University of BRISTOL

LTCC or LCP

A COMPARISON USING CAVITY BACKED SLOT ANTENNAS with PIN CURTAINS at 60 GHz

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University of Bristol in conjunction with Toshiba TRL

Outline

- Introduction
- Antenna Model
  - CBS antenna on LTCC
  - CBS antenna on LCP
  - Pin Curtains
- Simulations and Results
  - Return Loss and Radiation Pattern
  - Efficiency Calculations
- Conclusions

Introduction

- The 60 GHz band → 7 GHz unlicensed bandwidth
- Many materials used at microwave frequencies have unacceptably higher losses (more to consider, eg. substrate water absorption)
- Low temperature co-fired ceramic (LTCC) and liquid crystal polymer (LCP) → most popular !
- They both offer good electrical performance however LCP has lower cost

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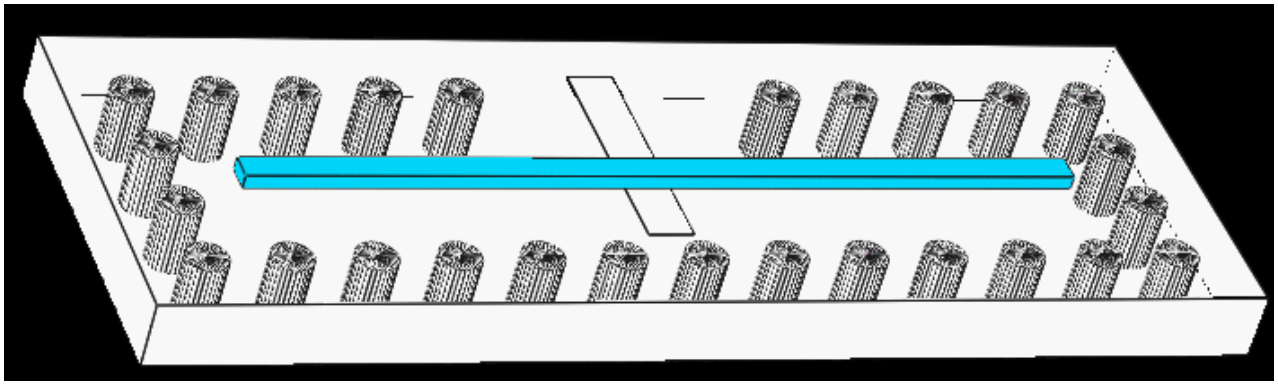
Antenna Model

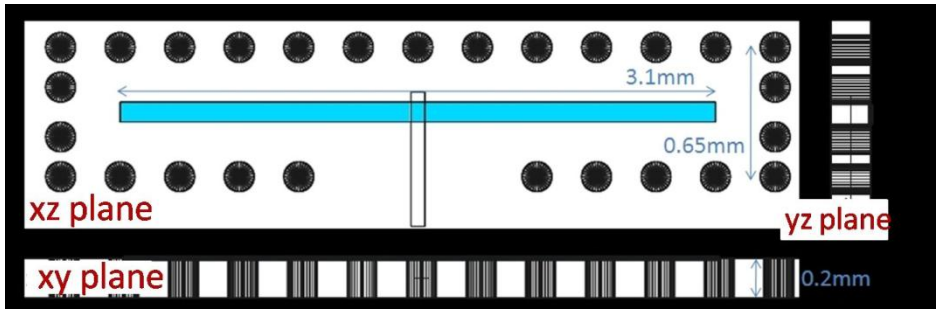


CBS

- 2 layers are needed for the strip.
- t < λg/4 (=538μm) to suppress TE and TM modes on the strip.
- Lowest slot resonance by slot length.
- Cavity mode with the lowest resonant frequency is TE_{101}.

$$f_{nml} = \frac{c}{\sqrt{\epsilon_r}}\sqrt{(\frac{l}{2d})^2 + (\frac{n}{2a})^2 + (\frac{m}{2b})^2}$$

