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(54) **AN ELECTRONICALLY SCANNED ANTENNA SYSTEM HAVING A LINEAR ARRAY OF YAGI ANTENNAS.**

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Description

Background of the invention

The present invention relates to an antenna system for conformal mounting on an aircraft, comprising a linear array of Yagi antennas.

Electronically scanned linear arrays of simple elements are well known. Such arrays are generally characterized by relatively low gain, and a broad elevation pattern. Arrays of Yagi antennas in which scanning is accomplished mechanically by rotating the entire array are also known. These arrays are unsatisfactory when conformal mounting in the plane of the array is required, e.g., on or within airfoil surfaces (wings and horizontal stabilizer) of an aircraft.

Various antenna element configurations are known, United States Patent 2,236,393 (Beck et al.) discloses a broad bandwidth endfire antenna. United States Patent 3,182,330 (Blume) dislcoses an antenna array having non-uniform spacing of the individual elements. United States Patent 2,425,887 (Lindenblad) discloses an endfire antenna in which all the elements are energized with equal voltages in proper phase. United States Patent 3,258,774 (Kinsey) discloses a series-fed phased antenna array. See also United States Patent 3,509,577 (Kinsey). United States Patent 2,419,562 (Kandoian) discloses a binomial array for producing a clover leaf pattern having highly directive properties. A Yagi antenna is referenced in United States Patent 3,466,655 (Mayes et al).

Moreover, generally in known antenna array construction mutual coupling is regarded as detrimental and means are taken to minimize its effect. In contrast the present invention utilizes mutual coupling to enhance antenna performance.

Endfire elements such as Yagi antennas are known to produce high density with narrow patterns in both planes (azimuth and elevation), and are therefore, according to conventional practice, considered unsuitable for wide angle electronic scanning when multiple elements are arrayed. (The scan angle limits being established by the width of the in-array element pattern). In contrast with conventional practice, the present invention advantageously utilizes arrayed Yagi elements for wide angle scanning by employing mutual coupling between the elements to broaden the element pattern in the plane in which electronic scanning is desired.

It is an object of the present invention to provide an antenna array having a high grain and narrow elevation beam, with a narrow azimuthal beam which can be electronically scanned throughout a wide azimuthal sector.

It is a further object of the present invention to provide an antenna array of very small elevation so as to be suitable for installation on or within the airfoil surfaces of an aircraft, e.g., wing leading edges and the horizontal stabilizer trailing edge, usable with a suitable radome which is an integral part of the airfoil.

It is a still further object of the present invention to provide an antenna array having a high gain and broadened in-array element pattern from increasing the angle over which the antenna mainlobe can be electronically scanned.

It is a still further object of the present invention to broaden the narrow in-array element pattern of a Yagi antenna array.

It is a still further object of the present invention to broaden the in-array pattern of a Yagi antenna array in one plane only.

Summary of the invention

According to the invention there is provided an antenna system for conformal mounting on an aircraft, comprising a linear array of Yagi antennas, each of the Yagi antennas including a driven element, a reflector member and a director member, each of which has a length less than the spacing between adjacent Yagi antennas, characterised in that the Yagi antennas each lie in the E-plane and are laterally spaced from one another a distance of between substantially 0.3λ and 0.9λ centre to centre, and the antenna system further comprises means connected to the Yagi antennas for electronically scanning the antenna system main lobe in the E plane over an angle A substantially greater than the free space beam width of the individual Yagi antennas in the E plane, whereby said scan angle A can be greater than 90°.

The invention also concerns an aircraft on which such an antenna system is conformally mounted, for example in a wing thereof.

"Electronic scanning" as the term is used therein entails adjustments in the excitation coefficients (e.g., phase and amplitude) of the elements in the array in accordance with the direction in which the formation of a beam is desired.

It is well known to those skilled in the art that the beam of an antenna points in a direction that is normal to the phase front. In phased arrays the phase front is adjusted to steer the beam by individual control of the phase excitation of each radiating element. Phase shifters are electronically actuated to permit rapid scanning and are adjusted in phase to a value between 0 and 2π radians. While this method of electronic scanning is perhaps the most commonly used, other means may be employed to effect the same changes in the phase front of the array to produce steerage of the beam. Control of the excitation coefficients of the elements of the array is commonly known as "antenna feed", and includes all means for independently or dependently controlling the amplitude and phase of the signals to or from the individual elements of the antenna array, and dividing or combining means therefor.

