Understanding the Unintended Antenna Behavior of a Product

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Radiating System

- Source of RF energy
- Radiator
- Coupling

Source Properties

- Current loop
- Potential difference
- Impedance

Basic Antenna Structures

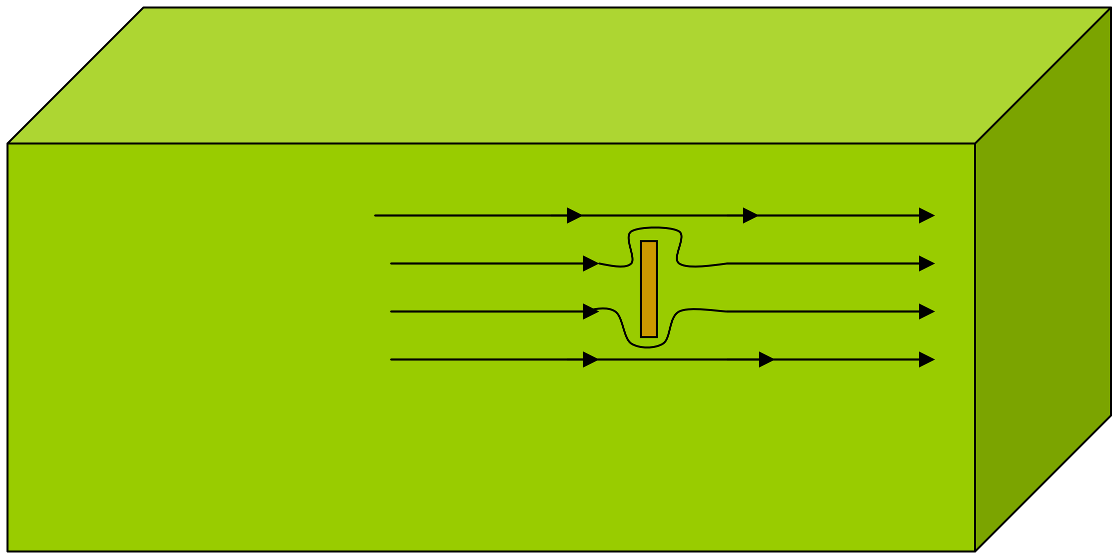
- Slot antennas
  - Seams
  - Unused connectors
- Monopole and dipole antennas
  - Interface cables
  - Other conductors
- Loop antennas
  - Cables
  - Other conductors

Typical Unwanted Slot Antennas

- Gaps in an EMI shield
- Splits or void areas in a plane (power or return)

Slot Antenna

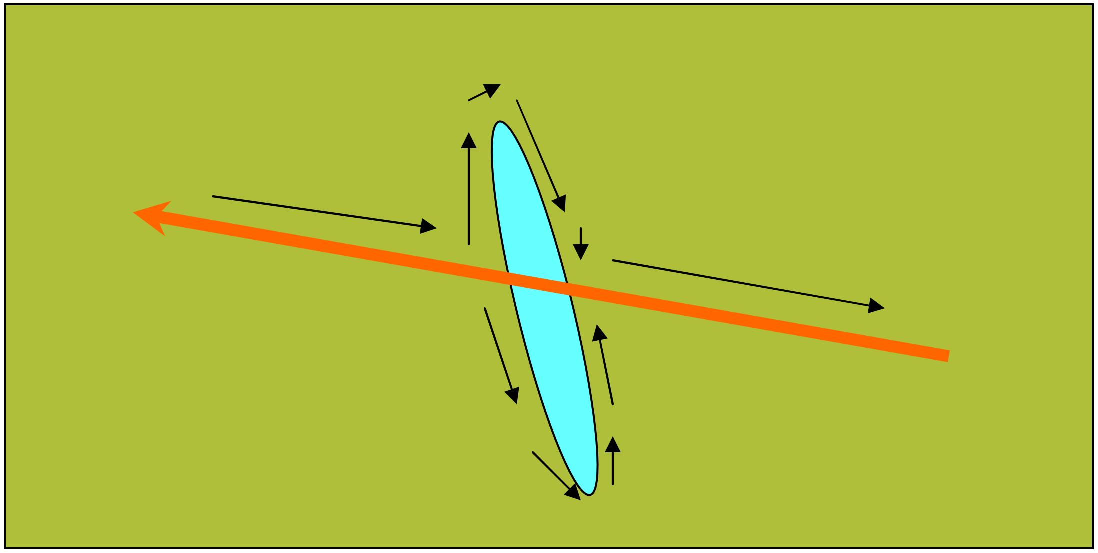
- Diverted Current Sheet



Typical Unwanted Loop Antennas

- Etch route to decoupling capacitor
- Terminations with shared return
- Within a large VLSI device
- Poorly implemented return path

