Microwave-Frequency Board Design

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Overview

- High-frequency boards have problems low-frequency boards don't.
- Medium-speed:
  - Propagation time
  - Reflections
  - Termination

Overview

- High-speed:
  - Antenna effects
  - Resonance modes
- All of these had to be taken into account for the microwave-frequency test board.

Reflections

- Propagation time means signals take a while to settle
  - Typically about 0.5 C (15 cm/ns) and faster.
- Settling time depends on number of round-trips needed!

Reflections

- At each end of the line, a reflection occurs.
  - Reflection coefficient formula in handout.
- For unmatched lines, 10 or more reflections!
  - Worse for high-precision analog circuits.
  - Need to match source, load, and line impedance.

Reflections

- Impedance match with source or with load means at most one reflection.
  - Imperfect match results in many bounces!
  - Even a 10% error is significant.
- Impedance of transmission line must be known!
  - Microstrip waveguides typ. 50-120 Ohms.

Reflections Summary

- Reflections happen.
- Settling time without termination is about 10 round-trips at 15 cm/ns.
- Compensation requires well-known waveguide impedance, and source or load termination!

Antennas and Mode Effects

- Unshielded transmission line couples to the universe!
  - Broadcasts RF, and accepts RF interference.
  - Coupling between nearby lines (usually accidental).
  - Unshielded also has varying impedance if other traces are near it!

Antennas and Mode Effects

- Wavelength shorter than transmission line causes resonance modes.
  - Multiples of half-wavelength.
  - Causes spikes or notches in frequency domain transfer function.
  - Can enhance antenna transmission!
- Resonances are frequency-dependent!

Antenna/Mode Summary

- Unshielded waveguides radiate. Shield them.
- Traces longer than 0.5 wavelengths have modes. Keep them shorter if possible, expect transfer function weirdness if not.

Case Study: Microwave Board

- Microwave-frequency tests of CT3 chip needed.
  - Up to 20 GHz!
- Inputs and outputs at 50 Ohms. Chip connection traces at 120 Ohms.
  - Reflections hard to avoid!

Case Study: Microwave Board

- Solution chosen: Confine reflections.
  - Thick traces to coupling point. Varying length.
  - Thin traces from coupling to chip. Fixed length.
- Reflections occur within chip zone, and have consistent timing and modes.

Case Study: Microwave Board

- Alternate solution: Antenna coupling.
  - Shielded gives poor coupling.
  - Unshielded gives unwanted coupling.
  - Modes happen!
  - Reflections don't happen.
- Shielded antenna coupling test structures are implemented.

Microwave Board Summary

- Microwave board coupling is imperfect, producing artifacts.
- Artifacts should be consistent, and can be calibrated out.
- Alternate coupling method tested for use with future boards.

Conclusion

- Nonzero transit time means reflections are important.
- Impedance matching between source, load, and waveguides becomes important.
- Short wavelengths means antenna effects and resonance modes are important.

Conclusion

- Avoid high-frequency boards if possible!
- Other test options are available.
  - Pre-made high-frequency boards from CMC.
  - GSG-type high-frequency probes.