Using an Oscilloscope And Sniffer Probe To Solve EMI Problems

Part I: *Locating the Source*

**by H. Stephen Berger, The Electro-Mechanics Co.,
10620 Metric Blvd., Austin, TX 78758 (512) 835-4684**

Few tools are more helpful to an engineer wrestling with an EMI problem than a good set of near-field sniffer probes. Used with an oscilloscope, this tool is very useful in quickly answering these crucial questions:

- Where is the source of a failing signal within a piece of equipment?
- Which design approach has the best prospects for yielding an effective solution?
- Which fix, among an array of alternate design solutions, has the highest probability for success?

The combination of a set of sniffer probes with an oscilloscope is an inexpensive and readily available combination which provides a solid tool for the informed engineer. This series of articles explains how sniffer probes used with an oscilloscope can answer these questions. This article deals with locating a signal source within a given unit. In succeeding articles, questions will be dealt with concerning how to diagnose the cause and how to prescreen various options.

It usually surprises an engineer when he is first shown how much good EMI work can be done with an oscilloscope and sniffer probe (**Figure 1**). The first lesson most engineers learn about EMI is that getting accurate, repeatable results requires a carefully established and calibrated test setup, usually an open field test site or a shielded room. Generally such a test environment is priced at a total initial cost of $100,000 to $250,000. It is absolutely true that final qualification of equipment to FCC, VDE or MIL- STD specifications requires such precision. It is easy to assume that all good EMI work requires the support of elaborate equipment. However, a great deal of useful development work can be done in a lab setting with far less precise and more readily available equipment.

This series of articles explores the use of sniffer probes and oscilloscopes in EMI engineering. To put it in more technical terms, we will discuss the application of using time domain instrumentation in conjunction with near-field probes (**Figure 2**) for solving far-field frequency domain problems.

There are, however, trade-offs which should be understood up front. First, working in the near-field with an oscilloscope and a sniffer probe perturbs the field being measured and causes some inaccuracy in the measurements for which adjustments cannot be made. Hence, final qualification must be performed in the required test environment of a screen room or an open field site.

More important for our purposes, there is a relative loss of precision which can be countered by the mental acumen of the engineer. As a general rule, less expensive equipment requires more thought and understanding from the engineer. Einstein had the amazing capacity to perform his "gedunken" or

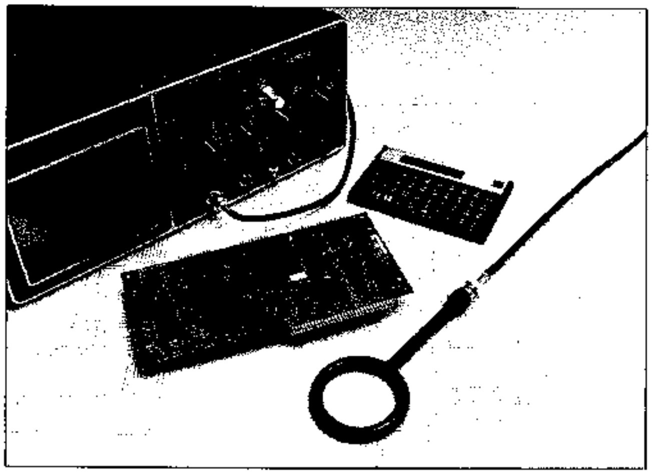


Figure 1. An oscilloscope and diagnostic probe provide a powerful tool in dealing with EMI/RFI problems. This combination enhances the engineer's efficiency by providing fast and accurate diagnostic insight into an emanating circuit.

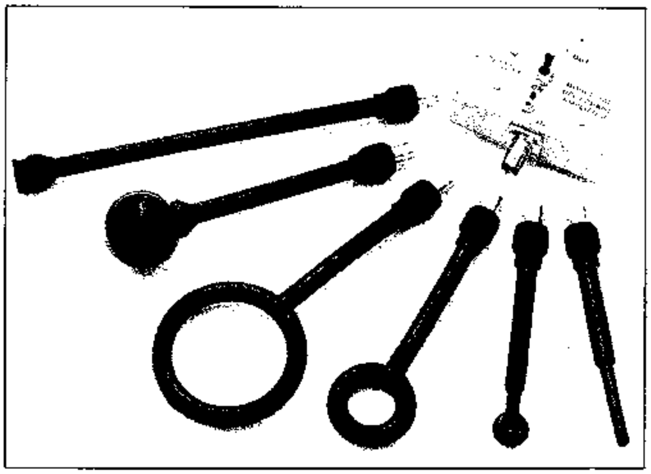


Figure 2. The Electro-Mechanics 7405 Probe Set. Both magnetic and electric field probes are required for maximum diagnostic versatility. A broadband pre-amplifier is useful and often required to provide sufficient signal strength to the oscilloscope.

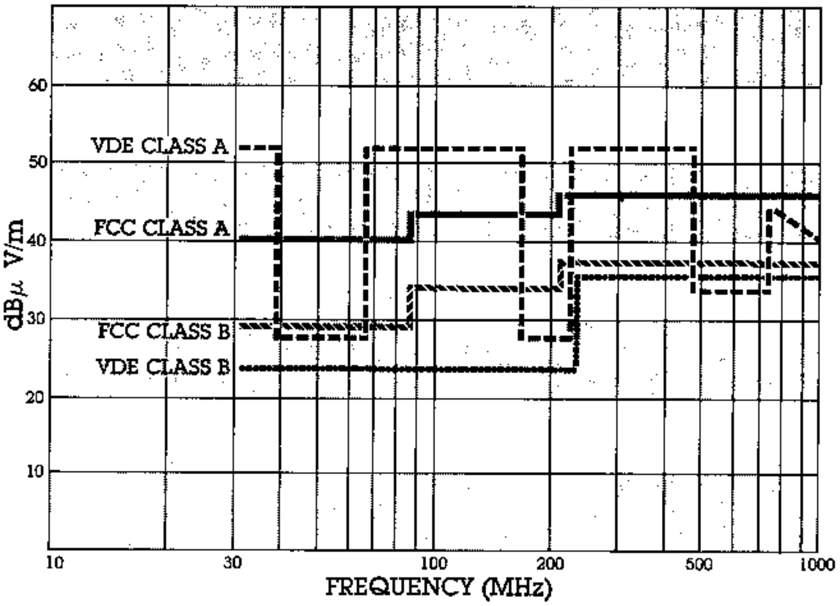


Figure 3. FCC and VDE Radiated Requirements. While these requirements are stated in terms of the frequency domain, the engineer must find the source in the time domain.

thought experiments. He would think through a complex physical experiment and deduce the correct result from his understanding of the physics involved.