Brief description of the drawings

The present invention is illustrated in the accompanying drawings, in which:

Figure 1 is a top plan view of a linear array of Yagi elements according to the present invention;

Figure 2 is a perspective view of a Yagi element for the linear array of the present invention;

Figure 3 is a top plan view of a linear array of

Yagi elements of the type shown in Fig. 2 in which all the endfire elements have a common reflector;

Figure 4 is a top plan view of a linear array of Yagi elements similar to Fig. 3 being scanned at an angle θ_o; and

Figure 5 is a perspective view of an aircraft with parts broken away to indicate the mounting thereon of linear arrays of Yagi elements in accordance with the present invention.

Detailed description

Referring to Fig. 1, an antenna according to the present invention is generally illustrated at 10. The antenna 10 includes a linear array of Yagi elements 12 electronically coupled to an element driving network 14 which is conventionally known as an antenna feed.

Each element 12 is laterally spaced a distance (D) between 0.3 λ and 0.9 λ apart, preferably about 0.55 λ apart (center-to-center) to enhance the effects of mutual coupling between the elements 12, resulting in a broadened element pattern of the mainbeam in the plane of the array. The length (L) of each individual element 12 is approximately 1.25 λ.

Referring to Fig. 2, a Yagi element 12A for use in the array of the present invention is shown. As is well known, a Yagi array includes at least two parasitic elements in addition to the driven element. The Yagi element 12A includes six conductive elements 16, 18, 20, 22, 24 and 26. Such a multiparasitic array is known as a 6-element beam. Each element has a diameter of approximately 0.01 λ and a length of approximately 0.5 λ.

The six elements 16, 18, 20, 22, 24 and 26 are positioned in spaced parallel relationship along the same line of sight (transverse axis) with the spacing between adjacent elements being approximately .25 λ. The six elements 16, 18, 20, 22, 24 and 26 are supported on a pair of non-conductive Plexiglass supports 28 and 30, e.g., by inserting the elements 16, 18, 20, 22, 24 and 26 into mating holes in the Plexiglass support. The supports 28 and 30 electrically insulate the elements 16, 18, 20, 22, 24 and 26 from one another, and advantageously are substantially invisible to the resulting electromagnetic waves.

Element 16 is a reflector element, element 18 the driven element, and elements 20, 22, 24 and 26 the director elements. A coaxial cable 32 is electrically coupled to the driven element 18 for providing a signal thereto. The reflector 16 and directors 20—26 interact in a conventional manner to provide increased gain and unidirectivity to the radiated signal pattern. The free-space half-power beam-widths of element 12A is 42° in the E plane and 48° in the H plane.

Referring to Fig. 3, ten Yagi elements 12A-J of the type shown in Fig. 2 are arranged in a linear array 10A. The elements 12A-J have a common reflector 16A and are closely spaced laterally a distance of between about 0.3 λ and about 0.9 λ apart, preferably about 0.55 λ apart (center-to-center), to increase the effects of mutual coupling therebetween. With such an arrangement, the in-array pattern, i.e., the angle over which the antenna mainlobe can be electronically scanned increases from 42° for the single endfire element 12A of Fig. 2 to greater than 90° in the array 10A. The narrow H plane pattern of 48° for the single element 12A is maintained in the array 10A. Thus the effect of closely spacing the elements 12A in the linear array 10 is to broaden the element pattern in the plane of the array 10A (E plane) while preserving the narrow H plane pattern.

The broadened E-plane pattern of the in-array element may be demonstrated as follows: The elements 12A-D and 12F-J have individual terminating impedances 34A-D and 34F-J coupled to ground 36 in the array 10A. The terminating impedances 34A-D and 34F-J are chosen to match the antenna driving point impedance to an antenna scan angle of 0° in the E-plane. In the embodiment illustrated in Fig. 3, the terminating impedances 34A-D and 34F-J are 50 ohms. Element 12E is monitored by meter 38 which measures the power received by element 12E when the array 10A is used as a receiving device to receive signals transmitted by a radiating device (not shown) positioned at sufficient distance from the array 10A so as to be in the far field of the array 10A. As the array 10A is rotated in angle with respect to the radiating device, the power measured in meter 38 will vary in proportion to the in-array element pattern of element 12E. This method of pattern measurement is well known in the art. Moreover, it is also well known in the art that the in-array element pattern measured in this manner is approximately proportional to the gain of the array 10A as a function of angle when the outputs of all of the elements 12A-J are utilized to form a beam.

