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Why are two set of Dk and Df need for?

We are on providing two sets of permittivity (Dk) and loss tangent (Df) for our principal high-frequency board material for designer’ s conveniences. One is measured by a balanced-type circular disk resonator (BCDR) method, and the other is extracted by a transmission line method (TLM) using microstrip lines (MSLs) with characteristic impedance of 50 ohm. Why is the two data sets needed? As a serious designer has already aware, the two sets of data are generally not coincide and generally show different frequency dependencies as shown in the figure, therefore, he or she should use the two set of data properly according to the situation.

Electric fields in a BCDR is widely spreading out in the resonator and polarizing strictly perpendicular to the circuit board under test. Accordingly extracted Dks and Dfs by the method are quite accurate for the electric fields with such field distribution and polarization, and they can be considered as volume averaged values of materials consisting of the board. Designers can determine from this data whether the board material is adequate for their purpose at coarse design. However, the data isn’ t suitable for detailed design. As is well known that electric fields propagating through all planar transmission lines are generally not perpendicular to a board and localized near the lines. Therefore, RF properties of the measured and of designed using the BCDR data occasionally show discrepancies. This is the reason why we provide the data by a TLM. If a board designer designs RF circuits or antennas with microstrip lines using the TLM data, it is expected that the discrepancy becomes much small.

TLM data we provide is every 10 GHz, up to 110 Hz. It is extracted by a numerical fitting by an electromagnetic simulation basing on a finite element method to measured S-parameters for a test coupon with microstrip lines (Details of the measurement were reported in the previous white paper. Please consult it if interested in). As mention above, TLM data generally shows slightly different values from that by our BCDR method, because that the Dk and Df extraction are performed with respect to the quasi-TEM mode supported by microstrip lines, and because that electromagnetic fields are easy to be influenced by non-uniformity of permittivity in the board since they concentrate at quite narrower area nearby strips than BCDR modes.

In addition, we would like to mention that designers should pay attention to the board thickness when using TLM data for designing RF circuits and antennas, especially when the thickness of the board under design is much thicker than 4 mil which is the TLM test coupon thickness, or when design frequencies are higher than about 80 GHz. As is already thoroughly analyzed in the early literature [1],[2] about microstrip line behaviors, the quasi-TLM mode is easily coupled to surface wave modes (especially to the lowest TM-mode, TM0), if using the thick board at higher frequency than a threshold frequency which is a function of the width of the strip, the thickness and the Dk of the board. Then, the quasi-TLM and the surface wave TM0-mode become a mixed-mode slightly polarizing along to propagating direction. And it has been found that the mixed-mode always shows large Dk for quasi-TLM mode. In order to analyze the mixed-mode, full-wave analysis hypothesizing a large board is indispensable, however, is much time-consuming. Therefore, TLM date we provides are extracted one with respect to the quasi-TEM mode. If using a thick board, for example, in order for realizing a high radiation efficiency for microstrip antennas, re-extraction of a true Dk for the board might be demand to a board designer. We of course do know this process is very time consuming work, so please consult us when performing accurate RF design.

References:

[1] C.P. Hartwig, D. Masse and R.A. Pucel, "Frequency Dependent Behavior of Microstrip", G-MTT International Microwave Symposium, pp. 110-116, 1968-May, DOI: 10.1109/GMTT.1968.1123419.

[2] H.A. Wheeler, “Transmission-Line Properties of Parallel Strips Separated by a Dielectric Sheet,” IEEE Trans. Microw. Theory Tech., MTT-13, Issue: 2, pp. 172 – 185, Mar 1965, DOI: 10.1109/TMTT.1965.1125962.

Figure: Frequency dependencies of Dks for Megtron7 (GN, 4 mil) extracted by a TLM and a BCDR method. A fitted curve is overlaid in order for clarifying the dispersion by the TLM. It can be seen that Dks by BCDR behave flatter and show larger than by TLM, and that those by TLM are increasing as the frequency becomes higher. The former is because of the deference of electromagnetic modes used for Dk extraction between the two methods, and the latter is caused by the mode coupling of the TLM quasi-TEM mode with the surface wave TM0-mode.