User Guide

Near-Field Probe Set

Anritsu Part Number: 2000-1689

/inritsu

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$$C\hspace{-0.3em}\epsilon$$

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To prevent the risk of personal injury or loss related to equipment malfunction, Anritsu Company uses the following symbols to indicate safety-related information. For your own safety, please read the information carefully *before* operating the equipment.

Symbols Used in Manuals

Danger

This indicates a risk from a very dangerous condition or procedure that could result in serious injury or death and possible loss related to equipment malfunction. Follow all precautions and procedures to minimize this risk.

Warning

WARNING ⚠

This indicates a risk from a hazardous condition or procedure that could result in light-to-severe injury or loss related to equipment malfunction. Follow all precautions and procedures to minimize this risk.

Caution

This indicates a risk from a hazardous procedure that could result in loss related to equipment malfunction. Follow all precautions and procedures to minimize this risk.

Safety Symbols Used on Equipment and in Manuals

The following safety symbols are used inside or on the equipment near operation locations to provide information about safety items and operation precautions. Ensure that you clearly understand the meanings of the symbols and take the necessary precautions *before* operating the equipment. Some or all of the following five symbols may or may not be used on all Anritsu equipment. In addition, there may be other labels attached to products that are not shown in the diagrams in this manual.

This indicates a prohibited operation. The prohibited operation is indicated symbolically in or near the barred circle.

This indicates a compulsory safety precaution. The required operation is indicated symbolically in or near the circle.

This indicates a warning or caution. The contents are indicated symbolically in or near the triangle.

This indicates a note. The contents are described in the box.

These indicate that the marked part should be recycled.

For Safety

| Warning | Always refer to the operation manual when working near locations at which the alert mark, shown on the left, is attached. If the operation, etc., is performed without heeding the advice in the operation manual, there is a risk of personal injury. In addition, the equipment performance may be reduced. Moreover, this alert mark is sometimes used with other marks and descriptions indicating other dangers. |

| Warning / or | When supplying power to this equipment, connect the accessory 3-pin power cord to a 3-pin grounded power outlet. If a grounded 3-pin outlet is not available, use a conversion adapter and ground the green wire, or connect the frame ground on the rear panel of the equipment to ground. If power is supplied without grounding the equipment, there is a risk of receiving a severe or fatal electric shock. |

| Warning / **WARNING** ⚠ | This equipment can not be repaired by the operator. Do not attempt to remove the equipment covers or to disassemble internal components. Only qualified service technicians with a knowledge of electrical fire and shock hazards should service this equipment. There are high-voltage parts in this equipment presenting a risk of severe injury or fatal electric shock to untrained personnel. In addition, there is a risk of damage to precision components. |

| Caution | Electrostatic Discharge (ESD) can damage the highly sensitive circuits in the instrument. ESD is most likely to occur as test devices are being connected to, or disconnected from, the instrument's front and rear panel ports and connectors. You can protect the instrument and test devices by wearing a static-discharge wristband. Alternatively, you can ground yourself to discharge any static charge by touching the outer chassis of the grounded instrument before touching the instrument's front and rear panel ports and connectors. Avoid touching the test port center conductors unless you are properly grounded and have eliminated the possibility of static discharge.

 Repair of damage that is found to be caused by electrostatic discharge is not covered under warranty. |

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Chapter 1 — General Information

1-1   Introduction

The Anritsu Near-Field Probe set (p/n: 2000-1689) includes three magnetic (H) field and two electric (E) field probes designed for use in the resolution of emission problems. The set also includes a 20 cm extension handle and comes in a wood carrying case.

The probe set provides a means of accurately detecting H-field and E-field emissions, while the 20 cm extension handle provides access to remote areas in larger units. Made of injection molded industrial grade plastic, the probes are durable, light weight, and compact.

The probes offer a fast and easy means of detecting and identifying signal sources which may cause a product from meeting federal regulatory requirements. The probe set is a convenient and inexpensive tool for extending the capability of your Anritsu spectrum analyzer.

A near-field probe is an essential tool for quick and efficient EMC/EMI engineering. Using near-field probes and a spectrum analyzer can produce the following results:

- Gain information about the source and location of the radiation member.
- Reduce test expense by adding inexpensive equipment for solving EMC/EMI problems.
- Reduce test time by pre-screening various solutions and alternate implementations.

Table 1-1.   Anritsu's 2000-1689 Near Field Probe Set

Model	Sensor Type	E/H or H/E Rejection	Upper Frequency
901 6 cm loop	H-Field	41 dB	790 MHz
902 3 cm loop	H-Field	29 dB	1.5 GHz
903 1 cm loop	H-Field	11 dB	2.3 GHz
904 3.6 cm ball	E-Field	30 dB	> 1 GHz
905 6 mm stub tip	E-Field	30 dB	> 3 GHz
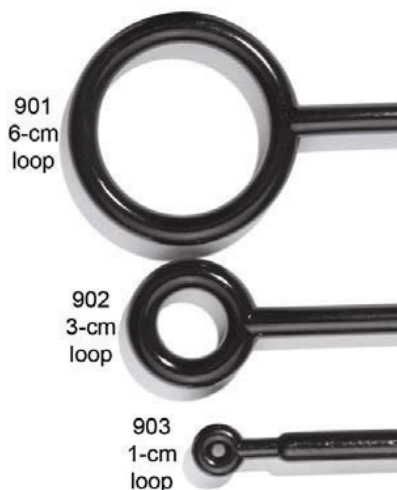
Magnetic (H) Field Probes

The probe set includes three H-field probes of varying size and sensitivity: models 901, 902, and 903. These probes are highly sensitive to the H-field while being relatively immune to the E-field.

Each H-field probe contains a single turn, shorted loop inside a balanced E-field shield. The loops are constructed by taking a single piece of 50 ohm, semi-rigid coax from the connector and turning it into a loop. When the end of the coax meets the shaft of the probe, both the center conductor and the shield are 360 degrees soldered to the shield at the shaft.

