

# Study on Multi-tone Signals for Analog/Mixed-Signal IC Testing

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## 1. Objective

Analog/Mixed-Signal IC becomes rapidly complicated

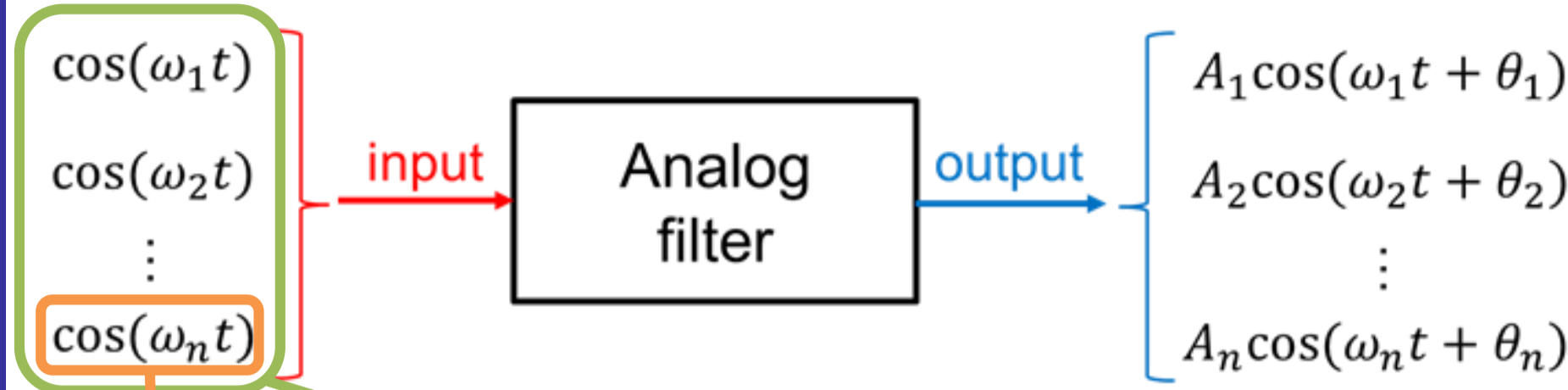


Require :

- To improve quality
- To reduce cost by shorting test time in analog circuit parts

## 2. Background

Analog IC test (frequency response)



