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개방 선로와 전압조정 발진기를 이용한 능동 위상 배열 안테나

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A Novel Active Array Antenna using Open Stub and Voltage Controlled Oscillator with Varactor Diode

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요 약

본 논문에서는 버렉터 다이오드로 조절되는 전압조정발진기(VCO)와 개방선로가 연결된 전송선로망을 이용하여 1*4 능동 위상배열안테나가 설계제작 되었다. 버렉터 다이오드는 VCO의 튜닝범위를 넓히기 위하여 FET에 병렬로 연결되었으며 개방선로는 안테나의 주사범위를 넓히기 위하여 전송선로망 끝부분에 접속되었다. 안테나의 주사범위는 버렉터 다이오드의 인가전압과 전송선로망을 조정함으로써 조정되었으며 2.44GHz에서 -20 ~ 20도 까지 측정되었다.

ABSTRACT

In this paper, a 1*4 active phased array antenna was designed using the voltage controlled oscillators(VCO) with the varactor diode and the transmission line network with open stub. The varactor diode was connected in parallel to the FET for the wide tuning range of the VCO and the open stubs were connected at the end of the transmission line network to increase the scan range. The scan range, -20 degree to 22 degree at 2.44GHz, was controlled by the applied varactor diode voltage and the transmission line coupling network.

I. INTRODUCTION

Active phased array antenna without phase shifter has recently been received attractive attention because it provides a new paradigm designing modern microwave and millimeter wave architecture for both military and commercial application. Many new mobile communication system needs to lead to continuing research in system and component designs to produce a highly integrated and compact design. Coupled oscillators and trans -mission lines were integrated for beam scan technique in the active phased array antenna [1-4]. Liao and York used arrays of the coupled oscillators for phase-shifterless beam-scanning technique [5-6] and reported a wideband VCO using a varactor-tuned microstrip patch antenna for the active array [7]. There are the radiative coupling and the transmission-line coupling between oscillators on array elements [8-10]. Arrays exploiting radiative coupling between antennas would not be useful in practice, because the inter- actions are typically weak and difficult to control and/or predict accurately [9]. It is possible to adjust coupling parameters between array elements and to increase cou- pling strength by proper selection circuit parameter in the transmission line coupling which is coupling for

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increasing the coupling strength and compensating the undesired radiative coupling with stub [10].

In this paper, we employed the trans-mission line coupling network to couple the array elements and the varactor diode for the wideband VCO. The wideband VCO was easily integrated in the active phased array antenna by connecting the varactor diode in parallel to the FET. The transmission line coupling network consisted of the trans-mission lines, the chip resistors and the open stubs. The transmission lines and the chip capacitors connected the antenna elements together. Open stubs were added to each end of the antenna elements. The scan range was controlled by varying the applied varactor diode voltage and by adjusting the trans- mission line coupling network.

Ⅱ. VCO and ARRAY DESIGN

A configuration of the active array antenna is shown in Fig. 1. The array was subsequently fabricated on 0.76 mil thick GML-1000, which has a relative dielectric constant of 3.2. 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 30.75 mm wide, which provides a load impedance of 120 Ω at re-sonance. The quaterwave transformer was used to match this mismatch. It was = 19.17 mm long by 0.84 mm wide. The bandwidth of antenna was 30MHz (2.42GHz-2.45 GHz).

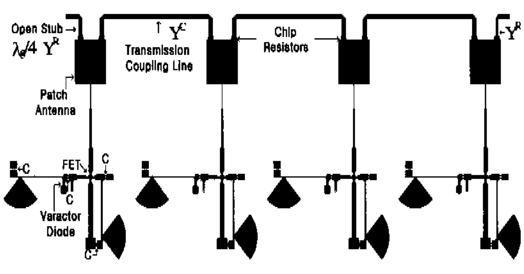


Fig. 1 Configuration of 1×4 active array antenna with the transmission line coupling network and the VCO with the varactor diode. All transmission-lines are 100 Ω characteristic impedance and length lg

The VCOs in the array were designed to provide maximum power at the design frequency 2.45 GHz. The VCOs of this design used an NE32484 GaAs FET and were constructed using same substrates in the antenna design. The FET has two sources leads; one was directly connected to the microstrip patch and the other was shortened to prevent RF signal. The bias circuit was simplified by applying voltage on only the drain and V_{GS} = 0.

It is possible to control the oscillating frequency by varying the bias voltage but it affects on the overall characteristics of the array elements. Therefore a varactor diode was connected in parallel to the gate of the FET to control the oscillating frequency. The applied varactor diode voltage doesn't affect the bias voltage of the FET and the oscillating frequency was varied by the equivalent capacitance of the varactor diode according to the voltage. Toshiba, 1SV86 for the varactor diode was used in this design.

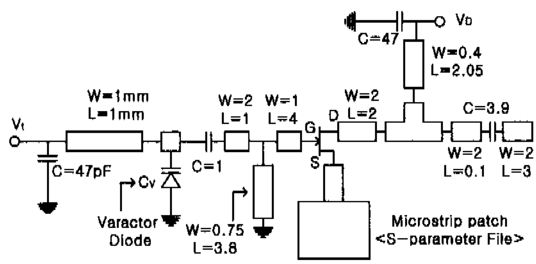


Fig. 2 Circuit structure of the VCO with varactor the diode

Transmission line coupling network coupled nearest neighbor antennas. The chip resistors were connected to the each end of the transmission-line of characteristic admittance Y_0 and length λ_g. The overall admittance of the transmission line and the chip resistors were Y_c in Fig. 1. We considered only the radiative coupling (Y^R) of an element with its nearest neighbors out of the radiative coup- ling with other elements. Therefore total ad- mittance (Y_{ij}) was given by the sum of the transmission line coupling (Y_c) and the radiative coupling (Y^R). Provided that Y^R is purely real and positive, this can be achieved by connectiong a $\lambda_g/4$ length open ended stub to each end antenna with a resistor of admittance Y^R to maintain the uniform in- jection current[10]. The characteristics of the coupling circuit slowly vary for the frequency compared with those of the oscillating circuit. It shows that the Q-factor of the coupling circuit should be smaller than that of the oscillating circuit. This condition was realized by inserting some loss into the coupling circuit. The chip resistors were directly con- nected to the transmission line for the loss.

