# DTFT: Touch-Tone Signals & FIR Filter Design

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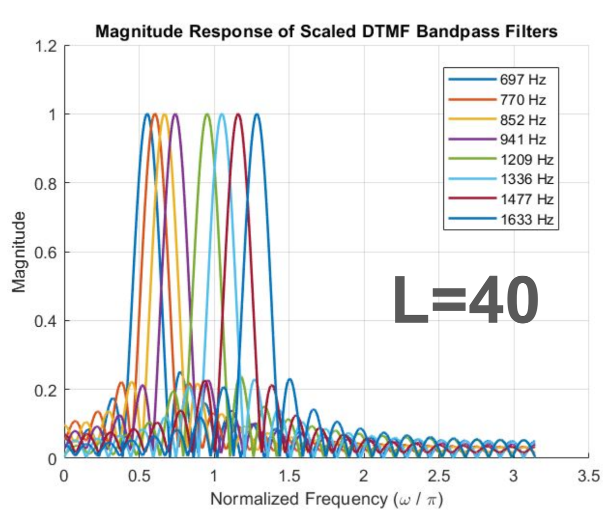
## Introduction

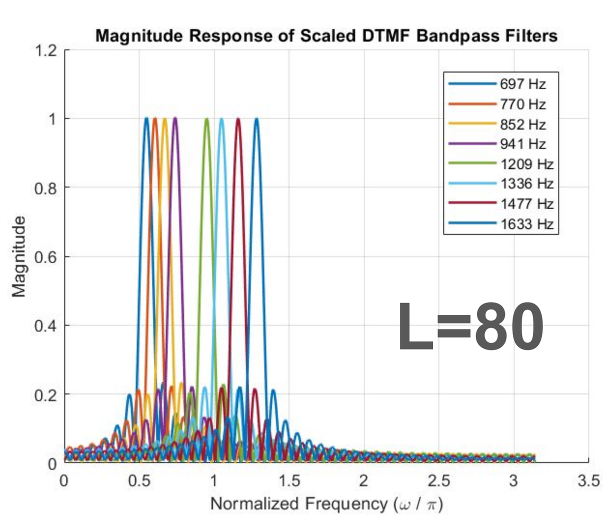
- Aim is to design and implement bandpass FIR filters in MATLAB, and perform automatic decoding
- Designing bandpass filters under specifications such as bandwidth, noise correlations, window lengths etc.
- Application of dual tone multi frequency phone dial sounds

