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(54) Abstract Title
Wide-band micropstrip dipole antenna array

(57) A microstrip dipole antenna array includes N equally spaced PCBs 22 parallel. Each PCB 22 includes at least one microstrip dipole 24 and microstrip feed 26. The PCBs 22 are symmetrically located between (N+1) metal plates 32. The metal plates 32 act as a back reflector for the antenna array in substitution for a perpendicular ground plate (18, fig 1). The use of such metal plates 32 gives the antenna a lower wind-load area, than it would have if a ground plate(18, fig 1) was used. The use of such plates 32 reduces the coupling between dipoles in the H-plane whilst increasing the antenna's band width and allowing the free flow of air if device needs to be cooled. In an alternative embodiment the antenna array further comprises slender wires (36, fig 3), which are located between the PCBs 22 and the plates 32 so as to improve the front-to-back radiation ratio of the antenna.

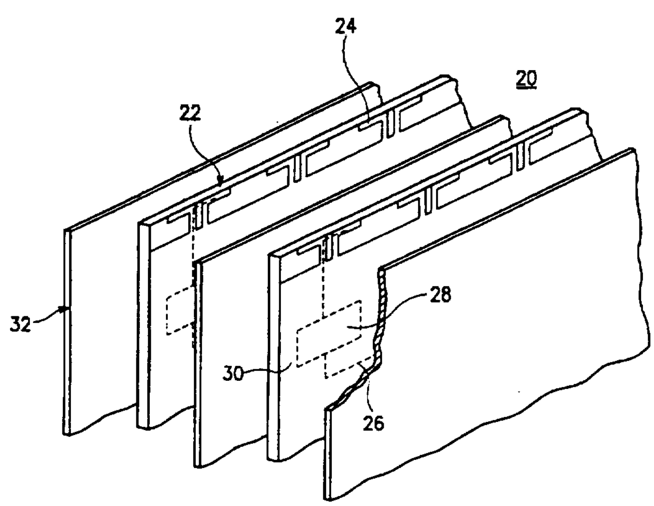

FIG. 2

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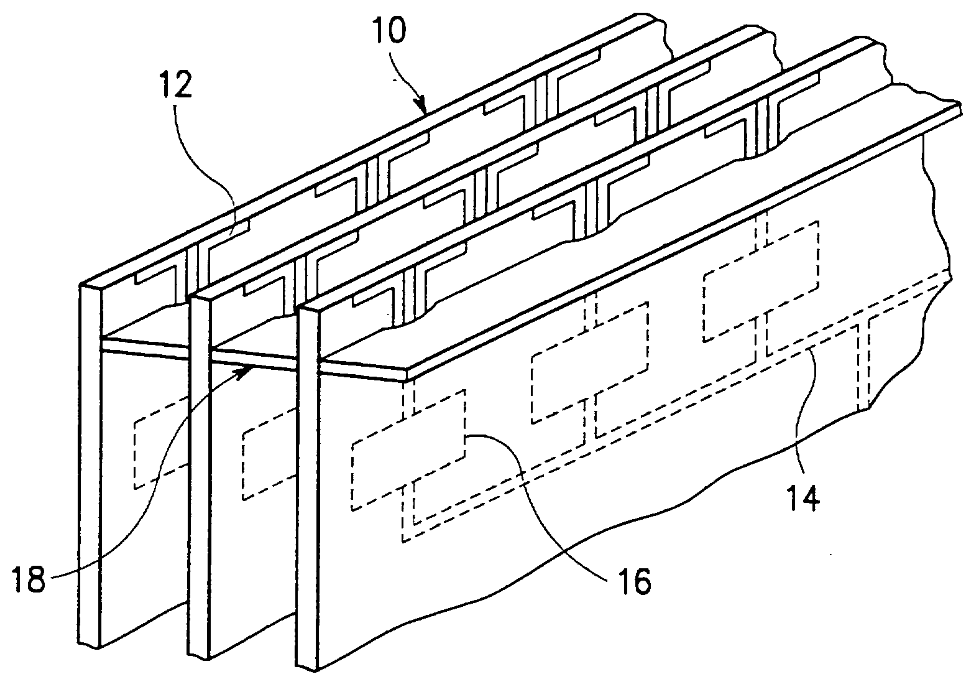

