



US 20180076510A1

(19) **United States**

(12) **Patent Application Publication**  
**KITCHENER et al.**

(10) **Pub. No.: US 2018/0076510 A1**

(43) **Pub. Date: Mar. 15, 2018**

(54) **FABRIC ANTENNA**

**Publication Classification**

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(51) **Int. Cl.**  
*H01Q 1/27* (2006.01)  
*D02G 3/44* (2006.01)  
*H01Q 1/22* (2006.01)  
*A41D 27/00* (2006.01)  
(52) **U.S. Cl.**  
CPC ..... *H01Q 1/273* (2013.01); *D02G 3/44* (2013.01); *A41D 27/00* (2013.01); *H01Q 1/27* (2013.01); *H01Q 1/22* (2013.01)

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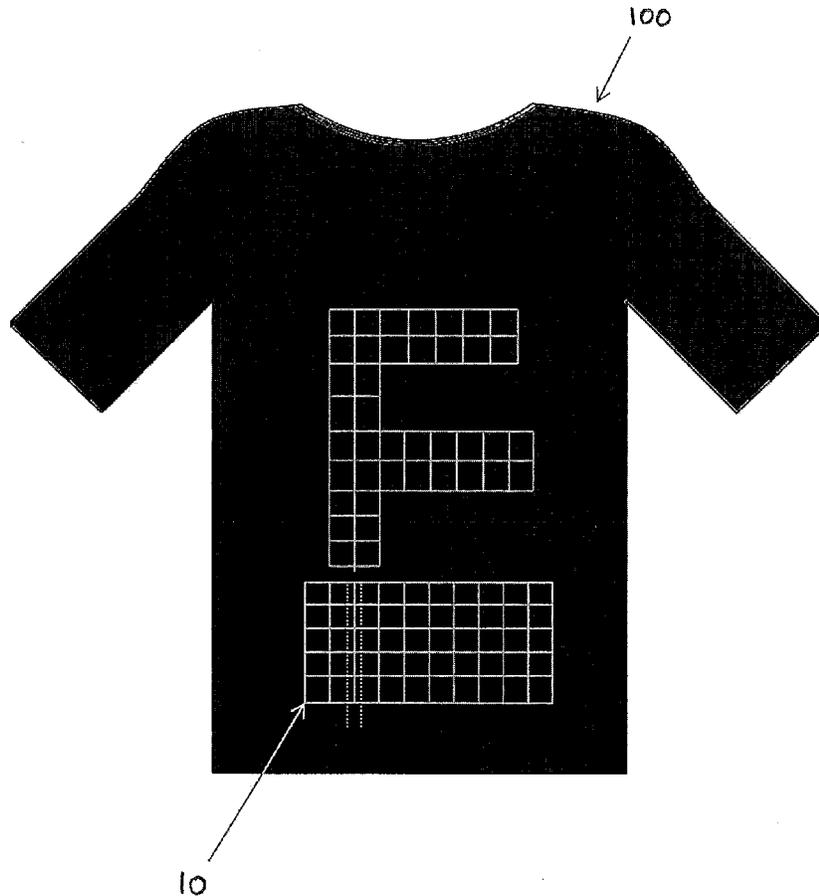
(57) **ABSTRACT**

