2023 Joint CORM / CIE USNC CNC
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Improving the Mp metric for evaluation of flicker

Jiaye Li, Yoshi Ohno and Andrew Bierman
National Institute of Standards and Technology, Gaithersburg, Maryland, USA
Namreiba. LLC, Albany, New York, USA

National Institute of Standards and Technology
U.S. Department of Commerce

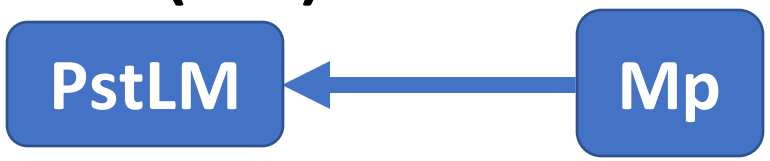
Outline

- Background
- Methodology
- Characterizing the original ASSIST Mp
  - Effect of measurement duration
  - Effect of starting phase
  - Effect of sampling rate
- Improving the Mp metric
  - Hann window and correction factor
  - Some exceptions
    - Modulation frequency
    - Duty cycle in PMW waves
- Conclusions

Temporal light artefacts

Recent regulations in many countries (e.g. EC 2021, EASC 2022, SADCSTAN 2021) specified the limit values for TLM TLA metrics for LED lighting products to guarantee ensure the product safety.

Temporal light artefact (TLA) metrics:

- Flicker: 

- Stroboscopic effect: SVM
- Phantom array effect: under investigation

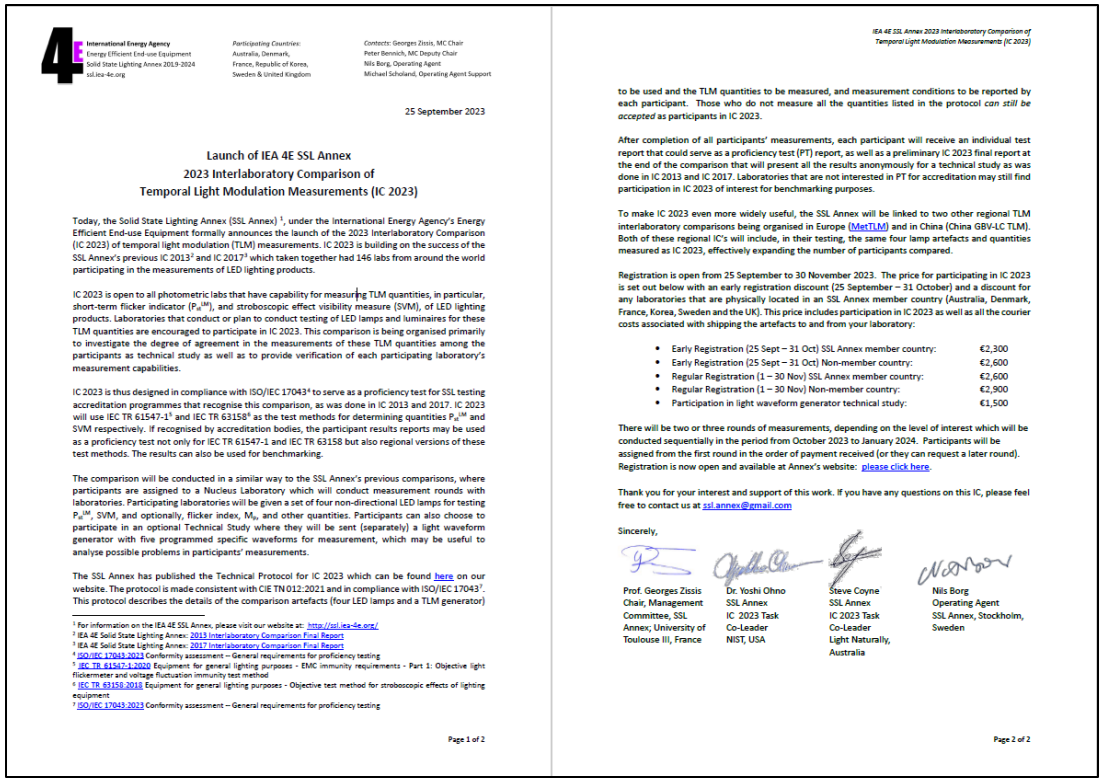
Mp vs PstLM

- **Mp (ASSIST vol. 11,2015)**
  - Measurement duration >2s
  - Frequency domain
  - Already used in some commercial TLM measuring instruments

- **PstLM (IEC TR 61547-1-2020)**
  - Measurement duration ≥180s
  - Time domain
  - Commonly used in regulations and industry

Interlaboratory Comparison 2023 (IC 2023) for Temporal Light Modulation (TLM) measurement

https://www.iea-4e.org/ssl/our-work/testing-standards/interlaboratory-comparison-2023/



International Energy Agency
Energy Efficient End-use Equipment
Solid State Lighting Annex 2013-2024
ssl.iea-4e.org

Participating Countries:
Australia, Denmark, France, Republic of Korea, Sweden & United Kingdom

Contacts: Georges Zissis, MC Chair; Peter Bennich, MC Deputy Chair; Nils Borg, Operating Agent; Michael Scholand, Operating Agent Support

25 September 2023

Launch of IEA 4E SSL Annex
2023 Interlaboratory Comparison of
Temporal Light Modulation Measurements (IC 2023)

Today, the Solid State Lighting Annex (SSL Annex) [1], under the International Energy Agency's Energy Efficient End-use Equipment formally announces the launch of the 2023 Interlaboratory Comparison (IC 2023) of temporal light modulation (TLM) measurements. IC 2023 is building on the success of the SSL Annex's previous IC 2013[2] and IC 2017[3] which taken together had 146 labs from around the world participating in the measurements of LED lighting products.

IC 2023 is open to all photometric labs that have capability for measuring TLM quantities, in particular, short-term flicker indicator (P_{st}^{LM}), and stroboscopic effect visibility measure (SVM), of LED lighting products. Laboratories that conduct or plan to conduct testing of LED lamps and luminaires for these TLM quantities are encouraged to participate in IC 2023. This comparison is being organised primarily to investigate the degree of agreement in the measurements of these TLM quantities among the participants as technical study as well as to provide verification of each participating laboratory's measurement capabilities.

IC 2023 is thus designed in compliance with ISO/IEC 17043[4] to serve as a proficiency test for SSL testing accreditation programmes that recognise this comparison, as was done in IC 2013 and 2017. IC 2023 will use IEC TR 61547-1[5] and IEC TR 63158[6] as the test methods for determining quantities P_{st}^{LM} and SVM respectively. If recognised by accreditation bodies, the participant results reports may be used as a proficiency test not only for IEC TR 61547-1 and IEC TR 63158 but also regional versions of these test methods. The results can also be used for benchmarking.

The comparison will be conducted in a similar way to the SSL Annex's previous comparisons, where participants are assigned to a Nucleus Laboratory which will conduct measurement rounds with laboratories. Participating laboratories will be given a set of four non-directional LED lamps for testing P_{st}^{LM}, SVM, and optionally, flicker index, M_{fl}, and other quantities. Participants can also choose to participate in an optional Technical Study where they will be sent (separately) a light waveform generator with five programmed specific waveforms for measurement, which may be useful to analyse possible problems in participants' measurements.

The SSL Annex has published the Technical Protocol for IC 2023 which can be found here on our website. The protocol is made consistent with CIE TN 012:2021 and in compliance with ISO/IEC 17043[7]. This protocol describes the details of the comparison artefacts (four LED lamps and a TLM generator)

[1] For information on the IEA 4E SSL Annex, please visit our website at: http://ssl.iea-4e.org/
[2] IEA 4E Solid State Lighting Annex: 2013 Interlaboratory Comparison Final Report
[3] IEA 4E Solid State Lighting Annex: 2017 Interlaboratory Comparison Final Report
[4] ISO/IEC 17043:2023 Conformity assessment – General requirements for proficiency testing
[5] IEC TR 61547-1:2020 Equipment for general lighting purposes - EMC immunity requirements - Part 1: Objective light flickermeter and voltage fluctuation immunity test method
[6] IEC TR 63158:2018 Equipment for general lighting purposes - Objective test method for stroboscopic effects of lighting equipment
[7] ISO/IEC 17043:2023 Conformity assessment – General requirements for proficiency testing

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IEA 4E SSL Annex 2023 Interlaboratory Comparison of Temporal Light Modulation Measurements (IC 2023)

to be used and the TLM quantities to be measured, and measurement conditions to be reported by each participant. Those who do not measure all the quantities listed in the protocol *can still be accepted* as participants in IC 2023.