(PRIOR ART)
FIG. 1

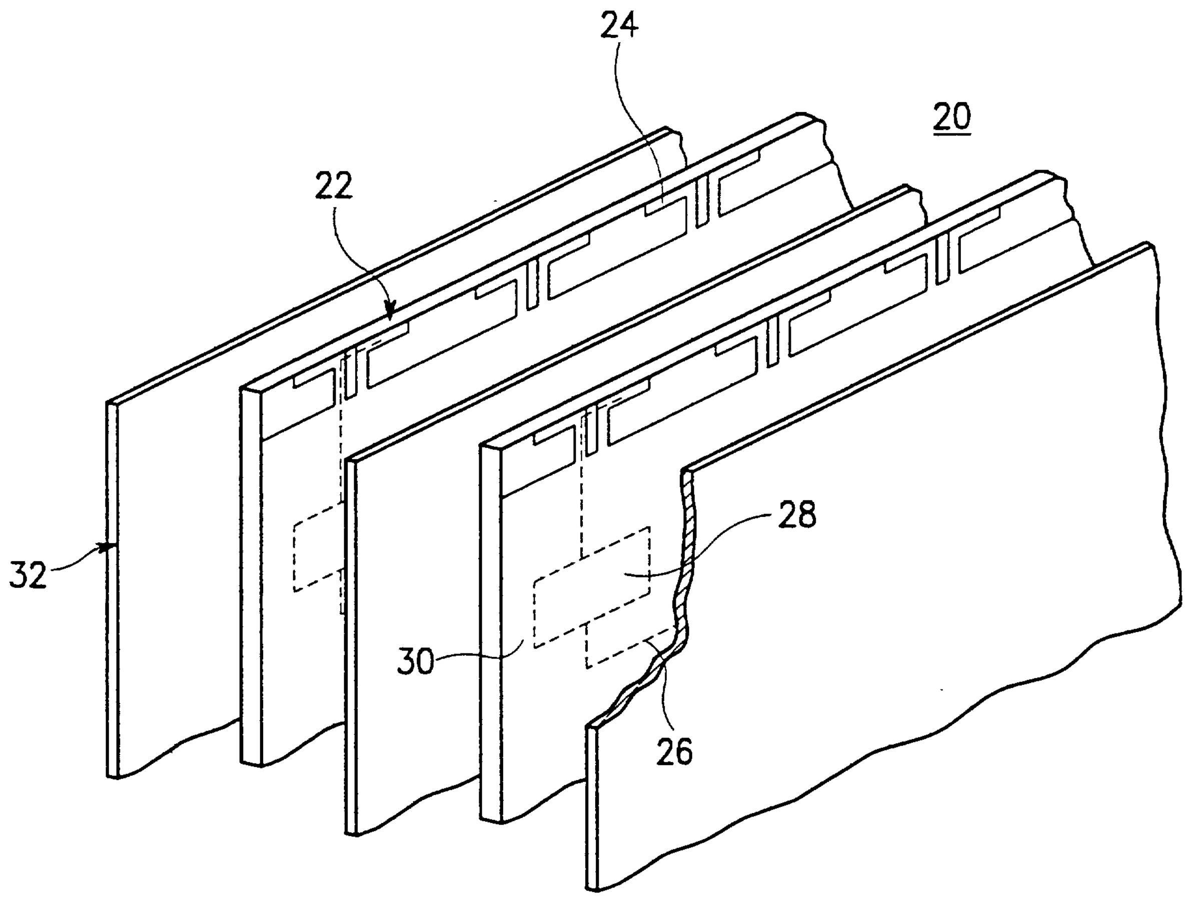

FIG. 2

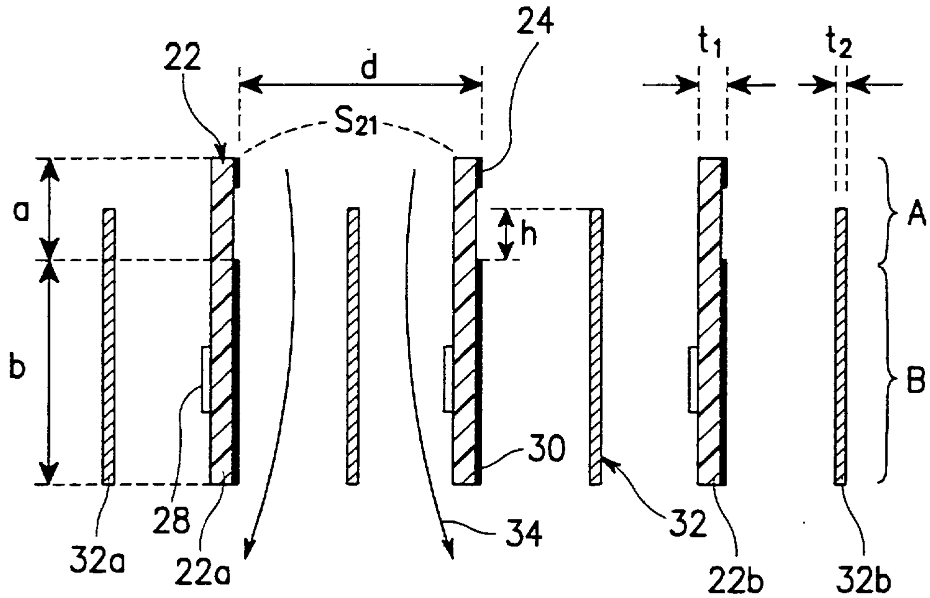

FIG. 3

