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[54] **TRACKING ANTENNA SYSTEM**

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[73] Assignee: **Mitsubishi Denki Kabushiki Kaisha**, Tokyo, Japan

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[51] **Int. Cl.**..**G01s 3/42**

[58] **Field of Search** ....343/113 R, 117 A, 343/7 A, 16 M

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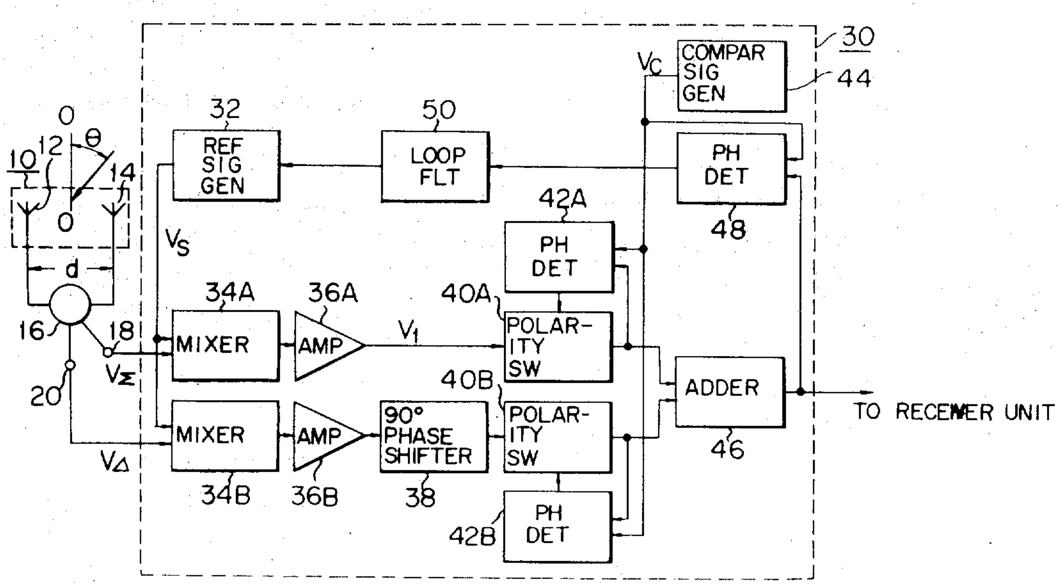
Attorney—Robert E. Burns and Emmanuel J. Lobato

[57] **ABSTRACT**

A tracking antenna system utilizing a sum and a difference signal of radio wave signals received by a pair of antennas. A control unit controls signals based upon the sum and difference signals to always bring them into in-phase relationship and adds the signals thus controlled, whereby a radio wave from a source is received always at its maximum sensitivity.

