KIMMEL GERKE Bullets

Summer , 2000

Welcome to KGB...

And to this issue of our "personal communications" to our friends, clients, and colleagues about EMI issues, problems and solutions.

This issue discusses "microwave EMI", or EMI problems above 1 GHz. Thanks to faster clocks and new wireless services, the world above 1 GHz is no longer an "EMI frontier". In the past year alone, we've worked on several projects where we had to deal with both emissions and immunity in the 1-10 GHz range. No, these were not military designs — they were commercial designs, and the concerns were very real.

We'll take a quick look at these microwave effects on several key EMI areas: circuits, circuit boards, cables, grounding, and shielding. We'll share our thoughts and concerns, and we'll give you some simple guidelines as well.

When dealing with microwave EMI, it is very important to scale for frequencies and propagation times. Remember, a wavelength at 10 GHz (3 cm) is 1/100 of the wavelength at 100 MHz (3 meters). Furthermore, at 1 nsec, the propagation distance in free space is about 1 foot, while at 100 psec, the propagation distance is a little over an inch.

As always, give us a call if we can help you with any of your EMI problems, from "DC to daylight..."

Best Regards,

Daryl Gerke, PE, and Bill Kimmel, PE

Please Requalify

Please return the enclosed card if you wish to continue to receive *Kimmel Gerke Bullets*. If you joined us or updated in the last few months, you can disregard this request. If in doubt, send in the card and we'll make sure you stay on our mail list. You can also requalify by e-mail at *bkimmel@emiguru.com*. Be sure to include you current address information.

Since many businesses no longer deliver bulk mail, feel free to use your home address. Besides, if you change companies, you'll still receive the KGB. *By the way, our list is PRIVATE... it is never used by anyone else.*

Shows and Conferences...

Here are some shows and meetings we are involved with that may be of interest. Call us if you'd like more details.

IEEE International EMC Symposium... August 21-25, 2000, at the Washington Hilton & Towers in Washington, DC. Daryl will be presenting *"An Introduction to EMC Engineering"* during the Monday tutorial workshops. Both Bill and Daryl will participate in Tom Chesworth's *"EMC War Stories"* session on Friday.

Fifteenth Annual Minnesota EMC Event... September 19, 2000, at the Thunderbird Hotel in Bloomington, MN. Combined day of training and exhibitions.

EMI Courses...

We are in the process of setting up the fall schedule for our popular *EMI Made Simple* classes. Once again, we are offering both the one day *Systems Grounding & Shielding* class, and the two day *Designing for EMI* class. You may take either or both, depending on your EMI information needs.

- Denver, CO - October 2-4
- Seattle , WA - October 9-11
- Phoenix, AZ - October 22-24
- San Jose, CA - November 6-8
- Los Angeles, CA - November 1-3

These classes have been sponsored by Tektronix since 1993, and are very popular. If you have been to a recent class, you know that we also discuss *Signal Integrity* and *Power Quality* issues, and how these complement good EMI design. See our web site, *www.emiguru.com*, for more information.

emicatalog.com sold...

In May 2000, Canon Communications, the publisher of *Compliance Engineering* and *Medical Device & Diagnostic Industry* (among many others) purchased *emicatalog.com,* the web site we developed with Conway Technology Associates. We will still be very much involved with the technical aspects of this popular EMI resource.

If you are an EMI vendor, expect to hear from Canon about listing your products on *emicatalog.com.* (Call 310-445-4200, or e-mail *sales@emicatalog.com*) If you are an EMI "user", please visit. Lot's of neat features , with more to come. Best of all, it is FREE to users!

Kimmel Gerke Bullets is a newsletter on electromagnetic interference/Compatibility (EMI/EMC).
Published by Kimmel Gerke Associates, Ltd., 300 Christine Lane, W. St. Paul, MN 55118 • 1-888-EMI-GURU • http://www.emiguru.com

Focus on "Microwave EMI"...

In the spirit of the "new millennium", we were recently asked to muse about the future of EMI/EMC for a magazine article. With increasing clock speeds and shrinking device geometries, there is no doubt that EMI problems will increase even in the next decade, let alone the next millennium.

We fully expect to see emissions go up in frequency, and immunity levels go down in amplitude. As a result, EMC engineers will need to become "microwave engineers" as well as "microcircuit engineers." Just understanding PCBs and the effects of 10 or 100 MHz clocks won't be enough.

As we reflected on these issues, however, we realized that we've already seen a number of GHz problems, thanks to some 500 MHz + clocks and 1-10 GHz data rates. So we thought we would share our observations and predictions with our KGB readers, as we move into the realm of "microwave EMI."

Effects of Clocks, Logic, and Data Rates - As we all know, increased *clock rates* mean increased emissions. For commercial equipment, these usually extend to at least the tenth harmonic. Thus, even a 500 MHz clock may cause problems at 5 GHz. We're also seeing direct data rates in the 1-10 GHz range, which could push harmonics in the 100 GHz range.

