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H1Q QAA QJC

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INT CL^7 **H01Q**
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(54) Abstract Title: **Multi-band antenna**

(57) The multi-band antenna comprises a substrate having first 5, second 7 and third 9 electrically conductive elements formed on a first surface. The first element 5 comprises a limb 5a defining an antenna terminal at a first end 5b, and having first and second fingers 5c, 5d extending from a second end of the limb and a third finger 5e extending from an intermediate portion of the limb. The second element 7 comprises a limb adjacent to and parallel to the intermediate portion of the first element limb. The third element 9 comprises a limb defining an intermediate antenna terminal 9b, first and second end portions 9c, 9d of the limb being adjacent and parallel the first and second element limbs respectively and connected together 9a at the first and second end portions adjacent the first end of the first element limb.

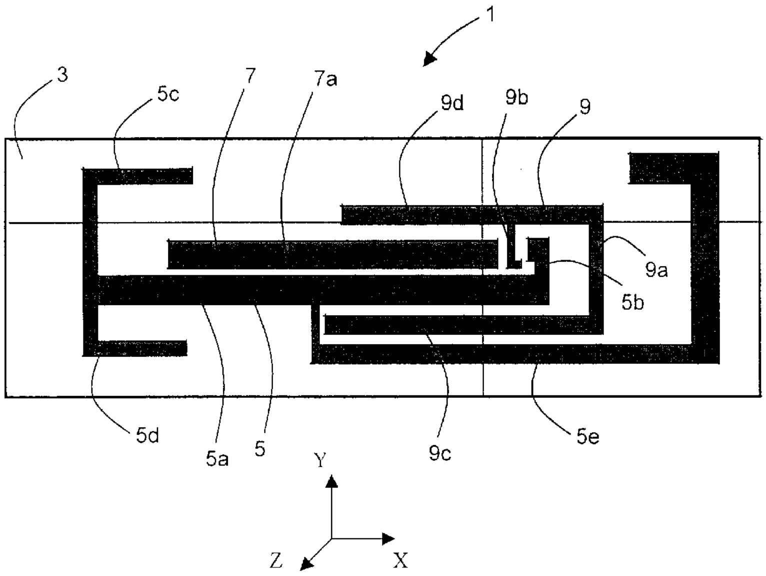


Fig. 1

GB 2 416 625 A

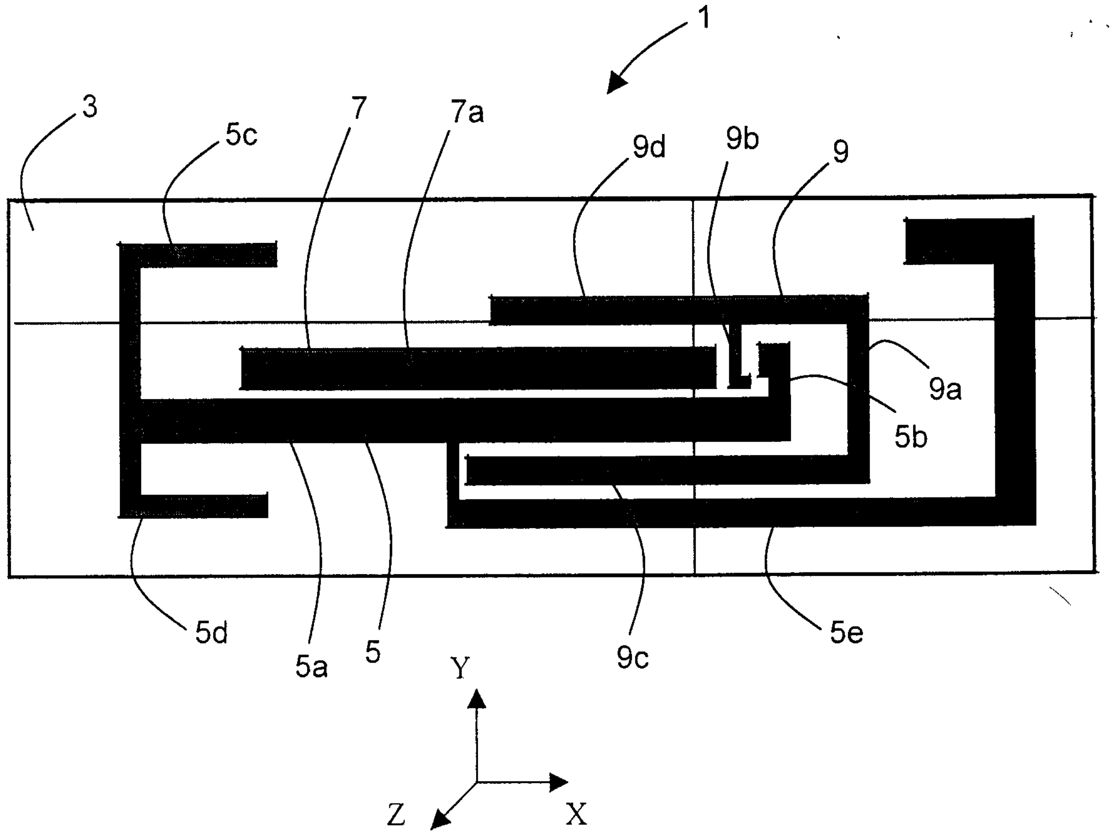
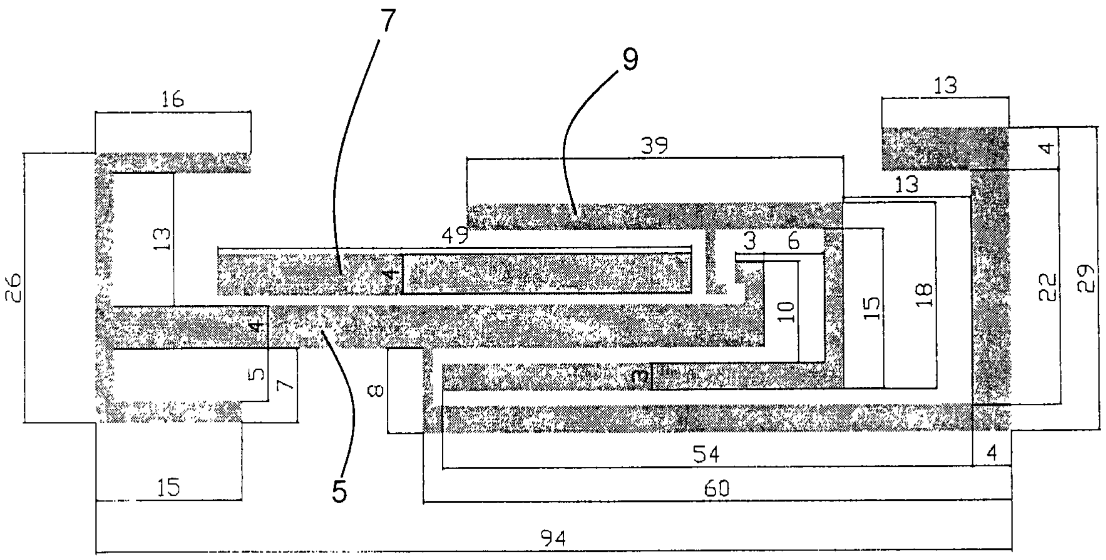

