Title: WIDEBAND MONOPOLE ANTENNA

Abstract: The present invention is directed to a wideband monopole antenna arrangement (400, 400') for a portable radio device (300), which antenna arrangement (400, 400') comprises a substantially continuous conductor plate (410, 410') with a first antenna element (412, 612) and a second antenna element (414), and a signal ground (420) arranged to interact with said antenna elements (412, 414, 612) so as to form a wideband monopole antenna arrangement (400, 400'), wherein the first antenna element (412, 612) extends substantially at an angle $\theta$ with respect to the second antenna element (414), which angle $\theta$ forms the acute angle of a right-angled triangle T in which the first antenna element (412, 612) extends substantially in parallel to the hypotenuse h of the triangle T and the second antenna element 414 extends substantially in parallel to the longer cathetus c1 of the two catheti c1, c2 in the triangle T.
Published: with international search report

ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL,
NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG,
CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
WIDEBAND MONOPOLE ANTENNA

TECHNICAL FIELD OF THE INVENTION

5 The present invention relates to the field of monopole antennas. Embodiments of the invention relate to monopole antennas for operating at multiple frequency bands. Other embodiments relate to portable radio devices comprising such antennas.

DESCRIPTION OF RELATED ART

10 Within the field of portable radio devices there is commonly a need to make these devices operational at several frequency bands. Typically, portable radio devices are small and usually there is a limited space for providing this operational capacity.

15 The antenna arrangement in particular has turned out to be a crucial factor. Basically, different frequency bands require separate antennas which may not fit in the limited space of a portable device. Therefore, a single wideband antenna has frequently been used in portable radio devices.

20 However, it is a difficult task to design a single antenna small enough to fit in a portable device and efficient enough to provide a high performance over several different frequency bands. One approach has been to utilize the fundamental principles of a so-called monopole. As is well known, a monopole is basically a half dipole.

25 A typical dipole antenna 100 is schematically illustrated in Fig. 1. The dipole antenna 100 comprises two feed lines 110, 110'. The end portion of each feed line 110, 110' is bent in a substantially perpendicularly direction with respect to the feed line 110, 110' so as to form two antenna elements 112, 112'. The length of each antenna element 112, 112' is approximately one-quarter of the wavelength at the resonant frequency f₀ (e.g. λ/4 where λ is the wavelength of the resonant frequency f₀). In other words, a total length of the antenna elements 112, 112' is about one half of the wavelength at the resonant frequency f₀ (e.g., λ/2). The dipole antenna 100 is typically operated at a single frequency f₀.

For making the conventional dipole antenna more compact a simplification of the antenna can be formed on a suitable substrate arrangement, e.g. a circuit board or a similar. This
has been schematically illustrated in Fig. 2a and in Fig. 2b. Figure 2a presents a view from above of a so-called monopole antenna 200 and Fig. 2b presents a cross-section of the monopole antenna 200 in Fig. 2a, seen in the direction indicated by the arrows A–A.

5 The monopole antenna arrangement 200 in Fig. 2a and 2b comprises a substrate 250 (preferably a dielectric substrate), an electrically conductive patch line 210 (preferably a metallic patch line) and a ground metal plate 220 formed on the top surface of the dielectric substrate 250 at the same side as the patch line 210. Alternatively, the ground plane 220 may be formed on the bottom surface of the dielectric substrate 250, or in the dielectric substrate 250. One end of the patch line 210 is formed as a signal feed point 230, whereas the other end of the patch line 210 is formed as an antenna element 212 having an L-shape so that the antenna element 212 extend from the ground plane 220 in a direction substantially perpendicular to the patch line 210. In this manner a monopole antenna arrangement 200 is formed by the antenna element 212 interacting with the ground plane 220.

10 The monopole antenna arrangement 200 takes advantage of the ground plane 220 and the well known image theory to map the patch line 210 and the inverted L-shaped antenna element 212 so as to form a fictive second antenna element 212' indicated by dashed lines in Fig. 2a. As a result, a monopole antenna arrangement 200 having antenna elements 212, 212' substantially equivalent to the antenna elements 112, 112' of the above dipole antenna arrangement 100 is formed. The monopole antenna arrangement 200 is typically operated at a single frequency.

20 Even if the fundamental principles of monopoles may be used to accomplish an antenna that is smaller than a full dipole antenna it is still only suitable to operate in one frequency band. It would therefore be beneficial to have a small monopole antenna arrangement that fits in a portable device and that provides a high performance over several different frequency bands. This is particularly so considering the well known difficulties of designing small and efficient wideband antenna arrangements.
SUMMARY OF THE INVENTION

Embodiments of the present invention are directed to solving the problem of providing a small monopole antenna arrangement with a high performance over several different frequency bands. In addition, embodiments of the present invention are directed to a portable radio device comprising a small monopole antenna arrangement that provides a high performance over several different frequency bands.

