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중간주파수 처리를 이용한 빔추적 능동위상 배열안테나

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A New Beam Tracking Technique Using Intermediate Frequency Processing

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요 약

본 논문에서는 능동 배열 안테나에서 RF 대신 중간주파수를 이용하여 빔 추적을 하는 방법이 연구되었다. 안테나의 각 배열은 전압제어 발진기, 위상추적기, 혼합기와 결합되어 있으며 혼합기는 안테나상에서 직접 RF 신호를 직접 중간주파수 신호로 변환시킨다. 전압제어 발진기 입력은 위상추적기에 의하여 조절되며 배열 안테나의 주사 범위는 위상추적기와 전압제어발진기에 의하여 결정되었다.

ABSTRACT

A method for the electronic beam self tracking using the intermediate frequency (IF) processing is introduced in this paper. The array elements of antenna were coupled to the phase detector, the voltage controlled oscillator (VCO) and the mixer which converted the RF signal into the IF signals on the array elements. The input voltage of the VCO was controlled by the phase detector. The phase detector and the VCO determined the scan range of the array.

Ⅰ. Introduction

Recent advances in designing modern microwave and millimeter wave architecture have generated considerable interest in the active phased array antenna for both military and commercial applications. Many innovative approaches have been proposed for realizing efficient quasi-optical power-combing active array [1-3]. It is possible to realize the beam-steering arrays without requiring the phase shifters, which are considered indispensable in conventional system. An array of inter-injection-locked oscillators was used to establish a progressive interelement phase shift [4]. An active beam switching and a polarization control was proposed and demonstrated [5].

Coupled VCOs was used in several elements power combining and beam scanning array [6]. The phase noise performance and the multimode operation were analyzed in the beam steering arrays [7]. Retrodirective arrays reflected any incident signal primarily back toward the source without prior knowledge of the sources location [8]. The use of fiber optics for implementing the true time delay control of microwave phased-array antenna systems has been investigated for many years [9-10]. The true time delay was used in place of simple phase-shifting techniques in the wide bandwidth application.

Now the size of the active phased array antenna needs to be minimized for reducing noise and integrating with other microwave devices. In

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this paper, it is described a new self-steering phased array antenna controlled by the VCO, the mixer and the phase detector. Because the RF signal was converted into the IF signal on the array element, the loss of RF signal was very small and the system size was reduced compared with the conventional system. The phase difference between the incoming signals was set as zero by varying the applied voltage of the phase detector to the VCO. The scan range of the array was controlled by the VCO and the phase detector which reduced the phase difference between the input signals of the array elements and input signal with frequency f_s

Ⅱ. Basic Theory

Fig. 1 shows 1×4 the beam self-tracking using the Intermediate Frequency Processing (IFP). Each active antenna is coupled to the mixer, the VCO, and the phase detector. The reference oscillator is tuned at the intermediate frequency f_0 in Fig. 1. The outputs of the mixer and the reference oscillator are connected to the inputs of the phase detector, which compares the phases of them. This phase difference determines the output voltage of the phase detector, which controls the VCO. The output of the VCO makes it to be zero phase locking. The beam steering is performed by controlling the VCO and the phase detector. Let two elements with $\lambda/2$ spacing be operated in phase and broadside beams employed. If the incidence angle of signal is 30°, the path difference of two incoming signals becomes 90°. The output voltage of the phase detector is proportional to the phase difference between the phases of two inputs and applied to the VCO. The input voltages of two VCOs have the same magnitude but different polarity so that the output signals from both mixers are locked in phase, as following:

$$\varphi_0 = \varphi_1 = \varphi_2 \qquad (1)$$

where φ_0, φ_1, φ_2, are phases of the reference oscillator, the first and the second mixer, respectively. This means that the phase difference between the reference oscillator and the mixer becomes zero. If both active mixers are set with equal gain, two inputs of summation have same amplitude and phase as follows;

$$V(\varphi_1) = V(\varphi_2) \qquad (2)$$

After the IFP, the total voltage, $2V(\varphi_1)$, finally is obtained at the summation and it shows that it is possible to maximize the response of the phased array by steering the beam onto the incoming signals.

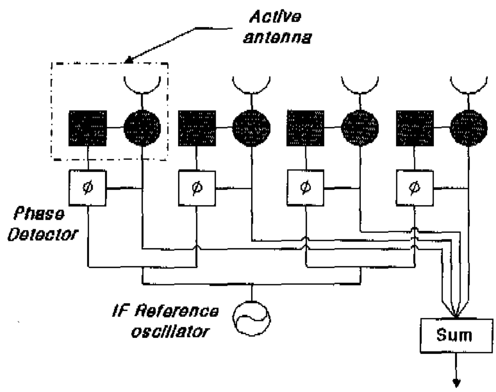

Fig. 1 Block diagram of the proposed phased array antenna system using the intermediate frequency processing

