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(54) Patch antenna

(57) An antenna for radiating at a plurality of frequencies including a ground plane (1) serving as a reflector against which a patch (2) is electrically driven. A further patch (3) is stacked above the first patch (2) and is intended to resonate at a frequency in the upper frequency band and utilises the first patch (2) as its ground plane. The lower patch (2) is driven from voltage sources (4a, 4b, 5a and 5b) established on the ground plane (1) and connected to the patch (2) by means of probe wires (10a-d) and series capacitors (8a-d) formed within the patch. Similarly, the upper patch (3) is driven by voltage sources (6a, 6b, 7a, 7b) established in the lower frequency patch and connected by respective wire probes (11a-d) and series capacitors (9a-d) within the upper frequency patch. Respective lines joining the pairs of points are orthogonal.

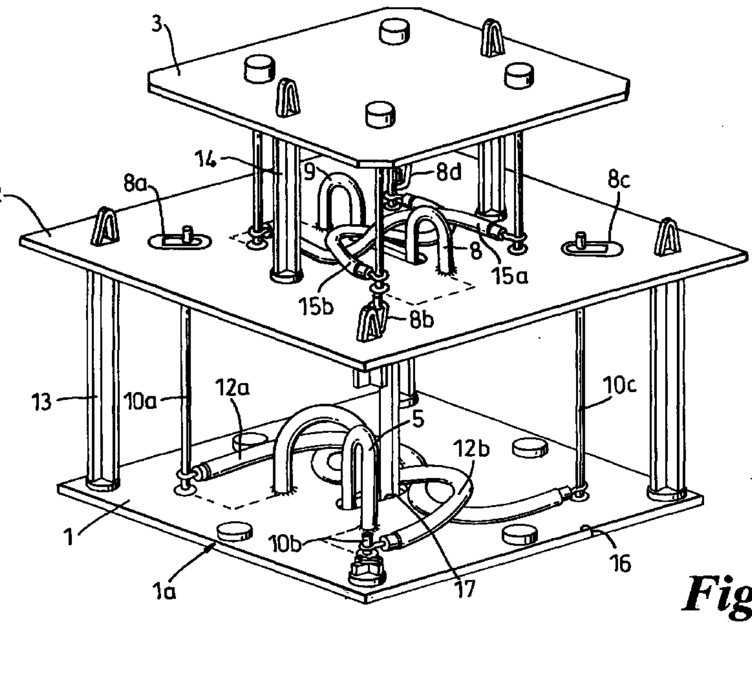

Fig. 2

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Description

[0001] This invention relates to a patch antenna.

[0002] The mobile telephone market has experienced a phenomenal growth in subscribers over the last year, leading to traffic capacity problems in certain areas. As it is becoming increasingly difficult to install extra base stations because of planning restrictions, increasing the band width and channels available is the most preferable solution to the problem. Most of the operators possess licences to operate in both mobile telephone bands (GSM:872-960 MHz and PCN:170-1880 MHz) and indeed dual band handsets are becoming available. This means there is an increasing requirement for base station antenna to be capable of operating over both bands.

[0003] Obviously two separate antennae could be used, however the Applicants have appreciated that it would be extremely advantageous to place an antenna for each band inside the same package, because this would reduce tower or building space rental costs, reduce wind load, provide a better visual appearance and simplify installation. For similar reasons it is also advantageous to minimize the length of the antenna. The Applicants have realised that this could be achieved if the antenna share the same aperture and indeed be constituted by two arrays that have intersecting or collocated elements. Further the Applicants have appreciated that if the antenna elements could have separate feeds and distribution circuits for both bands, then it would permit complete independence between the services and flexibility in antenna performance, e.g. gain and patterns.

[0004] From one aspect the invention consists in an antenna for radiating at a plurality of frequencies including a ground plane for a first patch and a patch for each frequency, the patches being spaced and arranged in a stack with the ground plane such that the or each preceding patch constitute the ground plane for its succeeding patch; each patch being electrically surrounded by its respective ground plane whereby each ground plane will not resonate at its respective patches associated frequency .