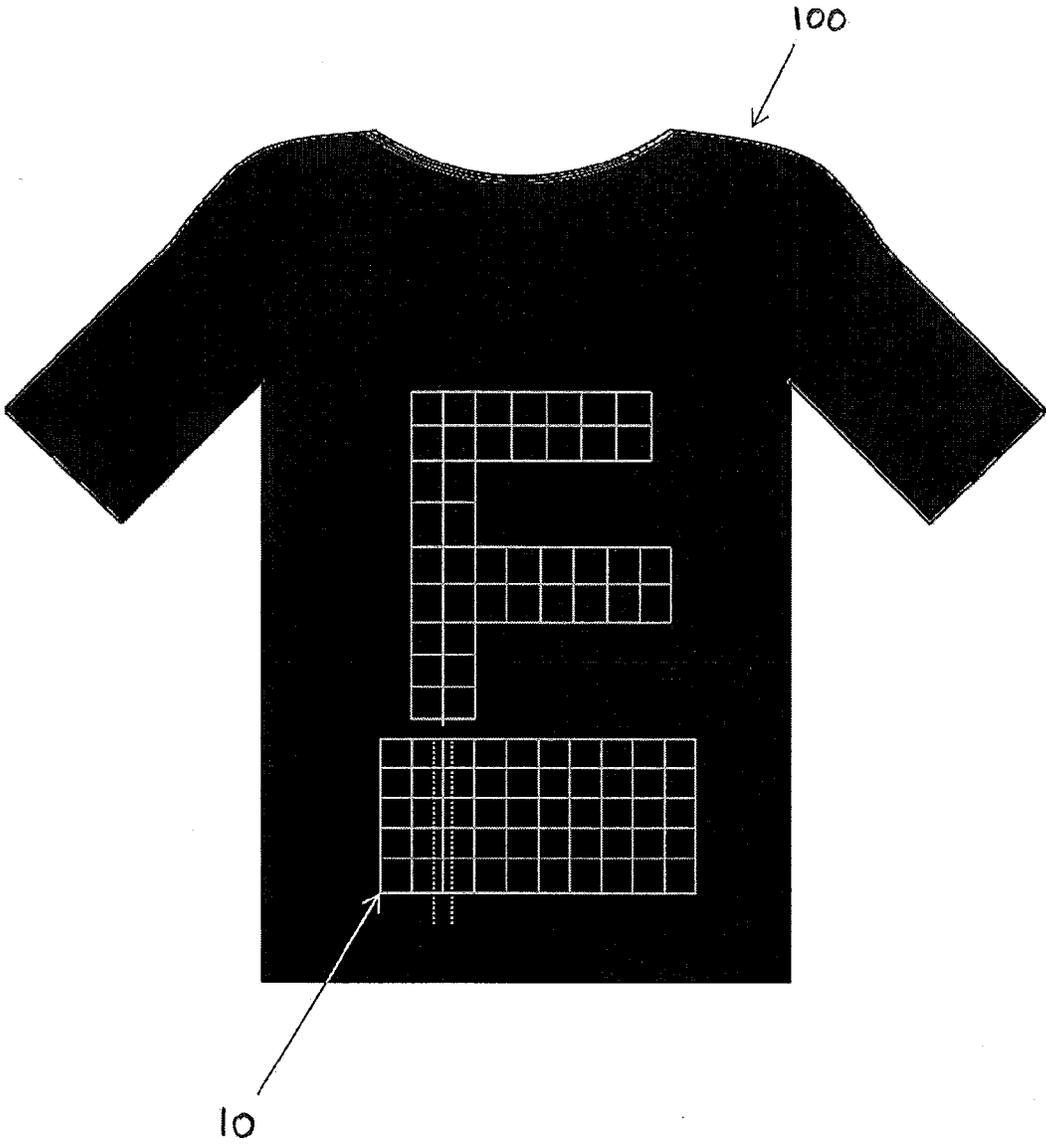
(21) Appl. No.: **15/558,930**  
(22) PCT Filed: **Mar. 11, 2016**  
(86) PCT No.: **PCT/GB2016/050671**  
§ 371 (c)(1),  
(2) Date: **Sep. 15, 2017**

A fabric antenna for telecommunications is disclosed. The fabric antenna comprises a host yarn, which is substantially electrically non-conducting, and an antenna yarn, which is substantially electrically conducting. The host yarn and antenna yarn are knitted together to form a host fabric comprising an antenna grid. The antenna grid comprises a plurality of intersecting antenna tracks formed of antenna yarn. The tracks are separated by regions of the host fabric and are electrically coupled together at the regions where the tracks intersect.