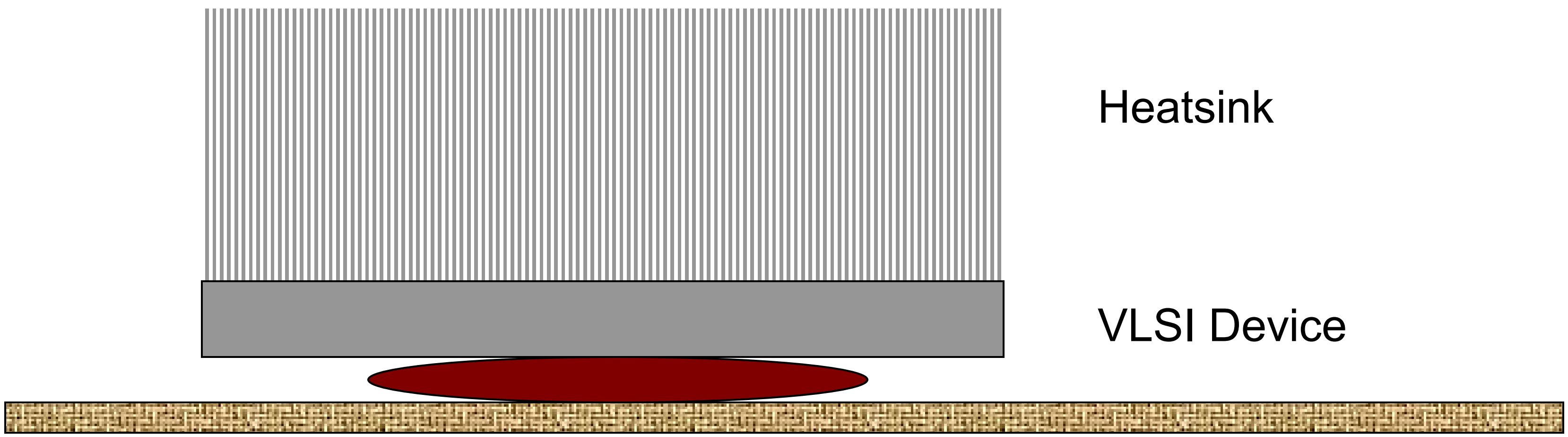
Loop Antenna
- defined current path



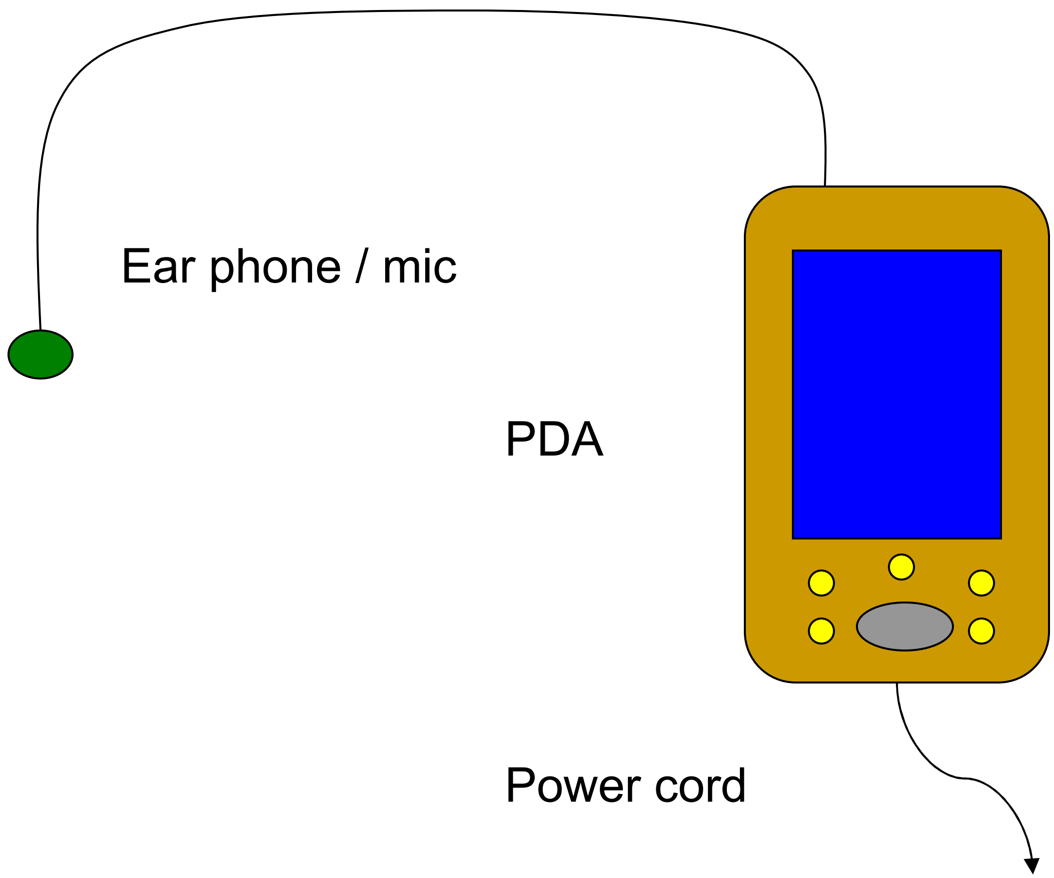
Typical Unwanted Dipole Antennas

- Heat pipes or sinks
- Power wiring
- Interface wiring

Dipole Antenna
- RF potential exists between two conductors



PDA Antenna Example



Coupling Mechanisms

- Close and small
  - Directly coupled
  - Inductance
  - Capacitance
- Small and remote
  - Uncoupled
  - Point source
    - Current loop
    - Current element
- Large and very close
  - Tightly coupled
  - Distributed inductance
  - Distributed capacitance
  - Complex EM coupling
- Resistive
  - Common paths
  - Intentional and unintentional chassis to logic return connections

Source Examples

- Current loops
  - Multi-point chassis to logic
  - Cable shield currents
- Voltage potentials
  - Between VLSI device and heat-sink
  - Between mother and daughter boards
- Common impedance

Radiator Properties

- Terminal Impedance
  - Radiation resistance

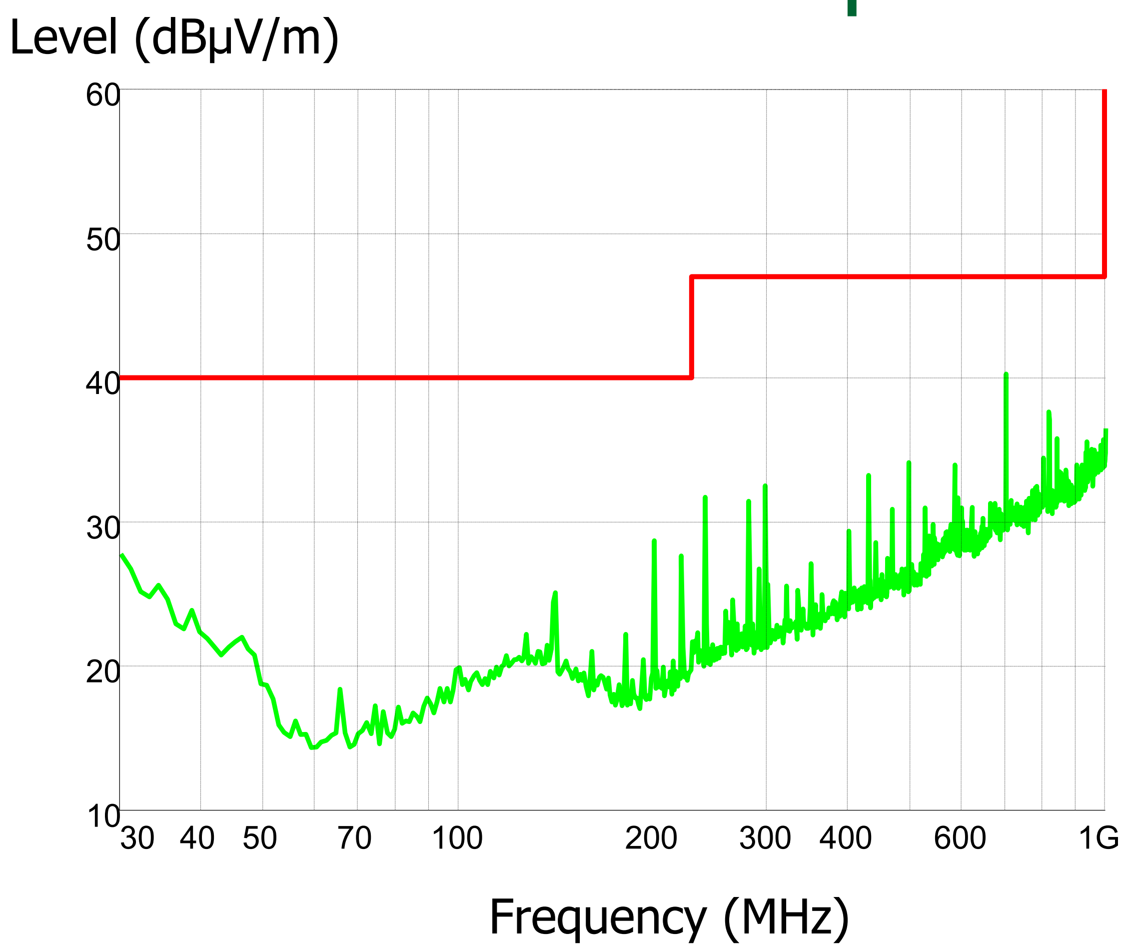
    represents energy radiated
  - Terminal reactance

