A Definition of FR-4

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Subject : IEEE 802.3ap Backplane Ethernet

Abstract : This presentation is an update to the one given at the March2004 IEEE Plenary and examines the definition of FR-4 material, the reference to UL, and proposed constants to the implied definition of 'Improved FR-4'.

FR-4 Definition

- **Flame retardant type 4 Brominated woven glass reinforced epoxy resin system[1].**

- [1]Electronics Manufacture and Test Online. WWW.emtonthenet.net/glossary/fr4laminate.html.
- [1]UL Confirms definition in phone conversation 29April04. New definition and testing process to be released for review in June/July.

UL Involvement in FR-4

- FR-4 was established in 1968.
- Infrared scans where done for conformance then.
- Later a thermal degradation scan was implemented.
- Position of UL: With various Tg, Dk, Df, Halogen Free materials … FR-4 is too vague. Re-classification to be suggested in June of 2004. At this time, re-classification will only cover flame rating based on resistance of material suppliers to position Dk and Df values within class groups tested by UL.
- Though UL is not an International Body, the results of the degradation coupons are accepted World-Wide. PCB Manufacturers test to no other recognized Body/Standard, with exception to additional GR-78/NEBS conformance tests as required by Telecom Carriers.
- UL suggests reviewing concerns and comments with both itself and IPC.

Materials Classified as FR-4

- FR-4 ‘generic’ material, FR402/4000-2, and FR406/4000-6. Typical Dk of 4.3 and higher.
  - Reference Nationwide Circuits, Inc., Materials Specification. www.nciproto.com/info/Base%20/mat.htm
  - Reference Electronics Manufacture and Test Online. WWW.emtonthenet.net/glossary/fr4laminate.html.
- GETEK. Typical Dk of 3.6 to 4.2.
  - Reference Nationwide Circuits, Inc., Materials Specification. www.nciproto.com/info/Base%20/mat.htm

Materials Classified as FR-4

- 4000-13 and 4000-13SI. Typical Dk of 3.5 to 3.7.
  - Reference Park Nelco. www.parknelco.com
- FR408. Typical Dk of 3.7
  - Reference Isola Laminate Systems. www.isola-usa.com/products/productdetail.shtml?16
- Isola620. Typical Dk of 3.7 but low Df. Similar to Nelco SI glass.
  - Reference Isola Laminate Systems. www.isola-usa.com

