July 28, 1964 C. E. GREELEY 3,142,795

CAPACITOR DISTRIBUTOR

Filed May 31, 1962 2 Sheets-Sheet 1

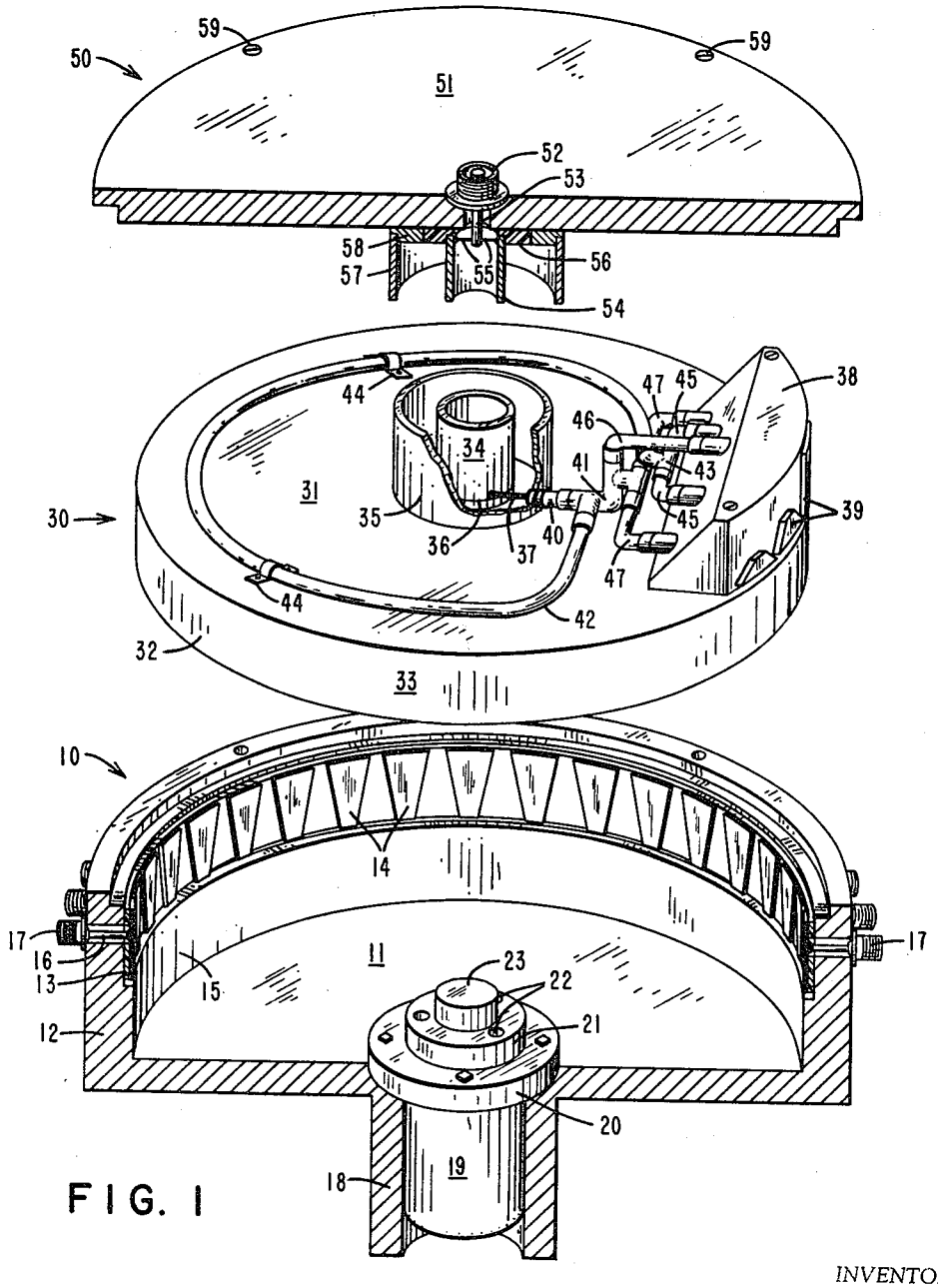


FIG. 1

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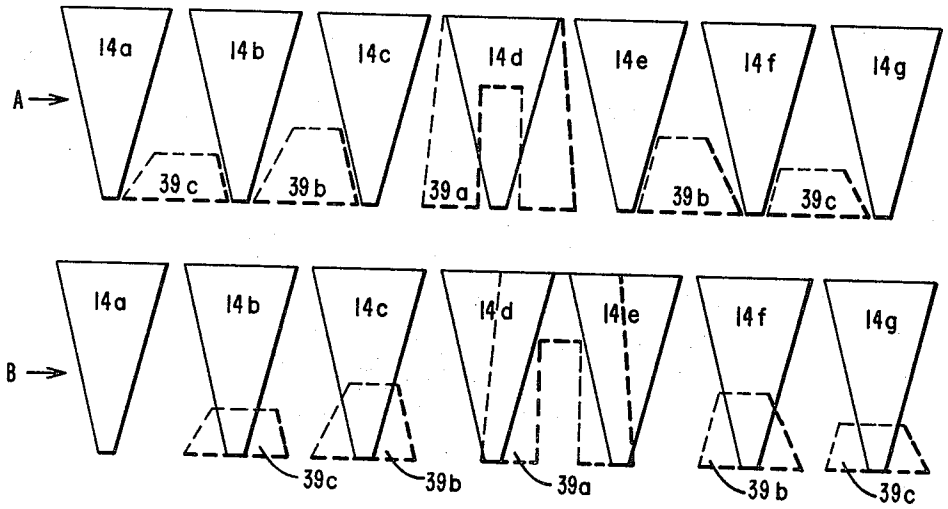


FIG. 3

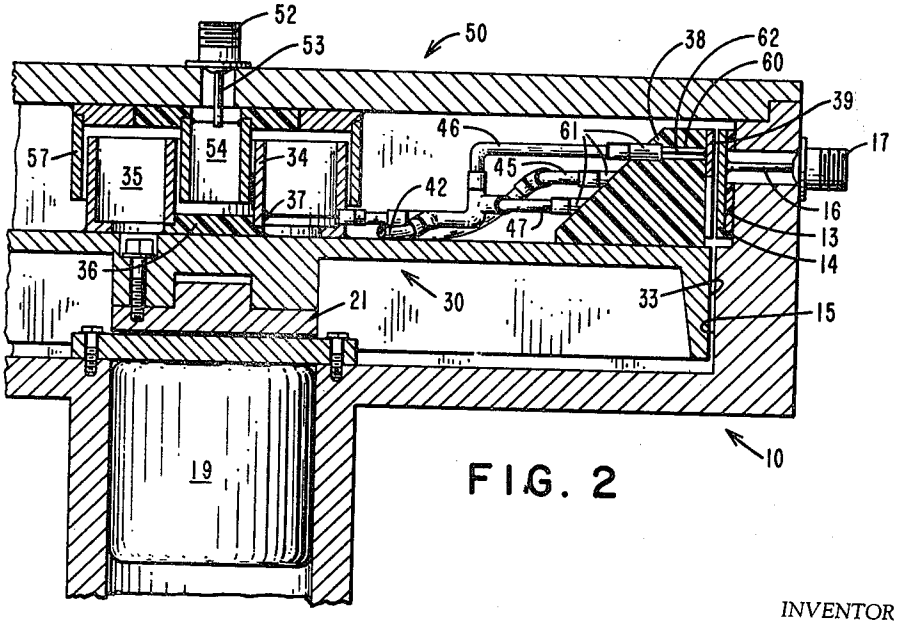


FIG. 2

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CAPACITOR DISTRIBUTOR

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10 Claims. (Cl. 323—93)

This invention relates to electrical distributors and in particular to a capacitor distributor capable of coupling one or more input signals to a plurality of output channels.

Radio navigation systems of the type known as Doppler VOR provide R.-F. radiation containing two modulation signals having a fixed frequency. One modulation signal has a phase which varies directly with azimuth while the other signal has a phase that is constant with azimuth such that a receiving system, by comparing the phase relationship of two signals, can determine its azimuth relative to the transmitting antennas.

The signal whose phase varies with azimuth is transmitted from a circular array of generally fifty antennas successively energized to create what appears to be a moving source of radiation. This apparent or virtual source of radiation by its movement produces the Doppler frequency shift used in the system.