Most of us require a little more physical equipment when performing an experiment. Good engineering requires the accurate analysis of physical parameters. This quest for accuracy is complicated by the real life demands of limited budgets and tight schedules. Elegance in engineering often is finding solutions which satisfy such complex or even conflicting demands.

In order to create such elegance in the arena of EMI, the engineer must develop a practical working understanding of near-field to far-field changes and of frequency-to-time domain transforms. For the engineer willing to expend a bit more mental energy, there can be a real payoff in reduced equipment requirements and a savings of schedule time. The job of solving EMI problems becomes less expensive and more convenient. The insightful engineer can accomplish a great deal of solid EMI engineering in the comfort of his own lab.

How do you locate the source of a signal in a piece of equipment? The first step is to understand the nature of the time domain to frequency domain transform. The various specifications are all given in the frequency domain (**Figure 3**), a given number of dB/μV at a particular bandwidth over a given frequency range.

When you test your equipment, you may be told something like, "It fails by 10 dB at 40 MHz and 3 dB at 120 MHz." Now, how do you find out where the offending frequency is being generated? Enter the oscilloscope.

The most helpful first step is to demodulate the offending signal in order to get a time domain representation of it. To accomplish this, first set the spectrum analyzer for a 0 Hz frequency span and peak up on the signal of interest. This essentially changes the spectrum analyzer into a tuner receiver and makes its display a frequency filtered oscilloscope.

Take the video output off your spectrum analyzer and run it to the scope. You could use the spectrum analyzer display (**Figure 4**), but the oscilloscope will allow you much greater flexibility in adjusting the signal amplitude and triggering according to your purposes.

Get a clear picture of the signal produced on the oscilloscope. You now have on the oscilloscope a good representation of what you are looking for when you start sniffing with your probe.

A few scope photos of the demodulated trouble frequencies prepare you to return to your lab. Now with a set of sniffer probes, you begin to look for similar signals in your equipment. As you locate close matches to the demodulated signals, you have strong clues to the source of these signals. As you find the sources, you know on which subassemblies, circuits or even gates to work.

As you develop your skills, you will want to study the various types of modulation which take place. There are several physical phenomenon which cause lower frequency signals to modulate and radiate out as higher frequency signals. A working knowledge of FM, AM, audio rectification and other phenomenon gives greater facility in understanding and interpreting the data revealed by demodulated signals. This understanding gives good insight into what kind of radiating structure must be present to produce the observed event. This understanding also allows greater facility in recognizing the original signal from its altered and often distorted modulated representation.

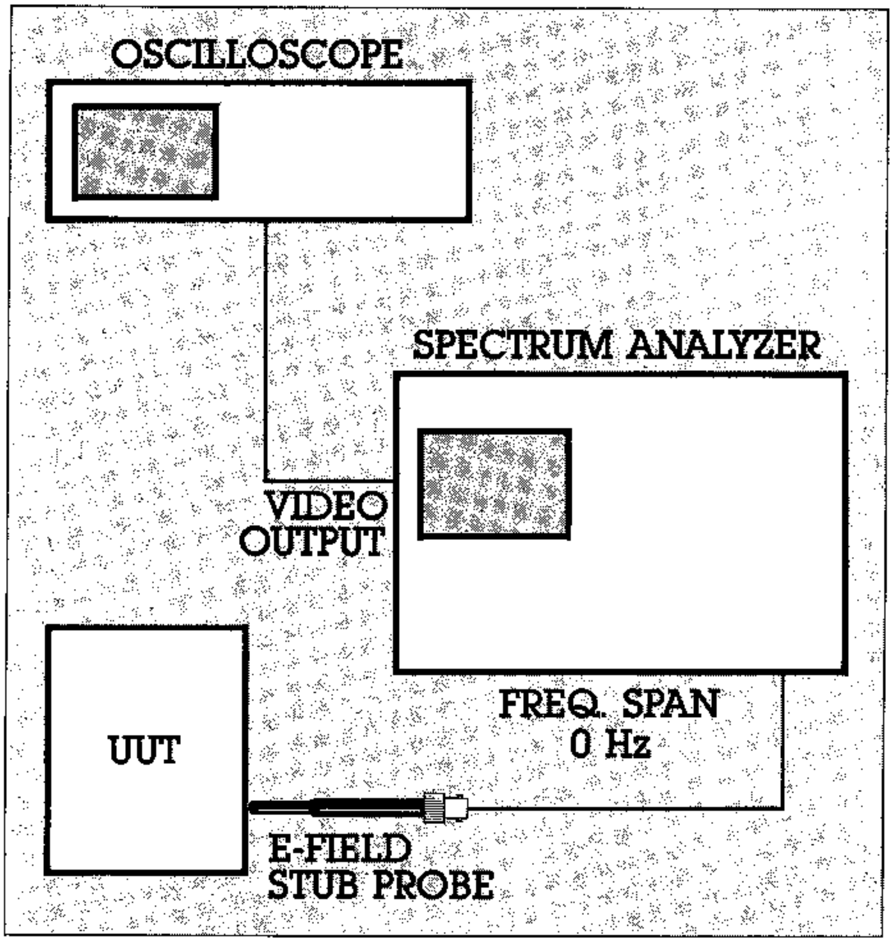


Figure 4. A Simple Technique for Signal Demodulation. By using the video output of a spectrum analyzer, an oscilloscope may be used to capture a time domain representation of the signal of interest.

Often the demodulated picture will contain just the transitions of a digital signal. At times, only the rising or falling edge will be present in a high-frequency signal. Understanding the radiation physics allows the appearance of the original signal to be surmised. Often all that will be present in the photograph from the oscilloscope presentation is the high-frequency components of a signal. These components are what are radiating.

