Pilot Study on Visibility of Phantom Array and Stroboscopic Effects

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Naomi J Miller, FIES, FIALD
Designer/Scientist

Jianchuan Tan, PhD, PMP, LC, WELL AP
Engineer/Scientist

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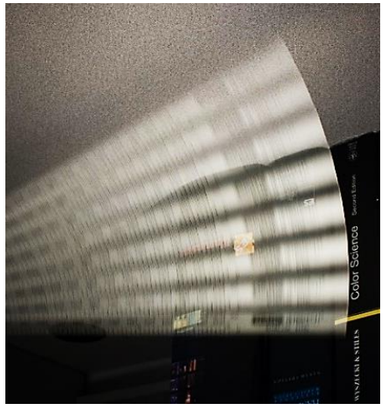
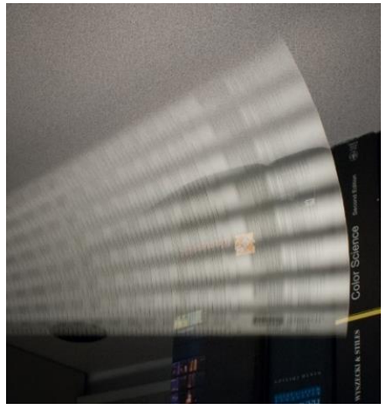
Scope of Study

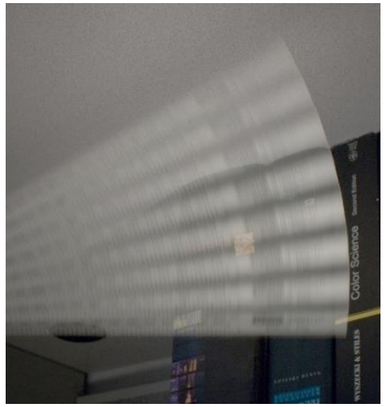
- Background
  - Stroboscopic effect and the phantom array are commonly observed phenomena of temporal light modulation (TLM), also called “flicker”.
  - Stroboscopic Visibility Measure (SVM) is a widely used metric to evaluate stroboscopic effect from a light source.
  - There is not a well-established metric yet to evaluate the phantom array effect.

- Goals of this pilot study
  - For stroboscopic effect:
    - Investigate the subjects’ visibility rating scores of stroboscopic effect with respect to wave shape, frequency, modulation depth and duty cycle.
    - Investigate the relationship between subjects’ visibility rating scores and SVM metric values.
  - For phantom array:
    - Investigate the subjects’ visibility rating scores of phantom array with respect to wave shape, frequency, modulation depth and duty cycle.

