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(54) Title: A DEVICE FOR FEEDING MULTIMODE MONOPULSE SIGNALS FROM ANTENNAS FOR TRACKING SATELLITES

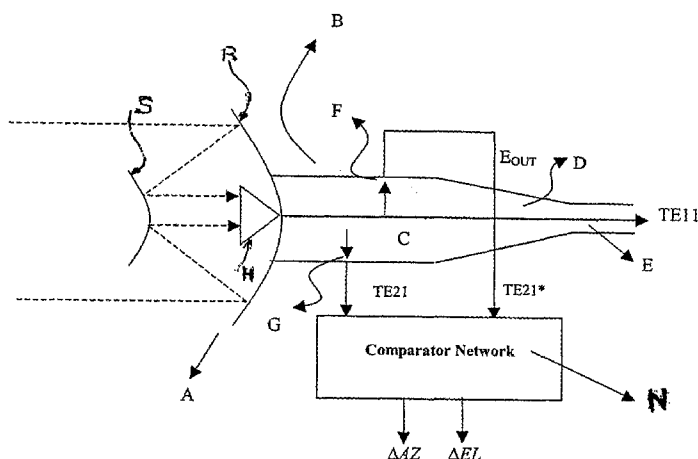


FIG-1

(57) Abstract: The device for feeding multimode monopulse signals from antennas for tracking satellites comprises: (i) a single antenna (A) having reflector (R), subreflector (S) and horn (H); and (II) a feeder (B) of multimode monopulse signals, containing a smooth-walled cylindrical waveguide (C) connected co-axially to antenna reflector (R) at one end, and at the other end to a cylindrical waveguide (D) having a tapered end which is co-axially connected to another cylindrical waveguide (E) of diameter equal to that of the said tapered end to allow passage of the signals of dominant mode only. Two pairs of longitudinal slots are milled on the wall waveguide (C) for decoupling signals of higher modes only. The slots of each pair are disposed in diametrically opposite positions and at angular displacement of 45° between the two pairs of slots with respect to the axis of the waveguide. The axial separation between the two pairs of slots is half the waveguide wavelength of the signals propagated.

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The present invention relates to a device for feeding multimode monopulse signals from antennas for tracking satellites.

The invention relates more particularly to a compact device of relatively simple design and low cost construction, suitable for tracking satellites which transmit linear beacon signals for performing inter-satellite links as well as communicating with antennas at ground earth stations to track targets. Along with providing the tracking information in an efficient manner the invented device can be used also for satellite communications in the Ka band at high conversion efficiency and mode purity.

US 3, 758, 880 discloses a mode coupler for evaluating higher waveguide wave modes resulting from aperture deviation of an antenna exciter (horn) for determining angular deviation in the azimuth plane as well as in the elevation plane.

The device used for separating the waves of dominant mode containing the ranging signal from the waves of higher modes, excited by the dominant mode, containing the deviation signals, comprises a first wave guide section coupled to an antenna for propagating waves of all modes, and a second waveguide section of smaller cross-section than the first waveguide section, for propagating only the waves of dominant mode, which is introduced into the first waveguide section at the outlet end thereof, the gap between the periphery of the first and second waveguide sections being divided into a plurality of apertures for propagation of only the waves of higher modes therethrough.

US 4,048,592 describes a device for tracking satellites or missiles by extracting waves of higher modes propagating through a corrugated-walled waveguide connected at one end to a corrugated-walled horn antenna and at the other end to a utilisation device. Two pairs of elongated collector waveguides are disposed on the surface of the corrugated-walled waveguide along the axial

direction thereof lying in mutually orthogonal planes, the two collector waveguides of each pair being in diametrically opposite positions, and coupled to a plurality of slots formed in the wall of the corrugated-walled waveguide. The method of extracting waves of higher modes in the device is not applicable
5 for smooth-walled waveguides and the device is not usable with a reflector antenna.