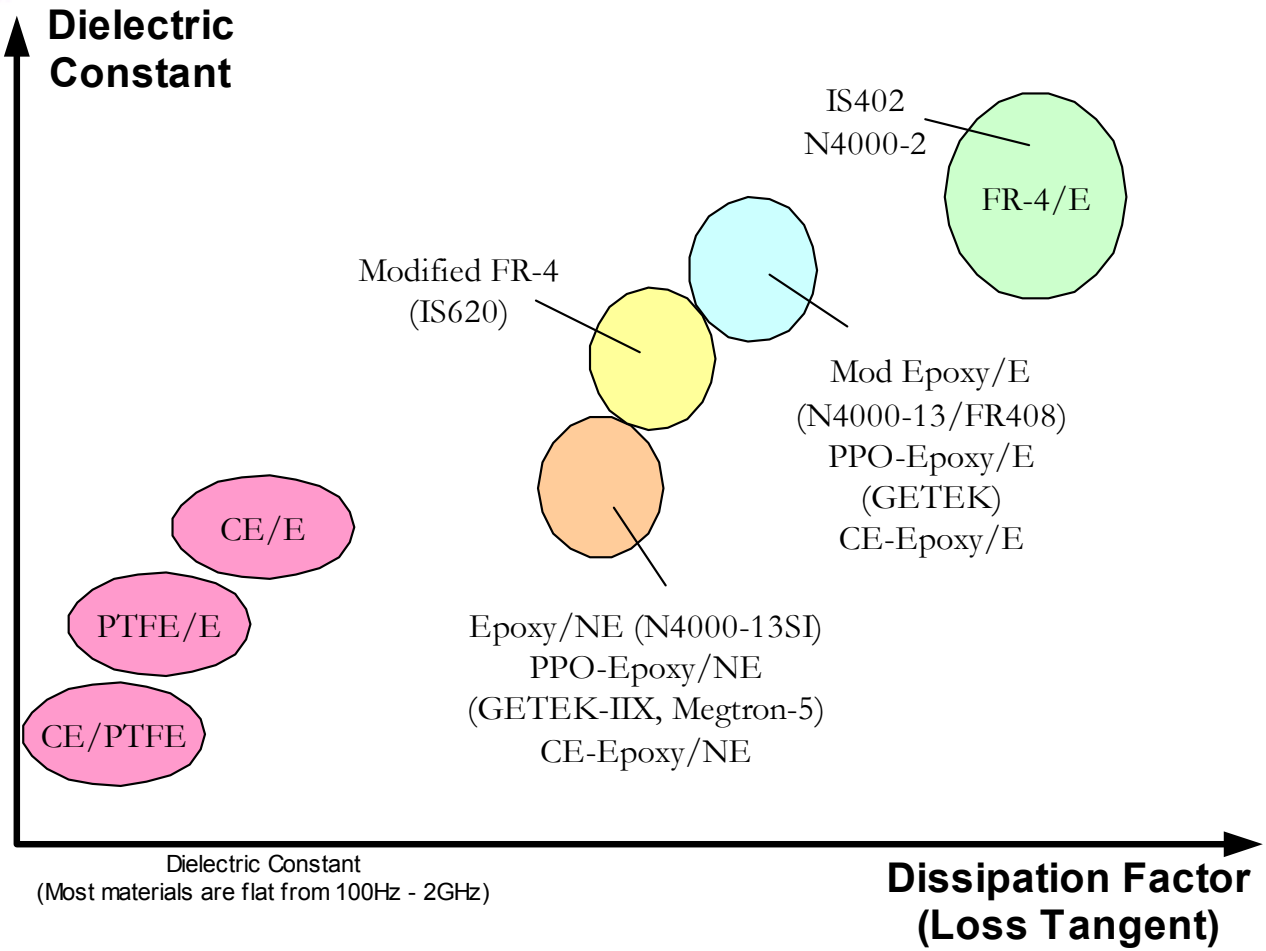
Materials NOT Classified as FR-4

- BT/Epoxy (Isola G200 or N5000-30/32). Typical Dk of 4.1 to 4.4.
  - Reference Park Nelco. www.parknelco.com or www.isola-usa.com
- Polyimide (Isola P95 or N7000). Typical Dk of 3.8 to 3.9.
  - Reference Park Nelco. www.parknelco.com or www.isola-usa.com
- PTFE (Taconic TLT or N9000-13/N9000-13RF). Typical Dk of 3.0 to 3.5 but very low Df.
  - Reference Park Nelco. www.parknelco.com or www.isola-usa.com
- CE (N8000). Typical Dk 3.5 to 3.7.
  - Reference Park Nelco. www.parknelco.com
- GIL (MC3D)

Materials NOT Classified as FR-4

- BEND/flex (Rogers BEND/flex 2400)
  - Reference www.rogerscorporation.com
- Kapton (Dupont Pyralux LF)
- Rogers non-PTFE 4003/4350. Typical Dk of 3.38 to 3.48 but very low Df
  - Reference www.rogerscorporation.com/mwu/pdf/ro4000ds_4.pdf

