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Design Guide for RF/ Microwave Circuit Boards

Developed by the High Speed/High Frequency Design Task Group (D-21b) of the High Speed/High Frequency Committee (D-20) of IPC

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Users of this standard are encouraged to participate in the development of future revisions.

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1 GENERAL

1.1 Purpose The purpose of this document is to aid in the design of manufacturable microwave circuit boards. This document is not intended to include information relating to the detailed electrical design of microwave circuits. Rather, it is intended to include information from which practical, functional, and cost-effective circuit boards may be designed once the design engineer has determined the circuit requirements. The document also provides information on the manufacturing options available to the designer for the achievement of realistic and cost-effective circuit designs. This design aid is to be used by RF and microwave circuit design engineers, printed wiring board designers, packaging engineers, and drafters.

1.2 Scope This document addresses microwave circuitry. For the purpose of this document microwaves apply to radio waves in the frequency range of 100 MHz to 30 GHz. The document also applies to operations in the region where distributed circuits are used instead of conventional lumped circuit elements.

1.3 Terms and Definitions

Anisotropy The condition for a substance having differing values for properties, such as permittivity, depending on the direction within the material. Isotropy describes the case where a property is the same in all directions. Isotropy may exist in non-crystalline homogeneous (single phase) substances. In a microwave laminate based on a polymer composite, anisotropy of the dielectric layer exists.

***Characteristic Impedance* (Z_O)** A transmission line parameter dependent on the distributed series impedance per unit length and the distributed shunt admittance per unit length of the transmission line. The series impedance is given by $R + j\omega L$ and the shunt admittance by $G + j\omega C$, where R,L,G, and C are the resistance, inductance, conductance, and capacitance per unit length of the transmission line, j is $\sqrt{-1}$ and ω is the angular frequency. The characteristic impedance, Z_0, is the square root of the ratio of the impedance to the admittance.

***Coaxial Cable* (Coax)** A transmission line (see Transmission Line) structure where a round signal conductor centered coaxially inside a round tubular return (ground) conductor. The inside diameter of the return conductor is greater than the outside diameter of the signal conductor.

***Coefficient of Thermal Expansion* (CTE)** The linear dimensional change of a material per unit change in temperature.

Copper Weight The mass of copper per unit area for a foil. The copper foil industry typically expresses weight in ounces per square foot (oz/ft^2). A copper foil weight of 1 oz/ft^2 corresponds to a nominal 34 µm [1350 µin] thickness. This designation is being replaced by thickness in micrometers (µm). (See IPC-4562.)

Copper Thickness The thickness dimension of the copper cladding on a laminate.

Dielectric A material that has a zero or nearly zero electrical conductivity.

Dielectric Constant See definitions of Relative Permittivity, Static Relative Permittivity, and Effective Permittivity.

Dielectric Thickness Thickness dimension of the dielectric of the laminate averaged over an area.

Directional Coupler A device or structure which causes some of the energy propagating along one transmission line to be transferred to a second transmission line so that most of the transferred energy propagates in a specific direction along the second line. The other direction is considered isolated. At lower frequencies this function can be accomplished in a design with lumped capacitive and inductive elements while at microwave frequencies two stripline or microstrip traces that run parallel to each other for a certain distance can serve the purpose. One use for such devices is to sample amplitude or phase of a signal traveling in a specific direction.

Directivity The difference between the isolation and the coupling values of a directional coupler.

Dissipation Factor The ratio of loss current to charging current. The dissipation factor or loss tangent, $\tan\delta$, is given by $\varepsilon''/\varepsilon'$, where ε' and ε'' are the real and imaginary parts of the permittivity (see Permittivity). The loss tangent is a parameter used to express the tendency of insulators or dielectrics to absorb some of the energy in an ac signal.

Distributed Component An electrical component with dimensions greater than or on the order of the wavelength of the propagating signal. The reactive and resistive electrical characteristics of such a component are said to be distributed.

***Effective Permittivity* (effective dielectric constant or $\varepsilon_{r,eff}$)** The permittivity of a mixed media configuration, such as air and the solid dielectrics used in microstrip, that has the equivalent electromagnetic wave propagation characteristics of a single dielectric medium.

Ground Plane An electrically conductive metal layer within a printed wiring board that provides a low inductance ground reference (return path) for signal conductors