Temporal Light Artifacts
(Flicker + Stroboscopic Effect)

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Outline

Temporal Light Artifacts (TLA)

IEEE 1789

NEMA efforts

Standards

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Temporal Light Artifacts

=

“flicker” (see it when nothing is moving, 0 to ~80Hz)

+

“stroboscopic effects” (see it when object is moving and you are not, ~50Hz to ~2kHz)

+

“phantom array” (see it when your eye is moving and object is not, ~50Hz to ~2 kHz)

Formal Definitions

Flicker

Perception of visual unsteadiness induced by a light stimulus whose luminance or spectral distribution fluctuates with time, for a static observer in a static environment.

~0-80Hz

Stroboscopic Effects

Change in motion perception induced by a light stimulus whose luminance or spectral distribution fluctuates with time, for a static observer in a non-static environment.

~80Hz-2kHz

Phantom Array

Perception of a spatially extended series of light spots when making a *saccade* (image transition across the retina) across a light source that fluctuates with time

~80Hz-2kHz

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Formal Definitions

Temporal Light Artifact (TLA)

An undesired change in visual perception, induced by a light stimulus whose luminance or spectral distribution fluctuates with time, for an observer in a certain environment.

LED Lighting

LEDs do not intrinsically produce flicker. They faithfully reproduce the current waveform

Electrical distortion in

Optical distortion out

Why the big deal with flicker all of a sudden?

- LEDs have fast response
- New types of drivers emerge
- Simpler electronics usually result in large temporal modulation
- Interaction between dimmers and LED Lamps

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Common Sources of TLA

- Sunlight or moonlight, shining on moving water - often seen as a desirable effect
- Sunlight or moonlight, shining through a canopy of trees, when the wind is blowing sufficiently to cause motion of leaves, produces flicker - often seen as a desirable effect
- Flame light sources (candles, campfires) - often seen as a desirable effect.
- Shadows from trees or posts falling across a road. Similar effects are commonly observed in moving trains and subways - rows of light sources and/or rows of shadow-producing poles or trees are present. Fences containing an array of holes or slits with a light source on the opposite side of the fence, shining through the holes or slits can produce flicker for a person walking, running or bicycling past the fence.
- Television, cell phones and other displays
- Emergency vehicles
- Entertainment (concerts, discos, etc)

Existing work

- IEC flicker metric, IEC/TR 61547-1 and IEC 61000-3-3
- IEEE 1789-2015
  http://standards.ieee.org/findstds/standard/1789-2015.html
- Pacific Northwest National Labs (involved in #2)
  http://www.e3tnw.org/Documents/2011%20IES%20flicker%20paper%20poplawski-miller-FINAL.pdf
  http://energy.gov/eere/ssl/downloads/characterizing-photometric-flicker
- ASSIST (Lighting Research Center)
  http://www.lrc.rpi.edu/programs/solidstate/assist/flicker.asp
  http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/flicker.asp
- CIE technical committee on TLA (TC 1-83)
  http://www.cie.co.at/index.php/Technical+Committees
- CA Title 20/24
- NEMA Position paper
  https://www.nema.org/Standards/Pages/Temporal-Light-Artifacts-Flicker-and-Stroboscopic-Effects.aspx

