

**ORIENTATION-INSENSITIVE ULTRA-WIDEBAND
COUPLING CAPACITOR AND METHOD OF MAKING**

CROSS REFERENCE TO RELATED APPLICATIONS

The instant non-provisional application claims priority from provisional application number 60/503,183, filed September 15, 2003, and entitled ULTRA-WIDEBAND COUPLING CAPACITOR.

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to an ultra-wideband coupling capacitor, and more particularly, the present invention relates to an orientation-insensitive ultra-wideband coupling capacitor and method of making.

Description of the Prior Art:

As shown in FIGURES 1 and 2, which are, respectively, a schematic diagram of a prior art ultra-wideband coupling capacitor, and an exploded diagrammatic perspective view of a prior art ultra-wideband coupling capacitor, a prior art ultra-wideband coupling capacitor 10 is a parallel combination of a high value capacitor 12, typically 10 nanofarads or greater, and a low value capacitor 14, typically 20 picofarads to 250 picofarads. As can be seen, capacitors in parallel result in wider operating bandwidths.

The prior art ultra-wideband coupling capacitor 10 is either composed of two or more physical items which require precise assembly or a single ceramic assembly which must

1 internally include complex multiple capacitor configurations, and via holes that interconnect
2 internal electrodes to external contacting pads. Both of these family of devices have larger
3 than desired physical footprints and can only be mounted on one specific side of the device
4 making them difficult to use where surface mount technology (SMT) is employed.
5 Electrically, size limitations result in both high insertion and return losses and also cause
6 excessive surface moding at higher microwave frequencies.

7 The high value capacitor 12 is a multi-layer capacitor, while the low value capacitor
8 14 is generally either a single layer capacitor or two single layer capacitors in a balanced
9 configuration. The multi-layer capacitor is a multi-layer structure with interdigitated plates,
10 each separated by a thin dielectric layer, while the single layer capacitor is a single layer
11 structure with two plates separated by a thin dielectric layer.

12 The high value capacitor 12, with its relatively low series resonance, is most effective
13 on lower frequency signals, while the low value capacitor 14, with its relatively high series
14 resonance, is most effective on high frequency signals.

15 The high value capacitor 12 and the low value capacitor 14 of the prior art ultra-
16 wideband coupling capacitor 10 have different operating characteristics in different portions
17 of an ultra-wideband operating spectrum, as will be discussed *infra*.

18 As shown in **FIGURE 3A**, which is a schematic diagram of a prior art ultra-wideband
19 coupling capacitor operating at a low frequency, when the prior art ultra-wideband coupling
20 capacitor 10 is operating at a low frequency, the prior art ultra-wideband coupling capacitor

1 **10** electrodes exhibit insignificant skin effect. The ceramic structure looks like a bulk
2 dielectric.

3 As shown in **FIGURE 3B**, which is a schematic diagram of a prior art ultra-wideband
4 coupling capacitor operating at a mid frequency, when the prior art ultra-wideband coupling
5 capacitor **10** is operating at a mid frequency, the prior art ultra-wideband coupling capacitor
6 **10** electrodes exhibit significant skin effect. The dielectric region begins to take on the effect
7 of a meandering parallel plate transmission line structure. Additional resonances emerge.

8 As shown in **FIGURE 3C**, which is a schematic diagram of a prior art ultra-wideband
9 coupling capacitor operating at a high frequency, when the prior art ultra-wideband coupling
10 capacitor **10** is operating at a high frequency, the prior art ultra-wideband coupling capacitor
11 **10** electrodes exhibit full skin effect. The dielectric region acts as a lossy meandering parallel
12 plate transmission line. Additional resonances emerge at the higher frequencies.

13 The prior art ultra-wideband coupling capacitor **10** has a few associated shortcomings.
14 Firstly, since the prior art ultra-wideband coupling capacitor **10** is a two-piece structure, the
15 prior art ultra-wideband coupling capacitor **10** requires additional production assembly effort,
16 which increases per unit cost. Secondly, the prior art ultra-wideband coupling capacitor **10**
17 is orientation-sensitive restricting it to being mounted only on one specific surface, creating
18 surface mount technology (SMT) compatibility issues. Thirdly, the assembly height of the
19 prior art ultra-wideband coupling capacitor **10** exceeds the 0.020" dimension of a standard
20 0402 package by 0.012".

1 Thus, there exists a need for an ultra-wideband coupling capacitor which is one-piece
2 and thereby eliminates additional production assembly effort which thereby decreases per unit
3 cost, which is orientation-insensitive and thereby eliminates restricting it to being mounted
4 only on one specific surface which thereby eliminates surface mount technology (SMT)
5 compatibility issues, and which does not exceed the 0.020" dimension of a standard 0402.

6 Numerous innovations for high frequency capacitors have been provided in the prior
7 art. Even though these innovations may be suitable for the specific individual purposes to
8 which they address, they each differ in structure and/or operation and/or purpose from the
9 present invention in that they do not present an ultra-wideband coupling capacitor which is
10 one-piece and thereby eliminates additional production assembly effort which thereby
11 decreases per unit cost, which is orientation-insensitive and thereby eliminates restricting it
12 to being mounted only on one specific surface which thereby eliminates surface mount
13 technology (SMT) compatibility issues, and which does not exceed the 0.020" dimension of
14 a standard 0402.

