Conductive Port Receiver

Application Note 1057

Introduction

This application note compares the performance of fiber optic receivers with conductive ports to fiber optic receivers with non-conductive ports (Figure 1). It explains how conductive port receivers solve specific problems encountered in some applications and how they help to improve the electromagnetic immunity of part number HFBR-24X6 XC, required by such standards as MIL 461 and IEC 801-3. The application note also presents test data that shows why HP's low-resistance conductive port has an advantage over the higher-resistance conductive ports of other manufacturers.

This application note focuses specifically on the receiver preamplifier, because it is a crucial electronic element in the optical link. The preamplifier must process input signals as low as or lower than -30 dBm and must also have a wide bandwidth to accommodate high data rates. The preamplifier's high gain and wide bandwidth make it sensitive to electromagnetic interference (EMI). Small-junction devices used in its construction may make it inherently sensitive to electrostatic discharge (ESD). Exposure to either of these phenomena, especially to EMI, can affect the overall performance of the receiver.

Background

Pulses of EMI with large electric field strengths can induce currents to flow in the input circuitry of the fiber optic receiver. These currents can interfere with the photocurrent generated by the desired optical signals and can prevent the receiver from faithfully reproducing an electrical signal based on the received optical input. This condition degrades the bit-error ratio (BER), the ratio of the number of erroneous bits at the output of the optical receiver to the total number of received bits. Modern transmission systems routinely require a BER better than 1×10^{-9} and very often require a BER better than 1×10^{-12}.

In some systems the degraded BER can result in either correction of the data by error-correction software or frequent re-transmission of data. Thus, the

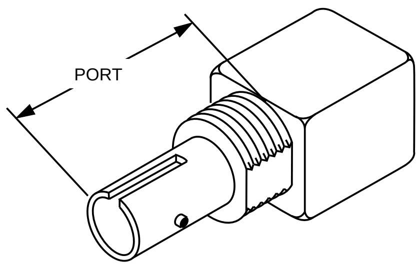


Figure 1. Fiber Optic Receiver.

system appears much slower than normal. This condition is known as a detectable error. By contrast, high BER can overwhelm the error correction software or hardware. Errors of this type prevent proper operation of the system.

In systems using fiber optic components, errors can garble the data as long as an excessive electromagnetic field exists. If the system is removed from the field or the field is eliminated the data will once again be valid.

EMI is generated by radio transmitters, transients from electrical equipment switching on and off, test equipment, and so forth. ESD can also generate electromagnetic fields (more will be said about this mechanism later).

Conductive Port Receivers

The main benefit of a fiber optic receiver with a conductive port is that it reduces coupling of external fields by partially shielding the very sensitive input node of the fiber optic receiver. The shield is not complete, however; the field can propagate through the hole in the center of the port, but it is greatly attenuated.

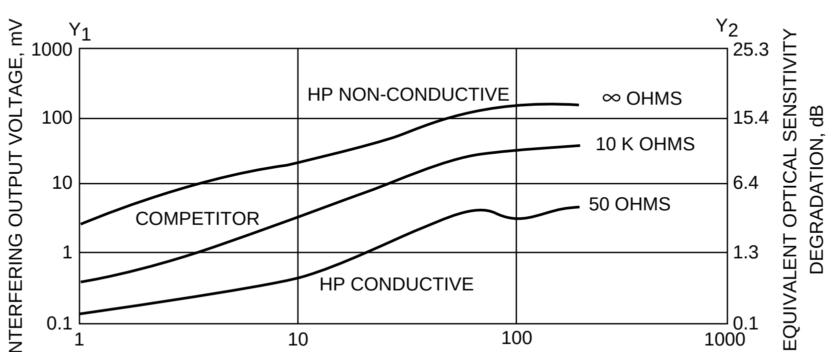
A metal-ferrule connector can degrade the sensitivity of a receiver with a non-conductive port in an electromagnetic field by about a factor of four. The electric field couples to the metal connector and ferrule, which act as a receiving antenna. Because the end of the metal ferrule is close to the amplifier IC, the field easily capacitively couples to the input of the amplifier, inducing an interfering current. The coupling capacitance is several femtofarads. In the case of the conductive port, a low-impedance path to ground, provided by pins 1, 4, 5, and 8, reduces the potential on the ferrule. So, in terms of coupling from the external field, the ferrule then becomes a poorer antenna.

HP's conductive port uses a low-resistance (50 ohm) material[1] for a very low impedance to ground. Measurements on a sample of conductive ports from a competitor showed higher resistance (of about 10,000 ohms). A lower resistance port material could be expected to provide lower coupling from an electric field to the output of the receiver and improved immunity to EMI.

