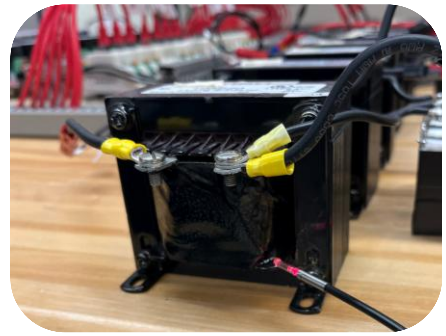
Non-Contact Acoustic Characterization of Magnetic Components in Power Electronic Converters Using BROADSONIC

Resolving magnetostrictive force signatures from DC/AC inverter filter inductors at ultrasonic frequencies

The Challenge



Acoustic emissions from magnetic components (inductors, transformers, reactors) contain diagnostic information about the mechanical state of the core, windings, and air gaps. However, measuring these emissions in operating power converters is difficult: contact-based accelerometers are susceptible to electromagnetic interference from switching transients, and conventional microphones lack bandwidth above 20 kHz, where the most useful spectral content from modern converters resides.

BROADSONIC is an optical ultrasonic sensor that addresses both limitations. It is non-contact, inherently immune to electromagnetic fields, and provides broadband acoustic sensitivity from Hz to 5 MHz with configurable sub-Hz frequency resolution.

Result: Acoustic Fingerprinting via B^2 Force Mechanism

BROADSONIC was used to measure acoustic emissions from the filter inductor of a 60 Hz DC/AC converter operating at a 10 kHz switching frequency. The acoustic spectrum was compared against the spectrum of the squared electrical current (I^2), which serves as a proxy for the magnetostrictive force $F \propto B^2$.

The results demonstrate three key findings:

1. No acoustic energy at the switching frequency. The B^2 force nonlinearity eliminates the carrier, producing sidebands at $f_{sw} \pm n \times 60$ Hz instead. This confirms the sensor is measuring real mechanical vibration, not electrical crosstalk.

2. Sideband positions match I^2 predictions across 12 harmonics. From 10 kHz to 120 kHz, acoustic peak frequencies align with the I^2 spectrum, confirming the magnetostrictive B^2 force mechanism. The measurement bandwidth of BROADSONIC extends to 5 MHz; the 120 kHz upper limit here reflects the emissions of this particular converter, not the sensor.

3. Relative amplitudes reveal the mechanical transfer function. Deviations between acoustic and I^2 amplitudes at lower harmonics (10–20 kHz) indicate structural resonances in the inductor body. This sensitivity to mechanical state is the physical basis for condition monitoring.

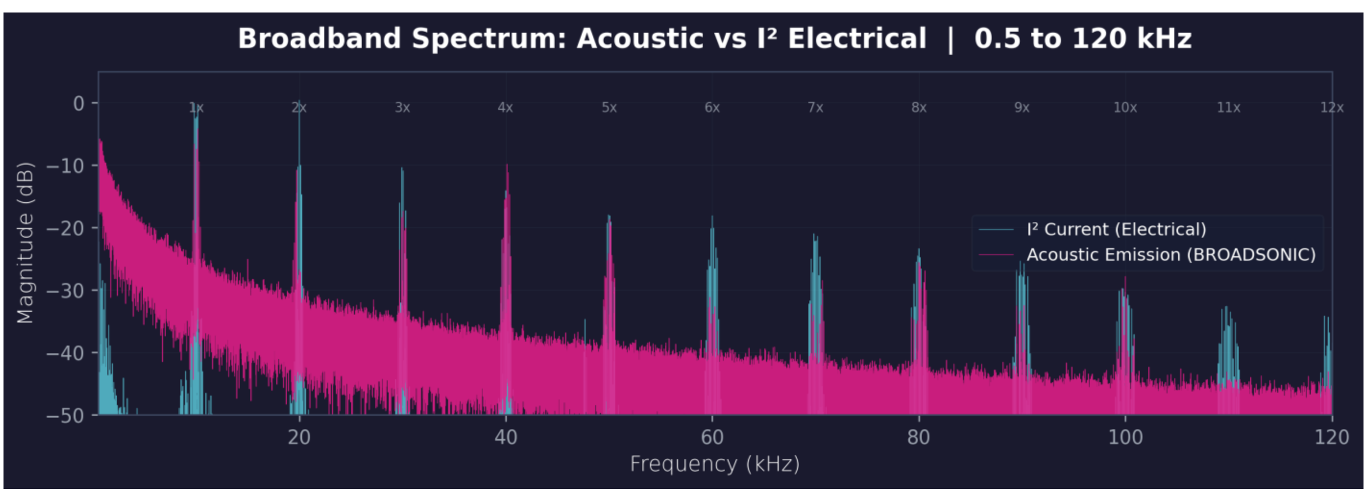


Figure 1: *Broadband spectrum, 0.5 to 120 kHz. Twelve switching harmonics are visible in both the acoustic emission (pink) and I^2 current (cyan) spectra. The acoustic noise floor rises at higher frequencies while the electrical noise floor remains flat, confirming distinct measurement physics.*