At least one of the problems mentioned above is solved according to a first embodiment of the invention in which a wideband monopole antenna arrangement for a portable radio device. The antenna arrangement comprises a substantially continuous conductor plate with a first antenna element and a second antenna element, and a signal ground arranged to interact with said antenna elements so as to form a wideband monopole antenna arrangement. The first antenna element extends substantially at an angle \( \theta \) with respect to the second antenna element, which angle \( \theta \) forms the acute angle of a right-angled triangle \( T \) in which the first antenna element extends substantially in parallel to the hypotenuse \( h \) of the triangle \( T \) and the second antenna element extends substantially in parallel to the longer cathetus \( c_1 \) of the two catheti \( c_1, c_2 \) in the triangle \( T \).

A second embodiment of the invention is directed to an antenna arrangement including the features of the first embodiment and comprising at least one long-side of the first antenna element has a stair-like shape.

A third embodiment of the invention is directed to an antenna arrangement including the features of the first embodiment and comprising a connecting part forming a part of the first antenna element by elongating the first antenna element and the second antenna element by extending between an end of the first antenna element close to the acute angle \( \theta \) and an end of the second antenna element close to the acute angle \( \theta \).

A fourth embodiment of the invention is directed to an antenna arrangement including the features of the third embodiment and wherein the connecting part extends in a direction that is substantially perpendicular to the extension of the second antenna element.

A fifth of the invention is directed to an antenna arrangement including the features of the first embodiment and comprising a first extension part forming a part of the second
antenna element by elongating the second antenna element by extending from an end of the second antenna element that is distant from the acute angle \( \theta \).

A sixth embodiment of the invention is directed to an antenna arrangement including the features of the fifth embodiment wherein the first extension part extends towards the first antenna element at an end that is distant from the acute angle \( \theta \).

A seventh embodiment of the invention is directed to an antenna arrangement including the features of the fifth embodiment and wherein the first extension part extends in a direction that is substantially perpendicular to the extension of the second antenna element.

An eighth embodiment of the invention is directed to an antenna arrangement including the features of the fifth embodiment and wherein a second extension part elongates the second antenna element by extending from an end of the first extension part that is distant from the first antenna element.

A ninth embodiment of the invention is directed to an antenna arrangement including the features of the eighth embodiment and wherein the second extension element extends towards the second antenna element at an end that is close to the acute angle \( \theta \).

A tenth embodiment of the invention is directed to an antenna arrangement including the features of the eighth embodiment and wherein the second extension element extends in a direction that is substantially parallel to the second antenna element.

An eleventh embodiment of the invention is directed to an antenna arrangement including the features of the first embodiment and wherein the first antenna element is longer than the second antenna element with the effect that the first antenna element is dimensioned so as to radiate in the lower operating band or bands of the antenna arrangement, and the shorter second antenna element is dimensioned so as to radiate in the upper operating band or bands of the antenna arrangement.

A twelfth embodiment of the invention is directed to an antenna arrangement including the features of the first embodiment and wherein the second antenna element is longer than the first antenna element with the effect that the second antenna element is dimensioned
so as to radiate in the lower operating band or bands of the antenna arrangement, and the shorter first antenna element is dimensioned so as to radiate in the upper operating band or bands of the antenna arrangement.

5 A thirteenth embodiment of the invention is directed to an antenna arrangement including the features of the first embodiment and comprising a feed point is arranged near the end of the second antenna element that is close to the acute angle $\theta$, for connecting a feed conductor to the antenna elements.

10 A fourteenth embodiment of the invention is directed to an antenna arrangement including the features of the thirteenth embodiment and wherein the feed point comprises a matching network for maximizing the power transfer from said feed conductor to the antenna elements.

15 A fifteenth embodiment of the invention is directed to an antenna arrangement including the features of the fourteenth embodiment and wherein the matching network is a PI-network comprising three components $Z_1$, $Z_2$ and $Z_3$.

A sixteenth embodiment of the invention is directed to an antenna arrangement including the features of the fifteenth embodiment and wherein a first component $Z_1$ in the matching network is arranged to be operatively connected between a feed line and the conductor plate, a second component $Z_2$ is arranged to be operatively connected between the feed line and the signal ground 420, and a third component $Z_3$ is connected between the conductor plate and the signal ground.

20 A seventeenth embodiment of the invention is directed to an antenna arrangement including the features of the sixteenth embodiment and wherein a the first component $Z_1$ in the matching network is a capacitance of approximately 5 pF, the second component $Z_2$ is a capacitance of approximately 1 pF and the third component $Z_3$ is an inductance of approximately 9 nH, so as to match a feed conductor having a characteristic impedance of approximately 50 ohms.

