

THREE-WIRE FOLDED DIPOLE ANTENNA FOR HIGH TERAHERTZ OUTPUT POWER

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1. Introduction

Recent advances in terahertz (THz) technology have made possible a new field of applications related to the spectroscopy, sensing, and imaging. Despite the increasing use of THz systems in many research areas, the virtual absence of practical, compact THz sources has limited widespread use of THz technologies. Many efforts have been made to make practical sources in THz frequencies, but no THz sources concurrently satisfy size, output power level, and operating temperature requirements.

A photoconductive antenna is an attractive THz source because of its compactness and wide tunability at room temperature [1]. However, the photoconductive antenna has the significant disadvantage of low output power [2]. This is mainly due to the high impedance inherent to the photomixer. When an antenna with moderate input impedance is connected to a photomixer, the power transfer from the photomixer to the antenna is poor due to the severe impedance mismatching. Impedance matching between the photomixer and the antenna can be improved by increasing the antenna resistance, which has the result of increasing the power radiated from the antenna [3]. In this paper, we report the design of a three-wire folded $\lambda/2$ dipole antenna for high output power in the THz region. It is shown that the three-wire folded $\lambda/2$ dipole antenna has higher antenna resistance than the full-wavelength dipole antenna, and therefore it is able to achieve higher output power.

2. Photoconductive antenna design

There are several types of folded dipole antennas, all of which are characterized by high antenna resistance. Since photoconductive antennas need DC biases, antennas with closed loops cannot be used. Given this restriction, the three-wire folded $\lambda/2$ dipole antenna shown in Fig. 1 is a good choice. The currents, as indicated by arrows in Fig. 1, are equal in individual wires and in phase. Therefore, the current distribution of the three-wire folded $\lambda/2$ dipole antenna is similar to that of a simple $\lambda/2$ dipole antenna, as is the radiation pattern [4].

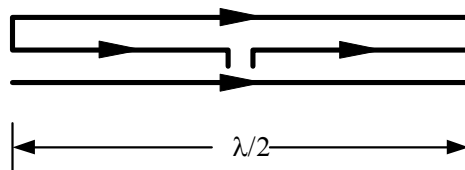


Fig. 1. Three-wire folded $\lambda/2$ dipole antenna.

Fig. 2 shows the input resistances of the full-wavelength dipole antenna and the three-wire folded $\lambda/2$ dipole antenna. They are calculated using MWS, which is a commercially available electromagnetic (EM) simulator. Both antennas have a resonant frequency at around 1.0 THz. At resonance, the input resistances of the full-wavelength dipole antenna and the three-wire folded $\lambda/2$ dipole antenna are 256 Ω and 517 Ω , respectively. The input resistance of the three-wire folded $\lambda/2$ dipole antenna is larger than that of the full-wavelength dipole antenna, and, as a result, the output power from the three-wire folded $\lambda/2$ dipole antenna is expected to be larger than that from the full-wavelength dipole antenna.

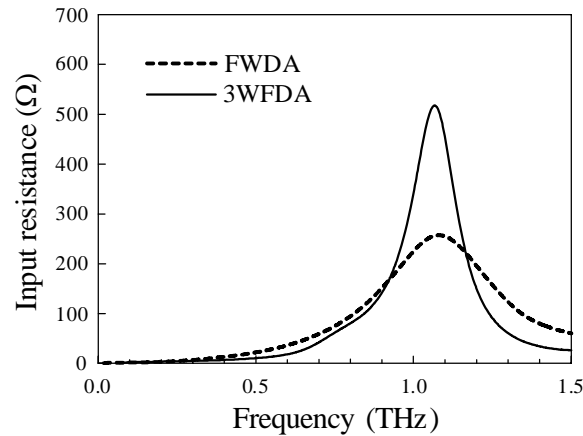


Fig. 2. Simulated input resistances.

3. Results and discussions

The antennas are fabricated on low-temperature-grown gallium arsenide (LT-GaAs) substrate with 1 μm thickness. The metal, composed of 0.05 μm thick titanium for adhesion and 0.3 μm thick gold, is 3 μm wide. The full-wavelength dipole antenna is 88 μm long and the three-wire folded $\lambda/2$ dipole antenna is 60 μm long. The wire spacing in the three-wire folded $\lambda/2$ dipole antenna is 2 μm . The photomixer is made up of 3 μm wide metal electrodes separated by a gap of 5 μm . Photographs of the fabricated antennas are shown in Fig. 3.

