
15 the EBG structure.

17. The method as claimed in any one of claims 11 to 16, wherein forming
the EBG structure includes forming one or more second EBG planes each electrically connected via one or more stubs to the other one of the power or ground
20 planes.

18. The method as claimed in claim 17, further comprising forming one or
more further magnetic dielectric layers between the said other one of the power or ground planes and the second EBG planes for selective inductive loading of the
25 EBG structure.

19. The method as claimed in any one of claims 11 to 18, further
comprising providing a lossy material for contributing to inductive or capacitive loading of the EBG structure.

20. The method as claimed in any one of claims 11 to 19, wherein the
composite structure is in the form of an SiP or a PCB.

21. A method of noise suppression utilising a composite structure for an electronic circuit, the method comprising providing selective inductive loading of an EBG structure formed in the composite structure.

5 22. The method as claimed in claim 21, further comprising providing different inductive loading in different areas of the composite structure.

23. The method as claimed in claims 21 or 22, further comprising choosing a distribution of EBG electrodes to accommodate via transitions between
10 EBG electrodes.

24. The method as claimed in claim 21 or 22, further comprising choosing a distribution of EBG electrodes to provide different suppression characteristics for different areas of the method.
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25. The method as claimed in claims 21 or 24, wherein the different areas comprise respective areas for analog and digital signal processing.

26. The method as claimed in any one of claims 21 to 25, further
20 comprising providing selective capacitive loading of the EBG structure.

27. The method as claimed in any one of claims 20 to 26, wherein the EBG structure includes a stacked EBG structure.

25 28. The method as claimed in any one of claims 20 to 27, wherein the composite structure is in the form of an SiP or a PCB.