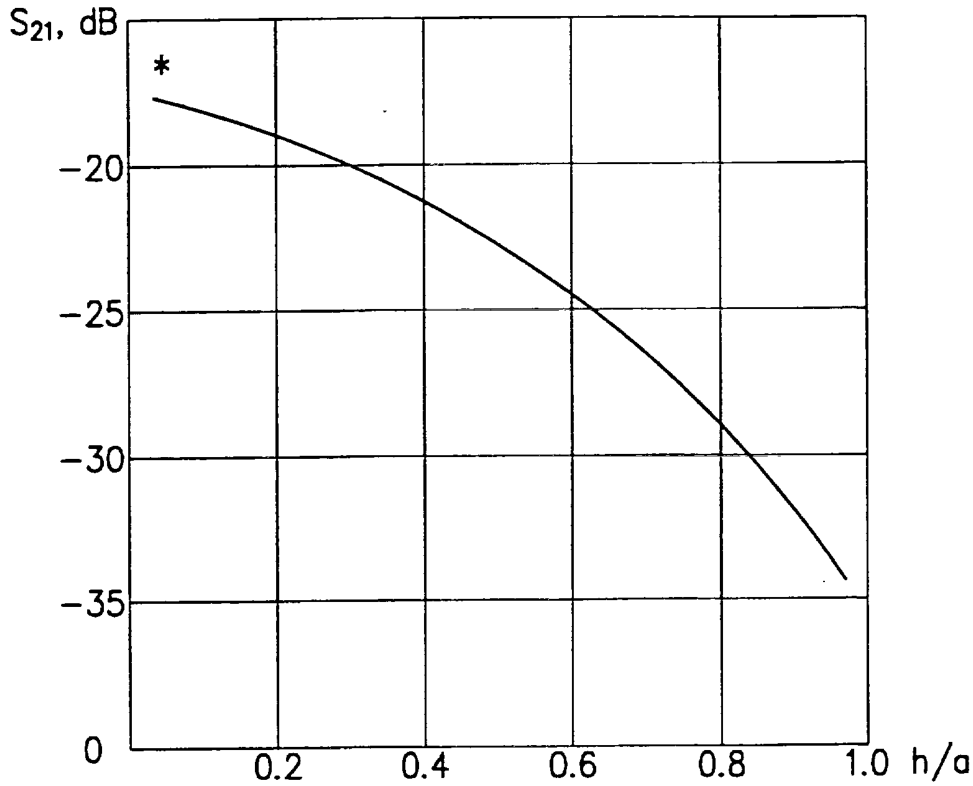

FIG. 4

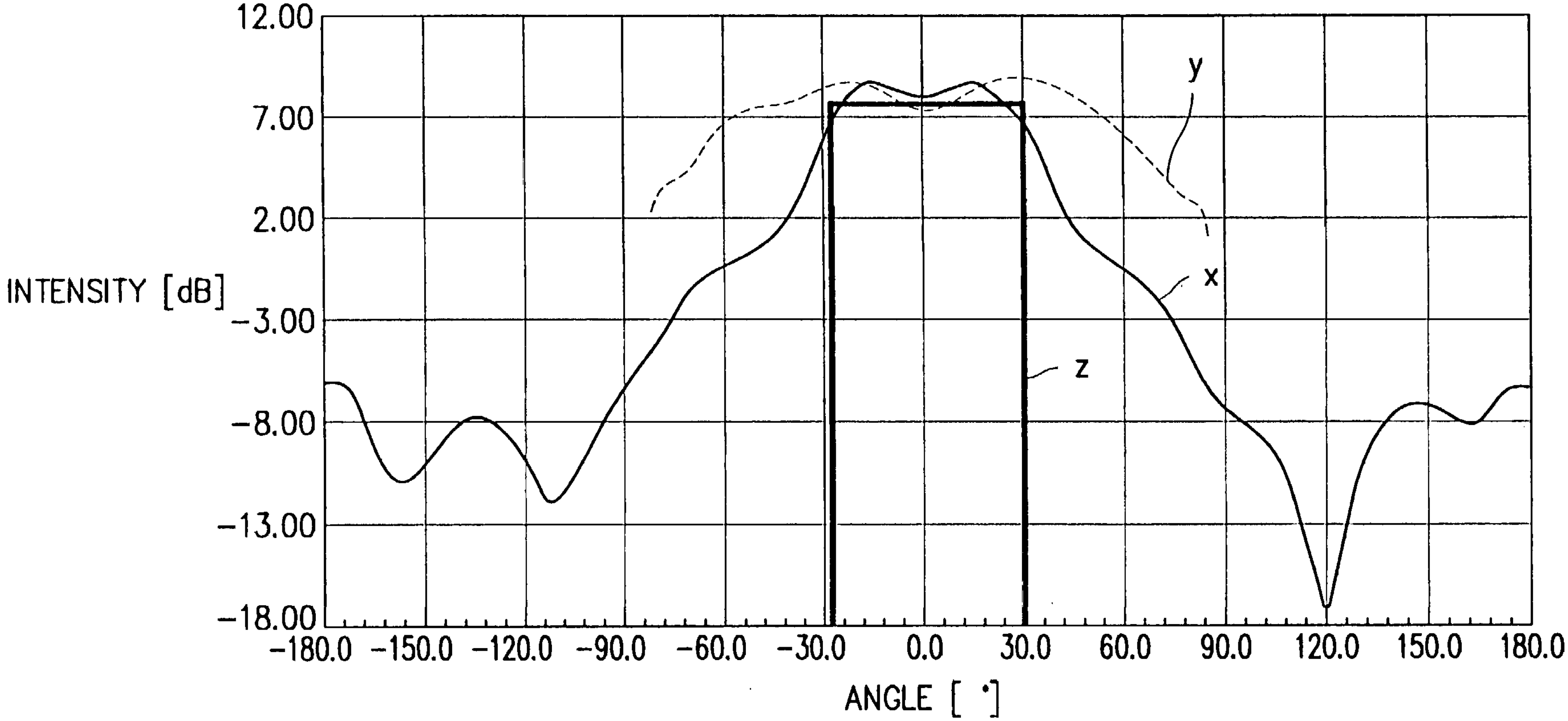
12.00
7.00
2.00
-3.00
-8.00
-13.00
-18.00
INTENSITY [dB]
-180.0 -150.0 -120.0 -90.0 -60.0 -30.0 0.0 30.0 60.0 90.0 120.0 150.0 180.0
ANGLE [°]
y
x
z