The antennas were pulsed as the preliminary stage of the continuous wave (CW) operation. A typical THz time-domain spectroscopy setup was used to measure the THz pulse signals [5, 6], and the measured detected signals are shown in Fig. 4.



Fig. 3. Photographs of fabricated three-wire folded $\lambda/2$ dipole antenna.

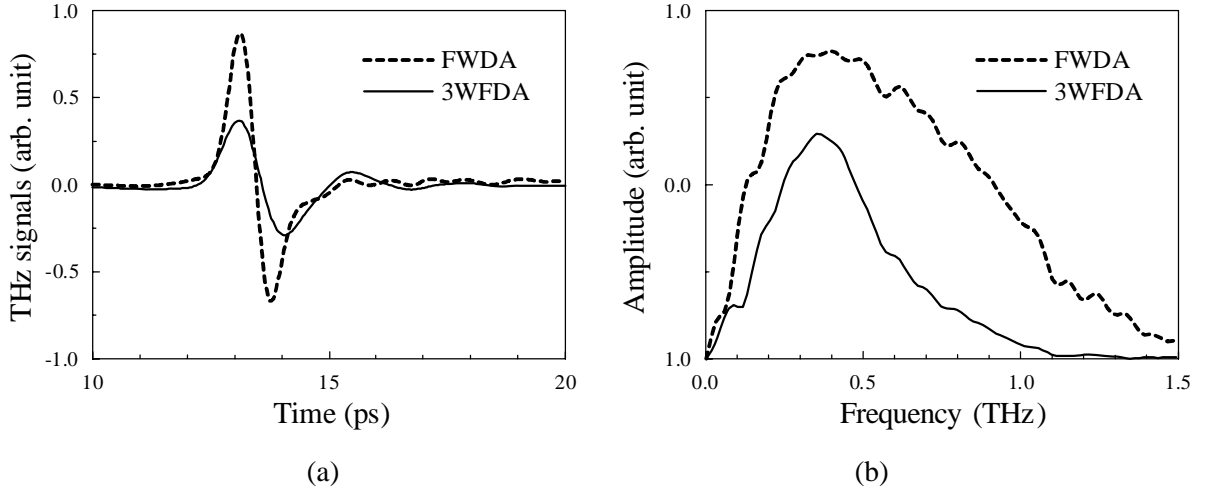


Fig. 4. (a) Measured THz pulsed signals. (b) Fourier transformed THz signals.

In order to analyze the measured signals, the simple analytical model is derived based on the equivalent circuit shown in Fig. 5. Total radiated power from the antenna is given by

$$P_{rad}(\omega) = \frac{1}{2} |i(\omega)|^2 \frac{G_L(\omega)}{[G_L(\omega) + G(\omega)]^2 + [B_L(\omega) + \omega C]^2} \quad (1)$$

where $G_L(\omega)$ and $B_L(\omega)$ are the real and imaginary parts of $Y_L(\omega)$, respectively. The validity of the equation was proved by the bolometric measured data [3]. Using Eq. (1), the detector currents are calculated in the frequency domain, including the detector responses [6]. Results of these calculations are shown in Fig. 6. The calculated signals are in good agreement with the measured signals, which indicates the validity of our analytical model. On the basis of the model, the radiated powers expected under CW operation are plotted in Fig. 7. Both antennas are designed to operate at about 1 THz. It is expected that the radiation power peaks, which are proportional to the antenna resistances, will be observed at resonant frequencies. However, the result for the three-wire folded $\lambda/2$ dipole antenna is different than predicted. This is likely because the photocarriers of the photoconductive three-wire folded $\lambda/2$ dipole antenna may be generated between the wires due to the large spot size of the input beam. This results in added capacitance between the wires. The additional capacitance, which was not considered in the EM simulation, causes the position of the radiation power peak to move to the lower frequency. This problem can be remedied by fixing the physical dimensions of the three-wire folded $\lambda/2$ dipole antenna and tuning out the capacitance.

