The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates generally to radar tracking systems and in particular to an improved radar lobbing antenna system for tracking and command guidance of a guided missile.

Antenna lobbing per se is not new, but the prior art devices producing same in many instances have proven unsatisfactory. For example, lobbing may be effected by moving the center of phase of the projector by mechanically shifting the entire projector left or right or rotating it completely with respect to its on-axis position, or it may be achieved by mechanically switching two or more antennas. Sector-scanning in the former instance results in excessive wear of both the drive and bearing repeat systems and may also allow the antenna to be beamed on the target for only ten to thirty percent of the time and at a rate determined by the sector-switch which, in turn, requires that any radar computer associated therewith must store commands and transmit only when the antenna swings by the target. Mechanical switching between antennas in the latter instance requires additional equipment which makes inefficient use of space as a result of increased bulk and adds additional weight to the carrier vehicle or other support structure. Both of the foregoing systems are subject to the disadvantage that instability may be introduced as a result of mechanical imperfections that cause undue noise and distortions in the received image. Moreover, inasmuch as the operator of radar systems, such as the SV-X, cannot ordinarily determine small target bearing changes, and since he is responsible for the information fed to the computer, the signals representing said information may be erratic and contain undesirable noise components that require heavy smoothing circuits which, in turn, tends to limit the response time of the computer.

The present invention overcomes these disadvantages in that antenna lobbing is effected by using a unique and improved electronic switching circuit in conjunction with an improved antenna structure and radar equipment.

It is, therefore, an object of this invention to provide an improved lobbing antenna system for radar tracking and controlling guided missiles.

Another object of this invention is to provide an improved lobbing antenna system which will feed smooth, relatively noise-free data signals to a radar computer.

A further object of this invention is to provide an improved lobbing antenna system having increased target bearing accuracy and resolution.

Another object of this invention is to provide a radar antenna lobbing system eliminating the necessity of rapid sector scanning.

Another object of this invention is to provide increased radar accuracy.

A further object of this invention is to provide a radar lobbing antenna system having improved reliability.

A still further object of this invention is to provide means for continuously beaming maximum radar energy at all times on a missile being guided thereby.

Another object of this invention is to provide a more secure missile tracking and guiding antenna system which is less susceptible to enemy determination and countermeasures.

Another object of this invention is to provide an improved lobbing antenna system that may be used in conjunction with navigation instruments.

Still another object of this invention is to provide a means for improving fire-control accuracy.

A further object of this invention is to provide a means for permitting missile guidance commands to be transmitted by a radar system as rapidly as they are generated by the guidance computer thereof.

Another object of this invention is to provide an electronically actuated lobbing antenna system which reduces the wear and maintenance requirements of the radar antenna drive and repeater mechanisms.

Another object of this invention is to provide an improved lobbing antenna system that may be adapted for waterproof installation on missiles and submarines.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a block diagram of the complete radar lobbing system constituting this invention;

FIG. 2 is a block diagram of the signal synchronizer portion of the diagram of FIG. 1;

FIG. 3 is a schematic circuit diagram of the signal synchronizer;

FIG. 4 is an elevational view of the transmit-receive switch assembly incorporated in this invention, partially in pictorial form and partially with parts broken away to diagrammatically depict a cross-section of pertinent internal structure;

FIG. 5 contains theoretical views of the receive lobes and corresponding bearing scope display signals; and

FIG. 6 shows a composite of transmit and receive patterns of the subject antenna system when lobbing.

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. 1 an entire radar antenna lobbing system comprising a reflector unit 21 and an antenna array 22 having a trio of horns, including a central transmit and receive waveguide horn 23 of the one and one-half by three inch horizontally polarized type, or the like, connected to a radar transmitter 24 in the usual manner by means of conventional waveguides 25 and 26 and to a radar receiver 27 by means of the aforesaid waveguide 25. Of course, radar transmitter 24 and radar receiver 27 may be considered as the transmit and receive portions of the same radar set if so desired and each may be timely switched into and out of operation as necessary to comply with overall operational requirements, conditions, and circumstances. Thus, it should be understood that the interconnection thereof shown herein is merely diagrammatical for the purpose of this disclosure and may in actual application take the form of any appropriate preferred radar-computer embodiment. This is true, although it should be understood that the subject was invented and originally intended as an improvement adjacent of the U.S. Navy SV-1 Radar and is still experimentally used therein to an advantage.

