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54 **Hybrid monopole/log-periodic antenna.**

57 A monopole antenna (13) having a total length of about one-half wavelength of a signal in a desired broadcast band is provided having a log-periodic shape to increase its gain over a large bandwidth. The resulting hybrid of a log-periodic antenna and a half-wave monopole antenna has a small size adapted to be employed on a vehicle, such as being deposited on the glass of a vehicle in association with a de-misting heater grid.

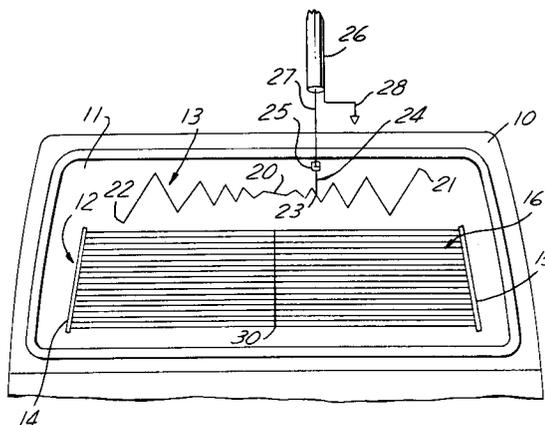


FIG. 1

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The present invention relates in general to an antenna for motor vehicles and more specifically to an on-glass window antenna for receiving FM broadcasts.

Radio antennas are designed with an aim to provide good gain over an entire frequency band of interest (e.g., from 535 to 1605 kHz for AM broadcasting and from 88 to 108 MHz for FM broadcasting in the United States). However, because of the automobile environment and its requirements for minimizing size, height, and obtrusive appearance, automobile antenna design has been greatly constrained and has achieved limited performance. Monopole and dipole antennas are typically employed since their total length is short compared to the wavelengths of interest. However, the resulting antennas possess narrow bandwidth. A typical whip antenna used on automobiles has the form of a quarter-wave monopole with a height of less than about one meter since a wavelength of a signal in the FM broadcast band of interest is about three meters. Typical dipole antennas have a length corresponding to one-half wavelength.

The gain provided by a whip antenna is strongly dependent on frequency even within the desired reception band due to the inherently narrow bandwidth of monopole and dipole antennas. The antenna is typically optimized for the center frequency in the desired band.

Other antenna designs are known that provide wider bandwidth, or even substantial frequency independence. However, such antennas have a total length of at least one full wavelength. Such larger structures are impractical on automobiles, especially antennas printed on vehicle windows. The rear window is often used for such an automobile antenna but the majority of the rear window surface is typically occupied by an electrical heater grid for defrosting the rear window. Thus, limited space is available for an antenna to be fabricated on a window containing a heater grid.

It is an object of the present invention to provide good gain over a large bandwidth in an automobile radio antenna having a short total length.

The present invention employs a hybrid antenna having characteristics of a half-wave monopole and a log-period antenna. Specifically, the antenna has an antenna arm with a plurality of scaled segments connected in series between a first location and a second location on a surface of a vehicle. The scaled segments provide a substantially log-periodic progression from the first location to the second location. A feedline is coupled to the segments at a feed point for feeding the antenna as a monopole. The antenna has a total length in the range of about one-fourth to about one full wavelength corresponding to a frequency within the broadcast band of interest.

The invention will now be described further by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a front plan view showing a rear automobile window having a printed-on glass antenna and heater grid.

Figure 2 illustrates the log-periodic progression employed in one embodiment of the invention.

Figure 3 is one embodiment of an antenna arm according to the invention.

Figure 4 is another embodiment of an antenna arm according to the present invention.

Figure 5 shows a further embodiment of the antenna of the present invention.

Figure 6 shows a modification of the antenna of the Figure 5.

A vehicle body surface 10 includes an opening for receiving a backlite (or rear window) 11. Contained on or within the glass or backlite 11 are a heater grid 12 and an antenna 13. Heater grid 12 includes a bus bar 14 and a bus bar 15 having a plurality of heater conductors 16 running therebetween. Power connections to bus bars 14 and 15 are not shown.