US 4, 706, 093 discloses a monopulse tracking system in which at least two channels, each having a different noise function associated therewith, are
10 used in conjunction with an antenna, one of the two channels being utilised to develop a SUM signal and the other channel is utilised to develop a DIFFERENCE signals. The SUM and DIFFERENCE signals are processed in a phase detector to generate error signals.

15 EP 0 408 263 A2 describes a method of processing two-channel monopulse signals comprising: (a) forming composite signals $S + (p + jy)$ and $S - (p + jy)$ where S is a monopulse SUM signal, P is a pitch error signal and y is a yaw error signal; (b) alternately passing the composite signal through a two-channel amplifier; and (c) separating the components of the amplified signal
20 for conventional monopulse processing.

IN JP 10 221 421, four planar-surface antennas are arranged in two lines and two rows for reducing the size and weight of an orthogonal biaxial monopulse tracking antenna which requires three-dimensional coiring.
25

One disadvantage of the existing devices for tracking satellites is that a plurality of antennas are required to be installed on a satellite for feeding different signal components into a reflector system. For example, a cumbersome array of 4 or 5 horns is required to develop the
30 sum and difference signals for tracking satellites.

Another disadvantage of the existing devices for tracking satellites is that the design of these devices is not adequately simple for fabrication at a reduced cost.

5 The object of the invention is to provide a relatively compact, light weight, small-size, low-cost construction device of simple design, which is capable of feeding the multimode monopulse signals for tracking satellites using a single antenna.

10 The other object is to provide a device which is capable of separating different signal modes efficiently.

Another object is to provide a device for coupling an antenna to a two-way communication system, in addition to functioning as a feeder of
15 multimode monopulse signals for tracking satellites.

A further object is to provide a device which is capable of ensuring a high degree of isolation between the dominant mode and the individual higher mode components of the multimode monopulse signals for tracking satellites.

20

In the multimode monopulse system of tracking satellites, when an antenna on the satellite receiver an incident wave, the level of the signal is maximum if the bore axis of the antenna points directly to the source of the signal. On the other hand if the bore axis of the antenna is not in line with the
25 signal source, then signals of modes higher than the dominant mode are excited in the waveguide connected to the antenna. For example, if the dominant mode of the signal is TE₁₁, two orthogonal higher modes TE₂₁ and TE₂₁^{*} are excited in the waveguide, which may be used to generate the error signals for controlling the servo system used to turn the satellite till the bore axis of the
30 antenna is brought in line with the source of signal.

It may be noted that the waves of various possible modes can exist in a waveguide. The modes are of two dominant types. In one dominant mode, the electric field is transverse to the axis of the waveguide and therefore such mode is termed transverse-electric mode and denoted as TE mode. In the other
5 dominant mode the magnetic field is transverse to the axis of the waveguide and such mode is therefore termed transverse magnetic mode and denoted as TM mode.

Numerical subscripts are written against symbols TE and TM
10 to denote the number of half wavelengths present in the horizontal and vertical directions of the waveguide. Thus TE_{11} indicates that there is one half wavelength each in the horizontal and the vertical directions each of the waveguide and TE21 indicates that there are two half wavelengths in the horizontal direction and one half-wavelength in the vertical direction of the
15 wave guide.

The invented device comprises a smooth-walled cylindrical waveguide connected to a reflector antenna at one end and to a cylindrical tapered waveguide at other end. Two pairs of longitudinal slots are milled on the
20 surface of the smooth-walled cylindrical waveguide for decoupling the waves of higher modes TE 21 AND TE_{21}^* propagated through the waveguide together with the waves of dominant mode TE 11. Two longitudinal slots of each pair are disposed in diametrically opposite positions on the waveguide at an angular displacement of 450° with each other with respect to the axis of the
25 waveguide and at a separation in the axial direction of half the guide wavelength of the signals propagated through the waveguide.

