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Second Level Interconnects: BGA, Leadless

Presented At IEEE, International Microwave Symposium, 2006 Workshop
On "MICROWAVE AND MILLIMETER-WAVE PACKAGING 101"

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Outline

- **Definition Of 2nd Level Interconnect**
- **Challenges and Issues**
- **Material Considerations**
- **Example Designs**
  - **MEMS Switch Package**
  - **Leadless Chip Carrier**
  - **Ball Grid Array Package**

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Benefits Of Using Ceramics For Microwave Circuits

- **Good electrical characteristics**
  - **Low dielectric losses**
  - **Stable dielectric constant**

$$\text{Dielectric Loss} = \frac{\pi \cdot \tan\delta}{\lambda}$$

- **Able to incorporate passive elements into the ceramic**
  - **Buried power dividers, couplers and bias networks.**
- **Hermetic IC packages are possible**
  - **Critical for some applications such as military, MEMS, high rel commercial.**

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Challenges In Designing Microwave Ceramic IC Packages

Choosing the correct material

- **HTCC:** Excellent material stability, electrical performance is good with IC packages to 30GHz demonstrated. Multi layer process.
- **LTCC:** Good material stability, electrical performance is very good with IC packages to 60GHz. Buried resistors. Multi layer process.
- **Thick Film:** Great material stability, electrical performance is very good with IC packages to 40GHz possible.
- **Thin Film:** Highest cost solution at high volume, excellent electrical performance, fine lines.

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Microwave IC Packages Require Electrical Design Of 2nd Level Interconnect

- Ball Grid Array Interconnects
  - Ball size affects electrical performance.
    - Wide bandwidth operation requires the use of smaller balls
    - Smaller ball size reduces reflections of signal and the 2nd level interconnect
  - Ball pitch also affects electrical performance.
    - Pitch can be varied and used as a "tuning" element to optimized electrical performance.
- Leadless Interconnects
  - Edge castallations can provide a good electrical connection.
    - Must be optimized to account for extra inductive effect in transition.
    - Can be easily used to 30GHz
  - QFN Package can be used to 30GHz
    - Requires careful design of motherboard interface.

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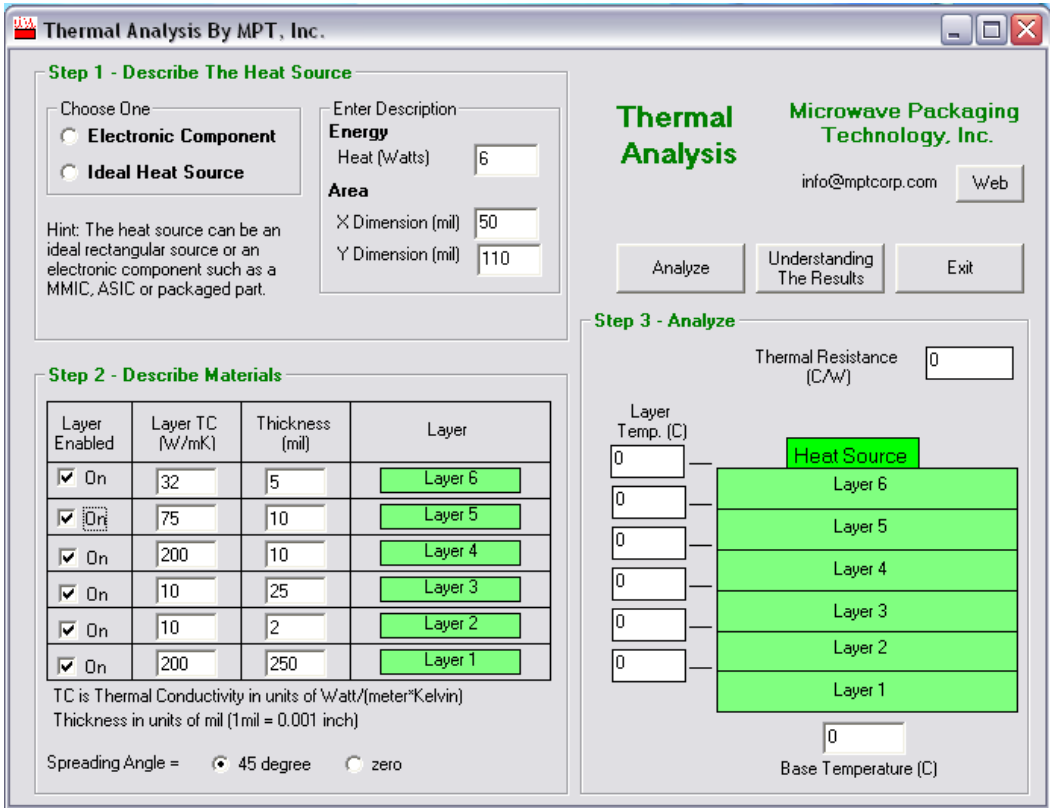
Thermal Performance Is Part Of The Design Cycle