In addition, at least on of the problems mentioned above is solved according to an eighteenth aspect of the invention in which a portable radio device comprises a wideband monopole antenna arrangement, which antenna arrangement comprises a substantially
continuous conductor plate with a first antenna element and a second antenna element, and a signal ground arranged to interact with said antenna elements so as to form a wideband monopole antenna arrangement. The first antenna element extends substantially at an angle \( \theta \) with respect to the second antenna element, which angle \( \theta \) forms the acute angle of a right-angled triangle \( T \) in which the first antenna element extends substantially in parallel to the hypotenuse \( h \) of the triangle \( T \) and the second antenna element extends substantially in parallel to the longer cathetus \( c1 \) of the two catheti \( c1, c2 \) in the triangle \( T \).

10 A nineteenth embodiment of the invention is directed to a radio device including the features of the eighteenth embodiment and wherein at least one long-side of the first antenna element has a stair-like shape.

A twentieth embodiment of the invention is directed to a radio device including the features of the eighteenth embodiment and comprising a connecting part forming a part of the first antenna element by elongating the first antenna element and the second antenna element by extending between an end of the first antenna element close to the acute angle \( \theta \) and an end of the second antenna element close to the acute angle \( \theta \).

20 A twenty-first embodiment of the invention is directed to a radio device including the features of the twentieth embodiment and wherein the connecting part extends in a direction that is substantially perpendicular to the extension of the second antenna element.

25 A twenty-second embodiment of the invention is directed to a radio device including the features of the eighteenth embodiment and wherein a first extension part forming a part of the second antenna element by elongating the second antenna element by extending from an end of the second antenna element that is distant from the acute angle \( \theta \).

30 A twenty-third embodiment of the invention is directed to a radio device including the features of the twenty-second embodiment and wherein the first extension part extends towards the first antenna element at an end that is distant from the acute angle \( \theta \).

A twenty-fourth embodiment of the invention is directed to a radio device including the features of the twenty-second embodiment and wherein the first extension part extends in
a direction that is substantially perpendicular to the extension of the second antenna element.

A twenty-fifth embodiment of the invention is directed to a radio device including the features of the twenty-second embodiment and comprising a second extension part extends the second antenna element 414 by extending from an end of the first extension part that is distant from the first antenna element.

A twenty-sixth embodiment of the invention is directed to a radio device including the features of the twenty-fifth embodiment and wherein the second extension element extends towards the second antenna element at an end that is close to the acute angle θ.

A twenty-seventh embodiment of the invention is directed to a radio device including the features of the twenty-fifth embodiment and wherein the second extension element extends in a direction that is substantially parallel to the second antenna element.

A twenty-eighth embodiment of the invention is directed to a radio device including the features of the eighteenth embodiment and wherein the first antenna element is longer than the second antenna element with the effect that the first antenna element is dimensioned so as to radiate in the lower operating band or bands of the antenna arrangement, and the shorter second antenna element is dimensioned so as to radiate in the upper operating band or bands of the antenna arrangement.

A twenty-ninth embodiment of the invention is directed to a radio device including the features of the eighteenth embodiment and wherein the second antenna element is longer than the first antenna element with the effect that the second antenna element is dimensioned so as to radiate in the lower operating band or bands of the antenna arrangement, and the shorter first antenna element is dimensioned so as to radiate in the upper operating band or bands of the antenna arrangement.

A thirtieth embodiment of the invention is directed to a radio device including the features of the eighteenth embodiment and comprising a feed point that is arranged near the end of the second antenna element that is close to the acute angle θ, for connecting a feed conductor to the antenna elements.
A thirty-first embodiment of the invention is directed to a radio device including the features of the thirtieth embodiment and wherein the feed point comprises a matching network for maximizing the power transfer from said feed conductor to the antenna elements.

A thirty-second embodiment of the invention is directed to a radio device including the features of the thirty-first embodiment and wherein the matching network is a PI-network comprising three components Z1, Z2 and Z3.

A thirty-third embodiment of the invention is directed to a radio device including the features of the thirtieth embodiment and wherein a first component Z1 in the matching network is arranged to be operatively connected between a feed line and the conductor plate, a second component Z2 is arranged to be operatively connected between the feed line and the signal ground, and a third component Z3 is connected between the conductor plate and the signal ground.

A thirty-fourth embodiment of the invention is directed to a radio device including the features of the thirty-third embodiment and wherein a first component Z1 in the matching network is a capacitance of approximately 5 pF, the second component Z2 is a capacitance of approximately 1 pF and the third component Z3 is an inductance of approximately 9 nH, so as to match a feed conductor having a characteristic impedance of approximately 50 ohms.

The present invention provides an improved single antenna arrangement for a portable radio device, which antenna arrangement provides excellent properties over a wide range of frequency bands at the same time as it is small enough to fit within the portable device.

