VIETNAM NATIONAL UNIVERSITY – HO CHI MINH CITY
UNIVERSITY OF INFORMATION TECHNOLOGY

Chapter 3

SIGNAL PROCESSING

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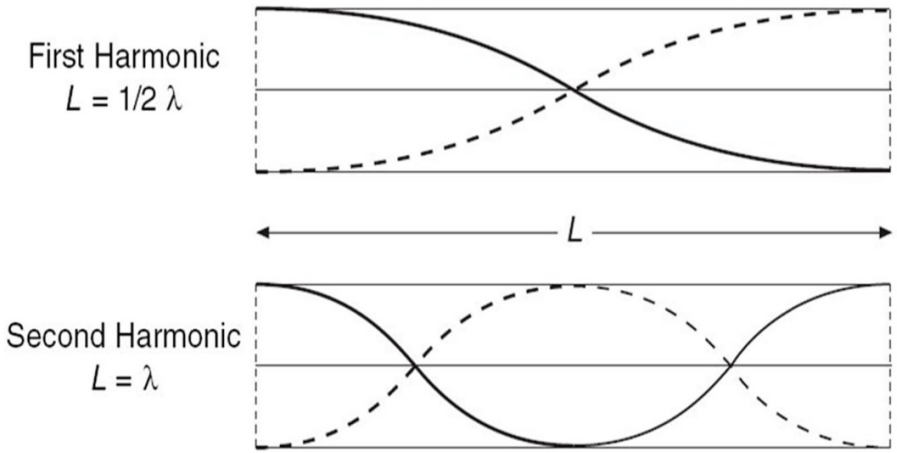
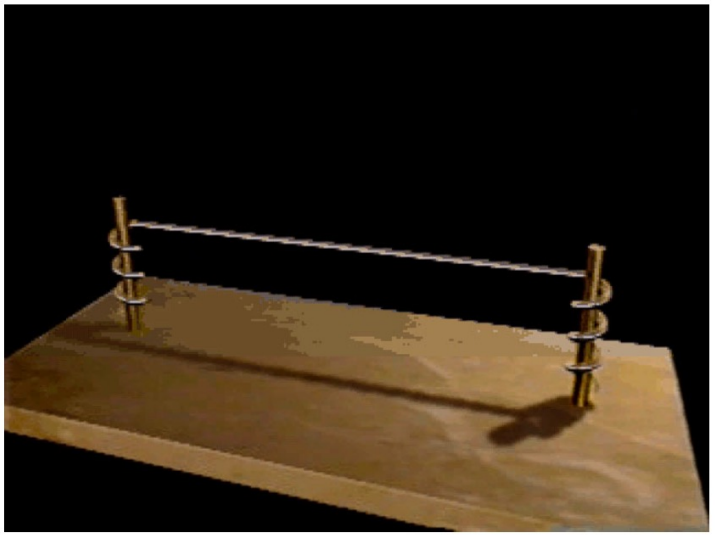
Sound Generation and Propagation