Getting an idea of what the waveform may look like through demodulation is not the only use for the time domain-frequency domain transform. A little analysis and thought usually will reveal what part of the waveform is causing the problem. For example, if you have a 16 MHz clock and you have a 16 MHz problem, then you know that the base signal is causing the problem. More typically, your probing may lead you to the 16 MHz clock when trying to find a 208 MHz problem. Now we think a minute. A 208 MHz signal has a wavelength 1/13 of 16 MHz.

If the problem is caused by a rise or fall time, we may be looking for a waveform component which is between a wavelength and 1/8 of a 208 MHz wavelength. So we look at the oscilloscope picture for waveform components on the 16 MHz clock that are 1/13 to 1/104 of the 16 MHz wavelength. We soon begin to zero in on undershot and overshot or other parasitic components. We may not have to quiet the entire circuit but rather just roll off the offending components. What we have done is mentally transform a frequency domain failure to a time domain picture which we can work on in our lab.

Having identified what the signal of interest looks like on the oscilloscope, it must now be located within the equipment. At times, this already will have been accomplished during the demodulation process. For example, as you demodulated a 50 MHz signal, it became clear that the 50 MHz was pulsing on at a 40 kHz rate. You may know that the only 40 kHz source in your unit is the switching rate in the power supply.

Using an Oscilloscope And Sniffer Probe To Solve EMI Problems

Part II: *Finding Solutions*

by H. Stephen Berger, The Electro-Mechanics Co.
10620 Metric Blvd., Austin, TX 78758 (512) 835-4684

Understanding why a particular circuit is radiating is difficult at best. Often the task seems so formidable that this vital step is skipped totally when dealing with an emissions problem. However, when correctly handled, a small sniffer probe used with an oscilloscope can diagnose the cause of an electromagnetic interference problem. By determining the nature of the radiating structure, the engineer quickly may select the most appropriate design techniques. Good diagnosis saves many false starts and random attempts to rectify a problem.

This is the second article in a series on using small electromagnetic sniffer probes with an oscilloscope in dealing with EMC/EMI problems. The first article in the series dealt with using small sniffer probes to locate a signal within a unit. This article will deal with using sniffer probes to get a rough estimate of the field impedance. The field impedance then is used to diagnose the radiation physics of a given situation. The final article in this series will outline an efficient method for prescreening alternate design solutions.

Knowing the field impedance of an EMI problem can bring great efficiency to the engineering process by guiding the engineer quickly to appropriate solutions to the problem. The engineer presented with an EMC/EMI problem needs to know two things before he can efficiently address the situation. First, he must know what is radiating inside the unit. Secondly, he must know why that component or circuit is radiating.

Radiation is caused either by an instantaneous change in current flow, causing a magnetic field, or by an instantaneous change of a potential difference, causing an electric field (**Figure 1**). Experience has shown a high degree of correlation between magnetic fields with differential mode current flow and electric fields with common mode current flow. Although a change in voltage will cause a change in current and vice versa, one of these vectors will predominate. The impedance of the radiating source will determine whether a predominately magnetic or predominately electric field is produced.

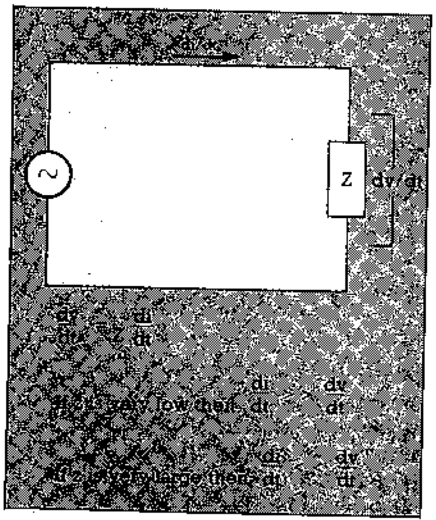


Figure 1. All electromagnetic radiation is caused by either a change in the current or a change in the voltage. A radiating circuit's source impedance determines whether magnetic or electric flux will dominate in the near-field.

Magnetic fields typically are produced by local current loops within a unit. These loops may be analyzed as differential mode. Electric fields require high impedance sources. Since the changing potential is isolated by a substantial impedance on all lines into the circuit, all lines will carry just the forward current.

Remember that the impedance spoken of here is the total impedance at the radiating frequency. Often what appear to be low-impedance connections turn out to be high impedance due to the inductance in the physical circuit.

One of the most common ways for all lines in a circuit to become high-impedance lines is for the ground servicing that circuit to contain a significant inductance. At some frequency, this ground inductance becomes a high impedance. Because the entire circuit references ground, this impedance becomes effectively in series with every line in the circuit. The return flow in this situation is developed by capacitive coupling to conductors external to the unit or to fortuitous conductors within the unit.

From the local perspective of the unit, this is a common mode situation (**Figure 2**). In other words, EMC/EMI problems may be classified principally as current-related or voltage-related. Current-related problems normally will be associated with differential mode situations. Likewise, voltage problems normally will be associated with common mode circuit situations. Too often solutions are attempted before the radiating parameter is understood. Unfortunately, solutions effective for differential mode are seldom effective against a common mode problem. Hence, knowledge of the field impedance is essential if many fruitless attempts are to be avoided.

Before proceeding to the measurement procedure, a brief review of the physics of the situation is required. In the far-field, that is more than about one wavelength from the source, the ratio of the E and H field components of the propagating wave resolve themselves to the free space impedance of 377 ohms. In the far-field, the E and H field always will have a ratio of 377 ohms. In the near-field that ratio changes radically. The ratio of E to H field or field impedance is determined in the near-field by the source impedance. Now as we probe in close to the equipment, we can switch between an E field probe and an H field probe. By noting the rate of change of the field strength vs. distance from the source and the relative amplitude measured by the probes, the relative field impedance may be determined.

Low-impedance sources or current-generated fields initially will have predominately magnetic fields. The magnetic component of the field will predominate in the near-field but will display a rapid fall-off as you move away from the unit. This change may be observed through an H field probe.

Low-impedance sources also will give a much higher reading, in the near-field, on an H field probe than on an E field probe (**Figure 3**). Alternately, high-impedance sources will display a rapid fall-off when observed through an E field probe.

