

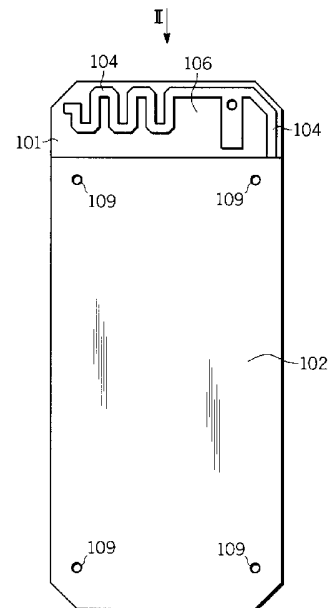
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(54) Abstract Title: **Planar antenna with elements on both sides of supporting substrate**

(57) An antenna structure includes an insulating substrate 101, 107 a conductive sheet 102 formed on the insulating substrate, a first radiative element 104 and a second radiative element 105 wherein each of the radiative elements includes a first strip portion 404, for example a linear strip portion extending away from the conductive sheet, and a second strip portion 403 connected to the first strip portion and extending from the first elongate strip portion at an angle thereto, e.g. at an angle of ninety degrees, wherein the first and second radiative elements are formed on opposite faces of the substrate in adjacent regions 106, 107. When the antenna structure is arranged horizontally, the adjacent regions may lie one 106 over the other 107 and the first and second portions of the first radiative element may lie over the first and second portions of the second radiative element. The antenna structure may conveniently be in the form of a plate-like module formed on the substrate.



100
FIG. 1

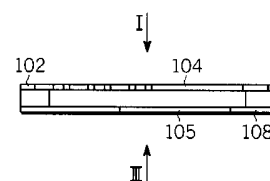
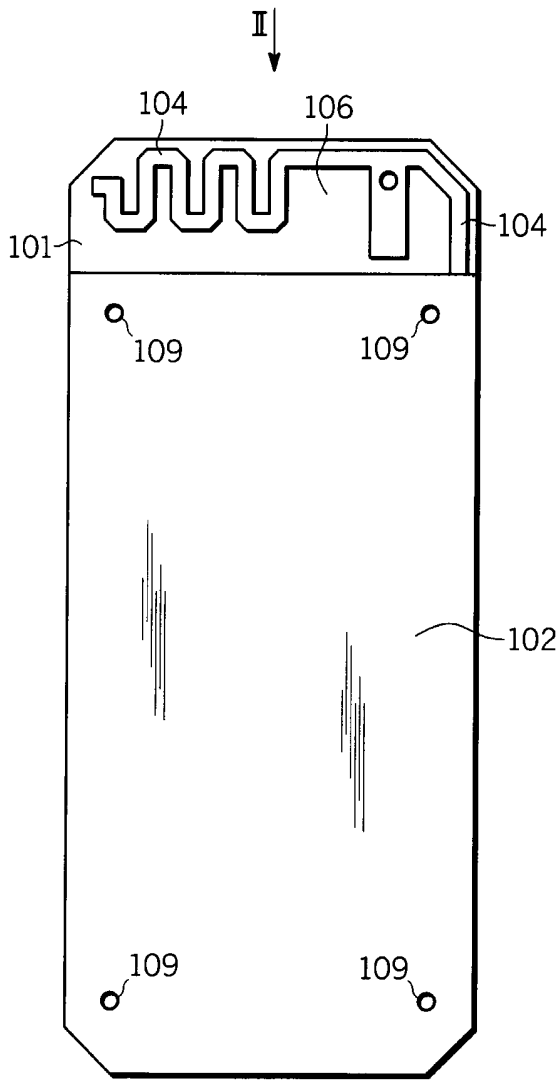