Sound is generated by vibration

$f_n = \frac{nc}{2l}$, Two-end closed, or open





Historical Review of Speech Processing

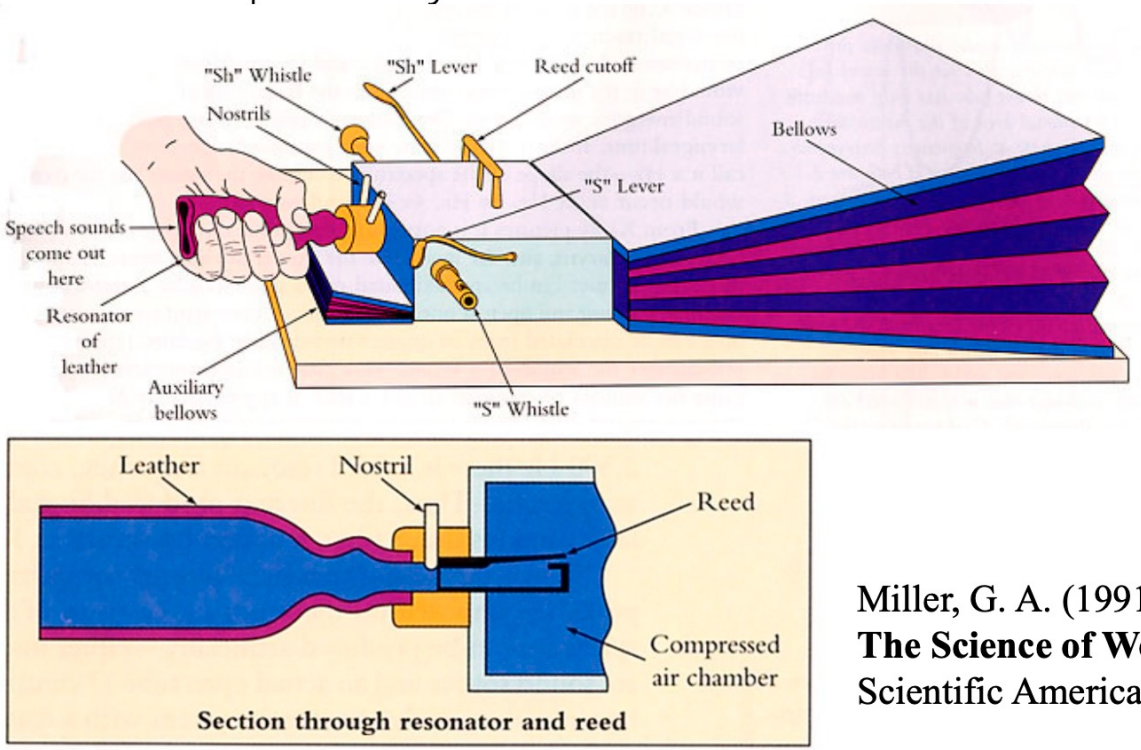
- 19th Century
  - Classic acoustics with mechanical instruments
- 1900 – 1945
  - Development of microphone, amplifier, and Fourier theorem
  - Studies on vowel: vocal-tract resonance and vowel formants
- 1945 – 1980
  - Development of Sound Spectrograph and Pattern Playback
  - Studies on consonants, syllables, and connected speech

Historical Review of Speech Processing

- 1965 – Present
  - Development of digital systems
  - Methods for speech analysis, synthesis, and recognition
  - Artificial intelligence (G1) for spoken language processing

Historical Studies on Articulation

Mechanical speech synthesizer



Miller, G. A. (1991).
The Science of Words.
Scientific American.

Reproduction of von Kempelen's ***Speaking Machine*** by Sir C. Wheatstone (1837)

Vowel synthesizer by H. von Helmholtz

19th-century physicists replicated **harmonic structure of vowels** rather than vocal tract resonance.

Helmholtz' synthesizer used electromagnetic **tuning forks** and **Helmholtz resonators**

