A Folded Dipole Antenna Having Extremely High Input Impedance for Continuous-wave Terahertz Power Enhancement

Han C. Ryu[a], Sung I. Kim[a], Min H. Kwak[a], Kwang Y. Kang[a], and Seong O. Park[b]
[a] Electronics and Telecommunications Research Institute, Daejeon, 305-350, Korea
[b] School of Engineering, Information and Communications University, Daejeon, 305-732, Korea

Abstract— **It is very important to increase the input impedance of a antenna for continuous-wave terahertz photomixers because the output impedance of terahertz photomixers is extremely high compared to the antenna impedance. Folded dipole antennas are analyzed to increase the input impedance by varying geometrical dimensions. The input impedance of the optimized folded dipole antenna is about 40 times as high as that of a self-complementary antenna at the resonant frequency.**

I. Introduction And Background

FOR past decade, a continuous-wave(CW) terahertz(THz) system based on optical-heterodyne photomixers has been received a considerable amount of attention as an important candidate for the THz spectroscopy and imaging measurement system[1]. A CW THz system driven by semiconductor lasers is superior to a pulsed-THz system driven by a mode locked Ti:Sapphire laser and a high-power pump laser in terms of frequency resolution, cost, size, and measurement time.

Figure 1 shows an equivalent circuit diagram of a CW THz device with the photomixer and antenna[2]. The photocurrent $i(f, t)$ is modulated at the difference frequency of two lasers by the voltage-biased photomixers, with resistance $R(f, t)$, based on photoconductor having short carrier lifetime, such as low-temperature-grown (LTG) GaAs. The capacitance $C(f, t)$ represents the charge accumulating effects in the interdigitated photomixer. The bias voltage $V_B(f_1)$ is modulated at several hundred Hz for the THz signal detection by using lock-in detection techniques.

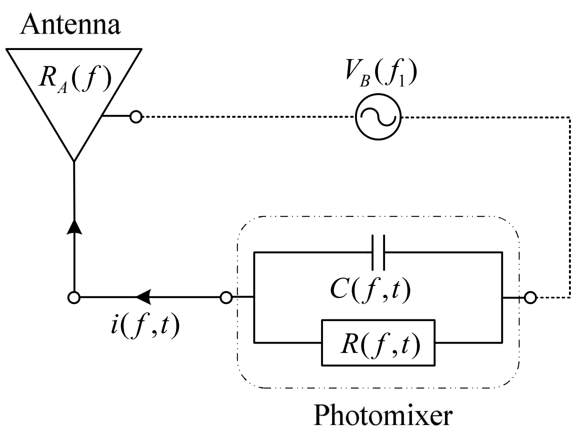

Figure 1. Equivalent circuit diagram of a CW-THz device with photomixer and antenna

The generated photocurrent is coupled to an antenna according to the impedance matching condition between a photomixer output impedance $R(f, t)$ and an antenna input impedance $R_A(f)$. The output impedance of a photomixer is very high, typically 10~100 kΩ, and the input impedance of a conventional broadband THz antenna is below 100 Ω. A broadband self-complementary THz antenna on GaAs is about 72 Ω. Consequently, the CW THz output power is proportional to the input impedance of the antenna. Resonant antennas are suitable for a CW THz system because they can be designed to have higher input impedance at the operating frequency[3]. In this report, we propose a folded dipole antenna on GaAs that has very high input impedance, 3000 Ω[4].

II. Results

For the optimum CW THz antenna design, the input impedance of a folded dipole antenna is numerically calculated by electromagnetic simulation. There are several parameters to optimize for high impedance of a folded dipole antenna: width of line, length of line, distance between lines, and number of lines. A configuration of a folded dipole antenna is shown in Fig. 2.

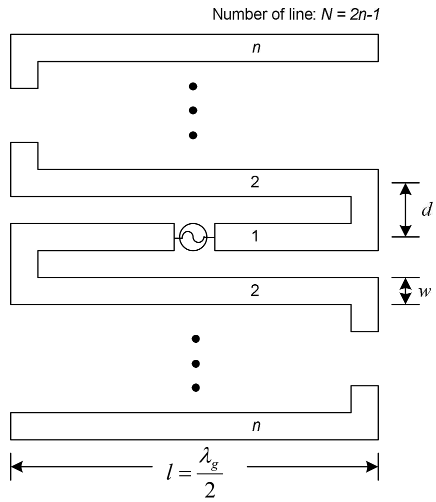

Figure 2. A configuration of a folded dipole antenna

The width of line is fixed at 6μm to connect with a photomixer which has a 8 x 6 μm^2 active area with four 0.3 μm interdigitated metal electrodes separated by 1.7 μm gaps. If we use the thinner line than 6μm, we can obtain higher impedance. The length of the folded dipole antenna line is chosen as $\lambda_g/2$ for the half wavelength dipole operation. Thus, the folded dipole antenna is optimized with varying distance between lines from $0.025\lambda_g$ to $0.06\lambda_g$. The guide wavelength λ_g is defined as

978-1-4244-2120-6/08/$25.00 ©IEEE.

