ELECTRONICALLY STEP-BY-STEP ROTATED DIRECTIVE RADIATION BEAM ANTENNA

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ABSTRACT
This invention relates to an electronically rotatable antenna which includes several radially arranged Yagi antennae having a common drive element. Reflector and director elements of each Yagi antenna are sequentially rendered operative by biasing suitable diodes short-circuiting them to a ground-plate. The radiation pattern is step-by-step rotated. Directivity is increased by short-circuiting other elements belonging to other arrays than the main one, those elements defining generatrices of a parabola having the driver element as a focus and the reflector element as an apex.

2 Claims, 8 Drawing Figures
ELECTRONICALLY STEP-BY-STEP ROTATED DIRECTIVE RADIATION BEAM ANTENNA

The present invention relates to a fixed frequency operation antenna having directional radiation pattern with a main lobe as narrow as possible and being electronically rotatable step-by-step. More particularly, it relates to an electronically rotatable antenna using Yagi-type arrays.

As it is known, a Yagi array comprises several parallel planar dipoles including, in order, a not-fed dipole called reflector, a fed dipole called driven dipole and a number of not-fed suitably spaced parasitic dipoles called directors. Such an array has a maximum radiation in the array plane toward directors.

Yagi array dipoles are typically constituted by antennas in the form of rods or wires having a height close to the spatial half-wave of the RF radiated signal, at frequency $F = c/\lambda$, the feeding point being the driven dipole middle point.

It is easily conceivable that such a Yagi array is rotatable around the driven dipole, selected as an axis, so as to scan an area located in a predetermined angle, by the radiation beam.

However, when scanning velocity is relatively high and when scanned angle is so large as 360°, mechanical rotation is difficult to perform, and it is preferable to rotate the beam by electronic means, either in a continuous manner or step-by-step.

Known art includes a number of electronic control embodiments for rotating fixed-antenna radiation beam. Particularly, it is known to use arials made of a cylindrical reflector illuminated by a plurality of linear sources, wherein scanning is produced by either continuous or step-by-step electronic controlled variable phase shifts applied to linear sources (ferrite phase shifters, varactor phase shifters). Such arials are difficult to operate and the produced rotating beam is distorted in the course of the rotation.

Thus, a purpose of this invention is to provide a simple operational arial having a directional radiation pattern which is step-by-step rotatable under electronic control without beam distortion.

According to this invention, the provided arial is derived from a system including an assembly of $S$ identical Yagi arials having a common driven dipole and each comprising a reflector wire and $p$ director wires, the array ranked $Q$ being possibly considered as produced by rotating array ranked $(Q-1)$ by an angle $\theta$ round the axis constituted by the driven dipole common to all arials and rotation angle $\theta$ being 360°/S.

According to a feature of this invention, the driven dipole and the $(S + 1)p$ wires have a height close to $\lambda/4$ and are normal to a ground plane made of a metal plate. The $(S + 1)p$ wires are connected to the said ground plane by unidirectional elements such as PIN diodes which may have either a high impedance or a very low impedance depending on the bias voltage applied thereto.

Due to the image principle, a so constituted antenna roughly has — with respect to the horizontal radiation beam over the said ground plane and taking into account hereafter mentioned considerations — the same properties as an antenna driven by a ground plane wherein driven dipole and the $(S + 1)p$ wires would have twice this height, thus would be close to $\lambda/2$. In a so designed antenna, the driven dipole is fed from an RF source, at frequency $F$, mounted between its base and the ground plane. As a result thereof, wires associated to diodes operating at very low impedance may be considered as equivalent to dipoles tuned at the RF frequency $F = c/\lambda$ while wires associated to diodes operating at very high impedance are considered as elements of height $l/4$, free in space, which do not substantially contribute to the synthesis of the radiation beam.

In the following of this specification, "short-circuited wire" means every wire, when it is associated to a diode operating at very low impedance and "insulated wire" means every wire, when it is associated to a diode operating at very high impedance.

The above considerations show that the radiation beam aligned with angular coordinate $(Q-1)\theta$ is produced by utilizing the $(p+1)$ short-circuited wires of the array ranked $Q$ while the $(S-1)(1+p)$ other wires are insulated wires.