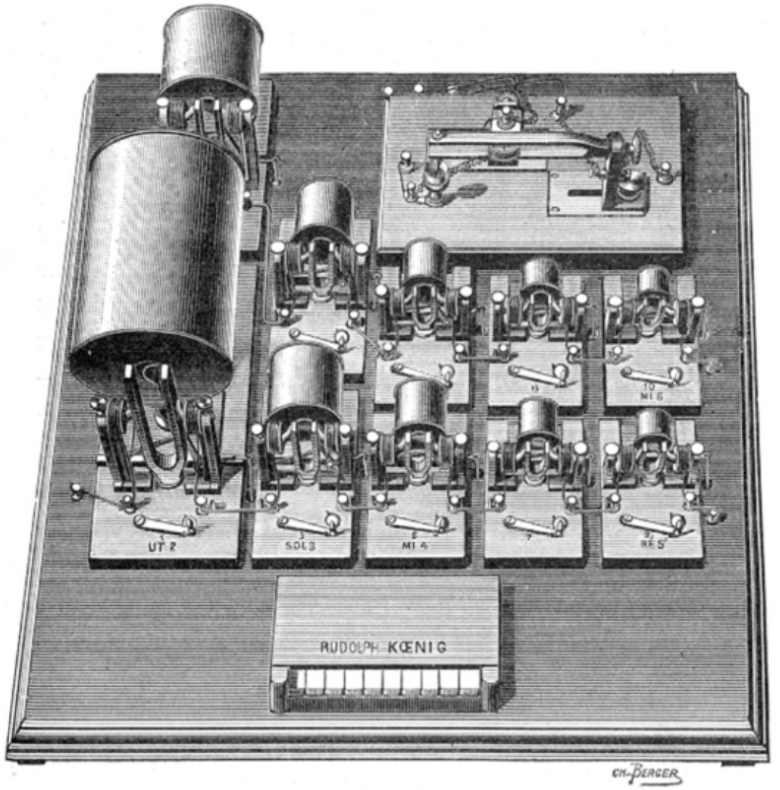
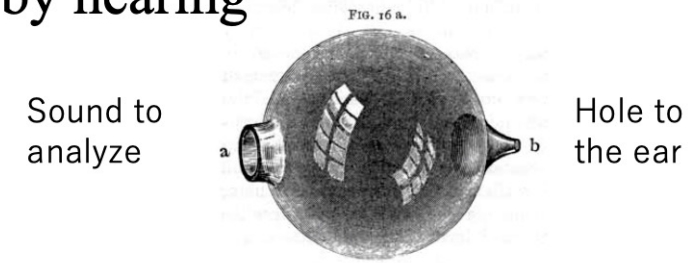


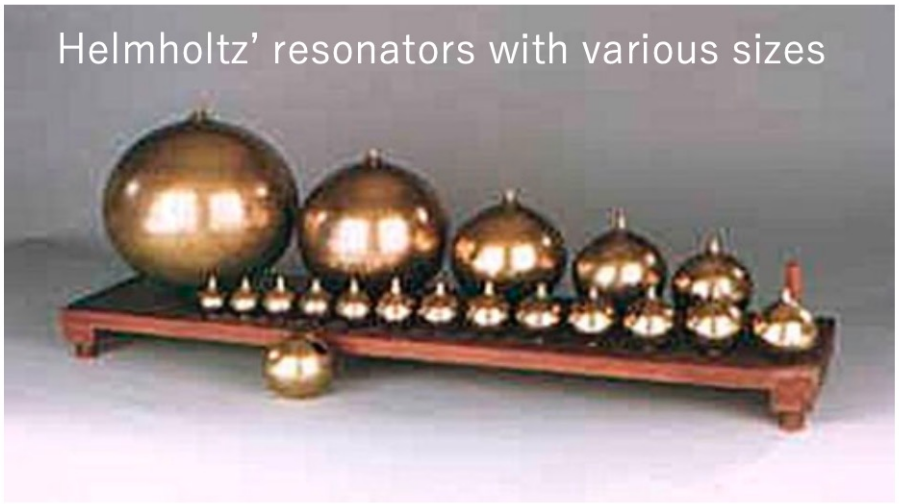
Fig. 78.

Appareil pour reproduire les voyelles, de Helmholtz.