Then a notch is cut at the high point of the loop. This notch creates a balanced E-field shield of the coax shield. The loops reject E-field signals due to the balanced shield.

Electric (E) Field Probes

The probe set also includes two E-field probes: the stub probe (model 904) and the ball probe (model 905). Due to the small sensing element, the stub probe is relatively insensitive. This is an advantage when the precise location of a radiating source must be determined. For example, while moving the stub probe over the pins of an IC chip, variations can be noted at spaces as close as two or three pins.

By comparison, the ball probe is much more sensitive. The larger sensing element does not offer the highly-refined definition of the source location which the stub probe allows, but it is capable of tracing much weaker signals. The impedance of the stub probe is essentially the same as that of a non-terminated length of 50 ohm coaxial cable.
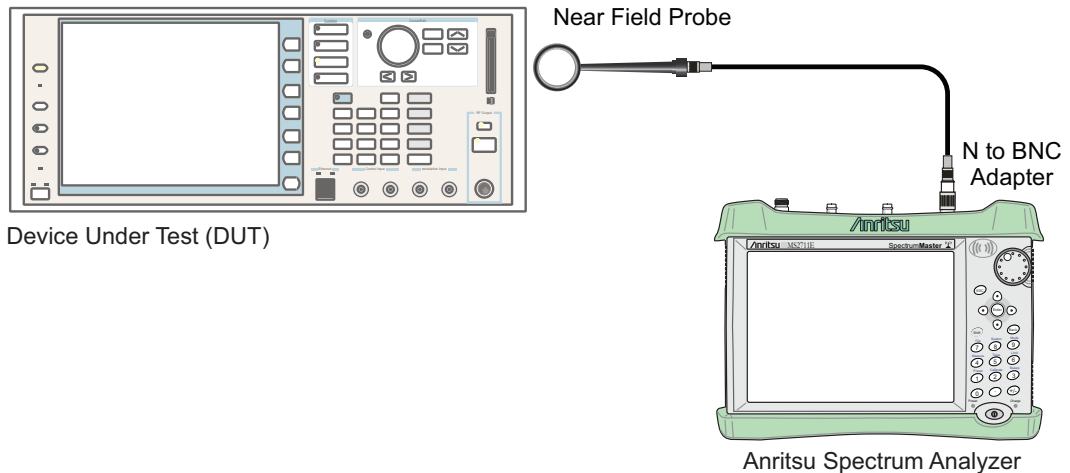
Stub Probe

The model 905 stub probe is made of a single piece of 50 ohm, semi-rigid coaxial cable with 6 mm of the center conductor exposed at the tip. This short length of center conductor serves as a monopole antenna to pick up E-field emanations. With no loop structure to carry current, the stub probe rejects the H-field.

Ball Probe

The shaft of the model 904 ball probe is constructed of a length of 50 ohm coax. The coax is terminated with a 50 ohm resistor in order to present a conjugate termination to the 50 ohm line. The center conductor is extended beyond the 50 ohm termination and attached to a 3.6-cm diameter metal ball, which serves as an E-field pick up. The absence of a closed loop prevents current flow, allowing the ball probe to reject the H-field.

1-2   Typical Configuration

1. Choose the appropriate probe from the Near-Field Probe Set. Refer to Table 1-1 on page 1-1.

2. Connect a coaxial cable from the probe to an N-connector adapter and then to RF In connector on the Anritsu spectrum analyzer. If needed, place the extension handle between the probe and the coaxial cable.

Figure 1-1.   Typical Setup

3. Adjust the spectrum analyzer frequency to the range of interest.

1-3   Probe Selection

Choosing the Correct Probe is determined by:

- Whether the signal is E or H: If the signal is primarily E-field, use the ball probe or stub probe. If the signal is primarily H-field, use one of the loop probes. If unknown, try one of each and select the probe that best picks up the signal.

- The strength of the signal: Select a probe that adequately receives the desired signal of interest. The ball probe is the most sensitive E-field probe and the 6 cm loop is the most sensitive H-field probe. Respectively, the stub probe and the 1 cm loop are the least sensitive E-field and H-field probes.

- The frequency of the signal: If the signal is above 790 MHz, the probe may go into resonance. See the upper resonant frequency listed for each probe in Table 1-1 on page 1-1.

- The physical size of the space where the probe must fit. Refer to Table 1-1 for a description of each probe.

- How closely you want to define the location of the source: Choose the probe that gets as close to the signal source as required. Select a large probe and begin outside a unit, then move closer to the source and switch to smaller probes to identify the location of the source. For example, the smallest probes should allow you to determine exactly which circuit on a printed circuit board is radiating. This kind of refinement provides the ability to stop the radiation at the source rather than shielding an entire unit.

- In Figure 1-2 a ball probe is used to examine a flat cable. The distributed inductance over the length of the cables makes cables particularly susceptible to common mode problems. High impedance sources such as this are best examined with an E-field probe.

Figure 1-2.   Examining a Ribbon Cable

Chapter 2 — Performance and Usage

2-1   Typical Performance Factors

The following graphs show the performance factors (in dB) as a function of frequency for each probe. Individual probe results may vary.

