

NUMERICAL INVESTIGATION OF 1 kW MICROWAVE HEATING APPLICATOR FOR ENHANCED POWER ABSORPTION IN ASPHALT PAVEMENTS

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1. INTRODUCTION

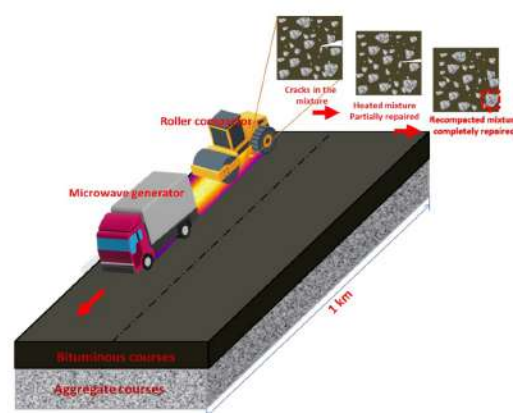
Bituminous Pavements

- Suffer with fatigue cracking, rutting and moisture damage
- Require periodic maintenance to retain and/or enhance the functional life



Cores from NH 60, India taken in 2018 (3-4 years after construction) showing fatigue cracking, moisture damage and rutting

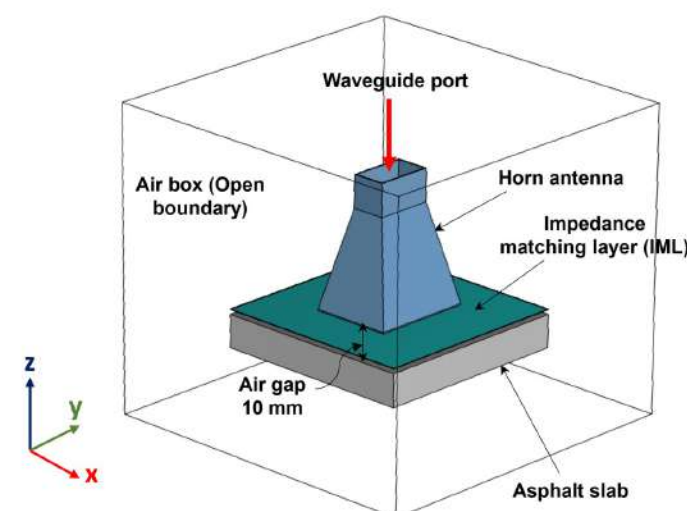
Microwave heating for accelerated healing



- Heating enables the flow and crack healing
- Non-invasive and site-operable technique!

Efficient electromagnetic power coupling into lossy asphalt media remains a key challenge for high-power microwave heating systems.

3. WAVEGUIDE-FED MICROWAVE APPLICATOR



Material properties

Component	Material	Relative Permittivity (ϵ_r)	Loss Tangent ($\tan \delta$)
Horn Antenna	PEC	-	-
Impedance Matching Layer (IML)	Dielectric (ϵ_r varied)	$\epsilon_r = 1 - 5$	$\tan \delta_{IML} (0.01 - 0.05)$
Asphalt Pavement	Lossy dielectric	5.41	0.34

Simulation setup

Source: Equivalent waveguide-port excitation representing a 2.45 GHz, 1 kW magnetron

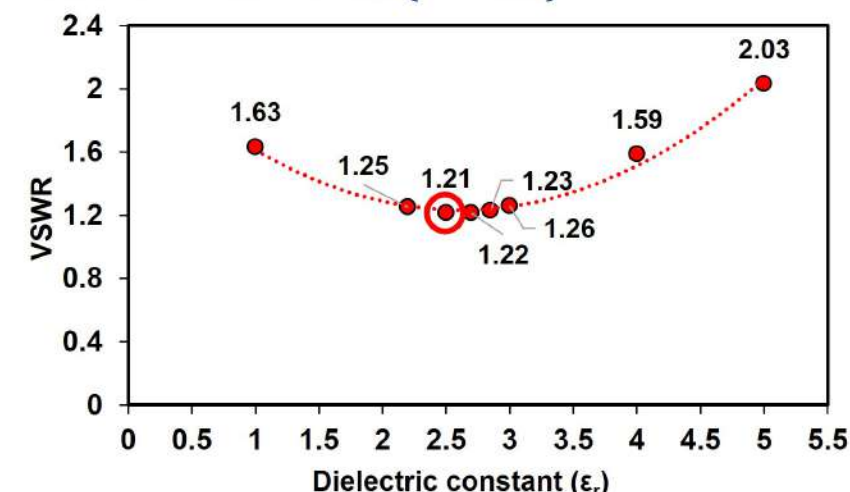
Solver: 3D Full-wave Frequency-domain Solver

Boundary: Radiation

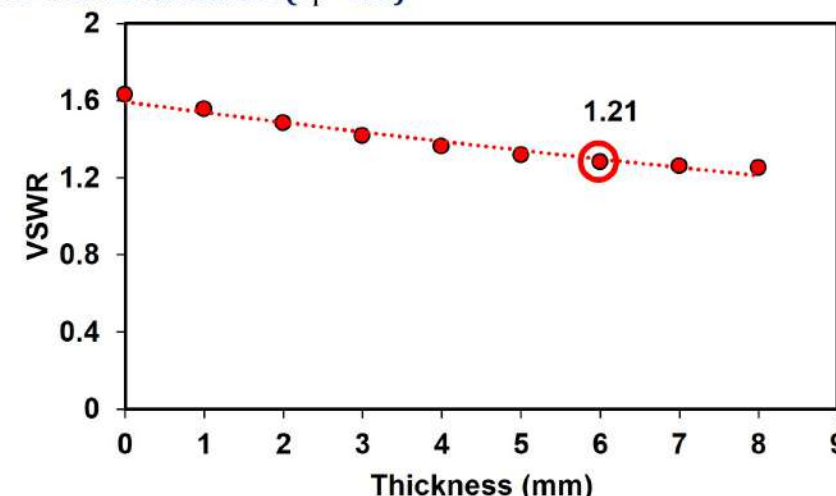
Parametric study: ϵ_r and t_{IML} of IML