Antenna 13 is preferably printed on backlite 11 using the same process and materials as heater grid 12. Antenna 13 includes a center point 20 and log-periodic segments running from center point 20 to end points 21 and 22. A feed point 23 is located on one of the log-periodic segments and is connected via a feedline 24 to an on-glass terminal 25. A coaxial cable 26 has its center shielded conductor 27 connected to terminal 25 and has its outer shield connected to ground at 28 on the vehicle body.

A shorting line 30 interconnects heater conductors 16 at equipotential points along the center line of backlite 11.

Antenna 13 is comprised of a plurality of scaled segments connected in series and following a log-periodic progression. Thus, a first antenna arm is provided between point 20 and point 21 wherein each successive segment is scaled according to a predetermined geometric ratio. Likewise a second antenna arm extends from point 20 to point 22 according to an identical log-periodic progression such that the antenna is negative symmetrical with respect to the vertical centerline of backlite 11 passing through point 20. Other embodiments may include additional antenna arms or may include only a single antenna arm.

The complete length of antenna 13 is on the order of about one-fourth to about one full wave in the desired frequency band and preferably is about one-half wavelength long. Thus, where antenna 13 is desired to receive FM signals from 88 to 108 MHz, the wavelength of a signal in the center of the desired band is about 3 meters long

and the total length of antenna 13 is preferably about 1.5 meters.

The preferred antenna length of one-half wavelength corresponds to the length which is typical for a dipole antenna. However, the antenna of the present invention is preferably fed as a monopole via the monopole feed point 23 and feed line 24. Thus, the antenna of the invention is a hybrid of a log-periodic antenna and a half-wave antenna with a monopole feed. The antenna is not a true log-periodic antenna as known in the prior art since none of the individual scaled segments corresponds to either a quarter or a half wavelength. However, the antenna of the present invention provides good gain over an improved bandwidth by exhibiting some of the best characteristics of log-periodic antennas and monopole antennas.

A further important advantage of the hybrid antenna of the invention is the ability to locate feedpoint 23 in a location where 1) the inductive or capacitive reactance of the antenna can be essentially tuned out and 2) the resistive impedance of the antenna provides good matching to the coaxial line for transmitting the antenna signal to the radio. The specific location of the feedpoint depends upon many variables, including antenna geometry, heater grid geometry, and other vehicle structures. The specific feedpoint location for a particular antenna in a particular vehicle can be determined by empirical measurement or by modeling.

Shorting line 30 across the heater grid is used to control resonances of the heater grid to minimize interaction with the antenna in the desired reception band of antenna 13. Thus, one or more shorting lines may be required. Since the shorting lines are located at equipotential points on the heater grid, there is no effect on the flow of heater grid current.

Antenna 13 and heater grid 12 can be formed on backlite 11 using known techniques such as a silk screen printing operation for depositing a silver ceramic paste to form the heater grid, bus bars, heater conductors, antenna segments, feed line, and antenna and heater terminals. After depositing the silver ceramic paste, the backlite is placed on a fixture and heated to a temperature adequate to bond the silver ceramic paste to the glass sheet. Further details on forming conductive segments and terminals on a glass sheet are provided in commonly assigned U.S. Patents 4,246,467 and 4,388,522, incorporated herein by reference.

A first embodiment for obtaining the log periodic progression of the present invention is shown in Figure 2. A substantially vertical centerline 31 includes a center point 32. A line 33 and a line 34 pass through center point 32 defining an included angle  $\theta$ .

A series of logarithmically scaled points on lines 33 and 34 define the log-periodic progression of the antenna. Thus, a first point  $R_1$  is selected at the maximum radius of the antenna. A geometric scaling factor  $\tau$  is selected for deriving additional points on lines 33 and 34. Point  $R_2$  is thus derived by multiplying the radius of point  $R_1$  by the scaling factor  $\tau$ . In general the radius of each point is obtained by the formula  $R_{i+1} = t \times R_i$ . In the preferred embodiment of Figure 2, the logarithmically derived points alternate between lines 33 and 34 as shown. Furthermore, each point is duplicated at a negative radius on the same line 33 or 34, thus providing a negative symmetry for the resulting antenna.

