INSTRUCTION MANUAL

for

NEAR FIELD PROBE SET

Model:

PS-500

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Warranty

All equipment manufactured by Com-Power Corporation is warranted against defects in material and workmanship for a period of two years from the date of shipment. Com-Power Corporation will repair or replace any defective item or material if notified within the warranty period.

You will not be charged for warranty service performed at our factory. You must, however, prepay inbound shipping costs and have a return authorization.

This warranty does not apply to:

a) Products damaged during shipment from your plant or ours.
b) Products which have been improperly installed.
c) Products operated outside their specifications.
d) Products which have been improperly maintained.
e) Modified products.
f) Normal wear of material.
g) Calibration.

Any warranties or guarantees, whether expressed or implied, that are not specified in this document will not be considered applicable to any equipment sold or otherwise furnished by Com-Power Corporation. Under no circumstances does Com-Power Corporation recognize or assume any liability for any loss, damage, or expense arising either directly or indirectly from the use or handling of products manufactured by Com-Power Corporation, or any inability to use them separately or in combination with other equipment or material.

The warranty is void if items are shipped outside the United States without Com-Power Corporation's prior knowledge.

Warranty Limitations

The above warranty shall not apply to defects resulting from improper or inadequate maintenance by the buyer, unauthorized modification or misuse, operation exceeding specifications, or improper site preparation.

Safety Precautions

The Near Field Probe Set PS-500 is designed to locate sources of electromagnetic energy for use in an EMI or electronics test laboratory. These sources are generally very weak RF sources for low-voltage circuits. Therefore, the probes' sensing tips are insulated solely to isolate them from low-voltage circuitry. Care should be taken not to exceed the voltage ratings. In addition, if the probes show any signs of wear or insulation breakdown, their use should be stopped immediately. The BNC connectors on the probes have exposed metal, and their contact with any active circuit must be avoided.

When probing equipment with high voltage or high RF energy, only personnel trained to work with such circuits should be permitted. All necessary safety precautions must be taken to avoid shock hazards or RF exposure during testing or examination of such equipment.

Maintenance and Service:

There are no user-serviceable parts inside the probes. Call the factory if service is required.

About this Manual

This manual provides instructions for using the Probe Set.

If You Need Assistance

If you encounter problems while using the model PS-500, contact Com-Power Corporation at (949) 459-9600.

1.0 General Information

This section includes the following:
a) Introduction
b) General Description
c) Specifications
d) Equipment Supplied

1.1 Introduction

This Section contains general performance and background information on the PS-500 Probe Set. A more detailed functional description is provided in Sections 2 and 3.

1.2 General Description

The Probe Set PS-500 consists of four probes. One of these probes is a magnetic-field (H-field) sensing probe. There are two electric-field (E-field) sensing probes. The fourth probe is a voltage-sensing probe. All four probes were specifically designed to find EMI noise sources in electronic systems. They provide an output voltage which is usually observed with a 50-ohm RF instrument, such as a spectrum analyzer or an RF receiver, and the optional preamplifier inline.

The H-field probe is designed to detect magnetic fields and minimize the effects of the electric field on its output. A loop at the end of the probe acts as its sensor; therefore, this probe is also called a “loop probe”. This loop is shielded to minimize E-field pickup.

The two E-field probes were designed to detect the presence of an electric field while minimizing the effects of a magnetic field. One of these probes is called the “Tip Probe” because of its fine tip. It is extremely sensitive to the tip's position relative to the source. The second E-field probe is called a “broadband” probe because it is sensitive over a relatively wider frequency range. The probe has a rounded end and has a higher amplitude sensitivity than the fine tip probe.

The third probe has a conductive metal tip. The contact probe allows direct electrical contact to with a potential noise source such as circuit traces or component leads. These three probes are complementary in function, as explained later in Section 2.

EMI noise suppression is required by several agencies in the USA and around the world. This noise is usually RF in nature and very low (about 60 dB microvolts per meter) at a distance of about 3 meters from the equipment under test (EUT). These probes help achieve compliance quickly, economically, and efficiently for electronic systems by enabling probing close to circuits. Guessing and overdesign are avoided by identifying the exact noise sources in systems and suppressing the noise at their sources.

The procedure for investigating electronic enclosures and circuits is described in Section 2.

The theory of operation of the probes is described in Section 3. This section also has a brief description of how to suppress the noise, once the source is located using the probes.