Ⅲ. Active Antenna For the Beam Tracking Antenna

A configuration of the active array antenna is shown in Fig. 1. The array was sub-sequentially fabricated on 0.76 mil thick GML-1000, which has a relative dielectric constant of 3.25. A microstrip line antenna was employed as a load for each VCO. The antennas were designed to be one-half wavelength long at 2.45 GHz. Each antenna was 33 mm long by 30 mm wide, which provides load impedance of 120 W at resonance. The quarterwave transformer was used to match this mismatch. It was = 19.17 mm long by 0.84mm wide. The bandwidth of antenna was 30MHz (2.42GHz 2.45 GHz)

The mixers in the array were designed to convert the RF signal into the IF signal at the design frequency 2.45 GHz. In this research was chosen the single type mixer which had the low noise characteristics. The local oscillator (LO) and the RF ports were simultaneously connected to the gate of the FET. LO had high level power for inducing the nonlinearity of the FET. Fig. 2 shows the layout of the active antenna element with the mixer and the VCO. 2.4 GHz to 2.5 GHz and 100 MHz to 200 MHz were the RF passband and the IF passband, respectively. The mixers of this design used an NE32484 GaAs FET and were constructed using same substrates in the antenna design. The VCOs in the array were designed to provide maximum power at the design frequency 2.44 GHz which was 100 MHz lower than 2.5 GHz of the mixers RF frequency. The oscillating frequency was controlled by the applied voltage of the varactor diode. NE32484 GaAs FET, Toshiba 1SV281 and 2SC4226 BJT were used for this design of the VCO, the varactor diode, the oscillating circuit. The common emitter configuration of BJT was employed for the negative resistance.

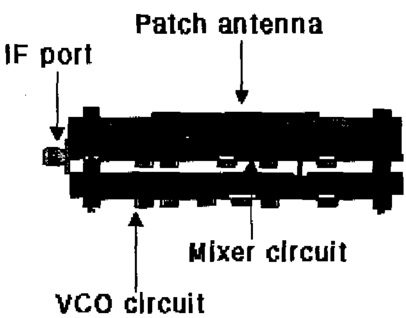

Fig. 2 Layout of the active antenna element coupled to the mixer and the VCO

IV. Measurements

The conversion gain of the mixer was 9.5dB in the passband in which the bias condition was V_{ds}=3V, I_{ds}=10mA, V_{gs}=0.75V. The LNA was placed before the mixer for obtaining the low noise characteristics and the radiation stub was used to isolate the RF circuit form the bias circuit. The isolations of RF to IF port and LO to IF were 30dB and 45 dB, respectively.

The VCO was oscillated at 2. 4 GHz and 3V of the applied varactor diode voltage which controlled the oscillating frequency of the VCO. The negative resistance of the oscillator was 20 at 2.4 GHz. The 6 dB power divider was designed to apply the reference signal to the phase detector and integrated with it on same substrate.

The directivity of the array antenna was maximum at 0.9 λ_g element separation but the sidelobe level was high compared with other element separation. As the element separation was increased, the scan range was decreased. We have

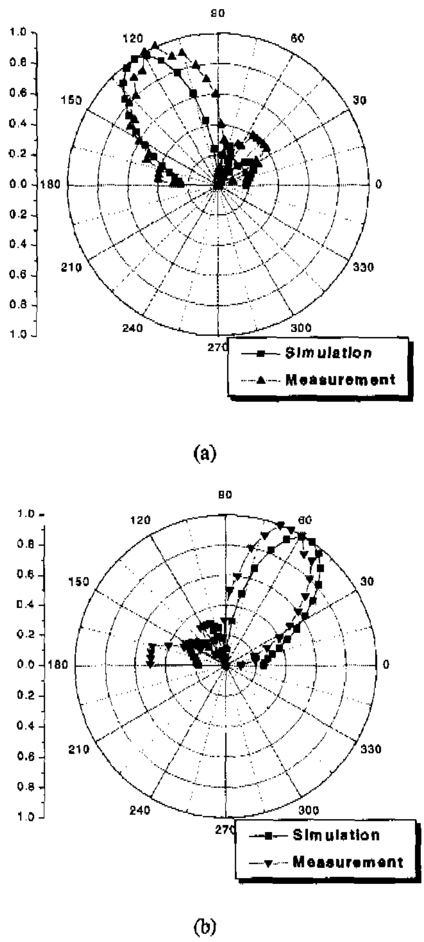

Fig. 3 Comparisons of the theoretical and the measured results (a) 28.7o of scan angle (b) 26.4o of scan angle.

chosen element separation to be $0.45\lambda_g$ after considering the directivity, the sidelobe level, and the scan range. 35° to 35° and 28.7° to 26.4° were the theoretical scan range and the measurement with $0.45\lambda_g$ element separation in Fig. 3.a and Fig. 3.b, respectively. If the bandwidth of the array antenna is wide and the current of the phase detector is large, the measurements will close to the theoretical one.

V. Conclusion

A new beam tracking technique employed the intermediate frequency processing in this paper and the phased array antenna was coupled to the VCO, the mixer, and the phased detector. The voltage of the phase detector was applied to the input of VCO according to the phase difference between the incoming signals. The scan range of the phased array antenna, 28.7° to 26.4°, was controlled by the VCO and the phase detector. The size of the phased array was small. This beam tracking active array is operated in the IF range and has very low loss.

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