Noise Measurement on a Small Motor using Different Types of Suppression

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Abstract:

The purpose of this article is to present current probe measurements of the common and differential mode noise generated by a small electrical motor. The base line noise profile of the motor in different measurement configurations with different types of filtering will be characterized.

Introduction:

In today's environment, the use of electronic modules to control electrical motors has increased dramatically. Applications include automatic rewind cameras, electronic control toy cars, automatic window shade openers, etc. A problem associated with this new use of motors on a large scale is the RF ramifications to the radio wave spectrum. In general, an electrical motor is a very noisy RF source that transmits and interferes with other electronic devices through common mode noise on the power lines. Once the common mode noise gets on the power lines at or above a certain frequency, the lines act like an antenna and radiate in free space. The best way to stop a motor from causing other electronic devices to malfunction is to suppress the noise at the source.

Test Configuration:

The test setup is shown in Figure 1. The device under test (DUT) is a small production motor, which is tested in four different configurations, as shown in Figure 2. The DUT is characterized in normal condition and then with three different types of filtering, as shown in Figure 3. The DUT is powered by a 12 V regulated DC power supply with a one-meter cable having three conductors (+12 V, return 12 V, & case ground). One of the variables tested is the connection of the case ground to the DUT.

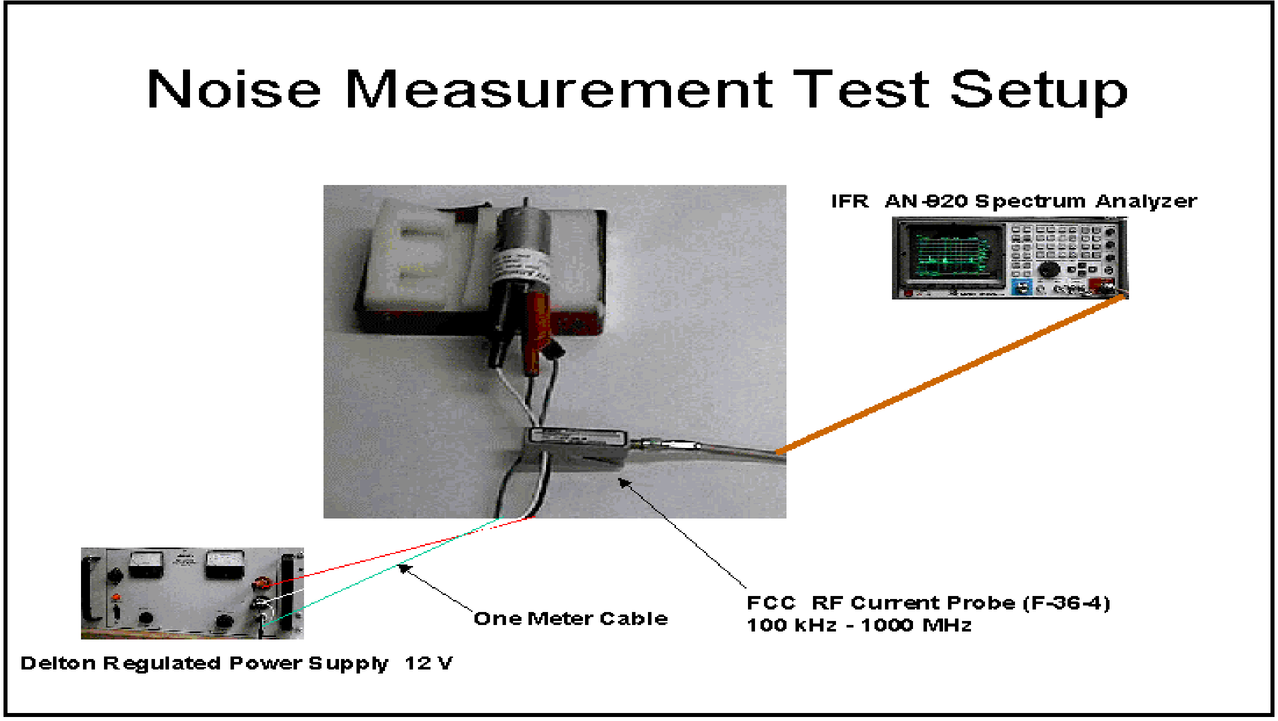

Figure 1. ***Motor noise measurement test setup.***

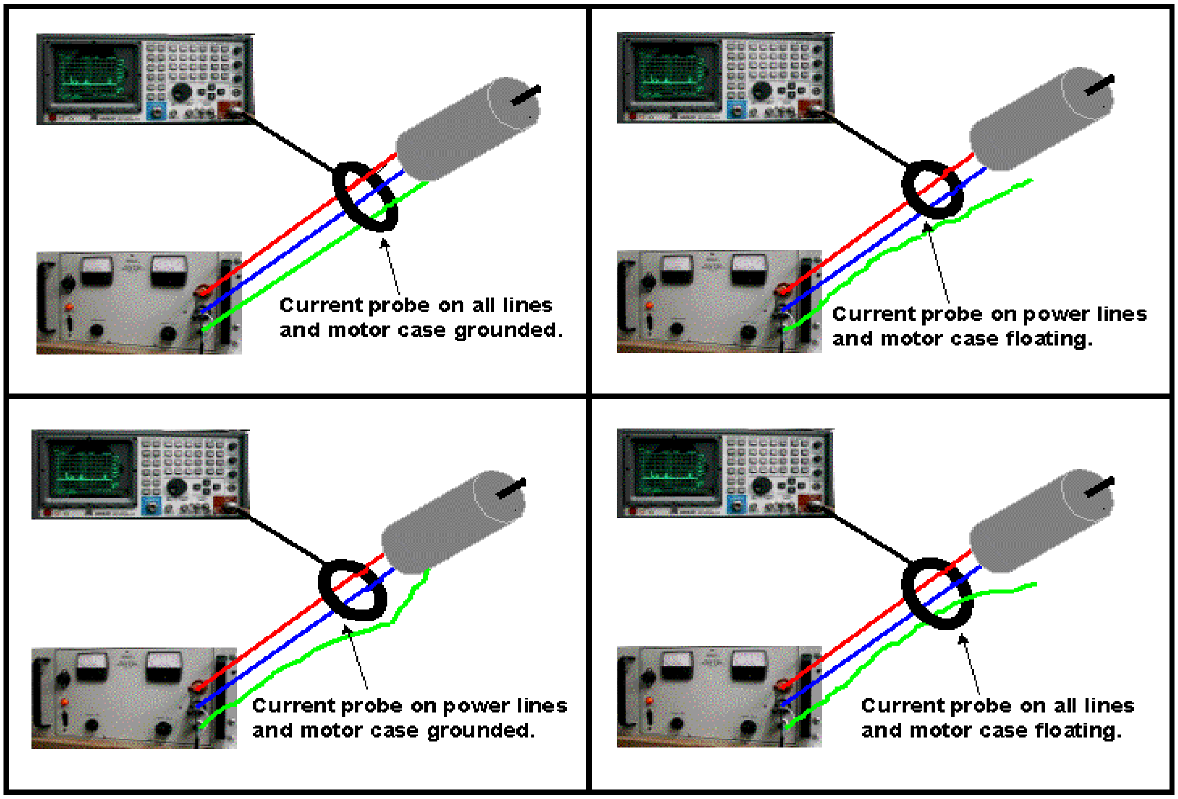

Figure 2. ***Motor in four different test configurations.***

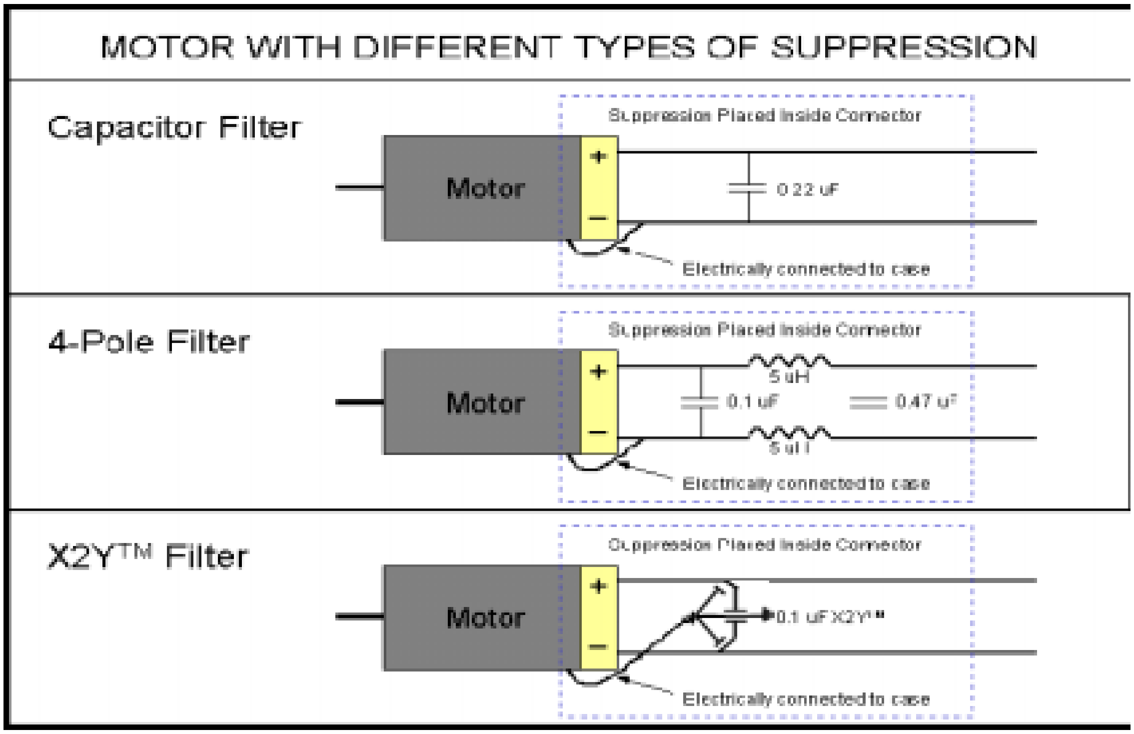

Figure 3. ***Motor with different types of suppression.***

Test Methodology:

The purpose for using a miniature current probe (Fischer Custom Communications F-36-4) is to make quantitative measurements of the currents (magnetic fields) generated by the electrical motor on the power lines. The current probe can be used in a non-shielded room because only the magnetic fields related to the electromagnetic radiation potential of the electrical motor affect the probe and it is relatively insensitive to stray electrical fields. The windings of the probe are in a shield that reduces E-field pickup. Typical values of shielding from external E-fields vary from 60 dB below 100 MHz to greater than 30 dB at 450 MHz. The power lines of the motor are characterized by clamping the probe on the 12 V and return 12 V lines, and then repeating the measurement after adding the case ground line in the current probe.