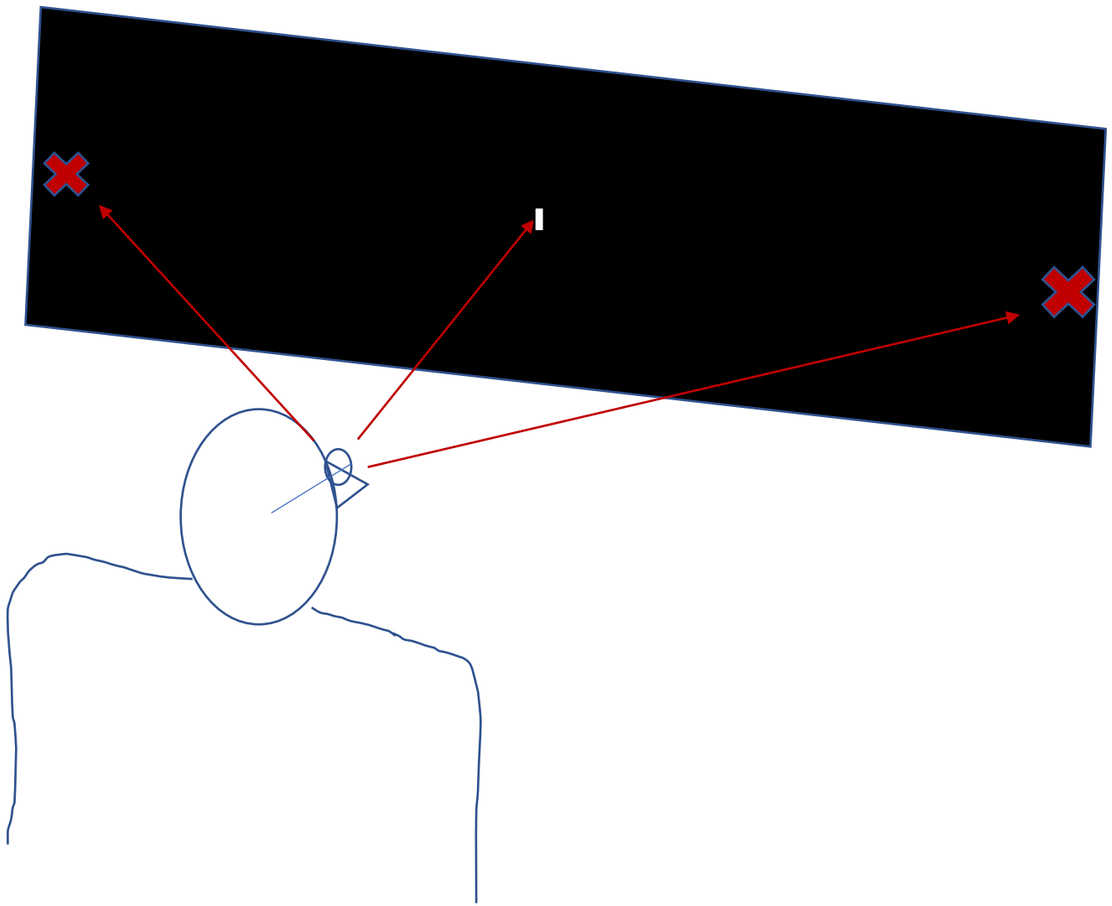
Stroboscopic effect – Visual patterns







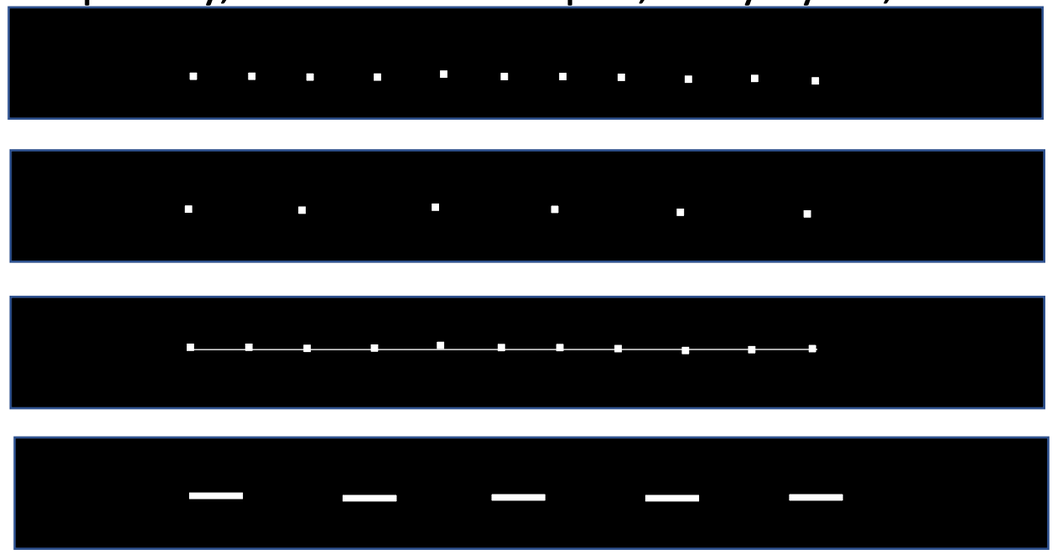
Phantom array effect – Visual patterns



Fixed view on-axis view

Scanning view of continuous (DC) source

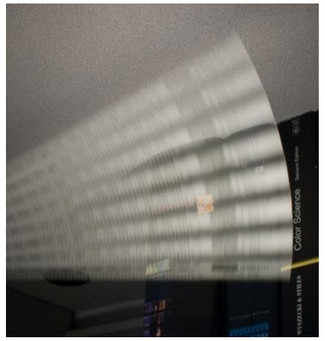
Scanning view of TLM source, depending on frequency, modulation depth, duty cycle, etc.



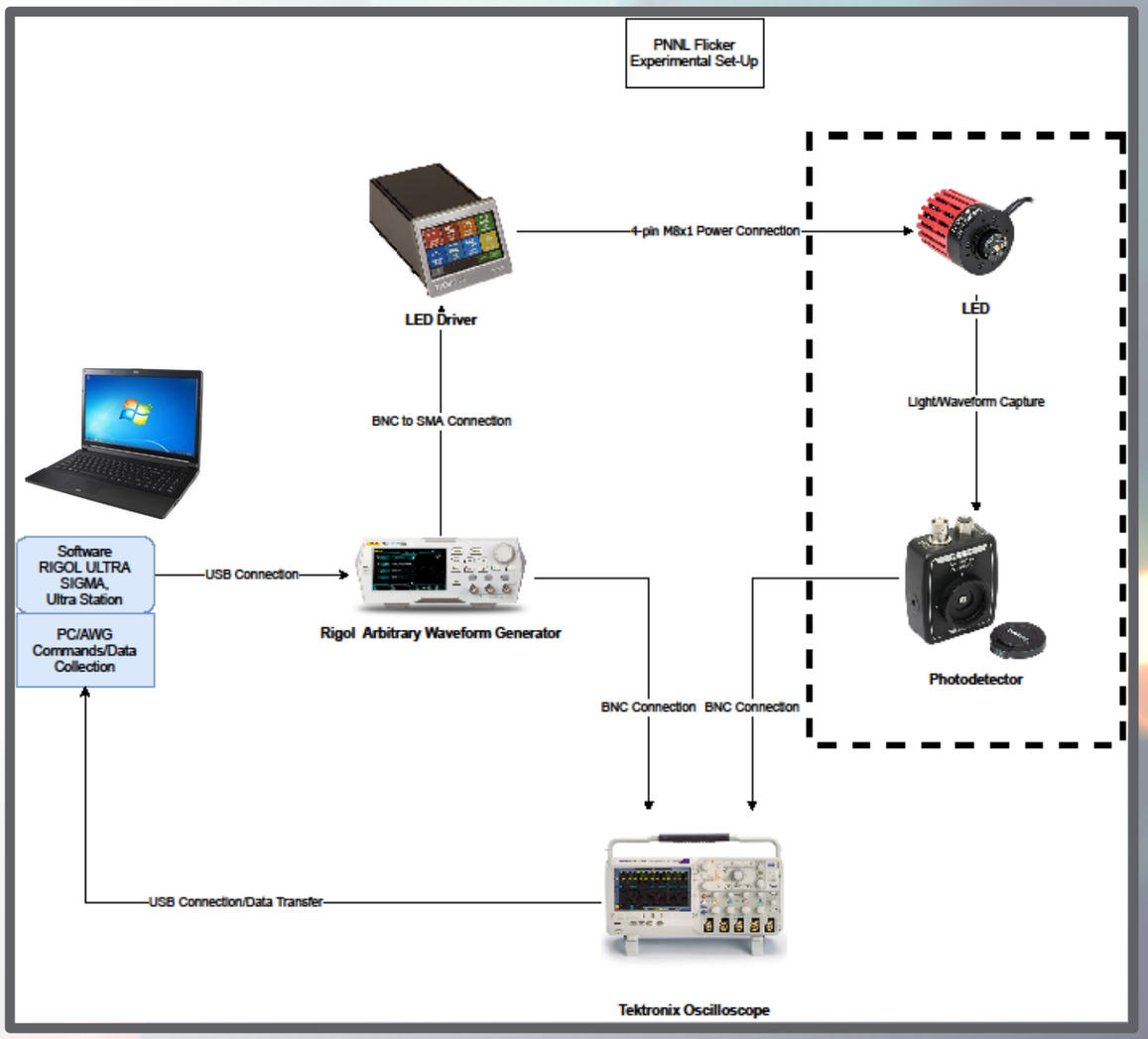
Subjects, Test Setup and Rating Scales

- Subjects
  - Gender
    - Female: 5
    - Male: 6
  - Age range
    - 24 – 66

- Scale of ratings for Stroboscopic Effect
  - 6 – Highly visible stripe pattern
  - 5
  - 4
  - 3
  - 2
  - 1
  - 0 – No stripe pattern visible