Download Free at: www.mptcorp.com

- Capable of simulating multilayer electronic packages
- Can include effects of substrate and package
- Able to specify thermal resistance of the IC device or component mounted on top of the material stack
- Best of all it is FREE and fast (solves in a few seconds)

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Challenges For Microwave IC Packaging Add A Layer Of Complexity

Normal IC Packaging Issues

- **Choose compatible materials for reliability**
- **Die attach method and interconnect method**
- **Metal system**
- **Sealing and die encapsulation**

Additional Issues When Developing A Microwave IC Package

- **Design of the metal pattern and dielectric thickness to maintain 50 ohms**
- **Short interconnect lengths to minimize reflections.**
- **Careful material selection to minimize effect on electromagnetic fields in IC**
- **Coupling between traces, package resonance**

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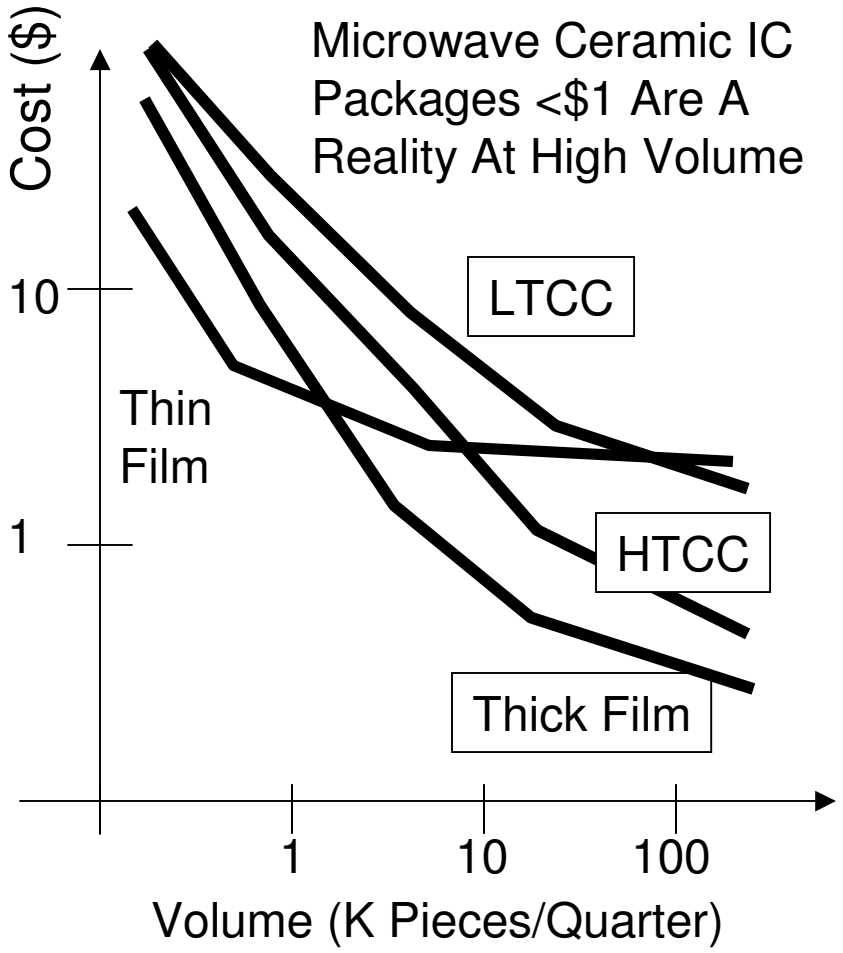
Microwave IC Package Costs Often Drive Material Choice



- **LTCC cost at high volume is dominated by raw material costs**
- **Thin film ceramic package costs start out low, but saturate quickly due to equipment and processing time**
- **Thick film and HTCC costs drop rapidly since material costs are a smaller portion of overall cost**