FIG. 5

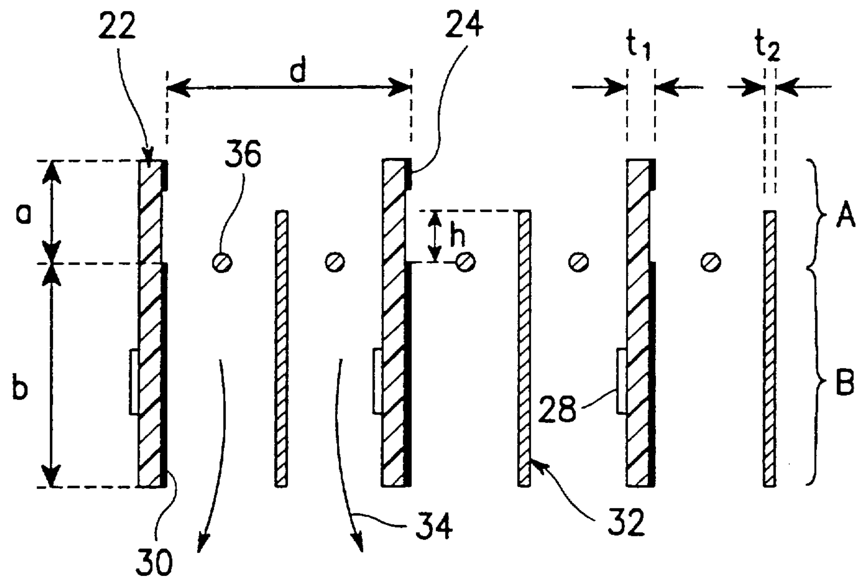

FIG. 6

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WIDE-BAND MICROSTRIP DIPOLE ANTENNA ARRAY

BACKGROUND OF THE INVENTION

The present invention relates to a printed dipole antenna array.

In general, printed dipole antenna arrays are utilised in wide-band communication systems, e.g. point-to-point, radio relay, cellular, PCS and satellite communications, radars and electromagnetic support measurement (ESM) and electromagnetic counter measurement (ECM) systems.

The printed array antenna technology enables a light-weight and low-cost antenna structure to be achieved. One of the most popular elements in printed arrays is the microstrip dipole using a wide frequency range from UHF to Ka band (see R. J. Mailloux, "Phased Array Antenna Handbook", Artech House, 1994, p.251).

At pages 310 and 311 of the above-mentioned book is described a conventional microstrip dipole array, fully available with low-cost fabrication. Microstrip dipoles and a microstrip corporate feed having phase shifters and other integrated devices are etched together on the same PCB. In "Antenna Engineering Handbook" by R. C. Johnson, 3rd edition, McGraw Hill, NY, 1993, two other examples of printed-dipole array antennas with a similar architecture are described (pp. 32-22 and 20-29).

FIG. 1 is a schematic perspective view of a conventional printed-dipole antenna array (see "Phased Array Antenna Handbook", Fig. 5.28A). In FIG. 1, PCBs 10 each having microstrip dipoles 12 and a feed 14 are installed in parallel with one another and perpendicular to a common flat ground screen 18 providing the antenna array structure. The feed 12 includes integrated devices 16 such as amplifiers and phase shifters. The common flat ground screen 18 functions to eliminate back radiation of the antenna array and separates a dipole area from a feed area. A low side-lobe level over a relatively wide bandwidth (15-20%) can be achieved by this type of antenna array, as the number of elements is large (see, "Low Side-lobe Phased Array Antennas" by H. E. Schrank, IEEE APS Newsletter, 25, pp. 5-9). These printed dipole array antennas are widely used in many applications.

