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Another EMC resource
from EMC Standards

The Physical Basis of SI, PI and EMC

Updated for 2018 Ver 3.9

Helping you solve your EMC problems

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Module 1: The Physical Basis of SI, PI, and EMC

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Update July 2018: v3.1 to v3.9

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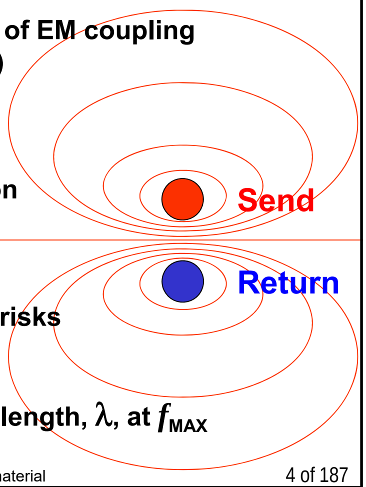
Change Record: v3.1 to v3.9, 19 July 2018

- Change Record added, as new slide 1.0.1a (this one)
- 'EMC' replaced (where appropriate) by 'SI, PI and EMC' throughout this whole module
- 'Cherry Clough confidential training material' added at the foot of every slide
- New slide 1.0.1b added
- Slide 1.0.3 improved a little
- Old slide 1.1.4 completely replaced by the two new slides 1.1.4 and 1.1.5
- Old slides 1.4.4 - 1.4.8 replaced with mostly new slides 1.4.4 - 1.4.8c
- New slide 1.4.21 added
- New slides 1.5.5a and 1.5.5b added, slides 1.5.6 and 1.5.7 improved
- Old slides 1.6.9 - 1.6.18 and 1.7.6 modified and improved
- Section 10 slides all completely replaced with new ones: 1.10.1 - 1.10.11
- Sections 15 and 16 swapped, renumbered as Sections 16 and 15 respectively
- Title of Section 18 improved (slide 1.18.1)
- Slide 1.18.2a improved
- Title of slide 1.18.4 improved
- Slide 1.18.5 improved
- Twelve new slides 1.18.9a - 1.18.9l added
- Slides 1.18.10 - 1.18.12; 1.18.15; 1.18.17, and 1.18.18 improved
- New slide 1.18.19 added
- Slides 1.19.3 – 1.19.5 updated and improved

Signal Integrity (SI), Power Integrity (PI) and Electromagnetic Compatibility (EMC) are *easy*, when you are used to this understanding of electromagnetism

- **Electrical/electronic/radio/digital design, and Maxwell's Equations, are rarely taught in a way that makes SI, PI and EMC easy to achieve in practice…**
  - **the approach described in this *almost-maths-free* Webinar 1 (and employed through all our "design-guide" webinars) makes SI, PI and EMC design *easy*…**
  - **saving a lot of time and money, reducing financial risks, and greatly increasing the chances of success**

Contents



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This module mostly deals with radio frequency (RF) techniques

– **because low-frequency SI, PI and EMC issues are easy to understand using normal circuit design techniques**
with strays included, *see later*…

- **This module focuses on the SI, PI and EMC issues that most engineers find difficult…**
  - **because of the *apparently* weird things that can happen at frequencies above a few MHz**
    - **EMC = Electromagnetic Compatibility: controlling emissions and immunity so radiocommunications and other equipment don't cause or suffer Electromagnetic Interference (EMI)**

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1. The Physical Basis of SI, PI, and EMC

1.1

Electromagnetic fields and waves,

and the importance of the return current path

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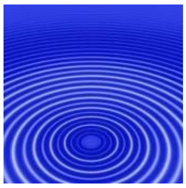
Electromagnetic (EM) fields

- ***Every*** **voltage/current (power, signal, data, etc. or stray, parasitic, sneak, leak) is *really* a propagating EM wave...**
  - **guided by send and return conductors *and* the insulators (dielectrics) that surround them (e.g. air, PVC)…**
    [*Strictly:* Transverse Electromagnetic: 'TEM' waves]
  - **EM waves spread out and create EM fields**
    like ripples spreading out on a pool of water



- **Design for good SI, PI and EMC is mostly about controlling fields: so they are high where we want signals, data and power to be…**
  - **and low where we don't want them to be, to control crosstalk, noise, emissions and susceptibility**

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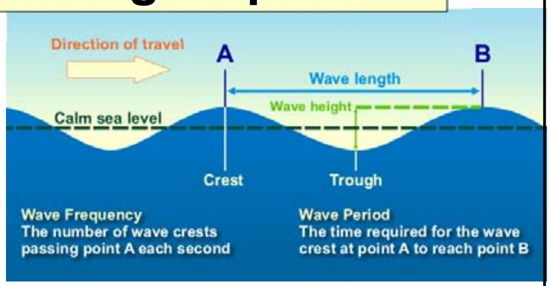
Of course, a wave has different amplitudes along its path



- **So a long conductor *can't* have the same voltage or current over its whole length, at the same time…**
  - **and this is what causes the 'EMC weirdness'!**
  - **the ratio between wavelength (λ) and conductor dimension is what is important…**
  - **we can usually ignore 'wave effects' for any dimension that is < λ/100   e.g. at 1GHz: < 3.0mm in air (λ = 300mm)**
    < 1.5mm in FR4 (λ = 150mm)

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Importance of the return current path

- ***All*** **currents *always* flow in closed loops**
  all **power, signals, data, *and* stray / parasitic / sneak / leaked currents etc…**
  - **and we can control their E and H field patterns by designing their send and return current paths…**
    - **which can include flowing through dielectrics (air, plastic, etc.) as "displacement currents"**
- **Currents *always* "prefer" to flow in loops with lower *overall* impedances, at any given frequency…**
  - **generally the loops with least enclosed areas, *because they have the most compact E and H field patterns*…**
    - **i.e. the laws of nature/physics are trying to help us achieve good SI, PI and EMC – we just have to work *with* them!**

Importance of the return current path continued…

- **The current (at any given frequency) will automatically divide up between the available loops, in inverse proportion to their overall loop impedances…**
    - **just like DC current divides up between parallel resistors…**
  - **this generally means that return currents will always "choose" to flow as physically close to their send currents as they can…**
    - **even if this means flowing through air, or other dielectrics…**
  - **so we can easily achieve good, cost-effective SI, PI and EMC, by creating send/return loops that have very low overall impedances…**
    - **for all of the frequencies we want/need to control**