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CASCADED ALL-PASS FILTERS WITH RANDOMIZED CENTER FREQUENCIES AND PHASE POLARITY FOR ACOUSTIC AND SPEECH MEASUREMENT AND DATA AUGMENTATION

CAPRICEP

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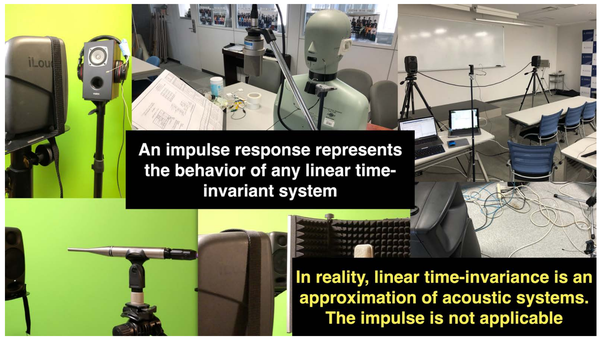
Resource

Take home message

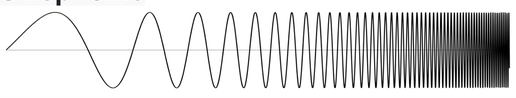
A new Time-Stretched-Pulse provides a solid foundation of acoustic measurements

- **Motivation:** Measure and record speech data acquisition and presentation conditions
- **Issues:** The target (real-world) systems consist of not only linear time-invariant but also non-linear time-invariant, random, and time-varying responses
- **Solution:** We invented a simultaneous measurement of multiple paths by combining extended TSP signals with binary orthogonal weight sequences
- **Solid foundation:** Cascading all-pass filters with randomized center frequencies and phase polarity yields an extended TSP, called **CAPRICEP**
- **Example application:** We open-sourced an interactive and real-time tool

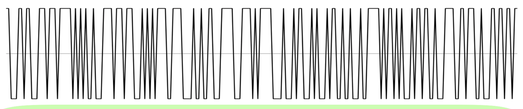


Time Stretched Pulses: TSPs

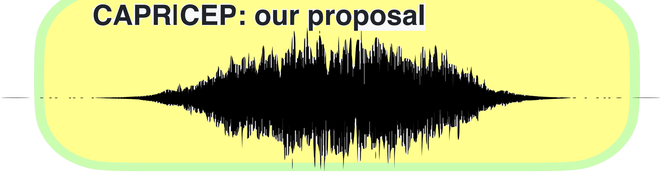
Swept sine



Maximum Length Sequence

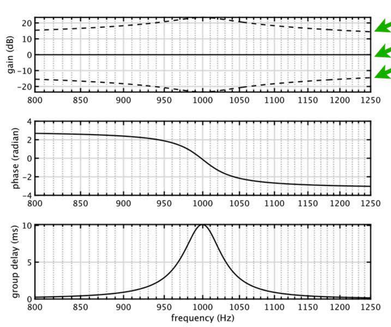


CAPRICEP: our proposal



All-pass filter: a building unit

Example: center frequency 1000Hz, bandwidth 20Hz



Gain by denominator (pole)
Cancelling yields constant gain
Gain by numerator (zero)

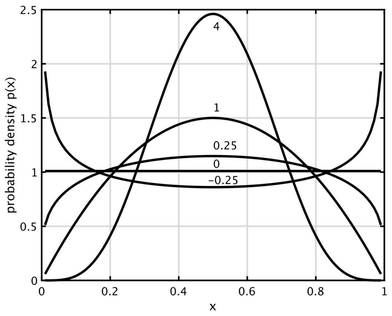
Cascading all-pass filters yields another all-pass filter

$$H_k(z) = \frac{z^{-1} - z_k^*}{1 - z_k z^{-1}}, \quad \left(\text{where: } H_k^*(z)H_k(z) = 1\right)$$

$$z_k = \exp\left(-\frac{\pi b_k}{f_s} + j\frac{2\pi f_k}{f_s}\right)$$

Randomization of center frequencies and phase

Beta distribution of center frequency distances and random polarity inversion for time axis reversal provide design flexibility



