Terahertz Memos

Memo 01

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Switched oscillator as an antenna

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Abstract

The radiation characteristics of a switched oscillator, mounted over a substrate of thickness $\lambda/8$ and designed to radiate at 0.5 THz, are examined. The resonant frequency, quality factor, maximum electric field in the farfield region, radiated gain pattern and radiated power pattern are obtained for this antenna.

1 Aim

1. To examine the radiation characteristics of a switched oscillator, mounted over of a substrate, designed to radiate at 0.5 THz.

2. To determine the following parameters for such an antenna design,

   - resonant frequency,
   - Q (quality factor),
   - maximum electric field, $E_{\max}$, in the farfield region, and
   - the radiated gain and power patterns for frequencies in the range 0-1 THz.

2 Setup

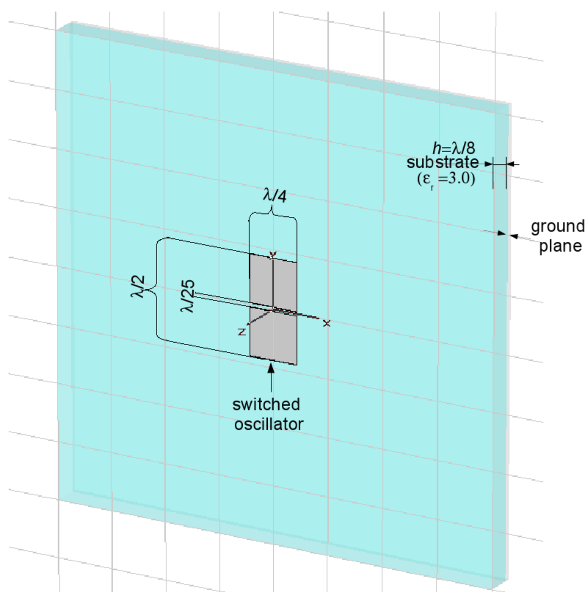


Figure 2.1: Perspective view of switched oscillator mounted over a substrate of height $\lambda/4$. A ground plane is placed behind the substrate.

The switched oscillator (SWO) dimensions were determined for a free space wavelength of $\lambda_0 = 600$ μm corresponding to a frequency of 0.5 THz. The SWO is mounted over a substrate of relative dielectric constant, $\epsilon_r = 3.0$. The wavelength, λ, in the substrate is, $\lambda = \lambda_0/\sqrt{\epsilon_r} = \lambda_0/\sqrt{3.0} = 346.41$ μm.

Fig. 2.1 shows the perspective view of the simulation setup. The dimensions of the various components are tabulated below

The input signal of 1 V, a ramp rising excitation with a rise time of 0.1 ps, is shown in Fig. 2.2. A discrete port between the switch gap was used to source this excitation in CST.

Probes : A far-field probe, oriented in the y-direction, was placed at 1 cm (1000 μm) from the origin on the z-axis (see Fig. 2.1 for coordinate system).

Table 1: Dimensions of components in Fig. 2.1

Component/paramter	Dimension
length of SWO (swo_l)	$\lambda/2 = 173.2\ \mu$m
width of SWO (swo_w)	$\lambda/4 = 86.6\ \mu$m
thickness of SWO (swo_t)*	0.5 μm
switch gap (swgp)	$\lambda/25 = 13.86\ \mu$m
relative dielectric constant of substrate (ϵ_r)	3.0
height of substrate (h)	$\lambda/8 = 43.3\ \mu$m
thickness of ground plane behind substrate	1.0 μm

*Not shown in Fig. 2.1

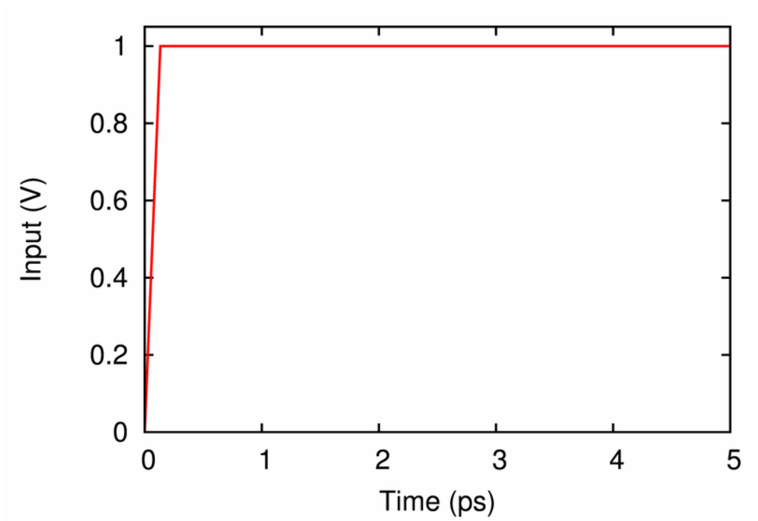


Figure 2.2: Ramp rising excitation signal applied between the switch gap. Rise time is 0.1 ps.