4 Claims, 7 Drawing Figures



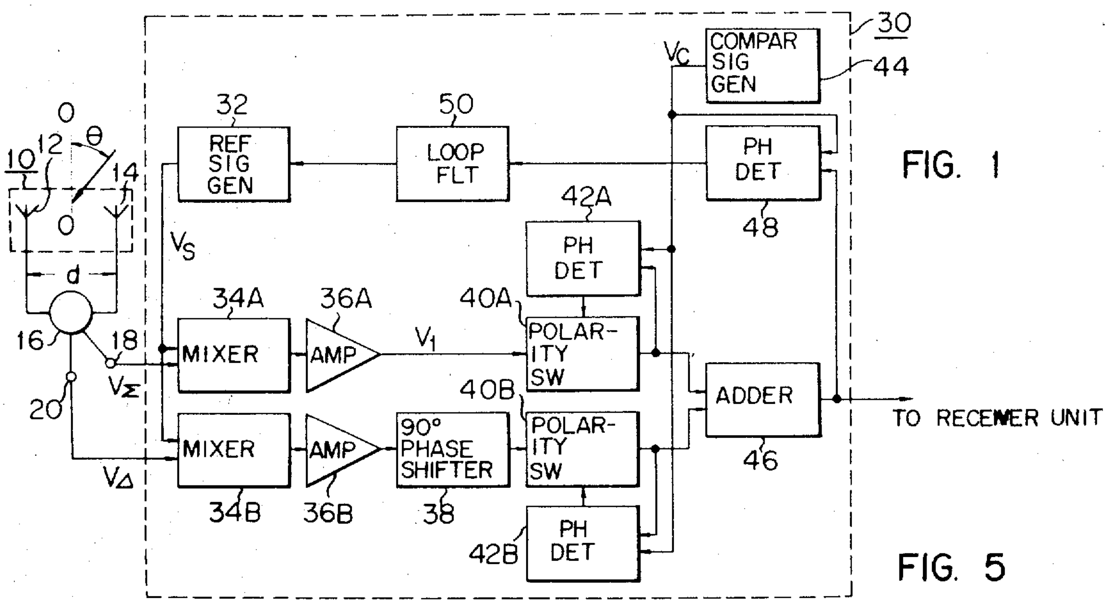


FIG. 1

FIG. 4

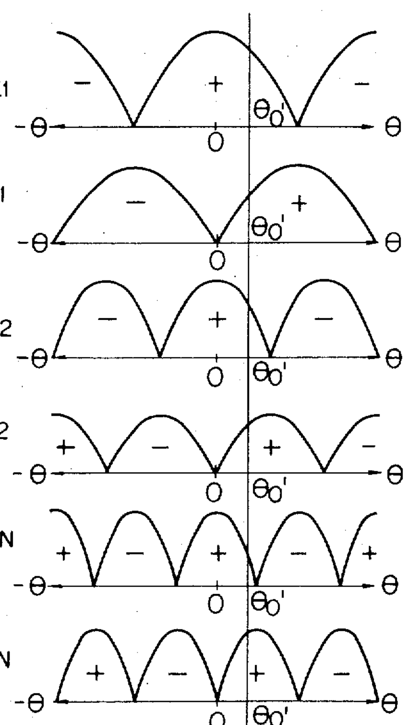


FIG. 5

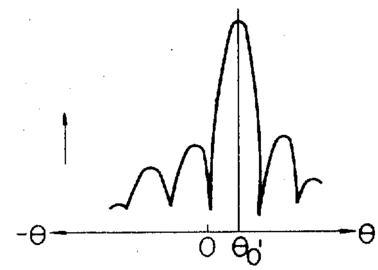


FIG. 2

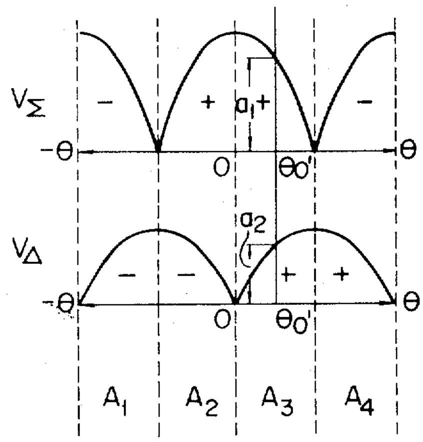
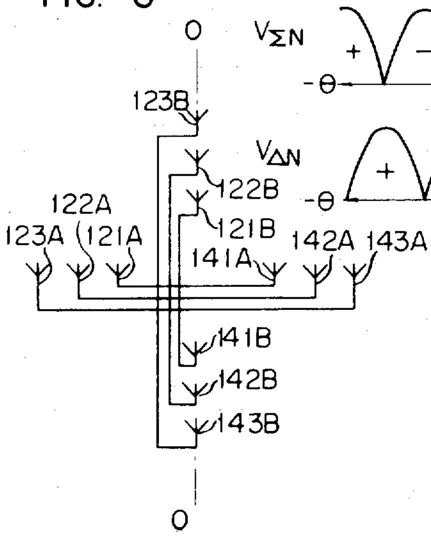


