Calculating RF Windows with MAFIA

Daniel Pinzon

Physics Department, Cornell University, Ithaca, NY, 14853

Abstract

MAFIA is a CAD program that is used to design a waveguide or cavity and numerically calculate the physical properties of an electromagnetic field interacting with it. An RF window is a vacuum barrier that, in this case, is transparent to microwaves (500 MHz) and can be used to allow the electromagnetic waves to go through a waveguide and into an RF cavity. My project was to assert that the program was working properly, and then to calculate whether certain geometries heated the ceramic less than the current geometry so that more power could be sent through the waveguide without cracking the window. The "sidewall" geometry proved no better than the standard "frontwall" geometry.

Verification

The new version of MAFIA[1] that I worked on was designed to be more user-friendly, in that most of the processes were only a couple of mouse-clicks away. In order for the program to be used by others with confidence that MAFIA's results were accurate, tests needed to be run. I proceeded, using the new version, to design and calculate the fields for waveguides that were previously done by an earlier version of MAFIA that was in common use. After comparing the results, I found that they did agree.

Also, a feature of sending a band of frequencies through the waveguide at the same time was much easier to do in the new version. Comparison showed that although there were discrepancies between the discrete and broadband features, they were small enough for most calculations. The broadband is mostly used to locate an appropriate frequency and then physical properties are calculated using a target frequency.

Certain bugs and nuances were found in the program, however. The normal S-parameter wizard sometimes cannot find the variable it names for the in port. Also, certain parameters are not included in the GUI interface and they need to be loaded in through *.com files or through an input interface that is given. I found that defining variables through a text file and loading it was a lot easier than the interface they give.

Another important bug is that when the S-parameters are calculated for a monotone wave at the frequency that is supposed to give very low reflection and high transmittance, the program can take very long to converge and stop, regardless of the number of Ntime steps that are given. I found that the results seem to be valid despite this defect.

The new version of MAFIA makes it easier to do simple calculations and structures, but for more complicated projects, or physical properties not explicitly placed on a menu bar, com files are needed.

Tuning Posts

Tuning posts are used to change the throughput of a waveguide. My next project was to map the reflectivity of a post, using MAFIA, across a hollow rectangular waveguide with the post placed axially, half a wavelength into the guide. I used 500 MHz waves and recorded the results for 1/2” and 1” diameter posts. This information will be used to know where to locate a post to match a mis-matched geometry.