The current probe has transfer impedance from 100 kHz to 1000 MHz, as shown in Figure 4. The transfer impedance Z_t is defined as the ratio of voltage developed across the output of the probe to the conductor under test. The current I_P in the conductor is calculated from the receiver reading of the current probe output E_S in volts divided by the probe transfer impedance Z_t:

$I_P = E_S / Z_t$ (Equation 1)

The spectrum analyzer used in this test is an IFR AN920 (9kHz - 2.9 GHz) and the frequency range is set from 100 kHz to 200 MHz. The resolution is set to 120 kHz and the video bandwidth is turned off so that the spectrum analyzer does not filter the signals being analyzed.

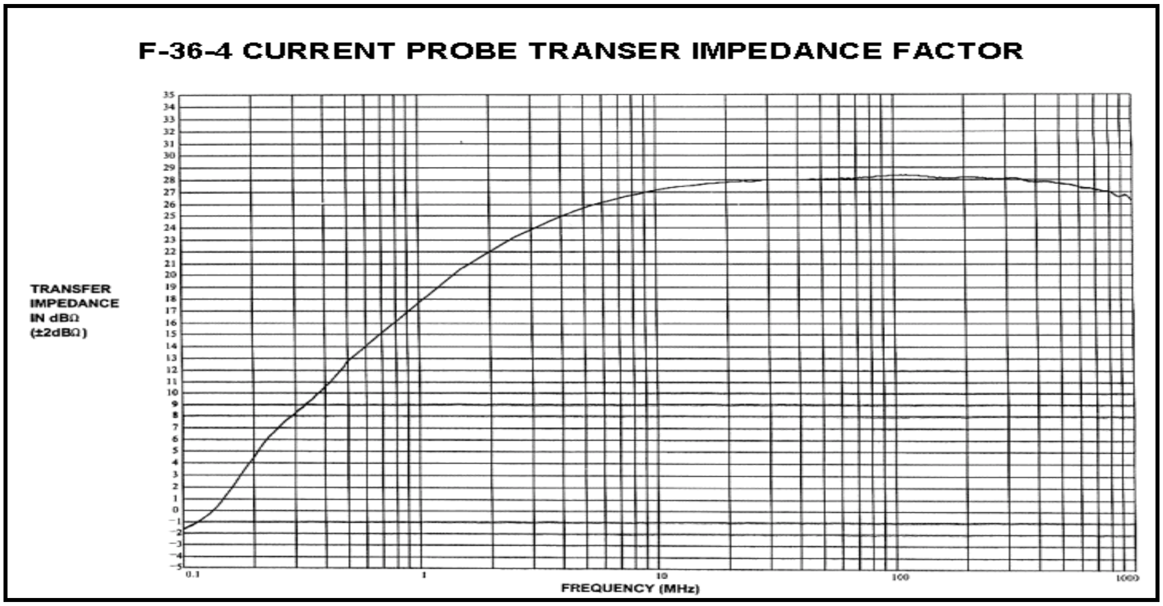

Figure 4. ***Current probe transfer impedance factor.***

The DUT will be run in a steady state condition to minimize variability in the data and the spectrum analyzer will be set to capture the signal in peak hold mode.

Test Results:

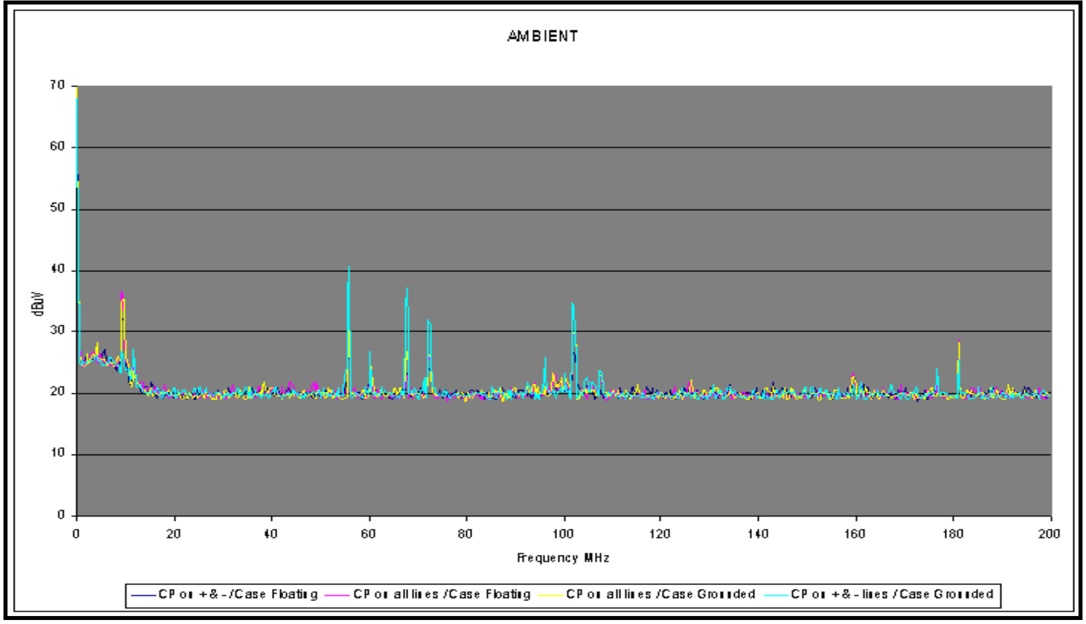

Figure 5. ***Ambient noise measurements of four different test configurations.***

Figure 5 shows ambient noise measurements of the four different test configurations. The worst-case ambient noise occurs when the current probe is placed on the power lines of the motor and the case ground connected to motor is left out of the current probe. This is the worst-case because the current probe is measuring the common mode noise on the power lines and the differential mode noise between the power lines and case ground line of the motor.

