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Distortion Caused by Magnetics in Cenelec A NB PLC Application Circuit

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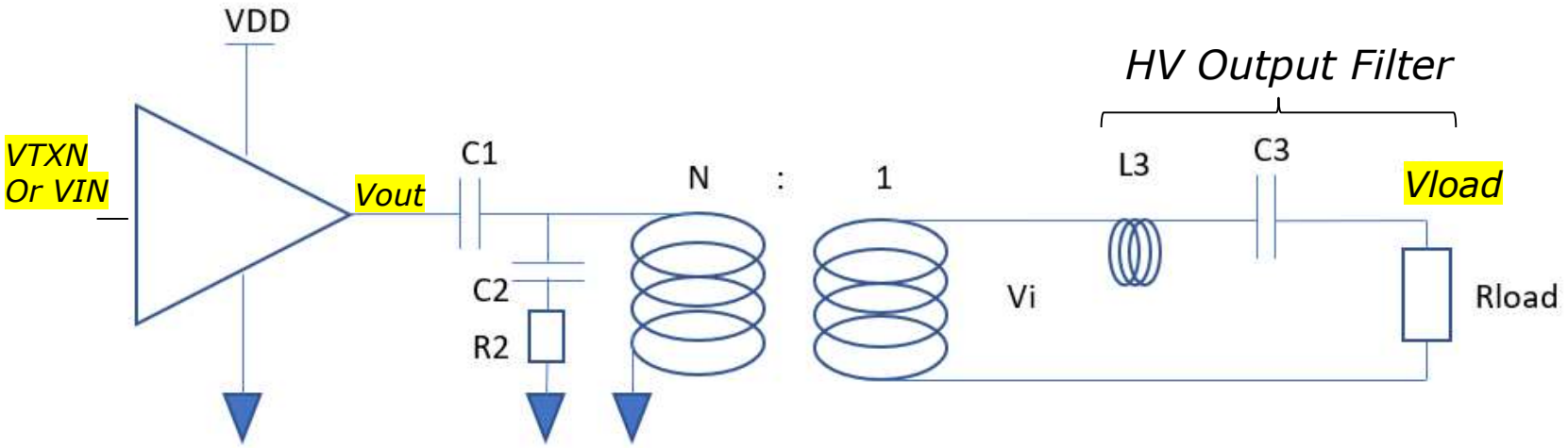
Contents

- When developing the applications circuits for low frequency, high-current narrow-band power line communications interface circuitry, the inductors and transformers can make a difference to the distortion due to saturating or non-linear magnetics.
- This report will look at three different inductors (L3 on schematic) used to shape the Cenelec A band BPF.
- OFDM signals are applied and the MTPR is measured to illustrate the distortion.

