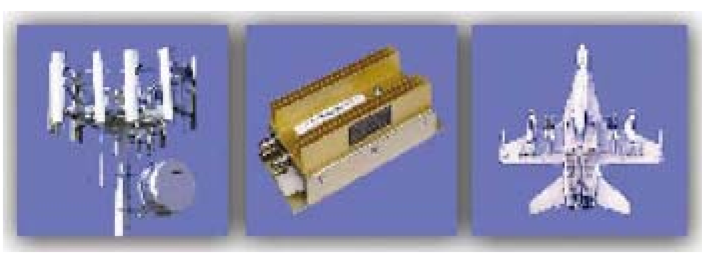
The Anisotropy of Dielectric Constant (ε_r) in TLY-5A Material by Bereskin

By Seth J Normyle
Process Engineer



Petersburgh, NY – Tel: 800-833-1805 Fax: 518-658-3988
Europe – Tel: +353-44-95600 Fax: +353-44-44369
Asia – Tel: +82-31-704-1858 Fax: +82-31-704-1857
www.taconic-add.com
www.taconic.co.kr

Background
The general definition of anisotropy is variation in a given material property with respect to orientation. In the case of woven fiberglass composite laminates such as TLY-5A, E_r anisotropy specifically refers to the differences in dielectric constant in the X and Y plane of the laminate compared with the Z axis. For a laminate material the degree of anisotropy is defined as the ratio of the average E_r in the X and Y axis to the E_r in the Z axis.

Degree of anisotropy (E_r) = Average E_r (x, y) / E_r (z)

In printed circuit boards, the degree of anisotropy has relevance in cases where electric field lines are oriented in perpendicular to the Z axis. For fields in the Z plane, E_r anisotropy may also impact field fringing effects, effecting equivalent lengths of transmission lines.

Method
To evaluate E_r in the X and Y planes of Y-5A material a thick test laminate was constructed by sequential lamination from a Y-5A-1870 building block using 1080-74% glass as a bond ply. The thick laminate was pressed in a laboratory scale high temperature/pressure press in keeping with standard Taconic lamination conditions. The final laminate had a thickness of 1.3”. The panel was then cut on a panel saw, slicing a strip approximately 60 mils thick from both the length and width of this thick laminate, to obtain test coupons in both the x (fill yarn direction) and y (warp yarn direction).

These pieces were cut to the appropriate size and tested by the Bereskin method (Modified IPC TM-650 2.5.5.5.1). Briefly, two samples of identical thickness are placed in the test fixture under pressure with a standardized copper strip sandwiched in between to create an imbedded stripline resonator. A signal is propagated through the z axis of the sample and the resonant frequency is found. Using the resonant frequency E_r is derived from the equation:

$$E_r = C / (2.54*F_0*Leq)^2$$

Where
C = speed of light,
F_0 = resonant frequency and
Leq = conductor length including field fringing.

Dissipation Factor (DF) is derived by observing the 3dBm or half power points around the resonant frequency. This procedure is repeated at each harmonic to yield data for E_r and DF across a frequency bandwidth from ~ 2 - 24 GHz.

Results

Figure 1: E_r results of Y-5A in the x, y and z by Bereskin.