3 Results

3.1 Resonant frequency, quality factor (Q) and maximum electric field

The damped sinusoidal electric field response from the far-field probe is shown in Fig. 3.1(a). The current at the input port follows as similar profile as shown in Fig. 3.1(b).

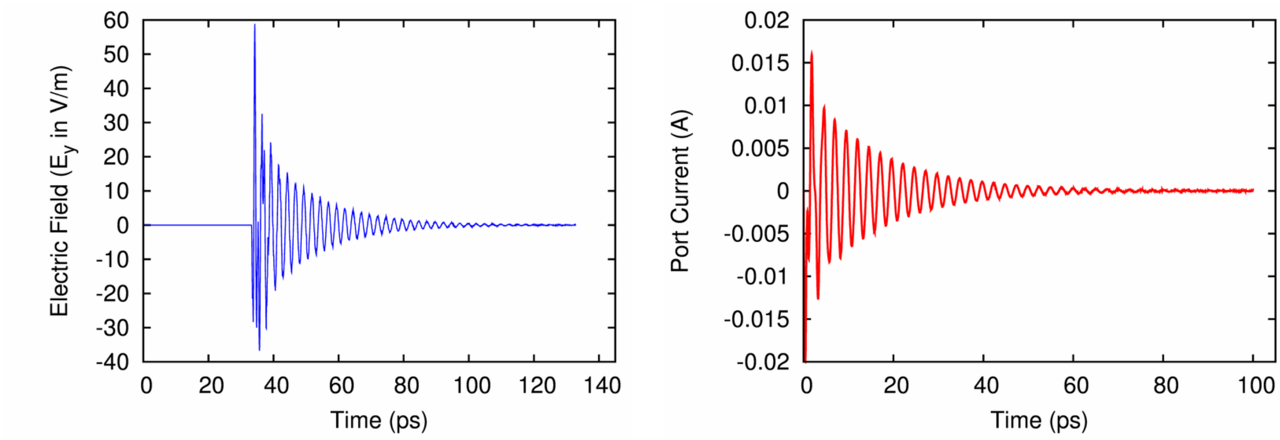
The simplest way to determine the resonant frequency and Q is by examining the time signals in Fig. 3.1 in the frequency domain. The Fourier transforms of the the signals in Fig. 3.1 are shown in Fig. 3.2.

The double peak in Fig. 3.2 is a direct consequence of taking the discrete Fourier transform.

A "zoomed-in" view of Fig. 3.2(a) is shown in Fig. 3.3. f_0 is the resonant frequency and υ_{max} the corresponding maximum amplitude of the Fourier transformed signal. f_1 and f_2 are the frequencies at $\upsilon_{\text{max}}/2$. The bandwidth is therefore given by $BW = |f_2 - f_1|$.

The required parameters are easily determined from Fig. 3.3 and are tabulated below

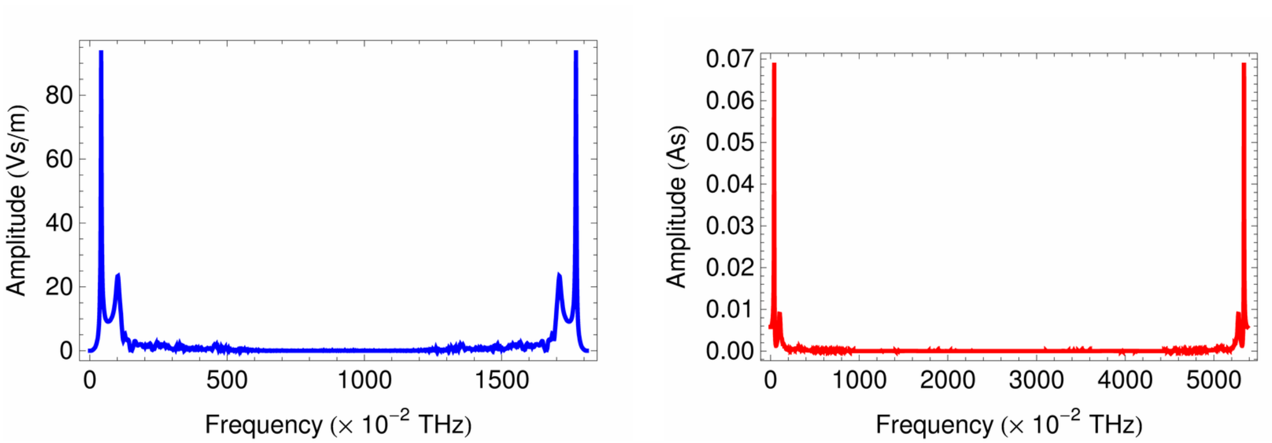
The most important point to note from the table above is that the SWO does *not* resonate