Single tone

😊 Good SNR

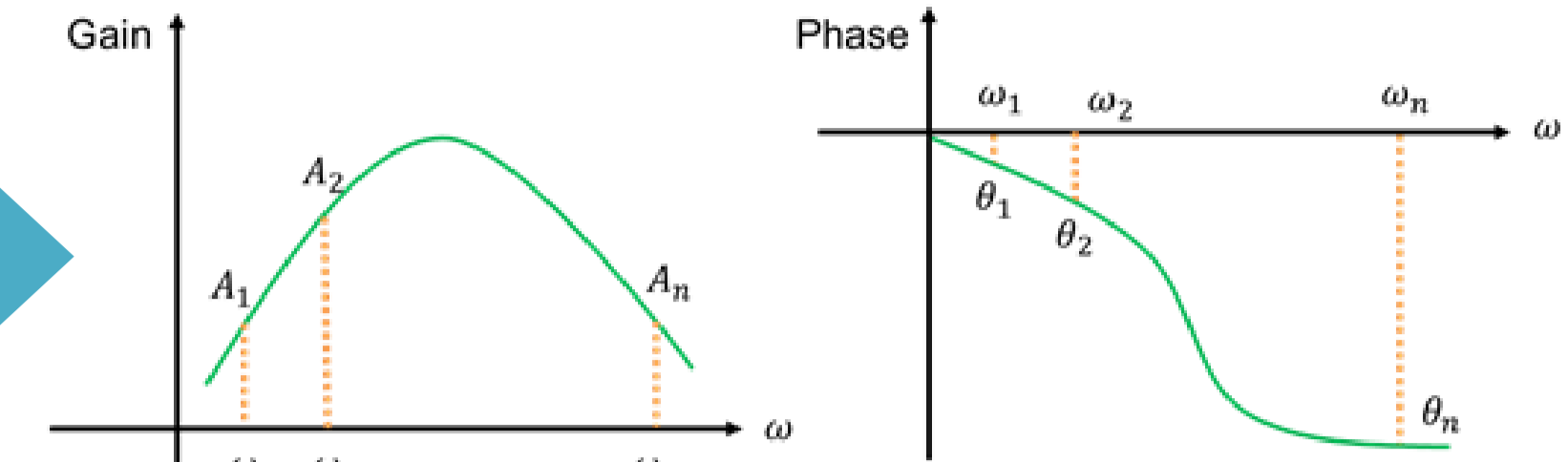
😞 Long testing time

Multi-tone

😊 Short testing time

😞 Bad SNR → Low quality test

Bode plot of analog filter

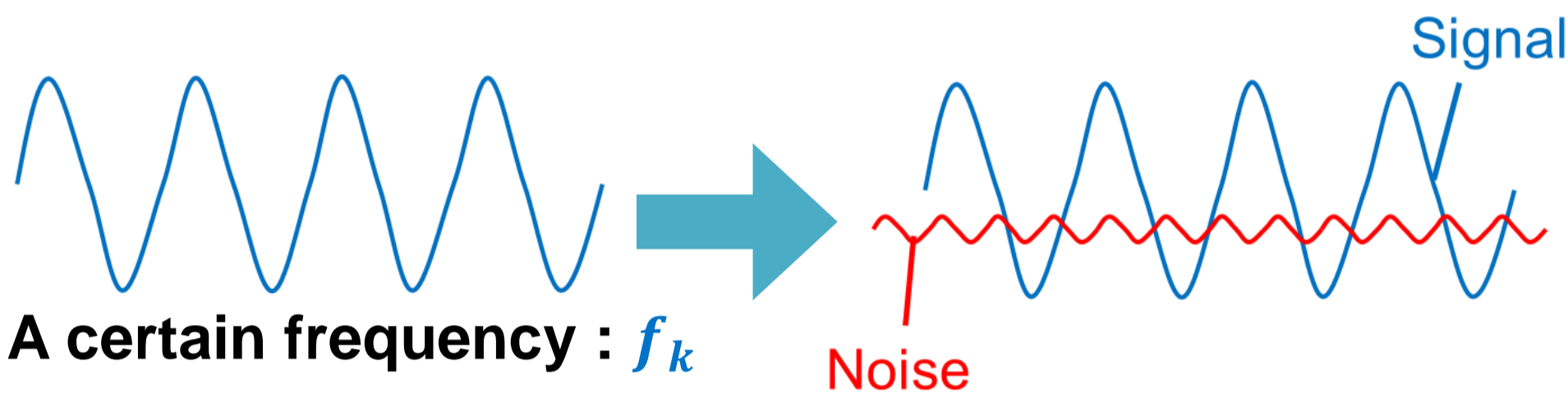


Purpose of this work :

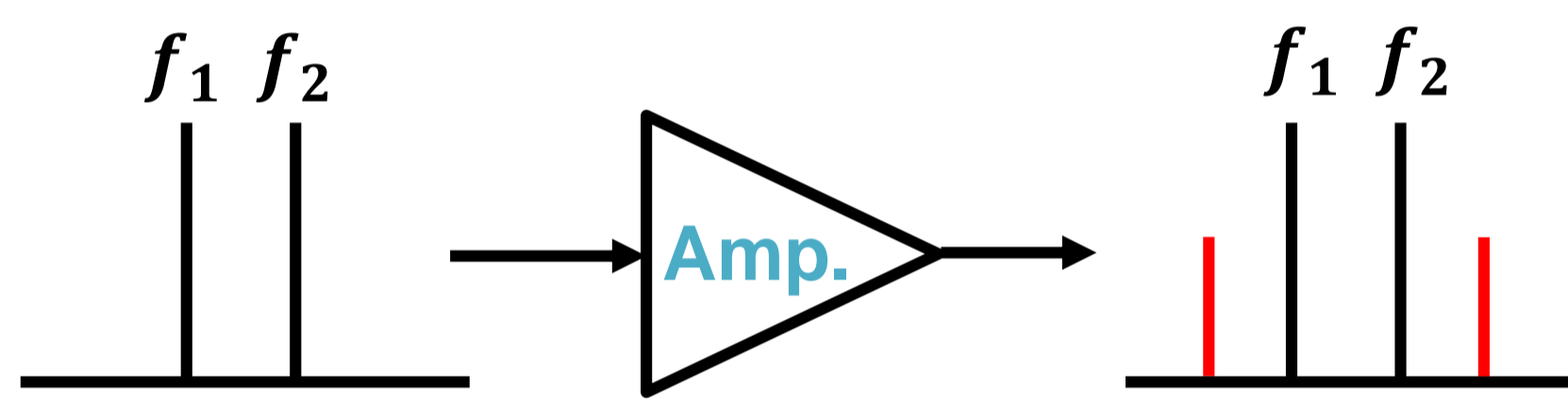
Short-time & high quality testing for analog IC using multi-tone signal

Cause of bad SNR :

① Get smaller signal for each frequency component



② Occur intermodulation distortion in nonlinear system



## 3. Multi-tone Signal

Effective measure :

- Suppress maximum amplitude
- Minimize crest factor (CF)
- Maximize dynamic range (DR)

Using algorithm to maximize dynamic range by adjusting phases of multi-tone signal

## 4. DR Maximize Algorithm

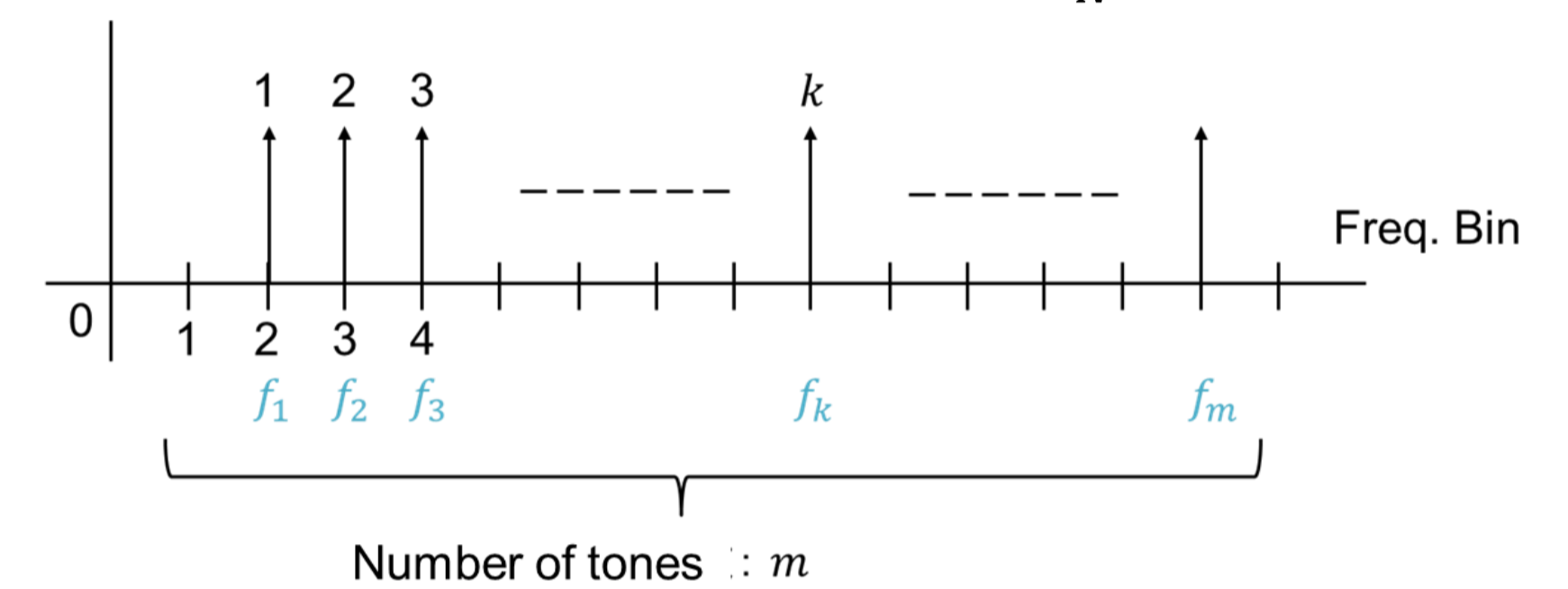
Basic formula :

