

[54] **ANTENNA ARRAY BEAM SCANNING SYSTEM**
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[73] Assignee: **Ryan Aeronautical Company**, San Diego, Calif.
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[52] U.S. Cl. **343/117 A, 343/16 M, 343/100 SA, 343/854**
[51] Int. Cl. **H01q 3/26**
[58] Field of Search... **343/16 M, 100 SA, 117 A, 854**

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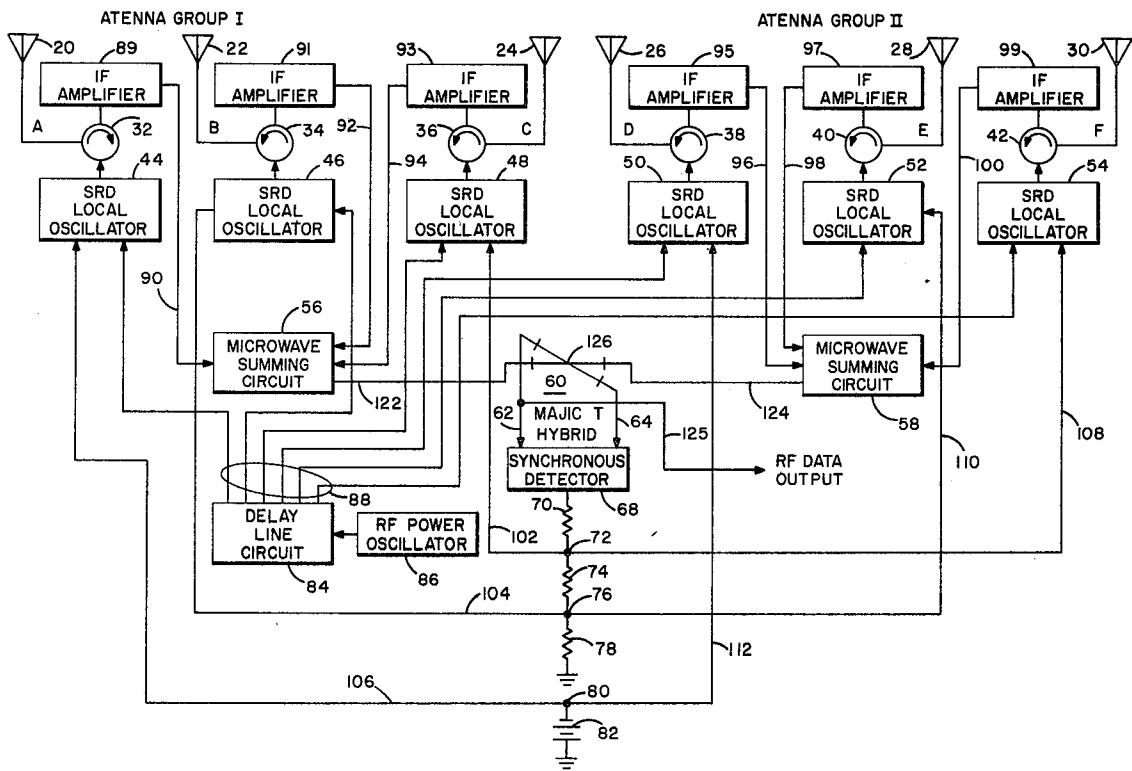
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[57] **ABSTRACT**

An antenna array beam scanning system in which the antenna system beam pointing positions are scanned by providing a typical discriminator response for targets located at different angles to a given phase front alignment. The discriminator output is used to progressively phase the antenna array through step recovery diode local oscillators by using the discriminator output as a DC bias to linearly phase shift the step recovery diode local oscillators and make the antenna array beam track a target.

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9 Claims, 12 Drawing Figures