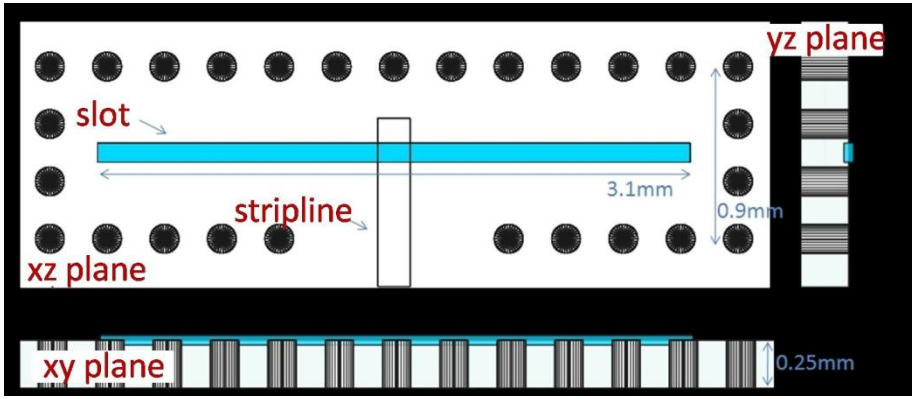
Antenna Model



CBS antenna on LTCC

- ε_r = 5.4 and tanδ = 0.0015
- Thickness (t) of LTCC layers ranges: 80 - 125 μm
- Cavity mode with the lowest resonant frequency is TE_{101} at approx. 109 GHz

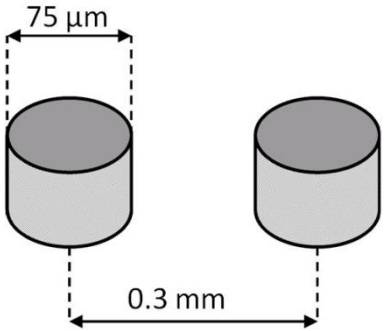
Antenna Model



CBS antenna on LCP

- The electrical properties of ULTRALAM 3850
- $\varepsilon_r = 2.9$ and $\tan\delta = 0.0049$
- Substrate thickness is chosen as 250 μm.
- Cavity mode occurs at 100 GHz

Antenna Model



Shorting Pins

- Manufacturing repeatability
- Integration with other SIW structures

- The dimensions of the pins -> not critical in terms of antenna performance but watch the leakage!

- Design restrictions due to the manufacturing capabilities.

- Via diameter, via pitch, line or slot width (since the sizes get smaller at 60 GHz.)

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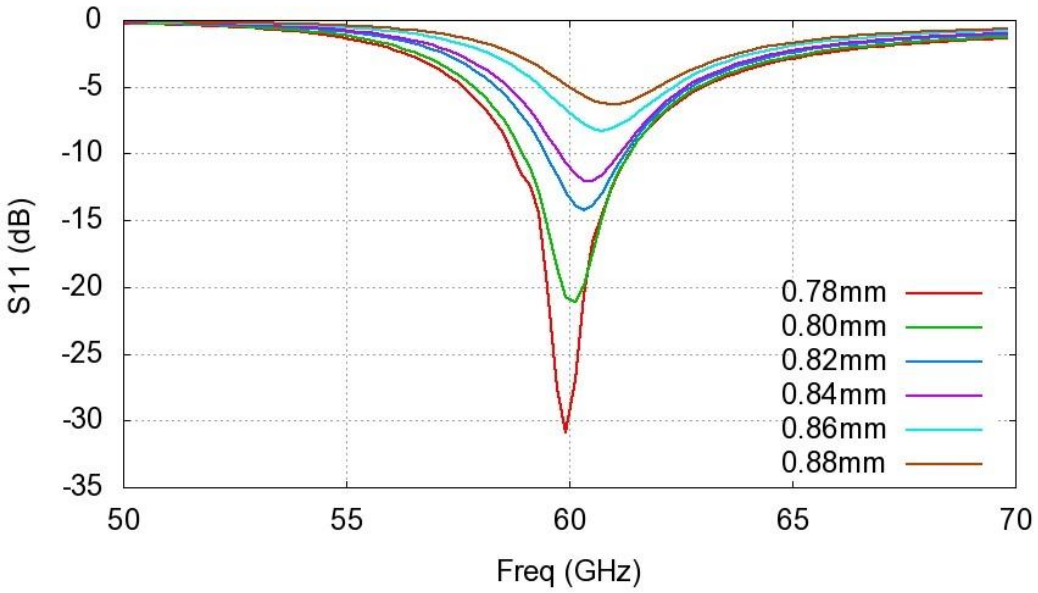
Simulations and Results