Faster logic also means faster *edge rates*. At 1 nsec, the equivalent EMI frequency ($1/\mu$ tr) is about 300 MHz, but at 100 psec, this is now 3 GHz. 30 psec edge rates mean 10 GHz bandwidths, which translate to both increased emissions and immunity problems.

Effects of Dimensions - When dealing with microwave problems, we've often had to remind ourselves (and our clients) that critical dimensions drop accordingly, and that factors like direct chip radiation can no longer be safely ignored. Let's look at these effects in both the frequency domain, and in the time domain.

Frequency domain - At 1 GHz, a wavelength is 30 cm, while at 10 GHz, it drops to 3 cm. Since most of us assume that a wire/trace/seam becomes an antenna at about 1/20 wavelength, 15 mm is enough to cause problems at 1 GHz, and only 1.5 mm at 10 GHz. In the latter case, even ordinary window screen can leak at these frequencies.

A KGB Bullet... Some upcoming EMI dates:

- January 1, 2001 - Mandatory date to meet Harmonics and Flicker (En-61000-3-2 and 3-3). Mandatory date for EN55011, 1998 for ISM emissions.
- July 1, 2001 - Mandatory date for EN55024, 1998, for ITE immunity. Mandatory date for EN50082-1, 1997 for "generic" immunity standards.
- August 1, 2001 - Mandatory date for EN55022, 1998 for ITE. Must measure disturbances at telecomm ports.

(Thanks...DLS Electronics Systems)

Time domain - Many of us like to work in the time domain, particularly when dealing with digital Signal Integrity issues. With a 300 psec edge (about 1 GHz), the propagation delay in free space is about 10 cm, while at 30 psec (about 10 GHz), it drops to 1 cm. On a circuit board, those lengths often drop to less than 1/2 of those values, thanks to the board's dielectric constant. This means diminished dimensions for crosstalk, reflections, and placement of decoupling capacitors.

Effects on Circuits - Microwave EMI often means direct radiation from (and into) individual integrated circuits. At 1-10 GHz, the dimensions of the die, bond wires, lead frames, and even pins can no longer be ignored. Any of these can become "hidden antennas" that support direct electromagnetic radiation.

If you are a chip designer, welcome to the exciting world of EMI. You'll probably need to design in features that board designers have done for some time - planes, I/O filtering, and maybe even local decoupling and/or power regulation. Oh yeah, and lots of power and ground pins (what do you mean, you don't have enough pins???)

If you are a board designer, you may need individual IC shielding. If used, a multi-point seal must be maintained between the local shield and the board ground plane, and traces entering/leaving the IC may also need filtering. We've had to do both in stubborn cases.

A final caution. If you are using metal heat sinks, be sure to make multiple connections to the signal ground plane as well. If not, you may start to drive the heat sink as an efficient "patch antenna" at microwave frequencies.

Effects on Circuit Boards - Materials, component layout, and traces all become crucial at microwave frequencies.

Several recent articles have shown that the old "tried and true" FR4 material starts to degrade above 1 GHz. As a result, newer low loss materials may be needed. Furthermore, the power and ground planes may need tighter coupling (such as "buried capacitance) to be fully effective at microwave frequencies.

Component layout also becomes more critical above 1 GHz. With a 30 psec edge rate, even a "perfect" decoupling capacitor is of no use if it is located more than 1 cm away from the circuit. By the time the charge from the capacitor reaches the device, the whole transition is done. (Time to start putting the caps right in the IC.)

Like components, traces become critical above 1 GHz too. Reflections and crosstalk can become a problem at 1/2 the propagation distance or less. With 300 psec edge rates, this means we start to worry at about 2 cm (under an inch). We recently saw a humorous "rule of thumb" that applies here - *"As a rule of thumb, if your trace is longer than your thumb, you need to terminate."*

KGB by E-mail... Send us your e-mail address and we'll send you the PDF version of the KGB. This makes it easier to store or forward to colleagues. Just e-mail to *bkimmel@emiguru.com*.

Effects on Cables and Connectors - The two big factors here are losses and impedance discontinuities. Coaxial cables are often needed above 1 GHz, but their performance can be limited by line losses and phase delay. Fortunately, fiber optics offer good performance in the 1-10 GHz range, and are increasingly used for "long haul" signal interfaces. We expect to see increased use of wireless links (perhaps even inside the box) for the same reasons. We often joke about putting a mini-satellite dish right on the chip - who knows, that may not be far off.

Connectors, of course, are severely affected by microwave frequencies. Without special care, these can cause severe impedance "bumps" and associated reflections and emissions. If the connectors are shielded, the problems become even more interesting. We once tested several connectors in the 5 GHz range, and saw significant differences above 1 GHz due to very subtle design features.

Effects on Shielding & Enclosures - Good news and bad news here. The good news is that even very thin conductive materials work quite well in the GHz range. Even a thin coating on plastic (or maybe an IC cover) can be very effective.

The bad news, however, is that any discontinuity or penetration can cause major shielding leaks. At 10 GHz, a 1.5 mm opening only provides 20 dB of shielding (1/20 wavelength). If you need more, the openings need to be even smaller. Gaskets need to be continuous, of course. You may need to resort to special tricks, like adding a metal collar to a hole for a fiber optic penetration. This is known as the "wave guide beyond cutoff" technique.