FIG. 2



100

FIG. 1

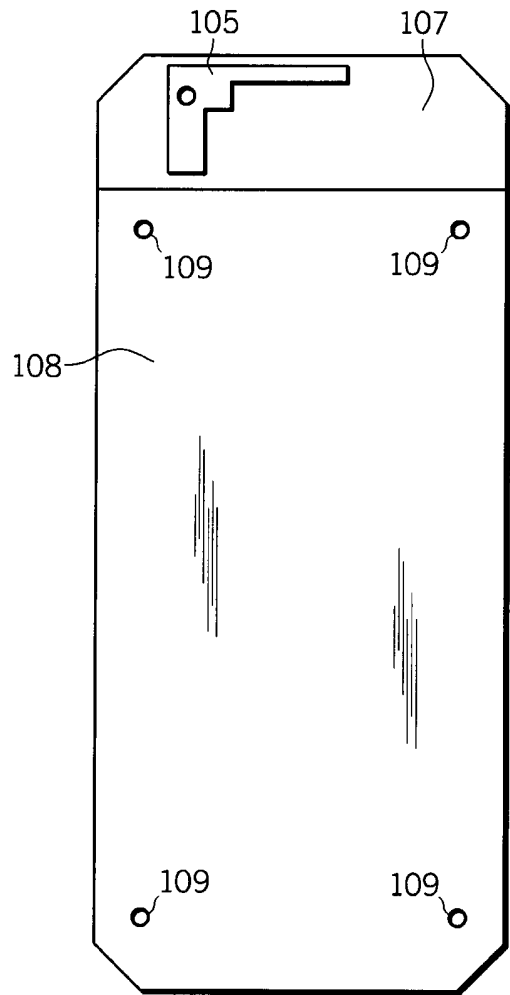


FIG. 3

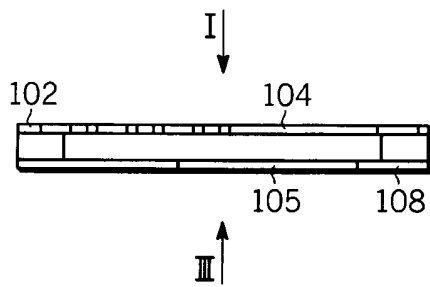


FIG. 2

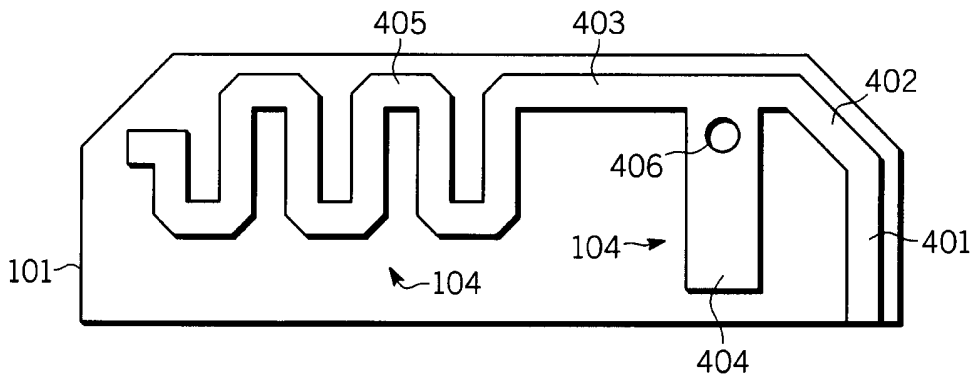


FIG. 4

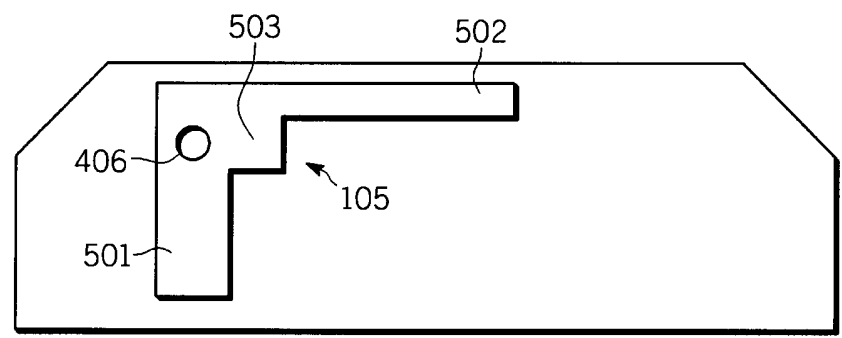


FIG. 5

FIG. 6