1
3
5c
7
7a
9d
9b
9
9a
5b
5d
5a
5
9c
5e
Y
Z
X

Fig. 1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60
94

Fig. 2

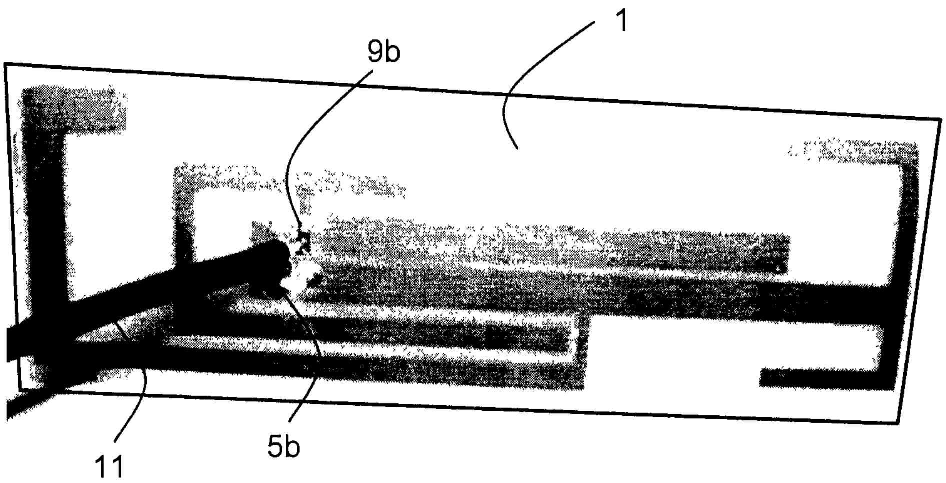

1
9b
11
5b

Fig. 3

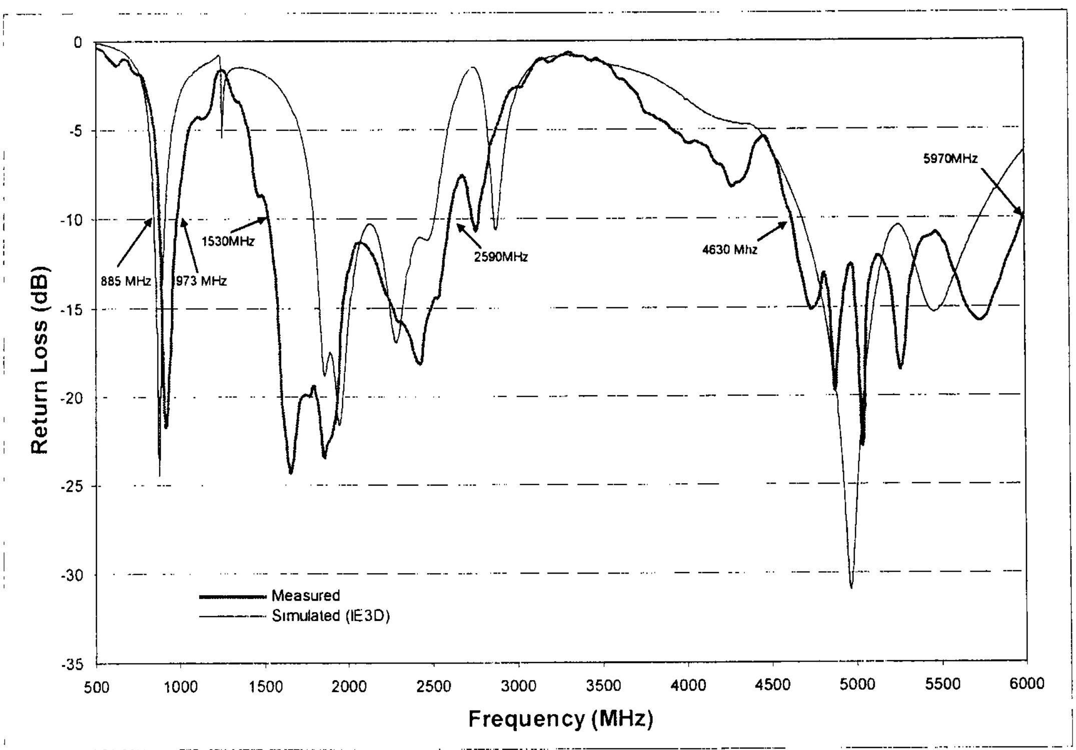

Return Loss (dB)
Frequency (MHz)
885 MHz
973 MHz
1530MHz
2590MHz
4630 Mhz
5970MHz
Measured
Simulated (IE3D)

Fig. 4

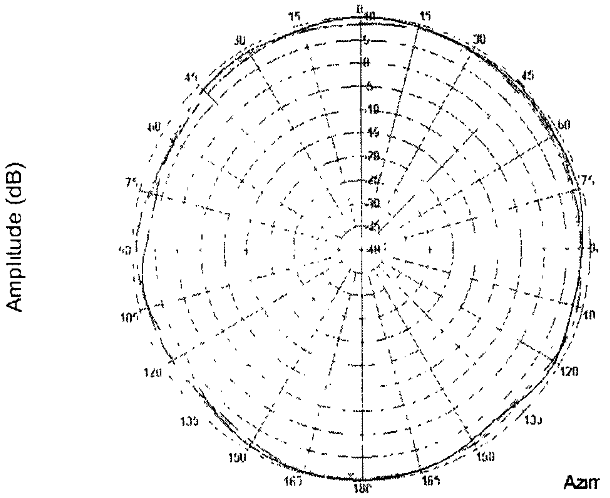


Fig. 5a

YZ plane

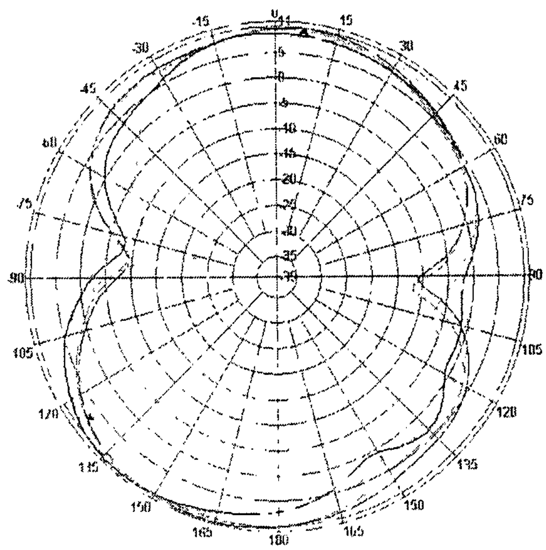


Fig. 5b

XZ plane

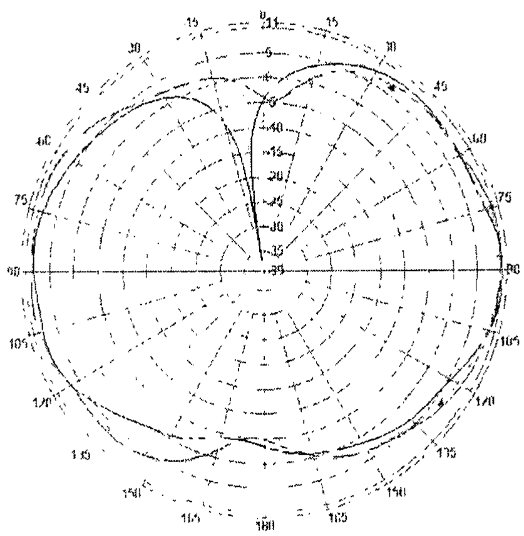


Fig. 5c

XY plane

Amplitude (dB)