Materials in Perspective



- Graph provided by Zhi Wong zwong@altera.com

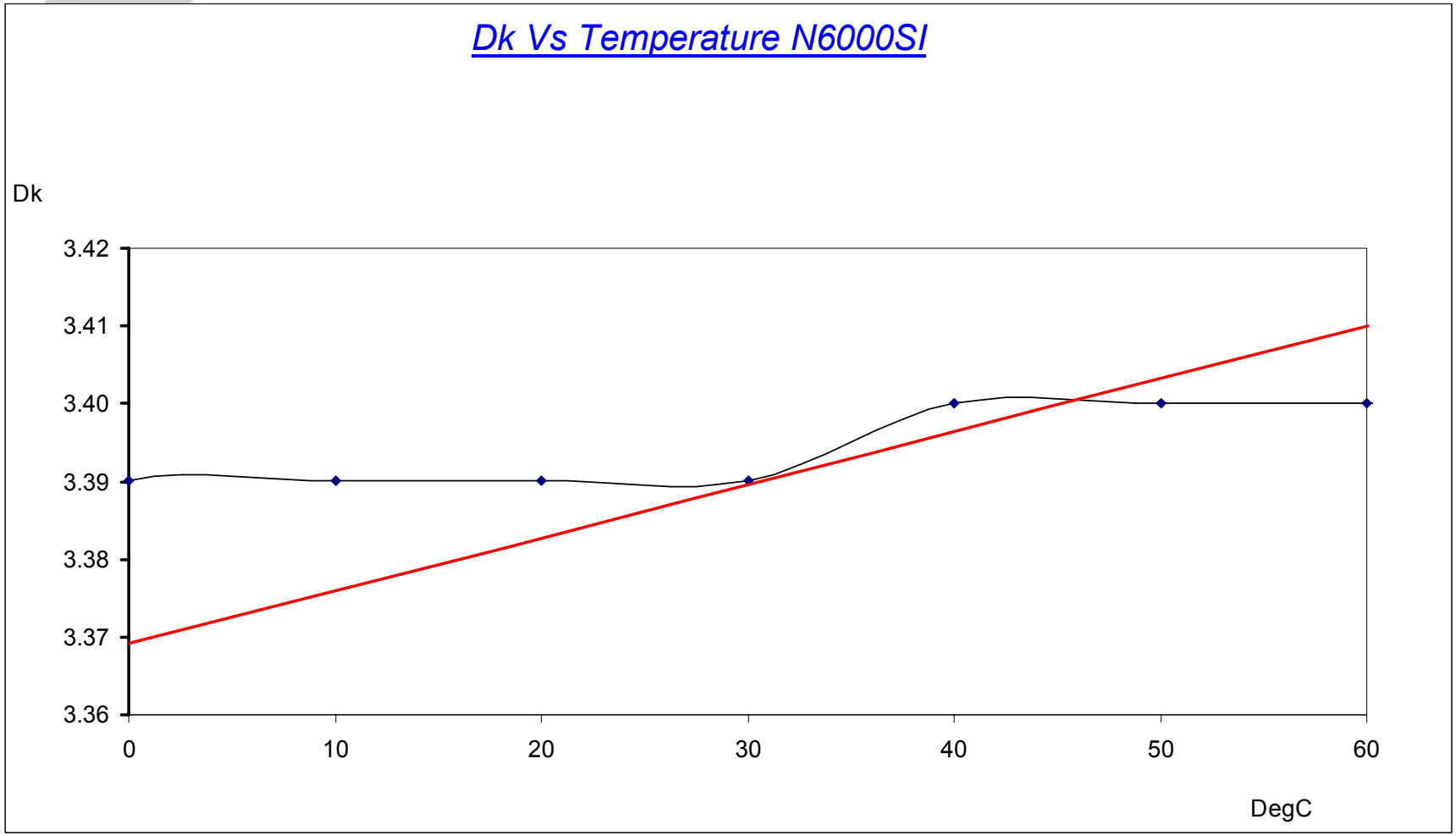
My Thoughts on Classification

- FR-4 (Low Resolution Signal Integrity):
  - Dk@2Ghz 3.9 to 4.7
  - Df@2Ghz .015 to .022
- Improved FR-4 (Mid Resolution Signal Integrity):
  - Dk@2Ghz 3.1 to 3.9
  - Df@2Ghz .008 to .015
- Supper FR-4 or Ceramics (High Resolution Signal Integrity):
  - Dk@2Ghz 2.4 to 3.1
  - Df@2Ghz .002 to .008
- Note: classes above to be defined at 1, 100, 1000, 2000, 5000, 10000, 15000 and 20000 Mhz. 2Ghz is shown for reference.