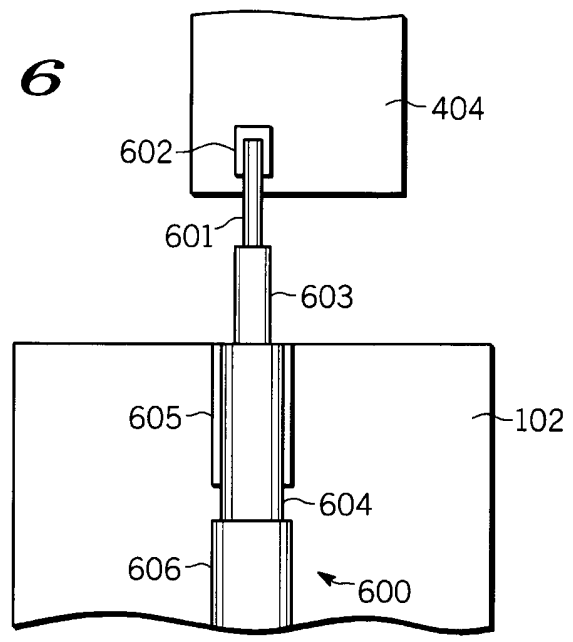


FIG. 7

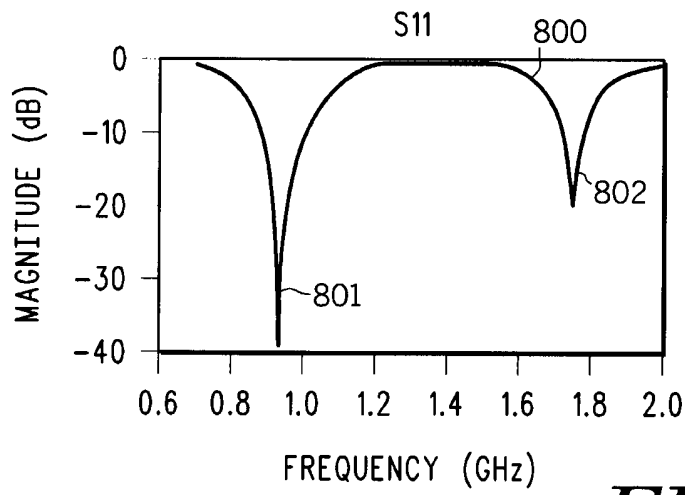
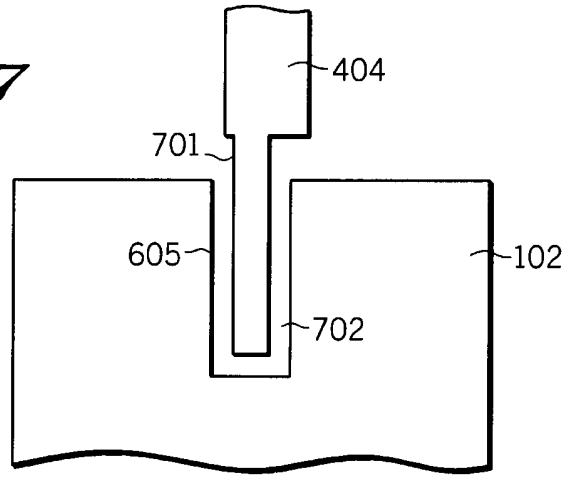
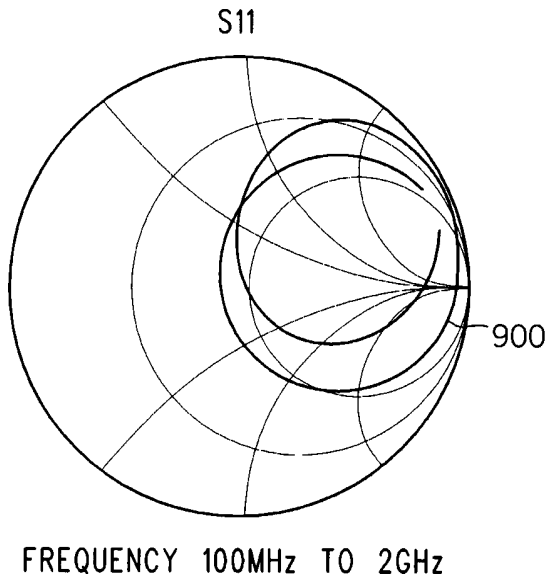
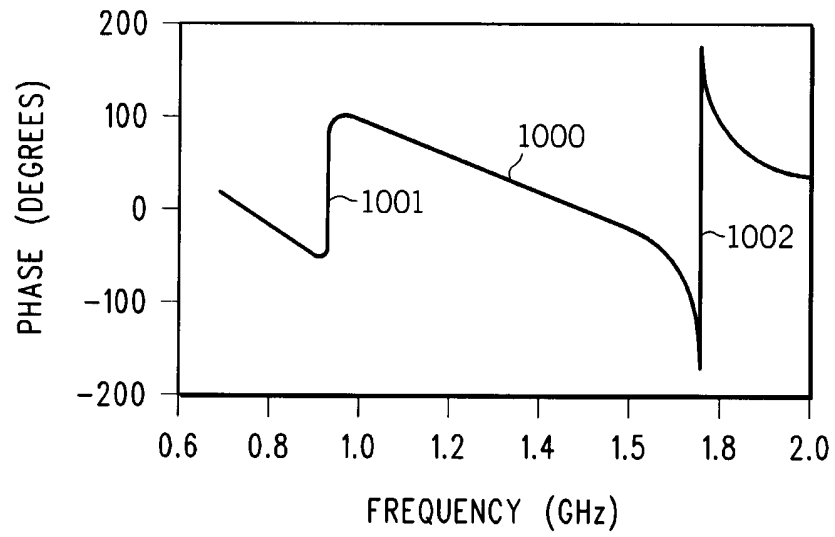
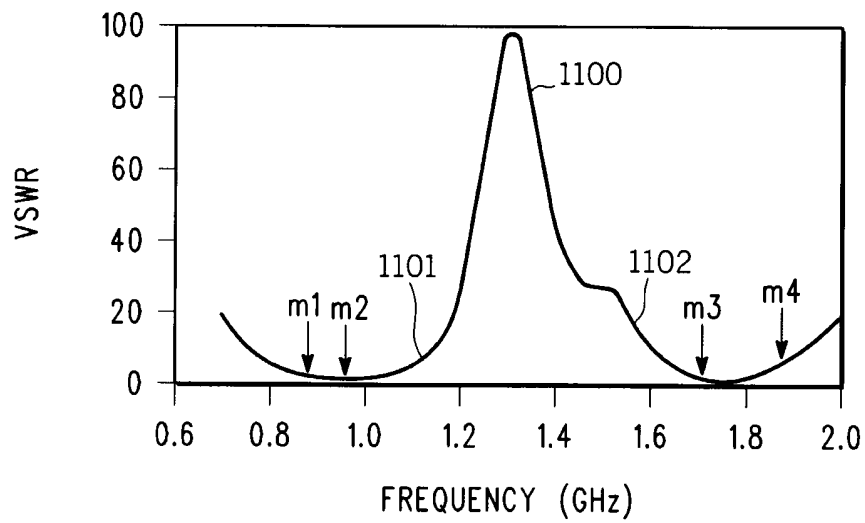