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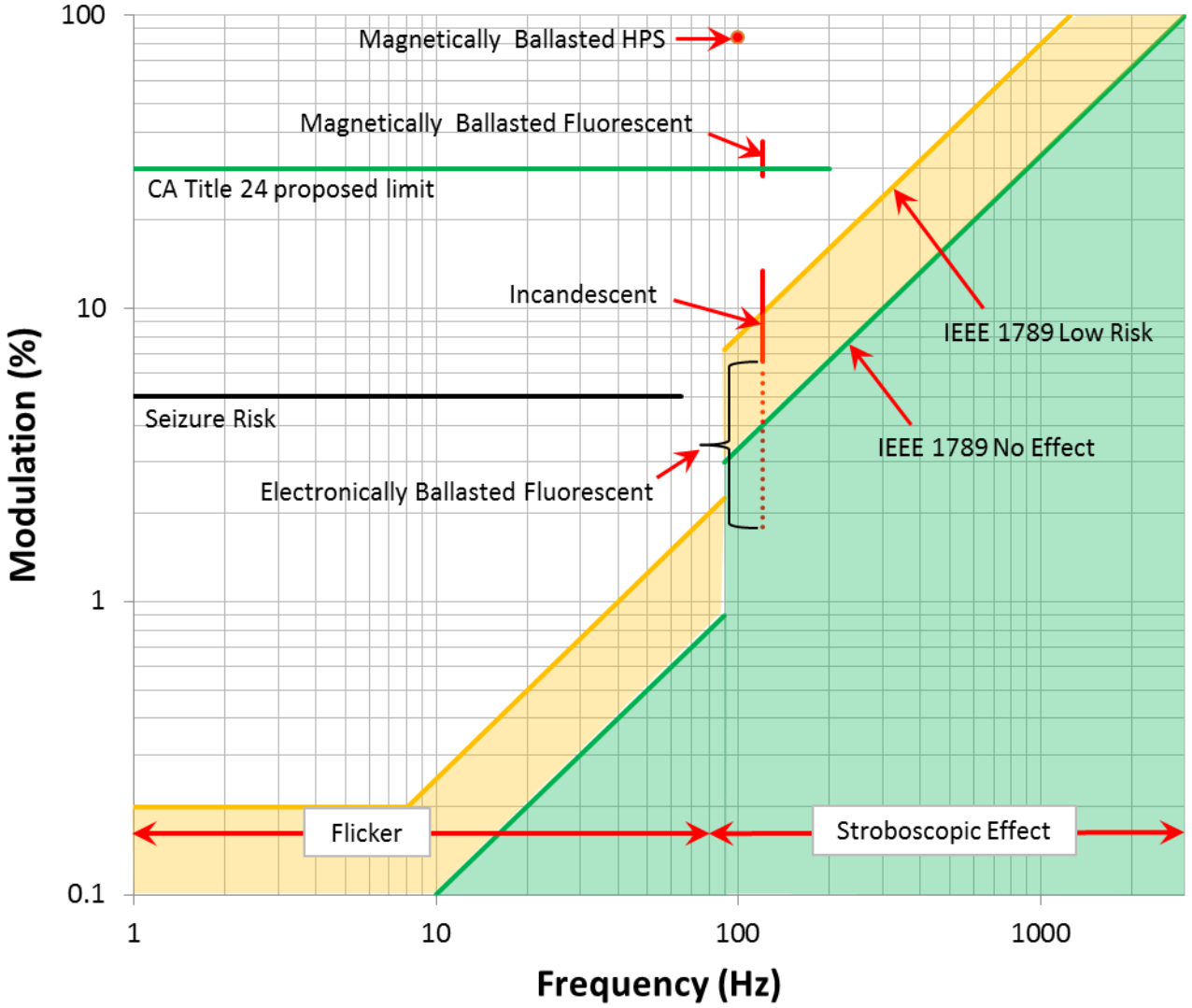
IEEE 1789



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Considerations

One does not need a light source that is suitable for use with rotating saws in every application.

Is it necessary for a dimmer/lamp combination to have TLA below a certain limit across the entire range of dimmer settings? Can we rely on the user to select a dimming condition that is suitable for the room inhabitants? If implemented, how could one verify and enforce such a specification?

Strict specifications will rule out certain electronic approaches for driving LEDs. This removes options for reducing lamp cost. This slows adoption.

http://gbimg.org/g67IW

IEEE 1789 Cautions

"It should be mentioned that operating outside the low-risk recommended practice regions presented in Clause 8 does not necessarily imply high risk. However, following the recommended practices would lead to high confidence that there is low risk of health problems to viewers due to flicker. This issue is further discussed in Clause 8."

"it could be the next step for other organizations to develop lighting-application-specific recommended practices."

"In the meantime, magnetically ballasted high-intensity discharge (HID) lamps have been continuously used for outdoor light with relatively few complaints despite their high modulation depth."

"Turning to historical precedent, HPS lamps on magnetic ballasts have been reported to have 84% modulation depth, and LPS lamps sometimes have nearly 100% modulation depth. These are both at 100 Hz or 120 Hz and have been used without widespread complaints about flicker for almost 50 years in many applications, such as outdoor lighting, greenhouse lighting, etc."

"The authors of IEEE Std 1789 acknowledge that some lighting designers consider that applications, such as roadway lighting, in which there has been widespread acceptance of HID lamps, might not need restriction on flicker above 90 Hz."

NEMA Activities

Position Statement: "IEEE P1789's proposed limits may avoid any chance of health or distraction effects, but appear to be overly strict for many applications, which could add unnecessary cost to the electronics in LED (light-emitting diode) products. Even incandescent lamps do not fall within the low-risk or no-effect regions"

Produce a Standard:

Add experimental dimension to IEEE 1789. Account for frequency & wave-shape.

