Active Integrated Antenna Using T-Shaped Microstrip-line-fed Slot Antenna

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This paper presents an active integrated antenna using a T-shaped microstrip-line-fed slot antenna which acts as DC isolation in the RF path and has a wide bandwidth. A fabricated parallel feedback antenna oscillator has a stable oscillation and a clean spectrum at the frequency of 10.05 GHz, which is only 0.5 % deviation from the designed frequency of 10 GHz. The measured EIRP is 37.79 mW, and the cross-polarization levels are at least -15 dB lower than the co-polarization ones for all directions.

Introduction

Active integrated antennas (AIAs), which are implemented by combining microwave oscillators and radiating elements, have received much attention due to low weight, compact size, low cost, and adaptability in array antenna systems. In an application as a source generator, the antenna acts as both a resonant load for the oscillator and a radiating element, through a feedback loop. The various geometries of the AIA with parallel feedback loop where the antenna is placed in the feedback path of an amplifier circuit have been proposed for several years [1], [2]. In this case, since this antenna plays a role of the frequency selector and radiator element, the multi-mode problem can be easily solved. Especially, it can be classified into two kinds in terms of the number of substrate layer; AIA consisted of single- and multi-layer. The former approach is to use the two port microstrip patch antenna as a feedback resonator of the oscillator on the single layer [3]. This results into easy fabrication, but it has a drawback with an additional chip capacitor for blocking the DC current in the RF path. The latter approach uses a multilayer slot coupled antenna where is consisted of a radiator placed on the upper substrate and an active element on the bottom substrate [4], [5]. Since the radiator is isolated from the FET source, EMI/EMC problem and DC isolation on the active circuit can be easily solved as compared to single-layered AIA. However, it is difficult to match to active devices and expensive to be implemented on the multi-layer.

In this paper, we proposed the parallel feedback antenna oscillator using the T-shaped microstrip-line-fed slot antenna as the feedback resonator on the single substrate [6]. The slot antenna contains two T-shaped microstrip line ports, that is, one is a feeding port and the other is a coupling port. The field coming from one T-shaped microstrip line on the circuit layer is fed into the slot on the ground plane. Part of the field is then electromagnetically coupled back to a second T-shaped microstip line. Since this antenna oscillator is separated between the feeding line and the radiation element by using the rectangular slot, chip capacitors for blocking the DC current in the RF path can be avoided and it is easy to fabricate.

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Feedback Antenna Oscillator Design

The proposed AIA configuration is shown in Fig. 1. The oscillator contains an amplifier and an electromagnetically coupling T-shaped microstrip-line-fed slot antenna. Extra microstrip lines placed both opposite sides of the rectangular slot are required to adjust the loop phase (multiple of 2π at the operating frequency) for oscillation. In order to maintain the constant load impedance at each antenna port, the proper input and output matching circuit was designed. The oscillator was fabricated on the substrate with thickness of 0.508 mm and relative dielectric constant (ε_r) of 3.0. For an operating frequency of 10 GHz, we let the slot has a size L × W of 4.3 × 10.8 mm^2 with an optimized T-microstip line length w_i = 8.8 mm and the width of 1.56 mm which is the same as the width of 50 Ω microstrip line, and then vary the distances l_i and l_g. The results come out to be l_i = 0.2 mm and l_g = 1.04 mm. With these parameters, a two-port T-shaped microstrip-line-fed slot antenna is fabricated and measured.

Fig. 2 shows the measured and simulated results of the S-parameters for the two-port slot antenna. At the center frequency of 10 GHz, the measured return loss of the feeding is approximately -34 dB and the coupling power is -3.6 dB. The impedance bandwidth (2:1 VSWR) is 27 %, which show a wide bandwidth. It seen that the measured results agree very well with those of the simulations.

Measurement

A bias condition for the oscillator with an ATF-13786 GaAs MESFET is V_{DS} = 3 V and V_{GS} = 0.5 V with a drain current (I_{DS}) of 30 mA, and the oscillator is driven by the self-biasing technique.