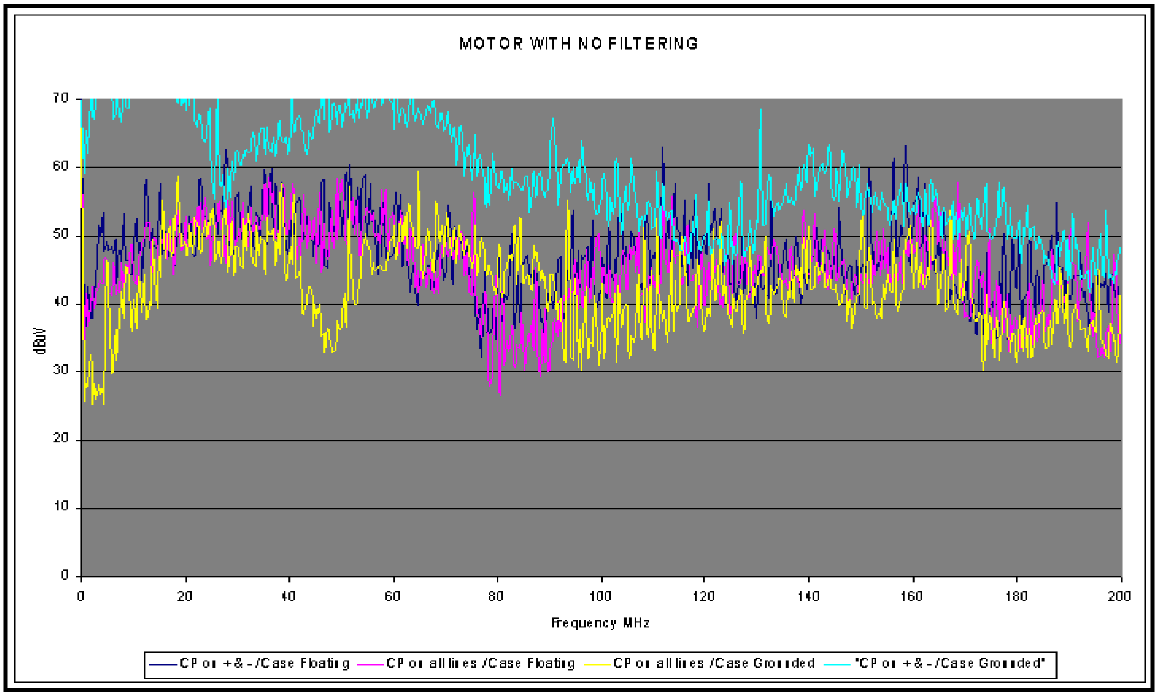

Figure 6. ***Normal production motor with no filtering applied.***

Figure 6 shows the test results for the normal production motor with no filtering applied. In analyzing the data, there is little difference between measurements taken when the current probe is on all lines (motor case grounded or floating) and measurements taken with the current probe on power lines only when the motor case is floating. The worst-case condition on the motor with no filtering is when the current probe is on power lines only and the motor case is grounded.

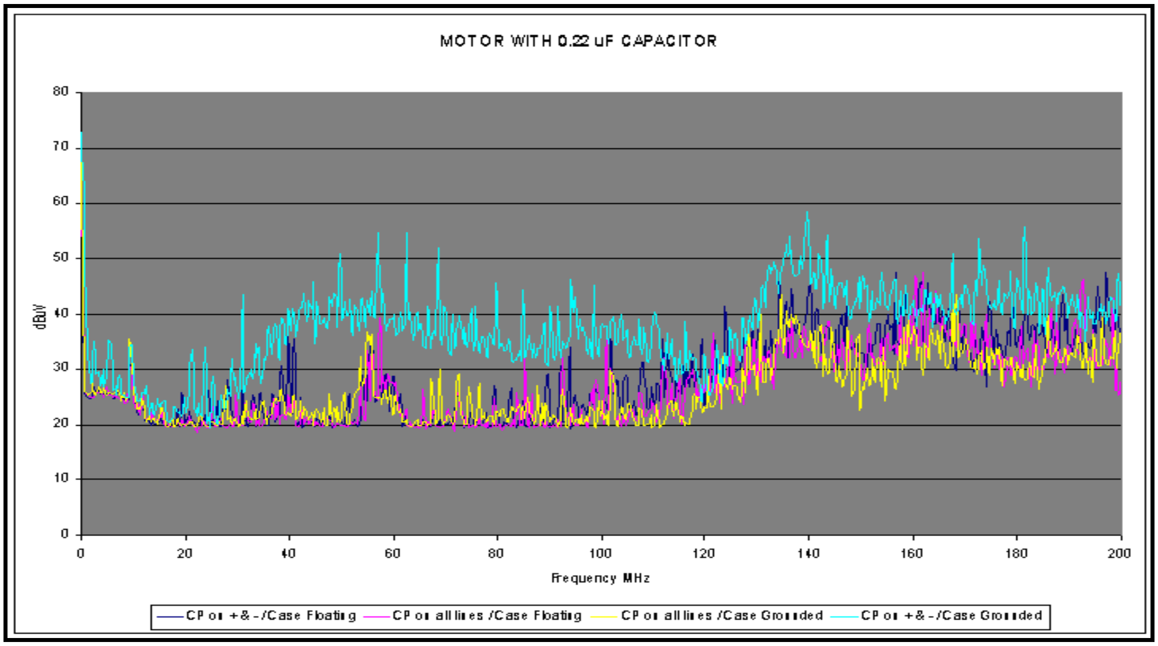

Figure 7. ***Motor with 0.22 uF capacitor connected across power lines.***

In Figure 7, the motor has a 0.22 uF capacitor placed across the power lines. The worst-case condition is again when the current probe is on power lines only and the motor case is grounded. Test measurements of the other three configurations are similar to each other.