Sidewall with one elliptical window

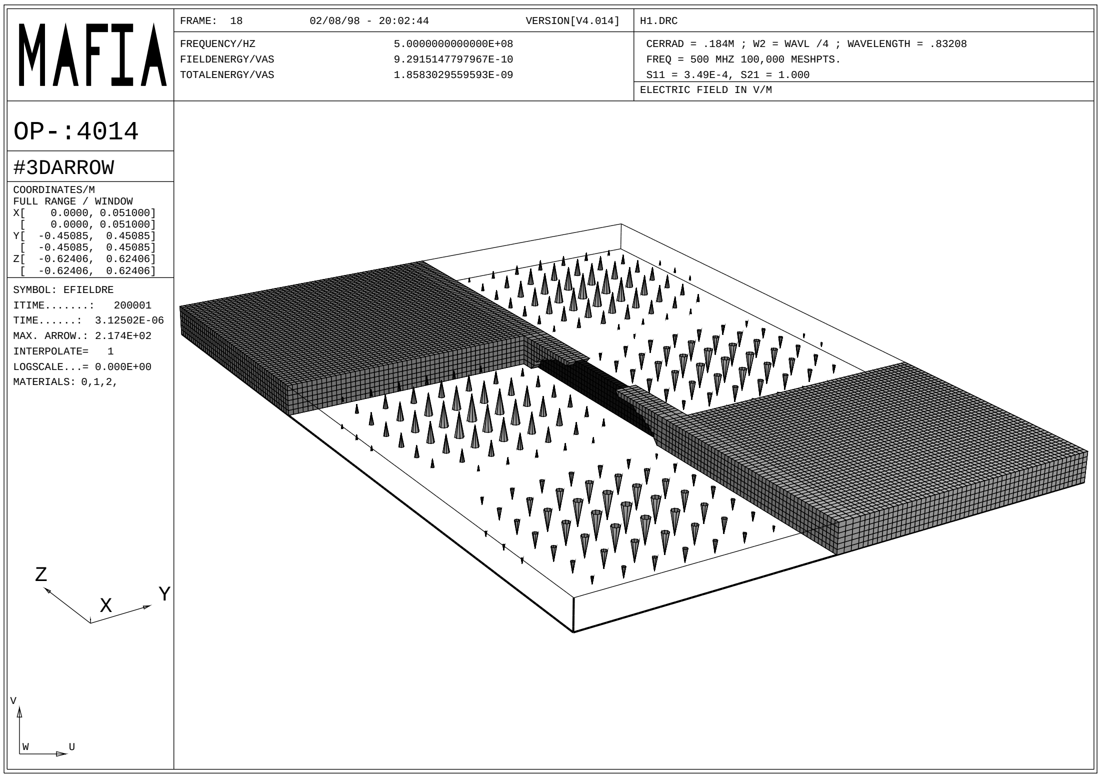

FIGURE 1. Sidewall – the figure shows the top half of the waveguide and the electric field.

The objective for using this design was to have the RF window ceramic located at an electric field minimum as opposed to at a maximum as in most of the waveguides that are under consideration. See Fig. 2, showing a quarter of one of the typical head-on geometries with the electric field. The idea of a sidewall is not new and I worked on it at the suggestion of Eric Chojnacki(see Figs. 1 and 2). This geometry consists of two waveguides coupled by their sidewalls, each of dimension 4” x-height, 17” y-width, and plus an undetermined distance to the short They are separated by 1.5” of metal to allow for the 0.5” width ceramic, as shown in Fig. 1 with its electric field at maximum throughput. We allow a half wavelength of input and output waveguide so that the wave settles before it reaches the ceramic area. The distance from the ceramic center to the short turned out to be a quarter wavelength long.

I started with two variables, the z-axis length of the ceramic and the length to the short. The point was to try to get the throughput as high as possible using 500 MHz microwaves. After some initial experimenting, I decided to keep the length to the short constant at half a wavelength(0.83208 m/2).

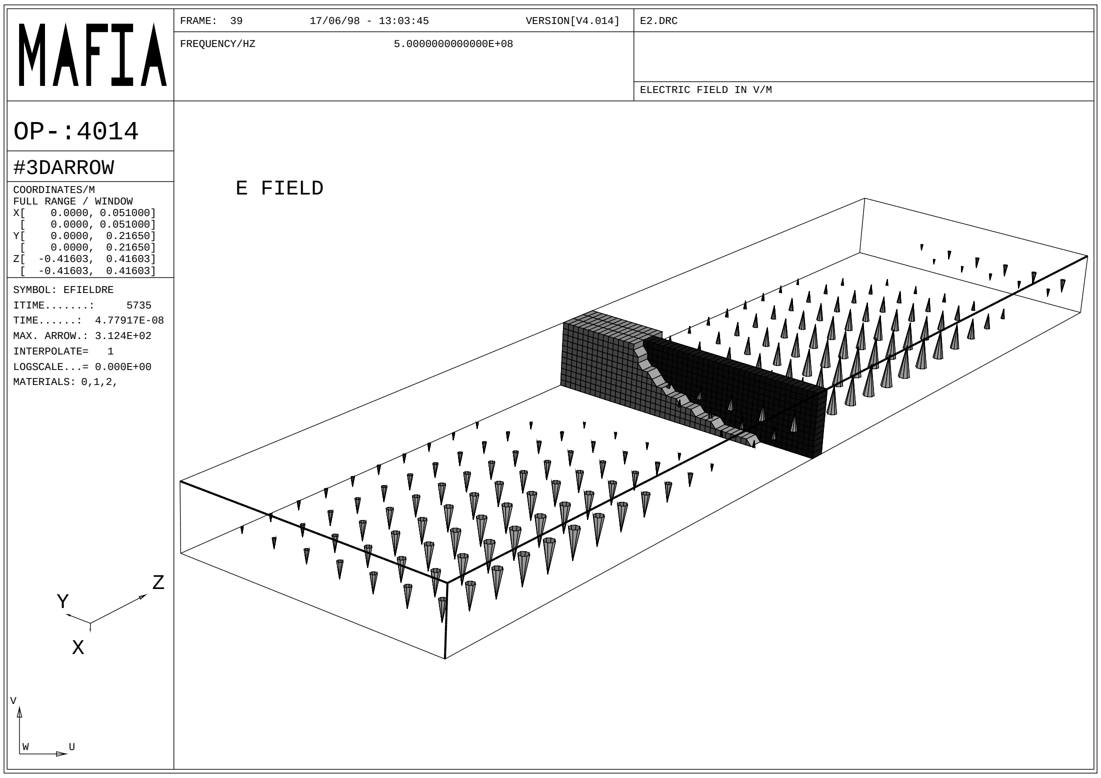

FIGURE 2. Head on – the quarter part of the previous waveguide model with electric fields.

