

GTEM cell simplifies EMC test

Check the EMC performance of your designs in the lab with a GTEM cell and a spectrum analyzer.

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EMI suppression and filtering are becoming increasingly important as the use of small DC motors proliferates (see "[Small DC motors and RFI](#)"). In an effort to develop a compact filter whose performance surpasses that of traditional filters, we employed a production version of a small automotive windshield-washer DC-motor assembly as a DUT in an EMI measurement setup.

Our test setup (**Figure 1**) included a broadband GTEM (gigahertz transverse-electromagnetic) cell for our radiated emissions measurements. Research papers show good correlation between the GTEM cell and open-area test sites (OATS) for frequencies from 150 kHz to 1 GHz (Ref. 1 and 2), and conducting tests using a GTEM cell is more convenient than performing field tests. Equipment (including your DUT, instruments such as spectrum analyzers, and a series of tuned antennas or a single wideband antenna) need not be transported to remote sites. The cell simulates an open site in your lab, acting as its own wideband antenna. In addition, the cell simplifies the process of compensating for ambient signals.

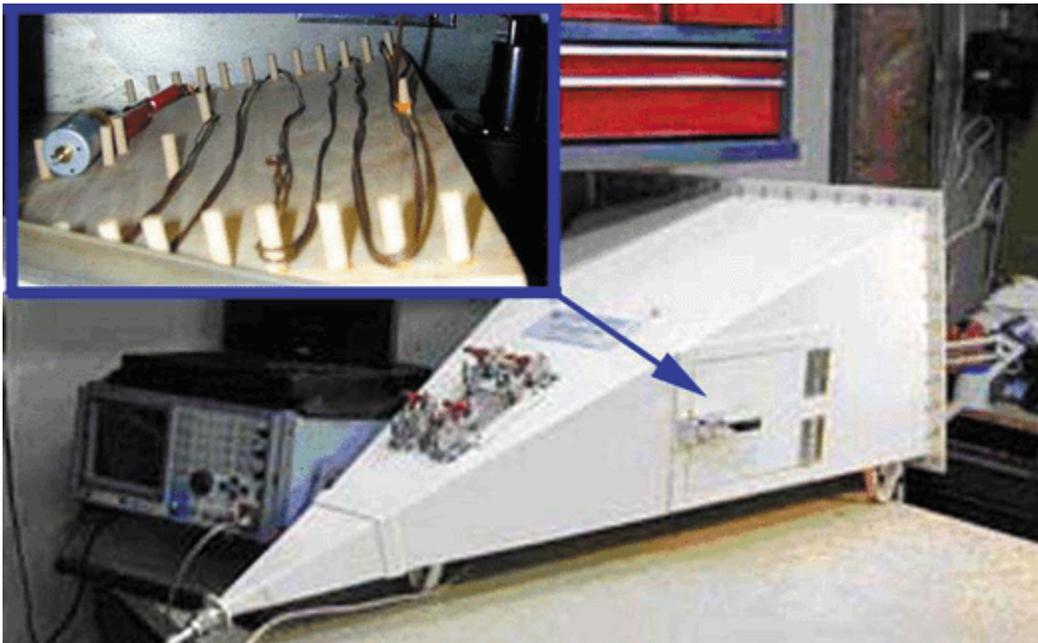


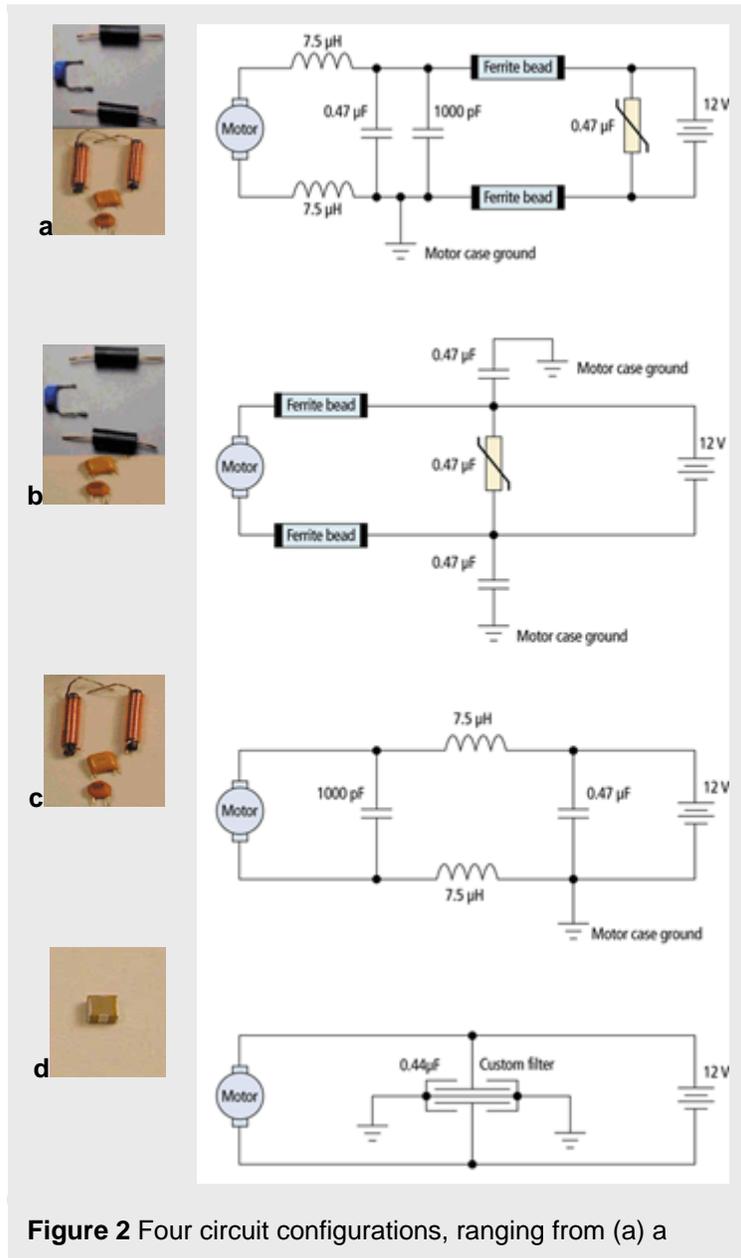
Figure 1 A KuTEM Omnicell test chamber from Lindgren RF Enclosures served as the basis for the measurements reported in this article. Wooden dowels hold the motor and cable in place (inset).

For our GTEM cell, we chose the KuTEM Omni-Cell from Lindgren RF Enclosures (Glendale Heights, IL), because its low ambient noise floor permits accurate measurements of various filter

GHz Model AN920, whose frequency range we set from 100 kHz to 1000 MHz, with 9-kHz resolution. We connected the two pieces of equipment through the cell's N connector and spectrum analyzer's BNC connector.

We turned off the spectrum analyzer's video-bandwidth filter so the instrument would not filter the signals being analyzed. The video bandwidth filter can improve the visibility of spectrum-analyzer traces but could mask signal components of interest to us. We ran the DUT in a steady-state condition to minimize variability in the data. We set the spectrum analyzer to capture the signal in peak-hold mode and ran the motor for a period sufficient to capture four complete sweeps in peak-hold mode.