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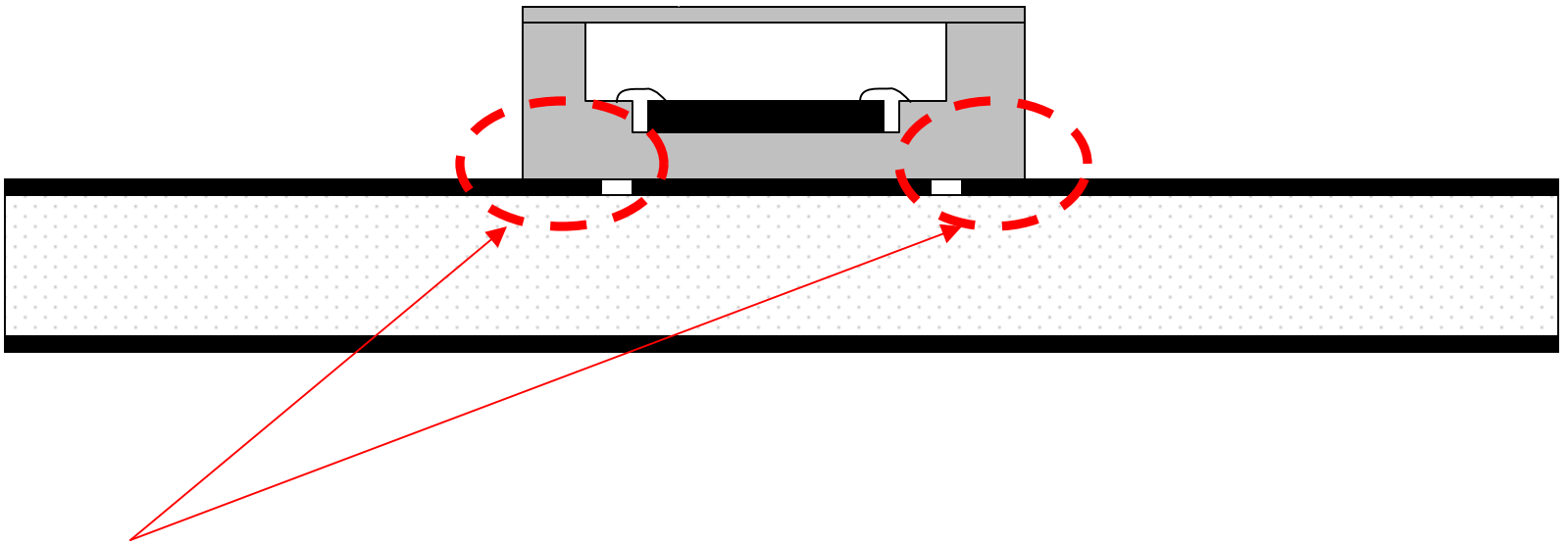
The Most Critical Area For Optimum Electrical Performance Is The 2nd Level Interconnect

Air Cavity Microwave Die Package



Motherboard to package transition normally dominates the electrical performance of the package

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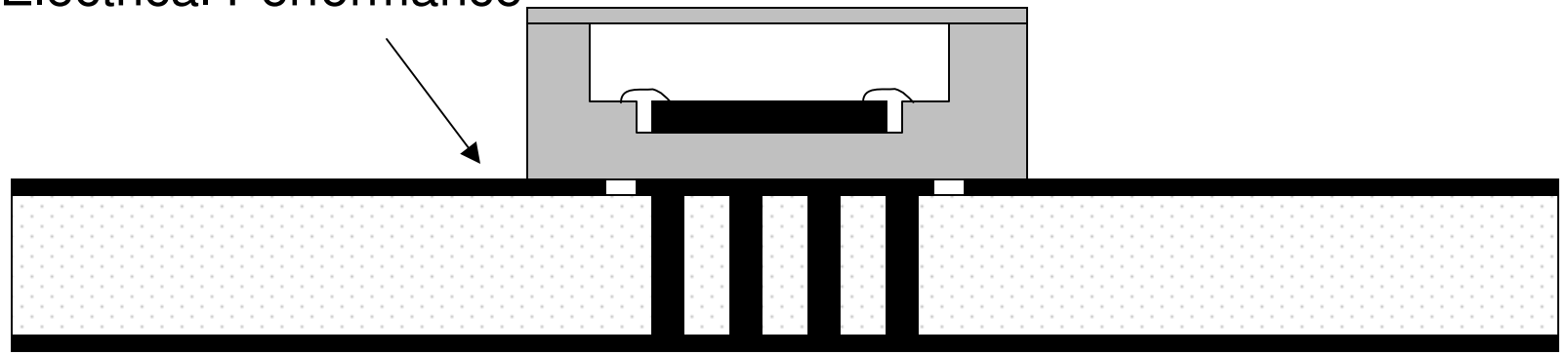
Carefully Placed Ground Vias Are Added To The Mother Board