FIG. 8

FIG. 9



**FIG. 10****FIG. 11**

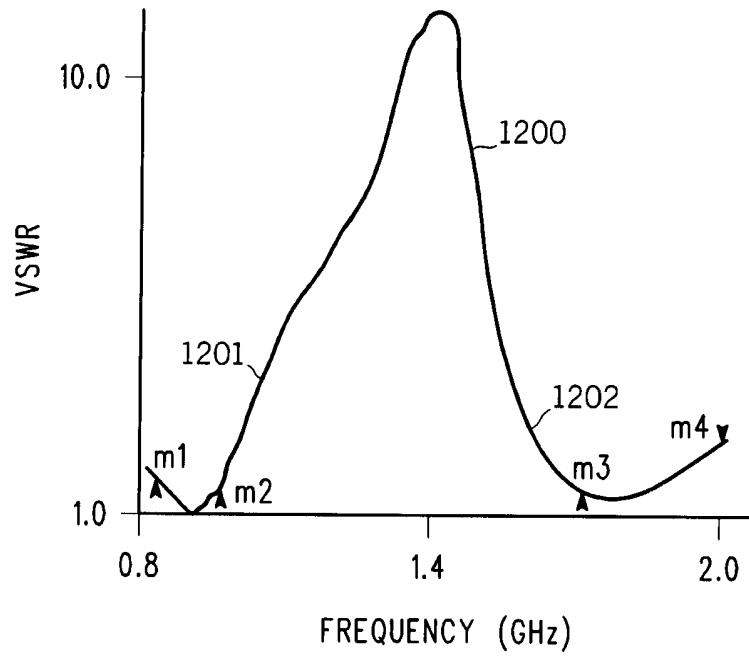


FIG. 12

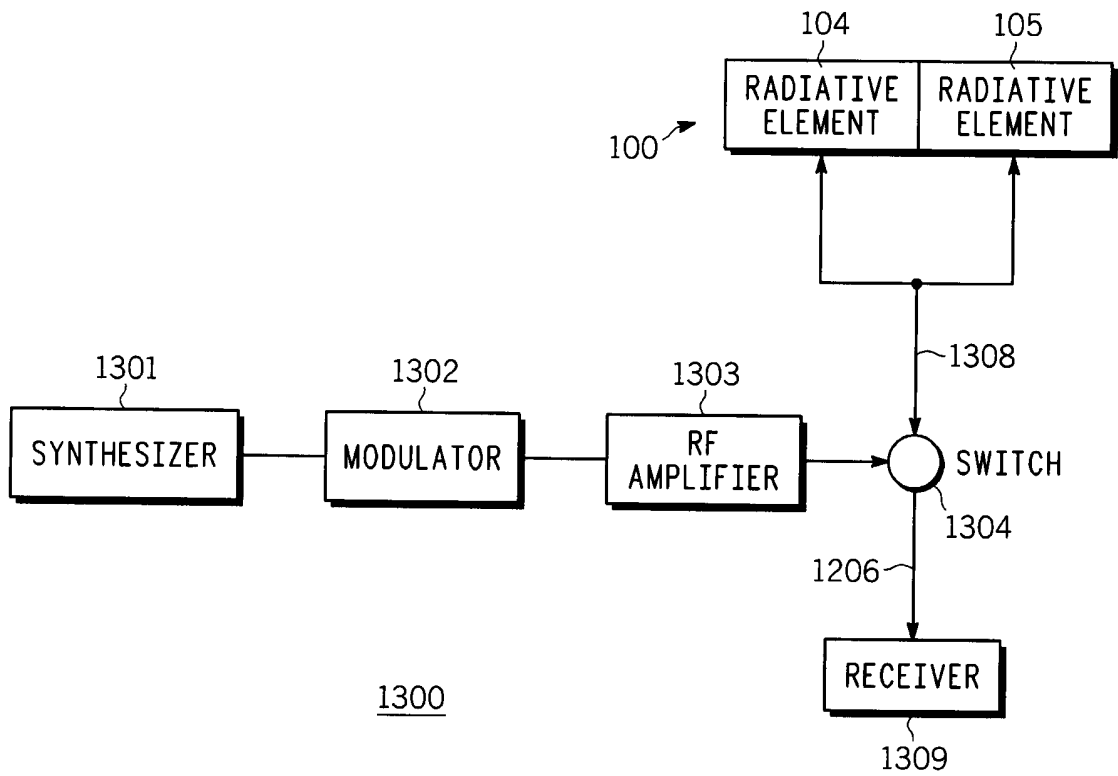


FIG. 13

**TITLE: ANTENNA STRUCTURE AND RF TRANSCEIVER
INCORPORATING THE STRUCTURE**

FIELD OF THE INVENTION

5

The present invention relates to an antenna structure and a RF transceiver incorporating the structure. In particular, the invention relates to an antenna for use in a transceiver of a portable
10 communications device to provide RF communications in at least two different frequency bands.

BACKGROUND OF THE INVENTION

15 Various antenna types are known for use in portable communication devices. For example, monopole and dipole antennas, patch and so called planar inverted 'F' (PIF) antennas are all known for this application.

Some modern wireless communication devices are
20 designed for multi-mode use in more than one communication system. Generally, dedicated multiple antennas are required for use in each separate mode in which the device is to operate, usually in different frequency bands. In some cases, this can cause the
25 overall antenna structure to be large. This is undesirable where there are practical space and size constraints on the antenna structure and on other components used in the device.

30

SUMMARY OF THE INVENTION

The present invention provides a novel antenna structure including multiple active antenna or radiative elements suitable for use in a portable wireless communication device such as a mobile handset which provides multiple operational modes.

According to the present invention in a first aspect there is provided an antenna structure as defined in claim 1 of the accompanying claims.

According to the present invention in a second aspect there is provided a RF transceiver as defined in claim 22 of the accompanying claims.

The invention provides an antenna structure which can provide efficient operational performance in at least two quite different RF bands by a novel construction. The structure includes two radiative elements formed on opposite faces of an insulating substrate. The capacitance between the two radiative elements can be controlled so that it does not give rise to substantial unwanted interferences. The structure can be made in a surprisingly compact and lightweight form for wideband UHF operation in the required bands. The antenna structure can for example be made in the form of a thin plate-like module which can be fitted neatly into a RF transceiver device or alternatively can form part of a printed circuit board employed in such a device. The antenna structure is particularly suited for use in a transceiver of a handheld or portable RF communications device, for example a mobile terminal for use in speech and/or data communication.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of an antenna module embodying the invention.

