A Novel Technology of Microwave Direction Finding With a Combination of Amplitude-measurement and Phase-Measurement.

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I. Introduction

This paper describes a technology on how to find the direction of the microwave signal sources using electronic warfare support(ES), electronic intelligence(ELINT) or Radio Frequency(RF) monitoring systems which can be set on ground or mobile vehicle. This technology uses a combination of the amplitude-measurement technology which use the amplitude difference of the RF signal received by the array antennas and the phase-measurement technology which use the phase difference of the RF signals received by the same array antennas

At first, a direction finding technology was stated to find the direction of the signal source by using the horn antenna or a parabolic antenna that had a narrow beam width and high gain. We rotated the antenna with respect to the azimuth angle or elevation angle that we wanted to monitor and measure. Nowadays, since the array antenna technology and phase-comparison technology are advanced, the amplitude comparison method or phase comparison method is used for a direction finding(DF) of microwave signals.

Generally, a phase-comparison technology has better DF accuracy than amplitude-comparison technology when the direction of the signal that comes from the same angle range is measured using the same number of array antennas, because phase-comparison method is robust to noise parameters. But it has an ambiguity angle problem that they indicate the 2nd, 3rd harmonic direction angles simultaneously. An example of the suggested technology is designed to place 8 array antennas in a 45° distance around the 360° circle. Also it is designed to use the phase-difference of the received signal from two nearby antennas to measure the incident signal direction accurately and to use the amplitude-difference to eliminate the direction ambiguity.

II. Technical Analysis

The principle of the amplitude-measurement technology is shown in Fig. 1. Number 1 antenna is set on −α azimuth angle and number 2 antenna is set on +α azimuth angle. G1(θ) is the antenna beam pattern of number 1 antenna, and G2(θ) is the antenna beam pattern of number 2 antenna. When a RF signal comes from 0 degree in Fig. 1, the received signal amplitude of antenna 1 is same to that of antenna two. But when a RF signal comes from -α azimuth angle, the received signal amplitude of antenna 1 is larger than that of antenna two. If we know the beam pattern of two antennas, we can calculate the incident angle to measure the amplitude of incident RF signal [1][2][3].

The interferometer method is a way to find out the direction of incident RF signal by setting up the antennas at different positions and measuring the phase differences of same coming signals. When the interval of two antennas is D and the signal incidence direction is θ , λ is the wavelength of the incidence signal. ϕ is the phase difference of RF signals measured at the two antennas with the interval of D in Fig.2. We can calculate the signal incidence direction (θ) with Eq. (1).
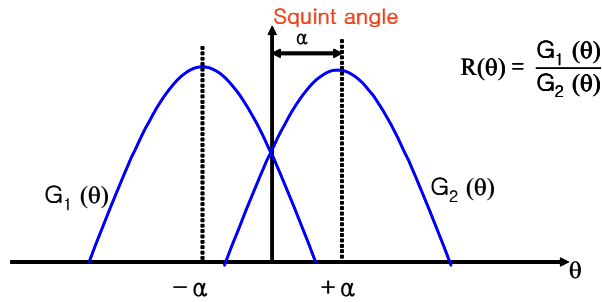
$$\phi = \frac{2\pi}{\lambda} D.\sin\theta \tag{1}$$

Fig.1. Principle of amplitude measurement DF technology.

To measure the incidence angle more accurately, we can enlarge the distance (D) with 2λ, 3λ or 4λ in Fig. 2. However an ambiguity occurs when D become larger than λ that is $\phi > 2\pi$. Multi baseline interferometer system is developed to eliminate the ambiguity that have many interferometer sets of different baselines($D_1, D2, \ldots D_n$). In multi-baseline, phase-difference from D_n baseline is used to get a precision direction angle in Eq. (2) and the rest of the phase differences of other baseline($D_1, D2, \ldots$) are used to solve the ambiguity.

$$\phi_n = \frac{2\pi}{\lambda} D_n . \sin\theta \qquad\qquad (2)$$
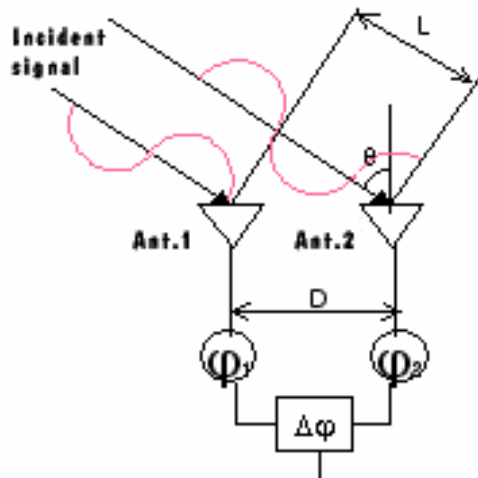

Fig.2. Principle of interferometer DF technology.

III. The principle of a Combination Technology of amplitude-measurement and phase-measurement.

As above mentioned, the multi baseline interferometer system measures the direction of incident signal accurately but it is very complicated and large in size to solve ambiguity. This paper suggests new technology to calculate the direction accuracy with long baseline interferometer and to solve the ambiguity with same long baseline interferometer antenna array.

