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3D effects in dielectric haloscopes and dish antennas

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The presence of axions modifies the Maxwell equations. This is exploited by many axion direct detection search experiments. Feasibility studies and optimizations of the experiment require computing the E-fields in 3D. Using finite element methods (FEM) in full 3D this is computationally very expensive and time consuming. We present two techniques to compute the 3D E-field solutions for open systems, such as dielectric haloscopes and dish antennas. Our two approaches elude the bottlenecks of a pure 3D FEM solution. The first approach reduces the problem to two dimensions by using the radial symmetry even in the case when external fields break this symmetry. The second approach is based on a scalar diffraction theory which is applied recursively to construct the emitted E-field.

The simplified 3D simulation techniques are used to perform feasibility studies of the MADMAX prototype experiment. The power emitted by the dielectric haloscope is studied and compared to 1D calculations. We find that diffraction effects can reduce the emitted power, especially for a large photon wavelength / small axion mass. The beam shape in 3D is found to be in good approximation Gaussian allowing a good coupling to a Gaussian antenna. From the beam shapes and a comparison of the two methods we see that near field effects are not dominant in dielectric haloscopes. We also study the influence of tilts and B-field inhomogeneities.
Finally we also look at velocity effects in dish antennas and dielectric haloscopes.
In conclusion we have not found any potential show stoppers for the realisation of dielectric haloscopes in the studied cases.

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