(a) Electric field, E_y, response from far-field probe.

(b) Current at input port.

Figure 3.1: Damped sinusoidal electric field and port current signals.



(a) Fourier transform of the electric field, E_y, response from far-field probe in Fig. 3.1(a).

(b) Fourier transform of current at input port in Fig. 3.1(b).

Figure 3.2: Fourier transformed signals of the damped sinusoidal electric field and port current signals in Fig. 3.1.

Table 2: Parameters as determined from electric field response

Parameter	Value
resonant frequency (f_0)	0.4 THz
quality factor (Q=f_0/BW)	20.5
maximum electric field (E_{max})	58.88 V/m

at 0.5 THz but resonates at 0.4 THz. This is most likely due to electromagnetic factors such as fringing electric fields, surface waves and the free space above the antenna, that were not taken into account. Exactly the same resonant frequency is obtained from the Fourier transform of the current response at the input port is used.

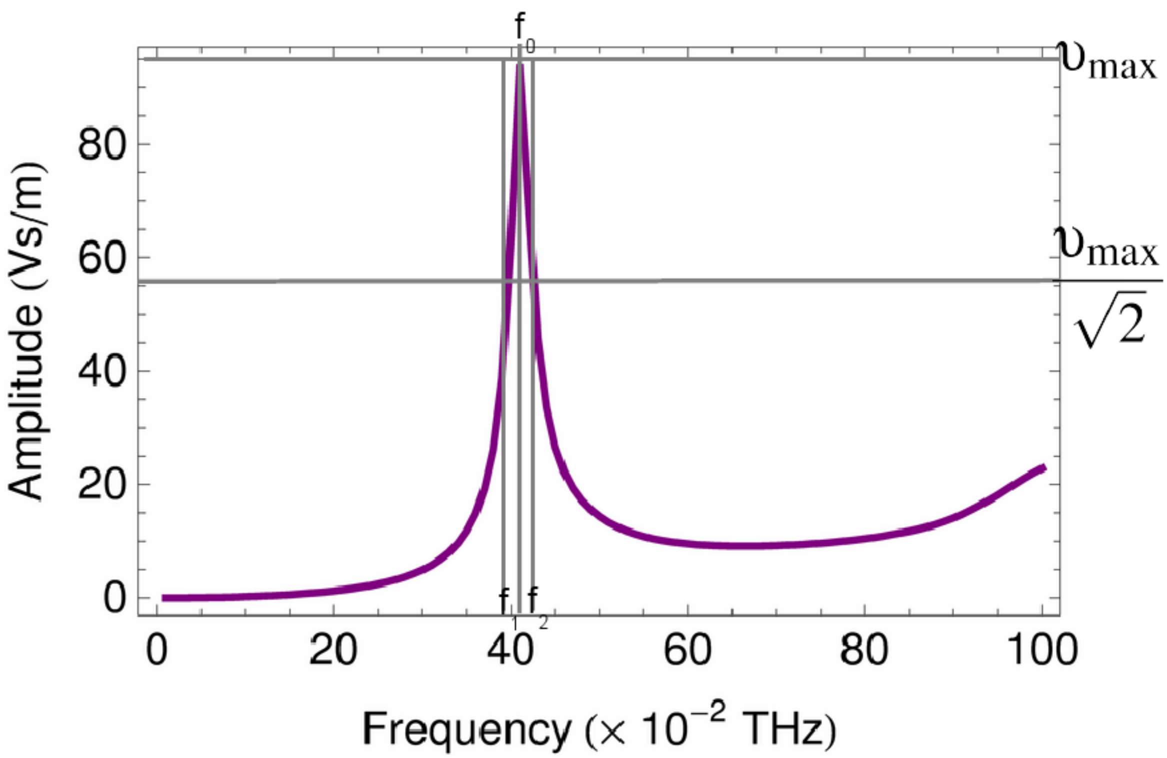


Figure 3.3: Fig. 3.1(a) "zoomed" in.