$$s(t) = \sum_{n=1}^m \cos\left(\frac{2\pi f_k t}{N} + \phi_k\right)$$

N : 8192

m : a power of 2

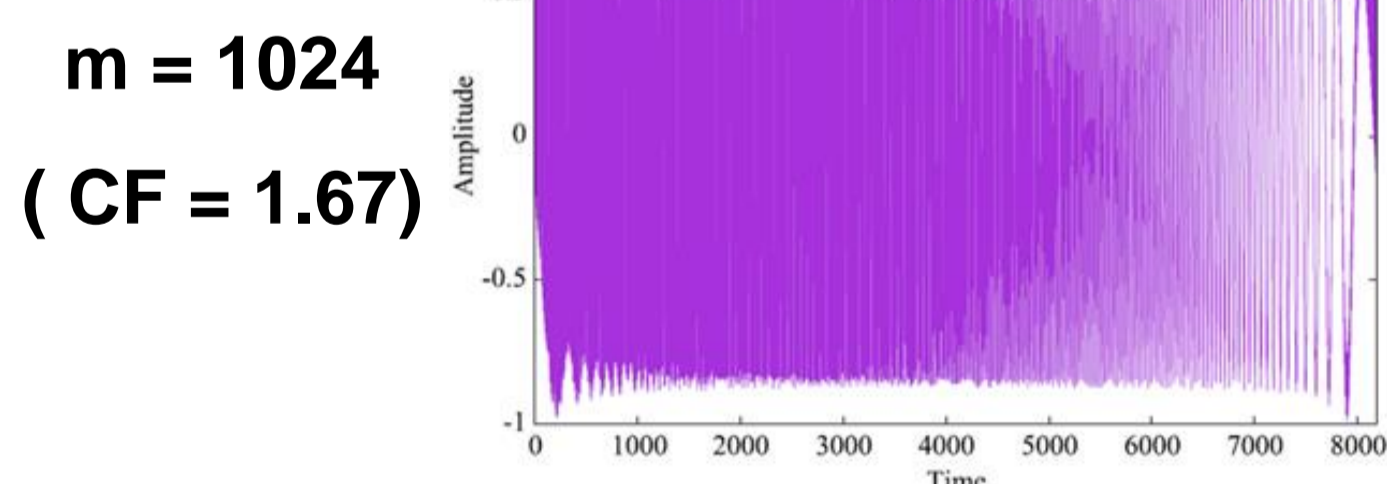
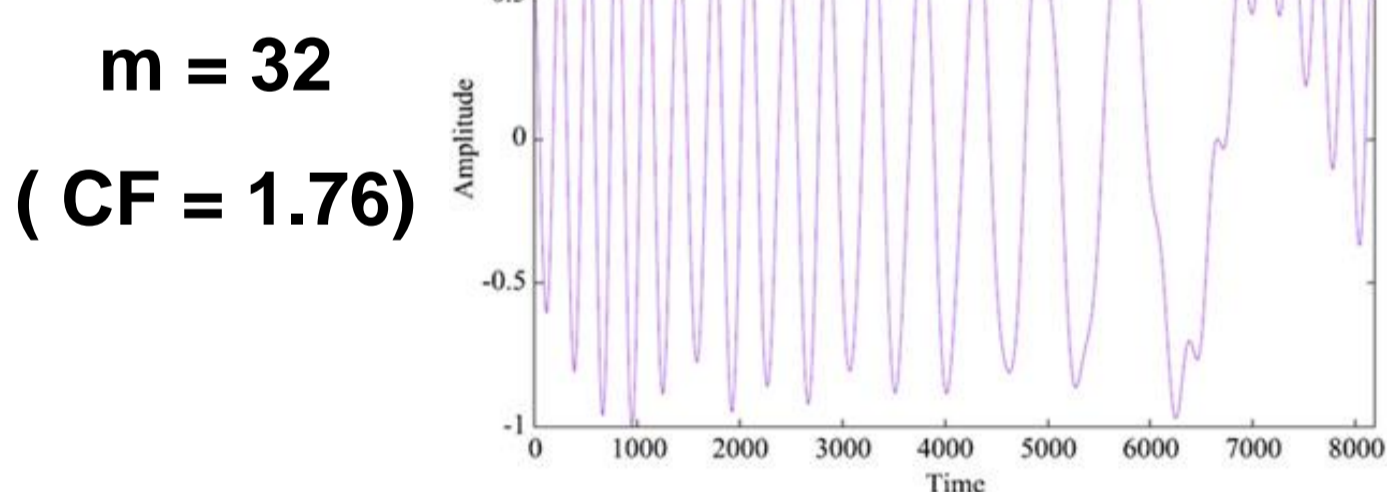
- Kitayoshi phase :  $\phi_k = \frac{\pi}{N} k(k+1)$
- Newman phase :  $\phi_k = \frac{\pi}{N} (k-1)^2$
- Schroeder phase :  $\phi_k = -\frac{\pi}{N} k(k-1)$



