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A Measurement Technique for Characterizing Performance Degradation Caused by EMI on Radio Equipment

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Outline

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Abstract

- An RF audio distortion measurement technique exists to characterize degradation to communications equipment.
- Degradation is a result of EMI from active vehicle components.
- This measurement technique provides a way to quantify the performance of a radio receiver under a variety of states.

Measured Degradation

- The measured degradation is the result distortion caused by EMI

  conducted,

  radiated,

  and/or coupled

  from active components into the receiver's passband.

SINAD

- SINAD: signal plus noise and distortion
  - A common reference used to measure a communication receiver's sensitivity
  - Provides a quantitative measure to the quality of the receiver's audio signal.
  - Can be viewed as the reciprocal of THD+N

$$\mathrm{SINAD}_{\mathrm{dB}} = 20\ \log_{10}\left(\frac{\mathrm{Noise(V)} + \mathrm{Distortion(V)} + \mathrm{Signal(V)}}{\mathrm{Noise(V)} + \mathrm{Distortion(V)}}\right)$$

The SINAD Receiver Measurement

- First Measurement
  - Modulate carrier frequency w/ known audio signal
  - Measure power level at receiver
  - Power level includes the following signals:

    known audio signal, noise, and distortion

- Second Measurement
  - Apply bandstop filter centered at the known audio signal to the audio output of the receiver
  - Measure power level of receiver
  - Power level includes the following signals:

    noise and distortion

A SINAD value of 12 dB corresponds to a 4:1 SNR

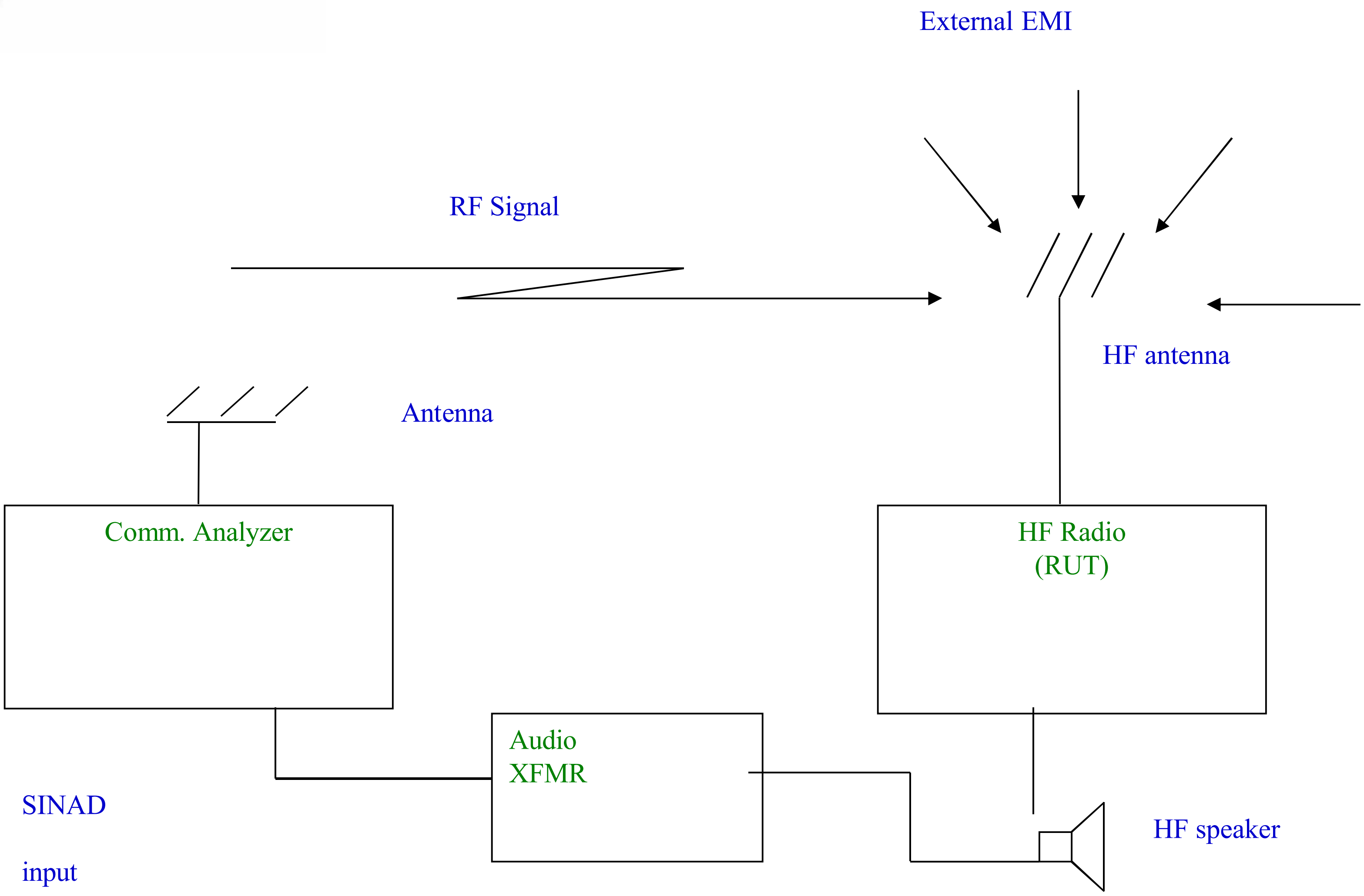
The SINAD Receiver Measurement

- Audio Tone
  - Typically a 1 kHz sine wave
  - Representative of the mid-band frequency for voice communications
- Power Meter
  - A true RMS voltmeter is required for accurate measurement of non-sine waveforms
- Audio Filter
  - C-MESSAGE: most popular in North America
  - CCITT (P53): recommended by the ITU

SINAD Measurement – Sources of Error

- Any source in the receiver that can effect audio distortion, e.g., audio amplifier: most LMRs are limited to adding a small percentage of audio distortion
- Non-realizable Filtering, e.g. bandstop filter: passband ripple, cutoffs, distortion signals are affected less than noise signals due to harmonics

Test Setup



External EMI
RF Signal
HF antenna
Antenna
Comm. Analyzer
HF Radio
(RUT)
Audio
XFMR
SINAD
input
HF speaker

Test Location

- Anechoic chamber best.
  - Expensive for vehicle applications
  - May require long travel distance
- Rural “quiet areas” can prove satisfactory.
  - Check area for background noise level
  - Avoid power lines, substations, etc.
  - High winds can produce static precipitation

The Baseline Measurement

❖The First Measurement

- Obtain with only the radio under test (RUT) and test equipment powered on.
- Obtain several measurements over a period of time to check for variability.
- Proceed to the Degradation Measurements if a small variance in the baseline readings is obtained, < 1 dB.
- Repeat Baseline measurement at the end of the Degradation Measurements to check Baseline.

Receiver Degradation Measurement

1. Once a baseline measurement is established

   Systematically begin adding potential EMI sources to obtain their individual contributions to receiver degradation.

   Be sure to exercise all possible states of the candidate sources. (i.e. satellite tracking antenna)

2. Measure degradation with all potential EMI sources active to obtain the overall degradation amount

3. Repeat degradation measurement after trying to reduce EMI source(s) or coupling if needed to test for improvements to system configuration (i.e., vehicle's layout and/or install)

Repeatability

- Strict control over vehicle layout is critical:
  - body panels (open doors, etc.)
  - cabling
  - antenna placement
  - test equipment
  - personal locations