The main technical problems of the conventional dipole array are as follows.

(1) A big wind-loaded area is present from a face direction. This is caused by the solid ground screen. To reduce the wind-loaded area, special radomes are used, increasing the cost of the antenna system.

(2) Bandwidth and wide-angle scan limitations exist due to mutual coupling phenomena. The mutual coupling is one of the main factors which limit wide-band antenna array operation. In the H-plane the mutual coupling is proportional to $1/\gamma$ and in the E-plane to $1/\gamma^2$ (γ is the distance between dipoles). The mutual coupling in the H-plane is more significant than in the E-plane (see "The Ultimate Decay of Mutual Coupling in a Planar Array Antenna" by P. W. Hannan, IEEE Trans., v. AP-14, March

1966, pp. 246-248), and it is very important to decrease mutual coupling in the H-plane. The mutual coupling produces impedance mismatch in a scan area, reduces bandwidth and scan angles, and in the case of a relatively small array, increases side-lobes (see "Phased Array Antenna Handbook", Chapter 6).

(3) The element pattern of a dipole in the array is far from an ideal top-flat element pattern with a constant level at a scan angle and a zero level at other angles. In the top-flat element pattern, scan losses are minimised and grating lobes are suppressed. Use of top-flat radiators, for instance, sharp dielectric bars, allows dramatic reduction in the number of elements and the cost of a phased array. Further, the top-flat element pattern is very useful in a fixed-beam antenna array, because of suppression of far side-lobes.

(4) Quite different parameters exist at the edge dipoles from those in the central dipoles (see "Phased Antenna Handbook", p.330). The parameters include element pattern, impedance and polarisation properties. This edge phenomenon results in the increase of back lobes and side-lobes, especially in a small array (the number of elements N = 4-100).

(5) In the case of an active array, a ground screen may hinder effective cooling of an active device such as a high power amplifier due to poor ventilation.

SUMMARY OF THE INVENTION

An object of the present invention, therefore, is to provide a wide-band microstrip dipole antenna array which can overcome the problems of large wind-loaded area, significant mutual coupling between dipoles, poor element pattern, edge phenomena and poor ventilation.

To achieve the above object, there is provided a microstrip dipole antenna array comprising N PCBs equally spaced parallel to one another and each having a microstrip dipole and a microstrip feed and (N+1) metal fences, in which each PCB is symmetrically located between metal fences and parallel to them. The PCBs and the metal fences may be rectangular and the size of the metal fences may be substantially equal to that of the PCBs. The antenna array may further comprise an active device formed on each PCB.

Preferably, the microstrip dipole antenna array further comprises 2N elongate cylindrical conductors disposed in parallel between the metal fences and the PCBs. The cylindrical conductors may be substantially the same length as the PCBs.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a schematic view of a conventional microstrip dipole antenna array;

FIG. 2 is a schematic view of a wide-band microstrip dipole antenna array according to one embodiment of the present invention;

FIG. 3 is a sectional view of the microstrip dipole antenna shown in FIG. 2;

FIG. 4 is a graph showing the dependence of measured mutual coupling coefficients on the distance between a dipole and a metal fence;

FIG. 5 is a graph showing a measured element pattern in the H-plane of the antenna of FIG. 2; and

FIG. 6 is a schematic sectional view of a wide-band microstrip dipole antenna according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 2, an antenna array 20 is a periodic structure in which PCBs 22 alternate with thin metal fences 32. Each PCB 22 has microstrip dipoles 24, a microstrip feed 26, and integrated devices 28. Each metal fence 32 is disposed between PCBs 22 in parallel with them. Given the number of the PCBs 22 as N, the number of the metal fences 32 is (N+1).