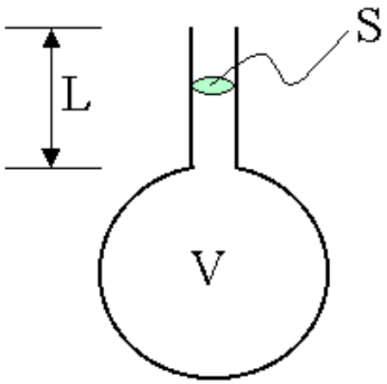
Subjective Analysis by H. von Helmholtz

Helmholtz resonator for sound analysis by hearing





Resonance frequency of a typical Helmholtz resonator

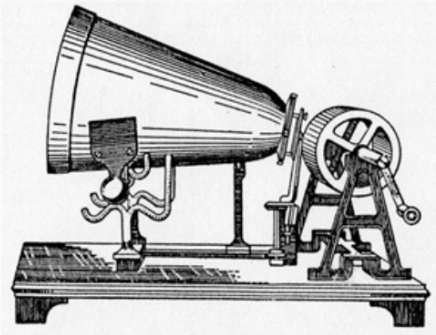


$$f_0 = \frac{c}{2\pi}\sqrt{\frac{S}{LV}}$$

Mechanical Recording and Analysis

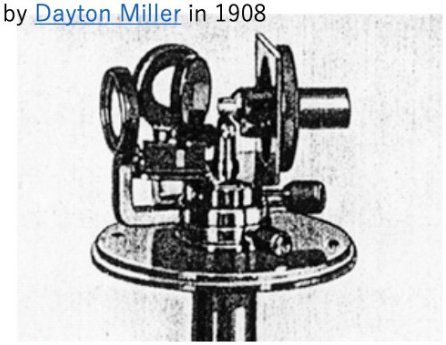
Phonautograph

(1857, by Franch) vibrating a needle



Phonodeik

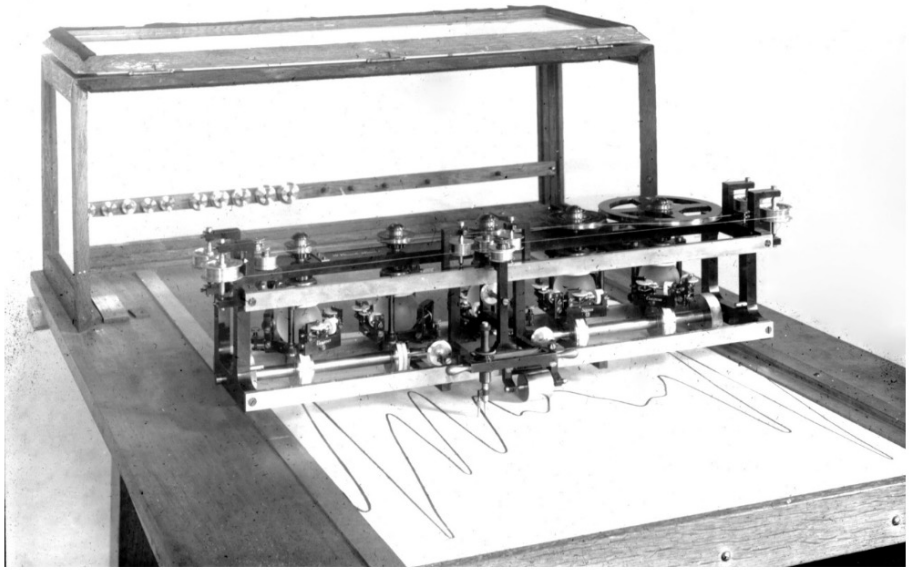