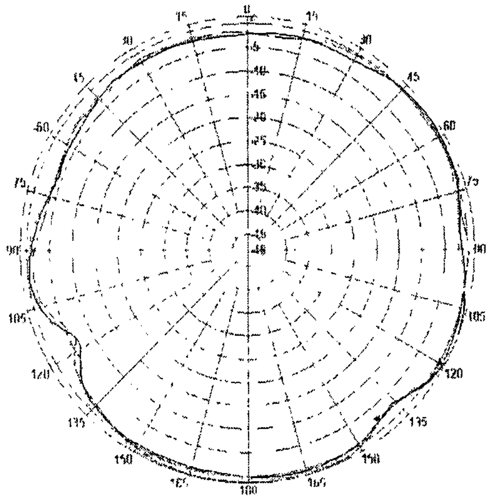
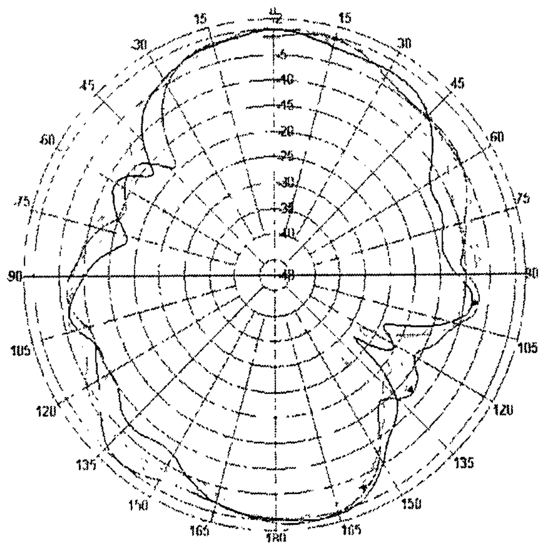


