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(54) INTERLACED MULTIBAND ANTENNA ARRAYS

INEINANDERGESCHACHTELTE MEHRBANDGRUPPENANTENNEN

GROUPEMENTS MULTIBANDE D'ANTENNES ENTRELACEES

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Description

Object of the Invention

[0001] The present invention consists of antenna arrays which can be operated simultaneously in various frequency bands thanks to the physical disposition of the elements that constitute it, as well as the multiband behaviour of some elements situated strategically in the array.

[0002] The array configuration is described on a basis of the juxtaposition or interleaving of various conventional single-band arrays operating in the different bands of interest. In those positions where elements of different multiband arrays come together, use is made of a multiband antenna which covers the different working frequency bands.

[0003] The use of a multiband interleaved antenna array (hereinafter simply Multiband Interleaved Array, MIA) implies a great advantage over the classical solution of employing an array for each frequency band: there is a cost saving in the overall radiating system and in its installation (one array replaces several), its size is reduced as well as its visual and environmental impact in the case of base and repeater stations for communication systems.

[0004] The present invention finds its application in the field of telecommunications and more specifically in radiocommunication systems.

Background and Summary of the Invention

[0005] Antennas started to be developed at the end of the nineteenth century based on the fundamental laws of electromagnetism postulated by James Clerk Maxwell in 1864. The invention of the first antenna has to be attributed to Heinrich Hertz in 1886 who demonstrated the transmission through air of electromagnetic waves. In the mid-1940's the fundamental restrictions regarding the reduction in size of antennas were shown with respect to wavelength and at the beginning of the sixties appeared the first frequency-independent antennas (E.C. Jordan, G.A. Deschamps, J.D.Dyson, P.E. Mayes, "Developments in Broadband Antennas,"IEEE Spectrum, vol.1, pp. 58-71, Apr. 1964; V.H.Rumsey, *Frequency -Independent Antennas.* New York Academic, 1966; R.L. Carrel, "Analysis and design of the log-periodic dipole array," Tech. Rep. 52, Univ. of Illinois Antenna Lab., Contract AF33 (616)-6079, Oct 1961; P.E. Mayes, "Frequency Independent Antennas and Broad-Band Derivatives Thereof", Proc. IEEE, vol.80, no.1, Jan. 1992). At that time proposals were made for helical, spiral, log-periodic arrays, cones and structures defined exclusively by angle pieces for the implementation of broadband antennas.

[0006] Antenna array theory goes back to the works of Shelkunoff (S.A. Schellkunhoff, "A Mathematical Theory of Linear Arrays," Bell System Technical Journal, 22,80), among other classic treatises on antenna theory. Said theory establishes the basic design rules for shaping the radiation properties of the array (principally its radiation pattern), though its application is restricted mainly to the case of mono-band arrays. The cause of said restriction lies in the frequency behaviour of the array being highly dependent on the ratio between the distance between elements (antennas) of the array and the working wavelength. Said spacing between elements is usually constant and preferably less than one wavelength in order to prevent the appearance of diffraction lobes. This implies that once the spacing between elements is fixed, the operating frequency (and the corresponding wavelength) is also fixed, it being particularly difficult that the same array work simultaneously at another higher frequency, given that in that case the magnitude of the wavelength is less than the spacing between elements.

[0007] The log-periodic arrays suppose one of the first examples of antenna arrays capable of covering a broad range of frequencies (V.H.Rumsey, *Frequency-Independent Antennas.* New York Academic, 1966; R.L. Carrel, "Analysis and design of the log-periodic dipole array," Tech. Rep. 52, Univ. Illinois Antenna Lab., Contract AF33 (616)-6079, Oct 1961; P.E. Mayes, "Frequency Independent Antennas and Broad-Band Derivatives Thereof", Proc. IEEE, vol.80, no.1, Jan.1992). Said arrays are based on distributing the elements that constitute it in such a manner that the spacing between adjacent elements and their length vary according to a geometric progression. Although said antennas are capable of maintaining a same radiation and impedance pattern over a broad range of frequencies, their application in practice is restricted to some concrete cases due to their limitations regarding gain and size. Thus for example, said antennas are not employed in cellular telephony base stations because they do not have sufficient gain (their gain is around 10 dBi when the usual requirement is for about 17 dBi for such application), they usually have linear polarisation whilst in said environment antennas are required with polarisation diversity, their pattern in the horizontal plane does not have the width necessary and their mechanical structure is too bulky.

[0008] The technology of individual multiband antennas is markedly more developed. A multiband antenna is understood to be an antenna formed by a set of elements coupled to each other electromagnetically which interact with each other in order to establish the radioelectric behaviour of the antenna, behaviour which with respect to radiation and impedance patterns is similar in multiple frequency bands (hence the name multiband antenna). Numerous examples of multiband antennas are described in the literature. In 1995 antennas of the fractal or multifractal type were introduced (the coining of the terms fractal and multifractal is attributable to B. B. Mandelbrot in his book *The Fractal Geometry of Nature,* W.H. Freeman and Co. 1983), antennas which by their geometry have a multifrequency behaviour and, in determined cases, a reduced size (C. Puente, R. Pous, J. Romeu, X. Garcia "Antenas Fractales o Mulitfractales", (Spanish patent ES2 112 163). Subsequently multi-triangular antennas were introduced (Spanish patent ES 2 142 280) which could work simultaneously in the GSM 900 and GSM 1800 bands and, more recently, multilevel antennas (WO-A-0122528), which offer a clear example of how it is possible to shape the geometry of the antenna in order to achieve a multiband behaviour.

[0009] Document WO-A-9735360 discloses a dual band array operating in the L-band and UHF band. The array comprises a center unit with a stacked patch element operating in the UHF band and a plurality of crossed dipoles forming an L-band ring array being mounted on the UHF element.

[0010] The present invention describes how multiband antennas can be combined in order to obtain an array that works simultaneously in several frequency bands.

[0011] A Multiband Interleaved Array (MIA) consists of an array of antennas which has the particularity of being capable of working simultaneously in various frequency bands. This is achieved by means of using multiband antennas in strategic positions of the array. The disposition of the elements that constitute the MIA is obtained from the juxtaposition of conventional mono-band arrays, employing as many mono-band arrays as frequency bands that it is wished to incorporate in the Multiband Interleaved Array. In those positions in which one or various elements originating in the conventional mono-band arrays coincide, a single multiband antenna (element) shall be employed which covers simultaneously the different bands. In the remaining non-concurrent positions, it can be chosen to employ also the same multiband antenna or else recur to a conventional mono-band antenna which works at the pertinent frequency. The excitation at one or various frequencies of each element of the array depends therefore on the position of the element in the array and is controlled by means of the signal distribution network.

Brief Description of the Drawings

[0012] The characteristics expounded in the foregoing, are presented in graphical form making use of the figures in the drawings attached, in which is shown by way of a purely illustrative and not restrictive example, a preferred form of embodiment. In said drawings:

Figure 1 shows the position of the elements of two classic mono-band arrays which work at frequencies f and f/2 respectively, and the disposition of elements in a multiband interleaved array, which has a dual frequency behaviour (at frequencies f and f/2), working in the same manner as classic arrays but with a smaller total number of elements.

Figure 2 shows another particular example of multiband interleaved array but with three frequencies in this case, and the respective three classic mono-band arrays which constitute it. It is a matter of extending the case of figure 1 to 3 frequencies f, f/2 and f/4.

Figure 3 shows another particular example of multiband interleaved array, in which the different working frequencies are not separated by the same scale factor. It is a matter of extending the case of figures 1 and 2 to 3 frequencies f, f/2 and f/3.

Figure 4 shows a further particular example of multiband interleaved array, in which the different working frequencies are not separated by the same scale factor. It is a matter of extending the case of figure 3 to 3 frequencies f, f/3 and f/4.

Figure 5 shows a multiband interleaved array configuration which requires a repositioning of the elements to obtain frequencies that do not correspond to an integer factor of the highest frequency. In this particular example the frequencies f, f/2 and f/2,33 have been chosen.

Figure 6 shows the extension of the design of an MIA to the two-dimensional or three-dimensional case, specifically, an extension of the example of figure 1 to two dimensions.

Figure 7 shows one of the preferred of operating modes (AEM1). It is a matter of an MIA in which the multiband elements are multi-triangular elements. The array works simultaneously at dual frequencies, for example in the GSM 900 and GSM 1800 bands.

Figure 8 shows another of the preferred operating modes (AEM2). It is a matter of an MIA in which the multiband elements are multilevel elements. The array works simultaneously at dual frequencies, for example in the GSM 900 and GSM 1800 bands.

Figure 9 shows another of the preferred operating modes (AEM3). It is a matter of an MIA in which the multiband elements are multilevel elements. The configuration is similar to that of Figure 8 (AEM2 mode), the difference being that the new disposition permits the total width of the antenna to be reduced.

Figure 10 shows another example of multiband antenna which can be employed in MIAs. It is a matter of a stacked patch antenna, which in this specific example works at two dual frequencies (for example, GSM 900 and GSM 1800).

Figure 11 shows the disposition of said patches in the MIA type array (AEM4 configuration). Observe that, in contrast to the previous cases, in this case multiband antennas are employed only in those positions where it is strictly necessary; in the remainder mono-band elements are employed the radiation pattern of which is sufficiently like that of the multiband element in the pertinent band.

Figure 12 shows another configuration (AEM5), in which the elements have been rotated through 45° in order to facilitate . the procurement of double polarisation at +45° or -45°.