I found a nice cusp shape to the reflection term, S11, to the broadband spectrum using 10,000 mesh points at this short length. In other words, there was a point where there was zero reflection, or at least very close. I then simply varied the width of the elliptical ceramic. I found that this only shifted the cusp left and right across the frequencies and so I could zero in on 500 MHz at the higher resolution of 100,000 meshpoints. The final width that worked well was 0.184 m (See Fig. 3).

The next step was to calculate the the power dissipated on a lossy ceramic. Using a dielectric constant 9.8, and a loss tangent of 0.0001. It was found that the total power dissipated came out the same as the head-on elliptical case, as evidenced by an arrow plot of electric field in the geometry.

Sidewall with Three Circular Holes

Since in circular windows, the peak stress points are lower than in an ellipse and because they are easier to make than elliptical ceramics, the next application of MAFIA involved using multiple circular windows on the sidewall model and find if a solution was feasible.

After experimenting with the 4” by 17” waveguide, I found that the 500 MHz wave would not easily penetrate small 2” radius circular windows. I decided to use the 9” by 18” full height standard 500 MHz waveguide. They turned out to be large enough to allow transmittance, but it required one center ceramic at the full radius of 4.5” and two equidistant to it.

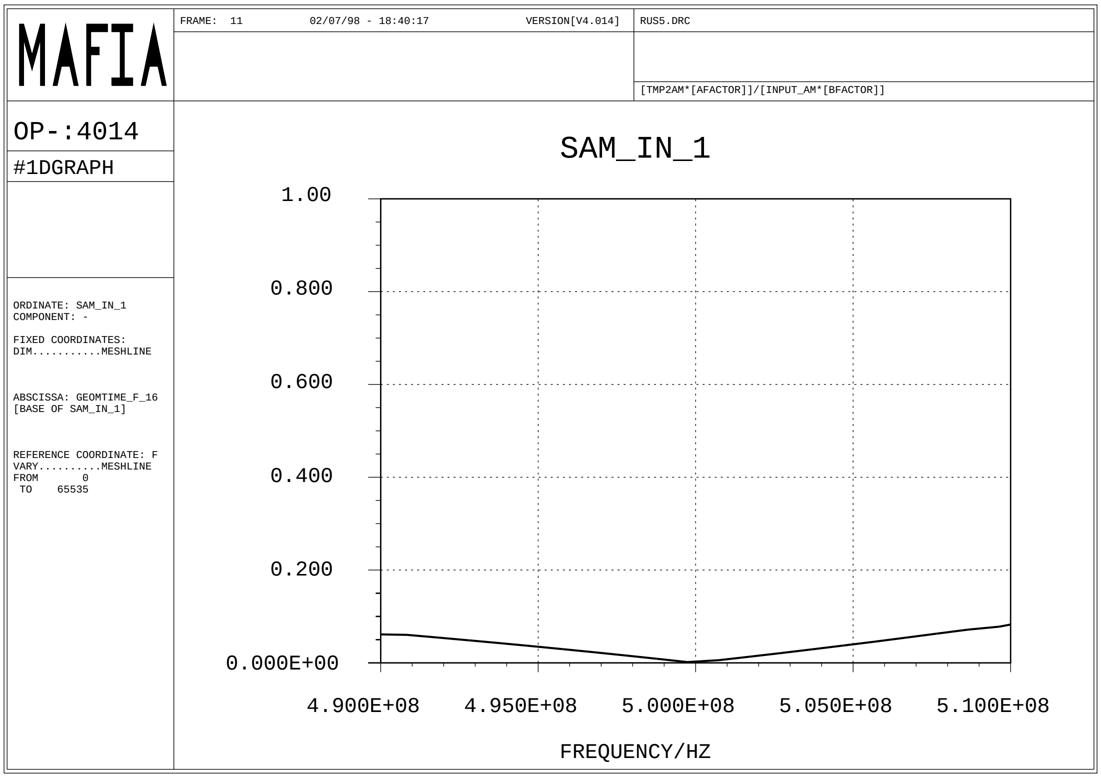

FIGURE 3. S11 reflection term using the broadband frequency option and ceramic width 0.184 m.