The cylindrical tapered waveguide which acts as a cut-off for the propagation of waves of higher modes TE 21 and TE_{21}^* though it, and allows
30 the propagation of the waves of dominant mode TE 11 only, is connected at its tapered end to another cylindrical waveguide of diameter equal to that of the

tapered end of the cylindrical tapered waveguide, to allow propagation through it of waves of dominant mode TE 11 only to the signal processing networks.

5 Thus the present invention provides a device for feeding multimode monopulse signals from antennas for tracking satellites, characterised in that the device comprises: (i) a single antenna having a reflector, a sub-reflector and a horn; and (ii) a multimode monopulse signal feeder comprising a smooth-walled cylindrical waveguide which is co-axially connected at one end to
10 antenna reflector and at other end to a cylindrical waveguide having a tapered end, connected co-axially to one end of another cylindrical waveguide of diameter equal to that of the said tapered end, two pairs of longitudinal slots being milled in the wall of the smooth-walled waveguide in the axial direction thereof in a manner such that the two slots of each pair lie in diametrically
15 opposite positions.

The invention is described in detail without restricting the scope of the invention in any manner with reference to the accompanying drawings in which -

20

Figure 1 is a schematic block diagram of the invented device;

Figure 2 is a perspective view of the invented device excluding the antenna;

25

Figure 3 is a view of the realised hardware of the invented device without antenna and comparator network;

Figure 4 is the measured return loss plot;

30

Figure 5 is the measured radiation pattern of TE₂₁ and TE₁₁ modes; and

Figure 6 is the measured isolation plot between TE₂₁, TE₂₁^{*} and TE
5 modes.

Referring to Figs. 1, 2 and 3, the invented device comprises:

(i) a single antenna (A) containing the reflector (R), subreflector (s) and horn(H); and (ii) a multimode monopulse signal feeder (B) containing the
10 smooth-walled cylindrical waveguide (C) of dimensions suitable for allowing propagation of TE₁₁, TE₂₁ and TE₂₁^{*} wavemode signals, which is connected at one end to reflector (R) of antenna (A) and at other end to the cylindrical tapered waveguide (D) which allows propagation of only TE₁₁ mode signals, and the cylindrical waveguide (E) of diameter equal to the diameter at tapered
15 end of waveguide (D) and connected thereto at one end and at other end to the mark (not shown) for processing the error signals used for tracking satellites.

Two pairs of longitudinal slots are milled on the wall of waveguide (C) in the axial direction thereof and at an axial distance of half the guide
20 wavelength of the signal at positions (F and G). The longitudinal slots of each pair are disposed in diametrically opposite positions on the wall of waveguide (C) with an angular separation of 45° between the two pairs with respect to the axis of the waveguide (C). One pair of the longitudinal slots is used for decoupling the signal of TE₂₁ mode and the other pair is used for
25 decoupling the signal of orthogonal TE₂₁^{*} mode through deformed E-plane Tee couplers (not shown) which transfer signal from circular to rectangular wave guides.

The higher mode signals TE₂₁ and TE₂₁^{*} decoupled by the two pairs of
30 longitudinal slots at positions marked (G and F) are fed into the comparator network (N) through two deformed E-plane Tees at positions (I, J) (shown in

Fig. 2), which act as 1:2 power combiners for conversion of the signals into azimuth and elevation plane errors.

The comparator network (N) is a 3 db hybrid coupler.

5

The waveguides (C, D and E) are constructed using lightweight Aluminium metal in a Computer Numerical Controlled lathe machine with dimensional tolerances of ± 0.015 mm.