Radar receiver 27 has three output signals that are pertinent to this invention. One of these signals is the target bearing intelligence signal which is applied to a bearing indicator oscilloscope 28. Another is a synchronizing pulse applied to a range indicator oscilloscope 29 delayed by an amount set by the range dial. And the third of these signals is the range intelligence signal which is likewise fed to the range scope. The aforementioned range
scope synchronizing pulse passes through the range scope and is applied as the input signal to a signal synchronizer 30, which will be explained in detail below.

Signal synchronizer 30 performs two functions which are of paramount importance in this invention. First, it provides a sweep synchronizing voltage for bearing scope 25; second, it provides voltages to a pair of TR switch tubes 31 and 32, such as, for example, of the 721b or BL-601 type, disposed in the cavities of a transmit-receive switch assembly 33 connected to waveguide 25. Said TR switch tubes 31 and 32 are respectively connected through coaxial cables 34 and 35 to a left-hand waveguide horn 36 and a right-hand waveguide horn 37 flanked on each side of the aforementioned central horn 23, all of which continue to form antenna array 22. These left and right-hand horns may be of the order of three-eighths inch wide, but are the same height dimensions as central waveguide 25. A pair of shorting pin solenoids 38 and 39 deactivate left-hand horn 36 and right-hand horn 37, respectively, by means of shorting pins 40 and 41 which are mechanically actuated thereby to short said horns when the entire system is being used as a conventional radar with an antenna lobing effect by this invention. Hence, said solenoids 38 and 39 are also appropriately connected to radar transmitter and receiver 24 and 27 for manual or other control purposes thereat.

As previously mentioned, an important component of the entire antenna lobing system constituting this invention is the signal synchronizer. Referring now to FIGS. 2 and 3, signal synchronizer 30 is shown as receiving trigger pulse T—T from the range scope and applying it to a bistable multivibrator 42 which generates a square wave at one-half the repetition frequency of said trigger pulse. The outputs of alternate stages of multivibrator 42 are respectively differentiated in differentiators 43 and 44 which, in turn, produce positive pulses that are, respectively, applied to fire twenty-five microsecond multivibrators 45 and 46 on alternate pulses from the range scope unit. The outputs from multivibrators 45 and 46 are positive pulses approximately twenty-five microseconds wide and have amplitudes of about fifty volts. They are, respectively, fed through circuit isolation cathode followers 47 and 48 to pulse amplifiers 49 and 50.

The positive pulse output from multivibrator 46 is also applied to an integrator 51 where it is integrated and fed to trigger amplifier 52 for appropriate amplification thereof before being applied to the input of a normal sweep trigger blocking oscillator 53. Blocking oscillator 53 also receives as a second input thereto one of the outputs from the aforementioned pulse amplifier 49. Due to the normal delay of the oscillator 53 it is alternately triggered thereby. But, while it is being actuated by one of said inputs, it automatically blocks any interference signals that may be applied as the other of said inputs and vice versa. Thus, it can be seen that blocking oscillator output 5—5 is a clean twenty-five volt pulse of five microseconds width that is used to simultaneously synchronize the sweep of the aforementioned target bearing display oscilloscope 28 with the operation of the left and right antenna receiving lobe patterns, whereby the signals received by the subject antenna system due to lobe operation are appropriately displayed as a pair of synchronous signals on said bearing scope.

By setting the bias on trigger amplifier 52 by means of a manually operable sweep separation adjustment 54, it is possible to delay the triggering of blocking oscillator 53 by a predetermined amount, causing the sweep trigger synchronized with the right antenna lobe to be started at a latter time, which, in turn, causes the sweep of bearing scope 28 to be delayed and the separation of the signals displayed thereon adjusted accordingly.