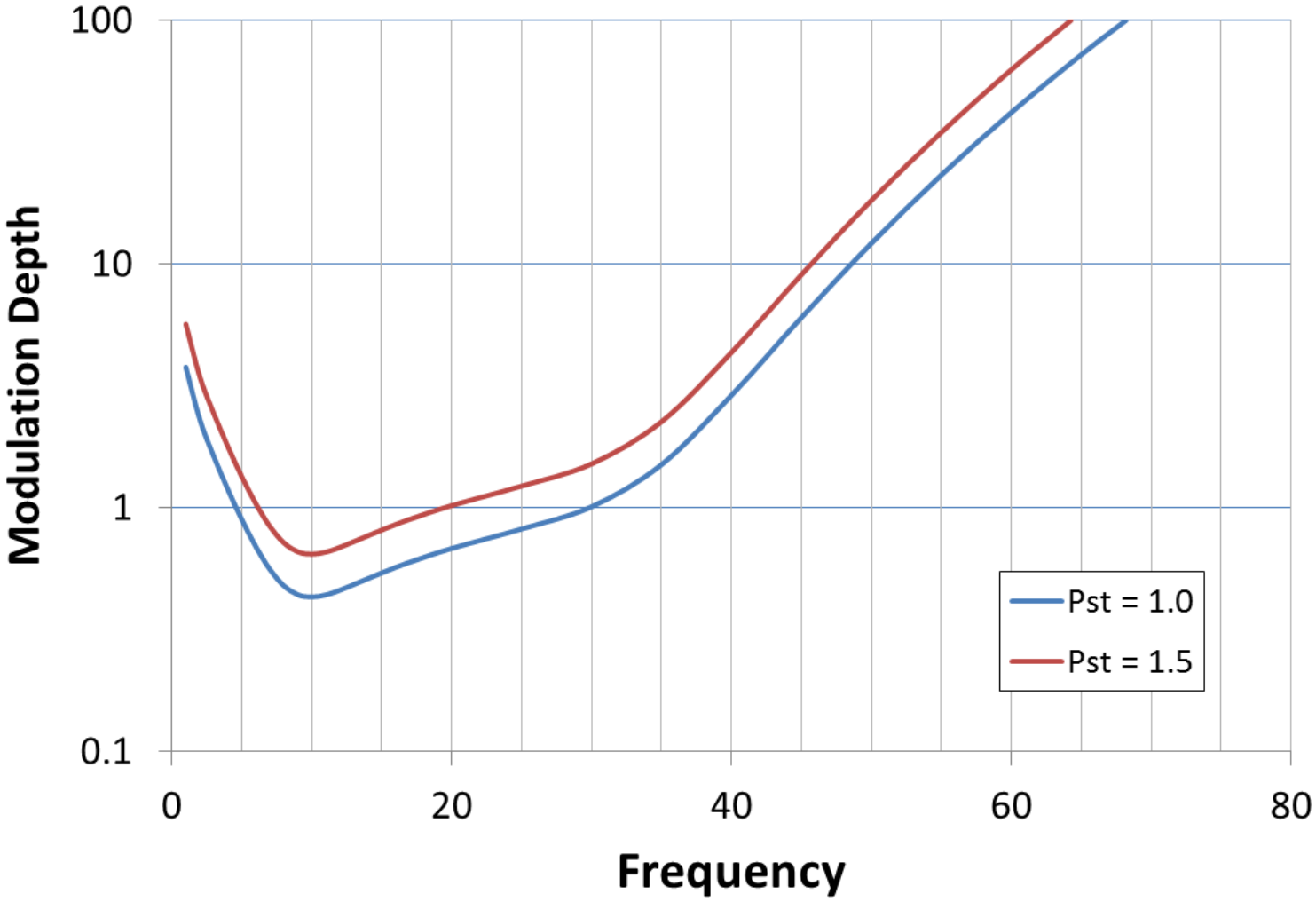
Agree method of quantifying TLA.

Recommend/set limits

- Visibility or Acceptability?
- Allow for Application Dependence

SSL7 Connection

Human Eye Sensitivity (IEC)
Visible Flicker only, sine wave



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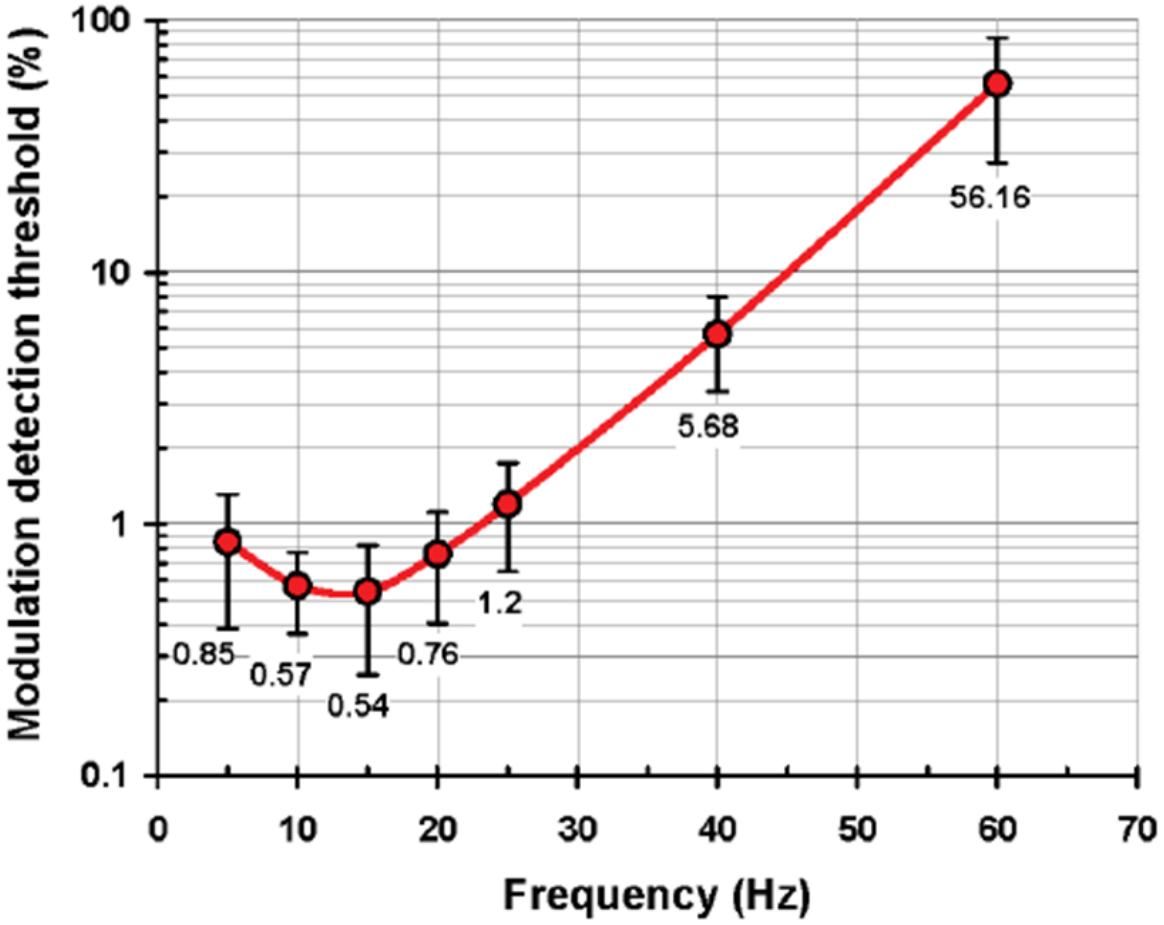
Human Eye Sensitivity (ASSIST)
Visible Flicker only