Fig. 6a

YZ plane

Fig. 6b

XZ plane



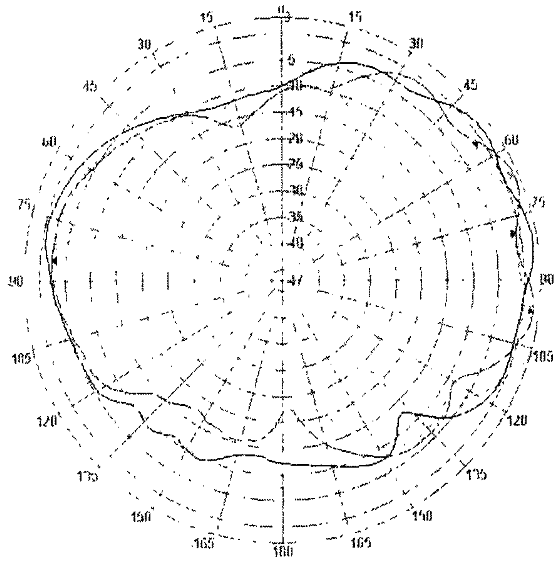


Fig. 6c

XY plane

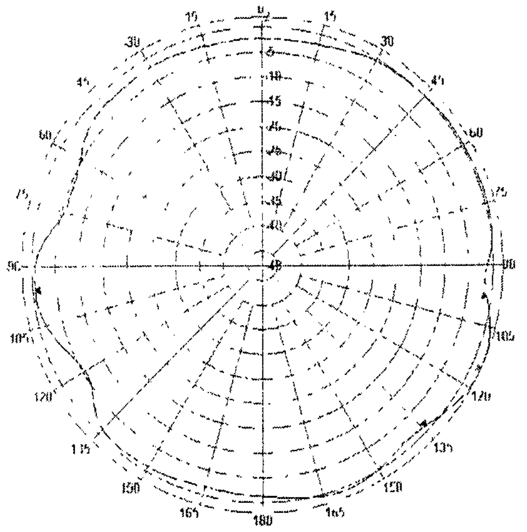


Fig. 7a

YZ plane

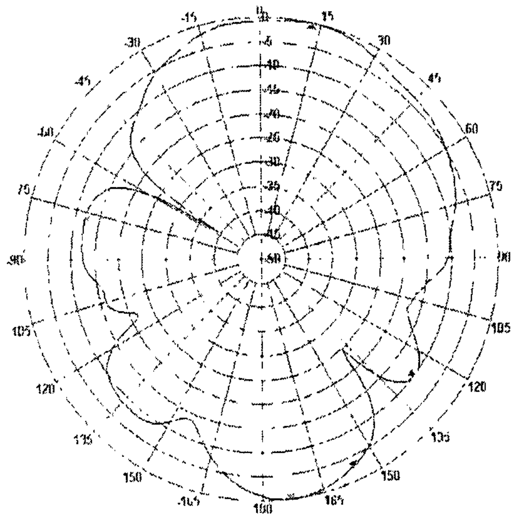


Fig. 7b

XZ plane

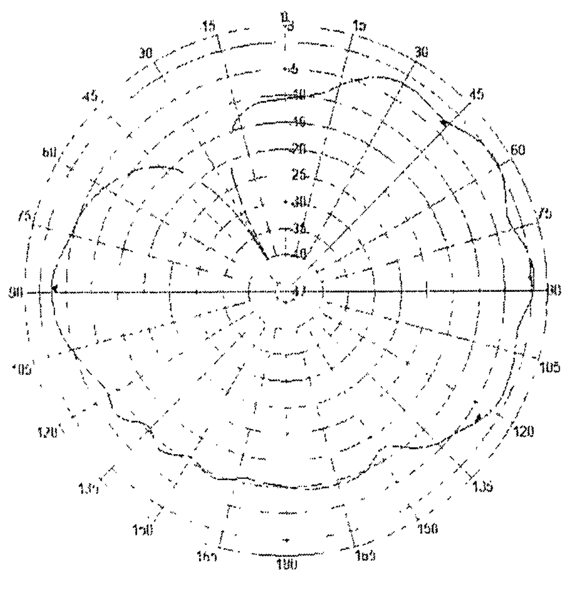


Fig. 7c

XY plane

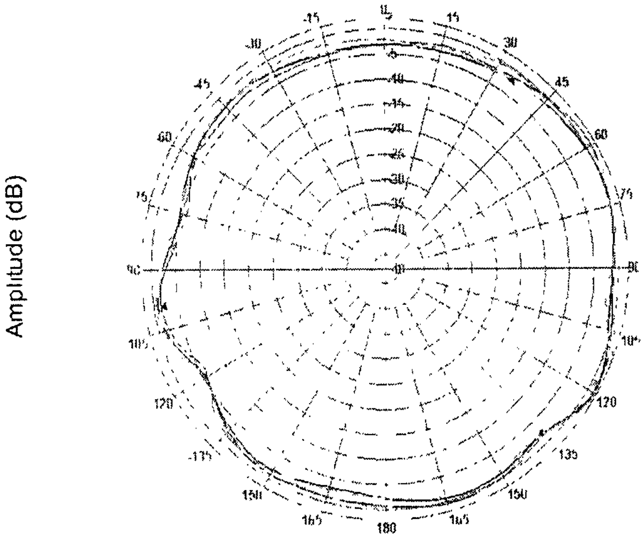


Fig. 8a

YZ plane

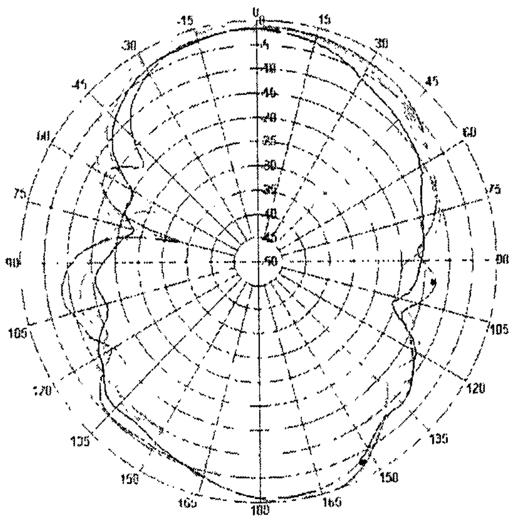


Fig. 8b

XZ plane

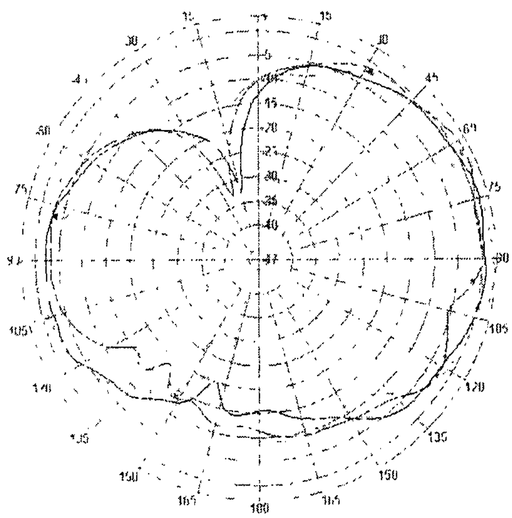


Fig. 8c

XY plane

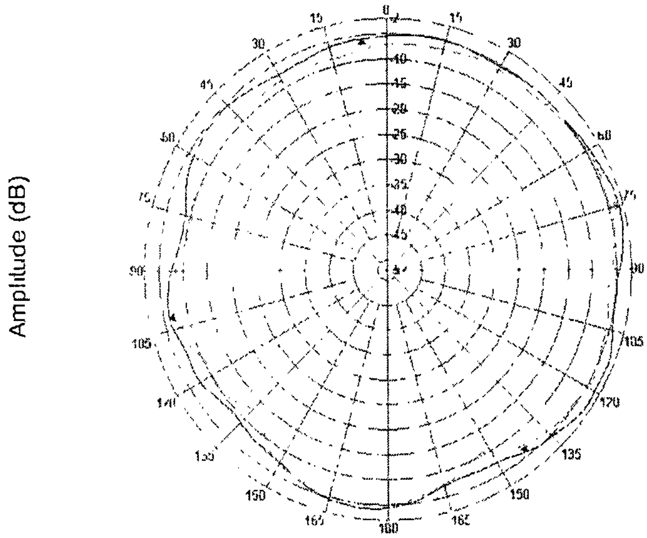


Fig. 9a

YZ plane

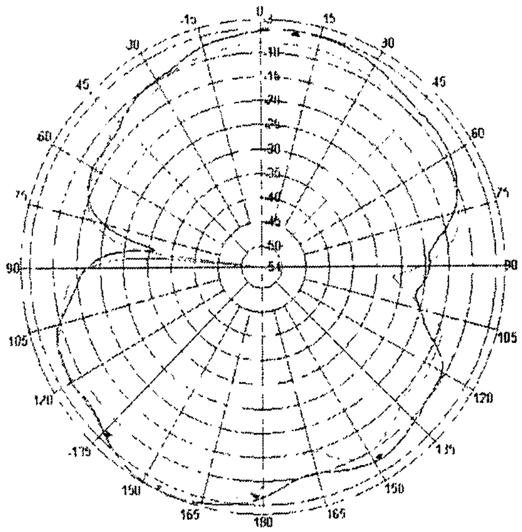


Fig. 9b