After completion of all participants' measurements, each participant will receive an individual test report that could serve as a proficiency test (PT) report, as well as a preliminary IC 2023 final report at the end of the comparison that will present all the results anonymously for a technical study as was done in IC 2013 and IC 2017. Laboratories that are not interested in PT for accreditation may still find participation in IC 2023 of interest for benchmarking purposes.

To make IC 2023 even more widely useful, the SSL Annex will be linked to two other regional TLM interlaboratory comparisons being organised in Europe (MetTLM) and in China (China GBV-LC TLM). Both of these regional IC's will include, in their testing, the same four lamp artefacts and quantities measured as IC 2023, effectively expanding the number of participants compared.

Registration is open from 25 September to 30 November 2023. The price for participating in IC 2023 is set out below with an early registration discount (25 September – 31 October) and a discount for any laboratories that are physically located in an SSL Annex member country (Australia, Denmark, France, Korea, Sweden and the UK). This price includes participation in IC 2023 as well as all the courier costs associated with shipping the artefacts to and from your laboratory:

- Early Registration (25 Sept – 31 Oct) SSL Annex member country: €2,300
- Early Registration (25 Sept – 31 Oct) Non-member country: €2,600
- Regular Registration (1 – 30 Nov) SSL Annex member country: €2,600
- Regular Registration (1 – 30 Nov) Non-member country: €2,900
- Participation in light waveform generator technical study: €1,500

There will be two or three rounds of measurements, depending on the level of interest which will be conducted sequentially in the period from October 2023 to January 2024. Participants will be assigned from the first round in the order of payment received (or they can request a later round). Registration is now open and available at Annex's website: please click here.

Thank you for your interest and support of this work. If you have any questions on this IC, please feel free to contact us at ssl.annex@gmail.com

Sincerely,

Prof. Georges Zissis, Chair, Management Committee, SSL Annex; University of Toulouse III, France
Dr. Yoshi Ohno, SSL Annex IC 2023 Task Co-Leader, NIST, USA
Steve Coyne, SSL Annex IC 2023 Task Co-Leader, Light Naturally, Australia
Nils Borg, Operating Agent, SSL Annex, Stockholm, Sweden

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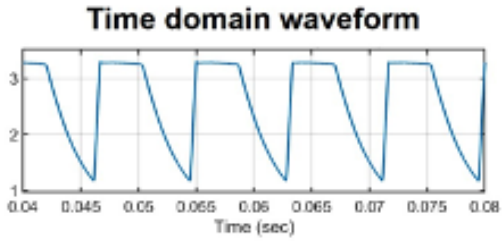
Control and measurement system

Power supply

Lighting equipment

Light measurement system



Anti-aliasing filter

Cut-off frequency
1 kHz or 3 kHz

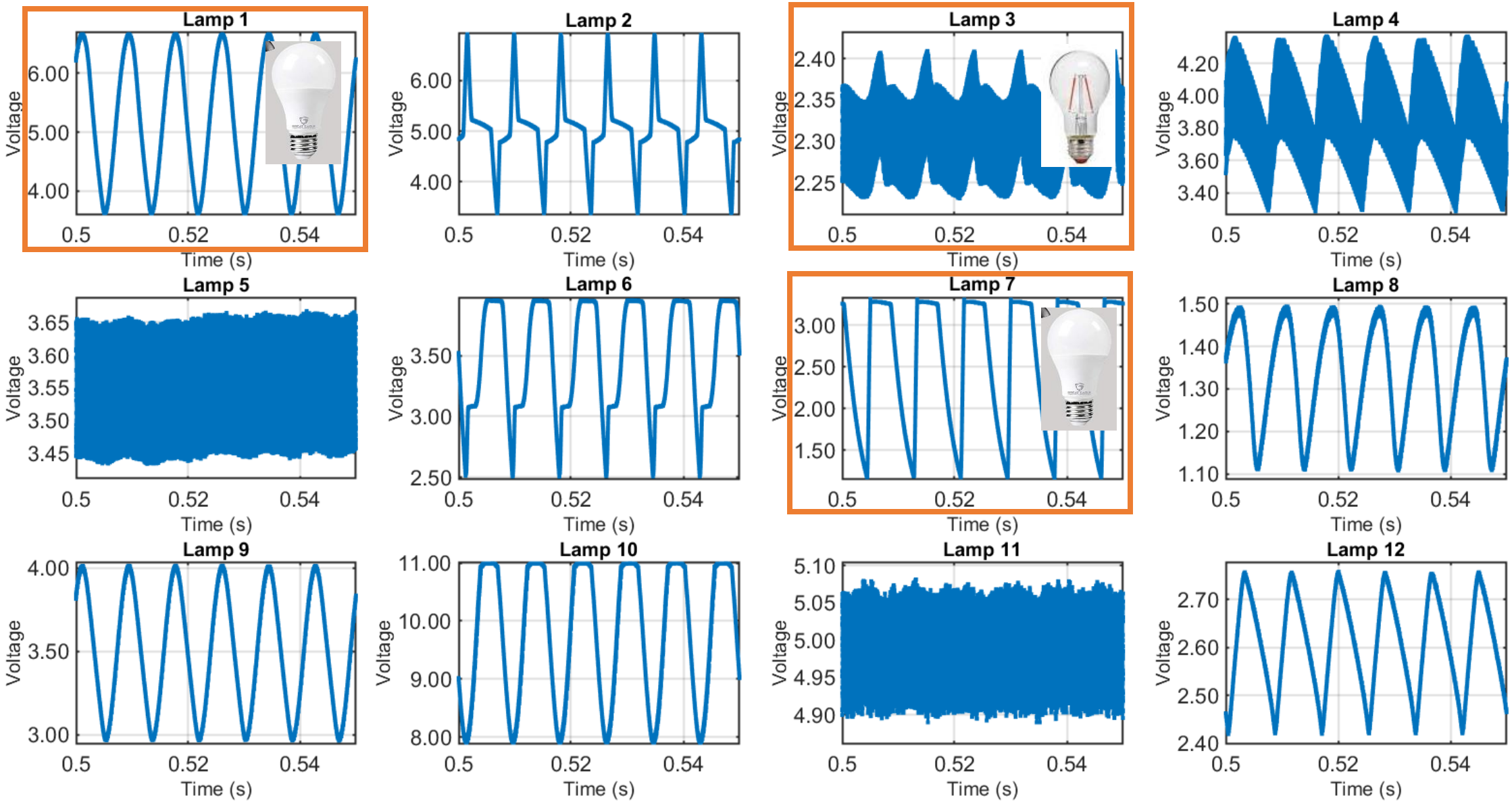
Metric calculations (ASSIST Matlab codes)

- Mp
- P_{st}^{LM}
- SVM

A/D conversion: 16 bit
System bandwidth (system low-pass filter). 20 MHz
Sampling frequency: 20 kHz
Measurement duration: 2s-180s

