Transmission basics 2

[AN1051, rosu, bahl]

- A line *must* be considered transmission line if

$$2 \times T_{PD} \times \text{ trace length} > T_R \text{ or } T_F \text{ (minimum of the two)}$$

- main parameters:

$$Z_O = \sqrt{(L_O/C_O)}\ \Omega$$

$$T_{PD} = \sqrt{(L_O \times C_O)}$$

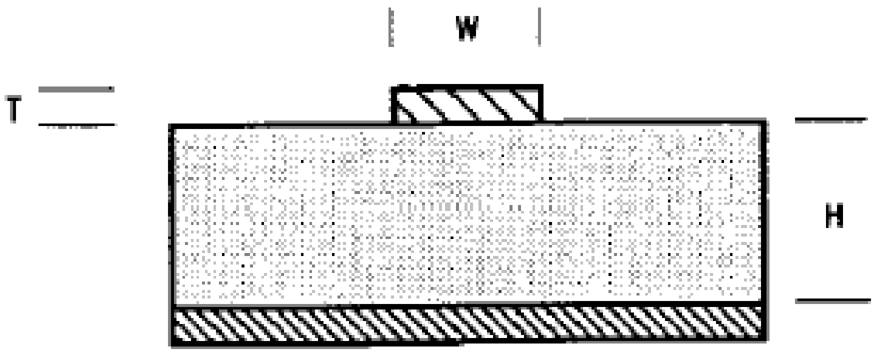
  - => $C_0 = T_{PD} / Z_0$
- T_{PD} depends only on ε_R, not on the geometry of the trace
  - of course, $T_{PD} = 1/ V_p$; with
    - ε_{r_eff} effective dielectric constant for microstrips
    - V_c speed of light in vacuum, 11.8 in/ns
      - so that in vacuum T_{PD} = 0.084 ns/in = 1.017 ns/ft

Signal speed on striplines: $V_{p\ (inner)} \approx \frac{Vc}{\sqrt{Er}} \approx \frac{11.8\ in/ns}{\sqrt{Er}}$

Signal speed on microstrips: $V_{p\ (outer)} \approx \frac{Vc}{\sqrt{Er_{eff}}} \approx \frac{11.8\ in/ns}{\sqrt{Er_{eff}}}$

PCB trace types

- Attention! In these slides, T_{PD} is in ns/ft!