15 **FOR EXAMPLE**, U.S. Patent Number 5,576,926 to Monsorno has an assignee
16 common with the instant application and presents a capacitor which has a superior ability to
17 operate in the upper regions of the RF spectrum. The capacitor includes a planar electrode
18 layer which is mounted between a pair of dielectric layers. The electrode layer generally is
19 centered inwardly with respect to the dielectric layers leaving an outward margin of dielectric
20 material. One of the dielectric layers has two spaced apart contact members, each having a
21 different polarity from the other. The electrode layer is isolated from electrical contact with
22 any conductor and is buried within the dielectric layers. The electrode layer, in combination
23 with the dielectric layer on which the contact members are mounted and the contact members,

1 allow development of a selected value of capacitance between the contact members. Providing
2 trimmed contact members, as well as controlling their size and spacing, allow for convenient
3 preselection of desired operative characteristics of the capacitor. The contact members could
4 be positioned on a substrate to which a buried electrode is mounted.

5 **ANOTHER EXAMPLE**, U.S. Patent Number 6,690,572 to Liebowitz teaches an SLC
6 which has a thin brittle ceramic dielectric layer less than 0.0035 inches thick and as low as
7 0.0005 inches or less. Electrodes are thick and strong enough, either singly or together, to give
8 the structure required physical strength for manufacture, handling, and usage. Electrodes are
9 (1) a ceramic metal composite, (2) a porous ceramic infiltrated with metal or other conductive
10 material, (3) a resin filled with metal or other conductive material, or (4) combinations of the
11 above. The very thin and, in itself, fragile dielectric layer provides exceedingly high capacity
12 per unit area with temperature stability and low losses. A 0.00001-inch thick dielectric of
13 titanium dioxide is also used.

14 It is apparent that numerous innovations for high frequency capacitors have been
15 provided in the prior art that are adapted to be used. Furthermore, even though these
16 innovations may be suitable for the specific individual purposes to which they address, they
17 would not be suitable for the purposes of the present invention as heretofore described,
18 namely, an ultra-wideband coupling capacitor which is one-piece and thereby eliminates
19 additional production assembly effort which thereby decreases per unit cost, which is
20 orientation-insensitive and thereby eliminates restricting it to being mounted only on one
21 specific surface which thereby eliminates surface mount technology (SMT) compatibility
22 issues, and which does not exceed the 0.020" dimension of a standard 0402.

SUMMARY OF THE INVENTION

Embodiments of the present invention seek to provide an orientation-insensitive ultra-wideband coupling capacitor that avoids the disadvantages of the prior art.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which has improved electrical performance over that of the prior art.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which has more attractive physical/mechanical characteristics than that of the prior art.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which is one-piece and thereby has inherently higher reliability and eliminates additional production assembly effort which thereby decreases per unit cost.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which is smaller than a two-piece prior art ultra-wideband coupling capacitor and thereby consumes less space and reduces the propensity to launch surface modes.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which is orientation-insensitive and

thereby eliminates restricting it to being mounted only on one specific surface which thereby eliminates surface mount technology (SMT) compatibility issues, *i.e.*, operates equally well regardless of the surface used to mount it.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which does not require special orientation during tape-and-reel loading.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which does not exceed the 0.020" dimension of a standard 0402 so as to form a true 0402 package which can be handled with standard SMT equipment.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which is electrically identical to a two-piece prior art ultra-wideband coupling capacitor.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which has lower insertion loss than a two-piece prior art ultra-wideband coupling capacitor.

Embodiments of the present invention also seek to provide an orientation-insensitive ultra-wideband coupling capacitor which has better VSWR than a two-piece prior art ultra-wideband coupling capacitor.

Embodiments of the present invention also seek to provide a volumetrically efficient means for enclosing a functional RF component within a gapped low-loss conductor pair, each of which surrounds the RF component on four sides and is co-terminal with it on a remaining two sides.

According to a first aspect of the present invention there is provided an orientation-insensitive ultra-wideband coupling capacitor, comprising: a plurality of external surfaces, a low frequency portion, and a high frequency portion; wherein the high frequency portion is so disposed on, and electrically connected to, the low frequency portion so as to allow the orientation-insensitive ultra-wideband coupling capacitor to work identically when mounted on any external longitudinal surface of the plurality of external surfaces thereof.

According to a second aspect of the present invention, there is provided an improved orientation-insensitive ultra-wideband coupling capacitor of the type having a plurality of external surfaces, a low frequency portion, and a high frequency portion, wherein said improvement comprises: the high frequency portion being so disposed on, and electrically connected to, the low frequency portion so as to allow said improved ultra-wideband coupling capacitor to work identically when mounted on any external longitudinal surface of the plurality of external surfaces thereof.

According to a third aspect of the present invention, there is provided a method of making an orientation-insensitive ultra-wideband coupling capacitor, comprising the steps of: a) securing an unterminated multi-layer capacitor of a low frequency portion of the orientation-insensitive ultra-wideband coupling capacitor; b) coating completely the unterminated multi-layer capacitor of the low frequency portion with an adhesion layer having opposing ends; c) creating a circumferential slot around the adhesion layer and

thereby electrically separating the opposing ends of the adhesion layer from each other restoring capacitance and forming a slotted body; d) applying a solder dam coating to all surfaces defining the circumferential slot to protect the circumferential slot; and e) plating the opposing ends of the adhesion layer so as to form solderable connections and thereby form the orientation-insensitive ultra-wideband coupling capacitor.

