A Terahertz Yagi-Uda Antenna for High Input Impedance

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Abstract—This paper presents the design of a new type of Yagi-Uda antenna that operates in the terahertz frequency region. This antenna achieves a high input resistance of approximately 2600 Ω at the resonance frequency by using a full-wavelength dipole as the driver element instead of a half-wavelength dipole. The output power of this antenna is expected to be appreciably greater than that of existing terahertz photomixer antennas.

I. INTRODUCTION

Terahertz (THz) waves are found in the transition region between the microwave and infrared regions, with frequencies in the range 0.1–10 THz. Compared to other frequency regions, scientific and technological progress at terahertz frequencies has been slow, impeded by a lack of suitable signal sources. However, recent advances in lasers and semiconductors technology have stimulated the development of new THz sources, and given new impetus to THz research.

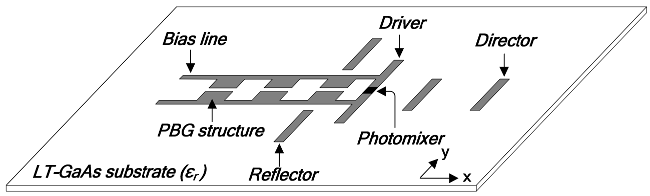
The photomixer is one of the most useful THz sources because it is compact, has wide frequency tunability, and operates at room temperature [1]. It is fabricated on a low-temperature-grown GaAs (LT-GaAs) substrate that has an ultrashort carrier lifetime, high electrical breakdown voltage, and high carrier mobility [2]. The photomixer is usually integrated with the antenna and used as both a detector and emitter of THz waves. However, the input resistance of the photomixer under illumination is typically above 10 kΩ, while an antenna that is integrated with the photomixer generally has a very low input resistance [3]. This causes a major impedance mismatching problem between the photomixer and the antenna, which leads to the reduction of the THz output power. Several efforts have been made to design the antennas with high input impedance characteristics, such as the dual dipole, dual slot, and folded dipole antennas [3, 4]. However, the input impedances of those antennas are only several hundred ohms at best, so the impedance mismatching problem remains. In this paper, we describe the design of a Yagi-Uda antenna that achieves better impedance matching with a photomixer by using a full-wavelength dipole as the driver element.

II. ANTENNA DESIGN AND CHARACTERISTICS

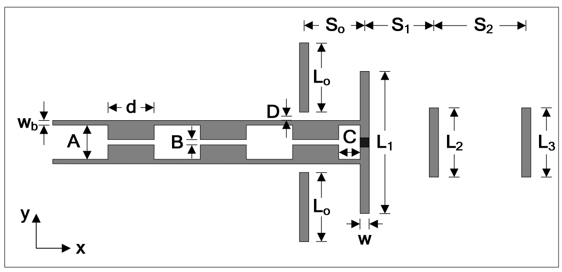
Figure 1 shows a schematic diagram of the proposed Yagi-Uda antenna. The antenna is designed on a 1200×400 μm^2 GaAs substrate with a relative dielectric constant (ε_r) of 12.9 and a thickness of 4 μm. The antenna is composed of a driver, directors, reflectors, and the photomixer, which is located at the center of the driver. The reflectors and directors are placed on the left and right sides of the driver, respectively. The respective lengths of the reflector and dirver are L_o and L_1, and the lengths of the first and second directors are L_2 and L_3, respectively. The space between the driver and the reflector is S_o, and the distances between the driver and the first and second directors are S_1 and S_2, respectively. The widths of the driver, reflectors, and directors are all set to w.

A coplanar stripline (CPS) type of bias line is attached to the driver element to apply a DC bias to the photomixer. The width of the CPS is w_b, and the distance across the CPS is A. When the bias line is connected to the driver, AC current will flow into the bias line to produce the radiation of electromagnetic waves. Therefore, the bias line will operate as a part of the antenna, which eventually changes the antenna characteristics. The photonic bandgap (PBG) structure with a period of $\lambda_g/2$ is inserted to minimize the flow of AC current into the bias line [3]. The length of a PBG cell is d, while the gap between the PBG cells is B, and the distance between the driver and the first PBG cell is C. In this design, the first PBG cell near the driver also acts as a parasitic element of the antenna. By adjusting the distance between the first PBG cell and the driver, the cell can be designed to serve as an effective antenna reflector.