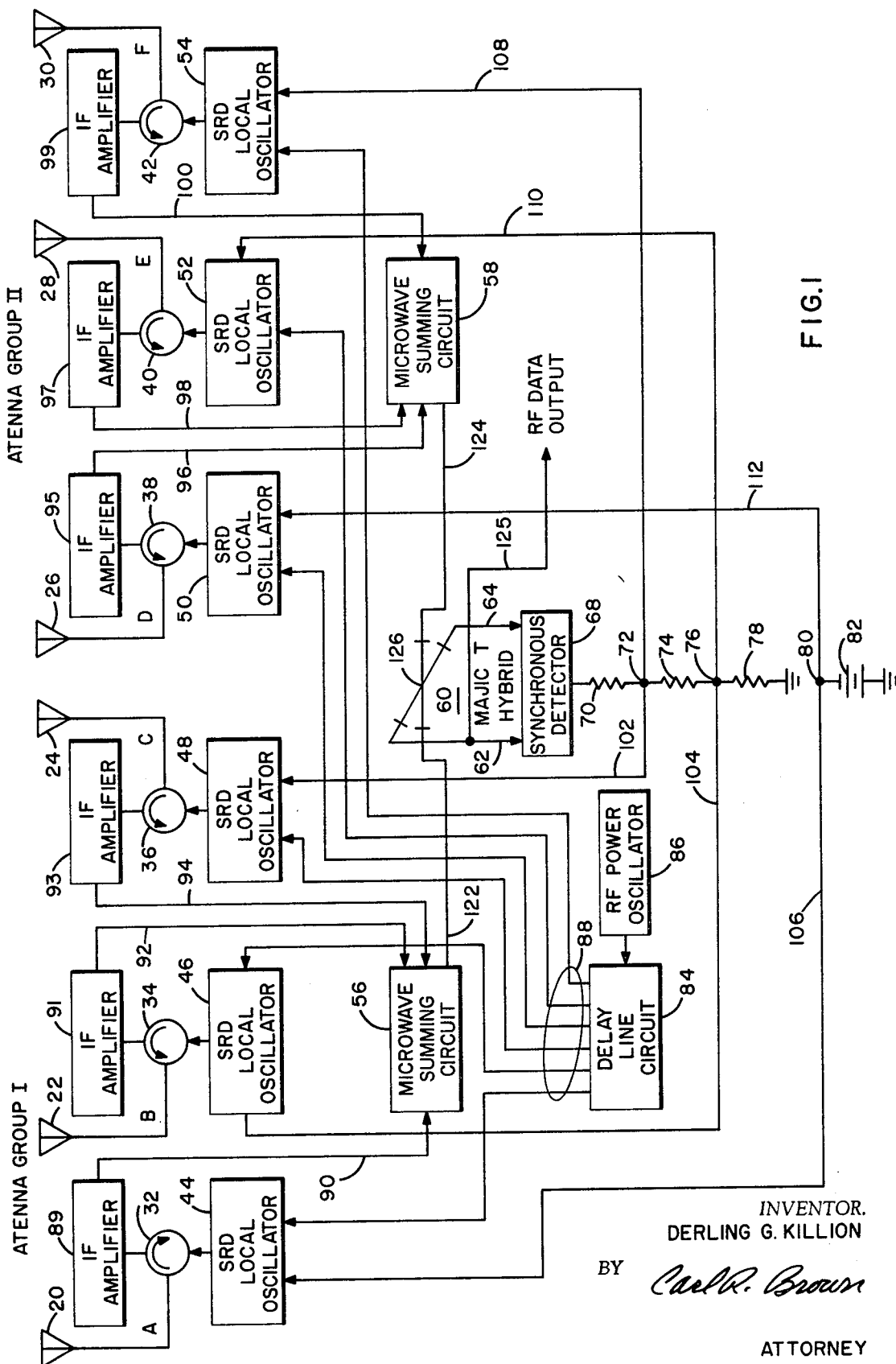


FIG. 1

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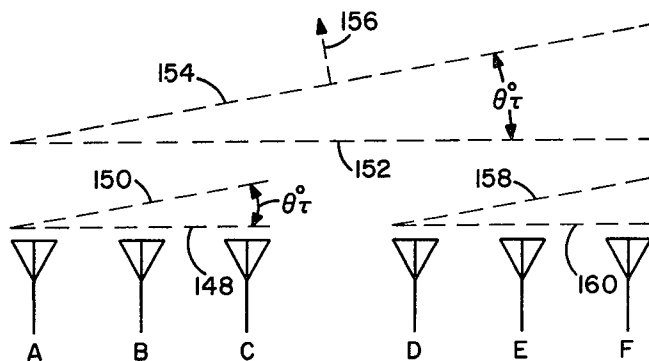


FIG. 2

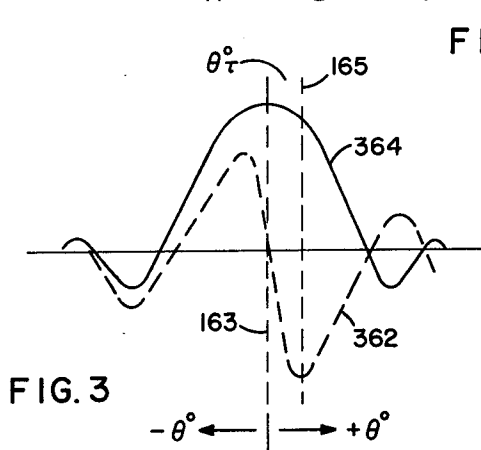


FIG. 3

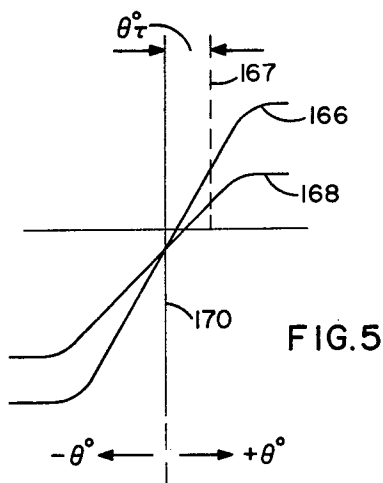


FIG. 5

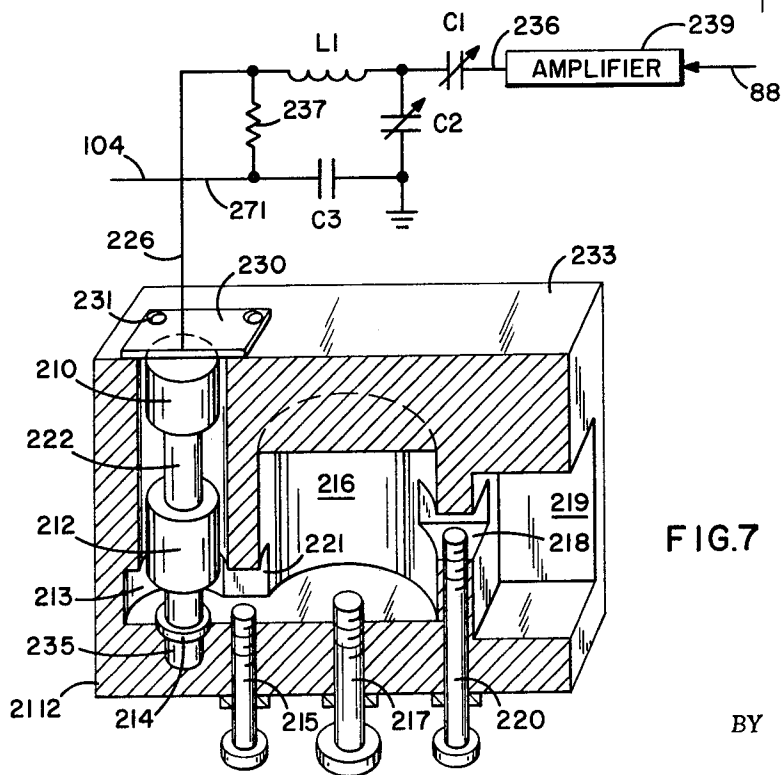


FIG. 7

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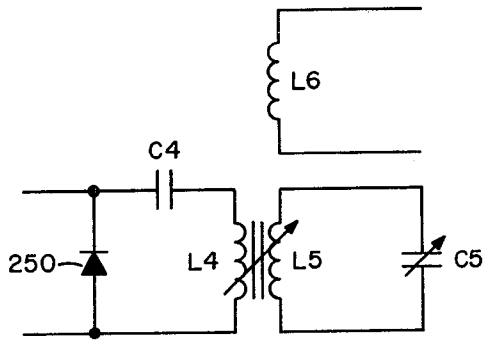


