Varactor-tuned Active Integrated Antenna Using Slot Antenna

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A varactor-tuned active integrated antenna which is consisted of a series feedback voltage-controlled oscillator (VCO) and a matched slot antenna is proposed. The fabricated antenna has a stable oscillation at 5.8 GHz band, and the frequency varies form 5.73 GHz to 5.97 GHz, with less than 1.28 dB of amplitude deviation over the frequency range.

Introduction

In recent years, active integrated antennas (AIAs) become very popular in microwave and millimeter-wave applications due to low weight, compact size, low cost, and adaptability. However, various AIA topologies have some drawbacks such as interference between the feeding network and the radiator element, and the attachment of a capacitor for the DC isolation. A nice solution to the problem has been proposed [1], [2], using the multi-layered substrate where the oscillator antenna is consisted of a radiator placed on the upper substrate and an active element on the bottom substrate, but it is difficult to match to active devices and expensive to be implemented on the multi-layer. In this paper, we proposed the varactor-tuned active integrated antenna using the T-shaped microstrip-line-fed slot antenna which has a wide bandwidth [3]. Since the proposed oscillator antenna is consisted of the ground plane which is notched a rectangular slot on the one side of the substrate and the active circuit on the other side, the proposed active antenna have some benefits that chip capacitors for blocking the DC current in the RF path can be avoided and it is easy to fabricate, and we can also apply to the transmission system such as phase-shifterless array antenna and spatial power combiner by varying the operating frequency with the varactor.

VCO Antenna Design

The proposed VCO antenna configuration is shown in Fig.1. The VCO antenna contains an electromagnetically coupled slot antenna which is fed by the T-shaped microstrip line for radiator, the active device for generating the negative resistance, and the resonator using microstip line loaded with the varactor diode. The circuit was fabricated on a Duroid 5880 substrate with thickness of 0.508 mm and the relative dielectric constant (ε_r) of 2.2. In order to oscillate, we obtain the maximum negative resistance using the open stub connected by a source port of a transistor, and adjust the length of the resonator considering the frequency shifting into lower by attaching the varactor diode. For achieving the maximum output power, the antenna port is optimized with the bended open stub. A bias condition for the oscillator with an ATF-13786 GaAs MESFET is V_{DS} = 4.1 V and V_{GS} = 0.1 V with drain current (I_{DS}) of 50 mA, and the oscillator is driven by self-biasing technique.

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Measurements

The VCO antenna is designed using the T-shaped microstrip-line-fed slot antenna. It was found that the impedance bandwidth of the slot antenna depends highly on the vertical offset position and length of the horizontal strip in the microstrip line. We determine the optimum offset position for various slot widths. Fig. 2 shows the measured and simulated results of the return loss for the T-shaped microstrip-line-fed slot antenna. There is a reasonably good agreement between the results. At the center frequency of 5.8 GHz, the return loss is -28 dB and the 10-dB impedance bandwidth is 20 %, which is a wide bandwidth.

Fig. 3 shows the radiated output power from the fabricated VCO antenna using the slot radiator, at the inverse bias voltage of the varactor diode of 5.5 V, measured in an anechoic chamber. The output power is obtained about -20.75 dBm using an Agilent E4440A spectrum analyzer and a double ridged horn antenna (Gain = 17 dBi) as a reference antenna away from a distance of 2 m. An EIRP (Effective Isotropic Radiated Power) correspond to the above data is 16.29 dBm [4]. The VCO antenna is observed to tune from 5.73 to 5.97 GHz with approximately 1.28 dB of amplitude variation, according to the variation of the inversely biased voltage to the varactor diode, as shown in Fig. 4, and the control voltage sensitivity is 19.2 MHz/V. Since the reactance component of the slot antenna is rapidly varied near the resonant frequency, the slope of the frequency is not perfectly linear.

The simulated and measured co-polarization and cross-polarization patterns for x-z lane and y-z plane are shown in Fig. 5. The simulated radiation patterns are calculated by using the gap source technique, in the commercial EM simulator HFSS, considering the complete series-feedback active antenna which has same layout except an active transistor. Both of the radiation patterns are similar to those of the x-directed dipole antenna. It is considered that the radiation patterns of the x-z plane is asymmetry due to the asymmetrically presence of the distributed VCO antenna circuitry and those of the y-z plane have the elliptical shape owing to the finite ground plane. The received cross-polarizations in the x-z plane and y-z plane of the AIA are approximately -16 dB and -14 dB lower than the maximum co-polarization, respectively. The measured co-polarization radiation patterns in x-z and y-z plane have a similar trend with those of the simulated results.