FIG. 6



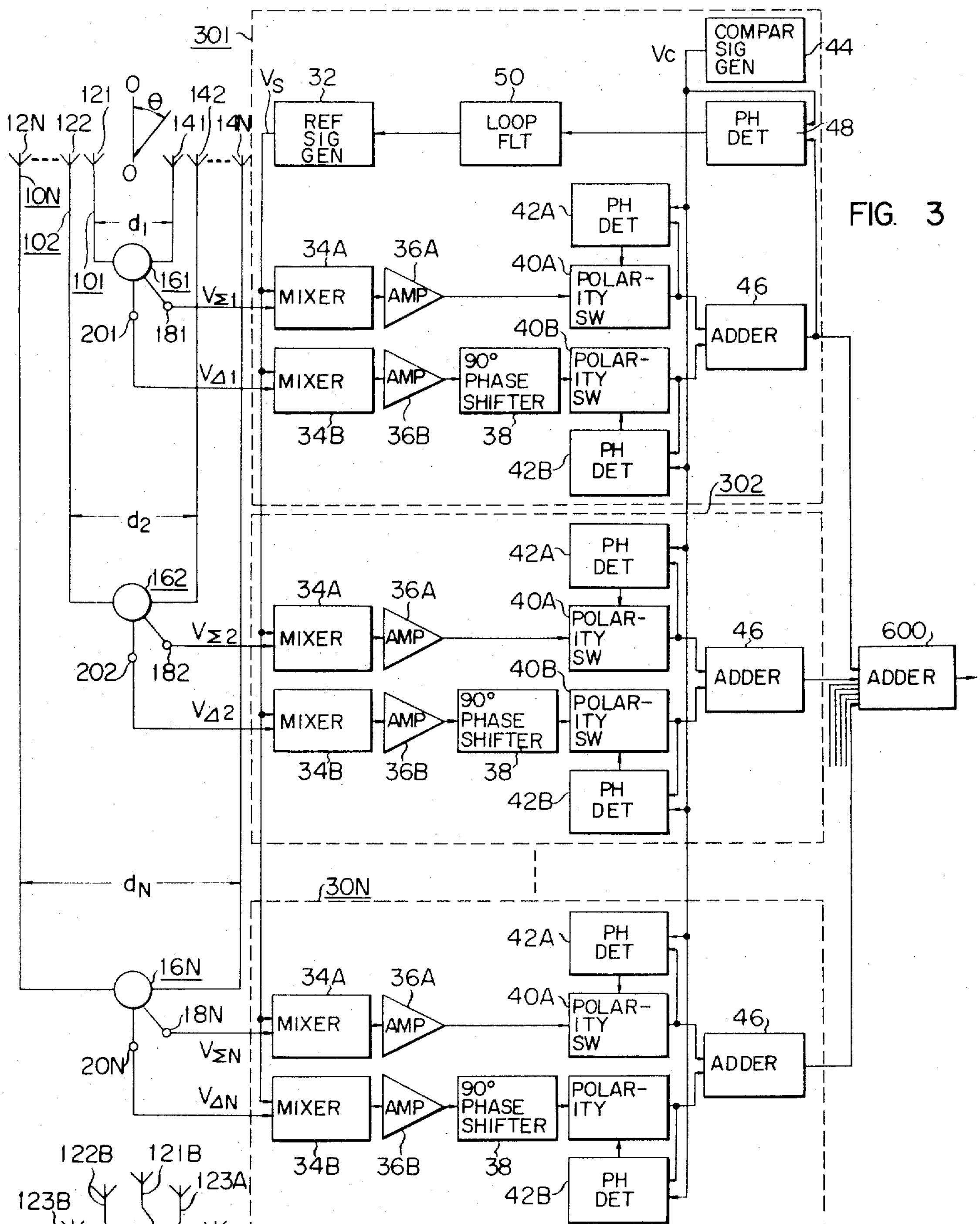

301
302
30N
12N
122
121
142
141
14N
10N
102
101
161
162
16N
181
182
18N
201
202
20N
d_1
d_2
d_N
V_S
V_c
$V_{\Sigma 1}$
$V_{\Delta 1}$
$V_{\Sigma 2}$
$V_{\Delta 2}$
$V_{\Sigma N}$
$V_{\Delta N}$
REF SIG GEN
32
LOOP FLT
50
COMPAR SIG GEN
44
PH DET
48
MIXER
34A
34B
AMP
36A
36B
90° PHASE SHIFTER
38
POLAR-ITY SW
40A
40B
42A
42B
ADDER
46
600

FIG. 3

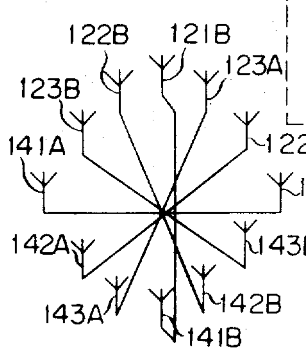

122B
121B
123A
123B
122A
141A
121A
142A
143B
143A
142B
141B

FIG. 7

TRACKING ANTENNA SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This inventin relates to tracking antenna systems capable of tracking a radio wave signal source such as a flying missile so as to receive the radio wave from the signal source at its maximum sensitivity.

2. Description of the Prior Art

As a tracking system of this kind, the one whose antenna is mechanically rotated in accordance with the movement of the signal source has first come to the fore. The system utilizes a sum and difference signals of the radio wave signals received by a pair of antennas (one type of signal to each of the pair) to produce an analog signal having a polarity depending upon the phase relationship as well as the relationship in signal intensity between the sum and difference signals. Through the use of the analog signal thus produced, the antenna system is mechanically rotated to face the direction in which the sensitivity of the antenna is at its maximum with respect to the incoming radio wave. However, the system as above outlined has disadvantages that the mechanism for rotating the antenna is complicated and that an accurate and rapid tracking is difficult to be achieved.