We used two techniques in our design to increase the input resistance of the antenna. First, a full-wavelength dipole is used as the antenna driver element. This means that the input resistance of the antenna can be greatly increased since the



(a) 3-dimensional view.



(b) top view.

Fig. 1. Schematic of the proposed antenna.

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input resistance of the full-wavelength dipole is about 10 times greater than that of a conventional half-wavelength dipole. Second, the antenna is designed on a thin substrate. The effective dielectric constant of the substrate is very low, which allows a higher input resistance than would be possible for an antenna on a thick substrate.

CST Microwave Studio was used to optimize the design of the proposed Yagi-Uda antenna. The thickness and conductivity of the Ti-Au thin film used for the antenna elements was 0.35 µm and 1.6×10^7 S/m, respectively [5]. The optimized design parameters were calculated as follows: L_o=120 µm, L_1=230 µm, L_2=120 µm, L_3=120 µm, w=8 µm, S_o=108 µm, S_1=128 µm, S_2=160 µm, A=3 µm, B=35 µm, C=60 µm, D=4 µm, *and* E=80 µm. Figure 2 shows the impedance curve of the proposed antenna, which has a resonance frequency of 590 GHz and an input impedance value of 2590 Ω. This impedance value is much higher than that of any other THz antenna, and the proposed antenna has the advantage of improved impedance matching with the photomixer. Figure 3 shows the radiation pattern of the proposed antenna in the xz- and yz-planes. The antenna has an end-fire radiation pattern with a maximum directivity of 10.9 dBi, front-to-back ratio of 11.2 dB, and a radiation efficiency of 80.8% at the resonance frequency. The half-power beamwidth of the antenna is 40^o in the xy-plane and 58^o in the xz-plane.

III. CONCLUSIONS

In this paper, we describe the design of a Yagi-Uda antenna for use in the THz frequency region. With a full-wavelength dipole as the driver element, the antenna has an input impedance of approximately 2600 Ω, which is much higher than that of any other THz photomixer antenna to date. To apply DC bias to the photomixer, a CPS-type of bias line was connected to the driver element, and the AC current leakage into the bias line was minimized by inserting a PBG structure in the bias line. We expect this proposed Yagi-Uda antenna to achieve increased terahertz output power because of the improved impedance matching with the photomixer.

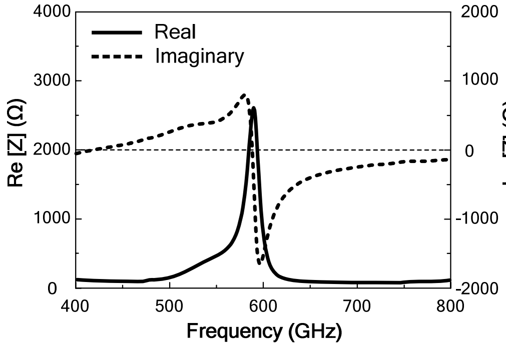
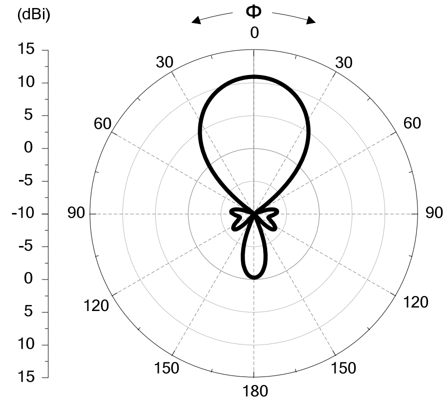
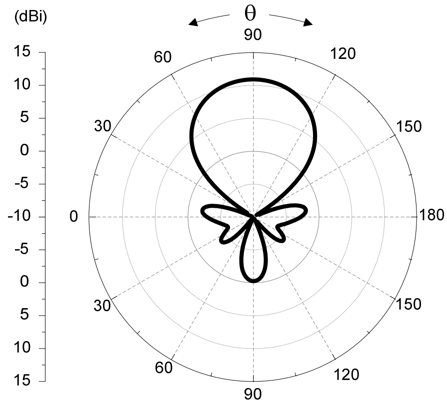


Fig. 2. Input impedance as a function of frequency.



(a) xy-plane.



(b) xz-plane.

Fig. 3. Radiation patterns of the antenna.

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