FIG. 8

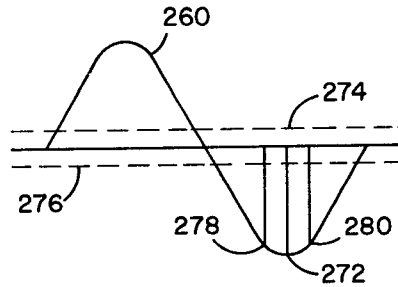


FIG. 9

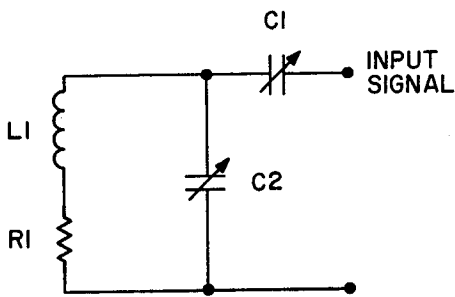


FIG. 10

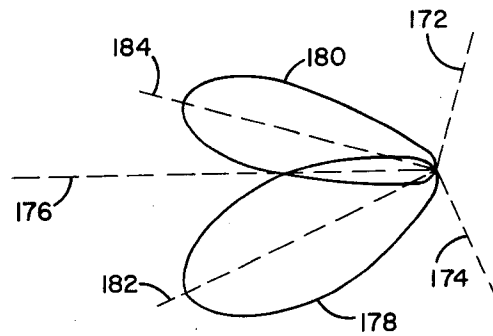


FIG. 6

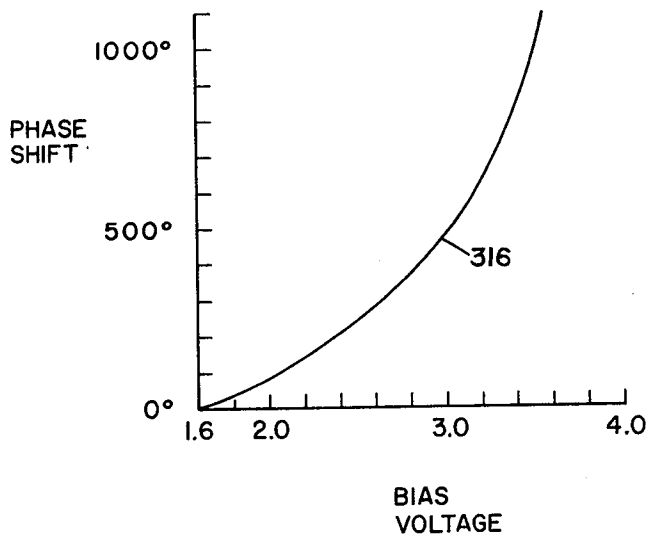


FIG. 11

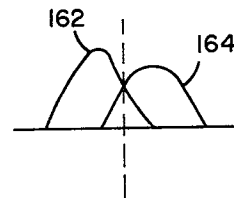


FIG. 4

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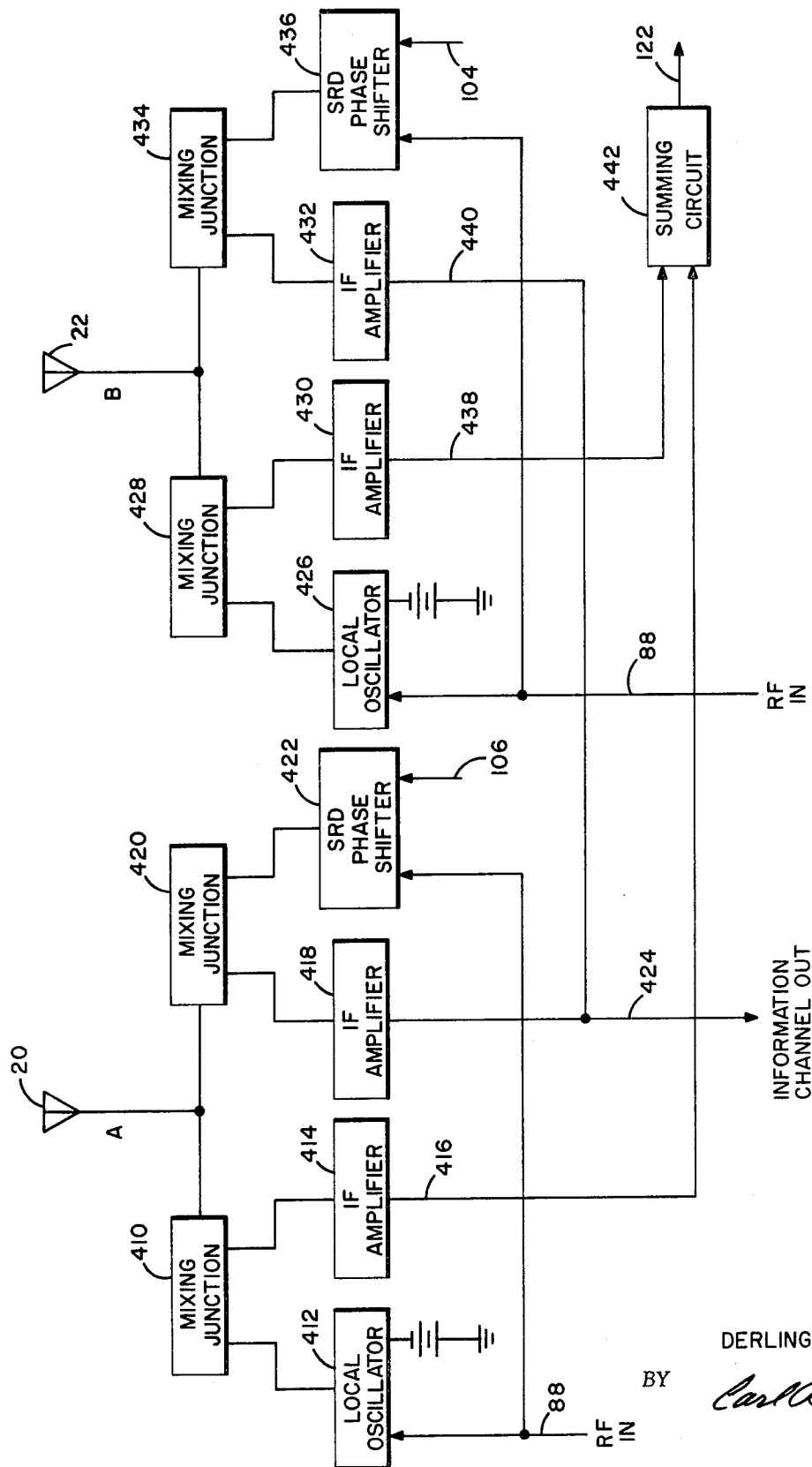


FIG. 12

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ANTENNA ARRAY BEAM SCANNING SYSTEM

BACKGROUND OF THE INVENTION

In scanning antenna arrays to steer or tilt the scanning beam, the RF energy to the individual antennas are varied in phase individually. If the phase distribution varies linearly across the array, then the antenna array is scanned. In known systems, the power is normally generated by a single oscillator. The oscillator output is amplified and if necessary, multiplied to obtain the proper RF power at the desired frequency. The output of the single oscillator is split into several outputs, one for each antenna element. The phase of the signal to each element is then controlled generally by an individual phase shifter that can be variable delay line circuit elements that are switched in or out by diodes, or ferrite phase shifters.