With reference to Fig. 4, the array 10A operates as follows: A feed means (not shown) applies transmission signals to a combining/dividing network 40 which splits the signals for transmission by the individual elements 42 of the array 44 (N elements are shown). N phase shifters 46 shift the phase of the signals in accordance with the direction in which a beam is desired. In applications where unequal amplitudes are desired for each antenna element to provide lower antenna sidelobes (commonly known as amplitude taper, the combining/dividing network 48 advantageously provides such a distribution.

The antenna array 10A with its feed is linear, passive and bilateral and is subject to the law of reciprocity so that when it is used in the receiving mode its characteristics are unaltered.

Referring to Fig. 5, an aircraft 48 is illustrated with antenna arrays 10 B, C and D in accordance with the present invention positioned in the wing leading edges 50 and 52 and in the horizontal stabilizer 54. With this arrangement 360° azimuthal coverage is obtained by electronically scanning the arrays 10B-D and conventional side-looking antennas 56 and 58 mounted on opposite sides of the fuselage 60 in a back-to-back relationship. Advantageously, such an arrangement avoids the need for a large dome mounted on the fuselage 60 which must be mechanically rotated to provide the same 360° azimuthal coverage.

Claims

1. An antenna system (10 for conformal mounting on an aircraft, comprising a linear array of Yagi antennas (12), each of the Yagi antennas including a driven element (18), a reflector member (16) and a director member (20), each of which has a length less than the spacing between adjacent Yagi antennas, characterised in that the Yagi antennas each lie in the E-plane and are laterally spaced from one another a distance of between substantially 0.3 λ and 0.9 λ centre to centre, and the antenna system further comprises means connected to the Yagi antennas for electronically scanning the antenna system main lobe in the E plane over an angle A substantially greater than the free space beam width of the individual Yagi antennas in the E plane, whereby said scan angle A can be greater than 90°.

2. An antenna system of Claim 1 wherein: the spacing between said Yagi antennas is substantially 0.55 λ.

3. An antenna system as claimed in Claim 1 or 2, wherein: each Yagi antenna has a main lobe beam width in the E plane of substantially 42°.

4. An antenna system of any preceding Claim, wherein: the system main lobe beam width in the H plane is substantially 48°.

5. An antenna system claimed in any preceding Claim wherein: said linear array includes ten Yagi antennas (12A—12J) which are arrayed in the E-plane, each Yagi antenna further including three additional director members (22, 24, 26).

6. An antenna system of any preceding Claim, wherein the reflector member of each of said Yagi antennas is a common reflector member (16A).

7. An antenna system of any preceding Claim, wherein each Yagi antenna has a length of substantially 1.25 λ.

8. An antenna system of any preceding Claim, wherein said Yagi antennas each include non-conductive support means (28, 30) for fixedly positioning the driven element (18), reflector member (16), and the or each director member (20) relative to one another.

9. An antenna system of any preceding Claim in which said driven element, reflector member and the or each director member of each Yagi antenna are spaced from one another a distance of substantially 0.25 λ.

10. An aircraft comprising an antenna system as defined in any preceding Claim, said system being conformally mounted in a wing of the aircraft.

11. An aircraft comprising an antenna system as defined in any of claims 1 to 9 said system further including a pair of side-looking antennas (56, 58) known *per se*; and said system being conformally mounted in an aircraft whereby wide azimuthal coverage is obtained.

12. An aircraft as defined in Claim 11, in which said system is conformally mounted within the wing of said aircraft.

13. An aircraft as defined in Claim 11, wherein there are two of said antenna systems which are mounted in a back-to-back relationship.

14. An aircraft as defined in Claim 13, in which said two systems are conformally mounted in the wing and horizontal stabilizer of said aircraft, respectively.

15. An aircraft as defined in Claim 11, wherein said side-looking antennas are conformally mounted on an aircraft fuselage.