Description of the Preferred Embodiment of the Invention

[0013] In making the detailed description that follows of the preferred embodiment of the present invention, reference shall constantly be made to the Figures of the drawings, throughout which use has been made of the same numerical references for the same or similar parts.

[0014] A multiband interleaved array (MIA) is constituted by the juxtaposition of various conventional mono-band arrays. The conventional antenna arrays usually have a mono-band behaviour (that is, they work within a relatively small frequency range, typically of the order of 10% about a centre frequency) and this is not only because the elements (antennas) that constitute it have a mono-band behaviour, but also because the physical spacing between elements conditions the working wavelength. Typically, the conventional mono-band arrays are designed with a spacing between elements of around a half-wavelength, spacing which may be increased in some configurations in order to enhance directivity, though it is usually kept below one wavelength to avoid the appearance of diffraction lobes.

[0015] This purely geometric restriction (the magnitude of the wavelength conditions the geometry of the elements of the array and their relative spacing) signifies a major drawback in those environments and communication systems in which various frequency bands have to be employed simultaneously. A clear example is the GSM cellular mobile telephony system. Initially located in the 900 MHz band, the GSM system has turned into one of the most widespread on a world scale. The success of the system and the spectacular growth in demand for this type of service has led to the cellular mobile telephony operators expanding its service into a new band, the 1800 MHz band, in order to provide coverage for a greater customer base. Making use of classic mono-band antenna technology, the operators have to duplicate their antenna network in order to provide coverage simultaneously to GSM 900 and GSM 1800. Using a single MIA specially designed for the system (like that described in the particular cases of figures 7 through 12), the operators reduce the cost of their network of base stations, the time to expand into the new band and the visual and environmental impact of their installations (through the simplification of the overall radiating structure).

[0016] It is important to point out that the scenario which has just been outlined above deals only with one particular example of a type of MIA and its application; as may well be gauged by anyone familiar with the subject, in no way are the MIAs which are described in the present invention restricted to said specific configuration and can easily be adapted to other frequencies and applications.

[0017] The multiband interleaved arrays base their operation on the physical disposition of the antennas which constitute them and on the particular type of element that is employed in some strategic positions of the array.

[0018] The positions of the elements in an MIA are determined from the positions of the elements in as many mono-band arrays as there are frequencies or frequency bands required. The design of the array is, in that sense, equal to that of the mono-band arrays insomuch as it is possible to choose the current weighting for each element, in order to shape the radiation pattern according to the needs of each application. The configuration of the MIA is obtained from the juxtaposition of the positions of the different mono-band arrays. Naturally, such juxtaposition proves difficult to implement in practice in those positions in which various antennas of the different arrays coincide; the solution proposed in this invention rests in the use of a multiband antenna (for example of the fractal, multi-triangular, multi-level, etc. type) which covers all the frequencies associated with its position.

[0019] A basic and particular example of how to arrange the elements in an MIA is described in Figure 1. In the columns of the figures (1a) and (1b) two conventional mono-band arrays are shown in which the positions of the elements (indicated by the black circles and the circumferences respectively) are chosen in such a manner that the spacing between elements is typically less than the working wavelength. Thus, taking as reference the working frequency f of the array (1a), the array (1b) would work at a frequency *f/2* as the elements have a spacing double that of the previous case. In figure (1c) the disposition is shown of the elements in the MIA which is capable of working simultaneously on the frequencies *f* and *f/2* conserving basically the same facilities as the two arrays (1a) and (1b). In the positions in which elements of the two conventional arrays (indicated in figure (1c) by means of black circles located at the centre of a circumference) coincide, a multiband antenna is employed capable of working in the same manner (same impedance and pattern) on the frequencies (1a) and (1b). The remaining not common elements (indicated either by a black circle, or by a circumference) can be implemented either by means of the same multiband element employed in the common positions (and selecting the working frequency by means of the signal distribution network of the array), or by employing conventional mono-band elements. In this example the array (1c) has a dual behaviour frequency-wise (at frequencies f and f/2), working in the same manner as the arrays (1a) and (1b) but with a smaller total number of elements (12 instead of 16).

[0020] Multiple examples of multiband antennas are already described in the state of the arc. Antennas with fractal geometry, multi-triangular antennas, multi-level antennas even stacked patch antennas are some examples of antennas capable of working in like manner in multiple frequency bands. These, and other multiband elements can be employed in the positions of the MIAs in which elements of various mono-band arrays come together.

[0021] In the following figures other MIA configurations are shown, based on the same inventive concept, though having the disposition of the elements adapted to other frequencies. In Figure 2 the configuration described is that of a tri-band MIA working at frequencies f, f/2 and f/4. The disposition of elements in the three classic mono-band arrays at the frequencies f, f/2 and f/4 is illustrated in the figures (2a), (2b) and (2c) by means of black circles, circumferences and squares respectively. The position of the elements of the MIA is determined from the configuration of the three mono-band arrays designed for each one of the three frequencies. The three arrays come together in the MIA that is shown in figure (2d). In those positions where elements of the three arrays would come together (indicated in the drawing by the juxtaposition of the different geometric figures identifying each array) use is made of a multiband element. The three-frequency array of figure (2d) behaves in the same manner as the three arrays (2a), (2b) and (2c) at their respective working frequencies, but employing only 13 elements instead of the 21 required in the total of the three mono-band arrays.

[0022] Figures 3, 4 and 5 describe, by way of example and not restrictively, the design of other MIAs based on the same principle though at other frequencies. In the first two cases the frequencies employed are integer multiples of a fundamental frequency; in the case of-figure 5 the ratio between frequencies is not restricted to any particular rule, though it supposes an example of array in which the frequencies the GSM 900, GSM 1800 and UMTS services can be combined.

[0023] Specifically, Figure 3 illustrates another particular example of multiband interleaved array, in which the different working frequencies are not separated by the same scale factor. It concerns the extension of the case of Figures 1 and 2 to 3 frequencies f, f/2 and f/3. The disposition of elements of the three classic mono-band arrays at the frequencies f, f/2 and f/3 is shown in figures (3a), (3b) and (3c) by means of black circles, circumferences and squares respectively. The column of figure (3d) shows the disposition of elements in the tri-band interleaved array. In those positions in which elements of the three arrays come together (indicated in the drawing by the juxtaposition of the different geometric figures identifying each array), use is made of a multiband element; the same strategy is followed in those positions in which elements of two arrays coincide: use should be made of a multiband element capable of covering the frequencies pertinent to its position, preferentially the same element as that used in the remaining positions, selecting those frequencies which are necessary by means of the feeder network. Notice that as the three-frequency array of figure (3d) behaves in the same manner as the three arrays (3a), (3b) and (3c) at their respective working frequencies, but employing only 12 elements instead of the 21 required in the total of the three mono-band arrays.

[0024] Figure 4 illustrates a new particular example of multiband interleaved array, in which the different working frequencies are not separated by the same scale factor. It concerns the extension of the case of Figure 3 to 3 frequencies f, f/3 and f/4. The disposition of elements of the three classic mono-band arrays at the frequencies f, f/3 and f/4 are shown in figures (4a), (4b) and (4c) by means of black circles, circumferences and squares respectively. The column of figure (4d) shows the disposition of elements in the tri-band interleaved array. In those positions where elements of the three arrays would come together (indicated in the drawing by the juxtaposition of the different geometric figures identifying each array), use is made of a multiband element. The three-frequency array of figure (4d) behaves in the same manner as the three arrays (4a), (4b) and (4c) at their respective working frequencies, but employing only 15 elements instead of the 24 required in the total of the three mono-band arrays.

[0025] It is convenient to re-emphasise that in the particular cases of Figures 3 and 4 the arrays can work at 3 frequencies simultaneously. The disposition of elements is such that the three frequencies do not always coincide in all the elements; nonetheless, by employing a tri-band antenna in those positions and selecting the working frequencies for example by means of a conventional frequency-selective network, it is possible to implement the MIA.

[0026] In some configurations of multiband interleaved array, especially in those in which the different frequencies do not correspond to an integral factor of the highest frequency 1, it is required that the elements be repositioned, as in Figure 5. In this particular example the frequencies f, f/2 and f/2,33 have been chosen. The disposition of elements of the three classic mono-band arrays at the frequencies f, f/2 and f/2,33 is represented in figures (5a), (5b) and (5c) by means of black circles, circumferences and squares respectively. The column of figure (5d) shows what would be the disposition of elements in the tri-band interleaved array according to the same plan as in the previous examples. Notice how in this case the ratio of frequencies involves the collocation of elements at intermediate positions which make its practical implementation difficult. The solution to be adopted in this case consists in displacing the position of the element of the array that works at the lowest frequency (indicated by arrows) until it coincides with another element (that nearest) of the highest frequency array; then the two or more coincident elements in the new position are replaced with a multiband element. An example of the final configuration once the elements have been repositioned, is shown in figure (5e). It is important that the element displaced be preferentially that of the lowest frequency array, in this way the relative displacement in terms of the working wavelength is the least possible and the appearance of secondary or diffraction lobes is reduced to the minimum.

[0027] Figure 6 illustrates how the configuration MIAs is not limited to the linear (one-dimensional) case, but it also includes arrays in 2 and 3 dimensions (2D and 3D). The procedure for distributing the elements of the array in the 2D and 3D cases is the same, replacing also the different coincident elements with a single multiband antenna.