Four test configurations



We tested our motor using several different filter configurations, four of which we describe here (**Figure 2**). We characterized the motor in its normal production (unfiltered) condition and then with the different filter configurations. A 12-V battery connected to a 3-m cable having two conductors (+12 V and ground) carried power to the motor. The 3-m length is a standard length for automotive EMC tests (a typical vehicle is about 3 m long).

seven-component filter to a (d) single-component version, yielded the noise-measurement results shown in Figure 3.

We built a wooden test fixture that uses wooden dowels to hold the motor and the cable in place, as shown in the Figure 1 inset. It's important that the fixture be nonmetallic to minimize interference with the GTEM cell's response. To conduct a test, we simply put the fixture with the DUT and cabling in place on the floor of the cell.

To determine ambient EMI conditions, we first placed an unfiltered motor in the cell and took a measurement without the +12-V energy source connected to the motor. We then repeated the test with the motor powered up to set the baseline.

We ran the test several more times to gather data with all of the filter configurations. The first motor filter (Figure 2a) has seven components. Two 7.5-mH inductors limit the amount of noise that passes through the supply lines; then, a 0.47-mF X-capacitor and 1000-pF X-capacitor bypass the noise to ground and to the motor case. The filter network also uses two ferrite beads that provide high impedance to unwanted noise. The beads' ferromagnetic material dissipates the noise as heat. The last component in the network is a 0.47-mF capacitor-varistor placed across the power leads to clamp the noise to a 14-V level and to bypass any remaining noise to ground.

The second type of filter we tested (Figure 2b) is a five-component network that uses two ferrite beads that provide high impedance at the frequencies of the unwanted noise. It also includes a 0.47-mF capacitor-varistor to clamp the noise to 14 V. Two 0.47-mF Y-capacitors connected from the power leads to motor case bypass the remaining noise to ground.

The third type of filter network (Figure 2c), uses a 1000-pF X-capacitor to bypass the noise to ground at the motor case. Then two 7.5-mH inductors limit the noise, and a second, 0.47-mF, X-capacitor bypasses the remaining noise to ground at the motor case.