In that case, the step-by-step beam rotation is produced by biasing each of the diodes of the $(1+p)$ wires ranked $Q = 1$ by logic signals, at level "1" for instance, then each of the diodes of the $(1+p)$ wires ranked $Q = 2$, and so on up to $Q = S$.

For convenience, each director wire will be considered as determined by its "angular" rank $Q$ [$1 < Q < S$] and by its "radial" rank $k$ [$1 \leq k \leq p$], and will be defined by the symbol $Dp(k).

Any director wire $Dp(k)$ will have as Rho-Theta coordinates in the ground plane:

Rho: $(Q-1)\theta$

Theta: $d_{k} = d_{k}$ being the radius of a circle centered on driven dipole base and which includes on its circumference all the director wires of "radial" rank $k$.

To be noted that, in a known Yagi array, the beam directivity — directed from driven dipole to directors — would be substantially improved by setting, behind the driven dipole at a distance of about $\lambda/4$, a reflecting surface constituted by a parabolic cross-section cylinder. Typically, such a reflecting surface could be simulated by its "skeleton" constituted by the reflector wire and some additional parasitic wires suitably arranged with their axes confused with some generatrices of the said parabolic reflecting surface.

To be noted that, in the device according to this invention, there are, for each radiation beam position, only $(p+1)$ short-circuited wires while the other $(S-1)(p+1)$ wires are not used to produce the radiation beam "synthesis" since they are insulated wires.

But, amongst those unused wires belonging to arrays of radial rank $(Q_{M}+k_{r})$ or $(Q_{M}-k_{r})$, $\pm S$, some of them are very close to a generatrix of the fictive parabolic reflecting surface which might accompany the Yagi array of radical rank $Q$.

As a consequence, according to another feature of this invention, each time the $(p+1)$ wires of radial rank $Q$ are short-circuited, each of the $p$ director wires of radial rank $k$ and of angular rank $(Q_{M}+k_{r})$ or $(Q_{M}-k_{r})$, if $(Q+M_{r}) > S$ or each of the $p$ director wires of radial rank $k$ and of angular rank $(Q_{M}-k_{r})$, if $(Q-M_{r}) < 0$ are simultaneously short-circuited. The numbers $M_{r}$ are independent of $Q$ and there is only one $M_{r}$ for a value of $k$. The values of $M_{r}$ are determined by the Rho and Theta coordinates of the $Dp(k)$ closer director wires to the generatrices of a parabolic cross-section cylinder having as a focus the driven dipole base and as an apex the base of the reflector wire $R_{1}$ in the array ranked 1.
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Thus, it is to be noted that, in that device, at each time, (1+3$p$) wires are short-circuited and that, in a complete radiation pattern rotation, a director wire is used three times, i.e., once as a properly said director and twice as an additional reflector wire.

According to another feature of this invention, the logic control device controlling the radiation beam step-by-step rotation is constituted by a S-stage shift-register fed by a clock having a frequency equal to $S/r$ ($r$ being the duration of the radiation beam rotation by $360^\circ$) and an assembly of $P S$ three-input OR gates whose outputs are each connected to the bias input of the PIN diode associated to one of the $P S$ director wires.

Each of the $S$ shift-register outputs is provided with $(1+3$p$)$ connections. A first connection connects the output of the $Q^p$ stage to the bias input of the PIN diode associated to reflector wire ranked $Q$; $p$ second connections connect the output of the $Q^p$ stage to one input of each of the $Q$ OR gates whose outputs control the diodes associated to director wires of angular rank $Q$; $p$ third connections connect the output of the $Q^p$ stage to one input of each of the $Q$ OR gates whose outputs control the diodes associated to the director wires of arrays of angular rank $(Q+M_S)$ or $(Q+M_S-S)$. $p$ fourth connections connect the output of the $Q^p$ stage to one input of each of the $Q$ OR gates whose outputs control the diodes associated to the director wires of arrays of angular rank $(Q-M_S)$ or $(Q-M_S+S)$.

Other features of the present invention will appear more clearly from the following description of an embodiment, the said description being made in conjunction with the accompanying drawings, wherein:

FIG. 1a shows a Yagi array on a ground plane.
FIG. 1b is a cross-sectional view of the radiation pattern along the ground plane.