4. RESULTS

Effect of IML dielectric constant ($t = 6$ mm)



Effect of IML thickness ($\epsilon_r = 2.5$)



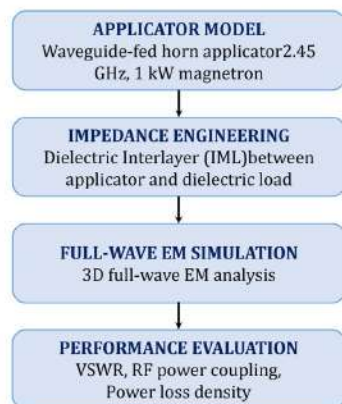
OPTIMUM IMPEDANCE MATCHING CONFIGURATION

Dielectric constant (ϵ_r) = 2.5 | Thickness (t_{IML}) = 6 mm

VSWR_{with IML} $\approx$ 1.21 $\rightarrow$ VSWR_{without IML} $\approx$ 1.63

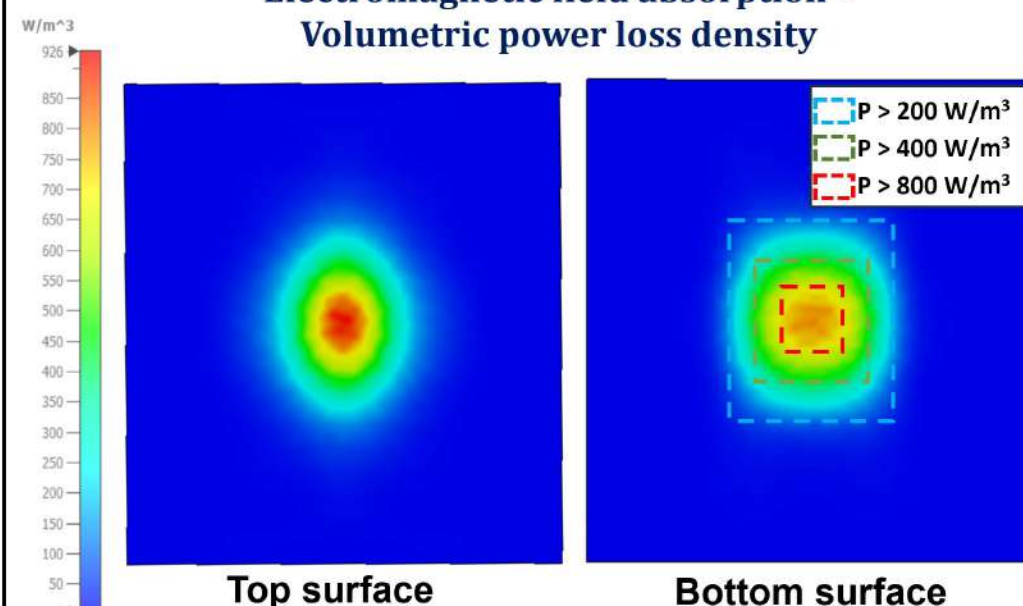
2. OBJECTIVES & METHODOLOGY

Objective: To enhance RF power coupling through impedance-engineered dielectric interlayers.



Novelty: Impedance matching of a magnetron-driven microwave applicator for enhanced RF energy transfer into lossy asphalt media.

Electromagnetic field absorption - Volumetric power loss density



Threshold based power absorption area

Power loss density threshold	Base case (No IML)	IML (Optimized)	Improvement (IML over base)
$P > 800 \text{ W/m}^3$	568	1161	+104.4%
$P > 400 \text{ W/m}^3$	13,551	15,346	+13.2%
$P > 200 \text{ W/m}^3$	38,218	41,263	+8.0%

COLOR SCALE (Area Magnitude) LOW $\rightarrow$ HIGH

The optimized impedance matching layer significantly increases the distributed power absorption region, indicating stronger localized field concentration and improved microwave coupling into the asphalt medium

5. KEY FINDINGS

- The proposed impedance-engineered dielectric interlayer enhanced RF power coupling by minimizing impedance mismatch at the applicator-load interface.
- The optimum IML ($\epsilon_r = 2.5$, $t = 6$ mm) reduced the VSWR from 1.63 to 1.21 at 2.45 GHz.
- The optimized configuration improved electromagnetic energy deposition within the lossy dielectric medium through enhanced power transfer.
- The study demonstrates the potential of impedance engineering for improving the performance of magnetron-driven microwave heating systems.

6. ACKNOWLEDGEMENT

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- [3] Satya Lakshmi Aparna Noojilla and Kusam Sudhakar Reddy, In Proceedings of Asia Pacific Microwave Conference (APMC), Yokohama, Japan, 2022, p. 925-927, [10.23919/APMC55665.2022.9999855](https://doi.org/10.23919/APMC55665.2022.9999855)