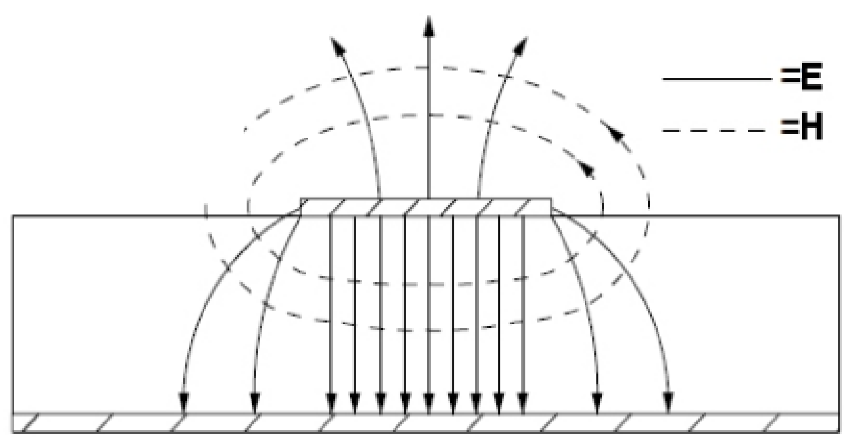


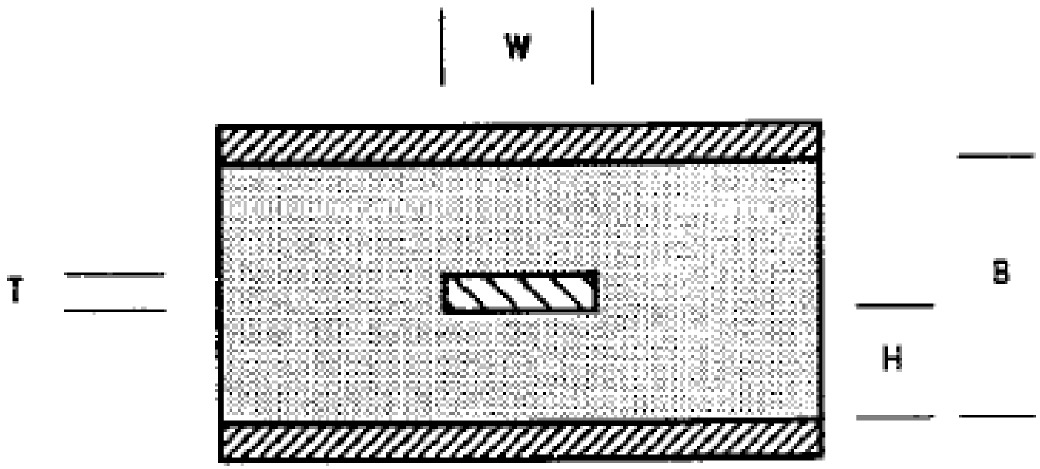
$$Z_O = \frac{87}{\sqrt{E_R + 1.41}} \ln\left\{\frac{5.98\ H}{0.8\,W + T}\right\}$$

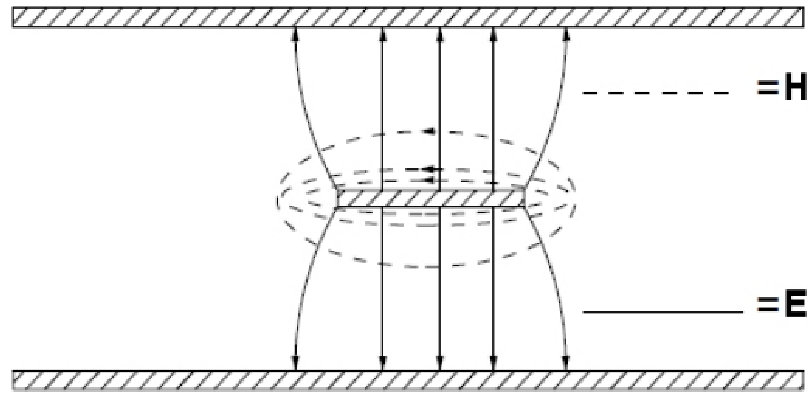
$$T_{PD} = 1.017\sqrt{0.475\,E_R + 0.67}$$

WHERE:
E_R = DIELECTRIC CONSTANT
H = DIELECTRIC THICKNESS
T = TRACE THICKNESS
W = TRACE WIDTH

(a) Surface Microstrip







Electric E and Magnetic H Fields

$$Z_O = \frac{60}{\sqrt{E_R}} \ln\left\{\frac{4B}{0.67\pi W\left(0.8+\frac{T}{W}\right)}\right\}$$

$$T_{PD} = 1.017 \times \sqrt{E_R}$$

WHERE:

E_R = DIELECTRIC CONSTANT

H = DIELECTRIC THICKNESS BETWEEN TRACE AND POWER/GROUND PLANE

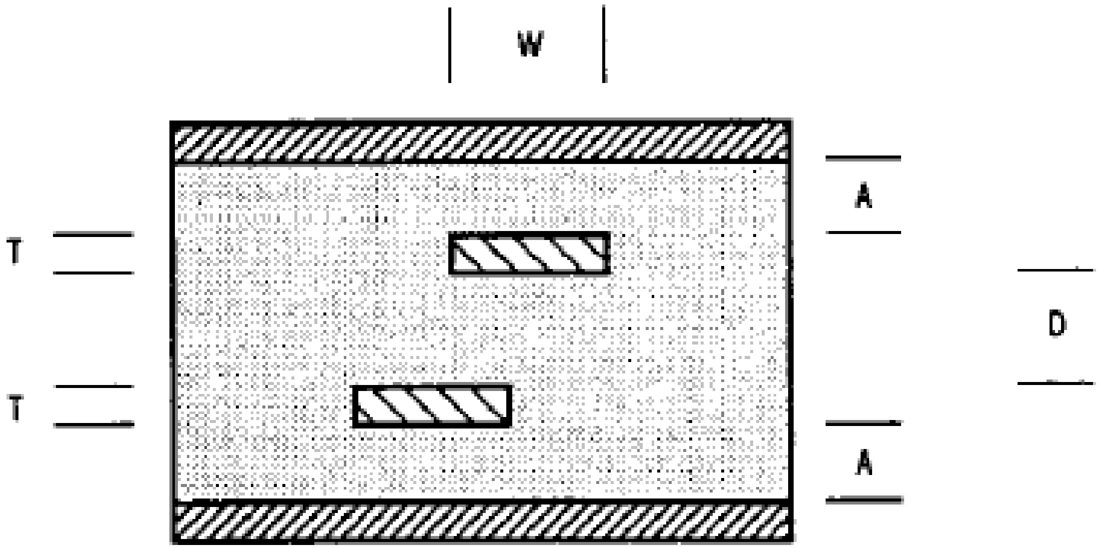
B = OVERALL DIELECTRIC THICKNESS

T = TRACE THICKNESS

W = TRACE WIDTH

VALID FOR $\frac{W}{(B-T)} < 0.35$ AND $\frac{T}{B} < 0.25$

(c) Stripline



$$Z_O = \frac{2\,Y\,Z}{Y + Z} \qquad \text{WHERE } Y = \frac{60}{\sqrt{E_R}} \ln\left\{\frac{8A}{0.67\,\pi\,W\left(0.8 + \frac{T}{W}\right)}\right\}$$

$$\text{WHERE } Z = \frac{60}{\sqrt{E_R}} \ln\left\{\frac{8\,(A + D)}{0.67\,\pi\,W\left(0.8 + \frac{T}{W}\right)}\right\}$$

LEGEND:

- DIELECTRIC
- TRACE
- GROUND OR POWER PLANE

(d) Dual Stripline

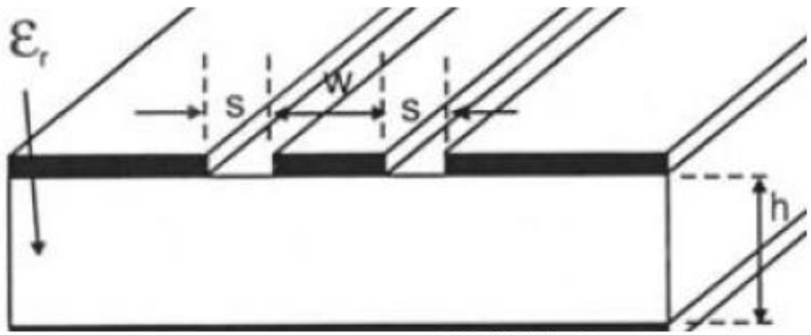
$$T_{PD} = 1.017 \times \sqrt{E_R}$$

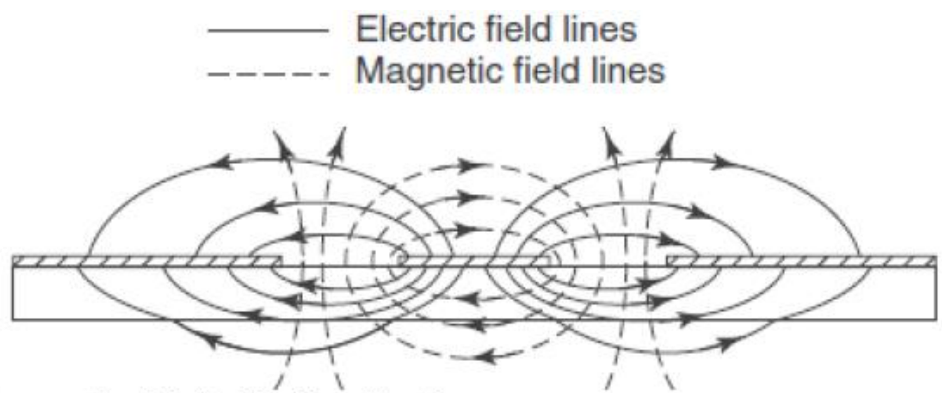
WHERE:

E_R = DIELECTRIC CONSTANT
H = DIELECTRIC THICKNESS BETWEEN TRACE AND POWER/GROUND PLANE
B = OVERALL DIELECTRIC THICKNESS
T = DIELECTRIC THICKNESS BETWEEN TRACES
W = TRACE WIDTH

These are two (independent) *offset* (or *asymmetric*) striplines (possibly orthogonal to each other to reduce crosstalk)