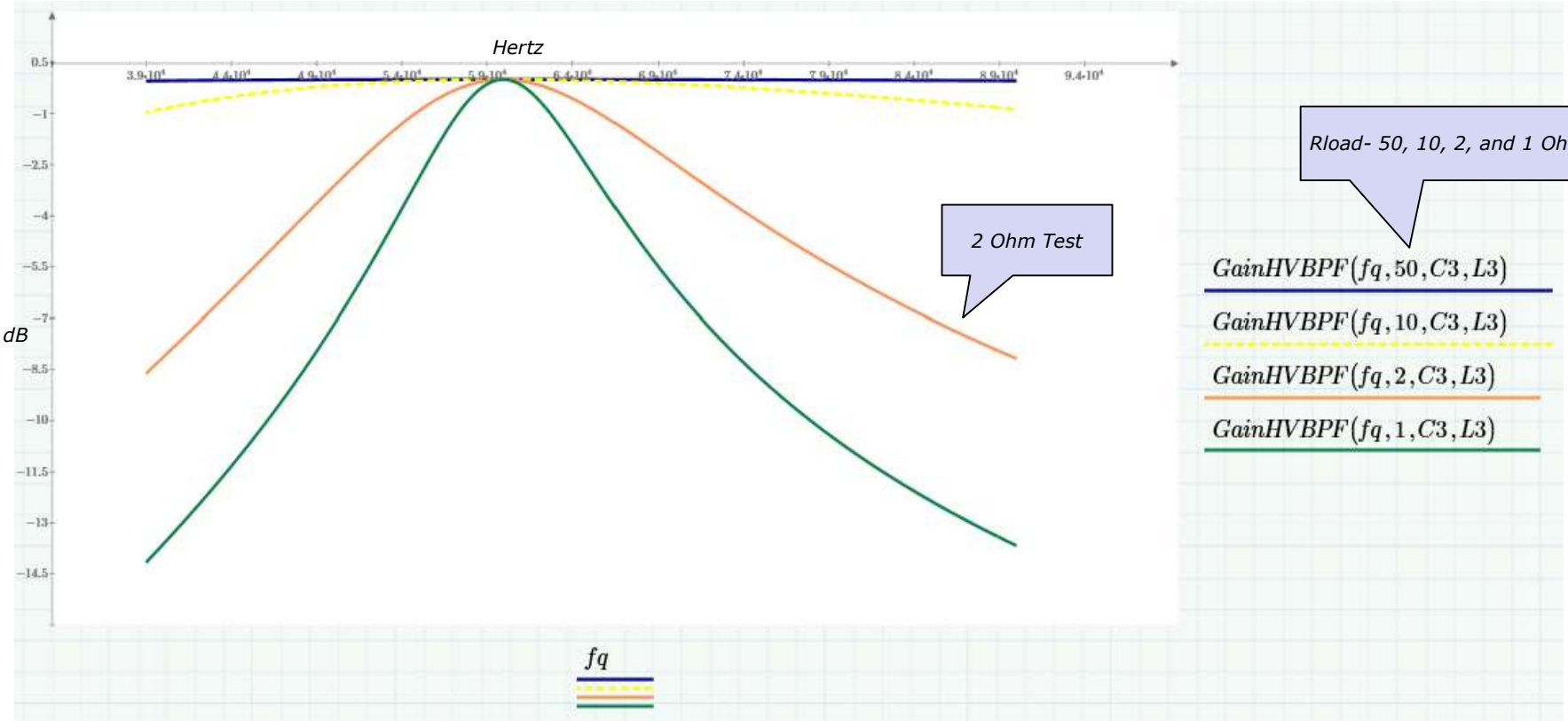
Circuit Diagram

Below is a typical Cenelec A HV output filter used to improve the low frequency response due the maximum allowable C3 capacitor being too small to use without the help of L3 to extend the lower range.



Cen A HV Output Filter

At higher Rloads, 50 and 10 Ohms, the response is nearly flat, but at more typical loads, 2 and 1 Ohms, the response looks like a significant bandpass filter to the 39kHz to 90kHz band (shown).



C3=470nFd, L3=15uH, Rload=50, 10, 2, 1 Ohms

Inductor L3 is investigated

- A 1.3 to 1 transformer (N=1.3) was used.
- Several inductor styles are measured to quantify the distortion caused by saturating cores of various materials.
- They are-
  - *Air core, hand wound inductor which takes the core effects saturation out of the measurement. (**ACI**)*
  - *A metal alloy powder core inductor with a high saturation point (**MAPCI**)*
  - *A typical ferrite core inductor (**FCI**)*
- Figure of merits for the testing are-
  - *Both Peak and Average MTPR*
  - *The out of band noise floor which usually increases as MTPR lowers*

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Measurements

- Distortion and noise have been measured using a LabVIEW ARB and waveform capture system. FFT of the sparse OFDM signal is processed to provide a Frequency domain plot of the signal bins (with tones) and distortion bins (the skipped tones).
- The measurements can be done at several locations shown on the diagram on the next page-
  - *Vout, which is the output of line driver while loaded*
  - *Vload, which is at the load*
- A 2 Ohm Load will be used unless otherwise noted for the tests listed in this report.

Peak and Average MTPR

- The following chart shows the signal characteristics at Vout (output of P1000 while under load) and Vload (output of application circuit under load).
- Vout characteristics under load exhibits low distortion across the whole band including the out of band spectrum.
- The output was adjusted to about 0.8Vrms (CF at Vo is 3.6) using the air core (AIC) L3. The same input was used in subsequent tests where the L3 choice may cause a slight change in the output voltage.
- The MPTR results were highly dependent on which inductor was used.
- See the signal data and then data related to inductor on the next two pages.