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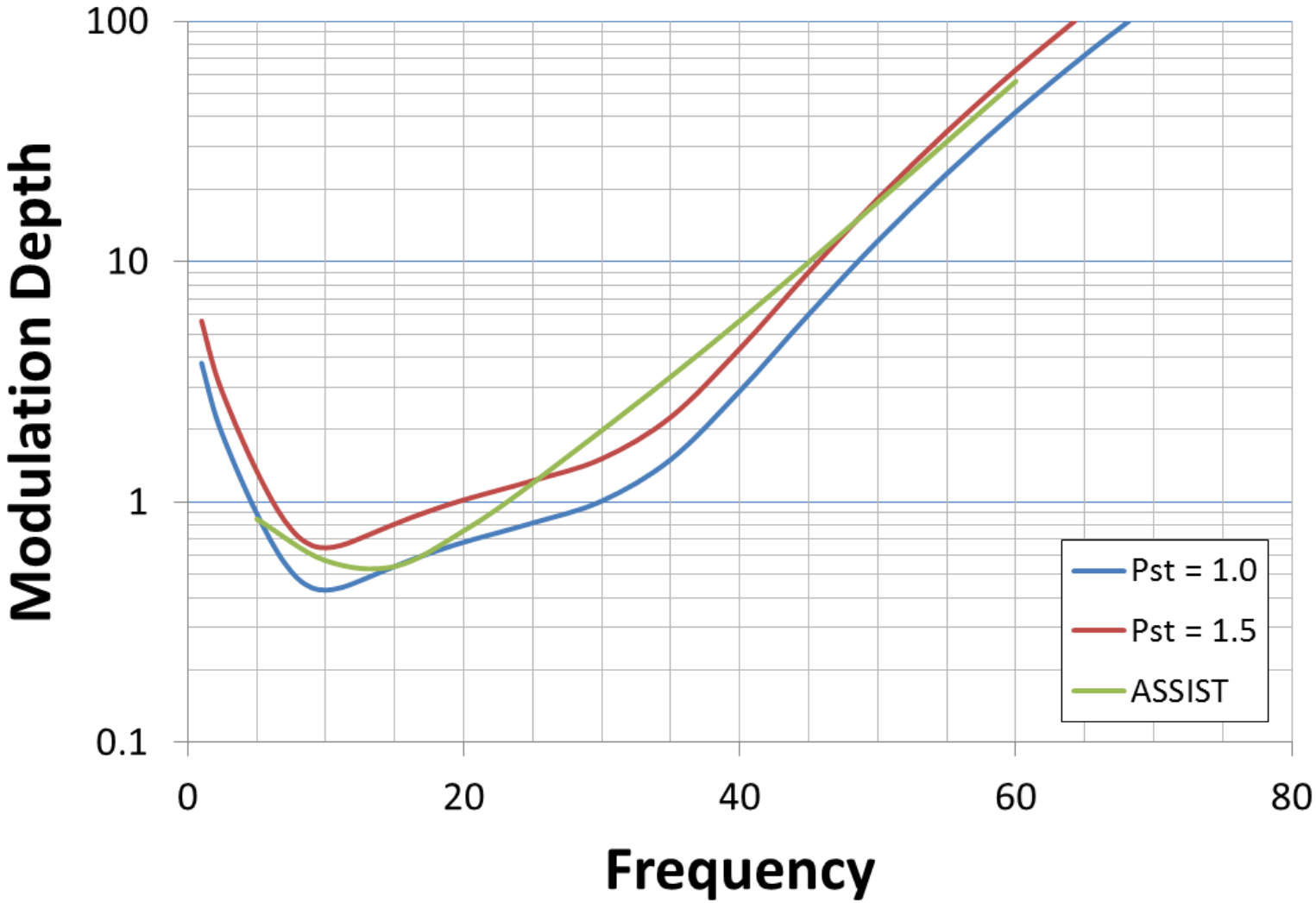
Comparison IEC P_{st} and ASSIST