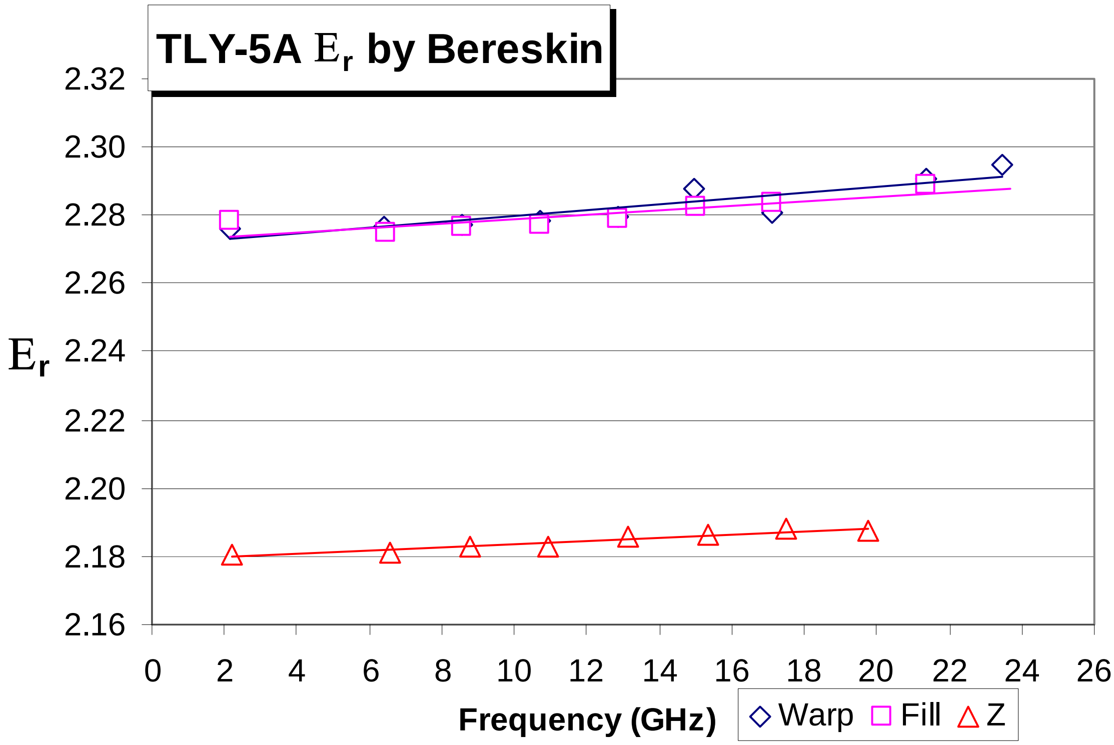
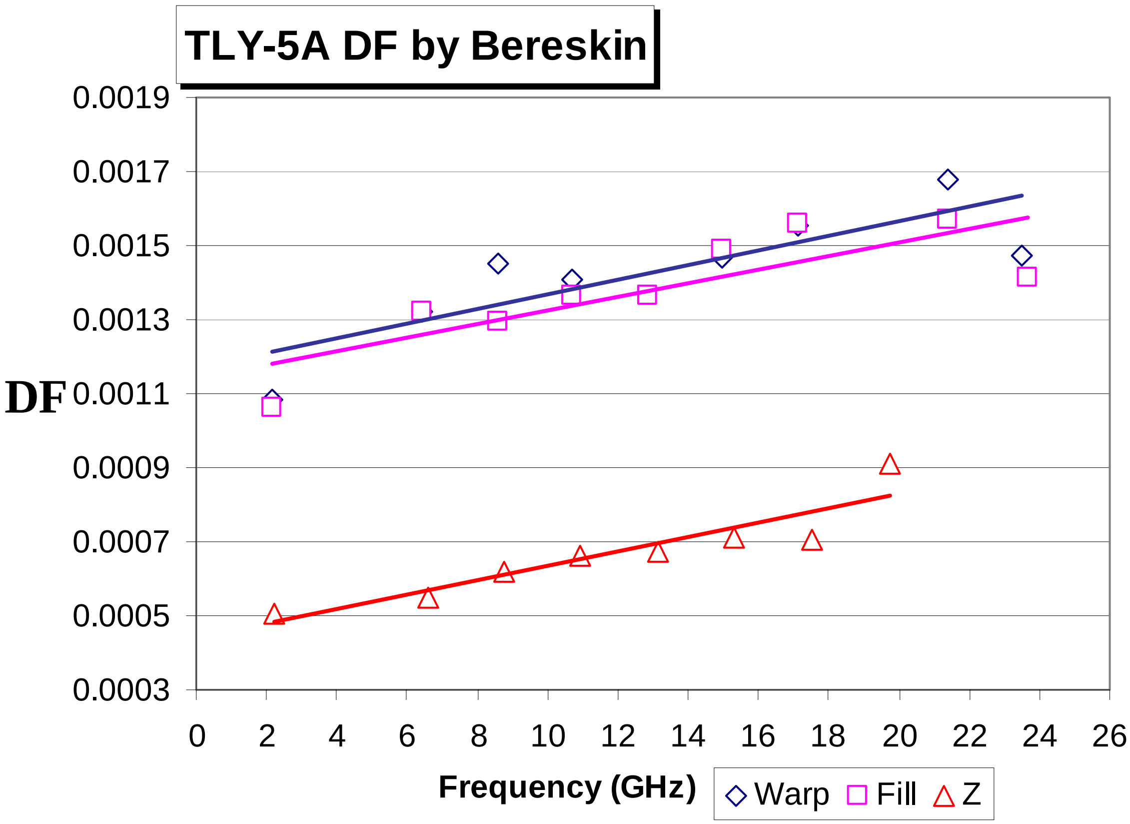


Table 1: Representative values for DF and DK of TLY-5A across frequency. The average Bereskin E_r across the bandwidth was used to calculate the degree of anisotropy.

	Avg E_r	DF @ 2 GHz	DF @ 10 GHz	DF @ 20 GHz
X (Warp)	2.2824	0.00108	0.00141	0.00168
Y (Fill)	2.2802	0.00106	0.00137	0.00157
Z	2.1844	0.00050	0.00066	0.00091
Degree of Anisotropy (E_r):		1.044		

Figure 2: Bereskin DF Results for Y-5A in the x, y and z planes across frequency.