XZ plane

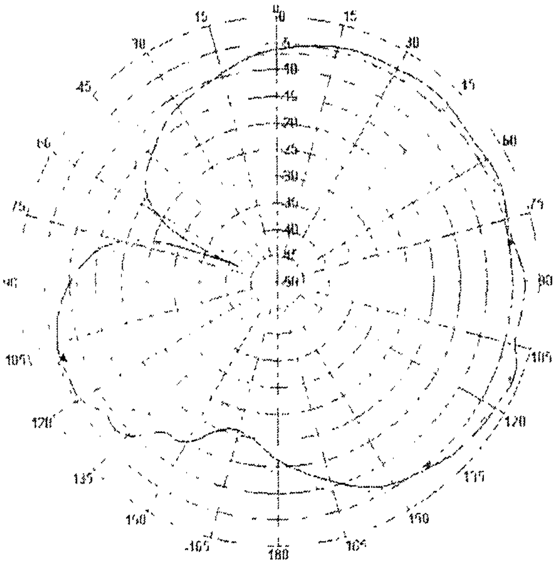


Fig. 9c

XY plane

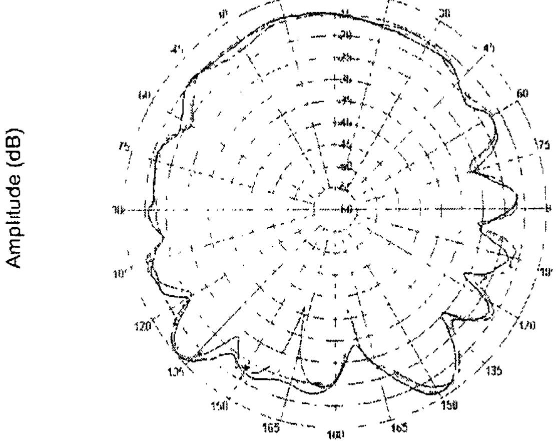


Fig. 10a

YZ plane

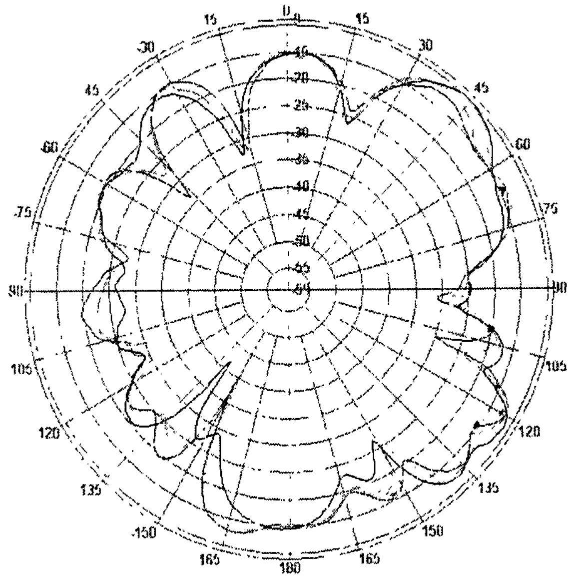


Fig. 10b

XZ plane

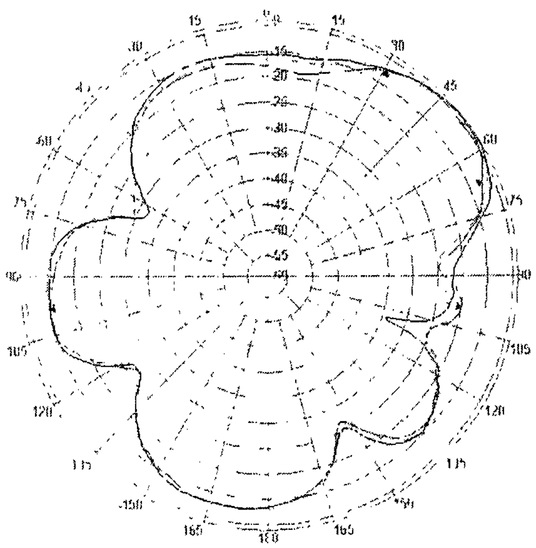


Fig. 10c

XY plane

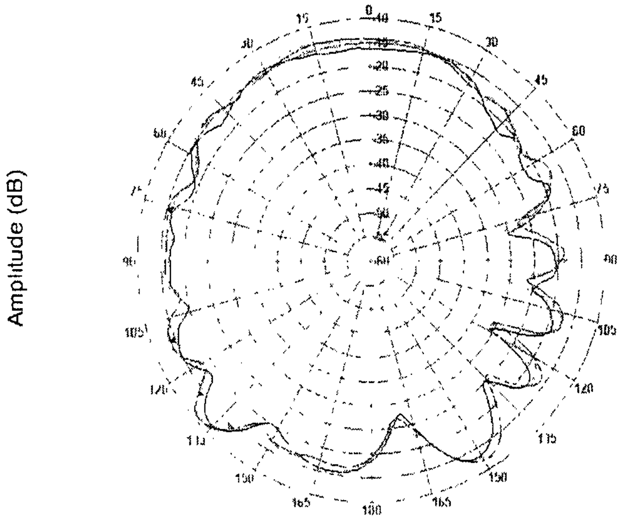


Fig. 11a

YZ plane

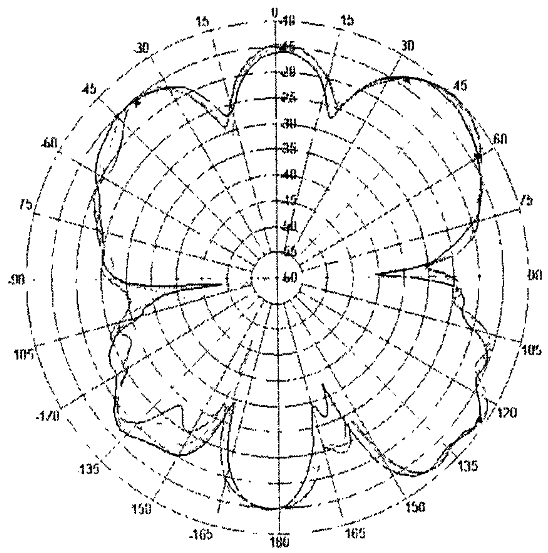


Fig. 11b

XZ plane

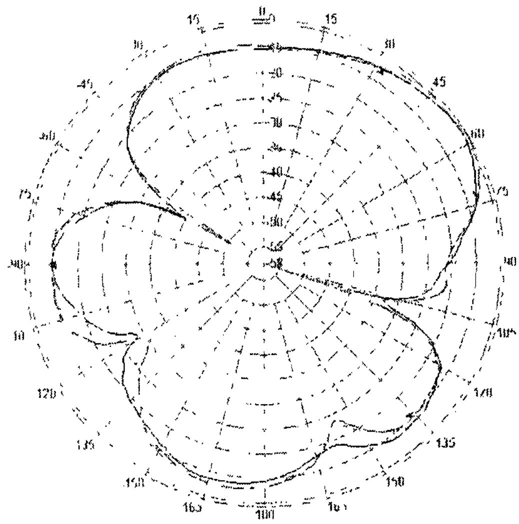


Fig. 11c

XY plane

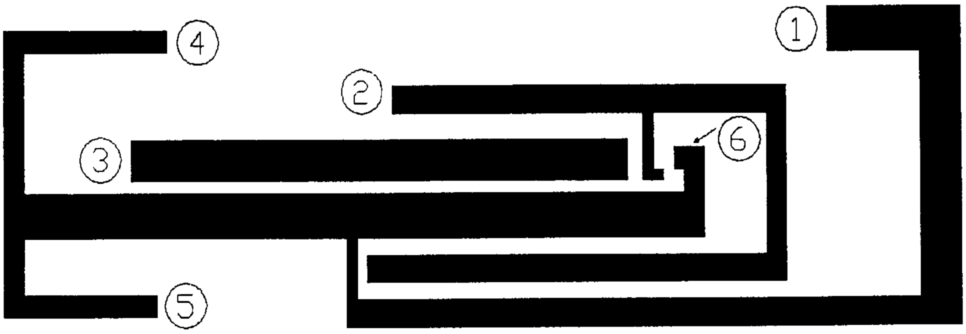


Fig. 12a

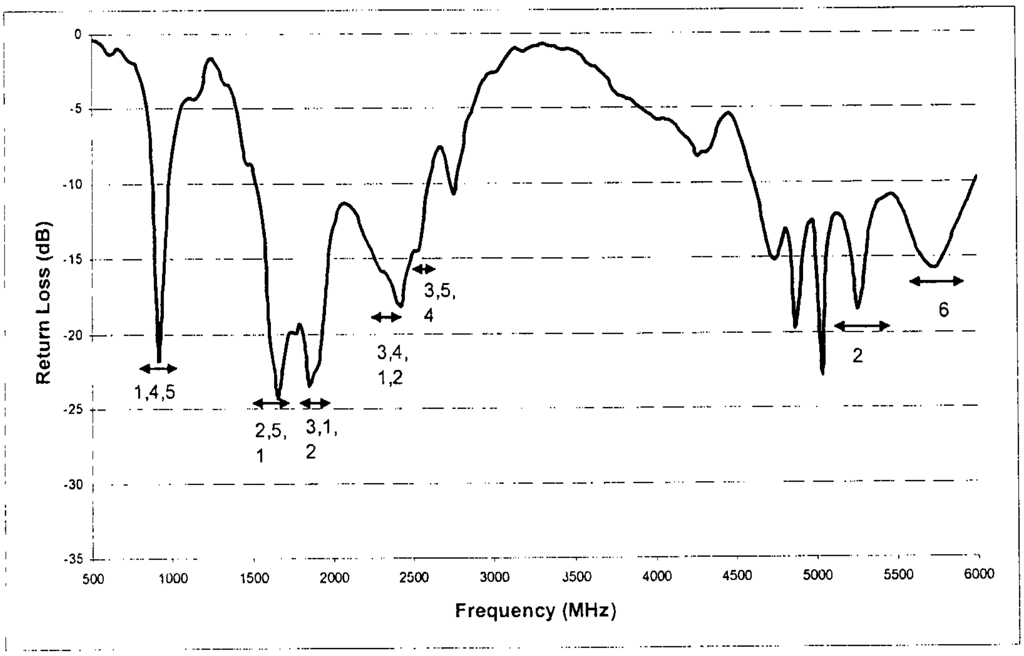
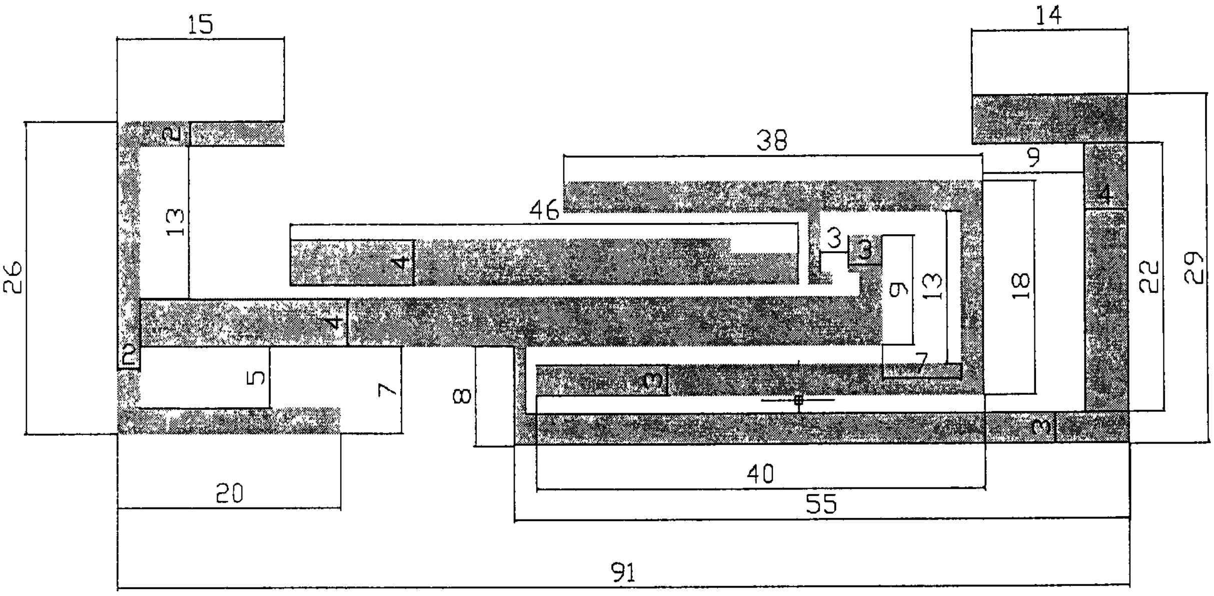


