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(54) **Title**: DIRECTION FINDING ANTENNA

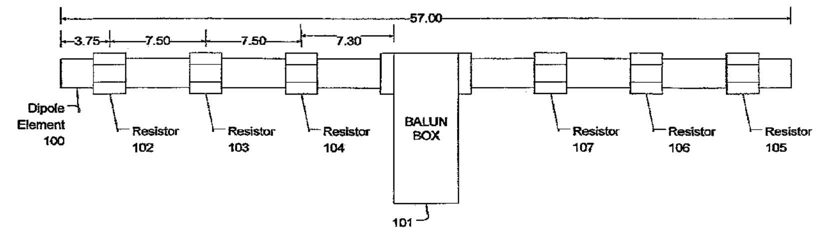

Figure 1

(57) **Abstract**: Systems and methods provide a HESA ("High Efficiency Sensitivity Accuracy") direction-finding ("DF") antenna system that operates over a range from 2 MHz to 18 GHz. The system may include components such as a dipole array, a monopole array and an edge-radiating antenna, each component being responsive to a specific frequency range. The system may further include biconical flares that optimally terminate a freespace wave in a small aperture.

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DIRECTION FINDING ANTENNA

RELATED APPLICATION

[0001] This application claims priority to provision application no. 61/037,941 filed March 19, 2008.

FIELD OF THE INVENTION

[0002] One embodiment is directed to antennas, and more particularly directed to direction finding antennas.

BACKGROUND INFORMATION

[0003] Radio direction finding is the process of electronically determining the direction of arrival of a radio signal transmission. The techniques for obtaining cross bearings of an emitter and using triangulation to estimate target positions are well-known. The ability to ascertain the geographical location of an emitting transmitter offers important capabilities for many modem communications applications, such as land, air, and sea rescue, duress alarm and location, law enforcement, and military intelligence. There are numerous direction-finding antennas and systems in the prior art.

[0004] It is advantageous to design direction finding antennas that can fit in small packages, especially where those direction finding antennas are intended to be portable and used in the field. However, it is difficult to build direction finding antennas for small packages without sacrificing bandwidth, frequency response, and signal detection quality.

SUMMARY OF THE INVENTION

[0005] Systems and methods in accordance with an embodiment are directed to a HESA ("High Efficiency Sensitivity Accuracy") direction-finding ("DF") antenna system. One embodiment is a direction-finding antenna with electronics for receiving radio signals in a frequency range of about 2 megaHertz to about 18 gigaHertz. The direction-finding antenna may include several components for different frequency ranges. In one embodiment, one component is an edge-radiating antenna comprising a first plate and a second plate disposed parallel to each other and radiating into open space, a concentric cylinder connecting the first plate to the second plate, eight feed points disposed equally around the outside of the concentric cylinder with eight feed lines extending from the first plate to the second plate, and a shunt resistor across each feed gap. The eight feed lines are electrically coupled to a beam forming matrix that detects the direction of a beam.

[0006] In another embodiment, a component is a monopole array comprising eight monopole elements connected to a first center mast. The monopole array is disposed inside the concentric cylinder and modified with resistors such that no resonance occurs. The eight monopole elements are electrically coupled to a beam forming matrix that finds a direction of a beam.

[0007] In yet another embodiment, a component is a dipole array comprising eight dipole elements connected to a second center mast. Each of the eight dipole elements is resistively loaded to increase bandwidth, and the eight dipole elements are electrically coupled to a beam forming matrix that detects the direction of a beam. The second center mast may include a plurality of resistors disposed on the mast to prevent resonance.

[0008] In yet another embodiment, a component is a biconical horn that houses the edge-radiating antenna or dipole array. The biconical horn comprises eight ribs connecting a top horn to a bottom horn. The eight ribs are electrically coupled to a high impedance resistor disposed at the center of the biconical horn. The top horn and bottom horn of the biconical horn may include a base having an aperture termination including resistors in shunt with each other.

[0009] In yet another embodiment, the beam forming matrix includes eight inputs, a sine pattern output, a cosine pattern output, and an omni directional pattern output. The eight inputs include inputs A, B, C, D, E, F, G and H, and the sine pattern equals (input C + input D) – (input G + input H), the cosine pattern equals (input A + input B) – (input E + input F), and the omni directional pattern is the sum of the eight inputs. The sine, cosine, and omni directional patterns are used to calculate a direction of arrival (period) versus "a beam."

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 illustrates the mechanical layout of one dipole element of a dipole array in accordance with an embodiment;

[0011] FIG. 2 illustrates a vertical cross section of a dipole array in accordance with an embodiment;

[0012] FIG 3. illustrates a horizontal cross section of dipole array in accordance with an embodiment;

[0013] FIG. 4 illustrates a cross section of edge-radiating antenna in accordance with an embodiment;

[0014] FIG. 5 illustrates a horizontal view of an edge-radiating antenna in accordance with an embodiment;

[0015] FIG. 6A illustrates a modified Vivaldi structure in accordance with an embodiment;

[0016] FIG. 6B illustrates a modified Vivaldi structure cross section view in accordance with an embodiment;

[0017] FIG. 7A illustrates stacked biconical antennas in accordance with an embodiment;

[0018] FIG. 7B illustrates stacked biconical antennas in accordance with an embodiment;

[0019] FIG. 8 illustrates a block diagram of the beam finding matrix in accordance with an embodiment;

[0020] FIG. 9 illustrates an On-the-Move antenna in accordance with an embodiment;

[0021] FIG. 10 illustrates OMNI pattern angle data from an edge-radiating antenna in accordance with an embodiment;

[0022] FIG. 11 illustrates OMNI pattern frequency gain data from an edge-radiating antenna in accordance with an embodiment;

[0023] FIG. 12 illustrates OMNI pattern frequency deviation data from an edge-radiating antenna in accordance with an embodiment;

[0024] FIG. 13 illustrates COSINE pattern angle data from an edge-radiating antenna in accordance with an embodiment;

[0025] FIG. 14 illustrates COSINE pattern frequency gain data from an edge-radiating antenna in accordance with an embodiment;

[0026] FIG. 15 illustrates COSINE pattern null depth data from an edge-radiating antenna in accordance with an embodiment;

[0027] FIG. 16 illustrates SINE pattern angle data from an edge-radiating antenna in accordance with an embodiment;

[0028] FIG. 17 illustrates SINE pattern frequency gain data from an edge-radiating antenna in accordance with an embodiment;

[0029] FIG. 18 illustrates SINE pattern null depth data from an edge-radiating antenna in accordance with an embodiment;

[0030] FIG. 19 illustrates OMNI pattern angle data from a modified Vivaldi biconical antenna in accordance with an embodiment;

[0031] FIG. 20 illustrates OMNI pattern frequency gain data from a modified Vivaldi biconical antenna in accordance with an embodiment;

[0032] FIG. 21 illustrates SINE pattern frequency gain data from a modified Vivaldi biconical antenna in accordance with an embodiment;

[0033] FIG. 22 illustrates SINE pattern angle data from a modified Vivaldi biconical antenna in accordance with an embodiment;

[0034] FIG. 23 illustrates SINE/COSINE null orthogonality data from a modified Vivaldi biconical antenna in accordance with an embodiment;

[0035] FIG. 24 illustrates COSINE pattern angle data from a modified Vivaldi biconical antenna in accordance with an embodiment;

[0036] FIG. 25 illustrates COSINE pattern frequency gain data from a modified Vivaldi biconical antenna in accordance with an embodiment;

[0037] FIG. 26 illustrates COSINE pattern frequency gain data from an On-the-Move ("OTM") antenna in accordance with an embodiment;

[0038] FIG. 27 illustrates OMNI pattern frequency gain data from an OTM antenna in accordance with an embodiment;

[0039] FIG. 28 illustrates SINE pattern angle data from an OTM antenna in accordance with an embodiment;

[0040] FIG. 29 illustrates SINE pattern frequency gain data from an OTM antenna in accordance with an embodiment; and

[0041] FIG. 30 illustrates COSINE pattern angle data from an OTM antenna in accordance with an embodiment.

DETAILED DESCRIPTION

[0042] Systems and methods in accordance with an embodiment are directed to a HESA ("High Efficiency Sensitivity Accuracy") direction-finding ("DF") antenna system that operates over a range from 2 MHz to 18 GHz. The basic antenna comprises an upper plate and a lower plate connected by a short circuit element. The feed region is spaced out from the short circuit a specific distance that enables the highest frequency of operation to produce an omni-directional pattern when connected to a beam forming network with a uniform amplitude and uniform phase distribution. The distance between each of the feed elements is such that an omni-directional pattern is achieved. The antenna may be circular as may be the arrangement of the feeds. The antenna aperture may be directly at the feed region or may be extended beyond the feed region by a parallel plate region or biconical flare region.

[0043] The feeds are launched from the top or bottom of the feed region and impedance matched to the antenna driving point impedance by using one or more of the following techniques: series transmission lines, shunt transmission lines, resistors placed in series with feed elements, and resistors placed in shunt with feed elements. The combination of techniques results in a highly sensitive feed region with efficient transfer of fields from the feed region to transverse electric and magnetic ("TEM") mode coaxial cable that connects to a beam forming network.

[0044] Resistors may be placed on the feed elements to stabilize the element impedance in electrically small antennas. The resistors may also be placed in series on an element in strategic areas to minimize higher order modes from propagating for bandwidth extension. Typically, resistors in an array configuration have a net value impedance (free space) around 377 ohms. For example, an Altshuler antenna array may be an example where this value is important. Instead, one embodiment here finds that in order to achieve more gain and minimize losses, an appropriate resistor value is a net value of 200-300 ohms/impedance range. Here, a total value for a typical array of eight resistors would be in the 1600-2400 ohm range to net out 200-300 ohms (impedance), which achieves more gain. For a 32 resistor array, for example, a total of 6400-9600 ohm range will net out a resistor array impedance of 200-300 ohms. Unlike conventional systems, more gain is achieved with a lower net ohms/impedance value in the resistors.

[0045] An antenna system may include multiple types of antennas operating in different frequency ranges. In one embodiment, an antenna system includes some or all of a dipole array, a monopole array, an edge-radiating antenna, and a modified Vivaldi launch structure. The components are connected to a beam forming matrix for determining the direction of a signal.

[0046] *Dipole Array*

[0047] Typically, the usual elements for small antenna direction finding antenna elements are dipoles or loop elements that have limited bandwidths. In an embodiment, dipoles are modified by adding resistors near the ends of the elements to pull up the input impedance. This increases the bandwidth to approximately 3:1. To increase the bandwidth even further, a second resistive termination located one half of a wavelength away may be added, the wavelength being determined by the desired highest frequency of operation. This increases the bandwidth to 5:1. Each additional resistive termination will increase the bandwidth to 7:1, 9:1, and so on. For very short dipoles at extremely low frequencies, resistors may be placed across the feed point to stabilize the driving feed point impedance to a level where the radiation resistance of the antenna is raised to a level where impedance matching can occur. There may be a tradeoff in efficiency vs. impedance, however. Efficiency is lost at the high end of the frequency band, while impedance stabilization is achieved at the lowest frequencies for uniform power transfer.

[0048] FIG. 1 illustrates the mechanical layout of one dipole element of a dipole array in accordance with an embodiment. In this example, dipole element 100 is 57 cm long with a balun box 101 disposed at the middle of dipole element 100. A resistor 102 is disposed 3.75 cm from the end of dipole element 100, with a second resistor 103 disposed 7.5 cm from the center of resistor 102, and a third resistor 104 disposed 7.5 cm from the center of resistor 102. A mirror image is made on the other side of balun box 101 with resistors 105, 106, and 107, respectively. In one embodiment, the impedance of resistors 102-107 is 200-300 Ohms. This type of dipole element is then arrayed around a cylinder or mast using eight such elements.

[0049] FIG. 2 illustrates an end view of a dipole array 200 in accordance with an embodiment.

Dipole elements 201-208 correspond to a dipole element such as dipole element 100. In one embodiment, these dipole elements 201-208 are spaced approximately a ¼ wavelength at the highest frequency of operation away from cylinder 209, and about ½ wavelength apart on the circumference so that when connected to a beam forming matrix (discussed infra), the direction finding patterns of omni, sine and cosine are formed. FIG 3. illustrates a horizontal view of dipole array 200 in accordance with an embodiment. In this view, dipole elements 208, 201, 202, 203, and 204 are shown, whereas dipole elements 205-207 are not visible from this angle. Dipole element 202 is shaded to differentiate it from cylinder 209. Cylinder 209 further includes resistors 301-304 decouple the dipole elements 201-208 to eliminate unwanted current resonances on the antenna body.

[0050] *Edge-radiating Antenna*

[0051] FIG. 4 illustrates a cross section of edge-radiating antenna 400 in accordance with an embodiment. Edge-radiating antenna behaves like an edge slot antenna because the signals radiate from the edge of the antenna. The edge-radiating antenna is formed by two plates, an upper plate and a lower plate (not shown), tied together by a concentric cylinder 401 to form a short circuit. Edge-radiating antenna 400 may be modified for two band operation by adding a circular array of eight monopoles 402-409 in an array with a center mast 410 modified so no resonance occurs on the upper plate. These monopole outputs are then connected to a beam forming network (discussed infra) to obtain the omni, sine, and cosine direction finding antenna patterns. FIG. 5 illustrates a horizontal view of edge-radiating antenna 400. This view demonstrates that there is a resistor 505 disposed at the end of each of the monopole elements, for example, 402. Furthermore, this view demonstrates that there are eight feed points at the outside edge of cylinder 401 with a feed line 501 extending from the bottom edge to the top edge for each feed point. Feed point impedance is stabilized by adding left shunt resistor 502 and right shunt resistor 503 across a feed gap in the feed region. With this configuration, a bandwidth in excess of 20:1 may be achieved.

[0052] *Modified Vivaldi Biconical Structure*

[0053] In an embodiment, an antenna may be modified by adding biconical flares to increase the bandwidth even further. In one example, a bandwidth of 100:1 may be achieved at the lowest frequency of operation where the aperture is 3% of a wavelength. Edge termination is applied to the outer edges of biconical flares to achieve this wide bandwidth, along with feed structure improvements. Feed structure improvements include modification of the Vivaldi rib taper and adding a resistor to the rib termination, replacing the short circuit normally used. Also, a ferrite bead is added through the center to allow cables to pass through from top to bottom.

[0054] A typical Vivaldi launch is modified to operate below its normal cutoff frequency. The matching network is changed from a short circuit to using a high impedance resistor to replace the short circuit. This allows fields to propagate into the biconical section. The vertical height of the structure is approximately one foot, therefore an aperture termination strip using resistors in shunt with each other and spaced around the top and bottom allows the waves to propagate in and out without mismatches. At the high end of the band (30 Mhz to 3 Ghz), the resistors on the aperture are not seen by the propagating wave. The feed system is arranged internally so that the eight elements provide direction finding information to the matrix.

[0055] FIG. 6A and 6B illustrates a side view and a cross section view, respectively, of a modified Vivaldi structure 600 in accordance with an embodiment. A first resistor ring array 601 and second resistor ring array 602 comprise low frequency resistor arrays that attach to the biconical horns 603 and 604. Biconical horns 603 and 604 each include eight launching ribs 605 in a radial placement at the top of each horn 603 and 604. Each launching rib 605 includes a feed point 606 across the rib 605, which connects to the matrix via a coaxial connection. The upper cone is a mirror image of the lower cone except the coaxial inputs in the lower cone ribs are short circuits in the upper cone ribs. Each rib 605 connects to a resistor in a third resistor array 607 that is disposed between horns 603 and 604 and around an epoxy glass cylinder 608 housing a ferrite cylinder 609. Third resistor array 607 replaces the short circuit in a typical Vivaldi element and thus allows the field to propagate in the biconical structure.

[0056] In another embodiment, bicones can also be stacked vertically as shown in FIG. 7A (measurements in inches). A broader band of coverage can be achieved according to an embodiment by vertically stacking a plurality of biconical antennas, e.g., 701 and 702. Each antenna would have a mode former to which the plurality of feed elements is connected, as previously discussed herein. In one embodiment, biconical antennas 701 and 702 are stacked in conjunction with edge-radiating antenna 703, previously described with reference to FIGS. 4 and 5. FIG. 7B illustrates another embodiment in which biconical antennas 701 and 702 are stacked in conjunction with a stacked Modified Vivaldi array 705, previously described with reference to FIGS. 6A and 6B, and further in conjunction with a dipole array antenna 707, previously described with reference to FIGS. 1-3. In one embodiment, high frequency direction finding component 709 is also included. Vertically stacking a plurality of such antennas provides direction-finding accuracy over a broad frequency range, since each antenna is designed to accommodate a particular frequency range.

[0057] *Direction Finding Matrix*

[0058] In one embodiment, the beam forming network for a circular direction finding array consists of 8 antenna array elements on the input and three antenna patterns at the output. The input array element patterns are equal amplitude and circularly disposed around the array. The input array elements may be dipoles, monopoles, Vivaldi elements, or any other type of element suitable for summing.

[0059] The output antenna patterns are omni, sine, and cosine patterns. The omni pattern is the sum of all 8 elements. The sine and cosine patterns are the difference of opposed sums of elements (opposite pairs), as explained below. The sine and cosine patterns provide for angularly offset patterns in amplitude and phase, whereas the omni pattern is of uniform amplitude and phase about the circular array.

[0060] Instead of the 4x3 beam finding matrix typically used, this embodiment includes an 8x3 matrix. The sine, cosine, and omni outputs allow the voltage vectors to analyzed to determine direction of arrival. Information appears at each port of the matrix instantaneously. Thus, the matrix can find signals that are only on for short periods of time. This embodiment does not need to store information to process the signals for direction finding.

[0061] FIG. 8 illustrates a block diagram of the beam finding matrix in accordance with an embodiment. Elements A-H represent the circular array of 8 antenna elements, where the angle of elements A-H is as follows: A = 0°, B = 45°, C = 90°, D =135°, E =180°, F = 225°, G = 270°, and H = 315°. Elements A and B are summed by power divider 801, elements E and F are summed by power divider 802, elements C and D are summed by power divider 803, and elements G and H are summed by power divider 804. Next, 0/180 hybrid element 805 produces a sum and delta (difference) signal for the A+B signal and the E+F signal, the delta of which is the cosine pattern COS = (A+B) – (E+F). This produces a null position halfway between signals, i.e., 180°. Then, 0/180 hybrid element 806 produces a sum and delta signal for the C+D signal and the G+H signal, the delta of which is the sine pattern SIN = (C+D) – (G+H). This produces a second null position halfway between the other null position, thus creating a 90° space. The sum signals of the 0/180 hybrid elements 805 and 806 are then summed by power divider 807 to produce the omni pattern OMNI = (A+B) + (E+F) + (C+D) + (G+H). The magnitude indicates the direction and the phase indicates the quadrant, thus allowing direction finding.