    the energy stored in the non radiating fields

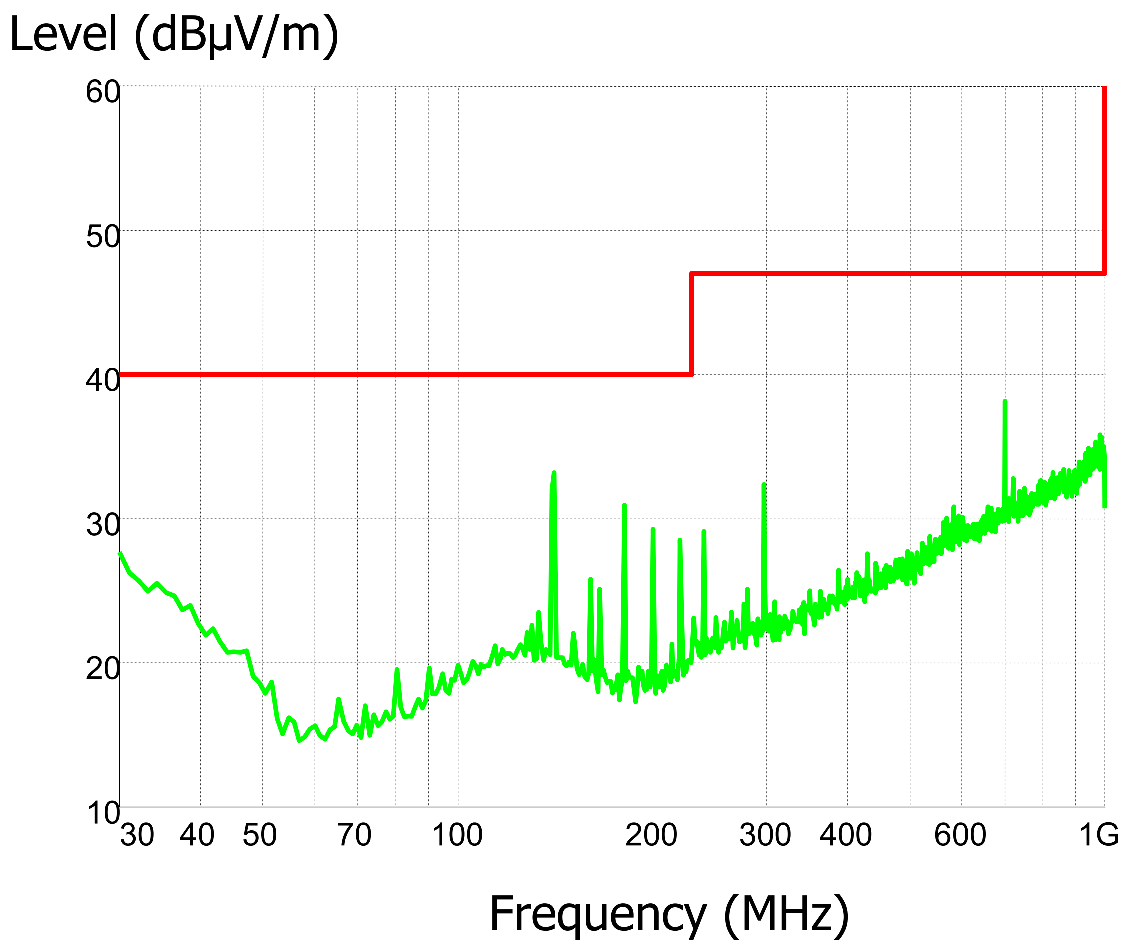
External Conductor Example

- Rack mount sub systems from a variety of vendors were mounted in a rack
- All sub systems were compliant alone
- Total system emissions were marginal at high frequencies
- Total system emission profile was changed when the doors were closed