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Performance vs. Inductor

Inductors >	ACI L3=15uH		MAPCI L3=15uH		FCI L3=15uH	
Measurements	Vload	Vout	Vload	Vout	Vload	Vout
Vrms (V)	0.805	1.68	0.753	1.68	0.755	1.68
VPP (V)	5.4	11.68	5.4	11.66	5.39	11.67
CF (V/V)	3.35	3.47	3.57	3.47	3.57	3.47
MTPRpeak(dB)	56.5	77.5	26.5	77.6	40.8	77.5
MTPRavg (dB)	69.2	88.6	37.6	89.2	52.4	88.9
Tone Amplitude (dB)	-25.6	18.93	-26.22	-18.95	-26.2	-18.95
IDD (A)	165m		158m		159m	

Rload=2 Ohms

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Inductor Comparison

Inductor	Inductance	Ind Isat A	Ind Irms A	Sig Ipk A	Sig Irms A	Core	Mount	MTPR Peak dB	MTPR Avg dB
Vout, no magentics								77.5	88.6
ACI, no xfmr	15uH			1.4	0.4	Air	Thru	67.5	80.5
ACI	15uH			1.4	0.4	Air	Thru	56.5	69.2
MAPCI	15uH	7.6	7	1.32	0.38	Metal Alloy powder	Surface	26.5	37.6
FCI	15uH	3	1.9	1.32	0.38	Ferrite	Thru	40.8	52.4