3.2 Comparison of radiated gain and power patterns

3.2.1 Gain

The three dimensional radiation gain pattern (at $f_0 = 0.4$ THz) and the spherical coordinate system used are shown in Fig. 3.4. As expected, the pattern is dipolar.

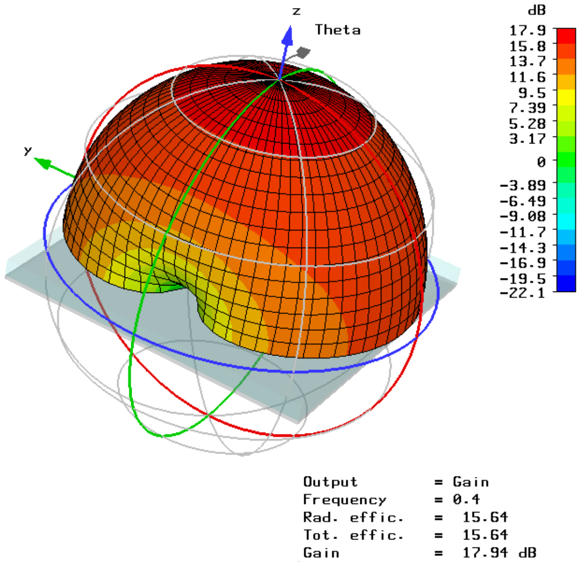
The radiation gain (normalized to 40 dB) is compared for several frequencies (including $f_0 = 0.4$ THz) in the $\theta = 90°$ plane in Fig. 3.5. The pattern is dipolar at 0.4 THz and ceases to be so at higher frequencies.

3.2.2 Power

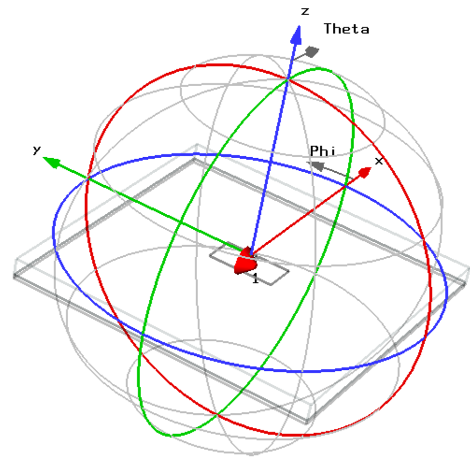
To further prove that the resonant frequency is indeed at 0.4 THz, the power patterns are compared for several frequencies in the $\theta = 90°$ plane in Fig. 3.6. The power at 0.4 THz is approximately an order of magnitude higher than at other frequencies.

4 Conclusion

An SWO mounted over a substrate of thickness $\lambda/4$ was designed to radiate at 0.5 THz. However, it was found that the structure radiated at 0.4 THz. The quality factor was determined to be Q=10.25. The maximum electric field was ≈ 0.6 V at a distance of 1 cm.



(a) Gain radiation pattern for SWO.



(b) Spherical coordinate system for radiation pattern.

Figure 3.4: Three dimensional radiation (gain) pattern and spherical coordinate system for SWO simulation.