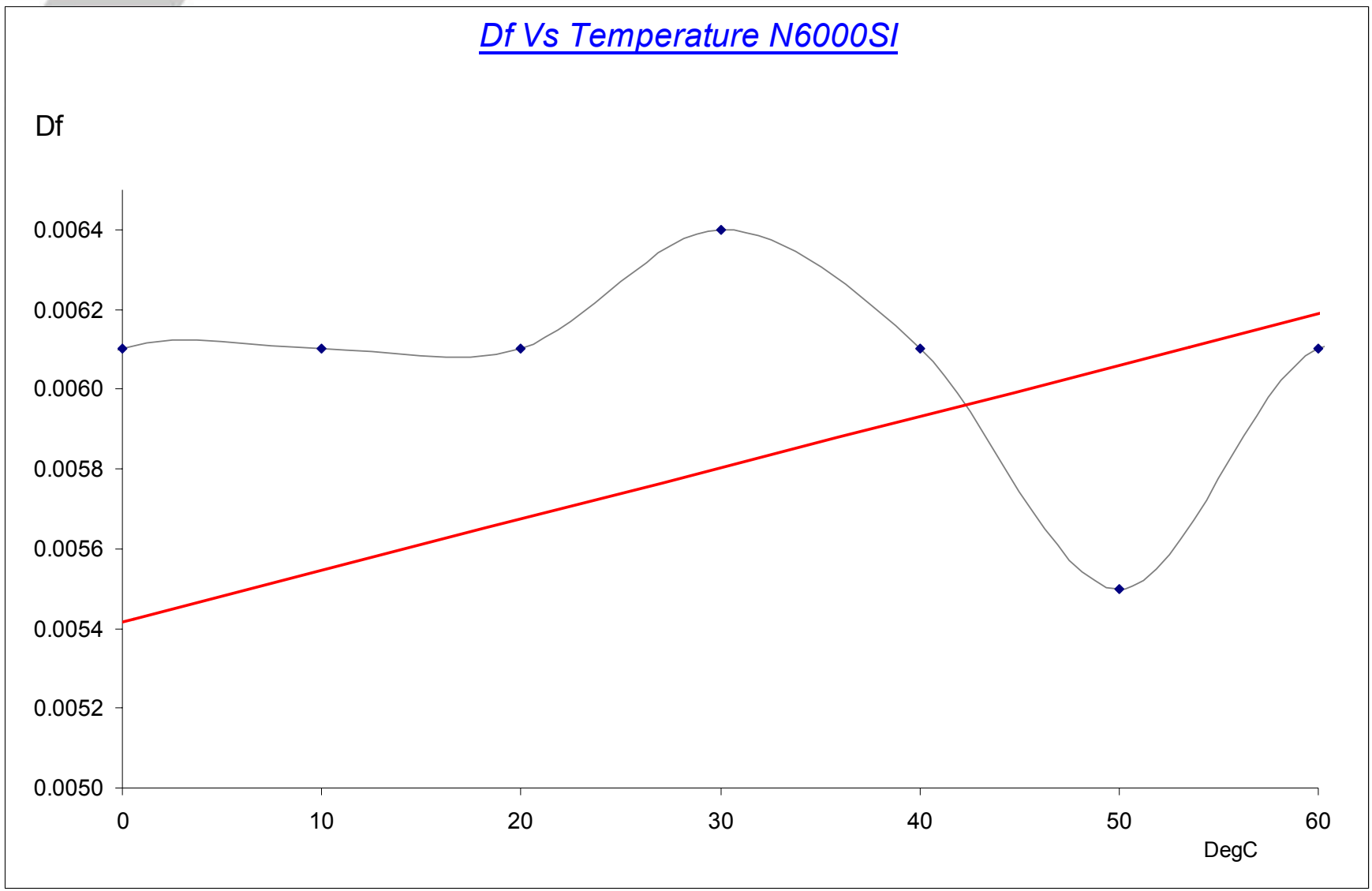
Temperature Effects Observations

- Fitted lines in red are from a -40 to +90 DegC temperature range.
- Data Collected with same trace width.
- Glass construction includes the thinner styles.