The radial points of Figure 2 are interconnected by antenna segments as shown in Figure 3. Thus, point  $R_1$  is directly connected by a straight segment with point  $R_2$ , while point  $R_2$  is connected by a straight segment with point  $R_3$ , and so on. Since a finite number of points are employed, the final point, such as point  $R_{13}$  in Figure 3, is directly connected to the center point 32. Furthermore, the location of some points, especially those near center point 32, may be altered by small amounts from the log-periodic progression to facilitate manufacturing. The antenna arm of Figure 3 may be employed alone or with other antenna arms, such as a negative symmetric antenna arm. The total length of all antenna segments in all antenna arms falls in the range of about one-fourth to about one full wavelength of a signal within the desired broadcast band. Most preferably, the total length equals about one-half of a wavelength. Once the total number of points have been selected and the total number of antenna arms is determined, a formula for the total antenna length can be obtained in terms of radius  $R_1$ . The total desired antenna length is then determined according to the desired wavelength. Thereafter, the radius of points  $R_1$  to  $R_{13}$  can be calculated. The resulting scaled segments of the antenna in the embodiment of Figure 3 take the form of a sawtooth with the tips of the sawtooth spaced along the included angle according to the log-periodic progression.

Figure 4 shows an alternate embodiment wherein each of points  $R_1$  to  $R_{13}$  are established on each of lines 33 and 34 defining the included angle  $\theta$ . The scaled segments in this embodiment are alternately located on opposite sides of the included angle along lines 33 and 34 such that their respective lengths follow the log-periodic progression. Thus, a scaled segment 35 extends between points  $R_1$  and  $R_2$  on line 33. The next scaled segment 36 is provided between points  $R_2$  and  $R_3$  on line 34. The scaled segments are interconnected by a plurality of shorting segments that connect points  $R_2$  on lines 33 and 34, points  $R_3$  on

lines 33 and 34, and so on. Shorting segments 37 are each perpendicular to a line 38 which bisects the included angle  $\theta$ . A second antenna arm may be included as shown at 39 which is negative symmetric with respect to the vertical centerline

Geometric scaling factor  $\tau$  is preferably equal to about .8 (which is the factor shown in Figures 3 and 4). However, a scaling factor  $\tau$  of between about .5 and .9 can be employed with good results.

Figures 3 and 4 further show the log-periodic progression as increasing from the center point to the end of each respective antenna arm. However, where two antenna arms are joined to form a single antenna, they may be joined at their largest scaled segments rather than their smallest.

Figure 5 shows an alternate embodiment employing scaled segments alternately connected with shorting segments in a zig-zag pattern. Thus, the scaled segments are provided as horizontal rather than exactly following the lines of an included angle. A scaled segment 40 has a length  $L_1$ . A second scaled segment 41 has a length  $L_2$  and is connected to scaled segment 40 via a shorting segment 42. Additional scaled segments 43-47 are interconnected with additional shorting segments 48-52. The scaled segments are perpendicular to the shorting segments.

The antenna of Figure 5 is symmetrical with respect to a vertical centerline 53, such that a scaled segment 54 and a shorting segment 55 are symmetrical with respect to scaled segment 46 and shorting segment 52. A monopole feed point 56 and feed line 57 are employed as shown.

As shown in Figure 6, the log-periodic progression may be decreasing from the center of the antenna to the ends of the antenna. Thus, the order of antenna segments in Figure 6 starting at the vertical centerline 53 to each end of the antenna is reversed from that in Figure 5. A feed point location 58 and a feed line 59 are selected to provide matching of the antenna resistive impedance and to tune-out reactive impedance of the antenna as described earlier.