Patentansprüche

1. Antennensystem (10) zur konformen Montage an einem Flugzeug, enthaltend eine lineare Gruppe von Yagi-Antennen (12), wobei jede der Yagi-Antennen ein gespeistes Element (18), ein Reflektorelement (16) und ein Direktorelement (20) aufweist, von denen jedes eine Länge aufweist, die kleiner als der Abstand zwischen benachbarten Yagi-Antennen ist, dadurch gekennzeichnet, daß die Yagi-Antennen jeweils in der E-Ebene liegen und in Querrichtung voneinander einen Teilungsabstand von etwa 0,3 λ bis 0,9 λ aufweisen, und daß das Antennensystem weiterhin eine Einrichtung aufweist, die mit den Yagi-Antennen verbunden ist, um die Hauptkeule des Antennensystems elektronisch in der E-Ebene über einen Winkel A abzulenken, der wesentlich größer ist, als die Freiraum-Keulenbreite der einzelnen Yagi-Antennen in der E-Ebene, wodurch der Ablenkwinkel A größer als 90° sein kann.

2. Antennensystem nach Anspruch 1, bei dem der Abstand zwischen den Yagi-Antennen im wesentlichen 0,55 λ ist.

3. Antennensystem nach Anspruch 1 oder 2, bei dem jede Yagi-Antenne eine Hauptkeulen-Keulenbreite in der E-Ebene von im wesentlichen 42° aufweist.

4. Antennensystem nach einem der vorhergehenden Ansprüche, bei dem die Systemhauptkeulen-Keulenbreite in der H-Ebene im wesentlichen 48° ist.

5. Antennensystem nach einem der vorhergehenden Ansprüche, bei dem die lineare Gruppe zehn Yagi-Antennen (12A—12J) aufweist, die in der E-Ebene angeordnet sind, wobei jede Yagi-Antenne weiterhin drei zusätzliche Direktorelemente (22, 24, 26) aufweist.

6. Antennensystem nach einem der vorhergehenden Ansprüche, bei dem das Reflektorelement jeder der Yagi-Antennen ein gemeinsames Reflektorelement (16A) ist.

7. Antennensystem nach einem der vorhergehenden Ansprüche, bei dem jede Yagi-Antenne eine Länge von im wesentlichen 1,25 λ hat.

8. Antennensystem nach einem der vorhergehenden Ansprüche, bei dem die Yagi-Antennen jeweils nicht-leitfähige Halteeinrichtungen (28, 30) zum festen Anbringen des gespeisten Elements (18), des Reflektorelements (16) und des oder jedes Direktorelements (20) relativ zueinander aufweisen.

9. Antennensystem nach einem der vorhergehenden Ansprüche, bei dem das gespeiste Ele-

ment, das Reflektorelement und das oder jedes Direktorelement einer jeden Yagi-Antenne voneinander einen Abstand von im wesentlichen 0,25 λ aufweisen.

10. Flugzeug mit einem Antennensystem nach einem der vorhergehenden Ansprüche, wobei das System konform in einem Flügel des Flugzeugs montiert ist.

11. Flugzeug mit einem Antennensystem nach einem der Ansprüche 1 bis 9, wobei das System weiterhin zwei zur Seite schauende Antennen (56, 58) an sich bekannter Art aufweist und das System konform in einem Flugzeug montiert ist, wodurch eine breite Azimutalbedeckung erzeilt ist.

12. Flugzeug nach Anspruch 11, bei dem das System konform im Flügel des Flugzeugs montiert ist.

13. Flugzeug nach Anspruch 11, bei dem zwei der genannenten Antennensysteme vorgesehen sind, die Rücken an Rücken montiert sind.

14. Flugzeug nach Anspruch 13, bei dem die zwei Systeme konform im Flügel bzw. im Horizontalstabilisator des Flugzeugs montiert sind.

15. Flugzeug nach Anspruch 11, bei dem die zur Seite schauenden Antennen konform am Flugzeugrumpf montiert sind.

Revendications

1. Système d'antennes (10) destiné au montage en configuration lisse sur un avion, qui comprend un réseau linéaire d'antennes Yagi (12), chaque des antennes Yagi comprenant un élément attaqué (18), un élément réflecteur (16) et un élément directeur (20), dont chacun a une longueur inférieure à l'espacement entre les antennes Yagi adjacentes, caractérisé en ce que les antennes Yagi sont toutes contenues dans le plan E et sont espacées latéralement l'une de l'autre d'une distance sensiblement comprise entre 0,3 λ et 0,9 λ, de centre à centre, et le système d'antennes comprend en outre des moyens connectés aux antennes Yagi pour faire balayer électroniquement le lobe principal du système d'antennes dans le plan E, sur un angle A sensiblement supérieur à la largeur de faisceau en espace libre des antennes Yagi individuelles dans le plan E, de sorte que ledit angle de balayage peut être supérieur à 90°.