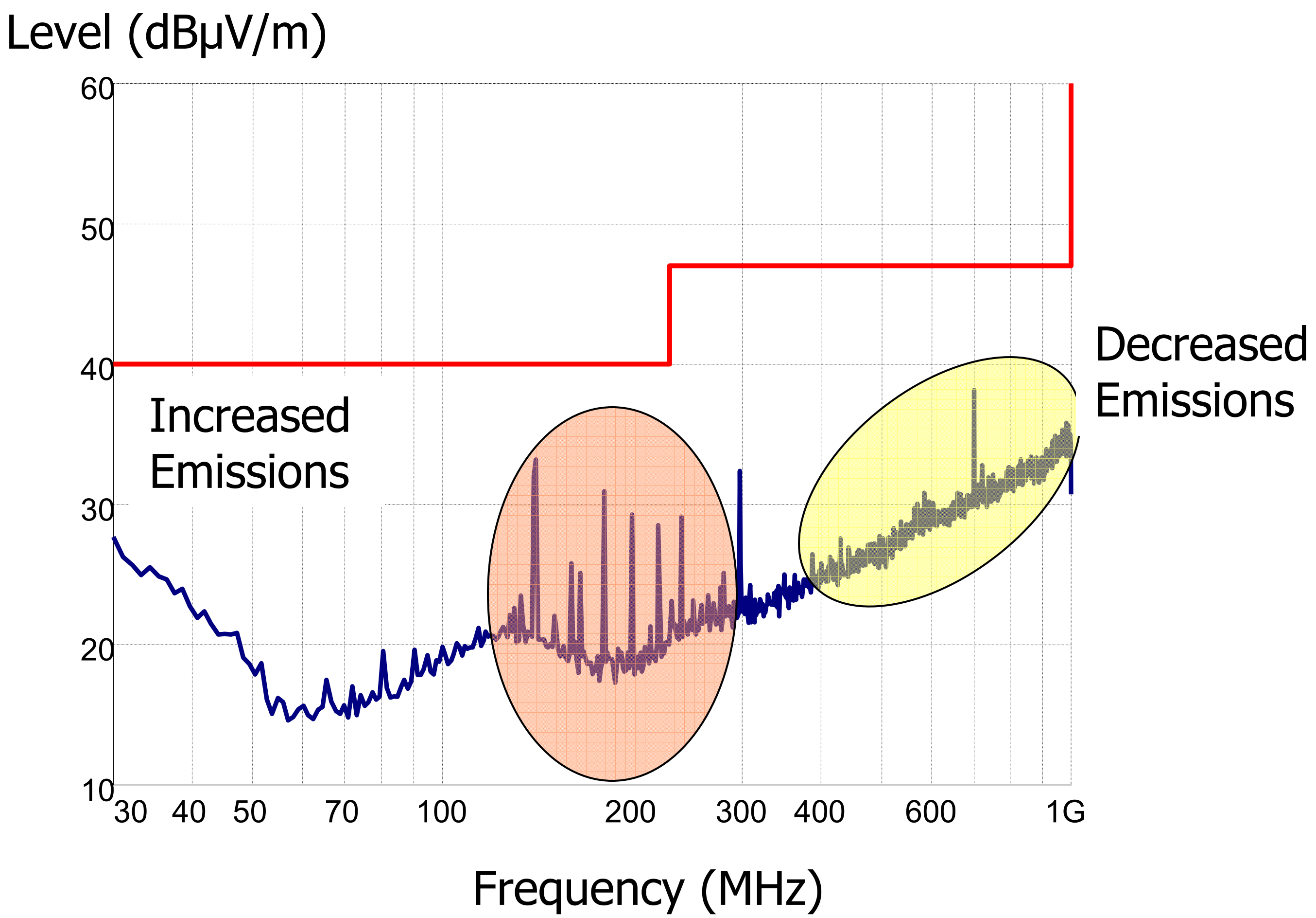
Product Emissions with Doors Open



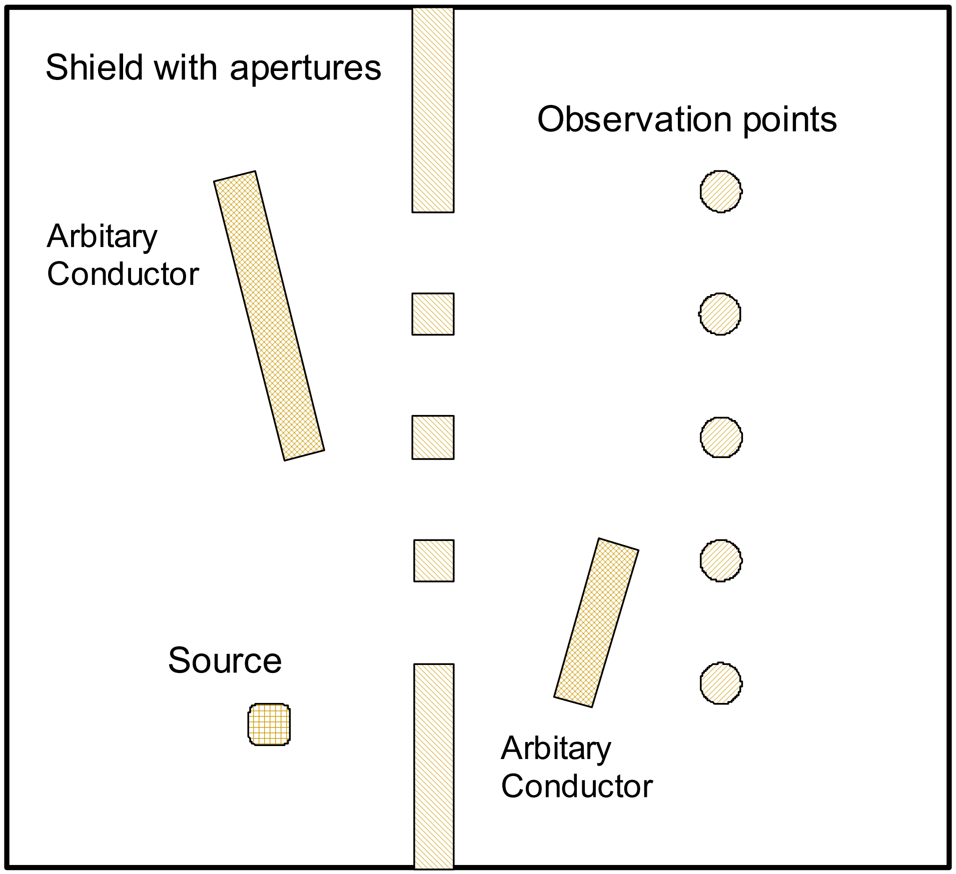
Product Emissions with Doors Closed



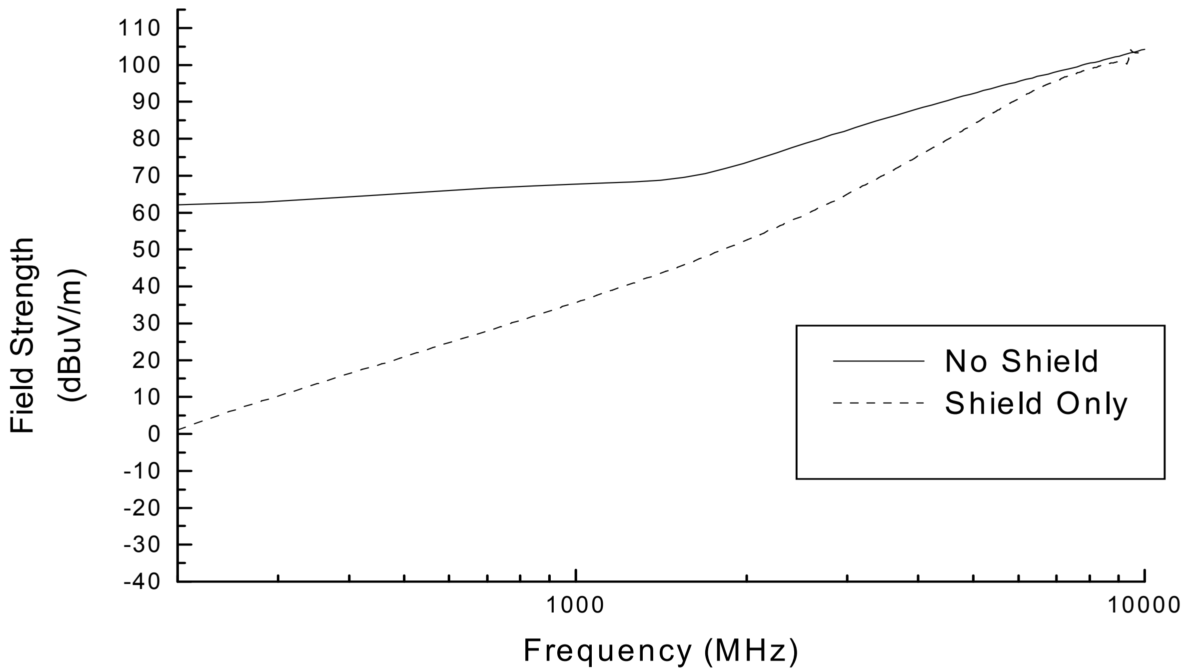
Product Emissions with Doors Closed



