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Finite Element Model of a Magnet Driven Reed Switch

Bryan M. LaBarge[1] and Dr. Ernesto Gutierrez-Miravete[2]

[1]Gems Sensors and Controls, [2]Rensselaer at Hartford

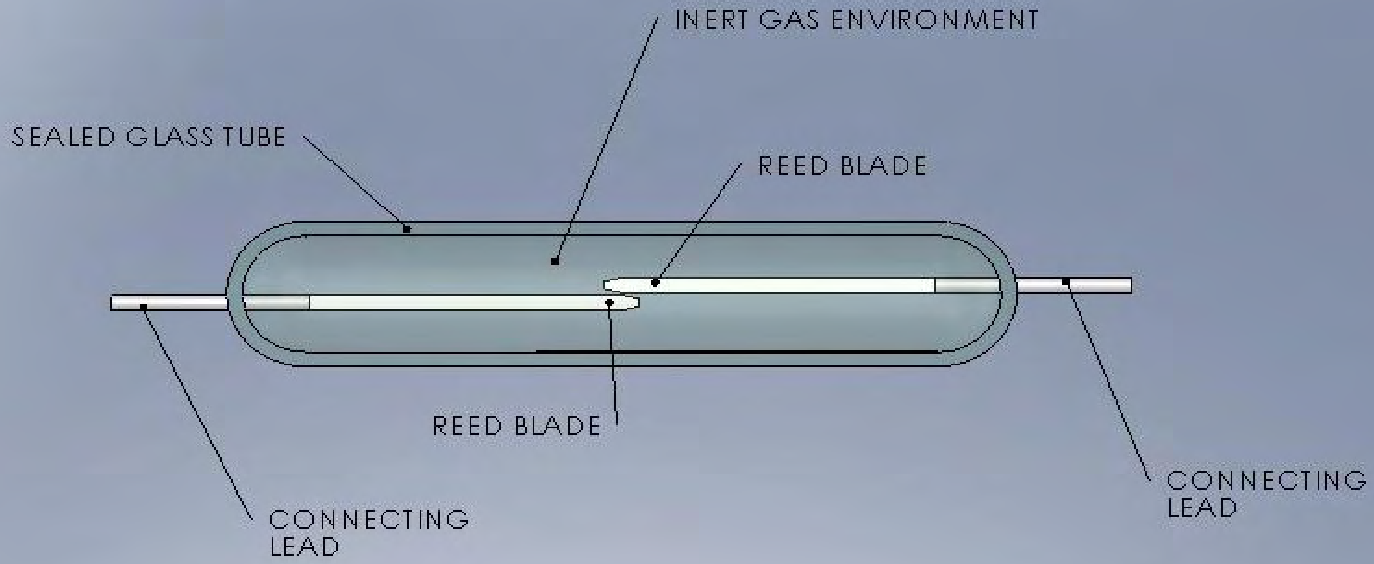
Scope

- Use COMSOL to predict and visualize a magnetic field
- Use further processing to determine field strength
- Correlate field strength to reed switch operation

Background

- Magnet/reed switch systems are used extensively for proximity sensing
- Ability to predict reed switch operation reduces testing time, time to market
- Knowing magnet strength at any point allows designer to focus on reed switch selection

What is a reed switch?