Specs *Tests*

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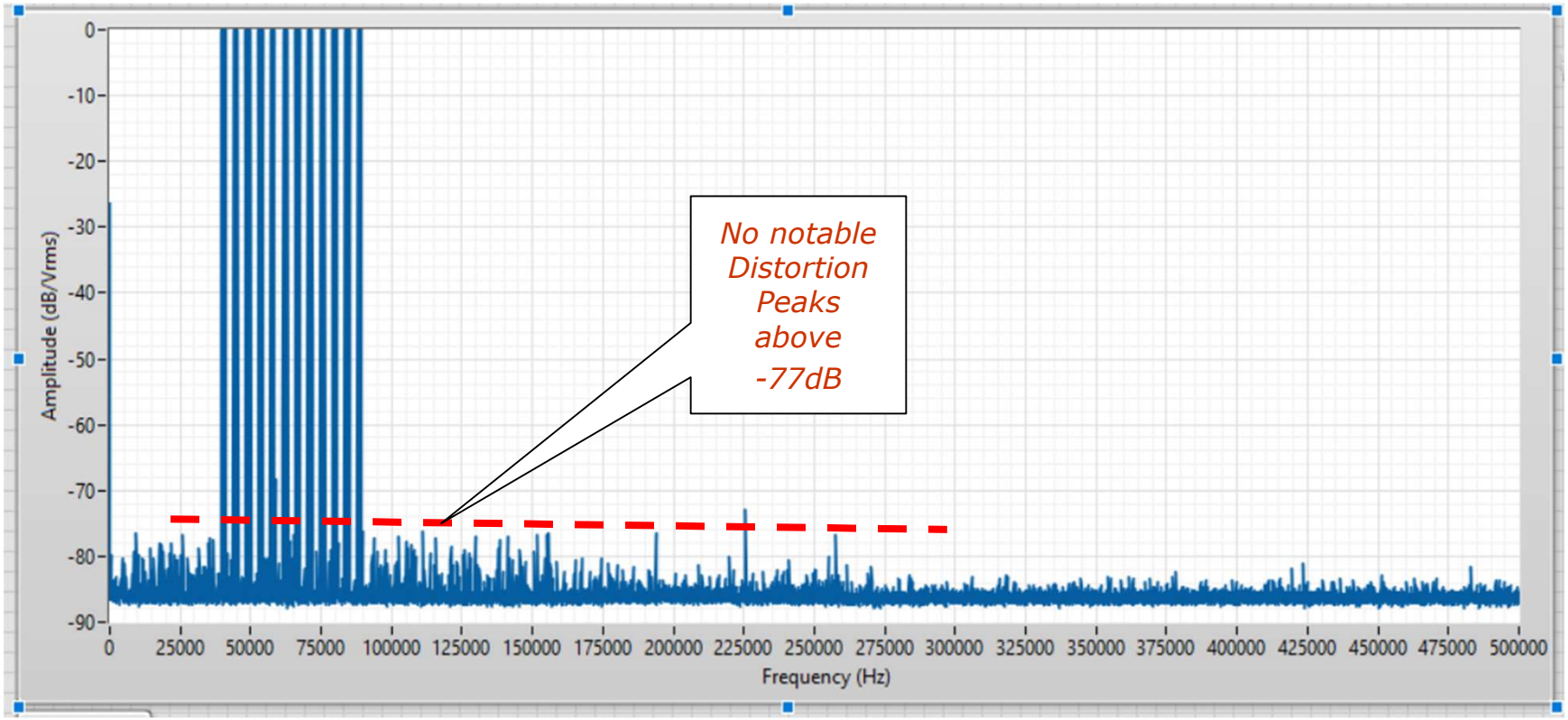
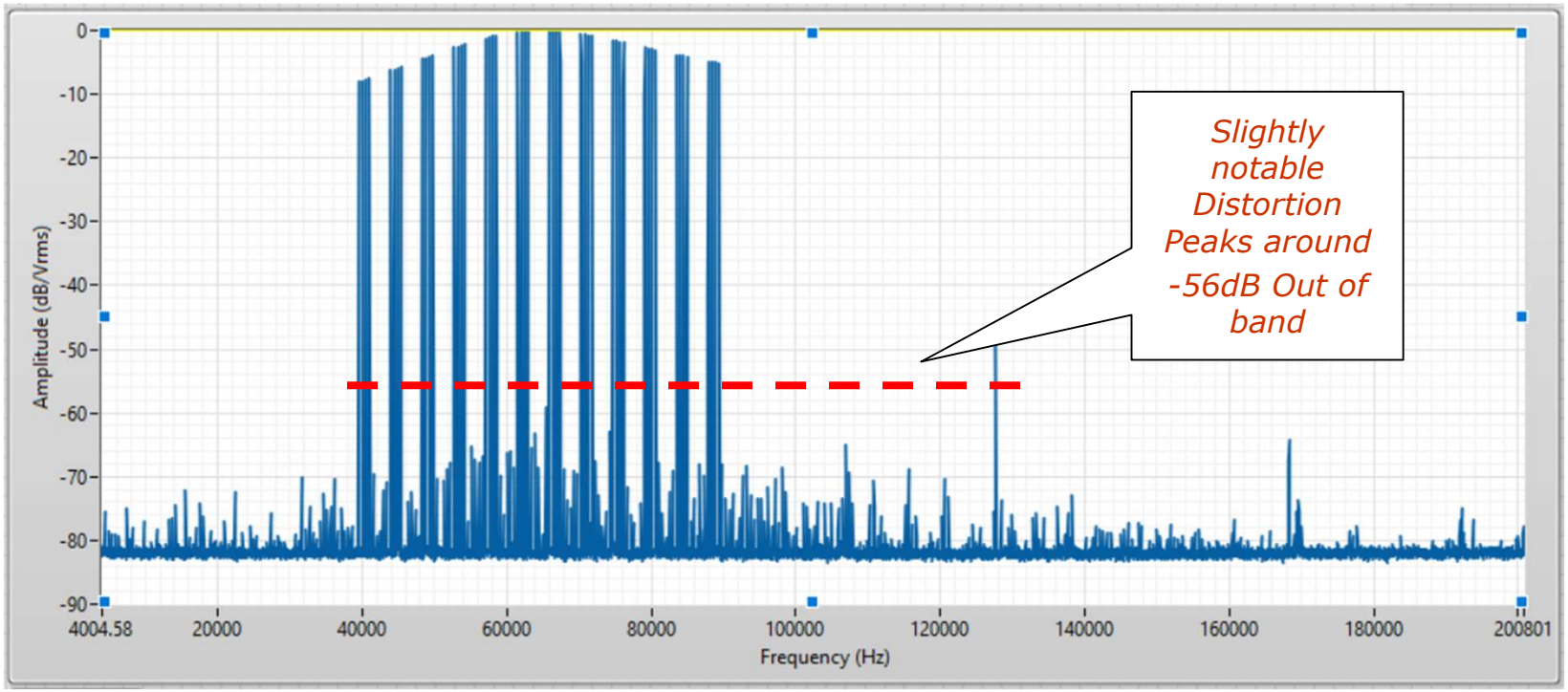
Inductor Specs

- The inductor specs provided sufficient margin over the normal current demands of the CenA application, but perhaps not the only specs that matter.
- The real disappointment was the high saturation current MAPCI inductor did by far the worse. The spec of 7.6A saturation current seems to be a good margin for the CenA test application; however, the nonlinear inductance created significant distortion without being close to its saturation.
- The normal FCI inductor performed ok and is probably the typical recommendation listed in most application BOMs.
- In addition, the circuit with the transformer and the ACI filter, exhibits about 10dB lower MTPR than just the filter which shows the transformer is also affecting the MTPR.