FIG. 2 shows schematically the projections of the ground plane of the various parasitic wires or elements constituting the antenna according to this invention, in the case of $p = 3$.

FIG. 3 shows how a PIN diode associated to a wire is mounted.

FIGS. 4-6 explain the antenna operation when utilizing additional reflector wires, and
FIG. 7 is a diagram of a logic control device, according to this invention, for step-by-step rotating the radiation beam.

FIG. 1 shows (in 1a) a driven dipole and four parasitic wires, i.e., a reflector $R$ and three directors $D_1$, $D_2$ and $D_3$, normal to a ground plane, forming a Yagi array (in this embodiment, $p = 3$).

The driven elements and the four parasitic elements are metal wires having a height of about $\lambda/4$, $\lambda$ being the free-space wavelength corresponding to the frequency $F$ of an RF source feeding the base of the driven element.

If the ground plane is infinite and perfectly conducting, the array radiation pattern is, when applying the image principle, identical — with respect to the portion located above the ground plane — to that which would be produced by use of a Yagi array comprising a driven element having a middle feeding point and four parasitic elements having a height of about $\lambda/2$. With such an assumption, there is no radiation under the ground plane since it is infinite.

1b shows the cross-section of the radiation pattern by the ground plane. It is to be noted the presence of a main lobe toward the three director wires and three subsidiary lobes on the other side.

Typically, the ground plane is not infinite and is constituted by a metal circular plate whose center is on the driven element and radius is $r_n$. In such conditions, due to diffraction effect at plate rim, electromagnetic radiation is no longer null under ground plane and the radiation pattern shape is, above ground plane, lightly modified with respect to its horizontal structure, more substantially modified with respect to its vertical structure, the shorter is $r_n$, the more oblique is the maximum radiation axis with respect to ground plane.

Still typically, ground plane conductance has a finite value, tangential electric field is thus not null, and "surface waves" may appear at the plate level, particularly when conductance thereof is rather bad. Reflections may occur due to plate rims and generate a stationary wave system which may disturb Yagi array operation if the junction point of one of the parasitic elements to ground plane is at a current node, since, in that case, electric charges flowing through the concerned wire flow with difficulty into ground plane. This drawback is overcome by providing a very good conductance to ground plate through a suitable surface processing.

FIG. 2 shows projections of an assembly of Yagi arrays on ground plane, according to this invention.

Several Yagi arrays are shown which have a driven element as a common axis. Those arrays having a similar structure, directors $D_1^S$, $D_2^S$ and $D_3^S$, and reflectors $R_n$ are respectively located on circles having the driven element as a center and radii $d_1$, $d_2$, $d_3$ and $d_r$, respectively.

The beam rotation angular step depends on the number of arrays selected to scan $360^\circ$.
Thus, the step is: $\theta = 360^\circ/5$, $S$ being the number of Yagi arrays. For instance, with $S = 72$, $\theta$ is of $5^\circ$.
Thus, the arrays are angularly shifted by $5^\circ$. However, for reason of convenience in the specification, but only for that reason, a privileged role has been, in the drawings, given to the Yagi array of angular rank $Q = 1$, with its four wires $R_1$, $D_1^1$, $D_2^1$ and $D_3^1$.
Either director or reflector wires are identical, but their heights close to $\lambda/4$, are different, all wires located on the same circle have the same height. Those wires are usually constituted by good conductance metal rods whose diameter is of about $\lambda/100$.

The ground plate having a radius $r_n$ is not shown in FIG. 2.

FIG. 3 shows how a PIN diode 2 connected to a parasitic element 1 is mounted. Diode 2 has one of its terminals connected to the ground plate 4. The other terminal is connected, through a choke inductance 3, to a bias source, not shown, but located under ground plate 4.

When a positive signal is applied to diode 2, through inductance 3, diode 2 passes a current 1. Direct resistance of diode 2 depends on 1, and, for a current of about 20 mA, resistance thereof is less than 1 ohm. The condition is the same as the element 1 was directly connected to ground plate 4. Then, applying the image principle, element 1 has the same behaviour as a wire insulated in free space, having a height close to $\lambda/2$ and then capable to ring.

