

Vocoder Taxonomy

a story of missed opportunities

Stefan Stenzel stefan@ioptigan.com

Vocoder purpose

civil and military

musicians

Vocoder purpose

civil and military

- Speech transmission

musicians

Vocoder purpose

civil and military

- Speech transmission
- Compression

musicians

Vocoder purpose

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- Speech transmission
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- Encryption

musicians

Vocoder purpose

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- Robotic voices

Vocoder purpose

civil and military

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musicians

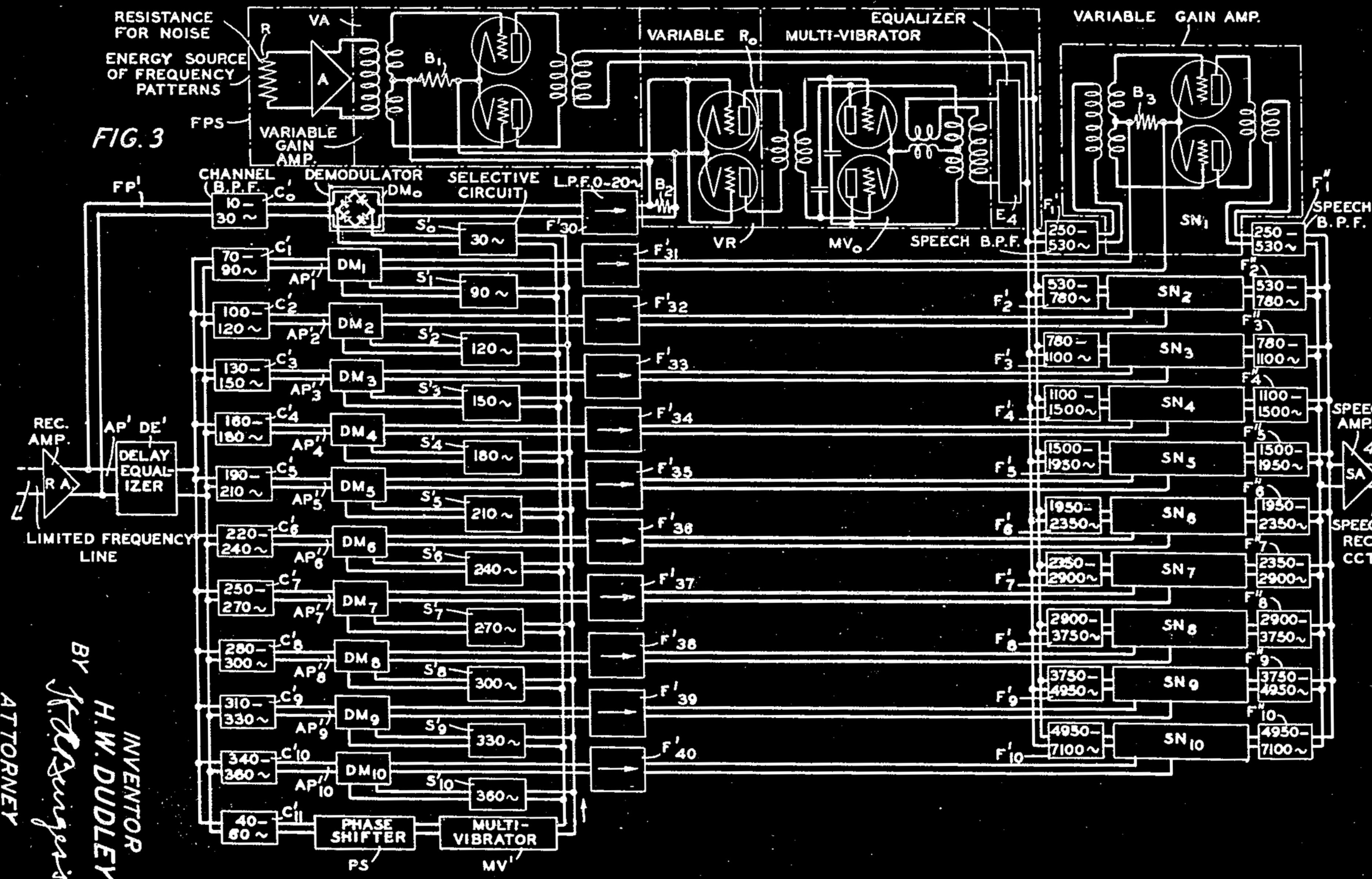
- Robotic voices
- Making music and hide the fact that you cannot sing