The novel features which are considered characteristic of the present invention are set forth in the appended claims. The invention itself, however, both as to its construction and its method of operation together with additional objects and advantages thereof will be best understood from the following description when read and understood in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The figures of the drawings are briefly described as follows:

- 1
- 2
- 3 **FIGURE 1** is a schematic diagram of a prior art ultra-wideband coupling capacitor;
- 4 **FIGURE 2** is an exploded diagrammatic perspective view of a prior art ultra-
- 5 wideband coupling capacitor;
- 6 **FIGURE 3A** is a schematic diagram of a prior art ultra-wideband coupling capacitor
- 7 operating at a low frequency;
- 8 **FIGURE 3B** is a schematic diagram of a prior art ultra-wideband coupling capacitor
- 9 operating at a mid frequency;
- 10 **FIGURE 3C** is a schematic diagram of a prior art ultra-wideband coupling capacitor
- 11 operating at a high frequency;
- 12 **FIGURE 4** is a diagrammatic perspective view of the orientation-insensitive ultra-
- 13 wideband coupling capacitor of the present invention;
- 14 **FIGURE 5** is a diagrammatic cross sectional view taken along **LINE 5-5** in
- 15 **FIGURE 4**;
- 16 **FIGURE 6** is a circuit equivalent to the orientation-insensitive ultra-wideband
- 17 coupling capacitor of the present invention; and
- 18 **FIGURES 7A-7D** are a flow chart of the method of making the orientation-insensitive
- 19 ultra-wideband coupling capacitor of the present invention.

1 LIST OF REFERENCE NUMERALS UTILIZED IN THE DRAWINGS

2 Prior Art

- 3 10 prior art ultra-wideband coupling capacitor
4 12 high value capacitor of prior art ultra-wideband coupling capacitor 10
5 14 low value capacitor of prior art ultra-wideband coupling capacitor 10

6 Present Invention

- 7 20 orientation-insensitive ultra-wideband coupling capacitor of present invention
8 22 plurality of external surfaces
9 24 low frequency portion
10 26 high frequency portion
11 28 unterminated multi-layer capacitor of low frequency portion 24
12 29 external surfaces of unterminated multi-layer capacitor 28 of low frequency portion 24
13 30 electrode layers of unterminated multi-layer capacitor 28 of low frequency portion 24
14 32 dielectric layers of unterminated multi-layer capacitor 28 of low frequency portion 24
15 34 first ends of electrode layers 30 of unterminated multi-layer capacitor 28 of low
16 frequency portion 24
17 36 opposing ends of external surfaces 29 of unterminated multi-layer capacitor 28 of low
18 frequency portion 24
19 38 second ends of electrode layers 30 of unterminated multi-layer capacitor 28 of low
20 frequency portion 24
21 40 pair of conductors of high frequency portion 26

- 1 42 circumferential slot between pair of conductors 40 of high frequency portion 26
- 2 46 exposed opposing ends of plurality of external surfaces 22 of orientation-insensitive
- 3 ultra-wideband coupling capacitor 20
- 4 48 quick curing protective UV-curable solder dam coating
- 5 50 plating
- 6 51 solderable connections
- 7 52 adhesion layer
- 8 54 opposing ends of adhesion layer 52
- 9 56 slotted body

1 DETAILED DESCRIPTION OF THE INVENTION

2 Referring now to the figures, in which like numerals indicate like parts, and
3 particularly to **FIGURES 4 and 5**, which are, respectively, a diagrammatic perspective view
4 of the orientation-insensitive ultra-wideband coupling capacitor of the present invention, and
5 a diagrammatic cross sectional view taken along **LINE 5-5** in **FIGURE 4**, the orientation-
6 insensitive ultra-wideband coupling capacitor of the present invention is shown generally at
7 **20**.

8 The orientation-insensitive ultra-wideband coupling capacitor **20** typically operates in
9 a range from below 20 KHz to over 40 Ghz, and fills a need for better blocking and decoupling
10 components by finding a use in almost all ultra-wideband digital signal processing
11 applications, *e.g.*, optical systems and their associated test equipment, closely related DC
12 returns and bias tees, fiber to the home (FTTH), and MMIC development, *e.g.*, amplifiers, *e.g.*,
13 ultra-wideband MMIC amplifiers and those using related technology.

14 The orientation-insensitive ultra-wideband coupling capacitor **20** comprises a plurality
15 of external surfaces **22**, a low frequency portion **24**, and a high frequency portion **26**. The high
16 frequency portion **26** is so disposed on, and electrically connected to, the low frequency
17 portion **24** so as to allow the orientation-insensitive ultra-wideband coupling capacitor **20** to
18 work identically when mounted on any external longitudinal surface of the plurality of external
19 surfaces **22** thereof and thereby be readily SMT compatible without regard to special orienting
20 procedures.

1 The orientation-insensitive ultra-wideband coupling capacitor 12 can operate below
2 16 KHz by using a larger value for the low frequency portion 24 than that used for the range
3 from below 20 KHz to over 40 Ghz, discussed *supra*.

4 The low frequency portion 24 is functionally equivalent to the high value capacitor 12
5 of the prior art ultra-wideband coupling capacitor 10, *e.g.*, a multi-layer capacitor, while the
6 high frequency portion 26 is functionally equivalent to the low value capacitor 14 of the prior
7 art ultra-wideband coupling capacitor 10, *e.g.*, a single-layer capacitor, so as to allow the
8 orientation-insensitive ultra-wideband coupling capacitor 20 to have functions of both the high
9 value capacitor 12 and the low value capacitor 14 solely in a single multi-layer ceramic body.