10 The operational characteristics of the device and optimum dimensions of the waveguides (C, D, E) and longitudinal slots used in the invented device are presented in Table I from which it is noted that :

- 15 (a) the device operates at a carrier frequency of 29.25 GHz of bandwidth ± 80 MHz;
- (b) the integrated return loss over the operating band is -20 db
- (c) the isolation between ports TE₂₁ and 11, and between TE₂₁^{*} and to TE₁₁ is better than -38 db and that between TE₂₁ and TE₂₁^{*} is better than -33 db;
- 20 (d) the insertion loss is 0.3 db at TE₁₁ port and 0.4 db at TE₂₁ and TE₂₁^{*} ports each ;
- (e) the diameter of waveguide (c) is 10.8 mm;
- (f) the diameter at tapered end of waveguide (D) is 7.6 mm;
- (g) the length of waveguide (D) is 20.0 mm;
- 25 (h) the taper angle of waveguide (D) is 4.85° ;
- (i) the dimensions of each longitudinal slot are length 7.1 mm, width 0.6 mm and depth/height 0.5 mm;
- (j) the total length of feeder (B) is 72.0 mm;
- (k) the operating temperature range is from -40°C to $+70^\circ\text{C}$;
- 30 (l) The stress limit is 1.5 Kg/mm^2 ; and
- (m) The null depth is 36.0 db.

From the observed performances features of the invented device presented in figures 4 to 6, the following the useful aspects of the device may be noted :

- 5 (i) the integrated return loss is relatively low over the operating the band;
- (ii) the radiation pattern of the device is well-defined; and
- (iii) the isolation between TE₂₁ and TE₂₁* modes is of high order.

The invented device has a number of advantageous features over the
10 existing devices, such as,

1. The device provides a highly efficient means of relatively simple construction for signal mode separation by using only a single antenna for developing the tracking error signals for a monopulse tracking receiver.
- 15 2. The decoupling of dominant/fundamental mode TE₁₁ signal by the longitudinal slots is negligible i.e. less than – 35db.
3. The isolation between the two higher mode signals TE₂₁ and TE₂₁* is
20 better than –35db with consequent reduction of cross polarization between the two higher mode signals.
4. In addition to feeding the tracking information, the device can be used also for carrying our satellite communication in Ka band.
- 25 5. The device is of relatively simple design and hence of light-weight and low-cost construction requiring reduced space for installation in spacecrafts.
6. The device is usable for scanning all earth station antennas, used in
30 satellite tracking systems and RADAR systems all over the world.

TABLE-I

Operational Characteristics of the invented device and Optimum dimensions of Waveguides and Longitudinal Slots

5

Parameters		Values
Frequency		29.25 GHz
Bandwidth		± 80 MHz
Integrated Return Loss		-20 dB over the Band
Isolations between ports	TE21 to TE 11	Better than -38 dB
	TE21* to TE11	Better than -38 dB
	TE21 to TE 21*	Better than -33 dB
Insertion Loss	TE11 Port	0.3 dB
	TE21 Port	0.4 dB
	TE21* Port	0.4 dB
Overall Size		
Rectangular Waveguide		WR28
Front Section Circular Waveguide Diameter		10.8 mm
Rear Section Circular Waveguide diameter		7.60 mm
Taper angle		4.85°
Length of taper Section		20 mm
Coupling slot length		7.10 mm
Coupling slot Width		0.60 mm
Coupling slot height		0.50
Total length of tracking feed		72 mm
Temperature range		-40° to 70°C
Maximum stress		1.5 Kg/mm^2
Null depth		36 dB

Claims :-

1. A device for feeding multimode monopulse signal from antennas for tracking satellites, characterised in that the device comprises: (i) a single antenna (A) having a reflector (R), a sub-reflector (s) and a horn (H); and (ii) a multimode monopulse signal feeder (B), comprising a smooth-walled cylindrical waveguide (C) which is co-axially connected at one end to antenna reflector (R) and at other end to a cylindrical waveguide (D) having a tapered end, connected co-axially to one end of another cylindrical waveguide (E) of diameter equal to that of the said tapered end, two pairs of longitudinal slots being milled in the wall of the smooth-walled waveguide (C) in the axial direction thereof in a manner such that the two slots of each pair lie in diametrically opposite positions.
2. The device as claimed in claim 1, wherein the angular displacement of the two pairs of slots with respect to the axis of waveguide (C) is 45° .
3. The device as claimed in claim 2, wherein the axial distance between the two pairs of slots is half the waveguide wavelength of the signals.
4. The device as claimed in claim 3, wherein waveguide (C) is adapted to allow propagation of signals of dominant mode TE₁₁ as well as of higher modes TE₂₁ and TE₂₁^{*}.
5. The device as claimed in claim 4, wherein the two pairs of slots are adapted to decouple the higher mode signals TE₂₁ and TE₂₁^{*} only from waveguide (C) and supply outputs through deformed E-plane Tee-couplers to a comparator network (N).