1.3 Equipment Specifications

The specifications for the Probe Set PS-500 are listed in Table 1.1.

Table 1.1. Specifications

	H-Field Probe	Broadband Probe	Fine Tip Probe	Contact Tip Probe
Frequency Range	9 kHz to 5 GHz	50 kHz to 5 GHz	100 kHz to 5 GHz	400 Hz to 5 GHz
Type	H-field	E-field	E-field	E-field
Connector	BNC (f)	BNC (f)	BNC (f)	BNC (f)
Dielectric Breakdown	1 kV	1 kV	1 kV	1 kV
DC Input at the Tip	N/A	N/A	N/A	50 VDC
Weight	4 oz / 113 g	4 oz / 113 g	4 oz / 113 g	4 oz / 113 g

Table 1.2. Optional Preamplifier Specifications

Model	PAP-501
Frequency Range	10 MHz - 1000 MHz
Nominal Gain	21 dB ± 2
Pout @ 1 dB comp	+ 10 dBm
Typical Noise Figure	6 dB
Output Impedance	50 Ohm
I/O Connection	BNC (f) input, BNC (m) Output
Power Input	6 VDC, 500 mA
Power Input Plug Type	2.1 (ID) x 5.5 (OD) center pin positive
Weight	1 lb. (0.45 kg)
Dimensions (L x W x H)	83 mm x 42 mm x 25 mm (3.27" x 1.65" x 0.985")

1.4 Equipment, Accessories, and Documents Supplied

The Equipment, accessories, and documents supplied with the Model PS-500 Probe Set are as follows:

a) Set of four probes
b) User's Manual
c) Storage box

2.0 Operating Procedures

This section contains the following:
a) Introduction
b) Set up
c) Application

2.1 Introduction

This Section describes how to set up the test system for probing and how to use the probes to identify noise sources in the system.

It is assumed that, prior to locating the noise source, emissions tests are performed at distances of 1 meter, 3 meters, or 10 meters using an antenna. These distances are generally considered to be far field. When the level of emissions at a particular frequency exceeds the specification, the engineer needs to reduce them. However, to reduce emissions, one needs to know where energy is leaking out of the system and where it is coming from. Often this is not known. Sometimes the source may not be known precisely. The first step in effectively reducing emissions would be to identify the source. The source is the part of the circuit that generates the energy and causes the emissions to be high. The probes are used to find the source and the point in the system where energy is leaking out.

2.2 Equipment Set Up

This paragraph describes how to set up the test equipment for finding the noise source. The EUT setup is described in Para. 2.3.

2.2.1 Test Equipment Set Up

The probes are used with a spectrum analyzer or a receiver functioning as an EMI meter. For the rest of the discussion, we will refer to it as a spectrum analyzer. A suitable probe is selected as described in section 2.2.2 below.

This probe is connected directly to the spectrum analyzer or via a preamplifier to reduce noise. A preamplifier may be necessary, especially with the tip probe. The tip probe is designed to maximize sensitivity to the tip's position, not its amplitude. The preamplifier input is connected using a short (typically a meter or less) 50-ohm coaxial cable. Also, the connection from the preamplifier output to the spectrum analyzer input uses a 50-ohm coaxial cable.

Set the spectrum analyzer to the signal's frequency. Set its span to about 1 MHz and the same resolution bandwidth as that of the far-field measurement.

2.2.2 Probe Selection

Select the probes based on the function to be performed. The H-field probe is more sensitive to magnetic fields, whereas the E-field probes (the tip probe and the broadband probe) are more sensitive to electric fields. Electromagnetic fields have both electric and magnetic components. A particular field may be strong near the source, and accordingly, the source may be called electric or magnetic. As the field travels away from the source, this distinction starts to fade, as shown in Figure 2.1. The region where this distinction is not possible is called the far field. That is, in the far field, the ratio of the E and H field strength is constantly equal to the characteristic impedance of the medium of propagation. For air or free space, this equals 120π or 377 ohms. The near field and far field distinction occurs at the approximate distance of λ / 2π, where λ is the wavelength. Of course, this distance depends on the wave's frequency.

Understanding the behavior of a field (see figure 2.1) is important for two reasons. First, it indicates that near the source, the field is strongly electric or magnetic, and the E-field or H-field probe can be used accordingly. Second, it indicates that the ratio of E to H field strength varies rapidly near the source. Even though it is not apparent in Figure 2.1. The E-field decays inversely proportional to the cube of the distance from the E-field source, and the H-field decays inversely proportional to the cube of the distance from the H-field source.