10 The low frequency portion 24 is an unterminated multi-layer capacitor 28 having
11 external surfaces 29, electrode layers 30, and dielectric layers 32, and preferably being 10 nF
12 or higher. The dielectric layers 32 of the unterminated multi-layer capacitor 28 of the low
13 frequency portion 24 alternate with the electrode layers 30 of the unterminated multi-layer
14 capacitor 28 of the low frequency portion 24. The electrode layers 30 of the unterminated
15 multi-layer capacitor 28 of the low frequency portion 24 extend at first ends 34 thereof from,
16 and are open for external electrical communication from, opposing ends 36 of the external
17 surfaces 29 of the unterminated multi-layer capacitor 28 of the low frequency portion 24, to
18 second ends 38 thereof which alternatingly stop short of the opposing end 36 of the external
19 surfaces 29 of the unterminated multi-layer capacitor 28 of the low frequency portion 24
20 opposite to that from which they extend so as not to be open for external electrical
21 communication therefrom.

1 The high frequency portion 26 is a pair of conductors 40. The pair of conductors 40
2 of the high frequency portion 26 cover the opposing ends 36 of the external surfaces 29 of the
3 unterminated multi-layer capacitor 28 of the low frequency portion 24, respectively, and
4 extend therefrom over the external surfaces 29 of the unterminated multi-layer capacitor 28
5 of the low frequency portion 24, to just short of each other so as to form a circumferential slot
6 42 therebetween and be separate from each other. The circumferential slot 42 is preferably
7 formed by laser scribing, but can be formed by either chemical etching, mechanical abrading,
8 or any similar procedure. Because the high frequency portion 26 does not employ additional
9 internal electrodes with separating layers, *i.e.*, does not employ a composite internal
10 interdigital electrode array as a single floating electrode that is coupled to the pair of
11 conductors 40 of the high frequency portion 26, there is less insertion and return losses.

12 The pair of conductors 40 of the high frequency portion 26 form the plurality of
13 external surfaces 22 and electrically communicate with the first ends 34 of the electrode layers
14 30 of the unterminated multi-layer capacitor 28 of the low frequency portion 24 associated
15 therewith so as to allow the orientation-insensitive ultra-wideband coupling capacitor 20 to
16 work identically when mounted on any external longitudinal surface of the plurality of external
17 surfaces 22 thereof. A set of coupled transmission lines is formed on the plurality of external
18 surfaces 22 between the pair of conductors 40 of the high frequency portion 26 and the
19 electrode layers 30 contained in the unterminated multi-layer capacitor 28 of the low frequency
20 portion 24 so as to allow low frequency energy to pass through the low frequency portion 24,
21 which is centrally located, and to allow high frequency energy to pass through the high
22 frequency portion 26, which is peripherally located.

1 The pair of conductors **40** of the high frequency portion **26** preferably comprise
2 titanium-tungsten (TiW) followed by nominally three microns of copper (Cu) and a gold (Au)
3 flash.

4 The circumferential slot **42** is preferably nominally 1.5 mil wide, is constantly
5 maintained completely through and completely around the high frequency portion **26** without
6 destroying the unterminated multi-layer capacitor **28** of the low frequency portion **24**, and is
7 disposed substantially midway between exposed opposing ends **46** of the plurality of external
8 surfaces **22** of the orientation-insensitive ultra-wideband coupling capacitor **20**, thereby
9 electrically separating the exposed opposing ends **46** of the orientation-insensitive ultra-
10 wideband coupling capacitor **20** from each other restoring capacitance thereto.

11 The orientation-insensitive ultra-wideband coupling capacitor **20** further comprises a
12 quick curing protective UV-curable solder dam coating **48**. The quick curing protective UV-
13 curable solder dam coating **48** covers all surfaces defining the circumferential slot **42** to protect
14 the circumferential slot **42**.

15 The orientation-insensitive ultra-wideband coupling capacitor **20** further comprises a
16 plating **50**. The plating **50** covers the exposed opposing ends **46** of the plurality of external
17 surfaces **22** of the orientation-insensitive ultra-wideband coupling capacitor **20** so as to form
18 solderable connections **51** which extend up to the protective UV-curable solder dam coating
19 **48** which acts as a stop-off barrier for the solderable connections **51**. The orientation-
20 insensitive ultra-wideband coupling capacitor **20** is thereby formed having a resistance across
21 the solderable connections **51** increased so that it exceeds 100 MegOhms. The plating **50** is

1 preferably either pure tin or solder or gold. When the plating 50 is gold, the solderable
2 connections 51 can also be gold/ribbon bonded or epoxy bonded.

3 A circuit equivalent to the orientation-insensitive ultra-wideband coupling capacitor
4 20 can best be seen in **FIGURE 6**, which is circuit equivalent to the orientation-insensitive
5 ultra-wideband coupling capacitor of the present invention.

6 The method of making the orientation-insensitive ultra-wideband coupling capacitor
7 20 can best be seen in **FIGURES 7A-7D**, which are a flow chart of the method of making the
8 orientation-insensitive ultra-wideband coupling capacitor of the present invention, and as such,
9 will be discussed with reference thereto.

10 The method of making the orientation-insensitive ultra-wideband coupling capacitor
11 20 comprises the following steps:

12 **STEP 1:** Secure the unterminated multi-layer capacitor 28 of the low frequency portion
13 24.

14 **STEP 2:** Coat completely the unterminated multi-layer capacitor 28 of the low
15 frequency portion 24 with titanium-tungsten (TiW) followed by nominally
16 three microns of copper (Cu) and a gold (Au) flash so as to form an adhesion
17 layer 52 having opposing ends 54.