An Example of EMI

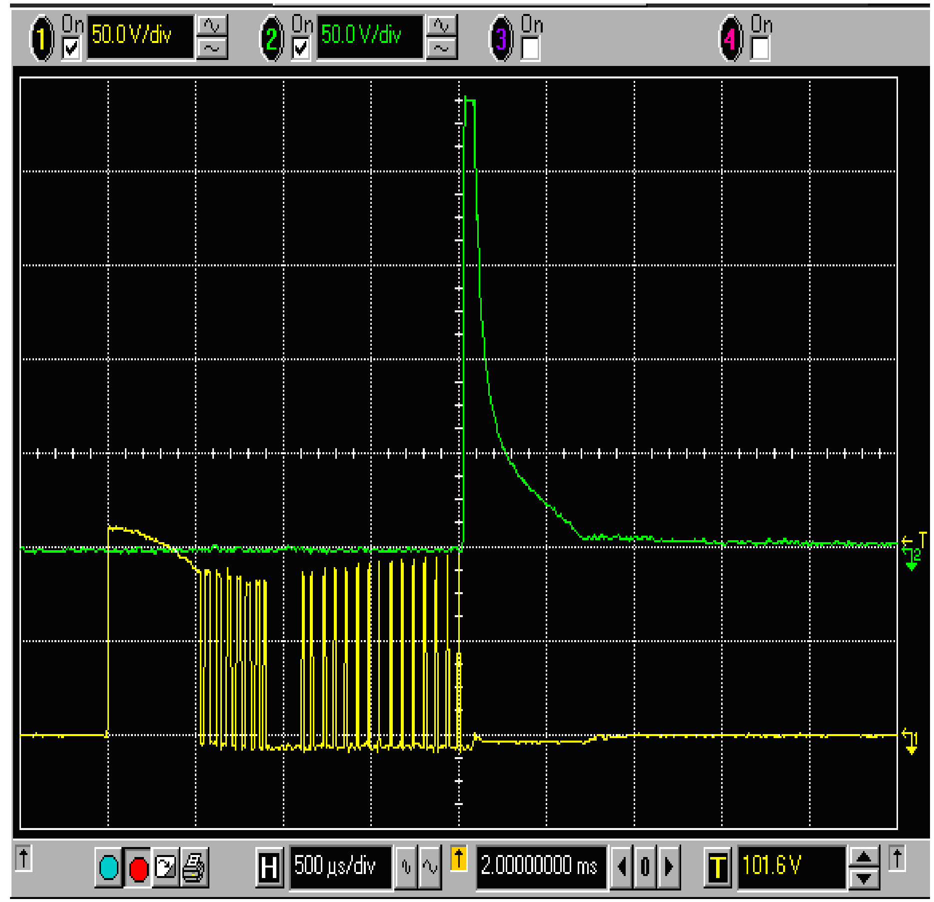
H.T. lines for spark plugs on typical gas engines are known for EMI

Diesels do not have spark plugs good thing right ??

Scope trace of diesel injector driver module

High voltage transients -> EMI radiation from diesel injector harness

Degraded HF performance by > 20 dB



Solution to EMI example

- Ferrite cores AB_2O_4 with a specific permittivity were installed around the diesel injector harness (A & B are metal cations).
- Ferrite cores are easy to install and inexpensive.
- Act as a "resistor" to high frequency EMI

  (absorbed EMI energy is converted to heat).

SINAD Measurement Table

Baseline

Channel	Engine Off (dBm)	Engine On (dBm)	Degradation (dB)
A	-59.6	-57.3	2.3
B	-62.4	-46.6	15.8
C	-63.9	-34.9	29.0
D	-70.9	-57.3 background noise	13.6

Channel	Ferrite: A	Degradation (dB)	Improvement (dB)
A	-57.8	1.8	0.5
B	-60.0	2.4	13.4
C	-50.9	13.0	16
D	-66.0	4.9	8.7

Channel	Ferrite: B	Degradation (dB)	Improvement (dB)
A	-52.9	6.7	-2.1
B	-56.7	5.7	10.1
C	-47.6	16.3	12.7
D	-65.6	5.3	2.0

Channel	Ferrite: C	Degradation (dB)	Improvement (dB)
A	-56.4	3.2	-0.9
B	-43.2	19.2	-3.4
C	-32.8	31.1	-2.1
D	-64.3	6.6	7.0

Channel	Ferrite: C+A	Degradation (dB)	Improvement (dB)
A	-59.1	0.5	1.8
B	-56.9	5.5	10.3
C	-50.1	13.8	15.2
D	-63.1	7.8	5.8

Conclusion

- Technique was presented to quantify amount of degradation upon RUT due to EMI.
- Can be used to determine if satisfactory performance of RUT is expected or if an engineered solution is needed.
- Has been useful in determining sources of EMI, quantifying degradation, evaluating vehicles, and for testing the effectiveness of EMI solutions.