Again, the length to the short was varied in order to get the cusp graph for the broadband spectrum wave reflection term, S11. It was found to be best at 0.5 m. The centers of the two outer circular ceramics are 9" away from the center of the middle ceramic and their radius is about 0.11 m. This configuration created the best transmittance with low reflection. The outer ceramics coupled with the magnetic field and the center one coupled with the electric field. See Fig. 4 showing the top half of the waveguide and it's electric field.

Conclusions

The next step, working with MAFIA, is to see how well it calculates particle dynamics in the waveguide. One of the major problems in RF technology occurs when electrons from the surface of the metal are loosened from walls and crash back into the wall, sending out more electrons and creating an avalanche pattern. Understanding the path that electrons take in a waveguide as it oscillates will in the end help to prevent such occurrences.

Acknowledgments

I would like to thank Prof. Hasan Padamsee and Dr. Eric Chojnacki of Cornell University, who set up this Research Experience for Undergraduates experience and helped me through it. This work was supported by and I would like to thank, the National Science Foundation

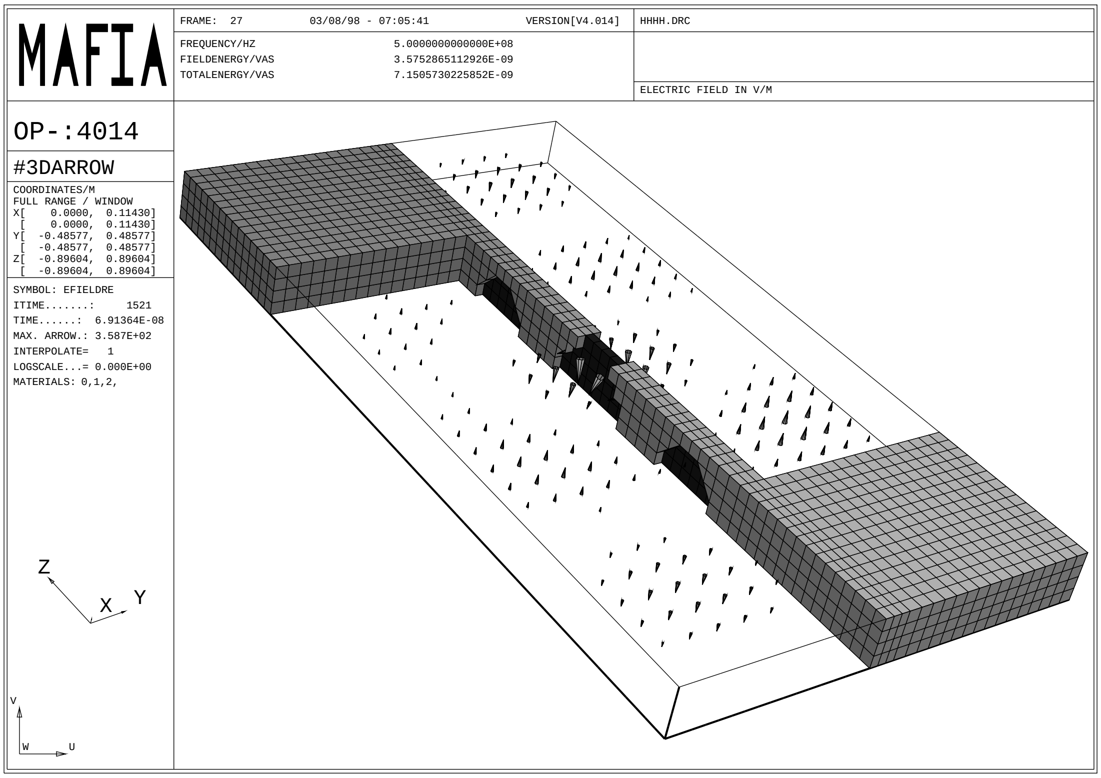

FIGURE 4. Ceramic with 3 circular holes – the top half of the waveguide with electric fields.

and their grant, PHY-9310764 and NSF REU grant PHY-9731882.

Footnotes and References

1. T. Wieland, computer code MAFIA (MAxwell Equation Finite Integration Algorithm), Computer Simulation Technology, Darmstadt, Germany, 1997, `http://www.cst.de`.