(30) **Foreign Application Priority Data**

Mar. 18, 2015 (GB) ..... 1504629.5  
Apr. 21, 2015 (EP) ..... 15275123.6





**Figure 1**

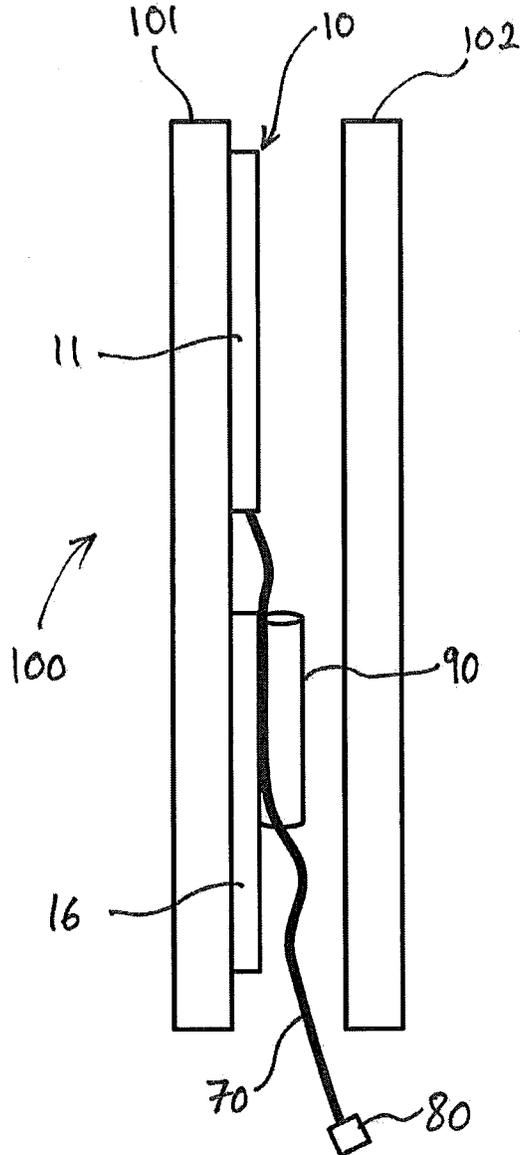


Figure 2

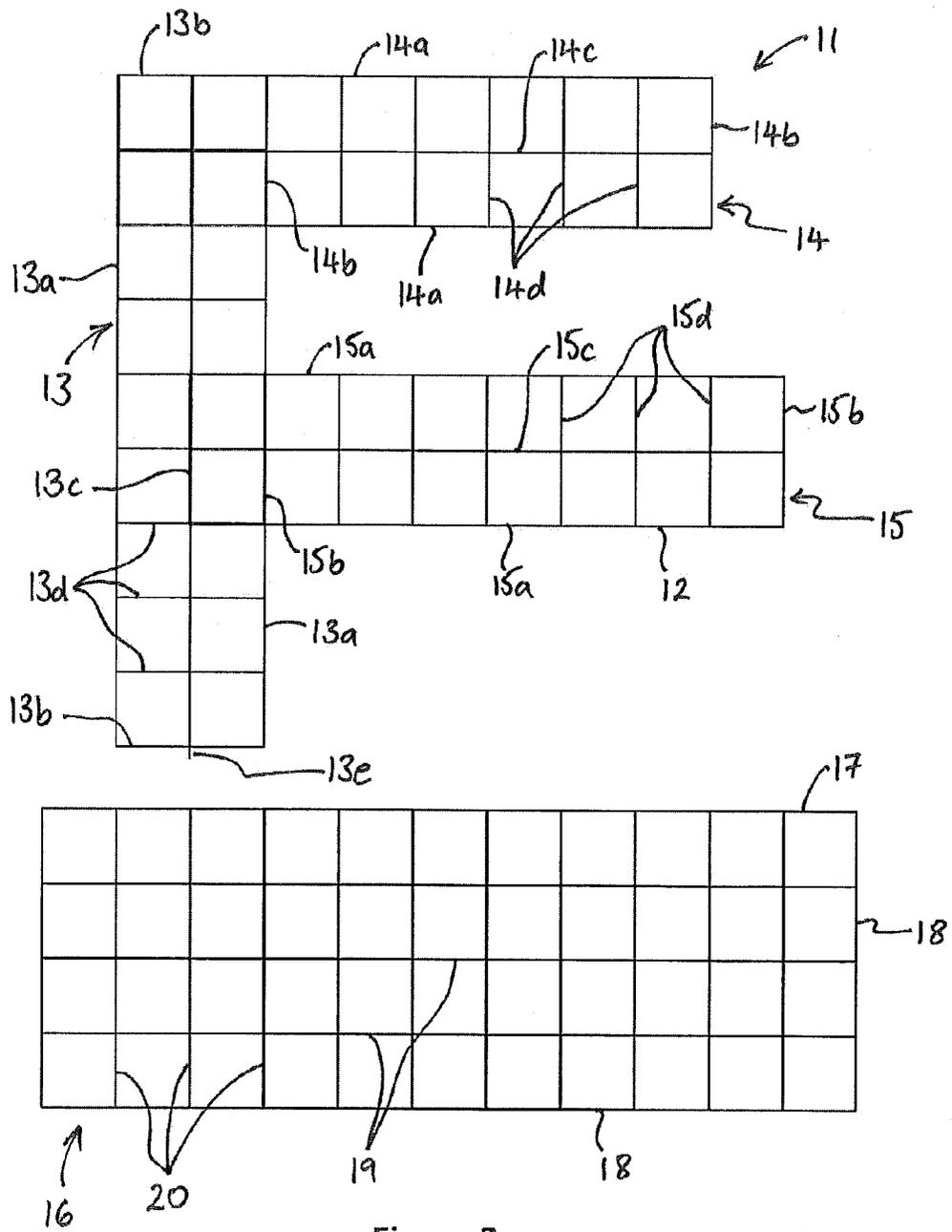


Figure 3

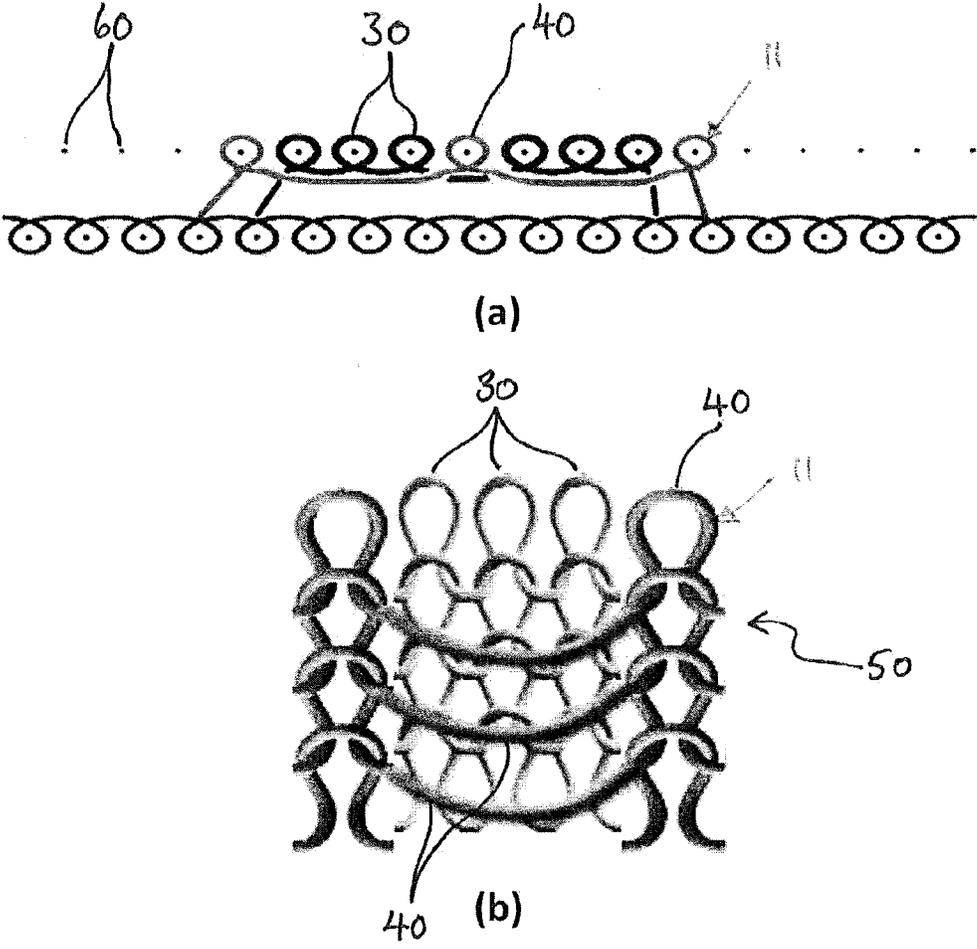


Figure 4

**FABRIC ANTENNA**

**[0001]** The present invention relates to a fabric antenna.

**[0002]** It is known to provide a garment with an antenna, such that the antenna can be worn by a user. Such antennas include an electrically conductive sheet, such as a Nora Dell sheet material, which may be ironed onto the surface of a t-shirt, for example. However, it is often difficult to electrically couple the sheet with a communications cable for enabling communications using the antenna. In addition, the sheet material has a relatively high optical reflectivity, which reduces the covertness of the garment. It is also found that the sheet material lacks sufficient strength to be suitably sewn onto a garment and degrades during washing of the garment or normal wear and tear expected of such a garment.

**[0003]** According to a first aspect of the present invention there is provided a fabric antenna for communications, the fabric antenna comprising a host yarn, which is substantially electrically non-conducting, and an antenna yarn, which is substantially electrically conducting, the host yarn and antenna yarn being knitted together to form a host fabric formed of host yarn comprising an antenna grid formed of antenna yarn, the antenna grid comprising a plurality of intersecting antenna tracks, the tracks being separated by regions of the host yarn, the tracks of the antenna grid being electrically coupled together at the regions where the tracks intersect.

**[0004]** Advantageously, the grid nature of the antenna provides for an increased flexibility in the fabric, whereas the knitted form of the antenna yarn with the host yarn provides for a secure coupling of the antenna with the host fabric which can be subsequently sewn onto a garment, for example.

**[0005]** In an embodiment, the antenna grid comprises a plurality of grid sections, each section comprising a first and second side track and a first and second end track which separately extend between opposite ends of the first and second side tracks to form a closed periphery of the grid section. Each section further comprises a central track which extends along a central axis of the respective grid section and a plurality of intermediate cross tracks which extend across the central track, between side tracks.