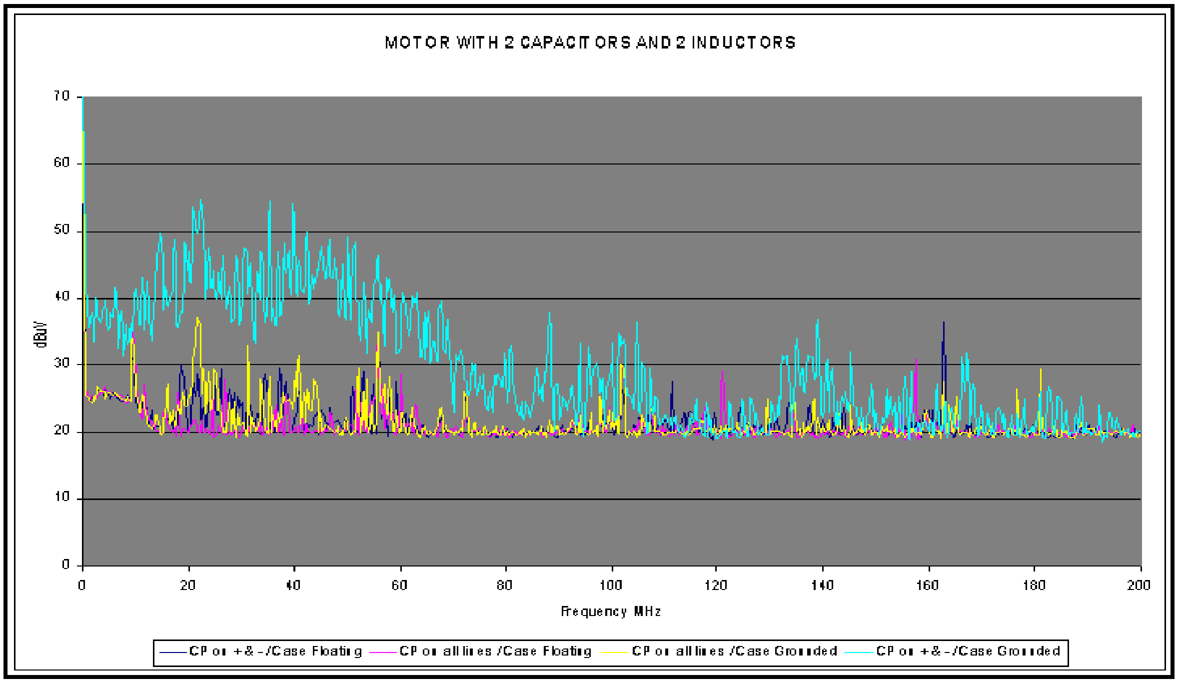

Figure 8. ***Motor with two 5 uH inductors (one on each line), a 0.1 uF capacitor directly across the motor, and a 0.47 uF capacitor across input lines in front of the series choke.***

In Figure 8, the motor has two capacitors and two inductors, which make up a 4-pole filter. This filtering configuration produces good results when the motor case is floating or when the case is grounded on the motor with the current probe placed on all lines. The results are not as good when the current probe is placed on the power lines only and the motor case is grounded. In this case, the motor has both elements of common and differential mode noise and the 4-pole filter works better above 100 MHz.

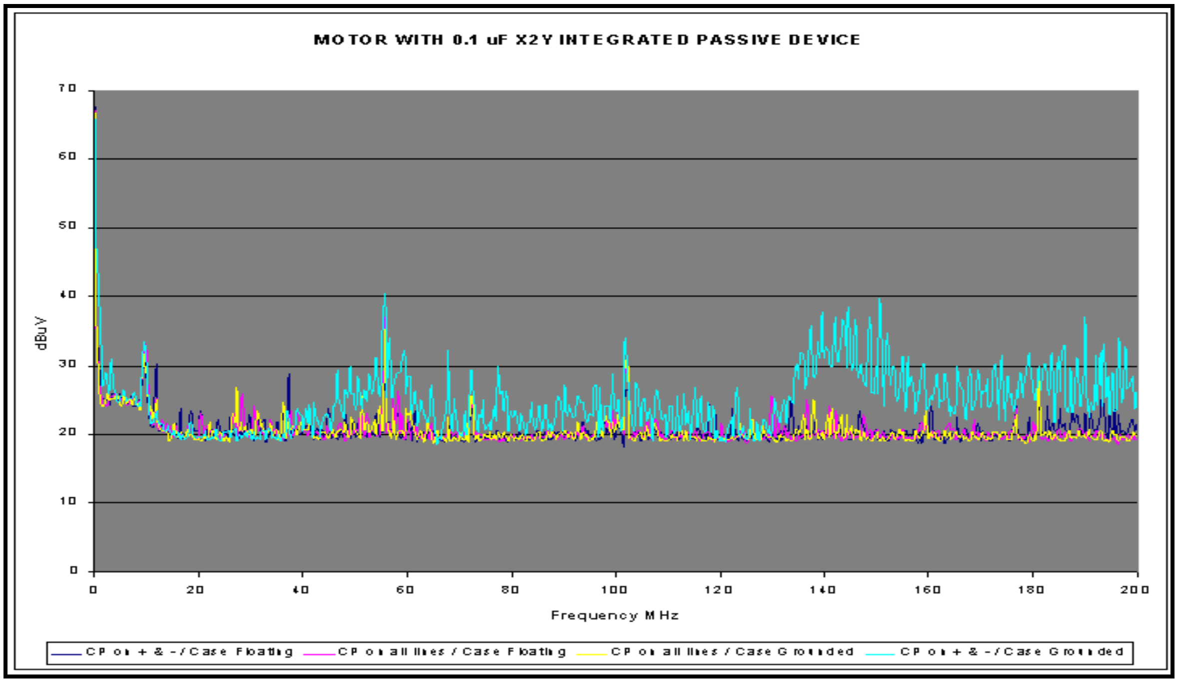

Figure 9. ***Motor with new technology 0.1 uF X2Y^{TM} integrated passive device.***