Summary: We hope you enjoyed our quick visit to the land of "Microwave EMI." And don't be too distraught - remember, all of this means job security for anyone who deals with EMI problems.

Some Humor...

Here are some things to ponder when you are working late at night at the test lab on an EMI problem...

- Why do you need a driver's license to buy liquor, when you can't drink and drive?
- Why are there interstate highways in Hawaii?
- Why do we park on driveways, and drive on parkways?
- Why is when you transport something by car, it's called a shipment, but when you transport something by ship it's called cargo?
- Why are there flotation devices under airline seats instead of parachutes?
- Why are cigarettes sold in gas stations when smoking is prohibited there?
- Why isn't phonetic spelled the way it sounds?
- Why is it when you are driving around looking for an address, you turn down the radio?
- Can you imagine a world with no hypothetical situations?

(From an e-mail on the Internet.)

EDN Supplement Update...

We are pleased to announce an update to the EDN Magazine *Designer's Guide to Electromagnetic Compatibility,* written entirely by us. We updated all the materials, and added two new chapters as well. The original 1994 version was very well received, and we hope you enjoy the new update as well.

If you are an EDN subscriber, you will be receiving this supplement as a FREE addition in October or November. If you are not an EDN subscriber, reprints will be available from Cahners for a nominal charge. (Or try to heist a copy from one of your EDN-reading colleagues.)

We have been told that the original reprint was very popular, and that a few companies even bought hundreds of copies for their engineers. We'll provide information on the reprints in the next issue of the KGB, and also on our web site, *www.emiguru.com.*

EMI-Toolkit® 2.0...

Now available, an updated version of our popular *EMI-Toolkit* ® software. The new version includes many useful features, plus an improved format. Come on CD, and runs under Windows 95/98/NT/2000. $150 single user, $750 for site license. Discounts for V1.0 users.

We are also shipping *EMI-Toolkit® Plus*, which includes additional summary information on most relevant EMI standards. For more details on either version, call 1-888-EMI-GURU, or email *bkimmel@emiguru.com*.

> Suppose you were an idiot -- suppose you were a member of Congress. But I repeat myself. **– Mark Twain**

Book Review...

Here is the latest offering from Mark Montrose on EMC and circuit boards, hot off the press. A useful addition to any EMC library.

"Printed Circuit Board Design Techniques for EMC Compliance, 2nd Edition" Mark Montrose, IEEE Press, 2000. First edition owners will find plenty of new information and updates in this edition. An in-depth treatment on printed circuit board design. Good nuts and bolts information, with quantitative guidelines. Targeted at the technician and circuit board designer, but also has good information for design engineers. ISBN 0780353765.

A KGB Bullet...

Here is a quick way to calculate low frequency magnetic field shielding for conduits or cable shields:

$SE = 20 \log (1 + ut/2R)$, where

SE = shielding in dB
u = relative permeability of shield
t = thickness of thickness or conduit
R = radius of shield or conduit
(t & R must be in the same units)

About Kimmel Gerke Associates...

We are often asked to give a quick description of what we do and who we are. If you are asked by someone needing EMI help, here are several key points about KGA...

Point I... We are a two-man **electrical engineering firm that specializes in consulting & training on EMI/EMC (electromagnetic interference and compatibility) issues.**

These include five areas:

- **Regulatory Compliance** (Emissions, immunity, FCC, CISPR, IEC, CE, MIL-STD-461, DO-160, SAE, etc.)
- **Radio Frequency Interference** - (RFI)
- **Electrostatic Discharge** -(ESD)
- **Power Disturbances** - (Transients, magnetic fields, etc.)
- **Self Compatibility** - (Signal Integrity, Analog, etc.)

Point II... We are Registered Professional Engineers (PE) and NARTE Certified EMC and ESD engineers. **Between us, we have over 70 years of industry experience.**

Point III... We are not a test lab - **our emphasis is on EMC design, troubleshooting, and training.** While we are knowledgeable on key EMC tests and regulations, our focus is on design/systems issues, and how to identify, prevent, and fix EMI problems.

Point IV... We serve many industries, and **our support ranges from circuit boards to complete systems.** We've helped clients in the following areas:

- **Computers** (PCs to supercomputers)
- **Industrial Controls** (Individual controls to full systems)
- **Vehicular** (Planes, trains, automobiles, farm machinery)
- **Medical** (Diagnostic, clinical, patient connected)
- **Telecommunications** (Small and large systems)
- **Military** (MIL-STD-461, TEMPEST, EMP, etc.)
- **Architecture** (Shielded rooms, lightning, power)

Point V... We are an independent consulting firm with no outside affiliations. **Our advice and recommendations are free from any bias or other business concerns.**

Please feel free to pass our name along to your colleagues. Your referrals are always sincerely appreciated.

Kimmel Gerke Associates, Ltd.
300 Christine Lane
W. St. Paul, MN 55118

1-888-EMI-GURU

FIRST CLASS MAIL