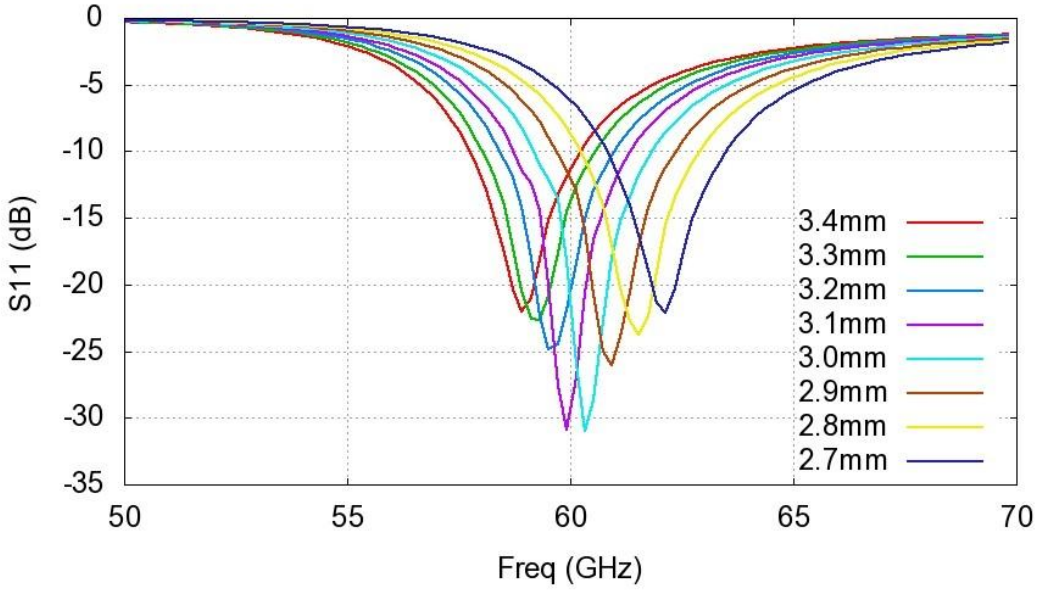


Tuning of CBS antenna on LCP, feed line lengths from 0.78 to 0.88 mm

- The feed line length -> optimized for best return loss (for each antenna).

- The tuning of S_{11} is shown in the figure.

Simulations and Results

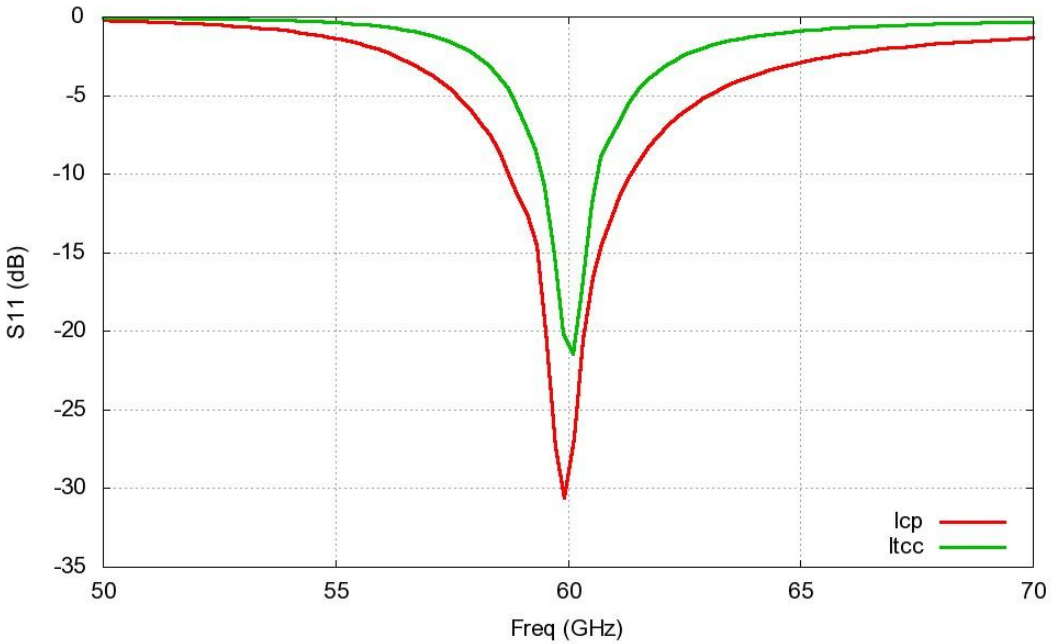


Tuning of CBS antenna on LCP, slot length from 3.4 to 2.7 mm

- The slot lengths are optimized -> 60 GHz.

- Figure shows the response of the LCP antenna to different slot lengths.