18 **STEP 3:** Create by either laser scribing, chemical etching, mechanical abrading, or
19 similar procedure the circumferential slot 42 nominally 1.5 mil wide,

1 completely through, completely around, and maintained constantly in, the
2 adhesion layer 52 without destroying the unterminated multi-layer capacitor 28
3 of the low frequency portion 24, and substantially midway between the
4 opposing ends 54 of the adhesion layer 52, thereby electrically separating the
5 opposing ends 54 of the adhesion layer 52 from each other restoring
6 capacitance thereto and forming a slotted body 56.

7 **STEP 4:** Soak prolongingly the slotted body 56 in highly diluted hydrogen peroxide if
8 the circumferential slot 42 was laser scribed to eliminate a residue film of
9 vaporized metal redeposited into the circumferential slot 42 after laser scribing.

10 **STEP 5:** Apply the quick curing protective UV-curable solder dam coating 48 to all
11 surfaces defining the circumferential slot 42 to protect the circumferential slot
12 42.

13 **STEP 6:** Plate the opposing ends 54 of the adhesion layer 52 with either pure tin or
14 solder or gold so as to form solderable connections 51 up to the quick curing
15 protective UV-curable solder dam coating 58 which acts as a stop-off barrier
16 for the solderable connections 51, and thereby form the orientation-insensitive
17 ultra-wideband coupling capacitor 20 having a resistance across the solderable
18 connections 51 increased so that it exceeds 100 MegOhms as a result of the
19 soak step if carried out. The plating 50 is preferably either pure tin or solder
20 or gold.

1 It is to be understood that even though the embodiment given is for a low frequency
2 capacitor within a high frequency capacitor, it is not limited to that combination, in that
3 generically an embodiment includes a volumetrically efficient means for enclosing a functional
4 RF component within a gapped low-loss conductor pair. Each of the pair of low-loss
5 conductors surrounds the RF component on four sides and is co-terminal with the RF
6 component on a remaining two sides. A gap formed between the conductor pair creates a low-
7 loss capacitor that is in parallel with the surrounded RF component. The surrounded RF
8 component may include, but is not limited to, either a multilayer capacitor, an inductor, a
9 resistor, other resonance circuitry, a filter, a transmission line, or a plurality of transmission
10 lines. The resultant overall device includes, but is not limited to, volumetrically efficient high-
11 performing parallel combinations of two capacitors, of an inductor and capacitor creating
12 thereby a parallel-resonant network, a resistor, other resonance circuitry and a capacitor or a
13 so-called R-C network, a filter and a capacitor creating thereby a filter with an additional pole
14 or coupling, a transmission line and a capacitor, or a plurality of transmission lines and a
15 capacitor.

16 It will be understood that each of the elements described above, or two or more
17 together, may also find a useful application in other types of constructions differing from the
18 types described above.

19 The invention has been illustrated and described as embodied in an orientation-
20 insensitive ultra-wideband coupling capacitor and method of making, however, it is not limited
21 to the details shown, since it will be understood that various omissions, modifications,
22 substitutions and changes in the forms and details of the device, materials employed and

1 methods utilized, illustrated and its operation can be made by those skilled in the art according
2 to knowledge in the art without departing from the spirit of the present invention.

3 Without further analysis, the foregoing will so fully reveal the gist of the present
4 invention that others can, by applying current knowledge, readily adapt it for various
5 applications without omitting features that, from the standpoint of prior art, fairly constitute
6 characteristics of the generic or specific aspects of this invention.

CLAIMS

The invention claimed is:

- 1 1. An orientation-insensitive ultra-wideband coupling capacitor, comprising:
 - 2 a) a plurality of external surfaces;
 - 3 b) a low frequency portion; and
 - 4 c) a high frequency portion;

5 wherein said high frequency portion is so disposed on, and electrically

6 connected to, said low frequency portion so as to allow said orientation-

7 insensitive ultra-wideband coupling capacitor to work identically when

8 mounted on any external longitudinal surface of the plurality of external

9 surfaces thereof.
- 1 2. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 1,

2 wherein said orientation-insensitive ultra-wideband coupling capacitor operates in a

3 range from below 20 KHz to over 40 GHz.
- 1 3. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 1,

2 wherein said low frequency portion is functionally equivalent to a high value capacitor

3 and said high frequency portion is functionally equivalent to a low value capacitor so

4 as to allow said orientation-insensitive ultra-wideband coupling capacitor to have

5 functions of both said high value capacitor and said low value capacitor solely in a

6 single multi-layer ceramic body.

1 4. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 1,
2 wherein said low frequency portion is functionally equivalent to a multi-layer capacitor
3 and said high frequency portion is functionally equivalent to a single layer capacitor
4 so as to allow said orientation-insensitive ultra-wideband coupling capacitor to have
5 functions of both said multi-layer capacitor and said single layer capacitor solely in a
6 single multi-layer ceramic body.

1 5. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 1,
2 wherein said low frequency portion is an unterminated multi-layer capacitor;
3 wherein said unterminated multi-layer capacitor of said low frequency portion has
4 external surfaces;
5 wherein said unterminated multi-layer capacitor of said low frequency portion has
6 electrode layers;
7 wherein said unterminated multi-layer capacitor of said low frequency portion has
8 dielectric layers;
9 wherein said dielectric layers of said unterminated multi-layer capacitor of said low
10 frequency portion alternate with said electrode layers of said unterminated multi-layer
11 capacitor of said low frequency portion; and
12 wherein said electrode layers of said unterminated multi-layer capacitor of said low
13 frequency portion extend at first ends thereof from, and are open for external electrical
14 communication from, opposing ends of said external surfaces of said unterminated
15 multi-layer capacitor of said low frequency portion, to second ends thereof which
16 alternatingly stop short of said opposing ends of said external surfaces of said
17 unterminated multi-layer capacitor of said low frequency portion opposite to that from

18 which they extend so as not to be open for external electrical communication
19 therefrom.