[0062] *On the Move ("OTM")*

[0063] Typical OTM antennas use monopole elements. In this case, whatever the OTM antenna is mounted on becomes part of the antenna. In one embodiment, monopoles are made to look like dipoles electrically so that the object the OTM is mounted on is no longer part of the antenna. An OTM in accordance with this embodiment may be mounted on a vehicle, boat, or aircraft. An OTM in accordance with this embodiment may operate at 30 MHz, while only being 31 inches in length.

[0064] FIG. 9 illustrates an OTM antenna 900 in accordance with an embodiment. OTM antenna 900 includes dipole elements 901, 902, and two other dipole elements that are not shown in this view. Dipole element 901 is shown in cross section, while dipole element 902 is show as an exterior view. The dipole elements include a feed point 903 located 26 inches from base 904. A large ferrite 905 is located at the base 904. In one embodiment, a resistor insert 906 is located approximately 7 inches from base 904. A small ferrite 907 is disposed between resistor insert 906 and matching section 908. In one embodiment, a second resistor insert is located approximately 2 inches from the end of dipole 901. The dipole elements feed into a 4x3 direction finding matrix 910. By adding the ferrites and suppressing currents in the base 904 and cables (not shown), the antenna impedance is isolated. This method of isolation allows for a much shorter height than OTM antennas of the prior art.

[0065] *Experimental Data*

[0066] FIGS. 10-3 illustrate example pattern data acquired from various embodiments of antennas discussed above. FIG. 10 illustrates OMNI pattern angle data from an edge-radiating antenna such as edge-radiating antenna 400 discussed above. FIG. 11 illustrates OMNI pattern frequency gain data from an edge-radiating antenna such as edge-radiating antenna 400 discussed above. FIG. 12 illustrates OMNI pattern frequency deviation data from an edge-radiating antenna such as edge-radiating antenna 400 discussed above. FIG. 13 illustrates COSINE pattern angle data from an edge-radiating antenna such as edge-radiating antenna 400 discussed above. FIG. 14 illustrates COSINE pattern frequency gain data from an edge-radiating antenna such as edge-radiating antenna 400 discussed above. FIG. 15 illustrates COSINE pattern null depth data from an edge-radiating antenna such as edge-radiating antenna 400 discussed above. FIG. 16 illustrates SINE pattern angle data from an edge-radiating antenna such as edge-radiating antenna 400 discussed above. FIG. 17 illustrates SINE pattern frequency gain data from an edge-radiating antenna such as edge-radiating antenna 400 discussed above. FIG. 18 illustrates SINE pattern null depth data from an edge-radiating antenna such as edge-radiating antenna 400 discussed above.

[0067] FIG. 19 illustrates OMNI pattern angle data from a modified Vivaldi biconical antenna such as modified Vivaldi biconical antenna 600 discussed above. FIG. 20 illustrates OMNI pattern frequency gain data from a modified Vivaldi biconical antenna such as modified Vivaldi biconical antenna 600 discussed above. FIG. 21 illustrates SINE pattern frequency gain data from a modified Vivaldi biconical antenna such as modified Vivaldi biconical antenna 600 discussed above. FIG. 22 illustrates SINE pattern angle data from a modified Vivaldi biconical antenna such as modified Vivaldi biconical antenna 600 discussed above. FIG. 23 illustrates SINE/COSINE null orthogonality data from a modified Vivaldi biconical antenna such as modified Vivaldi biconical antenna 600 discussed above. FIG. 24 illustrates COSINE pattern angle data from a modified Vivaldi biconical antenna such as modified Vivaldi biconical antenna 600 discussed above. FIG. 25 illustrates COSINE pattern frequency gain data from a modified Vivaldi biconical antenna such as modified Vivaldi biconical antenna 600 discussed above.

[0068] FIG. 26 illustrates COSINE pattern frequency gain data from an OTM antenna such as OTM antenna 900 discussed above. FIG. 27 illustrates OMNI pattern frequency gain data from an OTM antenna such as OTM antenna 900 discussed above. FIG. 28 illustrates SINE pattern angle data from an OTM antenna such as OTM antenna 900 discussed above. FIG. 29 illustrates SINE pattern frequency gain data from an OTM antenna such as OTM antenna 900 discussed above. FIG. 30 illustrates COSINE pattern angle data from an OTM antenna such as OTM antenna 900 discussed above.

[0069] While several embodiments of the invention have been described, it will be understood that it is capable of further modifications, and this application is intended to cover any variations, uses, or adaptations of the invention, following in general the principles of the invention and including such departures from the present disclosure as to come within knowledge or customary practice in the art to which the invention pertains, and as may be applied to the essential features hereinbefore set forth and falling within the scope of the invention or the limits of the appended claims.

WHAT IS CLAIMED IS:

1. A direction-finding antenna with electronics for receiving radio signals in a frequency range of about 2 megaHertz to about 18 gigaHertz, said direction-finding antenna comprising:

an edge-radiating antenna comprising a first plate and a second plate disposed parallel to each other and radiating into open space, a concentric cylinder connecting the first plate to the second plate, eight feed points disposed equally around the outside of the concentric cylinder with eight feed lines extending from the first plate to the second plate, and a shunt resistor across each feed gap, wherein the eight feed lines are electrically coupled to a first beam forming matrix that finds a direction of a beam;

a monopole array comprising eight monopole elements connected to a first center mast, wherein the monopole array is disposed inside the concentric cylinder and resistively modified such that no resonance occurs, and wherein the eight monopole elements are electrically coupled to a second beam forming matrix that finds a direction of a beam;

a dipole array comprising eight dipole elements connected to a second center mast, wherein each of the eight dipole elements is resistively loaded to increase bandwidth, and wherein the eight dipole elements are electrically coupled to a third beam forming matrix that finds a direction of a beam; and

a first and second biconical horn housing the edge-radiating antenna and dipole array, respectively, the first and second biconical horn each comprising eight ribs connecting a top horn to a bottom horn, wherein the eight ribs are electrically couple to a high impedance resistor disposed at the center of the biconical horn.

2. The direction finding antenna of claim 1, wherein the direction finding antenna is modular such that the edge-radiating antenna may be decoupled from the dipole array.

3. The direction finding antenna of claim 1, wherein the top horn and bottom horn of the first and second biconical horns each includes a base having an aperture termination including resistors in shunt with each other.

4. The direction finding antenna of claim 1, wherein the second center mast includes a plurality of resistors disposed on the mast to prevent resonance.

5. The direction finding antenna of claim 1, wherein the first, second and third beam forming matrices each comprise:

eight inputs;

a sine pattern output;

a cosine pattern output; and

an omni directional pattern output.

6. The direction finding antenna of claim 5, wherein the eight inputs include inputs A, B, C, D, E, F, G and H, and the sine pattern equals (input C + input D) – (input G + input H).

7. The direction finding antenna of claim 5, wherein the eight inputs include inputs A, B, C, D, E, F, G and H, and the cosine pattern equals (input A + input B) – (input E + input F).

8. The direction finding antenna of claim 5, wherein the omni directional pattern is

the sum of the eight inputs.

9. The direction finding antenna of claim 5, wherein the sine, cosine, and omni directional patterns are used to calculate a direction of a beam.

10. A direction finding edge-radiating antenna comprising:

a first plate and a second plate disposed parallel to each other and radiating into open space;

a concentric cylinder connecting the first plate to the second plate;

eight feed points disposed equally around the outside of the concentric cylinder with eight feed lines extending from the first plate to the second plate; and

a shunt resistor across each feed gap, wherein the eight feed lines are electrically coupled to a first beam forming matrix that finds a direction of a beam.

11. The direction finding edge-radiating antenna of claim 10, wherein the concentric cylinder houses a monopole array comprising eight monopole elements connected to a center mast, wherein the monopole array is resistively modified such that no resonance occurs, and wherein the eight monopole elements are electrically coupled to a second beam forming matrix that finds a direction of a beam.

12. The direction finding edge-radiating antenna of claim 10, wherein the first and second beam forming matrices each comprise:

eight inputs;

a sine pattern output;

a cosine pattern output; and

an omni directional pattern output.

13. The direction finding edge-radiating antenna of claim 12, wherein the eight inputs include inputs A, B, C, D, E, F, G and H, and the sine pattern equals (input C + input D) – (input G + input H).

14. The direction finding edge-radiating antenna of claim 12, wherein the eight inputs include inputs A, B, C, D, E, F, G and H, and the cosine pattern equals (input A + input B) – (input E + input F).

15. The direction finding edge-radiating antenna of claim 12, wherein the omni directional pattern is the sum of the eight inputs.

16. The direction finding edge-radiating antenna of claim 12, wherein the sine, cosine, and omni directional patterns are used to calculate a direction of a beam.

17. A direction finding antenna, comprising:

a dipole array comprising eight dipole elements connected to a center mast, wherein each of the eight dipole elements is resistively loaded to increase bandwidth; and

a beam forming matrix that finds a direction of a beam electrically coupled to the dipole array.

18. The direction finding antenna of claim 17, wherein the center mast includes a

plurality of resistors disposed on the mast to prevent resonance.

19. The direction finding antenna of claim 17, wherein each dipole element is disposed one quarter wavelength away from the center mast at the highest operating frequency and one half wavelength apart on the circumference of the array.

20. The direction finding edge-radiating antenna of claim 17, wherein the beam forming matrix comprises:

eight inputs;

a sine pattern output;

a cosine pattern output; and

an omni directional pattern output.

21. The direction finding edge-radiating antenna of claim 20, wherein the eight inputs include inputs A, B, C, D, E, F, G and H, and the sine pattern equals (input C + input D) – (input G + input H).

22. The direction finding edge-radiating antenna of claim 20, wherein the eight inputs include inputs A, B, C, D, E, F, G and H, and the cosine pattern equals (input A + input B) – (input E + input F).

23. The direction finding edge-radiating antenna of claim 20, wherein the omni directional pattern is the sum of the eight inputs.

24. The direction finding edge-radiating antenna of claim 12, wherein the sine, cosine, and omni directional patterns are used to calculate a direction of a beam.

25. A biconical horn antenna, comprising:

an antenna;

a top horn;

a bottom horn;

eight ribs connecting a top horn to a bottom horn, wherein the eight ribs are electrically couple to a high impedance resistor disposed at the center of the biconical horn antenna.

26. The biconical horn antenna of claim 25, wherein the top horn and bottom horn of the each includes a base having an aperture termination comprising resistors in shunt with each other.

27. An On-the-Move antenna, comprising:

a base;

four monopole elements attached to the base, each monopole element including ferrite beads between a feed point and the base;

a beam forming matrix electrically coupled to the four monopole elements, wherein the beam forming matrix determines a direction of a signal.

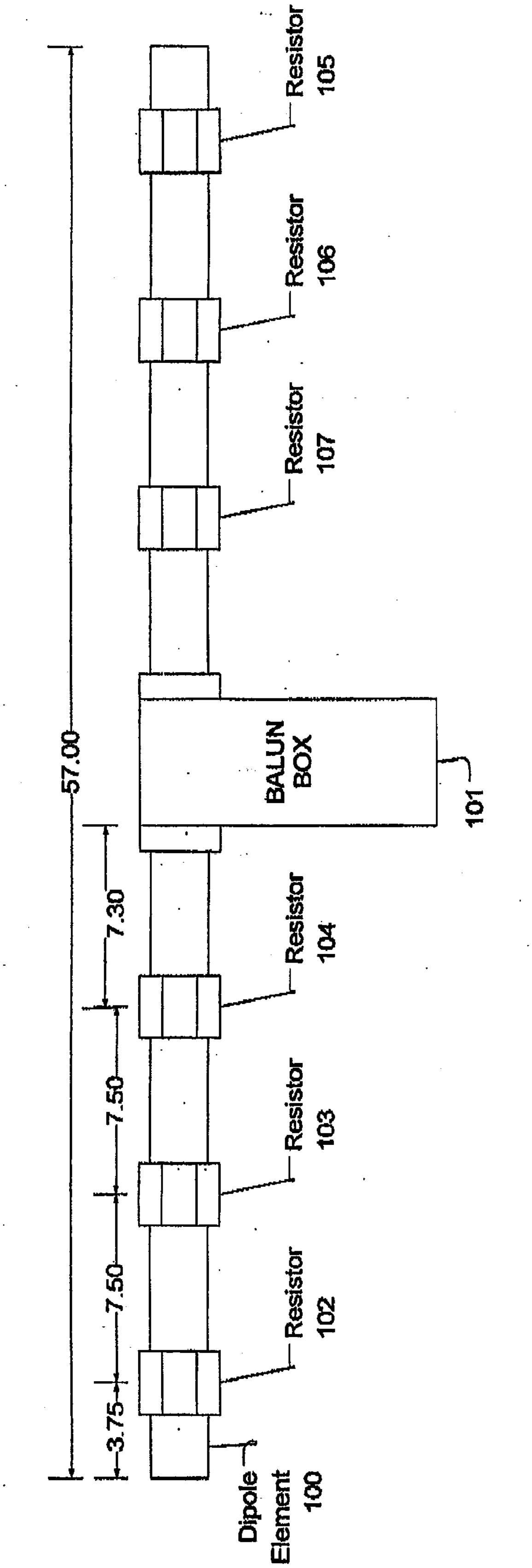

Resistor 105
Resistor 106
Resistor 107
BALUN BOX
101
57.00
7.30
Resistor 104
7.50
Resistor 103
7.50
Resistor 102
3.75
Dipole Element 100

Figure 1

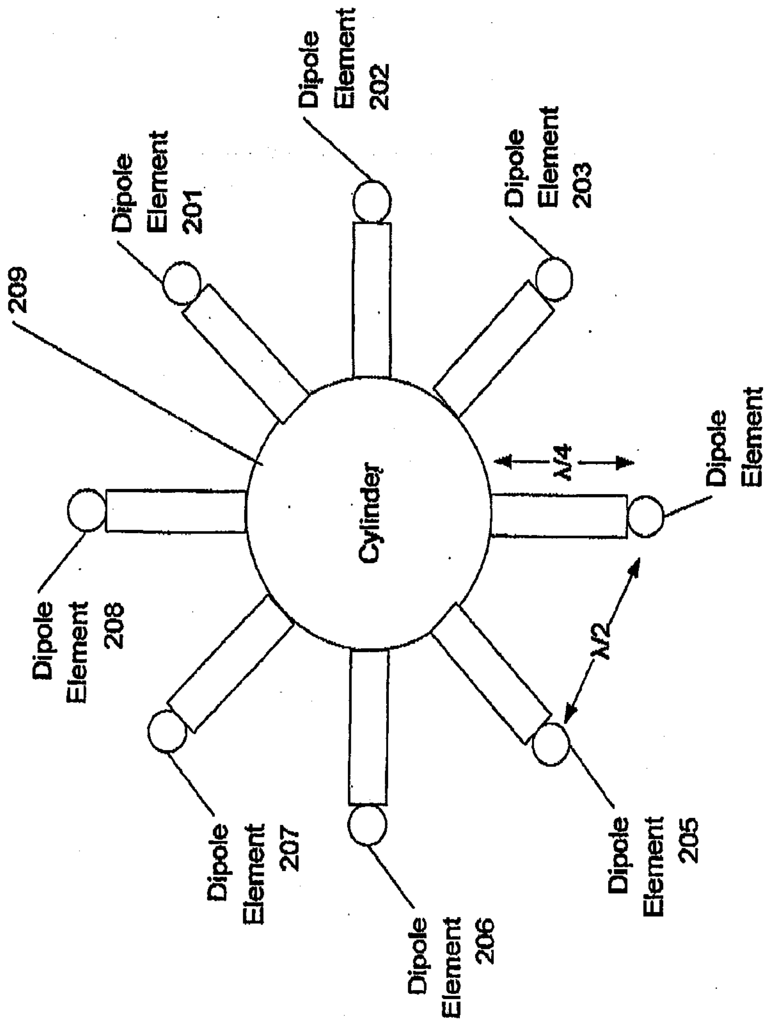

Dipole Element 201
Dipole Element 202
Dipole Element 203
Dipole Element 204
Dipole Element 205
Dipole Element 206
Dipole Element 207
Dipole Element 208
209
Cylinder
λ/4
λ/2

Figure 2

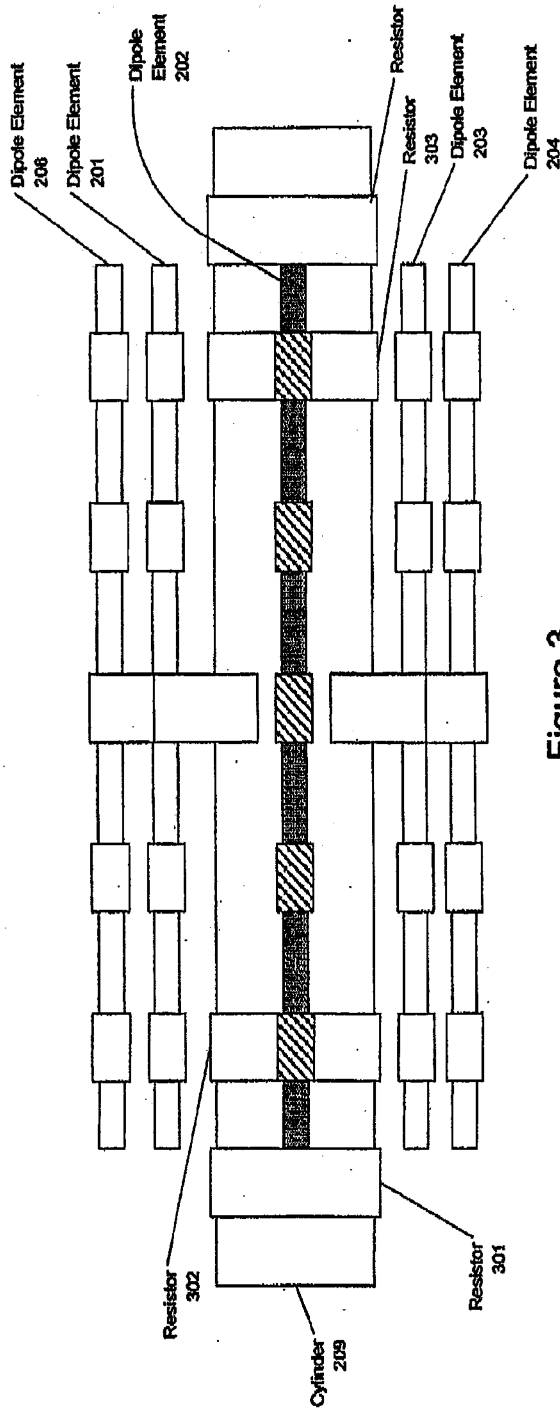

Dipole Element 206
Dipole Element 201
Dipole Element 202
Resistor
Resistor 303
Dipole Element 203
Dipole Element 204
Resistor 302
Cylinder 209
Resistor 301