Simulations and Results

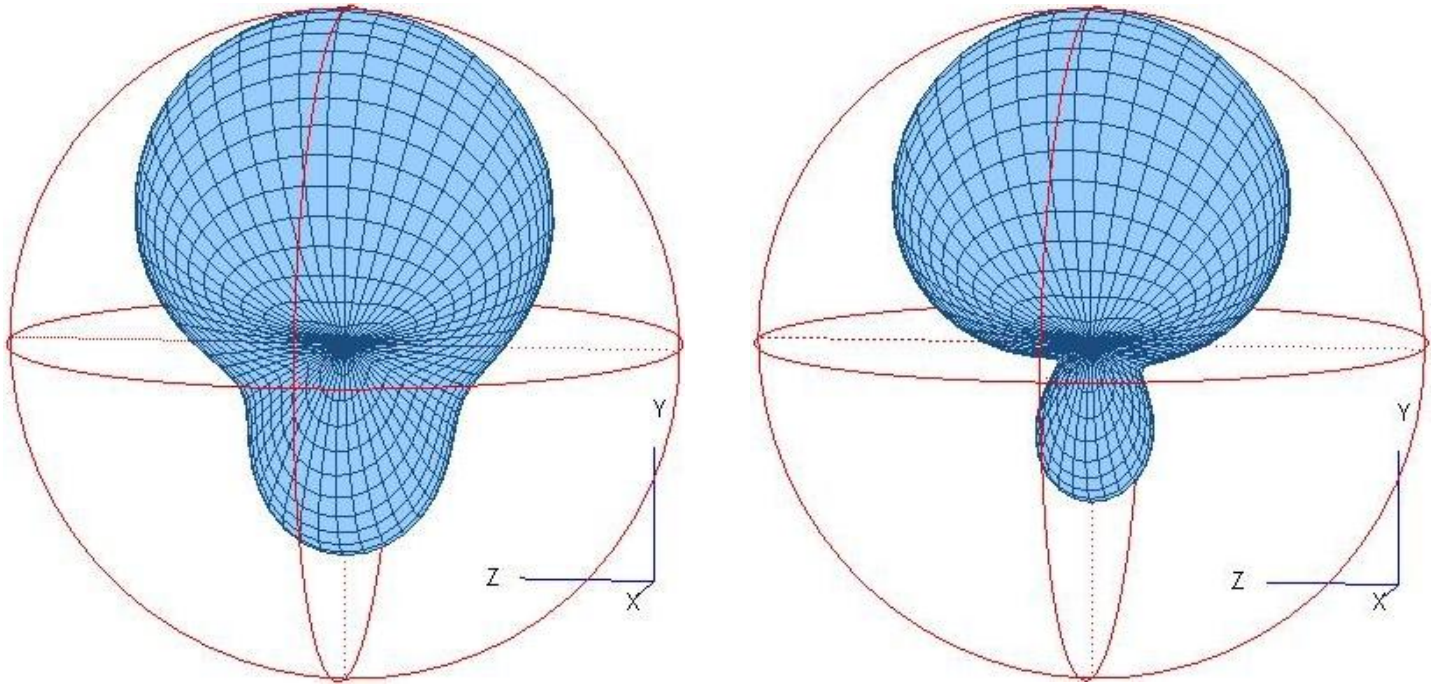


Frequency response of the CBS antennas

- 22 dB for LTCC and 31 dB for LCP at 60 GHz.

- CBS on LCP has a larger bandwidth -> the thickness of the substrate.