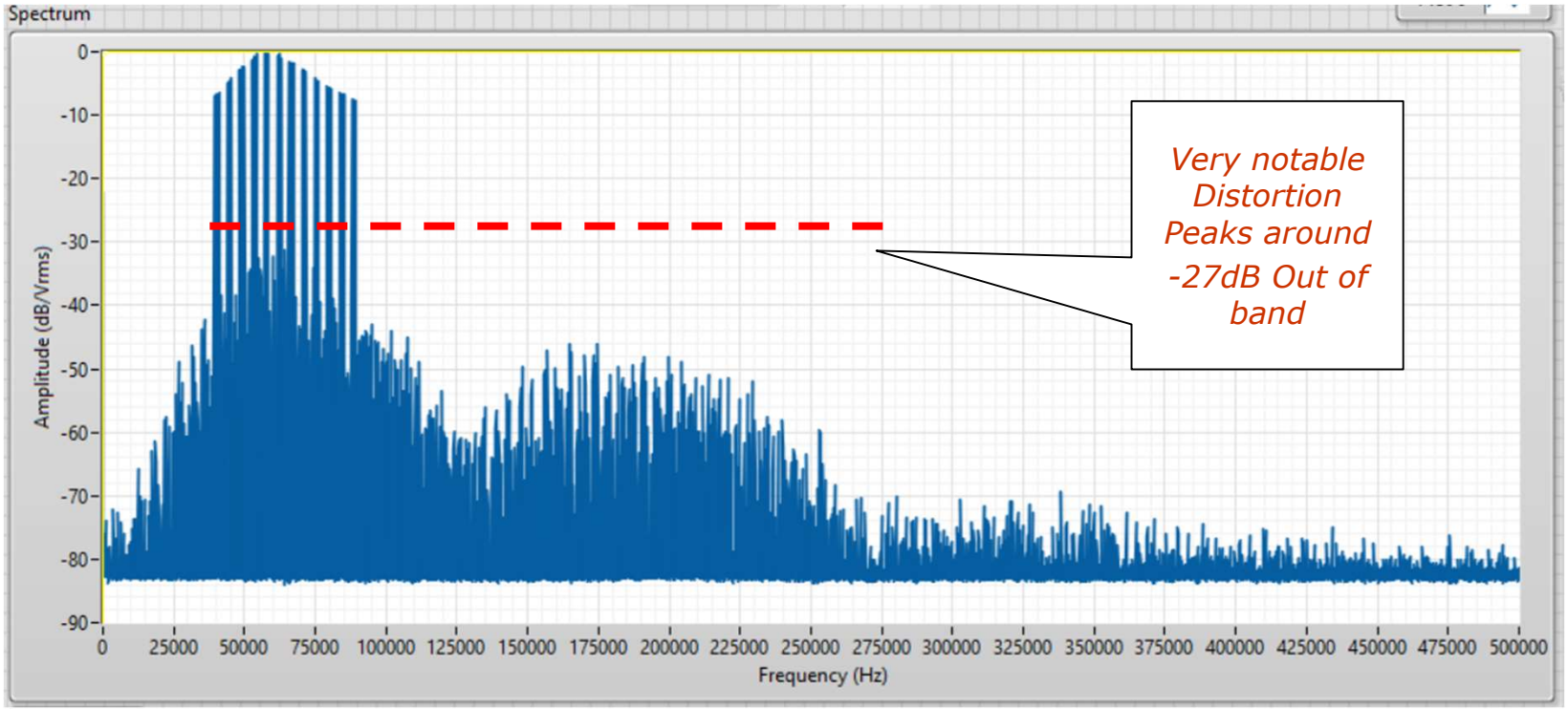
CenA Signal At Vout for all three Tests when loaded