The user may try all probes to find out the most suitable probe; however, generally, the E-field probes are most suited for the digital signals (clocks, data, address, chip select, read, write, etc.). The H-field probe is most suitable for the power supply circuits, high current circuits or enclosure evaluation.

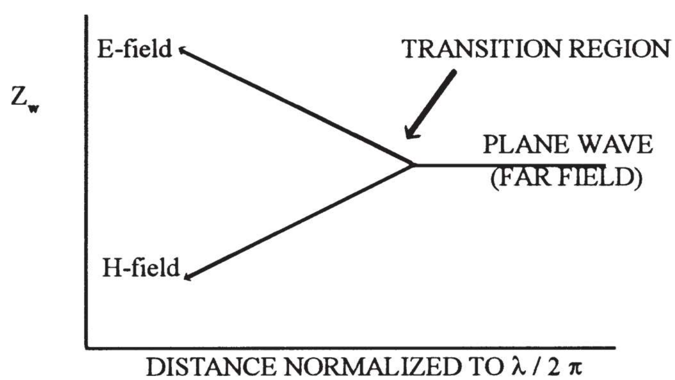

Figure 2.1 Wave Impedance (Zw) vs Distance

Broadband Probe

The rounded end probe in the probe set is the broadband E-field probe. It is usable over the frequency range of 50 kHz to 5 GHz. It has good amplitude sensitivity and is used for electric field sources. Such sources include logic circuits, controllers, microprocessors, clock lines, address lines, or control lines. This probe is used in conjunction with the fine tip probe to locate the noise source to a single trace or signal pin. The broadband probe is used first, to quickly identify the general area (usually about one square inch) because of its amplitude sensitivity. After that, the fine tip can be used in this area to locate the exact pin as described below.

Fine Tip Probe

As the name implies, this probe has a fine tip. This probe has a frequency range of 100 kHz to 5 GHz. Its fine tip, combined with sensitivity to tip position, is very useful for locating a single trace or pin on an IC. In many systems, the highest emissions are due to just a few traces (even one or two on some). Once these traces are identified, the overall far-field emissions can be reduced by addressing their circuits as described in Section 3.2.

Contact Tip Probe

As the name implies, this probe allows direct electrical contact with the circuit. It has a frequency range of 400 Hz to 5 GHz, which is wider than the fine tip probe. Just like the fine-tip probe, the contact-tip probe allows you to find the noise source on a trace or pin. However, when the traces run close together, touching the trace will reduce some measurement uncertainty. The contact tip probe was designed to allow capacitive coupling of the noise. This removes DC voltage. It can handle up to 50 VDC maximum. Therefore, it should be only used on low-voltage DC circuits.

H-Field Probe

This probe has a loop at its sensing end, so it is also called a “loop probe”. This probe is used for H-field sources, which are produced by stronger currents (compared to voltages) and by larger loop areas covered by their current paths.

Since all circuits generate both electric and magnetic fields, the electric and magnetic probes are interchangeable to some extent. In some cases, whether to use an electric field or a magnetic field probe is more suitable can be determined by trying.

2.3 EUT Set Up

The equipment to be tested is generally set up according to a specific regulatory agency document. These documents describe the details, including the exact placement of the EUT and its support equipment, the operating modes, and the software they perform. Still, some aspects may not be mentioned, and the test engineer may have to select an arbitrary mode. However, it is important to remember that the emission will depend on the exact operating mode of the EUT and the support equipment.

Therefore, during the investigation, the EUT mode must be carefully controlled to represent the final qualification test. That includes clock speed, software, function, etc.

The obvious exception to this rule is the enclosure, which must be opened to access the circuit boards for probing. Such changes must be taken into account to avoid any errors in conclusions.

2.4 Probing a Digital Circuit Card

It is assumed that the problem's frequency or frequencies are known from far-field tests using antennas. Begin the probing with the spectrum analyzer set to the highest emission frequency. (or the particular frequency of interest, which may be one of the highest emissions). Near-field probing reveals only the problem circuit, which is the main source of noise. Without this information, one may be just guessing or shooting in the dark, trying to reduce the noise by shielding the entire system or putting several suppression devices on the board. However, the near-field improvements must ultimately be verified in the far field, as required by the specifications.