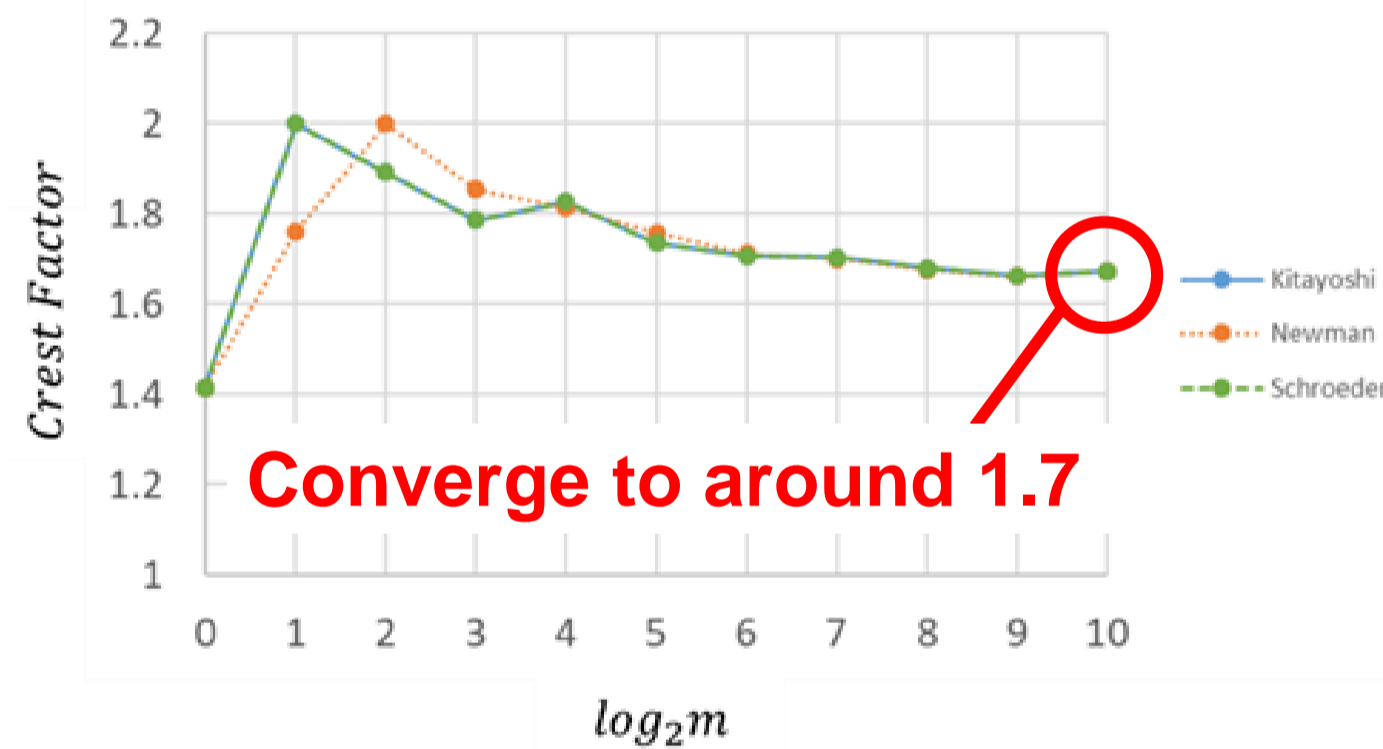
## 5. Simulation Results

< Dynamic range maximize algorithm >

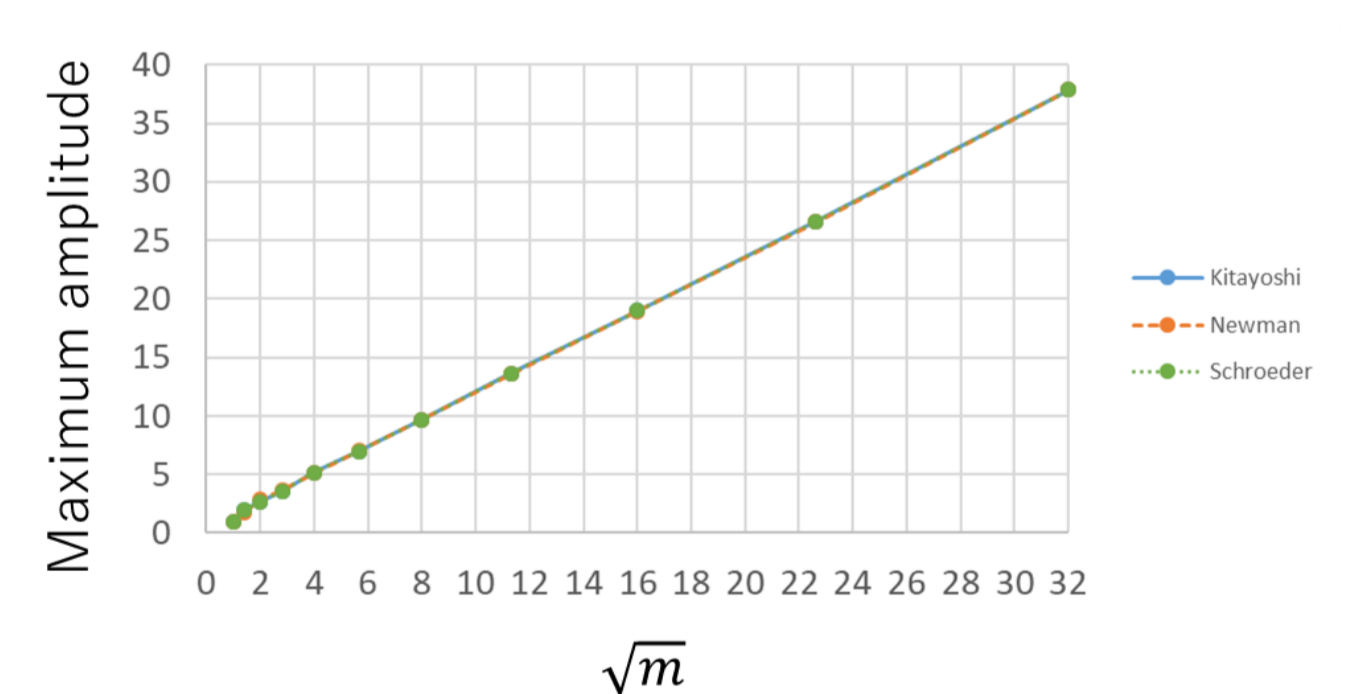
Waveform of Newman phase :