[0005] The use of each preceding patch as a ground plane for the succeeding patch enables a precisely co-located compact multi-band antenna to be constructed. In many situations only two patches will be required, for example one for each of a pair of frequencies in the respective mobile telephone bands, but there is no reason why a multi-band antenna with three or more patches should not be constructed, although as the desirable spacing of the patches decreases with frequency, there is obviously a physical limit to the number of patches that can be stacked. The area of the ground plane is preferably at least 50% greater than the area of the patch and ratio of 2:1 has been found to provide good 'forward' radiation.

[0006] Preferably the antenna includes respective means for feeding each patch. It is particularly preferred that these feeding means feed the patches for dual polarised operation because of the improvement in reception in adverse environments. If dual polarisation is used, then it is desirable that there is a high degree of isolation not only between the polarisations within the frequency band but also between the bands themselves.

[0007] Each feeding means may include two pairs of voltage sources connected to align points on the ground plane of a respective patch and probes extending from the points to the patch. For dual polarised operation the respective lines joining the pairs of points are orthogonal. To put this more broadly each means for feeding may include two pairs of diametrically placed capacitively coupled probes.

[0008] In any event the means for feeding may include a wire probe, in which case the probe may be coupled to its respective patch by an aperture in the patch. Preferably there is a dielectric bush in the aperture.

[0009] The patches may be of geometrically regular shape and are preferably square. In any event it is preferred that they are coaxial.

[0010] It is preferred that the resonant frequency of a patch is approximately twice the resonant frequency of its preceding patch, so that the resonant frequency increases as one moves along the stack from the ground plane.

[0011] Each patch may be separated from its ground plane by less than a quarter of the wave length of its operating or resonant frequency.

[0012] Although the invention has been defined above it is to be understood that it includes any inventive combination of the features set out above or in the following description.

[0013] The invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic view of an antenna according to the invention showing the concept of the design; and

Figure 2 is a perspective view of a practical implementation of the concept of Figure 1.

[0014] In Figure 1 a conducting ground plane 1 is provided and stacked above that are patches 2 and 3. The ground plane 1 co-operates with the patch 2 serving as a reflector against which the patch 2 is electrically driven. The patch 2 is resonant at a frequency in the lower operating frequency band, whilst the patch 3 is intended to resonant at a frequency in the upper frequency band and utilises the patch 2 as its ground plane. Each of the patches is spaced from its respective ground plane by less than a quarter of a wave length at the patch operating frequency and each is shaped so that it can operate in two mutually orthogonal modes and radiate respective orthogonal polarisations.

[0015] The lower patch is driven from voltage sources 4a, 4b and 5a, 5b established on the ground plane 1 and connected to the patch 2 by means of probe wires 10a - 10d and series capacitors 8a - 8d formed within the patch. Similarly the upper patch 3 is driven by voltage sources 6a, 6b and 7a, 7b established in the lower frequency patch and connected by respective wire probes 11a - 11d and series capacitors 9a - 9d within the upper frequency patch. It will be noted that imaginary lines drawn between the diametrically opposed probes e.g. 10a, 10c and 10b, 10d are orthogonal and hence well isolated dual polarised radiation can be achieved. Specifically the probe ends within a diagonal set are placed on the voltage node line of the mode orthogonal to that set ensuring that the feed voltages at for example, 4a and 4b and 5a and 5b are equal and opposite in magnitude.

[0016] With correct adjustment of the probe positions, the series capacitors, patch size and height and the length of cable between pairs of probes the antenna can be made to have a VSWR (Voltage Standing Wave Ratio) of less than 1.2:1 across each frequency band.

[0017] It is preferred that the feed to a pair of voltage sources is arranged such that the feed is initially to a first of the pair and then by a delay cable from the first of the pair to the second. If the delay cable is selected to create a delay of half a wavelength, then the two associated probes can be fed 180° out of phase at the operating frequency of the patch.

[0018] It will be seen that the patches are square, in the described embodiments and measurements of 40dB had been achieved when taken above the arrangement illustrated in the figure.