Figure 3

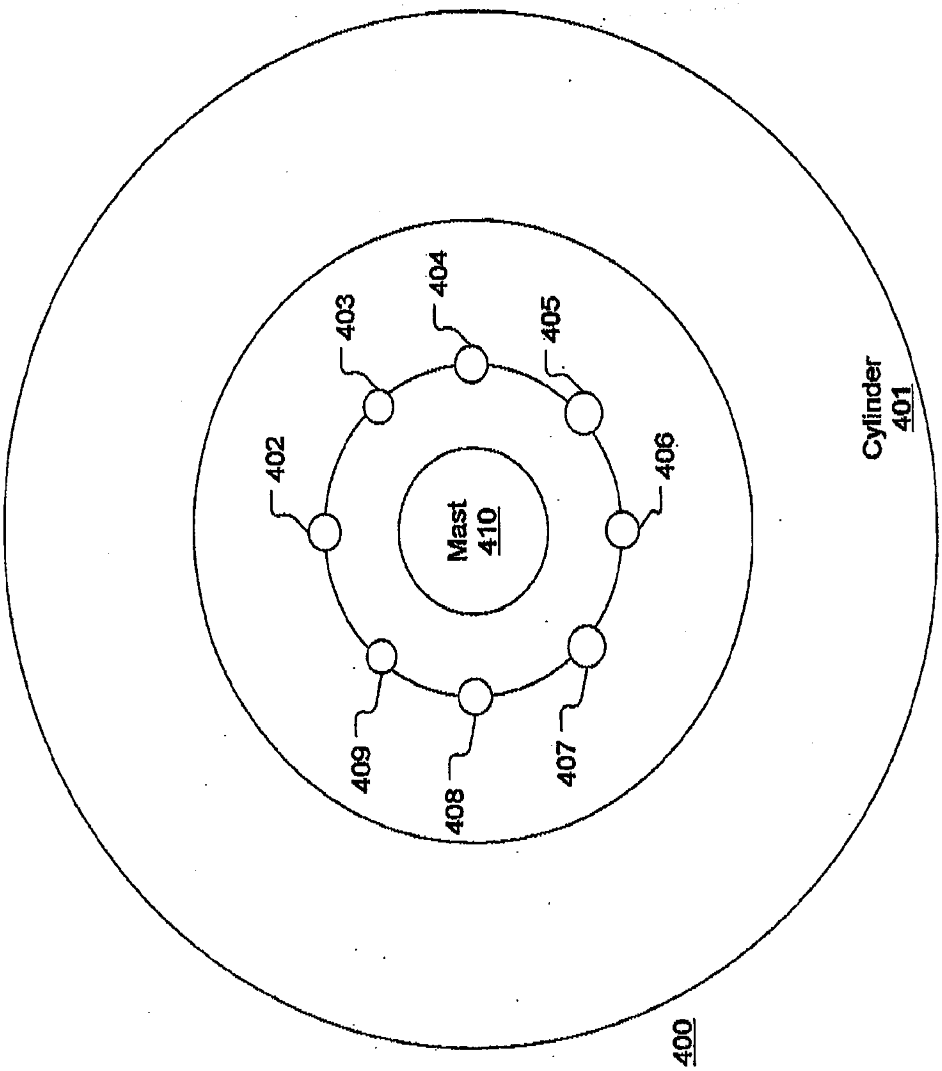


Figure 4

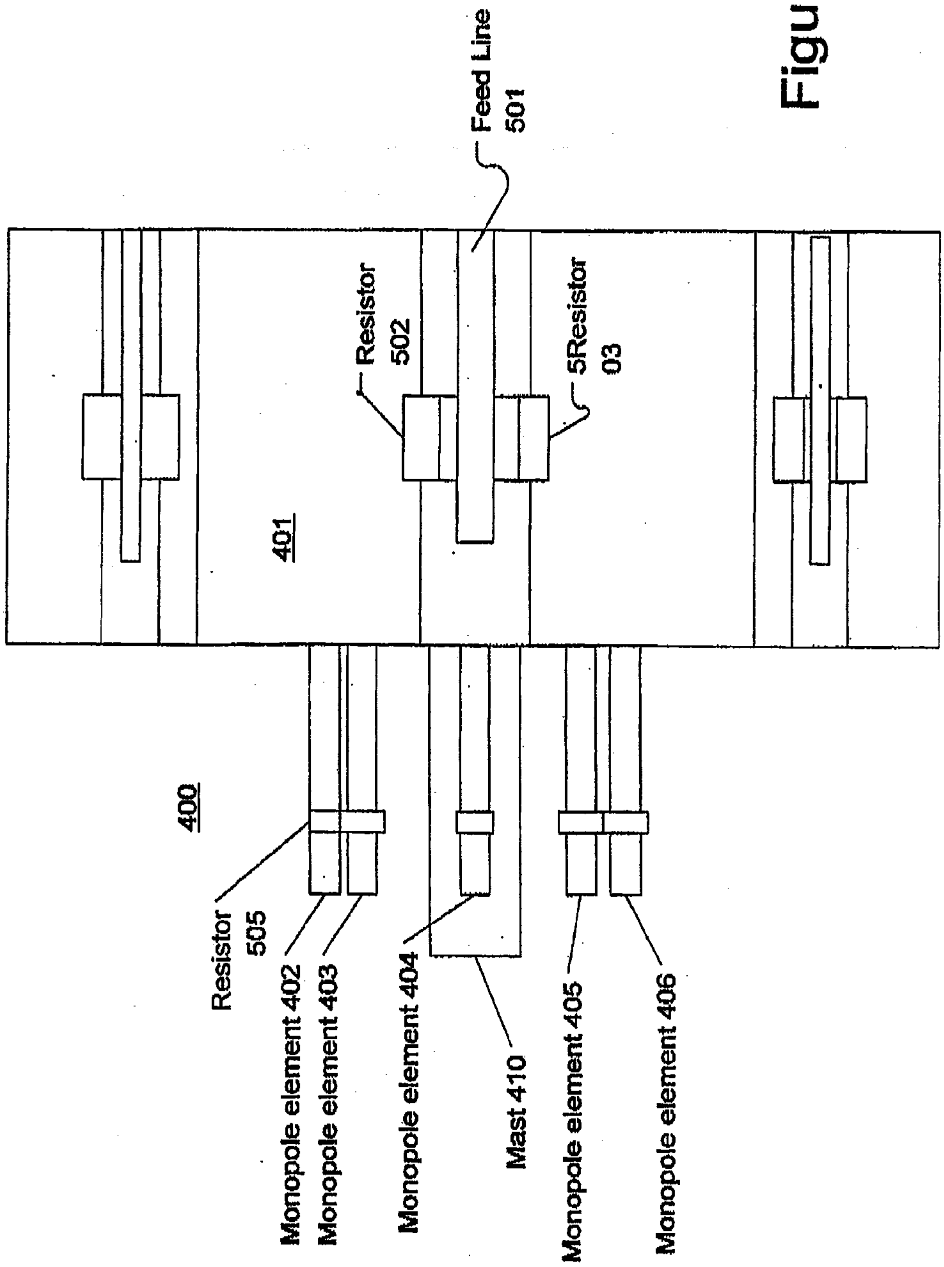

Feed Line
501
Resistor
502
5Resistor
03
401
400
Resistor
505
Monopole element 402
Monopole element 403
Monopole element 404
Mast 410
Monopole element 405
Monopole element 406

Figure 5

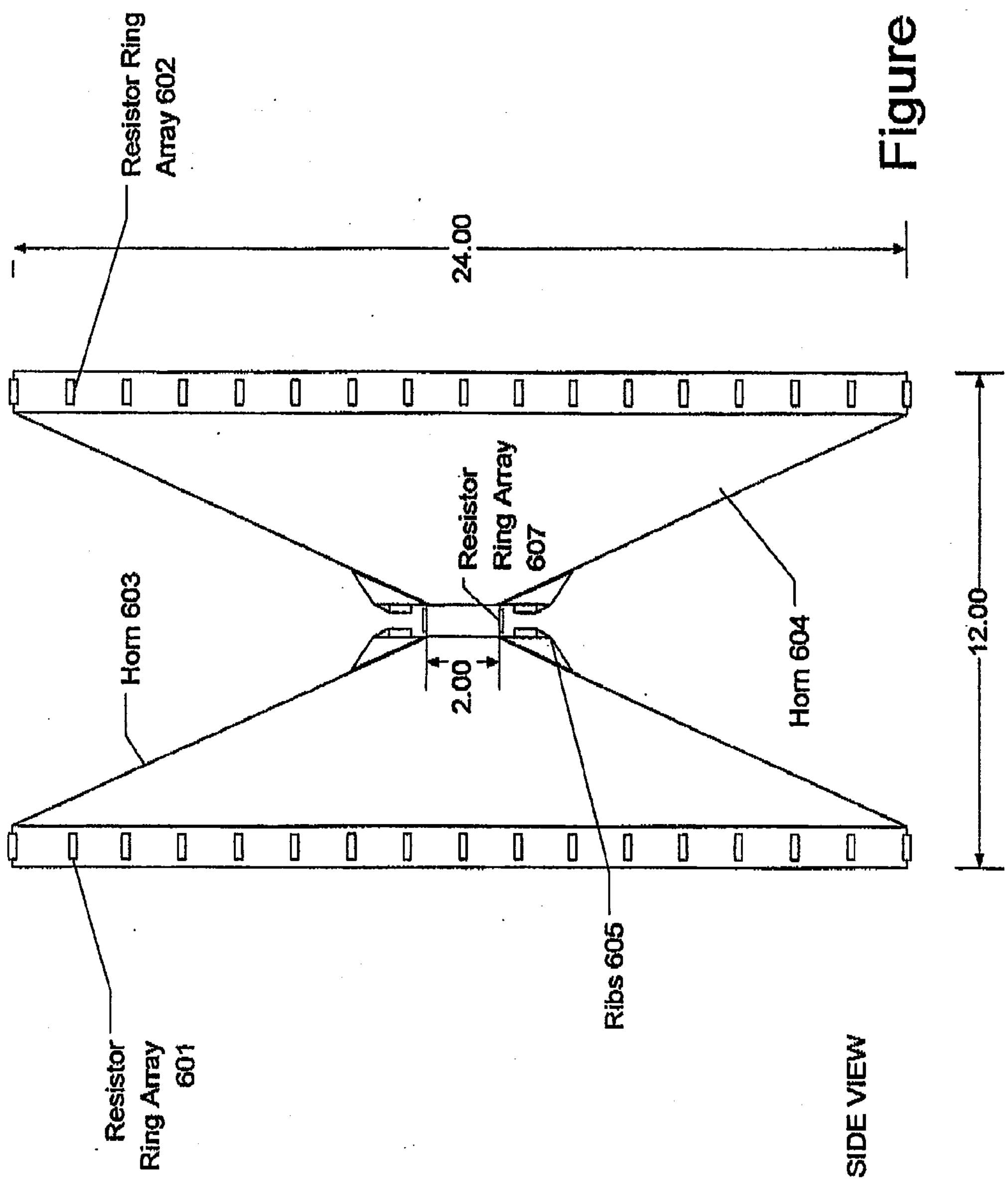

Resistor Ring Array 602
24.00
Resistor Ring Array 607
Horn 603
Horn 604
2.00
12.00
Ribs 605
Resistor Ring Array 601
SIDE VIEW

Figure 6A

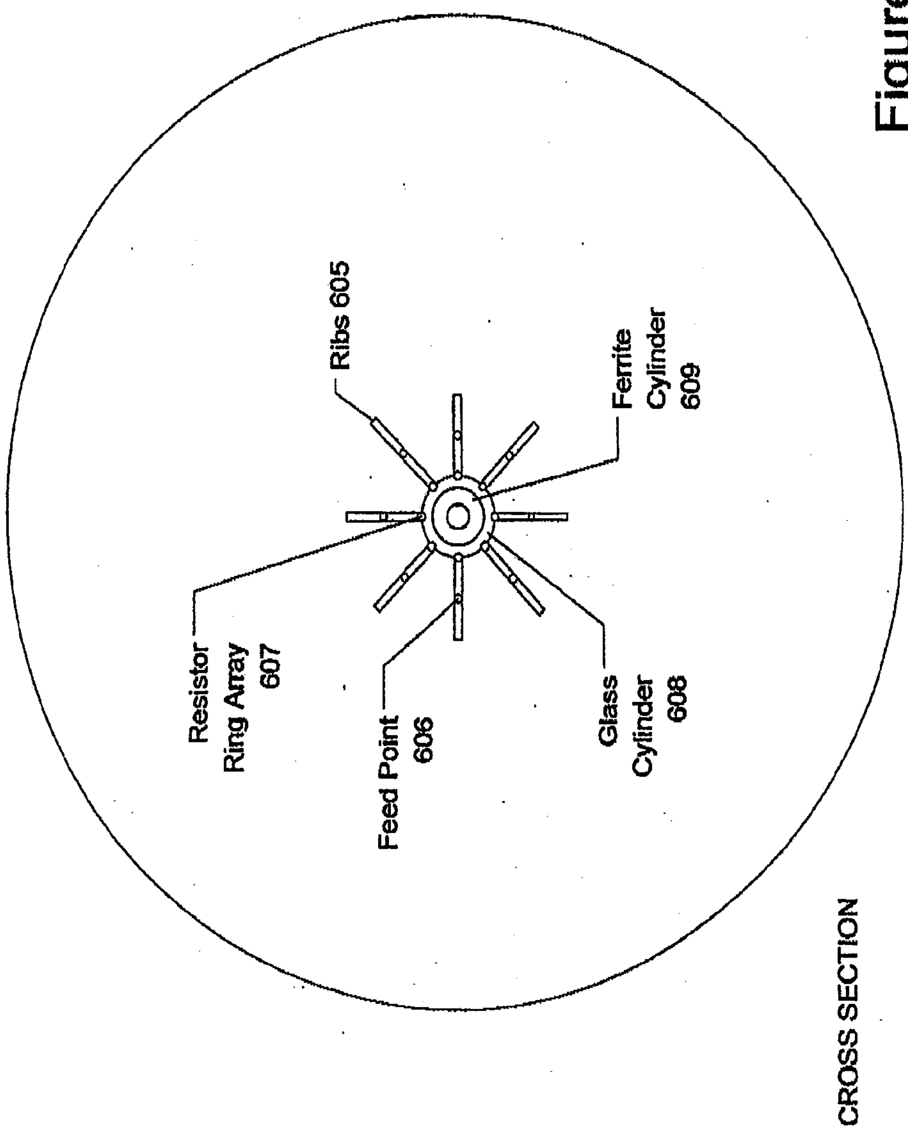

Ribs 605
Ferrite Cylinder 609
Resistor Ring Array 607
Feed Point 606
Glass Cylinder 608
CROSS SECTION

Figure 6B

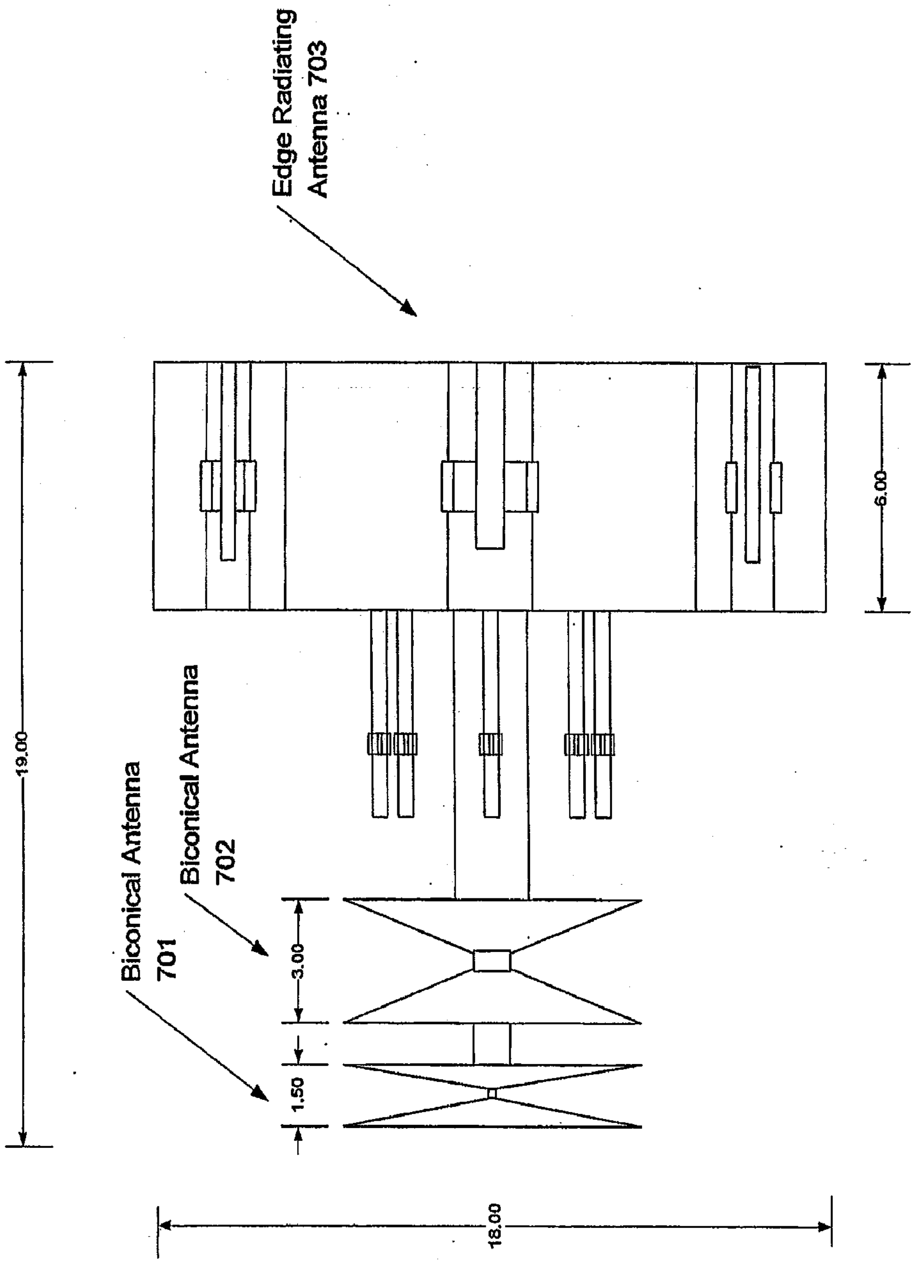

Edge Radiating Antenna 703
Biconical Antenna 702
Biconical Antenna 701
19.00
6.00
3.00
1.50
18.00