↓ 3 algorithms : almost consistent

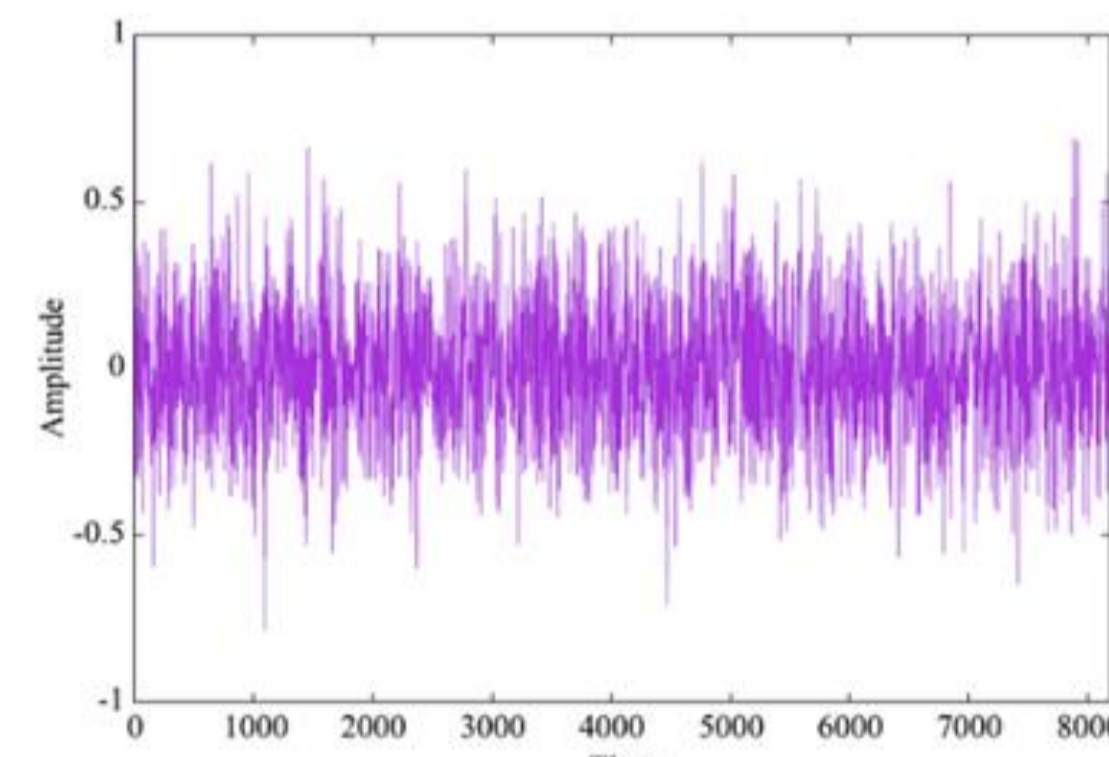


↓ Amplitude : proportional to sqrt(m)