## Simple Bandpass Filter Design




$$h[n] = \beta cos(\frac{2\pi f_b n}{f_s}).$$

$$0 \leq n \leq L-1$$



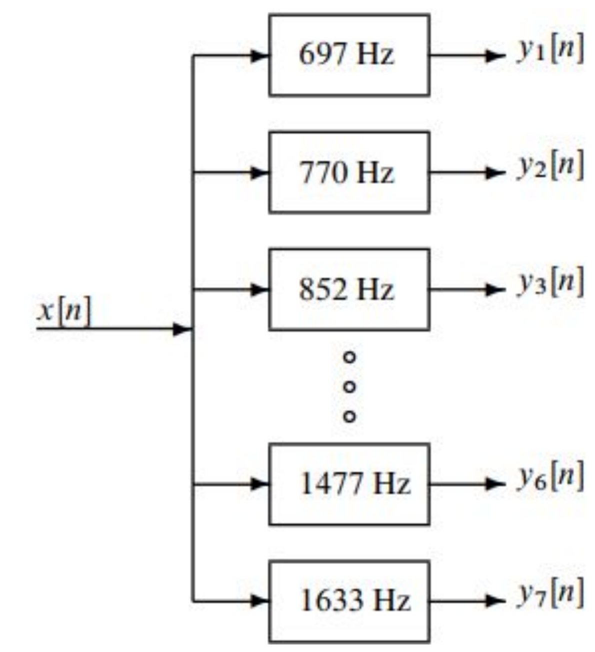

- L = filter length
- β = Gain scaling
- fs = Sampling Frequency

## Scoring Function

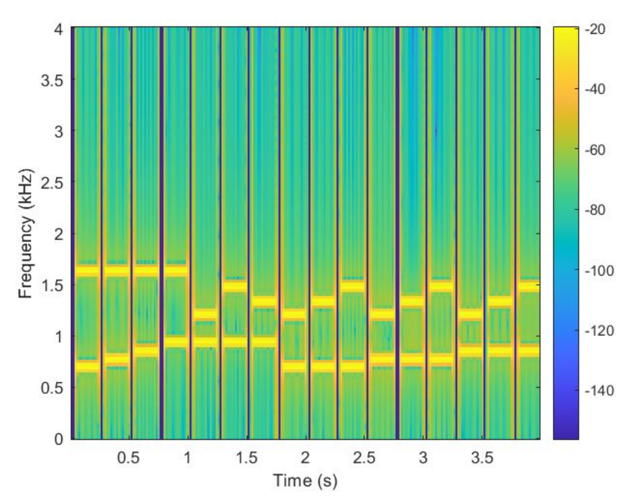
- This function made the binary decision of presence or absence of individual tones.
- Input signal is normalized, then scored using the following
  - if (max(|y[n]|) >= 0.59) return 1
  - else return 0
- Gain and attenuation factors in the two tonal sinusoids

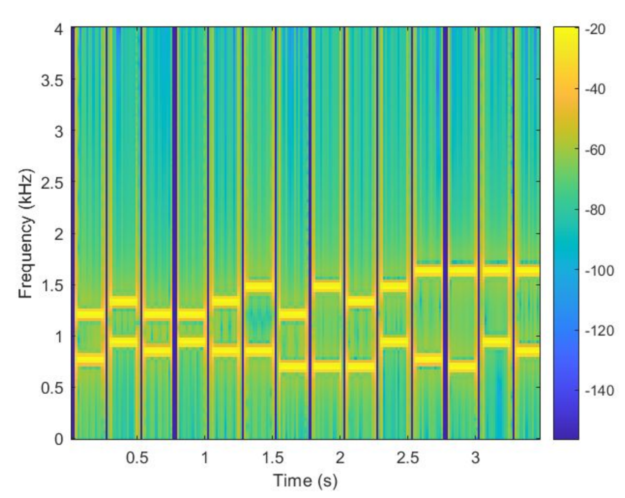
## DTMF Decode Function

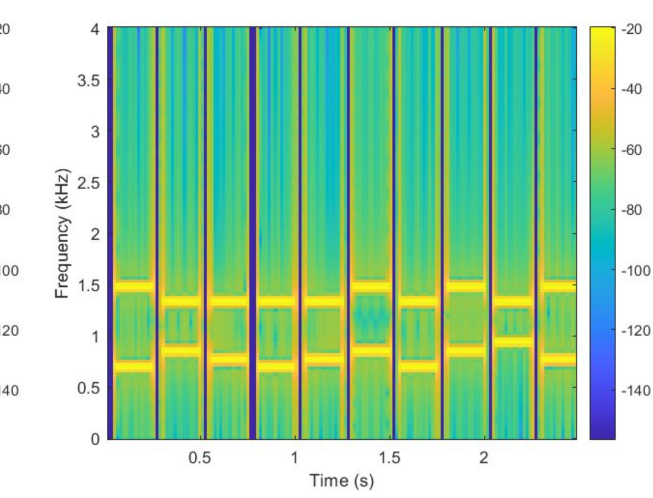
- Designs bandpass filters identifies pressed tone using the dtmfscore function
- If one row and one column identified by dtmfscore,
  - Success and return decoded keys
- Else return and try again