Figure 7A

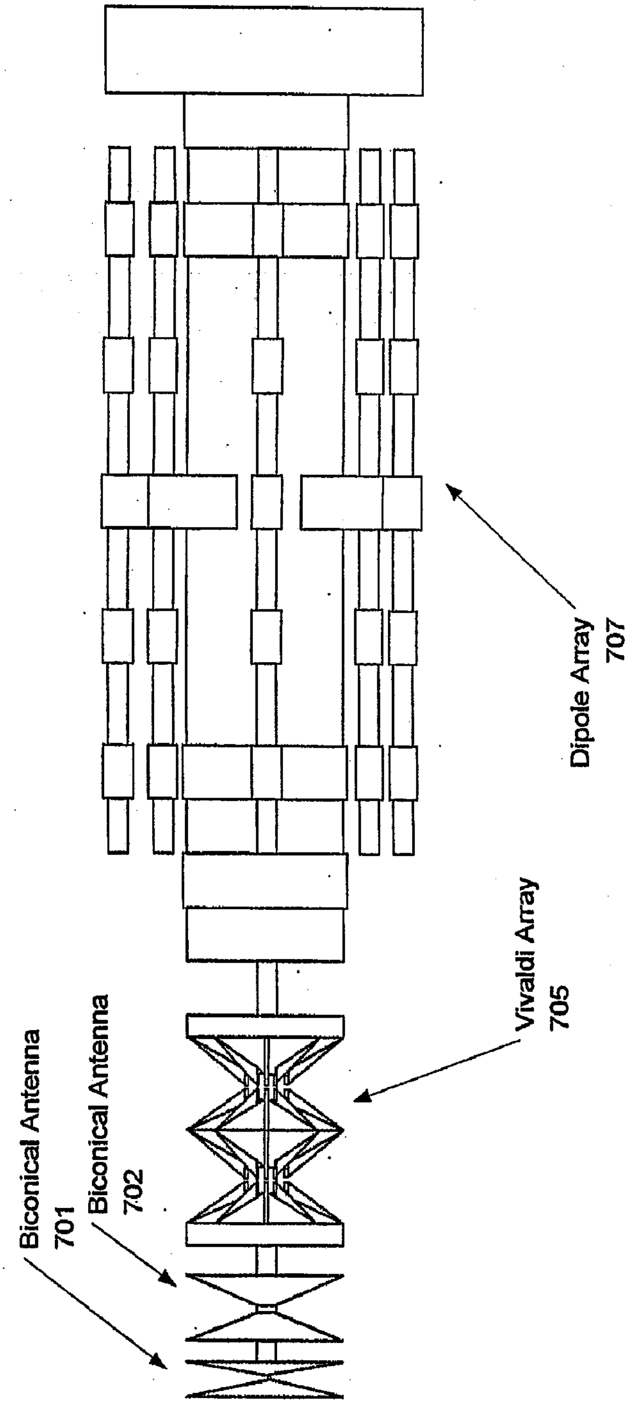

Dipole Array
707
Vivaldi Array
705
Biconical Antenna
701
Biconical Antenna
702

Figure 7B

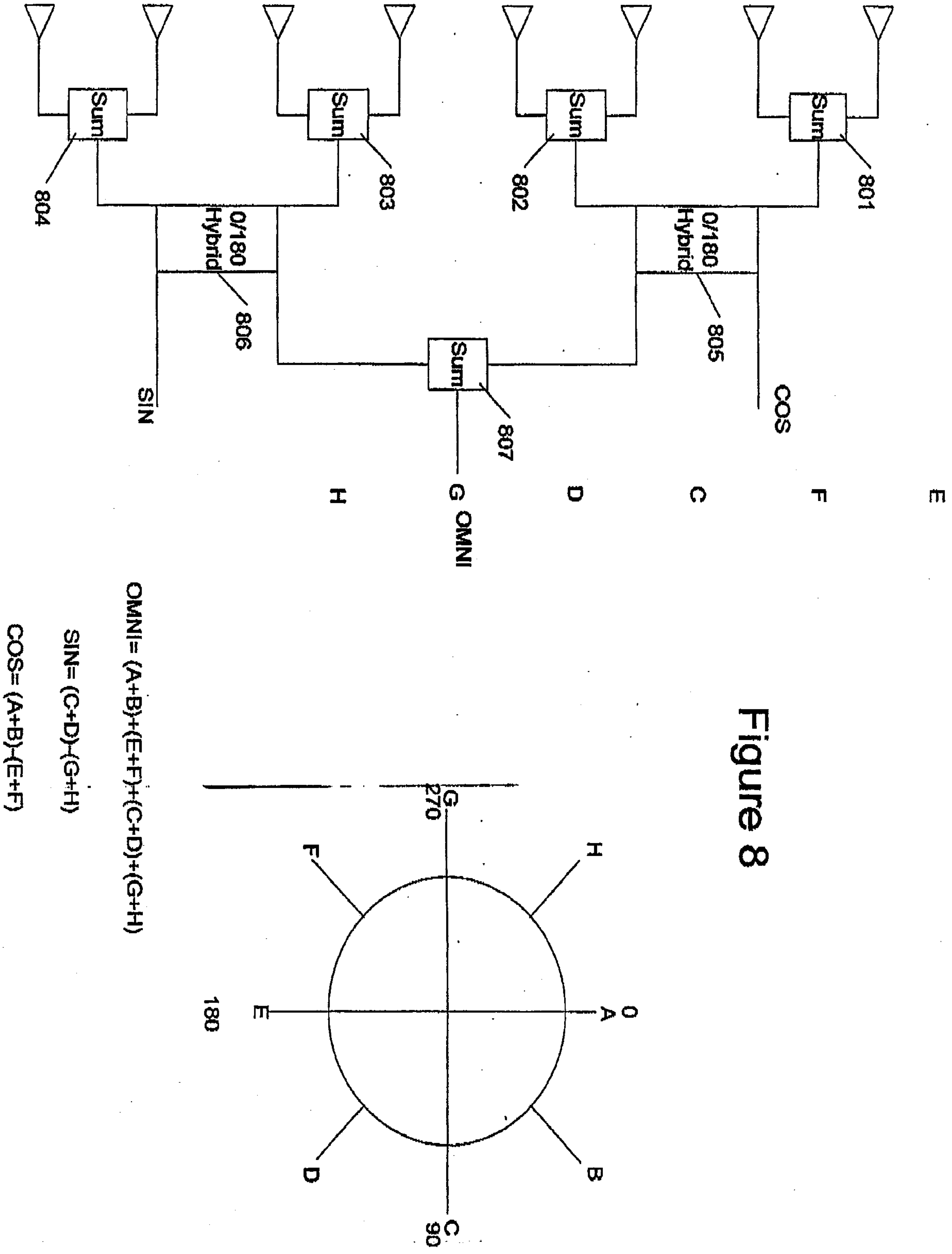

Sum
801
802
803
804
0/180 Hybrid
805
806
Sum
807
COS
SIN
E
F
C
D
G OMNI
H
OMNI= (A+B)+(E+F)+(C+D)+(G+H)
SIN= (C+D)-(G+H)
COS= (A+B)-(E+F)
0
A
B
90
C
D
180
E
F
270
G
H

Figure 8

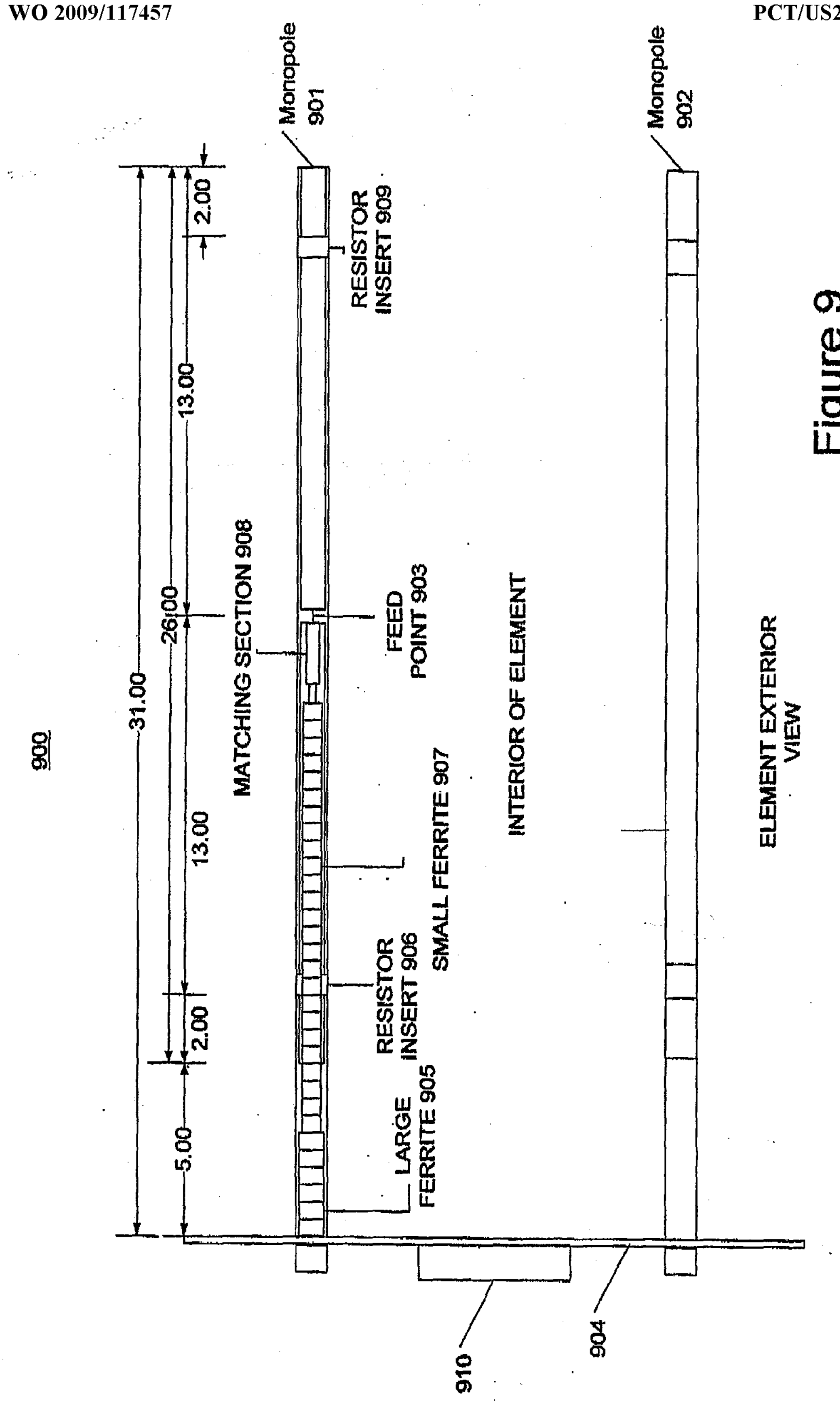

900
Monopole 901
Monopole 902
2.00
13.00
26.00
31.00
13.00
2.00
5.00
RESISTOR INSERT 909
MATCHING SECTION 908
FEED POINT 903
INTERIOR OF ELEMENT
SMALL FERRITE 907
RESISTOR INSERT 906
LARGE FERRITE 905
ELEMENT EXTERIOR VIEW
910
904

Figure 9

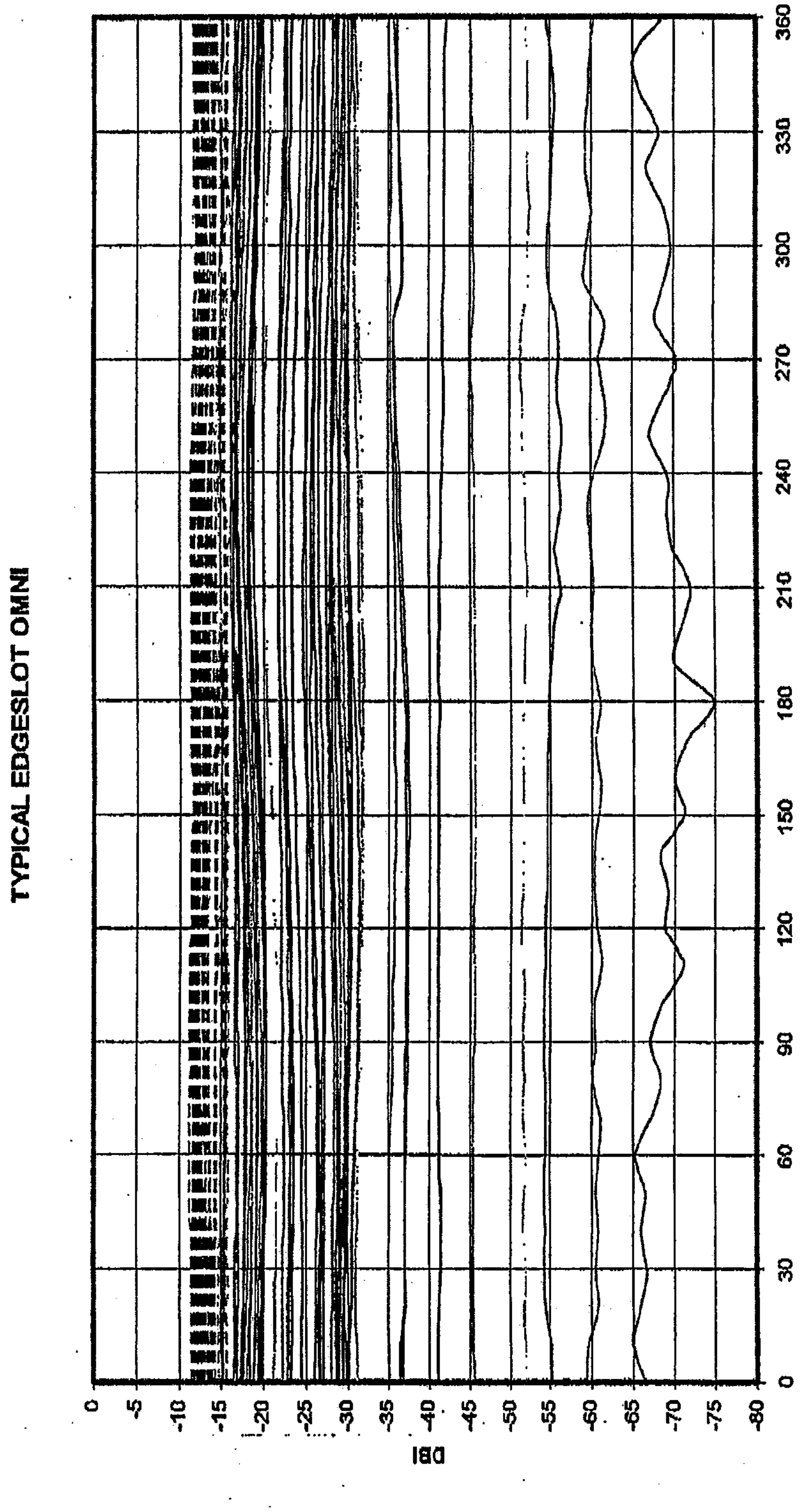

TYPICAL EDGESLOT OMNI
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
DBI
0
30
60
90
120
150
180
210
240
270
300
330
360
ANGLE

Figure 10

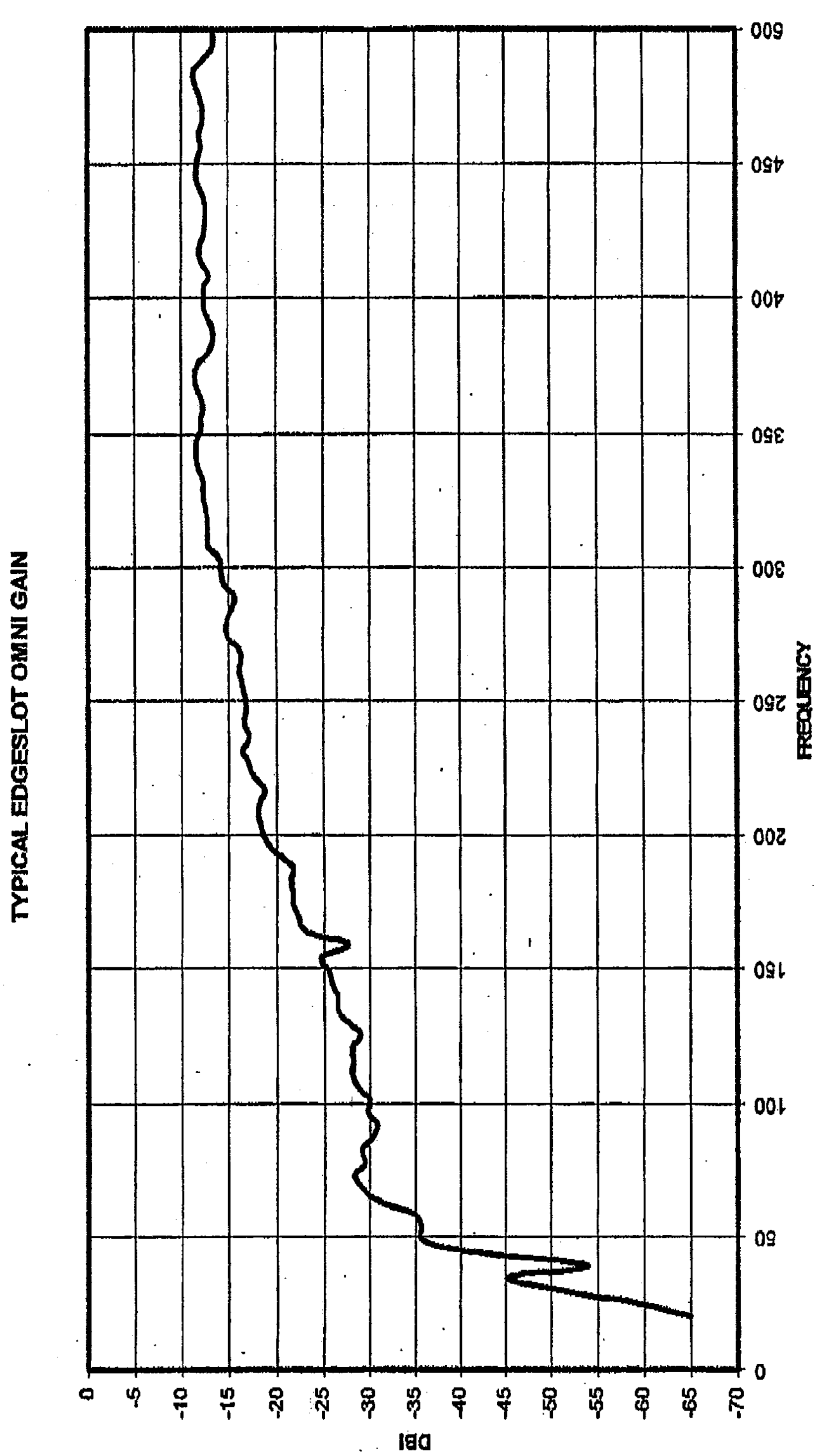

TYPICAL EDGESLOT OMNI GAIN
DBI
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
FREQUENCY
0
50
100
150
200
250
300
350
400
450
500