[0019] It is believed that for best isolation the upper frequency patch should be central with respect to the lower frequency patch and this should certainly be the best case for pattern symmetry. In practice isolation between each band has been found to be adequate for the GSM and PCN bands. This is attributed to the fact that each patch is considerably off resonance with respect to the other. In this connection it is generally desirable that the resonance frequency of an upper patch in a pair is approximately at least twice the frequency of the resonance frequency of the lower one in a pair.

[0020] Turning to Figure 2, the ground plane 1 and patches 2 and 3 are conveniently formed from squares of double sided printed circuit board, and for convenience, are spaced from each other by insulating pillars 13, 14. The patch 2 is fed via cables 4 and 5 and delay cables 12a, 12b, whilst patch 3 is similarly fed by cables 8 and 9 and corresponding delay cables 15a and 15b. The two sides of the double printed circuit 16 board forming the ground plane are electrically connected together so that even though the patch 2 extends slightly beyond the printed circuit board 16 it is electrically surrounded by the much larger ground plane 1. This ensures that the ground plane 1 does not resonate at the design resonant frequency of the patch 2 and reflects the radiation in the patch 2 away from the ground plane 1. Specifically the top metallic layer 1a overlaps the hole 17 in the board 16 and is strongly capacitively coupled to ground via the intervening dielectric. This enables RF connection of the two sides which make up the ground plane 16 to ground without the usual metallic connection problems of dissimilar metal junctions.

[0021] It will be noted that the probes 10 and 11 are coupled into the patches by respective dielectric bushes, for example those shown at 8a - 8d, and these allow for a controlled capacitive coupling.

[0022] It will be noted that the patch 3 is significantly smaller than the patch 2 and in any case should not extend beyond the ground plane constituted by the patch 2. The corners of the patch 3 are removed simply for assembly purposes and to all intents and purposes the patch 3 is effectively square.

Claims

1. An antenna for radiating at a plurality of frequencies including a ground plane for a first patch and a patch for each frequency, the patches being spaced and arranged in a stack with the ground plane such that the or each preceding patch constitute the ground plane for its succeeding patch; each patch being electrically surrounded by its respective ground plane whereby the ground plane will not resonate at its respective patch's associated frequency, the antenna further including respective means for feeding each patch, each feeding means including two pairs of voltage sources connected to aligned points on the ground plane of a respective patch and probes extending from the point to the patch.

2. An antenna as claimed in claim 1 wherein respective lines joining the pairs of points are orthogonal.

3. An antenna as claimed in claim 1 wherein each means for feeding includes two pairs of diametrically placed capacitively coupled probes.

4. An antenna as claimed in any one of claims 1 to 3 wherein the means for feeding includes a wire probe and the probe is coupled to its respective patch by an aperture in the patch.

5. An antenna as claimed in claim 4 wherein there is a dielectric bush in the aperture.

6. An antenna as claimed in Claim 1 wherein the area of the ground plane is at least 50% greater larger than the area of the patch.

7. An antenna as claimed in any one of the preceding

claims wherein the patches are geometrically regular shapes and co-axial.