by Dayton Miller in 1908



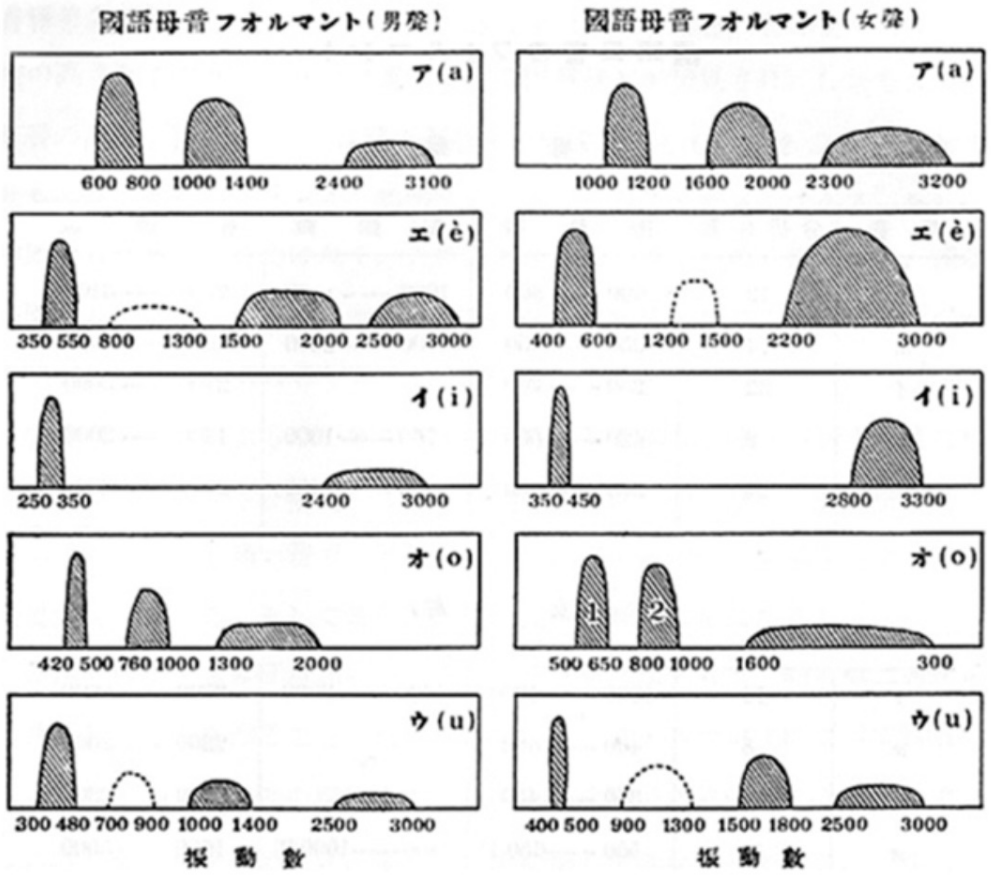
using photographic material to record sound.

Mechanical spectral analyzer by Henrici

Photograph of speech wave is traced by the analyzer to calculate intensity of harmonic components based on the Fourier theorem.



Analysis of Vowel Formant



Research topics in early 20th century

How many formants for each vowel?

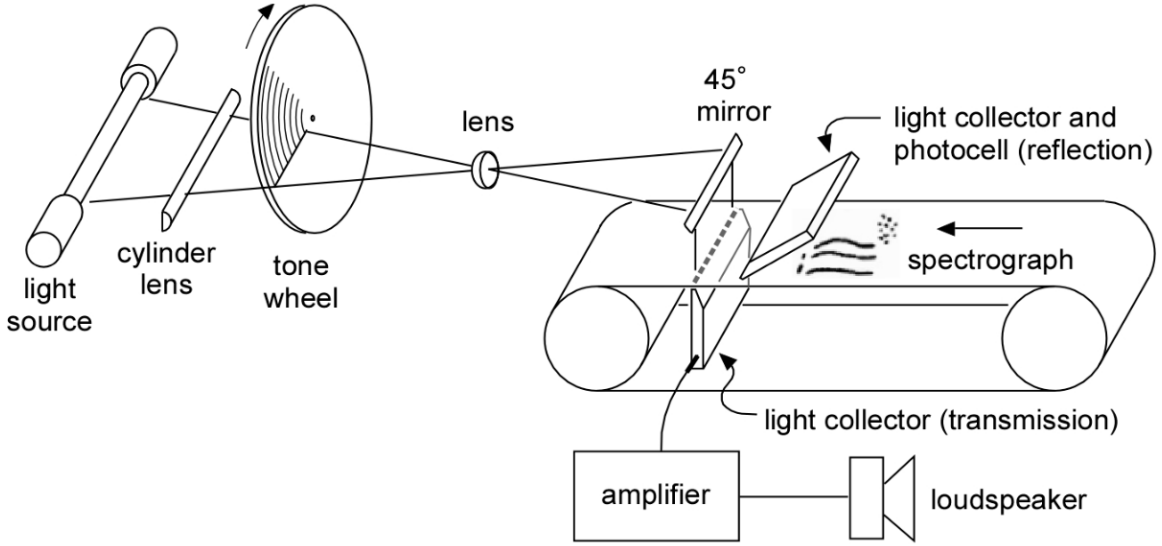
Vowel formants are fixed or variable?