Figure 11

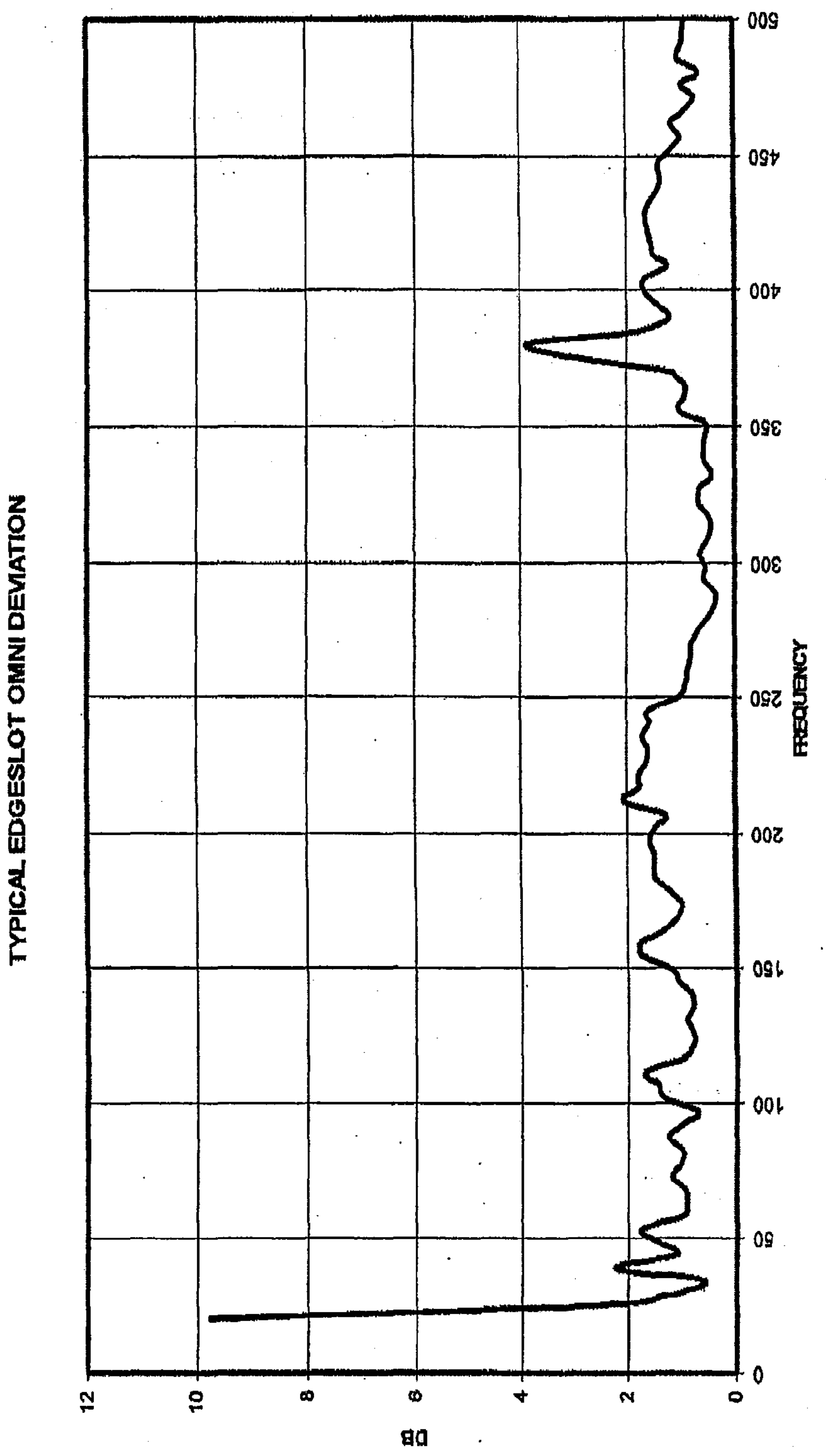

TYPICAL EDGESLOT OMNI DEVIATION
DB
12
10
8
6
4
2
0
50
100
150
200
250
300
350
400
450
500
FREQUENCY

Figure 12

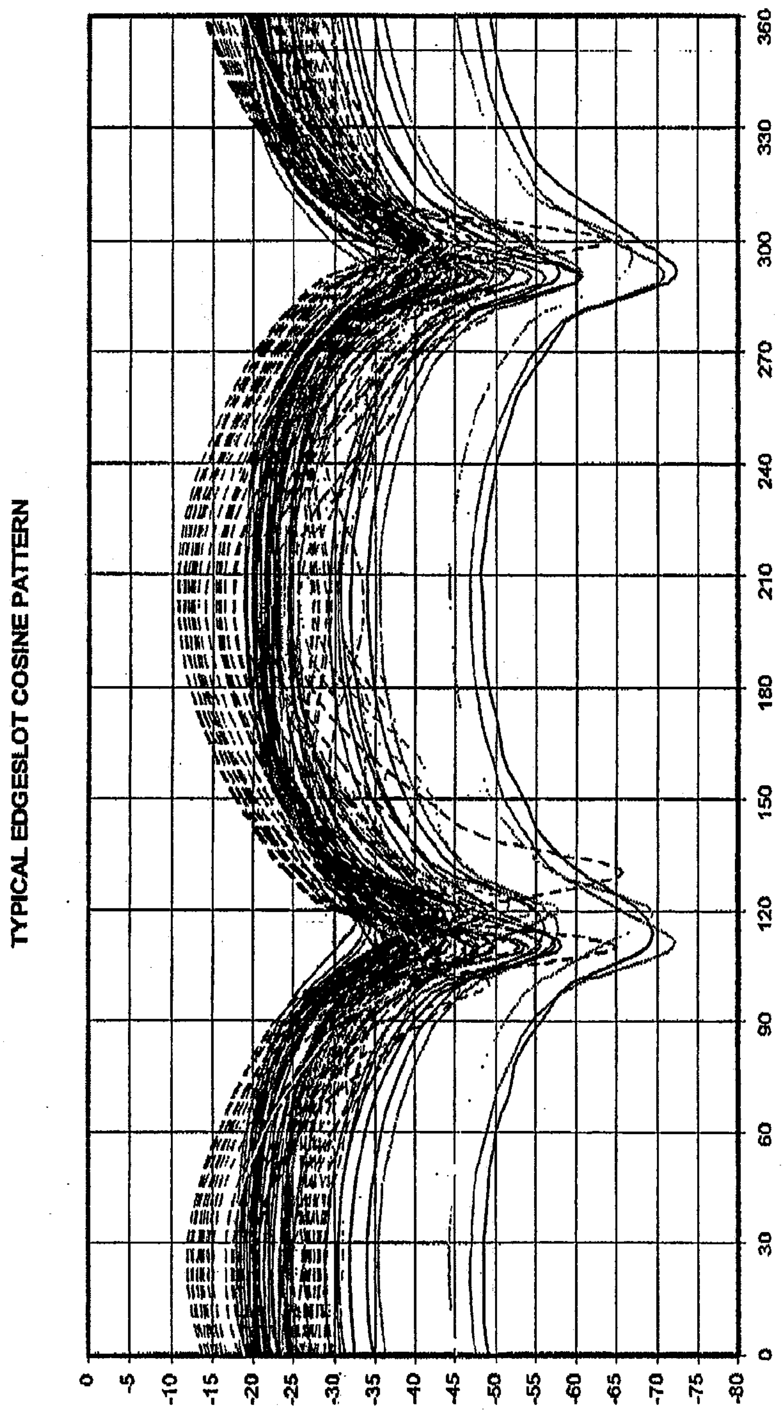

TYPICAL EDGESLOT COSINE PATTERN
DBI
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
ANGLE
0
30
60
90
120
150
180
210
240
270
300
330
360

Figure 13

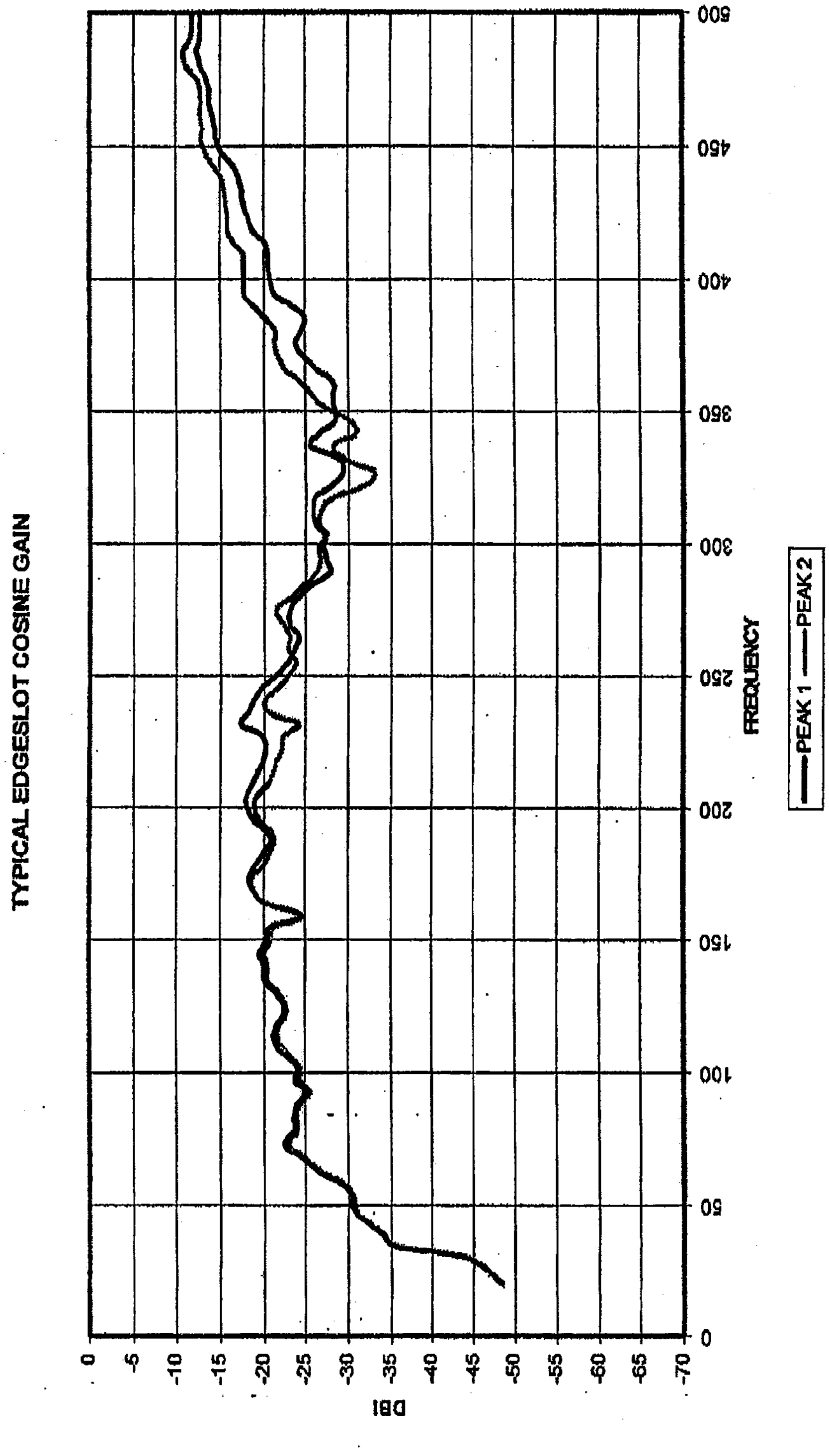

TYPICAL EDGESLOT COSINE GAIN
DBI
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
FREQUENCY
0
50
100
150
200
250
300
350
400
450
500
PEAK 1
PEAK 2

Figure 14

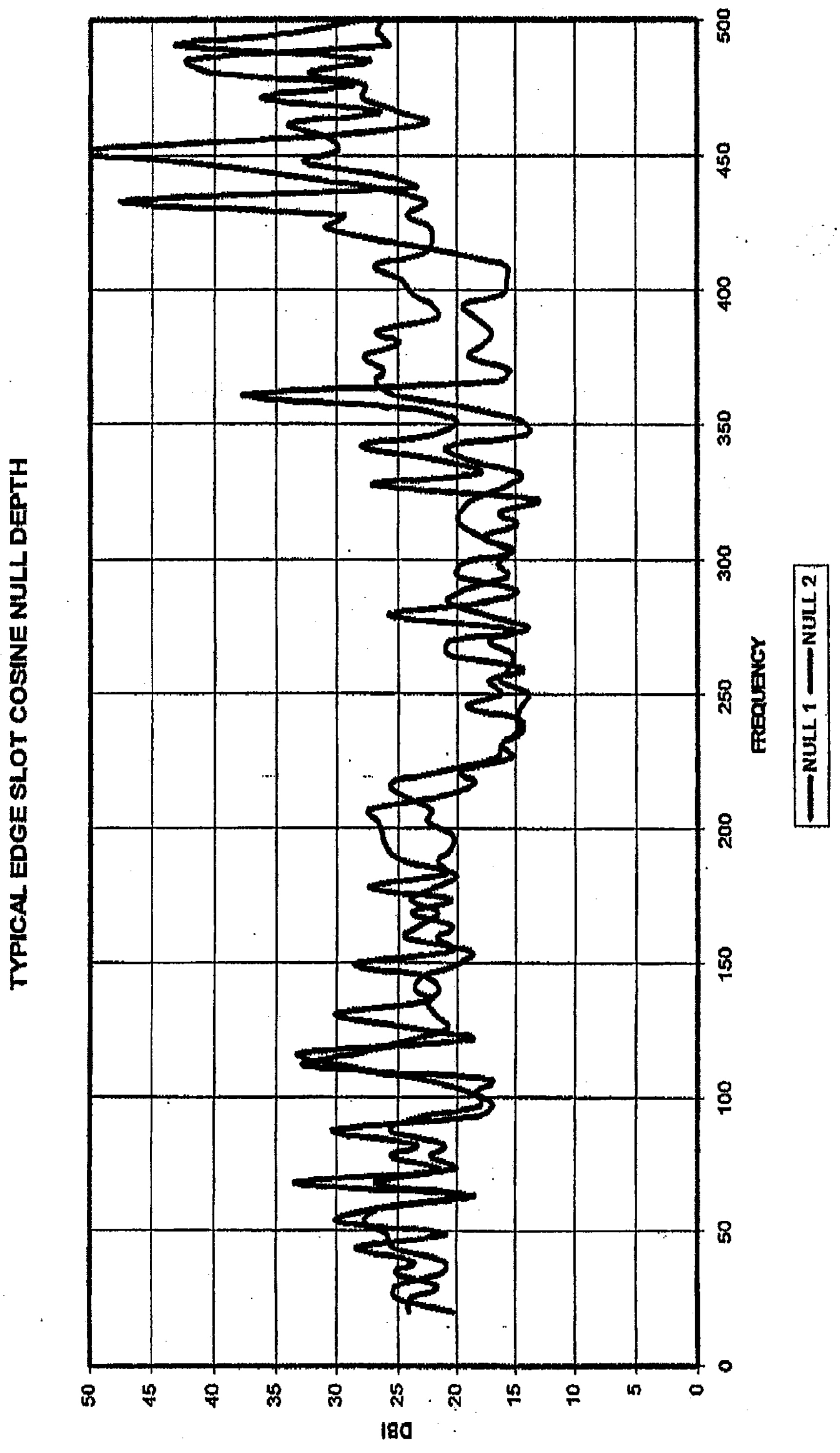

TYPICAL EDGE SLOT COSINE NULL DEPTH
DBI
50
45
40
35
30
25
20
15
10
5
0
FREQUENCY
0
50
100
150
200
250
300
350
400
450
500
NULL 1
NULL 2

Figure 15

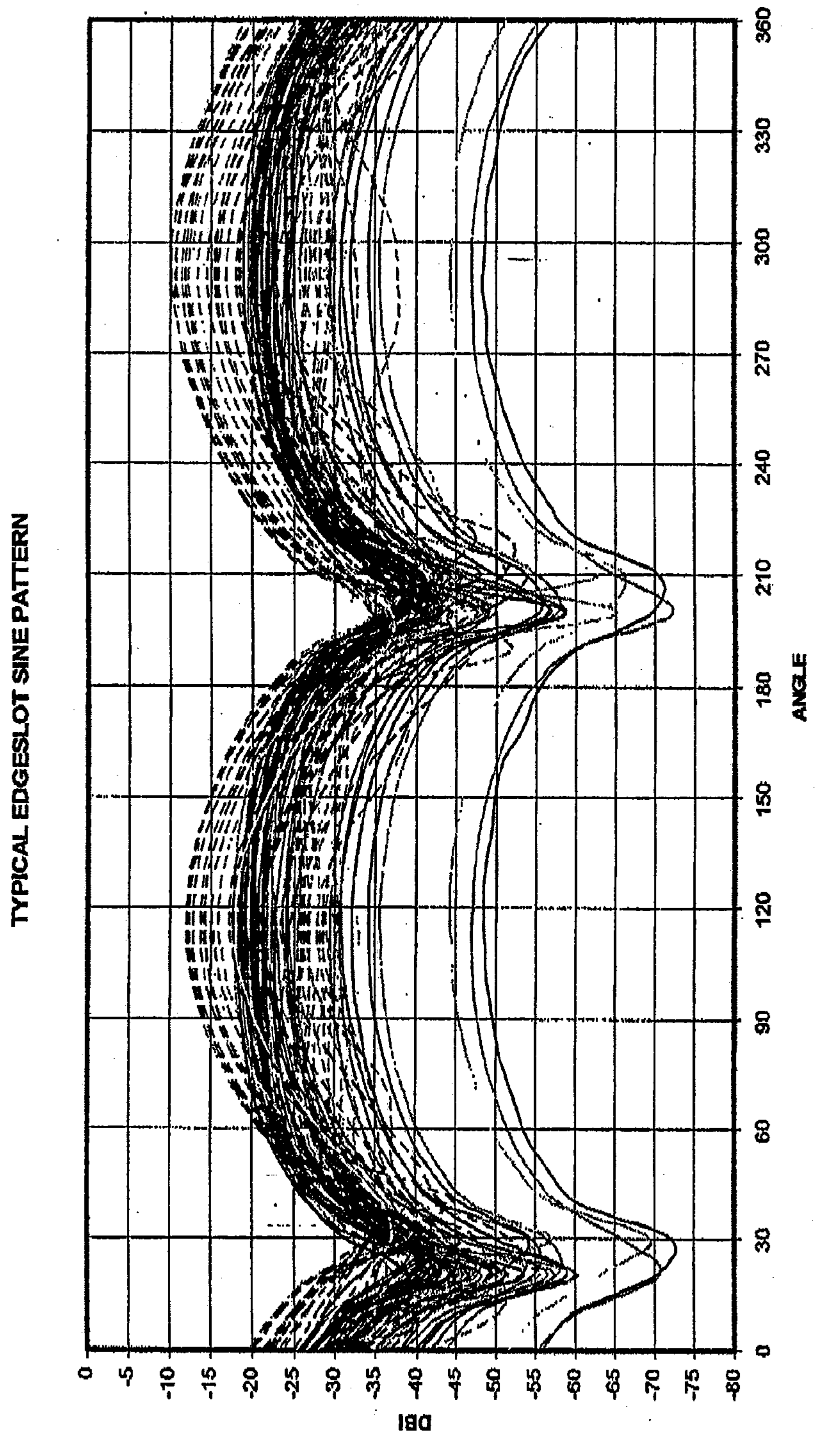

TYPICAL EDGESLOT SINE PATTERN
ANGLE
DBI
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
0
30
60
90
120
150
180
210
240
270
300
330
360