[0028] More examples of particular configurations of MIAs are described below. In the five examples described, various designs are presented for GSM 900 and GSM 1800 systems (890 MHz-960 MHz and 1710 MHz-1880 MHz bands). It is a question of antennas for cellular telephony base stations, which present basically the same radiofrequency behaviour in both bands; by employing such versions of MIA antenna the operators reduce the number of antennas installed to one half, minimising the cost and environmental impact of their base stations.

AEM1 MODE

[0029] The AEM1 configuration, represented in Figure 7, is based on the use of GSM 900 and GSM 1800 multi-triangular elements. The array is obtained by interleaving two conventional mono-band arrays with spacing between elements less than one wavelength ( ) in the pertinent band (typically a spacing is chosen less than 0.9 in order to minimise the appearance of the diffraction lobe in the end-fire direction). The original arrays can have 8 or 10 elements, depending on the gain required by the operator. The juxtaposition of both arrays in a single MIA is achieved in this case by employing dual multi-triangular elements. Such elements incorporate two excitation points (one for each band), which allows the working band to be selected according to their position in the array. In figure 7 the position of the elements is shown, as well as their working frequencies. The elements shown in white indicate operation in the GSM 900 band; the elements shown in black indicate operation in the GSM 1800 band and the elements marked in black in the lower triangle and in white in their two upper triangles indicate simultaneous operation in both bands. Precisely the simultaneous operation in both bands via a single multiband element (the multi-triangular element) in such positions of the array (those positions at which those of the original mono-band arrays coincide), is one of the main characteristic features of the MIA invention.

[0030] The manner of feeding the elements of the AEM1 array is not characteristic of the invention of the MIAs and recourse may be had to any conventionally known system. In particular and given that the multi-triangular elements are excited at two different points, it is possible to make use of an independent distribution network for each band. Another alternative consists in employing a broadband or dual band distribution network, by coupling a combiner/diplexer which interconnects the network and the two excitation points of the multi-triangular antenna.

[0031] Finally, the antenna may therefore come with two input/output connectors (one for each band), or combined in a single connector by means of a combiner/diplexer network.

AEM2 MODE

[0032] This particular configuration of AEM2, shown in Figure 8, is based on a multilevel antenna which acts as a multiband element. In addition to working simultaneously in the GSM 900 and GSM 1800 bands, the antenna has also double linear polarisation at +45° and -45° with respect to the longitudinal axis of the array. The fact that the antenna has double polarisation signifies an additional advantage for the cellular telephony operator, since in this manner he can implement a diversity system which minimises the effect of fading by multipath propagation. The multilevel element which is described in Figure 8 is more suitable than the multi-triangular element described previously since the element itself has a linear polarisation at +45° in GSM 900 and at -45° in GSM 1800.

[0033] The array is obtained by interleaving two conventional mono-band arrays with spacing between elements less than one wavelength ( ) in the pertinent band (typically a spacing less than 0.9 is chosen in order to minimise the appearance of the diffraction lobe in the end-fire direction). The original arrays can have 8 or 10 elements depending on the gain required by the operator. The juxtaposition of both arrays in a single MIA is achieved in this case by employing in-band dual multilevel elements. Such elements incorporate two points of excitation (one for each band), which permits the working band to be selected according to their position in the array. In Figure 8 the position of the elements is shown, as well as their working frequencies. The elements shown in white indicate operation in the GSM 900 band; the elements shown in black indicate operation in the GSM 1800 band and the elements marked in black in their lower triangle and in white in the upper triangles indicate simultaneous operation in both bands. Precisely the simultaneous operation in both bands via a single multiband element (the multilevel element) in such positions of the array (those positions in which those of the original mono-band arrays coincide), is one of the main characteristic features of the MIA invention.

[0034] It is possible to achieve double polarisation on a basis of exciting the multilevel element at various points on its surface; nonetheless in order to augment the isolation between connectors of different polarisation, it is chosen in the example described to implement a double column to separate the +45° polarization (left-hand column) from that of -45° (right-hand column). To increase the isolation between bands, it is even possible to interchange the polarisation inclination in the columns of the array in one of the bands (for example in DCS).

[0035] The manner of feeding the elements of the array AEM2 is not characteristic of the invention of the MIAs and recourse can be had to any conventionally known system. In particular and given that the multi-triangular elements are excited at two different points, it is possible to make use of an independent distribution network for each band and polarisation. Another alternative consists in employing a broadband or dual band distribution network, by coupling a combiner/diplexer which interconnects the network and the two excitation points of the multilevel antenna. The antenna may then come with four input/output connectors (one for each band and polarisation), or else combined in only two connectors (one for each independent polarisation) by means of combiner/diplexer network in each polarisation.

AEM3 MODE

[0036] The AEM3 configuration, as shown in Figure 9, is very similar to the AEM2 (the position of the multilevel elements and the type of element itself is the same as in the previous case), with the difference that the right-hand column is reversed with respect to that on the left. In this manner an antenna with dual band and polarisation is obtained, the total width of the antenna being reduced with respect to the previous case (in this particular example the width is reduced by about 10%). In order to increase the isolation between the columns of double polarisation it is convenient that oblique fins be inserted between contiguous elements. In that case, lateral fins are also incorporated in all the elements which work in GSM 1800, fins which contribute to narrowing the radiation beam in the horizontal plane (plane at right angles to the longitudinal axis of the array).

[0037] Nor is the signal distribution system especially characteristic of the MIA configuration and the same system can be used as in the previous case.

AEM4 MODE

[0038] Another example of multiband interleaved array is that termed herein AEM4 and which is shown in schematic form in Figure 11. In this case, the multiband element is a stacked square patch antenna (Figure 10), though it is obvious for anyone familiar with the subject that patches of other shapes could be employed. Square- or circular-shaped types are preferred in the event that is wished to work with double polarisation. In the example of Figure 10 the particular case is described of square patches.

[0039] The lower patch is of appropriate size for its resonant frequency (associated typically with the patch fundamental mode) to coincide with the lower band (GSM 900 in this specific case); moreover, this patch acts in turn as ground plane of the upper patch. The latter is of a size such that its resonance is centred in the upper band (GSM 1800). The elements of the array are mounted on a metallic or metal-coated surface which acts as ground plane for all the elements of the array. The feeder system is preferentially of the coaxial type, a cable being employed for the lower patch and band and another for the upper patch and band. The excitation points are collocated on the bisectors of the patches (for example, the approximate excitation points are marked by means of circles on the plan view of the antenna) if vertical or horizontal polarisation is desired, or on the diagonals if, on the other hand, linear polarisation inclined at 45° is desired. In the event it is desired that the array work with double polarisation, each of the patches is excited additionally on the bisector or diagonal opposite (orthogonal) to the first.

[0040] The feeding of the elements of the array AEM4 is not characteristic of the invention of the MIAs and recourse can be had to any conventionally known system. In particular and given that the stacked patch antenna is excited at two different points, it is possible to make use of an independent distribution network for each band and polarisation. Another alternative consists in employing a broadband or dual band distribution network, by coupling a combiner/diplexer which interconnects the network and the two excitation points of the multilevel antenna.

[0041] The antenna may then come with four input/output connectors (one for each band and polarisation), or else combined in only two connectors (one for each independent polarisation) by means of a combiner/diplexer network in each polarisation.

ARMS MODE

[0042] The AEM5 configuration, as shown in Figure 12, adopts the same approach as the AEM4, though all the elements are rotated through 45° in the plane of the antenna. In this manner the radiation pattern is modified in the horizontal plane, in addition to rotating the polarization through 45°.

[0043] It is of interest to point out that both in the AEM4 configuration and in the AEM5, the multiband element constituted by the stacked patches is really only strictly necessary in those strategic positions in which elements originating in the conventional mono-band arrays coincide. In the remaining positions, it shall be possible to employ indistinctly multiband or mono-band elements that work at the frequency determined for its location, as long as its radiation pattern is sufficiently like that of the stacked patch antenna in order to avoid the appearance of diffraction lobes.

[0044] It is not deemed necessary to extend further the content of this description in order that an expert in the subject can comprehend its scope and the benefits arising from the invention, as well as develop and implement in practice the object thereof.

[0045] Notwithstanding, it must be understood that the invention has been described according to a preferred embodiment thereof, for which reason it may be susceptible to modifications without this implying any alteration to its basis, it being possible that such modifications affect, in particular, the form, the size and/or the materials of manufacture.

Claims

1. Interlaced multiband antenna array which works simultaneously on various frequencies the position of the elements in the array being obtained from the juxtaposition of as many mono-band arrays as there are working frequencies required, **characterised in that**, a single multiband antenna, capable of covering the different working frequencies, is provided in those positions of the array in which the positions of two or more elements of the mono-band arrays coincide.

2. Interlaced multiband antenna array, in accordance with claim 1, the single multiband antenna being a fractal multiband antenna.

3. Interlaced multiband antenna array, in accordance with claim 1, the single multiband antenna being a multiband multilevel antenna.

4. Interlaced multiband antenna array, in accordance with claim 1, the single multiband antenna being a multiband multi-triangular antenna.

5. Interlaced multiband antenna array, in accordance with claim 1, the single multiband antenna being formed by the stacking of structures of the patch or microstrip type.

6. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** in those positions in which the elements of two or more mono-band arrays do not coincide the same multiband antenna, fractal, multilevel or multi-triangular is employed as in the common positions.

7. Interlaced multiband antenna array, in accordance with claim 6, **characterised in that** the working frequency of the fractal, multilevel or multi-triangular multiband antennas is chosen as a function of the position in the multiband interleaved array, by means of a frequency-selective structure.

8. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** in those positions in which the elements of two or more mono-band arrays do not coincide a monoband antenna is employed which works at the frequency which its position in the array determines.