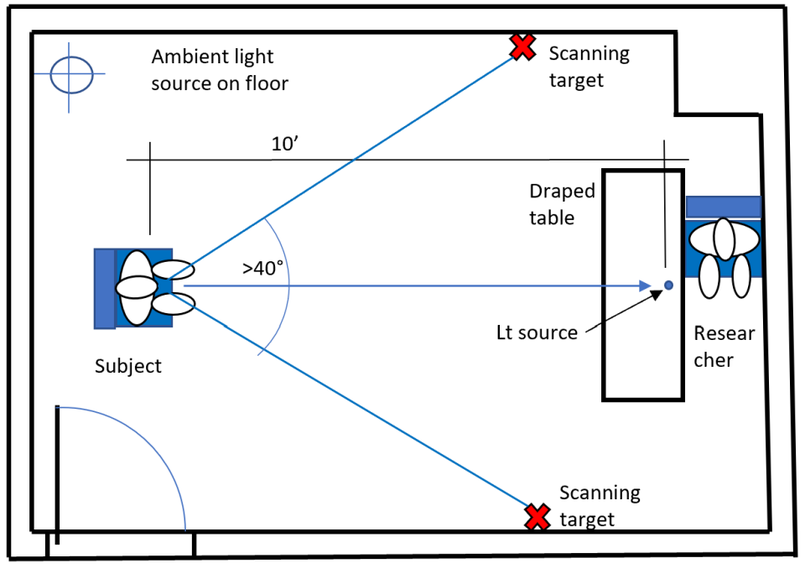


- Scale of ratings for Phantom Arrays
  - 6 – Highly visible repeating pattern
  - 5
  - 4
  - 3
  - 2
  - 1
  - 0 – No repeating pattern visible

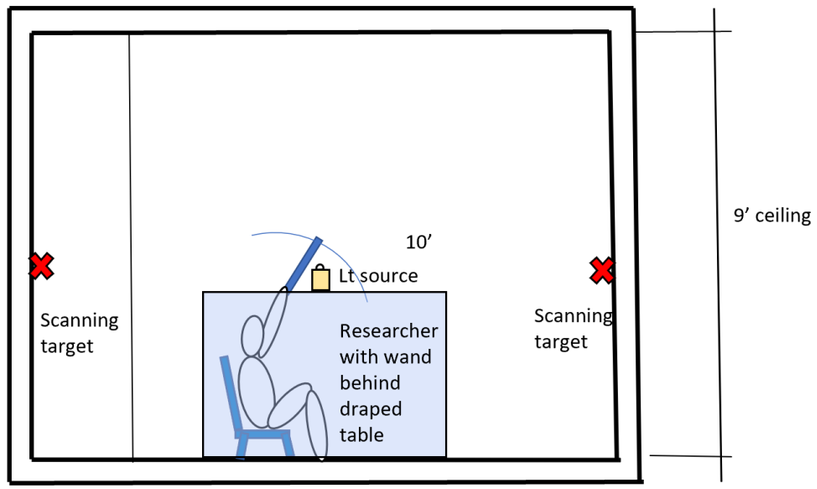


Test Setup

Test Room 8’-2” x 16’ x 9’ ceiling
10’ viewing distance from subject eye to LED
1.5 – 2 lux at eye, including 0.5 lx ambient light