Governing Equations

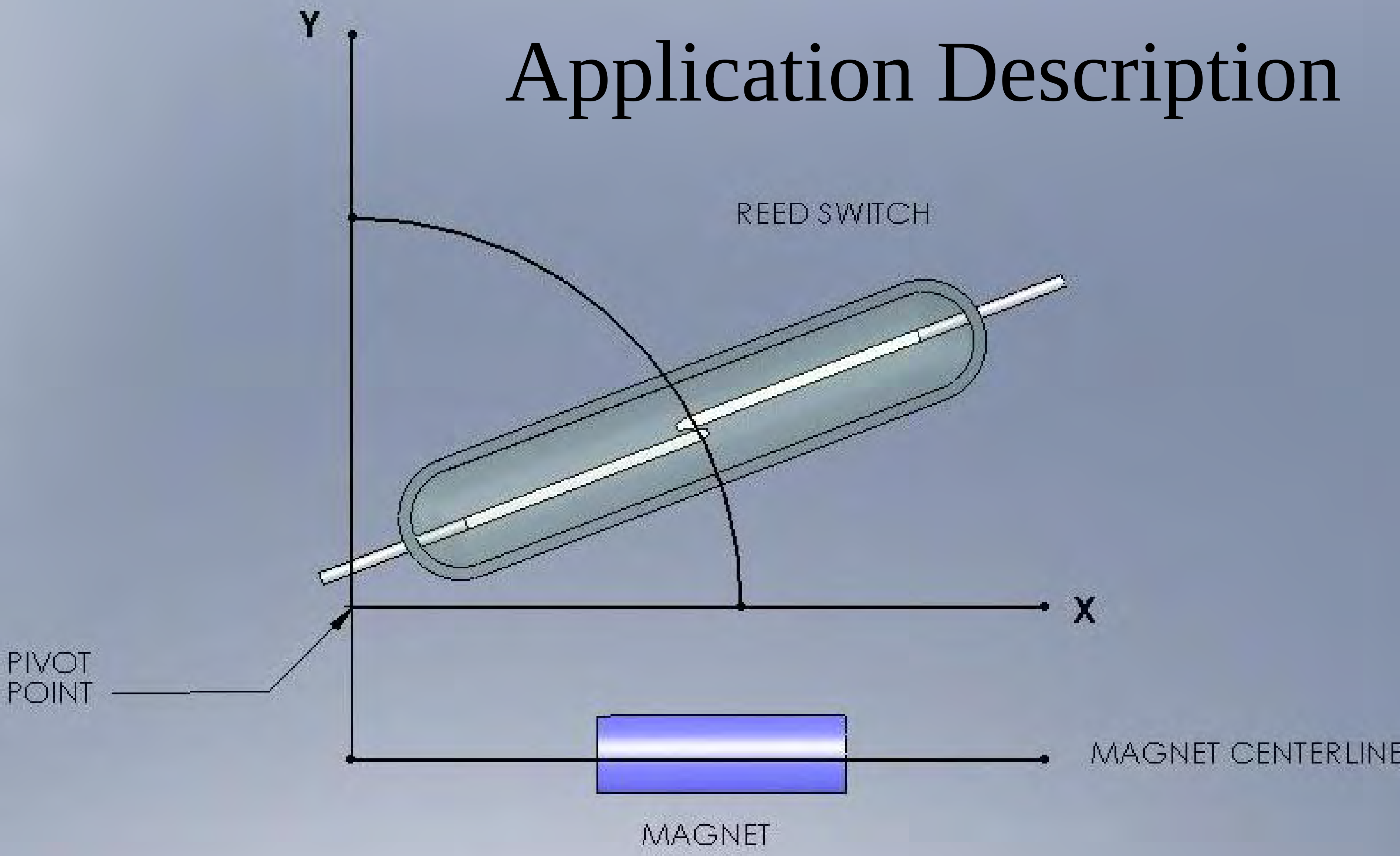
- Maxwell's Equations

$$\nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = 0$$

$$\nabla \times \mathbf{H} - \frac{\partial \mathbf{D}}{\partial t} = \mathbf{J}$$

- Magnetization Equation $\mathbf{B} = \mu(\mathbf{H}+\mathbf{M})$

Application Description



Model Creation

- 2-D (*r*-*z* coordinate) magneto-static analysis
- Magnet centerline bounds model
- Magnet modeled as iron, bounded by air
  - **M** = 1.6×10^5 A/m
  - Relative permeability (μ) = 4000
- Elements: 15,472 (triangular, 7859 nodes)
- Static, stationary solver
- Output = Gauss (*r*-, *z*-, normal direction)

Model Validation

- Magnet mounted to XY table, Gauss probe stationary, 3.9 mm parallel to magnet centerline
- Measurements taken every 0.3 mm
- Results plotted vs. COMSOL output

Procedure (in brief)

- Export COMSOL data to EXCEL
- Use EXCEL data as look-up table
- Calculate coordinates of switch movement along an arc
- Calculate magnetic field at coordinates using look-up table
- Determine switch operation

Procedure (continued…)

- COMSOL data exported to EXCEL
  - 0.3 mm resolution in (x,y) coordinates
- Magnet/Switch location measured relative to pivot point (origin)
- Open/closed positions of switch measured for later reference

Procedure (continued…)

- x_{max} defines arc radius
- Coordinates calculated on 0.02 mm resolution in x-direction
- Coordinates are interpolated from the look-up table to assign Gauss values to points on the arc
- Arc coordinates/Gauss values become second look-up table