**[0006]** Preferably, the end tracks and cross tracks are electrically coupled to each side track and the central track, and the grid sections are electrically coupled to each other. It is envisaged that the electrical coupling may be formed by the intimate contact of the knitted antenna yarn at the intersecting points.

**[0007]** In an embodiment, each grid section comprises a rectangular periphery and the grid sections are configured within the host fabric to form an F-shaped antenna grid.

**[0008]** In an embodiment, the antenna tracks of the antenna grid comprise a square arrangement of intersecting tracks.

**[0009]** In an embodiment, the antenna tracks may comprise a course or wale of knitted stitches in the host fabric. The number of knitted stitches of host yarn per unit length of the fabric is preferably greater than the number of knitted stitches of antenna yarn per unit length of fabric. The reduced number of stitches of antenna yarn provides for a more flexible fabric and reduces the length of antenna yarn required to create the antenna.

**[0010]** In an embodiment, one or more of the antenna tracks may be formed by two or more adjacent courses or wales of knitted stitches.

**[0011]** The fabric antenna further comprises an antenna ground, which comprises a ground grid formed of ground yarn which is substantially electrically conducting, the ground yarn and host yarn being knitted together to form a host fabric comprising the antenna ground.

**[0012]** The ground yarn and host yarn may be knitted together to form a single layer of host fabric. Thereby, providing a thinner antenna ground that is less bulky and which is more comfortable for a user to wear.

**[0013]** In an embodiment, the ground grid is knitted adjacent the antenna grid and comprises a plurality of intersecting ground tracks, similar to the antenna grid.

**[0014]** The ground grid comprises a closed periphery of ground tracks and a plurality of longitudinal and lateral ground tracks which extend within the periphery to form a square arrangement of intersecting ground tracks. The peripherally extending ground tracks, longitudinal ground tracks and lateral ground tracks are preferably electrically coupled together at the regions of intersection.

**[0015]** In an embodiment, the ground tracks may comprise a course or wale of knitted stitches in the host fabric. The number of knitted stitches of host yarn per unit length of the fabric is preferably greater than the number of knitted stitches of ground yarn per unit length of fabric. The reduced number of stitches of ground yarn similarly provides for a more flexible fabric and reduces the length of ground yarn required to create the antenna ground.

**[0016]** Preferably, the antenna grid and ground grid extend in substantially the same plane.

**[0017]** In an embodiment, one or more of the ground tracks may be formed by two or more adjacent courses or wales of knitted stitches.

**[0018]** In an embodiment, the antenna yarn and/or ground yarn comprises AmberStrand®.

**[0019]** The fabric antenna may comprise a lining to a garment, such as a jumper or t-shirt or be incorporated with a power and data distribution harness arranged to be worn on a user's body or incorporated within a tactical vest for wearing by a user, such that the garment may form a body worn antenna.

**[0020]** At least one track of the antenna grid preferably extends beyond the periphery of the antenna grid and terminates at a connector for connecting the antenna grid to a communications cable, for example a coaxial cable. The communications cable may extend to a communications module held within a bag which may be carried by a wearer of the fabric antenna, for example. Alternatively, the communication cable may extend to a power and/or data distribution harness to be worn by a user such that the antenna is connected to a communications module via the communication cable and distribution harness. The harness may be incorporated within a tactical vest to be worn by a user.

**[0021]** The antenna yarn and host yarn may be knitted together to form a single layer of host fabric. Thereby providing a thinner fabric antenna that is less bulky and which is more comfortable for a user to wear.

**[0022]** The intersecting antenna tracks may be arranged to form a single antenna element. Such that the fabric may comprise a single antenna element with a ground plane that is in substantially the same plane as the single antenna element.

[0023] According to a second aspect of the present invention there is provided a garment comprising an outer layer of fabric material and a lining comprising a fabric antenna of the first aspect.

[0024] In an embodiment, the garment further comprises a pocket for supporting a communications cable which is used for connecting the fabric antenna to a communications module.

[0025] In an embodiment, the pocket is disposed on an interior side of the garment, such as upon the lining.

[0026] Whilst the invention has been described above, it extends to any inventive combination of features set out above or in the following description. Although illustrative embodiments of the invention are described in detail herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to these precise embodiments.

[0027] Furthermore, it is contemplated that a particular feature described either individually or as part of an embodiment can be combined with other individually described features, or parts of other embodiments, even if the other features and embodiments make no mention of the particular feature. Thus, the invention extends to such specific combinations not already described.