Matching or Line Step
Sometime Needed For The RF In and Out
To Achieve Millimeter-wave Frequency
Electrical Performance



Motherboard to package transition normally dominates the electrical performance of the package

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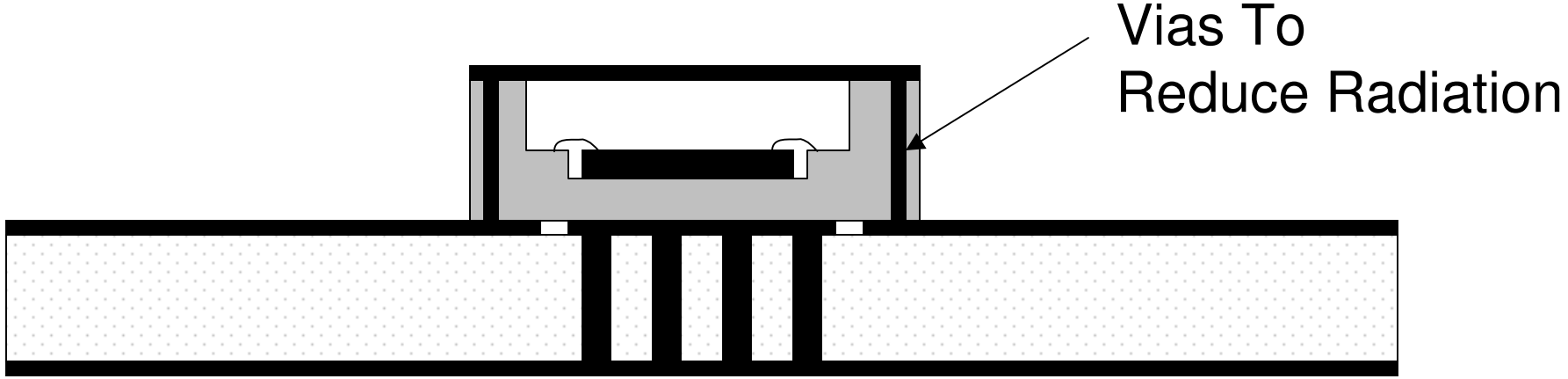
Package Resonance Is A Concern

- **Package resonances occur when the dimensions or physical feature of the package allow for it.**
  - **Most package resonances occur at half wave lengths.**
    - **For half wave resonance the package structure has symmetrical terminations of either open or short circuit.**
  - **Less common package resonances occur at quarter wave lengths**
    - **Quarter wavelength resonances occur when the resonator is non-symmetrically terminated. Open on one end and short on the other.**
- **The terminations don't have to be perfect shorts or opens to set up a resonance.**

Cavity Resonance Is A Common Problem For Millimeter-wave IC Packages

- **One possible package resonance can occur within the package as a cavity resonance.**
  - **A very common problem with metal housing packages.**
  - **Can be a problem for microwave packages that have shielding vias.**