9. Interlaced multiband antenna array, in accordance with claim 8, **characterised in that** the monoband element employed in those positions in which a multiband element is not required, has a radiation pattern sufficiently like that of the fractal, multilevel or multi-triangular multiband element, on the same frequency, in order that in the pattern of the multiband interleaved array the diffraction is conveniently attenuated.

10. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** the number of elements, their spatial distribution relative to wavelength, and also their current phase and amplitude is the same in all the monoband arrays that are juxtaposed in order to synthesise the multiband interleaved array, in order to achieve the same array factor in the different bands of interest.

11. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** the number of elements, their spatial distribution relative to wavelength, and also their current phase and amplitude is adjusted at each frequency in order to shape the radiation pattern in accordance with the particular needs of the communication system that is working in each band.

12. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** the operating bands are situated around 900 MHz and 1800 MHz in order to provide service simultaneously for the GSM 900 and GSM 1800 cellular mobile telephony systems.

13. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** the operating bands are situated around 1900 MHz and 3500 MHz in order to provide service simultaneously for the cordless and local radio access communication systems like for example those employing the DECT standard.

14. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** the operating bands are situated around 900 MHz, 1800 MHz and 2100 MHz in order to provide service simultaneously for the GSM 900, GSM 1800 and

UMTS cellular mobile telephony systems.

15. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** the operating bands are situated around 800 MHz and 1900 MHz in order to provide service simultaneously for the AMPS and PCS cellular mobile telephony systems.

16. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** a mono-band signal distribution network is employed for each working frequency and sub-array that forms the array.

17. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in that** a single multiband distribution network is employed in order to excite all the elements of the array at all the frequencies.

18. Interlaced multiband antenna array, in accordance with claim 16, **characterised in that** in the terminals of the distribution network is incorporated or integrated a frequency-selective element which permits selection of what elements are excited and at what frequency or frequencies.

19. Interlaced multiband antenna array, in accordance with claims 1, 2, 3, 4 and 5, **characterised in** the operating bands are situated around 800 MHz, 1900 MHz and 2100 MHz in order to provide service simultaneously for the AMPS, PCS and UMT 2000 cellular mobile telephony systems.

20. Interlaced multiband antenna array according to claims 3 or 4, **characterised in that** the single multiband antenna is excited at two different points.

21. Interlaced multiband antenna array according to claim 5, **characterised in that** the stacked structures are rotated through 45° on the plane of the antenna.

22. Interlaced multiband antenna array according to claim 1, **characterised in that** when working frequencies do not correspond to an integer factor of the highest frequency, some elements of the monoband array working at the lowest frequency, are repositioned to coincide with the nearest element of highest frequency mono-band array.

23. Interlaced multiband antenna array according to claim 1, **characterised in that** the mono-band arrays are two-dimensional or three-dimensional arrays.

24. Interlaced multiband antenna array according to claim 1, **characterised in that** the interlaced antenna comprises two columns of elements, one column for the +45° polarization, and the other column for the -45° polarization.

25. Interlaced multiband antenna array according to claim 24, **characterised in that** the elements of one of the columns are reversed with respect to the elements of the other column.

Patentansprüche

1. Zeilensprungmehrbandrichtstrahler, der gleichzeitig auf mehrere Frequenzen arbeitet, wobei sich die Anordnung der Elemente des Strahlers aus der Nebeneinanderschaltung so vieler Einzelbandstrahler ergibt, wie Arbeitsfrequenzen benötigt werden, **dadurch gekennzeichnet, dass** in den Positionen, bei denen zwei odere mehr Elemente der Einzelbandstrahler übereinstimmen, eine einzige Mehrbandantenne verwendet wird, die in der Lage ist, die verschiedenen Arbeitsfrequenzen abzudecken.

2. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 1, wobei die einzelne Mehrbandantenne eine fraktale Mehrbandantenne ist.

3. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 1, wobei die einzelne Mehrbandantenne eine mehrstufige Mehrbandantenne ist.

4. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 1, wobei die einzelne Mehrbandantenne eine Mehrfachdreiecksmehrbandantenne ist.

5. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 1, wobei die einzelne Mehrbandantenne aus dem Anordnen in Stapelspeichern von Strukturen aus Zusammenschaltungen oder Mikrostrips gebildet werden.

6. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** die selben fraktale, mehrstufige oder Mehrfachdreiecksmehrbandantennen wie auf den normalen Positionen angewendet werden, wenn auf einer Position die Elemente zweier Einzelbandstrahler nicht übereinstimmen.

7. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 6, **dadurch gekennzeichnet, dass** die Arbeitsfrequenz der fraktalen, mehrstufigen oder Mehrdreiecksmehrbandantennen in Funktion mit den Positionen bei den überlappenden Mehrbandstrahlern durch eine Frequenzwahlstruktur gewählt wird.

8. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass**, wenn auf einer Position die Elemente zweier Einzelbandstrahler nicht übereinstimmen, eine Einzelbandantenne verwendet wird, die auf der Frequenz arbeitet, die ihre Position in dem Strahler festlegt.

9. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 8, **dadurch gekennzeichnet, dass** das Einzelbandelement, das in den Positionen eingesetzt wird, in denen kein Mehrbandelement erforderlich ist, über ein Strahlungsmuster verfügt, dass dem der fraktalen, mehrstufigen oder Mehrdreiecksmehrbandantennen ausreichend ähnelt und die selbe Frequenz hat, damit bei dem Muster der überlappenden Mehrbandstrahler die Diffraktion angemessen vermindert wird.

10. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** die Anzahl der Elemente, ihre räumliche Andordnung im Verhältnis zur Wellenlänge und auch ihre Stromphase und Stromamplitude bei allen Einzelbandstrahlern, die nebeneinander geschaltet sind, gleich sind, damit die überlappenden Mehrbandstrahler synthetisiert, damit die selben Strahlfaktoren auf den fraglichen unterschiedlichen Bändern erzielt wird.

11. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** die Anzahl der Elemente, ihre räumliche Andordnung im Verhältnis zur Wellenlänge und auch ihre Stromphase und Stromamplitude auf jeder Frequenz eingestellt werden, um das Strahlungsmuster in Übereinstimmung mit den individuellen Bedürfnissen des Kommunikationssystems zu formen, das in jedem Band arbeitet.

12. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** die betriebenen Bänder um 900 MHz und um 1800 MHz angeordnet sind, um gleichzeitig die Mobiltelephonsysteme GSM 900 und GSM 1800 zu bedienen.

13. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** die betriebenen Bänder um 1900 MHz und um 3500 MHz angeordnet sind, um gleichzeitig die schnurlosen und lokalen Radiozugangskommunikationssysteme, wie zum Beispiel die, die DECT Standard verwenden, zu bedienen.

14. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** die betriebenen Bänder um 900 MHz, um 1800 MHz und um 2100 MHz angeordnet sind, um gleichzeitig die Mobiltelephonsysteme GSM 900, GSM 1800 und UMTS zu bedienen.

15. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** die betriebenen Bänder um 800 MHz und um 1900 MHz angeordnet sind, um gleichzeitig die Mobiltelephonsysteme AMPS und PCS zu bedienen.

16. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** ein Verteilernetzwerk mit Einzelbandsignal für jede Arbeitsfrequenz und jeden Einzelstrahler eingesetzt wird, aus denen der Strahler besteht.

17. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** ein einziges Verteilernetzwerk mit Mehrbandsignal eingesetzt wird, um alle Elemente des Strahlers auf allen Frequenzen einzuschalten.

18. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 16, **dadurch gekennzeichnet, dass** an den Anschlüssen des Verteilernetzwerks ein Frequenzwahlelement angebracht oder integriert ist, dass eine Wahl der Elemente erlaubt, die eingeschaltet werden und bei welcher Frequenz oder Frequenzen.

19. Zeilensprungmehrbandrichtstrahler gemäss den Ansprüchen 1, 2, 3, 4 und 5, **dadurch gekennzeichnet, dass** die betriebenen Bänder um 800 MHz, um 1900 MHz und um 2100 MHz angeordnet sind, um gleichzeitig die Mobiltelephonsysteme AMPS, PCS und UMT 2000 zu bedienen.

20. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 3 oder 4, **dadurch gekennzeichnet, dass** die einzige Mehrbandantenne an zwei verschiedenen Punkten eingeschaltet wird.

21. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 5, **dadurch gekennzeichnet, dass** die nebeneinander geschalteten Strukturen um 45° auf der Ebene der Antenne gedreht werden.

22. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 1, **dadurch gekennzeichnet, dass**, wenn unterschiedliche Frequenzen nicht mit einem integralen Faktor der höchsten Frequenz übereinstimmen, werden einige der Einzelbandstrahler, die auf der niedrigsten Frequenz arbeiten, neu ausgerichtet, damit sie mit dem nächsten Element des Einselbandstrahlers der höchsten Frequenz übereinstimmen.

23. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 1, **dadurch gekennzeichnet, dass** die Einzelbandstrahler zwei- oder dreidimensionale Strahler sind.

24. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 1, **dadurch gekennzeichnet, dass** die Zeilensprungantenne zwei Säulen von Elementen umfasst, wobei eine Säule für die +45°-Polarisierung und die andere Säule für die - 45°-Polarisierung zuständig ist.

25. Zeilensprungmehrbandrichtstrahler gemäss Anspruch 24, **dadurch gekennzeichnet, dass** die Elemente einer der Säulen umgekehrt angeordnet sind im Vergleich zu den Elementen der anderen Säule.

