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(54) **Multi-mode beam forming networks for multi beam reflector antenna**

Netzwerk zur Strahlformung für eine Mehrmoden-Mehrstrahl-Reflektorantenne

Réseau de formation de faisceaux pour une antenne multifaisceaux à modes multiples à réflecteur

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The file contains technical information submitted after the application was filed and not included in this specification

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Description

[0001] The present invention relates to recursive method for calculating the coefficients of a multimode beam forming network to be used for a multibeam antenna system as set forth in the preamble of claim 1.

[0002] Multi beam antennas till now were based on the optimization of the reflector (feed) beam-forming network combination which had a prefixed beam forming network. As a result of such optimization, all system parameters, including the feed network, were defined.

[0003] But this approach limited the number of degrees of freedom left for the optimization of coverage performance.

[0004] US-A 4 633 259, which is the most pertinent prior art document, shows a lossless orthogonal beam forming network, similar to that described in the preamble of claim 1 of the present invention.

[0005] In the presently proposed antenna system, the original network configuration separates the radiating optimization from that of feed network design.

[0006] The invention pertains to electronic antenna for space-borne applications and is best applied to multibeam antenna which have partially overlapping beams. In this case the overlapping sources are fed by a double cascade type of network.

[0007] The problem which may be solved by the present invention is that of the generation of overlapping beams which have a given number of common sources using the greatest number of degrees of freedom available. At the present state of the art, the implementation of multi-mode networks, starting from the excitation coefficients required has taken regard for two input networks and a maximum of four outputs. This set a limit to the number of degrees of freedom available to optimize the source excitation coefficients of the antenna system when the number of sources common to the two beams was greater than four, this limiting the achievable antenna performance.

[0008] With multiple overlapping beams only particular amplitude and phase distributions could be achieved (e.g. Butler matrices) with loss-less networks, restricting the field of application of this system.

[0009] The invention regards the definition of a peculiar configuration and implementation of a beam forming network which feeds N sources different than M (M < N) from the network.

[0010] In particular the network generates M orthogonal sets on n output parts previously calculated by optimizing the far-field of the antenna on the required coverage, with the only constraint of orthogonality among the calculated feed excitation coefficients.

[0011] This configuration optimizes the feed excitation coefficients for different coverages required, independently of the network, with the only constraint of orthogonality of the sets above. This results in improved performance, compared to present state of the art solutions, in terms of gain and flexibility.

[0012] The invention will now be described for illustrative and non limiting purposes, with reference to the tables attached hereto.

[0013] Figure 1 shows a schematic diagram of the antenna system. It shows the following items:

1 reflector (or other focussing element),
2 radiating elements,
3 multi-mode network.

[0014] Figure 2, more significant than the others, is a schematic diagram of the multi-mode network, where:

4 feed output parts,
5 input parts,
6 power splitters,
7 phase shifters.

[0015] Figure 3 is a schematic diagram of possible uses of the proposed antenna system.

[0016] The solution according to the invention generates two partially overlapped coverages 8 and a global coverage 9. At first, the optical system is optimized, concluding the multi-feed reflector, together with the excitation coefficients of the latter with the only orthogonality constraint. Then by considering the configuration shown in figure 2, the three multi-mode networks 10 are implemented.

[0017] The network is synthesized in a recursive manner by generating the first mode required coefficients with the first row of couplers and phase shifters, the second with the second row and so on for the other sets of coefficients required.

[0018] Figure 4 is the outline schematic of another possible application of the invention. Here we can see output ports U1-U9 and two input ports I1, I2, but these can vary in number according to the required configuration.

[0019] Now we shall describe the physical configuration of the invention, with, once again, reference to the tables of figures attached.

[0020] Figure 2, which shows the beam forming network, highlights outputs U from the network where M sets of N coefficients each are formed; input ports in-1, in-2 ...; the series of double cascaded couplers a1', a2', ..., a1'', a2'' ..., and phase shifters s1', s2' ....