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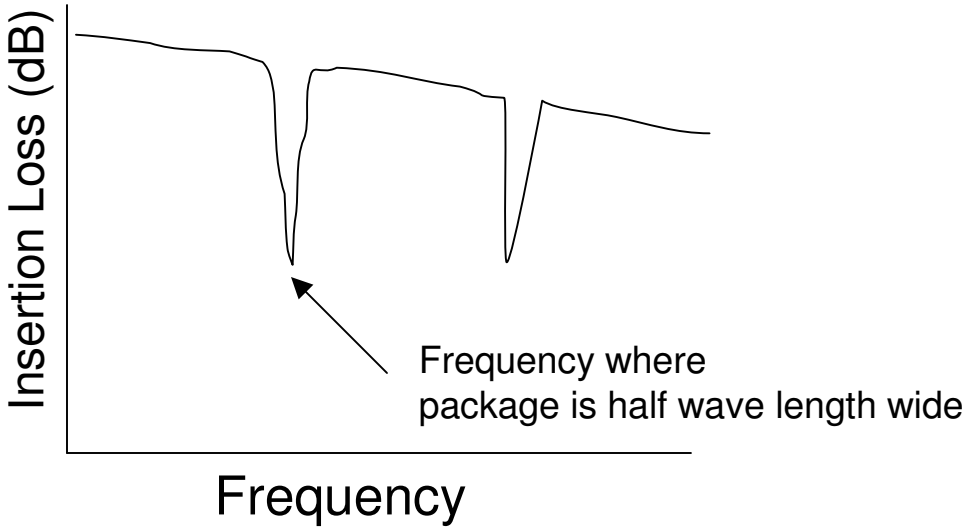
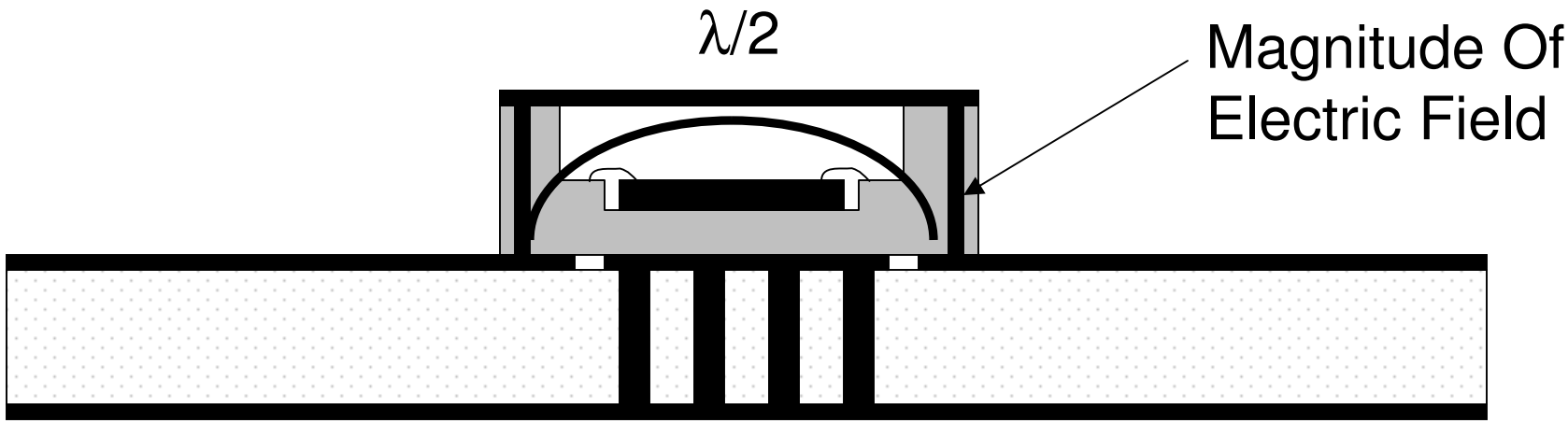
Half Wave Cavity Resonance Causes "Suck Outs" In The Pass Band





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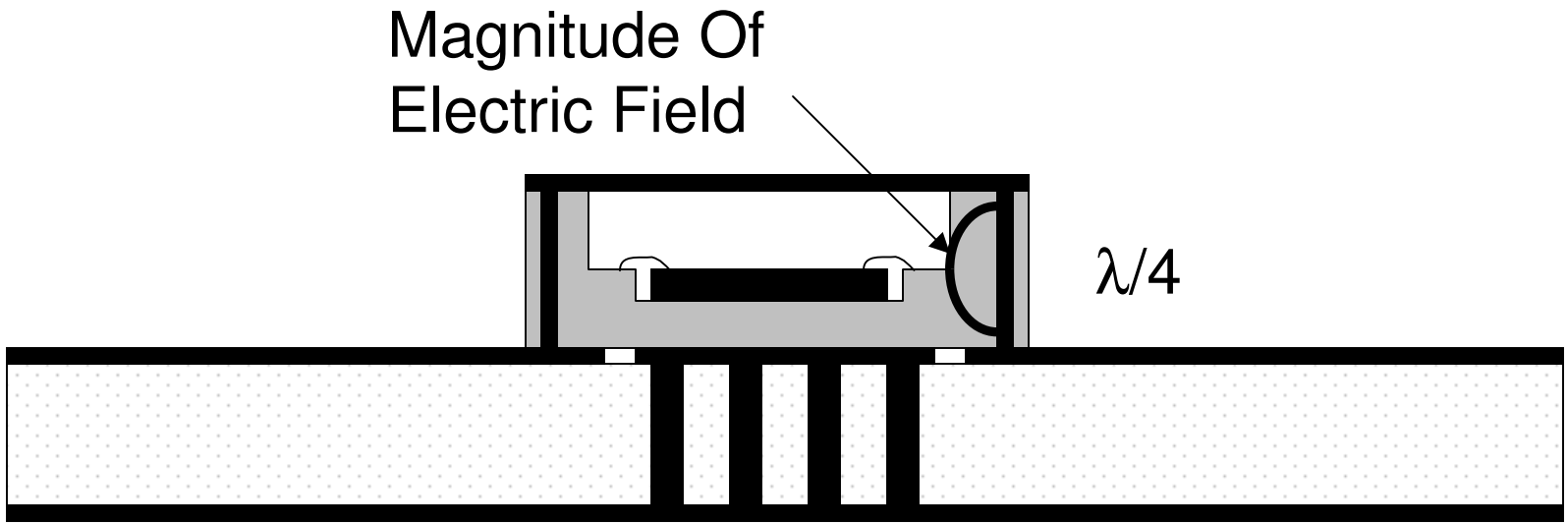
Quarter Wavelength Resonance