When it is desirable to point the antenna receiving beam at a given target, it is necessary to combine and process the signals received from the target by the individual antenna elements in the antenna array. From this information a discriminator response for the target is developed. This discriminator response must then be used to provide individual phase shifting of the RF power to the individual antenna elements in order to point the receiving beam in the direction of the target. To accomplish such a beam steering through use of the known individual phase shifters, requires the system to shift the phase of the radiated beams. Such systems are cumbersome, have poor reliability, require large amounts of power for beam steering, and in general have a low overall efficiency. This has been one of the primary reasons why scannable antenna arrays have not been used in many applications, such as on spacecraft.

SUMMARY OF THE INVENTION

This invention generally comprises a scannable antenna array in which the pointed positions of the scanning beam are controlled electronically by selectively varying the phase of the electromagnetic energy supplied to the antennas. The antenna system beam pointing positions, are scanned by controlling the bias on step recovery diode local oscillators that generally comprise a step recovery diode frequency multiplier located at each antenna element. The phase of the step recovery diode local oscillator is changed by changing the DC bias on the diode. This allows the step recovery diode local oscillator to control the phase of the intermediate frequency channels of each of the antenna elements to be shifted relative to each other by having the step recovery diode local oscillator control the phase shift of the local oscillator power and thus directly effect the phase of the mixed signal at the intermediate frequency. The phase of the radiated signals arriving at each antenna from a point source is used to adjust the DC bias to the individual SRD local oscillators. When the beam front of the antennas controlled by the SRD local oscillators or SRD phase shifters is aligned with a center line directed to the source of the radiated signals, then the phase adjustments to the SRD local oscillators through the DC bias stabilizers.

In one mode of operation, the SRD control circuit functions as the local oscillator for each antenna in the antenna array. These SRD local oscillators have a relatively small size and have individual phase shifting

capabilities and are capable of providing linear phase shifts of the beam front by simple DC bias control. In this first operational mode, the input signal passed through a summing circuit and into a magic T-hybrid circuit element that supplies sum and difference signals to a synchronous detector that in turn detects the phase and amplitude information differences between the input signals received from at least a pair of antenna groups. This comparison of information of each antenna group provides an error signal in the form of a discriminator voltage that is passed through a resistance circuit to provide controlled DC bias to the individual SRD local oscillators at each antenna. This provides the proper DC bias voltages to make the antennas track a target. The beam front is thus tilted by the change in phase of the output of each individual SRD local oscillator to a degree that eventually a null bias condition is achieved for a given position of the target.

In another mode of operation, the RF power source to the antenna groups provides RF power to the antennas through a separate local oscillator. In this case the SRD local oscillator's function as an SRD phase detector is replaced by a separate SRD phase detector to provide an output RF signal that is summed with the output of the individual local oscillators at each antenna. This provides a phase shift of the RF signal to the antennas that results in a shifting of the beam front of the antenna groups. In this mode, as in the previously described mode, the detected signal received by the antenna groups is summed to provide a bias error signal that is fed to each SRD phase shifter to shift the beam to the desired alignment with a target or a source of radiated signals.

It is therefore an object of this invention to provide a new and improved antenna array beam scanning system.

It is another object of this invention to provide a new and improved antenna array beam scanning system in which antenna arrays are scanned electronically to find targets located at different angles to a given phase front alignment, and to track the targets.

Other objects and many advantages of this invention will become more apparent upon a reading of the following detailed description and an examination of the drawings wherein like reference numerals designate like parts throughout and in which:

FIG. 1 is a block diagram of the circuit in one embodiment of this invention.

FIG. 2 is a schematic diagram illustrating the tilting of the beam front of the antenna array by the operation of the invention.

FIG. 3 is a schematic illustration of respective input signals that determine the bias for tilting the beam front.

FIG. 4 is an illustration of other signals in the system and their relationship one to the other.

FIG. 5 is a schematic illustration of the levels of bias to respective SRD local oscillators or SRD phase shifters relative to the desired target tracking position.

FIG. 6 is a schematic illustration of the tilt of the beam for each group of antennas.

FIG. 7 is an illustration of an SRD multiplier or oscillator circuit with parts shown in block diagram, parts shown schematically and parts shown in cross-section.

FIG. 8 is a schematic diagram of the equivalent circuit of the multiplier cavity structure illustrated in FIG. 7.

FIG. 9 is a diagrammatic representation of the input signal with bias control to the SRD multiplier circuit.

FIG. 10 is a schematic diagram of the equivalent circuit of the SRD frequency multiplier circuit.

FIG. 11 is a graph illustrating the substantially linear relationship between variation in bias voltage and phase shift in the SRD frequency multiplier circuit.

FIG. 12 is a block diagram illustrating a second embodiment of the invention.

Referring now to FIG. 1, there is illustrated an overall block diagram of an antenna array comprising antenna group I and antenna group II with control circuitry. Antenna group I has antenna elements A, B, and C and antenna group II has antenna elements D, E, and F. While three antenna elements are illustrated in each antenna group, it should be understood that such groups may comprise any additional number of antenna elements as may be desired. Each of the antenna groups I and II provide a receiving beam scan having a beam shape and an inner related pointed direction as illustrated in FIG. 6. Each of the antenna beams, as for example antenna beam 178 provided by antenna group I and the antenna beam 180 provided by antenna group II, have respective center lines 182 and 184 that are at an angle to each other. This angle is determined by a known delay line circuit 84 that appropriately changes the phase of the RF power supplied to the SRD local oscillators and the respective antennas. An RF power oscillator 86 provides RF energy that is supplied through delay line circuit 84 and lines 88 to each of the step recovery diode local oscillators 44, 46, 48, 50, 52 and 54 and through the respective circulators 32, 34, 36, 38, 40 and 42 to the antennas 20, 22, 24, 26, 28, and 30.