Simulations and Results



3D Radiation Patterns of the CBS antennas : LTCC, and LCP

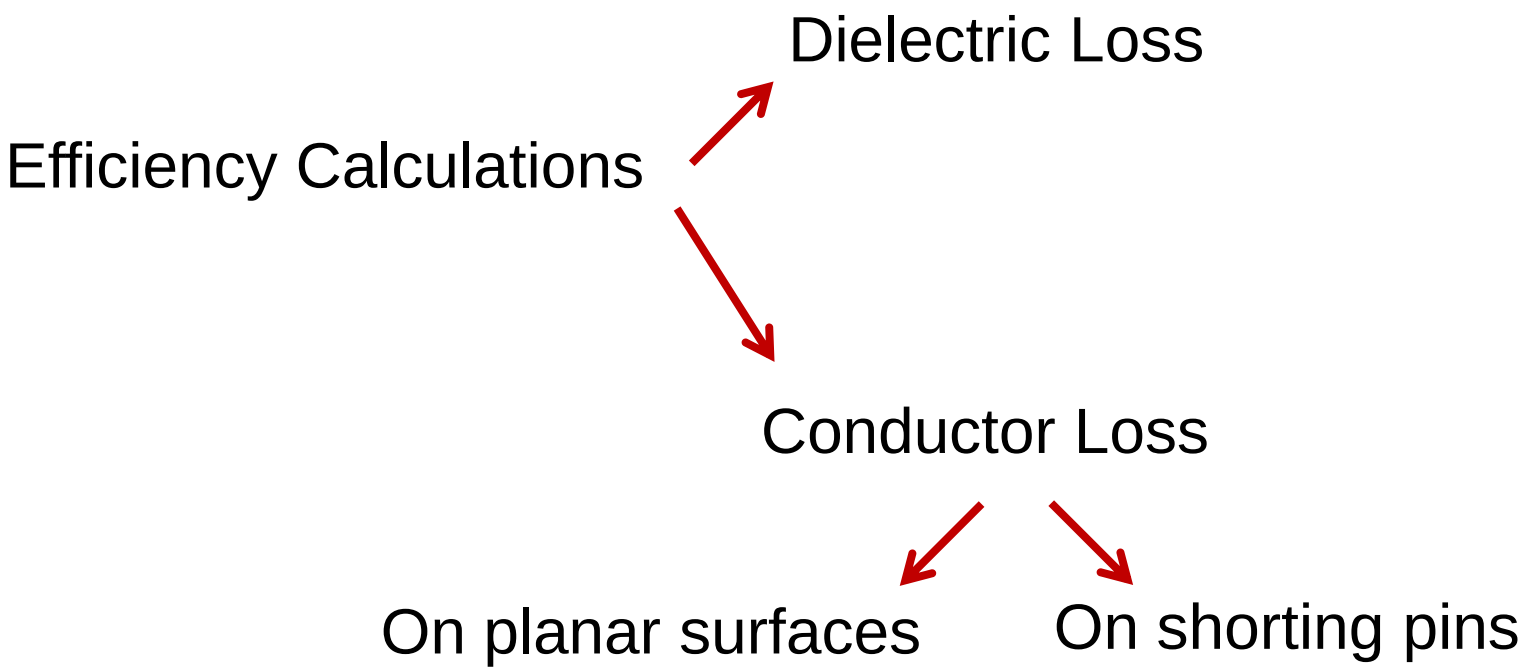
Simulations and Results

RADIATION CHARACTERISTICS OF THE CBS ANTENNAS

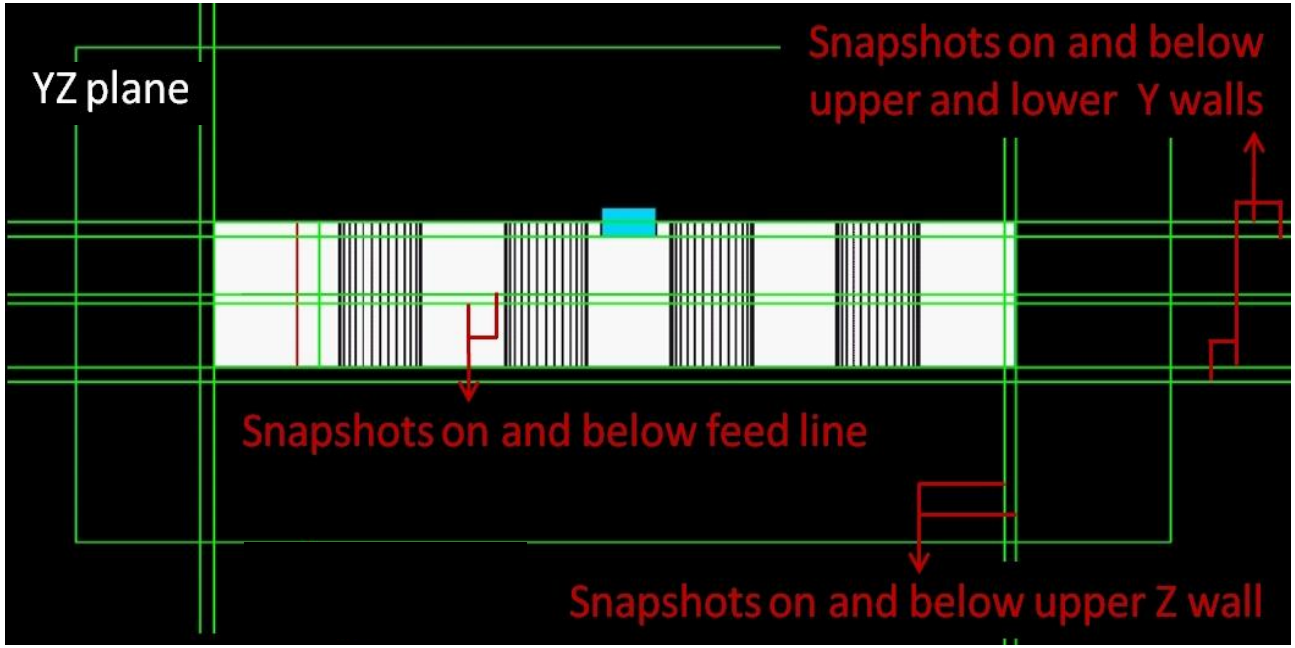
	CBS on LTCC	CBS on LCP
Directivity	5.7dB	6.4dB
Cross Pol Level	17%	14%