FIG. 3 is a sectional view of the antenna array 20 shown in FIG. 2, with the feeds 26 omitted for clarity. In FIG. 3, reference character A indicates a metal plate-absent area, and reference character B indicates a metal plate-present area. Other reference characters a, b, d, h, t_1, and t_2 indicate the sizes of their corresponding parts. As shown in FIG. 3, the height of the PCBs 22 is a+b, where a and b are the heights of a dipole area and a feed area, respectively. d is the distance between adjacent PCBs 22, t_1 is the thickness of each PCB 22 and t_2 is the thickness of each metal fence 32. The height of the metal fence 32 is b+h, where h can vary from 0 to a. Choice of sizes a and d is based on the same design principles, as for the conventional dipole array antenna.

(Equation 1)

$$a = 0.15 - 0.3\lambda$$
$$d = k\lambda / (1 + |\sin\beta_0|)$$

where λ is the wavelength in free space, β_0 is a maximal scan angle and k is a coefficient dependent on the array size, ranging from 0.7 to 0.9.

The antenna array 20 shown in FIGs. 2 and 3 according to the present invention will be considered from the mechanical point of view. As shown in FIG. 3, an air flow 34 can easily penetrate through the antenna array 20 and thus the wind-loaded area of the antenna array is far less than that of the conventional antenna array shown in FIG. 1. The reduction of the wind-loaded area can be approximately calculated from:

(Equation 2)

$$S_a / S_b = dN / \left[Nt_1 + (N+1)t_2 \right]$$

where S_a and S_b are the wind-loaded areas of the conventional array and the present invention, respectively, and the other parameters are shown in FIG. 3. The wind-loaded area can be reduced by 10 to 100 times because t_1, t_2 «d. The air flow 34 produces a heat transfer from the integrated active devices 28, providing more effective cooling in comparison with the prior art of FIG. 1.

Now to consider the antenna array 20 from the electrical point of view, the metal fences 32 operate in different ways in the areas A and B. In the area A, the metal fences 32 provide impedance matching and form an array element pattern, while in the area B, they eliminate back radiation. The metal fences 32 add another dimension to the antenna array 20 to optimise the impedance match of the dipoles 24 and improve a wide scan angle match by varying the size h, in the area A. This is achieved by reducing the mutual coupling between the dipoles 24 in H-plane with use of the metal fences 32. The measured dependence of a mutual coupling coefficient upon the size h is shown in FIG. 4. In FIG. 4, mutual coupling coefficients are measured with respect to h/a and S_{21} is a mutual coupling coefficient. The figure shows that the metal fences 32 reduce the mutual coupling coefficients by 10-15dB. Thus, the impedance of the dipoles 24 virtually does not change during scanning in the H-plane, thereby enabling a wider band and wider angle operation.

The metal fences 32 help to optimise an array element pattern by varying the size h. Due to the significant suppression of mutual coupling by the metal fences 32, the element pattern in H-plane is mostly dependent on two adjacent metal fences 32 and the top-flat element pattern can be obtained by choice of the sizes h, d, and a, which is shown in FIG. 5. In FIG. 5, a measured element pattern indicated by curve x is flat in a scan sector in a range of 30 , and sharply drops outside the scan sector. The flat element pattern provides a constant array gain at the scan angles, and the dropping element pattern decreases side-lobe and grating lobe outside the scan sector. This increases the distance d in the antenna array 20 and, as a consequence, reduces the number N of the PCBs 22. Therefore, the overall cost of the antenna is reduced in comparison with the conventional technology. The conventional element pattern is also shown as curve y in FIG. 5, for comparison. From FIG. 5, it is noted that the conventional element pattern (curve y) is far from the ideal top-flat element pattern (curve z) and the optimised element pattern of the antenna array 20 (curve x) is close to the ideal one.

In FIG. 3, edge fences 32a and 32b prevent current leakage of PCBs 22a and 22b to metal plates 30, thereby reducing back radiation. This is because, as described before, the major factor affecting the H-plane pattern of the dipoles 24 in the antenna array 22 is the influence of two adjacent metal fences 32, the pattern of all elements, central and edge, in the array 20 is almost the same, and the edge phenomenon is weaker than in the conventional array of FIG. 1.

