INSULECTRO

The Battles To Reduce RF Loss

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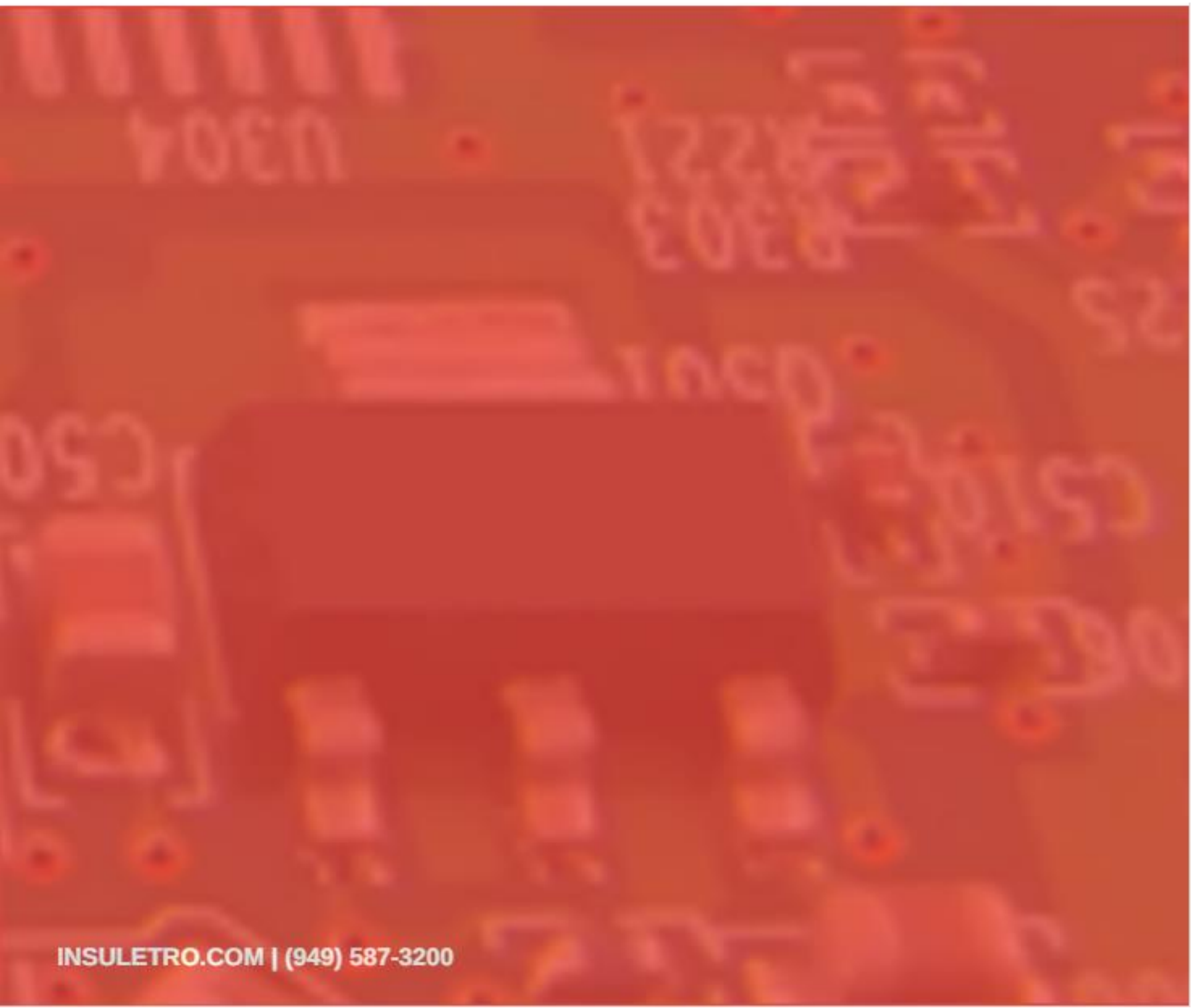