YE OLDE CHANNEL VOCODER

SIGNAL TRANSMISSION

Filed Oct. 30, 1935

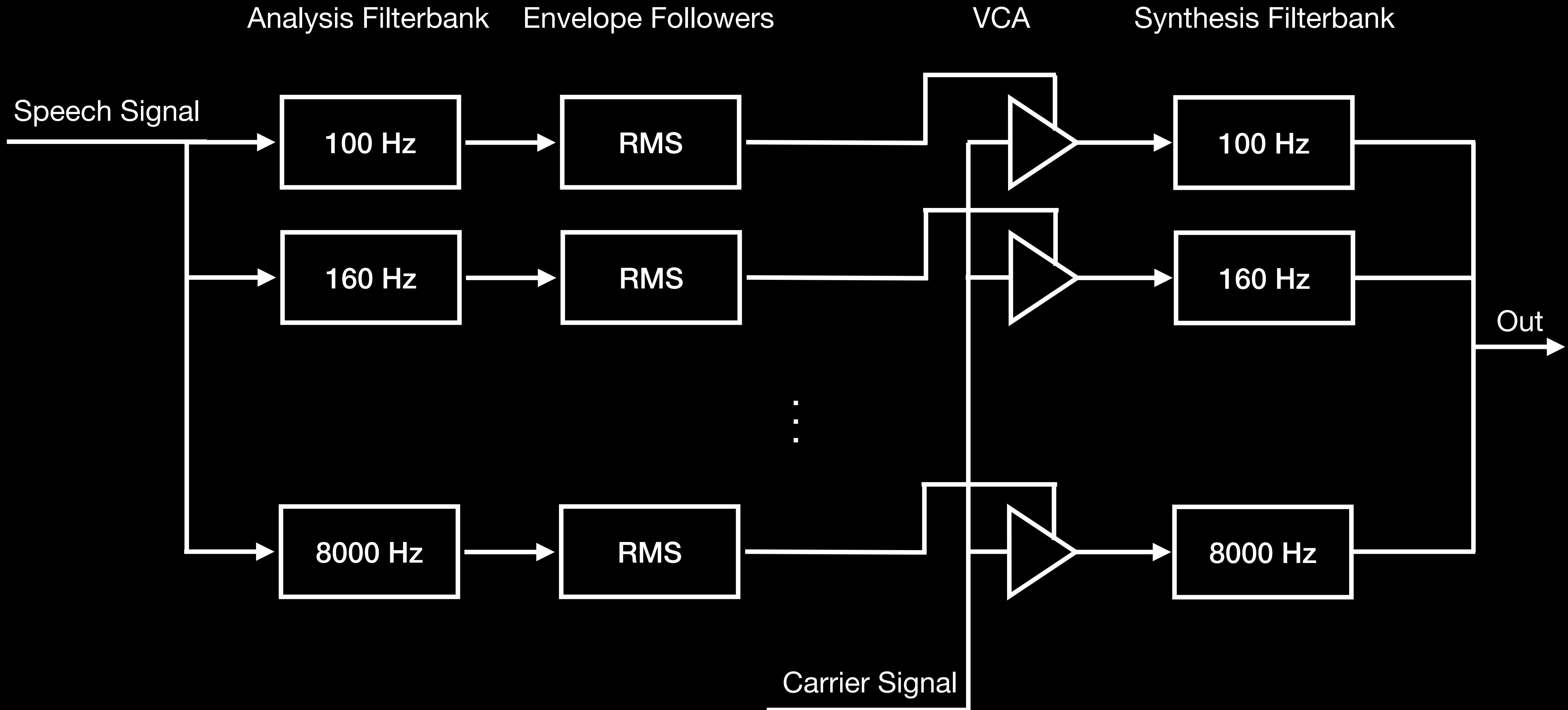
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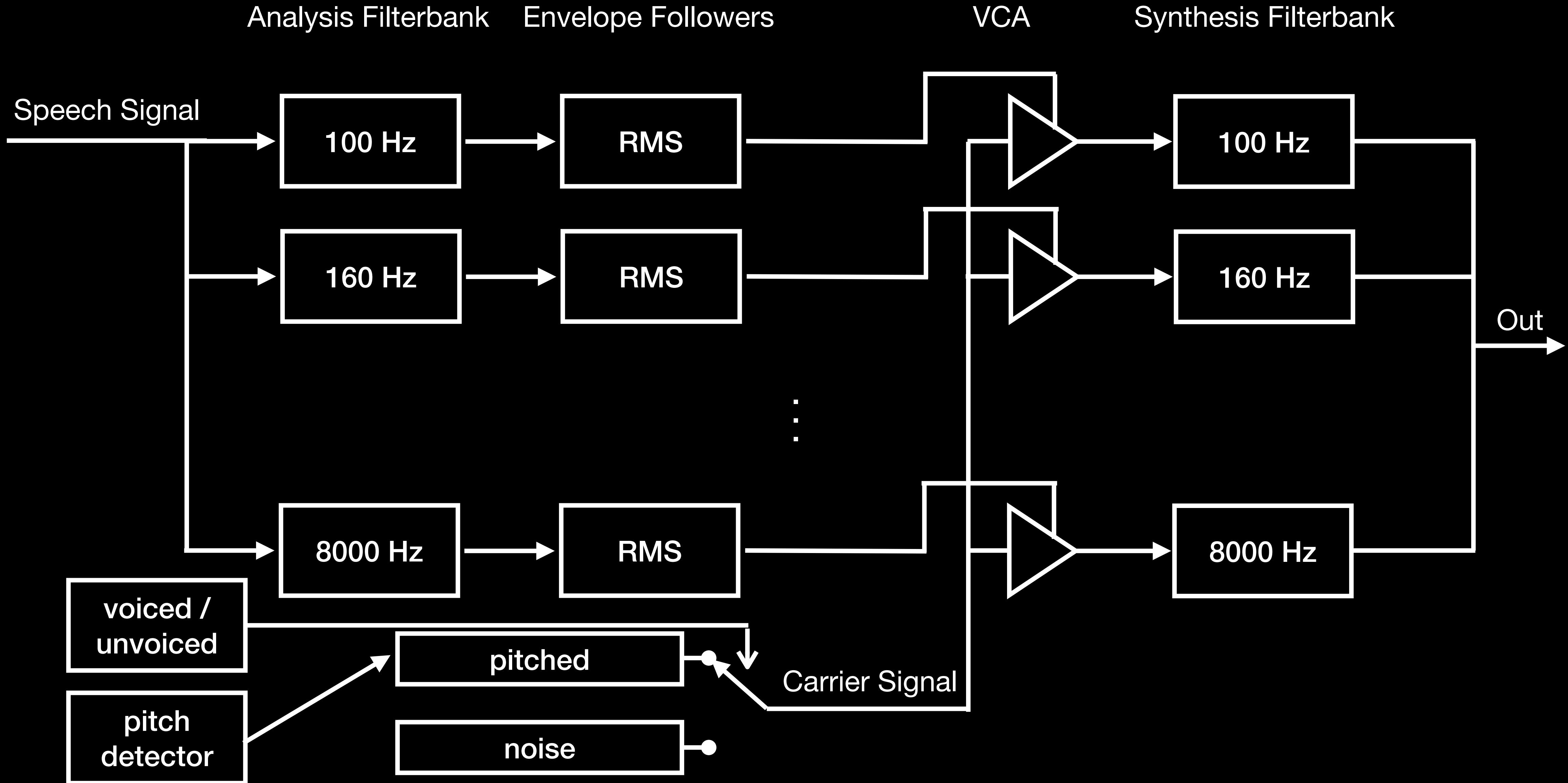


