MILLIMETER-WAVE PACKAGING

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In the development of millimeter-wave devices and components, package design and implementation have often lagged behind the development of other elements such as active devices, matching circuits, and integrated circuits. The result has been the surfacing of sometimes significant packaging issues late in the product development cycle, often with the result of substantial performance compromise. This situation is partly a result of having fielded only a very limited number of millimeter-wave components and systems, thus negating the need for extensive packaging development and a packaging infrastructure. It is noteworthy that no commercial RF packages exist for operation at frequencies above 20 GHz and significant performance degradation is already evident at X-band.

An RF package must provide a number of functions for the electronics that it contains. These include:

1. hermetic protection from hostile environments,
2. adequate means for removing heat generated by active devices within to an external heat sink,
3. mechanical support for the components, and
4. all required dc and RF IOs necessary for proper operation with minimum performance degradation.

In providing these functions, the package, in all cases, degrades the RF performance of the electronic components which it contains. Such degradation may take the form of reduced output power, increased noise figure, or reduced bandwidth. Since the amount of degradation in performance increases with RF operating frequency and the problems become more critical, the requirements placed on millimeter-wave packages are much more demanding than those for lower frequency applications. Dimensional tolerances and parasitics of packages and assemblies have increasingly pronounced effects at millimeter-wave frequencies.

Historically, millimeter-wave packages have been fabricated using high precision machining techniques, heavier and bulkier than should be, and relatively expensive. Design tools and methods have been inaccurate and have not dealt adequately with interactions between the active components enclosed within the package and the package itself. Dimensional electromagnetic simulation tools are now just beginning to provide the means for a more comprehensive approach to millimeter-wave package design.

In many instances, the intended application may have a large influence in package design and implementation. As an example, for transceiver applications such as phased arrays and automotive radars, the antenna element may become an integral part of the package.

Based on the analysis of the requirements and technology development, we expect the following trends for millimeter-wave packages:

1. Packaging at higher levels of integration -- the advent of millimeter-wave multichip packages.
2. The substantially increased use of electromagnetic simulation design tools.
3. The introduction of new materials and processes, for example AlN and cofired ceramic techniques.
4. The integration of a considerably higher complexity and multiplicity of electronic functions within the package envelope.
5. A substantial reduction in size, weight and cost of millimeter-wave packages.

This paper will review the current state-of-the-art of millimeter-wave packaging and

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analyze its potentials and limitations. We will then develop directions and approaches for future developments. In doing this, we will primarily address packages suitable for millimeter-wave integrated circuit chips.