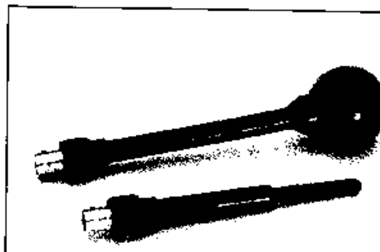
There are two ways of determining the nature of the source impedance. The first is to map the rate of fall-off of the E and H fields. One of these vectors will fall off more rapidly than the other. The second method is to measure both vectors at the same point and by their ratio determine the field impedance. The equation E/H=R is calculated and compared to the free space impedance of 377 ohms. Values higher than 377 ohms will indicate a predominance of the electric field. Lower values will indicate that the magnetic field component is predominating. From this the engineer may be guided to plan his approach to the problem by tailoring it to a differential mode situation or a common mode situation.

Field theory leads us to expect a 1/R fall-off for a plane wave, where R is the distance from the source. In the near-field, the nonpropagating, reactive field will drop off at multiple powers of the inverse of the distance, $1/R^N$. Typically, the reactive field will fall off at something approaching $1/R^3$. Hence, we would predict these measurements:

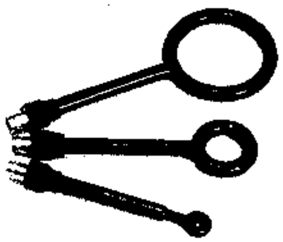
Distance			
A/B =	1.5	2.0	3.0
Propagating Field			
1/R	3.52 dB	6.02 dB	9.54 dB
Reactive Field			
$1/R^3$	10.57 dB	18.06 dB	28.63 dB

The way to perform these measurements is very straight forward. After the source is identified, two or three angles of approach are measured. A typical situation would record 2 points at .5 and 1.5 meters from the source along 2 radials from the source. The signal is measured at each point with a probe which is highly selective of the H field and another probe which is highly selective of the E field (**Figure 4**). The rate of fall-off is noted for each probe and the relative amplitude between the probes is noted. In deciding what the relative amplitude is, the conversion factor of each probe must be taken into account (**Figure 5**).

Generally, differential mode data is well behaved. The amplitude measured with the H field probe will be significantly higher than that measured with the E field probe. Also the H field will drop off at a much faster rate than the E field rate.

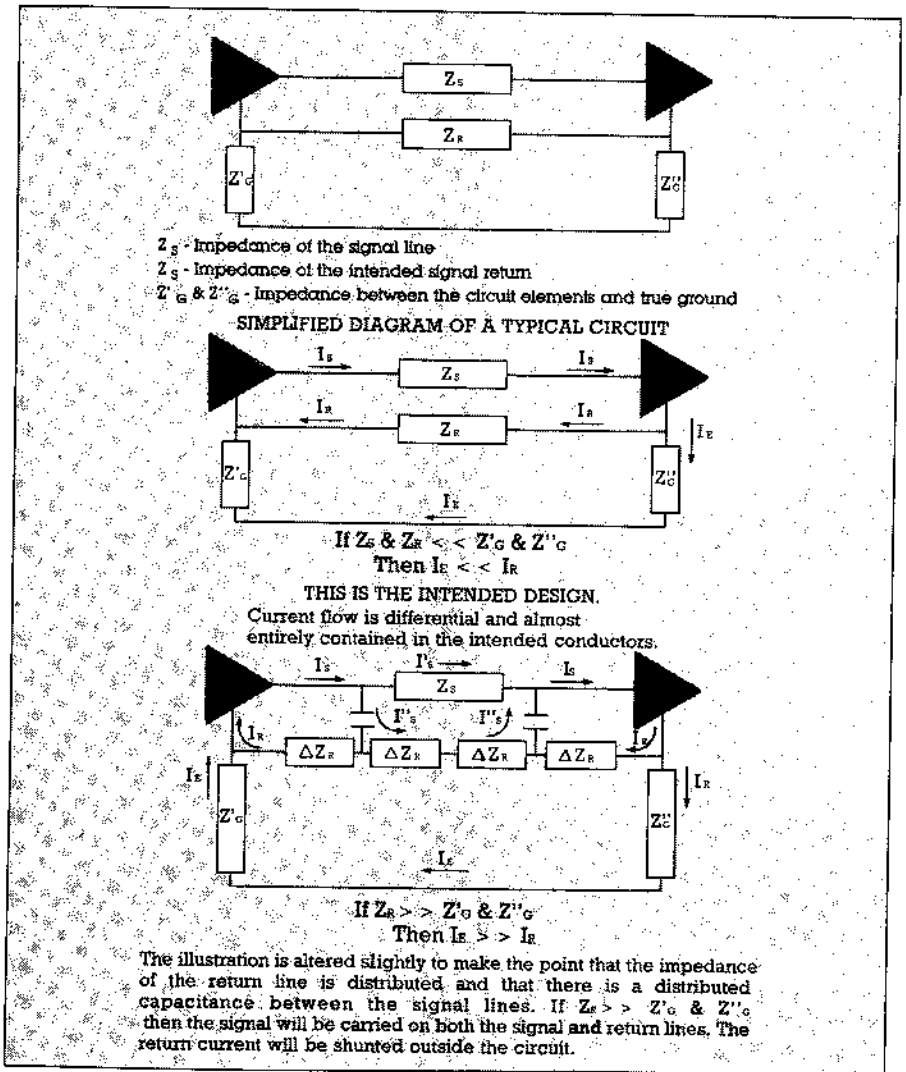


This stub probe and ball probe are sensitive only to the E field. Because they have almost no current pickup capacity, they are highly insensitive to the H field.



Some examples of single turn, shielded loop probes. These probes are highly selective of the H field while being relatively immune to the E field.

Figure 3.



Z_S - Impedance of the signal line
Z_S - Impedance of the intended signal return
Z'_G & Z''_G - Impedance between the circuit elements and true ground

SIMPLIFIED DIAGRAM OF A TYPICAL CIRCUIT

If Z_S & $Z_R << Z'_G$ & Z''_G
Then $I_E << I_R$

THIS IS THE INTENDED DESIGN.
Current flow is differential and almost entirely contained in the intended conductors.

If $Z_R >> Z'_G$ & Z''_G
Then $I_E >> I_R$

The illustration is altered slightly to make the point that the impedance of the return line is distributed and that there is a distributed capacitance between the signal lines. If $Z_R >> Z'_G$ & Z''_G then the signal will be carried on both the signal and return lines. The return current will be shunted outside the circuit.