SIGSALY Vocoder 1943 - 1946

Channel Vocoder Basic Operation



Channel Vocoder Basic Operation



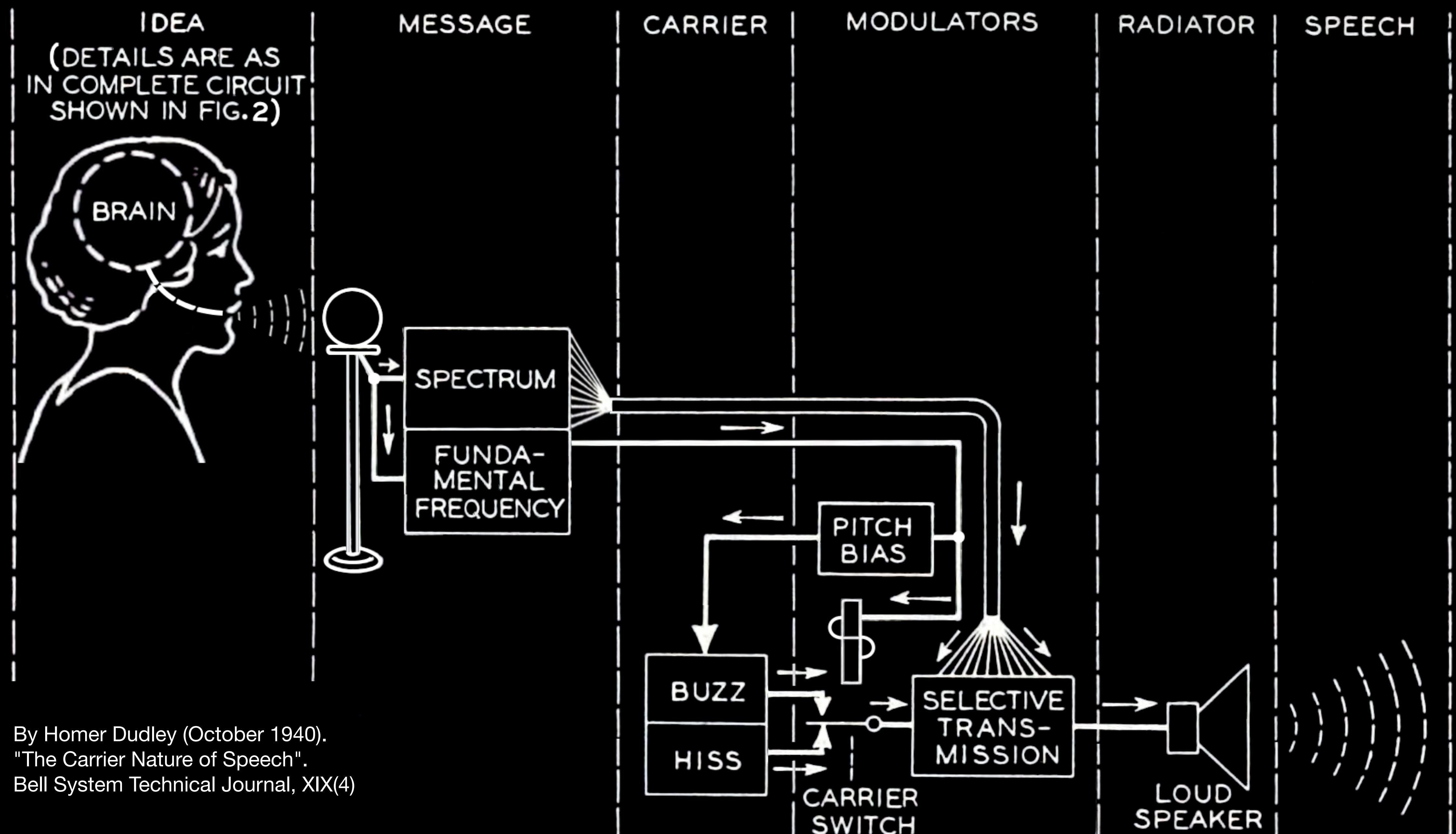


Fig. 7—Schematic circuit of the vocoder.

Channel Vocoder Frequency Response

$$H_v = \sum_{n=1}^N a_n H_n$$

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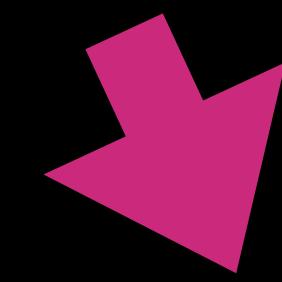
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Channel Vocoder Frequency Response