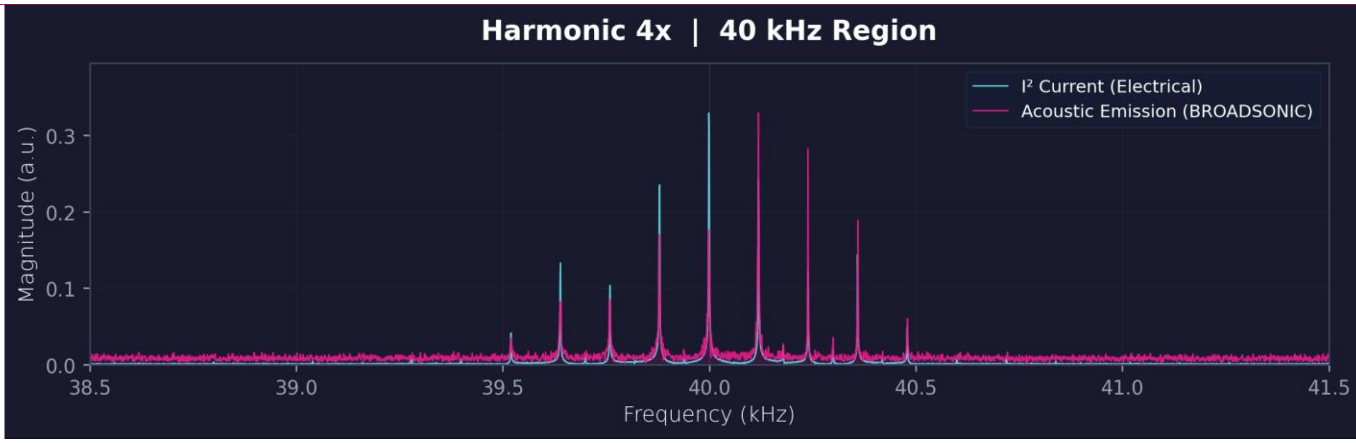


Figure 2: *4th switching harmonic (40 kHz region). Acoustic emission peaks (pink) align closely with I^2 current measurements (cyan), confirming B^2 force mechanism. The sideband spacing of 120 Hz (= 2 × 60 Hz) is clearly resolved at 1 Hz frequency resolution. Note the absence of energy at exactly 40,000 Hz.*

Implication: Non-Contact Condition Monitoring

Transformer and inductor failures are among the most costly events in power systems. Core degradation, winding looseness, lamination delamination, and air gap shifts can progress silently for months before causing unplanned outages, thermal runaway, or catastrophic failure. Replacement lead times for custom magnetics are often 6–12 months. Today, most operators have no visibility into the mechanical health of their magnetics until something breaks.

BROADSONIC changes this by providing continuous, non-contact monitoring of each component's acoustic fingerprint while the system is running. A baseline signature captured on a healthy unit becomes the reference. Any mechanical change (loose windings, developing cracks, shifting laminations) reshapes the sideband pattern in a detectable way, giving maintenance teams early warning to act before a failure occurs.

The same acoustic fingerprint that enables condition monitoring also serves as a powerful quality control tool. Every unit off a production line should produce the same sideband pattern under the same excitation. Deviations in peak amplitudes or sideband structure between units indicate manufacturing inconsistencies in core assembly, winding tension, or air gap tolerance. BROADSONIC can perform this comparison non-contact in seconds, providing a quantitative pass/fail metric for end-of-line testing without requiring destructive inspection or long-term deployment.

Key Advantages for Transformer and Inductor Monitoring

Detect winding degradation, core loosening, and insulation breakdown before they become unplanned outages.

Operational Challenge	How BROADSONIC Solves It
Sensor installation requires shutdown	Non-contact optical sensing: retrofit onto live systems with no mounting, no outage, no mechanical loading
Switching noise corrupts accelerometer data	Optical transduction is inherently immune to EMI; measures only true mechanical vibration
Microphones miss ultrasonic content	5 MHz bandwidth captures all switching harmonics where diagnostic information lives
Sideband clusters blur together	Sub-Hz resolution resolves individual 60 Hz sidebands, enabling precise fault signature identification
Hazardous or inaccessible environments	Standoff sensing monitors from a safe distance in high-voltage, high-temperature, or confined spaces

Contact: To discuss how BROADSONIC can support your power system monitoring requirements, please contact Ultracoustics Technologies Ltd. at kyle@ultracoustics.com