Technology Brief 3: Microwave Ovens

Percy Spencer, while working for Raytheon in the 1940s on the design and construction of ***magnetrons*** for radar, observed that a chocolate bar that had unintentionally been exposed to microwaves had melted in his pocket. The process of cooking by microwave was patented in 1946 and by the 1970s, microwave ovens had become standard household items.

Microwave Absorption

A microwave is an ***electromagnetic wave*** whose frequency lies in the 300 MHz–300 GHz range (see **Fig. 1-16**). When a material containing water is exposed to microwaves, the water molecule reacts by rotating itself in order to align its own ***electric dipole*** along the direction of the oscillating electric field of the microwave. The rapid vibration motion creates heat in the material, resulting in the conversion of microwave energy into thermal energy. The absorption coefficient of water, $\alpha(f)$, exhibits a microwave spectrum that depends on the temperature of the water and the concentration of dissolved salts and sugars present in it. If the frequency f is chosen such that $\alpha(f)$ is high, the water-containing material absorbs much of the microwave energy passing through it and converts it to heat. However, this also means that most of the energy is absorbed by a thin surface layer of the material with not much energy remaining to heat deeper layers. The penetration depth δ_p of a material, defined as $\delta_p = 1/2\alpha$, is a measure of how deep the power carried by an EM wave can penetrate into the material. Approximately 95% of the microwave energy incident upon a material is absorbed by the surface layer of thickness $3\delta_p$. **Figure TF3-1** displays calculated spectra of δ_p for pure water and two materials with different water contents.

► The frequency most commonly used in microwave ovens is 2.45 GHz. The magnitude of δ_s at 2.45 GHz varies beween $\sim$2 cm for pure water and 8 cm for a material with a water content of only 20%. ◄

This is a practical range for cooking food in a microwave oven; at much lower frequencies, the food is not a good absorber of energy (in addition to the fact that the design

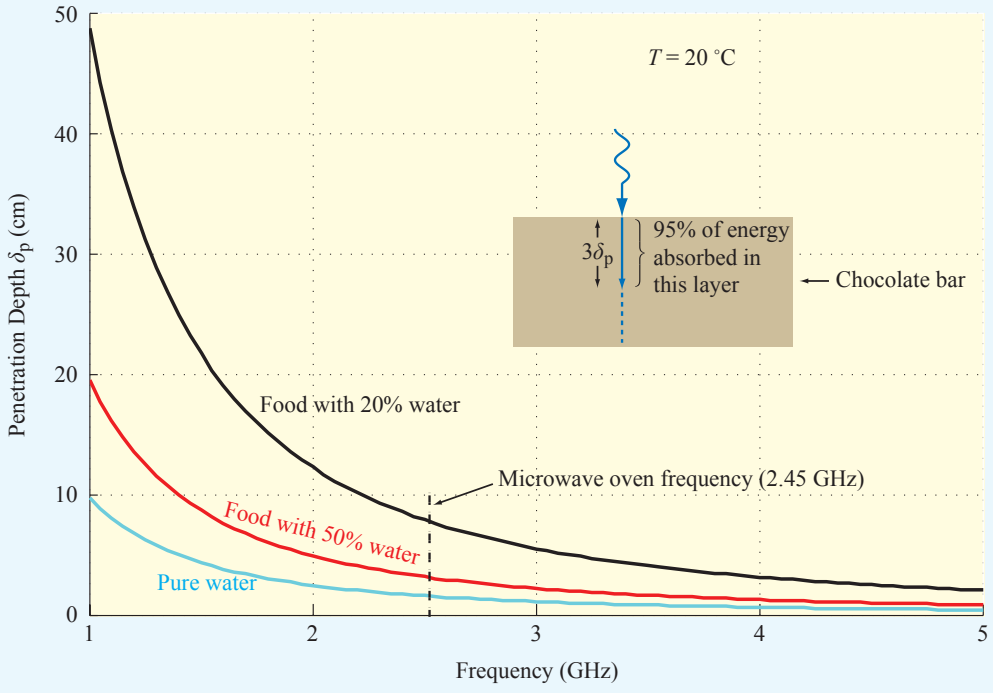

Figure TF3-1 Penetration depth as a function of frequency (1–5 GHz) for pure water and two foods with different water contents.