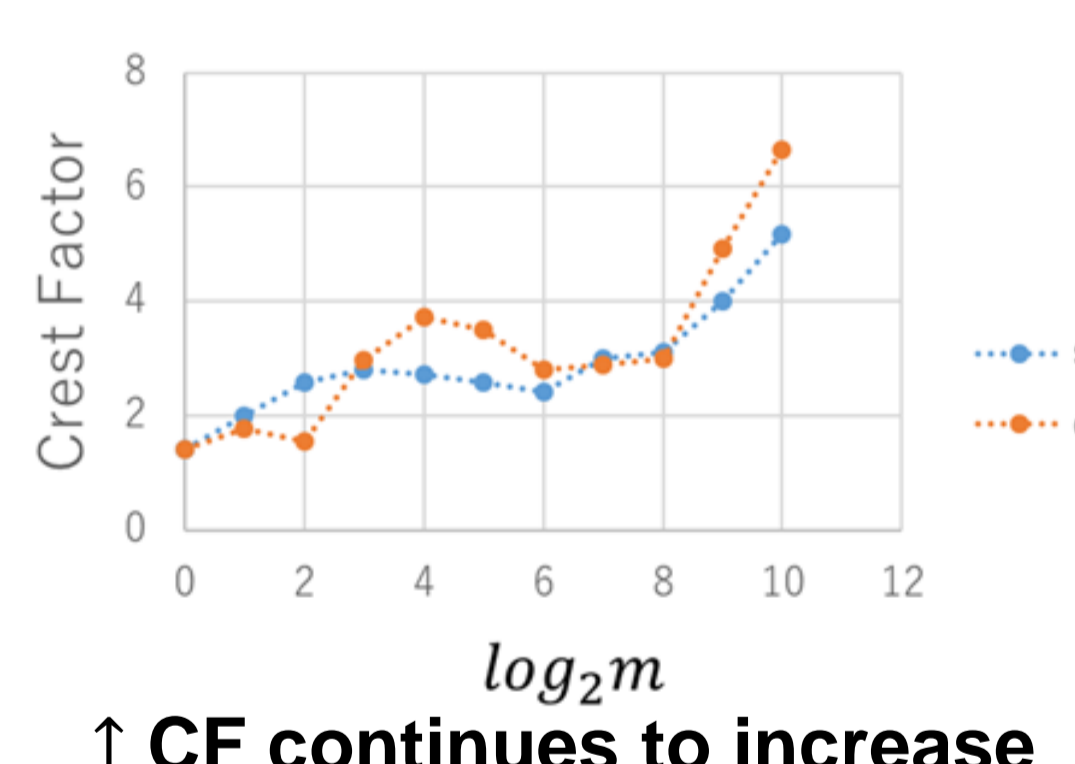


< Random phase >

Phase : random number



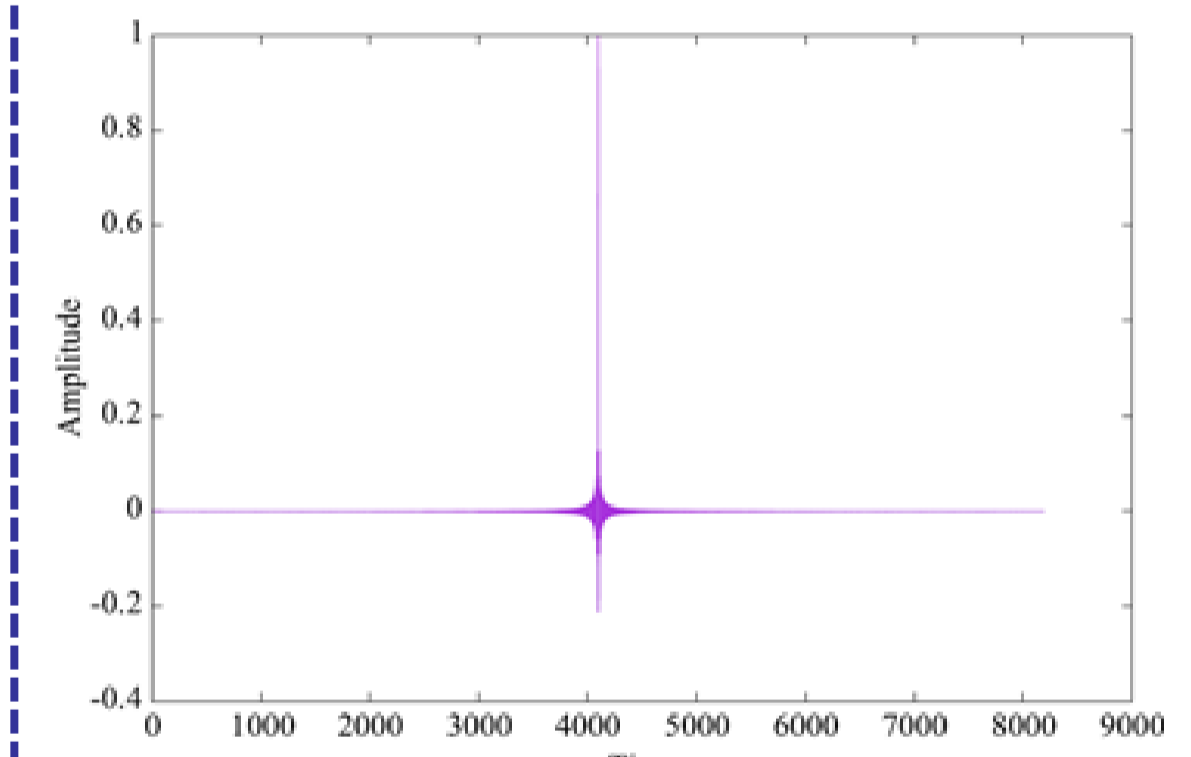
Waveform (m = 1024)