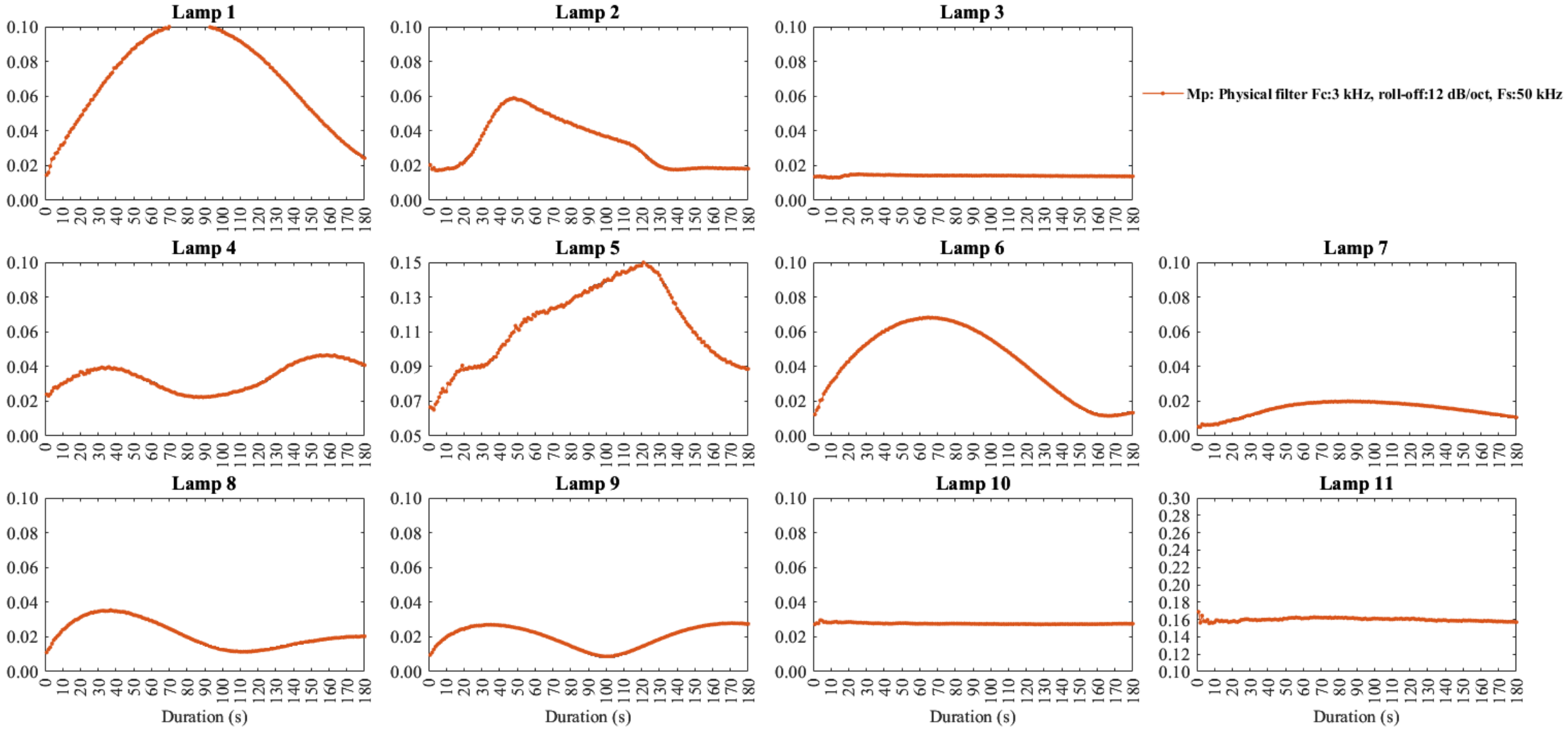
Measured waves

12 commercial lamps (60 Hz AC power operation): new to several year-old products (no filter)



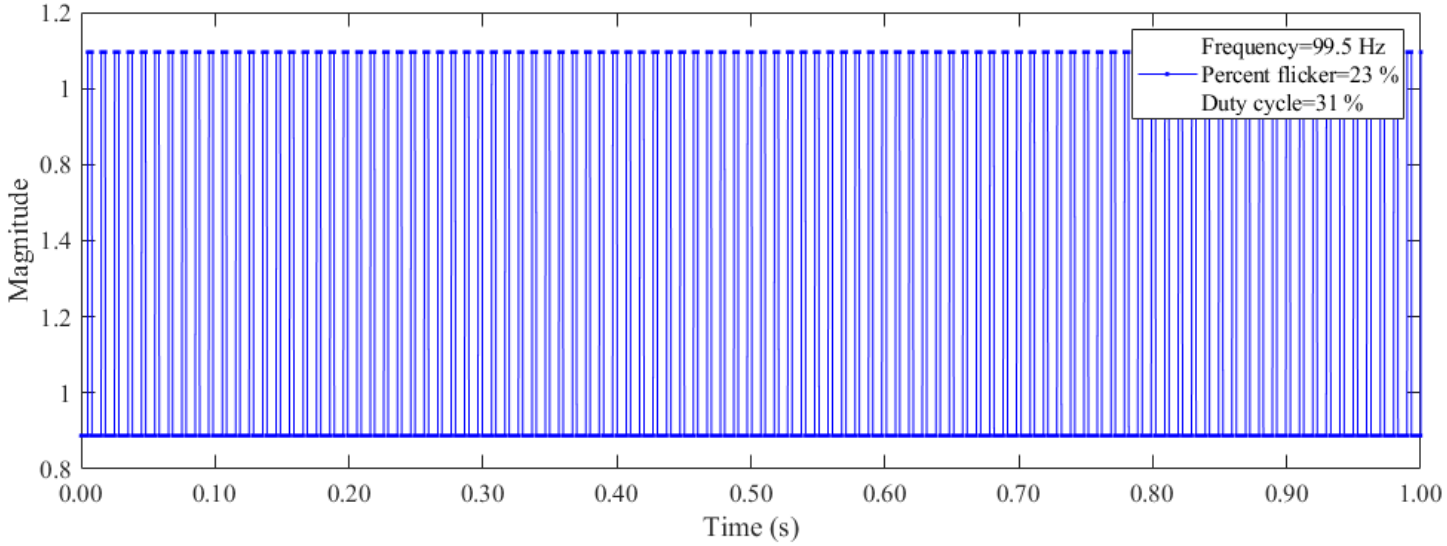
Effect of duration

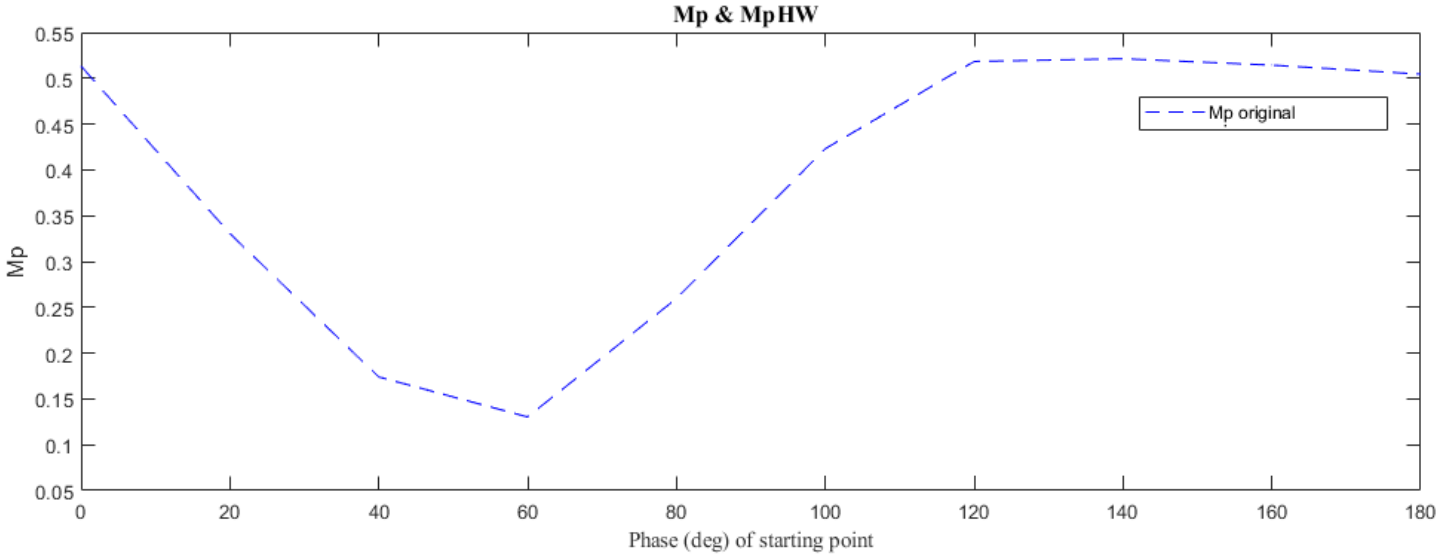
1. Variation of Mp due to different measurement duration