Referring now to FIG. 4, the previously mentioned transmit-receive switch assembly 33 and TR tubes 31 and 32 incorporated therein are shown in greater structural detail and as including a seven-eighths inch rigid coaxial T section 55 having flanges 56 and 57 at the ends thereof. Another flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1). A flange 58 is disposed at the end of a leg portion 59 of said T section and is adapted for connection at any pertinent location of the aforementioned waveguide 25 (FIG. 1).
Briefly, the operation of the subject invention when used as a missile tracking and guidance system is as follows: During the transmission period, high power electromagnetic energy is timely propagated through waveguides 26 and 25 to central horn 23 of antenna array 22, from which it is broadcast into space. To appropriately direct the path in space which said broadcast energy takes, said antenna may have an appropriate reflector, refractor, or electromagnetic lens such as reflected and associated therewith.

As the aforesaid electromagnetic energy travels up waveguide 25, part of the energy is coupled into each of the side guide portions of transmit-receive switch 33 to TR tubes 31 and 32. Because the radio frequency power thereof is sufficient to cause a low impedance breakdown to occur across the inner face of the window of each TR tube, a short circuit essentially occurs therein. This short effectivly deactivates both left-hand horn 36 and right-hand horn 37, simultaneously, while the electromagnetic energy is being broadcast by the center projector horn. Center horn 23 is actually the primary radiator and it ordinarily disposed at the focus of the reflector, thus causing the main lobe of the transmitted beam to be on axis, as is theoretically shown in FIG. 5 of the drawing. At the conclusion of the transmission period, the breakdown at the windows of both TR tubes decay in preparation for a receive period.

During reception, the three horn antenna array provides three diverging energy beams in space, as is also shown theoretically in FIG. 5 of the drawing. The left-hand and right-hand horns thereof are so disposed with respect to the center horn thereof to cause the left and right receive beams to be accurately positioned so that their common crossover is located on axis with the transmit beam, thereby providing a null for precision tracking purposes. Although the transmitted energy always radiates dead ahead, the received energy is alternately detected on the left and right sides of the antenna. This is true because either the left-hand and central horns or the right-hand and central horns are active at any given instant. Either one of the side horns may be prevented from feeding its energy to main waveguide 25 by application of a voltage of the order of 600 volts to its respective TR switch tube. This is the case when tube 32 is fired, that no energy will be conducted from left-hand horn 36, and the energy reaching radar receiver 27 will be determined by and come from right-hand horn 37 and central projector horn 23. Likewise, when tube 31 is fired, no energy will be conducted from right-hand horn 37, and the energy reaching radar receiver 27 will be determined by and come from left-hand horn 36 and central projector horn 23. Thus, it can be seen that the apparent center of phase of the antenna array can be moved electronically by making the beam sequence to follow, for example, the order of center, left, center, right, and then repeat. At a pulse rate of four hundred per second, the left beam detects two hundred pulses per second and the right beam detects two hundred pulses per second at a witching rate of 400 times per second.

Although the switching of electromagnetic energy occurs in the transmit-receive switch assembly as a result of the firing of the TR tubes, signal synchronizer 30 causes said TR tubes to timely fire to make said switching possible in accordance with realistic operational lobing patterns, such as, for example, those illustrated in FIG. 6. In order to achieve this end, synchronizing pulses are fed from radar receiver 27 through range scope 29 to signal synchronizer 30 where they are processed to define TR tubes 31 and 32. Thus, at the appropriate time, sweep trigger signals corresponding to reception lobing patterns and bearing scope sweep, respectively, and also characterized as desired by the radar operator at any given moment to provide optimum operational conditions. The signal synchronizer depicted in both FIG. 2 and FIG. 3 is the heart, so to speak, of this invention in that it plays an exceedingly important role therein. Of course, it must function in combination with the aforementioned elements, but in so doing, lends a unique function to the combination which causes vastly improved overall results to be effected.

