University of Victoria

ELEC 340

Applied Electromagnetics and Photonics

Lab 1 - Time-Varying Electromagnetic Fields

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1 Objective

This lab will demonstrate:

1. An application of the four Maxwell equations;
2. How Maxwell's equations explain time varying electromagnetic phenomenoa, and;
3. How MEFiSTo or similar software is used to model simple electromagnetic structures.

2 Introduction

This lab used the MEFiSTo software to create animations of the resonance in a magnetic and an electric cavity due to exciation of an impulse. The observable resonances verify Faraday's Law (1) and Ampere's Law (2).

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d}{dt}\int_A \vec{B} \cdot d\vec{s} \tag{1}$$

$$\oint \vec{H} \cdot d\vec{l} = \frac{d}{dt}\int_A \vec{D} \cdot d\vec{s} + \vec{I} \tag{2}$$

3 Procedure

We created a cylindrical structure in MEFiSTo that had perfect magnetic boundaries. The structure had an outer wall, a top and bottom and it was filled with air. It contained a distributed source, a probe and an animation region. We used a simulation mesh, initially with a grid spacing of 1mm, which we then changed to 0.5mm.

For the magnetic cavity, we excited it with an impulse and measured the resonance frequencies on the 1mm grid and on the 0.5 mm grid. We then excited the cavity with a Gaussian impulse with s frequency of 11.5 GHz, close to the measured resonance frequency and integrated the magnetic and electric fields over the animation region. This will verify Faraday's Law.

We also created a cavity very similar to the magnetic one, with perfect electrical boundaries and filled it with air. We excited this magnetic cavity with the same Gaussian impulse with a resonance frequency of 11.5 GHz. Then we integrated the magnetic and electric fields over the animation region of the electric cavity. This will verify Ampere's Law.

4 Discussion

4.1 Task 1

The first resonant frequency in the 1 mm grid spacing occurs at 11.502 GHz and in the 0.5 mm grid spacing it occurs at 11.4572 GHz (Figure 1). The amplitude is lower than in the examples in the lab manual due to the fact that we placed the probe off-centre in the structure. This way some of the different resonant frequencies cancel each other to lower the amplitude. However, the position of the resonant frequencies is preserved. Resonant frequency data is summarized in Table 1.

