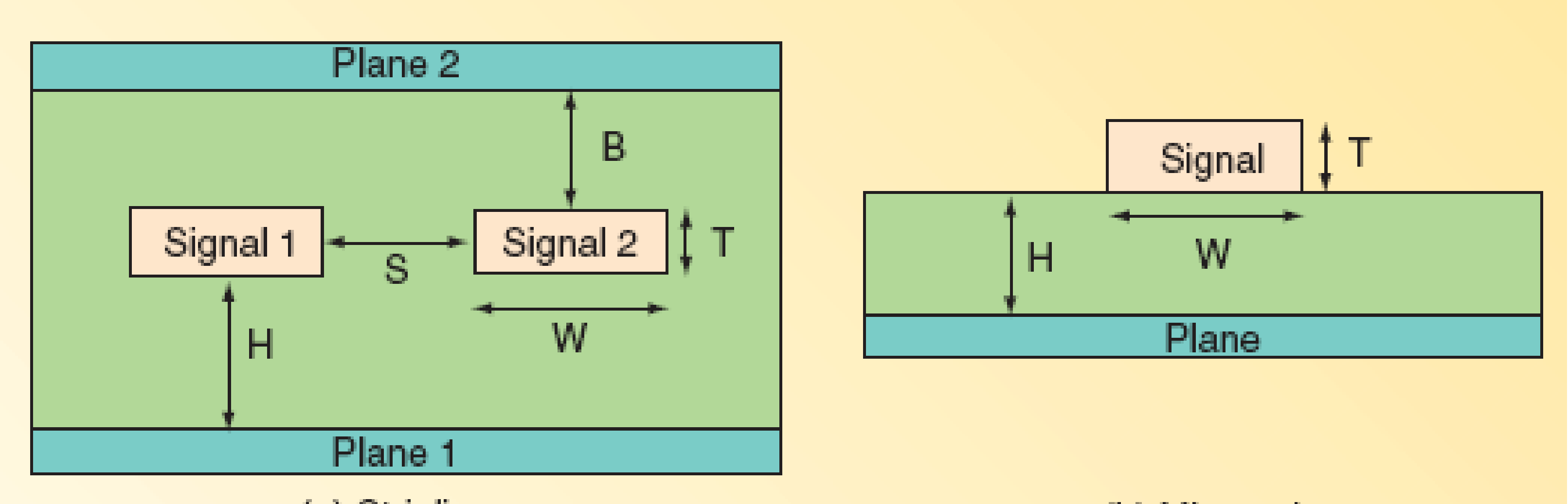
High speed design: introduction

[Sharawi_2004, AN-643, TI_SCAA082A]

Transmission line effects

- At high frequencies, copper traces behave as transmission lines; typically:
  - stripline
  - microstrip



(a) Stripline (b) Microstrip

Transmission line effects

- Stripline: most of the *E* and the *H* fields are contained within the two plane layers => not radiated outside
- Microstrips: some of the *E* and the *H* field lines get radiated outside => characteristic impedance and propagation delay may change
  - => routing the traces using the microstrip type is more critical