- **A Common area for quarter wave resonance is on via structures.**
- **Another common are is on traces, ground and rf ground planes.**



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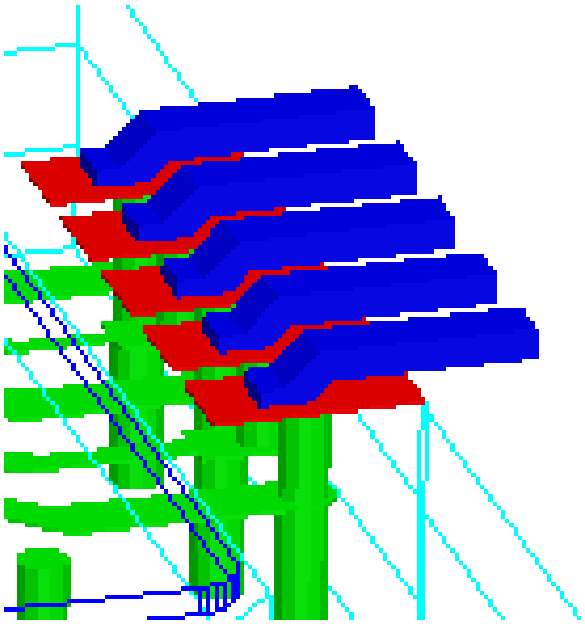
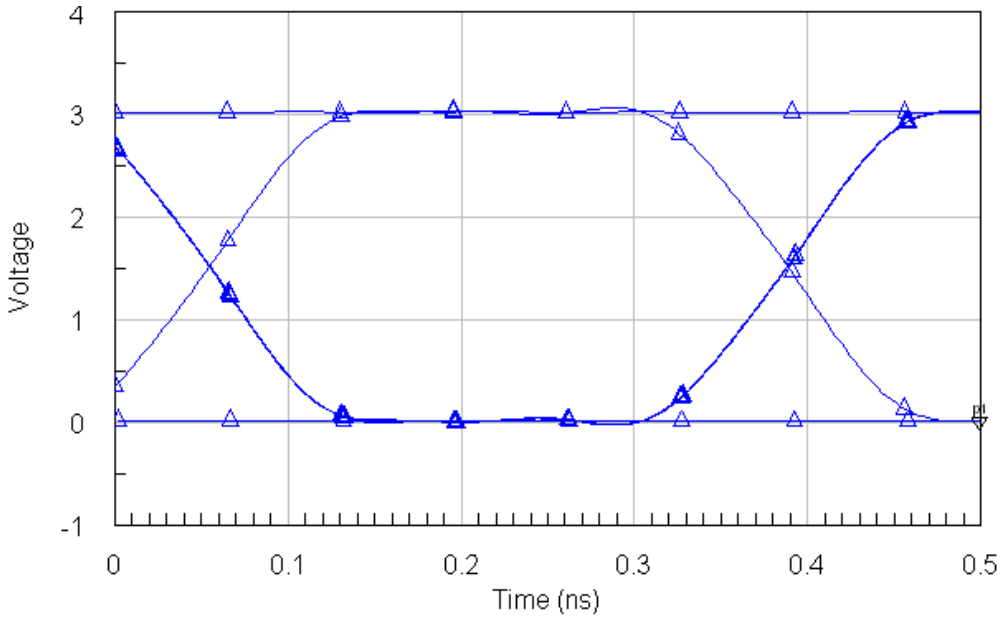
HTCC Alumina Package With Topside Leads For 2.5G Application