Revendications

1. Réseau d'antennes multibandes entrelacées qui fonctionne simultanément sur diverses fréquences, la position des éléments du réseau étant obtenue à partir de la juxtaposition d'autant de réseaux monobandes que de fréquences de travail existantes requises, **caractérisé en ce que** l'on prévoit une seule antenne multibande, apte à couvrir les différentes fréquences de travail aux positions du réseau dans lequel coïncident les positions de deux ou plusieurs éléments des réseaux monobandes

2. Réseau d'antennes multibandes entrelacées, selon la revendication 1, l'antenne multibande unique étant une antenne multibande fractale.

3. Réseau d'antennes multibandes entrelacées, selon la revendication 1, l'antenne multibande unique étant une antenne multibande multiniveau.

4. Réseau d'antennes multibandes entrelacées, selon la revendication 1, l'antenne multibande unique étant une antenne multibande multitriangulaire.

5. Réseau d'antennes multibandes entrelacées, selon la revendication 1, l'antenne multibande unique étant formé par l'empilement de structure du type patch ou microruban.

6. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5 **caractérisé en ce qu'**aux positions auxquelles les éléments de deux ou plusieurs réseaux monobandes ne coïncident pas, on utilise la même antenne multibande, fractale, multiniveau ou multitriangulaire qu'aux positions communes.

7. Réseau d'antennes multibandes entrelacées, selon la revendication 6 **caractérisé en ce que** la fréquence de travail des antennes multibandes multitriangulaires, multiniveaux ou fractales est choisie en fonction de la position dans le réseau intercalé multibande, au moyen d'une structure de sélection de fréquence.

8. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5 **caractérisé en ce qu'**aux positions auxquelles les éléments de deux ou plusieurs réseaux monobandes ne coïncident pas, on utilise une antenne monobande qui fonctionne à la fréquence déterminée par sa position dans le réseau.

9. Réseau d'antennes multibandes entrelacées, selon la revendication 8 **caractérisé en ce que** l'élément monobande utilisé aux positions auxquelles on n'a pas besoin d'un élément multibande, a un patron de rayonnement suffisamment similaire à celui de l'élément multibande, fractal, multiniveau ou multitriangulaire sur la même fréquence afin que dans le patron du réseau intercalé multibande la diffraction soit atténuée convenablement.

10. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5, **caractérisé en ce que** le nombre d'éléments, leur distribution spatiale par rapport à la longueur d'onde, et aussi leur phase et amplitude actuelles sont les mêmes dans tous les réseaux juxtaposés afin de synthétiser le réseau intercalé multibande, afin d'obtenir le même facteur de réseau dans les différentes bandes dignes d'intérêt.

11. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5, **caractérisé en ce que** le nombre d'éléments, leur distribution spatiale par rapport à la longueur d'onde, et aussi leur phase et amplitude actuelles sont ajustées à chaque fréquence afin de former le patron de rayonnement selon les besoins particuliers du système de communication qui est en train de fonctionner dans chaque bande.

12. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5, **caractérisé en ce que** les bandes opérationnelles sont situées environ à 900 MHz et 1800 MHz afin de desservir simultanément les systèmes de téléphonie cellulaire mobile GSM 900 et GSM 1800

13. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5, **caractérisé en ce que** les bandes opérationnelles sont situées environ à 1900 MHz et 3500 MHz afin de desservir simultanément les systèmes de communication à accès sans fil et boucle locale radio comme par exemple ceux qui utilisent la norme DECT.

14. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5, **caractérisé en ce que** les bandes opérationnelles sont situées environ à 900 MHz, 1800 MHz et 2100 MHz afin de desservir simultanément les systèmes de téléphonie cellulaire mobile GSM 900, GSM 1800 et UMTS.

15. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5, **caractérisé en ce que** les bandes opérationnelles sont situées environ à 800 MHz et 1900 MHz afin de desservir simultanément les systèmes de téléphonie cellulaire mobile AMPS (système avancé de téléphonie mobile) et PCS (système de communications personnelles).

16. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5, **caractérisé en ce que** l'on utilise un réseau monobande de distribution de signaux pour chaque fréquence de travail et sous-réseau formant le réseau.

17. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5, **caractérisé en ce que** l'on utilise un réseau multibande de distribution unique afin d'exciter tous les éléments du réseau à toutes les fréquences.

18. Réseau d'antennes multibandes entrelacées, selon la revendication 16, **caractérisé en ce que** les terminaux du réseau de distribution son incorporés ou intégrés dans un élément de sélection de fréquence qui permet la sélection des éléments à exciter et la sélection de la fréquence ou des fréquences à laquelle ou auxquelles ils sont excités.

19. Réseau d'antennes multibandes entrelacées, selon les revendications 1, 2, 3, 4 et 5, **caractérisé en ce que** les bandes opérationnelles sont situées environ à 800 MHz, 1900 MHz et 2100 MHz afin de desservir simultanément les systèmes de téléphonie cellulaire mobile AMPS (système avancé de téléphonie mobile) et PCS (système de communications personnelles) et UMT 2000.

20. Réseau d'antennes multibandes entrelacées, selon la revendication 3 ou 4, **caractérisé en ce que** l'antenne multibande unique est excitée à deux points différents.

21. Réseau d'antennes multibandes entrelacées, selon la revendication 5, **caractérisé en ce que** les structures empilées sont pivotées 45° sur le plan de l'antenne.

22. Réseau d'antennes multibandes entrelacées, selon la revendication 1, **caractérisé en ce que** lorsque des fréquences différentes ne correspondent pas à un facteur intégral de la fréquence la plus élevée, quelques éléments du réseau monobande qui fonctionnent à la fréquence la plus basse, sont repositionnés pour coïncider avec l'élément du réseau monobande ayant la fréquence la plus élevée.

23. Réseau d'antennes multibandes entrelacées, selon la revendication 1, **caractérisé en ce que** les réseaux monobandes sont des réseaux bidimensionnels ou tridimensionnels.

24. Réseau d'antennes multibandes entrelacées, selon la revendication 1, **caractérisé en ce que** l'antenne entrelacée comprend deux colonnes d'éléments, une colonne pour la polarisation +45°, et l'autre colonne pour la polarisation -45°.

25. Réseau d'antennes multibandes entrelacées, selon la revendication 24, **caractérisé en ce que** les éléments d'une des colonnes sont renversés par rapport aux éléments de l'autre colonne.