The principle of this technology is to use amplitude-difference and phase-difference together from the same baseline antenna array. Fig. 3. is a block diagram of combination DF system that has 8 array antennas on 360° azimuth angle and base line is 3 λ . Each baseline between two antennas is used to cover 45° in azimuth angle and 3 λ is for good DF angle

After the RF signal of antennas is divided in two, amplitude difference channel can calculate the direction roughly and phase-difference channel calculate the direction accurately with ambiguity in Fig.3. A combination of the calculated angle of amplitude-measurement and phase-measurement can eliminate the ambiguity and make a accurate DF angle without ambiguity..
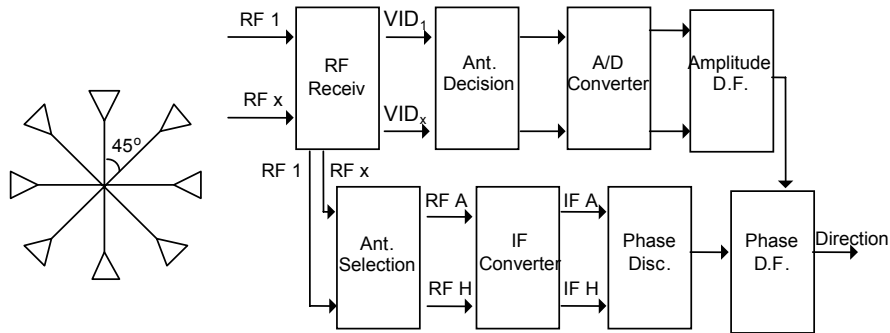

Fig. 3. Block diagram of a combination system of amplitude-measurement and phase-measurement.

Fig. 4 shows the principle how the ambiguity is eliminated. If a baseline is 3λ and is fixed to operate in 60 azimuth angle range, the azimuth angle ambiguity of phase difference occurs every 20° and the azimuth angle ambiguity of amplitude difference is zero. The ambiguity problem of this circuit can be solved by finding out that the DF error of the amplitude comparison is less than 10°. Using the IF narrow band phase difference measurement circuit in Fig. 3, it is possible to get a precise direction finding accuracy. It is also a very simple and small memory is used.
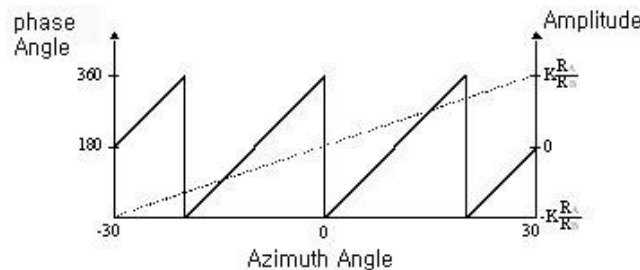

Fig. 4. Amplitude and phase difference in 60° azimuth angles.

Only two near antenna channels are needed to make an interferometer in a given azimuth angle in this combination method, the signal processing channels are greatly decreased and much more economical compared to the linear array multi-base line interferometer. Solving the ambiguity problem in interferometer technology has a close relationship with the configuration of antenna. The number of ambiguity occurrence(k) is depends on the interval of each antenna and the receiving azimuth angel. When 3λ is the set up interval and 60° is azimuth angel receiving range in the suggested device, k become 3[4][5].

After deciding ambiguity number(k), Eq. (3) is used to calculate the real direction. In a multi interferometer devices, the truth table in terms of ϕ_1, ϕ_2 ,.. ϕ_n are used to find k. Calculate the direction that has an ambiguity which is $\theta_k \big|_{k=0,2}$ by using Eq. (3). After comparing θ_k and the amplitude comparison results using Eq. (4), the final output would be θ_k that has the lesser difference and it will be used to solve the ambiguity problem.

$$\theta_K = \arcsin\left(\frac{\phi + 2\pi . K}{D_n . 2\pi / \lambda .}\right)\Big|_{k=0,2} \tag{3}$$

$$\theta = \theta_k, \quad \text{if} \quad \frac{\theta_{k-1} + \theta_k}{2} < \theta_{amp} < \frac{\theta_k + \theta_{k+1}}{2} \tag{4}$$

IV. Test results and conclusions

The direction finding device has been made by the suggest technology and the DF angle error tested in 2.0 – 6.0 GHz is less than 2.0° in horizontal polarization and 1.0° error in vertical polarization. The direction finding device that is developed using amplitude-measurement and phase-measurement together have a small direction finding error and can be directly adapted to shipboard or land base ES, ELINT systems, and mobile stations for monitoring the electromagnetic waves.
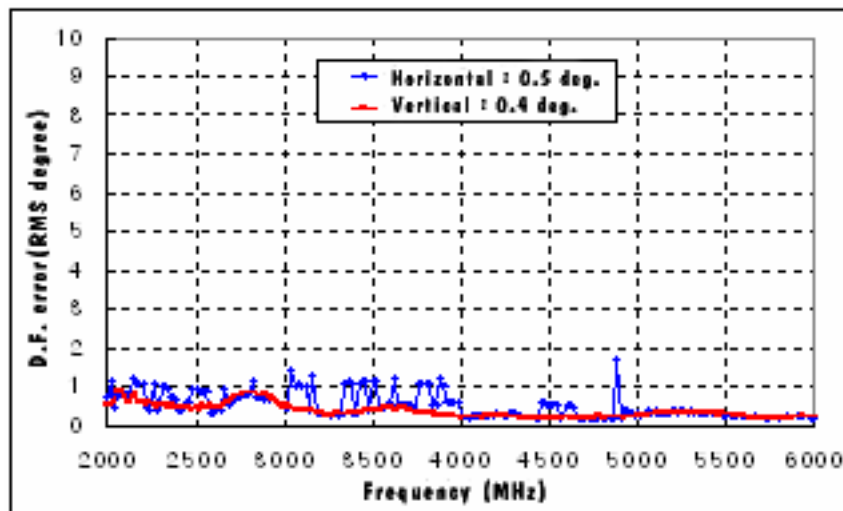

Fig.5 Test results of DF accuracy in C-band.

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