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Simulation results for 6-layer and 7-layer conical non-uniform launching lens

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Abstract

Simulation results for the 6-layer and 7-layer conical non-uniform launching lens designs are presented. Results are discussed in the context of semi-analytical calculations in [1].

1 Introduction

This paper presents simulation results for the 6-layer and 7-layer conical launching lens designs based on equations in [1]. Results for the conical case are easier to analyze (than the planar case described in [2]) since each ray travels along a path of fixed dielectric constant and hence undergoes minimum number of reflections inside the lens. Moreover, the lower dielectric constants required for the conical design make it practically more suitable than the planar design. Also, the availability of semi-analytical calculations in [1] enables easier analysis of the simulation results.

The simulation setup and CST parameters are identical to the planar case as described in [2], unless mentioned otherwise.

2 Simulation results for 7-layer case

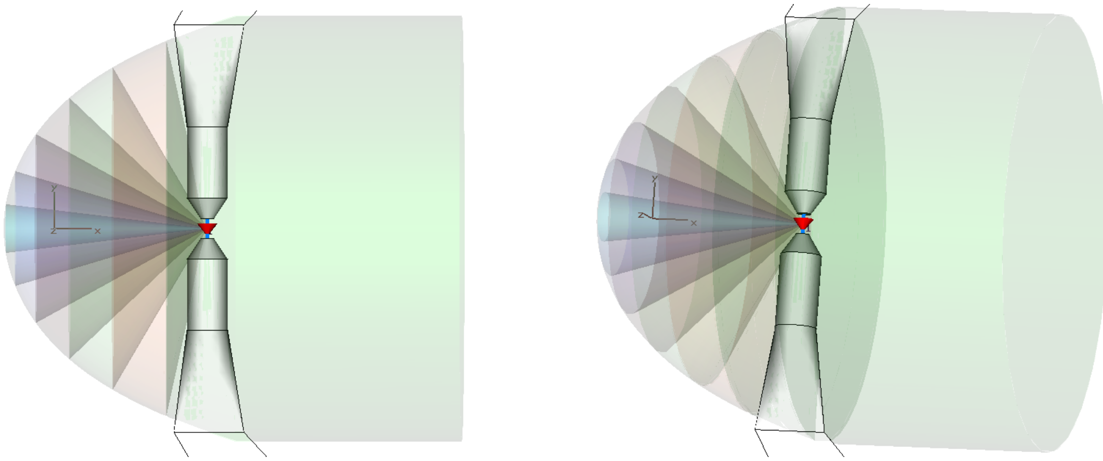
According to equations in [1], a minimum of 7-layers are needed for the conical launching lens design. The dielectric constants and angles obtained are tabulated in table 1.

Table 1: Dielectric constants and angles of for 7-layer conical launching lens design

Layer	ϵ_r	θ' (in degrees)
1	2.25	6.89
2	2.318	16.80
3	2.621	29.12
4	3.228	43.55
5	4.135	59.92
6	5.214	78.10
7	6.25	98.01

The front and perspective views of the lens are shown in Fig. 2.1. Two changes are made in this design. First, the layer closest to the switch (first layer) has been extended beyond $\theta' = 90°$ (see [3] for definition of the (r', θ') coordinate system). This layer is extended so as to include the entire switch. The extension ensures that the desired slope is maintained beyond $\theta' = 90°$. It also helps smooth discontinuities that may arise at the feed arm angle and therefore affect simulation results. The second, less important change, is that the plug has been extended to 12.5 cm. This was done to observe if changes in the plug dimensions would affect the results. Analytically, we do not expect the increase in plug length to have any affect on the results.

Simulation results for the 7-layer conical case are shown in Fig. 2.2. The 127° ray arrives later than the 105° ray. However, there is a large time spread, of the order of 150 ps, between the 0° and 105° rays (extrema). This is counter to analytical expectations as we would expect that the time difference between the rays to be much less compared to the planar case. This is because the dielectric constants are distributed so that the time difference between any two rays arriving on the measurement sphere is at most 7.5 ps. The fact that we observe such a large discrepancy leads us to suspect that there may be inherent numerical inconsistencies in CST. Note that the results of this case are quite easy to analyze, as it is easy to identify the cone through which individual rays travel before arriving at the measurement probes. It is worthwhile to note that simulations were done with the dielectric constant of the first layer increased from 6.25 to 9.0. The time difference



(a) (b)