[0021] Going back to figure 4, which shows another possible implementation of this invention, it is worth to emphasize that according to the inventors, this solution has a better frequency response, if possible, compared to that of figure 2.

[0022] For greater accuracy let us briefly digress on the operation of this system.

[0023] Starting from M sets of N excitation coefficients already optimized in the optical system (i.e. in the antenna optics), the first set of N coefficients is taken into examination; a ladder-network is implemented as shown in figure 2, i.e. the first excitation in amplitude and phase is effected by the first coupler 1' and phase shifter 1'. The remaining power is sent to the second coupler 2' through phase shifter 2', and so on till the n^{th} excitation coefficient of the first set is implemented. The remaining M-1 sets of N coefficients are converted into M-1 sets of N-1 coefficients at the ports of the already implemented N-1 couplers, where all four parts of the couplers are utilized.

[0024] The first set of coefficients is implemented by grouping them two by two through the first coupler as shown in figure 4 so as to reduce the order of the multi mode network to be implemented.

[0025] The process is repeated till an input for each of the M sets of coefficients required is achieved.

[0026] It is worth mentioning that the number of sets physically possible is less than or equal to the number of excitation coefficients which are characteristic of each set.

Claims

1. Recursive method for calculating the coefficients of a multimode beam forming network to be used for a multibeam antenna system, comprising a reflector (1) and a feed (2), the network having M input ports IN1...INm, coupled through a symmetrical configuration of a double or multiple cascade connection of power splitters (6) and phase shifters (7), with N output ports U1...Un, **characterised by** the following steps:

a) synthesizing the first row of couplers and phase shifters by using the coefficient of the first mode, thus obtaining a row with N-1 couplers and N fixed phase shifters;
b) calculating, for each of the M-1 modes not yet synthesized, a new set of N-1 complex coefficients that, applied to the N-1 free input ports of the first row synthesized, generate to the output ports of the network the desired original N complex excitation of each mode;
c) synthesizing the second row of the network by using the new set of coefficients corresponding to the second mode desired, thus obtaining a row with N-2 couplers and N-1 fixed phase shifters;
d) calculating, for each of the M-2 modes not yet synthesized, the new set of N-2 complex coefficients that give to the output ports of the second row the desired N-1 corresponding excitations for each mode;
e) repeating steps c and d to synthesize the other M-2 rows of the network by using the M-2 sets of coefficients, thus obtaining the third row synthesized by using the coefficients of the third mode and having N-3 couplers and N-2 fixed phase shifters.

2. Method according to claim 1, wherein M ≤ N.

3. Multimode beam forming network for an antenna system having a reflector (1) and a feed (2) calculated according the method of claim 1 or 2.

Patentansprüche

1. Rekursives Verfahren zur Berechnung der Koeffizienten eines Mehrmoden-Netzwerks zur Strahlformung für die Verwendung in einem Mehrstrahl-Antennensystem mit einem Reflektor (1) und einem Einspeiser (2), wobei das Netzwerk M Eingangskanäle IN1.... INm hat, die über eine symmetrische Konfiguration einer Doppel- oder Mehrfach-Kaskadenverbindung von Leistungsteilern (6) und Phasenschiebern (7) mit N Ausgangskanälen U1...Un gekoppelt sind, **gekennzeichnet durch** die folgenden Schritte:

a) Synthetisieren der ersten Reihe von Kopplern und Phasenschiebern unter Verwendung der Koeffizienten des ersten Modus, wodurch sich eine Reihe von N-1 Kopplern und N festen Phasenschiebern ergibt;

b) für jeden der M-1 noch nicht synthetisierten Moden Berechnen einer neuen Gruppe von N-1 komplexen Komponenten, die nach Anlage an die N-1 freien Eingangskanäle der ersten synthetisierten Reihe an den Ausgangskanälen des Netzwerks die gewünschten originalen N komplexen Erregungen für jeden Modus erzeugen;