Figure 2. Illustrations of common and differential mode current flow.

Common mode measurements often are less well behaved. Often the best indicator is the relative amplitude. The E field probe will have a much higher reading than the H field probe. The drop-off rate will be faster when measured with the E field probe. However, my experience is that the E field, being a high potential field, is much more susceptible to perturbation. Often the reading will be very sensitive to cable placement and differences in the position of the person holding the probe. This susceptibility to being perturbed can be a hint that the field is coming from a high potential source.

What does qualitative knowledge of the field impedance tell us? Basically, this insight tells us how to approach the EMC/EMI design for the problem. By determining the dynamics of the radiating structure, we may surmise what kinds of designs will be effective in solving the radiation problem. A primarily H field or magnetic field problem signifies that current flow predominates. The other possibility is that the problem is predominately electrical or E field. In this case, the field impedance is relatively high. A high field impedance means there is a potential build-up across some impedance, and this high potential region is the radiating source.

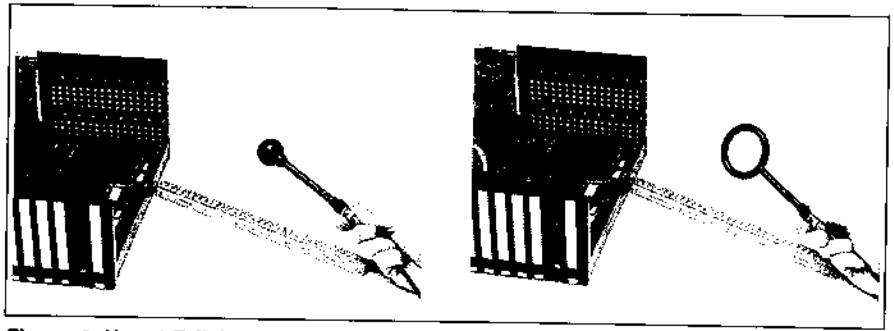
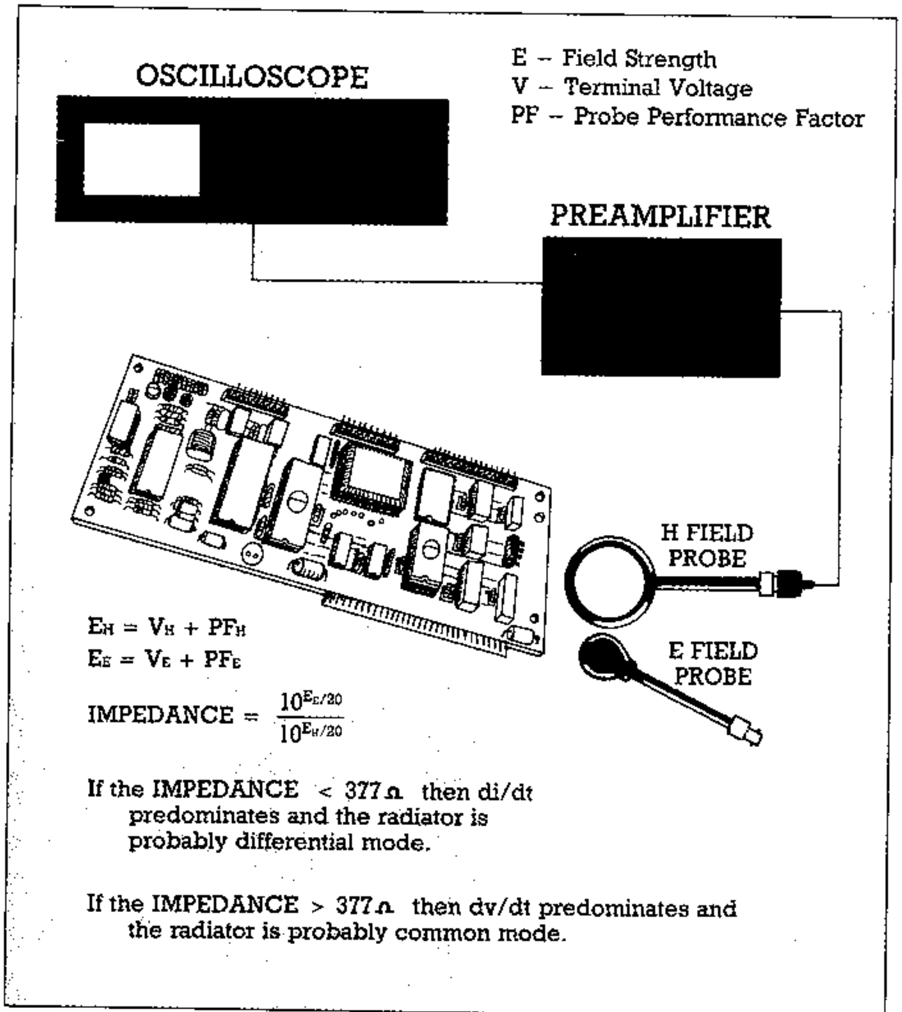


Figure 4. H and E field probes are being used to diagnose a problem on a printed circuit board. (By mapping the rate of roll-off of the H and E fields, the source impedance may be discerned.)



E – Field Strength
V – Terminal Voltage
PF – Probe Performance Factor

$E_H = V_H + PF_H$

$E_E = V_E + PF_E$

$$\text{IMPEDANCE} = \frac{10^{E_E/20}}{10^{E_H/20}}$$

If the IMPEDANCE $< 377\Omega$ then di/dt predominates and the radiator is probably differential mode.

If the IMPEDANCE $> 377\Omega$ then dv/dt predominates and the radiator is probably common mode.

Figure 5. By using two probes to measure the field strength at a single location, the file impedance at that point may be determined.