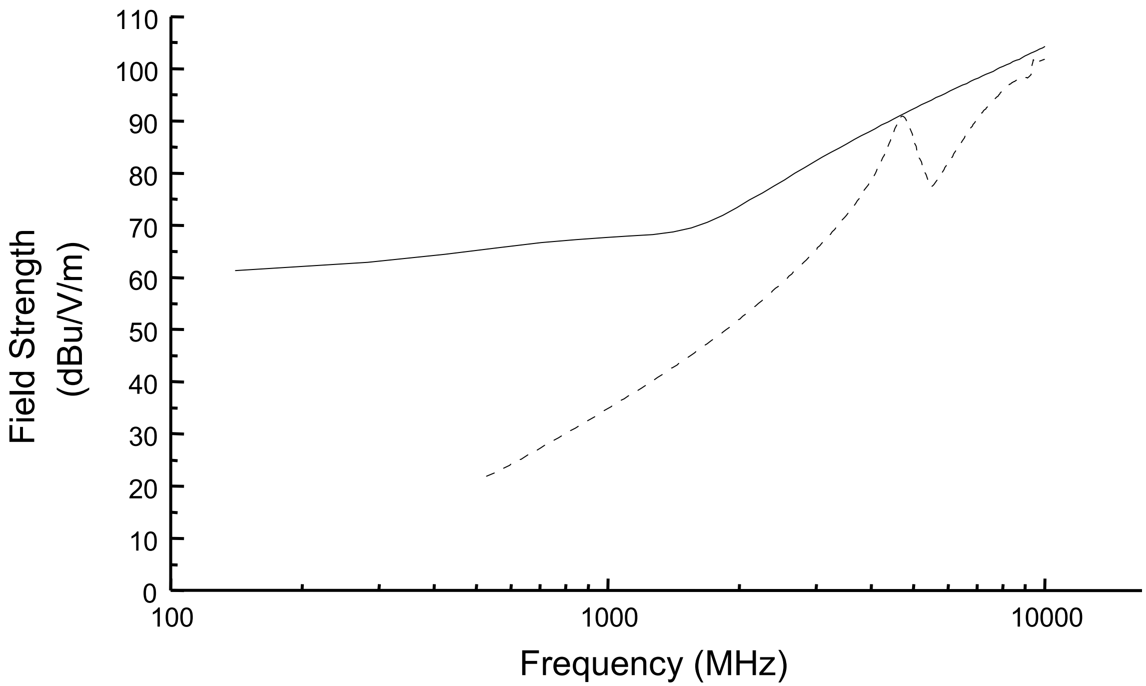
Computational Model



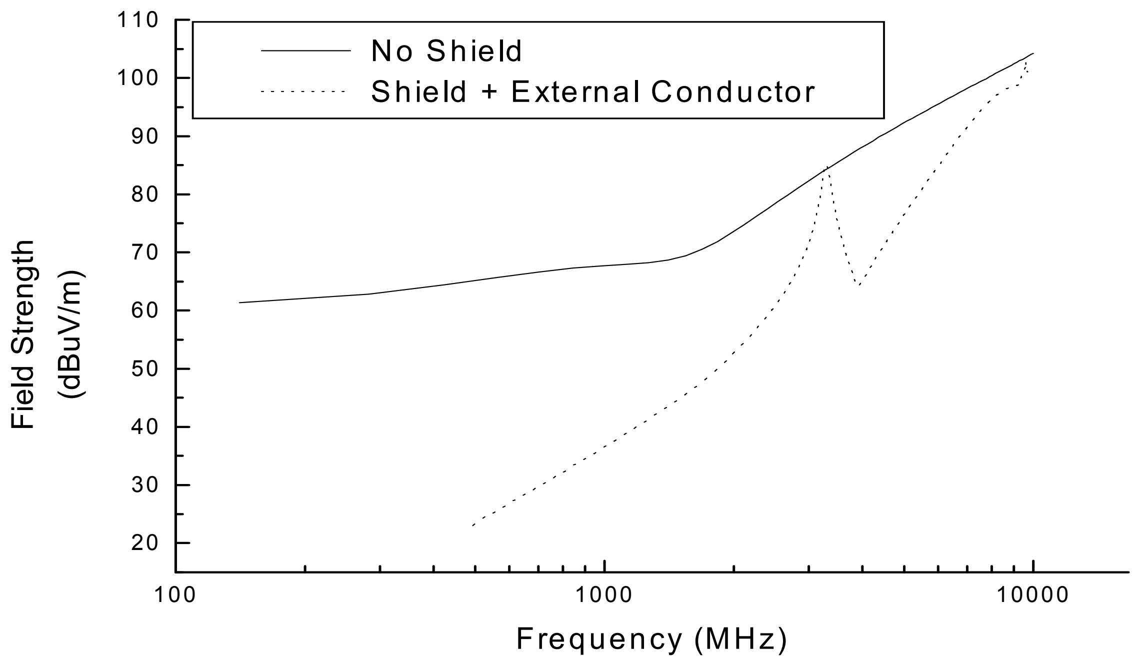
Shield Performance
With no Extra Conductors



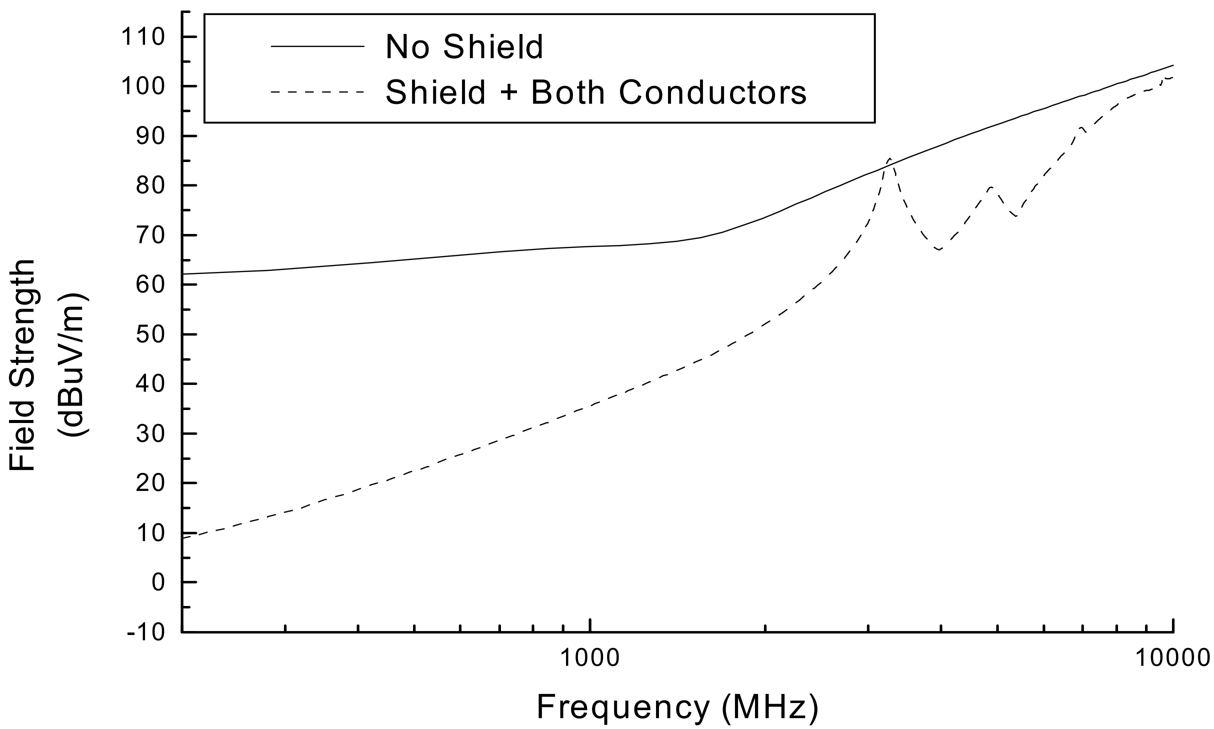
Shield Performance with Internal Conductor