c) Synthetisieren der zweiten Reihe des Netzwerks **durch** Anwendung der neuen Gruppe von Koeffizienten entsprechend dem gewünschten zweiten Modus, wodurch sich eine Reihe mit N-2 Kopplern und N-1 festen Phasenschiebern ergibt;

d) für jeden der M-2 noch nicht synthetisierten Moden Berechnen der neuen Gruppe von N-2 komplexen Komponenten, die an den Ausgangskanälen der zweiten Reihe die gewünschten N-1 entsprechenden Erregungen für jeden Modus erzeugen;

e) Wiederholen der Schritte c und d zum Synthetisieren der übrigen M-2 Reihen des Netzwerks unter Verwendung der M-2 Gruppen von Koeffizienten, wodurch sich die dritte synthetisierte Reihe ergibt, wobei die Koeffizienten des dritten Modus mit N-3 Kopplern und N-2 festen Phasenschiebern verwendet werden.

2. Verfahren nach Anspruch 1, wobei M ≤ N.

3. Mehrmoden-Netzwerk zur Strahlformung für ein Antennensystem mit einem Reflektor (1) und einem Einspeiser (2), das mit dem Verfahren nach Anspruch 1 oder 2 berechnet ist.

Revendications

1. Méthode récurrente pour calculer les coefficients d'un réseau de formation de faisceaux à modes multiples à utiliser pour un système d'antenne multifaisceaux, comprenant un réflecteur (1) et une alimentation (2), le réseau ayant M bornes d'entrée IN1...INm, couplées au moyen d'une configuration symétrique d'une connection en cascade double ou multiple de répartiteurs de puissance (6) et de déphaseurs (7), avec N bornes de sortie U1...Un, **caractérisée par** les étapes suivantes :

a) synthétiser la première rangée de coupleurs et de déphaseurs en utilisant le coefficient du premier mode, en obtenant ainsi une rangée avec N-1 coupleurs et N déphaseurs à phase fixe ;
b) calculer, pour chacun des M-1 modes non encore synthétisés, un nouvel ensemble de N-1 coefficients complexes qui, appliqués aux N1 bornes d'entrée libres de la première rangée synthétisée, génère sur les bornes de sortie du réseau les N excitations complexes originales désirées de chaque mode ;
c) synthétiser la seconde rangée du réseau en utilisant le nouvel ensemble des coefficients correspondant au second mode désiré, en obtenant ainsi une rangée avec N-2 coupleurs et N-1 déphaseurs à phase fixe ;
d) calculer, pour chacun des M-2 modes non encore synthétisés, le nouvel ensemble de N-2 coefficients complexes qui donnent aux bornes de sortie de la seconde rangée les N-1 excitations correspondantes désirées pour chaque mode ;
e) répéter les étapes c et d pour synthétiser les autres M-2 rangées du réseau en utilisant les M-2 ensembles de coefficients, obtenant ainsi la troisième rangée synthétisée en utilisant les coefficients du troisième mode et en ayant N-3 coupleurs et N-2 déphaseurs à phase fixe.

2. Méthode selon la revendication 1, dans laquelle M ≤ N.

3. Réseau de formation de faisceaux à modes multiples pour un système d'antenne ayant un réflecteur (1) et une alimentation (2) calculée selon la méthode des revendications 1 ou 2.