Once the regions with the highest readings (also called hot points or hot spots) on the board are identified with the broadband probe, the tip probe is used to locate the highest-reading trace or signal. This reading will increase as the noisiest trace is approached from either side. The reading will be two, three, or more dB higher at the noisiest pin or trace compared to its adjacent trace. For example, the readings are 51, 54, 57, 60, 56, 53, and 50 dB µV on the adjacent pins. The noisiest pin in this group reads 60 dBµV. If the other hot spots were at least 10 dB lower than the highest (60 dB in our case), one may conclude, as an engineering simplification, that this is the noise source in the system.

The contact tip probe can be used to verify the conclusion. Proceed to eliminate that problem as described in section 3.

Note that this is a simplification and an approximation, where the effect of the length of the trace is not considered. In general, there may be more than one noisy signal in the system. In that case, to determine the most likely cause of the problem, the trace's coupling capability needs to be considered. That is because the far field emission is the combined effect of (a) noise coupling from the noise source to its adjacent conductors and (b) these adjacent conductors radiating that energy into the space around the equipment. We improve our approximation considerably by including the effect of length.

	Group A	Group B
Reading	60 dBµV	57 dBµV
Length	2 inches	10 inches
Correction	6 dB	20 dB
Final effect	66 dBµV	77 dBµV

This example shows that the trace reading 57 dB in group B is likely to be a stronger source of noise than the one reading 60 dB in group A. This same approach is used when more than two groups are encountered.

	Group A	Group B	Group C
Reading	60 dB	57 dB	75 dB
Length	2 inches	10 inches	2 inches
Correction	6 dB	20 dB	6 dB
Final effect	66 dB	77 dB	81 dB

This indicates that the group C trace is likely to be the strongest source of noise. We say this with probability because other factors, such as (a) trace isolation or (b) the adjacent traces' ability to pick up the noise, also affect the far-field strength. For this reason, all hot locations may need to be evaluated.

Go to Section 3, after the noisy trace or traces are determined. Section 3 explains how to modify the signal circuit to reduce energy leakage and the theory behind it.

2.5 Probing an Enclosure

Even the enclosure used to shield electronic equipment can be probed with the probe set. Noise leaking out from the shielding enclosure is investigated using the H-field probe. That is because, as an electromagnetic wave passes through the shield, the magnetic field leakage is more predominant near the enclosure.

The probe will show higher emissions (a) near an opening or (b) near a seam. Seams are joints where a lack of electrical contact between two overlapping parts of the enclosure prevents electrical current from flowing. Compared to the opening, seams are difficult to detect just by observation because they are not always so obvious. The seams may be formed by nonconductive paint or by nonconductive surface treatment such as anodizing.

Leakage through an opening or seam depends on the wave frequency and the length of the opening (not its area).

3.0 Theory of Operation

This chapter explains the following:
a) Overview
b) Theory of Operation

3.1 Overview

This section describes the theory of operation of the probes.

3.2 Theory of Operation

The Near Field Probes pick up a strong localized field near the source. Once the source is located, potential design problems causing high emissions can be investigated. The specific function of each probe in the probe set used to locate the noise source is described below.

Broadband Probe and Fine Tip Probe

The broadband probe is usable over the frequency range of 50 kHz to 5 GHz, and the tip probe is usable over the frequency range of 100 kHz to 5 GHz. The broadband probe has good amplitude sensitivity, and the tip probe has excellent sensitivity to tip position. They are both used for electric field sources produced by circuit voltage. Such sources include logic circuits, controllers, microprocessors, clock lines, address lines, or control lines.

The broadband probe is used first to quickly identify the general area (usually about 1 square inch) due to its amplitude sensitivity. After that, the fine tip can be used in this area to locate the exact trace or pin.

H-Field Probe

The loop probe is used for H-field sources, which are produced by stronger currents (as opposed to voltages) and larger loop areas covered by their current paths. All circuits have voltages as well as currents to a varying degree; therefore, the electric and magnetic probes are interchangeable to some extent, and the most suitable probe can be determined by experimentation. A large energy reading does not imply that any particular probe is more suitable. If an E-field probe shows a higher energy reading, it could mean the source has a strong E-field or that the probe is more sensitive at that frequency than the H-field probe.

3.3 Suppressing Noise

Noise suppression techniques can be as simple as reducing the circuit voltage or adding a series resistor. In this section, only a few simple techniques used in digital circuits on multilayer printed circuit boards (PCBs) are discussed. (If a two-layer board has too many emissions, utilizing a multilayer board, employing a ground plane with a transmission line structure will help reduce the noise. The following is a limited discussion of a broad subject. More information can be found in the references given at the end of the section.