In order to eliminate the above disadvantages of the rotating antenna type systems, there has also been proposed an antenna system wherein one of the pair of antennas is equipped with a radio wave phase shifter or a microwave phase shifter. The radio wave phase shifter used in the system serves to phase shift the radio wave signal through the use of the analog signal as previously described so as to cause the sensitivity of the antenna with respect to the incoming radio wave to reach its maximum. According to the antenna system of this type, although the antenna is not required to be mechanically rotated, another problem arises in the associated phase shifter. More specifically, the phase shifter is so arranged that either one of the phase shifters exhibiting various amounts of phase shifts is selected, or, otherwise, a rotary type phase shifter (continuously variable phase shifter) is used, in order to change the amount of phase shift in accordance with the movement of the signal source. This arrangement, however, is also disadvantageous in that the system becomes complicated in structure and that the tracking speed is not so high as required. In addition, since the typical phase shifter of this type is made of ferrite, the phase shifter is apt to change in the amount of phase shift depending upon the change in ambient temperature, leading to a disadvantage that an accurate tracking operation is difficult to be achieved.

Accordingly, an object of the inventio is to provide a new and improved tracking antenna system with a simple construction which uses neither the mechanical rotation of the antenna nor the radio wave phase shifter capable of performing a rapid and accurate tracking of a signal source.

SUMMARY OF THE INVENTION

According to the present invention there is provided a tracking antenna system comprising at least one antenna pair, a hybrid junction coupled to said antenna pair to produce a sum signal and a difference signal of radio wave signals received by each of antennas of said antenna pair, and control means for controlling a first signal based upon said sum signal and a second signal based upon said difference signal to always bring these two signals into in-phase relationship and for adding said first and second signals.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a block diagram showing the tracking antenna system constructed in accordance with the invention;

FIG. **2** is a graph showing the sum and difference signals supplied from the hybrid junction employed in the system shown in FIG. **1**;

FIG. **3** is a block diagram showing another embodiment of the invention;

FIG. **4** is a graph showing the sum and difference signals supplied from the hybrid junctions employed in the system shown in FIG. **3**;

FIG. **5** is a characteristic diagram for showing sensitivity pattern of the antenna system shown in FIG. **3**;

FIG. **6** is a schematic diagram showing the disposition of antennas for use in still another embodiment of the invention;

FIG. **7** is a schematic diagram showing the antenna disposition for use in another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing for a more detailed understanding of the invention, and in particular, to FIG. **1**, an antenna array generally designated by the reference numeral **10** comprises a pair of antennas **12** and **14** spaced a distance d apart from each other. The antennas **12** and **14** are coupled to each other at the lower portion of the antenna array **10** by a hybrid junction **16** which may be a micro strip type coupler or the so-called magic T coupler. The hybrid junction **16** has first and second output terminals **18** and **20** respectively, the first output terminal **18** provides a sum signal V_{Σ} of the radio wave signals each received by the respective antennas **12** and **14**, and, on the other hand, the second output terminal **20** provides a difference signal V_{Δ} of the radio wave signals each received by the respective antennas **12** and **14**.

FIG. **2** shows amplitudes of and phase relationship between the sum and difference signals V_{Σ} and V_{Δ} with respect to the incident angle θ of the incoming radio wave. The incident angle θ of the radio wave is measured from a geometric central axis **0—0** of the antenna array which is perpendicular to a line connecting the antennas **12** and **14** and on a plane including both the antennas **12** and **14**.

The relationships between the sum and difference signals V_{Σ} and V_{Δ} and the incident angle θ are given by the following equations:

$$V_{\Sigma} \; \alpha \cos(\phi/2)$$

$$V_{\Delta} \; \alpha \sin(\phi/2)$$

where,

$\phi = kd \sin\theta$, $k = 2\pi/\lambda$,

λ = wave length of incoming radio wave, and

d = distance between antennas.

In FIG. 2, there are shown four ranges of angles A_1, A_2, A_3 and A_4, each range corresponding to 90°. More specifically, the ranges A_1 to A_4 range from −180° to −90°, −90° to 0°, from 0° to +90°, and from +90° to +180° respectively. It is also seen that the sum signal V_Σ is of minus phase and the difference signal V_Δ is of minus phase within the range A_1. Within the range A_2, the sum signal V_Σ is of plus phase and the difference signal V_Δ is of minus phase; within the range A_3, the sum signal V_Σ is of plus phase and the difference signal V_Δ is of plus phase; and within the range A_4 the sum signal V_Σ is of minus phase and the difference signal V_Δ is of plus phase. It is to be noted that the "-plus" and "minus" denote that these signals are in the inverted phase relationship to each other.

FIG. 2 also shows that the amplitudes of the signals V_Σ and V_Δ vary in accordance with the change of the incident angle θ of the incoming radio wave. For example, when the incident angle θ is θ_0, the amplitude of the signal V_Σ is a_1 while that of the signal V_Δ is a_2. in FIG. 2, the amplitudes a_1 and a_2 are shown as heights of the curves at the incident angle θ_0.