The antennas in the circular array are energized by a R.-F. transmitter which acts through a central distributor to feed R.-F. energy to each antenna in turn thirty times a second. The feeding is accomplished through a single bar or plate on a distributor rotor that is coupled during one complete rotation with each of fifty stator bars positioned on the stator housing, the stator bars being directly connected to fifty output terminals that lead to the antennas.

To simulate a rotating antenna movement exactly is impossible in a system using fifty antennas. However, a good approximation of this movement can be obtained if a virtual source can be made to move uniformly along the chords of the polygon described by the fifty antennas. By using a distributor having a desired output waveform, the uniform movement along the chords can be obtained. It has been found that the distributors presently being used are inadequate in that their output voltage waveform fails to provide the necessary uniform movement required by the system. As a result, the Doppler shift caused by the moving virtual source varies from its predicted value, resulting in an azimuthal error being generated in the receiving equipment.

Accordingly, it is an object of the present invention to provide a capacitor distributor having improved coupling characteristics.

A further object is to provide a capacitor distributor having an improved output waveform.

Another object is to provide a distributor for use with a VOR system such that a virtual source of radiation moves uniformly between adjacent antennas used with the system.

A still further object of the invention is to provide a capacitor distributor having more than one rotor bar whereby a plurality of stator bars may be coupled to the input signal simultaneously to improve the output characteristics of the distributor.

Other objects and advantages of the present invention will become apparent from the following description when read in conjunction with the drawings wherein:

FIGURE 1 is an exploded perspective view of the invention showing the distributor components in full, sectional and cut-away form.

FIGURE 2 is a cross-sectional view of the invention showing the distributor components in assembled relation.

FIGURE 3 is a diagram showing the relative positions of the rotor and stator bars.

Broadly speaking, the present invention comprises a distributor having a rotor and a stator, the stator being generally cylindrical in shape and having on its inner periphery a plurality of spaced bars or plates forming one-half of a capacitive coupling member. The rotor is designed to be concentrically mounted with the stator and is generally in the shape of a disc having mounted at its periphery a plurality of adjacent bars or plates. The rotor bars are less in number than the stator bars such that they are capable of coupling only a limited number of stator bars at any one instant of time during rotation of the rotor. The shape and spacing of the rotor bars together with the phase of the input signal applied thereto are the determinative factors in achieving a desired output wave shape. The area of the rotor side bars decrease outwardly from the center rotor bar while the input signal undergoes approximately a 180° phase reversal as it is fed to alternate rotor side bars.

FIGURE 1 is an exploded perspective view of the invention showing the general construction of the distributor with some of its parts in cross-sectional and cut-away form. The stator assembly **10** is generally cup shape and includes a base plate **11** having formed at its periphery an upwardly projecting flange member in the shape of a cylinder **12**. Mounted by an insulating adhesive compound **13** in a recess on the interior of the cylinder **12** are a series of evenly-spaced rotor bars **14**, the bars being slightly curved to conform to the curvature of the cylinder. The face of the bars **14** are in the shape of an isosceles trapezoid and are of sufficient thickness so that when mounted they are in line with the interior face **15** of the cylinder **12**. Each stator bar **14** is made of a conductive material such as aluminum or copper and is connected by a lead **16** to the center conductor of a conventional coaxial connector **17** mounted on the outside of the stator from which the output of the distributor is obtained.

Sleeve **18** concentric about the center of the stator aligns and contains the motor **19** which is attached to the stator by motor mount **20**. The shaft (not shown) of the motor **19** extends upward and is connected to plate **21** which has disposde on its upper face three or more tapped holes **22** for attachment of the rotor. Aligning boss **23** which can be formed integrally with plate **21** is constructed to fit within an appropriate recess in the rotor.

The rotor **30**, as is the stator **10**, is formed of a conductive material such as steel or aluminum and includes a circular disc **31** terminating on its periphery in a downwardly directed flange portion **32** whose outer face **33** opposes the interior face **15** of the stator in spaced relationship when the distributor is assembled. Concentrically spaced about the center of disc **31** are two electrically conductive cylinders **34**, **35**. The inner cylinder **34** is mounted on and insulated from the rotor by insulating disc **36**, while cylinder **35** is directly attached to the rotor.

