Filter Reconstruction and Program Material Characteristics Mitigating Word Length Loss in Digital Signal Processing-Based Compensation Curves used for Playback of Analog Recordings

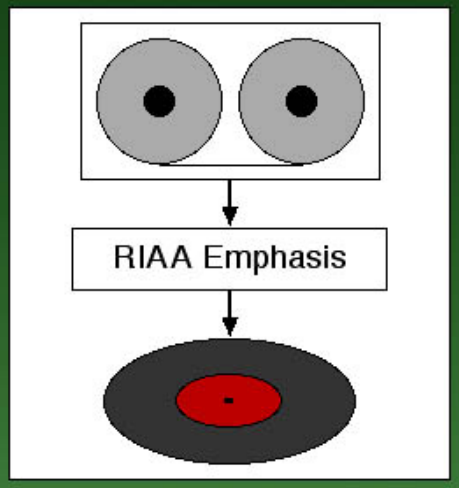
R. S. Robinson

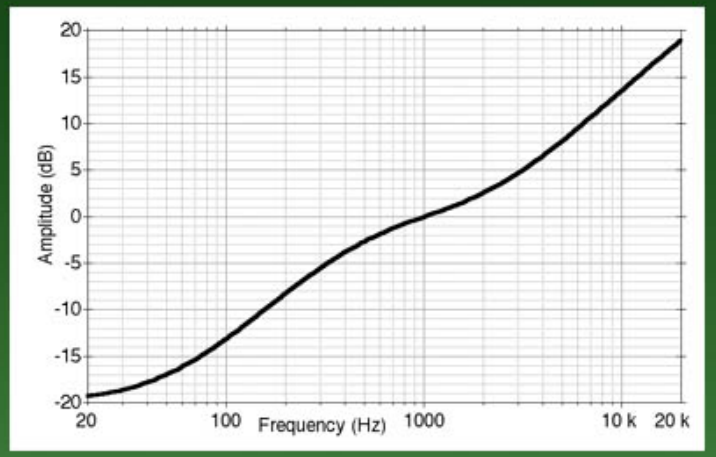
Channel D

Presented at the 123rd Audio Engineering Society Convention, New York City, October 4 - 7, 2007 **(Convention Paper 7185, Session P4-6)**