5 FIG. 2 is an end view of the antenna module shown in FIG. 1 as seen in a direction labelled II in FIG. 1.

FIG. 3 is an underside view of the antenna module shown in FIGS. 1 and 2 as seen in a direction labelled III in FIG. 2.

10 FIG. 4 is an enlarged plan view of a first radiative element of the antenna module shown in FIG. 1.

FIG. 5 is an enlarged underside view of a second radiative element of the antenna module shown in FIG. 3.

15 FIG. 6 is a plan view of an RF feed arrangement for radiative elements of the antenna module of FIG. 1.

FIG. 7 is a plan view of an alternative feed arrangement for radiative elements of the antenna module of FIG. 1.

20 FIG. 8 is a graph of magnitude in dB versus frequency in GHz for the simulated reflection coefficient S_{11} of the antenna structure of FIGS. 1 to 6.

25 FIG. 9 is a Smith Chart for the simulated reflection coefficient S_{11} of the antenna structure of FIGS. 1 to 6.

FIG. 10 is a graph of phase angle in degrees versus frequency in GHz for the simulated reflection coefficient S_{11} of the antenna structure of FIGS. 1 to 6.

FIG. 11 is a graph of simulated voltage standing wave ratio (VSWR) versus frequency in GHz for the antenna structure of FIGs. 1 to 6.

FIG. 12 is a graph of measured voltage standing wave ratio (VSWR) versus frequency in GHz for the antenna structure of FIGs. 1 to 6.

FIG. 13 is a block schematic diagram illustrating use of the antenna structure of FIGs. 1 to 6 in a RF communications transceiver.

10

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

FIGs. 1, 2 and 3 are respectively a plan view, an end view and an underside view of an antenna module 100 embodying the invention. As seen in FIG. 1, the antenna module 100 comprises an insulating substrate 101 on which is deposited, on an upper face seen in FIG. 1, a conductive sheet 102 and, made of the same conducting material as the sheet 102, a first radiative element 104 to be described in more detail later with reference to FIG. 4. The first radiative element 104 is formed within a region 106 of the upper face of the substrate 101 not covered by the conductive sheet 102. As seen in FIG. 3, there is deposited on a lower face of the substrate 101 a second conductive sheet 108 and a second radiative element 105 to be described in more detail later with reference to FIG. 5. The conductive sheet 108 and the second radiative element 105 may be made of the same conducting material as the sheet 102 and the first radiative element 104. The second radiative element 105 is formed within a region 107 of the lower face of the

substrate 101. The conductive sheets 102 and 108 form ground planes.

When the antenna module 100 is arranged with its lower face on a horizontal surface, the region 106 on the upper face is directly above the region 107 on the lower face. Four holes 109 are formed through the substrate 101 to allow the module 100 to be mechanically fitted into a communication device by suitable fasteners (not shown). The conductive sheets 102 and 108 may also be galvanically connected together by use of conductive fasteners (e.g. so called 'vias', not shown) providing good contact with the sheets 102 and 108, e.g. by having been pressed to the sheets 102, 108 by a rolling process, and extending around edges of the substrate 101.

The substrate 101 may conveniently be prepared from a material employed to make printed circuit boards (PCBs), e.g. a glass fibre reinforced resin material. The substrate 101 could actually be part of a printed circuit board but, as indicated in FIGs 1 to 3, may be a separate component.

The conductive sheets 102 and 108 and the radiative elements 104 and 105 may be made of any suitable conducting material known for use in producing printed conductors, e.g. copper or a copper based alloy, formed in a known manner on the substrate 101, e.g. by depositing coatings of copper on a PCB substrate material and using a known computer controlled cutting operation applied to the coated substrate to remove copper and to leave the desired shapes of copper.

Referring now to FIG. 4, the first radiative element 104 includes a strip portion 401 extending (upward as seen in FIG. 4) from and galvanically connected to the conductive sheet 102 (seen in FIG. 1) in a corner of the sheet 102 (the top left corner as seen in FIG. 1). A further strip portion 402 extends from the top of the portion 401 at an angle of about 45 degrees thereto. A further strip portion 403 extends from the portion 402 (from right to left as seen in FIG. 4) at an angle of about 45 degrees thereto and at an angle of about ninety degrees to the portion 401. A further strip portion 404 extends (downward as seen in FIG. 4) from the portion 403 parallel to the portion 401. The portion 404 is wider than the portions 401, 402 and 403. The portion 402 is narrower than the portions 401, 403 and 404. The portion 404 is not directly galvanically connected to the sheet 102. In other words there is a gap between the portion 404 and the upper edge of the sheet 102. A further strip portion 405 extends from the portion 403 (from right to left as seen in FIG. 4). The portion 405 is corrugated and has a free end near a side of the substrate 101 (the left side as seen in FIG. 4.)

Referring now to FIG. 5, the second radiative element 105 includes a strip portion 501 which extends upwardly as seen in FIG. 5. A strip portion 502 extends at an angle of about ninety degrees to the portion 501, i.e. from left to right as seen in FIG. 5. A square portion 503 of enlarged width in two dimensions is provided at the junction of the portions 501 and 502. Unlike the first radiative element 104, the second

radiative element 105 is not directly galvanically connected to a conductive sheet, i.e. the sheet 108. In other words, there is a gap between the radiative element 105 and the sheet 108.