The above description of the sum and differences signals V_Σ and V_Δ has been made in terms of the changes in phase and in amplitude with respect to the incident angle θ of the incoming radio wave, therefore, it is to be noted that "plus" and "minus" in phase shown in FIG. 2 denote the phase relationship with respect to the incident angle θ. Considering the phase relationship with respect to the incident angle θ between the sum and difference signals V_Σ and V_Δ together with the phase relationship with respect to time between the sum and difference signals V_Σ and V_Δ, both the sum and difference signals V_Σ and V_Δ are of minus phase while the difference signal V_Δ is delayed by a phase angle of 90° with respect to the sum signal V_Σ within the range A_1. Similarly, the phase delay of 90° is always present in the differences signal V_Δ with respect to the sum signal V_Σ also within the ranges A_2, A_3 and A_4.

Referring back to FIG. 1, there is illustrated a control unit generally designated by the reference numeral **30** is shown as encircled by a dotted line. This control unit **30** comprises a reference signal generator **32** such a voltage controlled oscillator, whose main function is to generate an a.c. reference signal V_s exhibiting a frequency lower or higher by an intermediate frequency than the radio wave signal coming into the antennas **12** and **14**. The control unit **30** also comprises a so-called mixers **34A** and B which convert the signal frequency to the intermediate frequency. The first mixer **34A** receives at its input terminals the sum signal V_Σ from the first output terminal **18** of the hybrid junction **16** and the reference signal V_s supplied from the reference signal generator **32**, and delivers an output of intermediate frequency equal to the difference in frequency between the sum signal V_Σ and the reference signal V_s. The second mixer **34B** receives at its input terminals the difference signal V_Δ from the second output terminal **20** of the hybrid junction **16** and the reference signal V_s supplied from the reference signal generator **32**, and delivers an output of intermediate frequency equal to the difference between the frequencies of the sum signal V_Σ and the reference signal V_s The intermediate frequency outputs supplied from the mixers **34A** and B are equal in phase to the sum and difference signals V_Σ and V_Δ respectively. The intermediate frequency output are, in turn, amplified by intermediate frequency amplifiers **36A** and B. The output from the intermediate amplifier **36A** will be called hereinafter a first signal V_1.

The output from the intermediate frequency amplifier **36B** is supplied to a 90° phase shifter **38** whose function is to compensate the time delay of 90°, therefore, the 90° phase shifter **38** provides an output or a second signal V_2 which is compensated by a time delay of 90°. It is to be recalled that the difference signal V_Δ is always delayed in time by an angle of 90° as compared with the sum signal V_Σ. Thus the 90° phase shifter **38** brings the difference signal V_Δ into in-phase relationship in terms of time with the sum signal V_Σ. As a result, within the ranges A_1 and A_3, the first and second signals V_1 and V_2 are brought into in-phase relationship with each other, while within the ranges A_2 and A_4 the first and second signals V_1 and V_2 are brought into inversed-phase relationship with each other; i.e., they are out of phase by an angle of 180°.

The control unit **30** further comprises polarity switches **40A** and B, phase detectors **42A** and B, and a comparison signal generator **44**. The polarity switches **40A** and B have a function similar to 180° phase shifters. The first and second signals V_1 and V_2 passing through the polarity switches **40A** and B are phase-detected by the phase detectors **42A** and B respectively through the use of a comparison signal V_c which is supplied from the comparison signal generator **44**. The comparison signal V_c is, for example, in in-phase relationship with the first signal V_1 which appears when the sum signal V_Σ shown in FIG. 2 is of plus phase.

Therefore, when the sum signal V_Σ is of plus phase, the first signal V_1 passing through the first polarity switch **40A** is borught into in-phase relationship with the comparison signal V_c, and therefore the first phase detector **42A** prevents the polarity switch **40A** from being operated. As a result, in this case, the first signal V_1 is passed through the polarity switch **40A** without being phase shifted by it and is supplied to an adder **46** whose function will be described in more detail later on.

On the other hand, when the difference signal V_Δ is of plus phase, the second signal V_2 passing through the second polarity switch **40B** is in in-phase with the comparison signal V_c. This is because the 90° phase shifter **38** has brought the second signal V_2 passing through the polarity switch **40B** into in-phase relationship with the first signal V_1 which appears when the sum signal V_Σ is of plus phase. Therefore, in this case, the second phase detector **42B** prevents the polarity switch **40B** from operating to deliver the second signal V_2 through the polarity switch **40B** without producing any shift in phase to the adder **46**.