The transmission coupling network can be easily realized but it limits the scan range. The phase difference between nearest neighbor elements should be increased to expand the scan range and is proportional to the admittance of the coupling network. The large admittance was obtained by connecting the resistive open stub to the each end of the antenna elements. This connection is shown in Fig. 1. The resistive open stubs were realized by the $\lambda_g/4$ length transmission lines of 100 Ω characteristic impedance and con- nected to the 100 Ω chip resistors. The coupling strength of the elements was exa- mined by measuring S_{21}.

The scan range is determined by the cou- pling phase and the antenna spacing. A greater scan range can be obtained with the smaller antenna spacing. Alternatively, the scan coverage can be increased by elec- tronically controlling the coupling phase. But if the antenna spacing is greater than $\lambda_g/2$, the grating lobe occurs in the phased arrays. The scan range was controlled by varying the applied varactor diode voltage and by adjusting the transmission line coupling net- work.

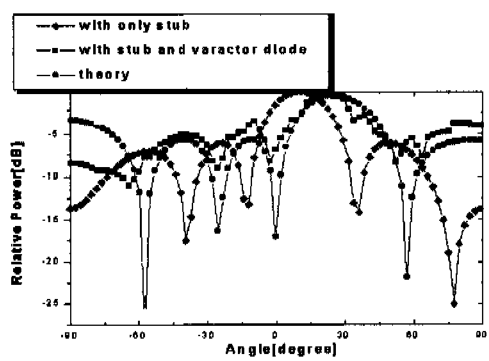
Ⅲ. MEASUREMENTS

The output power of oscillator was 10 dBm at 2.44 GHz and the phase noise was 90dBc/Hz with 10 kHz in which the bias condition was V_{DS}=2V, I_{DS}=10mA. We have chosen element separation to be $\lambda_g/2$ to avoid the grating lobe. The locking range and the tunning range were obtained 191 MHz, 240 MHz at a center frequency 2.44 GHz, res- pectively, within 1.5 dB power variation by changing the applied varactor diode voltage from 1 V to 4 V.

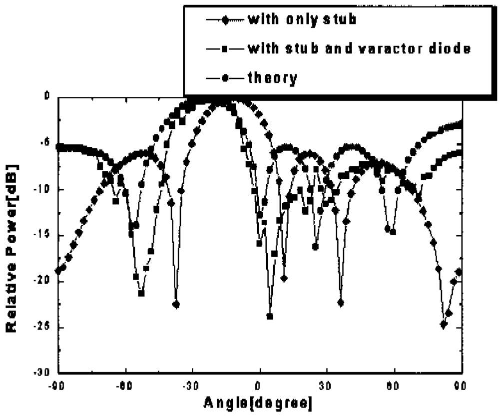
The chip resistors and the transmission lines connected the oscillator units to each other. The oscillation frequencies and the far- field radiation patterns were measured. The chip resistors suppressed the undesired modes, since the current distributions at the junction are all zero for the in-phase mode but are not zero for all the undesired modes.

For the 4-element linear array, the use of the chip resistors was able to achieve the stable in-phase mode oscillation. The stable in phase mode oscillation at 2.44 GHz was observed, which was only 0.4% deviated from the designed frequency 2.45 GHz.

Our measurements showed that the beam could be scanned from an angle of 20° to 22° away from broadside, using the applied varactor diode voltage to control the tunning range of the VCO. Fig. 3 (a) and (b) are the radiation patterns at the -20° and 22° scan angle, respectively. The measurement of array elements with stub had good agree- ments with the theoretical results compared with those of the array elements without the stub. They show that the stub and the va- ractor diode are important parameters to extend the scan range. The beam scan angle was 0° at the 2.99 V applied varactor diode voltage and increased according to variation of the its voltage. The scan range employing the varactor



(a)



(b)

Fig. 3 Radiation patterns of 1×4 array antenna, (a) -20° of scan angle (b)22° of scan angle.

tuned VCO and the transmission line coupling network was wider than that of employing only the varactor tuned VCO. Also the total output power was bigger than that of employing only the varactor tuned VCO.

Ⅳ. CONCLUSION

A novel active array antenna was designed by using the transmission line coupling network and the VCO with the varactor diode, which extended the tuning range of the VCO. The transmission line coupling in oscillators was achieved by adding the resistive stubs to the ends of elements. The wideband VOCs were easily integrated by connecting the varactor diodes in parallel to the FETs in the active phased array antenna. The scan range, from 20° to 22° at 2. 44GHz, was controlled by adjusting the transmission line coupling network and by varying the applied varactor diode voltage instead of the bias voltage.

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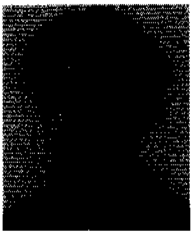

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