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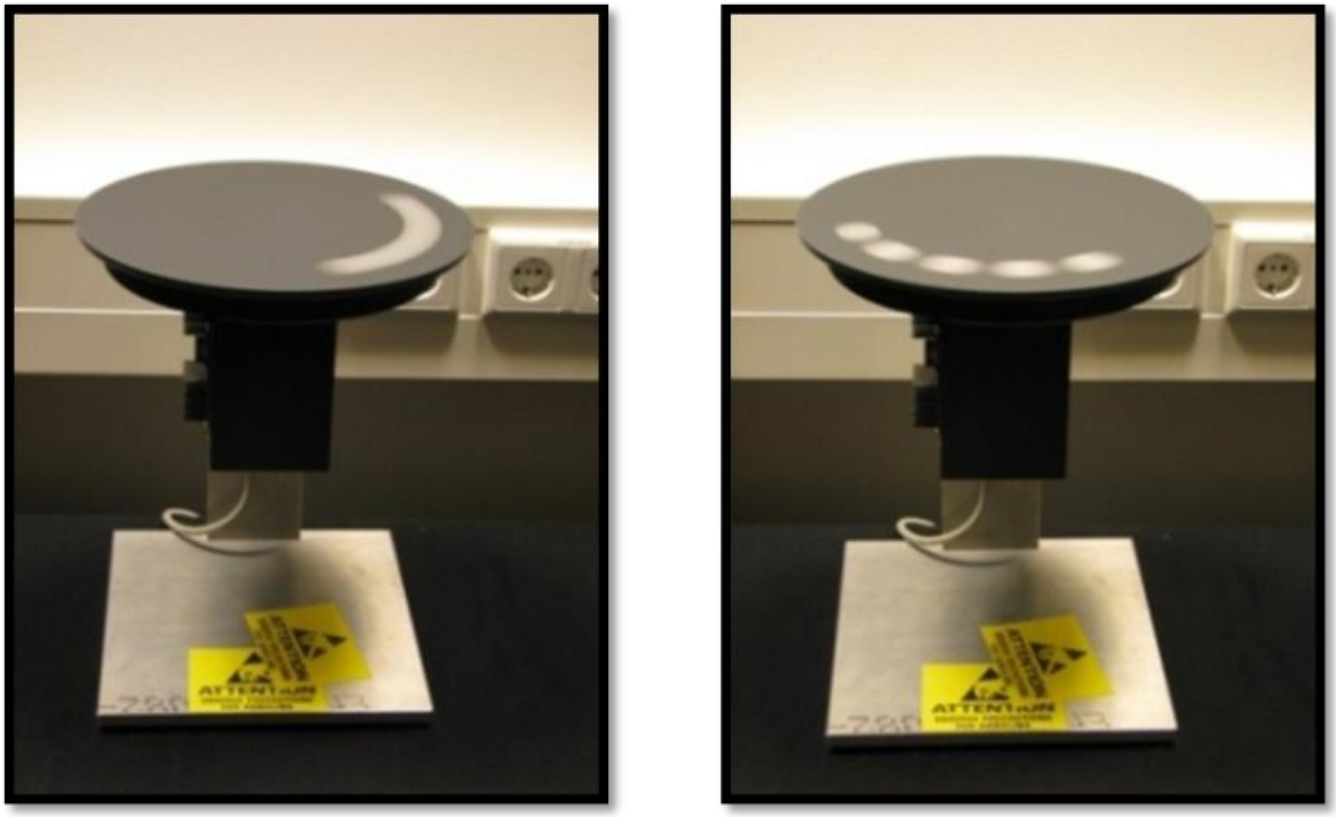
Stroboscopic Effect



Example of stroboscopic effect. The dark spinning disk is marked with one white dot. In the figure on the left, the frequency of light modulation is sufficiently high that the white dot appears as a white streak. In the right figure, the light is modulated at a low enough frequency that several dots seem to be present.