Further advantages of the present invention and embodiments thereof will appear from the following detailed description of the invention.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components, but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.
BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in more detail in relation to the enclosed drawings, in which:

Fig. 1 is a schematic illustration of a typical dipole antenna arrangement 100,
Fig. 2a is a schematic illustration of a monopole antenna arrangement 200, seen from the above,
Fig. 2b is a schematic illustration of a cross-section of the antenna arrangement 200 in Fig. 2a, seen in the direction indicated by the arrows A–A,
Fig. 3 is a schematic illustration of an exemplifying portable communication device comprising a wideband monopole antenna arrangement 400 according to an embodiment of the invention,
Fig. 4 is a schematic illustration showing relevant details of the antenna arrangement 400 in the exemplifying cell phone 300 in Fig. 3,
Fig. 5 shows the conductor plate 410 and the antenna element 412, 414 of the antenna arrangement 400 in relation to a right-angled triangle T,
Fig. 6 is a schematic illustration showing relevant details of a monopole antenna arrangement 400' according to another embodiment of the present invention,
Fig. 7 is a schematic illustration of the feed point 430 having a matching network 710,
Fig. 8 is an exemplifying graph showing the Voltage Standing Wave Ratio (VSWR) for the antenna arrangement 400,
Fig. 9 is an exemplifying graph showing the radiation efficiency for the antenna arrangement 400.

DETAILED DESCRIPTION OF EMBODIMENTS

Embodiments of the present invention relate to a wideband antenna for portable communication devices and a portable communication device comprising such an antenna. However, the invention is by no means limited to wideband antennas for portable communication devices or portable communication devices comprising such antennas. Rather, the invention can be applied to any suitable portable radio device.
Figure 3 is a schematic illustration of an exemplifying portable communication device 300 comprising a wideband monopole antenna arrangement 400 according to a preferred embodiment of the invention. The antenna arrangement 400 is assumed to be arranged within the device 300 and it is indicated in Fig. 3 by a rectangle with dashed lines. Preferably, the device 300 is a cell phone arranged to operate on a plurality of frequency bands, e.g. a plurality of frequency bands within the range of approximately 850 MHz to approximately 2400 MHz.

For example, it is well known that cell phones according to the Global System for Mobile communications (GSM) may be operational on three different frequency bands (e.g. 900/1800/1900 MHz or 850/1800/1900 MHz). Similarly, it is well known that cell phones according to the Universal Mobile Telecommunication System (UMTS) may operate on one or several frequency bands within the range of approximately 800–2600 MHz. Moreover, it is well known that cell phones and similar radio devices may have the ability to operate both as a GSM phone and as a UMTS phone. Moreover, it is well known that modern cell phones may have the ability to communicate with other networks in addition to one or several cellular telecommunication networks (e.g. in addition to GSM and/or UMTS). Modern cell phones may e.g. have the additional capability to communicate on the 2400 MHz band with Bluetooth devices and/or WiFi devices and/or with similar radio devices on other frequency bands. The frequency bands and the general radio properties of GSM devices, UMTS devices, Bluetooth devices and WiFi devices etc are well known to those skilled in the art and there is no need for a more detailed description.

Figure 4 is a schematic illustration showing relevant details of the exemplifying antenna arrangement 400 in the cell phone 300 in Fig. 3. The antenna arrangement 400 is a monopole antenna arrangement that fits within the cell phone 300 while still providing a high performance within the range of approximately 850 MHz to approximately 2400 MHz.

As will be further described below, the antenna arrangement 400 comprises a principally rectangular and substantially continuous conductor plate 410 enclosed by a rectangle with dashed lines in Fig. 4. Moreover, the antenna arrangement 400 comprises a substantially continuous signal ground 420 and a feed point 430.

The signal ground 420 is preferably arranged at a predetermined distance from a lower short-end 411b of the principally rectangular conductor plate 410 so that the conductor
plate 410 and its antenna elements 412, 414 can interact with the signal ground 420 to form a wideband monopole antenna as will be further described later. The properties of the signal ground 420 is less relevant to embodiments of the invention as long as the well known image theory can be utilized to map the antenna elements 412, 414 so as to form a monopole antenna arrangement, e.g. in the same or similar manner as previously indicated for the fictive antenna element 212' in Fig. 2a. It is preferred that the signal ground 420 is formed on the upper surface of a substrate 250 – e.g. a dielectric substrate – in the same or similar manner as shown in Fig. 2b for the ground metal plate 220 formed on the substrate 250.

The feed point 430 of the antenna arranged 400 is arranged approximately at the lower right corner of the principally rectangular conductor plate 410. The feed point 430 is adapted to connect the conductor plate 410 to a feed conductor 450. The feed conductor 450 may be any suitable waveguide for guiding microwaves to the feed point 430, e.g. such as a coaxial cable or a microstrip transmission line or similar. It is preferred that the feed point 430 is formed on the upper surface of the substrate 250.

Before we proceed it should be emphasized that the signal ground 420 and possibly also the feed point 430 may alternatively be formed at the lower surface of the substrate 250, or possibly even within the substrate 250.