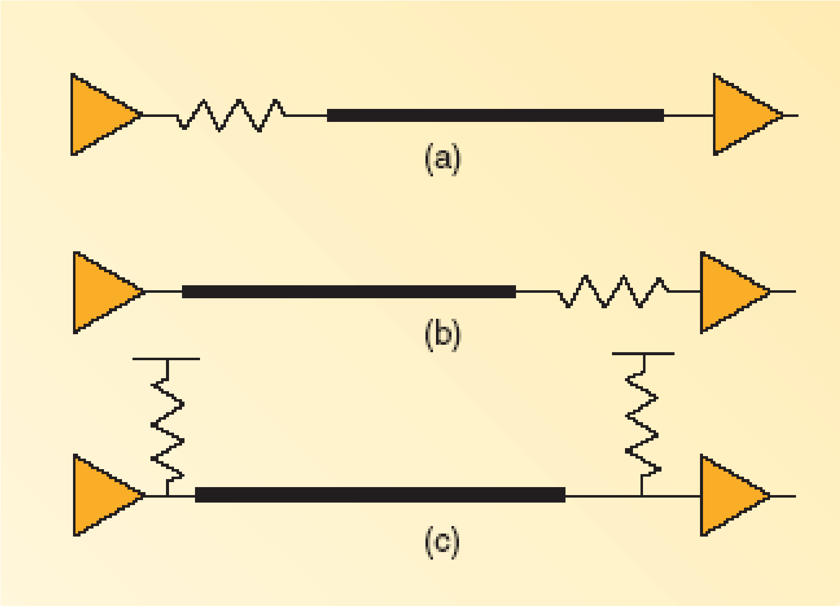
Transmission lines

- For any trace, we can compute

  - Z_0
  - τ_{prop}
  - R_{DC}
  - R_{AC} (due to the skin effect)
  - $R_{total}=(R^2_{DC}+R^2_{AC})^{1/2}$

Transmission lines

- Lines has to be terminated, in order to avoid reflections

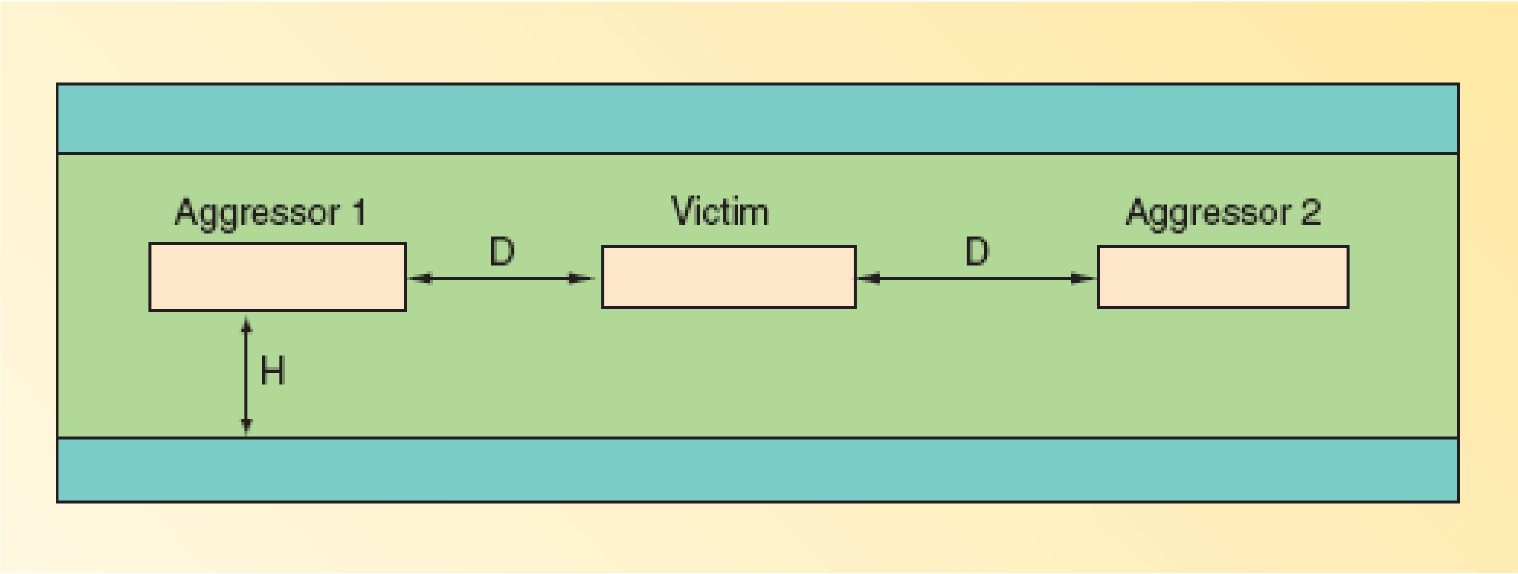


Coupling and crosstalk

- Two types of coupling between lines:

  - *capacitive coupling*: due to the electric field

  - *inductive coupling*: due to the magnetic field
- Coupling may generate *crosstalk*