Each SRD local oscillator circuit receives the RF energy from source 86 and increases its frequency and changes its phase as desired. The SRD local oscillators are so oriented in phase output, one to the other, as to provide correct phasing of the RF power to the respective antennas to maintain the beam divergence of FIG. 6 as established by the delay line 84. The local oscillators are set initially to either provide no phase control to the RF energy or to apply the same phase control at each of the respective oscillators. The phase of the RF energy received by the antennas in group I and in group II to provide the overall angular beam front 172 and 174 of FIG. 6, is provided in the known manner by the delay line circuit 84 that adjusts the phase of the RF power through lines 88. Additionally, each SRD local oscillator has a respective bias control circuit that receives through lines 102, 104, 106, 108, 110 and 112, corrective DC bias for varying the phase of the RF power supplied to the known circulators, thus directing the composite beam fronts 172 and 174. This is accomplished in the manner that will be more apparent hereinafter.

The SRD local oscillators employed in this circuit may comprise any suitable step recovery diode oscillator circuit capable of providing an RF signal, such as for example in the X-band range. The step recovery diode local oscillator comprises a step recovery diode multiplier, that is a simple and easily controlled unit for

providing an accurate and stable output RF frequency signal whose phase is controlled by a direct current bias. The step recovery diode multiplies the input frequency from the RF power oscillator 86 and effects a phase shifting output by means of a simple bias control. The process by which a step recovery diode converts power from one frequency to a harmonic of that frequency is well documented in the literature. Reference is made to Steward M. Krakauer, "Harmonic Generation, Rectification, and Lifetime Evaluation With the Step Recovery Diode," Proceedings I.R.E., Volume 50, No. 7, pages 1,665-1,676, July 1962. The step recovery diode is a diode with special function characteristics and which may also be called a snap diode or a snap varactor.

Basically, the step recovery diode is believed to operate as follows. During forward conduction, a semiconductor diode stores charges in the form of minority carriers in the region of the junction. When the polarity of the voltage applied to the diode is reversed, this stored charge must be swept out before the diode ceases to conduct. Thus the diode is, for a short initial period, able to conduct with relatively low impedance in the reverse direction. When a very abrupt transition from a reverse storage condition to cutoff occurs, this causes a very rapid drop in the current magnitude flowing through the diode. Accordingly, if the voltage applied to the diode is suddenly reversed, the diode continues to conduct until the charge is depleted. Then the diode suddenly goes from a low to a high impedance. The step recovery diode thus functions as a high speed switch and is simply a diode whose parameters have been optimized to make the transition from the stored charge condition to the zero current condition occur very rapidly.

When a step recovery diode is used in a frequency multiplier, the step recovery diode is driven alternately into forward and reverse conduction states by the driving voltage. The transition from reverse storage condition to cutoff, which occurs each negative half cycle, creates electromagnetic energy output that is rich in higher order harmonics of the driving frequency. These output bursts of the diode can be used to ring a very high Q tank circuit that selects the desired harmonic and supplies the output power between the bursts.

A DC biasing circuit is provided, for example, through line 104, for selectively adding positive or negative direct current bias to the input alternating signal and thus selectively positioning the point of current cutoff along the negative half cycle of the input signal. This allows through bias control, in a manner that will be more clearly explained hereinafter, for the exact positioning in time of the point of current cutoff providing a means for varying the phase of the output signal relative to the input signal from lines 88. This phase change is multiplied in the frequency multiplication of the step recovery diode multiplier and thus the phase change obtained between the phase of the input signal and the output signal can be quite large. Further this large phase is obtained with relatively little reduction in the magnitude of the output energy.

The step recovery diode multiplier can be built as a circuit or as a wave guide cavity of either rectangular or circular cross section, or it can be built in a coaxial configuration. The SRD multiplier or SRD local oscillator

44 is coupled directly to the RF energy, see FIGS. 1 and 7. An input signal from line 88 feeds an alternating input signal having a frequency of, for example, from 100 to 800 megacycles and a power of from 100 milliwatts to 10 watts to the driver amplifier 239. It should be recognized that the input signal is not limited to the above stated frequencies or power requirements. Rather the frequency and power ranges are given merely to be illustrative. The input signal is centered around ground with positive and negative peak voltages. The driver amplifier 239 amplifies the signal and feeds it to line 236. Variable capacitors C_1 and C_2 and choke L_1 in line 236 comprise an LC tank circuit that is tuned and matched to the incoming signal. The total resistances of the impedance matching structure 210, 212, and 222 and the resistance of the step recovery diode 214 constitute a resistance in the tuned tank circuit of capacitors C_1 and C_2 and choke L_1 as illustrated in FIG. 10. The high Q input matching tank circuit, as seen by the input signal, is essentially as shown in FIG. 10. The resistance R_1 is the combined resistances of the step recovery diode and the bias resistance. The tank circuit provides good energy storage of the incoming signal and the circuit is easily adjusted and can be made non-microphonic by foaming or potting the components.

The biasing signal is fed from, for example, line 104, to the input circuit line 236 through isolating resistor 237 and by-pass condenser C_3 . The input line 226 to the step recovery diode 214 includes to metal cylinders 210 and 212 and an intermediate conductor 222, all of which form a diode holder. The cylinders may be made of brass or from other similar and suitable materials and are wrapped with a thin layer of teflon tape. The cylinders are a quarter wave length in length at the output frequency and are separated by a small diameter section 222 that is also a quarter wave length long. To the output frequency, the diode holder appears as alternate quarter wave length sections of a high and low impedance coaxial transmission line or effectively as a choke. To the step recovery diode 214, the impedance of the diode holder structure is essentially zero and thus little RF energy at the output frequency escapes through the input line.

The wave guide structure 233 may be made of a conducting metal such as aluminum or the like or the structure can, if desired, be made of a plastic or other suitable material having a conductive metal coating. The holding structure functions to hold the step recovery diode 214 sufficiently rigid to prevent mechanical vibration. A plate 230, that is rigidly fastened to the wave guide structure 233 by screws 231, presses down against cylinder 210 and thus forces the structure and the step recovery diode 214 into a compressed physical structure that rigidly holds the diode 214 into a recess 235 and from physical movement.

