The Better the Ground, The Better the Performance

RF and microwave engineers sometimes complain that a filter is not providing performance levels even close to the manufacturer's test data when it is installed in their system. The problem is usually that the filter's rejection is substantially less than the test data furnished with the filter. This complaint is made even when the manufacturer's test data can be duplicated when the filter is tested by itself. In other words, where does the filter rejection go when it is installed in the system?

This is a valid concern as filters can represent a substantial portion of the purchased parts cost in a system. Why should a customer purchase an expensive filter, that has -70dBc rejection, when -40dBc rejection is all that is obtained in the system? Poor filter performance is often caused by faulty installation techniques, which can lower the isolation between the filter's input and output ports, or provide inadequate grounding of the filter assembly.

Isolation

Poor isolation between a filter's input and output ports can be caused by two problems: the circuit elements on either side of the filter are not adequately decoupled, or the filter input and output terminals are coupling through radiation or through the power supply. At low impedance (such as 50 ohms) and RF frequencies (less than 50 MHz), radiated coupling between the input and output traces on a circuit board is not usually the problem. This coupling is usually capacitive and can be modeled with familiar circuit simulation equations.

The capacitance between two traces on a circuit board is usually about one tenth of a picofarad. At 50 MHz, one tenth of picofarad is an impedance of over 20K ohms. This will not have a significant effect on a filter's performance when the requirement is for -50dBc rejection. However, at 1 GHz, one tenth of a picofarad leakage between the input and output ports will limit a filter's rejection to roughly - 30dBc.

For filter assemblies that are mounted on circuit boards, isolation can be improved by keeping the input and output traces as far apart as possible. One technique that can be effective is to place a shield or ground plane between the input and output traces. For example, at 1 GHz, the isolation between two circuit traces or wires 1/4" long, that are separated by 2", is only about 40dB. Properly applied shielding can significantly increase this isolation.

Another technique that can be used to increase the isolation between the input and output ports of a filter, is to specify a long, thin, rectangular package. This will provide greater separation between the input and output terminals, and more circuit board area will be available between the ports for installing shielding. However, the best way to isolate the input and output ports of a filter is to use shielded cables and coaxial connectors (SMA, BMA, etc.) When operating frequencies are greater than 1 GHz, coaxial interconnections are the only way to obtain reliable isolation.

Circuit decoupling around the filter is also important. For example, a filter might be located between two amplifiers that share a common power supply. If the decoupling provided by the power supply and power distribution circuits is only 25dB, then this leakage will limit the rejection of filter to -50dBc. If a filter is to provide all of its specified rejection, all of the circuitry surrounding the filter must be decoupled, at least as much as the required rejection, at all frequencies of interest.

Grounding

Poor grounding is another major cause of poor filter performance. Most filters have their input and output ports on opposite sides (or ends) of the case. In this configuration, the case is the ground reference for both ports. Problems occur when there are other transmission or ground paths between the two ports in addition to the filter. These secondary transmission paths are often formed by the printed circuit board grounding system.

Grounding problems are common with pin mounted components. Mounting pins have a finite length, and therefore tangible inductance. If a common ground plane is used under a filter, inductive coupling will exist between the input and output pins. This mutual inductance will limit the rejection floor of the filter. For example, a 20 gauge wire though a 0.062" thick PC board has roughly 1 nanohenry inductance. At 1 GHz, this is an impedance of about 6 ohms. If this impedance is in series with the filter's case ground terminals, the rejection of filter could be lowered to only -20dBc.

Additionally, a physical gap between a ground plane under the filter and the filter case, can act like a low impedance transmission line. Transmission along this spurious path will lower the rejection of the filter. In this case, performance can be improved by grounding the filter well at the input and the output ports, and eliminating any common ground returns.

When using pin mounted filters, common paths between the input and output pins are unavoidable. For this reason, pin mounted filters are not recommended for applications that require high rejection, or for use at higher frequencies. Even with the best installation techniques, it is difficult to obtain isolation and rejection greater than -60dBc with pin mounted cases. If pin mounted components are necessary because of size or cost, and high rejection is required, an approach that is usually successful is to use two filters separated by a pad or an amplifier.

If the filter requirement for rejection greater than -60dBc, coaxial interconnections (such as SMA, BMA, etc.) will provide much better performance. Coaxial connectors are well shielded and have virtually no coupling through the signal grounds. Filters with coaxial connectors are usually larger and more expensive than pin mounted configurations, but they are unsurpassed for shielding and lower connector loss.

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