6. The device as claimed in claim 1, wherein the waveguide (D) and waveguide (E) are both adapted to stop propagation of higher mode signals TE₂₁ and TE₂₁* and allow only the dominant mode signal TE₁₁ to pass through.

5 7. The device as claimed in claims 6, wherein the waveguide (D) is provided with a taper of angle 4.85°.

8. The device as claimed in claim 7, wherein the longitudinal slots are each of length 7.1 mm, width 0.6 mm and depth 0.5 mm.

10

9. The device as claimed in claim 8, wherein waveguide (C) is of diameter 10.8 mm, waveguide (E) is of diameter 7.6 mm and waveguide (D) is of length 20.0 mm, the total length of feeder (B) being 72.0 mm.

15 10. A device for feeding multimode monopulse signals from antennas for tracking satellites substantially as herein described and illustrated in figures 1 to 6 of the accompanying drawings.

20

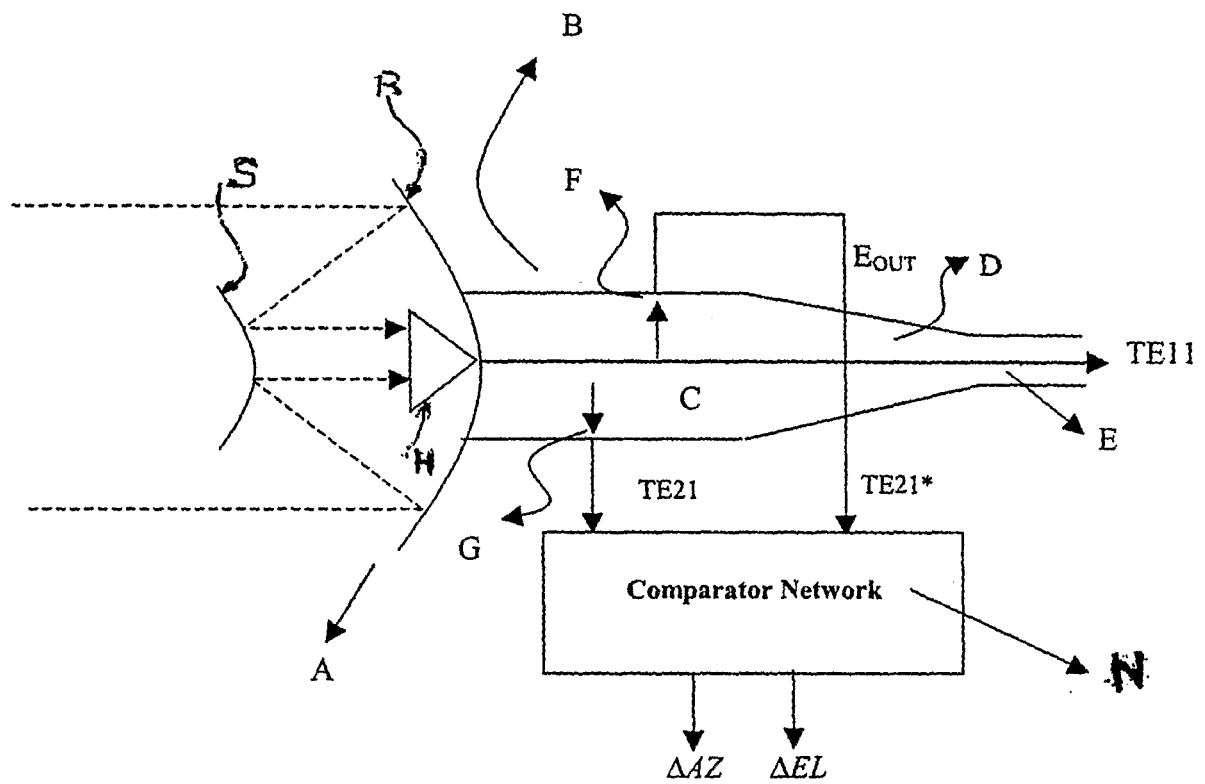


FIG-1

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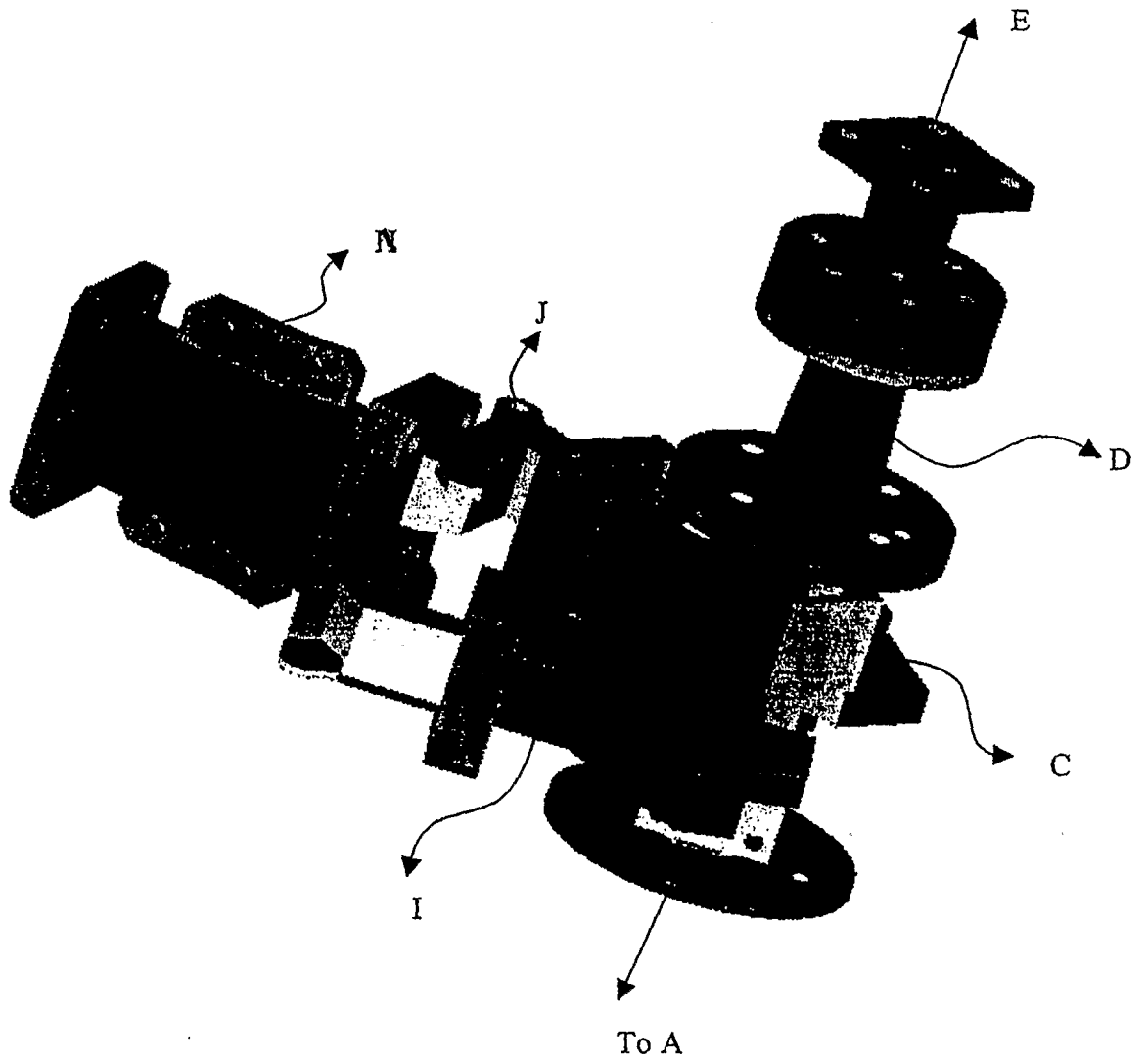