The attention is now directed to the substantially continuous and principally rectangular conductor plate 410. It is preferred that the conductor plate 410 is formed on the surface of the substrate 250, e.g. in the same or similar manner as shown in Fig. 2b for the antenna element 212 formed on the substrate 250. Alternatively, the conductor plate 410 may be formed at the lower surface of the substrate 250 or within the substrate 250. It should also be emphasized that embodiments of the conductor plate 410 may be formed by a rigid and self-supporting conductive sheet, e.g. a metal sheet. In such embodiments only parts of the conductor plate 410 may be formed on the substrate 250, whereas the rest of the conductor plate 410 is self-supporting.

As already indicated, the conductor plate 410 comprises a first antenna element 412 and a second antenna element 414. The antenna elements 412, 414 are generally formed by a slot 416 having plurality of branches.
A first branch 416a of the slot 416 starts at an end approximately at the upper left corner of the substantially rectangular conductor plate 410. From there it extends towards the feed point 430 to an end close to the feed point 430 along a stepped pattern and principally at an angle \( \alpha \) with respect to the upper short-end 411a of the substantially rectangular conductor plate 410. The first branch 416a of the slot 416 ends approximately at the lower short-end 411b of the substantially rectangular conductor plate 410.

In this manner, the first branch 416a of the slot 416 delimits a part of the conductor plate that extends from an end distant from the feeding point 430 to and end close to the feeding point 430 and substantially at the angle \( \alpha \) with respect to the lower short-end 411b of the conductor plate 410, which lower short 411b end is substantially parallel to the upper short-end 411a. This part forms the main part of an oblique first antenna element 412 of the antenna arrangement 400 extending from the feed point 430 at an angle \( \alpha \) less than 90° with respect to the lower short-end 411b of the conductor plate 410 (equivalent to an angle \( \beta = 180° - \alpha \) being more than 90° with respect to the lower short-end 411b).

A second branch 416b of the slot 416 extends from the end of the first branch 416a in a direction towards the feed point 430 and a long-side 411c of the conductor plate 410, and substantially in parallel to the lower short-end 411b. The second branch 416b of the slot 416 ends approximately at the long-side 411c. The second branch 416b delimits a connecting part 412' of the conductor plate 410. The connecting part 412' extends from the end of the first antenna element 412 that is closest to the feeding point 430 and substantially in parallel to the upper and lower short ends 411a, 411b. The connecting part 412' forms a substantially horizontal part of the first oblique antenna element 412.

A third branch 416c of the slot 416 extends from the end of the second branch 416b in a direction from the feed point 430 and substantially in parallel to the long-side 411c, in turn being substantially perpendicular to the upper and lower short-ends 411a, 411b. The third branch 416c of the slot 416 ends approximately at the upper short-end 411a. The third branch 416c delimits a part of the conductor plate that extends from an end close to the feeding point 430 to end distant from the feeding point 430 and in a direction substantially perpendicular to the upper and lower short ends 411a, 411b. This part forms the main part of the substantially straight and vertical second antenna element 414 of the antenna arrangement 400.
A fourth branch 416d of the slot 416 extends from the end of the third branch 416c in a direction from the long-side 411c and substantially in parallel to the upper and lower short ends 411a, 411b. The fourth branch 416d of the slot 416 ends approximately at the first branch 416a of the slot 416.

The fourth branch 416d delimits an extension part of the conductor plate that extends from the end of the second antenna element 414 being distant to the feed point 430 and towards the first antenna element 412 in a direction substantially parallel to the upper and lower short ends 411a, 411b. The extension part 414' forms a substantially horizontal part of the second vertical antenna element 414.

In addition, the first branch 416a, the second branch 416b and the third branch of the slot 416 delimits a second extension part 414” of the conductor plate that extends from the end of the first extension part 414’ being distant to the second antenna element 414 and towards the connection part 412’ in a direction substantially perpendicular to the upper and lower short ends 411a, 411b. The second extension part 414” forms an additional substantially vertical part of the second vertical antenna element 414.

From the above the observant reader realizes that the first oblique antenna element 412 extends substantially at an angle $\theta = 90^\circ - \alpha$ with respect to the second antenna element 414. In fact, as schematically illustrated in Fig. 5 the angle $\theta$ between the first oblique antenna element 412 and the second vertical antenna element 414 forms the acute angle in a right-angled triangle $T$ indicated by dashed lines in Fig. 5. In the triangle $T$ the first oblique antenna element 412 extend in parallel to the hypotenuse $h$ in the triangle $T$ and the second vertical antenna element 414 extend from the feed point 430 and in parallel to the longer cathetus $c1$ of the two catheti $c1$, $c2$ in the triangle $T$.

In addition, from the above it can be concluded that the connecting part 412’ connecting the first antenna element 412 and the second antenna element extends between the end of the first antenna element 412 that is close to the feeding point 430, and the end of the second antenna element that is close to the feeding point 430. In other words, the connecting part 412’ extends between the end of the first antenna element 412 that is close to the acute angle $\theta$, and the end of the second antenna element (414) that is close to the acute angle $\theta$. 

Moreover, from the above it can be concluded that the first extension part 414' extending the second antenna element 414 extends from the end of the second antenna element 414 that is distant from the feeding point 430 towards the first antenna element 412 and in a direction that is substantially perpendicular to the second antenna element 414.