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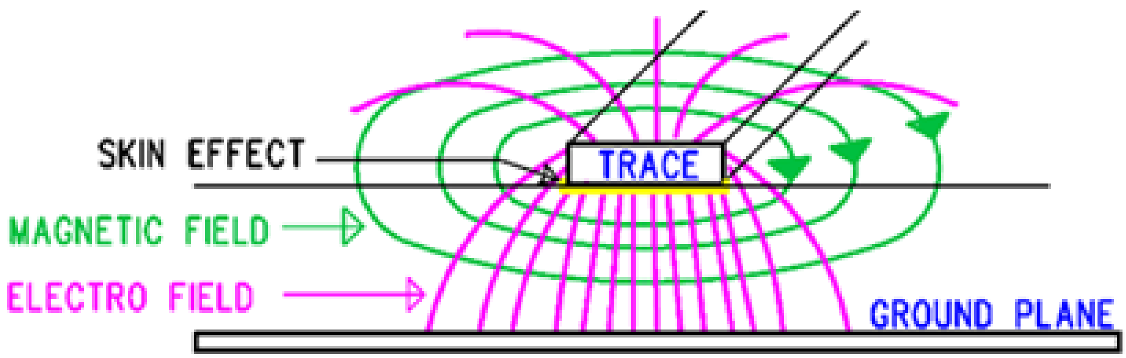
ABSTRACT

Dielectric Losses (Df) is the absorption of electromagnetic energy by the board material in a varying electric field. This is critical for minimizing dB loss calculations and is of high value to RF circuits. There are several other factors that should be considered for RF circuits, such as low copper tooth profile and RF low-loss design practices. Some chemistry processes may reduce copper tooth profile.

In a circuit board, a high capacitance and low inductance environment creates electric and magnetic energy fields. This energy exists and performs within the dielectric material with two references: a voltage and a return metal entity, such as copper traces or planes on our board. Energy fields exist between the trace and the plane (return path) within the dielectric material. Why this is important – you are not just connecting a route, rather you are managing an EM field.

BACKGROUND

In a circuit board, a high capacitance and low inductance environment creates electric and magnetic energy fields. This energy exists and performs within the dielectric material with two references: a voltage and a return metal entity, such as copper traces or planes on our board. Energy fields exist between the trace and the plane (return path) within the dielectric material. Why this is important – you are not just connecting a route, rather you are managing an EM field.



Electro-Magnetic (EM) Field Effect in Materials

MATERIAL SELECTION

Isola's Astra® MT77 has already proven its position as an industry leader in the realm of lowest loss laminates for RF and Microwave circuits. Df 0.0017. It also is available with low profile CU VLP-2 (2 micron).

Copper Tooth Profile – (Smooth Side and Rough Side)

Tooth profiles vary and the roughness is denoted by a term called (Rz), also referred to as, "Ten-point height." This is the average absolute value of the five highest peaks and the five lowest valleys, measured in microns. The smooth side can be less than a micron while the rough side can be anywhere from 2-10 microns.

Various Copper Profiles - Smooth Side and Rough Side

The smoothness of the copper profile helps signal propagation, while roughness helps adhesion, providing a peel strength. These two factors are in conflict and careful consideration of how decisions should be made are required. Peel strength is most needed on outer layers during bring-up efforts or rework. It may not be needed on production runs, or also on inner layers for proto-type or production.

SKIN EFFECT

The faster a signal's frequency is, the shallower the amount of depth the current will travel into the conductor and its return path. This is referred to as, "Skin Depth."

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Skin Depth in Copper Based on Frequency

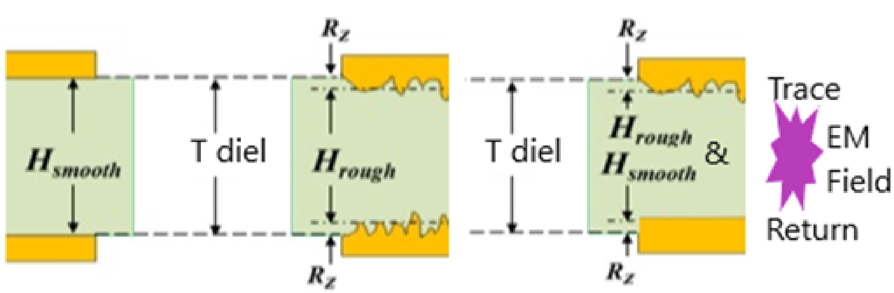
Frequency	Skin Depth (μm)
100 MHz	6.52
1 GHz	2.06
10 Ghz	0.652
100 Ghz	0.206

On printed circuit boards our traces are paired with an uninterrupted reference plane (preferably GND) adjacent to the trace. The presence of currents in the returning signal current distorts the flow of current in the conducting trace. Basically, it pulls more current onto the bottom side of the trace (the side nearest the reference plane). In a stripline configuration (reference planes above and below a trace) the current is going to be pulled over towards whichever reference plane is closest, or often GND (0.0V) as opposites attract. This effect is called the Proximity Effect.