Hewlett-Parkard Optical Communication Division has tested the EMI immunity of the HFBR-24X6 family (see Figure 2 and 3) and found less than 2 dB degradation of receiver sensitivity in a 10-volt-per-meter field for HP's conductive port. This value compares favorably with an average value of 9 dB sensitivity degradation for HP's non-conductive port. HP OCD also tested the EMI immunity of competitor's conductive ports, which had approximately 10,000 ohms resistance from the port to ground. These ports had an average sensitivity loss of 5 dB in a 10 volt-per-meter field, measured under conditions identical to the HP product measurements (see Figure 2). For all types of ports measured, the performance depends on the frequency of the field; measured between 10 kHz and 300 MHz, the worst values are between 100 and 200 MHz.

In cases where customers must meet specifications for fields of this strength or similar levels of strength, they should use HP's conductive port. With the conductive port, the receiver will tolerate a field strength roughly 30 times greater than with the non-conductive port before losing sensitivity. Some additional benefit is gained by running the port through a hole in a metal chassis. With this arrangement, the field strength experienced by part of the fiber optic receiver is reduced.

In applications where the received optical power is 20 dB or more above the equivalent optical noise input power, however, electric fields up to 10 volts per meter should not affect the performance of the receiver. For short links, enough signal strength is available for the receiver to function. Whether or not an application requires a conductive port depends on a number of factors, including field strength expectations, link performance expectations, bandwidth of the signal processing and digitizing, and so forth. For low data rates, high-frequency interference can be filtered.



NOTE: RELATIONSHIP BETWEEN Y AXES: $Y_2 = 10 \text{ LOG} \frac{12.07 \text{ mV} + 2\sqrt{2}\, Y_1}{12.07 \text{ mV}}$

Figure 2. Typical Output Signal Due to 10 V/m Field with Metal Ferrule.

[1]Hewlett-Packard's conductive ports have a resistance that is typically 5 to 15 ohms and always less than 50 ohms (measured from the port tip to ground pin 1, 4, 5 or 8) at the beginning of life. Long-term exposure to heat and humidity increases this resistance. After 168 hours at 121°C and 100 percent relative humidity, the typical resistance increases to 50 to 60 ohms, but may go as high as several hundred ohms. This level of resistance is still much lower than competitive parts and offers significant immunity to EMI. In a 10 V/m field, however, receiver sensitivity may be degraded 1 to 3 dB relative to a conductive port with resistance less than 50 ohms.

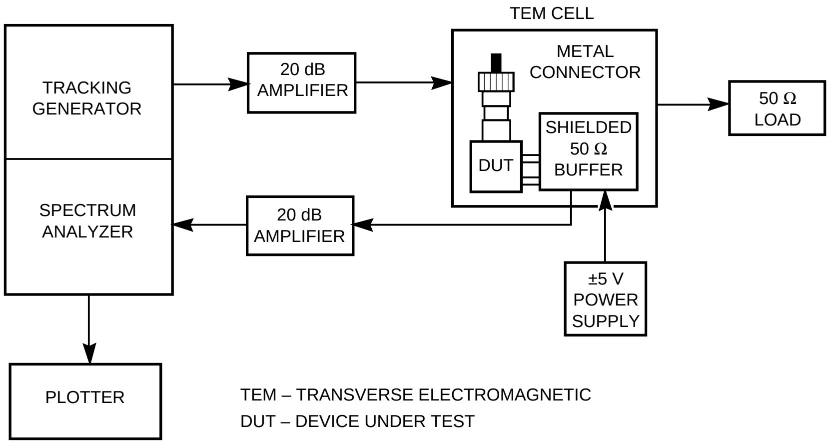


Figure 3. Block Diagram of Test Setup for Electromagnetic Susceptibility.

In those cases where the bandwidth is substantially narrowed to lower the data rates, as in applications of IEEE 802.3 and 802.5, insignificant changes in sensitivity are expected when the non-conductive fiber optic receiver is exposed to a 10-volt-per-meter field.

Although Europe will soon have requirements for EMI immunity (for example, IEC 801-3), as of the date of this document, products in the U.S. are usually not required to meet EMI immunity standards. For this reason, engineers must often design their products to either certain military or European standards, as in the case of products intended for worldwide markets.

ESD can also cause problems. Under conditions of low humidity we can accumulate a considerable amount of stored charge on clothing and skin surfaces merely by shifting position in a chair or walking across a carpet. Our bodies then become high-voltage, static-charge generators with voltages up to about 15 kV. If we touch a grounded electronic device or component we can produce an arc due to the voltage differences.