With the sum signal V_Σ which is of minus phase as in the case illustrated in FIG. 2, the polarity switch **40A** is brought into its operable state by the phase detector **42A** to shift the first signal V_1 passing through the polarity switch **40A** by an angle of 180° or invert in phase. This results in the polarity switch **40A** providing an output signal which is in in-phase relationship with the signal V_1 derived from the sum signal V_Σ of plus phase even when the sum signal V_Σ is of minus phase.

Similarly, with the difference signal $V\Delta$ of minus phase as in the case shown in FIG. 2, the polarity switch **40B** is brought into its operable state by the phase detector **42B** to shift the second signal V_2 passing through the polarity switch **40B** by an angle of 180° or invert in phase, thereby to provide an output signal which is in in-phase relationship with the signal V_2 based upon the difference signal $V\Delta$ of plus phase.

The signals V_1 and V_2 passing through the polarity switches **40A** and B and thus controlled in phase are supplied to the adder **46** of the conventional design. The adder **46** adds the input signals V_1 and V_2 to provide an output to a receiver unit (not illustrated) of the conventional design.

From the foregoing description, it is easily understood that the output from the adder **46** is always at its maximum in the direction of the incident angle θ of the incoming radio wave. For example, in the case the incident angle θ is of an angle θ_o which is an angle within the range A_3, the first signal V_1, based upon the sum signal $V\Sigma$ exhibiting an amplitude a_1 as illustrated in FIG. 2, and the second signal V_2, based upon the difference signal V_Δ exhibiting an amplitude a_2, are in the in-phase relationship with each other because the polarity switches **40A** and B do not operate and the signals V_1 and V_2 flow without any change. Therefore, after the first and second signals V_1 and V_2 have been added by the adder **46**, they increase in intensity. Similarly, when the incident angle θ of the incoming radio wave falls within any one of the ranges A_1, A_2 or A_4, the first and second signals V_1 and V_2 based upon the sum and difference signals $V\Sigma$ and $V\Delta$ respectively are added by the adder **46** after they have been brought into the in-phase relationship with each other, whereby the adder **46** always provides a high output to the receiver unit. Thus the tracking antenna system of the present invention can perform the tracking operation wherein the radio wave beamed from the moving signal source is always received at the maximum sensitivity.

To transmit a radio wave through the use of the antenna system of the invention, the polarity switches **40A** and B are operated in response to the ranges of angles in which the target to be aimed at exists. This enables the radio wave transmitted from the antenna array to always beam accurately at the target at its maximum intensity.

The control unit **30** further comprises a third phase detector **48** and a loop filter **50** which form a phase lock loop. The phase detector **48** phase detects the output from the adder **46** with respect to the comparison signal V_c. When the radio wave coming into the antenna array **10** varies in frequency, the phase relationship which has been extablished between the output from the adder **46** and the comparison signal V_c may become lost and result in the signals V_1 and V_2 becoming out of phase with each other. To remove this inconvenience the phase detector **48** generates a d.c. output having a polarity depending upon the direction of the phase shift and having a magnitude proportional to the amount of the phase shift as compared with the comparison signal V_c. The d.c. output from the phase detector **48** is supplied through the loop filter **50** to the reference signal generator **32** to change the oscillation frequency of the signal generator, thereby to maintain the output from the adder **46** in the in-phase relationship with the comparison signal V_c.

FIG. 3 shows another embodiment of the present invention capable of performing a tracking operation exhibiting a higher sensitivity. As seen from the FIGURE, the tracking antenna system comprises a plurality of antenna arrays **101**, **102**,... and **10N**, each composed of a pair of antennas **121** and **141**, **122** and **142**,..., and **12N** and **14N** respectively. Assuming that the distances between the respective antennas **121** and **141**, **122** and **142**,..., and **12N** and **14N** are d_1, d_2, –, d_N respectively, each of the antennas is disposed such that the relationship $d_1 < d_2 < - < d_N$ is held. The antenna array **101** is provided with a hybrid junction **161** having a first and second output terminals **181** and **201**. Similarly, the antenna arrays **102** to **10N** have hybrid junctions **162** to **16N** respectively which also have respective first and second output terminals **182** and **202** and **18N** and **20N**. The hybrid junctions **161** to **16N** are of the construction identical to the hybrid junction **16** which has been previously described in conjunction with FIG. 1. Therefore, the first output terminals **181**, **182**,...., **18N** provide sum signals $V\Sigma_1$, $V\Sigma_2$, – $V\Sigma_N$ of the incoming radio wave received by each of the antennas respectively, and the second output terminals **201**, **202**,–**20N** provide difference signals $V\Delta_1$, $V\Delta_2$, – $V\Delta_N$ of the incoming radio wave from the signal source respectively as in the case of the first embodiment previously described. The sum and difference signals V_Σ and $V_{\Delta 1}$ supplied from the hybrid junction **161** through the first and second output terminals **181** and **201** respectively are provided to a control unit generally designated by the reference numeral **301**. Similarly, the sum and difference signals $V\Sigma_2$ and $V\Delta_2$, and $V\Sigma_N$ and $V\Delta_N$ provided from the respective hybrid junctions **162** and **16N** are supplied through the output terminals **182** and **202**, and **18N** and **20N** to control the units **302** and **30N** respectively. The control units **301**, **302**, – **30N** are of the construction similar to those described in conjunction with FIG. 1 excepting that the reference signal generator **32**, comprison signal generator **44**, and third phase detector **48** and loop filter **50** incorporated in the control unit **301** are used in common with the other control units **302** to **30N** inclusive. In order to obtain an output signal which is to be supplied to a receiver unit (not shown), all the output signals from the adders **46** each involved in the control unit **301**, **302**, – **30N** are added by an adder **600**.