Mounted adjacent to the periphery of the rotor **30** is a block **38** of insulating material such as phenolic upon which are mounted a group of closely adjacent rotor bars **39** shown in the figures as being five in number. The rotor bars **39** are made of conductive material such as aluminum or copper and have a slightly curved face to conform to the curvature of the rotor. The bars are attached to the block **38** by screws or adhesive (not shown) and are of sufficient thickness such that their faces are in line with the outer face **33** of the rotor. In addition to serving as a mount, the block **38** insulates the rotor bars from the disc **31**. The rotor bars **39** are active in that they are all fed the input signal to the distributor. This input to the bars is provided through lead **37** attached to cylinder **34**. Lead **37** passes through an aperture in

cylinder **35** and connects to the center conductor of coaxial line **40**, the outer conductor of this coaxial line being attached to cylinder **35**. Line **40** is connected to a conventional coaxial connector **41** from which a number of branch lines emanate. One branch line **42** is considerably longer in length than the others for reasons hereafter explained and terminates at another coaxial connector **43**. The two coaxial lines **45** running from connector **43** feed the two rotor bars positioned on each side of the center rotor bar, and the remaining coaxial branch lines **46** and **47** running from connector **41** feed the center bar and the two outside bars. Coaxial line **42** is secured to the disc **31** by clamps **44**.

Cover plate **50** is composed of a conductive disc **51** having a number of peripheral screws **59** for attaching the plate to the stator **10** when assembling the distributor. Mounted at the center of disc **51** is a coaxial connector **52** which provides the means for applying the input signal to the distributor. Center conductor **53** extends through an aperture in the disc **51** and is connected to conductive cylinder **54** through leads **55**. Cylinder **54** is bonded or otherwise attached to insulating ring **56** which is in turn mounted on the underside of disc **51**. Cylinder **57**, concentric with cylinder **56** about the center of disc **51**, is attached to a conductive ring **57**, this ring also being mounted on the disc **51**.

The assembled relationship of these distributor parts can be seen by referring to the cross-sectional view of FIGURE 2. Rotor **30** is mounted on plate **21** to rotate in conjunction therewith. The electrical input to the rotor is applied from connector **52** through the feed capacitor formed by coaxial cylinders **54** and **34**. Cylinder **34** rotates about cylinder **54** during operation. Coaxial cylinders **35** and **57** also form a capacitor and serve as a ground path from the cover plate **50** to the rotor **40**. Cylinder **35** is sufficiently spaced from cylinder **34** to prevent capacitive coupling that would tend to short out the input signal. Block **38** is formed with five holes therethrough to provide passages for the conductors **62** attached at one end to the rotor bars **39**, and at the other to coaxial connectors **61**. In FIGURE 2 only the center rotor bar and its associated passage is shown in cross section. Connectors **61**, mounted on block **38**, form a termination for the branch lines **45**, **46**, **47**.

As assembled, the rotor bars **39** and stator bars **14** are separated by a narrow air gap and perform as capacitors to couple the input signal appearing at **52** to the multiple output connectors **17**. Faces **33** and **15** are likewise separated by this narrow air gap, thus forming a capacitive ground path between the rotor **30** and stator **10**.

FIGURE 3 illustrates the shape of the rotor and stator bars and their relative positions during the "full-on" position, line A, and the "half-on" position, line B. The center rotor bar **39***a* is an isosceles trapezoid having a rectangular notch at its center to flatten the peak of the approximate sinusoidal output waveform caused by the movement of the center bar past a stator bar. The side bars **39***b* and **39***c* are also trapezoids and decrease in area as they progress outwardly from the center bar.

The effect of these stator and rotor bars can best be understood by discussing them in relation to a Doppler VOR system. In the absence of side bars the output of the distributor would be obtained through the capacitive coupling of a single rotor bar with each stator bar, during rotation, resulting in each antenna coupled to the distributor being energized in turn. While the effect of a radiating antenna moving along the chord between adjacent antennas is obtained, the phase shift and output voltage variations caused mainly by the change in capacitance between the rotor and stator actually creates a non-uniform movement of the apparent or virtual source along the chord. As mentioned previously, this non-uniform movement causes undesirable shifts in the Doppler frequency creating errors in the system.