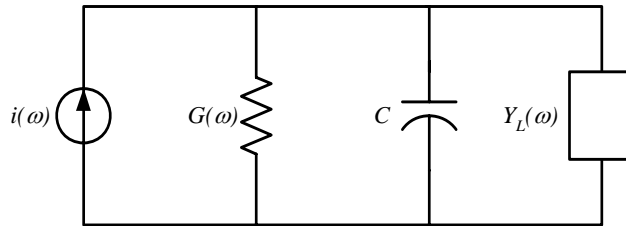


Fig. 5. Equivalent circuit for the photomixer coupled to the antenna.

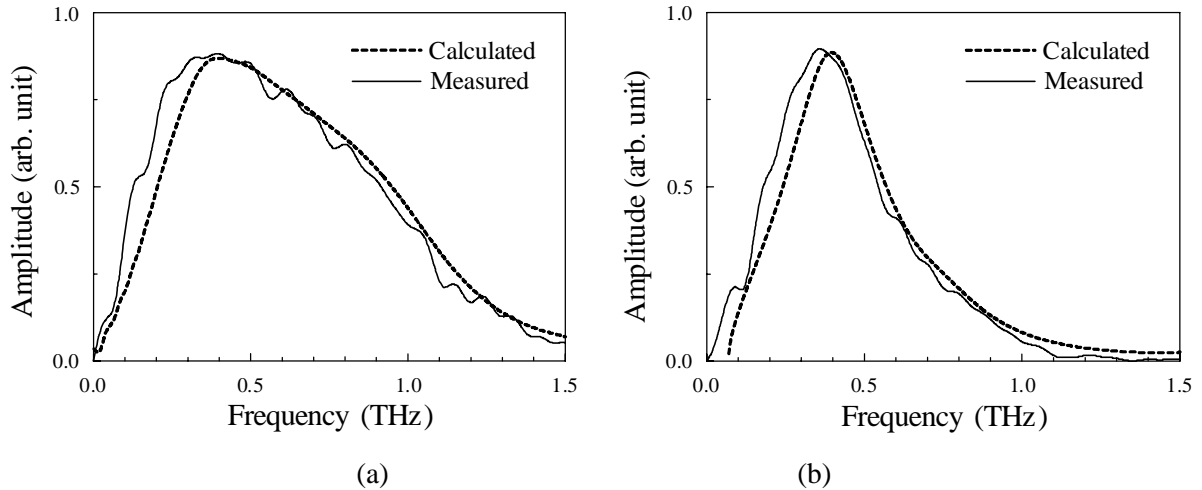


Fig. 6. Comparisons of the THz signals between the measured and the calculated signals. (a) Full-wavelength dipole antenna. (b) Three-wire folded $\lambda/2$ dipole antenna.

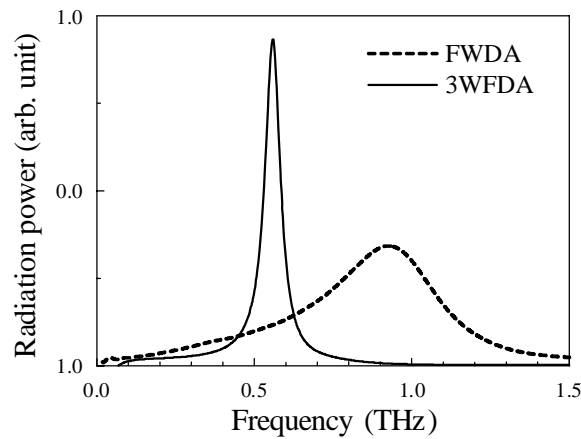


Fig. 7. Predicted radiation power from the antenna.

4. Conclusion

The photoconductive three-wire folded $\lambda/2$ dipole antenna have been introduced and its capacity for high power THz generation has been successfully demonstrated. The simple analytical model is derived based on the equivalent circuit, and the measured pulsed THz signals are shown to be in good agreement with the analytical model. The CW output powers from the antennas have been predicted by applying the simple analytical model. We can infer from the experiments and analyses that the three-wire folded $\lambda/2$ dipole antenna is able to achieve higher output power than the full-wavelength dipole antenna.

References

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