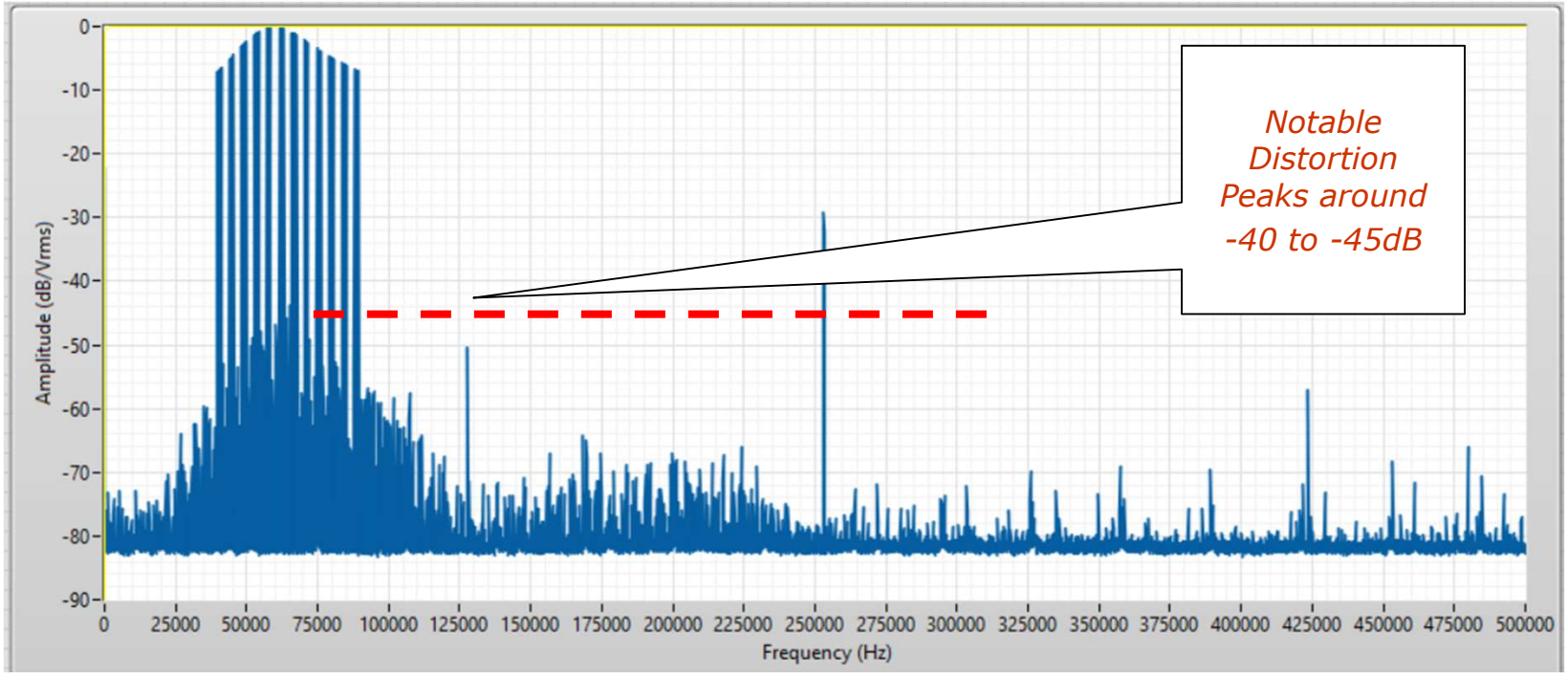
CenA Vload w/ ACI



Vload w/ MAPCI



Vload with FCI



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Summary

- The P1000's Vout output MTPR is high even when under load.
- L3-C3 form a BPF with most of the signal being within or just outside of the pass band. The non-linearities of these components in this configuration are more sensitive to the signal levels, whereas increasing the intermodulation distortion, than if the components were mostly were used in the out of band frequency range.
- There is a large difference in MTPR performance using various L3 inductor types. Try several inductors to see which one works the best for you. Going by the specs might not provide the best final choice.
- The distortion of the transformer dominates the ACI L3 with transformer tests. The MTPR of the ACI without the transformer is about 10dB greater. The induced distortion of some commercial inductors (L3) swamps all the other sources, but once you select a better L3, the transformer exhibits the next highest distortion and may become the next challenge.
- So, plan on checking several transformers, too.