Conclusion

In this paper, it is investigated the radiating VCO based on a slot antenna feeding T-shaped microstrip line at 5.8 GHz band. The tuning bandwidth of 240 MHz and control voltage sensitivity of 19.2 MHz/V are obtained through the used of the VCO and the wideband slot antenna. Since the fabricated active antenna utilizes the electromagnetic slot coupling on the both layers of the single substrate, we have some advantages such as no need of chip capacitor for DC isolation, easy fabrication, and reduction of EMI/EMC problems between active device and antenna. The obtained results of this active antenna show an attractive potential of using the circuit for low cost transmitter, phase-shifterless active array, and spatial power combiner.

References

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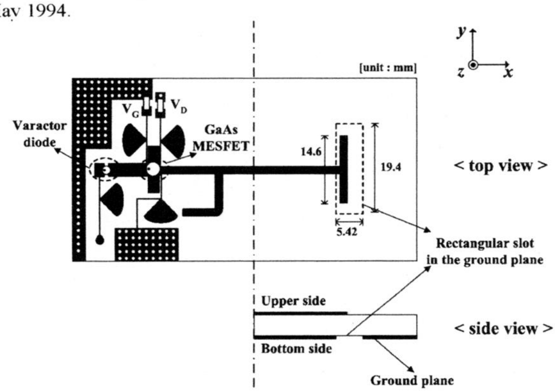


Fig. 1. Configuration of VCO antenna

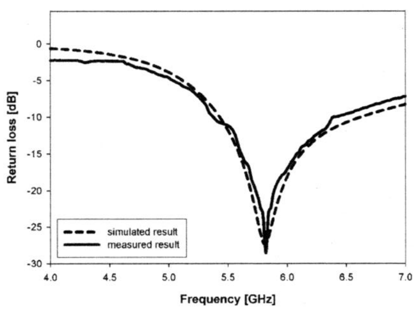


Fig. 2. Measured and simulated S-parameters for slot antenna

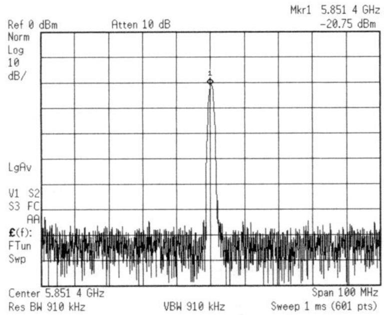


Fig. 3. Measured output power radiated from VCO antenna

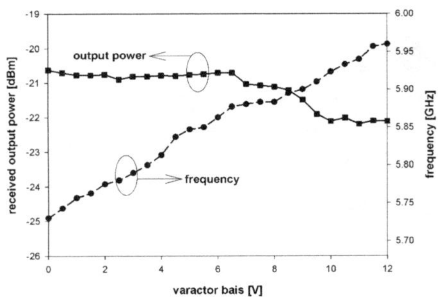
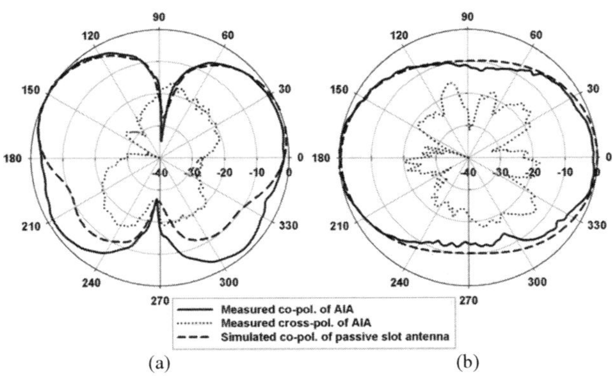


Fig. 4. Frequency and output power level in terms of control voltage



(a) (b)

Fig. 5. Radiation patterns in (a) x-z plane and (b) y-z plane, at 5.8 GHz