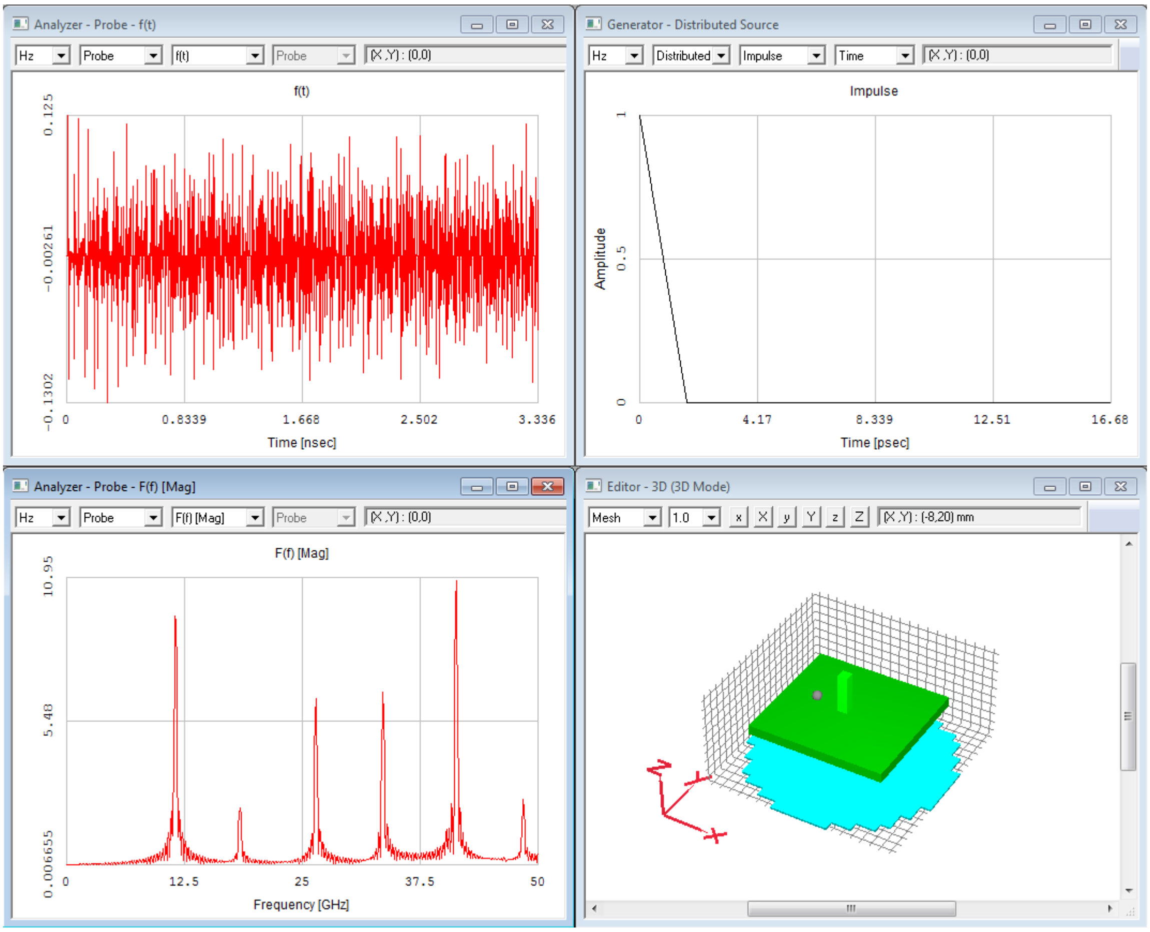

Figure 1: Time and frequency response of excitation by magnetic pulse in 1.0 mm resolution cylindrical cavity. Starting in the upper right and proceeding counter-clockwise: I shows the impulse excitation; II shows the time response of H_z; III shows the frequency response of H_z, and; IV shows the bottom of the cylinder, the animation plane, probe and source.

4.2 Task 2

The third, fourth and fifth resonant frequencies in the 0.5 mm resolution are quite different from the ones in the 1 mm resolution. This is possibly due to the fact that the cavity looks significantly more circular at 0.5 mm, than it does at 1 mm. As the resolution approaches 0 mm the geometry of the discretized volume approaches the ideal cylinder. The ideal cylinder is maximally (infinitely) symmetric along the cardinal axes and the degree of symmetry contributes to the maximum magnitudes of the resonant frequencies.