## Telephone Numbers





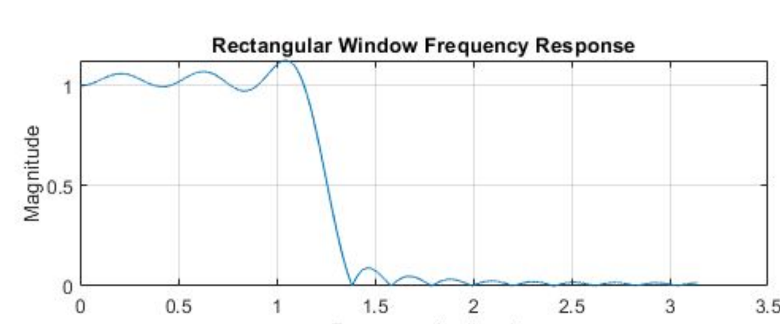


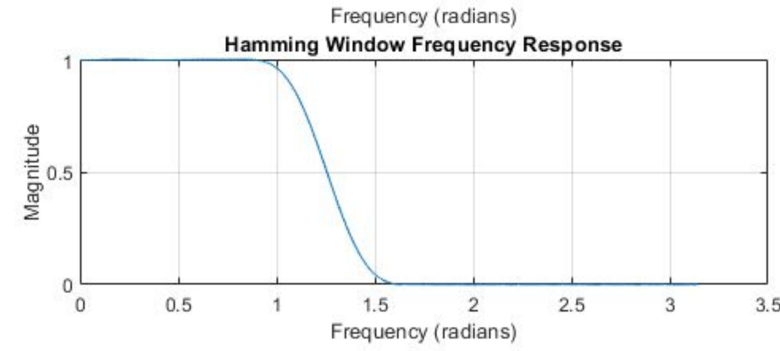
ABCD*#0123456789 407*89132#BADC 3852592906

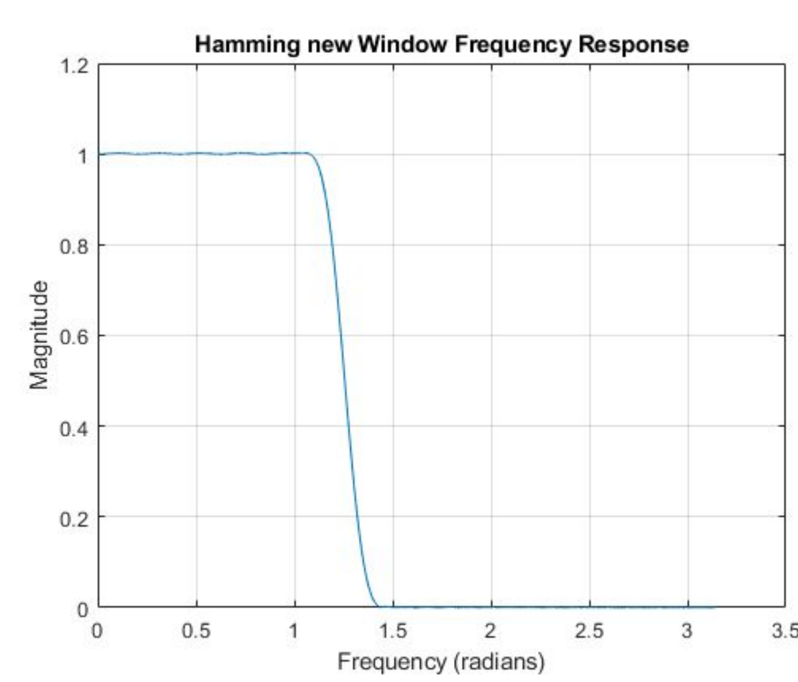
- These spectrograms represent different alphanumeric combinations to test outputs of the complete DTMF system

## Designing Two Lowpass Filters

- Visualization of filters' frequency responses
- Measurement of passband and stopband edges for Rectangular and Hamming windows
- Cutoff frequency comparison