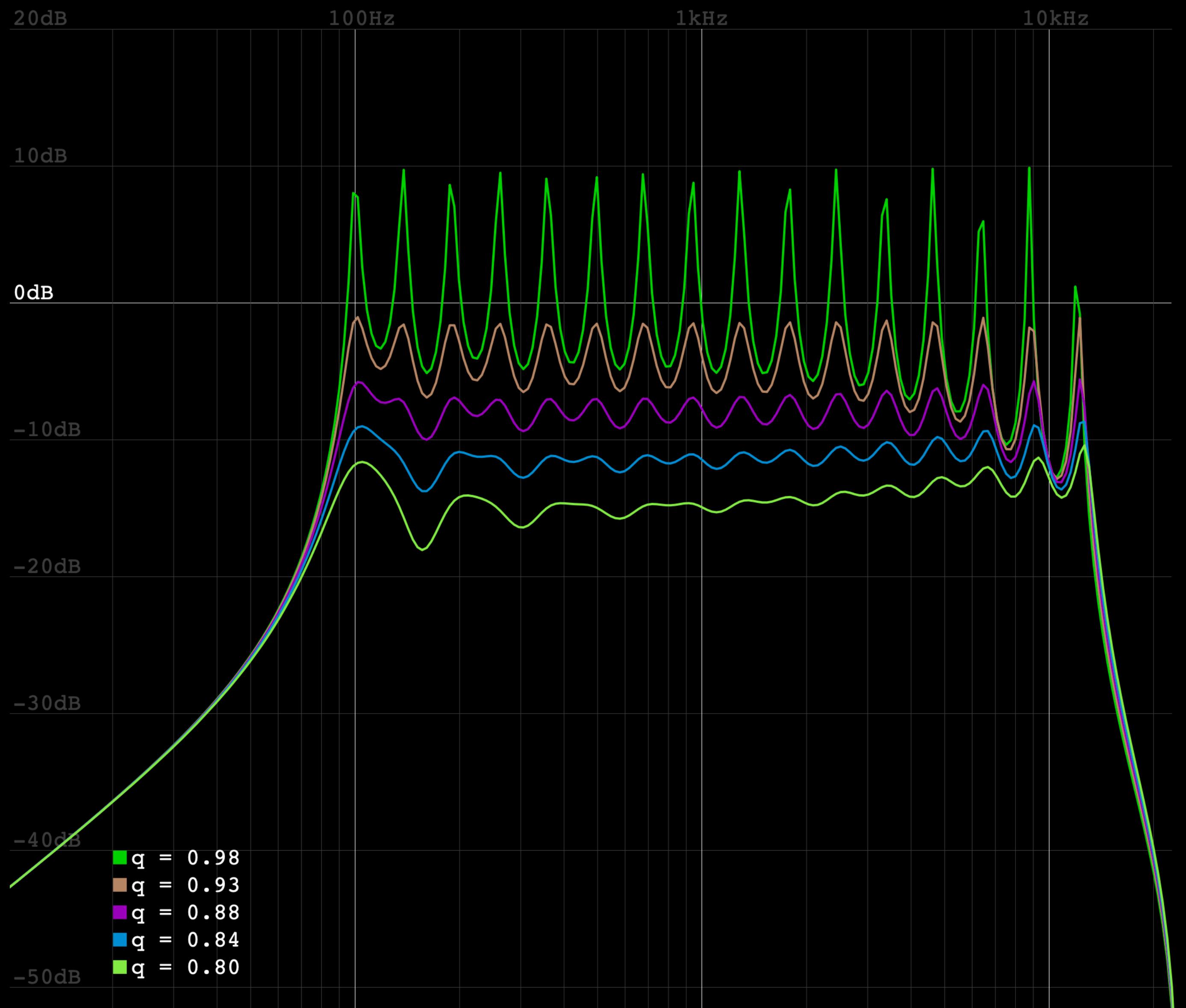
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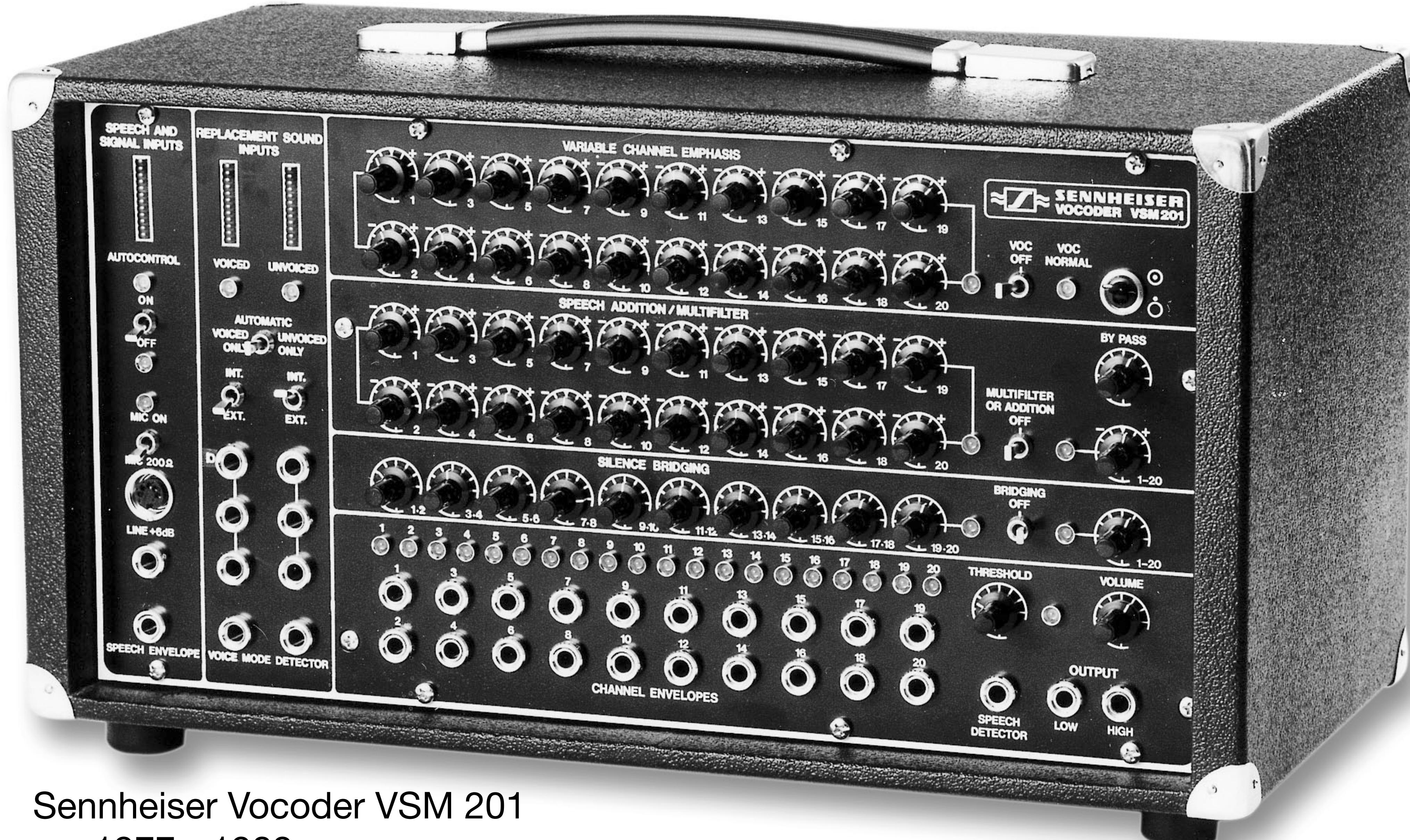
not so great.



$$H_n + H_{n+1} = \frac{A_n}{B_n} + \frac{A_{n+1}}{B_{n+1}} = \frac{A_n B_{n+1}}{B_n B_{n+1}} + \frac{A_{n+1} B_n}{B_n B_{n+1}} = \frac{A_n B_{n+1} + A_{n+1} B_n}{B_n B_{n+1}}$$



demonstrate channel vocoder



Sennheiser Vocoder VSM 201
ca. 1977 - 1982



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ca. 1977 - 1982



Kai Krause

Channel Vocoder Frequency Response

$$H_v = \sum_{n=1}^N a_n H_n$$

$$H_v = \prod_{n=1}^N a_n H_n \quad ?$$

Channel Vocoder Frequency Response

$$H_v = \sum_{n=1}^N a_n H_n$$

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LPC Vocoder

$$\hat{x}_n = \sum_{i=1}^P a_i x_{n-i}$$

$$\hat{e}_n = \hat{x}_n - x_n$$

$$A(z) = ?$$

Levinson/Durbin recursion
a bit complicated, but uses
Autocorrelation ->

$$R_l = \sum_n x_n x_{n-l}$$

demonstrate LPC vocoder

NEW VOCODER POLL

hear it?

explain math?

show code?

open source it?

amazing Autocorrelation properties

$$R_l = \sum_n^N x_n x_{n-l}$$

- easy calculation in time domain
- fast calculation via FFT
- useful for e.g. LPC or pitch detection
- symmetric
- loss of phase information
- linear phase
- H^2

Autocorrelation Vocoder?

$$R_l = \sum_n^N x_n x_{n-l}$$

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$$R_l = \sum_n^N x_n x_{n-l}$$

- easy

Autocorrelation Vocoder?

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- easy
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$$H_v = |H|$$