FIG.-2

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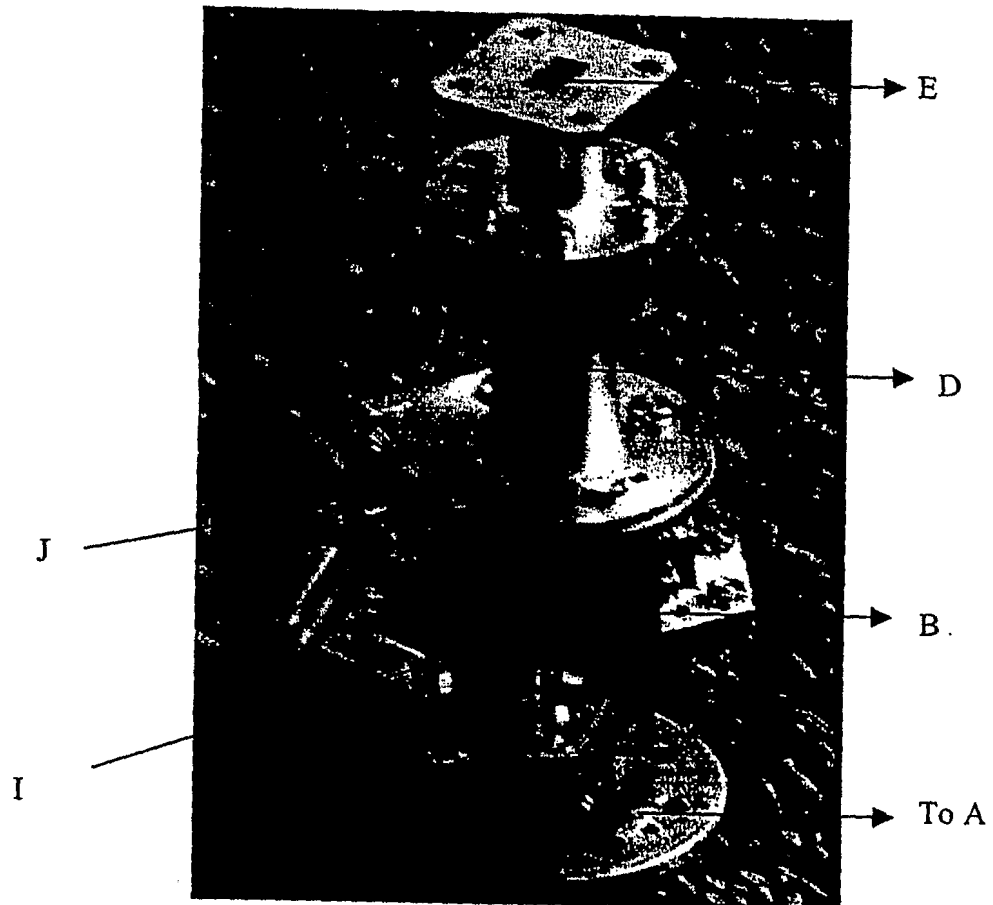