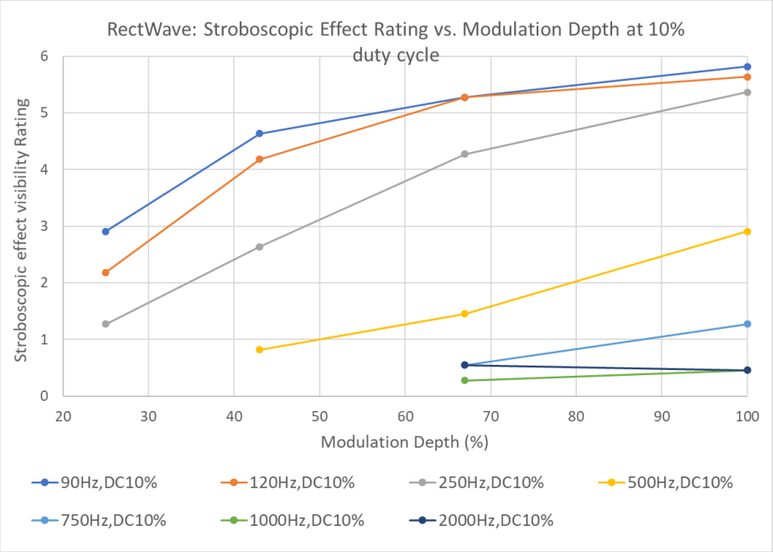


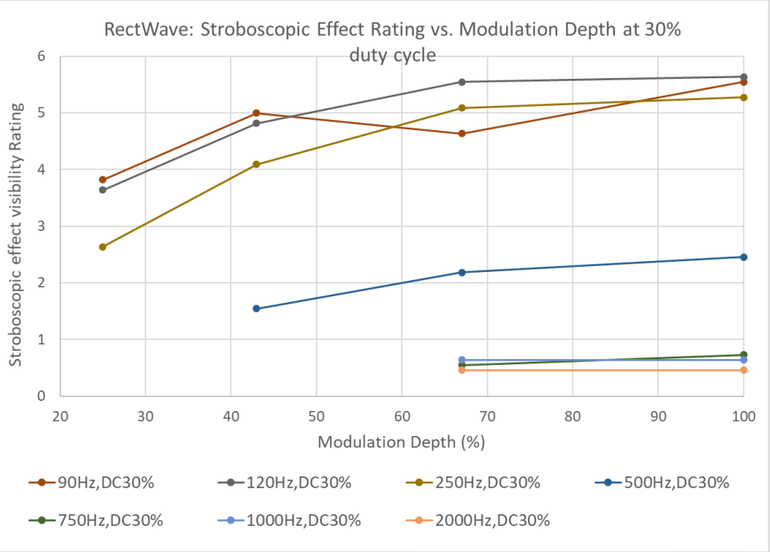
Floor Plan of Experiment Room, not to scale

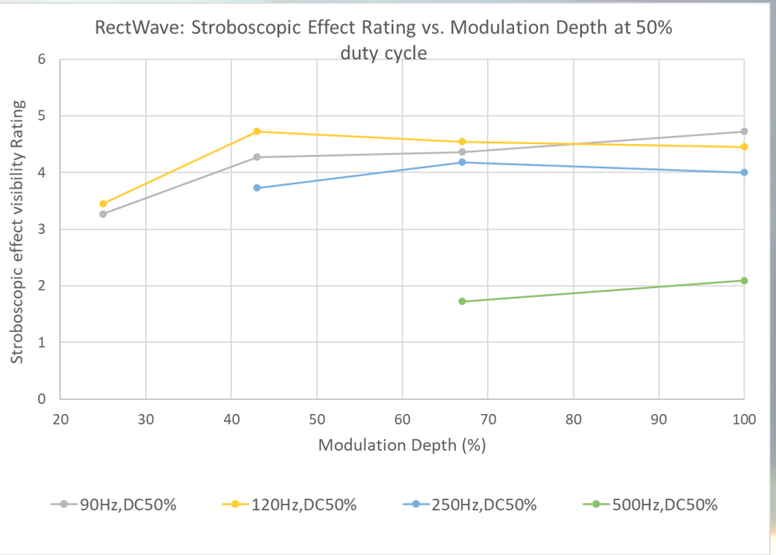


Elevation of Experiment Room, not to scale

Rectangular Wave: Stroboscopic Effect Rating vs. Modulation Depth – PRELIMINARY RESULTS – DO NOT CITE



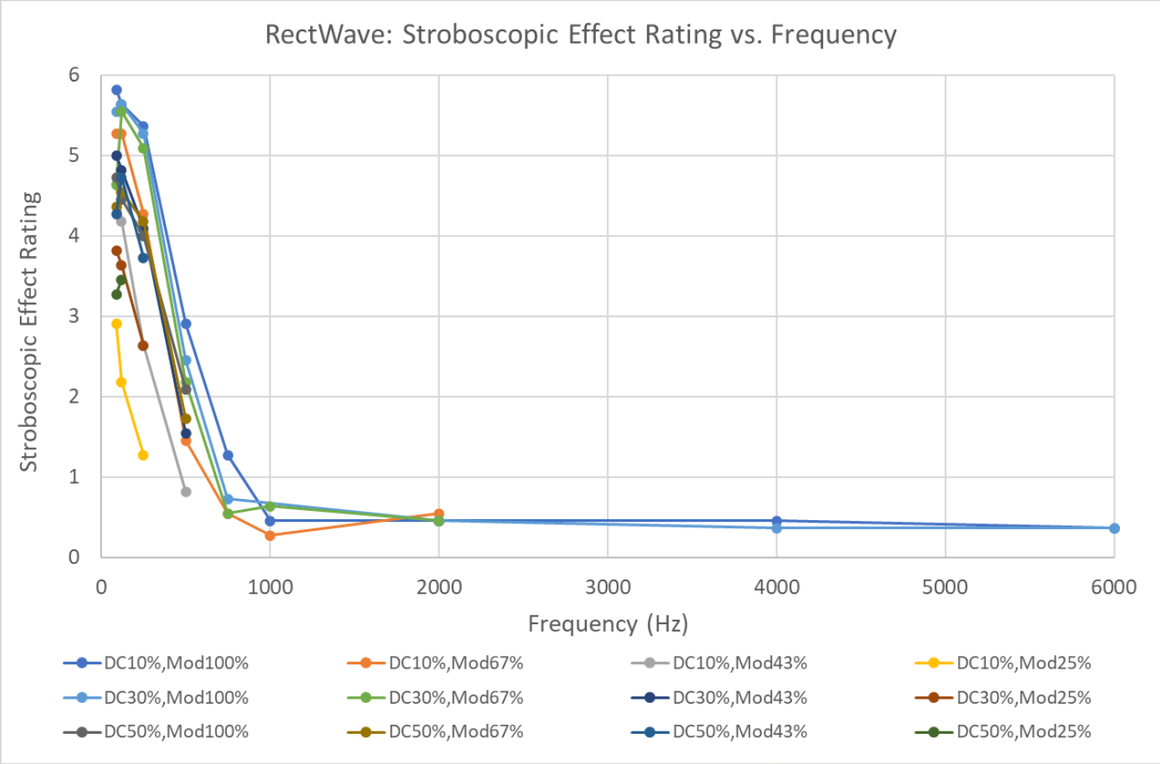




Visibility of the stroboscopic effect from rectangular waveforms:

- Generally, visibility increases as modulation depth increases.
- Visibility is almost always maximized at 67% - 100% modulation.
- Visibility is very low when frequency exceeds 1000 Hz.