Results

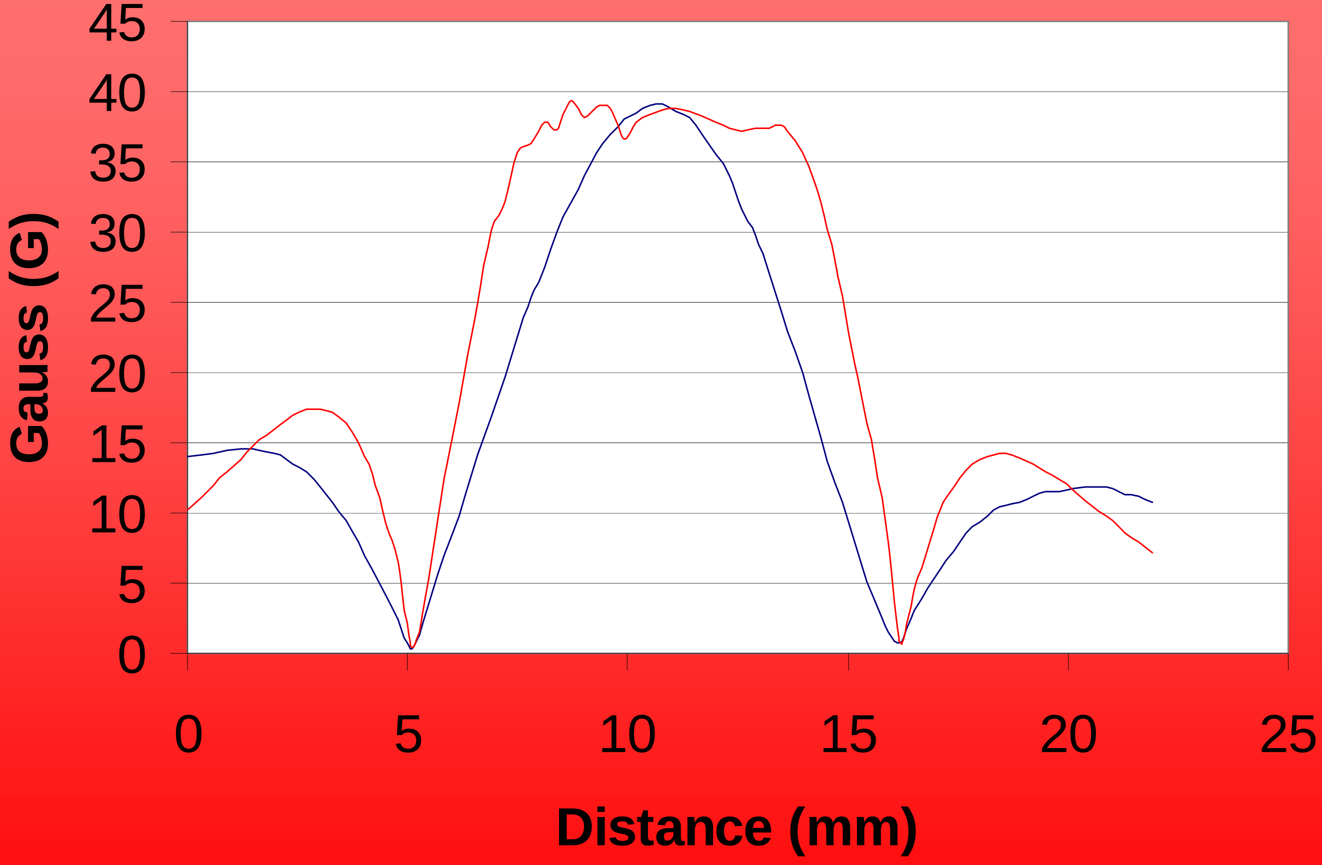
- Reed switches are tested using a test coil, measuring operation in terms of Ampere-Turns (AT)
- AT = I *n*
- I = current; *n* = number of coil turns
- Test switch open/closed values:
  - Open = 29.1 AT
  - Closed = 18.7 AT

Results (continued…)

- Prior empirical testing shows Gauss/AT correlation
- $G = 0.533AT - 0.857$
- Open = 14.7 G
- Closed = 9.12 G