By way of example, an antenna as defined in Figure 3 with negative symmetric antenna arms was constructed having an included angle  $\theta$  equal to 8.2. A log-periodic progression having 19 points was employed with a maximum radius  $R_1$  of 584 millimeters. A scaling factor of .825 was employed resulting in a total antenna length including both antenna arms of 1348 m. The thickness of each scaled segment was approximately 1 mm of silver ceramic.

An antenna as defined by Figure 4 was constructed employing a log-periodic progression of 8 points and an included angle of 8.2°. A maximum radius of 429 millimeters and a scaling factor  $\tau$  of about .8 resulted in lengths of the scaled segments

in millimeters moving out from the center point of each arm equal to 25, 31, 39, 49, 61, 76, 95, and 122. Respective shorting segments had lengths in millimeters of 15, 21, 31, 41, 56, 75, 97, and 120.

Each antenna provided good gain over the FM band while obtaining good impedance matching with a coaxial line and having a reduced antenna reactance by appropriate location of the feed points which were located 200 mm and 105 mm, respectively, from the center point.

Other log-periodic shapes are known in the art and are useful in the present invention, such as a trapezoidal tooth.

## Claims

1. A broadcast-band monopole antenna supported on a surface of a vehicle, comprising:
  - an antenna arm (13) having a plurality of scaled segments connected in series between a first location (20) and a second location (21,22) on said surface (11), said scaled segments providing a substantially log-periodic progression from said first location to said second location; and
  - a feed line (24) coupled to said scaled segments at a feed point (23) for feeding said antenna as a monopole;
  - said antenna having a total length in the range of about one-fourth to about one full wavelength corresponding to a frequency within said broadcast band.
2. An antenna as claimed in claim 1, further comprising:
  - a second antenna arm having a plurality of scaled segments connected in series between said first location and a third location on said surface, said scaled segments providing a substantially log-periodic progression from said first location to said third location, said total length of said antenna being the sum of all segments between said second location and said third location.
3. An antenna as claimed in claim 1, wherein said scaled segments are contained within an area defined by an included angle originating at said first location.
4. An antenna as claimed in claim 3, wherein said scaled segments take the form of a sawtooth and the tips of said sawtooth are spaced along said included angle according to said log-periodic progression.
5. An antenna as claimed in claim 3, wherein said scaled segments are alternately located on op-

posite sides of said included angle and have respective lengths according to said log-periodic progression, said antenna arm further having shorting segments connecting alternate scaled segments, said shorting segments being substantially perpendicular to an imaginary line bisecting said included angle. 5

6. An antenna as claimed in claim 1, further comprising a plurality of shorting segments alternately connected with said scaled segments in a zig-zag pattern. 10
7. An antenna as claimed in claim 6, wherein said shorting segments are perpendicular to said scaled segments. 15
8. An antenna as claimed in claim 1, wherein said log-periodic progression is increasing from said first location to said second location. 20
9. An antenna as claimed in claim 1, wherein said log-periodic progression is decreasing from said first location to said second location. 25
10. An antenna as claimed in claim 1, wherein said feed point is located on said antenna arm to maximize matching of the impedance of said antenna with a predetermined impedance. 30
11. An antenna as claimed in claim 1, wherein said vehicle surface is a glass window, and wherein said scaled segments are comprised of conductive material printed on said glass window. 35
12. An antenna as claimed in claim 11, wherein said scaled segments are formed on said glass window simultaneously with a heater grid comprised of said conductive material. 40
13. An antenna as claimed in claim 12, further comprising a shorting segment interconnecting equipotential points on said heater grid. 45