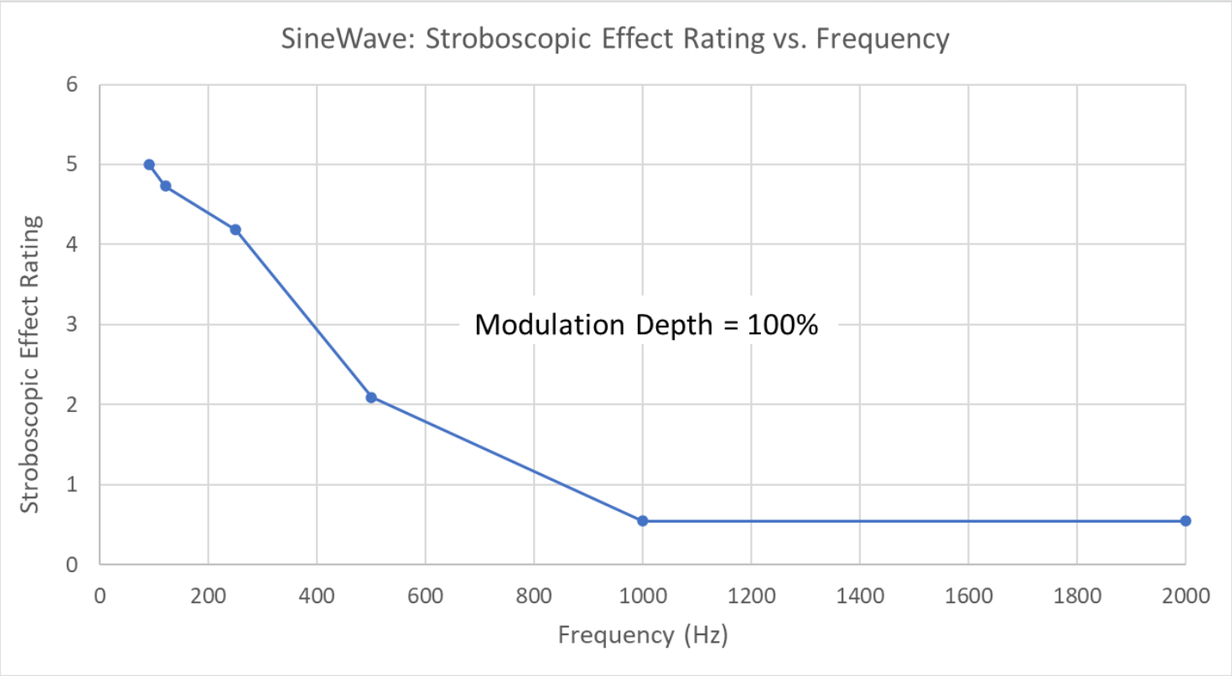
Rectangular Wave: Stroboscopic Effect Rating vs. Frequency - PRELIMINARY RESULTS – DO NOT CITE



Visibility of the stroboscopic effect from rectangular waveforms:

- Peaks at 90 – 120 Hz, but declines rapidly with frequency
- Greatest at 100% and 67% modulation
- Maximized at 10% and 30% duty cycle
- Barely visible at 1000 Hz at 100% mod, 10% duty cycle

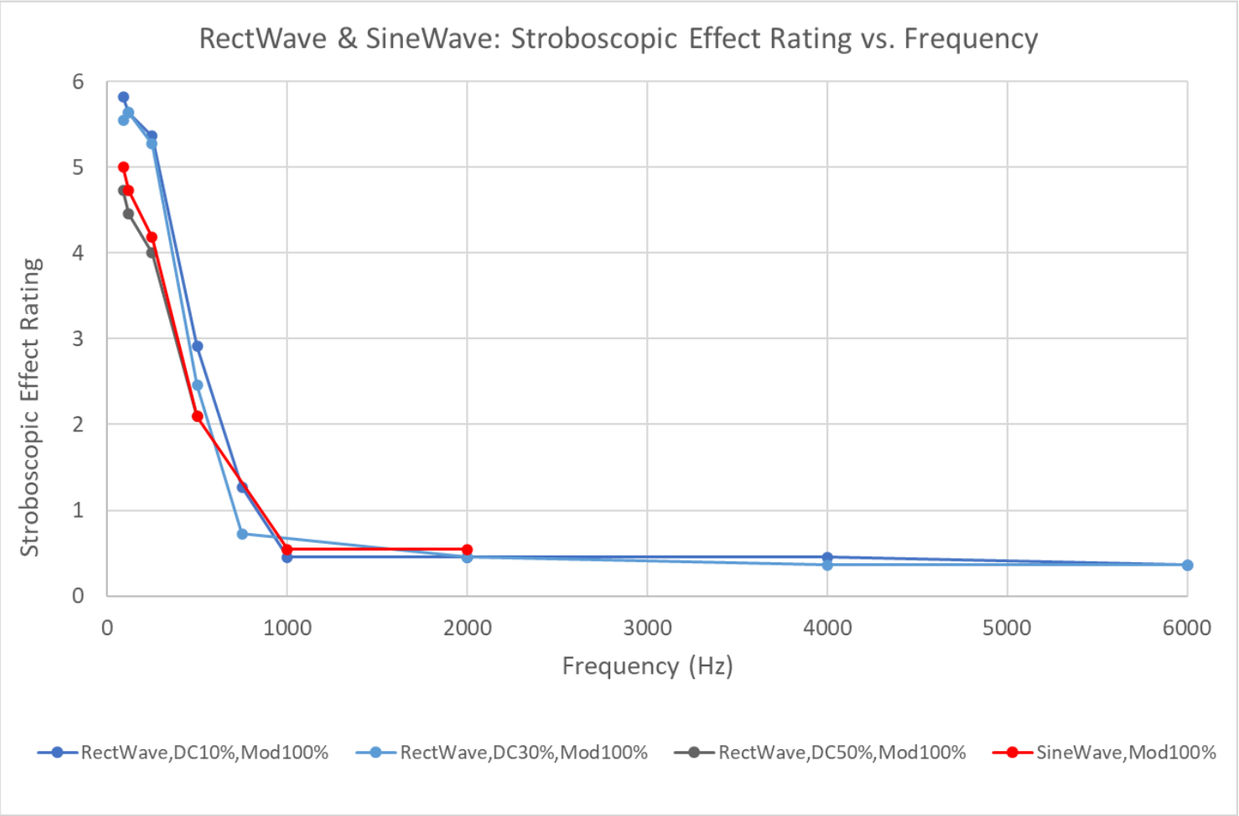
Sine Wave: Stroboscopic Effect Rating vs. Frequency - PRELIMINARY RESULTS – DO NOT CITE