PROXIMITY EFFECT

The Proximity Effect is a simple manifestation of the general rule that high-speed current tends to concentrate near its return path. It is important to have a clearly defined return path to know exactly where the return current will flow.

The reference plane dissipation has the effect, in this case, of a 36% increase in the apparent resistance of the signal conductor. The copper tooth profile should be considered on the return path side, also. Are we considering both sides of our EM Field or just the trace side? Depending on how we make our stackups we may be mixing these two surfaces, as shown below. The EM Field references both our traces and our return planes as it travels through the dielectric material. Smooth and rough copper foil sheets bonded to dielectric material. Capacitance increases in proportion to roughness profile Rz. When comparing a smooth vs. rough conductor and return plane, with same thickness of dielectrics: smooth surfaces, as shown on the left, the e-field strength is uniform, as expected. The roughness profile, as shown on the middle, increases or decreases the e-field strength proportional to the peaks and valleys, respectively. Average capacitance also increases proportionally to the roughness profile. We often will mix the two making this all the more confusing, as shown on the far right. Know that copper profile has many options to choose from: reverse treated, low profile, and chemical methods to reduce surface roughness.



Consider Both Tooth Profiles for EM Field Effect
– Smooth, Rough or Mixed

FEATURE SIZE

RF traces are often defined much wider than digital highspeed trace. This is referred to as a Non-Lossy Transmission Line. However, to still perform as a 50 ohm trace, they will often have a GND Well added by way of a keep-out on layer 2, now referencing layer 3 instead of layer 2.

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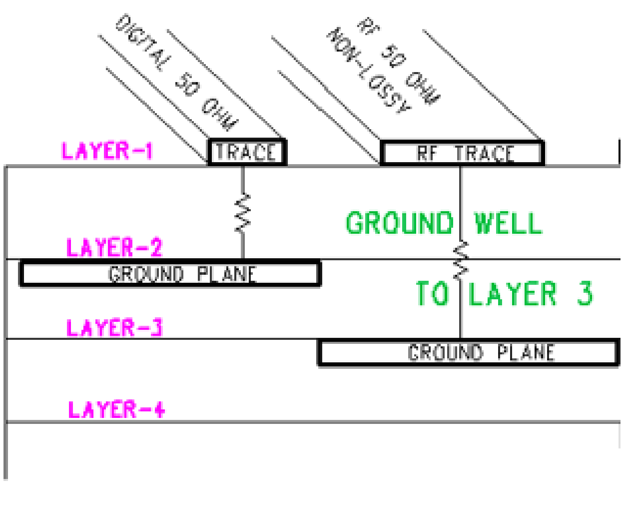

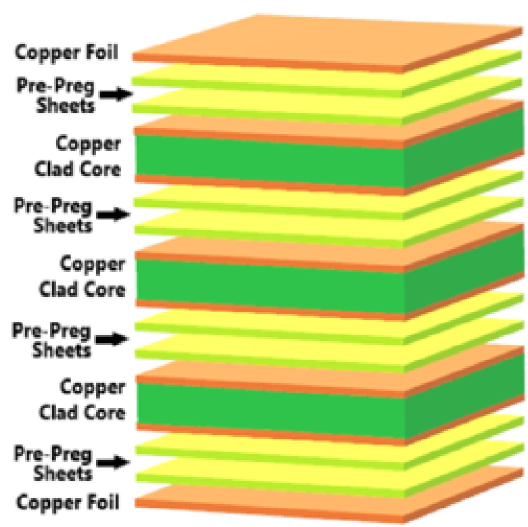

Make a Smart Stackup knowing where your Field will Exist