Shield Performance with an External Conductor



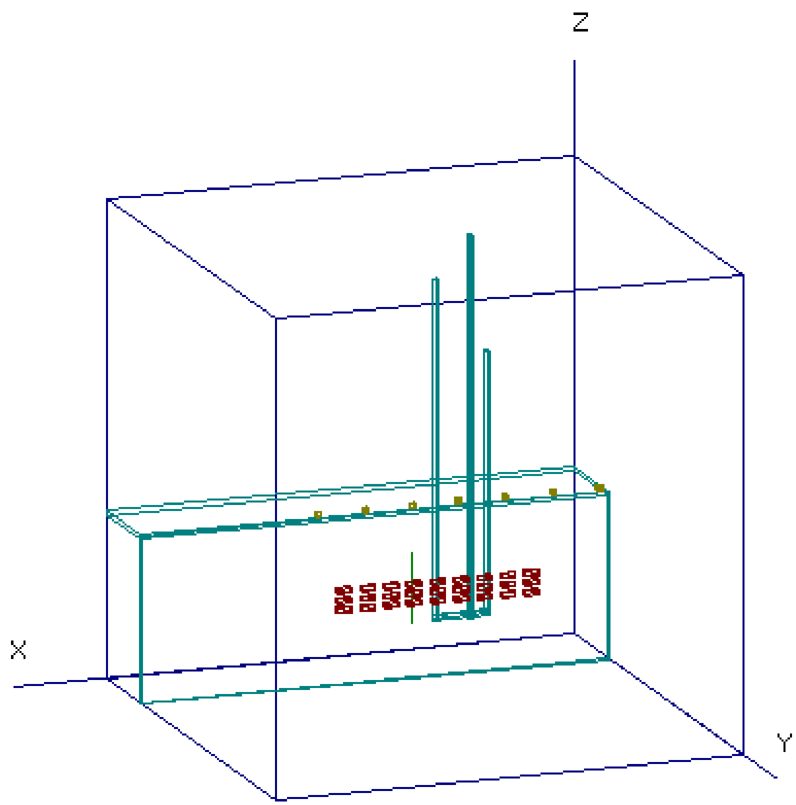
Shield Performance with Both Conductors



Adding Details

- Refined source model
  - includes direct coupling between source and shield or external conductor
- Imperfections
  - induce some cross polarization
- More complex external structures

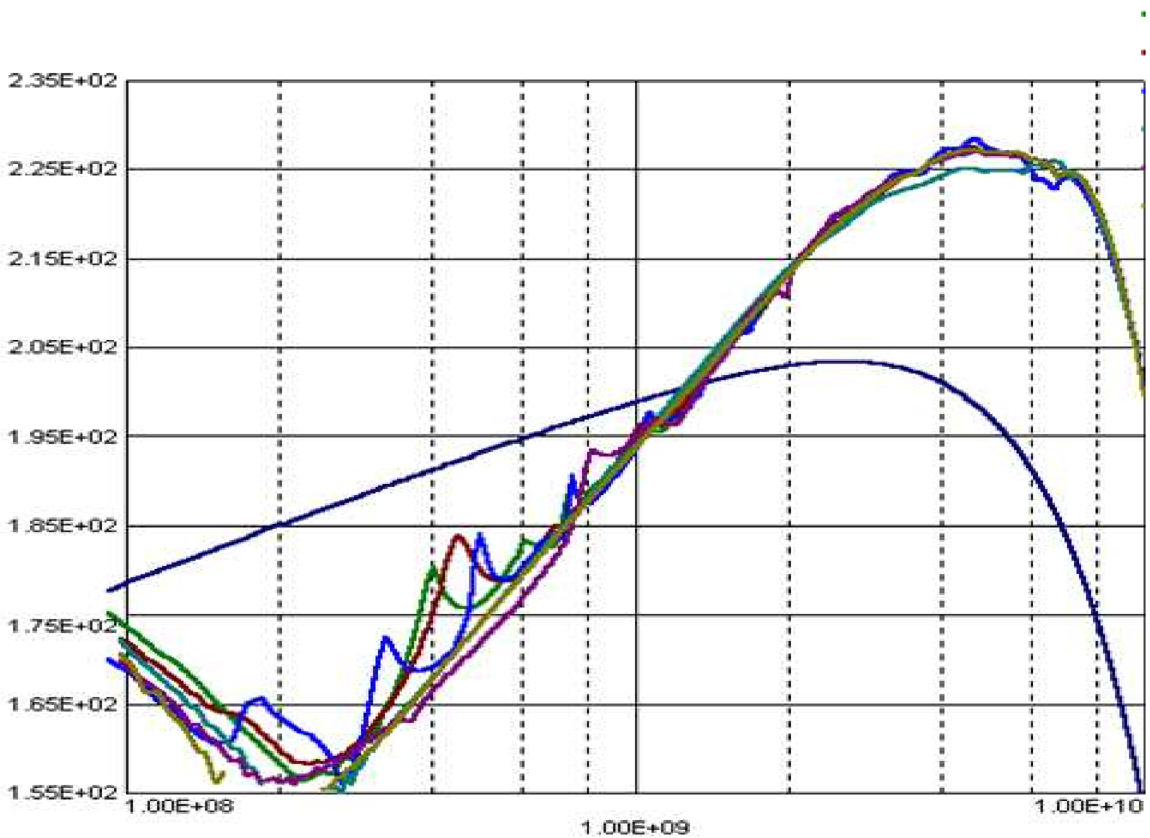
Multi-Wire FDTD Model



Animated Field Plots

- Time domain view of electric fields propagating through an aperture
- Electric fields propagating in the presence of external conductors
  - Slots in infinite plane
  - Slots in a real enclosure
  - Grounded external wire
  - Isolated external wire

Field Strength with External Wires



Product Realities

- Antennas happen!
- Result from unintentional discontinuities in a current path and RF potentials between conductors
- Cannot be completely avoided
- Design requires a balance of minimizing:
  - RF energy source
  - Coupling
  - Antenna size and geometry