Dec. 18, 1962

E. E. DAVID, JR.

3,069,507

AUTOCORRELATION VOCODER

Filed Aug. 9, 1960

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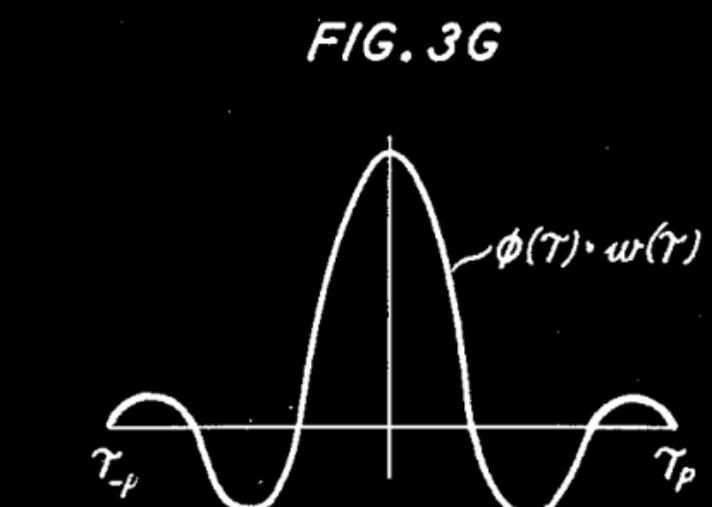
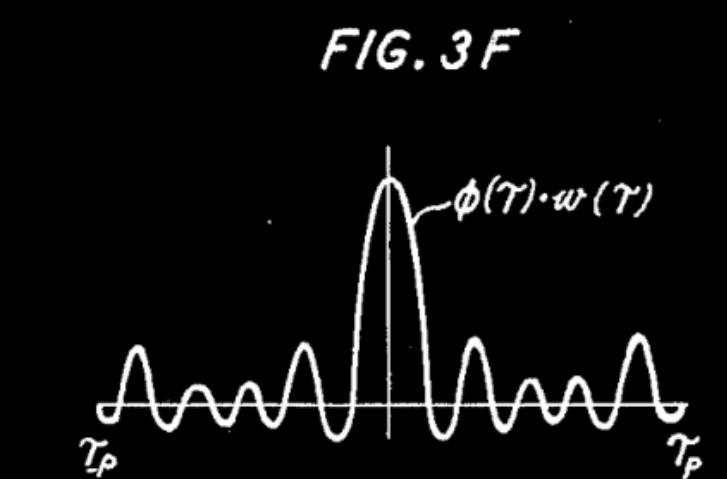
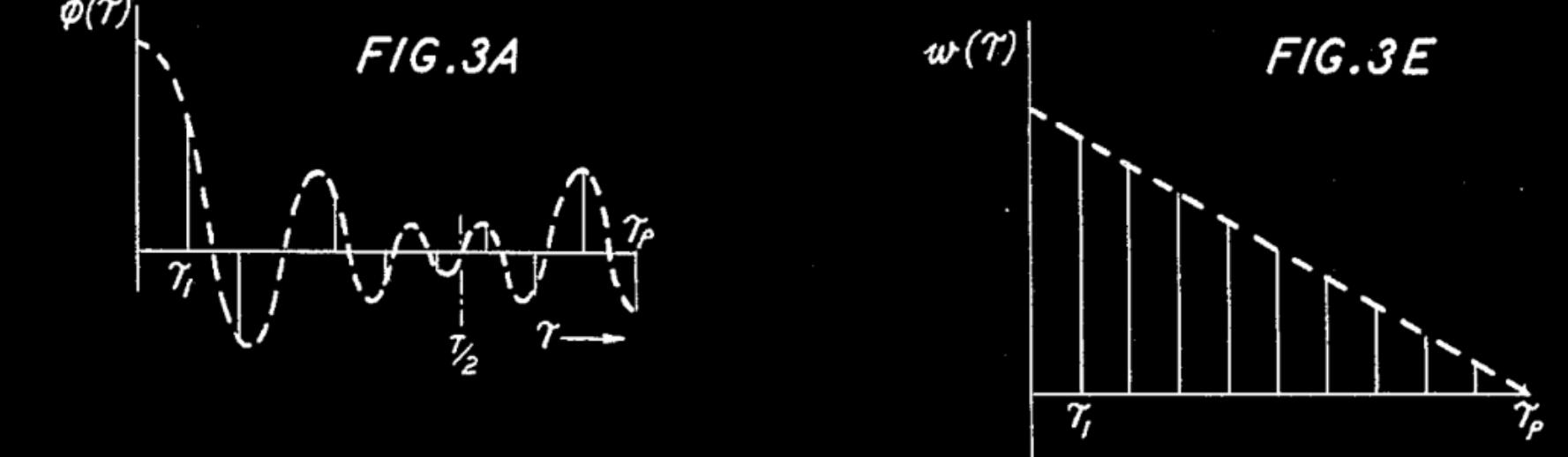
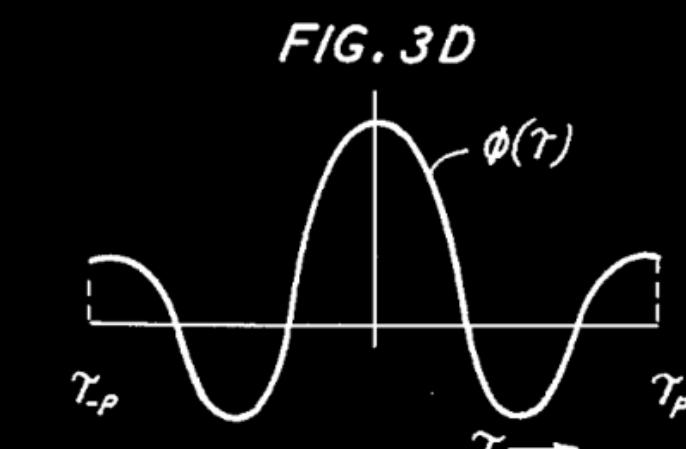
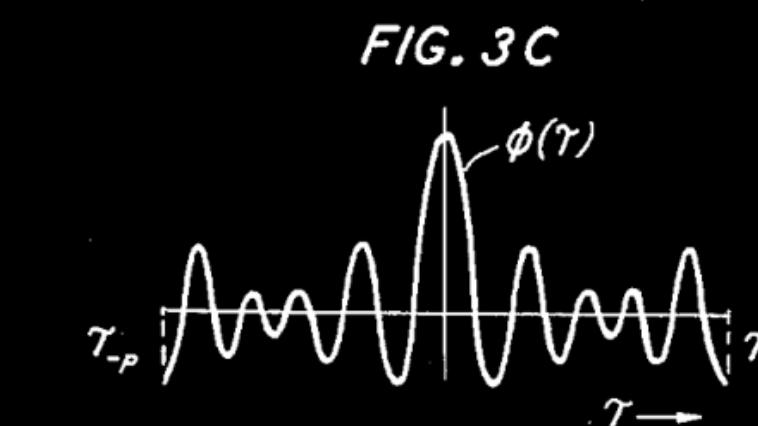
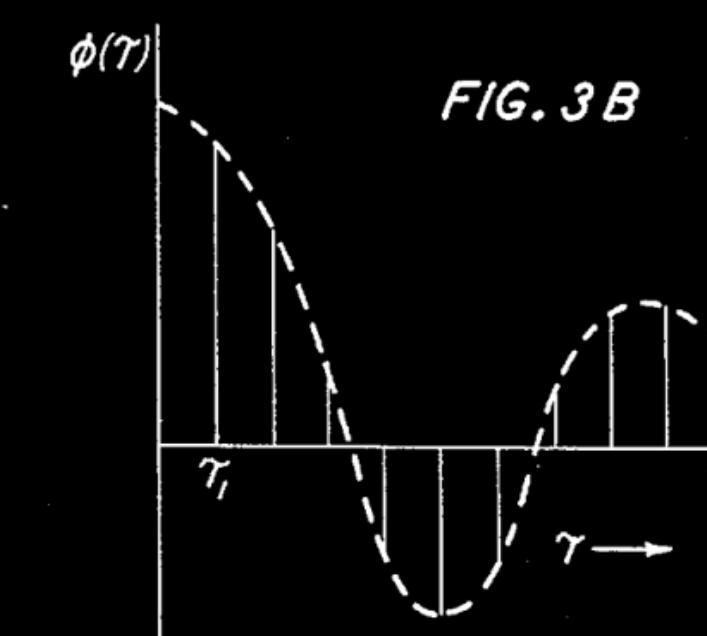
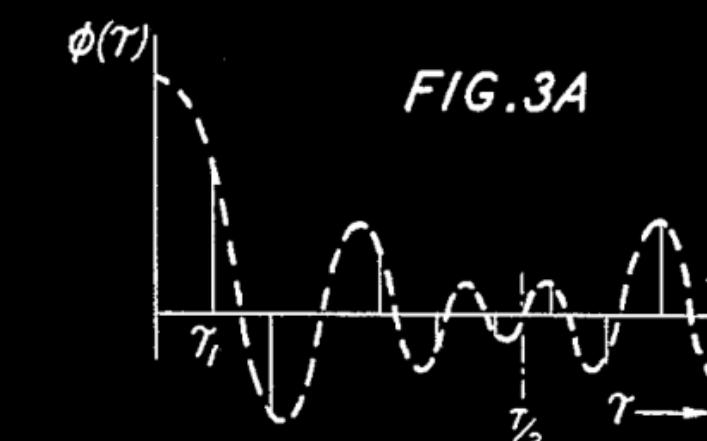
Autocorrelation Vocoder!

