Radiated EMI Measurement

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Radio frequency (RF) energy is conducted and radiated from a PD or arcing event location. Antennas are used to measure radiated RF energy. Here the EMI sniffer is used to locate PD activity from an Isolated Phase Bus.
Radiated EMI Measurement

EMI “sniffer” has a short antenna and a magnetic probe to measure the radiated EM (electromagnetic) field strength at the end of this generator.
Radiated EMI Measurement

When there is a variation in charge or current, electric (E) and magnetic (H) fields are produced. Maxwell’s equations tell us that with any change an electric field there will be a corresponding change in the magnetic field. This EM field, will propagate away from a source at the speed of light.

Wavelength is the distance for a RF sine wave to repeat itself. This is usually referred to free space conditions. A 10 MHz wavelength is 30 meters. A 1 MHz wavelength is 300 meters or 984 feet.
Radiated EMI Measurement

These lengths are important since radiated EMI is measured in what is called the near field. Where RF measurements are taken very close to the source.

The energy at far field measurements; where the antenna is many wavelengths from the source decreases as the inverse square of the distance \((1/ d^2)\); this is why there is a loss of signal as you travel away from an AM radio station. Gradually the ambient noise level will be higher than the station signal and a station lost in the static.
Radiated EMI Measurement

We collect EMI (electromagnetic interference) readings in the near field where the distance from source to antenna is much less than one wavelength and the electrical length of the antenna is much shorter than one wavelength.
Near-field energy is reduced with distance at powers higher than inverse square, typically inverse fourth \((1/d^4)\) or higher. This is very important since this implies there is a much stronger reading when an antenna is physically near the event location; thus helping to isolate each defect location.

In the near-field there are strong inductive and capacitive effects from the currents and charge transfer at the event location. If this is primarily a charge transfer as with a PD event the E field is high and the H field low. If there is arcing and current flow (loop currents) the H field is high and the E field low.
The ability to identify between PD and arcing is very important for defect documentation.

In the near-field region one type of field (E or H) will dominate the other. In order to measure an electric field signal we use a whip antenna, just a short length of conductor. Detection of a magnetic field requires a magnetic probe. With the device we use a coil is wound around a ferrite core and called a loopstick.

All the original AM transistor radios used loopstick antennas.
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The “sniffer” is a special AM radio used to measure radiated RF E & H fields.

Ear phones are necessary to hear and identify an EMI signal in high noise environments.
Radiated EMI Measurement

There are three frequency ranges and a gain adjustment on the model shown.

There are audio and EMI level outputs

The LF looks for a low frequency electric field (50 kHz – 5 MHz)
The HF looks for a high frequency electric field (2 MHz – 30 MHz)
The H looks for a low frequency magnetic fields (under 1 MHz)

It is a receiver only no signal is generated.
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Selection of the range to use and gain provides wide coverage of the RF spectrum.

**LF** is the **most** sensitive for detecting defects.

Use the HF scale when LF EMI levels are high.

**H** is the least sensitive scale and is very good when EMI levels are extremely high.

The end of the H probe is a coil around a ferrite core.

It is direction sensitive.
It is very difficult to confine an EM field. One entire area of engineering is focused on shielding against radiated EM fields and the interference that can result. Steel objects such as transformer tanks, cabinet doors or turbine hoods will become antennas by inductively receiving an EM field and then "re-radiating" energy in the near-field and a new radiating surface is now provided.

Depending on physical characteristics and primary frequencies, such coupling can be very efficient.
Radiated EMI Measurement

Measurement of radiated EM field on the side of an oil platform stainless steel generator housing.

The solid steel panel has now become a secondary radiating surface.
Radiated EMI Measurement

When a secondary radiating antenna surface is available, a new near-field EM region is created. The fact that these metal housings are “grounded” at 50 Hz or 60 Hz does not apply to high frequencies. These safety grounds are long, have inductance are not effective at radio frequencies. An EM field also “leaks” through any gaps or openings such as inspection windows or air ventilation holes.
The gaskets in most power equipment are non-conductive and open to EM field propagation. Splits in bearings and the gaps in cabinet doors are the usual places to measure radiated EMI.
Radiated EMI Measurement

EMI shielded rooms are built with a copper box inside an iron box fully insulated and each box grounded at one corner. Special conducting “finger” gaskets are used at the doors and other removable openings. Normal industrial equipment such as breakers, motors, generators and transformers do not have this necessary shielding to contain internal EMI. While the EM field is greatly attenuated it will escape and can be measured. Some believe a motor frame or transformer tank is a Faraday cage and eliminates passage of EM energy technically this is far from actual conditions.
The H setting looks for the magnetic “H” field resulting from high frequency current flow the H scale requires arcing usually with dc or ac current flow current at the defect to generate a magnetic “H” field.