It has been found that a more uniform movement of the virtual source between adjacent antennas can be obtained by the addition of the trapezoidal side bars. As shown in line A of FIGURE 3, the side bars are in an uncoupled position when the center bar **39***a* is in the "full-on" coupling position with stator bar **14***d*, the output of the distributor being fed to a single antenna in the array. Now, assuming that the rotor bars are moving to the right, movement of the virtual source in the array will be from the antenna connected to stator bar **14***d* to the antenna connected to stator bar **14***e*. As the center bar moves away from the "full-on" position toward the "half-on" position shown in line B, the center bar **39** is coupled to two stator bars **14***d* and **14***e* and the side bars become coupled to the stator bars **14***b*, **14***c*, **14***f* and **14***g* as shown. Thus, once the center bar is moved from the "full-on" position, upwards of six antennas are being fed by the five rotor bars in the distributor. When the center bar **39***a* reaches the half-on position shown in line B, it is feeding equal voltages to the antennas connected to stator bars **14***d* and **14***e*. The side bars at this time are approximately at their peak coupling position as shown. As the rotor bars move further to the right, center bar eventually assumes a "full-on" position with stator bar **14***e* and the side bars are again uncoupled. At this time the virtual source will have completed its movement from the antenna connected to stator bar **14***d* to the antenna connected to stator bar **14***e* and will begin its movement to the antenna connected to stator bar **14***f* as the rotor continues its rotation.

The reduced size of the side bars causes at least fifty percent or greater reduction in the voltage waveform appearing at the output to which a side bar is capacitively coupled. The total output waveform is no longer a sinusoid, but, instead is in the shape of a large main positive sinusoidal lobe having smaller alternately negative and positive side lobes progressively diminishing in amplitude outward on both sides from the main lobe. The leading edge of the side bars preceding the center bar and the trailing edge of the side bars following the center bar are less inclined than their opposite edge to give a non-symmetrical shape to the side lobes formed by the passage of a side bar past a stator bar. The negative lobes are obtained by applying a phase reversal to the signal applied to the side bars **39***b* immediately adjacent the center bar. One manner of accomplishing this phase shift relative to the center bar is by making the length of the coaxial line **42** shown in FIGURES 1 and 2 equal to one-half wave length at the input signal frequency. In this way each rotor bar is fed a signal 180 degrees out of phase with the signal fed to its adjacent bars. By thus feeding additional antennas with reduced voltages both in phase and 180 degrees out of phase with the antenna or antennas fed by the center bar when the rotor is not in the "full-on" position, a resultant radiation pattern occurs at the antenna array which appears to move almost uniformly along the chord between adjacent antennas.

Even though the desired movement of the virtual source is more nearly realized with the present distributor, there will still be present some inherent phase variations in the output wave forms. Since these small phase variations will adversely affect the motion of the virtual source, they can be compensated for by adjusting the lengths of the coaxial branch lines leading to the rotor bars. The length of line **47** can be adjusted so that the output signal from the stators coupled to the side bars **39***c* will be in phase with the output coupled to the center bar. The length of line **42** or **45** can also be adjusted so that the phase of the input signal is shifted 180 degrees plus or minus that required to insure that the phase of the output signal is 180 degrees out of phase with the center bar output. While it would be impossible to eliminate all phase shift due to the wide change in capacitance occasioned by the passage of a rotor bar over a stator bar, the phase shift of the side bars can be adjusted to approximate the

phase shift of the center bar by this adjustment in line length.

While the invention has been described with respect to an exemplary embodiment, it is evident that various modifications are obvious to one skilled in the art. An example would be to increase the number of rotor side bars frome four to six by adding an additional rotor bar outside of side bars 39*c*, and feed these additional bars with the signal reversed in phase 180 degrees, thus keeping every rotor bar 180 degrees out of phase with its adjacent rotor bars. Another modification would be to provide two inputs to the distributor and feed the additional input to a group of rotor bars mounted on the rotor diametrically opposite to the present rotor bars such that two moving virtual sources of radiation are obtained from the system. Thus, it is not intended to limit the scope of the invention except as defined by the appended claims.

I claim:

1. A capacitive distributor comprising a stator containing a cylindrical portion having mounted on its inner periphery a plurality of spaced electrically-conductive stator elements insulated from said stator, each of said stator elements being connected to output coupling means arranged on the exterior surface of said distributor, a rotor concentrically arranged and adapted to be rotated with respect to said stator, said rotor having mounted at its periphery a plurality of adjacent, spaced, electrically-conductive active rotor elements insulated from said rotor, input means on said distributor for feeding an input signal to said rotor elements and means positioned between said last-mentioned means and said rotor elements for reversing the phase of the input signal applied to alternate rotor elements.