Figure 16

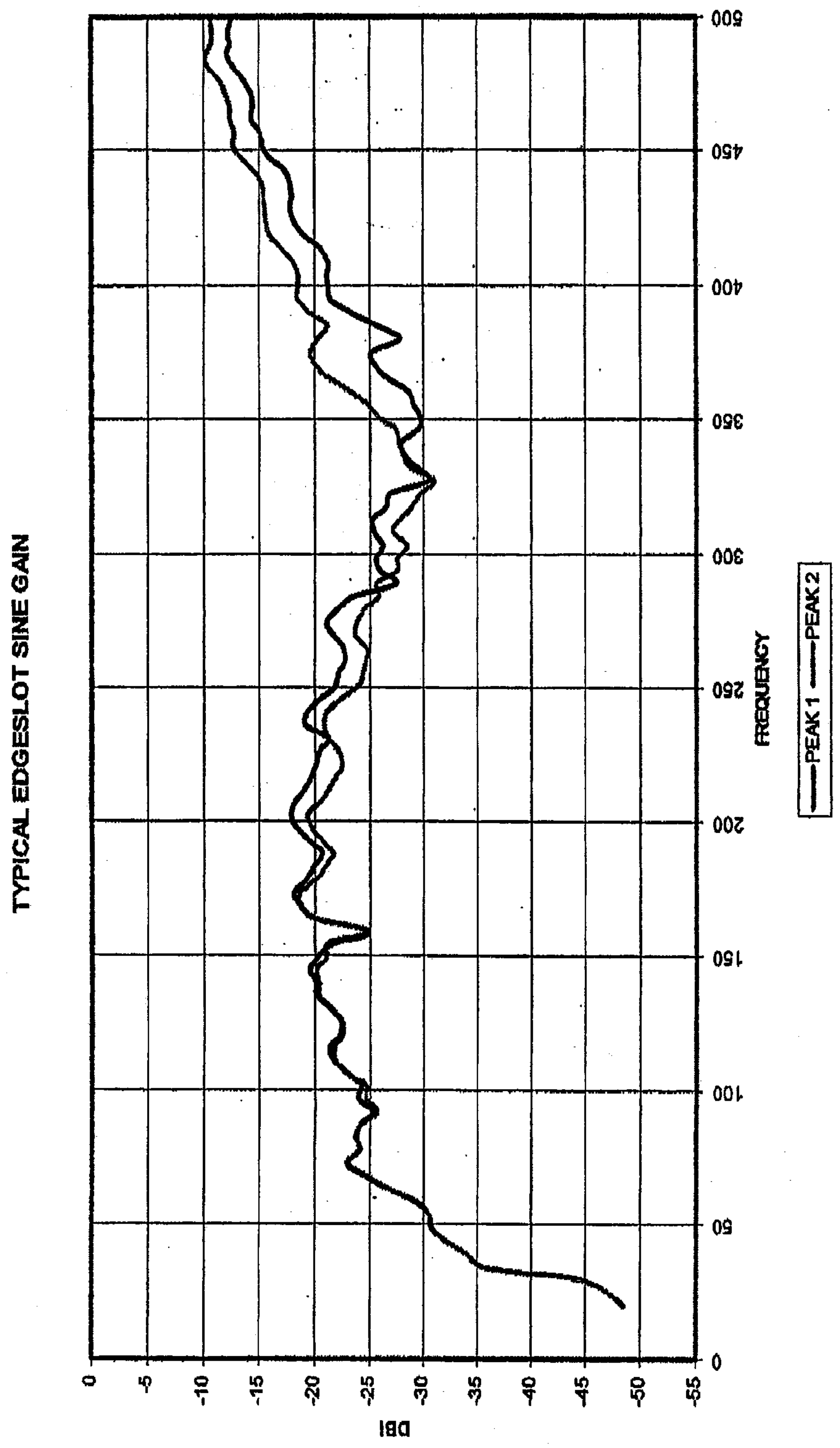
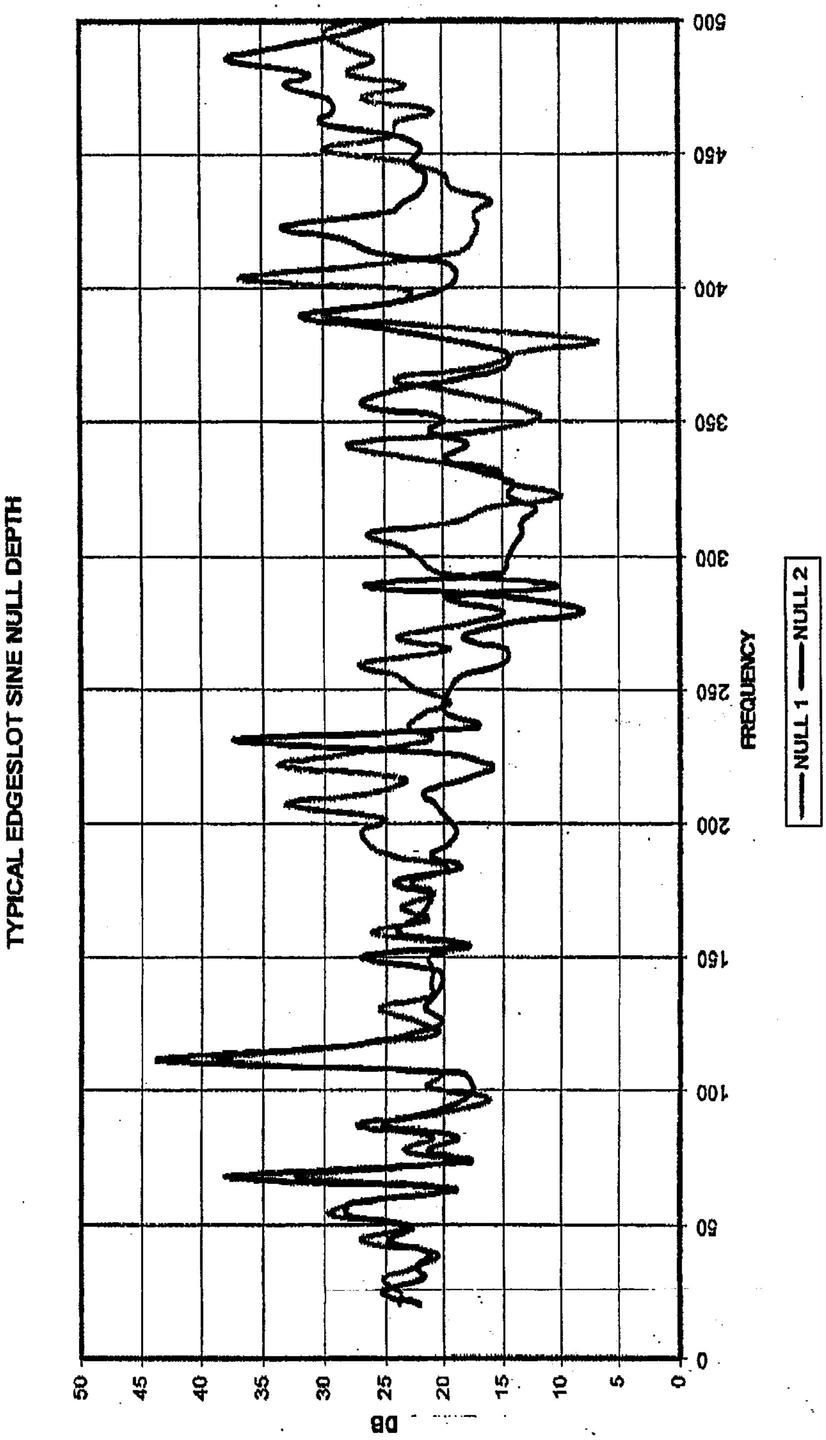

TYPICAL EDGESLOT SINE GAIN
DBI
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
FREQUENCY
0
50
100
150
200
250
300
350
400
450
500
PEAK 1
PEAK 2

Figure 17



TYPICAL EDGESLOT SINE NULL DEPTH
DB
50
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
500
FREQUENCY
NULL 1
NULL 2

Figure 18

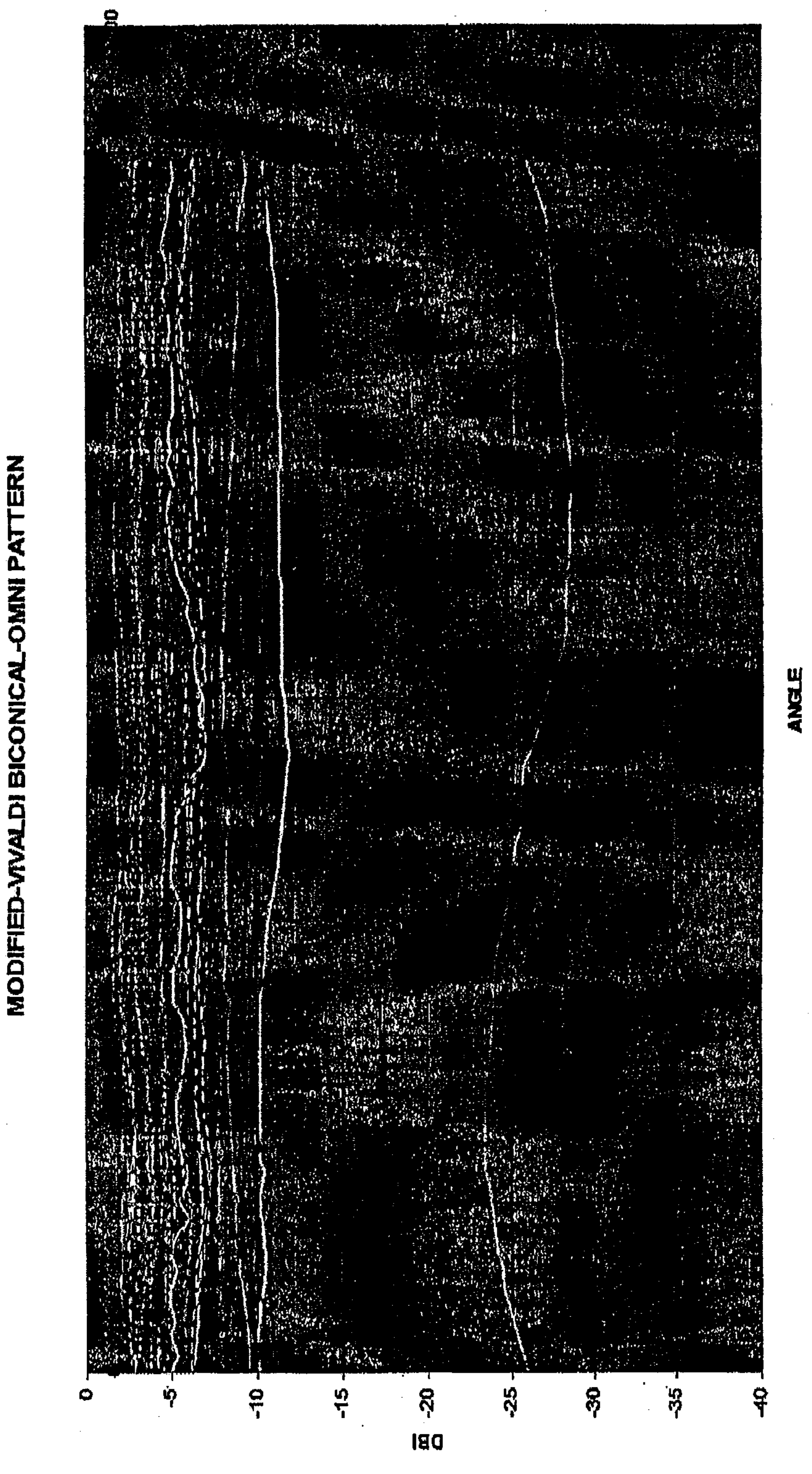

MODIFIED-VIVALDI BICONICAL-OMNI PATTERN
0
-5
-10
-15
-20
-25
-30
-35
-40
DBI
ANGLE

Figure 19

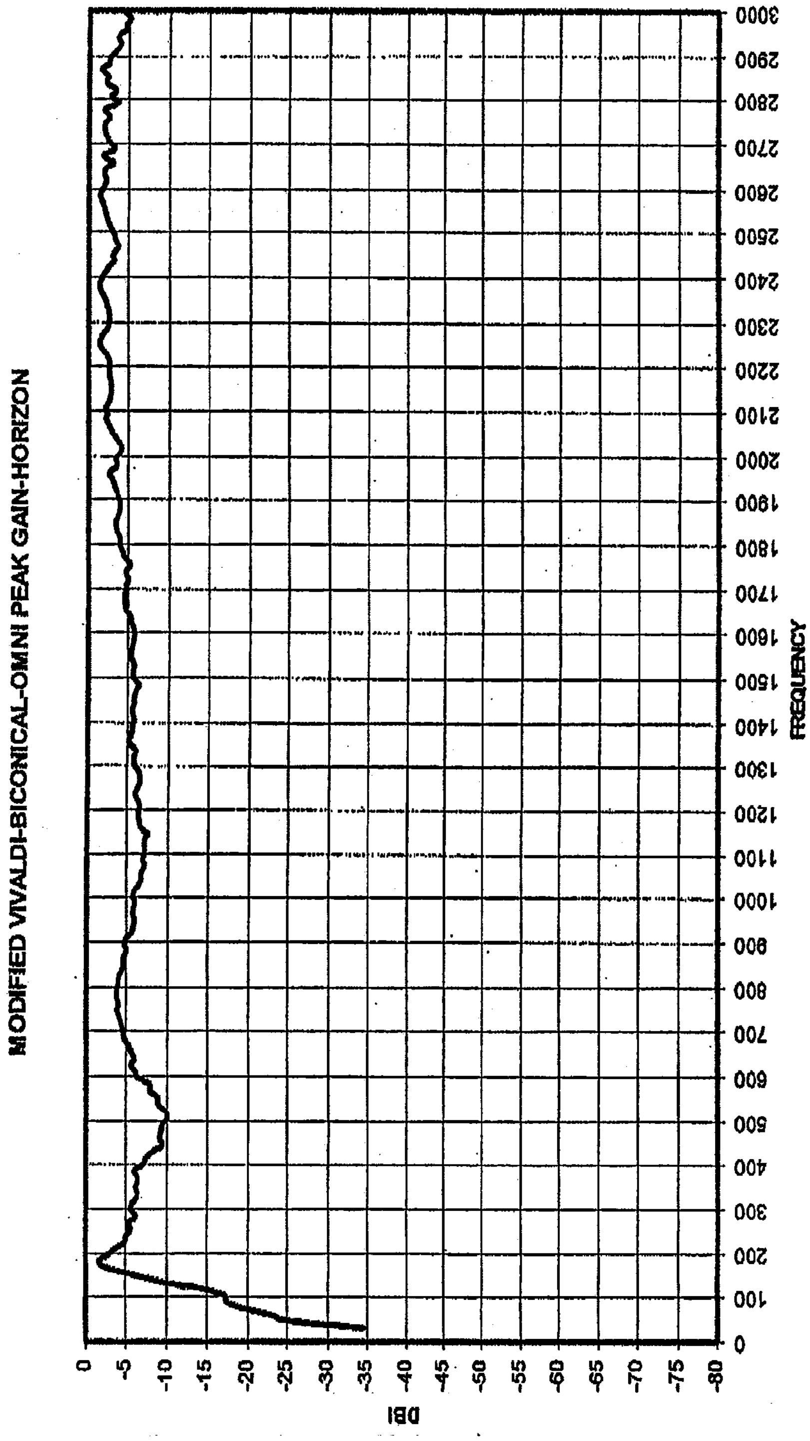

MODIFIED VIVALDI-BICONICAL-OMNI PEAK GAIN-HORIZON
DBI
0 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80
FREQUENCY
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600 2700 2800 2900 3000

Figure 20

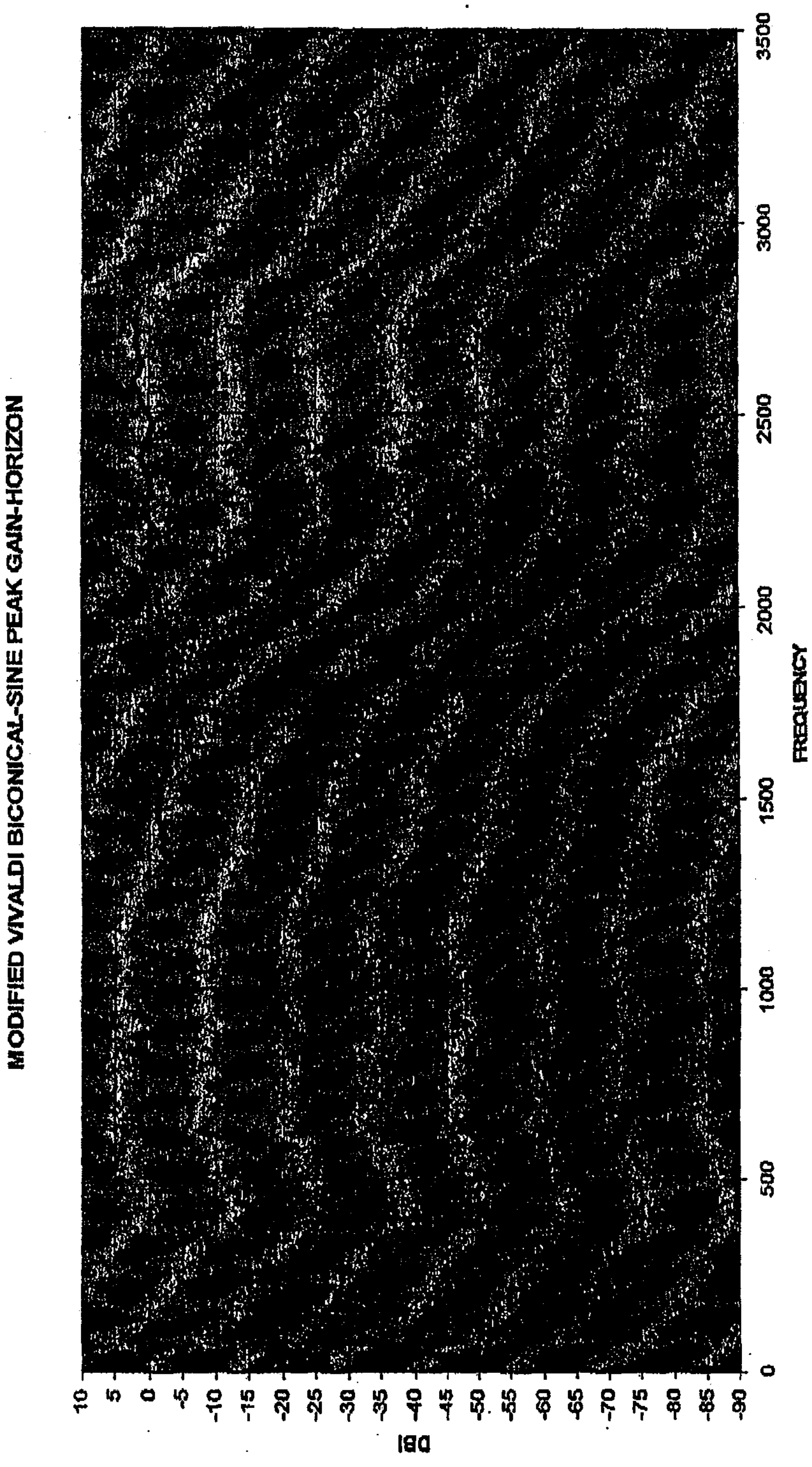

MODIFIED VIVALDI BICONICAL-SINE PEAK GAIN-HORIZON
DBI
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
FREQUENCY
0
500
1000
1500
2000
2500
3000
3500