From the above it can also be concluded that the second extension part 414" extending the second antenna element 414 extends from the end of the first extension part 414' that is distant from the first antenna element 414 towards the connecting part 412' and in a direction that is substantially parallel to the second antenna element 414.

The oblique first antenna element 412 may be longer than the second vertical antenna element 414 with the effect that the longer first antenna element 412 is dimensioned so as to radiate in the lower operating band or bands of the antenna arrangement 400, and the shorter second antenna element 414 is dimensioned so as to radiate in the upper operating band or bands of the antenna. This is particularly so if the connecting part 412' is considered to be a part of the first antenna element 412.

However, the second vertical antenna element 414 may be longer than the first oblique antenna element 414 with the effect that the longer second antenna element 414 is dimensioned so as to radiate in the lower operating band or bands of the antenna arrangement 400, and the shorter first antenna element 412 is dimensioned so as to radiate in the upper operating band or bands of the antenna. This is particularly so if the first extension part 414' is considered to be a part of the second antenna element 414, and this is even more so if the second extension part 414" is also considered to be a part of the second antenna element 414.

Exemplifying dimensions of the substantially rectangular conductor plate 410 may be approximately 40 millimeters x 60 millimeters. The oblique first antenna element 412 may be approximately 50 millimeters long and the second vertical antenna element 414 may be approximately 40 millimeters long. The connecting part 412' may be approximately 20 millimeters long and the extension part 414' may be approximately 25 millimeters long. The angle θ may be approximately 20°. It should be emphasized that other dimensions are conceivable, particularly dimensions that deviates from the given exemplifying dimensions by less than +/- 10%.
Figure 6 is a schematic illustration showing relevant details of a monopole antenna arrangement 400' according to another embodiment of the present invention. The antenna arrangement 400' comprises a conductor plate 410' that is substantially similar to the previously described conductor plate 410. However, the first branch 616a of the slot 616 in Fig. 6 extends along a straight line instead of the stepped or stair-like patter, along which the first branch of the slot 416 of the conductor plate 410 extends in Fig. 3. Hence, the first antenna element 612 of the conductor plate 410' has a substantially straight shape compared to the first antenna element 412 of the conductor plate 410 which has one long side that displays a stair-like (i.e. a stepped) shape.

Figure 7 is a schematic illustration of the feed point 430 that is adapted to connect the conductor plate 410 or 410' and the antenna elements 412, 414, 612 to a feed conductor 450 as previously indicated. The feed point 430 comprises a metal plate 750 or a similar mounting patch for connecting the feed conductor 450, e.g. by means of soldering or bonding or similar. The metal plate 750 is "free floating", i.e. the metal plate 750 is preferably not connected to other electrical components except those explicitly described herein.

In addition, and more importantly, the feed point 430 comprises a matching network 710. As can be seen in Fig. 7 it is preferred that the matching network is a so-called PI-network comprising a first component Z1 connected between the mounting patch 750 and the conductor plate 410 or 410', a second component Z2 connected between the mounting patch 750 and the signal ground 420, and a third component Z3 connected between the conductor plate 410 or 410' and the signal ground 420. In this manner the components form a stylized PI (i.e. the Greece letter π). The matching network 710 is arranged so as to maximize the power transfer from the feed conductor 450 to the conductor plate 410, 410' and the antenna elements 412, 414, 612 as may be the case.

Exemplifying values of the components Z1, Z2 and Z3 for matching a feed conductor 450 having a characteristic impedance of substantially 50 ohms may be substantially 5pF for Z1, substantially 1 pF for Z2, and substantially 9 nH for Z3. Here, it should be clarified that these values presuppose ideal components. However, a person skilled in the art is well aware of the fact that commercially available components always have resistive losses and possibly other loses that should be kept at a minimum. In addition, it is also well known to those skilled in the art, the selection of a suitable matching network and suitable
values for the components in the selected matching network is very difficult and absolutely
5 crucial for an antenna arrangement.

Figure 8 is an exemplifying graph showing the Voltage Standing Wave Ratio (VSWR) for
the antenna arrangement 400. The horizontal x-axis extend from 0,4 GHz to 2,8 GHz.
The vertical y-axis shows the VSWR at a certain frequency within the above frequency
span (0,4–2,8 GHz).

Figure 9 is an exemplifying graph showing the radiation efficiency for the antenna
arrangement 400. The horizontal x-axis extend from 0,6 GHz to 2,8 GHz. The vertical y-
axis shows the radiation efficiency at a certain frequency within the above frequency span
(0,6–2,8 GHz).