$$R_l = \sum_n^N x_n x_{n-l}$$

- easy
- fast
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$$H_v \sim H^2$$

$$H_v = |H|$$



INVENTOR
E. E. DAVID, JR.
BY

Autocorrelation Vocoder

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option #1: gain correction

$$R_0 = \sum_n^N x_n^2$$

$$\sqrt{R_0} \sim RMS(x)$$

scale by $\frac{1}{\sqrt{R_0}}$

option #2 - modified Autocorrelation - replace multiplication

$$R'_l = \sum_n^N f(x_n, x_{n-l})$$

$f(a, b)$ desired properties

$$f(a, 0) = 0 \quad f(a, a) = |a| \quad f(a, -a) = -a$$

modified Autocorrelation

$$R'_l = \sum_n^N f(x_n, x_{n-l})$$

$$f(a, b) = ab$$

$$f(a, b)$$

$$f(a, 0) = 0$$

desired properties

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modified Autocorrelation

$f(a, b)$	desired properties		
$R'_l = \sum_n^N f(x_n, x_{n-l})$	$f(a, 0) = 0$	$f(a, a) = a $	$f(a, -a) = -a$

$$f(a, b) = ab$$

$$f(a, b) = sign(ab)\sqrt{|ab|}$$

modified Autocorrelation

$f(a, b)$	desired properties		
$R'_l = \sum_n^N f(x_n, x_{n-l})$	$f(a, 0) = 0$	$f(a, a) = a $	$f(a, -a) = -a$
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$f(a, b) = sign(ab)\sqrt{ ab }$	✓ ✓ ✓
$f(a, b) = sign(ab)min(a , b)$	✓ ✓ ✓