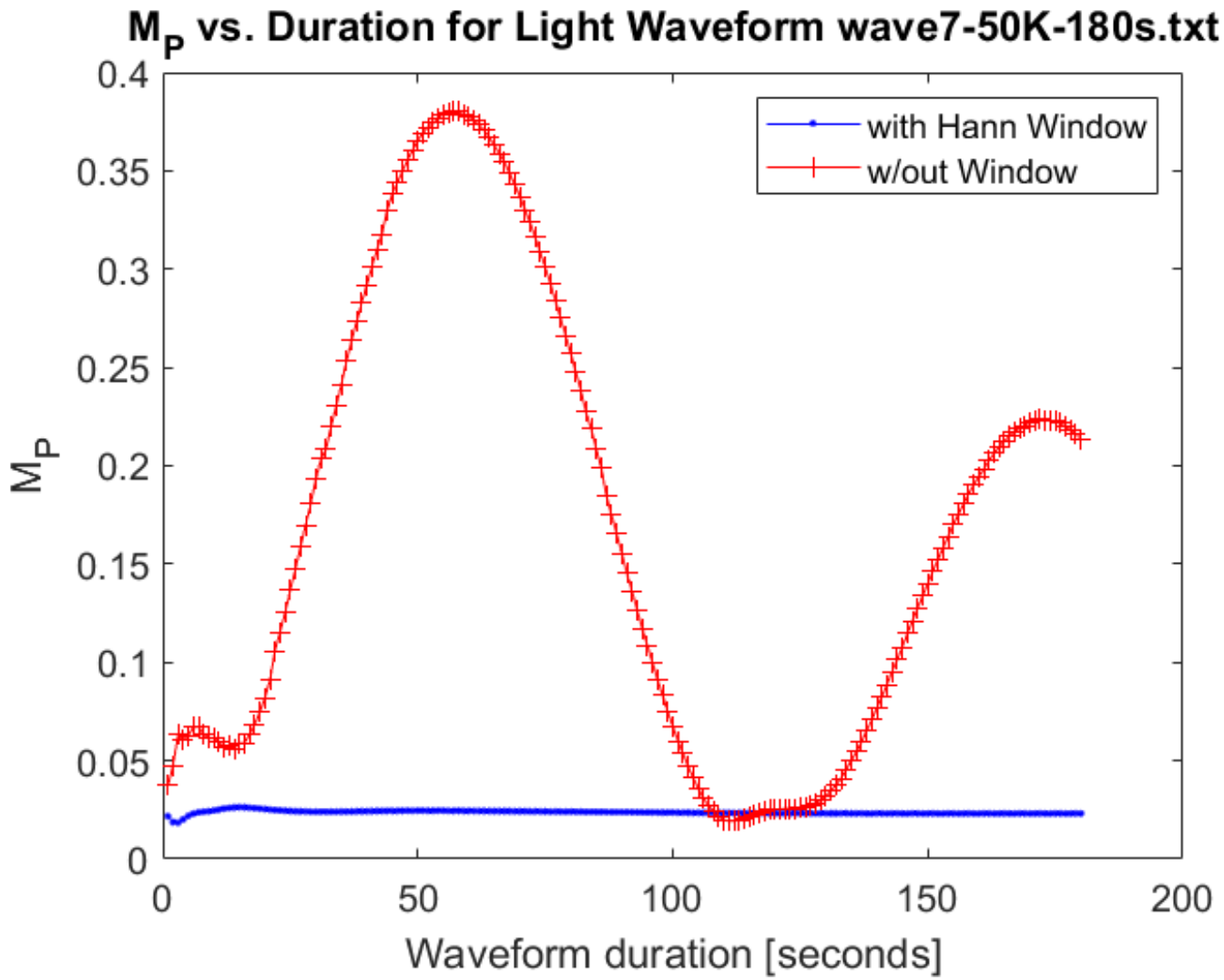
Effect of starting phase

2. Variation of Mp due to different starting phase





Hann window added

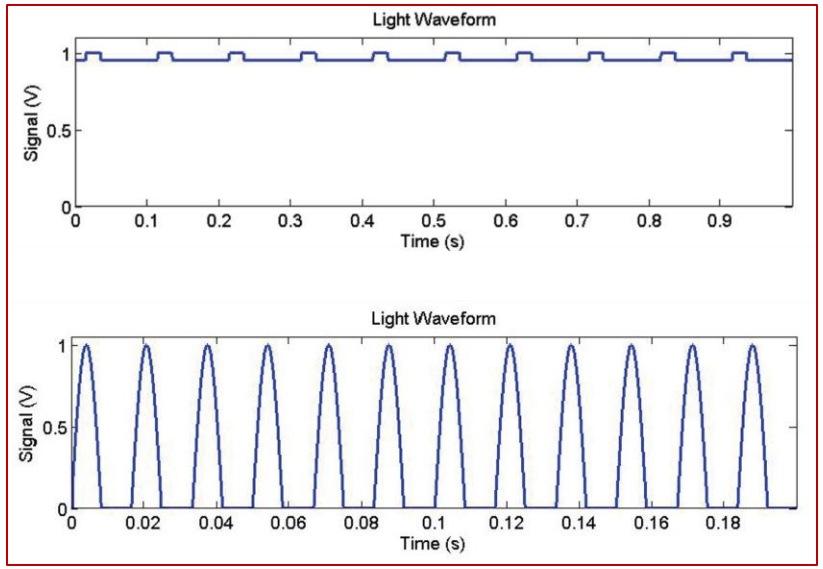


A Hann window has been added at Andrew's suggestion.

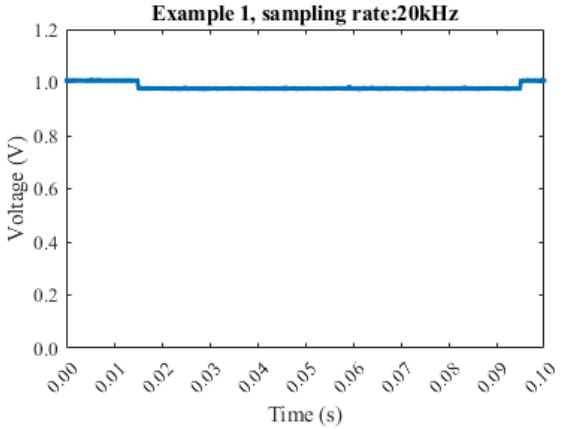
Adding the Hann window significantly reduces the variation in Mp for different durations.

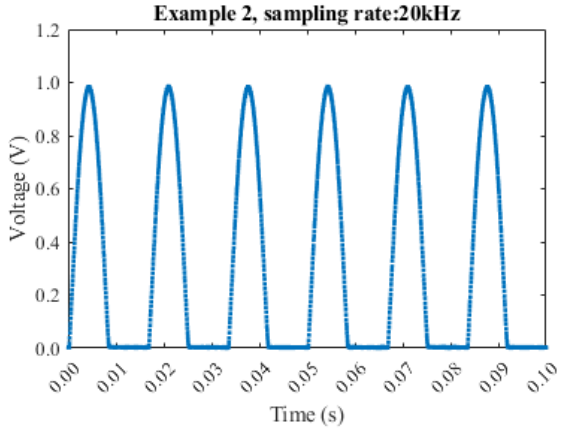
Characterize Mp using simulated and measured ASSIST example waves