8. An antenna as claimed in any one of the preceding claims wherein the patches are square.

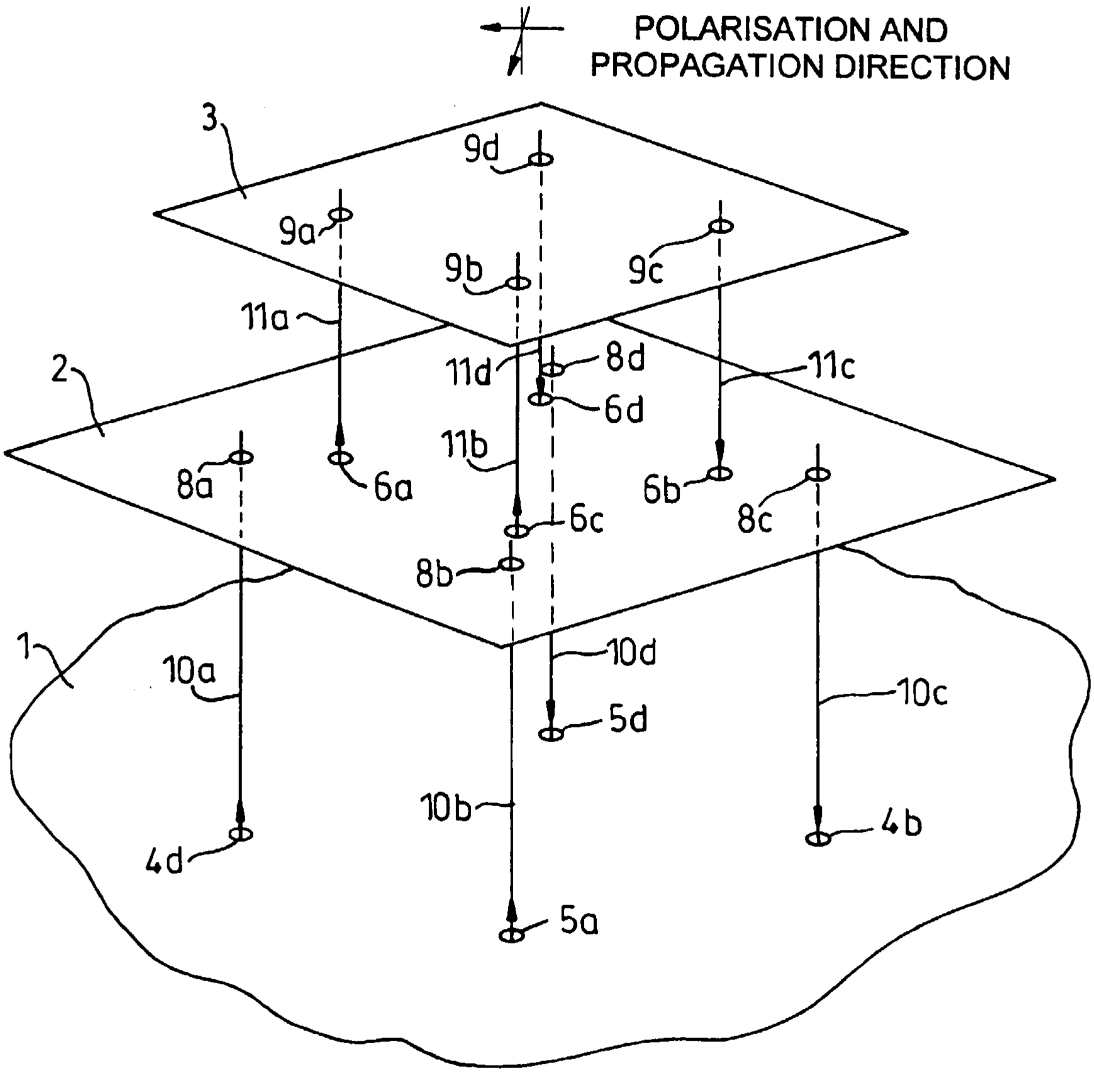
9. An antenna as claimed in any one of the preceding claims wherein the resonant frequency of a patch is approximately twice the resonant frequency of its preceding patch.

10. An antenna as claimed in any one of the preceding claims wherein each patch is separated from its ground plane by less than a quarter of the wavelength of its operating frequency.

11. An antenna as claimed in any one of the preceding claims wherein the ground plane is constituted by two sides of a double side printed circuit board or the like which are capacitively coupled together and to ground.

12. An antenna for radiating at a plurality of frequencies including a ground plane for a first patch and a patch for each frequency, the patches being spaced and arranged in a stack with the ground plate such that the or each preceding patch constitute the ground plate for its succeeding patch; each patch being electrically surrounding by its respective ground plane whereby the ground plane will not resonate at its respective patch's associated frequency, the antenna further including respective means for feeding each patch, wherein respective lines joining the pairs of points are orthogonal.

13. An antenna according to Claim 12, wherein each means for feeding includes two pairs of diametrically placed capacitively coupled probes.