When the signal is fed through line 226, the signal passes through cylinders 210 and 212 and conductor 222 to the step recovery diode 214. The signal flowing to the step recovery diode 214 has the alternating positive and negative waveform 260 as illustrated in FIG. 9. The diode 214 during the positive half cycle conducts in the forward conducting condition. During the negative half cycle or the reverse conducting condition, the diode opposes reverse current flow, but this condition does not occur instantaneously. Rather there is a delay

and this delay permits the step recovery diode to function as a high speed switch. When voltage is applied to the step recovery diode in the forward direction, then a charge, in the form of minority carriers, is stored in the region of the junction. In this condition, the diode 214 has a low impedance in the forward conducting condition. When the voltage applied to the diode is suddenly reversed, then the diode 214 continues to conduct while the stored charge of minority carriers is swept out. When the charge is depleted, the diode suddenly goes from low to high impedance. The step recovery diode thus makes the transition from stored charge conduction to zero current very rapidly. It has been found that this occurs in approximately 100 picoseconds. This sudden interruption of reverse current flow is called the snap action of the step recovery diode.

The particular point of snap of the diode depends upon the total minority carriers stored by a particular step recovery diode and because of variations in step recovery diodes 214, this point usually occurs at a point on the waveform other than at peak negative voltages. Thus the biasing current from the previously described biasing circuit is used to move the snap point to the point of peak negative voltage. As illustrated in FIG. 9, the biasing current 274 and 276 can be positive or negative and have selective magnitudes. The positive biasing current 274 causes the wave form 260 to cross over from positive to negative potential at an earlier point in time. Thus if the normal point of snap of a given diode 214 is at point 280 on waveform 260, then the positive biasing current 274 will move the snap point back to point 272; the desired point of peak negative voltage. Should the snap point of diode 214 occur earlier at point 278, then a negative bias 276 will advance the snap point to point 272. Thus it may be seen that by biasing the input circuit, it is possible to selectively adjust the snap point of the step recovery diode 214 to any desired point on the waveform and to selectively vary the time of occurrence of the snap action.

The rapid change of current magnitude in the step recovery diode creates electromagnetic wave energy in the wave guide cavity 213 in which it is mounted. Cavity 213 forms a small resonant cavity. While no means for tuning this cavity is provided, the Q of the cavity is comparatively low and therefore it is broad band. The diode cavity 213 is coupled to the high Q main cavity 216 through an iris 221. The coupling through iris 221 is adjustable by means of an adjustable capacitive post 215 in the center of the iris. The main resonator or cavity 216 is tunable over a narrow range by a center post 217. Output is taken from the main cavity by a second iris 218 coupled to a wave guide 219. The output coupling is adjustable by an iris screw 220 placed in its center.

The cavity structures 213, 216, and 219 form a variable frequency output control means that is represented by the equivalent circuit shown in FIG. 8. The cavity 213 is represented in the equivalent circuit as the resonant circuit having capacitor C_4 and inductance L_4 . Diode 250 represents the step recovery diode 214 of FIG. 7. The resonant circuit of cavity 213 is coupled with the resonant circuit of the cavity 216 that is represented in the equivalent circuit (FIG. 8) by the inductance L_5 and capacitance C_5 . The coupling between

these two resonant circuits of cavity 213 and 216 may be varied by post 215. The output wave guide cavity 219 is represented by the inductance L_6 and the coupling between cavity 216 and the output wave guide cavity 219 is varied by post 220. Cavity 216 is the resonator or filter for selecting the desired harmonic or frequency output. Adjustment of post 217 tunes the filter to the desired frequency output. Posts 215 and 220 are adjustable to optimize the high Q tank necessary for the step recovery diode output and thus functions to adjust the couplings. The tank circuit acts as the energy storage for the cyclic electromagnetic energy output of the step recovery diode and also acts as a filter or resonator to select the desired harmonic and thus the particular output frequency.

By adjusting the bias through line 271 to the input tank circuit, it is possible to selectively change the time or phase of the output frequency from the cavity 219 of the output wave guide relative to the phase of the signal supplied from the master oscillator. The bias can be effectively used to selectively position the snap point over a range of greater than 45° or $22\frac{1}{2}^\circ$ on either side of the peak of the input negative half cycle. This change in time and phase resulting from a change in the time or point of snap of the step recovery diode relative to the time or phase of the input signal, is multiplied in the output frequency. Thus a widely controlled phase change in the output signal is accomplished by varying the direct current bias and thus the snap point of the diode relative to the input signal. The amount of change in phase shift with change in bias has a substantially linear relationship. The curve 316 in FIG. 11 shows actual test results obtained that illustrate this fact. Suitable known wave guide structures carry the generated RF energy from cavity 219 to the next circuit element.

Each of the antennas 20, 22, and 24 in antenna group I in effect scans a target and receives transmitted RF energy from the target. The received RF energy is combined with the SRD local oscillators' output and passes through IF amplifiers 89, 91 and 93 and lines 90, 92, and 94 to a microwave summing circuit 56. Each of the input signals to the microwave summing circuit 56 have the same RF frequency, but can have differences in phase and amplitude as determined by the spacial position of the target transmitter relative to the angular position of the phase front of the antennas 20, 22, and 24 of antenna group I. The microwave summing circuit 56 passes the phase and amplitude differences through line 122 to the known magic T-hybrid waveguide unit 60. The antennas 26, 28, and 30 of antenna group II receive RF signals from the transmitting target in the same manner as the antennas of antenna group I and pass RF energy directly through the IF amplifiers 95, 97 and 99 and through lines 96, 98, and 100 to the microwave summing circuit 58 that passes the phase and amplitude differences through line 124 to the magic T hybrid circuit 60.