1 6. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 5,
2 wherein said unterminated multi-layer capacitor of said low frequency portion is at
3 least 10 nF.

1 7. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 5,
2 wherein said high frequency portion is a pair of conductors;
3 wherein said pair of conductors of said high frequency portion cover said opposing
4 ends of said external surfaces of said unterminated multi-layer capacitor of said low
5 frequency portion, respectively; and
6 wherein said pair of conductors of said high frequency portion extend from said
7 opposing ends of said external surfaces of said unterminated multi-layer capacitor of
8 said low frequency portion, respectively, over said external surfaces of said
9 unterminated multi-layer capacitor of said low frequency portion, to just short of each
10 other so as to form a circumferential slot therebetween and be separate from each
11 other.

1 8. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 1,
2 wherein said high frequency portion does not employ additional internal electrodes
3 with separating dielectric layers and thereby has less insertion and return losses.

- 1 . 9. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 7,
2 wherein said pair of conductors of said high frequency portion form said plurality of
3 external surfaces of said orientation-insensitive ultra-wideband coupling capacitor; and
4 wherein said pair of conductors of said high frequency portion electrically
5 communicate with said first ends of said electrode layers of said unterminated multi-
6 layer capacitor of said low frequency portion associated therewith so as to allow said
7 orientation-insensitive ultra-wideband coupling capacitor to work identically when
8 mounted on any external longitudinal surface of said plurality of external surfaces
9 thereof.
- 1 10. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 7,
2 wherein a set of coupled transmission lines is formed on said plurality of external
3 surfaces of said orientation-insensitive ultra-wideband coupling capacitor between said
4 pair of conductors of said high frequency portion and said electrode layers contained
5 in said unterminated multi-layer capacitor of said low frequency portion so as to allow
6 low frequency energy to pass through said low frequency portion, which is centrally
7 located, and to allow high frequency energy to pass through said high frequency
8 portion, which is peripherally located.
- 1 11. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 7,
2 wherein said pair of conductors of said high frequency portion comprise titanium-
3 tungsten.
- 1 12. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 11,
2 wherein said pair of conductors of said high frequency portion comprise copper; and

3 wherein said copper of said pair of conductors of said high frequency portion is
4 disposed on said titanium-tungsten of said pair of conductors of said high frequency
5 portion.

1 13. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 12,
2 wherein said copper of said pair of conductors of said high frequency portion is
3 nominally three microns.

1 14. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 12,
2 wherein said pair of conductors of said high frequency portion comprise a gold flash;
3 and
4 wherein said gold flash of said pair of conductors of said high frequency portion is
5 disposed on said copper of said pair of conductors of said high frequency portion.

1 15. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 7,
2 wherein said circumferential slot is constantly maintained in said high frequency
3 portion;
4 wherein said circumferential slot extends completely through said high frequency
5 portion without destroying said unterminated multi-layer capacitor of said low
6 frequency portion;
7 wherein said circumferential slot extends completely around said high frequency
8 portion; and
9 wherein said circumferential slot electrically separates exposed opposing ends of said
10 orientation-insensitive ultra-wideband coupling capacitor from each other restoring
11 capacitance thereto.

- 1 16. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 15,
2 wherein said circumferential slot is disposed substantially midway between said
3 exposed opposing ends of said orientation-insensitive ultra-wideband coupling
4 capacitor.
- 1 17. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 7,
2 wherein said circumferential slot is nominally 1.5 mil wide.
- 1 18. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 15;
2 further comprising a quick curing protective UV-curable solder dam coating; and
3 wherein said quick curing protective UV-curable solder dam coating covers all
4 surfaces defining said circumferential slot to protect said circumferential slot.
- 1 19. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 18;
2 further comprising a plating;
3 wherein said plating covers said exposed opposing ends of said plurality of external
4 surfaces of said orientation-insensitive ultra-wideband coupling capacitor so as to form
5 solderable connections; and
6 wherein said solderable connections extend up to said protective UV-curable solder
7 dam coating which acts as a stop-off barrier for said solderable connections.
- 1 20. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 19,
2 wherein said orientation-insensitive ultra-wideband coupling capacitor has a resistance
3 across said solderable connections of at least 100 MegOhms.

21. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 19, wherein said plating is one of pure tin, solder, and gold.
22. An improved orientation-insensitive ultra-wideband coupling capacitor of the type having a plurality of external surfaces, a low frequency portion, and a high frequency portion, wherein said improvement comprises:
 - the high frequency portion being so disposed on, and electrically connected to, the low frequency portion so as to allow said improved ultra-wideband coupling capacitor to work identically when mounted on any external longitudinal surface of the plurality of external surfaces thereof.
23. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in claim 22, wherein said improvement comprises said improved orientation-insensitive ultra- wideband coupling capacitor operating in a range from below 20 KHz to over 40 GHz.
24. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in claim 22, wherein said improvement comprises the low frequency portion being functionally equivalent to a high value capacitor and the high frequency portion being functionally equivalent to a low value capacitor so as to allow said improved orientation-insensitive ultra- wideband coupling capacitor to have functions of both the high value capacitor and the low value capacitor solely in a single multi-layer ceramic body.