Fig. 12b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40
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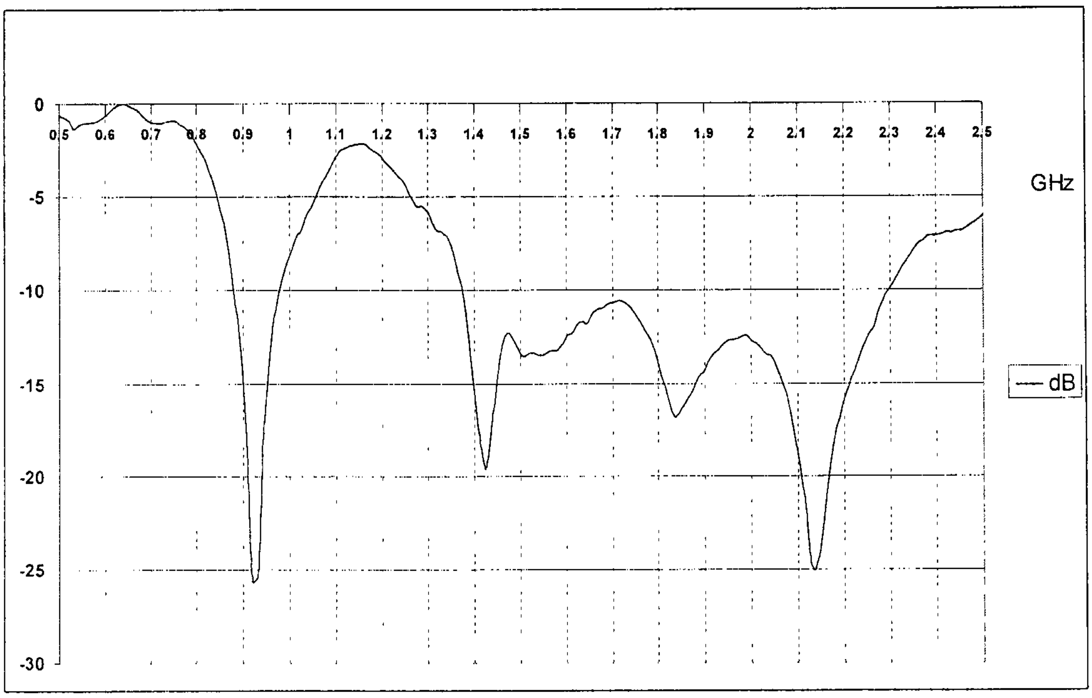
55
91

Fig. 13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0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
2.1
2.2
2.3
2.4
2.5
GHz
dB

Fig. 14

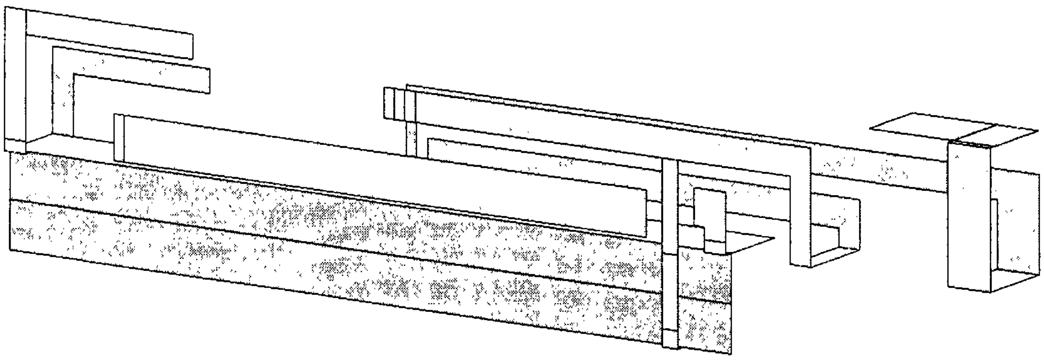

Fig. 15

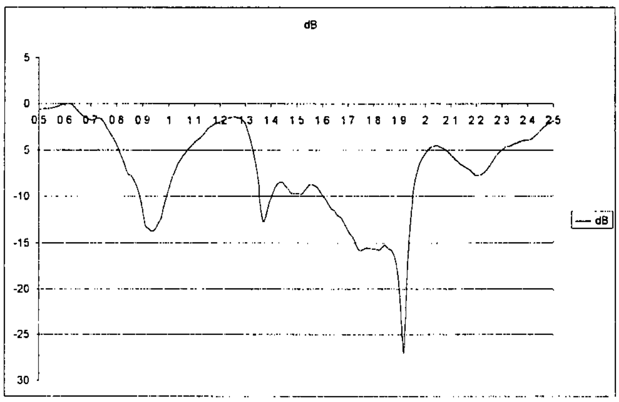
dB
5
0
5
-10
-15
-20
-25
30
05 06 07 08 09 1 11 12 13 14 15 16 17 18 19 2 21 22 23 24 25
dB

Fig. 16

ANTENNA

This invention relates to an antenna. More particularly, but not exclusively, this invention relates to a multi-band antenna for use with mobile communications equipment operating on a plurality of frequency bands.

Mobile telecommunications equipment or small terminal equipment such as a mobile, or cellular, telephone will typically have an antenna that is used for the wireless transmission and receipt of electromagnetic signals. In a mobile telephone, this antenna is primarily used to communicate with the base transceiver station for the cell in which the telephone is operating.

The frequency band in which the mobile telephone and base transceiver station communicate depends on the communications standard to which the mobile network, of which the base transceiver station is a part, conforms. For example, The GSM (Global System for Mobile communications) standard used throughout Europe and Asia defines two alternative frequency bands, 900MHz and 1800MHz, more exactly GSM900 from 890MHz to 960MHz and DCS1800 from 1710MHz to 1880MHz. Several systems are used In North America, including PCS (Personal Communications Service), which operate in frequency bands around 850MHz and 1900MHz respectively, for example GSM850 from 824MHz to 894MHz, and PCS from 1850MHz to 1990MHz. Further frequency bands have been defined for the UMTS (Universal Mobile Telephone Standard) "third generation" standard, which operate in the frequency band from 1920MHz to 2170MHz. Another network arrangement uses distribution of radio signals over fibre links to small local base stations.

The mobile telephone may also be designed to provide wireless connectivity to related equipment located in close proximity, and to local area networks (LANs) in the local vicinity. The Bluetooth standard, operating in the frequency band from 2400MHz to 2483.5MHz, is typically used to provide wireless connectivity to related equipment. Wireless connectivity to proximate LANs may be provided using the Hiperlan 1/2 standards operating in the frequency bands 5150MHz to 5350MHz and 5470MHz to 5725MHz.

Antennas for mobile communications equipment are well known. Most mobile telephones are designed to operate in a single, fixed frequency band and do not provide wireless connectivity to other related equipment or proximate LANs. Antenna designs for these mobile telephones are resonant around a single, fixed frequency. Capacity constraints and different bandwidth allocations in different countries have resulted in the use of a variety of frequency bands. To deal with these multiple bands, mobile telephones and base stations that are capable of operating in two or three frequency bands have been developed. More recently, developments in mobile telephones have added Bluetooth and Hiperlan 1/2 wireless functionality. Antenna designs for these mobile telephones and base stations must therefore be capable of operating in a plurality of defined frequency bands.

A number of antenna designs that are capable of operating in at least two defined frequency bands have been proposed. One approach for providing a multiple band antenna is to use separate antennas, each corresponding to a different frequency band. Another approach is to use a single antenna capable of resonance in a plurality of frequency bands. However, there remains a need for a compact and efficient multi-band antenna.