Probe performance factor is defined as the ratio of the field presented to the probe to the voltage developed by the probe at the BNC connector, PF = EN. By adding the performance factor to the voltage measured from the probe, the field strength amplitude may be obtained.
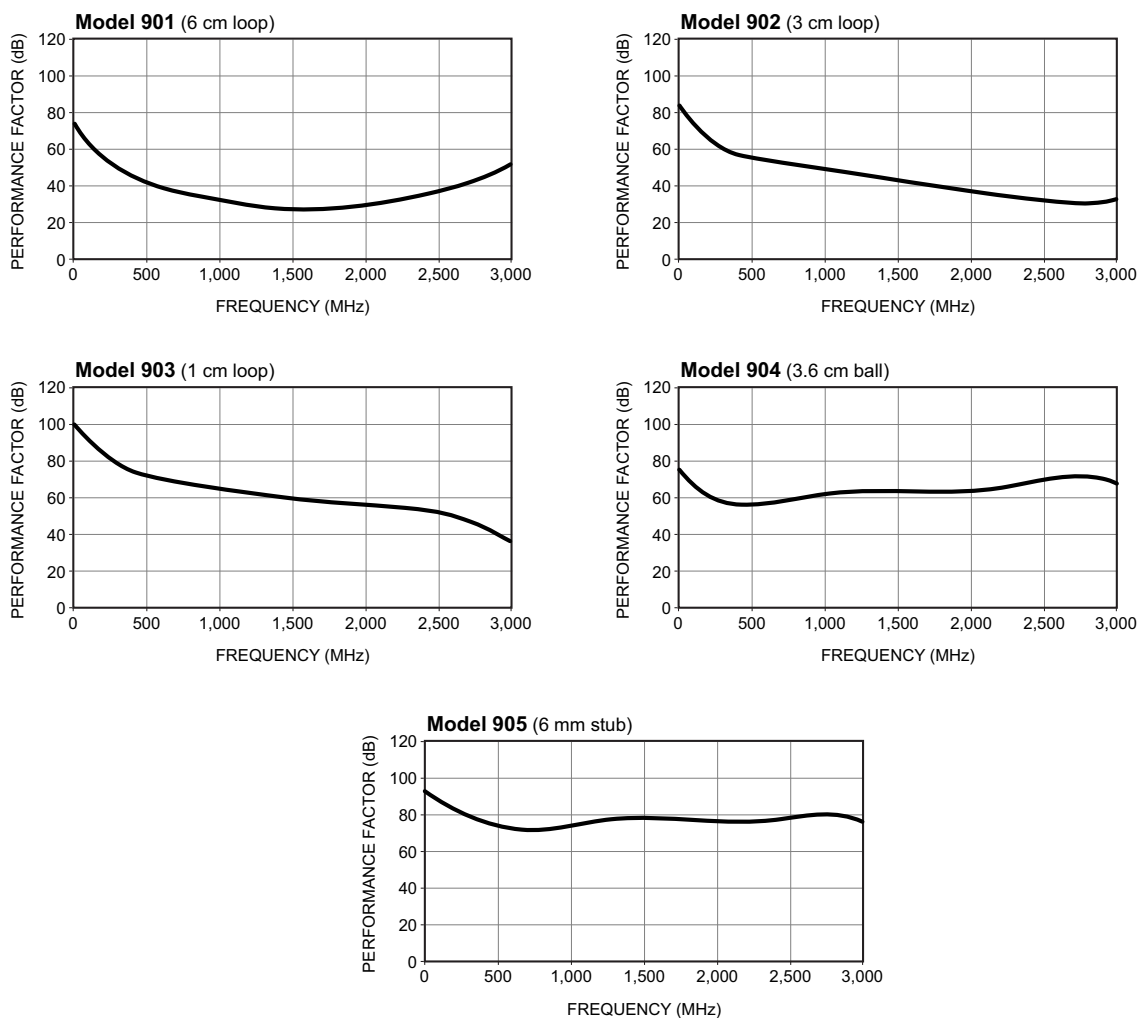

Figure 2-1.   Performance Graphs

All probes in the Near-Field Probe Set are calibrated in a transverse electromagnetic mode (TEM) cell which presents a 377 ohm field. The H-field probes only respond to the H-field; however, the equivalent E-field response is shown in Figure 2-1. This may be done if the field is assumed to be a plane wave with an impedance of 377 ohms. The reason for graphing the factors this way is to allow estimation of the strength of the far-field. If H-field amplitude is desired, subtract 51.52 dB from the performance factor indicated on the graphs in Figure 2-1.

Obtaining accurate, repeatable results from EMI testing requires a carefully established and calibrated test setup, usually an open field test site or a shielded room. Final qualification must be performed in the required test environment of a screen room or an open field site. However, a great deal of preliminary EMI testing can be done with a sniffer probe and signal analyzing instrument. The following sections describe how sniffer probes can be used in various phases of the engineering task.

2-2   Field Strength Measurements

Anritsu spectrum analyzers have the ability to measure field strength. Performance factors for each EMI probe are available in the spectrum analyzers.

Update Firmware

Please confirm that your spectrum analyzer has the latest firmware update. Firmware updates are located on the Anritsu web site:

http://www.anritsu.com/

Search for the product model number. The firmware updates are on the product page under the Library tab in the "Drivers, Software Downloads" section.

Setup Field Strength Measurement

To measure field strength:

   1. On the spectrum analyzer, press the **Shift** key then the **Measure** (4) key. Press the Power and Bandwidth submenu key followed by the Field Strength submenu key.

   2. Press the Antenna submenu key. Press Display until <u>EMI</u> is underlined and select the desired near field probe using the **Up/Down** arrow keys or the rotary knob. Press the **Enter** key to select the antenna factor or **ESC** to cancel.

   3. Connect the probe to the RF In port.

   4. Press the **Freq** main menu key, press the Center Freq submenu key, and enter the center frequency.

   5. Press the **Span** main menu key. At least a portion of the span has to include a frequency within the probe's specified range.

   6. Press the On/Off submenu key so that <u>On</u> is underlined. The instrument automatically adjusts the measurement by the antenna factor selected.

Note	Refer to Anritsu's "Spectrum Analyzer for Anritsu RF and Microwave Handheld Instruments" Measurement Guide (p/n 10580-00244) for additional information on spectrum analyzer measurements.

2-3   Locating Radiating Sources

The first step is to relate the emissions failure to signals used in the Device Under Test (DUT). To do this an understanding of the nature of the time domain to frequency domain transform is necessary.