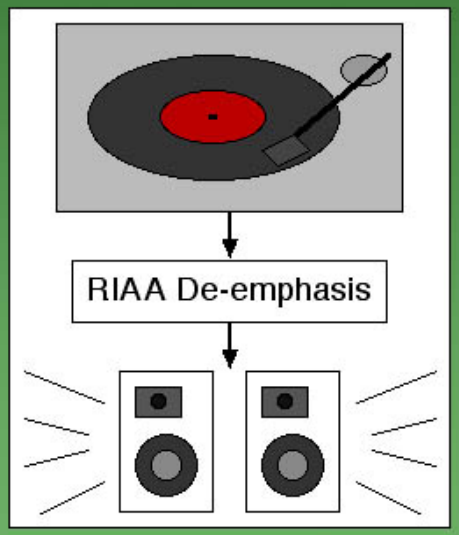
RIAA Compensation / Emphasis Curves

Recording



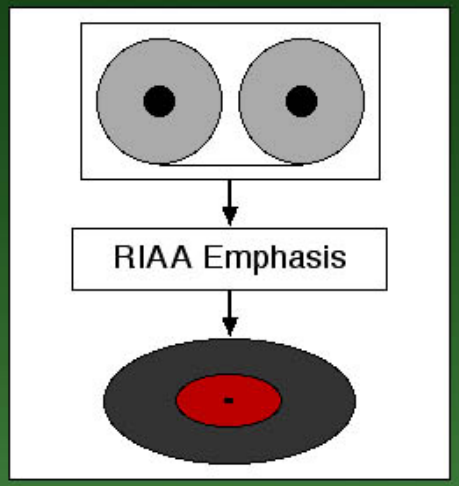


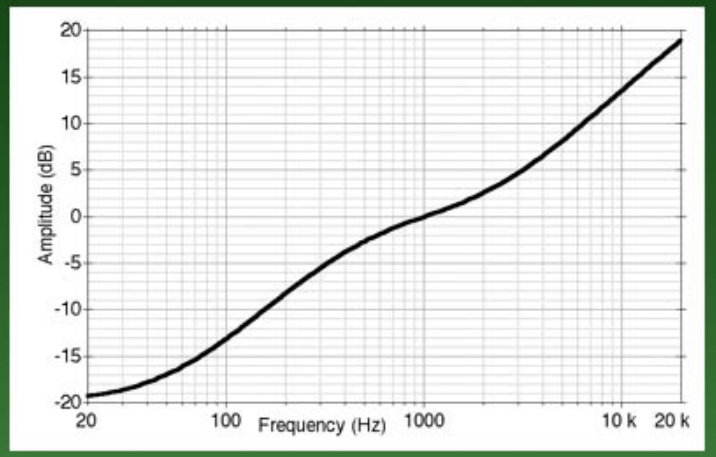
Playback



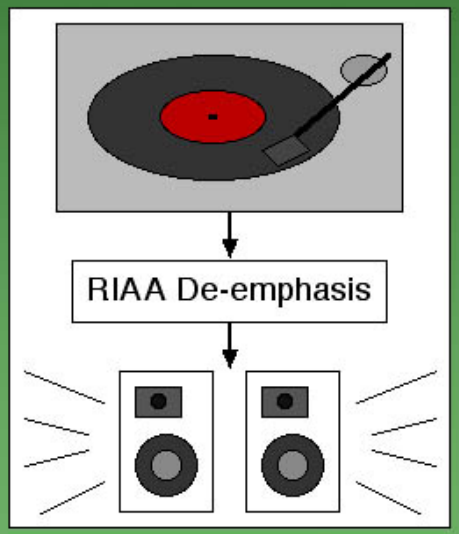
RIAA Compensation / Emphasis Curves

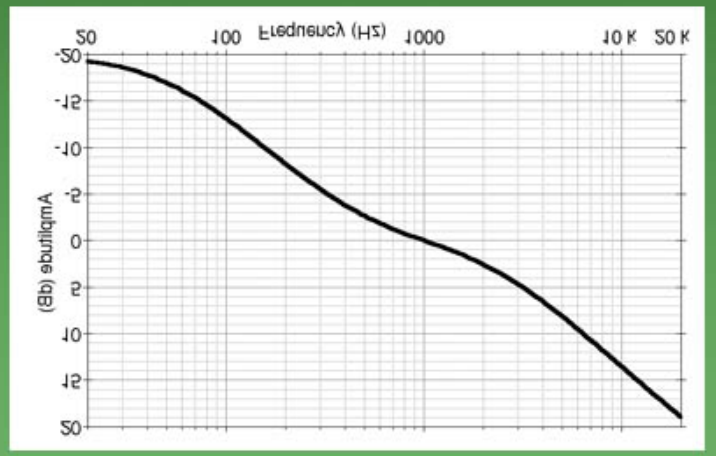
Recording





Playback





History

22 Bits (AD7716) and 24 bits of resolution! (AD7714)

ANALOG DEVICES

(1994 Databook)

LC²MOS

22-Bit Data Acquisition System

AD7716

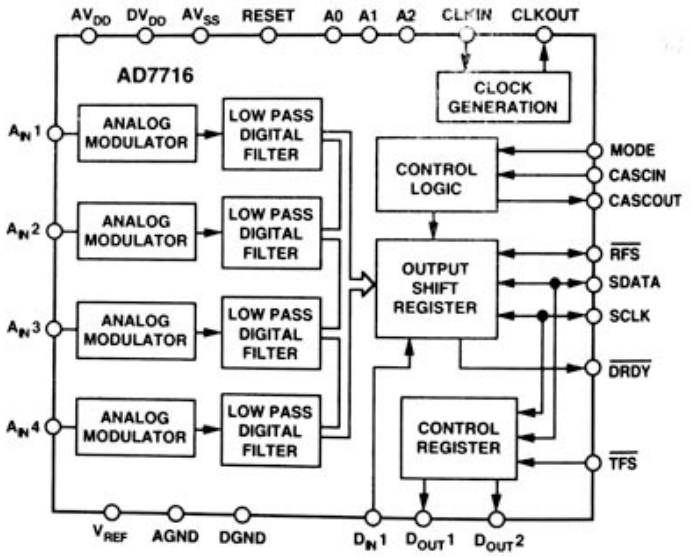
FEATURES

- 22-Bit Sigma-Delta ADC
  - Dynamic Range of 105 dB (146 Hz Input)
  - ±0.003% Integral Nonlinearity
- On-Chip Low-Pass Digital Filter
  - Cutoff Programmable from 584 Hz to 36.5 Hz
  - Linear Phase Response
- Five Line Serial I/O
- Twos Complement Coding
- Easy Interface to DSPs and Microcomputers
- Software Control of Filter Cutoff
- ±5 V Supply
- Low Power Operation: 50 mW