According to the invention, there is provided a multi-band antenna comprising a substrate having first, second and third electrically conductive elements formed on a first surface, wherein:

the first element comprises a limb defining an antenna terminal at a first end, and having first and second fingers extending from a second end of the limb and a third finger extending from an intermediate portion of the limb;

the second element comprises a limb adjacent and parallel to the intermediate portion of the first element limb; and

the third element comprises a limb defining an antenna terminal at an intermediate part of the limb, first and second end portions of the limb being adjacent and parallel to the first and second element limbs respectively and connected together adjacent the first end of the first element limb.

The invention provides a compact and efficient multi-band antenna capable of supporting a variety of frequency bands for cellular telecommunications and wireless connectivity.

The different limbs and fingers of the conductive pattern provide many different features which can be used to tune different frequency bands in a manner to allow near independent control of the different bands. In particular, the first element has two end fingers and an intermediate finger which may be individually tuned. The intermediate finger preferably folds around the third element, which itself folds around the end of the first element limb and the second element. The second element and the end portions of the third element limb also provide separate tuning capability. The positional relationship between the different conductive elements provides a number of useful frequency bands.

The antenna terminals preferably comprise perpendicular spurs that are parallel to each other. The third element antenna terminal spur is preferably intermediate the first element antenna terminal spur and an end of the second element limb.

The first and third element antenna terminals are preferably for connection to the core and outer conductors respectively of a coaxial cable, although other feed arrangements are possible.

The first and second fingers preferably extend in opposite directions perpendicular to the first element limb. The first and second fingers preferably define right-angled bends to provide end portions that are parallel to the first element limb They are thus folded back around the end of the first element limb.

The third finger preferably defines a first right-angled bend to provide a first intermediate portion adjacent and parallel to the first end portion of the third element limb. The third finger preferably also defines a second right-angled bend to provide a second intermediate portion adjacent and parallel to the connecting portion of the third element limb. The third finger preferably also defines a third right-angled bend to provide an end portion. The third finger is thus folded around the terminal end of the first element limb.

In preferred embodiments, the first and second element limbs have a width of 4mm, and the third element limb has a width of 3mm. The first and second fingers may have a width of 3mm.

The substrate may further have fourth, fifth and sixth electrically conductive elements formed on a second surface. In this case, the fourth, fifth and sixth elements may have the same shape and dimensions as the first, second and third elements respectively, thereby providing improved operating stability to the antenna. Alternatively, the fourth, fifth and sixth elements may have the same shape but slightly different dimensions as the first, second and third elements respectively, thereby broadening the operating bandwidth of the antenna.

The substrate is preferably a printed circuit board and the electrically conductive elements are preferably formed from a metallic material.

The substrate and the electrically conductive elements may be arranged together in a folded configuration, thereby minimising the packaging space required by the antenna.

Another aspect of the invention provides an antenna for use with five separate frequency bands, comprising the antenna described above. The bands are preferably centred around frequencies of 900MHz, 1800MHz, 2000MHz, 2400MHz and 5400MHz respectively.

The invention also provides a multi-band antenna comprising a substrate having three electrically conductive elements formed on a first surface, wherein: two of the elements define antenna terminals for connection to an electronic circuit, the other element not defining any antenna terminals; and the antenna provides frequency bands having a return loss of less than –10dB, the bands including frequencies of 900MHz, 1800MHz, 2000MHz, 2400MHz and 5400MHz.

The invention also provides mobile telecommunications equipment comprising the antenna described above.

Examples of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a schematic plan view of a first example of the invention;

Figure 2 shows the electrically conductive elements of the first example with dimensioning;

Figure 3 shows a photograph of the first example connected to a coaxial cable;

Figure 4 shows the predicted and measured return loss of the first example from 0.5GHz to 6GHz;

Figures 5a, 5b and 5c show the radiation patterns of the first example at frequencies from 890MHz to 960MHz and for the YZ, XZ and XY planes respectively;

Figures 6a, 6b and 6c show the radiation patterns of the first example at frequencies from 1700MHz to 1850MHz and for the YZ, XZ and XY planes respectively;

Figures 7a, 7b and 7c show the radiation patterns of the first example at a frequency of 1900MHz and for the YZ, XZ and XY planes respectively;

Figures 8a, 8b and 8c show the radiation patterns of the first example at frequencies from 1950MHz to 2150MHz and for the YZ, XZ and XY planes respectively;

Figures 9a, 9b and 9c show the radiation patterns of the first example at frequencies of 2400MHz and 2450MHz and for the YZ, XZ and XY planes respectively;

Figures 10a, 10b and 10c show the radiation patterns of the first example at frequencies from 5150MHz to 5350MHz and for the YZ, XZ and XY planes respectively;

Figures 11a, 11b and 11c show the radiation patterns of the first example at frequencies from 5470MHz to 5725MHz and for the YZ, XZ and XY planes respectively;

Figures 12a and 12b show how the return loss of the first example may be adjusted by altering the dimensions of the antenna;

Figure 13 shows the electrically conductive elements of a second example with dimensioning;

Figure 14 shows the measured return loss of the second example from 0.5GHz to 2.5GHz;

Figure 15 shows the electrically conductive elements of a third example; and

Figure 16 shows the measured return loss of the third example from 0.5GHz to 2.5GHz.

Figure 1 shows a schematic plan view of a first example of the invention. An antenna 1 comprises a substrate in the form of a printed circuit board 3. The printed circuit board 3 has a thickness of 0.8mm and is formed from FR4 material Three conductive elements 5, 7, 9 are formed on an upper surface of the printed circuit board 3 by a conventional process that will be known to the skilled person. The elements 5, 7, 9 comprise an arrangement of narrow tracks that do not cross each other and are separated by a minimum distance. A further three conductive elements (not shown) having the same shape and dimensions as the elements 5, 7, 9 are formed on a lower surface of the printed circuit board 3. The conductive elements 5, 7, 9 are formed from copper.

The first element 5 comprises a limb 5a defining an antenna terminal 5b at a first end. The first element 5 also comprises first and second fingers 5c, 5d that extend from a second end of the limb 5a, and a third finger 5e extending from an intermediate portion of the limb 5a.

The second element 7 comprises a single limb 7a adjacent and parallel to the intermediate portion of the first element limb 5a. The second element 7 does not include an antenna terminal.

The third element 9 comprises a limb 9a defining an intermediate antenna terminal 9b. First and second end portions 9c, 9d of the limb 9a are adjacent and parallel to the first and second element limbs 5a, 7a respectively. The first and second end portions 9c, 9d are connected together adjacent the first element antenna terminal 5b.

The antenna terminals 5b, 9b are perpendicular spurs that are parallel to each other. The third element antenna terminal spur 9b is located between the first element antenna terminal spur 5b and an end of the second element limb 7a.

The first and second fingers 5c, 5d extend in opposite directions perpendicular to the first element limb 5a. The first and second fingers 5a, 5b also include right-angled bends that provide end portions parallel to the first element limb 5a.

The third finger 5e includes a first right-angled bend that provides a portion that is adjacent and parallel to the first end portion 9c of the third element limb 9a. The third finger also includes a second right-angled bend that provides a portion that is adjacent and parallel to the connecting portion of the third element limb 9a. The third finger also includes a third right-angled bend that provides a portion that is parallel to another portion of the third finger 5e.

Figure 2 shows the dimensions of the elements 5, 7, 9. It can be seen from the Figure that the first and second element limbs have a width of 4mm, and the third element limb has a width of 3mm. The first and second fingers have a width of 3mm.