$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{eff}}}$$

$$\text{where, } \varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} \qquad (1)$$

Figure 3 shows the input impedance of the folded dipole antennas (3 lines) with varying distance. The GaAs substrate thickness was 350 μm and the electrode thickness was 150 nm.

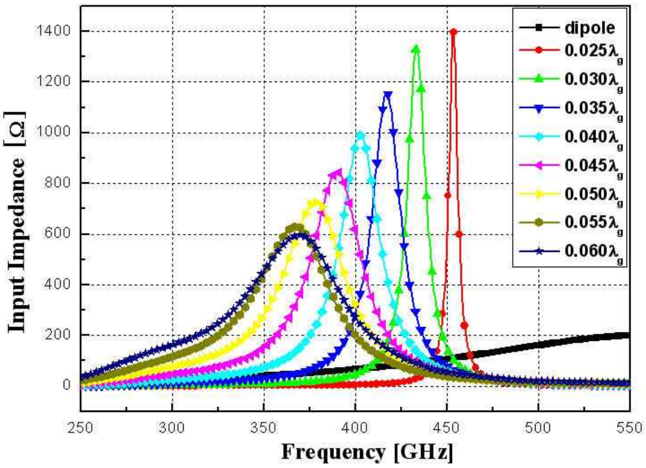

Figure 3. Input impedance of folded dipole antennas (3 lines) with varying distance between lines from 0.025 λ_g to 0.06λ_g

The input impedance decreased from 1400 Ω to 600 Ω as distance between lines increased from 0.025λ_g to 0.06λ_g. The frequency of peak input impedance also decreased as distance increased. Even though input impedance characteristics of the folded dipole having the shortest distance between lines is suitable for the photomixers, the radiation pattern and stability of that antenna is not good and the bandwidth of that antenna is too narrow. Thus the distance between lines is fixed at 0.04λ_g in consideration of the radiation pattern, stability, frequency bandwidth, and operation frequency. Figure 4 shows the input impedance of the folded dipole antenna having 0.04λ_g distance between lines with varying number of lines.

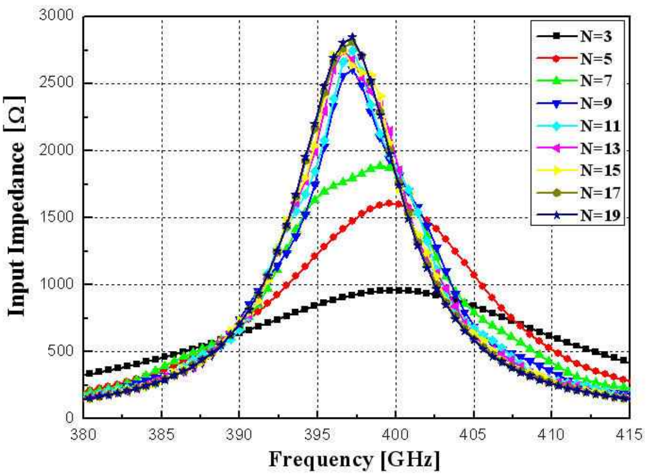

Figure 4. Input impedance of the folded dipole antenna having 0.04λ_g distance between lines with varying number of lines

The input impedance increased from 1000 Ω to 3000 Ω and the frequency of peak input impedance slightly decreased as the number of lines increased from three to nineteen. The folded dipole antennas having over thirteen lines have the similar input impedance. This small variation of the input impedance can reduce the side effect of the bias line.

The proposed folded dipole antenna having multiple lines has extremely high input impedance compared to conventional THz antenna. This antenna can make the remarkable enhancement of the THz output power.

References

[1] T. Loffler, "All-optoelectronic continuous-wave terahertz systems", *Phil. Trans. R. Soc. Lond. A*, vol. 362, pp 263-281, 2004.

[2] I. S. Gregory, "Optimization of Photomixers and Antennas for Continuous-Wave Terahertz Emission", *IEEE. J. Quan. Elec.,* vol. 41, no. 5, pp. 717-728, 2005.

[3] K. A. McIntosh, "Terahertz measurements of resonant planar antennas coupled to low-temperature-grown GaAs photomixers", *Appl. Phys. Lett*, vol 69(24), pp. 3632-3634, 1996.

[4] J. D. Kraus, Antennas, McGraw Hill, 1988.