Table 5.1 *Dielectric permittivity of materials at 1.5 GHz*

Material	Dielectric permittivity
Vacuum	1
Air	1.0005
Fresh water	$78.54 \times [1 - 4.579 \times 10^{-3}(T - 25)]$
Fresh water ice	3.2
Quartz	4–6
Granite	5

A variety of equations have been proposed to compute the water content from knowledge of the soil bulk dielectric permittivity (Topp *et al.*, 1980; Ledieu *et al.*, 1986; Roth *et al.*, 1990; Malicki *et al.*, 1996). Ledieu *et al.* (1986) proposed

$$\theta = 0.1138\sqrt{\epsilon_b} - 0.1758 \tag{5.10}$$

where ϵ_b is the measured bulk dielectric permittivity. Malicki *et al.* (1996) included bulk density in the following equation for water content:

$$\theta = \frac{\sqrt{\epsilon_b} - 0.819 - 0.168\rho_b - 0.159\rho_b^2}{7.17 + 1.18\rho_b} \tag{5.11}$$

where ρ_b is the bulk density [g cm^{-3}].

A different approach was proposed by Roth *et al.* (1990), by using a dielectric mixing model. This model is based on the same idea of the model used for thermal conductivity presented in Chapter 4, where the soil thermal conductivity is given by a weighted sum of the thermal conductivities of its components. Indeed, the de Vries (1963) model for thermal conductivity was developed by considering a dielectric model for a mixture of granules. The dielectric mixing model therefore computes the bulk dielectric permittivity as a weighted sum of the dielectric permittivity of each soil constituent:

$$\epsilon_b = (\phi_s\epsilon_s^\alpha + \theta\epsilon_l^\alpha + \phi_g\epsilon_g^\alpha)^{1/\alpha} \tag{5.12}$$

where ϕ_s, θ and ϕ_g are the solid-, liquid- and gas-phase volumetric fractions. The corresponding dielectric permittivities are ϵ_s, ϵ_l and ϵ_g, while α is a geometrical parameter related to the geometrical orientation of soil particles with respect to the electromagnetic field. A default value of 0.5 was used as suggested by the authors. The volumetric solid fraction can be also written as $\phi_s = 1 - \phi_f$, where ϕ_f is the porosity and the volumetric fraction of the gas phase is $\phi_g = \phi_f - \theta$. Since the model is used to quantify water content,