Knowing that a problem is differential mode tells us that it will respond to remedies such as:

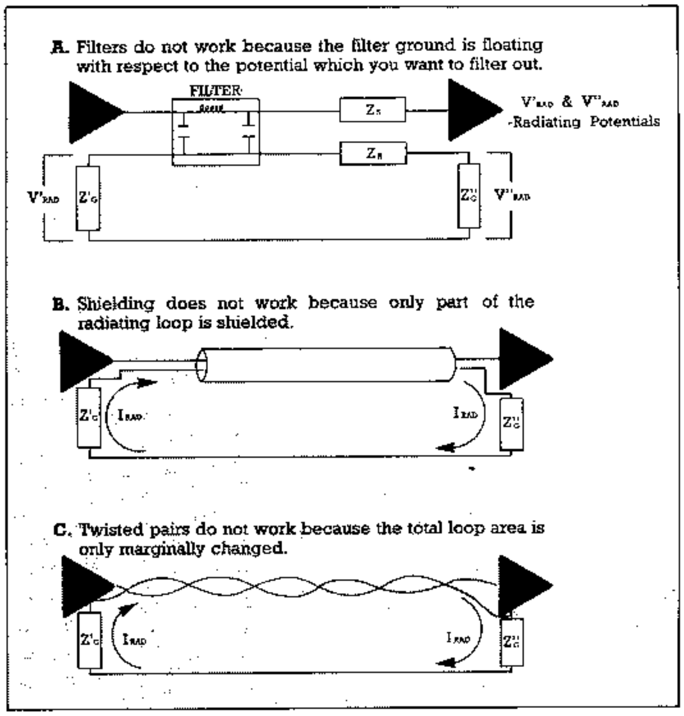
- Reducing circuit loop area.
- Reducing signal voltage swing.
- Shielding of the entire radiating loop. (But it will not respond well to partial shielding of the radiating loop. Partial shielding typically occurs when the path of the return current is mapped incorrectly and so not included inside the shield.)
- Filtering the radiating signal line.

However, notice the perplexing results which arise when differential mode solutions are applied to a common mode problem.

Many of the techniques useful in the differential mode context will prove totally ineffective (**Figure 6**). For example:

- Reducing circuit loop area. The radiating signal is on the signal and supposed return path so this will be ineffective. Things like using twisted pair wires or even coax will yield little in the way of signal reduction.
- Reducing the signal voltage swing. This may help. At other times, it too will be ineffective; for example, when the radiating potential is developed not at the output signal driver but more deeply in the circuitry. At times, the radiating potential will be built up on the power or ground system through the additive effects of a number of gates. Hence, suppression of any one of these gates in isolation will not yield much signal reduction.
- Shielding the entire loop. A problem arises when you try to decide where to ground the shield. The radiating potential is on signal ground. If you tie the shield to signal ground, all you have done is add more radiating antenna to the system.
- Filtering the signal line. To what ground do you tie the filter? Using signal ground will be totally ineffective since the filter simply will float with the radiating potential.

Once you know you are dealing with a common mode problem, you quickly can start using design techniques which have good potential for success. Usually you will start by analyzing the ground and power distribution system. The key



A. Filters do not work because the filter ground is floating with respect to the potential which you want to filter out.

B. Shielding does not work because only part of the radiating loop is shielded.

C. Twisted pairs do not work because the total loop area is only marginally changed.

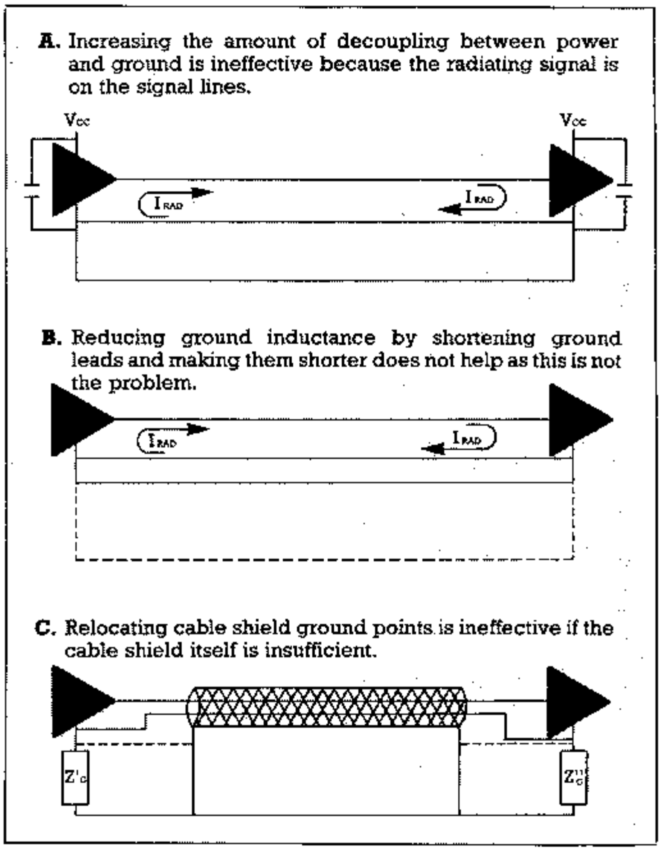
Figure 6. Why some traditional differential mode techniques do not work in common mode situations.

will be to understand what rf impedances these systems present and reduce the excessive impedance. Techniques which might be tried are:

- Increased decoupling of power to ground.
- Reduced lead or trace inductance by reducing their length or making them wider.
- Inserting ground and power grids or planes.
- Shielding using a ground separate from signal ground.
- Relocating I/O cables to lower impedance area on the ground structure.
- Placing common mode filters on the output lines using dissipating elements.

Some traditional common mode techniques do not work in differential mode situations (**Figure 7**).

Using sniffer probes to measure the relative field impedance is a simple yet powerful diagnostic technique. Properly understood, a knowledge of the field impedance allows quick sorting of design approaches. Before various solutions are attempted, the engineer must determine why a circuit is radiating. EMI may be reduced to either controlling currents or reducing voltages. Efficient engineering requires accurate diagnosis. Field impedance measurements are a powerful tool to aid the diagnostic process by guiding the design approach to current-oriented or voltage-oriented approaches. **EE**



A. Increasing the amount of decoupling between power and ground is ineffective because the radiating signal is on the signal lines.

B. Reducing ground inductance by shortening ground leads and making them shorter does not help as this is not the problem.

C. Relocating cable shield ground points is ineffective if the cable shield itself is insufficient.

Figure 7. Why some traditional common mode techniques do not work in differential mode situations.

Using an Oscilloscope And Sniffer Probe To Solve EMI Problems

by H. Stephen Berger, The Electro-Mechanics Co., 10620 Metric Blvd., Austin, TX 78758 (512) 835-4684

Part III: *Prescreening Possible Implementations*

Preview testing of alternate implementations of a solution is a vital, timesaving step in the process of resolving an electro-magnetic problem. Once an interference problem has been properly diagnosed, the responsible engineer often will find a myriad of possible solutions, and alternate implementations of solutions jump into his mind.