Coupling and crosstalk

To reduce crosstalk:

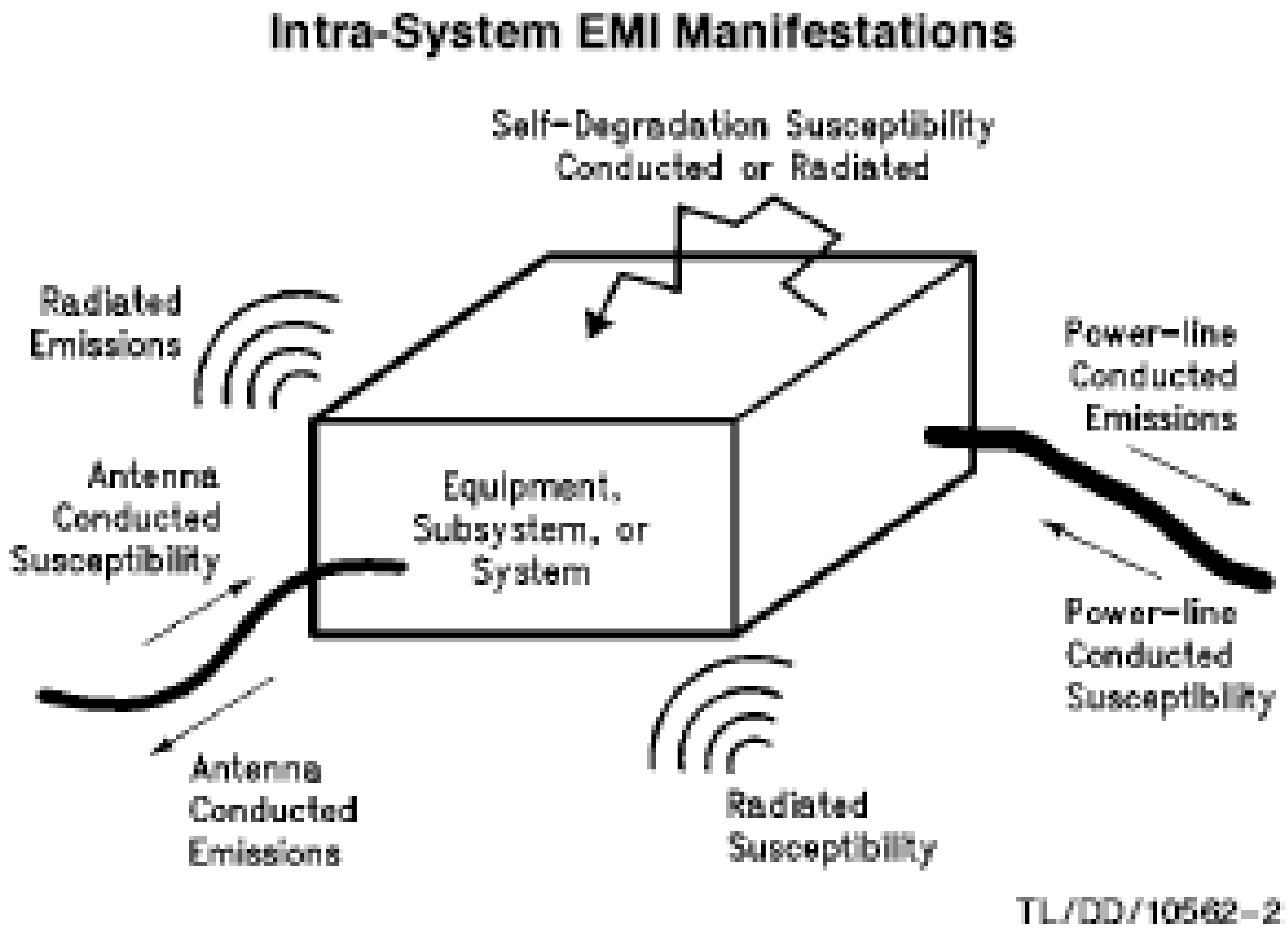
- one rule of thumb: increase the separation between adjacent traces
  - a 4*W* (i.e. 4 times the width of the trace) trace separation is usually a good margin
- minimizing the height from the reference plane (*H*) strongly couples the trace to its ground and minimizes mutual coupling
  - approximate formula for calculating the crosstalk percentage (*D*: distance between traces):