The magic T hybrid waveguide unit 60 functions in the known manner to provide the sum in line 62 and the difference in line 64 of the input signals to point 126 to the known synchronous detector circuit 68. The synchronous detector 68 detects the difference in phase and amplitude information, that is primarily amplitude information, and provides a DC output propor-

tional to the difference through resistors 70, 74, and 78 to ground. The DC voltage at 72 is supplied through line 102 as a DC bias to the SRD local oscillator 48 and through line 108 as a DC bias to the SRD local oscillator 54. The DC voltage at 76 is supplied through line 104 as a DC bias to the SRD local oscillator 46 and through line 110 as a DC bias to the SRD local oscillator 52. The voltage drops through resistors 70 and 74 provide a given voltage differential in the DC bias to create through the respective SRD local oscillators an appropriate phase shift of the phase front of antenna group I and antenna group II that causes the antennas to scan in a new angular direction, (see FIG. 3). The difference in phase between the DC bias in antennas B and C of antenna group I provides a given angular relationship of θ_T° as illustrated by line 150 of the phase front relative to the original phase front of line 148. The difference in voltage drop through resistors 70 and 74 provide a similar angular relationship of θ_T° between the phase fronts 158 and 160 of antennas E and F. This provides a coordinated phase front of angle θ_T° . A fixed bias from battery 82 is supplied to the SRD local oscillator 44 through line 106 from point 80 and to the SRD local oscillator 50 through line 112. Thus antennas A and D provide a fixed reference point for the swing of the phase front 150 and 158 as illustrated in FIG. 2 in either the clockwise or counter clockwise direction.

When a target transmitter is, for example, located along line 176, see FIG. 6, then the phase and amplitude of the radiated signals arriving at each antenna from a point source is adjusted by the outputs of the SRD local oscillators, so that they add in phase at the summing network and have equalized amplitudes. Accordingly the summing outputs of summing circuits 56 and 58, as processed by the magic T-hybrid 60 and synchronous detector 68 provides a DC bias to the SRD local oscillators through the resistors 70 and 74 that holds the phase front to provide the scanning beams illustrated in FIG. 6. However, when a target transmitter is located at a point displaced from line 176, as for example along line 182, then the difference in phase and amplitude of the received signals through antenna group I differs from that of antenna group II. This difference is processed by the magic T hybrid 60 and synchronous detector 68 to provide an appropriate DC bias output that, through resistor 70 and 74 and through lines 102, 104, 108, and 110, biases the SRD local oscillators to provide a phase front shift of the antenna groups I and II to a line normal to the direction of the target. As for example, referring to FIG. 2, the individual bias for each of the SRD local oscillators shifts the phase of the signals received by antennas B and C to cause the scanning beam front 150 to move at an angle θ_T° relative to the original beam phase front 148. A similar shift in the beam front 158 for antenna group II provides an overall coordinated beam front 154 that is at the angle to the original composite beam front 152 of θ_T° degrees providing an overall center line 156 of the composite radiated beams, which line 156 in null condition would intersect with the target.

Referring to FIG. 4, the amplitude and phase of an off-set input signal received by the antennas A, B, and C of antenna group I and summed by the microwave summing circuit 56, provides an output signal 162 through line 122. The received RF signal phase and

amplitude received by antenna units D, E, and F of antenna group II provides a summed or product output signal 164 to line 124. The magic T hybrid waveguide unit 60 provides a sum signal 364, see FIG. 3, to line 62 and difference output signal 362 to line 64 that when processed by the synchronous detector 68 provides an output DC bias signal that has a typical discriminator response for targets located at different angles θ_r from the original center 176 of the two scanning beams 178 and 180. Curve 166, see FIG. 5, corresponds to the DC bias plotted relative to scanning time from the combined amplitude of the signals 362 and 364 as provided through resistor 70. Line 168 corresponds to the same DC bias potential as reduced by the drop through resistor 74. Thus the varying DC signal 168 corresponds to that DC bias signal provided through lines 104 and 110 to respective SRD local oscillators 46 and 52, while the DC bias signal 166 is supplied to the respective SRD local oscillators 48 and 54 through lines 102 and 108.

The desired center point, when the radiated RF energy received is from a target to which the scanning beam is pointed, corresponds to line 163 in FIG. 3. Line 163 in FIG. 3 and line 170 in FIG. 5, corresponds to the center of the typical discriminator response signal of FIG. 5. Lines 165 and 167 corresponds to the condition where the beam front is off the target. When the phase front of the two antenna groups has been coordinated with the incoming signal location so that the composite scan along line 156 is pointed to the target, then line 167 of FIG. 5 corresponds with line portion 170 of FIG. 5 and line 165 of FIG. 3 will lay on line 163 of FIG. 3. Thus the phase of the radiated signals arriving at each antenna from a point source has been adjusted by the DC bias so that they add in phase at the summing network. The time space between line 165 and 163 of FIG. 3 and between lines 167 and 170 of FIG. 5 corresponds to the angle θ_r that the phase front must be shifted as illustrated in FIG. 2 to align the center composite line 156 with the given target transmitter. Line 125 provides the RF data output from the incoming signal.

In a brief description of this mode of operation, the antenna groups I and II receive amplitude and phase information that, through microwave summing circuits 56 and 58, hybrid waveguide unit 60, and synchronous detector 68, provides a DC signal that is proportional to the angular relationship between the direction of the phase front of the antenna group and the target. This DC bias is applied to bias circuits of phase of local oscillators to change the phase of the RF power received through delay line circuit 84 and lines 88 and causes the phase front 154 to assume a new alignment with the target. The delay line circuit 84 provides a given constant phase difference of the RF power signals to the respective antenna groups I and II to provide the angular beam fronts 172 and 174 of FIG. 6.

In the operation of the circuit arrangement illustrated in FIG. 1, the SRD local oscillators receive RF power from RF oscillator 86 and provide phase shifted RF power to the antenna through known circulators 32 through 42. In this mode of operation, the RF data output is removed from the sum line 62 through output line 125. In initial operation of this embodiment, the SRD oscillators receive zero bias from the biasing circuits and thus the beam is directed to a given straight

line direction along the antenna groups I and II. In a second mode of operation, as illustrated in FIG. 12, it is desirable to provide an error signal to phase direct the beam in a given direction as determined by the RF power oscillator 86 and a delay line circuit 84 to provide initial direction to the beam radiated by the antenna groups. This allows one oscillator to generate RF power and a second SRD oscillator to phase control the direction of the beam. Also in this circuit arrangement, IF information is removed from the input signals in addition to the RF data output. The circuits for each antenna are illustrated only with respect to antennas A and B, it being understood that similar circuit arrangements are provided for the antenna circuits of antennas C, D, E, and F.