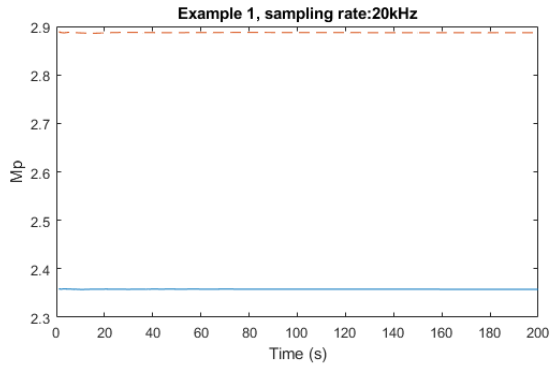
ASSIST examples from the document

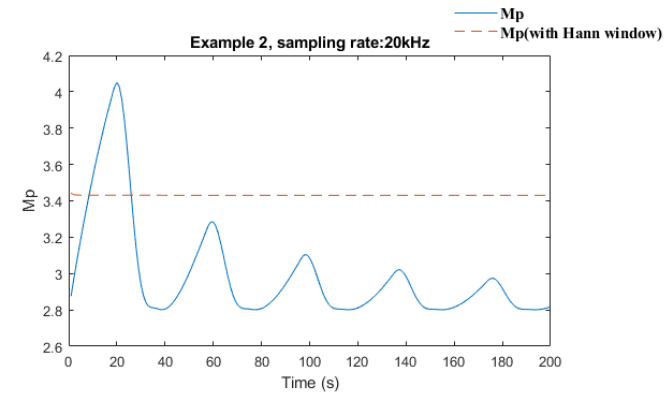


Before and after adding the Hann window
→ two different Mp values

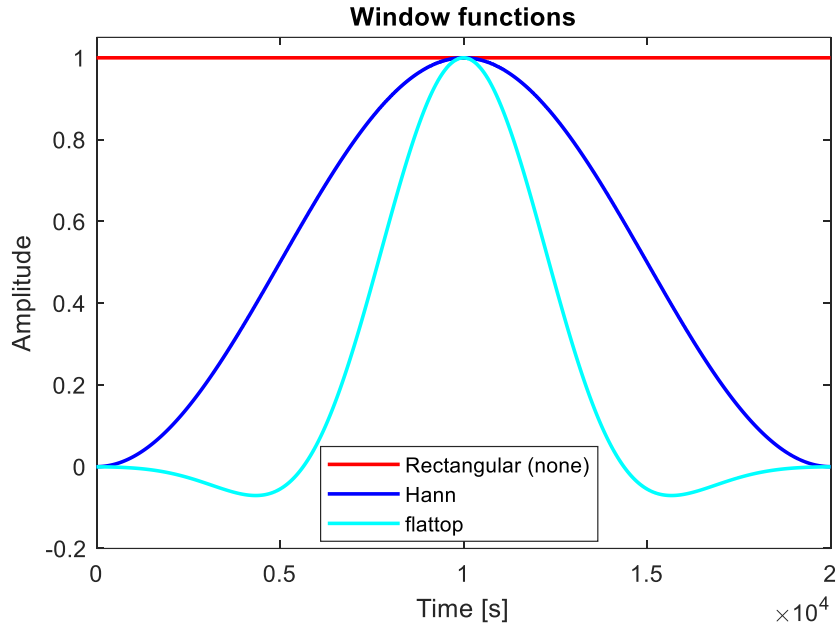


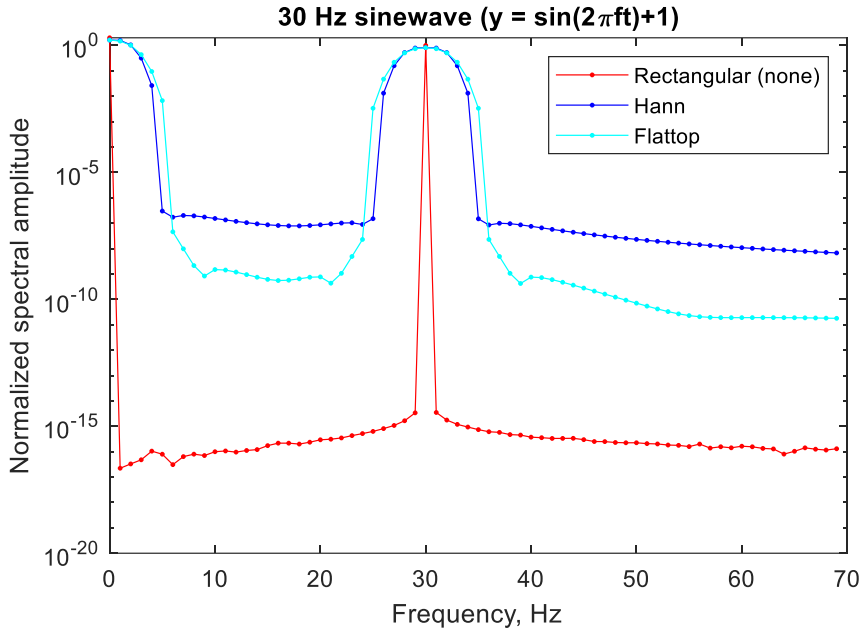






Correction factor for Mp with Hann window





Step 3: Calculate Weber Temporal Contrast

Divide each of the component amplitudes, A_k, by the dc value of the waveform, A_0. This operation normalizes the component amplitude values expressing them as modulation ratios, hence the symbol *M*.

$$M_k = \frac{A_k}{A_0}$$

(Eq. 3)

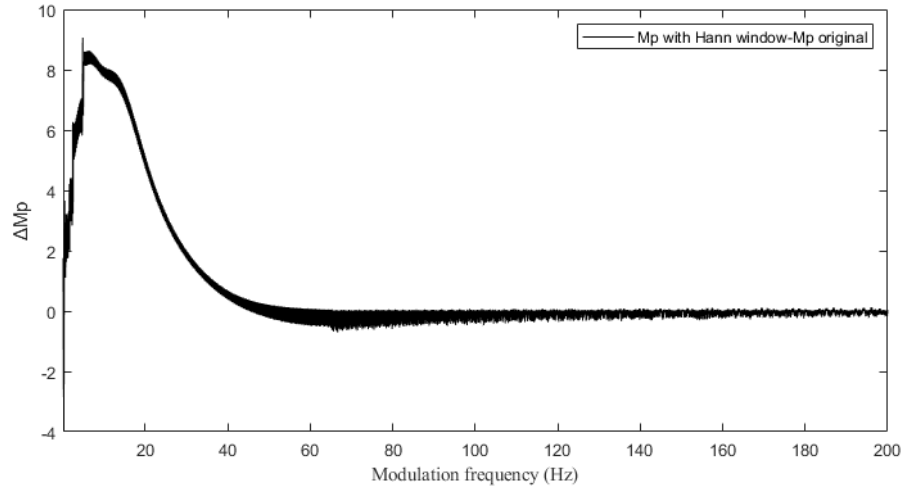
$$M_k = \frac{A_k}{wA_0}$$

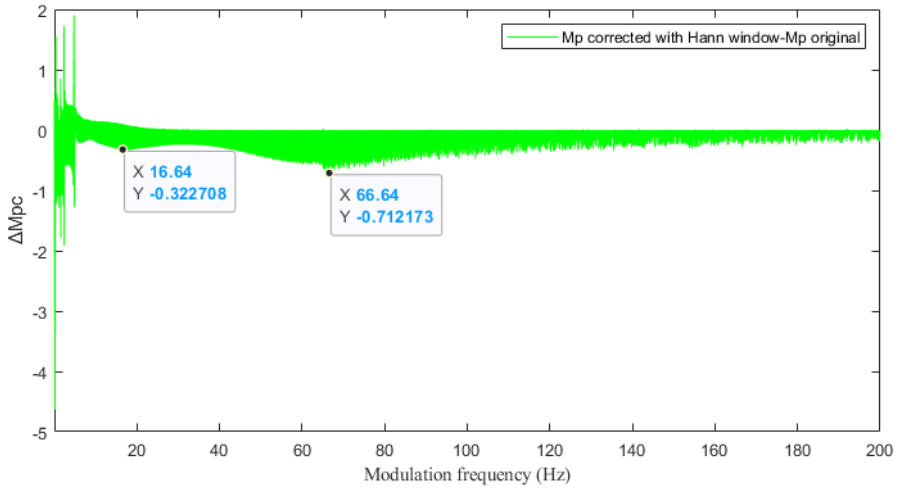
Where w is a window factor. It has a value of 1 for a rectangular window, 1.225 or sqrt(3/2) for a Hann window and approximately 3.770 for a flattop window.