- 1 25. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 22, wherein said improvement comprises the low frequency portion being
3 functionally equivalent to a multi-layer capacitor and the high frequency portion being
4 functionally equivalent to a single layer capacitor so as to allow said improved
5 orientation-insensitive ultra-wideband coupling capacitor to have functions of both the
6 multi-layer capacitor and the single layer capacitor solely in a single multi-layer
7 ceramic body.
- 1 26. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 22, wherein said improvement comprises the low frequency portion being an
3 unterminated multi-layer capacitor;
4 wherein said improvement comprises said unterminated multi-layer capacitor of the
5 low frequency portion having external surfaces;
6 wherein said improvement comprises said unterminated multi-layer capacitor of the
7 low frequency portion having electrode layers;
8 wherein said improvement comprises said unterminated multi-layer capacitor of the
9 low frequency portion having dielectric layers;
10 wherein said improvement comprises said dielectric layers of said unterminated multi-
11 layer capacitor of the low frequency portion alternating with said electrode layers of
12 said unterminated multi-layer capacitor of the low frequency portion; and
13 wherein said improvement comprises said electrode layers of said unterminated multi-
14 layer capacitor of the low frequency portion extend at first ends thereof from, and are
15 open for external electrical communication from, opposing ends of said external
16 surfaces of said unterminated multi-layer capacitor of the low frequency portion, to
17 second ends thereof which alternatingly stop short of said opposing ends of said

18 external surfaces of said unterminated multi-layer capacitor of the low frequency
19 portion opposite to that from which they extend so as not to be open for external
20 electrical communication therefrom.

1 27. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 26, wherein said improvement comprises said unterminated multi-layer capacitor
3 of the low frequency portion being at least 10 nF.

1 28. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 26, wherein said improvement comprises the high frequency portion being a pair
3 of conductors;
4 wherein said improvement comprises said pair of conductors of the high frequency
5 portion covering said opposing ends of said external surfaces of said unterminated
6 multi-layer capacitor of the low frequency portion, respectively; and
7 wherein said improvement comprises said pair of conductors of the high frequency
8 portion extending from said opposing ends of said external surfaces of said
9 unterminated multi-layer capacitor of the low frequency portion, respectively, over said
10 external surfaces of said unterminated multi-layer capacitor of the low frequency
11 portion, to just short of each other so as to form a circumferential slot therebetween
12 and be separate from each other.

1 29. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 22, wherein said improvement comprises the high frequency portion not
3 employing additional internal electrodes with separating dielectric layers and thereby
4 having less insertion and return losses.

1 30. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 28, wherein said improvement comprises said pair of conductors of the high
3 frequency portion forming the plurality of external surfaces of said improved
4 orientation-insensitive ultra-wideband coupling capacitor; and
5 wherein said improvement comprises said pair of conductors of the high frequency
6 portion electrically communicating with said first ends of said electrode layers of said
7 unterminated multi-layer capacitor of the low frequency portion associated therewith
8 so as to allow said improved orientation-insensitive ultra-wideband coupling capacitor
9 to work identically when mounted on any external longitudinal surface of the plurality
10 of external surfaces thereof.

1 31. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 28, wherein said improvement comprises a set of coupled transmission lines
3 being formed on the plurality of external surfaces of said improved orientation-
4 insensitive ultra-wideband coupling capacitor between said pair of conductors of the
5 high frequency portion and said electrode layers contained in said unterminated multi-
6 layer capacitor of the low frequency portion so as to allow low frequency energy to
7 pass through the low frequency portion, which is centrally located, and allow high
8 frequency energy to pass through the high frequency portion, which is peripherally
9 located.

1 32. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 28, wherein said improvement comprises said pair of conductors of the high
3 frequency portion comprising titanium-tungsten.

- 1 33. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 32, wherein said improvement comprises said pair of conductors of the high
3 frequency portion comprising copper; and
4 wherein said improvement comprises said copper of said pair of conductors of the
5 high frequency portion being disposed on said titanium-tungsten of said pair of
6 conductors of the high frequency portion.
- 1 34. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 33, wherein said improvement comprises said copper of said pair of conductors
3 of the high frequency portion being nominally three microns.
- 1 35. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 33, wherein said improvement comprises said pair of conductors of the high
3 frequency portion comprising a gold flash; and
4 wherein said improvement comprises said gold flash of said pair of conductors of the
5 high frequency portion being disposed on said copper of said pair of conductors of the
6 high frequency portion.
- 1 36. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 28, wherein said improvement comprises said circumferential slot being
3 constantly maintained in the high frequency portion;
4 wherein said improvement comprises said circumferential slot extending completely
5 through the high frequency portion without destroying said unterminated multi-layer
6 capacitor of the low frequency portion;

7 wherein said improvement comprises said circumferential slot extending completely
8 around the high frequency portion; and
9 wherein said improvement comprises said circumferential slot electrically separating
10 exposed opposing ends of said improved orientation-insensitive ultra-wideband
11 coupling capacitor from each other restoring capacitance thereto.

1 37. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 36, wherein said improvement comprises said circumferential slot being
3 disposed substantially midway between said exposed opposing ends of said improved
4 orientation-insensitive ultra-wideband coupling capacitor.

1 38. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 28, wherein said improvement comprises said circumferential slot being
3 nominally 1.5 mil wide.

