# Phase Tracking of Slow and Fast Tone Sequences in Human Auditory Cortex


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## Introduction

### *How does the human brain encode incoming auditory signals?*

• First an initial short-term Fourier transform at the inner ear

• Separate streams for envelope (e.g. the Hilbert transform) and fine structure processing (see, e.g. Smith et al., and Zeng et al.)

Auditory steady state response (aSSR) studies by Ross et al(2000) provide evidence for the deconvolution of sound **envelopes** in the human auditory cortex. Patel & Balaban (2004) suggest that the **phase** of the aSSR can track **fine structure** change.

### *Our questions*

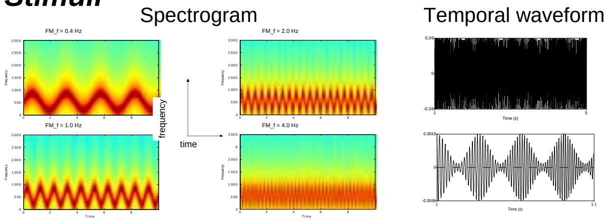
• How does the brain represent different dynamics in fine structure?

• To investigate the issue, using a high time resolution technique to record from human auditory cortex (MEG), we use AM-FM auditory stimuli, which have both simple dynamic envelope and simple dynamic fine structure properties.

• We investigate the following questions.
1) Is there any threshold in encoding fine structure dynamics?
2) Is there any transition in encoding from slow changing to fast changing fine structure?

## Methods

### *Stimuli*



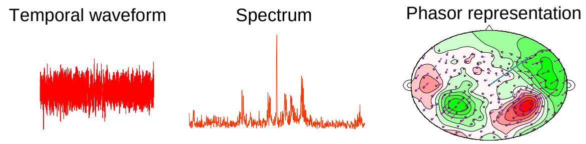

Frequency modulated tones with amplitude modulation of 37Hz
Stimulus duration: 10 sec ; Frequency range: 220-880Hz; AM_f (37 Hz);
Subject 1: FM_f (0.2, 0.4, 0.8, 1.0, 1.6, 2.0, 4.0, 6.0, 8.0 Hz)
Subject 2: FM_f (0.3, 0.5, 0.8, 1.0, 1.7, 2.1, 3.0, 5.0, 8.0 Hz)

### *Recording and Analysis*

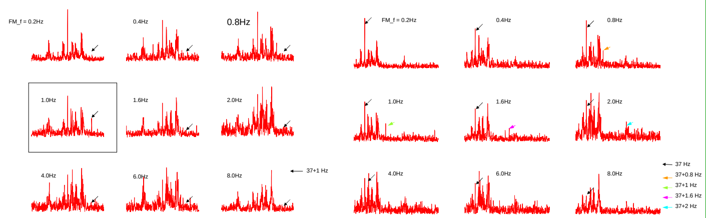
• 160 channel axial gradiometer whole head MEG (KIT system)
• Sampling rate 1000 Hz and on-line anti-aliasing filtering from 1~100Hz
• 9 conditions (9 FM_f) and 12 repetitions for each condition
• Single-trial data for identical conditions (same FM_f) were concatenated (12 epochs in total, 120 sec)
• DFT of the epoch data were calculated
• Based on the amplitude of the AM_f (37 Hz) frequency component, channels were sorted
• AM_f+FM_f and AM_f-FM_f frequency components were selected, and the amplitude for all channels (157) and all conditions (9) on these frequency points (9*2) were calculated (157 channel * 18 frequency points * 9 conditions)
• For each channel data, at single frequency points, the condition (stimulus) that evoked the maximum amplitude at this frequency was selected. (157*18*9 -> 157*18). On the 157*18 (channels*frequency points) data, the 157 channel maximum stimulus distribution was drawn.

## Results

### *Steady State Response (37Hz)*

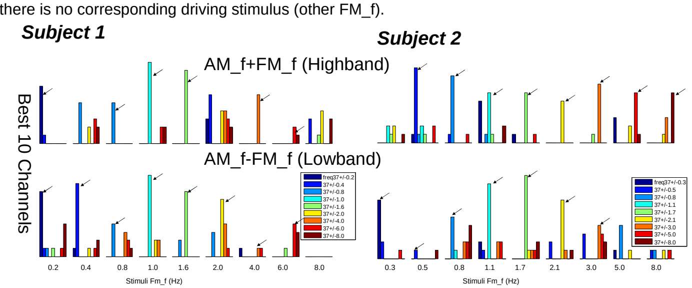



### *Steady State Response at sidebands (new!)*




### *Summary across channels*

To detect the aSSR at sidebands from noise, for each sideband frequency (AM_f+FM_f, AM_f-FM_f), we compare the power when there is a corresponding driving stimulus with the power when there is no corresponding driving stimulus (other FM_f).

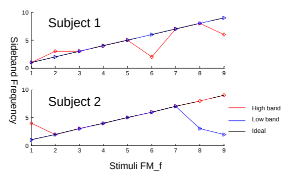



In the above distribution data, different color bar means different sideband frequencies, and x axis represents different FM_f stimuli conditions. For example, in subject 1 upper figure, the green bar means there are 9 out of 10 channels that have maximum power at sideband (37+1.6 Hz) when stimulus has FM_f of 1.6Hz. If we compare the different-color bar height (the number of channels) at same x axis (stimuli FM_f), we can tell which sideband frequency is relatively induced maximally by this stimulus with certain FM_f. For example, in subject 1 lower figure, when stimuli FM_f=0.2Hz, the deep blue bar has the maximum heights among all others, and it means sideband at 37-0.2 Hz is induced relatively maximally by stimuli with FM_f=0.2 Hz than other low sidebands.

#### *Summary of data*

To give a more concise summary of the above distribution data, for each x-axis points (the stimuli FM_f, and we use 1-9 to represent the FM_f from 0.2-8.0Hz for subject 1 or 0.3-8.0Hz for subject 2), we chose the bar that have maximum heights (we also use 1-9 to index the bar. For example, in the highband, frequency 37+(0.2~8) is represented by 1-9), and we draw a line based on this data.

Ideally, when stimuli FM_f=0.2 (index 1), the bar selected would be frequency 37+0.2 Hz (index 1) in highbands, and 37-0.2 Hz (index 1) in lowbands.



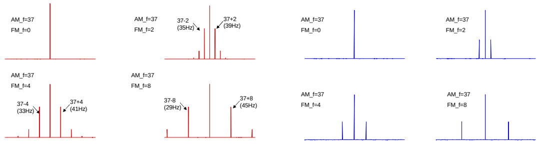

## *Simulations (Spectrum)*

**Phase Modulation**

sin(2*pi*AM_f*t+sin(2*pi*FM_f*t))

**Amplitude Modulation**

(1+m*sin(2*pi*FM_f*t))*sin(2*pi*AM_f*t)



Both models can account for the present data, subsequent experiments will be prepared to distinguish among the possibilities

## Conclusions

• The AM-FM co-modulation stimuli have both simple dynamic envelope and fine structure and can be used to investigate the **co-representation** of envelope and fine structure modulation in the brain.

• We propose a more simple and efficient analysis way to study the fine structure dynamics processing in human cortex by looking at sidebands steady state responses.

• At high FM_f as high as 8Hz (the highest tested), the fine structure dynamics tracked by auditory cortex are also tracked in MEG signal.

•Our experiment provides strong evidence of encoding fine structure dynamics by modulating the envelope frequency component in human auditory cortex.

•Our observation are consistent with Patel and Balaban's findings in low FM_f, and we extend their findings by testing high FM_f, the more dynamic fine structure stimuli.

## References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