The Benefits of Selecting RT/duroid® 6010LM for Band Pass Filter Applications

Microstrip microwave circuits operate in a frequency range where losses due to conductor and dielectric limit the performance of the design. Conductor losses vary according to the frequency of operation, width, thickness, and surface roughness of the conductor as well as, the height of the substrate. These factors are set by the design and usually will not vary greatly in the application. Dielectric losses depend on circuit configuration, dielectric constant, frequency, and loss tangent. Dielectric constant and loss tangent vary with operating temperature changes and levels of humidity. Dielectric constant (ε_r) values usually vary between 0 and 0.05% over a 100°C range for most PTFE based laminates. The loss tangent (tan δ) however, can change significantly, up to 200%, with moisture absorption as little as 0.25% of dielectric weight. Minimizing or eliminating loss tangent changes is a priority for reducing the overall circuit losses.

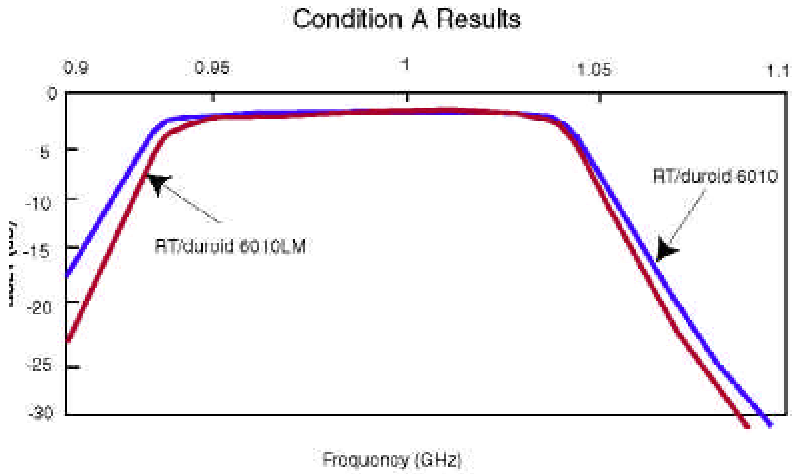
Until now, most designs were a compromise between high dielectric constant (RT/duroid 6010 material) or low moisture absorption laminates (RT/duroid 5880 material). The high dielectric constant materials allowed for a reduction of space but at the cost of having a higher moisture absorption level. RT/duroid 6010LM microwave laminates bridge the gap that exists between high ε_r and low moisture absorption substrates. RT/duroid 6010LM microwave laminates are a ceramic/PTFE composite designed for microwave circuit applications requiring a high dielectric constant and low moisture absorption (ε_r = 10.2± 0.25, tan δ = 0.0028 max., moisture absorption = 0.05% typ.).

Table 1 summarizes the results of an initial study comparing a similar (ε_r = 10.5 ± 0.25, tan δ ≤ 0.0027) competitive product as Brand X with RT/duroid 6010LM material for the effect of water absorption on electrical properties. Weight gain, ε_r and tan d were measured on ten specimens of each product. It is evident that 0.25% water absorption causes an ε_r change using over half the range allowed in the tolerance.

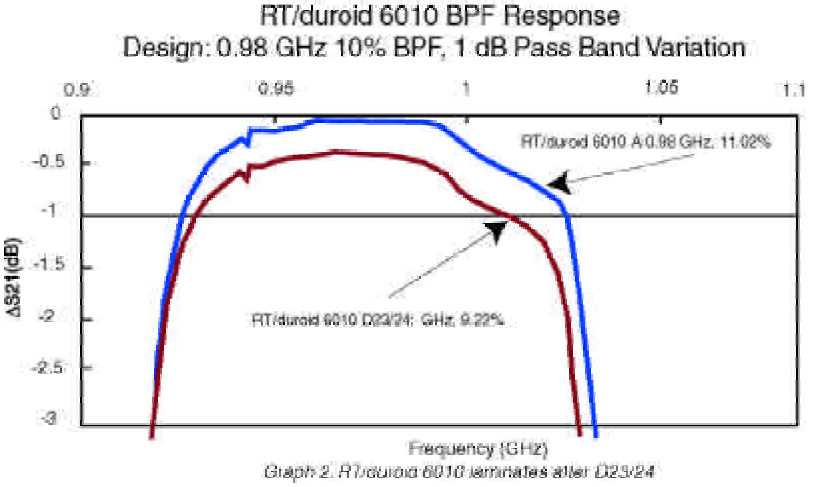
Table 1: Effect of Moisture Absorption on Electrical Characteristics (Refer to IPC-TM-650).