Shaft currents, wiped bearings, broken rotor bars, loose bus connections and sparking brushes are examples where there is current flow generating high “H” field levels.
Radiated EMI Measurement

A totally Non-invasive Diagnostic Technique
No signal is applied, completely passive
There is no need to open enclosures
Inherently safe data collection, no arc flash hazard

High sensitivity
The #1 rule is: If you think you have a problem you don’t!
If there is a problem it is obvious. EMI readings are full scale!!!
Radiated EMI measurement can be used to evaluate:
Generators or Motor windings
Exciters, Sliprings
Bearings and Seals; (detecting circulating (shaft) currents)
Power cables
HV isolated phase & LV non-segregated phase Bus
Breakers and SWGR
GSU & AUX Transformers
The Sniffer locates many types of problems.
This generator has a high speed steam turbine and a gear box drive.

There had been a history of gear and bearing damage.
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A scan of the shaft indicated sparking in the gear box. The shaft was not grounded properly.

A new ground was recommended.
The carbon shaft grounding brush had not been cleaned and was no longer working. Replacement with a copper braid was made over lunch.
Radiated EMI Measurement

With the new shaft ground; sparking at the gear box and the coupling and bearing disappeared. Still a problem at the OB end.

<table>
<thead>
<tr>
<th>Location</th>
<th>Reading (as found)</th>
<th>Reading (with Braid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6-7</td>
<td>Zero</td>
</tr>
<tr>
<td>B</td>
<td>10+</td>
<td>Zero</td>
</tr>
<tr>
<td>C</td>
<td>6-7</td>
<td>Zero</td>
</tr>
<tr>
<td>D</td>
<td>6-9</td>
<td>4-5</td>
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<tr>
<td>E</td>
<td>3</td>
<td>3</td>
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<td>F</td>
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There was severe sparking at the bearings and the gear box. The carbon shaft grounding brush was not working.

A copper braid was added and it eliminated the shaft currents at the gearbox and inboard generator bearing. There was no change in the sparking at the outboard bearing.
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This location had many engine bearing failures. The problem was the generator out board bearing insulation had failed. Shaft currents were flowing into the engine.
The generator outboard bearing insulation had failed. This resulted in engine bearing damage from shaft currents.

Measuring EMI at engine bearings is now routine.
The inboard bearing had just been replaced and it was also damaged. Mis-alignment. Sparking was at the top.

More than one problem was identified.
We have found EMI radiated from the engine at a few locations, alignment, bearing, turbo problems
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Radiated EMI Evaluation Engine #7

"B" side of engine 18V46

Reading are from the LF scale with a gain of 4.5 (max gain is 10)

A higher reading indicates more sparking activity.

Miss-alignment between the engine and generator is indicated.
Transformers
Arcing was detected near the GSU transformer.
A scan for radiated EMI found loose 138 kV cable grounds.
There was PD Associated with this transformer. A scan of the tank for radiated EMI found none.
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The PD source was located in a 69 kV disconnect switch several hundred yards away.
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Motors
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The rotor in this 1000 hp, 2300 volt 3580 r/min motor was so deteriorated the sniffer H scale could detect the broken rotor bars with minimum gain some 4 feet from the machine. Vibration was also very high. A shutdown was recommended.
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All motors are scanned for radiated EMI. Readings at the terminal box and bearings are measured first. Often the upper guide bearing insulation is compromised. Sparking results.
If the readings decrease the activity is located in the motor. If readings increase the activity is in the cable. Here the reading is decreasing.
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Readings were lowest when furthest from the motor.

If readings had increased the activity was in the cable. Wet cables and deteriorated splices have been identified.
Radiated EMI Measurement

Switchgear
and
Bus
Scanning cabinets for PD and arcing is a quick way to locate defects such as contamination, tracking and loose connections.

Doors are never opened.
There was strong arcing detected in this row of 6.9 kV breakers.

A short “E” Field probe was placed at the edge of each closed door.
It became apparent this arcing was in Cabinet 3.

The rear side of this row was then scanned top and bottom.
Further scanning located the activity at the top rear of the #3 cubical.

A loose potential transformer High Voltage connection was found and repaired.
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Locating a defective breaker

We found the entire room had very high radiated LF scale EMI levels.

Highest readings were near the generator field breaker.
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The gain was reduced and the LF readings plotted against location.

We had eliminated the FU 6 B row. Breakers 4 & 5 in FU 6 A where now suspect.
Radiated EMI Measurement

Further reduction in gain indicated a MG Set exciter/breaker problem existed.

An inspection of the Exciter breaker was recommended.
This AUX 4 kV bus system had experienced a failure. The disconnect links become loose and melted. This could have been prevented. Loose connections arc and the EMI can be detected.
The sniffer uses the bus supports as an antenna to bring any signal to ground level.

LF scale is used as it is the most sensitive.
Radiated EMI Measurement

The radiated EMI scan for the AUX bus noted increased activity along the 4 kV bus supports.

At center support.  LF level 8-9  Gain=9
The LF level dropped off to zero where the bus entered the plant and was maximum under the links. An inspection of the bus disconnect links was recommended.
Radiated EMI Measurement

A common failure mode is loose bolts or corrosion of connections.

All flat enclosures leak and corrosion is a problem.

Note rust on center phase bolts.
Summary

Measurement of radiated EM fields is an important part of the EMI evaluation of any system. This provides guidance of where to look for problems. Conditions are surveyed in real time while equipment remains in service.

The technique is fast and safe. No doors are opened.
No arc flash hazard.
No connection made to energized systems.
Great help for condition assessment and inspection planning.
Questions