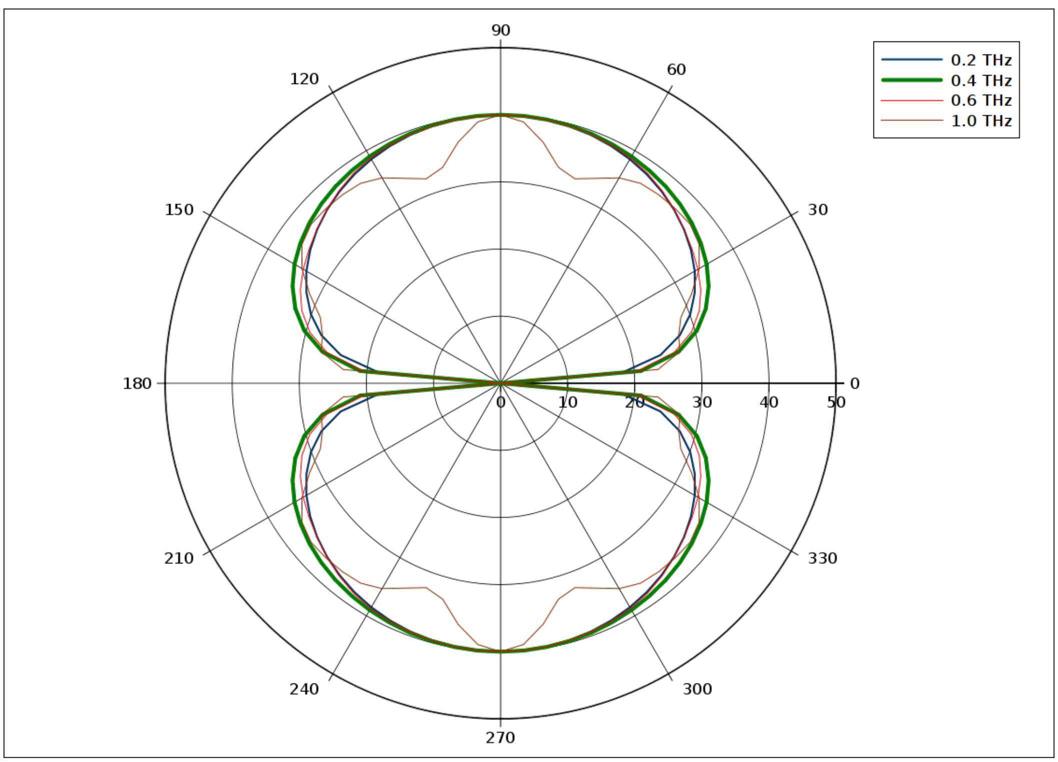


Figure 3.5: Comparison of radiation (gain) patterns for several frequencies in the $\theta = 90^\circ$ plane.

The radiation gain pattern was dipolar at the resonant frequency, as expected. The pattern ceases to be dipolar at higher frequencies. Also, the radiated power, at the resonant frequency of

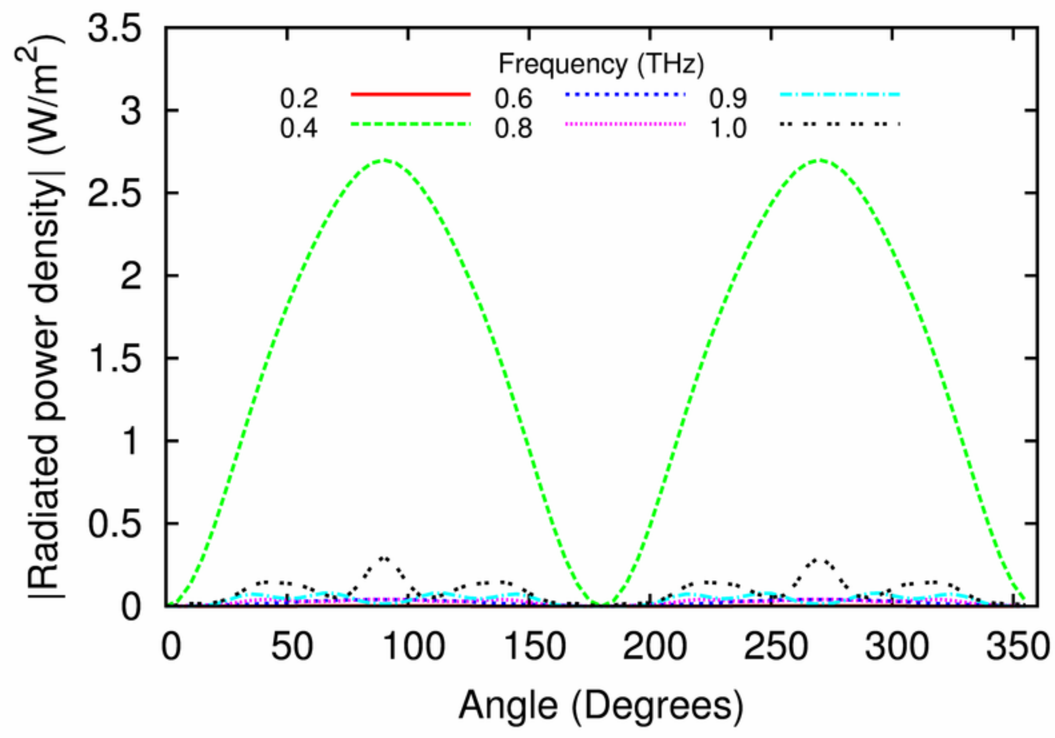


Figure 3.6: Comparison of power patterns for several frequencies in the $\theta = 90^\circ$ plane.

0.4 THz, is approximately an order of magnitude higher when compared to the radiated power at other frequencies in the 0-1 THz range.