Visibility of the stroboscopic effect from sine waveforms:

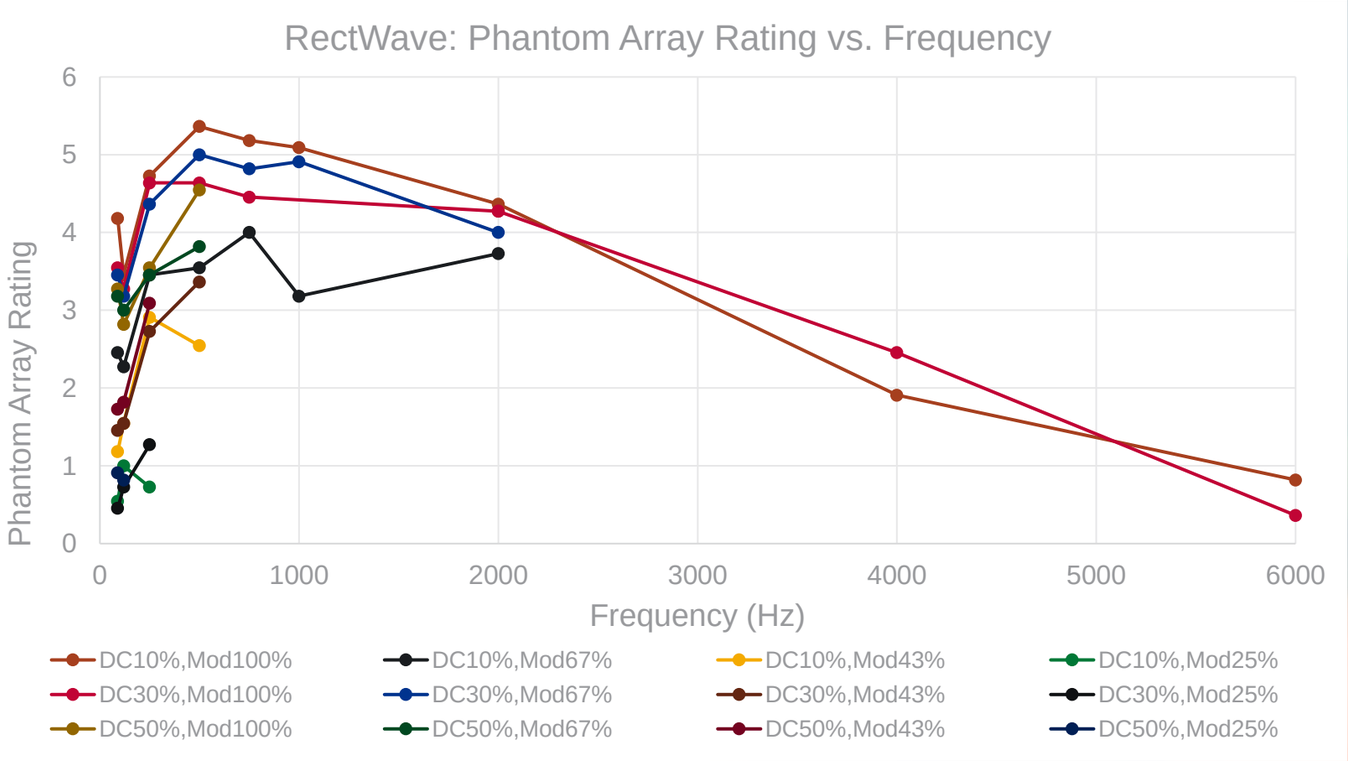
- Peaks at 90 Hz, but declines rapidly with frequency
- Studied here at only 100% modulation
- Barely visible at 1000 Hz

Rectangular & Sine Wave: Stroboscopic Effect Rating vs. Frequency - PRELIMINARY RESULTS – DO NOT CITE



- This shows that Rectangular Waves are more visible than Sine Waves at equal Modulation Depth for Stroboscopic Effects.