## Transition Zone of Lowpass Filter

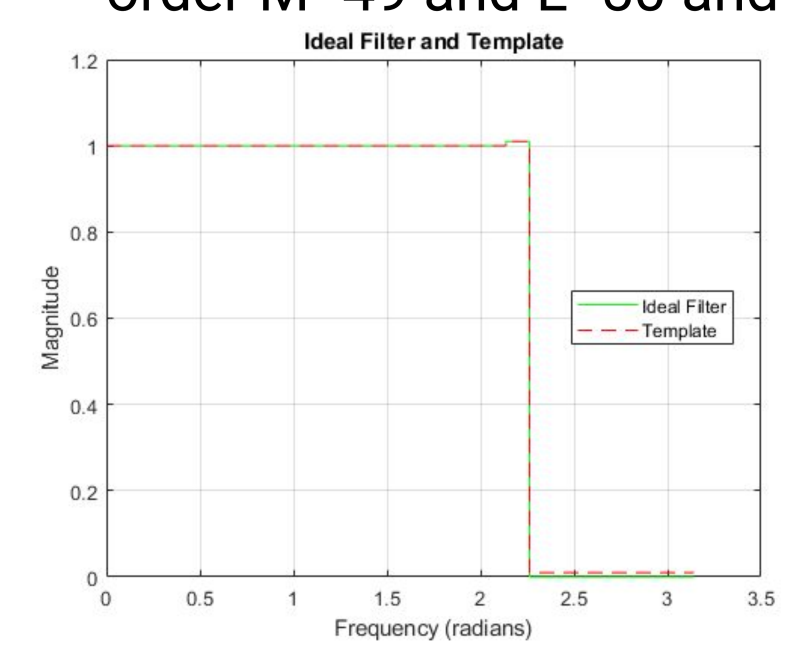
- Determination of transition width for both filters
- Insight into the relationship between transition width and filter order and C=18.3
- Design and measurement of a new Hamming-window LPF with double the order

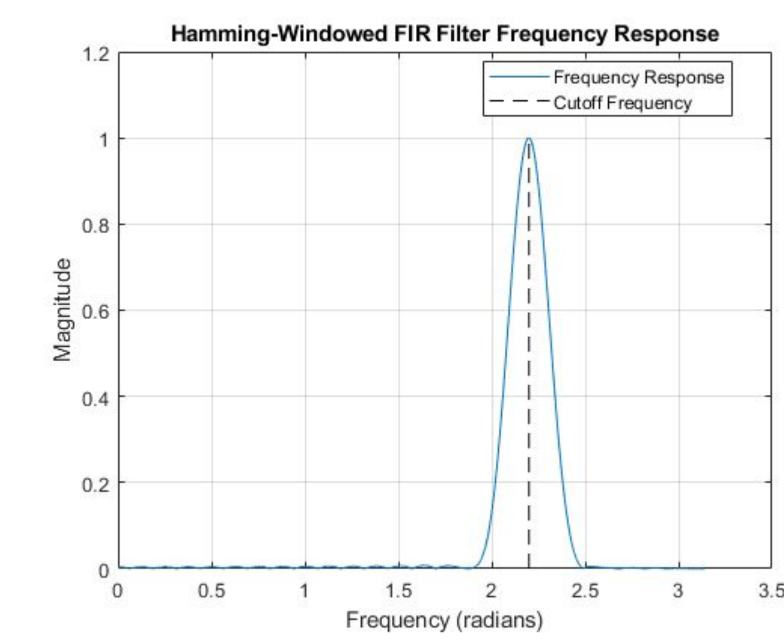
$$\Delta\hat{\omega} = \frac{C}{L}$$

## Filter Design from Specifications

- Prediction and justification of the filter length and order using the Hamming window design formula
- Design and measurement of a Hamming-windowed FIR filter with the predicted order M=49 and L=50 and cutof frq wc=2.199

$$M = \frac{-20\log_{10}(\delta_s)}{6.6\times(\omega_s-\omega_p)}$$




## Conclusions

- Intricacies of lowpass filters, comparing the performance of Rectangular and Hamming window designs were explored.
- Our journey led us through three key sections, each shedding light on different aspects of FIR filters.
- Application of FIR Bandpass filters were investigated using dual tone multi frequency (DTMF) signals
- Finally, we implemented FIR filters from given specifications