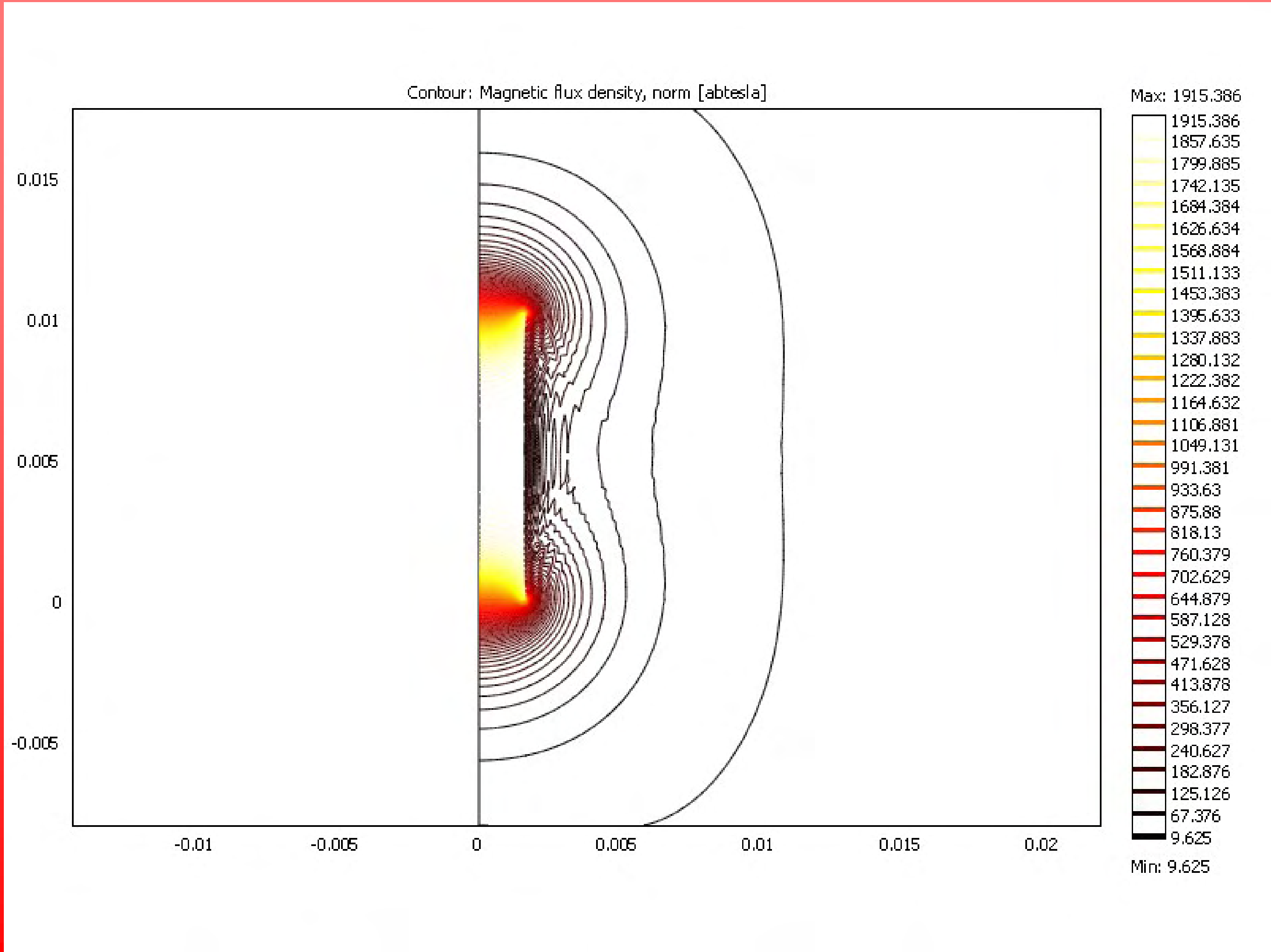
Results (continued…)