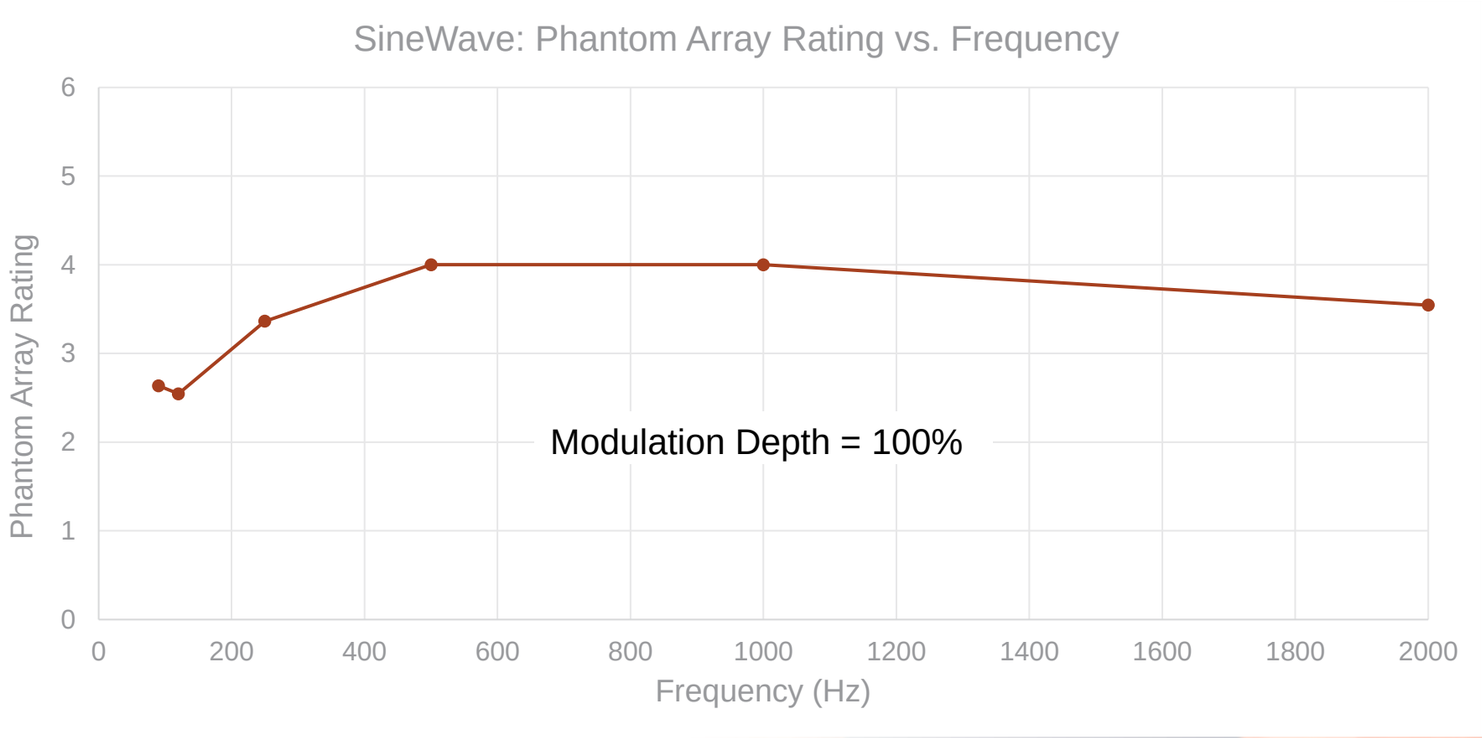
Rectangular Wave: Phantom Array Effect Rating vs. Frequency - PRELIMINARY RESULTS – DO NOT CITE



Visibility of the phantom array

- Peaks at 500 – 1000 Hz.
- Interesting dip at 120 Hz.
- Greatest at 100% and 67% modulation
- Maximized at 10% and 30% duty cycle
- Visible on average at 6000 Hz at 100% mod, 10% duty cycle

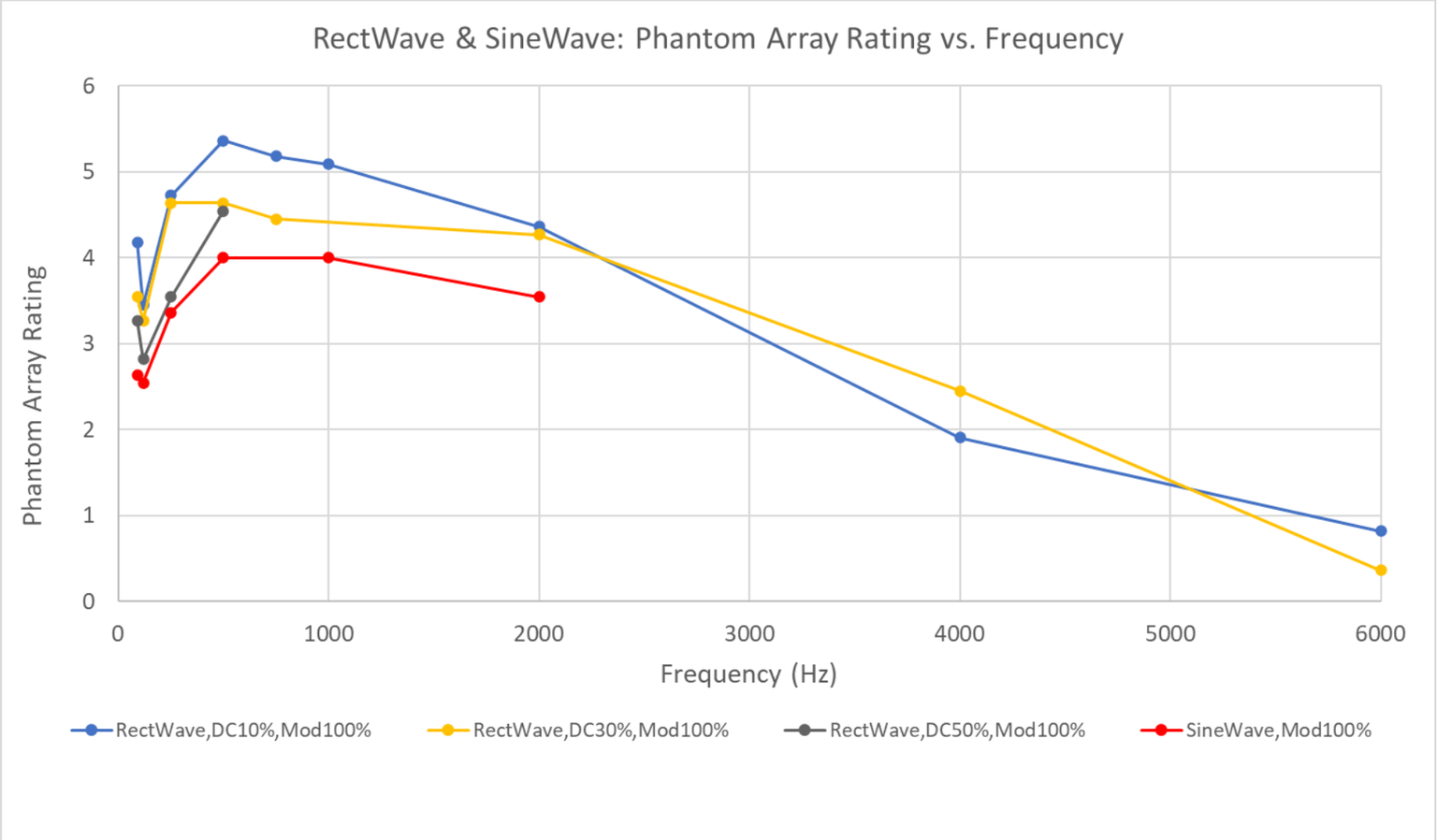
Sine Wave: Phantom Array Effect Rating vs. Frequency - PRELIMINARY RESULTS – DO NOT CITE



