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Crude approximations for fields near the focusing lens exit

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Abstract

Preliminary experiments on the focusing lens (lens-to-air interface at exit) have found the magnetic field to be 3-4 times smaller than the electric field. This paper attempts to explain these experimental observations by considering the fields at the focusing lens exit to be the near fields of a point electric dipole.

1 Introduction

This paper attempts to provide some crude estimations to explain results of preliminary measurements of the electric and magnetic fields at the focusing lens exit (dielectric lens-to-air interface at focus). These measurements seem to indicate that the amplitude of the electric field is about 3-4 times larger than that of the magnetic field. The approximate ratio of the magnitude of the electric and magnetic fields can be obtained by considering a point electric dipole source at the focusing lens exit. Consider the coordinates of the focusing lens in Fig. 1.1.

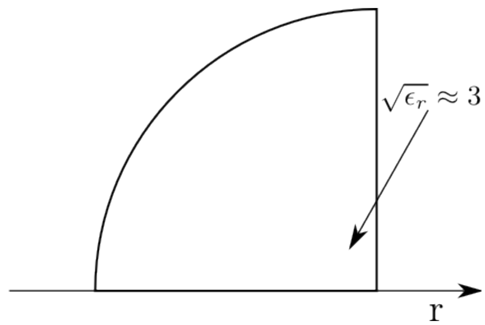


Figure 1.1: Coordinates and dielectrics for focusing lens

For a plane-wave transmission to air, the transmission coefficient is

$$T_e = \frac{2}{\frac{1}{3}+1} = \frac{3}{2}. \tag{1.1}$$

Image now that $T_e = 2$ i.e. $\epsilon_r \to \infty$. Further, let the electric field, E, transmit as doubled while the magnetic field transmits as zero. This is similar to the application of the surface equivalence theorm to a waveguide aperature mounted on an infinite ground plane (see for e.g. [1]). Thus, the interface is like a magnetic boundary. The magnetic surface current (equivalent, $\perp$ E) acts like an electric dipole.

2 Near-field approximations

First think of the entrance into air as a point electric dipole. It is actually a circle of radius ≈ 0.625 cm for $\epsilon_r = 9$. Consider a 100 ps pulse. This is a half cycle at $\approx$ 5GHz. The radian wavelength $\lambda = \lambda/(2\pi)$ for $\lambda \approx 6$ cm is ≈ 1 cm.

For $r > 1$ cm (far-field) the fields fall of like r^{-1}. For $r < 1$ cm (near-field), the fields for a point electric dipole behave like [1]:

$$\begin{aligned} E &\propto r^{-3} \\ H &\propto r^{-2}. \end{aligned} \tag{2.1}$$

At $r = 1/3$ cm, E is increased over H (in air) like

$$\frac{E}{H} = \frac{r^{-3}}{r^{-2}} = \frac{1}{r} = 3. \tag{2.2}$$

Figure 2.1 shows a plot of the near and far-fields for E and H.