- Model Verification
  - Red = COMSOL, Blue = Empirical



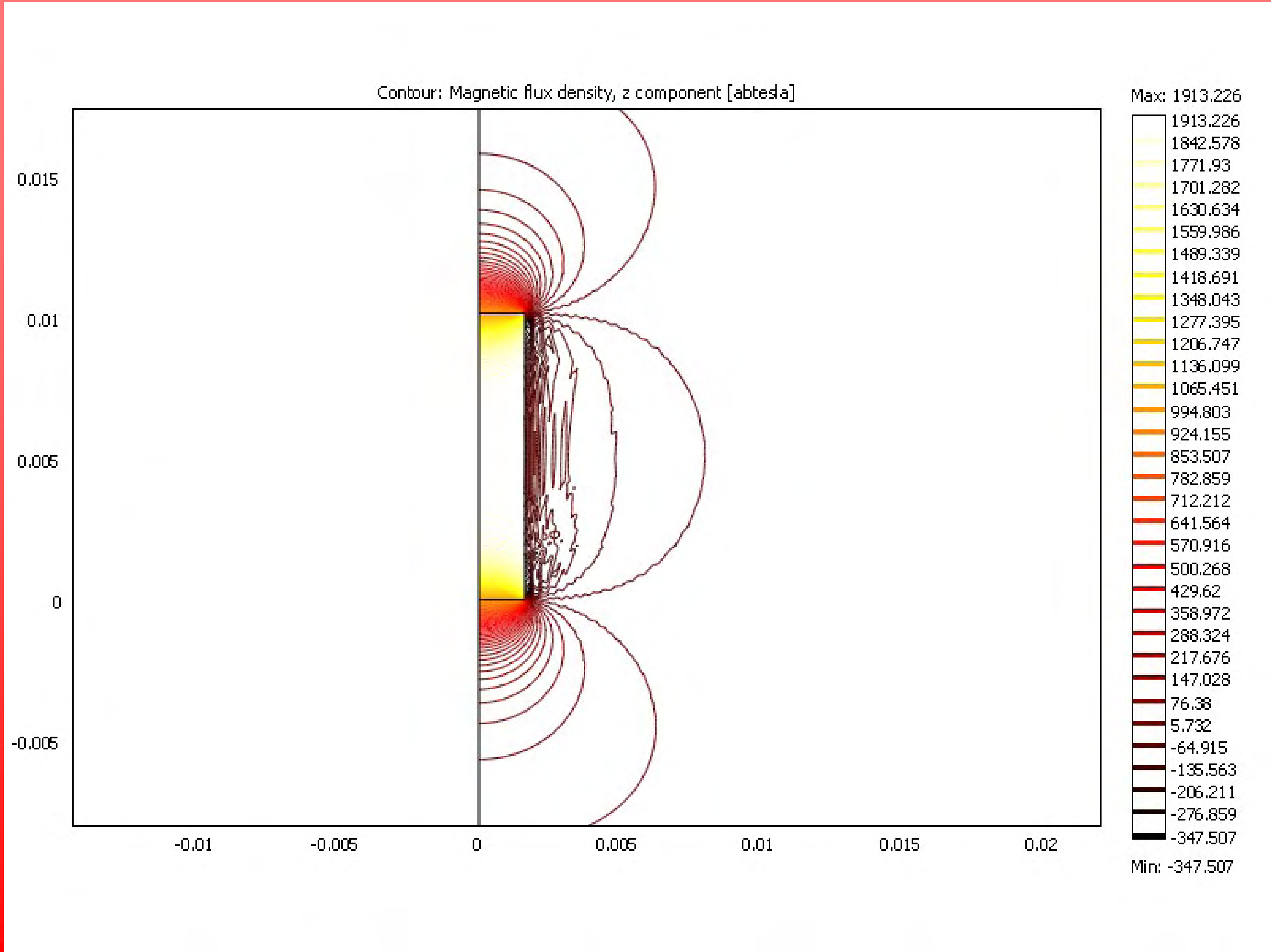
Results (continued…)

- COMSOL contour plot, normal direction



Results (continued…)

- COMSOL contour plot, *z*- direction



Results (continued…)

- Using the values of Gauss on switch arc and the Gauss values for switch operation, switch location can be interpolated.
- Example: 29 AT = 14.57 G = (15.47, 8.72) mm

Results (continued…)

- Actual switch points compared to calculated switch points

	x, closed	*y*, closed	*x*, open	*y*, open
Model	15.47	8.72	14.98	10.96
Observed	15.34	8.97	14.83	10.82
Error	0.84%	-2.87%	1.00%	1.27%

Conclusions

- COMSOL model agrees with empirical results to within 2%
- Increased error in *y* than *x* due to geometry

Conclusions

- Application requires 20^o maximum angle, switch should operate at 10^o
- Model says switch will open at 18.3^o and close at 9.9^o
- Decrease in AT on switch will close switch over full arc.

Conclusions

- Model is a simplification of actual system
- Further work can be done to model effects of reed blades
- Speaker’s first COMSOL model