FIG. 4 shows the relationships between the sum signals $V\Sigma_1$, $V\Sigma_2$, – $V\Sigma_N$ and the difference signals $V\Delta_1$, $V\Delta_2$, –, $V\Delta_N$ respectively in amplitude and in phase with respect to the incident angle θ of the incoming radio wave. As seen from the FIGURE, the variation in the intensity of the signals $V\ _2$ and $V\ _2$ from the second antenna array **102** with respect to the incident angle θ of the incoming radio wave is shorter in the cycle of variation as compared with the variation in the intensity of the signals $V\Sigma_1$ and $V\Delta_2$ derived from the first antenna array **101**. It is also seen that the cycle of the variation of the signals $V\Sigma_N$ and $V\Delta_N$ is shorter than those of the other signals. This will be easily understood by putting the relation of $d_1 < d_2 < - < d_N$ into the equations previously described.

The control units **301**, **302**, –, **30N** operate similarly to the control unit **30** previously described in conjunction with FIG. 1. More specifically, the control units **301**, **302**, –, **30N** control the sum signals $V\Sigma_1, V\Sigma_2, - V\Sigma_N$ and the difference signals $V\Delta_1, V\Delta_2, - V\Delta_N$ respectively to cause the respective sum and difference signals to be brought into the in-phase relationship as well as into the same polarity relationship independent of the variation in incident angle θ of the incoming radio wave. Under the above control, the control unit **301** provides an output signal which is an added signal of the signals based upon the sum and difference signals $V\Sigma_1$ and $V\Delta_1$, and the control unit **302** provides an output signal which is an added signal of the signals based upon the sum and difference signals $V_{\Sigma 2}$ and $V_{\Delta 2}$, and similarly, the control unit **30N** provides an output signal which is an added signal of the signals based upon the sum and difference signals $V\Sigma_N$ and $V\Delta_N$. As a result, each of the output from the control units **301**, **302**, – **30N** is controlled to exhibit a common polarity and a common phase independent of the variation of the incident angle θ. These outputs from the control units **301**, **302**, –, **30N** are added by the adder **600** to produce an output to be supplied to an unillustrated receiver unit.

FIG. **5** shows a sensitivity pattern of the antenna system shown in FIG. **3** under the condition of the incident angle θ of the incoming radio wave being θ_o'. From the FIGURE, it is apparent that the sensitivity is at maximum at this incident angle θ_o'.

FIGS. **6** and **7** illustrate antenna arrays for use with another embodiment capable of performing a tracking operation in the three-dimensional space. It is seen in FIG. **6** that six antennas **121A**, **122A**, **123A**, **141A**, **142A** and **143A** are disposed on a first plane including a geometric central axis **0—0** and that the other six antennas **121B**, **122B**, **123B**, **141B**, **142B** and **143B** are disposed on a second plane including the geometric central axis **0—0** and perpendicular to the first plane. In FIG. 7, the antennas as shown in FIG. **6** are disposed on a circle. In both the antenna arrays shown in FIGS. **6** and 7, each of the antennas **121A** and **141A**, **122A** and **142A**, **123A** and **143A**, **121B** and **141B**, **122B** and **142B**, and **123B** and **143B** is coupled by the hybrid junction identical to those previously described to form antenna pairs. It is to be understood that the antennas are disposed symmetrically with respect to the geometric central axis **0—0**, while, in FIG. **6**, the distances between the antennas are different from one another according to the respective antenna pairs.