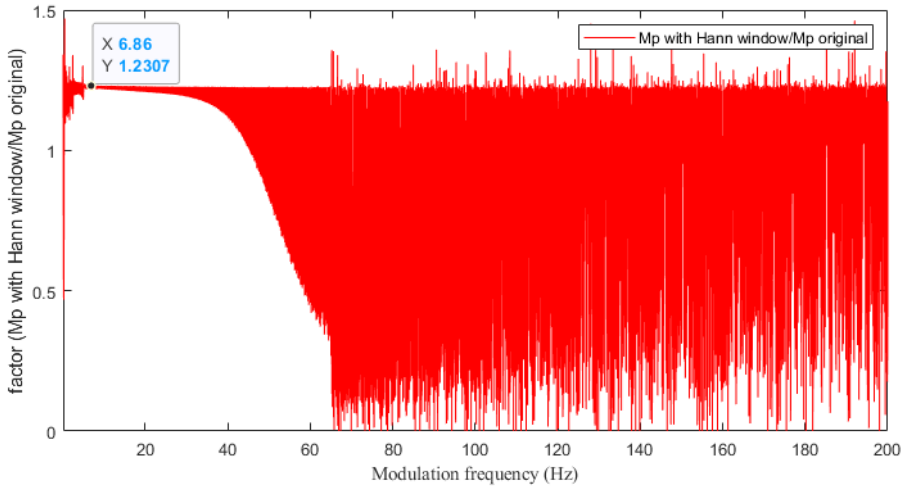
Divide FFT amplitude by a correction factor 1.225 (for Hann window).

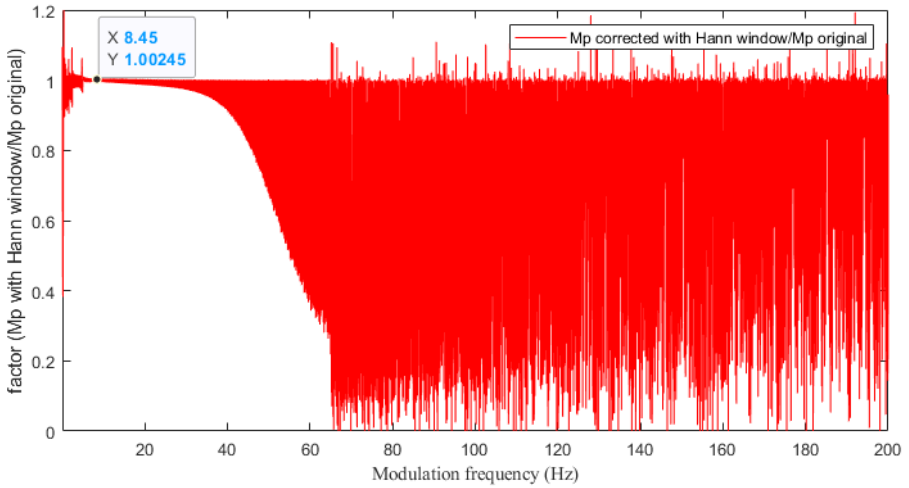
Difference between the corrected Mp and the original Mp

Varied modulation frequency (0.01 Hz to 200 Hz): ΔMpc(Mpcorrected-Mporginal)