The pulses received by synchronizer 30 are divided by two in bistable multivibrator 42 and the pair of resulting square wave outputs thereof are led to a pair of corresponding processing channels which are herein referred to as the odd-number signal channel and the even-number signal channel and disclosed as the top and bottom substantially identical channels of FIG. 2, respectively. In these channels, said bistable multivibrator output signals are differentiated in differentiators 43 and 44 to form positive pulses which are applied to multivibrators 45 and 46 in such manner as to fire same on alternate pulses from the range unit, thereby delaying the output of multivibrator 46 relative to the output of multivibrator 45, after which said multivibrator outputs are fed through cathode followers 47 and 48 for circuit isolation purposes and then amplified to approximately 600 volt outputs L—L and R—R in pulse amplifiers 49 and 50, respectively. Output signal L—L is twenty-five microseconds (2 miles) in width and is, of course, applied to TR tube 31 for timely firing thereof for antenna lobing purposes. Likewise, output signal R—R is twenty-five microseconds (2 miles) in width and is applied to TR tube 32 for the same reason.

Since multivibrators 45 and 46 are both twenty-five microsecond multivibrators, their positive pulse outputs are twenty-five microseconds wide and have fifty volt amplitudes. Since, as previously mentioned, these multivibrators are connected for alternate firing by the input pulses from the range scope, even-number signal channel multivibrator 46 should be considered for the purpose of this disclosure as having its output delayed twenty-five microsecond relative to the output of odd-numbered signal channel multivibrator 45.

In order to appropriately synchronize the sweep of the bearing scope with the reception lobe patterns for monitoring thereof by the radar operator, the delayed output from multivibrator 46 is also applied to integrator 51 for shaping function it is amplified in trigger amplifier 52 and coupled as one of the inputs to normal sweep trigger blocking oscillator 53. An output signal taken from the cathode of pulse amplifier 49 is likewise coupled as one of the inputs to said trigger blocking oscillator 53 where it is timely correlated with the other input thereof to provide an output S-S which appropriately synchronizes the sweep of bearing scope 28 to display the signals received by the left and right antenna lobes, as is shown in FIG. 5b. Because the sweep length of the bearing scope is set by some predetermined distance such as, for instance, two miles, delaying the start of the even-numbered pulses causes two targets to appear on the face of the cathode ray tube thereof, and these two targets represent the signals from said left and right lobes. As said FIG. 5b also shows, when the antenna array points directly at the target, the signals from the two lobes are equal in amplitude. It can, therefore, be seen that to keep the antenna pointed directly at the target, the radar operator has only to turn it on its mounting structure until the left and right lobe signals are equal in amplitude. In order to facilitate displacement of said left and right lobe signals for visual purposes, said displacement is accomplished by means sweep separation adjustment 54 which is manipulated as desired by the radar operator.

In event it is desired or necessary to use the radar set incorporating the subject system as a conventional radar for search or other purposes without benefit of the inventive aspect thereof, the left-hand and right-hand horns
may be deactivated and, for all practical purposes, eliminated by shorting them out. This is simply accomplished by the radar operator's energizing shorting pin solenoids 38 and 39 by appropriate switch operation at the radar set control panel which, in turn, causes shorting pins 40 and 41 to short out side horns 36 and 37, respectively. When said side horns are shorted, center transmit-receive horn 23 is the only one that is active, and the entire radar then functions in the usual manner.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claim the invention may be practiced otherwise than as specifically described.

What is claimed is:

For use with a lobing antenna system having a left-hand antenna horn, a center antenna horn, a right-hand antenna horn, a radar receiver, and a main waveguide interconnecting said center antenna horn and said receiver;

a transmit-receive switch connected between said left-hand and right-hand horns and said main waveguide;

said switch including a coaxial T section having a first flange adapted for connection to said main waveguide,

second and third flanges at opposite ends thereof,

a pair of cavitated cylindrical members attached to said second and third flanges respectively,

means connected to each of said cylindrical members adapted to electrically connect same to the afore-said left and right-hand horns respectively,

a pair of TR tubes supported in the cavities of said pair of cylindrical members respectively,

a pair of insulating washers surrounding said TR tubes respectively,

a pair of electrodes insulatedly mounted within said washes respectively, and

means connected to said TR tubes for alternately actuating said TR tubes for effectively connecting said center and left-hand horns thereto simultaneously and for effectively connecting said center and right-hand horns thereto simultaneously in alternation with the simultaneous connection of said center and left-hand horns thereto.

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