5 The portion 404 seen in FIG. 4 is formed on the upper face of the substrate 101 in a position which overlies the position where the portion 501 seen in FIG. 5 is formed on the opposite lower face of the substrate 101. Similarly, the portion 403 is formed on the upper
10 face of the substrate 101 in a position which overlies the position where the portion 502 seen in FIG. 5 is formed on the opposite lower face of the substrate 101. The portions 104 and 105 are galvanically connected together by a conducting lead-through connection 406 or
15 'via' formed through the substrate 101.

 The radiative elements 104 and 105 form a coupled pair which transmit or receive RF radiation together and provide resonances respectively at two different frequency bands. The longer radiative element 104
20 provides mainly a resonance at a lower frequency band and the shorter element 105 provides mainly a resonance at a higher frequency band. For example, the coupled elements 104 and 105 may be adapted to provide operation in a lower frequency band of 824-894 MHz or of 880-960
25 MHz and in a higher frequency band of 1710-1880 MHz or 1850-1990 MHz. Graphical illustrations of these resonances are given later.

 Various features of the radiative elements 104 and 105 which have been described are provided to give
30 suitably enhanced antenna performance without significant unwanted degrading effects such as from

mutual interference between the radiative elements. The element 104 approximates to the form of an 'inverted F' antenna in the same plane as its corresponding ground plane, sheet 102 (unlike conventional inverted F antennas which are perpendicular to their ground plane). The corrugated portion 405 allows the length of the portion 503, which corresponds to the 'backbone' of the letter 'F', to be extended significantly without making the overall profile size of the element 104 too large. The shape of the corrugations of the portions 405 also enhances the self capacitance of the radiative element 104 thereby providing an enhanced width of the lower frequency band resonance. In addition, the corrugations of the portion 405 encourage the surface current to follow looped paths, hence causing the resulting electromagnetic field strength to be increased, thereby enhancing the resonance and the gain at the lower frequency band. The portion 402, having a form known in the art as a 'taper', i.e. a narrowed portion, allows impedance matching of the antenna over a wider bandwidth. The wider portion 404 resembles a stub feed in known antennas and allows a wider and deeper resonance to be obtained.

The element 105 has a shape which approximates to the form of an 'inverted F' without one of the arms of the 'F'. The enlarged portion 503 is provided to give good coupling between the elements 104 and 105 without mutual interferences. This is achieved by the portion 503 providing a local variation in length to width ratio and thereby in capacitance between the elements 104 and 105.

The conductive sheet 102 provides the function of a ground plane in the same plane as the element 104 to which it is galvanically connected. As noted earlier, the conductive sheet 102 is galvanically connected (by
5 vias around the edges of the substrate 101) to the conductive sheet 108 which thereby extends the surface area of the ground plane. As noted earlier, the radiative element 105 is galvanically connected to the radiative element 104 but is not galvanically connected
10 directly, only indirectly via the element 104, to the conductive sheet 108 or the conductive sheet 102.

In use, an RF signal may be delivered to or extracted from the radiative elements 104 and 105 by an RF lead connected to an RF transceiver (shown later in
15 FIG. 12) of a communication device in which the antenna module 100 is incorporated. The RF lead may comprise a coaxial cable or microstrip conductor.

FIG. 6 shows use of a coaxial cable 600 as an RF lead. The portion 404 of the element 104 and the
20 conductive sheet 102 (in its top region) are also seen in FIG. 6. The coaxial cable 600 has an inner conductor 601 which carries an RF signal. The inner conductor 601 is soldered to the portion 404 of the radiative element 104 at a land 602. Outside the inner conductor 601 the
25 cable 600 has an insulating sheath 603 and an outer conductor 604 outside the sheath 603. The outer conductor 604 is in the form of a braiding covering the outer surface of the insulating sheath 603. The outer conductor 604 is soldered to the conductive sheet 102 at
30 a land 605. The coaxial cable has an outer insulating sheath 606 over the outer conductor 604 allowing the

cable to be run over the surface of the conductive sheet 102.

FIG. 7 shows a microstrip 701 as an RF lead. The portion 404 of the element 104 and the conductive sheet 102 are also seen in FIG. 7. The microstrip 701 is much narrower than the portion 404. The width of the microstrip 701 can be chosen by use of known microstrip theory to give a desired impedance. The microstrip 701 extends from the lower end of the portion 404 to a region 702 of the substrate 101 on which the sheet 102 has not been formed. The region 702 thereby forms an insulation between the sheet 102 and the microstrip 701. A connection (not shown) is soldered to the lower end of the microstrip 701. The connection leads to an RF port of a RF transceiver (illustrated later in FIG. 12) incorporated in the communication device in which the antenna module 100 is incorporated.

The inner conductor 601 in the arrangement shown in FIG 6 and the microstrip 701 shown in FIG. 7 each provides an RF lead to the radiative element 104 as well as to the radiative element 105 connected thereto by the lead-through connection 406.

Electromagnetic radiation is emitted in a substantially omnidirectional pattern by the antenna formed of the coupled radiative elements 104 and 105. The radiation includes two linear polarisation components which are substantially vertical and horizontal along axes parallel respectively to the portions 401 and 403 in FIG. 4. The antenna formed of the radiative elements 104, 105 can also receive radiation having components with these polarisations.