1 39. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 36, wherein said improvement comprises a quick curing protective UV-curable
3 solder dam coating; and
4 wherein said improvement comprises said quick curing protective UV-curable solder
5 dam coating covering all surfaces defining said circumferential slot to protect said
6 circumferential slot.

1 40. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 39, wherein said improvement comprises a plating;

3 wherein said improvement comprises said plating covering said exposed opposing
4 ends of said plurality of external surfaces of said improved orientation-insensitive
5 ultra-wideband coupling capacitor so as to form solderable connections; and
6 wherein said improvement comprises said solderable connections extending up to said
7 protective UV-curable solder dam coating which acts as a stop-off barrier for said
8 solderable connections.

1 41. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 40, wherein said improvement comprises said improved orientation-insensitive
3 ultra-wideband coupling capacitor having a resistance across said solderable
4 connections of at least 100 MegOhms.

1 42. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 40, wherein said improvement comprises said plating being one of pure tin,
3 solder, and gold.

4 43. A method of making an orientation-insensitive ultra-wideband coupling capacitor,
5 comprising the steps of:
6 a) securing an unterminated multi-layer capacitor of a low frequency portion of
7 the orientation-insensitive ultra-wideband coupling capacitor;
8 b) coating completely the unterminated multi-layer capacitor of the low frequency
9 portion with an adhesion layer having opposing ends.
10 c) creating a circumferential slot around the adhesion layer and thereby
11 electrically separating the opposing ends of the adhesion layer from each other
12 restoring capacitance and forming a slotted body;

- 13 d) applying a solder dam coating to all surfaces defining the circumferential slot
14 to protect the circumferential slot; and
15 e) plating the opposing ends of the adhesion layer so as to form solderable
16 connections and thereby form the orientation-insensitive ultra-wideband
17 coupling capacitor.

1 44. The method as defined in claim 43; further comprising the step of soaking the slotted
2 body if said circumferential slot was created by laser scribing to eliminate a residue
3 film of vaporized metal redeposited into the circumferential slot after the laser
4 scribing.

1 45. The method as defined in claim 43; further comprising the step of soaking
2 prolongingly the slotted body if said circumferential slot was created by laser scribing
3 to eliminate a residue film of vaporized metal redeposited into the circumferential slot
4 after the laser scribing.

1 46. The method as defined in claim 43; further comprising the step of soaking the slotted
2 body in highly diluted hydrogen peroxide if said circumferential slot was created by
3 laser scribing to eliminate a residue film of vaporized metal redeposited into the
4 circumferential slot after the laser scribing step.

1 47. The method as defined in claim 43, wherein said coating step includes coating
2 completely the unterminated multi-layer capacitor of the low frequency portion with
3 titanium-tungsten.

- 1 48. The method as defined in claim 43, wherein said coating step includes coating
2 completely the unterminated multi-layer capacitor of the low frequency portion with
3 titanium-tungsten followed by copper.
- 1 49. The method as defined in claim 43, wherein said coating step includes coating
2 completely the unterminated multi-layer capacitor of the low frequency portion with
3 titanium-tungsten followed by nominally three microns of copper.
- 1 50. The method as defined in claim 43, wherein said coating step includes coating
2 completely the unterminated multi-layer capacitor of the low frequency portion with
3 titanium-tungsten followed by copper and a gold flash.
- 1 51. The method as defined in claim 43, wherein said creating step includes laser scribing
2 a circumferential slot .
- 1 52. The method as defined in claim 43, wherein said creating step includes creating a
2 circumferential slot nominally 1.5 mil wide.
- 1 53. The method as defined in claim 43, wherein said creating step includes creating a
2 circumferential slot maintained constantly in, completely through, and completely
3 around, the adhesion layer.
- 1 54. The method as defined in claim 43, wherein said creating step includes creating a
2 circumferential slot substantially midway between the opposing ends of the adhesion
3 layer.

55. The method as defined in claim 43, wherein said applying step includes applying a quick curing protective UV-curable solder dam coating to all surfaces defining the circumferential slot to protect the circumferential slot.
56. The method as defined in claim 43, wherein said plating step includes plating the opposing ends of the adhesion layer with one of pure tin, solder, and gold so as to form solderable connections.
57. The method as defined in claim 56, wherein said plating step includes plating the opposing ends of the adhesion layer so as to form solderable connections up to the quick-curing protective UV-curable solder dam coating which acts as a stop-off barrier for the solderable connections.
58. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 1, wherein said orientation-insensitive ultra- wideband coupling capacitor operates below 16 KHz.
59. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in claim 22, wherein said improvement comprises said improved orientation-insensitive ultra- wideband coupling capacitor operating below 16 KHz.
60. The orientation-insensitive ultra-wideband coupling capacitor as defined in claim 7, wherein said high frequency portion does not employ a composite internal interdigital

3 electrode array as a single floating electrode that is coupled to said pair of conductors
4 of said high frequency portion and thereby has less insertion and return losses.

1 61. The improved orientation-insensitive ultra-wideband coupling capacitor as defined in
2 claim 28, wherein said improvement comprises the high frequency portion not
3 employing a composite internal interdigital electrode array as a single floating
4 electrode that is coupled to said pair of conductors of said high frequency portion and
5 thereby has less insertion and return losses.

1 62. The method as defined in claim 43, wherein said creating step includes one of laser-
2 scribing, chemical etching, and mechanical abrading a circumferential slot around the
3 adhesion layer and thereby electrically separating the opposing ends of the adhesion
4 layer from each other restoring capacitance and forming a slotted body.