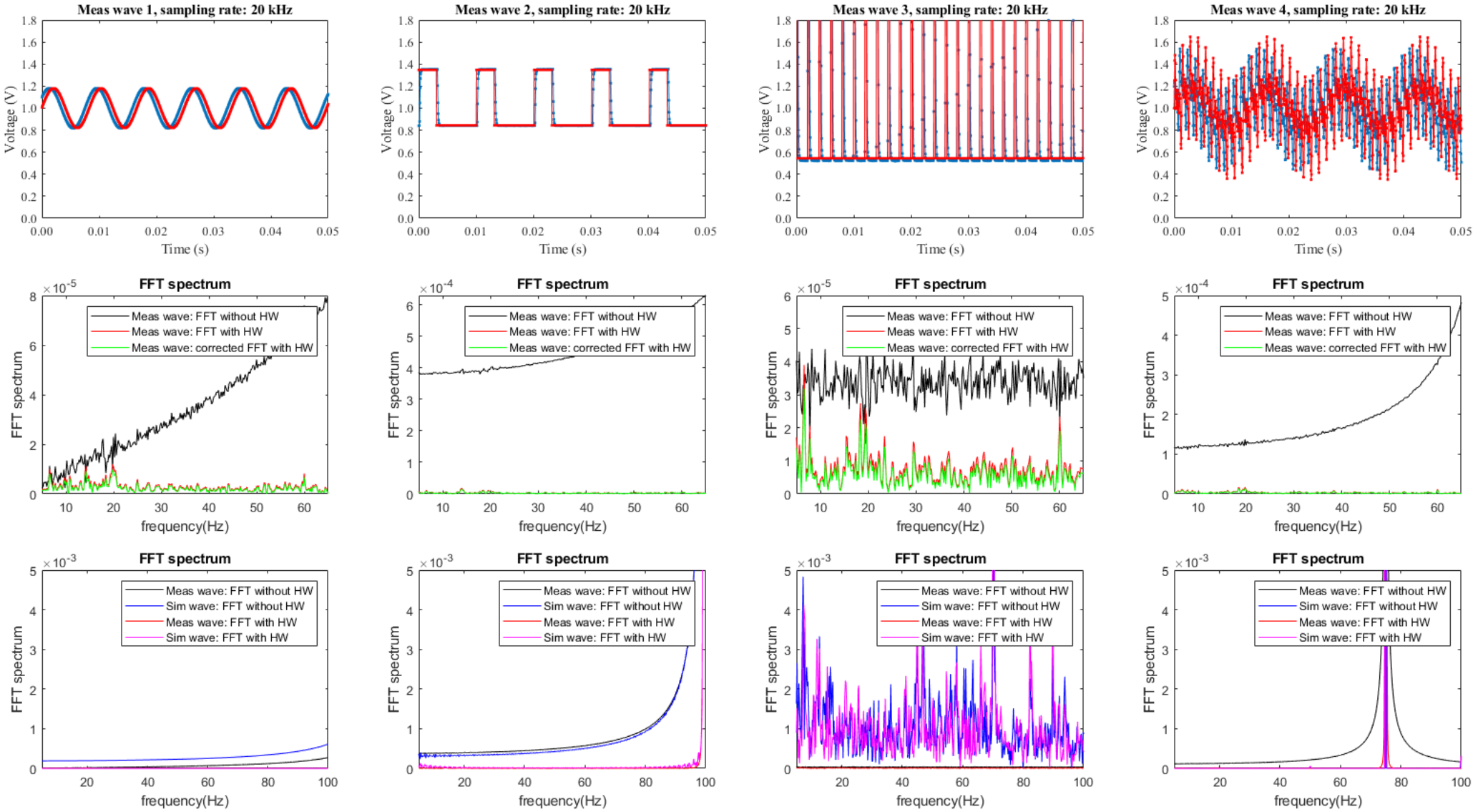




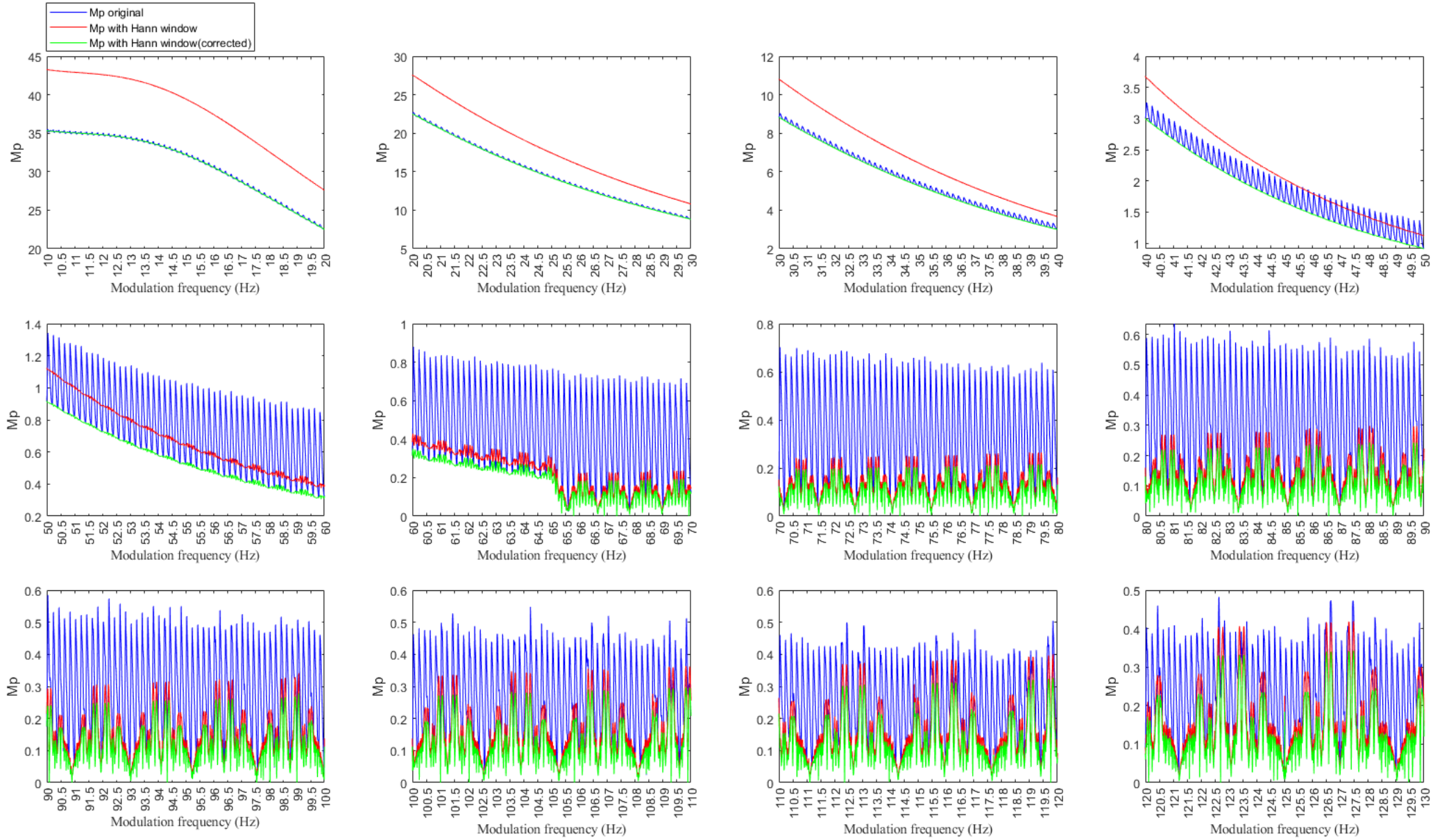
Which cases?

Four exceptions

1, Non-integer modulation frequency. 2, Non-integer duty cycle.

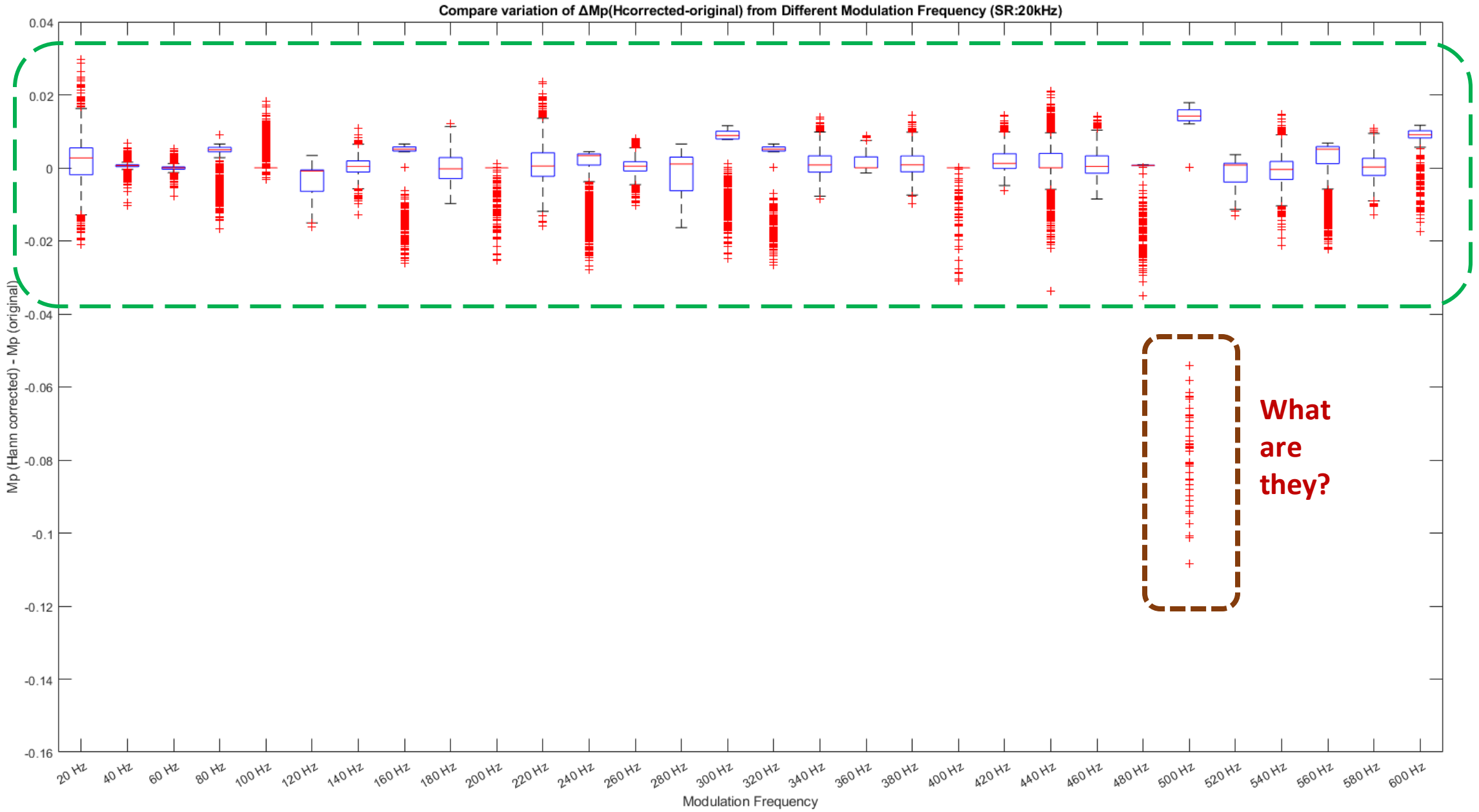


Non-integer modulation frequency



When the modulation frequency is a multiple of 0.2, original Mp = corrected Mp.

