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How thin laminates suppress resonances

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In the column "Resonances in power planes" you learned that power-ground plane pairs exhibit a double series of modal resonances. In this column we show how thin laminates help you to suppress these resonances.

It may seem counter-intuitive that just by making the dielectric thinner, leaving the dielectric constant and dielectric loss as well as the copper-plane characteristics the same, we could suppress the resonances in un-terminated plane pairs. But this is exactly what is happening. To understand how it works, we have to recall a fundamental signal-integrity expression, which tells us how the attenuation of an interconnect depends on its impedance and per-unit-length resistance and conductance.

$$A^{[dB]} = 4.35\left[G(f)Z_0 + \frac{R(f)}{Z_0} \right]$$

In the expression A is the attenuation in dB, G(f) is the frequency-dependent dielectric (parallel) loss, R(f) is the frequency dependent conductor (series) loss and finally Z_0 is the characteristic impedance of the interconnect. We assume that Z_0 approximately equals sqrt[L(f)/C(f)], the characteristic impedance of the interconnect. The simple equivalent circuit of *Figure 1* shows how these parameters are inter-related.

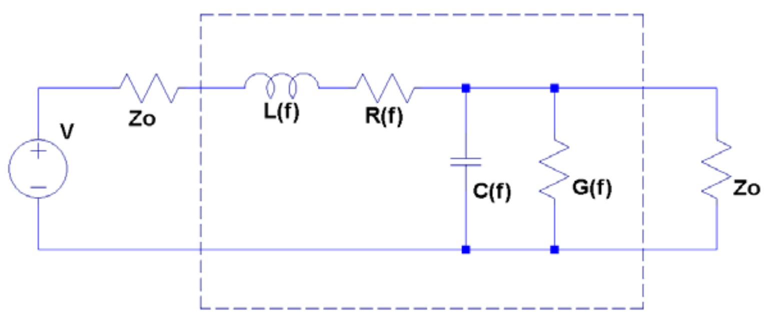

Figure 1: *Equivalent circuit of a lossy transmission line between matched terminations.*

R(f) depends on the conductor cross-section dimensions and conductivity, but not on dielectric spacing. However, the same conductors, if we place them closer, will create lower inductance and higher capacitance, both will reduce the Z_0 characteristic impedance. As Z_0 gets smaller, even if R(f) stays the same, the attenuation will increase, because the $R(f)/Z_0$ ratio will go up. So what is not good for signal integrity (namely higher attenuation), will help us with power integrity: by simply putting the planes closer, we get higher attenuation. The higher attenuation eventually will suppress modal resonances.

Figure 2 shows the impedance plot of a 100-mm square plane pair with different thicknesses of FR4 dielectric. The impedance magnitude is shown at the center. Notice that as the dielectric gets thinner, the entire curve shifts to lower impedance values. At low frequencies the higher capacitance reduces the impedance, at high frequencies the impedance is lower because of the lower inductance of the planes. At the series resonance frequency all curves go through the same value, because it is determined by the conductor loss, which does not change as we make the dielectric thinner. You can also notice that as the dielectric thickness gets below 0.05 mm, the resonances are highly suppressed.

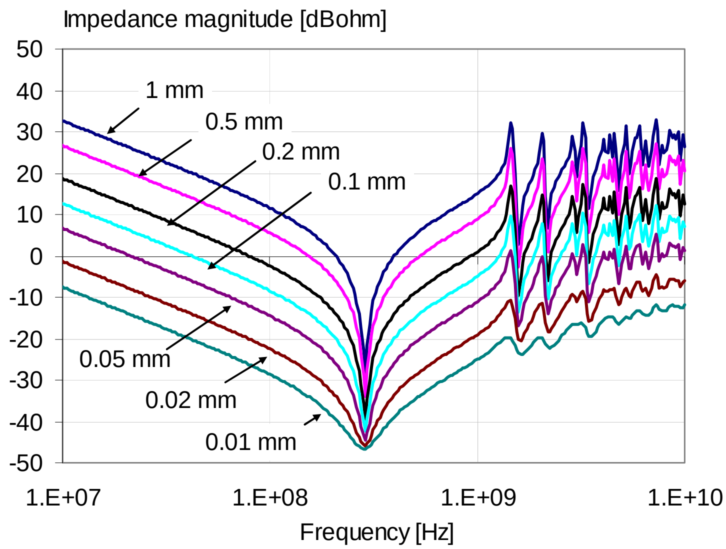

Figure 2: *Simulated impedance magnitude of a square plane pair with different dielectric thickness values.*

You can find more data about thin laminates in [1] and [2]. [1] lists a number of commercially available thin laminates and it also shows measured data on test boards with different materials.

Dielectric constant and plane size also have an effect on the suppression of modal resonances. With a given dielectric thickness, larger dielectric constant and larger planes tend to suppress modal resonances more [2].

References:

[1] "Thin and Very Thin Laminates for Power Distribution Applications: What is New in 2004?," DesignCon2004, Santa Clara, CA, Feb 2-5, 2004, available at http://www.electrical-integrity.com/

[2] "Impact of PCB Laminate Parameters on Suppressing Modal Resonances," DesignCon2008, Santa Clara, CA, February 4-7, 2008, available at http://www.electrical-integrity.com/