In the initial mode of operation, the RF power from RF power oscillator 86 and through delay line 84 and through line 88 is supplied to the local oscillator 412 for antenna A and to local oscillator 426 for antenna B. The local oscillator provides RF power through mixing junction 410 and to the antenna 20. This directs the beam front of the antenna groups I and II as determined by the delay line circuit 84 in the direction as previously described or along line 176. The signal from a transmitter being scanned by the beam provides an input signal through antenna 20, mixing junction 410 and through the IF amplifier 414 that supplies an IF signal through line 416 to a summing circuit 442 that corresponds to the microwave summing circuit 56 of the embodiment of FIG. 1. Similarly, antenna 22 receives RF power from local oscillator 426 through mixing junction 428 and passes a received input signal from antenna 22 through mixing junction 428 and IF amplifier 430 and line 438 to the summing junction 442. The output of the summing junction circuit 442 is supplied through line 122 to the magic T-hybrid waveguide unit 60 in FIG. 1. The output of the magic T-hybrid waveguide unit through lines 62 and 64 are detected by the synchronous detector 68 of FIG. 1 providing biasing signals through the respective output lines for a given rotational movement of the beam front.

The SRD phase shifter 422 receives RF power from line 88 and in addition receives biasing current through line 106 from the biasing current input as described relative to FIG. 1. The SRD phase shifter 422 operates in the same manner as the SRD local oscillator previously described relative to FIG. 1. However in this case the output of the SRD phase shifter 422 provides an input signal to the mixing junction 420 and antenna 20 that combines with the input RF signal from the local oscillator 412 to antenna 20. Thus in this mode the phase shifted RF signal from the SRD phase shifter 422 provides in effect an error signal that continues to shift the beam front of the antenna group until the bias received through the synchronous detector 68 reaches a substantially nulled condition as previously described relative to FIGS. 3, 4, 5, and 6, and thus the antenna beam front is aligned with the particular target. The SRD phase shifter 422, thus provides a phase shifted RF error signal through the mixing junction 420 that shifts the beam front to the target. The received information from the target that has been previously described as passed through IF amplifier 414 also passes through mixing junction 420 and through the IF

amplifier 418 and through line 424 to an information channel output. This provides IF information output from the received signal that is in addition to the intelligence from the RF data output received through line 125 of FIG. 1, as previously described.

Accordingly in the operation of the circuit of FIG. 12, the beam is originally aligned in a given direction by the local oscillator 412 that is capable of providing a large power to the antenna A. The local oscillator 412 may comprise an SRD oscillator or an other suitable oscillator. However for ease of operation it is advantageous if the local oscillator 412 is an SRD oscillator, even though there is no phase shifting required of the local oscillator 412 in this mode of operation. As previously described, the SRD oscillator permits the phase of the local oscillator 412 to be selectively adjusted to provide peak power output in a controlled phase manner. Thus each of the antennas utilize the RF power in both the local oscillator 412 and the SRD phase shifter 422 to provide a controlled phase shifting of the RF input to selectively move the beam front of the antenna array. The IF information is removed from all of the antennas in both antenna groups to an information channel output and the IF information from each of the antenna groups is supplied to a pair of summing circuits to provide the biased control information to the SRD phase shifter to provide the error signal as well as providing an RF data output through the magic T-hybrid circuit in line 125.

Thus I have provided for two circuit arrangements both of which provide an antenna array beam scanning system in which the beam pointing positions are scanned by providing a typical discriminator response for targets located at different angles to a given phase front alignment of the beam. The scanning antenna array employs a single DC biased control to steer or tilt the scanning beam, and employs a circuit and component arrangement that is greatly simplified and can be used in many places where more complicated systems are presently unable to be used.

Having described my invention I now claim:

1. An antenna array beam scanning system for tracking a target comprising,
 - groups of a plurality of antenna elements having a given beam phase front with each of said antenna elements providing received signal outputs relative to the position of a target to the phase front,
 - means for summing said signal outputs and supplying said summed signal outputs to a magic T-hybrid unit that provides sum and difference outputs,
 - detector means for converting said sum and difference outputs to DC error signals having magnitudes that reflect the angle of said phase front to said target,
 - each of said antenna elements having oscillator means for supplying RF energy to each of said antenna elements,
 - and said oscillator means being responsive to said DC error signals for changing the phase front of said antenna elements to track the target.
2. An antenna array beam scanning system for tracking a target as claimed in claim 1 in which, said detector means includes a synchronous detector

that supplies a DC signal to a resistance ladder, and said oscillator means being electrically connected to appropriate points along said resistance ladder.

3. An antenna array beam scanning system for tracking a target as claimed in claim 2 in which, said groups comprise a pair of groups of antenna elements,
- power oscillator means for supplying RF energy to said oscillator means,
- delay means for changing the phase of the RF energy from said power oscillator means to individual ones of said antenna elements,
- and said means for summing comprises a summing circuit for each of said antenna groups.
4. An antenna array beam scanning system for tracking a target as claimed in claim 3 in which, each of said groups of antennas have related and corresponding pairs of antenna elements,
- and each pair of said antenna elements are connected to a common point on said resistance ladder.
5. An antenna array beam scanning system for tracking a target as claimed in claim 4 in which, said oscillator means comprises a step recovery diode oscillator for each antenna element whose RF output frequency is determined by said power oscillator,
- and each of said step recovery diode oscillators being responsive to the magnitude of said DC bias for providing a given phase to said RF output.
6. An antenna array beam scanning system for tracking a target as claimed in claim 5 including, circulator means electrically positioned between said step recovery diode oscillator and said antenna element and said summing circuit.
7. An antenna array beam scanning system for tracking a target as claimed in claim 4 in which, said oscillator means comprises a first oscillator and a second oscillator for each antenna unit,
- said first oscillator in response to the RF energy from said power oscillator supplies RF energy to said antenna unit,
- and said second oscillator comprises a step recovery diode oscillator that in response to the RF energy from said power oscillator and the magnitude of said DC bias provides a given phased error signal RF output to said antenna unit.
8. An antenna array beam scanning system for tracking a target as claimed in claim 7 including, a first mixing junction means for mixing the output of said first oscillator and the antenna received signal,
- and a second mixing junction means for mixing the output of said second oscillator and the antenna received signal.
9. An antenna array beam scanning system for tracking a target as claimed in claim 8 including, means for feeding the signal from said first mixing junction to said summing circuit,
- and means for feeding the signal from said second mixing junction to an information channel output.

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