When a negative signal is applied to diode 2, through inductance 3, diode 2 remains blocked. To such an extent that the negative signal is high enough to preclude RF signal peak to switch diode 2 on. In that case, im-
apedance of wire 1 with respect to ground plate 4 is high and only limited by the diode capacitance (about 0.25 pF), which represents, with $F = 1$ GHz, an insulation of about 600 ohms. In such conditions, it is the same as the wire, having a height close to $\lambda/4$, was insulated in free space. It cannot then ring at frequency $F$ and does not contribute to the radiation beam synthesis.

Electronic beam rotation results from the fact that the four parasitic elements of array angularly ranked $Q = 1$, are first short-circuited by applying a positive signal to the four associated diodes, then a positive signal is applied to the four parasitic elements of array angularly ranked $Q = 2$, and so on to angular rank $Q = S$.

To improve the directivity of the antenna according to this invention, as shown in FIG. 4, other elements have to be considered. In FIG. 4, the four wires $R_1, D_1, D_2$, and $D_3$ of array angularly ranked $Q = 1$ are located on axis $R_{1x}$ as well as driven element $P$. Axis $R_{2y}$ is normal to axis $R_{1x}$. Dotted line paraola is determined by apex $R_1$, focus $P$ and directrix $H_2$, $R_1 = R_2P = r$. Circles of radii $d_1, d_2, d_3$ intersect the said paraola at points $A, A'$, $B$ and $B'$, $C$ and $C'$, respectively.

In the coordinate system $xR_{1y}$, paraola equation is

$$y^2 = 4rx$$

or in Rho-Theta coordinates

$$\phi = \frac{r}{\sin \phi}$$

$\rho$ being modulus $PA$ and $\phi$ argument of vector $PA$ from $P$ to any point $A$ of the paraola.

If additional parasitic wires are located on that paraola and are normal thereto, antenna directivity is emphasized toward axis $R_{1x}$, according to this invention.

To make it clear, reference may be made to FIG. 5 wherein paraola is indicated in solid line. Considering a parasitic wire which projects on ground plane at $A$ on paraola, it appears that, in ground plane, projection $T$ of $P$ on axis $Ax'$ parallel to $R_{1x}$ is such that $AP + AT = 2r$, according to well known paraola characteristics.

The parasitic wire, normal to ground plane at $A$, is responsive to electric field radiated by driven element with a delay due to distance $PA$ and to Lentz law effect relating to the field induced into a parasitic wire.

$E = E_a e^{j\omega t}$, the field at $P$ created by driven element $(\omega = 2\pi f)$. The field close to point $A$ is: $E = KE_a e^{j\omega (2 \pi / \lambda)(x - z)}$ $(0 < K < 1)$

The field in the paraola wire is out of phase by $180^\circ$ and is

$$E = KK' E_a e^{j\omega (2 \pi / \lambda)(x - z)} (0 < K' < 1)$$

The field radiated by the parasitic wire at point $T$ is: $E = KK' E_n e^{j\omega t}$ $t = (2 \pi / \lambda - \pi)(x - z)$ $(0 < K' < 1)$

Or if $(AP + AT) = 2r = \lambda/2$,

$$E = KK' E_n e^{j\omega t} t = (2 \pi / \lambda - \pi)(x - z)$$

Then, the field at $T$ is phased with the field radiated by driven element. As a result, directivity toward $R_{1x}$ is emphasized. The importance of that emphasis will depend on product $KK'K''$, factors $K$ and $K''$ depending on distances $PA$ and $AT$, and factor $K'$ on length of parasitic wire at $A$. Any way, even if product $KK'K''$ has not the optimum value, it is always over zero, and there is a more or less important directivity emphasis. The same considerations would be valuable for other points of FIG. 4 ($A', B$ and $B', C$ and $C'$).

According to this invention, it will be noted that there are always amongst director elements, which are not used and belong to arrays angularly ranked $(M_e + 1)$ or $(S + 1 - M_e)$, certain ones which are very close to the hereabove determined parasitic reflector wires. There will be two such director wires per circle of radius $d_k (k = 1, 2$ or $3), M_e$ having the values $M_1, M_2$ and $M_3$. Those six director wires will be, according to this invention, utilized as additional reflector wires.