The present invention has been described above with reference to exemplifying
15 embodiments. However, the invention is not limited to the embodiments described herein.
On the contrary, the full extent of the invention is only determined by the scope of the
 appended claims.
CLAIMS

1. A wideband monopole antenna arrangement (400, 400') for a portable radio device (300), which antenna arrangement (400, 400') comprises a substantially continuous conductor plate (410, 410') with a first antenna element (412, 612) and a second antenna element (414), and a signal ground (420) arranged to interact with said antenna elements (412, 414, 612) so as to form a wideband monopole antenna arrangement (400, 400'),
   wherein:
   the first antenna element (412, 612) extends substantially at an angle (θ) with respect to the second antenna element (414), which angle (θ) forms the acute angle of a right-angled triangle (T) in which the first antenna element (412, 612) extends substantially in parallel to the hypotenuse (h) of the triangle (T) and the second antenna element (414) extends substantially in parallel to the longer cathetus (c1) of the two catheti (c1, c2) in the triangle (T).

2. The antenna arrangement (400, 400') according to claim 1,
   wherein:
   at least one long-side of the first antenna element has a stair-like shape.

3. The antenna arrangement (400, 400') according to claim 1,
   wherein:
   a connecting part (412') forming a part of the first antenna element (412) by elongating the first antenna element (412, 612) and the second antenna element (414) by extending between an end of the first antenna element (412) close to the acute angle (θ) and an end of the second antenna element (414) close to the acute angle (θ).

4. The antenna arrangement (400, 400') according to claim 3,
   wherein:
   the connecting part (412') extends in a direction that is substantially perpendicular to the extension of the second antenna element (414).
5. The antenna arrangement (400, 400') according to claim 1, wherein:
a first extension part (414') forming a part of the second antenna element (414) by
elongating the second antenna element (414) by extending from an end of the
second antenna element (414) that is distant from the acute angle (θ).

6. The antenna arrangement (400, 400') according to claim 5, wherein:
the first extension part (414') extends towards the first antenna element (412, 612) at
an end that is distant from the acute angle (θ).

7. The antenna arrangement (400, 400') according to claim 5, wherein:
the first extension part (414') extends in a direction that is substantially perpendicular
to the extension of the second antenna element (414).

8. The antenna arrangement (400, 400') according to claim 5, wherein:
a second extension part (414'') elongate the second antenna element (414) by
extending from an end of the first extension part (414') that is distant from the first
antenna element (414).

9. The antenna arrangement (400, 400') according to claim 8, wherein:
the second extension element (414'') extends towards the second antenna element
(414) at an end that is close to the acute angle θ.

10. The antenna arrangement (400, 400') according to claim 8, wherein:
the second extension element (414'') extends in a direction that is substantially
parallel to the second antenna element (414).
11. The antenna arrangement (400, 400') according to claim 1, wherein:
the first antenna element (412, 612) is longer than the second antenna element (414) with the effect that the first antenna element (414, 614) is dimensioned so as to radiate in the lower operating band or bands of the antenna arrangement (400, 410'), and the shorter second antenna element (414) is dimensioned so as to radiate in the upper operating band or bands of the antenna arrangement (400, 400').

12. The antenna arrangement (400, 400') according to claim 1, wherein:
the second antenna element (414) is longer than the first antenna element (412, 612) with the effect that the second antenna element (414) is dimensioned so as to radiate in the lower operating band or bands of the antenna arrangement (400, 410'), and the shorter first antenna element (412, 612) is dimensioned so as to radiate in the upper operating band or bands of the antenna arrangement (400, 400').

13. The antenna arrangement (400, 400') according to claim 1, wherein:
a feed point (430) is arranged near the end of the second antenna element (414) that is close to the acute angle (θ), for connecting a feed conductor (450) to the antenna elements (412, 414, 612).

14. The antenna arrangement (400, 400') according to claim 13, wherein:
the feed point (430) comprises a matching network (710) for maximizing the power transfer from said feed conductor (450) to the antenna elements (412, 414, 612).

15. The antenna arrangement (400, 400') according to claim 14, wherein:
the matching network (710) is a PI-network comprising three components (Z1, Z2, Z3).
16. The antenna arrangement (400, 400') according to claim 15, wherein:
a first component (Z1) in the matching network (710) is arranged to be operatively connected between a feed line (450) and the conductor plate (410 or 410'), a second component (Z2) is arranged to be operatively connected between the feed line (450) and the signal ground 420, and a third component (Z3) is connected between the conductor plate (410, 410') and the signal ground (420).

17. The antenna arrangement (400, 400') according to claim 16, wherein:
a first component (Z1) in the matching network (710) is a capacitance of approximately 5 pF, the second component (Z2) is a capacitance of approximately 1 pF and the third component (Z3) is an inductance of approximately 9 nH, so as to match a feed conductor having a characteristic impedance of approximately 50 ohms.