The problem in EMC/EMI engineering in general is that the guiding equations are too complex to calculate quantitatively in practical, real world situations. The engineer cannot run through a simple formula and calculate, "I need .3 μF of capacitance spread evenly and divided at 3 locations to reduce this common mode radiation by 6.0 dB." Usually, he is left to resolve a far more ambiguous situation. An example might be, "I have a common mode problem radiating off of the end of the unit holding the I/O connections. To reduce this I can:

- Improve the decoupling on the board in general.
- Improve the power and ground grid or put in a ground plane.
- Decouple that end to chassis ground.
- Place a common mode choke on the output I/O."

Any of these solutions may work. The most economical solution may be a hybrid of two of the options applied in conjunction. Obviously, every one of the options could be implemented in numerous ways. The physical mechanization of a particular approach will have a tremendous bearing on its effectiveness. The role of prescreening is to provide a relatively quick way to sort through a matrix of possible implementations and solutions.

This is the last in a series of articles on using small sniffer probes with an oscilloscope in EMC/EMI engineering. The first two articles in the series dealt with using probes to answer the questions:

- From where is the problem frequency coming (**Figure 1**)?
- What kind of techniques are likely to be effective in solving this EMI problem?

The next question to address is "How can I efficiently evaluate different solutions in the lab?"

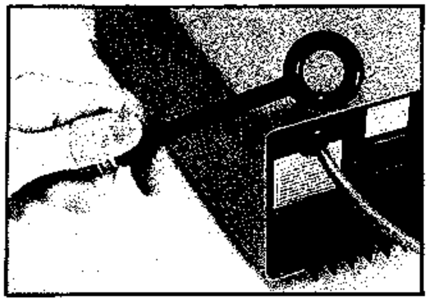


Figure 1. Locating the source of an emanating signal begins by finding its exit points. Cover seams and air flow vent holes are primary suspects. In this figure, a loop probe traces the cover seams in the effort to find where a signal is escaping.

In evaluating various solutions, we have to exercise great skill and awareness. Here the far-field/near-field effects can be the most misleading. The E and H field vectors initially are determined by the source impedance. As we move away from the source, these vectors increasingly balance until the radiating field is isolated as a plane wave with a characteristic impedance of 377 ohms.

In the near-field, the field strength can contain, in addition to the radiating field, a significant nonradiating reactive component. This reactive component does not propagate far. The radiating field will fall off proportionally with the reciprocal of the first power of the distance from the source, 1/R. However, the reactive component will fall off proportionate with the reciprocal of multiple powers of the distance from the source, $1/R^N$.

Typically, the reactive field will fall off at a rate approaching $1/R^3$. The presence of these different field components means that the near-field reading often will be dramatically different than one would expect based on an extrapolation of the far-field reading. Near-field readings often will seem higher than expected based on extrapolations from far-field data due to the presence of the reactive field. Alternately, they may be lower than expected because of nulls created by the interference pattern set up near the unit.

A reflection pattern often is established near the unit by the direct wave combining with its reflection off parts of the unit and other items in the vicinity. A design which reduces field strength by attenuating the nonradiating, reactive field may show relatively little effect on the far-field reading.

Another factor which affects near-field readings is that the presence of the probe affects the circuit being probed. There will be capacitance and inductance between the circuit being measured and the probe with its associated cabling (**Figure 2**). The probe itself will reradiate the received field and so alter the field it is measuring. In a nutshell, we should hold a healthy suspicion of the analytical validity of near-field readings.

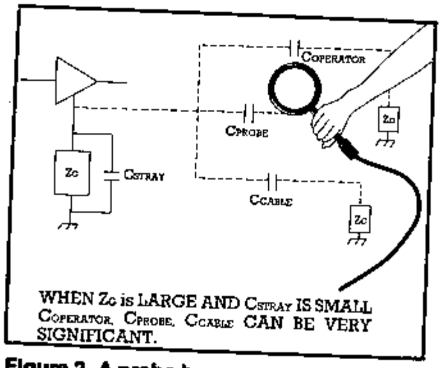


Figure 2. A probe becomes part of the circuit during near-field measurements. Stray capacitance to the probe, its cabling and the operator are particular problems with high-impedance sources. Furthermore, reradiation from the probe can alter the field distribution substantially.

However, technical imprecision does not eliminate a method totally. Often, perhaps even normally, an attenuation of the near-field, field strength will translate into an attenuation of the far-field reading as well. As long as we do not expect a linear relationship, we can get some real benefit from near-field probing. Generally, a reduction of the nonradiating field will mean that the radiating field also has been reduced. There are two approaches which typically yield good results in evaluating alternate design solutions.

The first step in each procedure is to choose a set of measurement points. **Figure 3** shows a typical fix evaluation setup. Two to six points would be a typical number. Since the object is to get some idea of what the far-field results will be, most of the points should be somewhat distant, say, one to four meters away. Also, choose one or two points quite close to the source. If a given solution gives a dramatic reduction, the close points may be the only ones which will allow quantitative measurement of the reduction.

The more distant measurement points may lose the signal into the system noise. It always should be kept in mind that a given solution may only redirect the beam. Especially with narrow beam problems, solution attempts frequently only shift the beam so that it radiates in a different direction (**Figure 4**). In choosing the test points, this possibility of shifting the signal should be guarded against.

After the measurement points are chosen, the unit is baseline. Each point is measured with both an E field and an H field probe. Then each design alternative is implemented and measured over the same set of points.

The two procedures differ at this point in how they approach the measurements which have been taken. The first method is based upon finding a solution with a large saftey margin. Suppose a signal fails the required limit by 3 dB. Once that signal source is located in the lab, it is measured in the near-field. Now we can set as our goal the reduction of this near-field reading by the required 3 dB plus a safety factor of 6 or 10 dB. We are allowing a large margin of error due to near-field effects. Furthermore, any solution which seems to pass even this criterion will be held only as a possible solution until it has been confirmed by far-field measurements.

