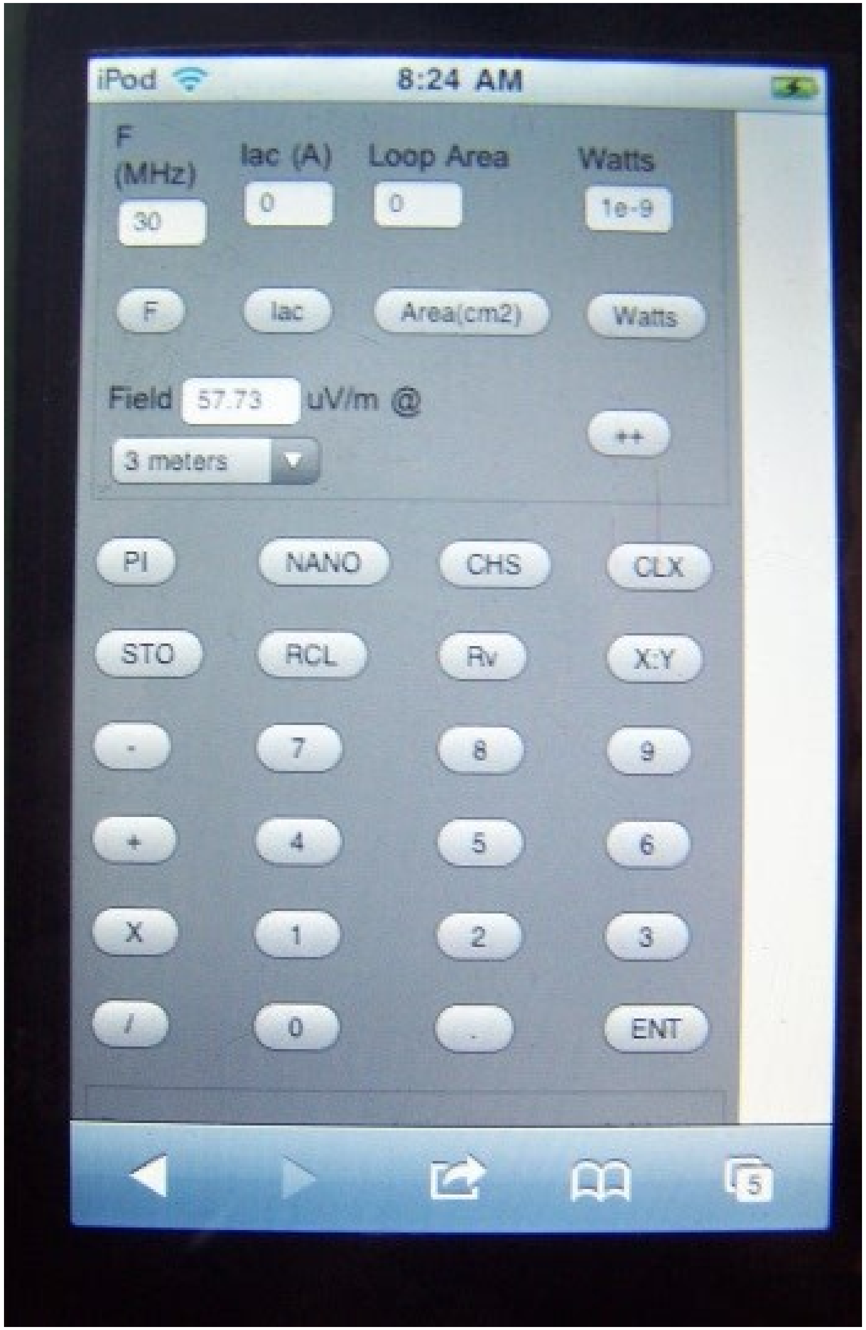

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QuickApp
Field Estimation
for EMI

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August 26, 2011

Abstract

- Products create Electro-Magnetic Interference (EMI) and can also be susceptible to EMI
- EMI can either be radiated in space or conducted through cables / power lines
- The FCC and other international bodies regulate how much EMI a product can create
- Radiated fields are also safety concerns with rules regarding human exposure
- The finger-friendly eightolives QuickApp EMI Estimation tool helps you estimate field strength and noise limits.