Fig. 3 shows the radiated output power from the fabricated feedback antenna oscillator measured in anechoic chamber. This oscillation frequency is measured at 10.05 GHz, which is 0.5 % close to the frequency of 10 GHz. The output power is measured about –20.75 dBm using an Agilent E4440A spectrum analyzer and a horn antenna (Gain = 16.5 dBi) as a reference antenna away from a distance of 1.2 m. An EIRP (Effective Isotropic Radiated Power) correspond to the above data is 37.79 mW.

The simulated and measured radiation patterns for x-z plane and y-z plane are shown in Fig. 4. In order to maintain the same measuring environment, the simulated radiation patterns are calculated by using the gap source technique, in the commercial EM simulator HFSS, considering the complete 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. The received cross-polarizations in the x-z plane and y-z plane of the AIA are approximately –20 dB and –15 dB lower than the maximum co-polarized radiation, respectively. The measured co-polarized radiation patterns in the x-z and y-z plane have a similar trend with those of the simulated results.

Conclusion

In this paper, the feedback antenna oscillator using the T-shaped microstrip-line-fed slot antenna is proposed. The fabricated active antenna is investigated with the comparison of the measured and simulated results. The oscillator antenna achieves an

EIRP of 37.79 mW and the cross-polarization level in the x-z and y-z plane are less than -20 dB and -15 dB, respectively. Since the T-shaped microstrip-line-fed slot antenna utilizes the electromagnetic slot coupling on both layer of the single substrate, we have some advantages such as no need of the chip capacitor for DC isolation, easy fabrication, and reduction of EMI/EMC problems between active device and antenna. This means that a cost and unnecessary effort by attaching the capacitor is able to be cut down.

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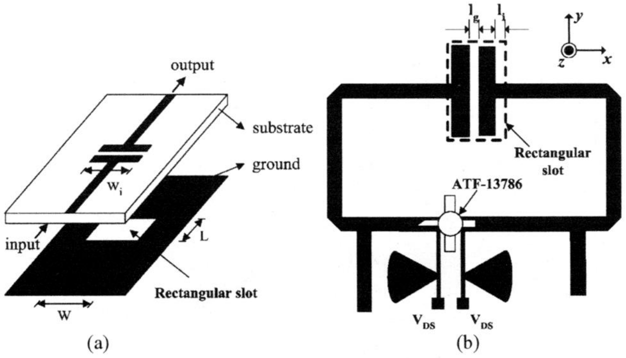


Fig. 1. (a) Two-port T-shaped microstrip-line-fed slot antenna. (b) Geometry of feedback antenna oscillator

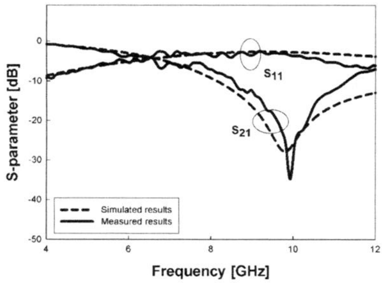


Fig. 2. Measured and simulated S-parameters for two-port slot antenna

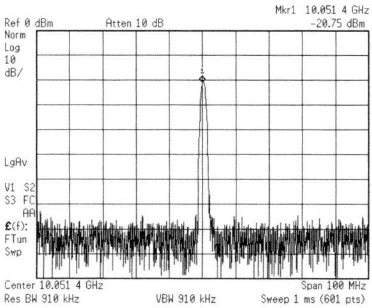
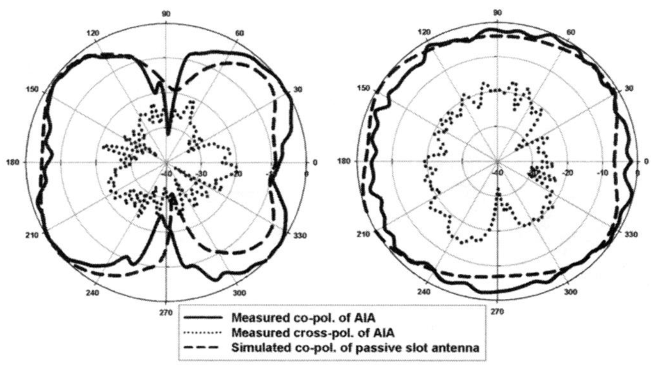


Fig. 3. Measured output power radiated from feedback antenna oscillator



(a) (b)

Fig. 4. Radiation patterns in (a) x-z plane and (b) y-z plane, at 10.05 GHz