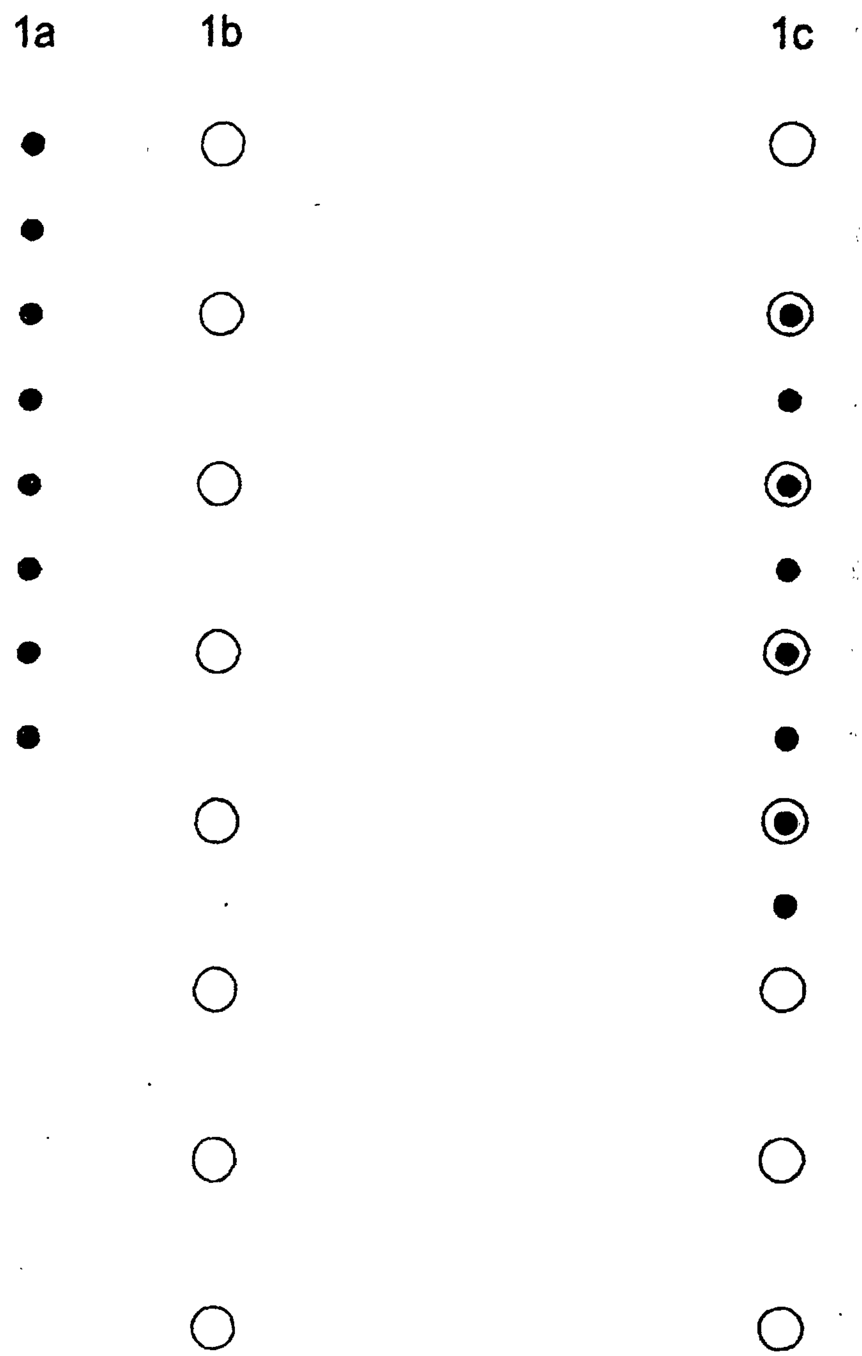

FIG. 1

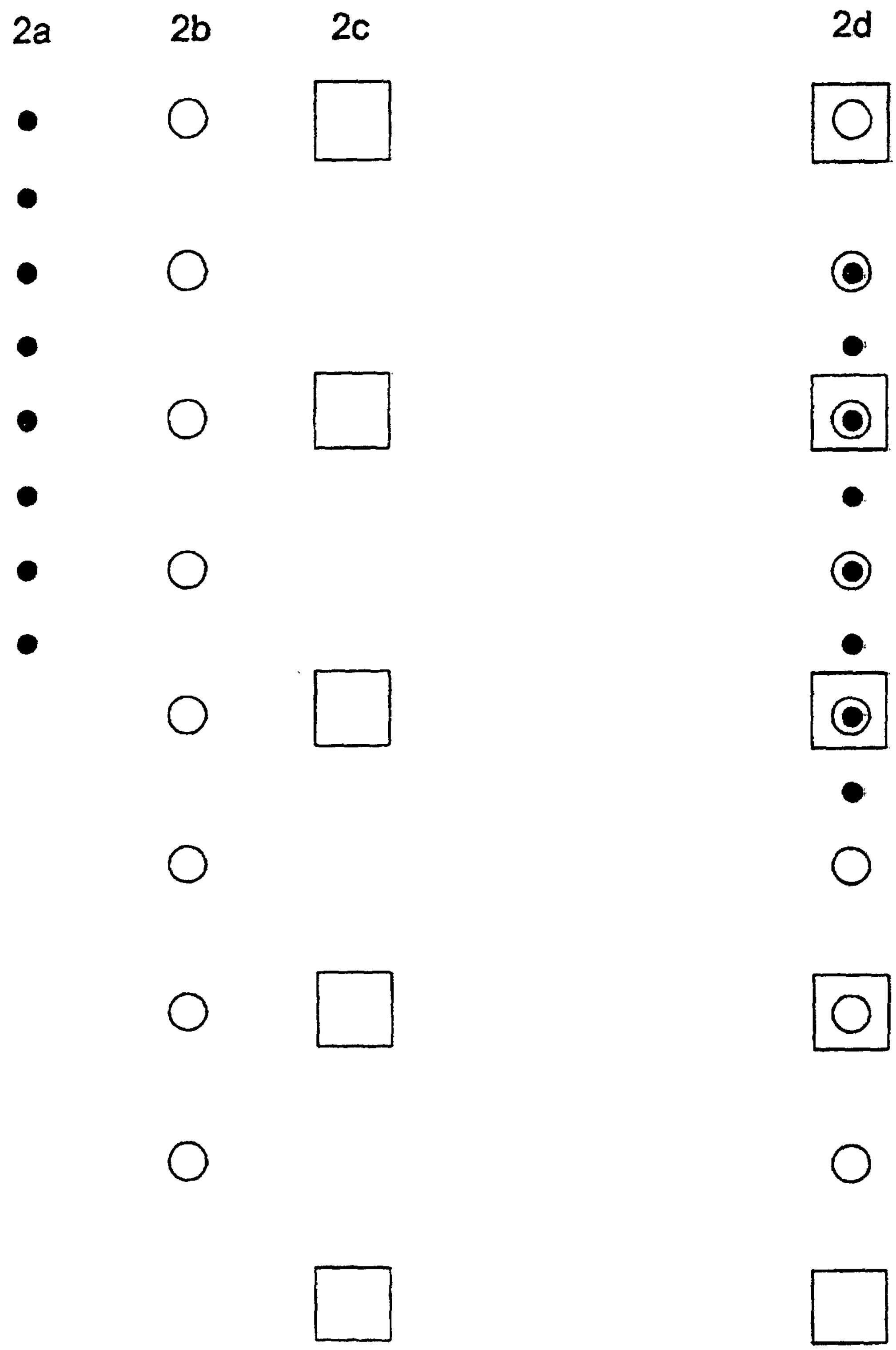

FIG. 2

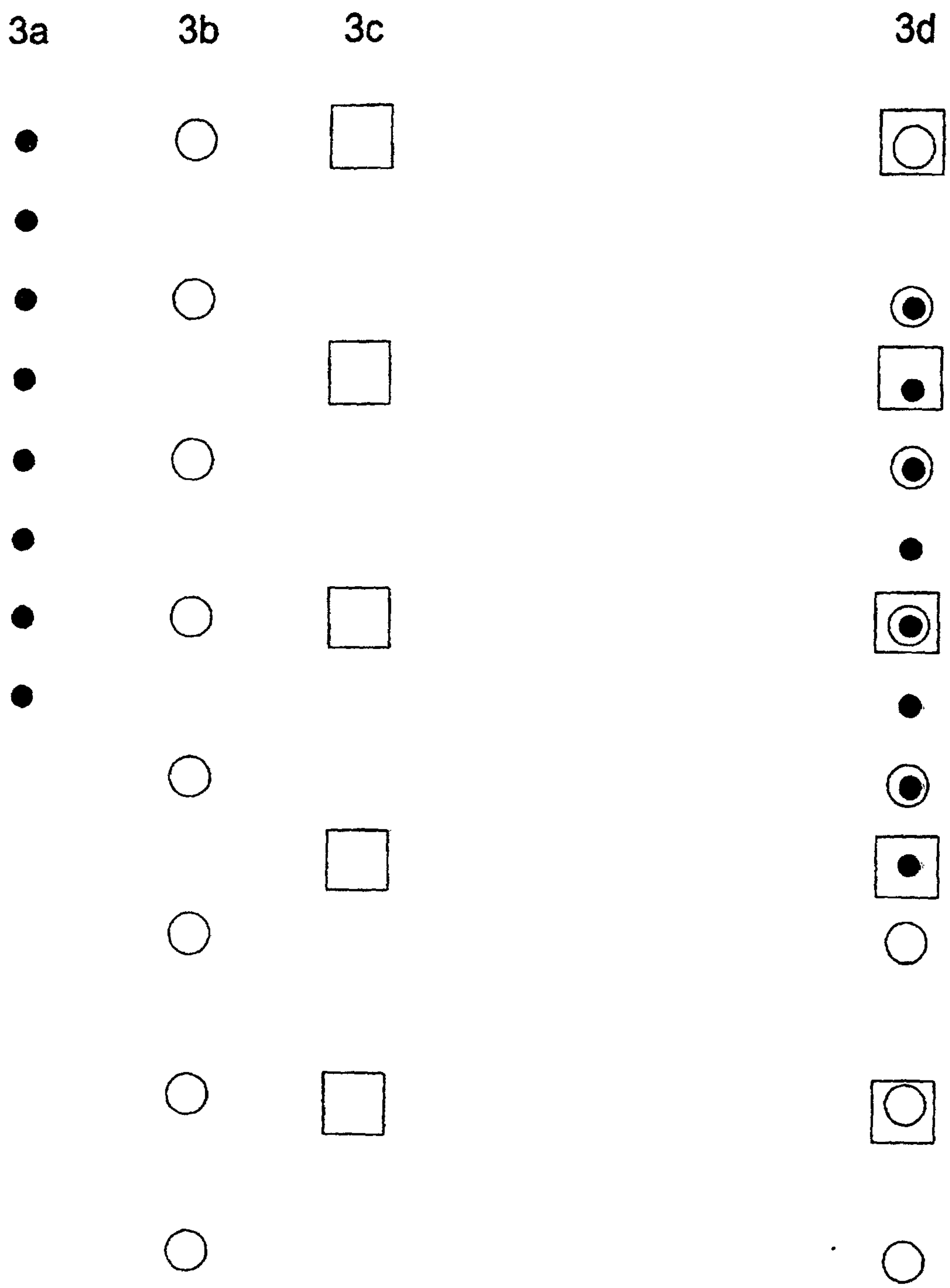

FIG. 3

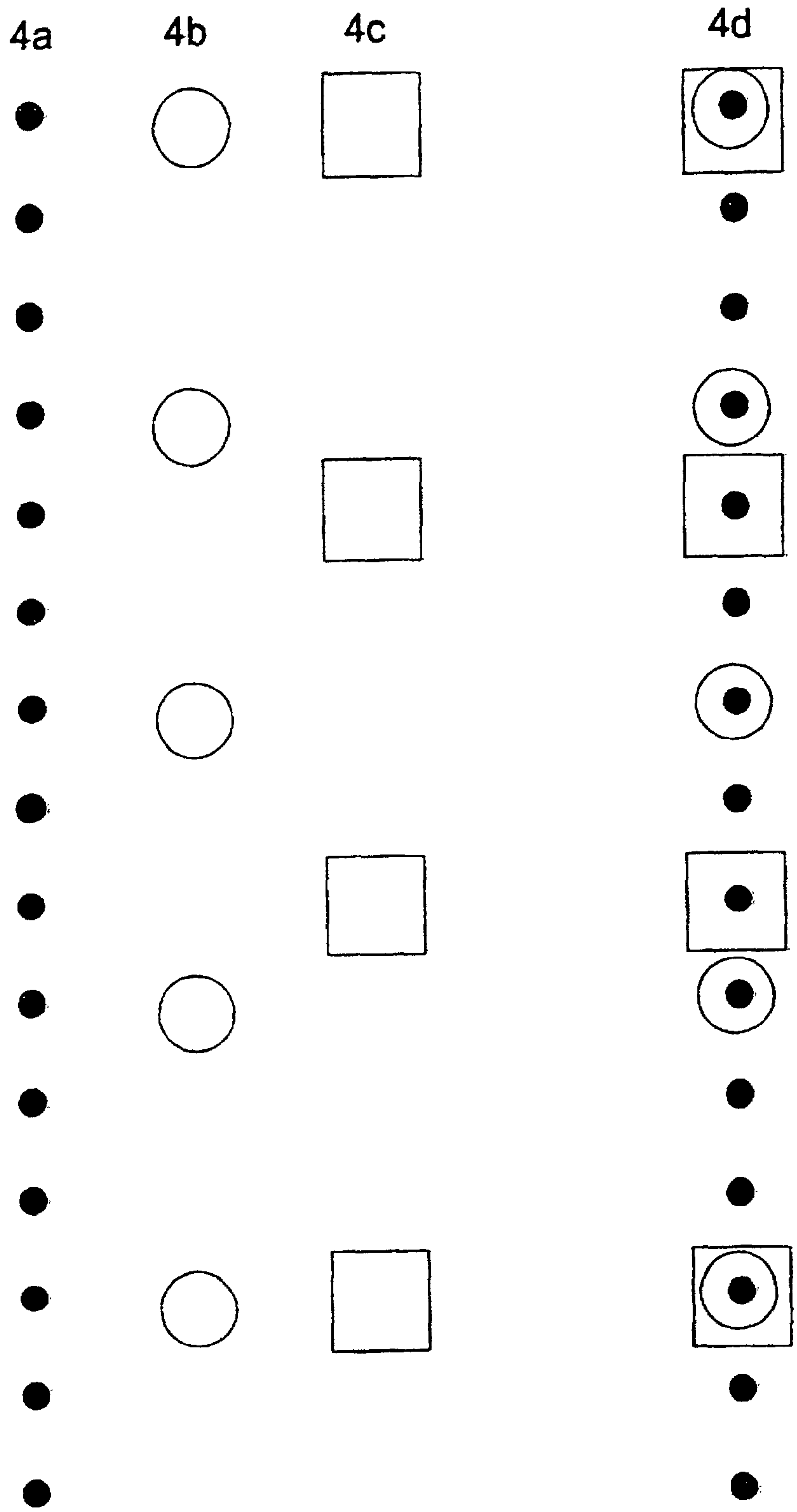

FIG. 4