The various specifications for conducted noise emissions standards are shown in the frequency domain in Figure 2-2 below. However, most DUT operations are characterized in the time domain: 150 ns memory access time, 300 V/ms slew rate, and so on. This section presents a technique that will aid in linking emissions with the signals that create them.
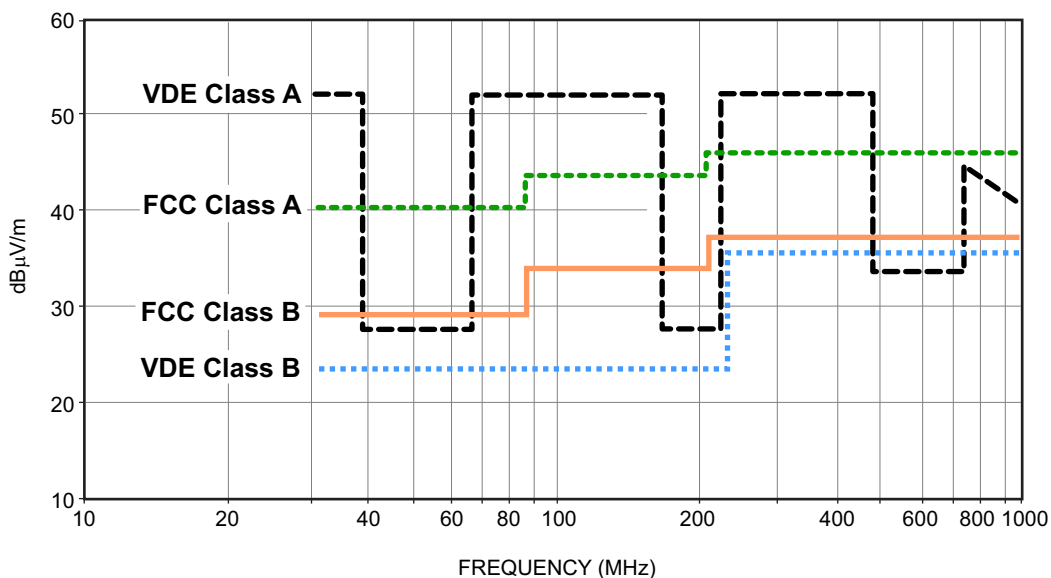

Figure 2-2.   Conducted Noise Emissions Standards

During testing you may receive information indicating, for example, that the emission failed by 10 dB at 40 MHz and 3 dB at 120 MHz. The challenge is to find the DUT signal that created the emissions. You may be able to connect the probe to a spectrum analyzer and locate the source; locating the source of an emanating signal begins by finding the exit points. Cover seams and air flow vent holes are primary suspects.

However, many sources can emit at a given frequency. Most of these emissions are non-propagating, reactive fields. There may be instances when an emission is measured at one frequency, but the source may be generating that emission at another frequency.

Signal Sourcing

Stub Probe

N to BNC
Adapter

Device Under Test (DUT)

Anritsu Spectrum Analyzer
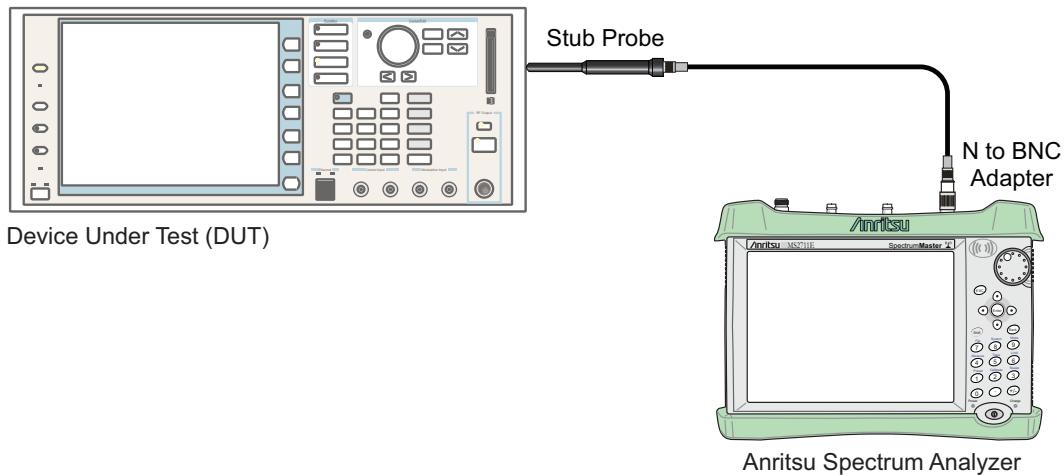
Figure 2-3.   Signal Sourcing

There are several physical phenomena that cause lower frequency signals to modulate and radiate as high frequency signals. A working knowledge of FM, AM, audio rectification, and other phenomena provides greater ability to understand and interpret the data revealed by demodulated signals. This understanding gives insight into the kind of radiating structure that must be present to produce the observed event. It also allows greater facility in recognizing the original signal from the altered and often distorted, modulated representation.

Frequently the EMI emissions measurement will show 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 on the Spectrum Analyzer display is the high frequency components of a signal. These waveform components are the source of the radiation.

Measurement Examples

Example 1: If you see a 16 MHz clock and you see 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 the 208 MHz problem shown on your spectrum analyzer. Remember a 208 MHz signal has a wavelength of 1/13 of 16 MHz.

If the problem is caused by a rise or fall time, you may be looking for a waveform component which is between a wavelength and 1/8 of a wavelength of the radiating frequency.

Example 2: In the 208 MHz example a wavelength is 1/13 of the 16 MHz clock; 1/8 of a wavelength is 1/104 of a 16 MHz pulse width. Look at the Spectrum Analyzer for waveform components on the 16 MHz clock that are 1/13 to 1/104 of the 16 MHz wavelength. You can then begin to zero in on undershoot and overshoot or other parasitic components. You may not have to quiet the entire circuit, but rather roll off the offending components.

After identifying what the signal of interest looks like on the Anritsu spectrum analyzer, it must be located within the DUT. Various probing of the DUT with the EMI probes can then often identify the source of the problem.

Example 3: As you view a 5 MHz signal, maybe 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. If nothing else in the unit operates at that frequency, you have identified your source. Thus, the first step in identifying a signal source is to review what subassemblies in the unit may produce a signal similar to the one you view radiating.