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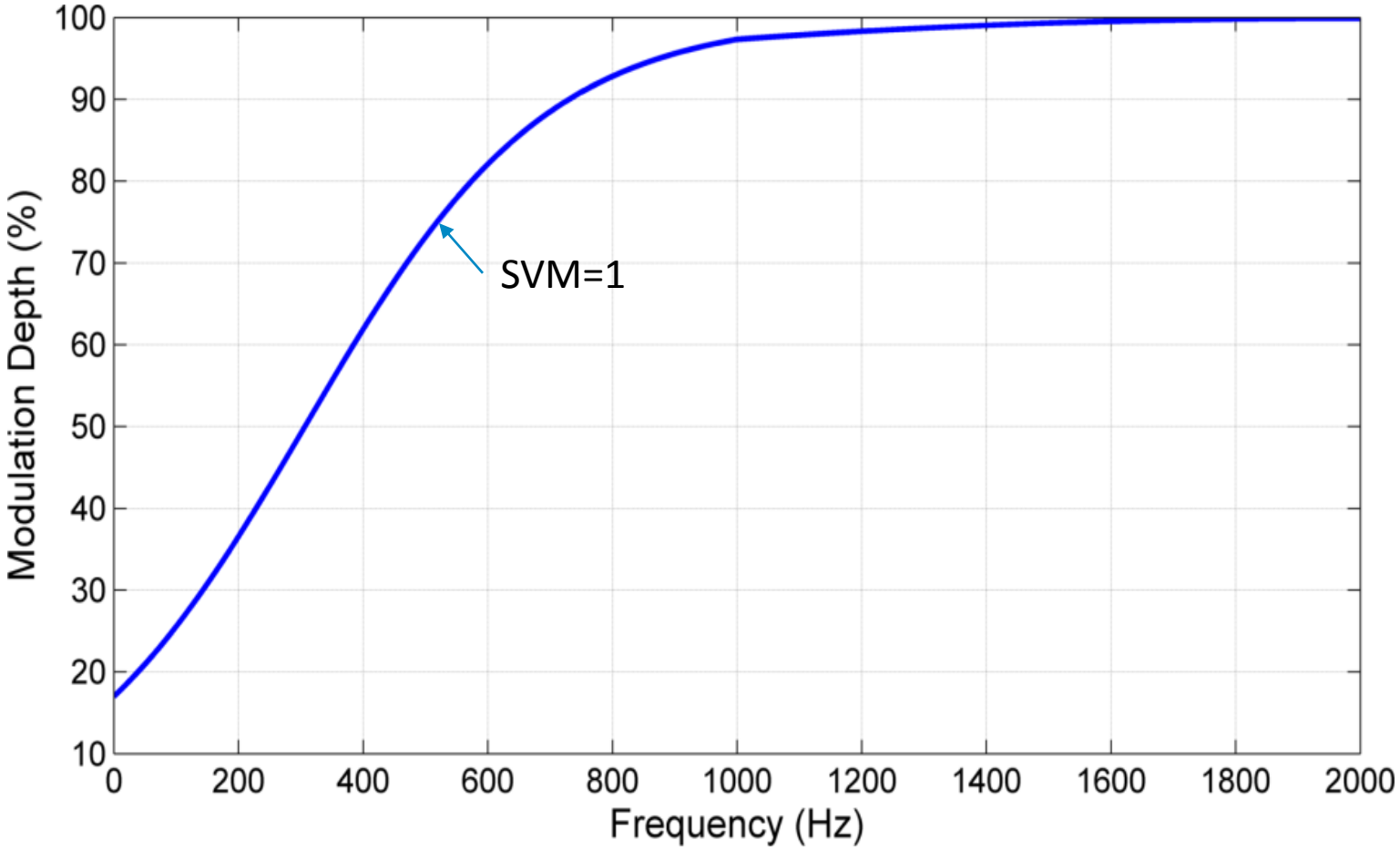
Human Eye Sensitivity
Stroboscopic only, sine wave



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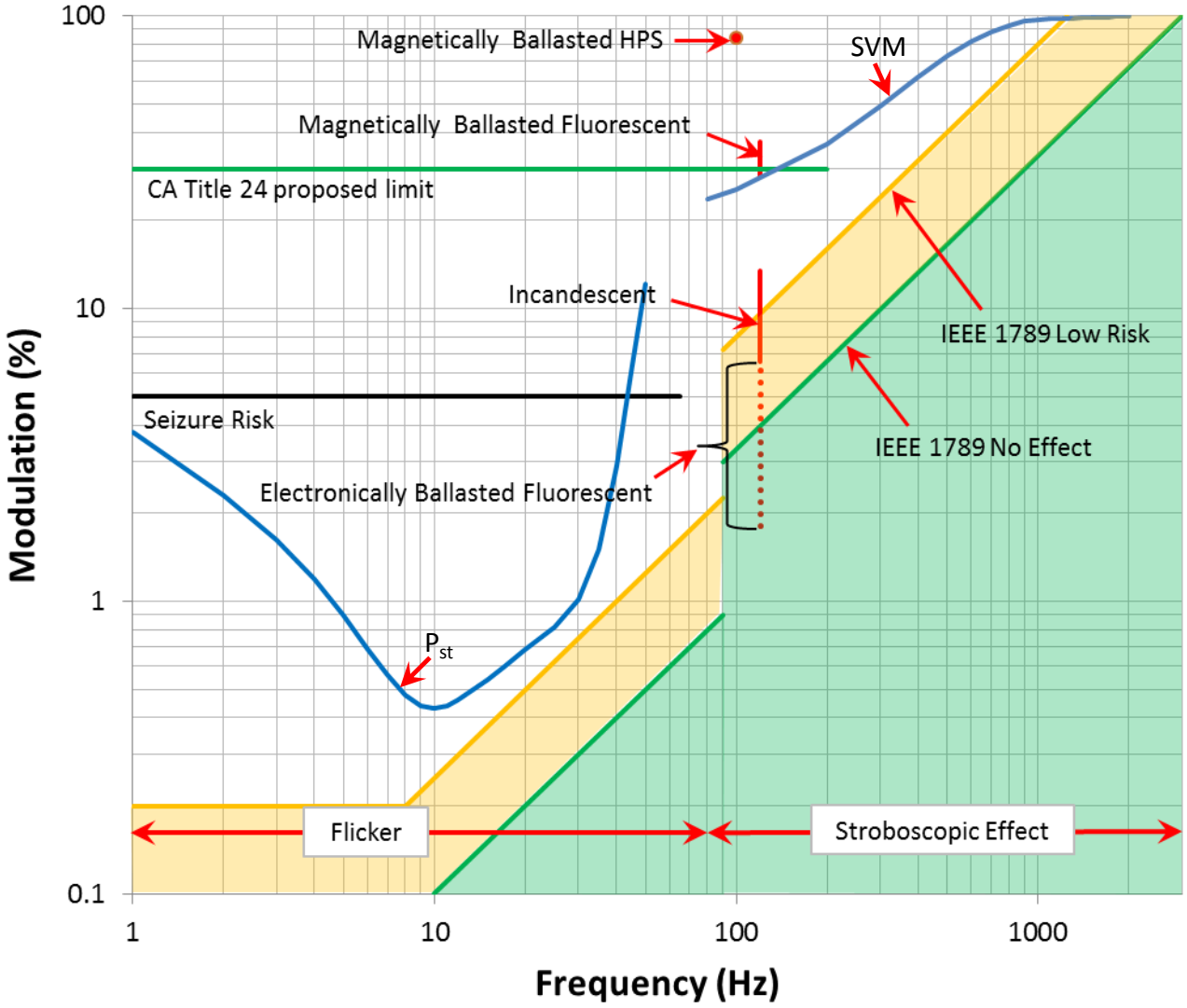
IEEE 1789 + detectability limits