$$\%Crosstalk = \frac{1}{1+\left(\frac{D}{H}\right)^2}$$

Vias and interconnects

- A via is considered a discontinuity in the wave path, i.e. it has a different characteristic impedance and propagation delay. This difference affects the signal flow between the various layers.
- Connector models also contribute to the integrity of the design.
- To have a more accurate modeling of vias and connectors, it is usually best to use a 3D electromagnetic field solver

Electro-magnetic interference: EMI



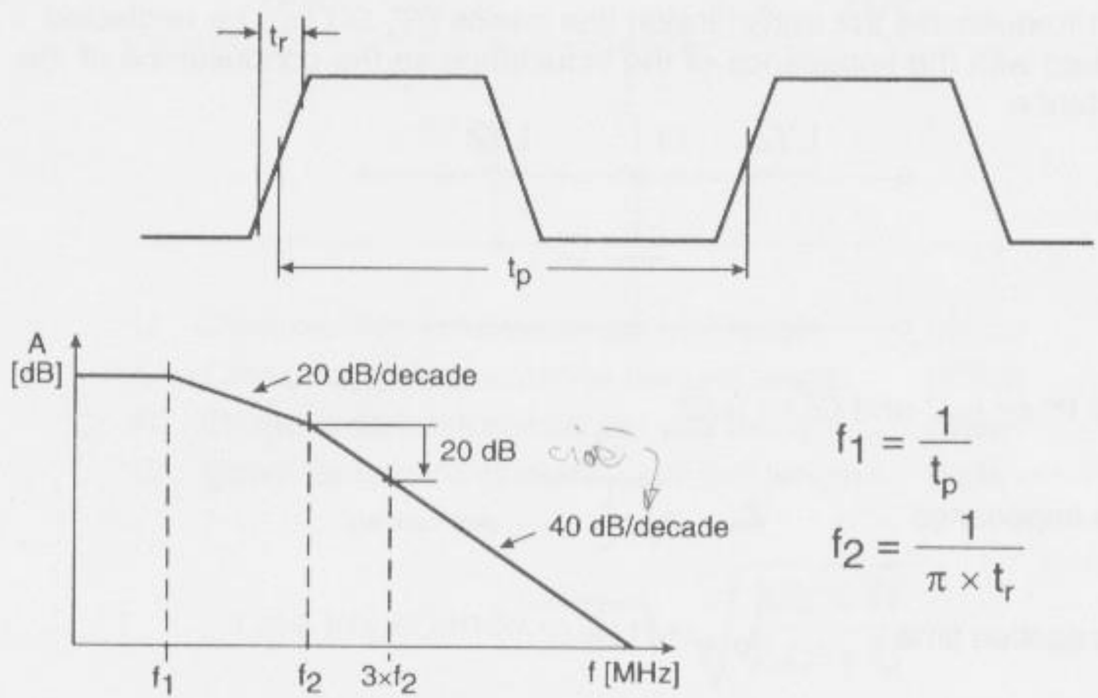
Single-ended transmission

- Advantages:
  - simplicity: minimum connections
  - low cost
- Disadvantages:
  - radiates RFI easily
  - poor noise immunity
  - limited line lengths and data rates due to susceptibility to interference signals
    - coaxial cable improves noise but is expensive

Differential (balanced) transm.

- Advantages:
  - high common mode rejection ratio
  - reduces line radiation – less RFI
  - improved speed capabilities
  - drive longer line lengths
- Disadvantages:
  - slightly higher costs (sometimes)
  - must be used with twisted pairs or other types of balances transmission lines

Frequency Spectrum of a Digital Signal



$$f_1 = \frac{1}{t_p}$$

$$f_2 = \frac{1}{\pi \times t_r}$$