Using EMI (Sniffer) Probes

Typically, there are several possible sources for a given signal. To identify the particular one in question, use the sniffer probes.
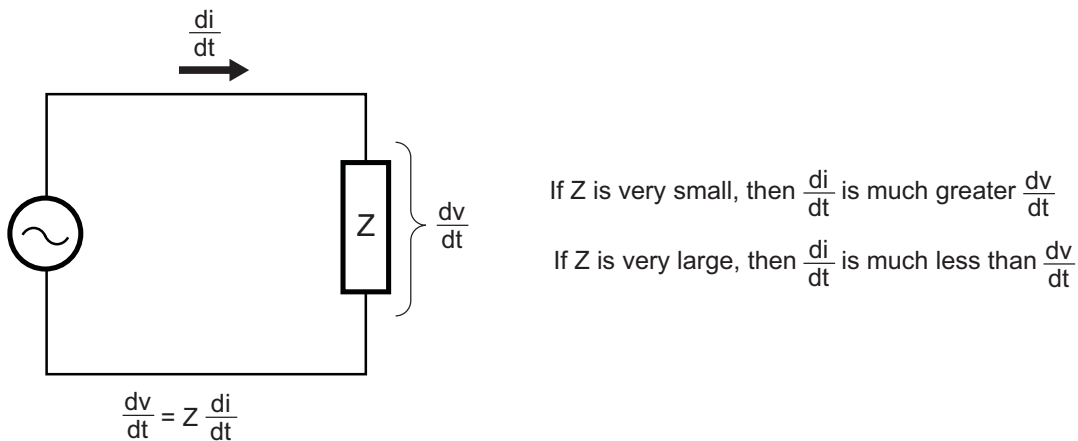
1. Start with the largest loop probe, which is also the most sensitive. Begin several feet from the unit and look at the signal of interest. Search for the maximum and approach the unit along the line of maximum emission.

2. As you near the unit, switch to the next smaller probe; this probe will be less sensitive, but will differentiate the signal source more narrowly. Often the initial probing locates where the signal is escaping from the unit, indicating the point of escape from the housing.

3. Once inside the unit and inside any shielding, look for the source of the signal; use the smallest diameter probe available. You may switch to the stub probe, which is a small and insensitive E-field probe that can be used to get close to the signal source.

Finding both the point of escape from the unit and the actual source provides options in engineering the solution: you may decide to improve the shielding or to suppress the source. The more solution alternatives you identify, the greater the chance of identifying one which meets the requirements of schedule, cost, and performance.

Knowing the field impedance can help find solutions to EMI problems. When presented with an EMC/EMI problem, you need to know two things:

1. What is radiating inside the unit?

2. Why the component or circuit is radiating?

Radiation is caused by an instantaneous change in current flow, causing a magnetic field. Radiation can also be caused by an instantaneous change of a potential difference, causing an electric field. Experience has shown a high degree of correlation between magnetic fields with differential 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.

If Z is very small, then $\frac{di}{dt}$ is much greater $\frac{dv}{dt}$

If Z is very large, then $\frac{di}{dt}$ is much less than $\frac{dv}{dt}$

$$\frac{dv}{dt} = Z\frac{di}{dt}$$

Figure 2-4.   Magnetic Field or Electric Field

Typically, magnetic fields are produced by local current loops within the DUT. These loops may be analyzed as differential mode. Electric fields require high-impedance sources. Because the changing potential is isolated by substantial impedance on all lines into the circuit, all lines will carry just the forward current.

Note	The impedance in this context is the total impedance at the radiating frequency. Often what appears as low-impedance connections are actually high-impedance due to the inductance in the physical circuit.

A common way 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 in the ground path effectively is 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.

2-4   Common and Differential Mode Current Flow

Refer to Figure 2-5 and the following paragraphs for a discussion on common mode and differential mode current flow.

Simplified Diagram of A Typical Circuit
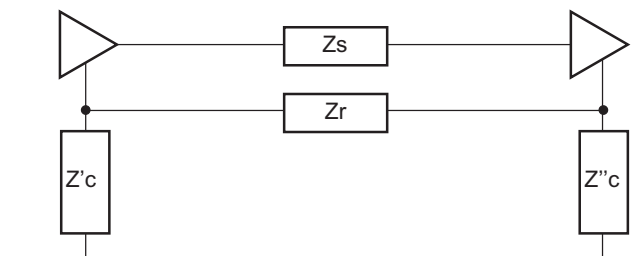
Zs: Impedance of the signal line
Zr: Impedance of the intended signal return
Z'c and Z''c: Impedence between the circuit elements and true ground

Intended Design
Current flow is differential and almost entirely contained in the intended conductors.
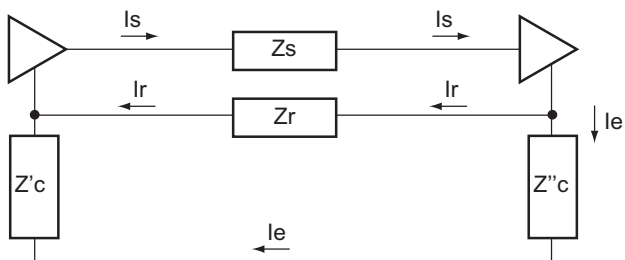
If Zs & Zr is much less than Z'c & Z''c, then Ie is much less than Ir.

Distributed Impedance
The illustration is altered slightly to make the point that the impedance of the return line is distribued and that there is a distributed capacitance between the signal lines.

If Zr is much greater than Z'c & Z''c, then the signal will be carried on both the signal and return lines. The return current will be shunted outside the circuit.
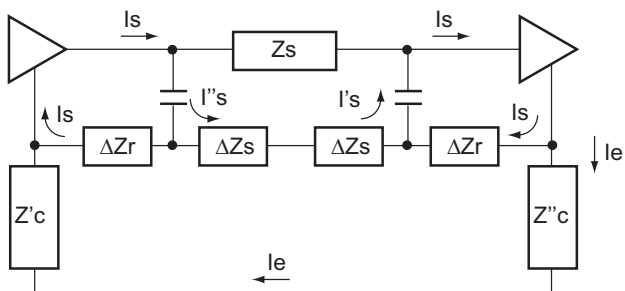
If Zr is much less than Z'c & Z''c, then Ie is much greater than Ir.

