Panasonic introduces an innovative test methodology for accurately characterizing PCB materials for high-speed communication system designs.

A precise knowledge of printed circuit board (PCB) dielectric constant (Dk) and loss tangent (Df) values in the 100 GHz range is essential information for circuit designers developing the next generation of wireless communication systems including 5G, automotive radar sensors, future high-speed data transmission systems. As a premier supplier of high-performance circuit board laminates, it is valuable for Panasonic to provide accurate Dk and Df data at high frequency bands to enable customer designs. In this vein, Panasonic is continually developing equipment and processes for evaluating high speed transmission properties and determining PCB Dk and Df values at frequencies up to 110 GHz.

Determining frequency-based insertion loss and time-delay behaviors for transmission lines, especially those with full-band and single-sweep from DC to 110 GHz, are some of the most basic criteria in determining if a PCBs design is suitable for the target application. This behavior is especially relevant for high speed data transmission applications, e.g., PAM4, because the time-domain propagation properties, namely signal integrity, mainly governs the data communication quality. One straightforward method for measuring printed circuit board skew with sub-nanosecond accuracy utilizes Fourier transformed S-parameters because are measured at fixed reference planes with fixed port impedance. For the present speed requirements, designing test coupons and controlling measurement environments that can control undesirable RF behaviors, e.g., electromagnetic resonances and couplings, is not overly complicated nor crucial for the application design. However, controlling RF interference is generally quite difficult in wide-band designs even now.

Panasonic uses standard microstrip and strip-line test coupons for evaluating material transmission properties. The circuit lines are measured using a 4-port semiconductor probe system based on the multi-line TRL calibration method, as shown Fig.1. However, extraction of the attenuation constant α[dB/m] and the wavenumber k[rad/m], (the direct data used to calculate the Dk and Df of the PCB under test), are performed using a

proprietary extraction method developed by Panasonic.

This new analytical method directly extracts both constants from measured S-parameters while assuming an equivalent circuit for the lines under test. This extraction method has the benefit that return losses, which are caused by the residual impedance mismatch between the probe and the line and which remain even after the calibration, never affect the extraction accuracy in principle. Therefore, the αs and the ks can be accurately determined even if the PCBs exhibit extremely low Df. A frequency dependency of the extracted attenuation constants for Panasonic R-5775(N) is shown in Fig.2. It can be observed that the data curve closely matches the theoretical behavior for distributed transmission lines up to 110 GHz.

The Dk and Df values of the PCB under test are extracted from the previously obtained αs and ks of the lines by a numerical optimization method based on electromagnetic simulation. To do this work manually can be time-consuming so Panasonic automated this process to assist design engineers. In addition, the surface roughness of the copper foils and the side-wall profiles of the circuit lines are incorporated into the Panasonic modelling process in order to improve the extraction accuracy for Dks and Dfs, since those parameters greatly influence the insertion loss and characteristic impedance of circuit traces, especially in millimeter-wave frequency bands.

As noted above, current high speed PCB materials and designs are now exhibiting sufficiently low Dfs, that the surface roughness of copper foil is becoming one of the dominant parameters determining data transmission speed, Therefore, estimating the influence of the copper roughness on the insertion loss becomes quite an important issue. Panasonic engineers are developing both apparatus and technologies for directly observing attenuation constants caused by copper roughness.

Panasonic believes that providing accurate mechanical and electrical performance information, including Dk and Df, for high speed circuit board laminates is critical in helping customers reduce the time and costs for developing future generations of high-speed communication systems.

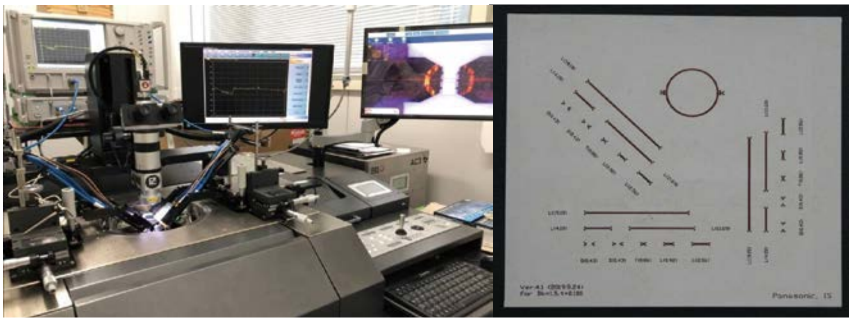

Fig.1 Panasonic 4-port probe system (LHS) and test coupon for microstrip line (RHS). These have the capability to evaluate transmission properties and to extract Dk and Df values of PCBs ranging from DC to 110 GHz.

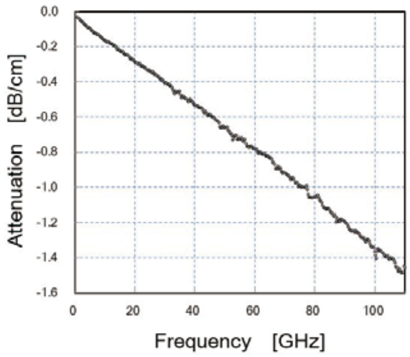

Fig. 2 Frequency behaviors of attenuation constants for a 50Ω microstrip line patterned on Panasonic R-5775(N) 100µm thick laminate with 18µm HVLP copper foil.