Using polar coordinates of the paraola, it is to be noted that cross-points $A, B$ and $C$ of that paraola and circles of radii $d_k$ have arguments:

$$\phi_k = 2 \arcsin \frac{r}{\sqrt{d_k^2}} (k = 1, 2$ or $3)$$

The rank $M_k$ of the closest director wires to cross-points will be determined by the double inequality:

$$M_k/S \leq \arcsin \frac{r}{\sqrt{d_k^2}} \leq M_k + 1/\theta$$

Among the possible values for $M_k$, obviously that which is selected will result in the smallest deviation $\Delta \phi_k$.

By way of example, it will be considered a Yagi array, wherein:

$$r = 0.25\lambda$$
$$d_1 = 0.34\lambda$$
$$d_2 = 0.68\lambda$$
$$d_3 = 1.02\lambda$$
$$\theta = 5^\circ (S = 72)$$

The resulting values for $M_1, M_2$ and $M_3$ (see FIG. 6) are:

$$M_1 = 24, \text{ i.e., } (M_1 + 1) = 25$$
$$M_2 = 15, \text{ i.e., } (M_2 + 1) = 16$$
$$M_3 = 12, \text{ i.e., } (M_3 + 1) = 13$$

Angular deviations $\Delta \phi_k$ are respectively:

$$\Delta \phi_1 = 0^\circ$$
$$\Delta \phi_2 = 0.4^\circ$$
$$\Delta \phi_3 = 0.6^\circ$$

Symmetrically, cross-points $A', B'$ and $C'$ of paraola and circles of radii $d_k$ have arguments:

$$d_k = 2(180^\circ - \arcsin \frac{r}{\sqrt{d_k^2}})$$

and values of $M_1', M_2'$ and $M_3'$ determining the closest parasitic wires are respectively by converting $(M_k + 1)$ into $(S + 1 - M_e)$:

$$M_1' = (S - M_1) = 48, \text{ i.e., } (S + 1 - M_1) = 49$$
$$M_2' = (S - M_2) = 57, \text{ i.e., } (S + 1 - M_2) = 58$$
$$M_3' = (S - M_3) = 60, \text{ i.e., } (S + 1 - M_3) = 61$$

Angular deviations $\Delta \phi_k'$ are obviously the same as those above mentioned for points $A, B$ and $C$. As a result therefrom, the directivity of the Yagi array angularly ranked $Q = 1$ is substantially improved, if at the same time as its parasitic wires are short-circuited the six director wires belonging to arrays ranked $(M_e + 1)$ and $(S + 1 - M_e)$ are short-circuited, that is in this case director wires of arrays ranked $25, 16, 13, 49, 58$ and $61$.

As the $M_k$ are independent of $Q$, electronic rotation of improved directivity beam will be obtained by sequentially short-circuiting at the same time parasitic
wires of arrays angularly ranked 2, 3, etc., as well as director wires belonging to arrays angularly ranked:
\((M_b + 2)\) and \((S + 2 - M_b)\)
\((M_b + 3)\) and \((S + 3 - M_b)\), etc.
Taking into account the rotation principle, which implies a period S in the definition of the angular rank when one of the ranks \((M_b + Q)\) or \((S + Q - M_b)\) reaches the value S, at the next radiation beam rotation step, angular rank 1 is obtained again.

By way of a numerical example, considering the 24th rotation step, short-circuited wires will belong to the following arrays:
for reflector wires: 24,
for director wires located on circle with radius \(d_4\): 24, 48, 72,
for director wires located on circle with radius \(d_4\): 24, 39, 9,
for director wires located on circle with radius \(d_4\): 24, 36 and 12.

At the next step, the 25th, the result will be:
25, 25, 49, 1,
25, 40, 10,
25, 37, 13.

