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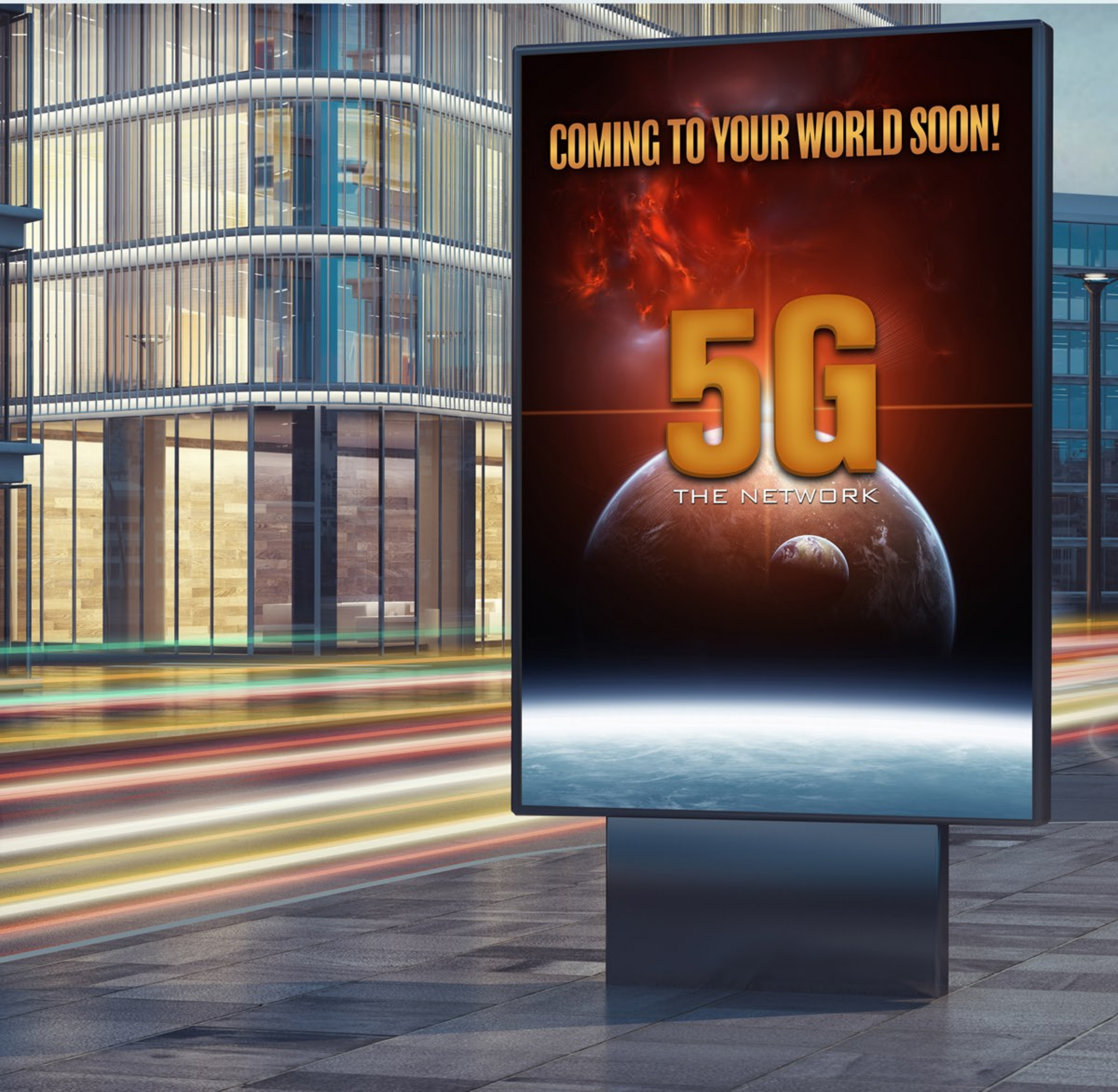

Making the Most of PCB Materials for 5G Microwave and mmWave Amps

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Millions of cellphones trying to connect voices and download unimaginable numbers of files worldwide point to the inevitability of fifth generation (5G) wireless communications networks. 5G is coming, and it will require the right circuit materials for many different types of high-frequency circuits, including power amplifiers (PAs). 5G represents the latest and greatest in wireless technology, and it will be challenging to design and fabricate, starting with the circuit board materials, because it will operate across many different frequencies, such as 6 GHz and below, as well as at millimeter-wave frequencies (typically 30 GHz and above). It will also combine network access from terrestrial base stations and orbiting satellites. But by careful consideration of mechanical and electrical requirements, high-frequency circuit materials can be specified that enable the design and development of 5G PAs no matter the frequency.

Ideally, a single circuit material would be a suitable starting point for PAs at all frequencies. However, amplifiers at different frequencies have different design requirements and are best supported by circuit materials with different characteristics best suited to the different frequencies. For example, insertion loss or dissipation factor can be more or less depending on the type of circuit material. Every circuit material will suffer some amount of loss, which typically increases with increasing frequency. The loss performance of a given circuit material may be acceptable within the microwave frequencies to be used in 5G networks but not within the millimeter-wave frequency range, where signal power tends to be less with increasing frequencies. The circuit material that provides the low loss needed for high PA gain and output power at microwave frequencies may not be the best choice of material for a PA at millimeter-wave frequencies.

The design requirements for a key circuit material parameter, dielectric constant (Dk), are much different for microwave frequencies, such as the 6 GHz and below used with 5G systems, than for millimeter-wave frequencies, such as 30 GHz and above, as will be used for short-range backhaul links in 5G wireless networks. Selecting an optimum circuit material for each band of frequencies requires understanding which Dk value best supports each of the two different frequency ranges. Then it is a matter of finding circuit materials that possess those Dk values along with as many as possible of the other circuit material attributes that help make a good, high-performance, high-frequency PA.