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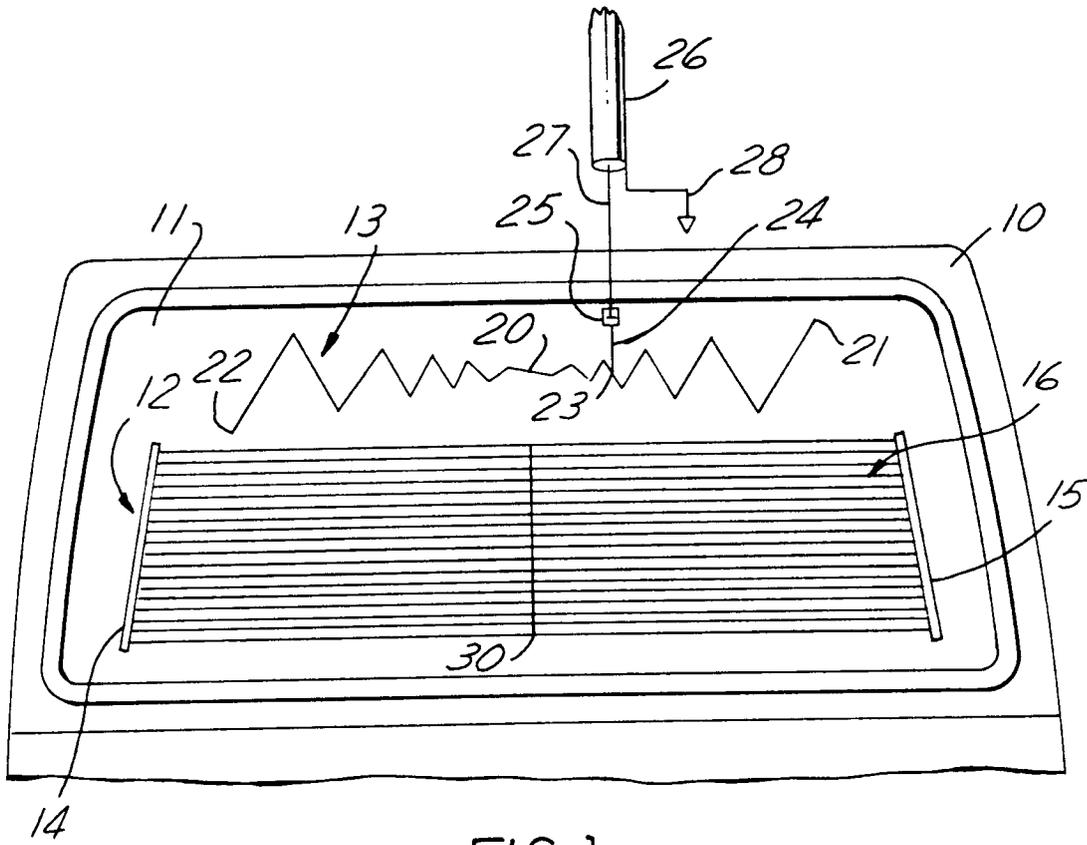