[0028] The invention may be performed in various ways, and, by way of example only, embodiments thereof will now be described, reference being made to the accompanying drawings in which:

[0029] FIG. 1 is a front view of a t-shirt showing the location of a fabric antenna according to an embodiment of the present invention;

[0030] FIG. 2 is schematic side view of the t-shirt illustrated in FIG. 1, as worn by a user;

[0031] FIG. 3 is a view of the antenna grid and ground grid of the fabric antenna;

[0032] FIG. 4a is a schematic illustration of the stitches associated with the host yarn and the antenna or ground yarn of the fabric antenna; and,

[0033] FIG. 4b is a magnified view of a portion of the fabric antenna, illustrating the stitches of the host yarn and antenna yarn.

[0034] Referring to FIGS. 1 and 2 of the drawings, there is illustrated a fabric antenna 10 according to an embodiment of the present invention secured upon a garment 100, according to an embodiment of the present invention, for enabling communication with a third party (not shown) over a VHF (very high frequency) or UHF (ultra high frequency) range. The fabric antenna 10 illustrated in FIGS. 1 and 2 is disposed at an interior side of the garment so that the fabric antenna 10 is not readily visible and thus substantially concealed and/or protected by the outer fabric 101 of the garment (the fabric antenna 10 has been shown in FIG. 1 to illustrate the location of the antenna upon the garment). In this respect, the fabric antenna 10 may be sewn or bonded along an interior of the garment 100 and thus form a lining thereof, or may be sandwiched between an inner and outer layer 101, 102 of the garment 100.

[0035] Referring to FIGS. 4a and 4b, the fabric antenna 10 is formed by knitting together a host yarn 30, such as cotton which is substantially electrically non-conductive and an antenna yarn 40, such as AmberStrand® (as provided by Syscom Advanced Materials Inc. of Columbus, Ohio) or Statex (as provided by Statex Engineering (P) Ltd of Tamilnadu, India), which is substantially electrically conductive,

to form a fabric 50 comprising the antenna 11. The knitted structure is formed by feeding the host yarn 30 and antenna yarn 40 into needles 60, shown in cross section in FIG. 4a, to create a series of knitted loops (as illustrated in FIG. 4b of the drawings). The loops which extend horizontally across the fabric form the so-called courses within the fabric 50, whereas the loops which extend vertically between adjacent courses form the wales within the fabric 50.

[0036] Like weaving, knitting is a technique for producing a two-dimensional fabric made from a yarn or thread. In weaving, threads are always straight, running parallel either lengthwise (warp) or crosswise (weft). By contrast, the yarn in knitted fabrics follows a meandering path (course), forming substantially symmetric loops (bights) which are substantially symmetrically above and below the mean path of the yarn. These meandering loops (wales) can be easily stretched in different directions giving knit fabrics much more elasticity than woven fabrics.

[0037] Referring to FIG. 3, the antenna 11 formed within the fabric 50 comprises an antenna grid 12 having a plurality of antenna tracks formed of antenna yarn 40 which extend along courses and wales within the fabric 50. The antenna grid 12 comprises three rectangular grid sections 13, 14, 15 which are orientated to form an F-shaped antenna 11.

[0038] The grid sections 13, 14, 15 separately comprise opposite side and end tracks 13a, 13b, 14a, 14b, 15a, 15b which are electrically coupled to form a substantially rectangular shaped periphery. In an embodiment, the outer periphery of the grid section 13 which forms the vertical portion of the F-shape comprises the largest (length×width) dimension of approximately 250×60 mm. In contrast, the outer periphery of the upper horizontal grid section 14 of the F-shape comprises a dimension of approximately 160×60 mm, whereas the outer periphery of the lower horizontal grid section 15 comprises a dimension of approximately 180×60 mm.

[0039] Each grid section 13, 14, 15 further comprises a central track 13c, 14c, 15c which extends along a central axis, such as the longitudinal axis of the grid section 13, 14, 15, and a plurality of cross tracks 13d, 14d, 15d which extend across the grid section 13, 14, 15 between opposite side tracks 13a, 14a, 15a. The end tracks 13b, 14b, 15b and cross tracks 13d, 14d, 15d are electrically coupled to each side track 13a, 14a, 15a and central track 13c, 14c, 15c by virtue of the intimate contact of the antenna yarn 30 at the intersections thereof. Moreover, the tracks 13a-d, 14a-d, 15a-d associated with each grid section 13, 14, 15 are electrically coupled together, such that an electrical signal which is to be communicated from the antenna 11 or received at the antenna 11, can access all of the tracks 13a-d, 14a-d, 15a-d of the antenna grid 12. However, the skilled reader will recognise that other antenna grids 12 forming other shapes may alternatively be used.