Quick Words on Quick App

- EMI field estimation is a non-trivial task as many factors affect radiation patterns and circuit switching
  - CAD tools exist that accurately predict EMI given appropriate data and equipment models
- The Quick App Field Estimator solves basic equations for a rough, order-of-magnitude approximation for maximum and factored conditions

Background

- EMI radiation consists of both electric and magnetic fields at various frequencies
  - In free-space (far field)
    - E(Volts/m) = H(Amps/m) * SQRT(ε/μ)
      - Where SQRT(ε/μ) = 377 ohms in free space (120 π)
- In general, circuits that are totally enclosed in metal will not radiate
  - Slot openings as small as 1/20 wavelength will radiate although at a reduced level (-20 db)
  - Wavelength λ = c / F where c = 300 000 000 m /sec

Radiation Characteristics

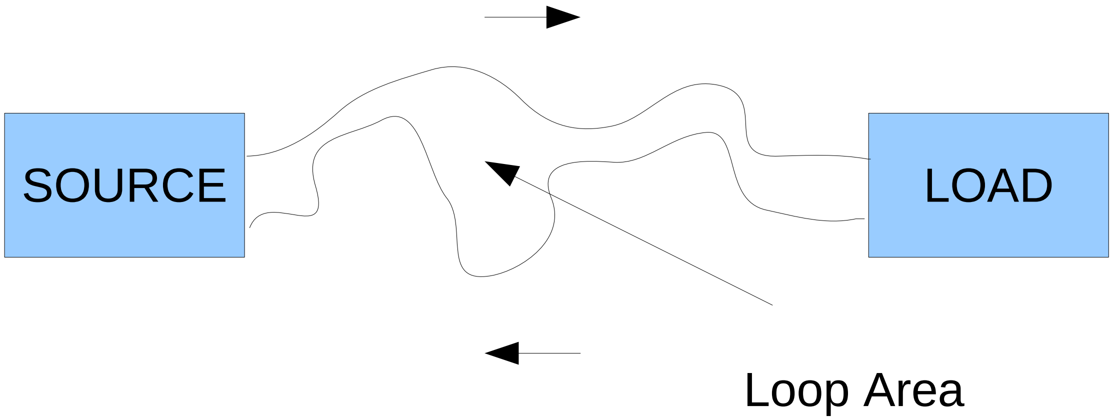
- Radiation is categorized by the observer's distance from the source in wavelengths
  - Near field (0 – 1 wavelength (λ))
    – Near field reactive (0 to λ/(2π)) – complex E-H has reactive component
    – Near field radiative (λ/(2π) to 1 λ) – complex E-H relation
  - Transition field (1 to 2 λ)
  - Far field (> 2λ) – E = H * 377 ohms is valid
- Field measurements are usually made in the far field at distances of 3, 10, 30 or 300 meters depending on frequency

Field Basics

- The relation of field, power and distance is
  - P * G / (4 * PI * D**2) = E**2 / 377
    - Where P = power in Watts
    - G = gain factor over isotropic radiator
    - D = distance in meters
    - E = field strength in Volts/meter
- Power Density in Watts/m**2 =
  - PD = (E**2) / 377 = 377 * H**2
    - Where E = field strength in Volts/meter
    - H = Magnetic field strength in Amps / meter

Field Basics

- A circuit loop traces current flow from source to destination and back
  - The area enclosed by this path is a factor in radiation



Field Basics

- The relationship of field, current, frequency and circuit loop area is
  - E = k * I * A * F**2 / D
    - Where k = 2 * 377 * π / c**2
    - I is current in Amps
    - A is loop area in meters**2
    - F is frequency
    - D is distance in meters
    - c = 3 x 10**8 meter/sec (speed of light)

FCC Radiation Limits

- The FCC Part 15 rules define
  - Incidental radiator (DC motors, mechanical light switch) (use “good practice” to minimize EMI)
  - Unintentional radiator (receiver, computer)
  - Intentional radiator (transmitter)
- For consumer (Class B) unintentional radiators the FCC limits

  at 3 meters

Frequency of emission	Field Strength
30 -88 MHz	100 uV/m
88 – 216 MHz	150 uV/m
216 – 960 MHz	200 uV/m
Above 960 MHz	500 uV/m