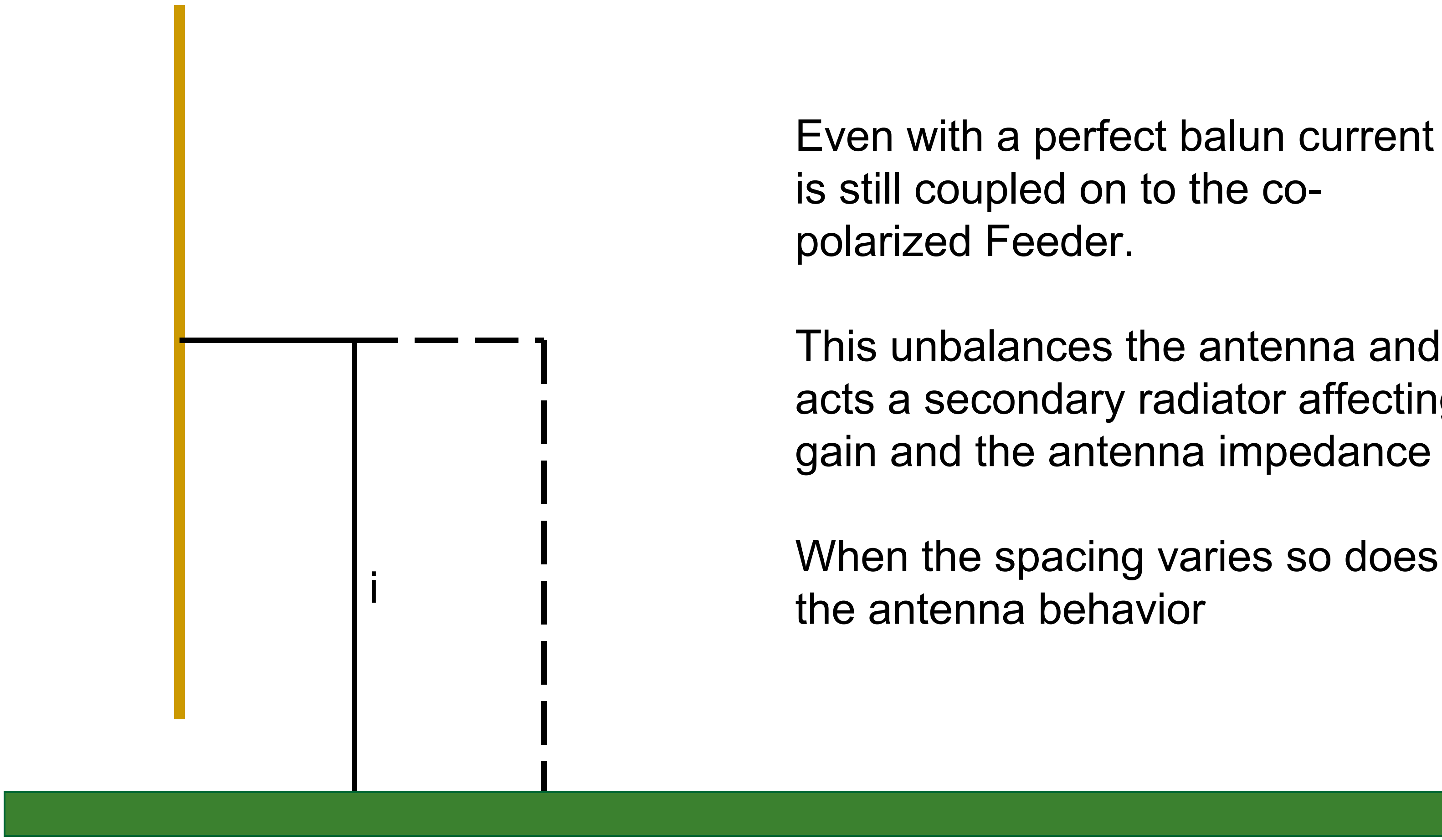
Measurement Antenna Example

- 30MHz half wave dipole
- Terminal impedance
  - Ideal
  - As used on site
    - 4m horrizontally polarized
    - 1m vertically polarized
  - With feed cable present
- Field distribution

30 MHz Dipole Impedance for Different Environments

Condition	Resistive Value	Reactive Value	Mismatch Loss
	(ohm)	(ohm)	(dB)
Free Space	71.0	+j 0.26	0.00
Horizontal	87.4	-j 13.00	0.95
Vertical	93.8	+j 2.10	1.29

Dipole With Feed Cable



Even with a perfect balun current is still coupled on to the co-polarized Feeder.

This unbalances the antenna and acts a secondary radiator affecting gain and the antenna impedance

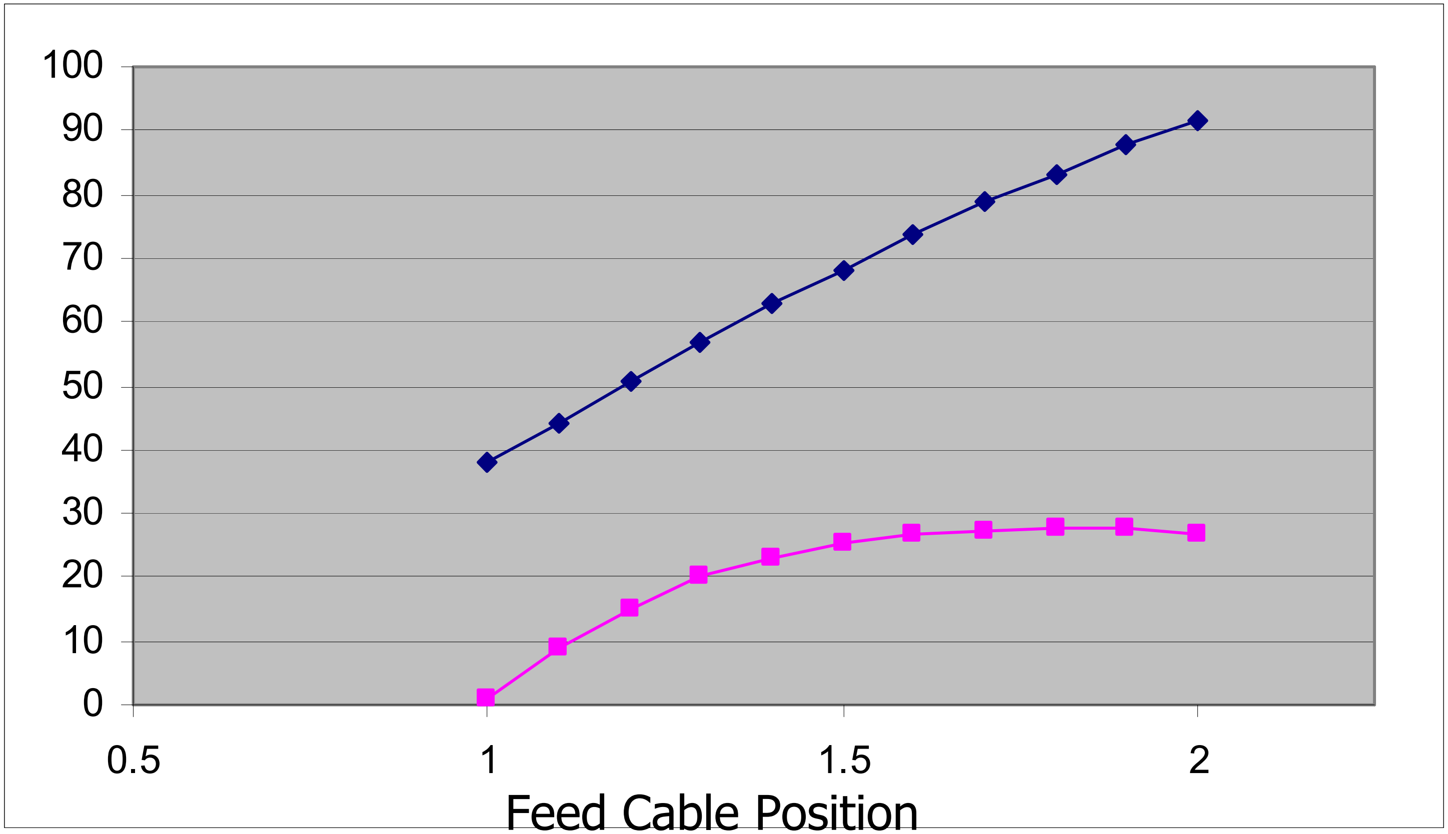
When the spacing varies so does the antenna behavior