18. A portable radio device (300) provided with a wideband monopole antenna arrangement (400, 400'), which antenna arrangement (400, 400') comprises a substantially continuous conductor plate (410, 410') with a first antenna element (412, 612) and a second antenna element (414), and a signal ground (420) arranged to interact with said antenna elements (412, 414, 612) so as to form a wideband monopole antenna arrangement (400, 400'), wherein:
the first antenna element (412, 612) extends substantially at an angle (θ) with respect to the second antenna element (414), which angle (θ) forms the acute angle of a right-angled triangle (T) in which the first antenna element (412, 612) extends substantially in parallel to the hypotenuse (h) of the triangle (T) and the second antenna element (414) extends substantially in parallel to the longer cathetus (c1) of the two catheti (c1, c2) in the triangle (T).

19. The portable radio device (300) according to claim 18, wherein:
at least one long-side of the first antenna element has a stair-like shape.
20. The portable radio device (300) according to claim 18, wherein:
a connecting part (412') forming a part of the first antenna element (412) by elongating the first antenna element (412, 612) and the second antenna element (414) by extending between an end of the first antenna element (412) close to the acute angle (θ) and an end of the second antenna element (414) close to the acute angle (θ).

21. The portable radio device (300) according to claim 20, wherein:
the connecting part (412') extends in a direction that is substantially perpendicular to the extension of the second antenna element (414).

22. The portable radio device (300) according to claim 18, wherein:
a first extension part (414') forming a part of the second antenna element (414) by elongating the second antenna element (414) by extending from an end of the second antenna element (414) that is distant from the acute angle (θ).

23. The portable radio device (300) according to claim 22, wherein:
the first extension part (414') extends towards the first antenna element (412, 612) at an end that is distant from the acute angle (θ).

24. The portable radio device (300) according to claim 22, wherein:
the first extension part (414') extends in a direction that is substantially perpendicular to the extension of the second antenna element (414).

25. The portable radio device (300) according to claim 22, wherein:
a second extension part (414'') extends the second antenna element (414) by extending from an end of the first extension part (414') that is distant from the first antenna element (414).
26. The portable radio device (300) according to claim 25, wherein:
   the second extension element (414") extends towards the second antenna element (414) at an end that is close to the acute angle (θ).

27. The portable radio device (300) according to claim 25, wherein:
   the second extension element (414") extends in a direction that is substantially parallel to the second antenna element (414).

28. The portable radio device (300) according to claim 18, wherein:
   the first antenna element (412, 612) is longer than the second antenna element (414) with the effect that the first antenna element (414, 614) is dimensioned so as to radiate in the lower operating band or bands of the antenna arrangement (400, 410'), and the shorter second antenna element (414) is dimensioned so as to radiate in the upper operating band or bands of the antenna arrangement (400, 400').

29. The portable radio device (300) according to claim 18, wherein:
   the second antenna element (414) is longer than the first antenna element (412, 612) with the effect that the second antenna element (414) is dimensioned so as to radiate in the lower operating band or bands of the antenna arrangement (400, 410'), and the shorter first antenna element (412, 612) is dimensioned so as to radiate in the upper operating band or bands of the antenna arrangement (400, 400').

30. The portable radio device (300) according to claim 18, wherein:
   a feed point (430) is arranged near the end of the second antenna element (414) that is close to the acute angle (θ), for connecting a feed conductor (450) to the antenna elements (412, 414, 612).
31. The portable radio device (300) according to claim 30, wherein:
the feed point (430) comprises a matching network (710) for maximizing the power transfer from said feed conductor (450) to the antenna elements (412, 414, 612).

32. The portable radio device (300) according to claim 31, wherein:
the matching network (710) is a PI-network comprising three components (Z1, Z2, Z3).

33. The portable radio device (300) according to claim 32, wherein:
a first component (Z1) in the matching network (710) is arranged to be operatively connected between a feed line (450) and the conductor plate (410 or 410'), a second component (Z2) is arranged to be operatively connected between the feed line (450) and the signal ground (420), and a third component (Z3) is connected between the conductor plate (410, 410') and the signal ground (420).

34. The portable radio device (300) according to claim 33, wherein:
a the first component (Z1) in the matching network (710) is a capacitance of approximately 5 pF, the second component (Z2) is a capacitance of approximately 1 pF and the third component (Z3) is an inductance of approximately 9 nH, so as to match a feed conductor having a characteristic impedance of approximately 50 ohms.
Fig. 1

Fig. 2a

Fig. 2b
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01Q1/24 H01Q5/00 H01Q9/40 H01Q9/42 H01Q9/44
H01Q9/46 H01Q21/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>WO 2005/076409 A (FRACTUS SA [ES]; SOLER CASTANNY JORDI [ES]; PUENTE BALIARDA CARLES [ES]) 18 August 2005 (2005-08-18) page 4, line 8 - page 5, line 19; figures 3, 4</td>
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Date of the actual completion of the international search 18 August 2008

Date of mailing of the International search report 26/08/2008

Name and mailing address of the ISA/ European Patent Office, P.B. 5518 Patentlaan 2 NL – 2280 HV Rijswijk, Tel. (+31-70) 340-2040, Tx. 31 651 epi nl, Fac. (+31-70) 340-3016

Authorized officer Van Dooren, Gerry

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