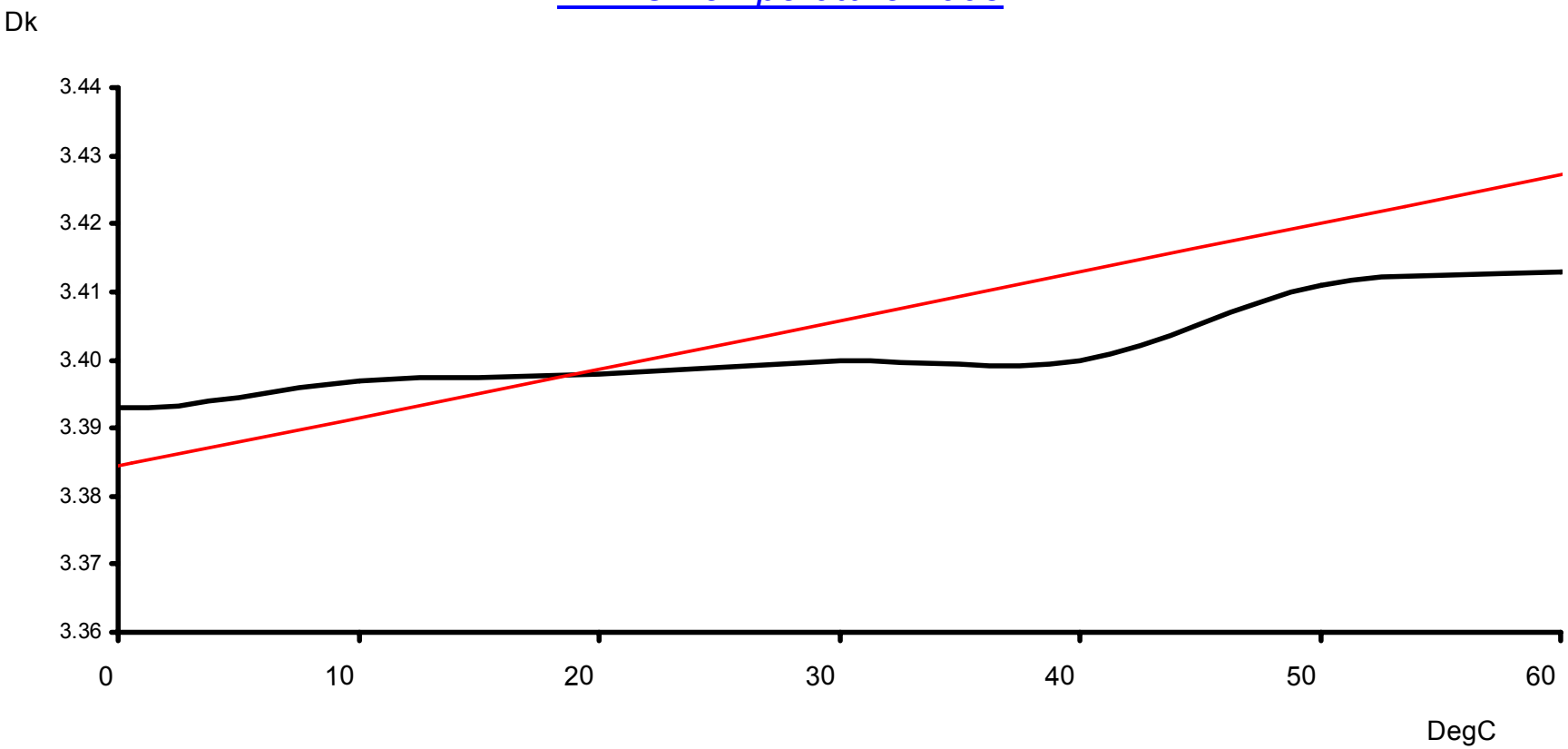
Temperature Effects at a Glance: N6000SI Dk