3.3.1 Transmission Line

When a ground plane and a power plane are added to a two-layer printed circuit board, noise is reduced because the signals have a transmission-line path in the 4-layer PCB. When a signal travels along a trace, its energy is distributed in space around the conductor and along its return path. With a four-layer board, this return path is generally right next to the signal. A transmission line is formed when this space between the trace and its return path is not shared by other signals. That is what eliminates crosstalk. However, simply adding a ground and a power plane does not guarantee a transmission-line structure; one should ensure that the reference plane (ground) is always close to the signal trace.

Any trace has relatively noisier and quieter locations on it. These can be discovered by just moving the E-field probe along its path. These hot spots along the trace also reveal the reasons for the energy leakage. The signal output pin and the trace end show high readings because of reflections from an impedance mismatch.

Mismatch at the source: For commonly used digital circuits (TTL and CMOS), the low-level output impedance (typically about 5 ohms) is much lower than the trace impedance, which is about 50 to 70 ohms. This mismatch and the corresponding reflection coefficient are high. Adding a series resistor near the source would minimize the mismatch and the reflections. This would reduce the total noise emitted from the trace.

Mismatch at the End: The commonly used digital circuits (TTL and CMOS) also have termination mismatch at the end of the traces because the trace impedance is of the order of 50 to 70 ohms, whereas the input of the gate is of the order of a few hundred ohms. This problem can be solved by adding a parallel termination to the load at the end of the trace. Since these device families cannot handle a load of 80 ohms, a series combination of a resistor and approximately 100 pf capacitor is used (see Figure 3.1).

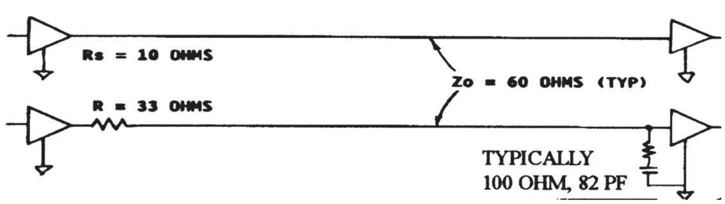

Figure 3.1, Line without termination and line with series and parallel termination.

Mismatch at the Vias: Even vias (also called feed throughs) on a trace change impedance. Probing near the via can verify whether excessive emissions occur there. Vias cause problems, especially for higher frequencies (30 MHz clocks and above). At frequencies above 100 MHz, special effort must be made to mitigate the adverse effects of vias. For such high-frequency signals, the preferred trace layout is shown in Figure 3.2.

1. MOST DESIRABLE

2. ACCEPTABLE
3. LESS DESIRABLE
4. LEAST DESIRABLE

Figure 3.2, Preferred trace layout

Mismatch due to Stubs: Stubs are locations on the trace where they are divided into two or more directions. The impedance cannot be maintained at a stub because all line impedances will be observed in parallel. This can be avoided by connecting all loads in a daisy chain fashion. See figure 3.3.

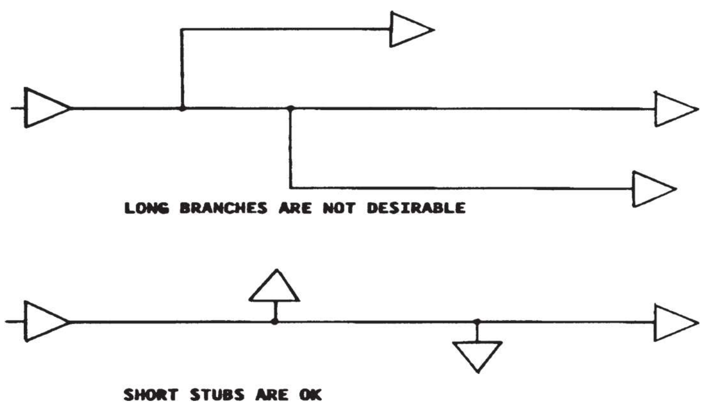

Figure 3.3 Stub Mismatch

References:

Some references on transmission lines are given below. It is hoped that these will be useful in reducing noise from digital circuits.

1. ECL Design Handbook - Robert Blood, Motorola Semiconductors 1988
2. Microcomputer Interfacing - Harold Stone, Addison-Wesley Publishing, 1982
3. EMC Design Seminar Notes - Compatible Electronics, 1992