FIG.-3

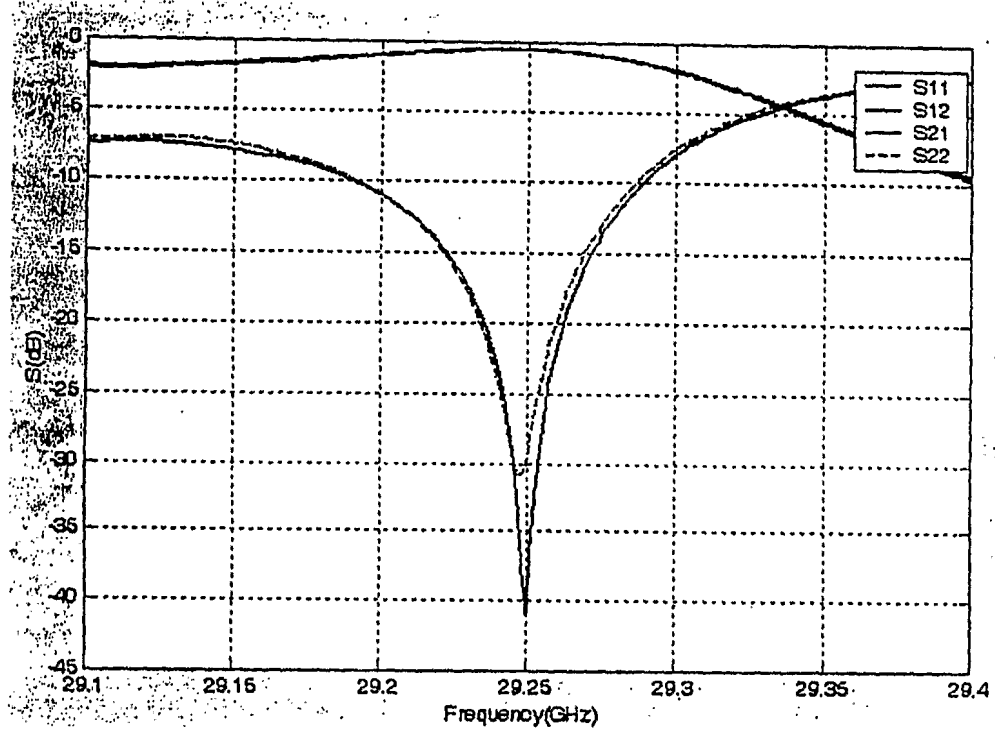


FIG-4

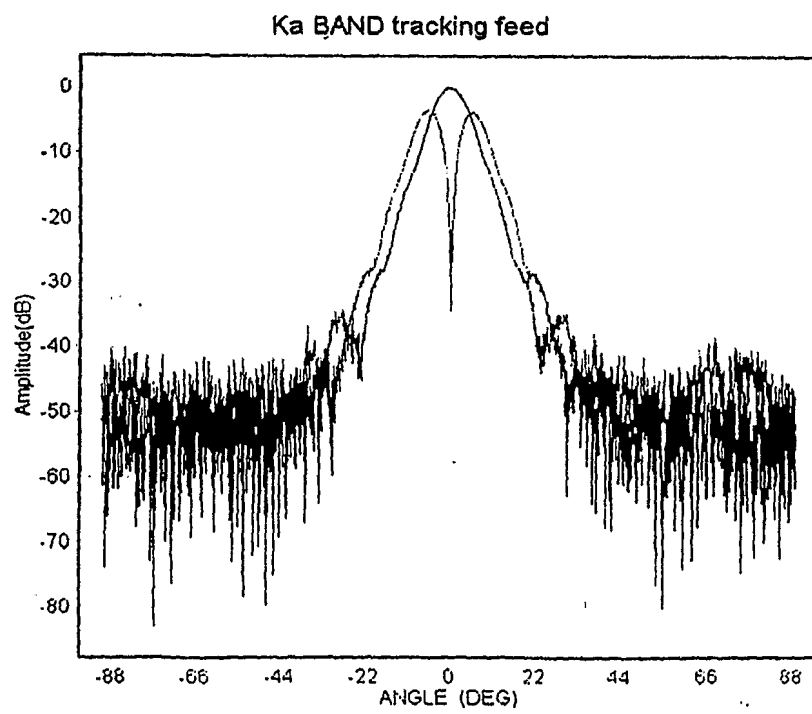


FIG-5

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