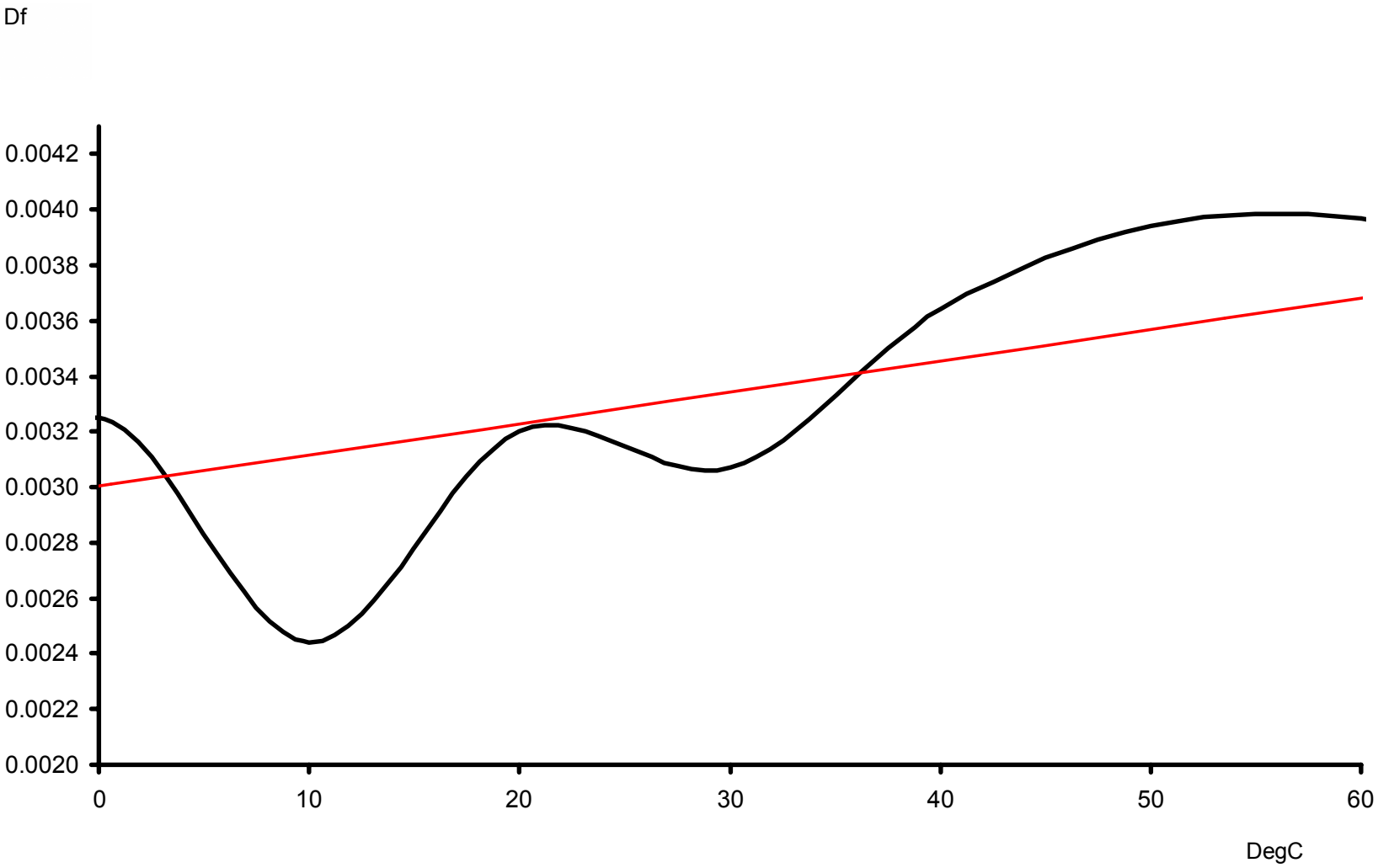
Temperature Effects at a Glance: N6000SI Df



Temperature Effects at a Glance: Rogers4003 Dk



Temperature Effects at a Glance: Rogers4003 Df



My Thoughts on 'Improved FR-4' in reference to IEEE802.3ap

- Improved FR-4 (Mid Resolution Signal Integrity):
  - 100Mhz: Dk ≤ 3.60; Df ≤ .0092
  - 1Ghz: Dk ≤ 3.60; Df ≤ .0092
  - 2Ghz: Dk ≤ 3.50; Df ≤ .0115
  - 5Ghz: Dk ≤ 3.50; Df ≤ .0115
  - 10Ghz: Dk ≤ 3.40; Df ≤ .0125
  - 20Ghz: Dk ≤ 3.20; Df ≤ .0140
- Temperature and Humidity Tolerance (0-55degC, 10-90% non-condensing):
  - Dk:+/- .04
  - Df: +/- .001
- Resin Tolerance (standard +/-2%):
  - Dk:+/- .02
  - Df: +/- .0005

Credits

- The following companies provided data and are listed because research was done in part with individuals or through web access. Direct quotes are referenced as such.
- Tyco
- TTM Technologies
- Sanmina-SCI
- Altera
- UL
- Isola
- Park Nelco