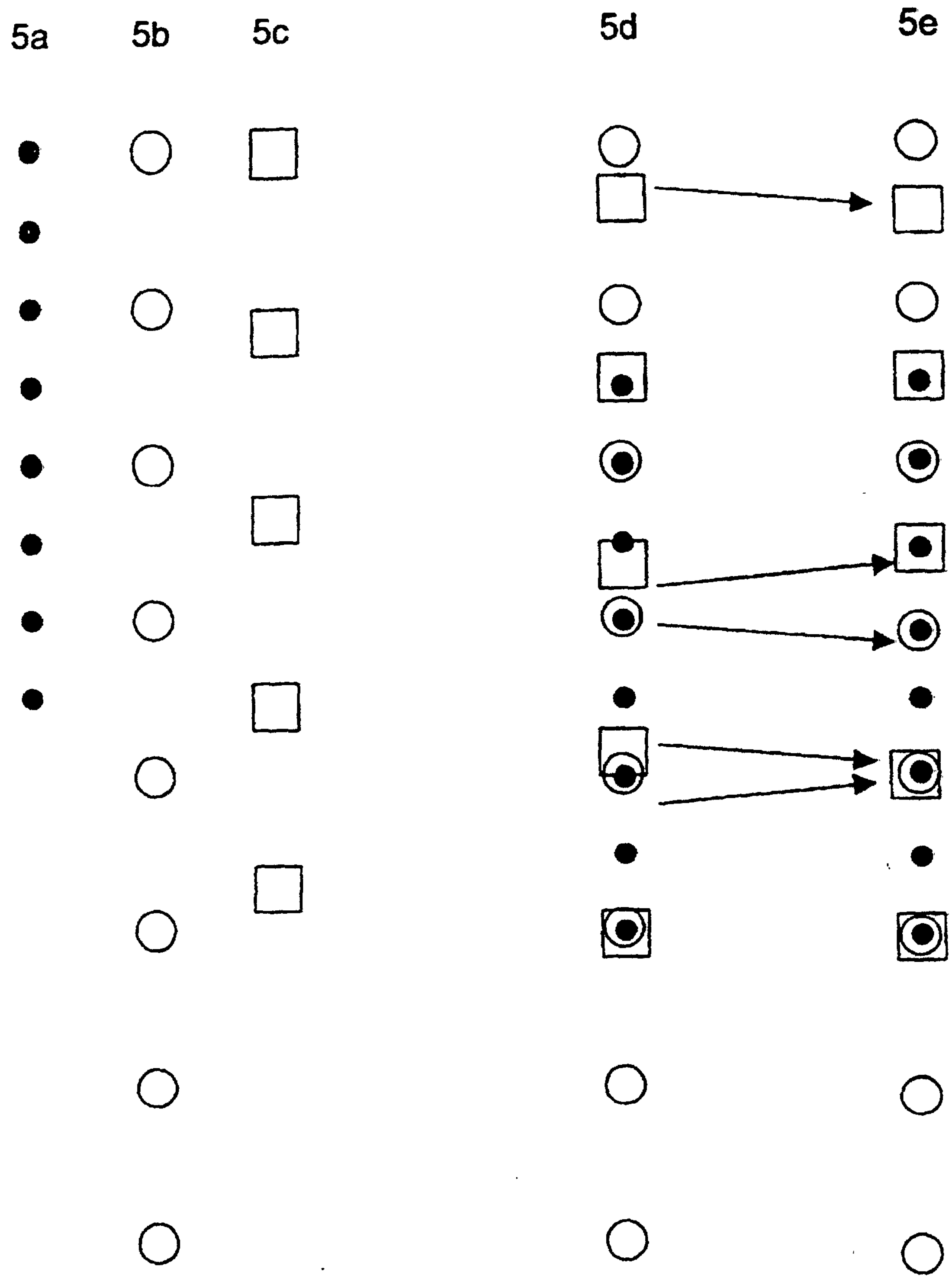

FIG. 5

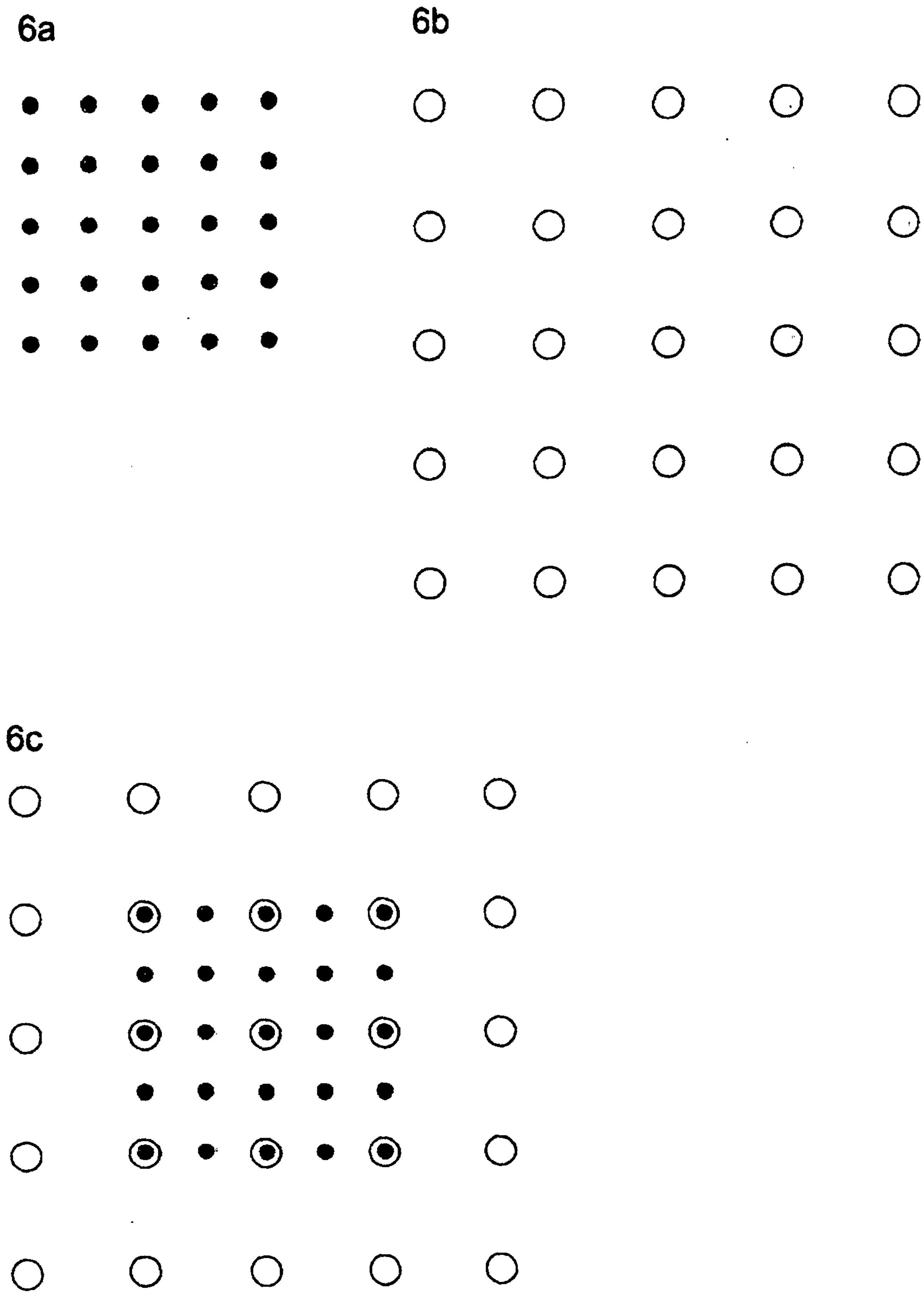

FIG. 6

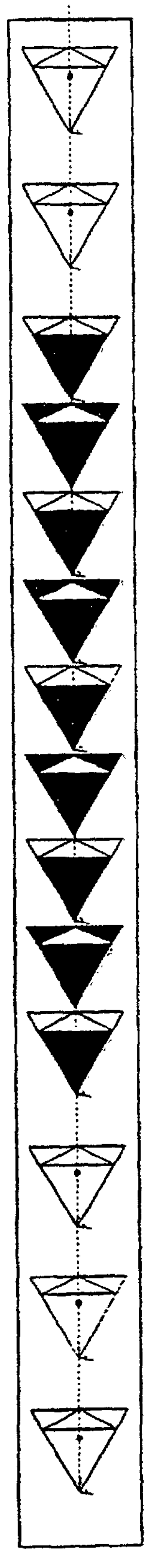

FIG. 7

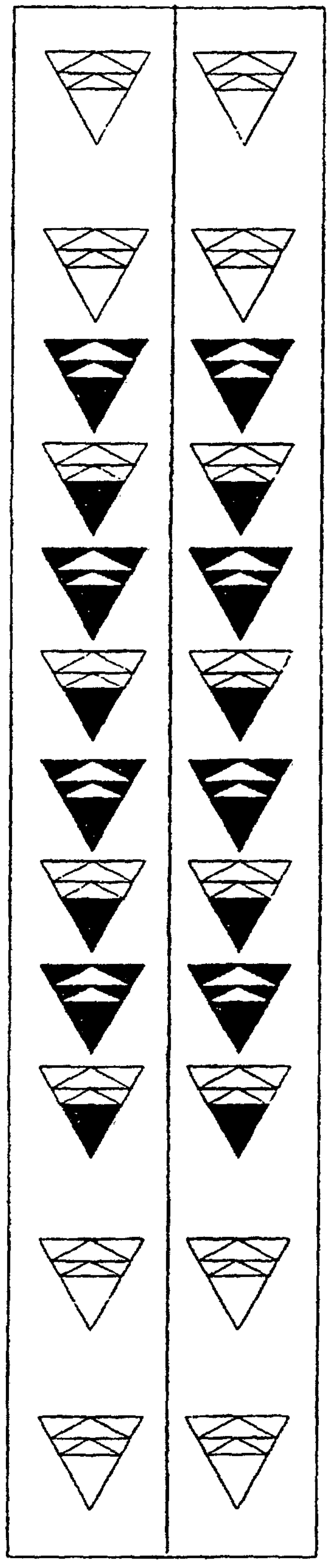

FIG. 8