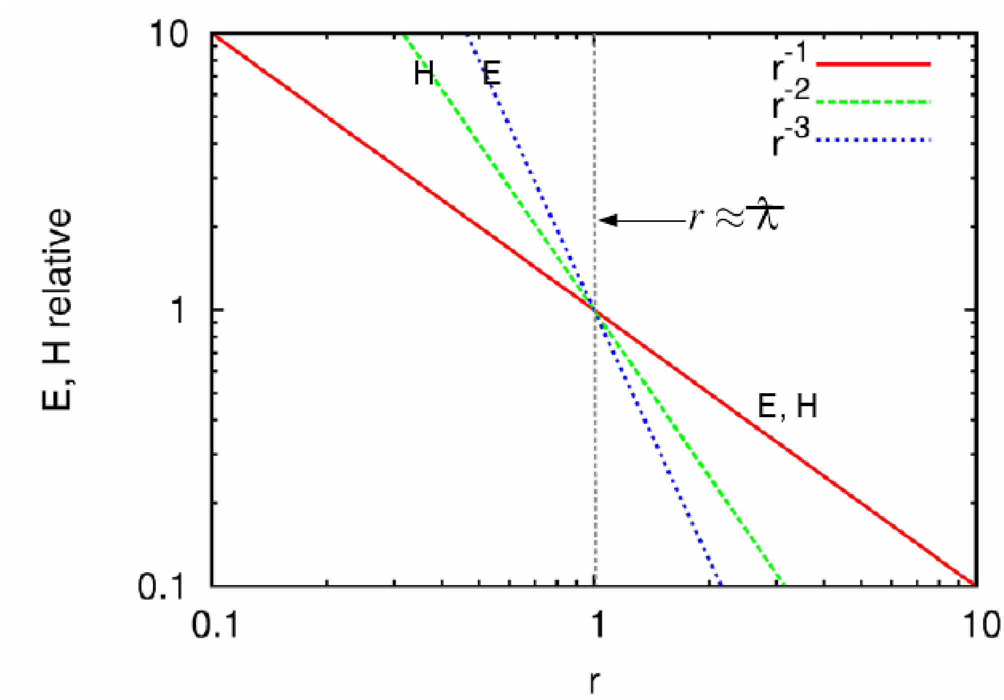
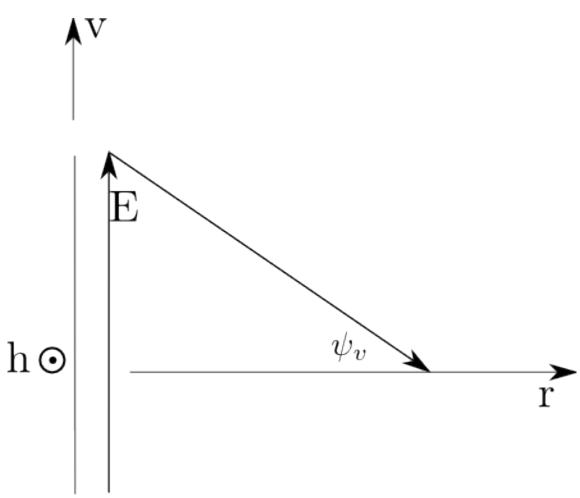


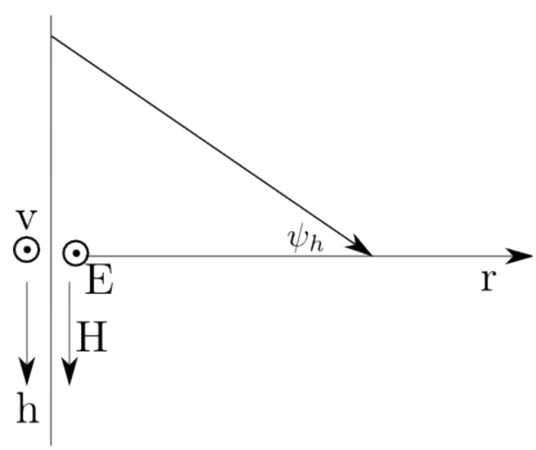
Figure 2.1: Log-log plot of near- and far-fields of a point electric dipole.

3 E and H focusing for different rays

Consider the disk shaped dipole (including image). Figure 3.1 shows the side and top views of rays and associated fields from the focusing lens.



(a) Side view of rays and fields from focusing lens.



(b) Top view of rays and fields from focusing lens.

Figure 3.1: Side and top views of rays and fields from focusing lens.

For the top and bottom rays,

$$
\begin{aligned}
E &\propto \cos^4 \psi_v && (3.1)\\
&\quad \cos \text{ for } E \text{ orientation}\\
&\quad \cos^3 \text{ for increase in distance } (r^{-3})\\
H &\propto \cos^2 \psi_v && (3.2)\\
&\quad \text{for increase in distance } (r^{-2}).
\end{aligned}
$$

For the side rays,

$$
\begin{aligned}
E &\propto \cos^3 \psi_h && (3.3)\\
&\quad \text{for increase in distance } (r^{-3})\\
H &\propto \cos^3 \psi_h && (3.4)\\
&\quad \cos \text{ for } H \text{ orientation}\\
&\quad \cos^2 \text{ for increase in distance } (r^{-2}).
\end{aligned}
$$

As the disk is approached (say ≈ 0.3 cm)

$$
\begin{aligned}
E &\rightarrow E_{\text{disk}} && (3.5)\\
H &\quad \text{becomes relatively small.} && (3.6)
\end{aligned}
$$

4 Conclusion

Very rough approximations of the experimentally observed smaller magnetic fields have been provided. The fields at the focusing lens exit are considered to be the near-fields of a (disk shaped) point electric dipole. The E/H ratios in the near field for this dipole source are close to those measured.

References

[1] Constantine A. Balanis, *Advanced Engineering Electromagnetics.* John Wiley and Sons, 1989.