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NEMA Efforts

NEMA task force - working on TLA

Round Robin test to check the metrics, and see if we all get the same answers.

Next: finalize our selection of methods to quantify TLA

Reconfirm sensitivity.

Work with IES and IEEE 1789 members to set application-dependent limits.

Thoughts on Standardization

Support standards that prevent serious health consequences.

Caution against adopting all recommendations without strong application-dependent need. Be aware of unintended consequences (e.g. elimination of incandescent).

Be careful of requirements that could impose high testing burden. (E.g. During dimming from 10% to 100%, flicker must meet IEEE 1789 recommendations 1 2 or 3.)

Continue work to define measurement methods that account for wave-shape, frequency.

Continue work to develop application-specific limits.

Demonstration

Where do you see flicker?
Where do you see stroboscopic effect?

Shows effect of frequency, waveshape, modulation depth, and duty cycle on TLA visibility.

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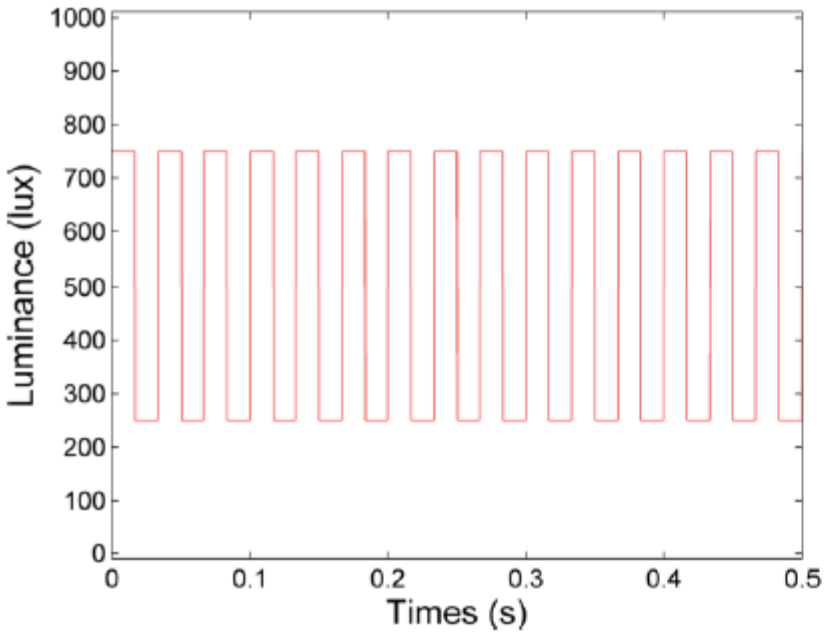
Demonstration

Left side - visible. Right side - not visible without motion.