ESD most often affects a fiber optic receiver by either or both of two mechanisms. In one mechanism, ESD current entering electronic equipment through the fiber optic receiver port generates thousands of volts per meter of instantaneous electric field strength surrounding the discharge. This field can momentarily disrupt recovery of data from the fiber optic link and introduce errors. Generally, these errors can be corrected by error correction software within the system.

In the other mechanism, catastrophic failure, a very large electrostatic potential difference suddenly discharged onto the transmitter port, receiver port or any other entry point, such as switches or connectors in an improperly grounded metal cabinet, rapidly distributes itself on the printed circuit board (PCB). This potential difference may adversely affect susceptible electronic components mounted on the PCB and can melt bond wires, damage IC metalization traces or destroy junctions.

ESD-related component failures can occur during PCB assembly also. The operators can prevent it by wearing static-grounding wrist straps and taking all ESD handling precautions, including proper packing materials, work surfaces, and so forth. ESD can occur, however, in the end user's environment.

Catastrophic failures from ESD can be avoided by using a metal chassis and either a ground plane or wide ground trace. The wide ground trace extends to the edge of the printed circuit board and so is closer to the user's fingers than the leads of the receiver housing. This creates a low-inductance path to ground and the current is directed away from sensitive components. This is especially important if the system's enclosure is not metal.

For systems designed without a true earth ground, a low-impedance path to a large area such as a ground plane or metal chassis is recommended. A low-impedance path will help divert the current away from the internal components.

HP recommends that pins 1, 4, 5, and 8 of the conductive receiver ports, HFBR-24OXC and HFBR-241XTC be connected to circuit ground, as shown in Figure 4. ESD will then follow this predefined, low-resistance path, preventing the possibility of internal discharge.

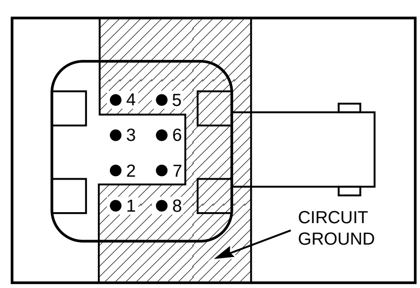


Figure 4. Bottom View.

Test Methods

HP has tested the ESD susceptibility of its HFBR-141X transmitter and HFBR-241X receiver fiber optic components per the IEC 801-2 contact discharge method. This test method was chosen for the more repeatable measurements of contact discharge as opposed to air discharge. Both the conductive port and the non-conductive port experienced discharges but survived 15 kV of ESD to or around the connector. Discharges flowed either along the surface of or through the air near the non-conductive port to the edges of the printed circuit board. With the conductive port discharges flowed through the port to the PC board. The HP conductive and non-conductive ports both withstood 15 kV electrostatic discharges, a value well above the requirements of 801-2.

No catastrophic damage occurred during HP's tests, although there were errors at very low levels of ESD. These errors resulted whenever a discharge occurred anywhere in the vicinity of the protruding fiber optic connector. A conductive port receiver improves the immunity to errors caused by electromagnetic fields (please see previous section for approximate values) but does not eliminate them. HP's conductive and non-conductive ports passed tests 15 kV for ESD immunity.

The IEC 801-2 ESD regulations are in effect only in Europe. The U.S. has no regulations of this type, although various U.S. companies have their own requirements.

In reliability testing, the mechanical strength of the conductive port has been shown to be similar to the mechanical strength of the non-conductive port. Both the conductive and non-conductive port have many features. They include high reliability, resistance to solvents and some other chemicals (please see data sheet), and resistance to thermal and mechanical shock. In addition, they are inexpensive.

Tests show that HP's non-conductive and conductive port receivers both have excellent immunity to ESD, so conductive ports offer little ESD performance improvement over non-conductive ports. Only users with exceptional ESD environments will benefit from conductive ports for ESD protection.

Conclusion

For applications at higher speeds and higher levels of electric field strength, a receiver with a conductive port has significantly better EMI immunity than a non-conductive port receiver. HP's low-resistance conductive port receivers have demonstrated superior EMI performance relative to receivers with higher-resistance ports. If your application requires an extra margin of protection against EMI, HP's conductive port receivers are recommended.

For technical assistance or the location of your nearest Hewlett-Packard sales office, distributor or representative call:

Americas/Canada: 1-800-235-0312 or (408) 654-8675

Far East/Australasia: (65) 290-6305

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Europe: Call your local HP sales office.

Data Subject to Change

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