- **-20dB Return loss to 4 GHz**
- **Low insertion loss**

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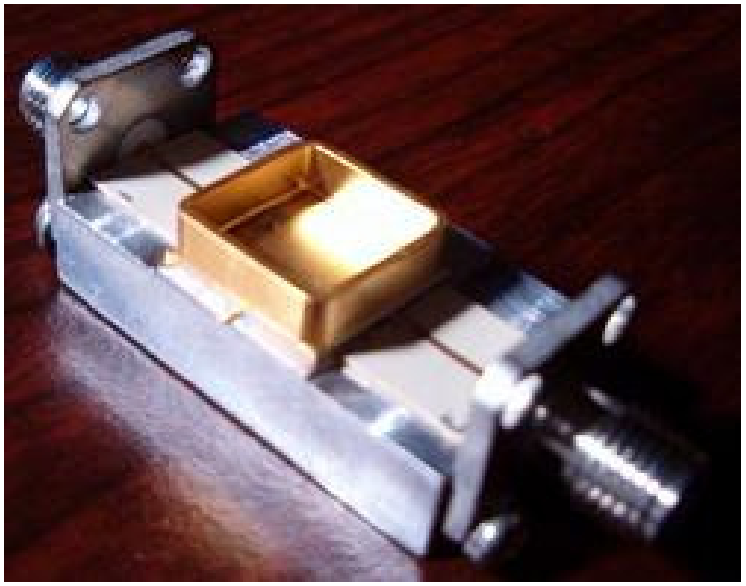
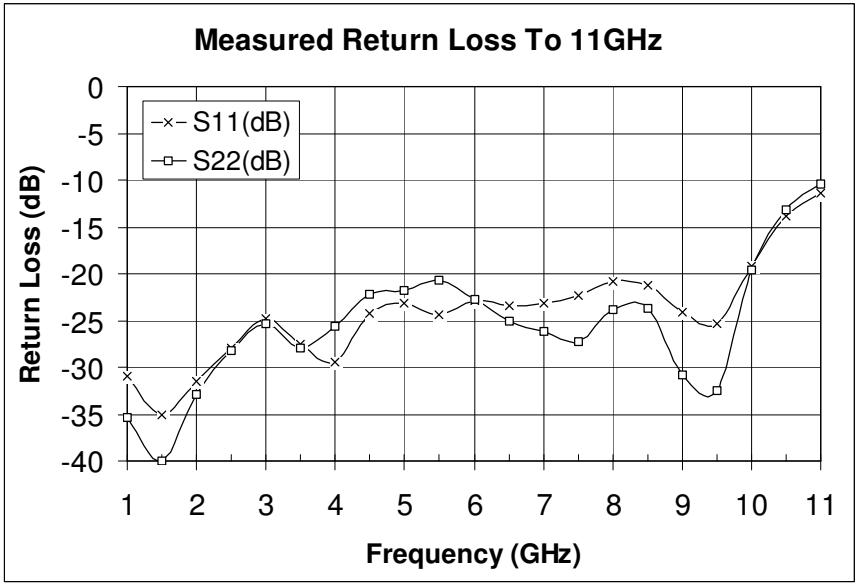
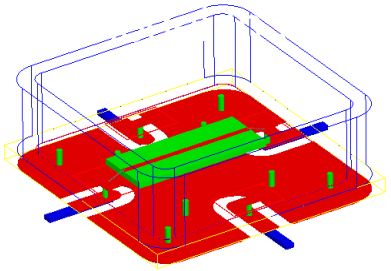
Hermetic HTCC Alumina Package With Kovar Seal Ring







- **Package has excellent electrical performance to 10GHz with –20dB return loss and low insertion loss.**

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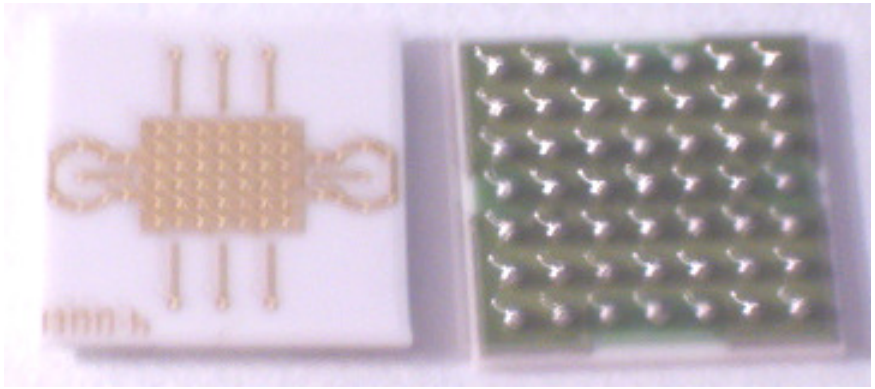
Thick Film IC Package Using BGA For Second Level Interconnects