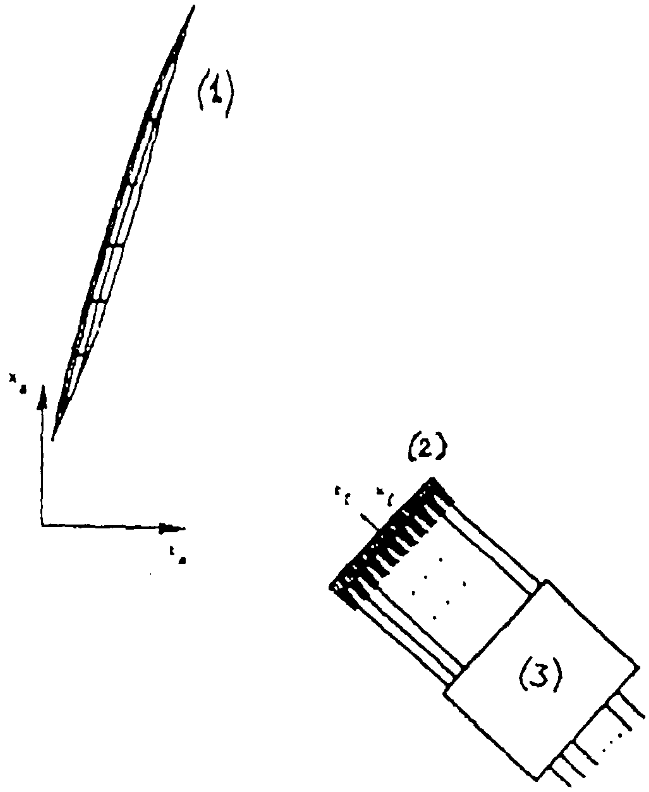
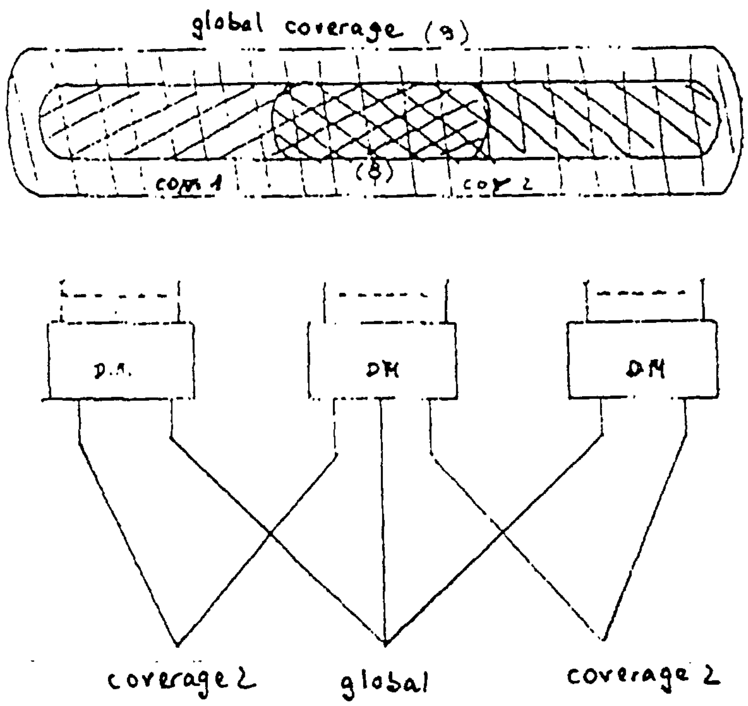

(1)
(2)
(3)

