

**Problem 7.19** Ignoring reflection at the air–soil boundary, if the amplitude of a 3-GHz incident wave is 10 V/m at the surface of a wet soil medium, at what depth will it be down to 1 mV/m? Wet soil is characterized by  $\mu_r = 1$ ,  $\epsilon_r = 9$ , and  $\sigma = 5 \times 10^{-4}$  S/m.

**Solution:**

$$E(z) = E_0 e^{-\alpha z} = 10 e^{-\alpha z},$$
$$\frac{\sigma}{\omega \epsilon} = \frac{5 \times 10^{-4} \times 36\pi}{2\pi \times 3 \times 10^9 \times 10^{-9} \times 9} = 3.32 \times 10^{-4}.$$

Hence, medium is a low-loss dielectric.

$$\alpha = \frac{\sigma}{2} \sqrt{\frac{\mu}{\epsilon}} = \frac{\sigma}{2} \cdot \frac{120\pi}{\sqrt{\epsilon_r}} = \frac{5 \times 10^{-4} \times 120\pi}{2 \times \sqrt{9}} = 0.032 \text{ (Np/m)},$$
$$10^{-3} = 10 e^{-0.032z}, \quad \ln 10^{-4} = -0.032z,$$
$$z = 287.82 \text{ m}.$$

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