POLARISATION AND PROPAGATION DIRECTION
3
9d
9a
9b
9c
11a
2
11d
8d
11c
6d
11b
8a
6a
6b
8c
6c
8b
1
10d
10a
10c
5d
10b
4b
4d
5a

Fig. 1

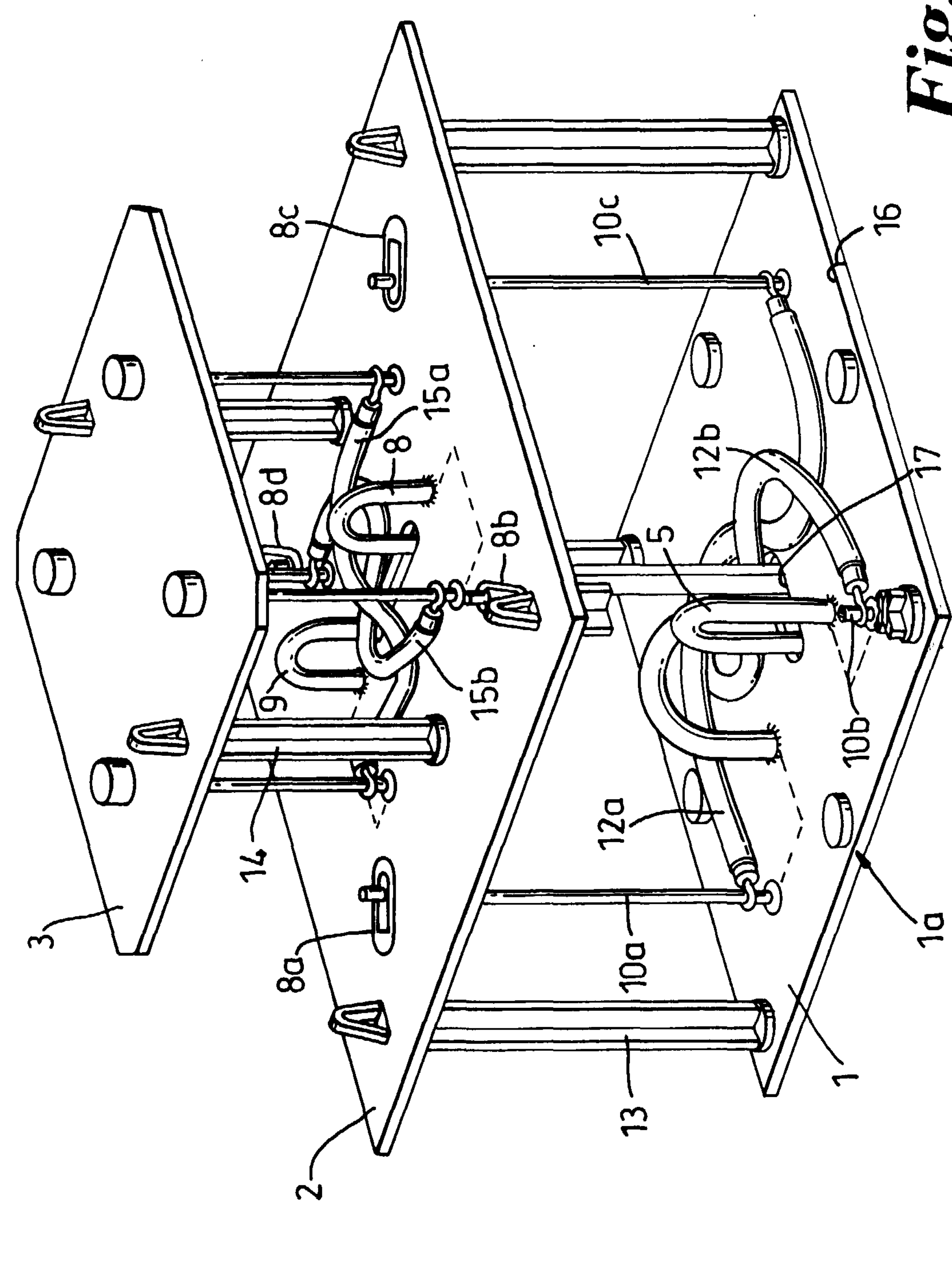


Fig. 2