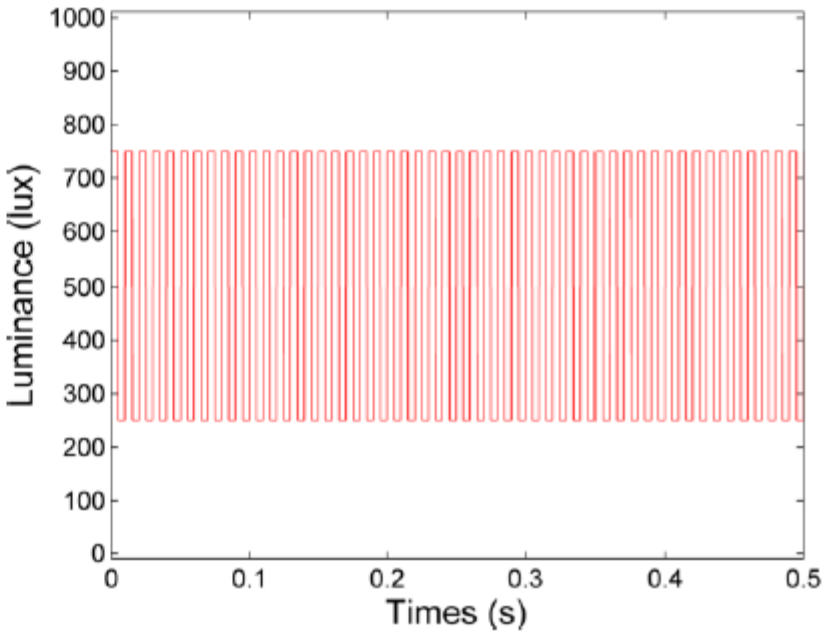
0

Flicker vs Stroboscopic effect

Flicker:
30Hz, 50% Modulation Depth



Stroboscopic effect:
100Hz, 50% Modulation Depth



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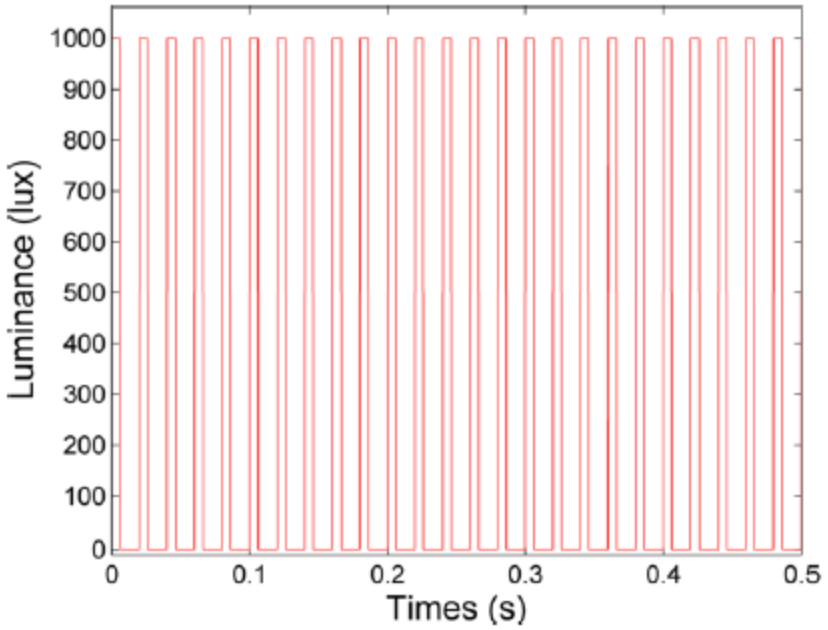
Demonstration

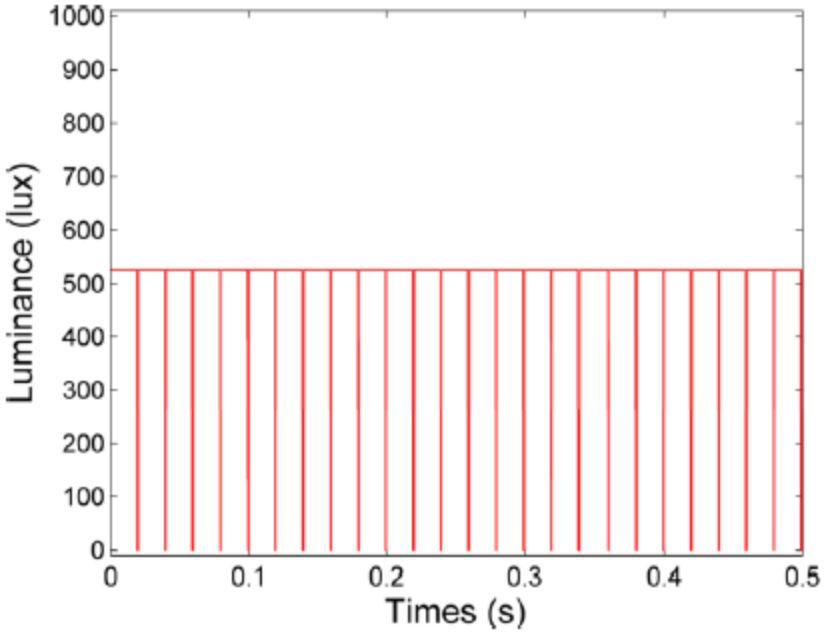
Left side - visible. Right side - not visible.

5 FLICKER: Duty Cycle

50Hz, 30% Duty Cycle
Flicker is visible



50Hz, 95% Duty Cycle
Flicker is not visible



Two square waveforms, at the same frequency but with different duty cycles (30% and 95%), will be very differently visible. According to IEEE recommendation, these waveforms are the same.

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