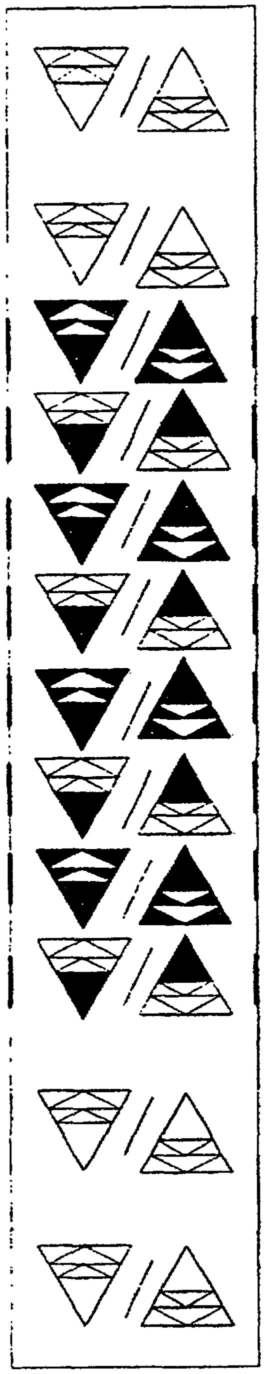

FIG. 9

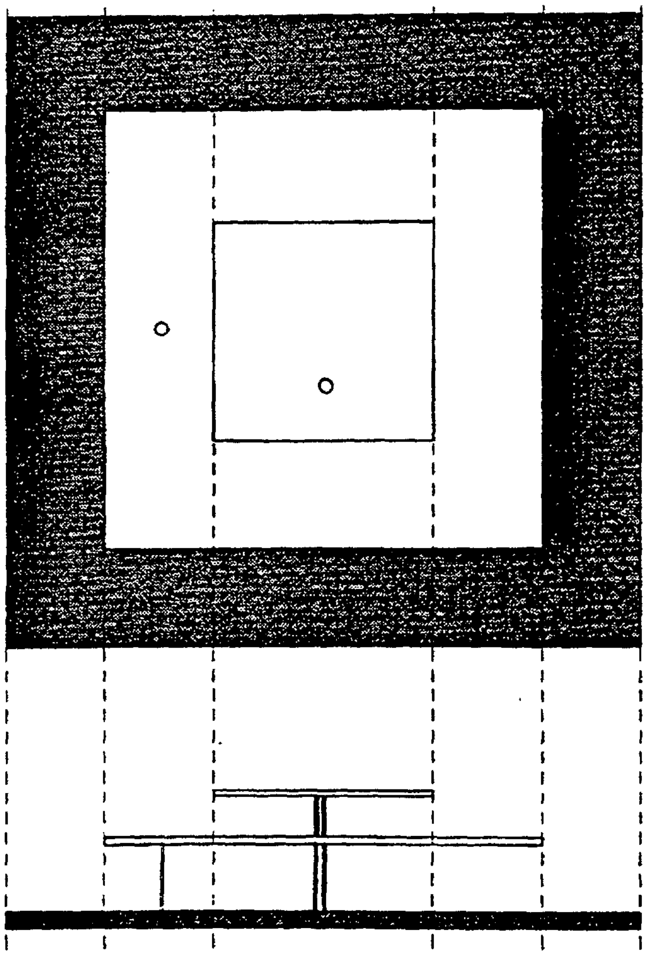

FIG. 10

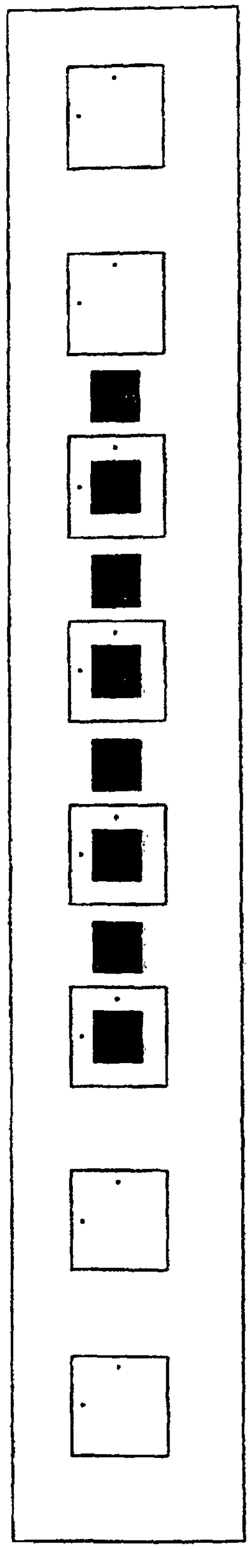

FIG. 11

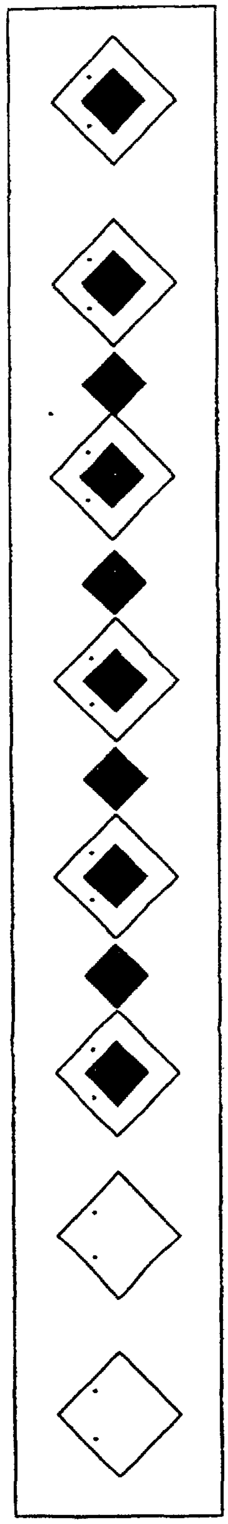

FIG. 12