Visibility of the phantom array

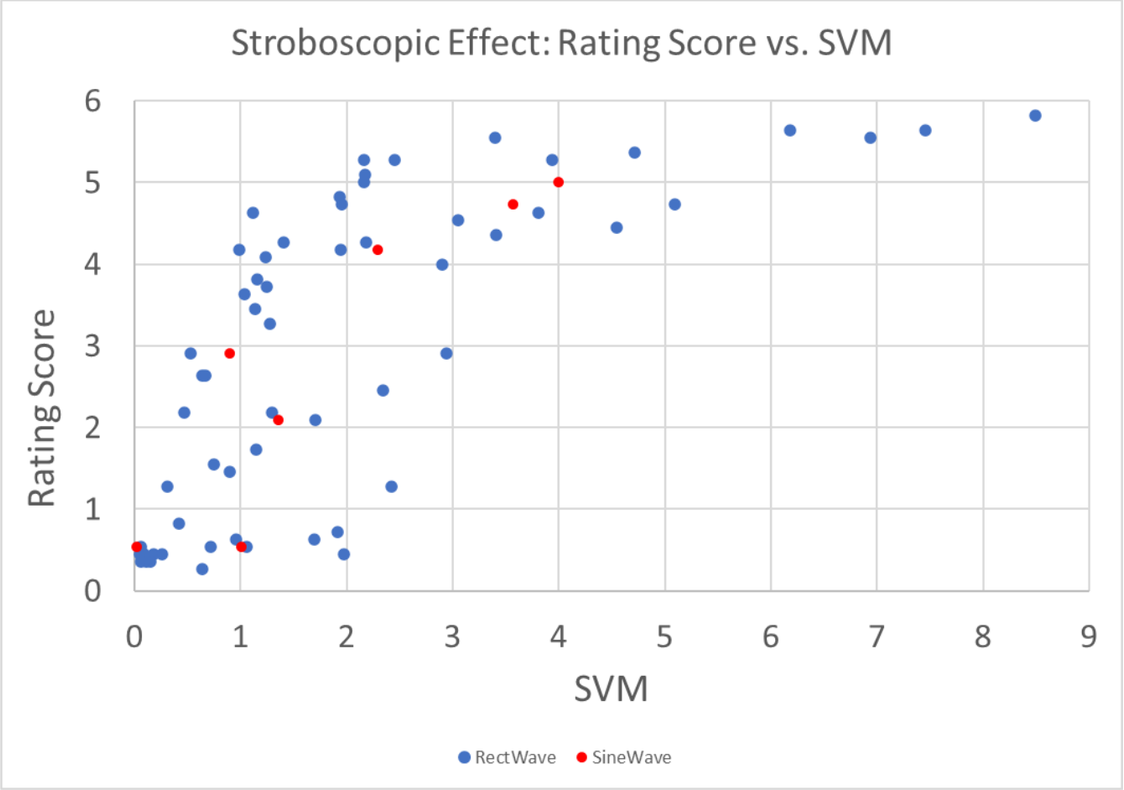
- Peaks at 500 – 1000 Hz
- Studied here only at 100% modulation
- Visible up to 2000 Hz at 100% mod (not studied at higher frequencies)

Rectangular & Sine Wave: Phantom Array Effect Rating vs. Frequency - PRELIMINARY RESULTS – DO NOT CITE



- This shows that Rectangular Waves are more visible than Sine Waves at equal Modulation Depth for Phantom Arrays.

Stroboscopic Effect: Rating Scores vs. SVM - PRELIMINARY RESULTS – DO NOT CITE



- Generally, the rating score increases as SVM increases.
- We are going to analyze the trends and build a mathematical model to depict the relationship between rating scores in a test and SVM values.

Preliminary Discussion and Summary

Stroboscopic effect

- Most visible at 90-120 Hz, and declines rapidly at higher frequencies
- Probably not visible above ~1000 Hz except in low duty cycle rectangular waves
- More visible from rectangular waves than sinusoidal waves
- More visible with high modulation depths (>50% modulation) and low duty cycles

Phantom array effect

- Interesting drop in visibility at 120 Hz (90 Hz and 250 Hz higher)
- Peaks from 500 to 750 Hz, declines more slowly than stroboscopic effect at higher frequencies
- Duty cycles of 10-30% are most visible when modulation depth is 100%, even at frequencies up to 6000 Hz
- More visible from rectangular waves than sinusoidal waves

Stroboscopic effect most visible from 90 to 250 Hz, the phantom array more visible ≥250 Hz.

If the phantom array is visible, the stroboscopic effect may or may not be.
Stay tuned……..

Acknowledgments

We appreciate our colleagues

- Lia Irvin and Eduardo (Eddy) Rodriguez-Feo Bermudez for preparing equipment and conducting subject tests
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Thank You!
Questions?

Naomi J Miller, FIES, FIALD
Designer/Scientist
Naomi . Miller @ pnnl . gov

Jianchuan Tan, PhD, PMP, LC, WELL AP
Engineer/Scientist
jianchuan.tan@pnnl.gov

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