Figure 2-5.   Comparison Between Common and Differential Current Flow

EMC/EMI problems may be classified principally as current-related or voltage-related.

- Current-related problems are normally associated with differential mode situations.
- Voltage problems are normally associated with common mode circuit situations.

Too often solutions are attempted before the radiating parameter is understood. Unfortunately, solutions effective for a differential mode problem are seldom effective against a common mode problem.

To review the physics of the situation: In a far-field that is more than about one wavelength from the source, the ratio of the E-field and H-field components to the propagating wave resolve themselves to the free space impedance of 377 ohms. In the far-field the E-field and H-field vectors will always have a ratio of 377 ohms, but in the near-field that ratio radically changes. The ratio of E-field to H-field, or field impedance, is determined in the near-field by the source impedance.

As you probe close to the equipment switch between an E-field probe and an H-field probe. By noting the rate of change of the field strength versus 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 higher reading in the near-field on an H-field probe than on an E-field probe. Alternately, high impedance sources will display a rapid fall-off when observed through an E-field probe.

There are two ways to determine the nature and source impedance:

- Map the rate of fall-off of the E-field and H-field. One of these vectors will fall off more rapidly that the other.
- Measure both vectors at the same point and by their ratio determine the field impedance.

The equation E/H = Z 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 predominate. From these results you can plan an approach to the problem by tailoring it to a differential model 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 non-propagating, reactive field will drop off at multiple powers of the inverse of the distance 1/RN. Typically, the reactive field will fall off at something approaching 1/R3. Therefore, we would predict these measurements relative to measurements at distance equal to one.

Table 2-1.

Distance (A to 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 d	–18.06 dB	–28.63 dB

After the source is identified, two or three angles of approach are measured. A typical situation would record two points at 0.5 meters and 1.5 meters from the source along two 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. 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.
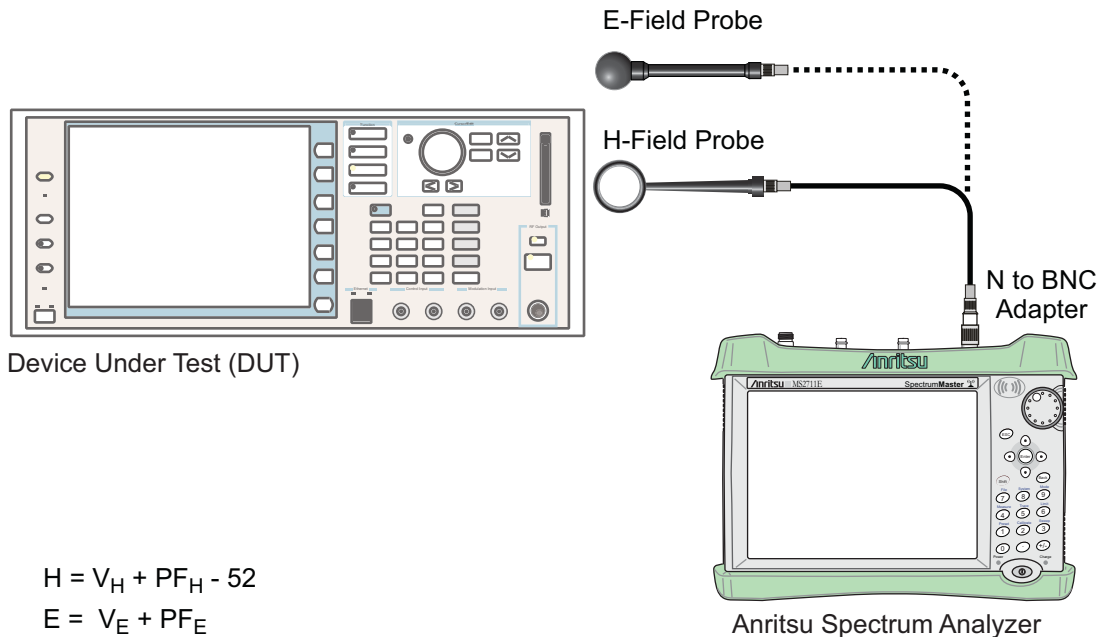
$H = V_H + PF_H - 52$

$E = V_E + PF_E$

$Z = 10^{(E-H)\,/\,20}$

IF Z < 377 Ω then dI/dt predominates and the radiator is probably differential mode.

IF Z > 377 Ω then dV/dt predominates and the radiator is probably common mode.

LEGEND: E = Electrical Field Strength, H = Magnetic Field Strength, PF = Probe Performance Factor, Z = Field Imbalance

Figure 2-6.   Comparing E-Field Strength with H-Field Strength

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

- Common mode measurements are generally 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, experience shows that the E-field, being a high potential field, is much more susceptible to perturbation. Often the reading will be 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.

A qualitative knowledge of the field impedance indicates how to approach the EMC/EMI design for the problem. By determining the dynamics of the radiating structure, it can be surmised what kinds of designs will be effective is solving the radiation problem. A primarily H-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.

A differential mode problem will respond to these types of remedies:

- Reducing circuit loop area.
- Reducing signal voltage swing.
- Shielding the entire radiating loop. 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 not included inside the shield.
- Filtering the radiating signal line.
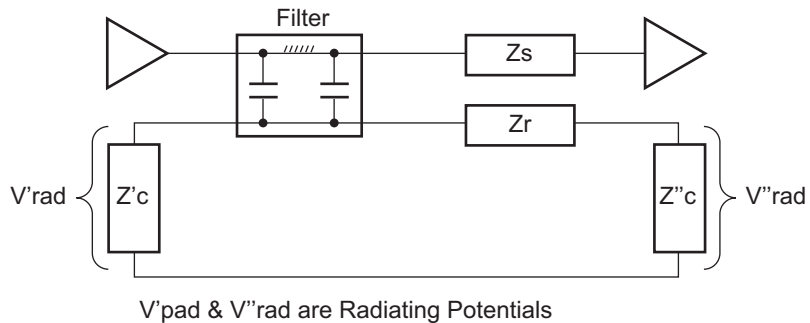
2-5   Differential Mode Techniques

Some traditional differential mode techniques do not work in common mode situations. Refer to .