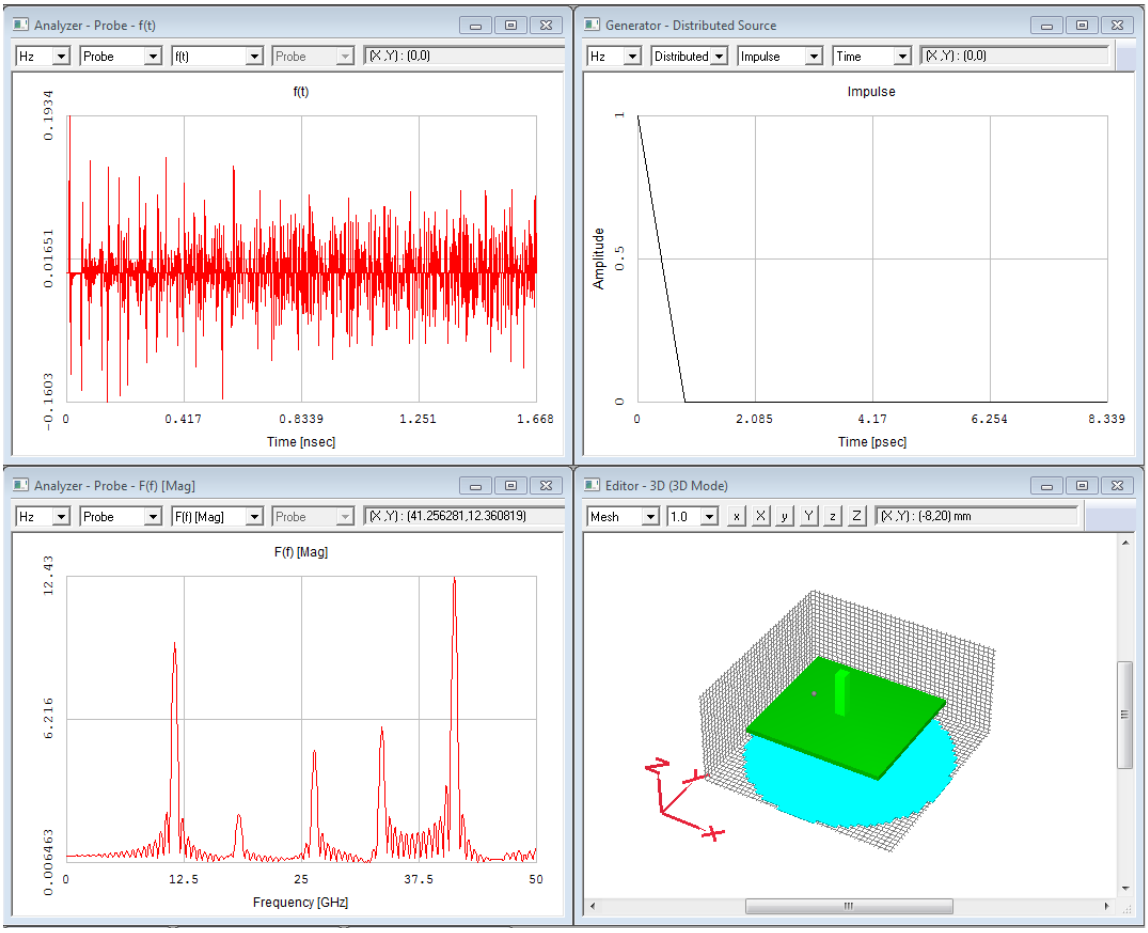

Figure 2: Time and frequency response of excitation by magnetic pulse in 0.5mm resolution cylindrical cavity. Starting in the upper right and proceeding counter-clockwise: I shows the impulse excitation; II shows the time response of H_z; III shows the frequency response of H_z, and; IV shows the bottom of the cylinder, the animation plane, probe and source.

Table 1: Effect of mesh resolution on resonance frequency and magnitude

1 mm		0.5 mm	
Frequency (GHz)	$\|F(f)\|$	Frequency (GHz)	$\|F(f)\|$
11.502347	9.4783414	11.457286	9.5471305
18.388106	2.1604907	18.341709	2.0439611
26.447574	6.3284078	26.38191	4.8253084
33.568075	6.5797428	33.567839	4.827887
41.314554	10.81526	41.2586281	12.360819

4.3 Task 3

In order to have accurate results from a numerical reading, it is important to have an idea of what the actual value should be. It is easy to get very precise readings that are very inaccurate. One way to know if the measurement is accurate is by comparing it to a known value. Comparison to a forecast or calculation of what it should be can also help with determining accuracy. Resolution varies directly with accuracy but inversely with computation time (as observed in the lab, 0.5mm took longer to run than 1.0 mm).

4.4 Task 7

The curves of `int_E_dot_dL.txt` and `d_int_B_dot_dS.txt` overlap completely (Figure 3). Variances could be caused by the way the derivative is taken. If the time steps are large, they could miss an important piece of information. This would cause the two graphs to look different.

4.5 Task 10

The curves of `int_H_dot_dL.txt` and `d_int_D_dot_dS.txt` overlap completely (Figure 4). Variances could be caused by the way the derivative is taken. If the time steps are large, they could miss an important piece of information. This would cause the two graphs to look different.

5 Conclusion

The simulation was an effective tool to see how the electric and magnetic waves are resonating in a perfect electrical and magnetic cavity, respectively. The different results in amplitude