2. Système d'antennes selon la revendication 1, caractérisé en ce que l'espacement entre lesdites antennes Yagi est sensiblement égal à 0,55 λ.

3. Système d'antennes selon les revendications 1 ou 2, caractérisé en ce que chaque antenne Yagi possède une largeur de faisceau de lobe principal dans le plan E sensiblement égale à 42°.

4. Système d'antennes selon une revendication précédente quelconque, caractérisé en ce que la largeur de faisceau de lobe principal du système dans le plan H est sensiblement de 48°.

5. Système d'antennes selon une revendication précédente quelconque, caractérisé en ce que ledit réseau linéaire comprend dix antennes Yagi (12A—12J) qui sont alignées en une rangée dans le plan E, chaque antenne Yagi comprenant en outre trois éléments directeurs additionnels (22, 24, 26).

6. Système d'antennes selon une revendication précédente quelconque, caractérisé en ce que l'élément réflecteur de chacune desdites antennes Yagi est un élément réflecteur commun (16A).

7. Système d'antennes selon une revendication précédente, quelconque, caractérisé en ce que chaque antenne Yagi a une longueur sensiblement égale à 1,25 λ.

8. Système d'antennes selon une revendication précédente quelconque, caractérisé en ce que lesdites antennes Yagi comprennent chacune des moyens supports non conducteurs (28, 30) servant à positionner l'élément attaqué (18), l'élément réflecteur (16) et le ou chaque élément directeur (20) dans des positions fixes les uns par rapport aux autres.

9. Système d'antennes selon une revendication précédente quelconque, caractérisé en ce que ledit élément attaqué, l'élément réflecteur et le ou chaque élément directeur de chaque antenne Yagi sont espacés les uns des autres d'une distance sensiblement égale à 0,25 λ.

10. Avion comprenant un système d'antennes selon une revendication précédente quelconque, caractérisé en ce que ledit système est monté sans modification de la forme dans une aile de l'avion.

11. Avion comprenant un système d'antennes selon une quelconque des revendications 1 à 9, caractérisé en ce que ledit système comprend en outre une paire d'antennes (56, 58) à vision latérale, connues en soi, ledit système étant monté en configuration lisse dans un avion, de sorte qu'on obtient une couverture azimutale large.

12. Avion selon la revendication 11, caractérisé en ce que ledit système est monté en configuration lisse dans l'aile dudit avion.

13. Avion selon la revendication 11, caractérisé en ce qu'il y a deux systèmes d'antennes de ce type qui sont montés dans des positions dos à dos.

14. Avion selon la revendication 13, caractérisé en ce que les deux systèmes précités sont montés respectivement en configuration lisse dans l'aile et dans le stabilisateur horizontal dudit avion.

15. Avion selon la revendication 11, caractérisé en ce que lesdites antennes à vision latérale sont montées en configuration lisse sur le fuselage de l'avion.