An antenna according to this invention will now be described. Considering the basic Yagi array, it comprises:
a driven element of height close to \(\lambda/4\),
a reflector element of height also close to \(\lambda/4\), distance from driven element being equal to \(\lambda/4\),
three director wires spaced respectively by about 0.34 \(\lambda\), and the first being distant from driven element also by 0.34 \(\lambda\).
All elements are constituted by metal rods having a diameter of about \(10^{-3}\lambda\).
Director element heights are relatively critical, since they influence gain value and antenna impedance. Usually, those heights are slightly less than \(\lambda/4\) and decreasing when farther from driven element.
Distances between director elements are less critical and modifications might be envisaged for avoiding — taking into account the finite ground plate conductance — to locate an element at a plate point where there is no surface wave current node.
Ground plate is constituted by a metal disc of radius \(r_o\), for instance longer than \(2\lambda\). Its surface must be carefully processed to provide a very good conductance so as to avoid too important surface stationary waves.
As already mentioned, the S arrays are identical and their positions on ground plate are derived from basic array position by successive rotations, each step being \(\theta = 360^\circ/S\).
By way of an example, an antenna according to this invention and designed to operate at frequency F of 1 GHz will comprise a ground plate of radius \(r_o\) 350 mm long.
Roughly, antenna performances are the following:
Radiation power higher than 2 kW, peak
Band width from 2 to 5 percent of center frequency
Input impedance close to 50 ohms
Maximum main lobe gain with respect to isotropic antenna: from 8 to 10 dB
Secondary lobe level: \(-10\) dB under main lobe.
Horizontal plane radiation beam total aperture: \(\pm 15^\circ\) at 3 dB

Vertical plane aperture: larger than \(30^\circ\) with maximum between \(15^\circ\) and \(25^\circ\).
That vertical plane radiation beam dissymmetry is produced by the finite dimension ground plate.
Beam rotation period: 1/15 s
Number of steps: 72
Time duration of each step: about 1 ms.
The logic device, as shown in FIG. 7, for rotating step-by-step the radiation beam will now be described.
S-stage shift register S, with pulse inputs \(t_1, t_2, \ldots, t_n\) and pulse outputs \(S_1, S_2, \ldots, S_n\), is controlled from a clock 6. Pulse frequency from 6 is equal to \(S/r\), \(r\) being the time duration of radiation beam rotation by \(360^\circ\).
First stage of 5 is constituted by a delay-flip-flop having a specific input d. Output \(S_0\) of 5 is connected to set input of a dissymmetric flip-flop 7. Output of 7 is connected to specific input d of 5. Reset input \(e_2\) of 7 is connected from output \(S_1\) of 5.
When pulse, at frequency \(S/r\), shifted in register 5, reaches the last stage, output \(S_0\) goes up to level “1”. That level is, through flip-flop 7, applied to input d of the first stage of 5 and, at the next pulse from clock 6, the same level “1” is present on output \(S_1\) of 5. 7 is turned off, d goes to level “0” and, at the second pulse from 6, \(S_1\) is reset to “0”.
Thus, pulses shifted along 5 have a width of about \(S/r\) and, at a time, only one output is at level “1”.
Pulses from outputs \(S_0, S_1, \ldots, S_n\) are utilized for biasing diodes which short-circuit:
reflector wires angularly ranked 1, 2, 3, \ldots
director wires angularly ranked 1, 2, 3, \ldots
director wires angularly ranked \((M_b + 1)\), \((M_b + 2)\), \((M_b + 3)\), \ldots
director wires angularly ranked \((S + 1 - M_b)\), \((S + 2 - M_b)\), \((S + 3 - M_b)\), \ldots
Each output \(S_0\) of resistor 5 is thus provided with (1 + 3p) connections. One of such connections is coupled to the terminal of the diode which short-circuits the reflector wire belonging to the Yagi array angularly ranked Q and the 3p other connections are used according to the following rules.
p OR gates, such as 8-1, 8-2 and 8-3 have their outputs connected to terminals of diodes which short-circuit \(D_1, D_2, D_3, D_4\) of array 1. Or gates 8-1, 8-2 and 8-3 are each provided with three inputs, one of them being connected from output \(S_1\) of register 5.
Due to the fact that there are S arrays, there are Sp OR gates similar to 8-1, 8-2 and 8-3, each group of p gates having its outputs connected to terminals of diodes which short-circuit \(D_1, D_2, D_3, D_4\) of array angularly ranked Q. The said OR gates have one of their three inputs connected from output \(S_0\) of register 5.
Due to the fact that each director wire is used three times during a beam rotation (once as a properly said director element and twice as an additional reflector element) each diode associated thereto is biased three time for a beam rotation, which explain the use of three-input OR gates.
Considering the director wire \(D_4\) of the Or gate, associated thereto, has its first input connected from input angularly ranked Q in register 5, its second input connected from output angularly ranked \((M_b + Q)\) and its third input connected from output angularly ranked \((S + Q - M_b)\).
By way of example, it will be assumed that \( S = 72 \) and \( p = 3 \). As already mentioned, in this case:
\[
\begin{align*}
M_1 &= 24 \\
M_2 &= 15 \\
M_3 &= 12 \\
(S-M_1) &= 48 \\
(S-M_2) &= 57 \\
(S-M_3) &= 60
\end{align*}
\]