'Formant' is given to a spectral peak in vocal and musical sounds.

Pattern Playback

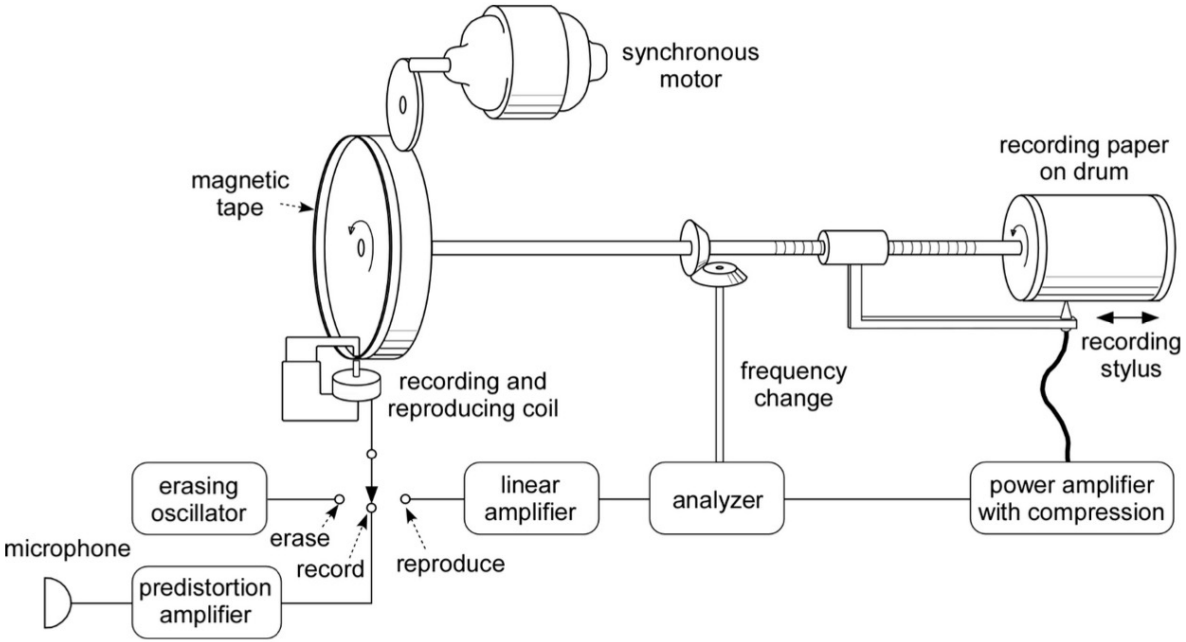
Opto-mechanical synthesizer (Cooper, et al., 1953)

- Mechanical speech synthesizer based on (1) long sheets of spectrograph and (2) transparent sheets with hand-written formant patterns
- 50-channel light beams are casted on spectrograph patterns.
- Harmonics of source sounds are intensified on formant bands.