As similar to the antenna system shown in FIG. 3, the antenna arrays shown in FIGS. **6** and **7** are connected to the respective control units (not shown) identical to the previously described control units **301** to **30N** inclusive through the hybrid junctions of the same construction as described in conjunction with FIG. 1. The control units are, in turn, connected to the adder as was the previous embodiment shown in FIG. 3. Therefore, similarly to the previous embodiments, the incoming radio wave from the signal source is controlled by the control unit for each of the antenna pairs to be brought into the in-phase relationship with each other and controlled to exhibit a common polarity independent of the variation of the incident angle θ of the incoming radio wave. As a result, the control units provide output signals, each exhibiting a common phase and a common polarity to each other, which are added by the adder.

It is easily understood from the disposition of the antenna arrays that the antenna systems shown in FIGS. **6** and **7** can perform the tracking in the three-dimensional space. Although the embodiments shown in FIGS. **6** and **7** have six antenna pairs, it is to be understood that the invention is also applicable to antenna systems having more or less than six antenna pairs.

What we claim is:

1. A tracking antenna system comprising at least one antenna pair, a hybrid junction coupled to said antenna pair to produce a sum signal and a difference signal of radio wave signals received by each of antennas of said antenna pair, control means for controlling a first signal based upon said sum signal and a second signal based upon said difference signal to always bring the first and second signals into in-phase relationship and for adding them, said control means comprising a first detector for phase-detecting said first signal with a comparison signal, a second phase detector for phase-detecting said second signal with said comparison signal, a first polarity switch for phase-shifting said first signal by an angle of 180° in response to an output from said first phase detector, a second polarity switch for phase-shifting said second signal by an angle of 180° in response to an output from said second phase detector, and an adder for adding the outputs from said first and second polarity switches.

2. A tracking antenna system comprising at least one antenna pair, a hybrid junction coupled to said antenna pair to produce a sum signal and a difference signal of radio wave signals received by each of the antennas of said antenna pair, control means for controlling a first signal based upon said sum signal and a second signal based upon said difference signal to always bring the first and second signals into in-phase relationship and for adding them, said control means comprising a first phase detector for phase-detecting said first signal with a comparison signal, a second phase detector for phase-detecting said second signal with said comparison signal, a first polarity switch for phase-shifting said first signal by an angle of 180° in response to an output from said first phase detector, a second polarity switch for phase-shifting said second signal by an angle of 180° in response to an output from said second phase detector, a reference signal generator for providing a reference signal, a first mixer for providing said first signal in response to an intermediate frequency output produced based upon said sum signal and said reference signal, a second mixer for providing said second signal in response to an intermediate frequency output produced based upon said difference signal and said reference signal, and an adder for adding outputs from said first and second polarity switches.

3. A tracking antenna system comprising at least one antenna pair, a hybrid junction coupled to said antenna pair to produce a sum signal and a difference signal of radio wave signals received by each of antennas of said antenna pair, and control means for controlling a first signal based upon said sum signal and a second signal based upon said difference signal to always bring the first and second signals into in-phase relationship and for adding them, said control means comprising a first phase detector for phase-detecting said first signal with a comparison signal, a second phase detector for phase-detecting said second signal with said comparison signal, a first polarity switch for phase-shifting said first signal by an angle of 180° in response to an output from said first phase detector, a second polarity switch for phase-shifting said second signal by an angle of 180° in response to an output from said second phase detector, a reference signal generator for providing a reference signal, a first mixer for providing said first signal in response to an intermediate frequency output produced based upon said sum signal and said reference signal, a second mixer for providing said second signal in response to an intermediate frequency output produced based upon said difference signal and said reference signal, a phase shifter for phase shifting an output from said second mixer by an angle of 90° to produce said second signal, thereby to compensate a phase shift of 90° between said sum signal and said difference signal, and an adder for adding the outputs from said first and second polarity switches.

4. A tracking antenna system comprising at least one antenna pair, a hybrid junction coupled to said antenna pair to produce a sum signal and a difference signal of radio wave signals received by each of antennas of said antenna pair, and control means for controlling a first signal based upon said sum signal and a second signal based upon said difference signal to always bring the first and second signals into in-phase relationship and for adding them, said control means comprising a first phase detector for phase-detecting said first signal with a comparison signal, a second phase detector for phase-detecting said second signal with said comparison signal, a first polarity switch for phase-shifting said first signal by an angle of 180° in response to an output from said first phase detector, a second polarity switch for phase-shifting said second signal by an angle of 180° in response to an output from said second phase detector, a reference signal generator for providing a reference signal, a first mixer for providing said first signal in response to an intermediate frequency output produced based upon said sum signal and said reference signal, a second mixer for providing said second signal in response to an intermediate frequency output produced based upon said difference signal and said reference signal, an adder for adding the outputs from said first and second polarity switches, and a third phase detector for phase-detecting an output from said adder with said comparison signal, said third phase detector controlling the frequency of said reference signal thereby to lock the phases of said first and second signals.

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