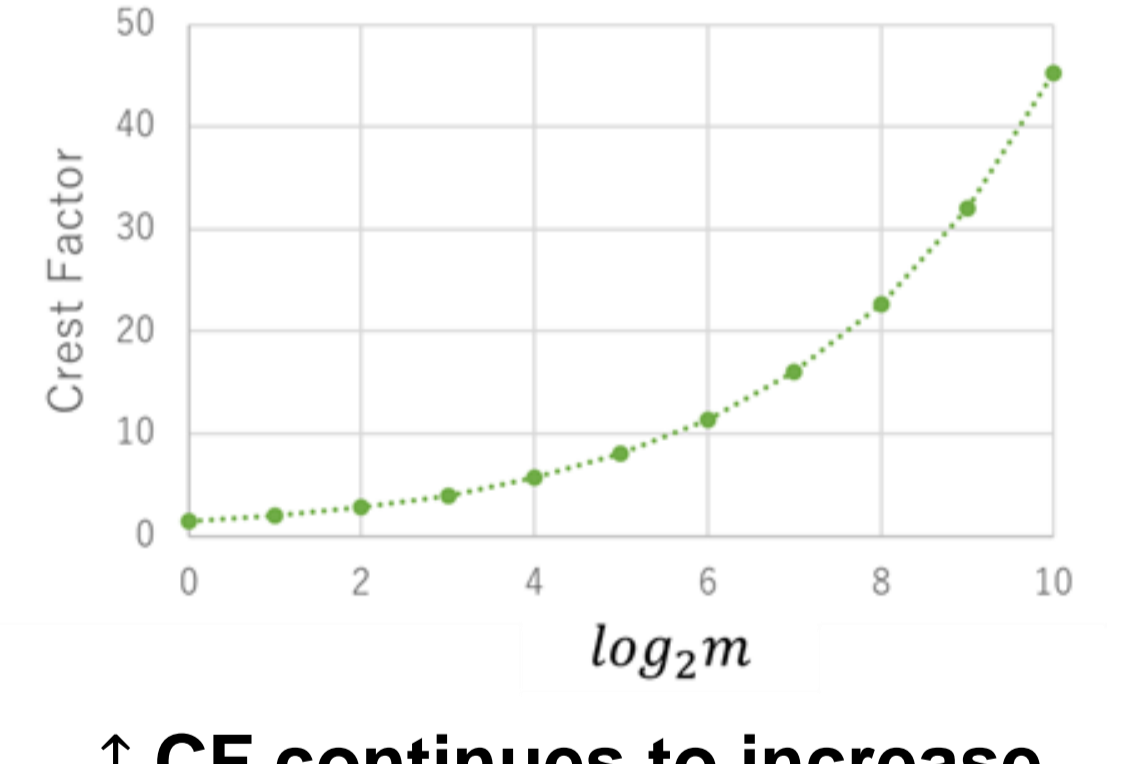
↑ CF continues to increase

< zero initial phase >

Phase : all 0

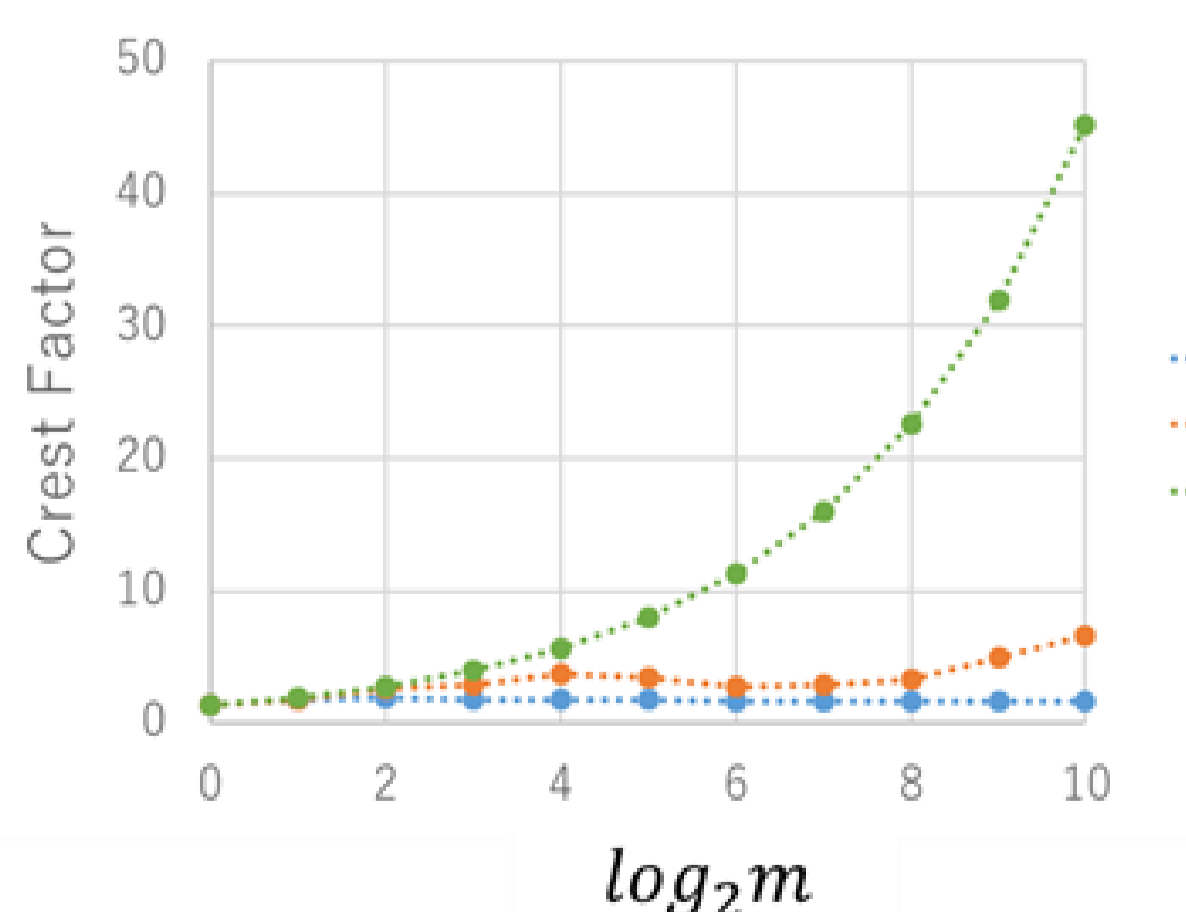


Waveform (m = 1024)