Sound Spectrograph

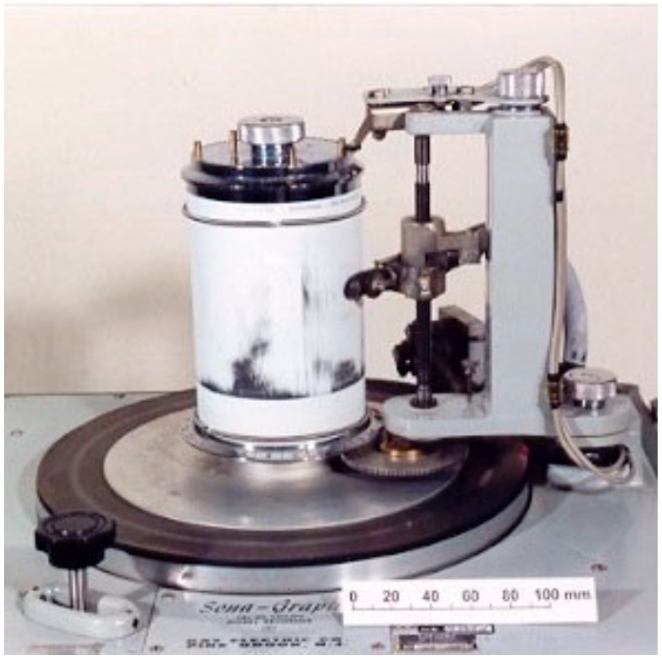
Electromechanical analyzer (Potter, et al., 1947)
The sound spectrograph was developed at the Bell Labs in 1941 as a military-purpose equipment for speaker identification of radio messengers. After the war, it was used for basic speech research (Joos, 1948; Delattre, et al., (1951).

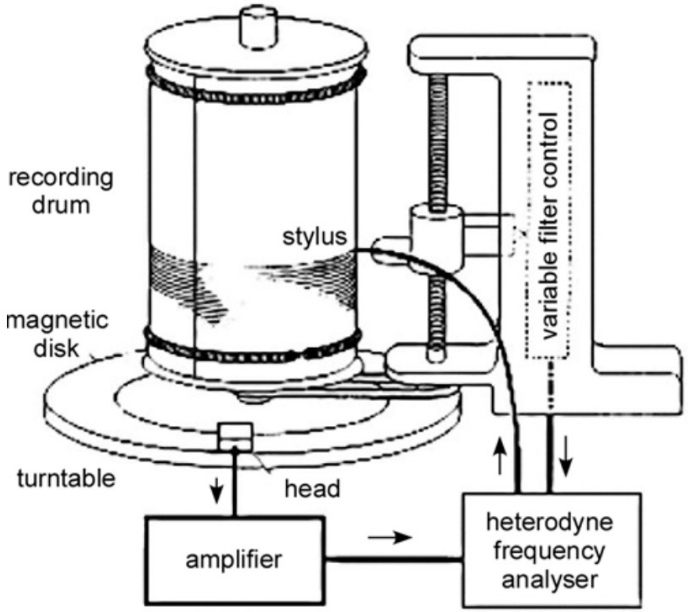


Heterodyne frequency analyzer was used.

Sound Sound Spectrograph (Sonagraph)

(1)Recording of sound (2.4 sec) is conducted on a magnetic tape of the turntable.
(2)Sound is played back repetitively synchronized with rotation of recording paper.
(3)Output signal via a bandpass filter burns on spark-sensitive paper.





Numerous Contributions of Sound Spectrograph to understanding speech signals

1. An F1-F2 diagram with reversed axes can classify vowels.
   - The first formant (F1) indicates tongue height.
   - The second formant (F2) tells front-back tongue position.

2. Formant frequencies differ within and across speakers.
   - Vowels are ‘coarticulated’ due to consonant environments.
   - Vowel formants may be normalized by the human ears.

3. Stop consonants are characterized by F1 and F2 transitions.

Speech Analysis Techniques

- Fast Fourier Transform (FFT)
  - Analyze harmonic structure
- Cepstral Analysis
  - Analyze spectral envelope
- Linear Predictive Coding (LPC)
  - Analysis of formants (spectral peaks)
  - Compression of speech signals
  - Two versions of LPC:
    - Autoregressive method
    - Covariance method (Burg's method)

Homework 3

Speech Analysis Techniques