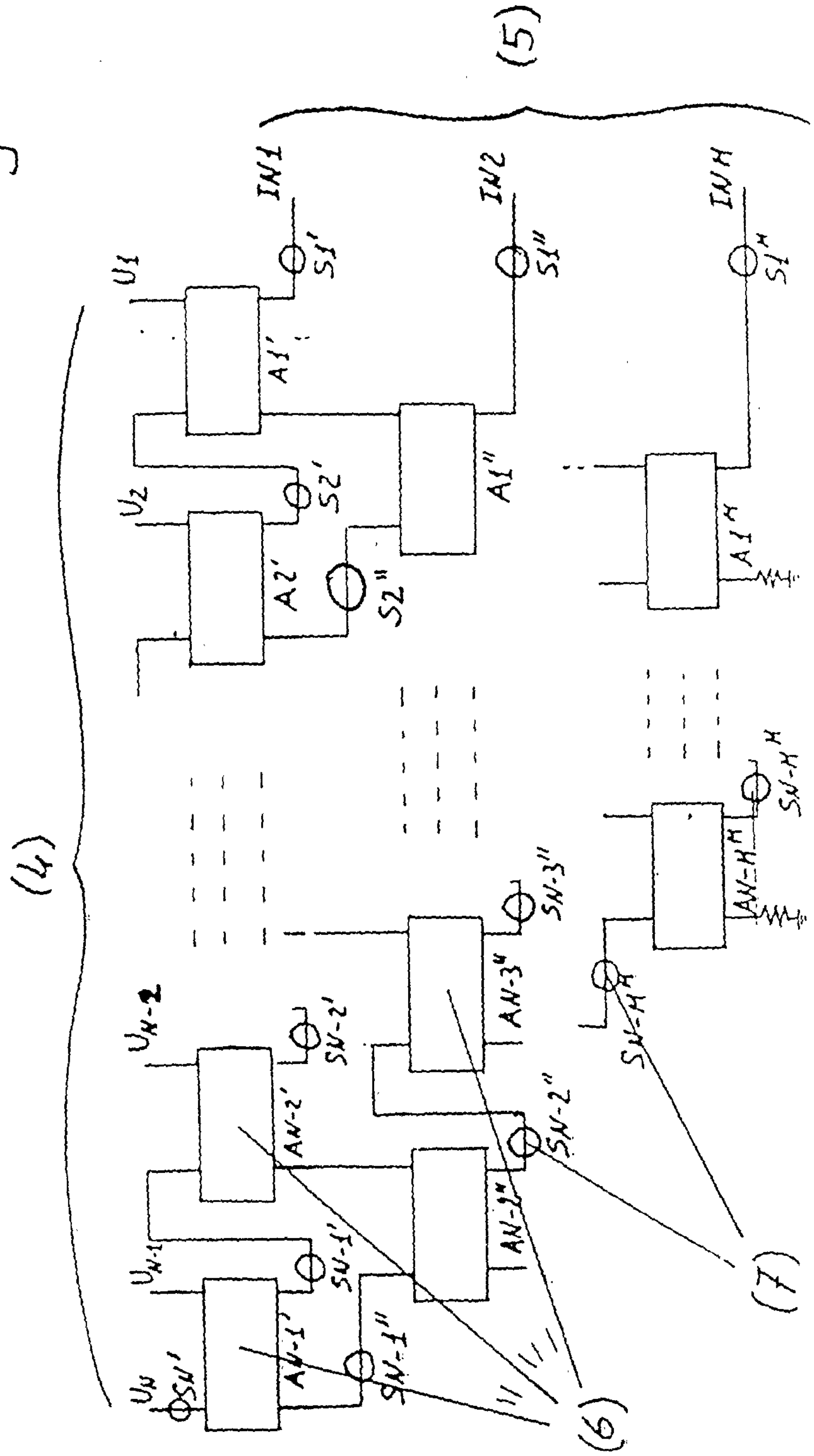
FIG. 1


global coverage (9)
cov 1
(8)
cov 2
D.M.
DM
DM
coverage 2
global
coverage 2

(10)