[0040] The electrical resistance of the antenna grid 12 is found to be different along the courses as opposed to along the wales of the fabric 50. This is because the resistance along a single course of antenna yarn 40 within the fabric 50 is determined by the resistance of the antenna yarn alone, whereas the resistance along a wale will also be influenced by the electrical coupling between adjacent courses of the antenna yarn 40. To improve the performance of the antenna 11, it is found that a lower resistance is required in the vertical direction, and so the F-shaped antenna grid is formed in a rotated configuration, namely a ¼ anticlockwise

turn, so that the courses in the fabric **50** extend between the top and bottom of the F-shape.

**[0041]** The fabric antenna **10** further comprises an antenna ground **16** which is formed by knitting ground yarn (not shown), which may be the same as the antenna yarn **40**, with the host yarn **30**. The antenna ground **16** formed within the fabric **50** comprises a ground grid **17** having a periphery of ground tracks **18** and a plurality of longitudinal and lateral ground tracks **19, 20** which extend within the periphery **18** to form a square arrangement of intersecting ground tracks **18, 19, 20**. The ground tracks **18, 19, 20** are formed of ground yarn (not shown) which extend along courses and wales within the fabric **50** and the peripherally extending ground tracks **18**, longitudinal ground tracks **19** and lateral ground tracks **20** are preferably electrically coupled together at the regions of intersection.

**[0042]** The antenna ground **16** is knitted into the host fabric such that the ground **16** is disposed below the antenna **11** when in use, and thus in substantially the same plane. The central track **13c** of the vertically orientated grid section **13** of the antenna grid **12** is arranged to extend beyond the periphery of the respective grid section **13** at the lower region thereof to form a tail **13e**.

**[0043]** The tail **13e** from the antenna grid **12** is coupled to a communications cable **70**, such as a coaxial cable. In this respect, the tail **13e** may be electrically coupled, such as via soldering to a proximal end of an inner conductor (not shown) of the coaxial cable. At least a portion of the outer conductor (not shown) of the coaxial cable is electrically coupled, such as via soldering and/or gluing directly to the one of the tracks of the ground grid. The distal end of the cable terminates at a connector **80**, such as an SMA (sub-miniature A) connector for electrically connecting the antenna **11** to a communications module (not shown), which may be disposed in a bag (not shown) carried by a user, for example, or in the alternative, incorporated with a power and/or data distribution harness or attached to a tactical vest, for example. The fabric antenna **10** may further comprise a pocket **90** for supporting the cable **70** and minimising any snagging of the cable **70** during use.

**[0044]** In the illustrated embodiment, the intersecting tracks **13a-d, 14a-d, 15a-d** of the antenna **11** and ground **16** are configured to a square grid, but the skilled reader will again recognise that other grid configurations may be used. Referring to FIGS. **4a** and **4b** of the drawings, the tracks of each grid **12, 17** may be separately formed by one or more adjacent courses or wales of antenna/ground yarn, such that the width of each track may be sized accordingly. The antenna yarn **40** and ground yarn (not shown) are knitted with the host yarn **30** according to a  $\frac{1}{3}$  knitting gauge whereby the antenna yarn **40** and ground yarn (not shown) are respectively looped around every fourth needle **60**, in contrast with the host yarn **30** which is looped around every needle **60**. In this respect, the antenna yarn **40** and ground yarn (not shown) are drooped between every fourth needle **60** and provide for a more flexible and thus wearable fabric **50**. Moreover, the reduced number of needle loops associated with the antenna yarn **40** and ground yarn (not shown) reduces the length of antenna yarn **40** and ground yarn (not shown) required and reduces distortion in the fabric **50** caused by the antenna yarn **40** and ground yarn (not shown).

**[0045]** It will be understood, that the grid structure of the antenna grid **12** and the ground grid **17** is to be contrast with conventional antenna designs that require continuous

metal surfaces for both antenna and ground elements. Thereby, the fabric antenna **10** benefits from a reduction in cost and weight when compared with a conventional continuous metal surface element. Furthermore, the antenna and ground grids **12** and **17** allow flexibility to the fabric **50**, thereby making the fabric **50** more comfortable to wear as the fabric **50** can stretch with a wearer's movements.

**[0046]** It will also be understood that the antenna grid **12** and ground grid **17** form a single layer with the fabric **50**; thereby the fabric **50** is thinner than conventional antenna structures.

**[0047]** The antenna grid **12** and ground grid **17** are arranged such that they are in the same plane with respect to one another, rather than in conventional solid metal surface antenna element structures that have a ground plane arranged in a parallel plane to the plane of the antenna element. Again, the arrangement of the present invention provides the fabric **50** with a thinner structure than a conventional antenna structure.