The last type of filter (Figure 2d) is our single-unit chip configured in what is called a layered architecture that uses an internal image plane between capacitor plates to minimize internal inductance and resistance. Alternating electrode layering allows opposing internal skin currents that are essentially 180° degrees out of phase to cancel out. The mutual inductance can be positive, negative, or zero. We designed this device to have its internal mutual inductance fields cancel.

Test results

In **Figure 3**, the fine lines represent raw data from our tests. To clarify the reading of the data, we set the spectrum analyzer to show a 10-point moving average, which it highlights with a thick line. A comparison of the different filters used in the motor shows that our one-component filter provides between 25 and 50 dB of attenuation from 150 kHz to 1000 MHz. In comparison, the five-component filter shown in Figure 2b provides between 25 and 40 dB of attenuation from 150 kHz to 180 MHz, but at higher frequencies, its performance suffers.

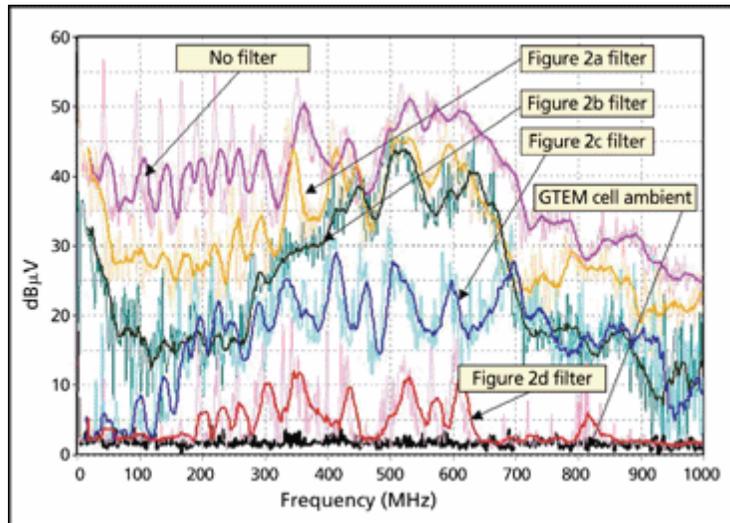


Figure 3 Spectrum-analyzer measurements indicate the results obtained from the various filter combinations under test. The baseline indicates ambient noise with no power applied to the DUT.

The test methodology used to measure the radiated emissions of the small DC motors in a broadband GTEM

cell proved to be very repeatable and easy to run. The wooden test fixture was instrumental in allowing us to quickly change the DC motors and place them back in the same location in the GTEM cell. Our test results illustrate the different types of DC motor filters and how they react in an open field site.

The GTEM-based test setup proved to be an effective method for quickly comparing the EMI performance of our single-component filter with traditional multicomponent filter configurations. Without resorting to expensive OATS tests, we confirmed our prediction that the mutual internal inductances of our filter would cause common- and differential-mode noise to cancel. (This cancellation effect is the reason the one-component filter does not emulate a normal filter at 20 dB per decade; the layered architecture allows a combination of cancellation and bypassing of common and differential mode noise at the source.)

You can use a similar test approach to evaluate the emissions performance of products aimed at a variety of markets, from telecommunications to automotive electronics. Ultimately, you may have to subject your product to full OATS-level EMI tests to comply with the requirements of governmental bodies having jurisdiction in your geographical region. But GTEM-based tests conducted in your lab can give you confidence that your initial field tests will be successful. *T&MW*

References

1. Clay, Stephen, "Improving the Correlation between OATS, RF Anechoic Room and GTEM Radiated Emissions Measurements for Directional Radiators at Frequencies between approximately 150 MHz and 10 GHz," *IEEE 1998 Electromagnetic Compatibility Symposium Record*, Vol. 2, IEEE, Piscataway, NJ, 1998. pp. 1119–1124.
2. Kim, Soo-hyung, and Jung-young Nam, Hynn-goo Jeon, and Sung-kook Lee, "A Correlation Between the Results of the Radiated Emission Measurements in GTEM and OATS," *IEEE 1998 Electromagnetic Compatibility Symposium Record*, Vol. 2, IEEE, Piscataway, NJ, 1998. pp. 1105–

1109.

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Small DC motors and RFI

The use of small DC motors in electronic products is increasing dramatically. Applications range from the single motor in a power tool to the as many as 100 motors in a luxury automobile. Such small DC motors can generate substantial RF noise because of the high-speed switching that occurs when the motors operate at angular velocities as high as 24,000 rpm at 12 VDC.