- **Package able to accept several different die sizes.**
- **Uses 20 mil solder balls on 40 mil pitch**
- **Excellent electrical performance to 15 GHz.**

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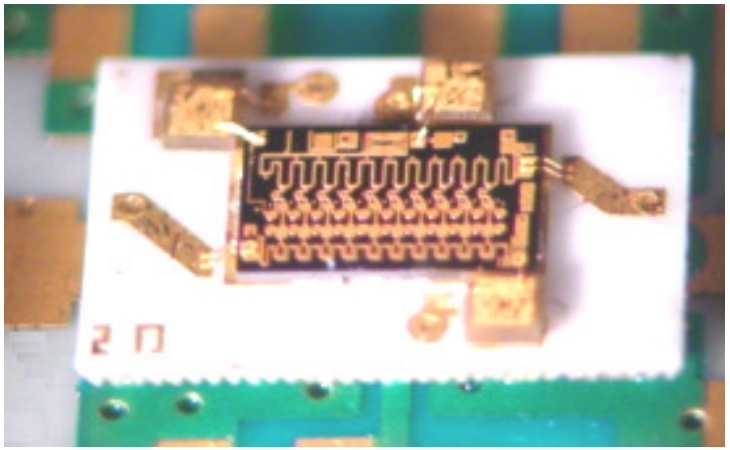
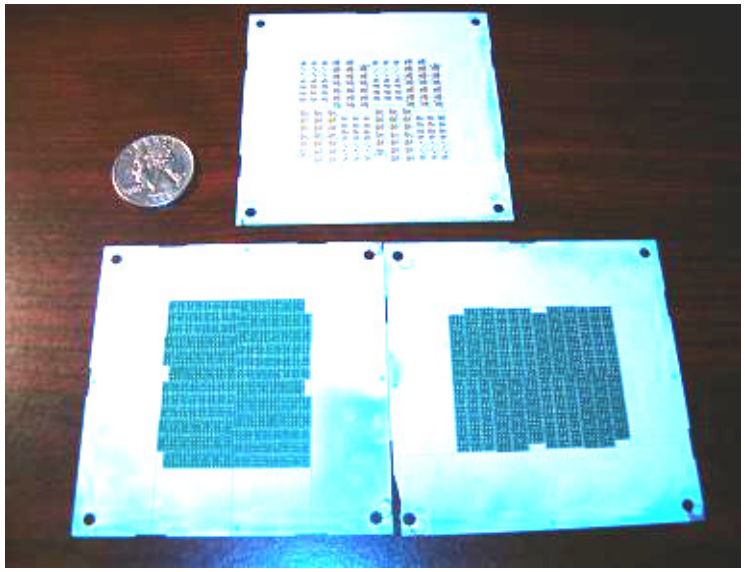
Thick Film IC Package With 25GHz Bandwidth





- **Non-hermetic packaging method using ceramic base and encapsulant.**
- **Very low cost solution.**

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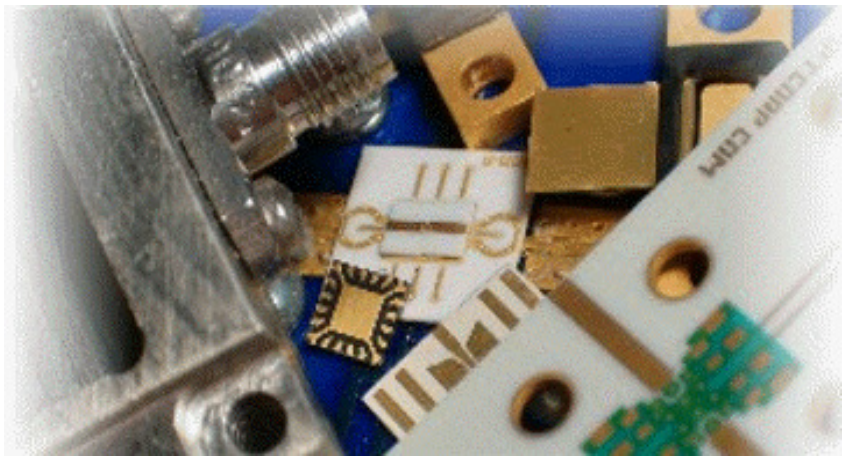
Providing The Optimum Microwave IC Packaging Solution



- **Providing the correct Microwave IC packaging solution requires:**
  - **Careful Materials Selection**
  - **Attention To RF Signal Path**
  - **Minimize Effect Of Package On IC**