Figure 21

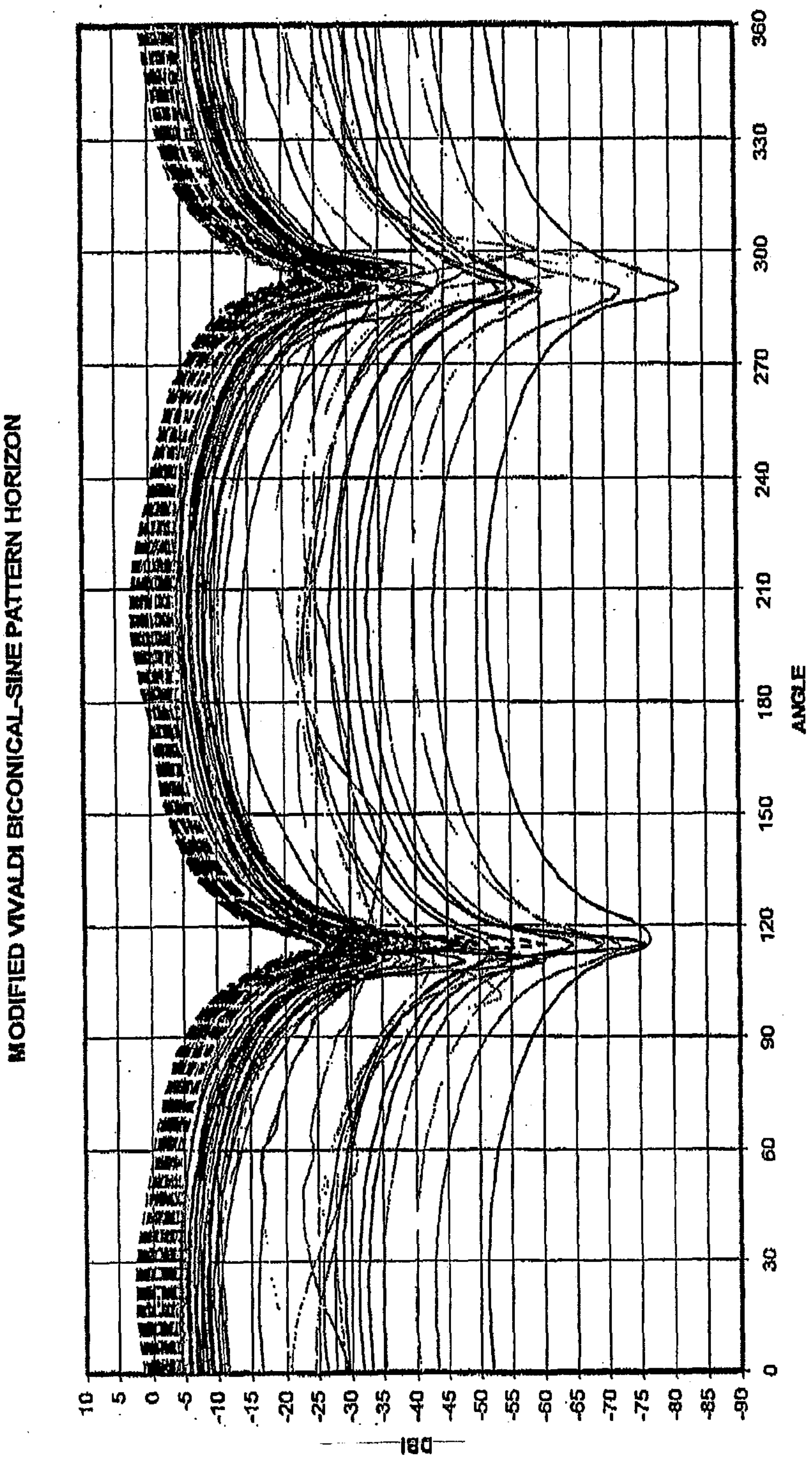

MODIFIED VIVALDI BICONICAL-SINE PATTERN HORIZON
ANGLE
0 30 60 90 120 150 180 210 240 270 300 330 360
DBI
10 5 0 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90

Figure 22

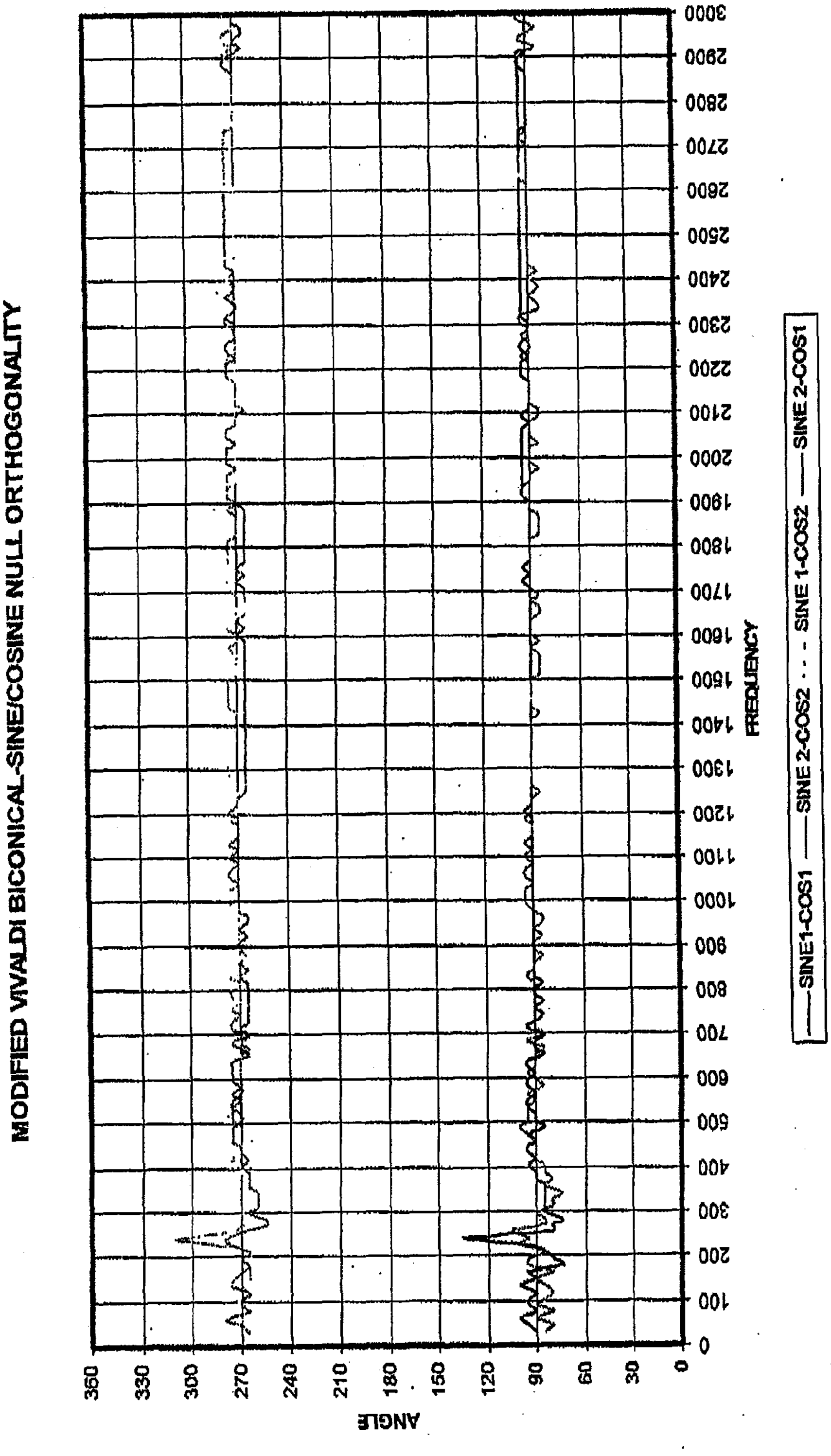

MODIFIED VIVALDI BICONICAL-SINE/COSINE NULL ORTHOGONALITY
ANGLE
360
330
300
270
240
210
180
150
120
90
60
30
0
FREQUENCY
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
SINE1-COS1
SINE 2-COS2
SINE 1-COS2
SINE 2-COS1

Figure 23

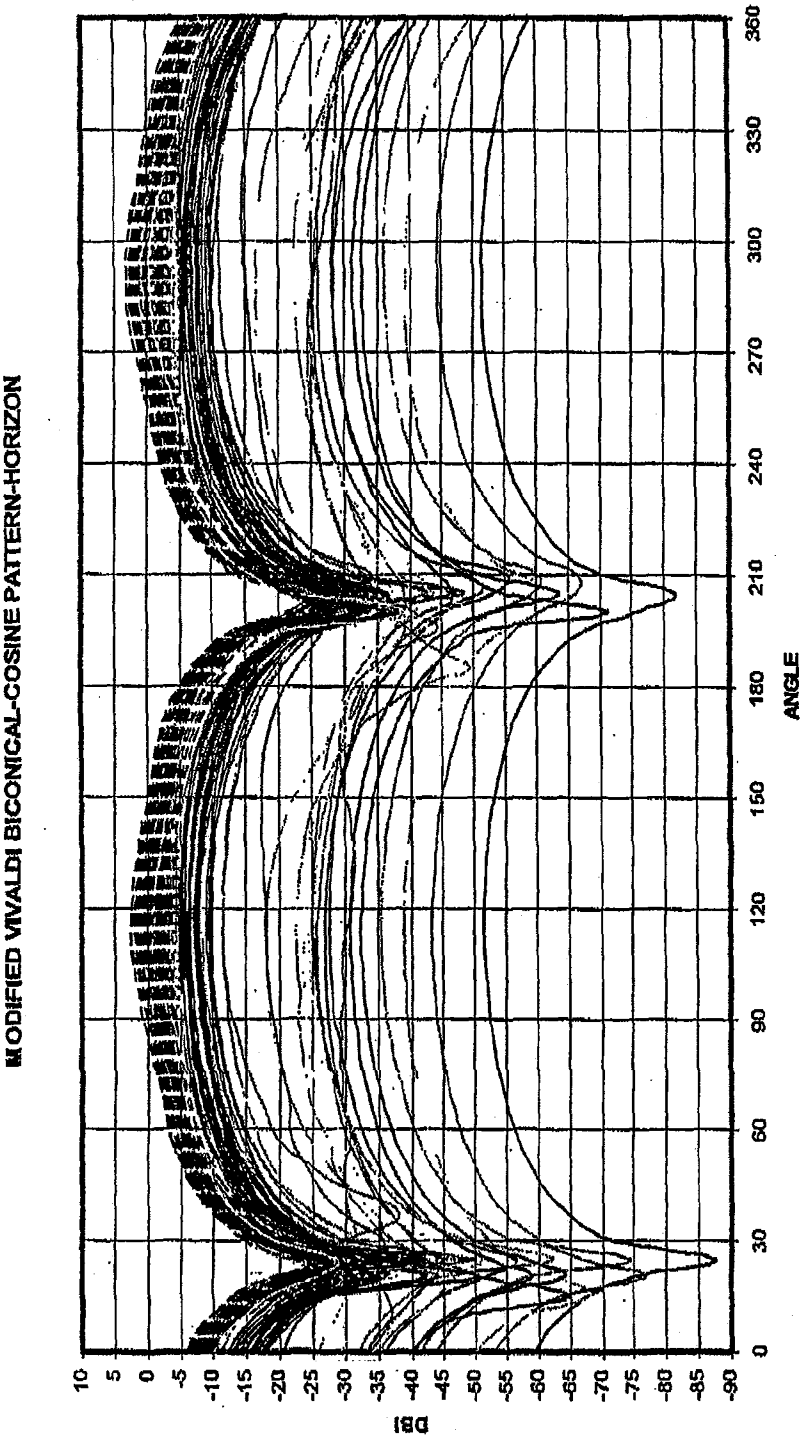

MODIFIED VIVALDI BICONICAL-COSINE PATTERN-HORIZON
ANGLE
DBI
0 30 60 90 120 150 180 210 240 270 300 330 360
10 5 0 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90

Figure 24

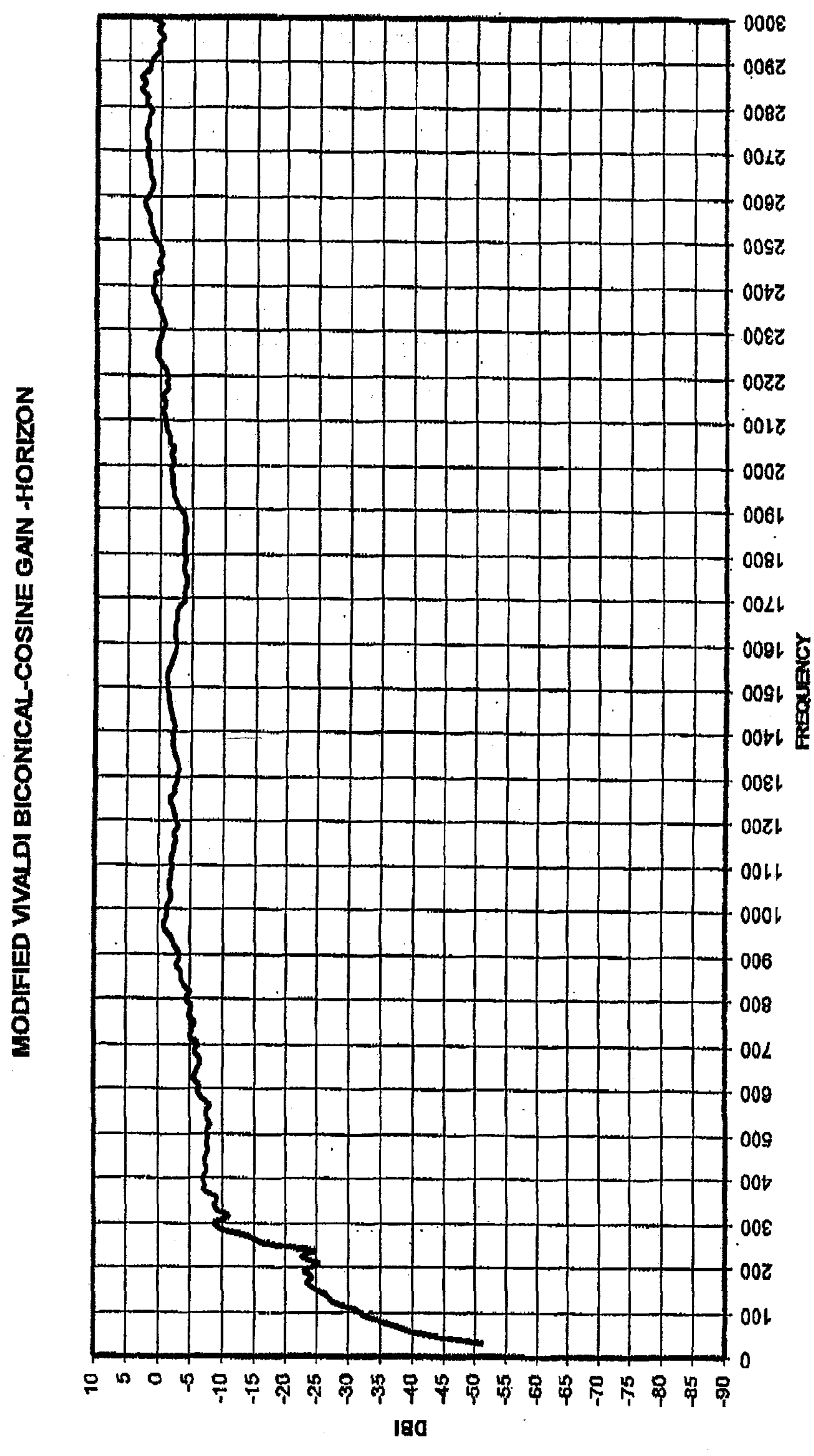

MODIFIED VIVALDI BICONICAL-COSINE GAIN -HORIZON
FREQUENCY
DBI

Figure 25

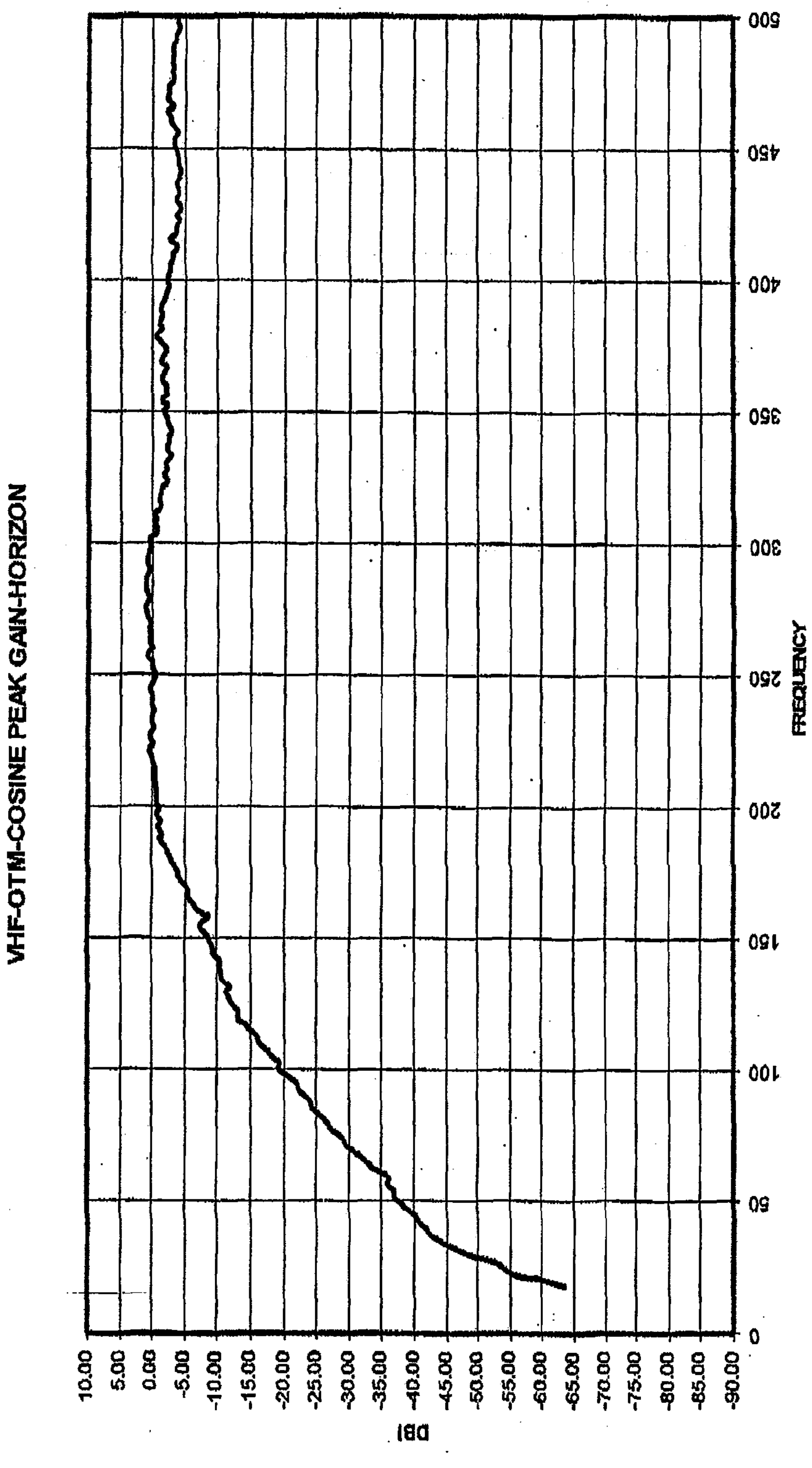

VHF-OTM-COSINE PEAK GAIN-HORIZON
DBI
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
-70.00
-75.00
-80.00
-85.00
-90.00
FREQUENCY
0
50
100
150
200
250
300
350
400
450
500