When differential mode solutions are applied to a common mode problem; many of the techniques will prove ineffective. For example:

- Reducing circuit loop area: The radiating signal is on the signal and return path, so this will be ineffective. Using twisted pair wires or coax will yield little in the way of signal reduction.
- Reducing the signal voltage swing: This will be ineffective when the radiating potential is developed deep in the circuitry, not at the output signal driver. At times the radiating potential will be built up on the power or ground system through the additive effects of a number of gates. Therefore, suppression of any one of these gates in isolation will not yield much signal reduction.
- Shielding the entire loop: A problem arises when deciding where to ground the shield. The radiating potential is on signal ground, but if you tie the shield to signal ground, you ultimately add more radiating antenna to the system.
- Filtering the signal line: A problem arises when deciding where to ground the filter. Using signal ground will be ineffective because the filter will float with the radiating potential.

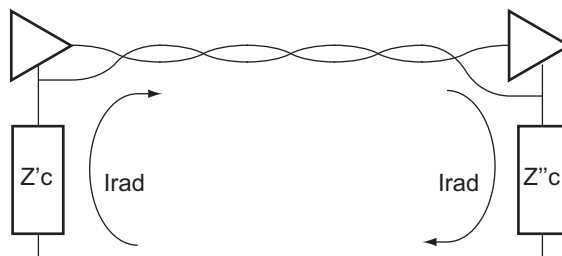Some traditional differential mode techniques do not work in common mode situations.

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

V'pad & V"rad are Radiating Potentials

B. Shielding does not work because only part of the radiating loop is shielded.
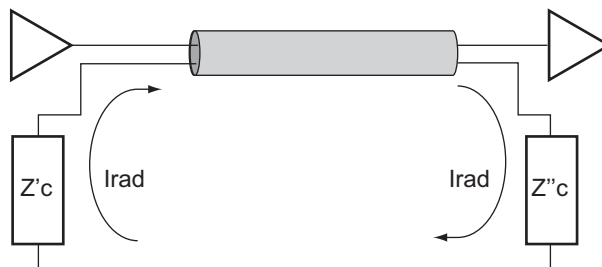
C. Twisted pairs do not work because the total loop area is only marginally changed.

Figure 2-7.   Ineffective Differential Mode Techniques for Common Mode Situations

2-6   Common Mode Techniques

Some traditional common mode techniques do not work in differential mode situations.

Once a common mode problem is determined, use techniques which have a good potential for success. Start by analyzing the ground and power distribution system. Understand what RF impedances these systems present, and then reduce the excessive impedance.

The following techniques are recommended:

- Increasing decoupling of power to ground.
- Reduce 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 a 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.

A. Increasing the amount of decoupling between power and ground is ineffective because the radiating signal is on the signal lines.
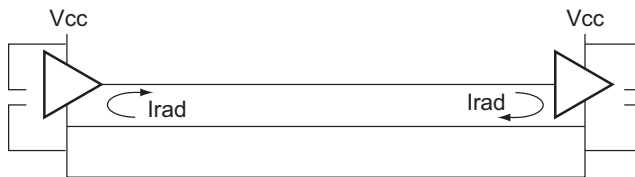
B. Reducing ground inductance by shortening ground leads does not help as this is not the problem.
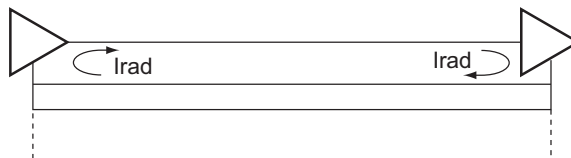
C. Relocating cable shield ground points is ineffective if the cable shield itself is insufficient.
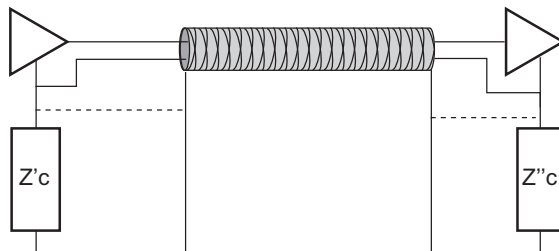
Figure 2-8.   Ineffective Common Mode Techniques for Differential Mode Situations

2-7   Pre-Screening Alternate Solutions

Pre-screening allows you to sort through ideas, formulate test plans, and consider several viable solutions. Pre-screening also provides empirical evidence that a noise reduction technique has been correctly applied, indicating when you have properly analyzed the problem to the point of designing an effective solution.

Testing alternate solutions can save time when troubleshooting an electromagnetic problem. For example, for a common mode problem that involves radiation from the end of a unit with the I/O connections, possible solutions could include the following:

- Improve the decoupling on the board.
- Improve the power and ground grading or put in a ground plane.
- Decouple the end with the I/O connections to chassis ground.
- Place a common model choke on the output I/O.

The most economical solution may be a hybrid of these options applied together. Each option could be implemented a number of ways, and the physical mechanization of an approach will directly impact overall effectiveness.

Evaluating various solutions requires great skill and awareness. It is in this area that the far-field/near-field effects can be the most misleading. The E-field and H-field vectors are initially determined by the source impedance. As you 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 non-radiating 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/RN.

Typically, the reactive field will fall off at a rate approaching $1/R^3$. Two points should be observed:

1. Often the near-field reading will be dramatically different than would be expected based on an extrapolation of the far-field reading. Near-field readings will seem higher than expected due to the presence of the reactive field; alternately, it may be lower than expected because of nulls created by the interference pattern set up near the unit. A reflection pattern is often established near the unit by the direct wave combining with the reflection off parts of the unit and other items in the vicinity. A design which reduces field strength by attenuating the non-radiating, reactive field may show relatively little effect on the far-field reading.