APPLICATIONS

- Biomedical Data Acquisition
  - ECG Machines
  - EEG Machines
- Process Control
- High Accuracy Instrumentation
- Seismic Systems

FUNCTIONAL BLOCK DIAGRAM

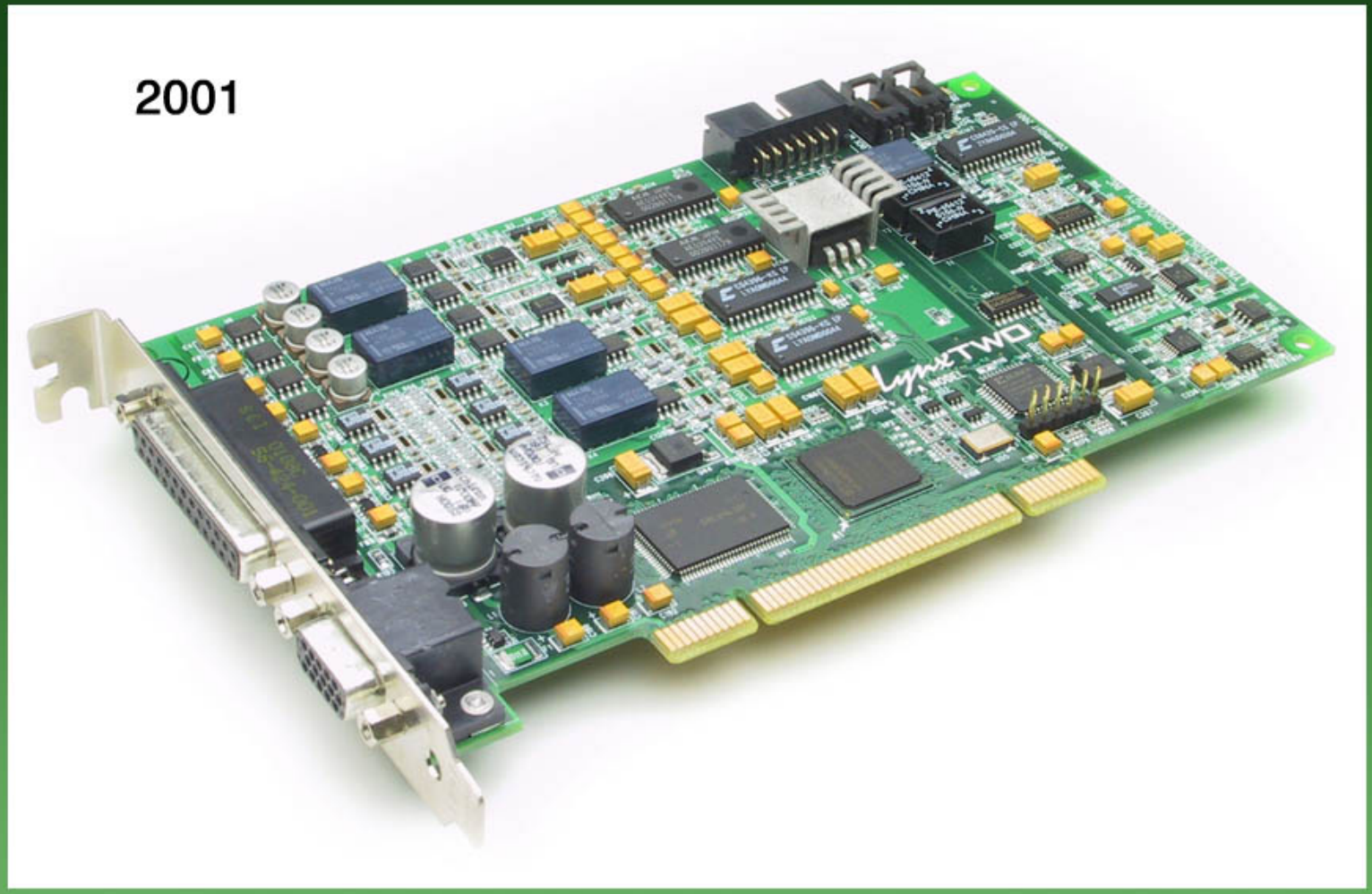


GENERAL DESCRIPTION

The AD7716 is a signal processing block for data acquisition systems. It is capable of processing four channels with bandwidths of up to 584 Hz. Resolution is 22 bits and the usable

There are 22 bits of data corresponding to the analog input. Two bits contain the channel address and 3 bits are the device address. Thus, each channel in a 32-channel system would have a discrete 5-bit address.