- LTCC has more back radiation.
- Main lobes are directed at an angle of $\theta = 90$; $\varphi = 90$ for both.
- Directivity and polarisation purity : LCP has a better performance

Simulations and Results



Simulations and Results



$$\overline{J_s} = \hat{n} \times \overline{H} = \overline{H_t}$$

&

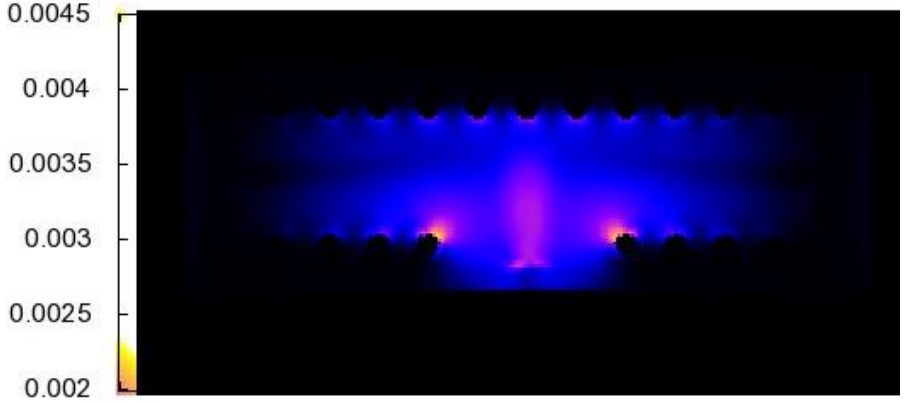
$$R_s = \sqrt{\frac{w.\mu}{2.\sigma}}$$

$$|\overline{J_s}|^2 \times R_s \times unitarea$$

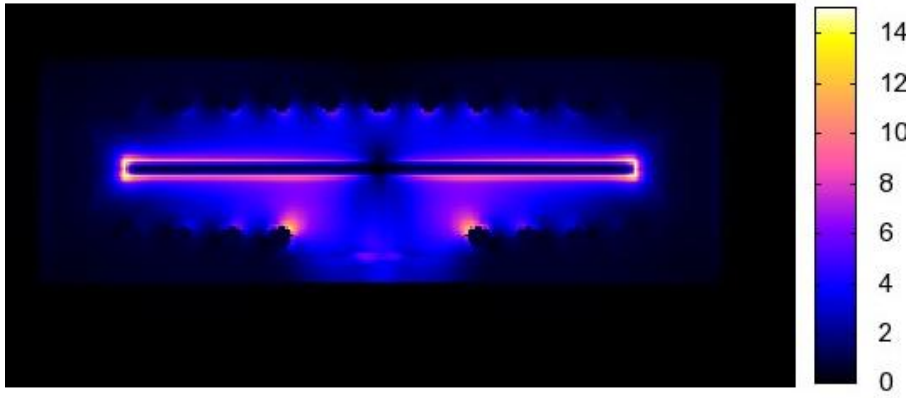
Conductivity of copper is taken as 5.813×10^7 Sm^{-1}, and the surface resistivity is calculated to be 0.064 at 60 GHz