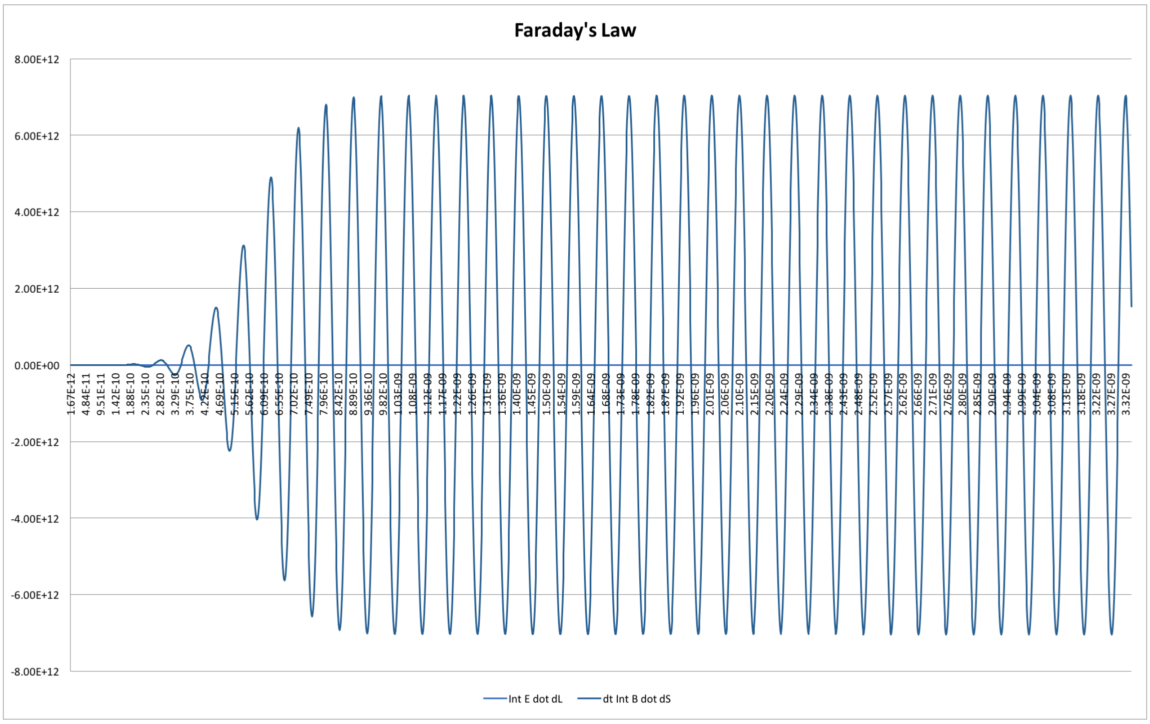

Figure 3: Complete overlap of $\oint \vec{E} \cdot d\vec{l}$ and $-\frac{d}{dt}\int_A \vec{B} \cdot d\vec{s}$

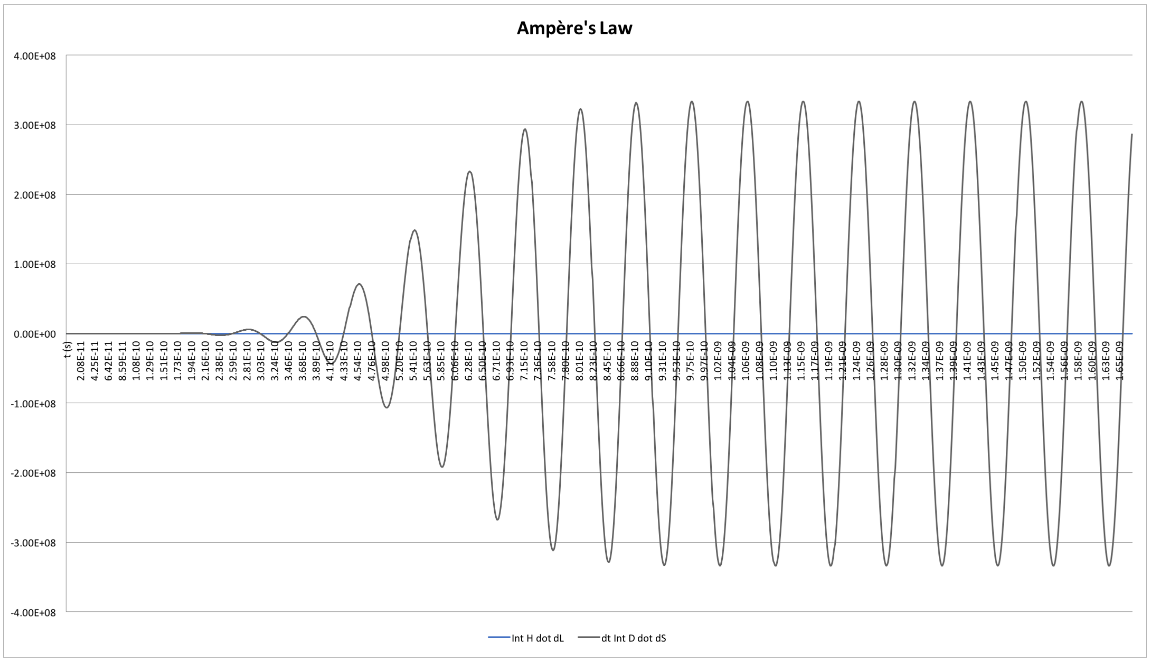

Figure 4: Complete overlap of $\oint \vec{H} \cdot d\vec{l}$ and $\frac{d}{dt}\int_A \vec{D} \cdot d\vec{s}$

illustrate the effect of the location of the probe and the time varying nature of the waves.