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Whether for microwave or millimeter-wave frequencies, circuit materials for high-frequency PAs must be capable of supporting circuitry that achieves the impedance match to the power transistors in those PAs. Such impedance matching is also necessary for the active devices in lower-power amplifiers, such as driver amplifiers and even in low-noise amplifiers (LNAs).

Suitable circuit materials for such impedance-matching networks must be capable of keeping circuit impedance variations to a minimum, and this is typically done through tight control of the substrate thickness, with no variations in thickness; tight control of conductor widths, such as microstrip transmission lines, to maintain the same impedance; tight control of the copper thickness on circuit laminates; and tight control of the circuit material's Dk, especially with temperature. Although using a circuit material with tight control of Dk, such as 3.50 ± 0.05, can help maintain the impedance of high-frequency transmission lines within a narrow window as might be needed for impedance matching within a PA circuitry, variations in the substrate thickness can have even more impact on maintaining consistent impedance of high-frequency transmission lines. A circuit material with a Dk tolerance of ±0.05 or lower is considered to have a tightly controlled Dk value.

With increasing frequencies, signal wavelengths are decreasing, requiring ever-smaller circuit features. Many of the PA circuit configurations used at both microwave and millimeter-wave frequencies, such as Doherty amplifiers, are dependent upon quarter-wavelength transmission-line circuit structures and the dimensions of these structures are a function of the substrate thickness. If that circuit substrate thickness is not tightly controlled, it is easy to understand how the impedance of extremely fine transmission-line and circuit structures can vary with those variations in substrate thickness. In general, a substrate thickness variation of ±10% or better is a sign of tightly controlled circuit material thickness.

Feeling the Heat

Whether at microwave or at millimeter-wave frequencies, PA circuits are subject to performance variations brought about by changes in temperature, from both the operating environment and from the PA's own active devices, such as power transistors or ICs. In the search for circuit materials for both microwave and millimeter-wave PAs for 5G applications, finding circuit materials capable of effective thermal management is critical to minimizing a PA's performance variations as a result of the thermal rise brought about by its own active devices. Two circuit material parameters are of particular interest when assessing a material's thermal behavior: thermal conductivity and thermal coefficient of dielectric constant (TCDk).

High thermal conductivity allows for efficient flow of heat away from any heat-generating active devices mounted on a PCB, such as a PA's power transistors. Consistent heat flow not only removes the heat as a threat to the reliability of the transistors, but helps minimize thermally inducted PA performance variations. Thermal conductivity of 0.5 W/mK or higher is considered good for a PCB material.

TCDk is a circuit material parameter that indicates how that material's Dk is affected by variations in temperature. Ideally, a material would have a TCDk of 0 ppm/°C for no change in Dk with temperature. But practical circuit materials exhibit some changes in Dk with temperature and a TCDk of 50 ppm/°C is considered good for a circuit material, resulting in only small changes in Dk with temperature. For the amplifiers and other circuits in 5G systems that will rely on fine quarter-wavelength circuit structures, circuit materials with low TCDk values will help minimize performance variations.

The smaller wavelengths and circuit features needed for millimeter-wave PAs and circuits in general will require thinner substrate materials compared to lower-frequency microwave PAs and circuits, and maintaining a tight tolerance in that thickness is just as critical as for thicker materials. Those thinner circuit materials can also be more sensitive than thicker circuit materials to the effects of other circuit material characteristics, such as copper surface roughness. Copper surface roughness can result in such circuit effects as transmission-line loss and phase variations, so copper surface roughness should be minimized in any circuit materials specified for the smaller-wavelength, higher-frequency circuits in both 5G microwave and millimeter-wave PAs.

As an example, Rogers offers a variety of materials with different thicknesses and other characteristics needed for the two different frequency ranges. For 5G PAs at 6 GHz and below, 20- and 30-mil-thick ceramic-based RO4385 circuit laminates are low-cost circuit materials that maintain consistent performance across wide temperature ranges. They have a Dk of 3.48 in the z-axis at 10 GHz, tightly controlled within ±0.05. They are ideal for competitive applications and can be fabricated with standard epoxy/glass (FR-4) processes.

For 5G PAs at millimeter-wave frequencies, 5- and 10-mil-thick RO3003 laminates consist of PTFE with ceramic filler. They feature a Dk of 3.0 in the z-axis at 10 GHz tightly controlled within ±0.04. They feature extremely low loss at higher frequencies that helps get the most gain from the active devices in an amplifier circuit, even at the various millimeter-wave bands expected to serve the many backhaul links of future 5G wireless networks. **DESIGN007**

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Design for Magnetoelectric Device May Improve Your Memory

For years, manufacturers have offered computers with increasing amounts of memory packed into smaller devices. But semiconductor companies can't reduce the size of memory components as quickly as they used to, and current designs are not energy-efficient. One promising version of magnetic device relies on the magnetoelectric effect. Existing devices, however, tend to require large magnetic and electric fields that are difficult to produce and contain.

One potential solution for this problem is a new switching element made from chromia (Cr2O3), which, one day, may be used in computer memory and flash drives. "The device has better potential for scaling, so it could be made smaller, and would use less energy once it's suitably refined," said Randall Victora, a researcher at the University of Minnesota and an author on the paper.

Next, Victora and Ahmed aim to collaborate with colleagues who work with chromia to build and test the device. If successfully fabricated, then the new device could potentially replace dynamic RAM in computers.