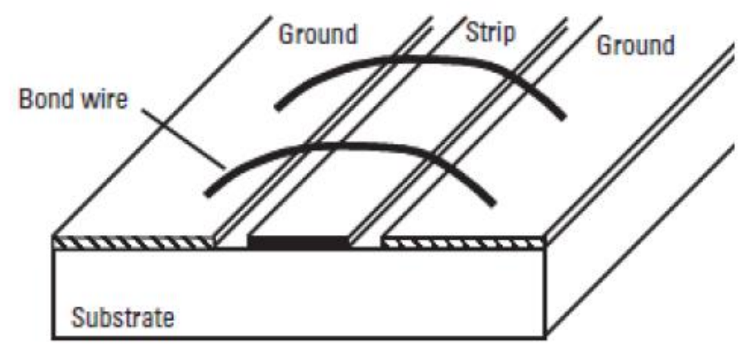
Coplanar waveguide (CPW)



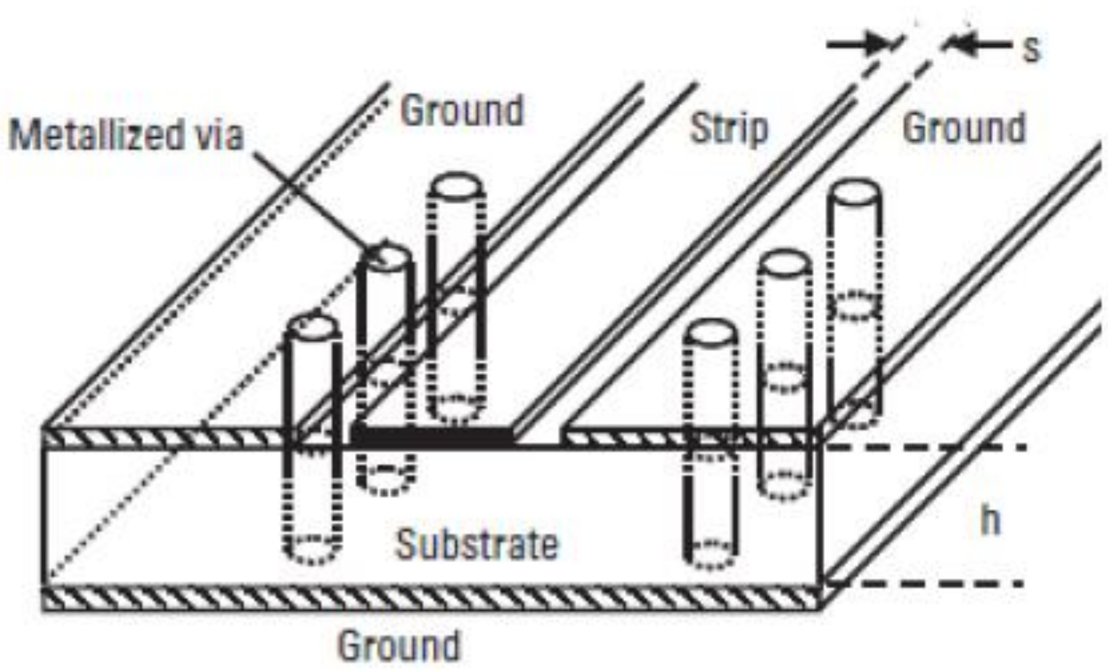


CPW Electric-E and Magnetic-H field distribution

CPW has two ground planes, which must be maintained at the same potential



Grounded coplanar waveguide (GCPW)



- used on printed circuit boards as an alternative to microstrip
- usually $s > h$, so GCPW field is concentrated between the strip and the substrate ground plane => GCPW behaves like a microstrip
- less prone to radiate and higher isolation than a microstrip

PCB impedence calculator

Fortunately, several tools do exist, e.g.

- https://www.multi-circuit-boards.eu/en/pcb-design-aid/impedance-calculation.html
- https://www.eeweb.com/tools/microstrip-impedance
- https://www.pcbway.com/pcb_prototype/impedance_calculator.html
- http://www.multek.se/index.php?page=trace-width-calculator-2

Device loading

- If there are devices along the line, their capacity (let C_D be their distributed capacity) loads it, so that T_{PD} and Z_0 are modified (C_D goes in parallel with C_O):

$$T_{PD}' = T_{PD} \times \sqrt{1+(C_D / C_O)}$$

$$Z_O' = Z_O / \sqrt{1+(C_D / C_O)}\ \Omega$$