FIGs. 8 to 12 illustrate results obtained for a specific antenna made as described with reference to FIGs. 1 to 6. FIGs. 8 to 11 show results obtained by simulation using a commercially available simulation software tool. FIG. 12 shows actually measured antenna results. The specific antenna investigated to produce the results in FIGs. 8 to 12 had overall dimensions of 116 mm (length) by 51 mm (width) by 0.8 mm (depth). The results to be illustrated refer to the parameters S11 and VSWR. As is well known in the art, S11 is an input return loss, or reflection coefficient, indicating relative results between an input electromagnetic wave that arrived from an antenna feed port (A^-) and an output wave transmitted by the antenna (A^+). S11 is given by:

$$S11 = \frac{A^-}{A^+}$$

Antenna performance is also indicated by VSWR (Voltage Standing Wave Ratio) in the desired band. VSWR is related to S11 by the following equation:

$$VSWR = \frac{1 + |S11|}{1 - |S11|}$$

VSWR is a measure of the resonance of the antenna in the desired band. If VSWR in the desired band is suitably small, the antenna performance for receiving and transmitting is considered to be good.

FIG. 8 shows a plot 800 of magnitude versus frequency for the S11 of the antenna made in accordance

with the embodiment of the invention described above. Two distinct dips 801 and 802 are shown corresponding to required resonances at 880-960 MHz and 1710-1880 MHz provided by the antenna.

5 FIG. 9 shows a Smith chart plot of S11 for the same antenna. A plot 900 is obtained for frequencies in the range 600 MHz to 2 GHz. The regular shape of the plot 900 indicates good impedance matching across the desired bands.

10 FIG. 10 shows a plot 1000 of phase angle versus frequency for the S11 of the same antenna. Two distinct step changes 1001 and 1002 are shown corresponding to the centre of the required resonances provided by the antenna.

15 FIG. 11 is a plot 1100 of VSWR versus frequency for the same antenna. Distinct troughs 1101 and 1102 in the VSWR are seen corresponding to the required resonances provided by the antenna. For two specific marker points, labelled m1 and m2, in the trough 1101 and two specific
20 marker points, labelled m3 and m4, in the trough 1102, the simulated VSWR values which were obtained are as shown in Table 1 as follows:

Table 1

25

Point on plot	VSWR	Frequency (GHz)
m1	1.869	0.8806
m2	1.311	0.9618
m3	2.204	1.711
m4	6.760	1.878

After optimization of the length of coaxial cable employed as the coaxial cable 600 (FIG. 6) to match the obtained resonance bands, a plot 1200 as shown in FIG. 12 of VSWR versus frequency for the same antenna was made. In this case the graph 1200 represents actual measured VSWR results obtained in use for the antenna (rather than obtained by simulation). Again, distinct troughs 1201 and 1202 in the VSWR plot 1200 are seen in FIG. 12 corresponding to the required resonances provided by the antenna. For two specific marker points, labelled n1 and n2, in the trough 1201 and two specific marker points, labelled n3 and n4, in the trough 1202, the actual VSWR values obtained were as shown in Table 2 as follows:

Table 2

Point on plot	VSWR	Frequency (GHz)
n1	1.75	0.824
n2	1.62	0.96
n3	1.46	1.71
n4	2.42	1.99

From Table 2 and FIG. 12 we can see that the new antenna embodying the invention even matches the required frequencies to operate at so-called 'quad band', namely the four major bands employed in the international GSM (Global System for Mobile communications), known respectively as 'GSM' or 'GSM 850' (824-894 MHz) 'EGSM' (Extended GSM) (880-960 MHz) 'DCS' (Digital Cellular System) (1710-1880 MHz) and

'PCS' (Personal Communications System) (1850-1990 MHz). The four marker points on the plot, n1 to n4, represent edges of these four bands.

In addition, the antenna gain is very important
5 parameter. The gain is the relative increase in
radiation power of the antenna at the point where the
radiation power is a maximum. The gain is also equal to
the efficiency times the directivity. For the antenna
investigated to give the results shown in Table 2 and
10 FIG. 12, the actually measured gain was found to be very
good, particularly in the required bands mentioned
above. For example, for an omnidirectional radiation
pattern, the measured antenna gain was 2.5 dBi at 850
MHz and 3.5 dBi at 1800 MHz. The efficiency (total
15 output power as a percentage of total input power)
obtained was at least 91 percent in the troughs 1201 and
1202.

As will be appreciated by those skilled in the art,
the experimental results which have been obtained and
20 set out above indicate suitably beneficial antenna
performance in at least two desired frequency bands of
dissimilar frequency.

FIG. 13 is a block schematic diagram of an RF
transceiver 1300 illustrating use of the antenna module
25 100 and embodying the invention. The transceiver 1300
may be incorporated in a communications mobile station
for data transmission, e.g. relating to tracking or
transport of parcels, packages and the like. The
transceiver 1300 includes in a transmitter portion a RF
30 synthesizer 1301 which generates a RF carrier signal.
The synthesizer is connected to a modulator 1302 in