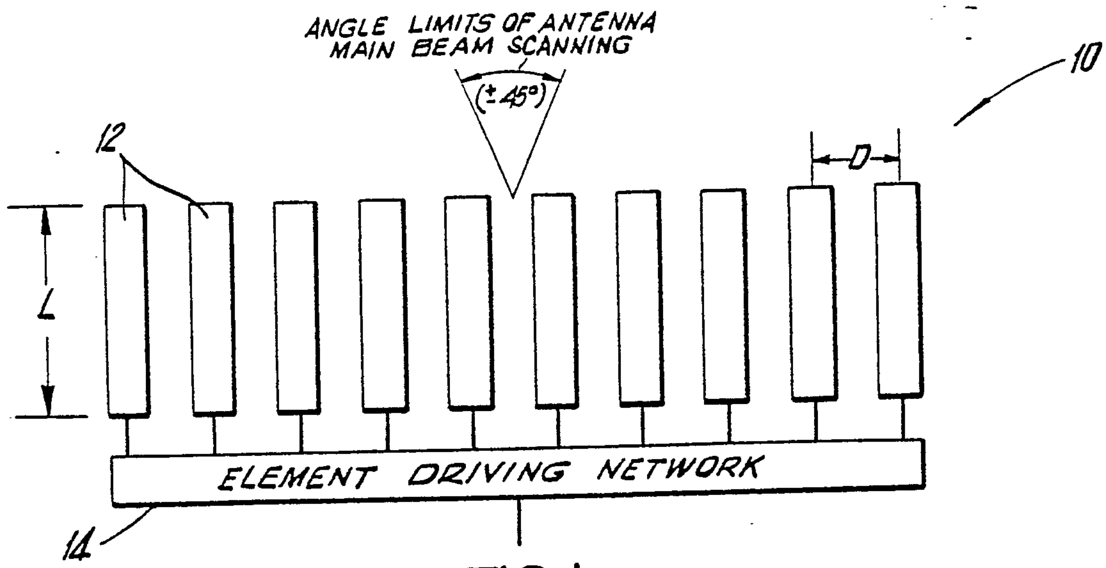


FIG.1

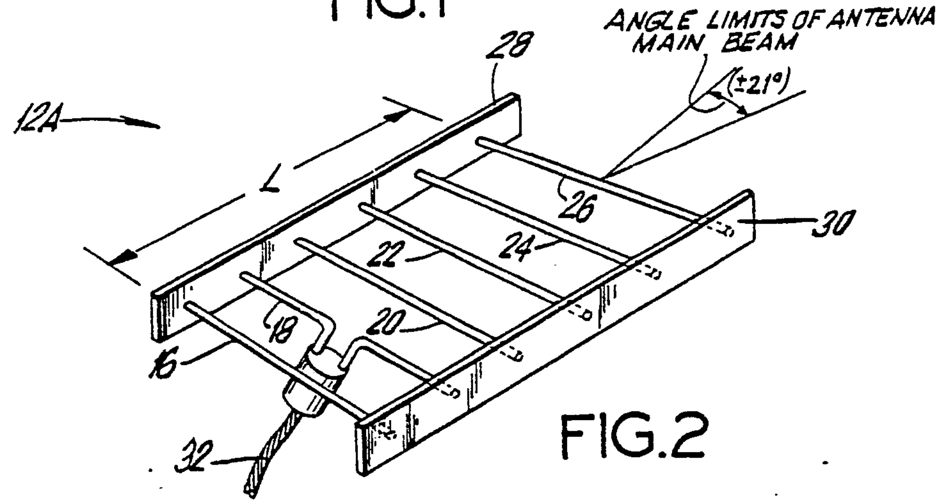


FIG.2

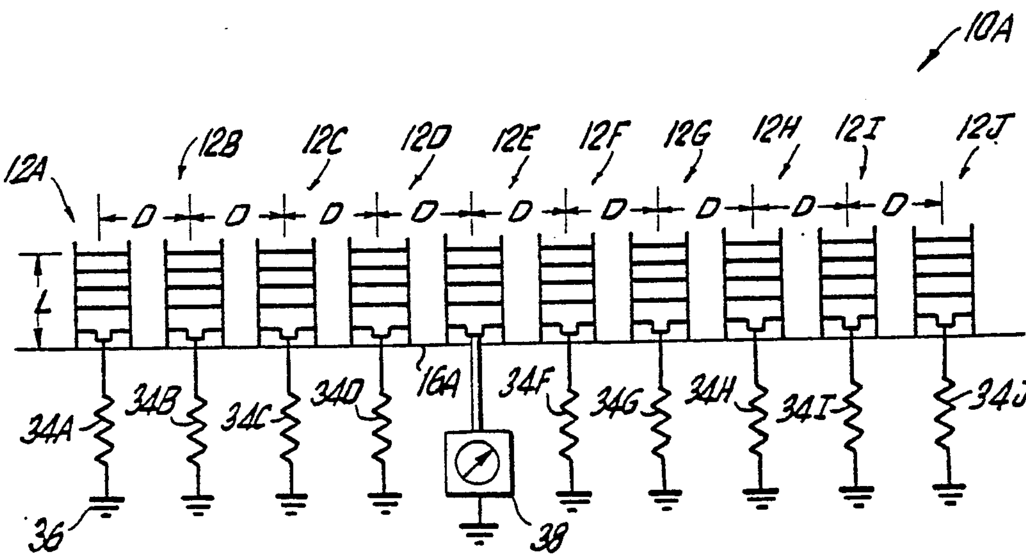
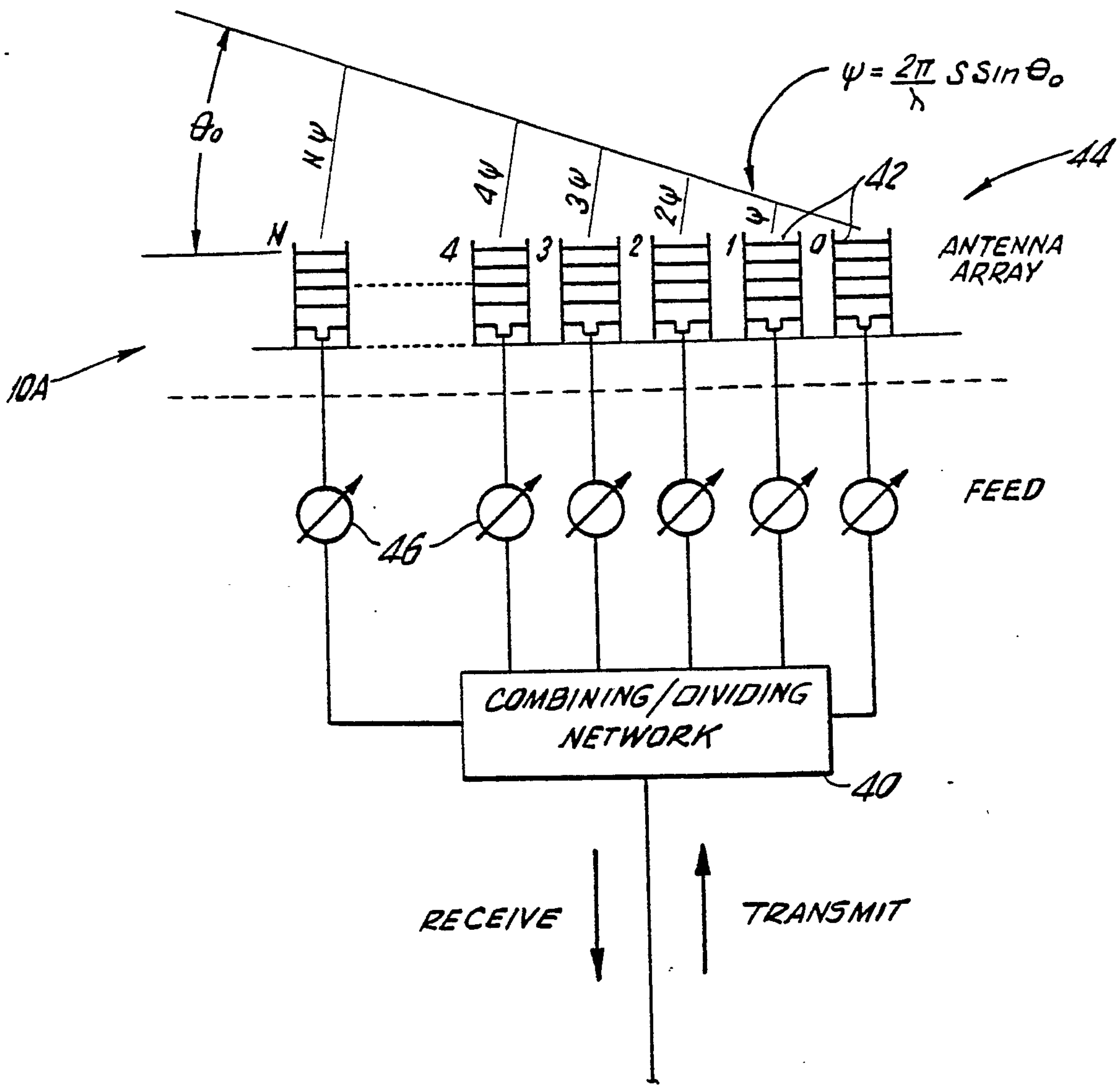


FIG.3



$\psi = \frac{2\pi}{\lambda} S \sin\theta_o$
44
42
θ_o
$N\psi$
4ψ
3ψ
2ψ
ψ
N
4
3
2
1
0
ANTENNA ARRAY
10A
FEED
46
COMBINING/DIVIDING NETWORK
40
RECEIVE
TRANSMIT