↑ CF continues to increase

## 6. Comparison



Newman : CF converge to around 1.7

Random : CF increase as m increase

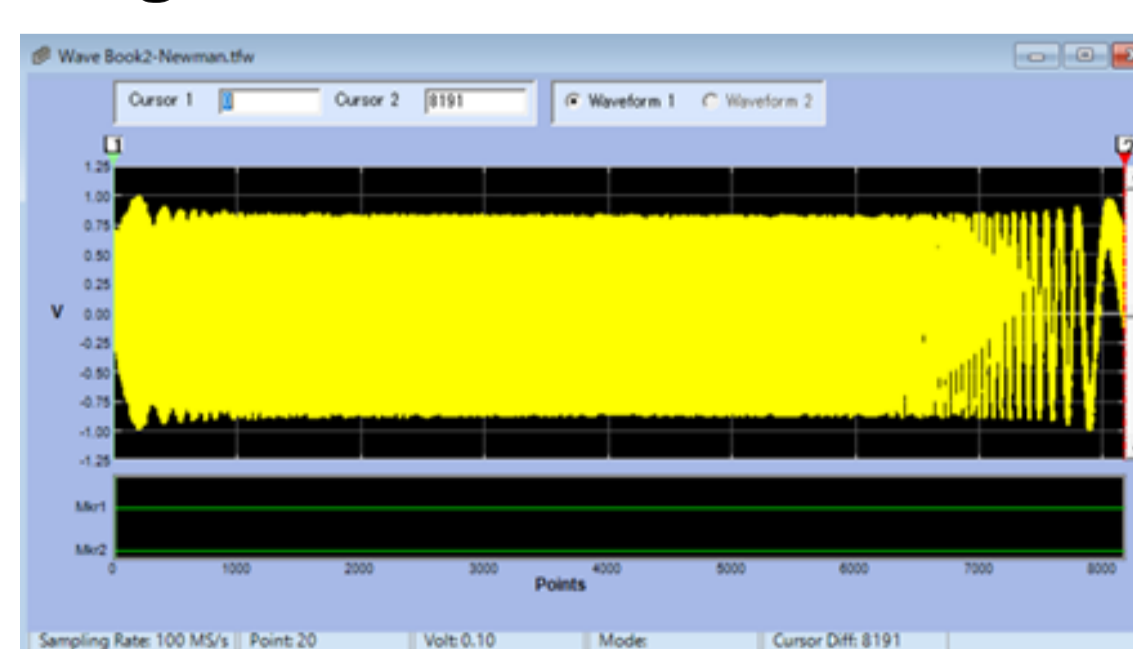
Zero : CF is rapidly increasing as m increase



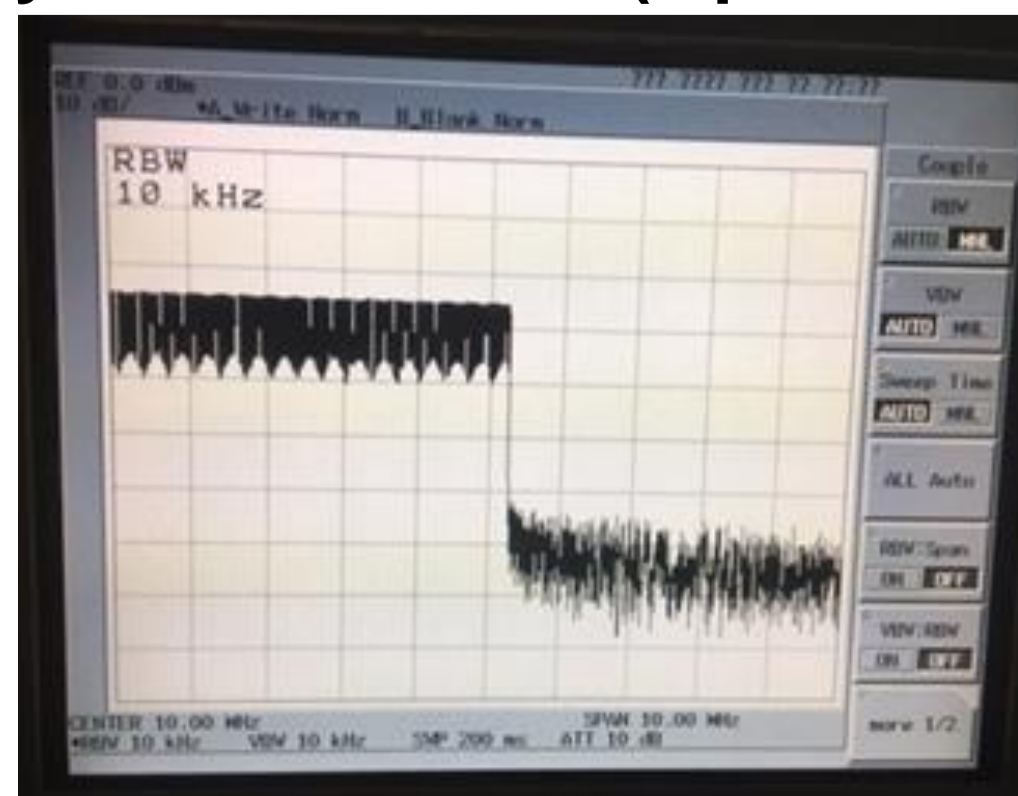
Algorithm properly reduces crest factor

## 7. Measurement Result

Kitayoshi algorithm:



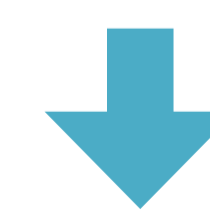
Frequency characteristics ( spectrum analyzer ) :



## 8. Conclusion

< Multi-tone signal >

Conventional : Bad SNR → Low quality test



Proposed :

Using dynamic range maximize algorithm for short-time & high quality testing

## References

- [1]H. Kitayoshi, et. al., "DSP Synthesized Signal Source for Analog Testing Stimulus and New Test Method", IEEE International Test Conference (1985).
- [2]D. J. Newman, "An L1 Extremal Problem for Polynomials", American Mathematics Society (Dec.1965).
- [3]M. R. Schroeder, "Synthesis of Low-Peak-Factor Signals and Binary Sequences with Low Autocorrelation", IEEE Trans. Information Theory (1970).