2. A capacitive distributor comprising a cylindrical stator having on its inner periphery a plurality of evenly-spaced electrically-conductive stator elements insulated from said stator, each of said stator elements being connected to electrical output means positioned on the exterior surface of said distributor, a rotor concentrically disposed and adapted to be rotated within said stator, said rotor having mounted at its periphery a plurality of adjacent, spaced, electrically-conductive active rotor elements insulated from said rotor, each of said rotor elements positioned to couple each of said stator elements during one complete rotation of said rotor, input means on said distributor for feeding an input signal to said rotor elements and means positioned between said last-mentioned means and said rotor elements for reversing the phase of the input signal applied to alternate rotor elements.

3. A capacitive distributor comprising a substantially cylindrical stator having on its inner surface a plurality of spaced electrically-conductive stator elements insulated from said stator, said stator elements being connected to electrical output means attached to the exterior surface of said distributor, a rotor concentrically disposed and adapted to be rotated within said stator, said rotor having mounted at its periphery a plurality of adjacent, spaced, electrically-conductive, active rotor elements insulated from said rotor, the spacing of said rotor elements being such that during rotation a varying number of stator elements greater than zero are coupled by said rotor elements, input means on said distributor for feeding an input signal to said rotor elements and means positioned between said last-mentioned means and said rotor elements for reversing the phase of the input signal applied to alternate rotor elements.

4. A capacitive distributor as claimed in claim 2 wherein said rotor elements are substantially trapezoidal in shape and said phase-reversing means comprises a transmission line approximately equal in length to one-half wave length of the signal applied to said input means.

5. A capacitive distributor as claimed in claim 3 wherein said rotor elements are substantially trapezoidal in shape and said phase-reversing means comprises a transmission line approximately equal in length to one-half wave length of the signal applied to said input means.

6. A capacitive distributor comprising a stator containing a cylindrical portion having mounted on its inner periphery a plurality of spaced electrically-conductive stator elements insulated from said stator, each of said stator elements being connected to output coupling means arranged on the exterior surface of said distributor, a rotor concentrically arranged and adapted to be rotated with respect to said stator, said rotor having mounted at its periphery a plurality of adjacent, spaced, electrically-conductive active rotor elements insulated from said rotor and having mounted concentrically about its center a first conductive cylinder, a cover plate substantially in the shape of a disc having on one side input coupling means and on its opposite side concentric about its center and electrically connected to said input coupling means a second conductive cylinder of different diameter than said first conductive cylinder such that said first and second cylinders form a capacitor when said stator, rotor and cover plate are in assembled relation and conductive means positioned between said capacitor and said rotor elements including means for reversing the phase of the input signal applied to alternate rotor elements.

7. A capacitive distributor as claimed in claim 6 wherein said rotor elements are substantially trapezoidal in shape and said phase-reversing means comprises a transmission line approximately equal in length to one-half wave length of the signal applied to said input coupling means.

8. A capacitive distributor comprising a substantially cylindrical stator having on its inner periphery a plurality of evenly-spaced electrically-conductive stator elements, a rotor concentrically disposed and adapted to be rotated within said stator, said rotor having mounted at its periphery an odd plurality of rotor elements arranged as a center element and an even number of side elements disposed equally outwardly from said center element, the faces of said rotor elements being substantially trapezoidal in shape and progressively decreasing in area outwardly from said center element, input means on said distributor for applying an input signal to said rotor elements and means positioned between said last-mentioned means and said rotor elements for reversing the phase of the input signal applied to alternate rotor elements.

9. A capacitive distributor as claimed in claim 8 wherein the spacing of said rotor elements is such that during rotation a varying number of stator elements greater than zero are coupled by said rotor elements and wherein said phase-reversing means comprises a transmission line approximately equal in length to one-half wave length of the signal applied to said input means.

10. A capacitive distributor as claimed in claim 8 wherein the area of the side elements is at least 50 percent less than that of said center element whereby at least a 50 percent reduction in output is obtained from the coupling of a side element to a stator element.

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