FIG. 3

Fig. 2


(4)
(5)
(6)
(7)
IN1
IN2
INM
U1
U2
A1'
A2'
A1''
A1M
S1'
S2'
S1''
S2''
S1M
UN
UN-1
UN-2
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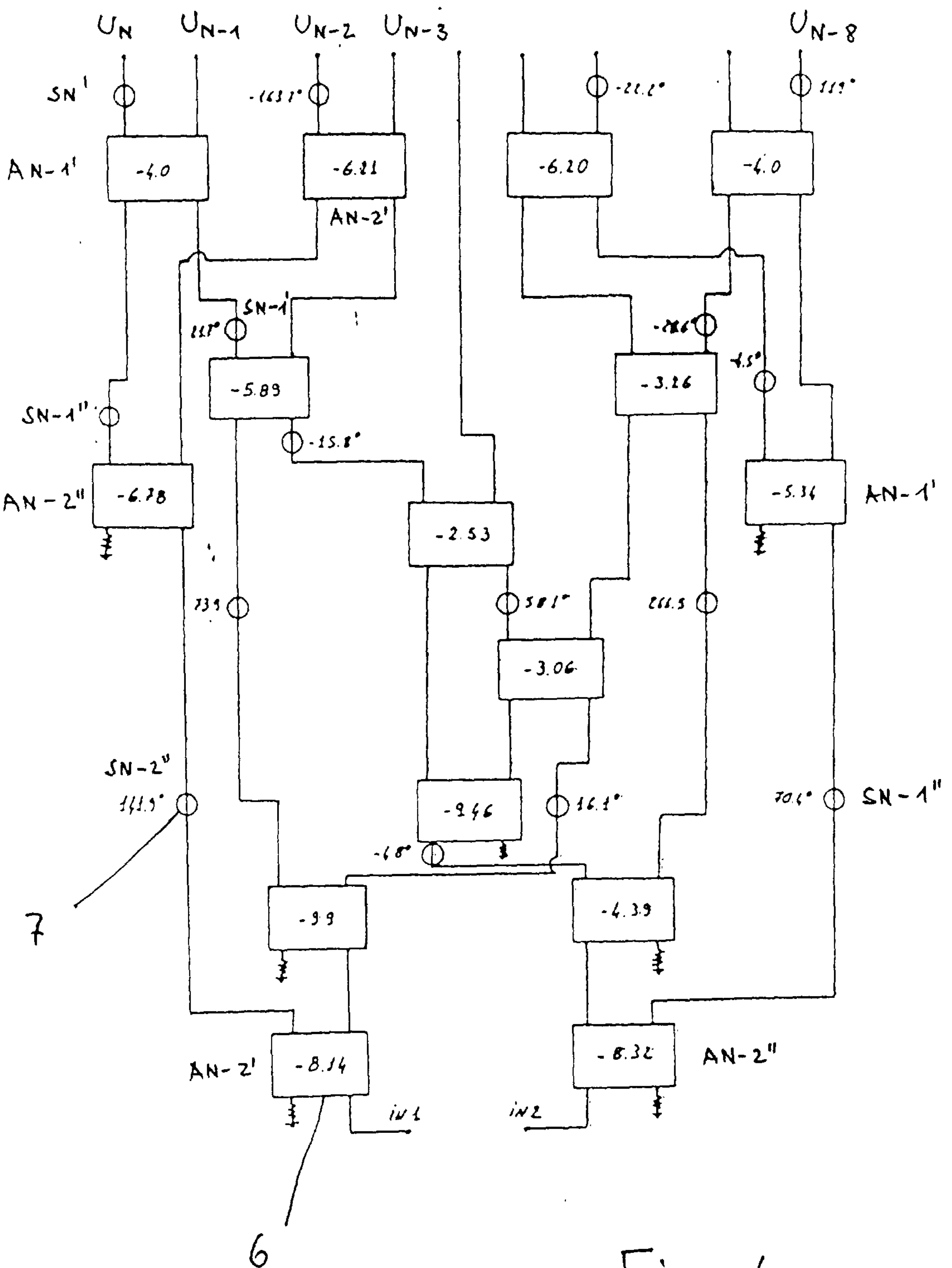
U_N
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U_{N-2}
U_{N-3}
U_{N-8}
SN'
AN-1'
-4.0
-6.21
AN-2'
-6.20
-4.0
SN-1'
-5.89
-15.8°
SN-1''
AN-2''
-6.78
-2.53
-3.26
-5.36
AN-1'
-3.06
SN-2''
-9.46
SN-1''
-9.9
-4.39
AN-2'
-8.14
-8.32
AN-2''
in1
in2
7
6

Fig. 4