modified Autocorrelation

$$R'_l = \sum_n^N f(x_n, x_{n-l})$$

$$x' = sign(x)\sqrt{|x|}$$

$$R'_l = \sum_n^N x'_n x'_{n-l}$$

$$f(a, b) = sign(ab)\sqrt{|ab|}$$

block Autocorrelation

$$R_l = \sum_n^N x_n x_{n-l}$$

leaky Autocorrelation

$$R_{l,n} = (1 - k)R_{l,n-1} + kx_n x_{n-l} \quad k \sim 0.001$$

Autocorrelation Vocoder

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AUTOCORRELATION VOCODER

3,

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Filed Aug. 9, 1960

7 Sheet

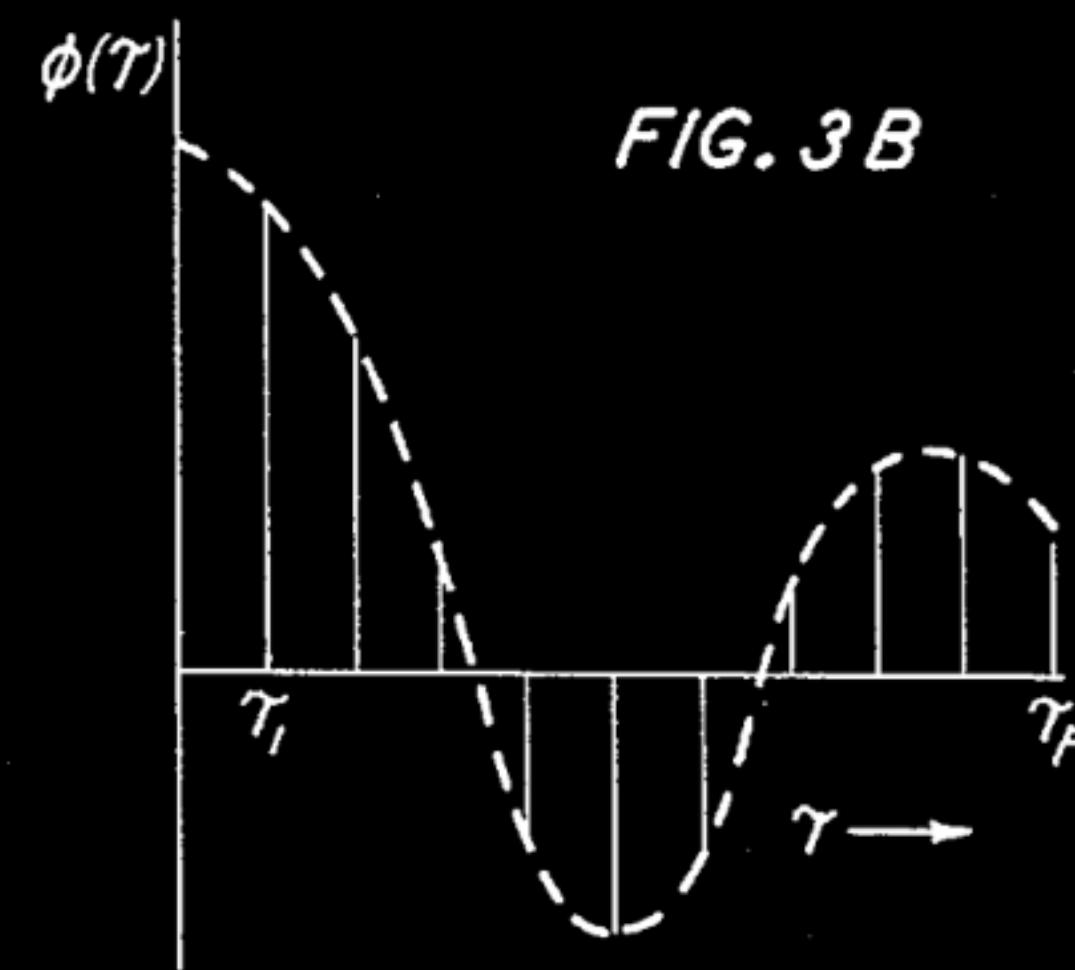
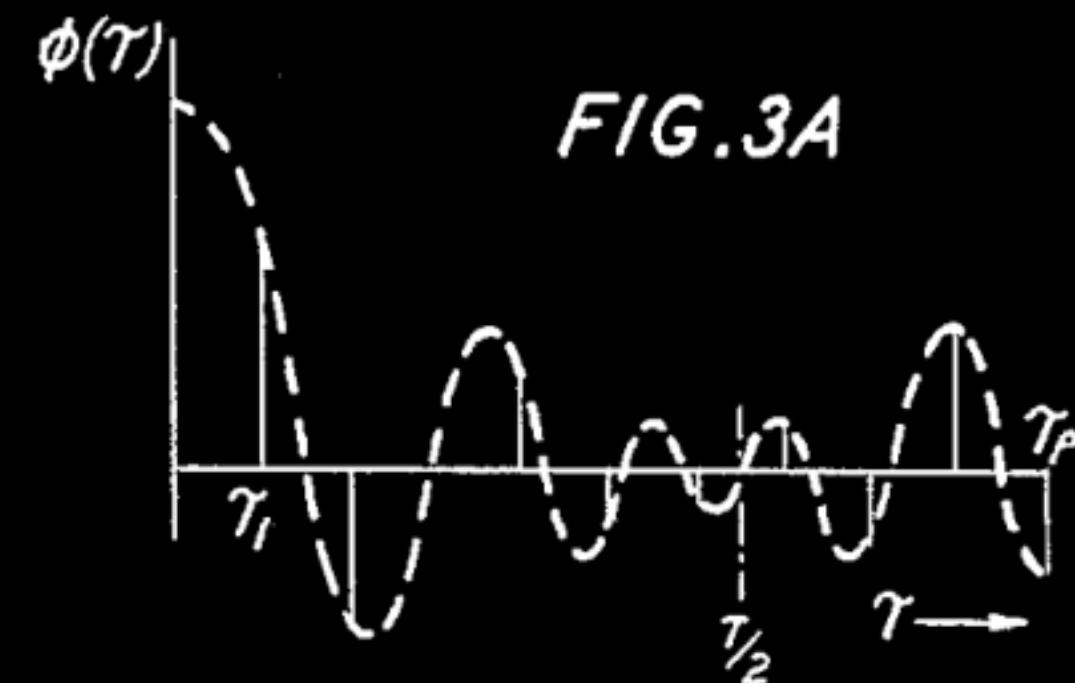
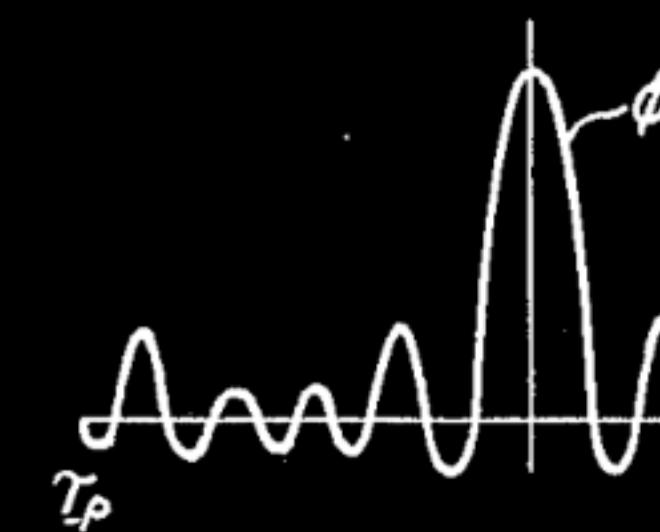
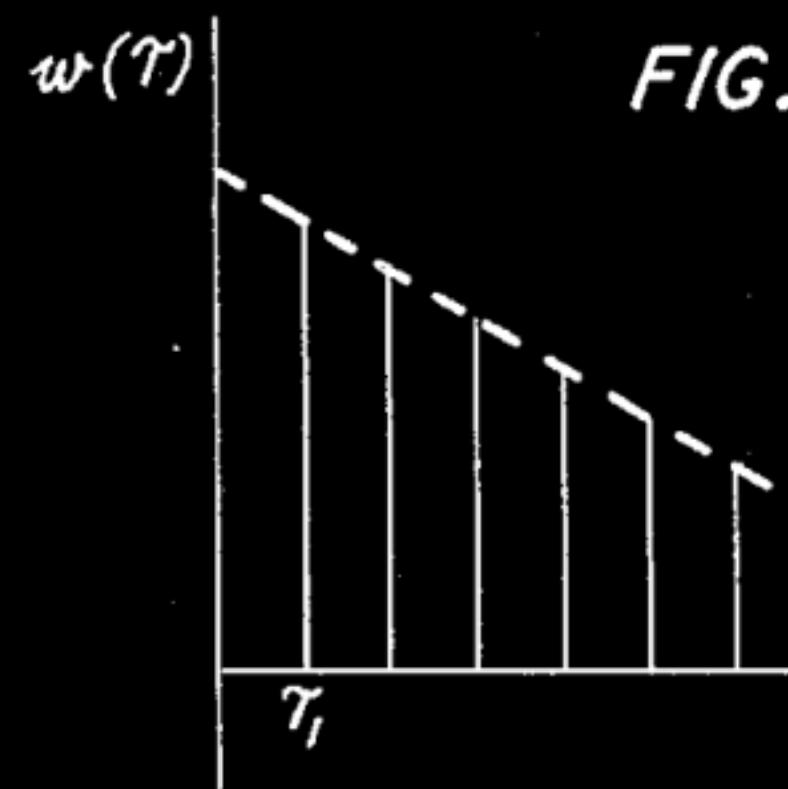