**[0048]** Furthermore, using a grid structure for the antenna grid **12** and ground grid **17** also means that conductive yarn does not need to be knitted into a complete filled structure to form the antenna and ground, respectively. This mitigates "rucking" of yarn material that tends to occur across a completely filled structure. It will be understood that "rucking" refers to the bunching of yarns such that the material does not appear to flat across the surface of the material.

1. A fabric antenna for telecommunications, the fabric antenna comprising a host yarn, which is substantially electrically non-conductive, and an antenna yarn, which is substantially electrically conductive, the host yarn and antenna yarn being knitted together to form a host fabric formed of host yarn comprising an antenna grid formed of antenna yarn, the antenna grid comprising a plurality of intersecting antenna tracks formed of antenna yarn, the tracks being separated by regions of the host yarn, the tracks of the antenna grid being electrically coupled together at the regions where the tracks intersect, wherein the antenna grid comprises a plurality of grid sections, one or more of the grid sections comprising a first and second side track and a first and second end track which separately extend between opposite ends of the first and second side tracks to form a closed periphery of the grid section.

2. The fabric antenna according to claim 1, wherein each grid section comprises a first and second side track and a first and second end track which separately extend between opposite ends of the first and second side tracks to form a closed periphery of the grid section.

3. The fabric antenna according to claim 2, wherein the grid sections are electrically coupled to each other.

4. The fabric antenna according to claim 1, wherein the antenna grid comprises an F-shape.

5. The fabric antenna according to claim 1, wherein the antenna tracks comprise a course or wale of knitted stitches in the host fabric.

6. The fabric antenna according to claim 5, wherein the number of knitted stitches of host yarn per unit length of the host fabric is greater than the number of knitted stitches of antenna yarn per unit length of the host fabric.

7. The fabric antenna according to claim 5, wherein one or more of the antenna tracks are formed by two or more adjacent courses or wales of knitted stitches.

8. The fabric antenna according to claim 1 further comprising an antenna ground, which comprises a ground grid

formed of ground yarn which is substantially electrically conductive, the ground yarn and host yarn being knitted together to form the host fabric comprising the antenna grid.

9. The fabric antenna according to claim 8, wherein the ground yarn and host yarn are knitted together to form a single layer of fabric.

10. The fabric antenna according to claim 8, wherein the ground grid is knitted adjacent the antenna grid and comprises a plurality of intersecting ground tracks.

11. The fabric antenna according to claim 8, wherein the ground grid comprises a closed periphery of ground tracks and a plurality of longitudinal and lateral ground tracks which extend within the periphery to form a square arrangement of intersecting ground tracks.

12. The fabric antenna according to claim 10, wherein the ground tracks comprise a course or wale of knitted stitches in the host fabric.

13. The fabric antenna according to claim 12, wherein the number of knitted stitches of host yarn per unit length of the host fabric is greater than the number of knitted stitches of ground yarn per unit length of the host fabric.

14. The fabric antenna according to claim 12, wherein one or more of the ground tracks are formed by two or more adjacent courses or wales of knitted stitches.

15. The fabric antenna according to claim 1, wherein the antenna yarn and host yarn are knitted together to form a single layer of host fabric.

16. The fabric antenna according to claim 1, wherein the intersecting antenna tracks are arranged to form a single antenna element.

17. The garment comprising an outer layer of fabric material and a lining comprising a fabric antenna according to claim 1.

18. The garment according to claim 17, further comprising a pocket for supporting a communications cable which is used for connecting the fabric antenna to a communications module.

19. A fabric antenna for telecommunications, the fabric antenna comprising a host yarn, which is substantially electrically non-conductive, and an antenna yarn, which is substantially electrically conductive, the host yarn and antenna yarn being knitted together to form a host fabric formed of host yarn comprising an antenna grid formed of antenna yarn, the antenna grid comprising a plurality of intersecting antenna tracks formed of antenna yarn, the tracks being separated by regions of the host yarn, the tracks of the antenna grid being electrically coupled together at the regions where the tracks intersect, wherein the antenna yarn and host yarn are knitted together to form a single layer of host fabric, and wherein the antenna grid comprises a plurality of grid sections, each grid section comprising a first and second side track and a first and second end track which separately extend between opposite ends of the first and second side tracks to form a closed periphery of the grid section.

20. The fabric antenna according to claim 19 further comprising an antenna ground, which comprises a ground grid formed of ground yarn which is substantially electrically conductive, the ground yarn and host yarn being knitted together to form the host fabric comprising the antenna grid.

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