In the area B, the metal fences 32 and the metal plates of the PCBs 20 form a system of parallel plate cut-off wave-guides. The distance between the walls of these wave-guides is d/2, smaller than a cut-off distance $d_c = \lambda/2$. Electromagnetic waves do not propagate in the area B and if the size b is larger than $\lambda/4$-$\lambda/2$, the front-to-back ratio of the antenna array 20 is more than 25-35dB. Transverse electric (TE) waves being co-polarised waves are reflected from the border between the areas A and B, and transverse magnetic (TM) waves being cross-polarised waves propagate in a back direction. Therefore, the antenna array 20 has a cross-polarisation level in a main beam direction less by 30dB than the equivalent conventional antenna array shown in FIG. 1. This is especially useful for a wide-band array because a wide-band microstrip dipole with wide arms can have a significant cross-polarisation level (see "Phased Array Antenna Handbook", Chapter 5.1.2).

FIG. 6 illustrates an another embodiment of the antenna array. Referring to FIG. 6, 2N slender cylindrical wires 36 acting as conductors are additionally located between the PCBs 22 and the fences 32 so as to improve the front-to-back ratio of the antenna array. The wires 36 improve the front-to-back ratio by 5-10dB, and give a dimension to the array to thereby optimise dipole parameters, that is, element pattern and matching.

In accordance with the present invention, a 6x6 element prototype of printed-dipole antenna array without phase shifters was fabricated and tested. It demonstrated a very wide operation at 1100-2000GHz or in a 60% wide-band, a high antenna efficiency more than 50%, low side-lobes below 20dB, a low cross-polarisation less than 25dB, a good front-to-back ratio more than 25dB, and a small wind-loaded area. The wind-loaded area is smaller by 30 times than in the equivalent conventional array.

As compared with the conventional technology, the present invention has the following main technical advantages:

(1) the wind-loaded area is reduced by a factor of 10 or more;

(2) the mutual coupling between dipoles in the H-plane is reduced by about 10dB, increasing bandwidth and reducing side-lobes;

(3) the cross-polarisation is reduced by 3dB;

(4) the cost of the array can be reduced by 10-15% thanks to the reduction of the PCBs in number due to the possible achievement of an optimal (i.e., top-flat) element pattern; and

(5) if active devices are present in the array, they can be more effectively cooled.

As described above, the present invention overcomes the problems of large wind-loaded area, significant mutual coupling between dipoles, poor element pattern, edge phenomenon and poor ventilation by disposing metal fences between PCBs with dipoles and feeds, instead of a ground screen.

CLAIMS

1. A microstrip dipole antenna array comprising N PCBs equally spaced parallel to one another and each having a microstrip dipole and a microstrip feed and (N+1) metal fences, in which each PCB is symmetrically located between metal fences and parallel to them.

2. A microstrip dipole antenna array according to claim 1 in which the PCBs and the metal fences are rectangular.

3. A microstrip dipole antenna array according to claim 2 in which the size of the metal fences is substantially equal to that of the PCBs.

4. A microstrip dipole antenna array according to any preceding claim further comprising an active device formed on each PCB.

5. A microstrip dipole antenna array according to any preceding claim further comprising 2N elongate cylindrical conductors disposed in parallel between the metal fences and the PCBs.

6. A microstrip dipole antenna array according to claim 5 in which the cylindrical conductors are substantially the same length as the PCBs.

7. A microstrip dipole antenna array, substantially as described herein with reference to and/or as illustrated in FIGs. 2 et seq. of the accompanying drawings.

The Patent Office
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INVESTOR IN PEOPLE

Application No: GB 9913358.9
Claims searched: all
Examiner: Russell Maurice
Date of search: 25 August 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H1Q (QBA, QBC, QBE, QBH, QBX, QJA)

Int Cl (Ed.6): H01Q (1/52, 21/06, 9/06)

Other: Online WPI EPODOC PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2135829 A	Cosser (see whole document)	
X	GB 2123215 A	Licentia (see whole document)	1-4 & 7
A	GB 1393081 A	Hazeltine (see whole document)	
A	WO/97/41622 A	Johnson (see whole document)	

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.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		