24 Bits / 192 kHz



RIAA Compensation Curves in the Digital Domain

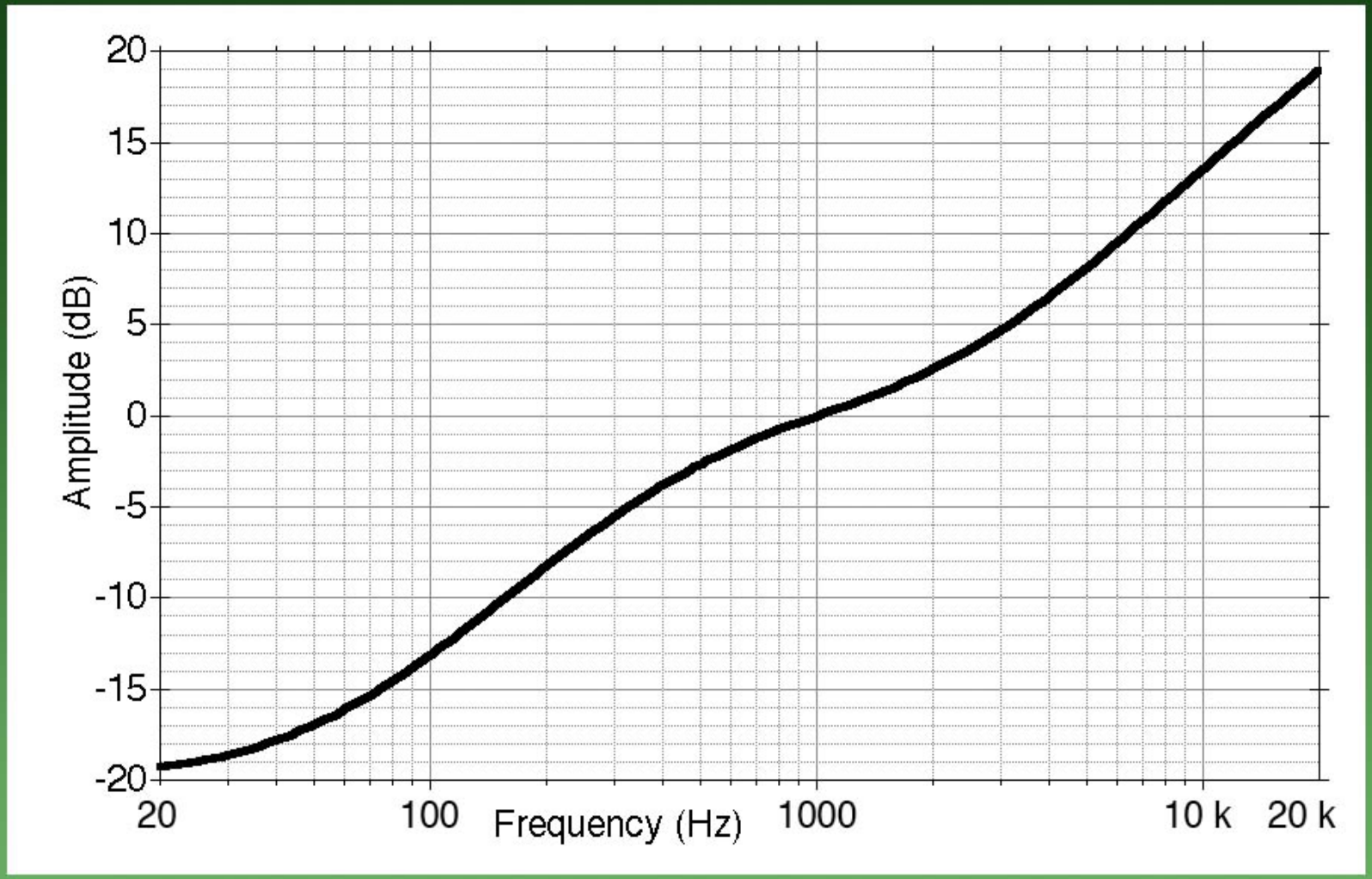
Motivation

RIAA Compensation Curves in the Digital Domain

Motivation

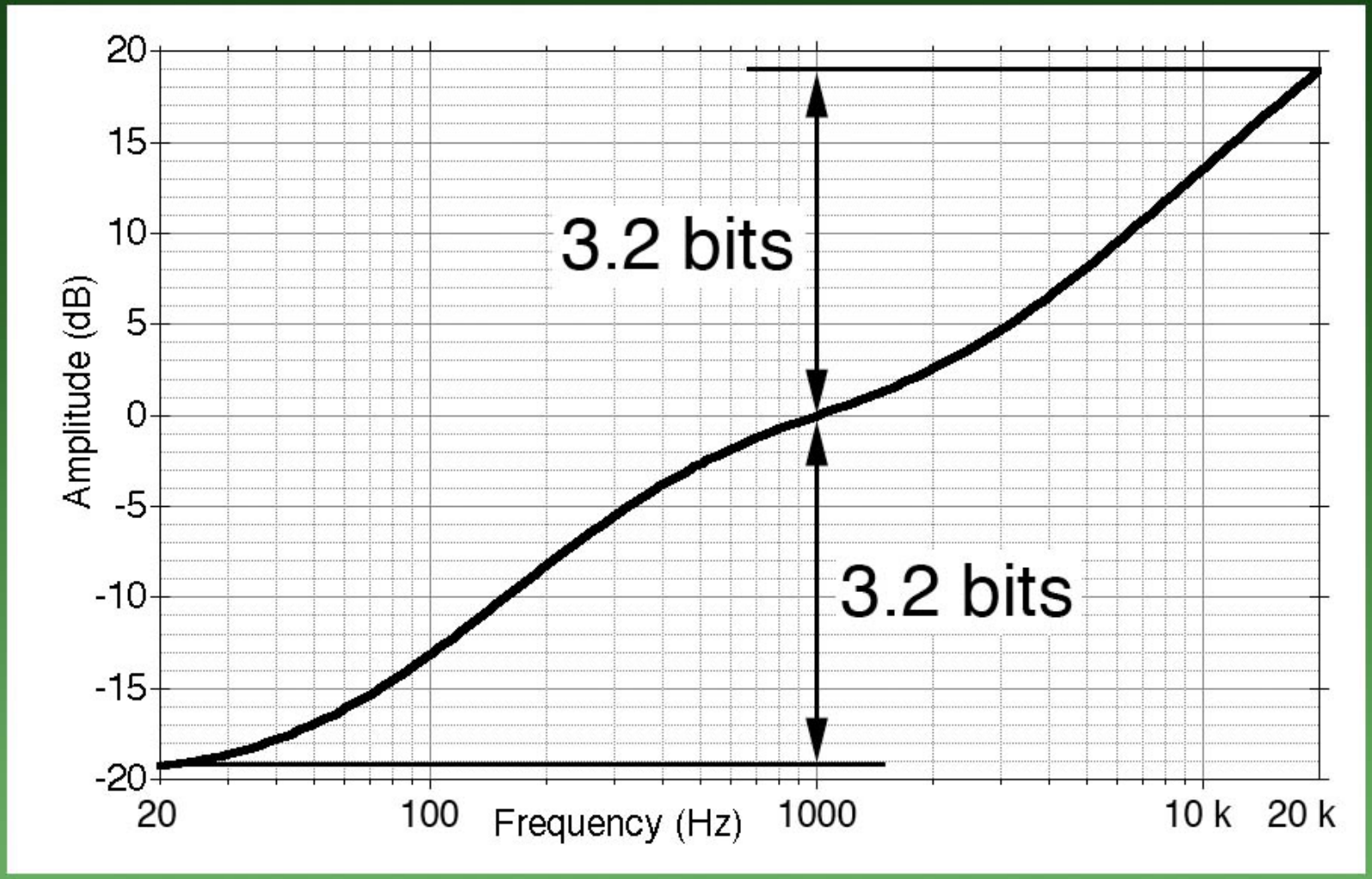
- Realization of “Perfect” compensation curve
- Eliminate RC Component Tolerances / Temp. Coefficients
- No Interchannel Differences
- Arbitrary Compensation Curves (Antique Recordings)
- Facilitates Pop / Click Removal