Figure 2.1: Front and perspective views of 7-layer conical lens

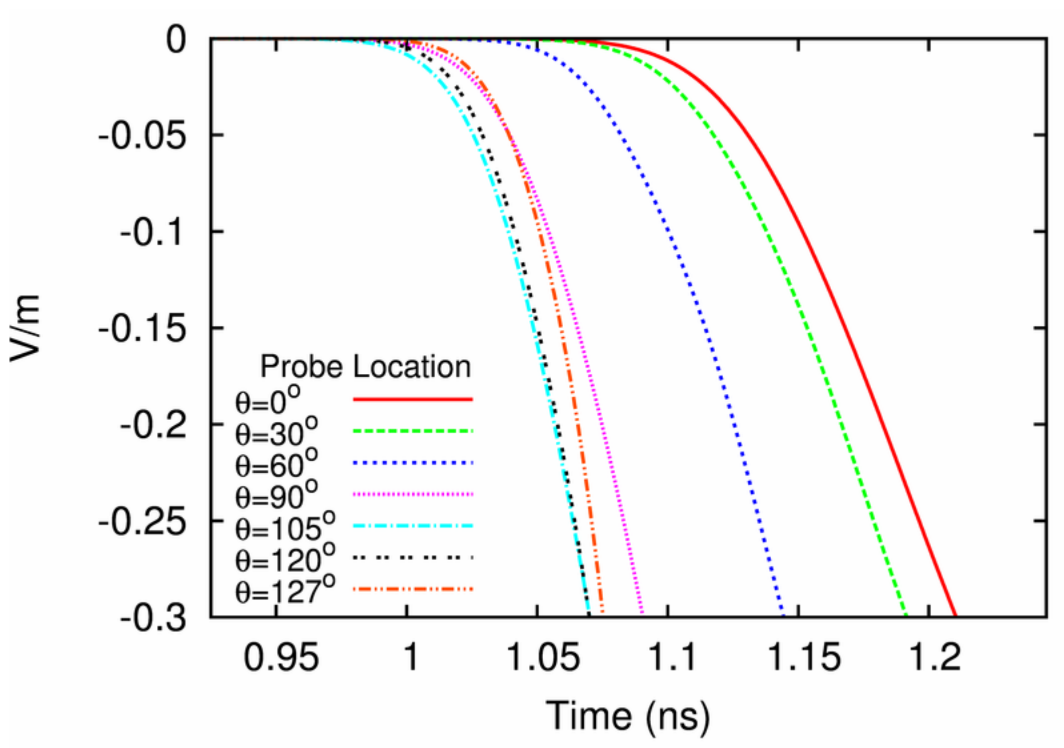


Figure 2.2: Electric field results for 7-layer conical lens design at various angles in the $x-z$ plane for probe setup.

between the 127° and 0° responses reduced considerably, from 100 ps (ϵ_r of first layer = 6.25) to approximately 30 ps (ϵ_r of first layer = 9.0). However, such changes in the results in response to changes in the dielectric are not analytically justifiable. Another way to affect the results is by changing the angle of any layer of the cone. This should enable us to selectively change the time of arrival of rays propagating through that cone. To verify this, the 6-layer conical lens design, described in the next section, was simulated.

3 Simulation results for 6-layer case

The front and perspective views of the 6-layer conical launching lens design are shown in Fig. 3.1. The 6-layer case was designed by linearly extrapolating the last point of the 6$^{\text{th}}$ layer, of the 7-layer design, to $\theta' = 90°$. This has the disadvantage that the desired slope is not maintained at $\theta' = 90°$. Note that unlike the 7-layer case, the 6-layer design was terminated at $\theta' = 90°$. Also, the height of the plug (cylinder) was changed back to 7.5 cm as it made no observable difference in the 7-layer case. The dielectric constants and angles for the 6-layer case are tabulated in table 2. Dielectric constants for the 2$^{\text{nd}}$−5$^{\text{th}}$ layers were calculated as follows : ϵ_r of layer n in table 2 = $[(\epsilon_r$ of layer n in table 1)+(ϵ_r of layer $n+1$ in table 1)]/2 where $2 \leq n \leq 5$. The angles (θ') of the layers are identical to table 1.

Table 2: Dielectric constants and angles of for 6-layer conical launching lens design

Layer	ϵ_r	θ' (in degrees)
1	2.25	6.89
2	2.47	16.80
3	2.92	29.12
4	3.68	43.55
5	4.67	59.92
6	6.25	78.10

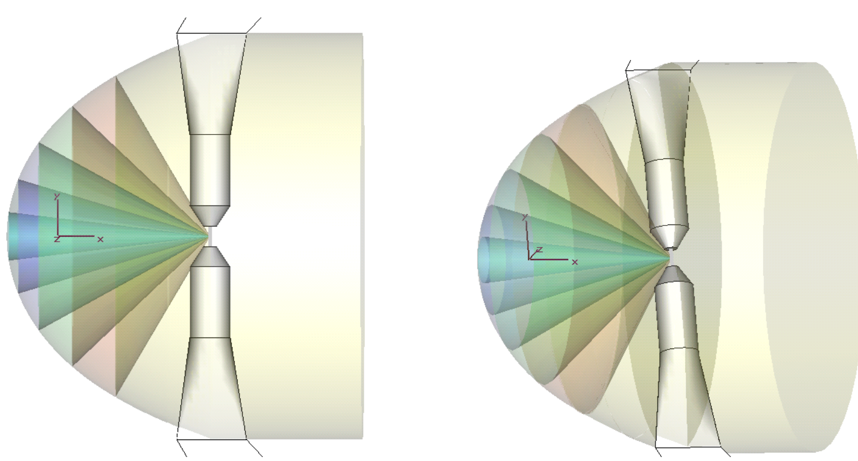

(a) (b)