Figure 26

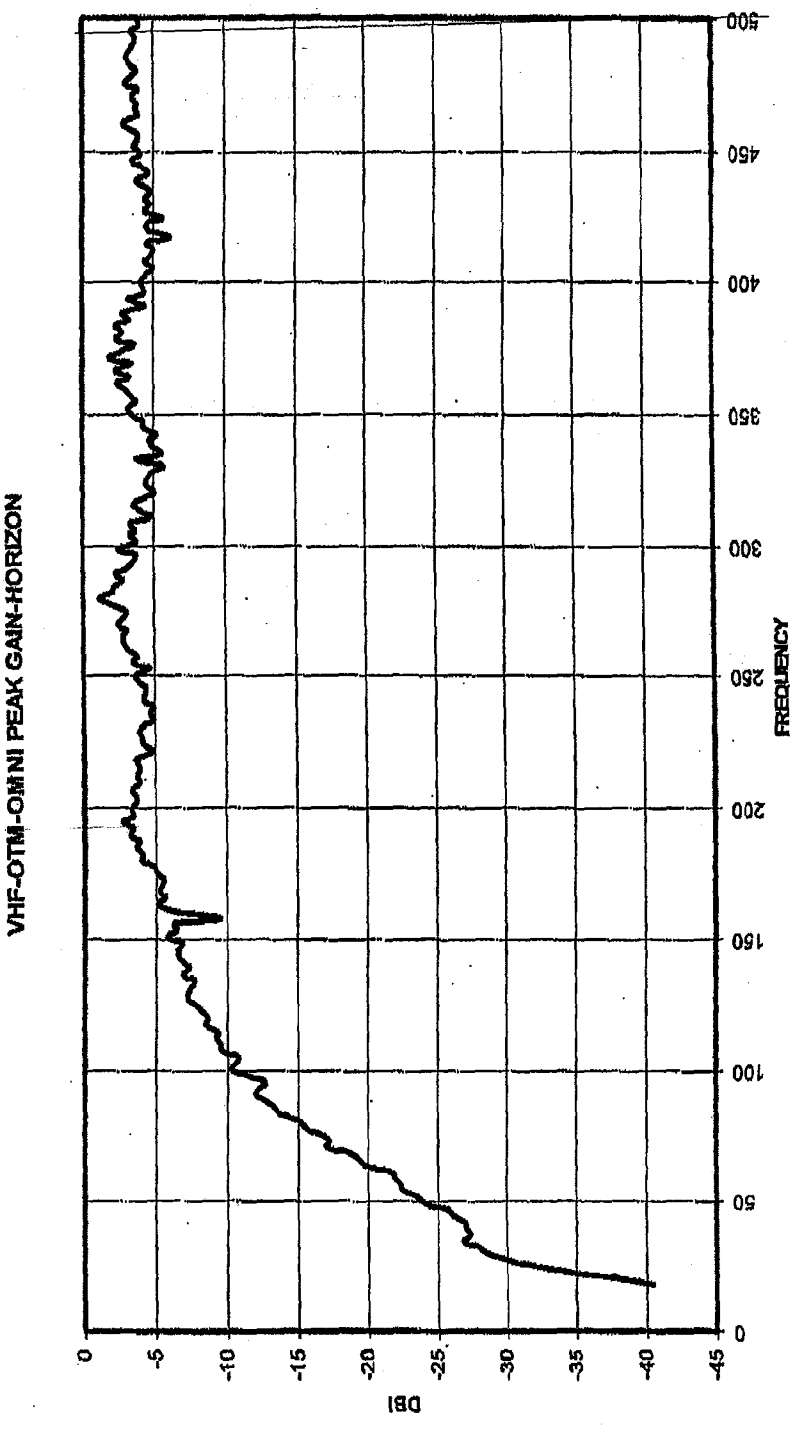

VHF-OTM-OMNI PEAK GAIN-HORIZON
DBI
FREQUENCY
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
0
50
100
150
200
250
300
350
400
450
500

Figure 27

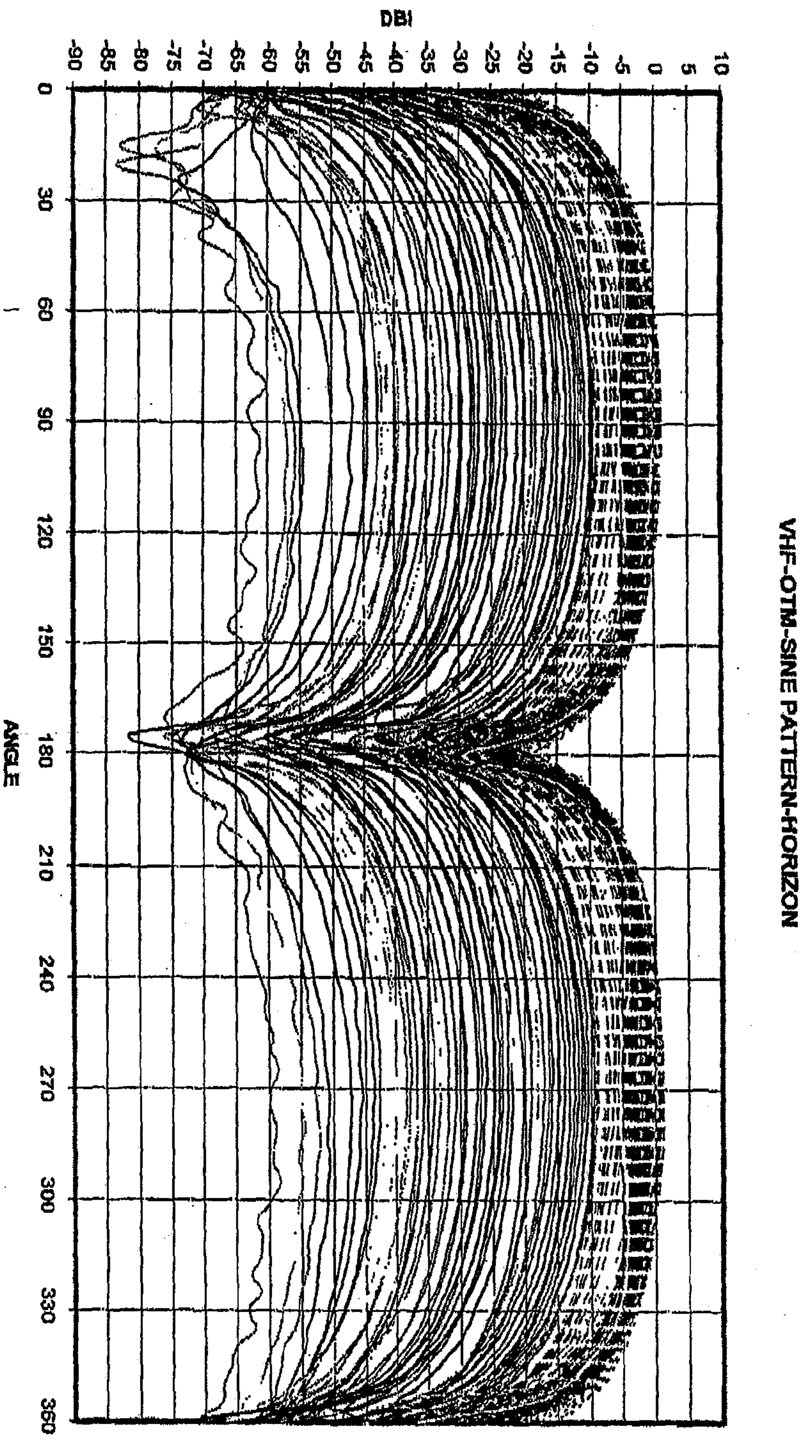

VHF-OTM-SINE PATTERN-HORIZON
DBI
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
ANGLE
0
30
60
90
120
150
180
210
240
270
300
330
360

Figure 28

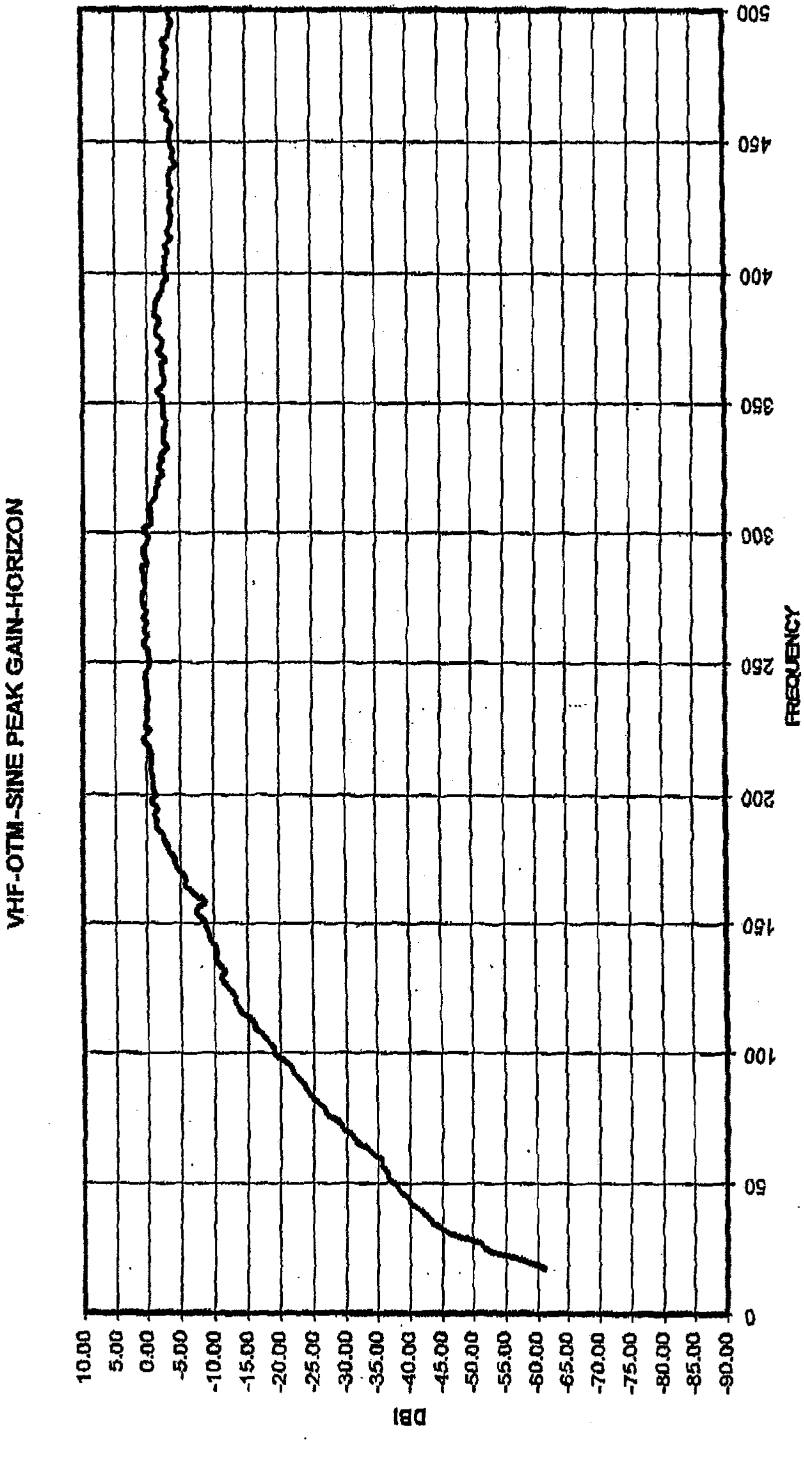

VHF-OTM-SINE PEAK GAIN-HORIZON
DBI
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
-70.00
-75.00
-80.00
-85.00
-90.00
FREQUENCY
0
50
100
150
200
250
300
350
400
450
500

Figure 29

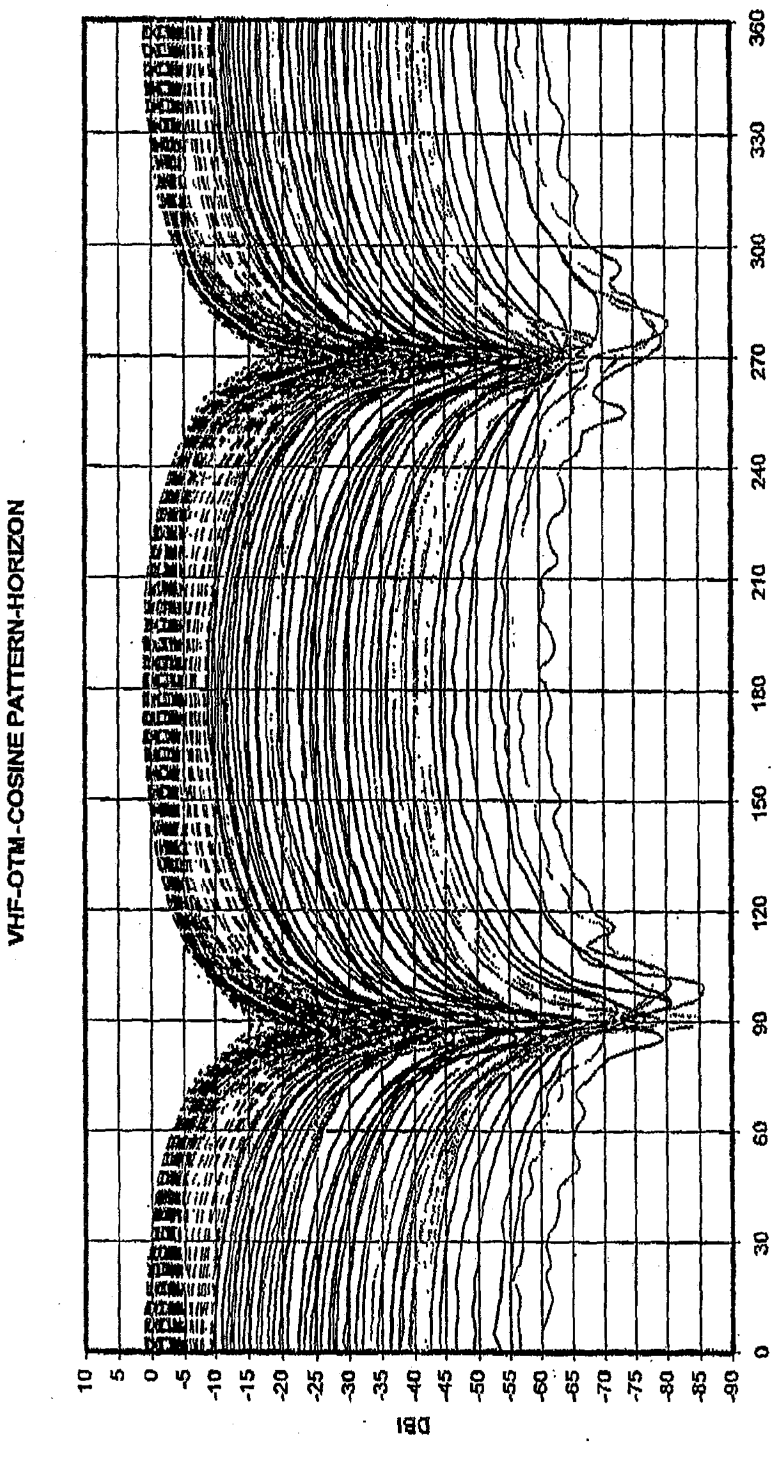

VHF-OTM-COSINE PATTERN-HORIZON
DBI
ANGLE
10 5 0 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90
0 30 60 90 120 150 180 210 240 270 300 330 360

Figure 30

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2009/037457

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H01Q 21/00 (2009.01)
USPC - 343/893

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - H01Q 21/00 (2009.01)
USPC - 343/774, 853, 893

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO EAST System (US, USPG-PUB, EPO, DERWENT), Patbase, IEEE Xplore, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,714,964 A (JACKSON) 03 February 1998 (03.02.1998) entire document	10-24
Y	US 5,767,814 A (CONROY et al) 16 June 1998 (16.06.1998) entire document	10-27
Y	US 6,249,261 B1 (SOLBERG, JR et al.) 19 June 2001 (19.06.2001) entire document	12-23
Y	US 5,644,321 A (BENHAM) 01 July 1997 (01.07.1997) entire document	17-23
Y	US 6,515,632 B1 (MCLEAN) 04 February 2003 (04.02.2003) entire document	10-16, 24-26
Y	US 6,346,920 B2 (SHARP et al.) 12 February 2002 (12.02.2002) entire document	25-27
A	US 6,570,543 B1 (SOLBERG, JR et al.) 27 May 2003 (27.05.2003) entire document	1-27
A	US 5,506,592 A (MACDONALD et al) 09 April 1996 (09.04.1996) entire document	1-27
A	US 6,295,035 B1 (HOLZHEIMER) 25 September 2001 (25.09.2001) entire document	1-27
A	US 4,584,582 A (MUNGER) 22 April 1986 (22.04.1986) entire document	1-27

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 May 2009	18 MAY 2009

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-3201

Authorized officer:
Blaine R. Copenheaver
PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774