FIG. 3C



Autocorrelation Vocoder option #3: FFT correction

$$R_l = \sum_n^N x_n x_{n-l}$$

$$H_v \sim H^2$$

$$H_v = |H|$$

$$|H| = IFFT \sqrt{FFT(H^2)}$$

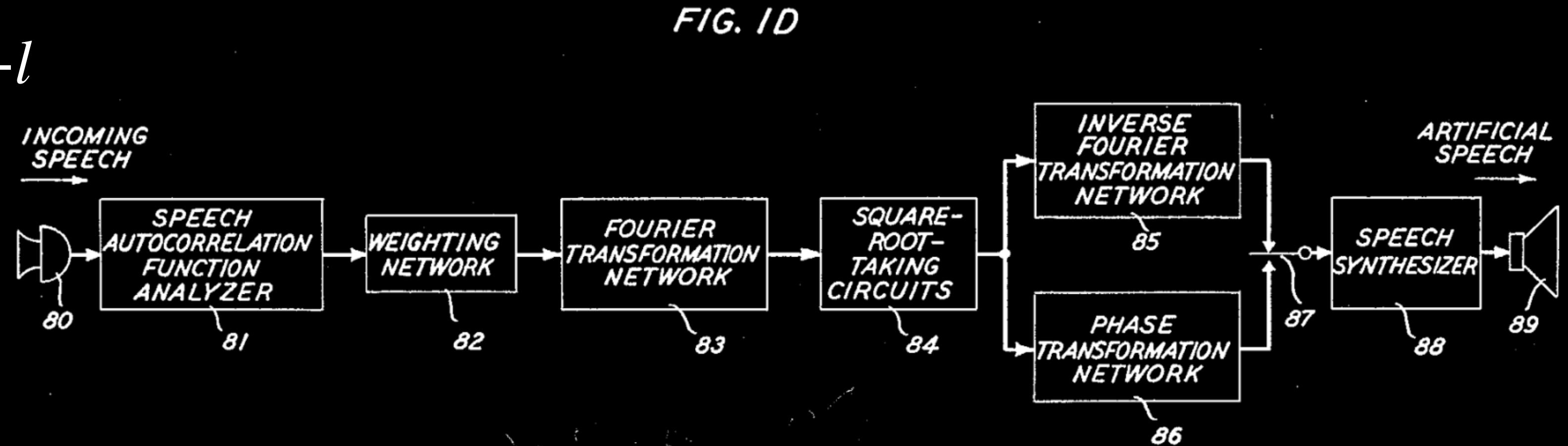
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STFT Vocoder

$$H_t = FFT[(x_t \dots x_{t+N})w_n]$$

STFT Vocoder

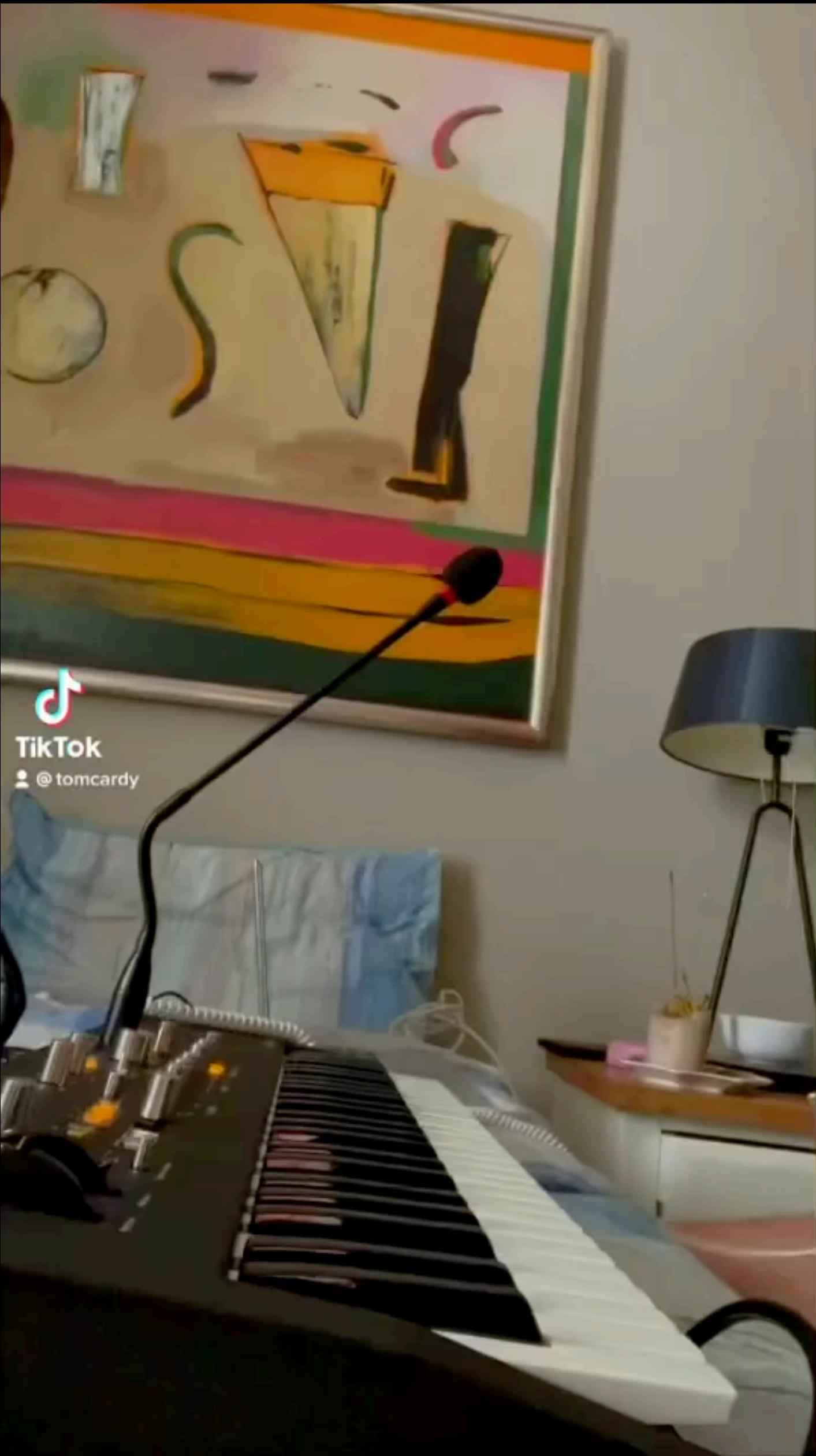
$$H_t = FFT[(x_t \dots x_{t+N})w_n]$$



STFT Vocoder

$$H_t = FFT[(x_t \dots x_{t+N})w_n]$$





Tom Cardy

with friendly permission

advanced Vocoder use

- follow pitch of speech
- unvoiced detection & noise injection
- formant modification to change perceived gender of voice

Vocoder Taxonomy

that was it, thanks.

Stefan Stenzel stefan@ioptigan.com