Figure 3.1: Front and perspective views of 6-layer conical lens

Simulation results for the 6-layer case are shown in Fig. 3.2. Since only the last layer has been changed, it is reasonable to expect a change in response times for rays at larger angles. This seems to be the case in Fig. 3.2. However, these results are worse than the 7-layer case since the 127° arrives earliest and hence the time difference between the 0° and 127° responses is maximum (of the order of 150 ps). Clearly, extending the last layer beyond $\theta' = 90°$ changes the time difference between the 0° and 127° responses.

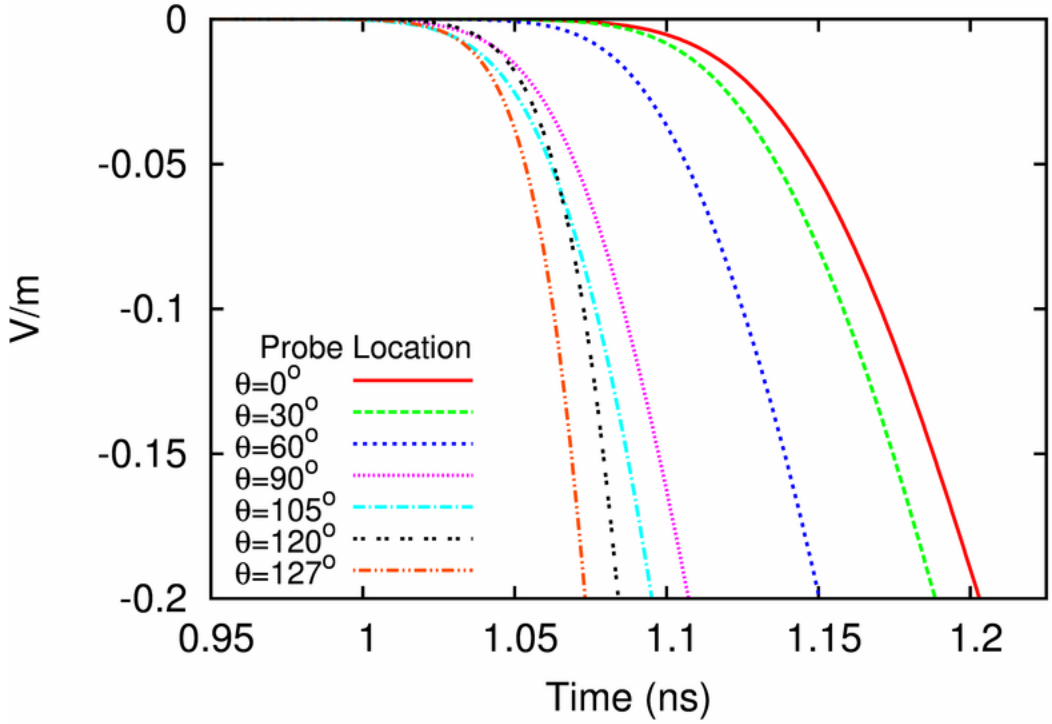


Figure 3.2: Electric field results for 6-layer conical lens design at various angles in the $x - z$ plane for probe setup.

4 Conclusions and Future Work

Results for the 6-layer and 7-layer conical designs have been presented. The 7-layer conical design seems to give better results than the 6-layer case. However, the constant spread in time of the order of 100 ps in *all* simulations (conical and planar) is a cause of concern. This leads us to suspect that the observed time spreads may be due to fundamental numerical errors in CST itself.

The next logical step would be to investigate simulations for which analytical results are exactly known. Two cases which would shed some light on the cause for observed discrepancies in our simulations are:

1. Unifrom launching lens as described in [4]

2. Feed arm and switch without lens; electrical center of switch at the origin

If any discrepancies are observed in the above cases we can be fairly certain that the errors are within CST itself. If errors are observed in the test cases above, it may very well be that the errors in the planar and conical simulation results are of the same order. If this is the case, it is likely that our simulation results are valid.

Nevertheless, we are inclined to consider the conical design described in this paper more trustworthy than the planar case due to the availability of semi-analytical results. Also, the rays within the lens undergo less number of reflections and the results are easier to analyze.

References

[1] Prashanth Kumar, Serhat Altunc, Carl E. Baum, Christos G. Christodoulou, Edl Schamiloglu, "Derivation of the dielectric constant as a function of angle for designing a conical non-uniform launching lens." EM Implosion Memo 28, June 2009.

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[4] Serhat Altunc, Carl E. Baum, Christos G. Christodoulou, Edl Schamiloglu, "Analytical Calculations of a Lens for Launching a Spherical TEM Wave." Sensor and Simulation Notes, Oct. 2008.