Numbers in Perspective

- 100 uV/m @ 3m → 3 nanoWatt of sine wave
- A 30 MHz, 1 Vrms sine wave traveling a circuit board 5 inches to a 50 ohm load (20 ma) with it's return path .1 inch away (loop area = 12.7 cm x .254 cm = 3.23 cm**2) produces a field of 51 uV/m @ 3 m
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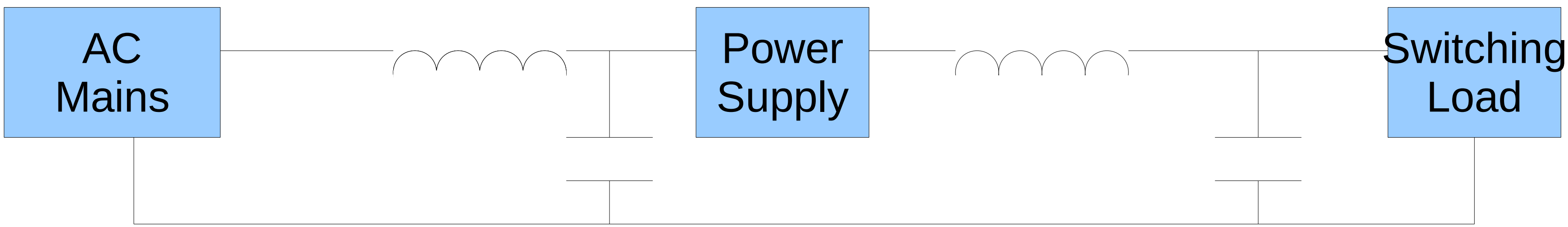
Conduction EMI is Noise in the Loop

- The concern is switching currents (noise) coupling into AC mains
- The switching currents in the loop are normally isolated from mains by LC low pass filters (bypass caps)



AC filter further reduces noise to AC mains

Switching currents in loop with bypass cap

FCC Conduction Limits

- For consumer devices (Class B) the limits of noise that can be conducted onto AC power lines

Frequency	Quasi-peak	Average
.15 to .5 MHz	66 – 56* dbuV	56 – 46* dbuV
.5 – 5 MHz	56 dbuV	46 dbuV
5 – 30 MHz	60 dbuV	50 dbuV

* decreases with logarithm of frequency

Measured with a 50 uH / 50 ohm line impedance stabilization network
Refer to Part 15 for additional product constraints.

Safety Issues

- The FCC and other government bodies (states) have issued rules regarding human exposure to EM fields
- IEEE C95.1 2005 IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagentic Fields 3 kHz to 300 GHz

Limits for General Population / Uncontrolled Exposure

Frequency Range MHz	Electric Field Strength V/m	Magnetic Field Strength A/m	Power Density mW/ cm**2	Average Time Minutes
0.3 - 1.34	614	1.63	100	30
1.34 – 30	824 / f	2.19 / f	180 / f**2	30
30 – 300	27.5	'.073	0.2	30
300 – 1500			F / 1500	30
1500 – 100000			1	30

From FCC 1.1310

Mobile Device Safety is Different

- Cell phone safety is specified by a Specific Absorption Rate (SAR) limit of 1.6 Watts / kg averaged over 1 gm of tissue
- Whole body SAR limit is 4 W/kg
  - Human body absorbs most at 70 MHz
- SAR = |E**2| * σ / ρ
  - Where σ = conductivity (~ 1.22 S/m)
  - And ρ = mass density (~ 1000 kg m**3)
- Non-trivial estimation as parameters vary greatly

Using the QuickApp

- In general, enter numbers then press a destination or function key
- Related text fields and the report at the bottom of the tool are automatically updated

Enter What You Know

- Watts : Enter the relevant switching, radiated or output power if known

Else specify:

- F (MHz) : The frequency of interest
- Loop Area (cm**2) : area enclosed by a circuit trace
- Iac (A) : The rms AC current in the loop

- An estimate of the field is reported at the specified distance

Refine Your Data

- Box Shield (%) : An estimate of the enclosing box's shield area / total box surface area (“none” if no box)
- Longest Opening (cm) : The longest dimension of any opening in the enclosing box or maximum length of an exposed circuit board
- Primary clock (MHz) : The main clock frequency from which harmonics and sub-harmonics might be expected

Select a Distribution

- Select one of the radio buttons if a non-zero Primary Clock is specified
  - Sinewave : All energy is at the Primary frequency
    - Useful for RF transmitters (maximum field strength estimates)
  - Digital Switching : Energy is distributed between harmonics and sub-harmonics
    - Use for computer based equipment
  - White noise : Energy is distributed over all frequencies
    - Useful for minimum field strength estimates

Accumulate All Sources

- Use the “++” key to accumulate multiple EMI contributers
    - First enter data for one source then hit the ++ key to accumulate the results
- Use the “CLRA” key to reset the accumulator
- View the accumulation results in the report at the bottom of the tool

Hints

- Bookmark the menu page so can easily access the tools

For more information

- Check the QuickApps Overview for more info on the other apps from the tutorials page at: http://www.eightolives.com/tutorials.htm
- Review bug reports and status from the QuickApps home page at: http://www.eightolives.com/docs/Mobile/index.htm