Figure 3 shows a photograph of the first example 1 connected to a coaxial cable 11. The first and third element antenna terminals 5b, 9b are connected to the core and outer conductors respectively of the coaxial cable 11, which is used to feed signals to the antenna 1 and receive signals from the antenna 1. The antenna is designed for 50 ohms input impedance.

Figure 4 shows the predicted and measured return loss of the first example from 0.5GHz to 6GHz. It can be seen from the Figure that the resonant frequencies of the antenna cover the following six commercially useful frequency bands:

System	Frequency Band
GSM 900	890 – 960 MHz
DCS1800	1710 – 1880 MHz
DECT	1900 MHz
UMTS	1920 – 2170 MHz
Bluetooth	2400 – 2483.5 MHz
Hiperlan 1/2	5150– 5725 MHz

Coverage of these commercially useful frequency bands is provided by the invention within the following three frequency bands, for which the measured return loss is less than –10dB:

Frequency band (MHz)	Bandwidth	System covered
885 – 973	88 MHz	GSM900
1530 – 2590	1060 MHz	DCS1800 UMTS Bluetooth DECT
4630 – 5970	1340 MHz	Hiperlan 1 Hiperlan 2

Figures 5 to 11 show the radiation patterns for the antenna of Figure 2 for different frequencies. In each case, the Figure (a) shows the YZ plane, the Figure (b) shows the XZ plane and the Figure (c) shows the XY plane. The orientation of these planes with reference to the antenna is shown in Figure 1, and the antenna substrate is defined as lying in the YZ plane.

Figures 5a, 5b and 5c show the radiation patterns of the first example at frequencies from 890MHz to 960MHz. Figures 6a, 6b and 6c show the radiation patterns of the first example at frequencies from 1700MHz to 1850MHz. Figures 7a, 7b and 7c show the radiation patterns of the first example at a frequency of 1900MHz. Figures 8a, 8b and 8c show the radiation patterns of the first example at frequencies from 1950MHz to 2150MHz. Figures 9a, 9b and 9c show the radiation patterns of the first example at frequencies of 2400MHz and 2450MHz. Figures 10a, 10b and 10c show the radiation patterns of the first example at frequencies from 5150MHz to 5350MHz. Figures 11a, 11b and 11c show the radiation patterns of the first example at frequencies from 5470MHz to 5725MHz. In these Figures, the a Figures show YZ plane co-polarisation, the b Figures show XZ plane co-polarisation, and the c Figures show XY plane co-polarisation.

Figures 12a and 12b show how the return loss of the first example may be adjusted by altering the dimensions of the antenna. Changes in the dimensions of the potions labelled in Figure 12a affect the position the respectively labelled frequency bands of Figure 12b. In Figure 12b, the portion labels are listed in order of sensitivity.

For example, it can be seen that altering the dimensions of the second element limb 7a, labelled as "3" in Figure 12a, affects the position of the middle three labelled frequency bands. The resonant frequencies of the antenna can thus be easily and predictably altered to cover a variety of desired frequency bands in Figure 12b

Figure 13 shows the electrically conductive elements of a second example of the invention, with dimensioning. Apart from the slightly different element dimensions, the second example is similar to the first example, except also that the substrate is 1.6mm thick.

Figure 14 shows the measured return loss of the second example from 0.5GHz to 2.5GHz. It can be seen from the Figure that the resonant frequencies occur at lower frequencies than was the case for the first example. The position of the resonant frequencies of the antenna can thus be easily and predictably altered by changing the thickness if the substrate.

Figure 15 shows the electrically conductive elements of a third example of the invention. In the third example, the substrate and the elements are folded to provide a compact antenna that is more easily packaged within mobile equipment. A microstrip line feeds the antenna, as shown in Figure 15.

Figure 16 shows the measured return loss of the third example from 0.5GHz to 2.5GHz.

Other frequency bands to those mentioned above may be tuned by changing the dimensions of the conducting patterns.

Various modifications to the antenna of the invention will be apparent to the skilled person. For example, the substrate need not be a printed circuit board, and the elements may be formed on any suitable surface.

CLAIMS

1. A multi-band antenna comprising a substrate having first, second and third electrically conductive elements formed on a first surface, wherein:

the first element comprises a limb defining an antenna terminal at a first end, and having first and second fingers extending from a second end of the limb and a third finger extending from an intermediate portion of the limb;

the second element comprises a limb adjacent and parallel to the intermediate portion of the first element limb; and

the third element comprises a limb defining an antenna terminal at an intermediate part of the limb, first and second end portions of the limb being adjacent and parallel to the first and second element limbs respectively and connected together adjacent the first end of the first element limb.

2. The antenna of claim 1, wherein the antenna terminals comprise perpendicular spurs that are parallel to each other.

3. The antenna of claim 1 or 2, wherein the third element antenna terminal comprises a spur which extends between the first element antenna terminal and an end of the second element limb.

4. The antenna of any preceding claim, wherein the antenna terminals of the first and third elements are for connection to the core and outer conductors respectively of a coaxial cable.

5. The antenna of any preceding claim, wherein the first and second fingers extend in opposite directions perpendicular to the first element limb.

6. The antenna of claim 5, wherein the first and second fingers define angled bends to provide end portions parallel to the first element limb.

7. The antenna of any preceding claim, wherein the third finger defines a first right angled bend to provide a first intermediate portion adjacent and parallel to the first end portion of the third element limb.

8. The antenna of claim 7, wherein the third finger defines a second right angled bend to provide a second intermediate portion adjacent and parallel to the connecting portion of the third element limb.

9. The antenna of claim 8, wherein the third finger defines a third right angled bend to provide an end portion parallel to the second end portion of the third element limb.

10. The antenna of any preceding claim, wherein the first and second element limbs have a width of 4mm, and the third element limb has a width of 3mm.

11. The antenna element of any preceding claim, wherein the first and second fingers have a width of 3mm.

12. The antenna of any preceding claim, wherein the substrate further has fourth, fifth and sixth electrically conductive elements formed on a second surface, and wherein the fourth, fifth and sixth elements have the same shape and dimensions as the first, second and third elements respectively.

13. The antenna of any of claims 1 to 11, wherein the substrate further has fourth, fifth and sixth electrically conductive elements formed on a second surface, and wherein the fourth, fifth and sixth elements have the same shape but different dimensions as the first, second and third elements respectively.

14. The antenna of any preceding claim, wherein the substrate is a printed circuit board and the electrically conductive elements are formed of a metallic material.

15. The antenna of any preceding claim, wherein the substrate is 0.8mm – 1.6mm thick.

16. The antenna of any preceding claim, wherein the substrate and the electrically conductive elements are folded.

17. An antenna for use with five separate frequency bands, comprising the antenna of any preceding claim.

18. The antenna of claim 17, wherein the five separate frequency bands comprise frequencies of 900MHz, 1800MHz, 2000MHz, 2400MHz and 5400MHz respectively.

19. A multi-band antenna comprising a substrate having three electrically conductive elements formed on a first surface, wherein:

two of the elements define antenna terminals for connection to an electronic circuit, the other element not defining any antenna terminals; and

the antenna provides frequency bands having a return loss of less than –10dB, the bands including frequencies of 900MHz, 1800MHz, 2000MHz, 2400MHz and 5400MHz.

20. Mobile telecommunications equipment comprising the antenna of any preceding claim.

21. An antenna substantially as hereinbefore described with reference to, and as illustrated in the accompanying drawings.

Application No: GB0416406.7 **Examiner:** Peter Easterfield

Claims searched: 1 to 20 **Date of search:** 12 October 2004

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	GB 2373637 A (ERICSSON)
A	-	EP 1294049 A1 (NOKIA)
A	-	US 2004/0075610 A1 (PAN)
A	-	WO 04/038856 A1 (SONY)

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Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[W] :

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Worldwide search of patent documents classified in the following areas of the IPC[07]

H01Q

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, JAPIO