The second method is to provide multiple solution paths and make the fina selection on an open field test site Several possible solutions are identified which seem to be effective. These then are taken to an open field test site and final selection between them is made. We will continue with our hypothetical situation in which a signal fails by 3 dB. Once the source of the problem has been identified, an experienced engineer seldom has much problem thinking of 5, 10, 20 or even more possible alternatives.

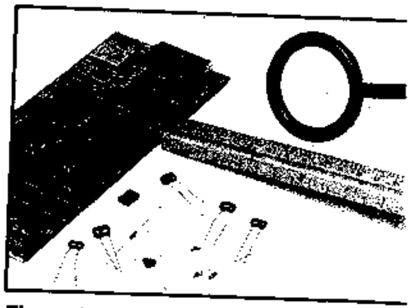


Figure 3. Using near-field measurement makes rapid evaluation of various fixe relatively simple. Although analytically imprecise, this technique offers tremendou qualitative insight in sorting through alternate implementations.

Based upon quick prescreening in the lab, perhaps three solutions may be selected from a matrix of possibilities. These three might show near-field reductions of 3 to 10 dB. These three then are taken to the test range and tried in order of their appeal.

We might try the least expensive solution first or the solution with the greatest potential for success, depending on our project priorities. The benefit is that, in the convenience and efficiency of our lab, we quickly sort through various ideas and go to the test range with some prescreening having been done. In effect, this process forces us to formulate a test plan with several fall-back positions. Just the process of formulating a test plan makes the prescreening effort worthwhile because of the efficiency it

Dealing...

brings to the range testing.

Prescreening provides empirical evidence that a noise reduction technique has been applied correctly. This type of probing tells us when we properly have analyzed the problem and carried our understanding to the point of designing an effective solution. Preview testing helps expedite the time it takes to close the gap between good analysis and to have a sufficient technical solution. It is an intermediate step between the thinking at the desk and achieving the final qualification.

A final benefit is the value prescreening adds to the inevitable failures which occur. Too often failures are walked away from with valuable information left behind. An EMC/EMI reduction effort fails for one of these reasons:

- The diagnosis was wrong.
- The technique used was inappropriate to the diagnosis.
- The technique was improperly applied.
- Some outside factor is involved, such as a second source radiating at the same frequency.

The exercise of trying to determine why a solution appeared to work in the lab but failed in the final test is well worth the effort. I will never forget the solution which worked in the lab and on the range before 10 a.m. but failed later in the day. It turned out that the rise in temperature was affecting the values of the decoupling capacitors and making them less effective at higher temperatures.

The key to being effective in the use of probes with an oscilloscope is to keep our purposes clearly in mind. The purposes of using near-field probes with a time domain oscilloscope are:

- To gain information which far-field, frequency domain instrumentation cannot give us. We gain information about the location of the radiating source which was previously unavailable to us.
- To reduce test expense by adding relatively inexpensive equipment into our store of resources available for solving EMC/EMI problems.
- To reduce test time by quickly prescreening various solutions and alternate implementations of the same solution.

If we keep in mind that our purpose is to gain insight and reduce time and expense, then the use of small sniffer probes with an oscilloscope will prove extremely valuable (**Figure 5**). As long as we do not force this tool to serve some other purpose, such as giving analytically precise far-field results, we will not be disappointed.

A good understanding of the physics of electromagnetic radiation combined with near-field probes and an oscilloscope provide a valuable, convenient and inexpensive tool to the EMI engineer. Properly used, probes can help locate a signal source, understand the radiating mechanism and choose probable design approaches and prescreen design alternatives. When constrained to its proper niche, the near-field probe is an essential tool for quick, efficient EMC/EMI engineering. **EE**

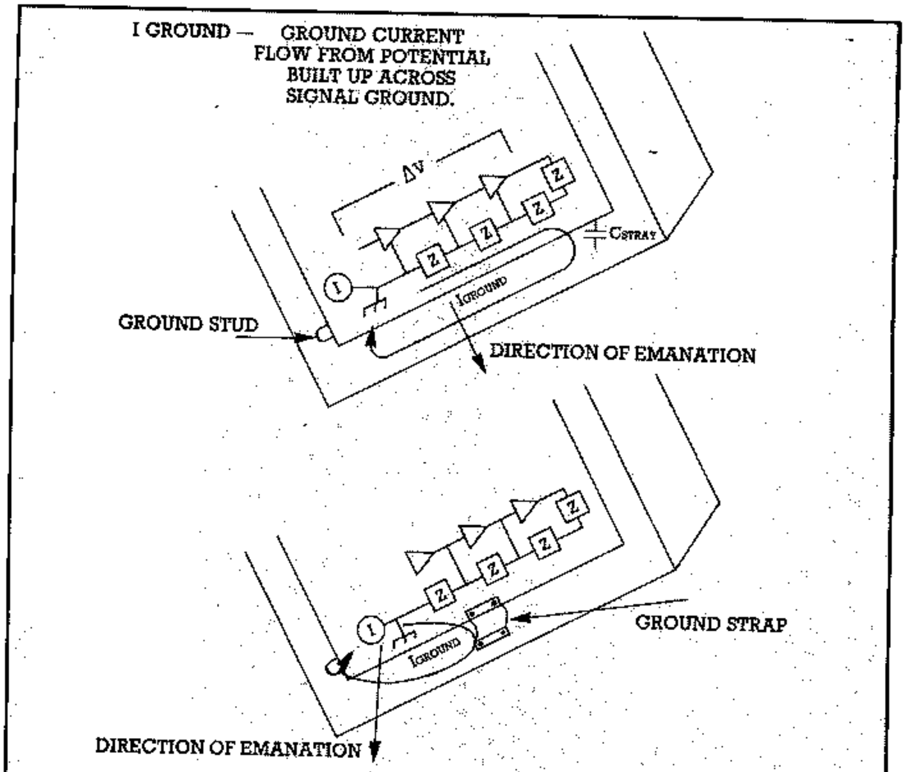


Figure 4. The possibility that a particular fix only redirects a signal always must be guarded against. In this example, the placement of ground strap changes the geometry of the radiating current loop. While such a ground strap may reduce the signal, it also will redirect it. To properly assess this modification, the perimeter of the unit must be scanned.

Figure 5. A ball probe is used to examine a flat cable. The distributed inductance over the length of the cables makes them particularly susceptible to common mode problems. High-impedance sources such as this cable are best examined with an E field probe.