Non-integer duty cycle (ΔMp at different modulation frequency)



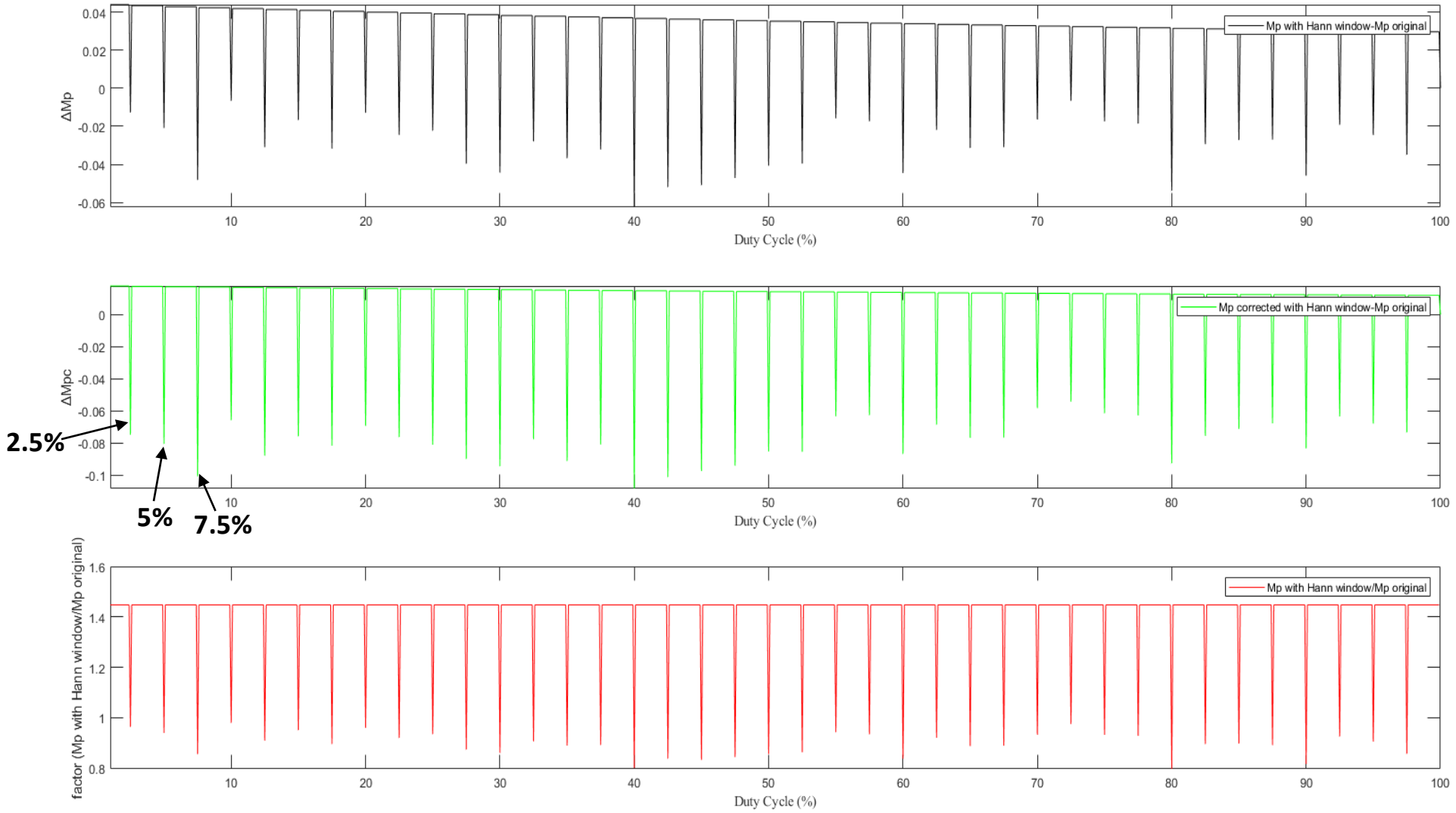
within ±0.04

What are they?

Non-integer duty cycle (ΔMp at F_{mod} = 500 Hz)

f_s =20 kHz
F_{mod} = 500 Hz

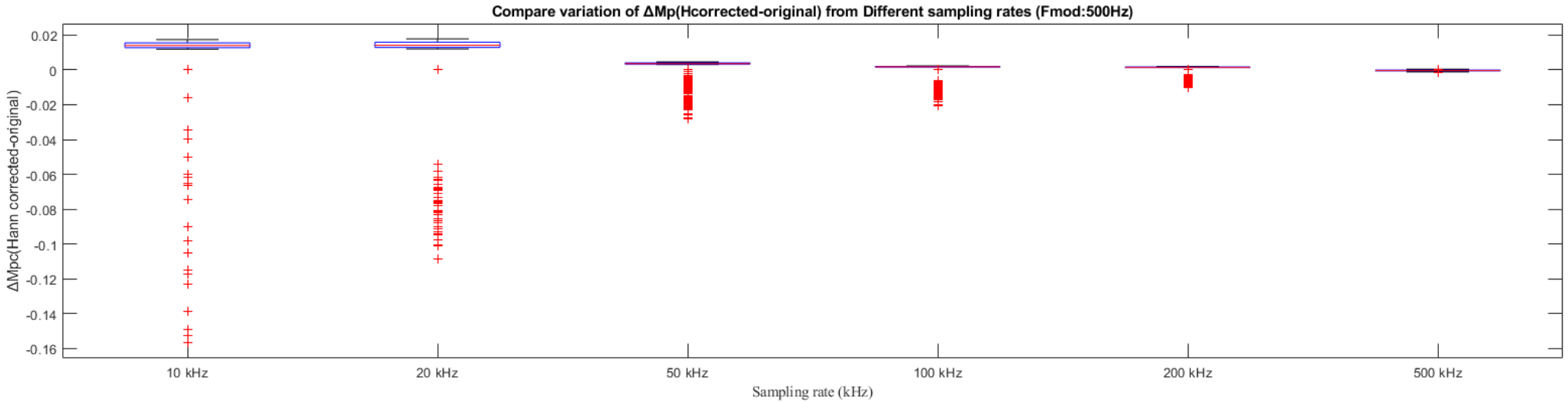
Larger Error: when duty cycle is an integer multiple of 2.5% (Fmod/fs)

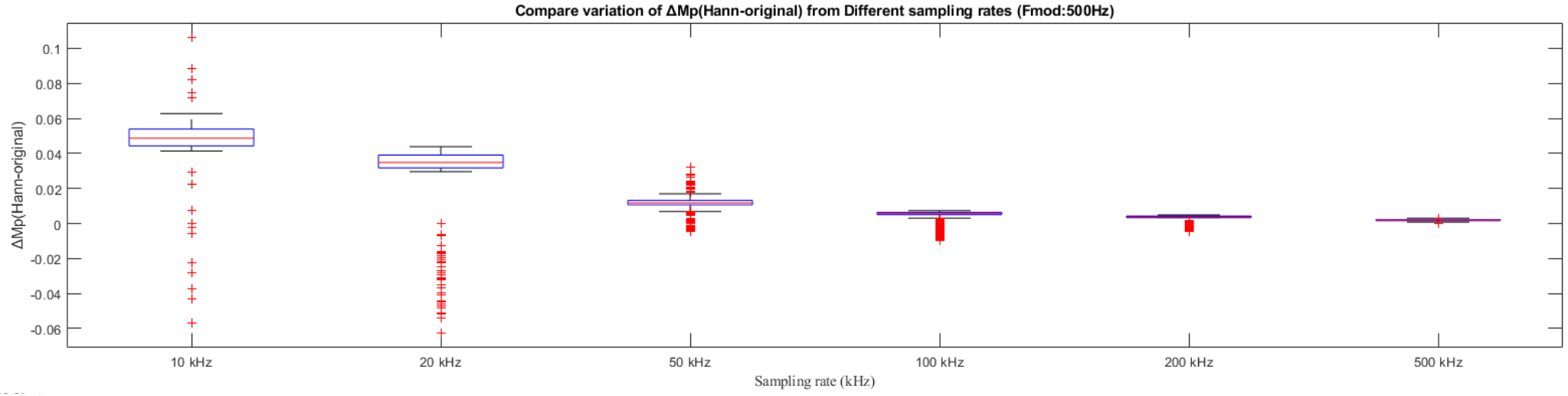


Depending on sampling rate.

Non-integer duty cycle (different sampling rates)

f_s =10, 20, 50, 100, 200, 500 kHz, F_{mod} = 500 Hz





Conclusions

1. Substantial variation in Mp was found when using different durations or starting phases.
2. The variation in Mp due to different durations is largely reduced by adding Hann window, but result in a different Mp value (Mp_Hann).
3. A correction factor was proposed to apply to the Mp_Hann to correct the difference, but it doesn't work for some exceptions.
4. The exceptions are found in waves at non-integer modulation frequency and/or non-integer duty cycle (only for PMW waves).
5. Higher sampling rate can reduce the difference between the corrected Mp and original Mp.
6. Such analysis will be performed for other shapes of waves and measured waves.

Thank you for your attention!