FIG.4

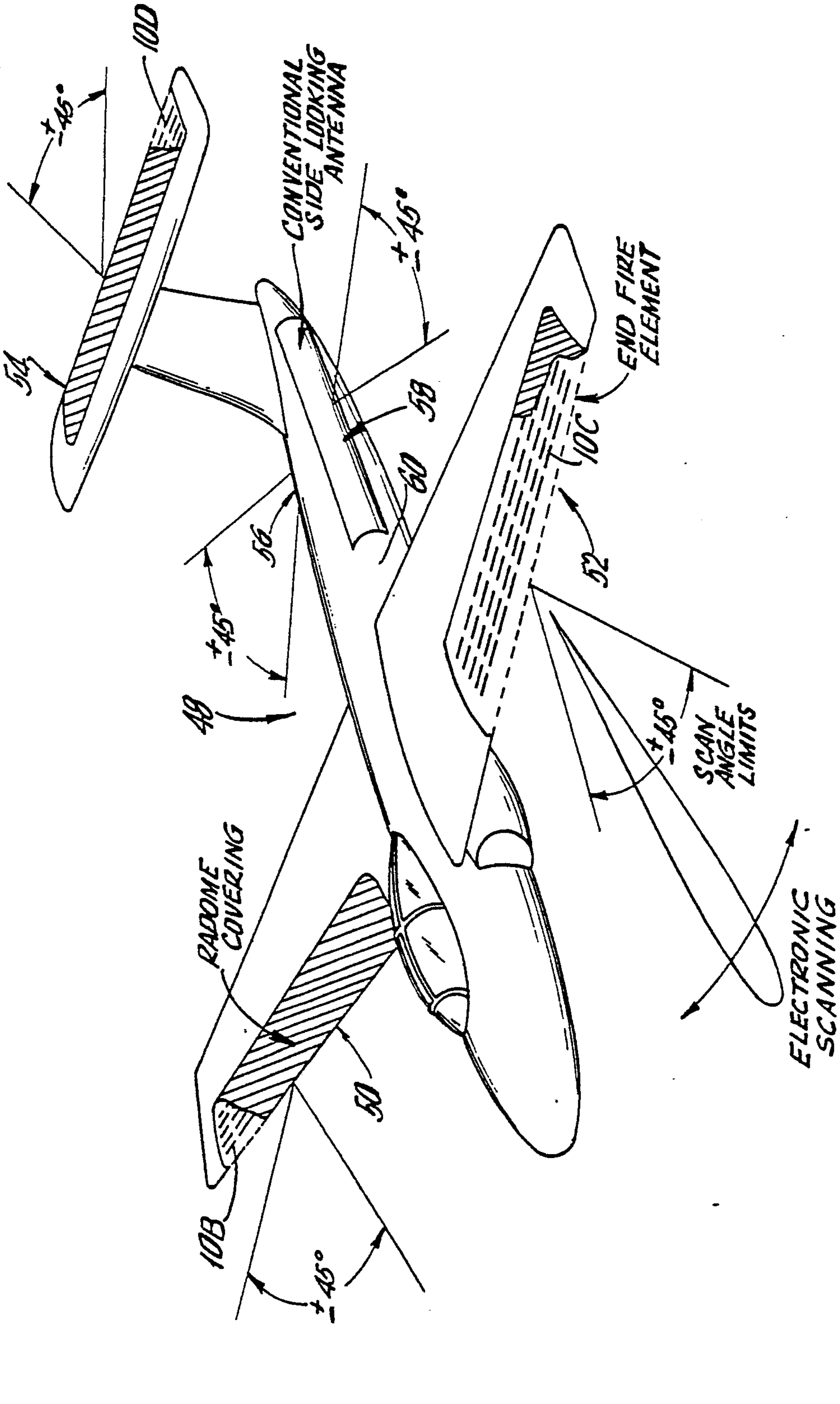

10D
±45°
CONVENTIONAL
SIDE LOOKING
ANTENNA
54
±45°
END FIRE
ELEMENT
58
60
10C
52
56
±45°
48
±45°
SCAN
ANGLE
LIMITS
RADOME
COVERING
ELECTRONIC
SCANNING
50
10B
±45°

FIG.5