Simulations and Results

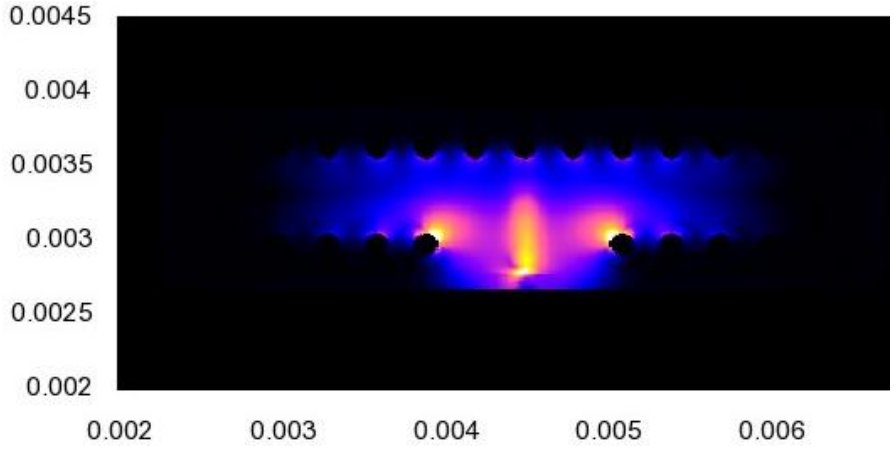
LCP YL



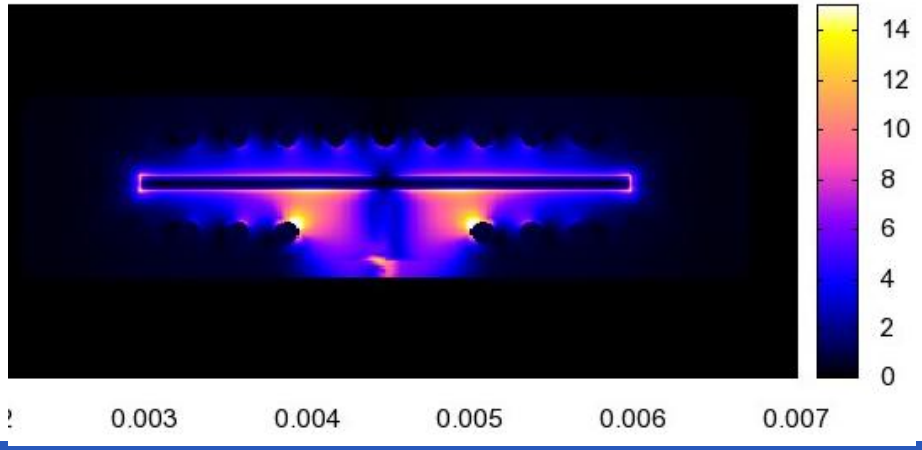
LCP YU



LTCC YL



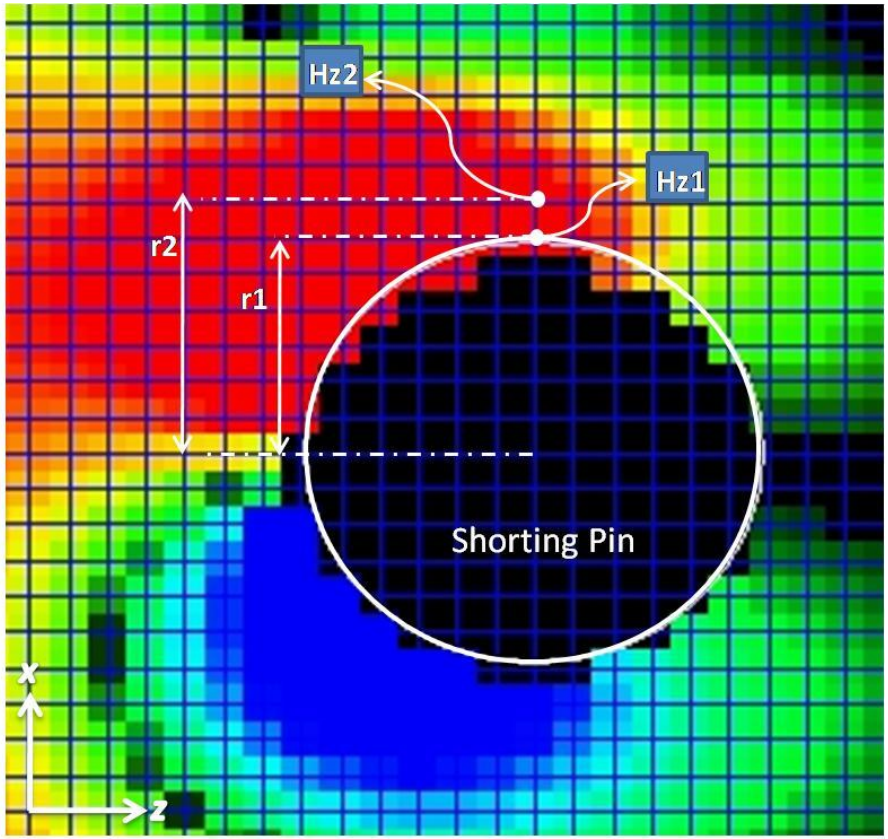
LTCC YU



Simulations and Results

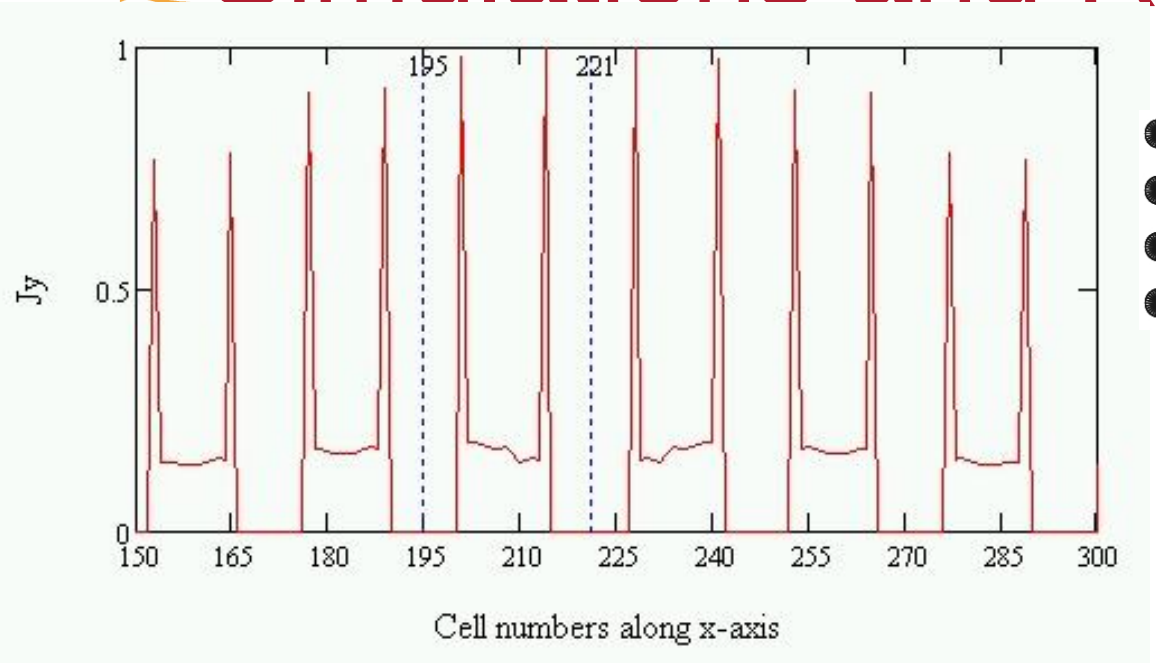
$$J_y = |\overline{H_{z1}} - \overline{H_{z2}}|$$

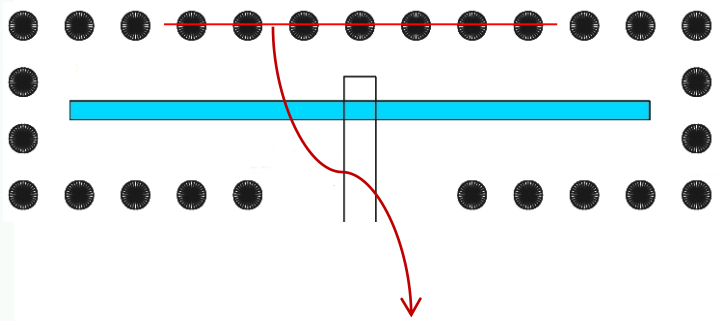
$$(2\pi.r_2.J_y)^2 \times R_s \frac{L}{\pi(2.r_1 - \delta_s)}$$



- H_{z2} and H_{z1} are subtracted from each other to find J_y.
- Flow from the outer surface of the pins with a skin depth of 2.695×10^{-7}m.

Simulations and Results





Current along the red line, CBS antenna on LCP

- The pins located at cell numbers x = 123, 147, 171, 195, 221, 247, 271, 295, 319
- The current goes down to zero towards the centre of the pin

Simulations and Results

CONDUCTOR LOSSES NORMALIZED TO THE POWER RADIATED IN LOSSLESS CASE

	CBS on LTCC	CBS on LCP
Feed Line	0.032	0.008
X Wall	0.072	0.016
Y Wall	0.066	0.020
Z Wall	0.040	0.014
Pin Curtains	0.009	0.002

$$\eta_m = 1 - \Gamma^2$$

$$Efficiency = \eta_m . \eta_\Omega$$

- The final efficiency values = 65% for LTCC
  84% for LCP.
- η_m = mismatch efficiency & η_Ω = conductor and dielectric losses.
- Mismatch efficiencies = 0.92 for LTCC
  0.94 for LCP

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Conclusions

- Two 60 GHz slot antennas are designed which are backed by cavities on LCP and LTCC.
- The performance of the antennas are compared to demonstrate the effect of the dielectric material by keeping the other factors as constant as possible.
- It is shown that LCP offers better performance in terms of efficiency and radiation purity as well as having lower cost.

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