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# PRELIM 1

**1.** For an RG058-model coaxial cable, given with a=0.9 mm, b= 2.95 mm, $\varepsilon_r$=2.3 , find:

**(a)** The characteristic impedance and wave velocity in the TEM mode.

$$Z_c = \frac{1}{2\pi}\sqrt{\mu/\varepsilon}\,\ln(b/a) \cong 46{,}97\,\Omega$$

$$V_p = c/\sqrt{\varepsilon_r} \cong 1{,}98 \cdot 10^8\ m/s$$

**(b)** The propagation time of a 1-ns pulse in a 10-m long section of this coaxial cable.

$$t_p = 10/V_p \cong 50nsec$$

**(c)** The phase accumulation vs. frequency (the term kz in Eqs. 1a, b), in the range 0 – 6 GHz.

**(d)** How the results above would be changed for b= 4 mm and for $\varepsilon_r$ = 4?

$$\rightarrow Z_c = 44{,}7\,\Omega \qquad V_p = 1{,}5 \cdot 10^8\ m/s$$

$$t_p = 66nsec$$

from the above formulas

**2.** For a rectangular waveguide, given with a=100 mm, b= 50 mm, find:

**(a)** The dispersion relation in the TE10 mode, also in a graph as in Fig. 3.

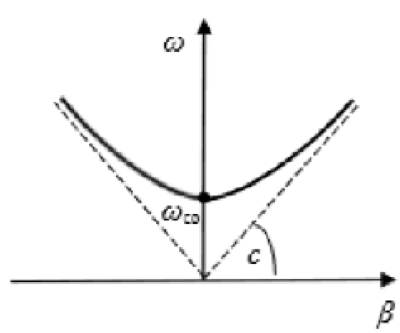



Figure 3: The dispersion relation of a rectangular waveguide in the $TE_{10}$ mode.

for the first mode:

$$K_{10} = \sqrt{\mu\varepsilon\omega^2 - \left(\frac{\pi}{a}\right)^2}$$

$$\beta_{10} = \sqrt{\left(\frac{\omega}{c}\right)^2 - \left(\pi/a\right)^2}$$

**(b)** The cutoff frequency and wavelength (how the latter relates to the waveguide width?)

$$\omega_{co} = \frac{\pi c}{a\sqrt{\varepsilon_r}} = 2\pi f_{co} \qquad \begin{cases} \varepsilon_r = 1 \\ c = 3\cdot 10^8\ m/s \\ a = 0{,}1\,m \end{cases}$$

$$f_c = 1{,}5\,GHz$$

$$\lambda = c/f_{co} = 0{,}2\,m = 200\,mm$$

**(c)** Repeat (a) and (b) for the second higher mode(s).

For the $2^{nd}$ higher mode $= TE_{20}$. $\beta_{20} = \sqrt{\left(\frac{\omega}{c}\right)^2 - \left(\frac{2\pi}{a}\right)^2}$

$$\omega_{co} = 2\pi c/a = 6\pi\cdot 10^9$$

$$f_{co} = \frac{\omega_{co}}{2\pi} = 3\,GHz$$

$$\lambda = \frac{c}{f_{co}} = 0{,}1\,m = 100\,mm$$

**(d)** This waveguide is now truncated to a length of 1 m with perfect mirrors, to form a rectangular cavity (as in Fig. 4). What would be the resonance frequencies of this cavity? Where would these frequencies appear on the dispersion diagram?

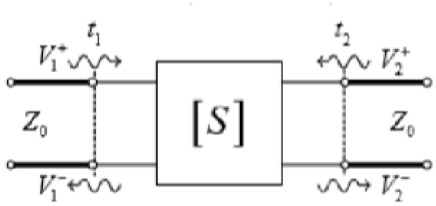
$$\omega_n = c\sqrt{(\pi/a)^2 + (n\pi/L)^2} \qquad L = 1\,m$$

Fig 4 $\rightarrow n = 3$ $\quad \omega_3 = 3\cdot 10^8 \sqrt{(10\pi)^2 + (3\pi)^2} \simeq 9{,}84\,GHz$

**3. Present the general form of a 2-port scattering matrix, and explain its various terms.**

Scattering matrix may be helpful to know that as voltage and current are to electrical circuit analysis, S parameters are to microwave network analysis. S parameter are formed from ratios of reflected and incident voltage wave amplitudes.

$$\left[V^-\right] = \left[S\right]\cdot\left[V^+\right]$$



$S_{11}$ can be written as the ratio of reflected wave and incident wave.

$$S_{11} = \frac{V_1^-}{V_1^+}, V_2^+ = 0$$

Therefore we obtain $S_{11} = \Gamma_{11}$ which is the voltage reflection coefficient at port 1.

$$S_{21} = \frac{V_2^-}{S_1^+}, V_2^+ = 0$$

With matched load at port 2 so $V_2^+ = 0$ then $S_{21} = \Gamma_{21}$ which is the voltage transmisson coefficient from port 1 to 2.

**4. Describe the VNA functions in general, and explain its calibration procedure.**

Vector Network Analyzer (VNA) is an instrument that measures the network parameters of electrical networks. VNA commonly measure s–parameters because reflection and transmission of electrical networks are easy to measure at high frequencies, but there are other network parameter sets such as y-parameters, z-parameters, and h-parameters. Network analyzers are often used to characterize two-port networks such as amplifiers and filters.

**5. What would you expect to get as $S_{11}$ for the cavity given in Question 2(c) above?**

Expect to get $S_{11}$=0 since input port is matched therefore there is no reflected wave.

**6. The formulae in Eqs. (6, 7) enable the analysis of a given micro-strip line (given the dimensions and dielectric fill, one can find the effective impedance and wave velocity). However, for the design of a micro-strip line, the desired impedance and wave velocity are known, but the line dimensions and dielectric fill shall be found. Find alternative equations and graphs for the design of a micro-strip line.**

**7. Given a dielectric fill for a micro-strip line of $\varepsilon_r$= 2.1 and h=82 mm, find the strip width w in order to realize a 50 Ω micro-strip line. What would be eff ε in this case?**

and for $w/h > 1$ by

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2 \cdot \sqrt{1 + 12h/w}}, \qquad Z_c = \frac{120\pi}{\sqrt{\varepsilon_{\text{eff}}}\left[\frac{w}{h} + 1.393 + \frac{2}{3}\ln\left(\frac{w}{h} + 1.444\right)\right]}.$$

$$w = 3.208 * 8.2\,x\,10^{-3} = 0.026[m]$$

$$\varepsilon_{eff} = 1.802$$