Material	Brand X	RT/duroid 6010LM
e_r, method 2.5.5.5		
A	10.553	10.204
D24/23	10.853	10.231
% change	2.84	0.27
tan d, method 2.5.5.5		
A	0.00249	0.00183
D24/23	0.00841	0.00253
% change	238	38
Water absorption method 2.5.2.1		
D24/23		
% weight	0.253	0.003

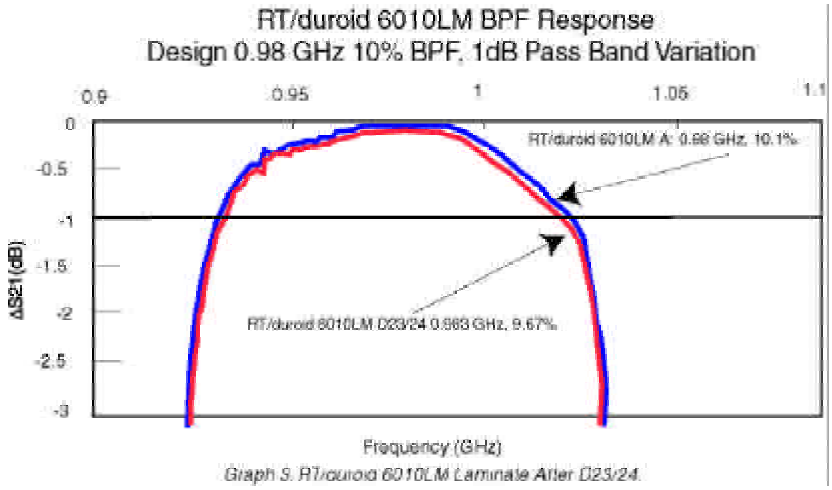
To better understand the effect of water absorption we can predict changes in insertion loss (α_0) as shown in Table 2 where the losses attributed to conductor and dielectric are separated. $\alpha_0 = \alpha_c + \alpha_d$.



Graph 1. Initial S21 response of Band Pass Filter (RT/duroid 6010LM inside curve)



Graph 2. RT/duroid 6010 laminates after D23/24



Graph 3. RT/duroid 6010LM Laminate After D23/24.

Table 2: Calculated Insertion Loss, a, of Before and After D24/23 Conditioning of α Z_0 = 50Ω Microstrip.

Material	α_c dB/in	α_d dB/in	α_T %	$\Delta\alpha_d$ %	$\Delta\alpha_T$ %
6010LM	0.219	0.135	0.353	38.43	14.75
Brand X	0.224	0.170	0.394	239.42	104.17

As shown, water being absorbed into the substrate will change the loss significantly in the system which could render the circuit inoperable . To test these differences in an actual application two band pass filters were made, one on standard RT/duroid 6010 material, which has similar water absorption as the competitors material, while the second was on RT/duroid 6010LM (this was chosen in order to keep the dielectric constant the same for both laminates, 10.2). Graph 1 compares RT/duroid 6010 LM material to standard RT/duroid 6010. Graphs 2 and 3 illustrate the change in response due to the D23/24 conditioning.

The effect of moisture on RT/duroid 6010LM material translates to a drop of 0.1 dB in the passband while standard material drops by 0.5 dB. This increased operational loss could take the filter from proper operation to the non-acceptable range.

The low value of moisture absorption of RT/duroid 6010LM microwave laminate allows it to operate in an environment of high humidity without having the increased loss problems usually associated with high K' materials, while still allowing the designer to reduce circuit size.

* Note: Values in Table 2 are calculated per equations given in Rogers Note SP8709.

CONTACT INFORMATION:

USA:	Rogers Advanced Circuit Materials, ISO 9002 Certified	Tel: 480-961-1382	Fax: 480-961-4533
Belgium:	Rogers Corporation - Gent	Tel: +32-9-2353611	Fax: +32-9-2353658
Japan:	Rogers Japan Inc.	Tel: 81-3-5200-2700	Fax: 81-3-5200-0571
Taiwan:	Rogers Taiwan Inc.	Tel: 886-2-86609056	Fax: 886-2-86609057
Korea:	Rogers Korea Inc.	Tel: 82-31-716-6112	Fax: 82-31-716-6208
Singapore:	Rogers Technologies Singapore Inc.	Tel: 65-747-3521	Fax: 65-747-7425

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