FIG. 1

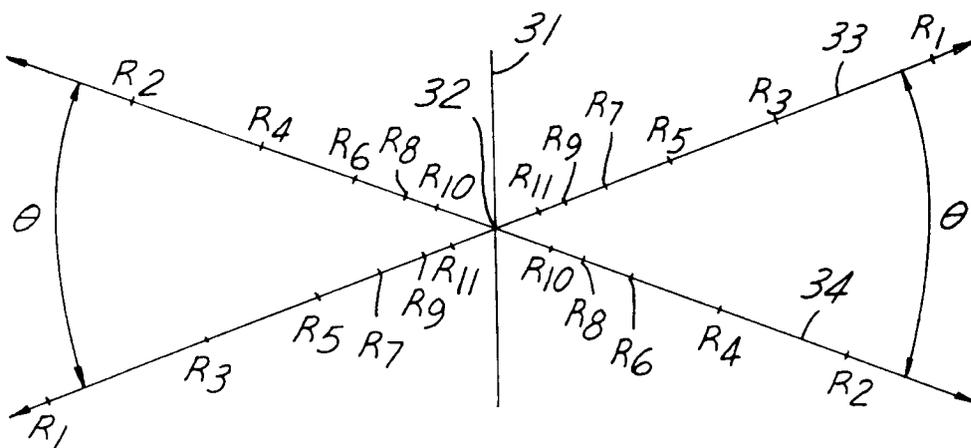


FIG. 2

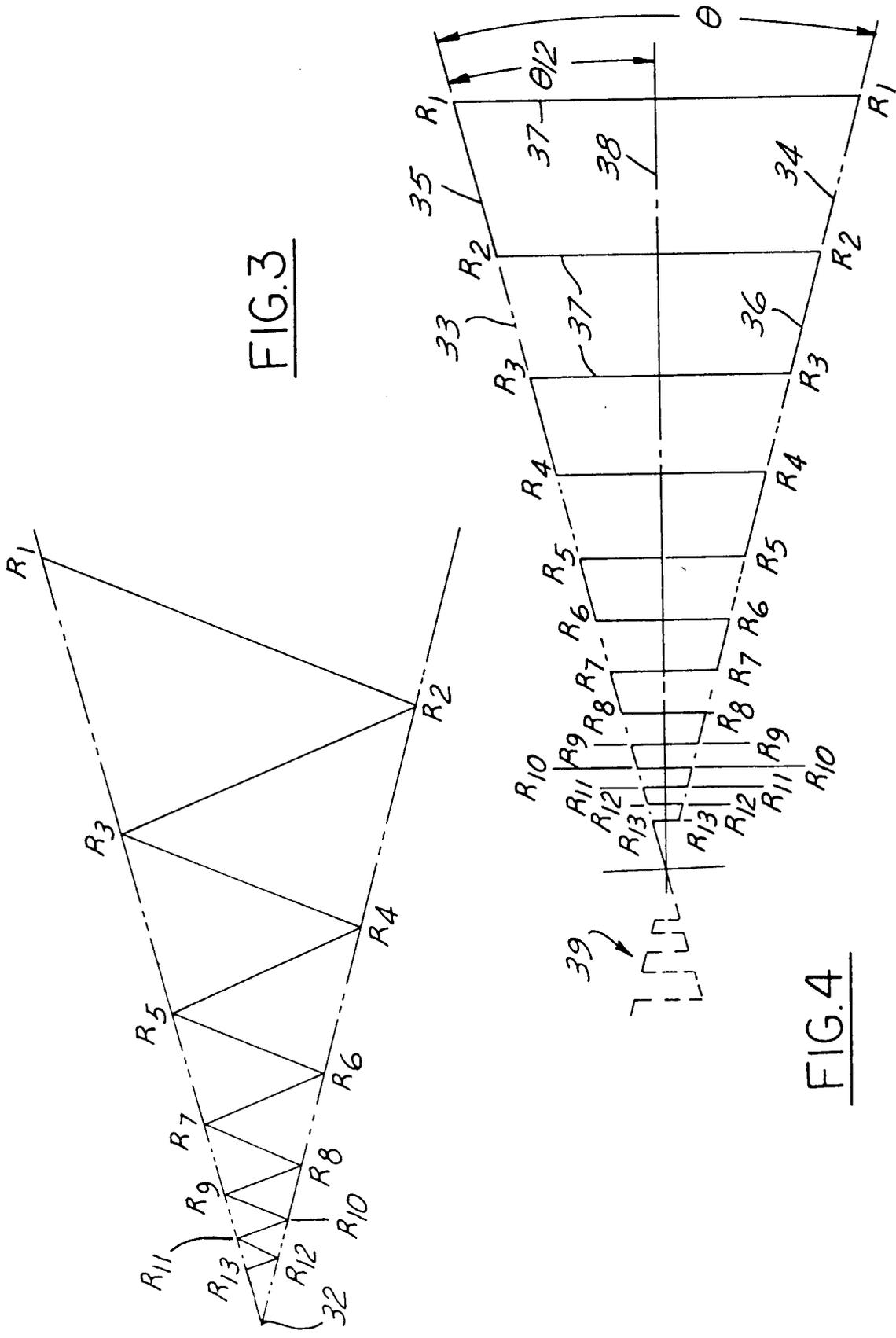


FIG.3

FIG.4

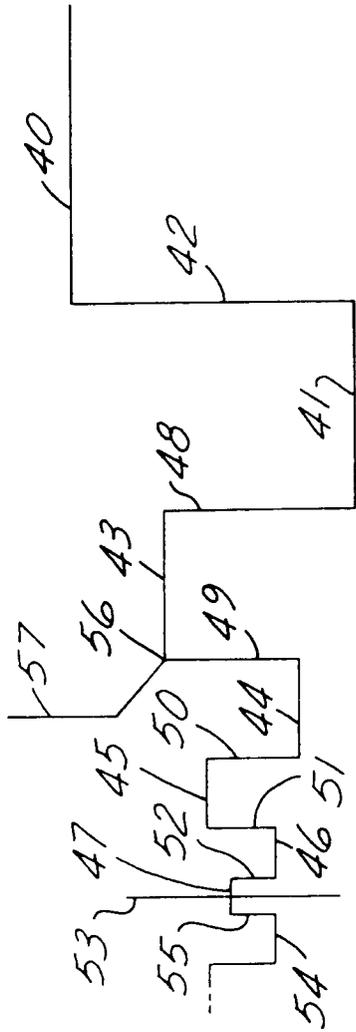


FIG.5

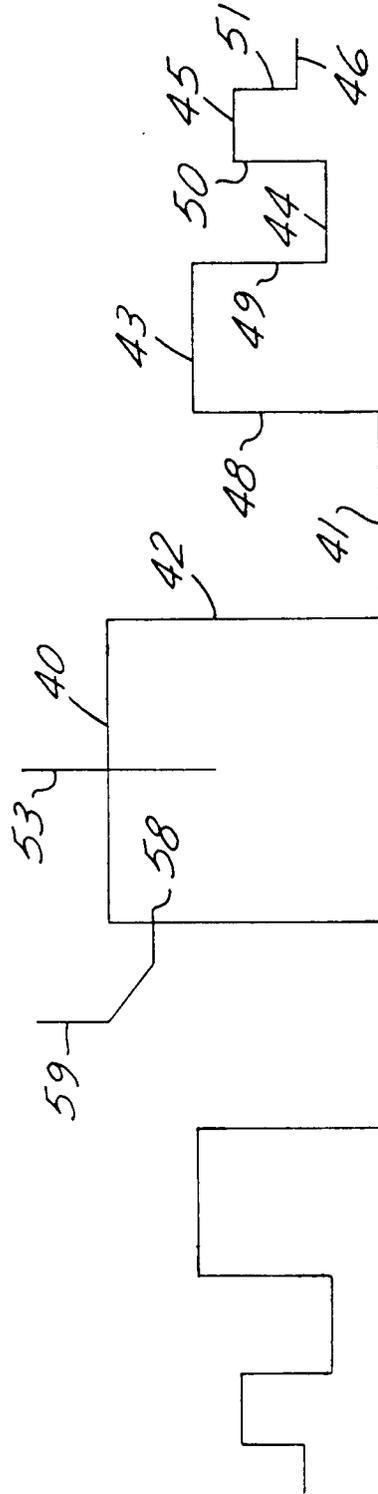


FIG.6



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EUROPEAN SEARCH REPORT

Application Number  
EP 93 30 6670

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
Y	EP-A-0 353 378 (BOSCH) * column 2, line 17 - column 3, line 42; figures 1-4 *	1-4, 8, 9, 11, 12	H01Q1/12 H01Q11/10
Y	US-A-4 286 271 (BARBANO ET AL.) * abstract; figures 1-6 *	1-4, 8, 9, 11, 12	
A	US-A-4 296 416 (HARADER) * abstract; figures 1, 4 *	1-4, 8, 9	
A	EP-A-0 079 001 (BOSCH) * claims 1, 4-6; figures 2, 3 *	1, 11, 12	
A	EP-A-0 367 555 (NIPPON SHEET GLASS) * claims 1-14; figures 1, 3, 8 *	1, 10-12	
A	EP-A-0 411 963 (NIPPON SHEET GLASS) * column 3, line 1 - column 5, line 15; figure 1 *	1, 5-7, 13	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			H01Q H05B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		1 December 1993	Angrabeit, F
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X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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