$$f_k = r_1[k]\, F_d \sum_{k=1}^{K} r_2[k]$$

polarity randomization — frequency distance randomization

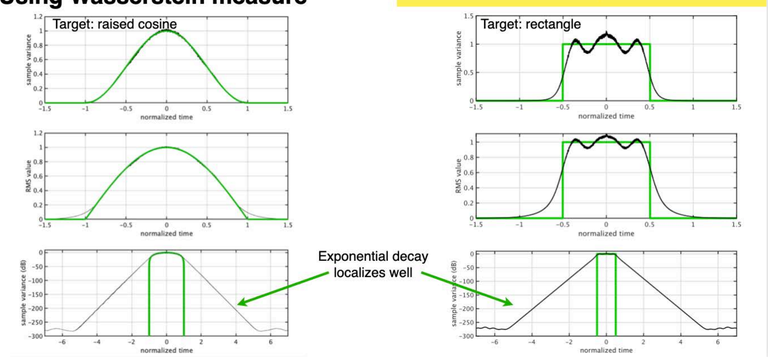
$$b(x) = \frac{x^{\alpha-1}(1-x)^{\beta-1}\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}$$

This time, for simplicity, we set $\alpha \equiv \beta$

Shape design examples

Using Wasserstein measure

More than thousands design parameters provides flexibility, and independence between TSPs
→ simultaneous multi-path measurement

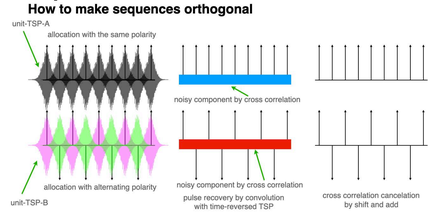


Simultaneous multi-attributes measurement:

Simultaneous multi-pass measurements yields linear time-invariant, non-linear time-invariant, as well as random and time-varying responses

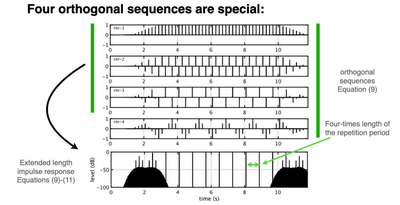
Repetitive allocation of unit-TSPs

How to make sequences orthogonal



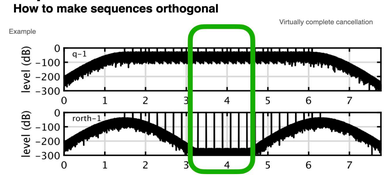
Simultaneous measurement

Four orthogonal sequences are special:



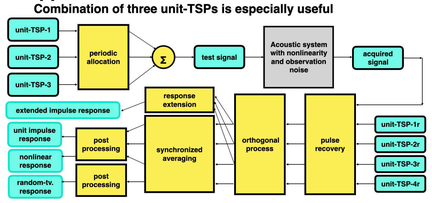
Repetitive allocation of unit-TSPs

How to make sequences orthogonal

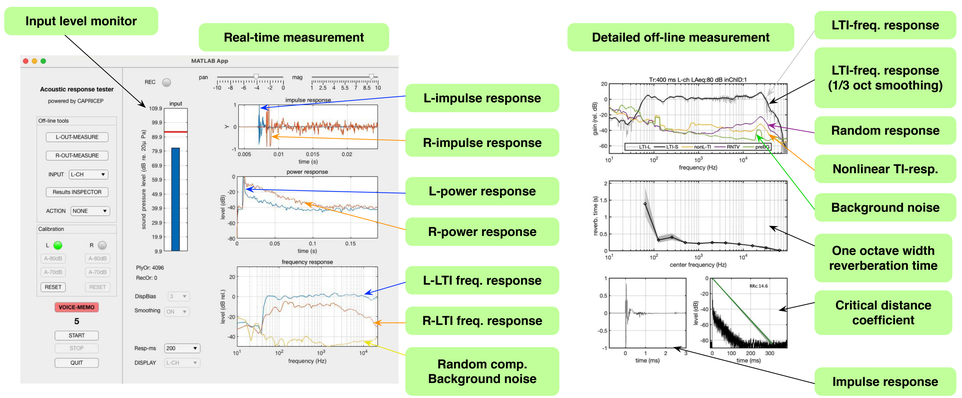


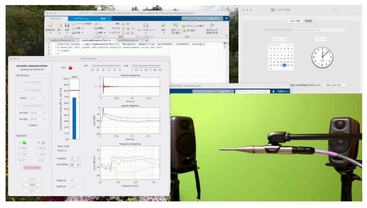
Application to acoustic measurement tool

Combination of three unit-TSPs is especially useful



Application example:
Interactive and real-time acoustic measurement tool





GitHub

YouTube