which the carrier signal is modulated with a modulation signal containing information to be carried by the carrier signal. The modulator 1302 is connected to an amplifier 1303 which may comprise one or more
5 amplification stages. The amplifier 1303 is connected to the antenna module 100 via a switch 1304. The switch 1304 separates output RF signals delivered from the amplifier 1303 to the antenna module 101 from input RF signals received by the antenna module 101 and delivered
10 to a RF receiver 1309 via a connection 1306. The switch 1304 may be replaced by another known separator device (not shown) such as an isolator or a circulator. An RF feed line 1308, e.g. of the form shown in FIG. 6 or of the form shown in FIG. 7, delivers the output RF signal
15 to the coupled radiative elements 104 and 105 of the antenna module 101. The appropriate radiative element 104 or 105 sends amplified, modulated RF signals provided as outputs by the amplifier 1303 over-the-air to one or more distant receivers (not shown). The
20 signals are sent by the radiative element 104 when in a lower frequency band 880-960 GHz and are sent by the radiative element 105 when in a higher frequency band 1710-1880 GHz. Similarly, RF signals received in these bands (including components having the appropriate
25 linear vertical polarisations referred to earlier) are picked up by the appropriate element 104 or 105 and are passed to the receiver 1309 via the switch 1204 to be demodulated and processed to provide a suitable data output in a known manner.

CLAIMS

1. An antenna structure comprising an insulating
5 substrate and, formed on the insulating substrate, a
conductive sheet, a first radiative element and a second
radiative element, wherein each of the radiative
elements includes a first strip portion and a second
strip portion connected to and extending from the first
10 strip portion at an angle thereto, wherein the first and
second radiative elements are on opposite faces of the
substrate in adjacent regions.
2. An antenna structure according to claim 1 wherein the
first and second radiative elements are formed on
15 opposite faces of the substrate which are substantially
parallel and wherein at least part of one of the
adjacent regions overlies at least part of the other of
the adjacent regions when the substrate is horizontal.
3. An antenna structure according to claim 1 or claim 2
20 wherein the first radiative element is on the same face
of the substrate as the conductive sheet and is
galvanically connected to the conductive sheet.
4. An antenna structure according to any one of the
preceding claims wherein the first and second radiative
25 elements are galvanically connected.
5. An antenna structure according to claim 4 wherein the
first and second radiative elements are galvanically
connected by a connection formed through the insulating
substrate.
- 30 6. An antenna structure according to any one of claims 3
to 5 including a further conducting sheet formed on the

same face of the substrate as the second radiative element.

7. An antenna structure according to claim 6 wherein the further conductive sheet and the second radiative
5 element are not directly galvanically connected.

8. An antenna structure according to claim 6 or claim 7 wherein the conductive sheet and the further conductive sheet are directly galvanically connected.

9. An antenna structure according to any one of the
10 preceding claims wherein the second strip portion of at least one of the first and second radiative elements extends substantially perpendicularly to the first strip portion of that element.

10. An antenna structure according to any one of the
15 preceding claims wherein the first radiative element and the conductive sheet are coplanar on one face of the insulating substrate and the first portion of the first radiative element has a free end near, and extends substantially perpendicularly away from, an edge of the
20 conductive sheet.

11. An antenna structure according to claim 10 wherein the second strip portion of the first radiative element extends substantially perpendicularly to the first strip portion of that element and wherein the first radiative
25 element includes, connected to the second strip portion, a third strip portion galvanically connected to the conducting sheet and extending substantially parallel to the first strip portion of the first radiative element.

12. An antenna structure according to any one of claims
30 9 to 11 wherein the first radiative element includes, connected to the second strip portion of the first

radiative element, a further strip portion which has a corrugated shape.

13. An antenna structure according to any one of the preceding claims wherein at least part of the first
5 strip portion of the first radiative element overlies at least part of the first strip portion of the second radiative element when the insulating substrate is horizontal.
14. An antenna structure according to any one of the
10 preceding claims wherein at least part of the second strip portion of the first radiative element overlies at least part of the second strip portion of the second radiative element when the insulating substrate is horizontal.
15. An antenna structure according to any one of the preceding claims 6 to 14 wherein the first strip
portions of the first and second radiative elements are not directly galvanically connected to the conductive sheets.
- 20 16. An antenna structure according to any one of the preceding claims and including an RF feed connector galvanically connected to the first strip portion of the first radiative element.
17. An antenna structure according to claim 16 wherein
25 the RF feed connector is an inner conductor of a coaxial cable.
18. An antenna structure according to claim 16 wherein the RF feed connector comprises a strip connector formed on the insulating substrate.
- 30 19. An antenna structure according to any one of the preceding claims wherein at least one of the radiative

elements includes an enlarged portion at a junction between two strip portions of the element.

20. An antenna structure according to claim 19 wherein the second radiative element includes the enlarged
5 portion at a junction between the first and second strip portions of the second radiative element and the enlarged portion has, in each of two dimensions, a width which is enlarged compared with the width of the first and second strip portions of the second radiative
10 element.

21. An antenna structure according to any one of the preceding claims and substantially as described herein with reference to the accompanying drawings.

22. An RF transceiver for use in a portable RF
15 communications device, the transceiver including an antenna structure according to any one of the preceding claims.



INVESTOR IN PEOPLE

Application No: GB0508641.8

Examiner: Gareth Lewis

Claims searched: All

Date of search: 19 August 2005

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	-	EP1363355 A2 (KOSAN) see whole document, especially figures 1, 4, 5 and 6
A	-	US6181282 B1 (TYCO) See whole document, especially figures 3, 4 and column 1.
A	-	US6040803 A (ERICSSON) See abstract and all figures
A	-	US4072951 A (US NAVY) See abstract and figures
A	-	GB2389964 A (HARADA) See abstract and figures

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

H1Q

Worldwide search of patent documents classified in the following areas of the IPC⁰⁷

H01Q

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

Online : WPI, EPODOC, OPTICS