In Figure 9, the motor was tested with a 0.1 uF X2Y^{TM} integrated passive device placed across the power lines and grounded to the case of the motor. The analysis of this data shows the X2Y^{TM} device to be very good at suppressing the noise when a current probe is placed on all lines with the case floating or grounded and when the current probe placed on the power lines only with the case floating. The X2Y^{TM} device also does well when the current probe is placed on the power lines only and the motor case is grounded (both common and differential mode noise generated by the motor are measured), although not quite as well as for the other test configurations. This is the only form of suppression that keeps the noise level below 40 dBuV for all test configurations.

Comparisons Of Test Results:

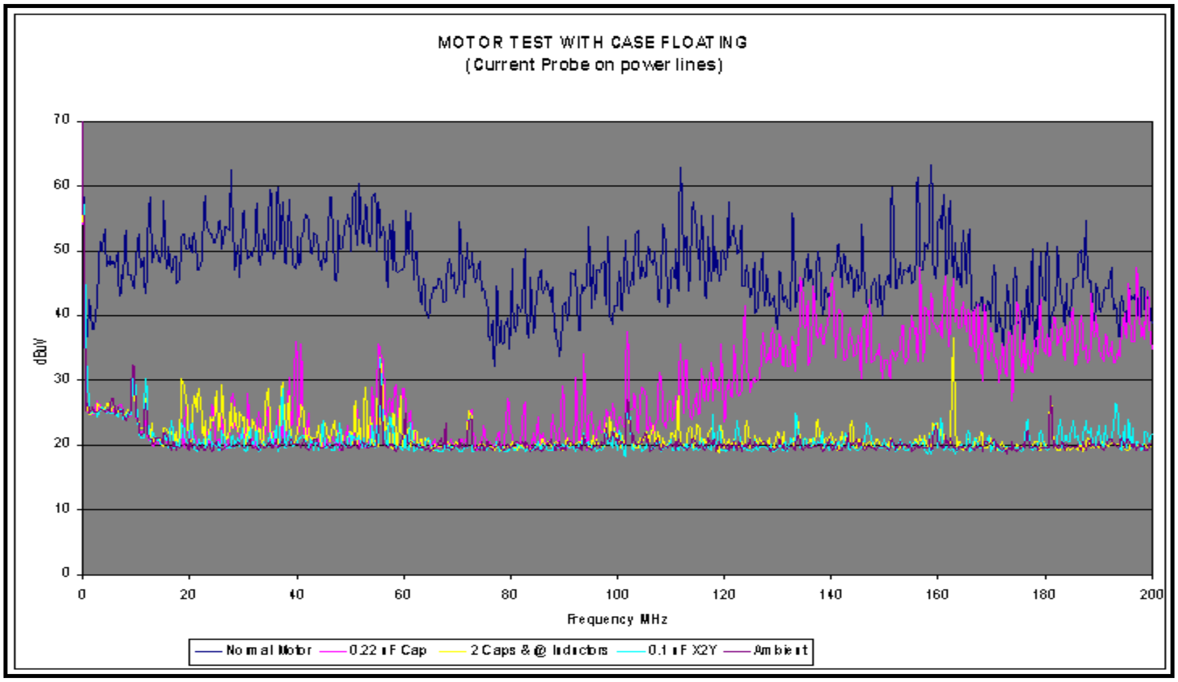

Figure 10. ***Motor with case floating and current probe on power lines only.***

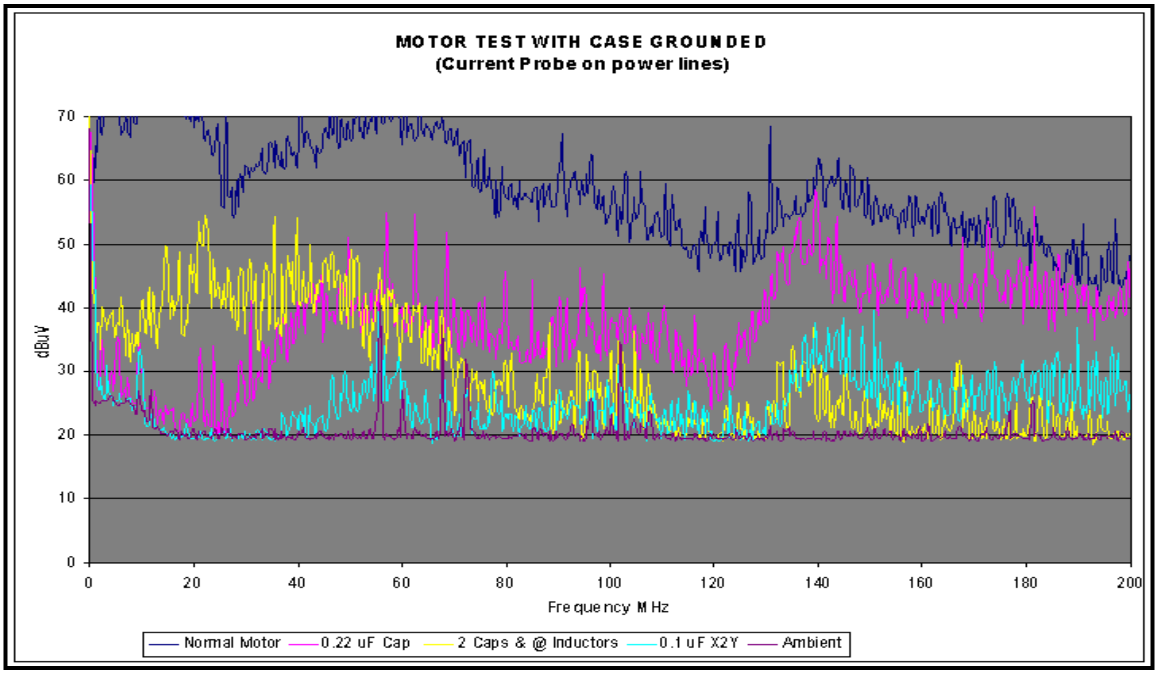

Figure 11. ***Motor with case grounded and current probe on power lines only.***

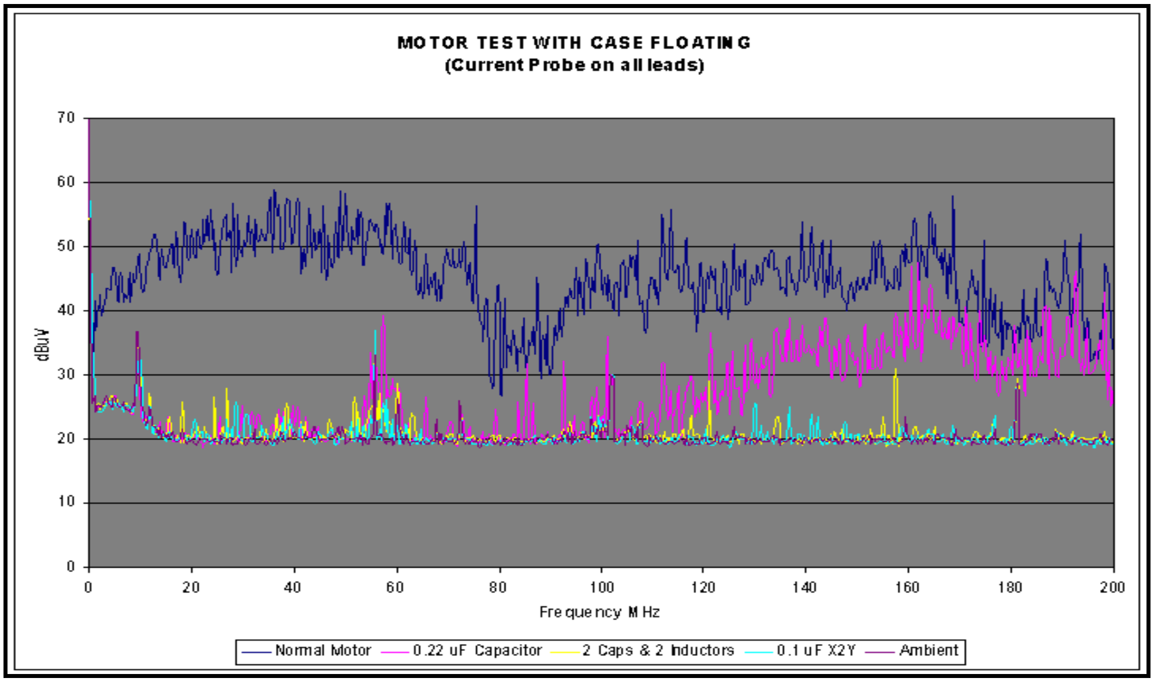

Figure 12. ***Motor with case floating and current probe on all lines.***

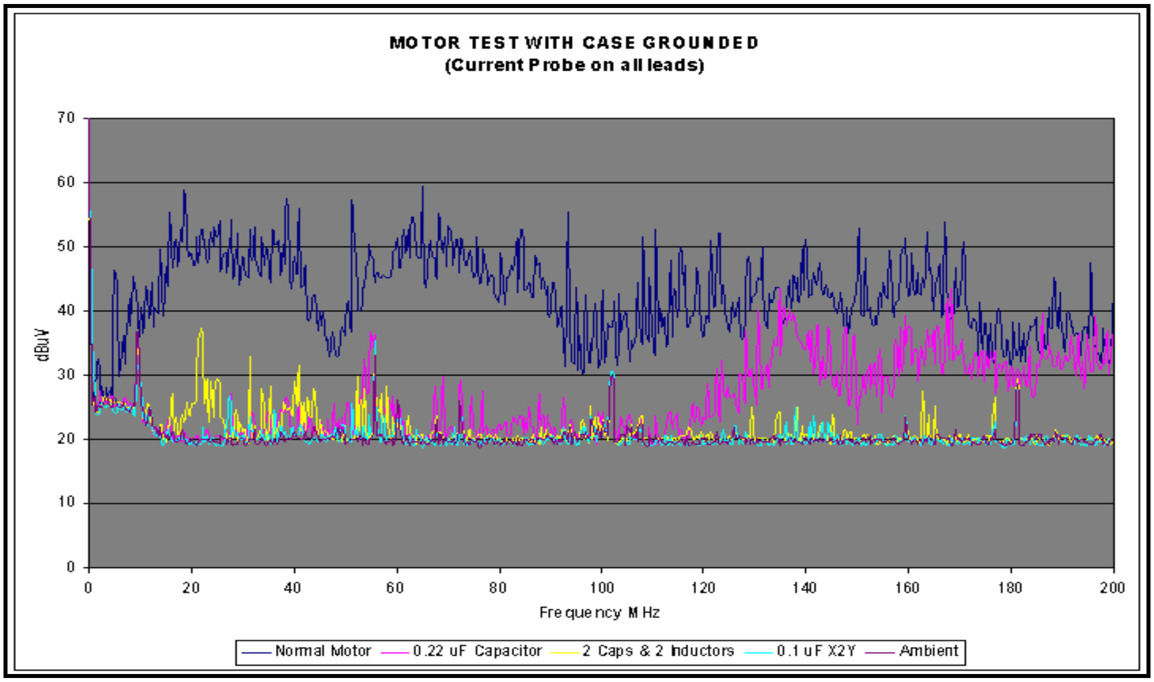

Figure 13. Motor with case grounded and current probe on all lines.