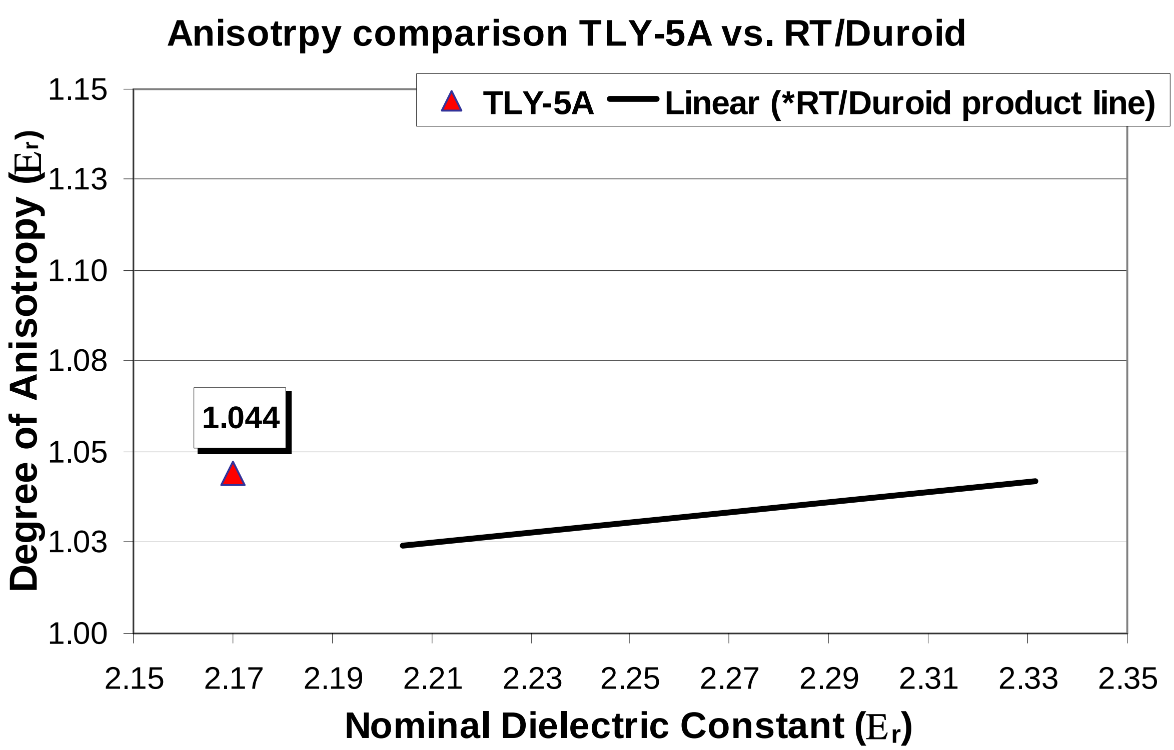
Discussion

The results of E_r testing by Bereskin of TLY-5A illustrate the influence of woven glass on signal propagation through the material. The differences seen between X and Y are likely due to the fabric construction. TLY-5A laminates may contain either 106 or 1080 glass depending on the construction called for. This thick test laminate was made with both 106 and 1080. Both 106 and 1080 glass styles are unbalanced weaves with differing fiber density in the warp and fill directions, effectively creating different resin contents in those planes.

TLY-5A is shown to have a degree of anisotropy for E_r of 1.044. This corresponds exactly with published values for competitive non-woven laminate materials (RT/Duroid 5870 = 1.04, see figure 3).

Figure 3: Degree of Anisotropy comparison of TLY-5A with the RT/Duroid product line.

*Data for RT/Duroid was obtained from product literature, see references. It should be noted that the RT/Duroid data shown in figure 3 was obtained by measuring E_r at 10 GHz whereas our data were measured up to 23 GHz. Also the published degree of anisotropy for RT/Duroid $E_r < 2.33$ was estimated.



Anisotropy is often regarded as a drawback for woven fiberglass composite laminates. The data presented in this study are in contrast to this argument. Here TLY-5A with woven fiberglass exhibits analogous anisotropy to the non-woven counterpart RT/Duroid 5870. Non-woven microfiber composites do in fact impart anisotropy to the material; fiber orientation is rarely random but rather parallel with the machine direction as a consequence of the manufacturing process. Taconic TLY-5A shows a low degree of anisotropy for E_r across a wide bandwidth to above 22 GHz. These data highlight TLY-5A as the material of choice where optimal low DF is required, providing all the advantages of woven fiberglass laminates with a very low degree of anisotropy.

References

1. Bereskin; Alexander B., U.S. Patent no. 5,083,088.
2. Rogers Corporation. The Advantage of Nearly Isotropic Dielectric Constant of RT/Duroid 5870-5880 Glass Microfiber PTFE Composite. RT 2.1.2.1. http://www.rogerscorporation.com/mwu/pdf/rt2121.pdf