2. The probe becomes part of the circuit during near-field measurements (Figure 2-9 on page 2-14). There is capacitance and inductance between the circuit being measured and the probe with the associated cabling. The probe will re-radiate the received field, altering the field being measured.

When Zg is large and Cstray is small, Coperator, Cprobe, and Ccable can be significant.
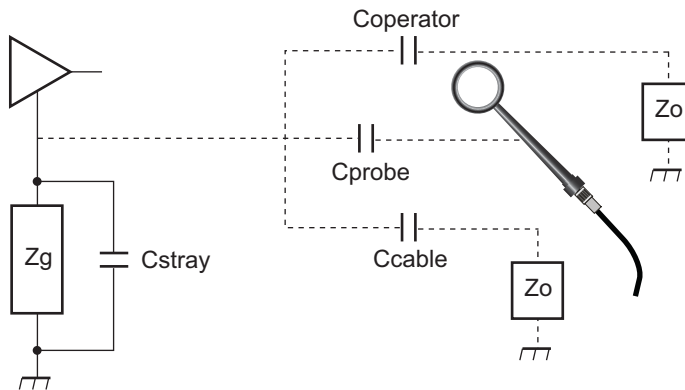
Figure 2-9.   Probe and Operator May Become Part of the Circuit

However, technical imprecision does not necessarily eliminate a method. Sometimes an attenuation of the field strength in the near-field will translate into an attenuation of the far-field reading. As long as a linear relationship is not expected, there can be real benefit from near-field probing. Generally, a reduction of the non-radiating field will also mean that the radiating field has been reduced.

Evaluating Alternate Solutions

There are two approaches that yield good results when evaluating alternate design solutions:

1. The first step in each procedure is to choose a set of points; for example, two to six points. Since the object is to determine what the far-field results will be, most of the points should be one to four meters away. Also, choose one or two points close to the source. If a solution results in a dramatic reduction, this point may be the only one that will allow quantitative measurement of the reduction (Figure 2-10 on page 2-15).

   The more distant measurement points may lose the signal into the system noise; a given solution may only redirect the beam. Especially with narrow beam problems, solutions frequently only shift the beam so that it radiates in a different direction.

   After measurement points are chosen, baseline the unit by measuring each point with an E-field and an H-field probe. That way, each design alternative can be implemented and measured over the same set of points.

The placement of ground straps changes the geometry of the radiating current loop. A ground strap may reduce the signal, but it will also redirect it. To properly assess the modification, the perimeter of the unit must be scanned.
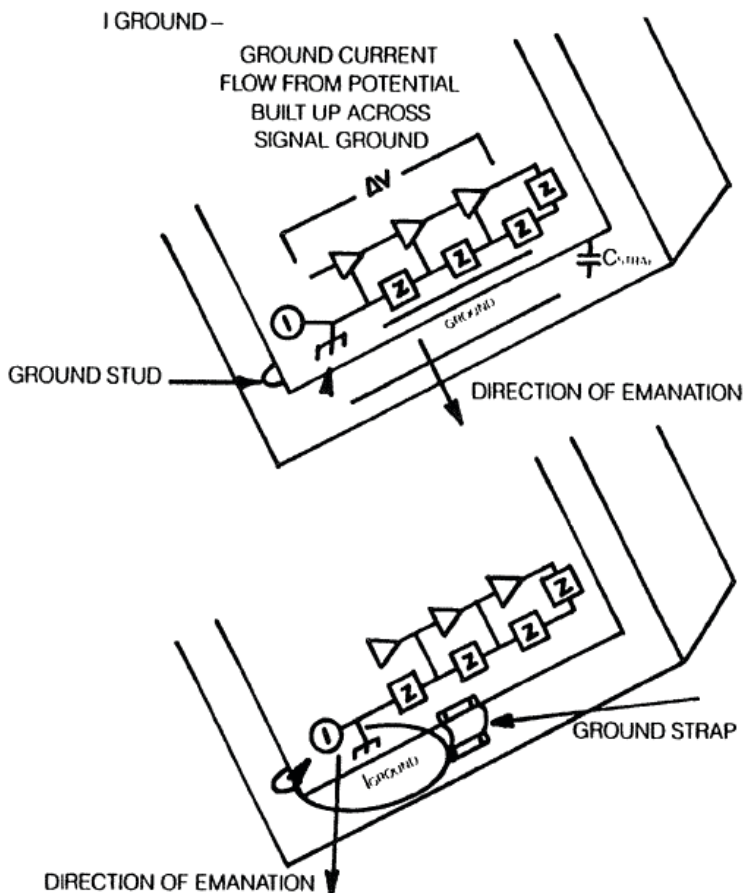
Figure 2-10. Changing the Geometry of Ground Straps

2. The two procedures differ here in how they approach the measurements that have been taken.

- The first method is based upon finding a solution with a large safety margin. For example, suppose a signal fails the required limit by 3 dB. Once that signal is found in the lab, it can be measured in the near-field. The goal is then to reduce in this near-field the 3 dB plus a safety factor of 6 dB or 10 dB. This allows a large margin of error due to near-field effects. Additionally, a solution that passes this must then be confirmed by far-field measurements.

- The second method identifies several solutions which could be effective. In the previous example where the signal failed by 3 dB, after pre-screening in the lab, a variety of solutions may be selected and tested.

A final benefit of pre-screening is that through the inevitable failures, new information can be discovered. For example, an attempt to reduce an emission may fail the following reasons:

1. The diagnosis was wrong.

2. The technique was inappropriate to the diagnosis.

3. The technique was improperly applied.

4. An outside factor is involved, such as a second source radiating at the same frequency.

Example: A solution that worked in the lab and on the range before 10:00 AM failed later in the day. Analysis revealed that the rise in temperature was affecting the values of decoupling capacitors, making them less effective at higher temperatures.

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