30 MHz Vertical Dipole

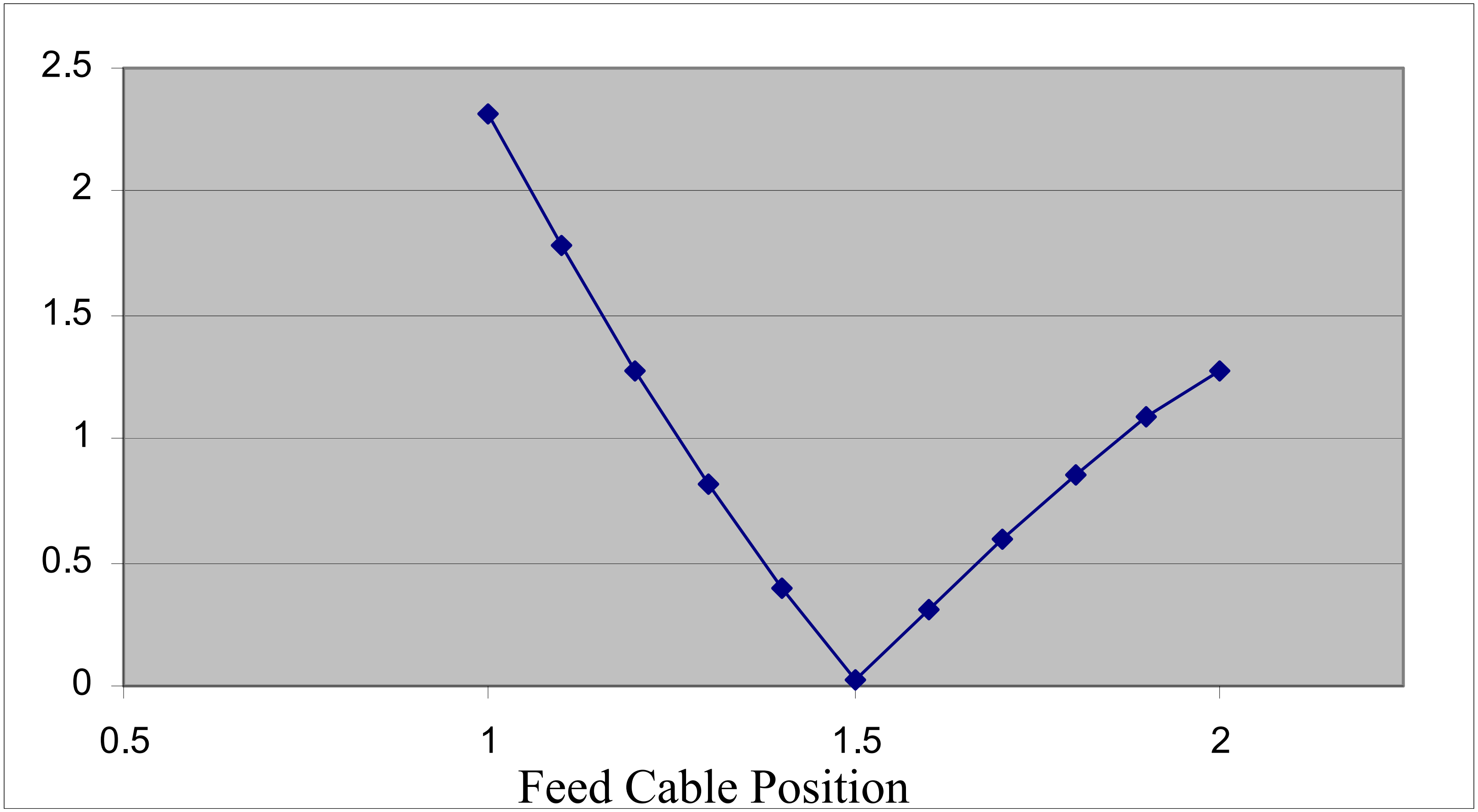
Impedance for different feed locations

Feed Location	Resistance	Reactance	Mismatch Loss
(m)	(ohm)	(ohm)	(dB)
Antenna Alone	93.8	+j 2.10	1.29
1.0	37.8	+j 1.16	2.31
1.1	44.3	+j 8.80	1.78
1.2	50.6	+j 14.9	1.28
1.3	56.7	+j 14.9	0.82
1.4	62.7	+j 23.0	0.40
1.5	68.3	+j 25.4	0.02
1.6	73.7	+j 26.9	0.31
1.7	78.7	+j 27.0	0.60
1.8	83.3	+j 27.9	0.86
1.9	87.6	+j 27.5	1.09
2.0	91.4	+j 26.6	1.28

30MHz Dipole Impedance

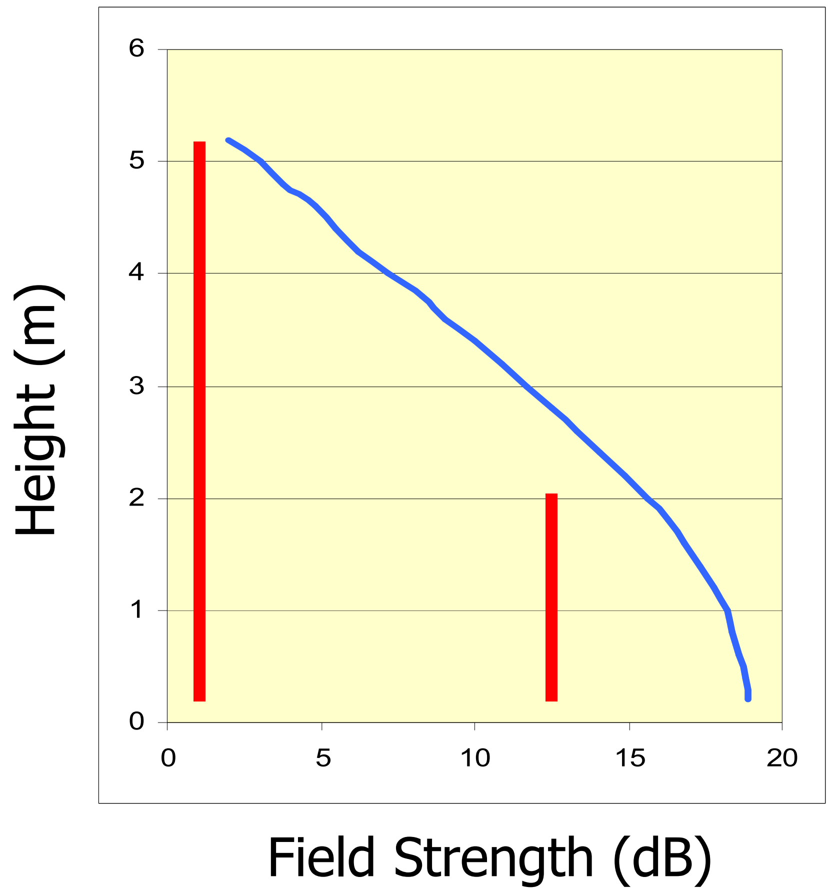


Mismatch Loss



Field Variation

30MHz Vertically Polarized Dipole



Product Antenna Summary

- It is important to recognize and separate the antenna effects from the coupling effects
- It is important to identify the true source
- Confusion between the source the coupling mechanisms and the radiator can cause an engineer to chase phantoms during EMI failure analysis