In Figures 10, 12, and 13, when analyzing these three different suppression configurations, the data shows that both the 4-pole filter and the X2Y^{TM} integrated passive device do an outstanding job keeping the noise level below 40 dBuV. The 0.22 uF capacitor does not do well above 100 MHz.

In Figure 11, where the current probe is placed on the power lines of the motor only and the case is grounded, both common mode and differential mode noise are measured. The only suppression device that keeps the noise level below 40 dBuV is the X2Y^{TM} integrated passive device.

New Suppression Technology:

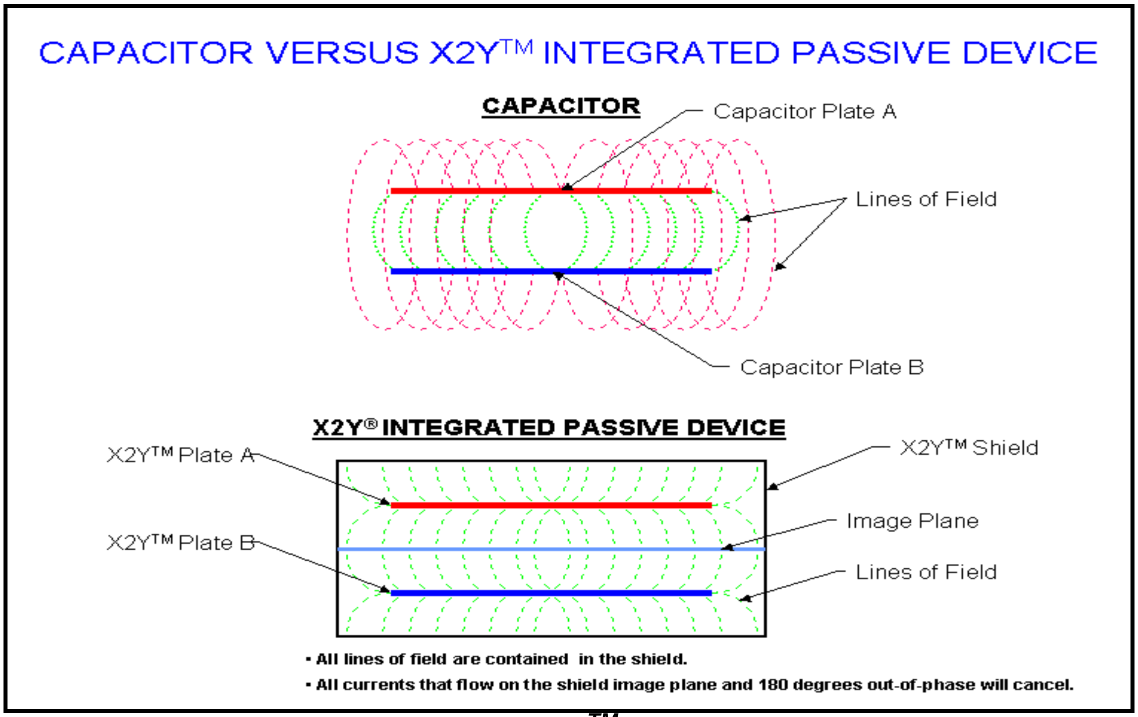

Figure 14. ***A normal capacitor vs. X2Y^{TM} integrated passive device.***

Figure 14 shows the differences between a normal capacitor and an X2Y^{TM} integrated passive device. In a normal capacitor, the lines of field extend beyond the capacitor plates. When the capacitor goes into self-resonant frequency, the signal will short. In the X2Y^{TM} integrated passive device, the capacitor plates are completely enclosed by a shield, which keeps the lines of field from radiating. The X2Y^{TM} device, in addition to acting like a normal capacitor, cancels the currents that flow on the image plane which are 180 degrees out-of-phase.

Conclusion:

The test methodology used to measure the noise on a small motor is very repeatable and easy to run. The current probe used in this test procedure was very effective in measuring both common mode and differential mode noise. In the real world, the placement of small motors sometimes makes it very difficult to measure both common mode and differential mode noise. The test results shown in this paper illustrate the different ways the data can change depending on which wires are placed in the current probe. One might think the worst-case scenario would occur when all the wires are placed in the current probe. This test data shows that this is not the case because the current probe is only measuring the common mode noise. The worst-case scenario shown from the data is when the current probe is placed only on the power lines and a case ground connected to the motor is left out. One might argue that this is not a representative scenario. However, if the motor were mounted to a metal bracket that supplies case ground to the motor and the only lines coming out of motor are the power lines, then this would represent real world use.

In summary, this article shows both common mode and differential mode noise being generated from a small electrical motor with three different ways to reduce the noise. Both the 4-pole filter and the X2Y^{TM} integrated passive device proved to be very effective in reducing the motor noise.

When cost is brought into the equation and you need to meet more stringent EMC requirements than with a normal capacitor, the X2Y™ integrated passive device looks especially promising.

Acknowledgements:

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References:

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