The three inputs of OR gates 8-1, FIG. 7, are connected from outputs: \( S_1, S_{p6} \) and \( S_{p9} \) of register 5.

The three inputs of OR gate 8-2 are connected from outputs: \( S_1, S_{p6} \) and \( S_{p9} \) of register 5.

The three inputs of OR gate 8-3 are connected from output: \( S_1, S_{p6} \) and \( S_{p9} \) of register 5.

While the principles of the present invention have been hereabove described in relation with a specific embodiment, it will be clearly understood that the said description has only been made by way of example and does not limit the scope of this invention.

What is claimed is:

1. A directive radiation beam antenna of the type wherein said beam is rotated angularly in a step-by-step fashion comprising:
   - a plurality of \( S \) identical Yagi-type arrays having a common driven element, each of said plurality comprising:
     - one reflector parasitic element; and
     - a plurality \( p \) of director parasitic elements \( D_k \) where \( 1 \leq k \leq p; \)
   - wherein the array angularly ranked \( Q \) is derived from the array O-1 by rotating it by an angle \( \theta = 360^\circ/S \) around the axis of said common driven element;
   - a ground plane comprising a circular metal ground plate having a common axis with said common driven element, the \( S \) \((1+p)\) parasitic elements having a height of approximately \( l/4 \) and arranged perpendicular to said ground plate;
   - a source of a bias signal;
   - a source of RF energy mounted between the base of said common driven element and said ground plate for feeding said common driven element;
   - a plurality of unidirectional current conducting elements each coupled to said ground plate, said source of bias signal and one of the \( S \) \((1+p)\) parasitic elements, the impedance of each of said unidi-

rectional elements being dependent upon said bias signal; and

a logic control device for controlling the step-by-step radiation beam rotation, said control device comprising:
   - an \( S \)-stage shift register having a clock frequency equivalent to \( S/\tau \), \( \tau \) being the time duration required for a 360° beam rotation; and
   - a plurality of \( p \) three input OR-gates, each having outputs connected to the bias input of each unidirectional current conducting element associated with a director element, each of the \( S \) shift register outputs being provided with \( (1+3p) \) connections, the first coupled from the \( Q \)th stage to the bias input of the unidirectional element associated with the director element angularly ranked \( Q \), \( p \) second ones coupled from the \( Q \)th stage output to the input of each of the OR-gates having outputs which control unidirectional elements associated with director elements angularly ranked \( Q \), \( p \) third ones coupled from \( Q \)th stage output to the inputs of each of the \( p \) OR-gates whose outputs control the unidirectional elements associated with director elements of arrays angularly ranked \((Q\pm M_k)\) or \((Q\pm M_{k-5})\) if \((Q\pm M_k)\) is greater than \( S \), and \( p \) fourth ones coupled from the \( Q \)th stage to the input of each of the OR-gates whose outputs control unidirectional elements associated with director elements of arrays angularly ranked \((Q-M_k)\) or \((Q-M_{k+5})\) if \((Q-M_k)\) is less than 0, where the \( k \) values of \( M_k \) are independent of \( Q \) and are determined by the polar coordinates of the closest director elements \( D_k \) of generatrices of a cylinder having a parabolic cross-section having as a focus the base of the driven element and having as an apex the base of the reflector element of the associated array.

2. A directive radiation beam antenna according to claim 1 wherein unidirectional elements are PIN diodes having one terminal being connected to ground plate and the other terminal connected to the corresponding parasitic element base and to a choke inductance through which a suitable bias voltage is applied thereto.