RIAA Vinyl Emphasis Curve



RIAA Vinyl Emphasis Curve

Potential additional headroom required

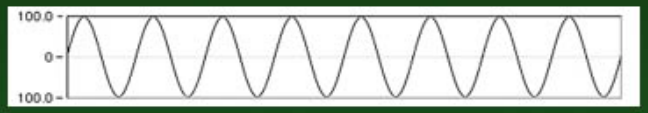


Factors Mitigating Word Length Loss

- Signal Reconstruction from Low-Pass Filtering

  RIAA de-emphasis curve *is* a low-pass filter

Measurement of Word Length Loss



20 Hz
Digital F.S.
Sine Wave

Attenuate (-40 dB)

Truncate
Word Length

Gain (40 dB)

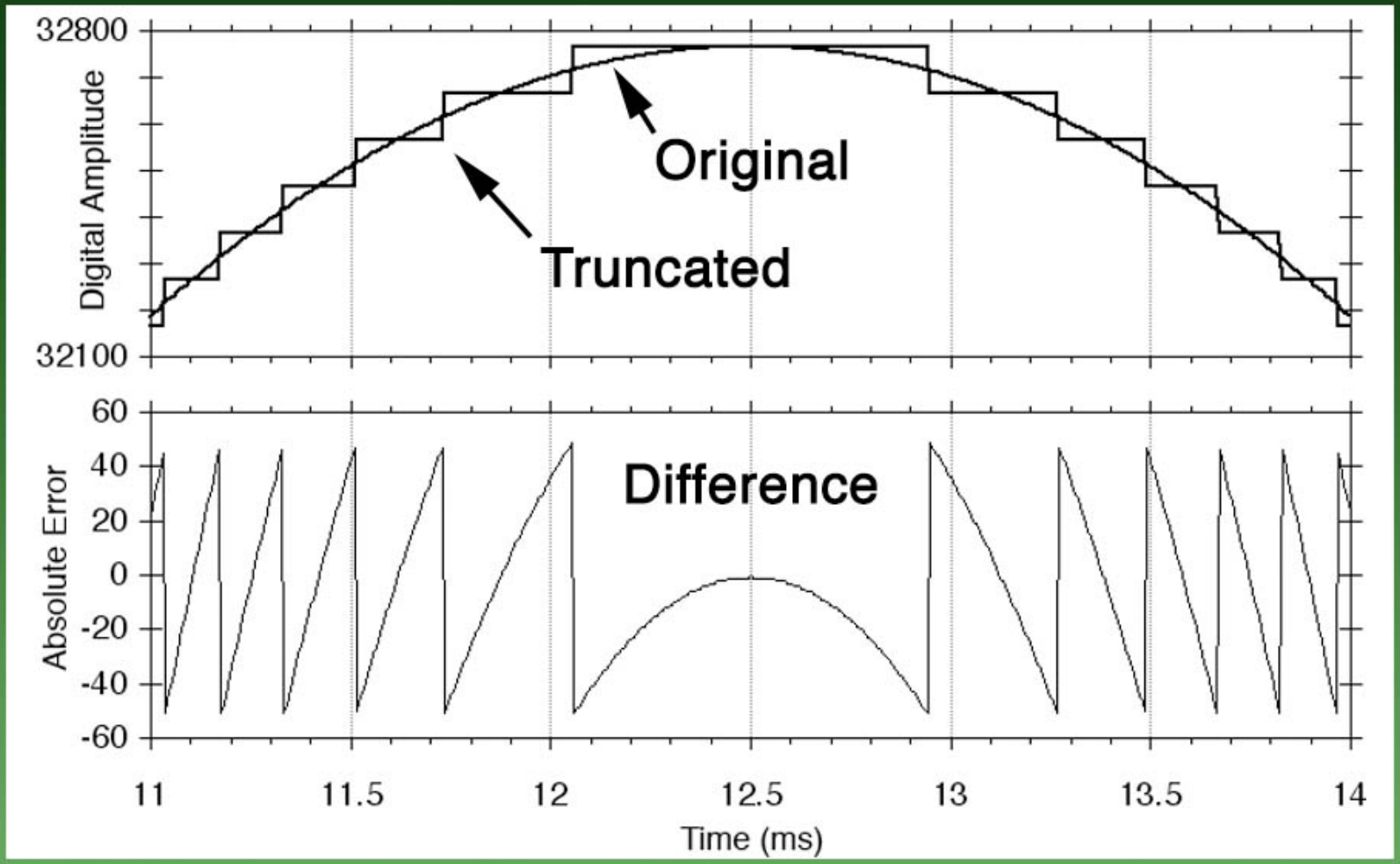
–

+ Σ

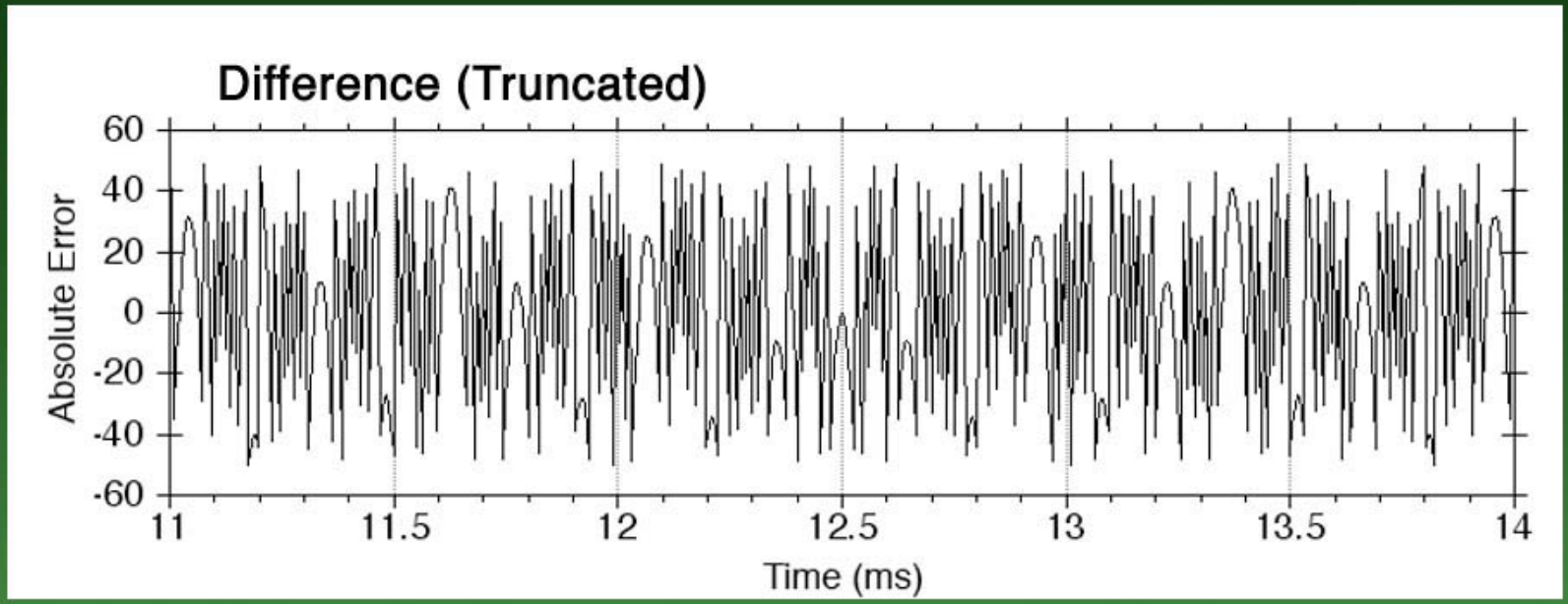
Gain

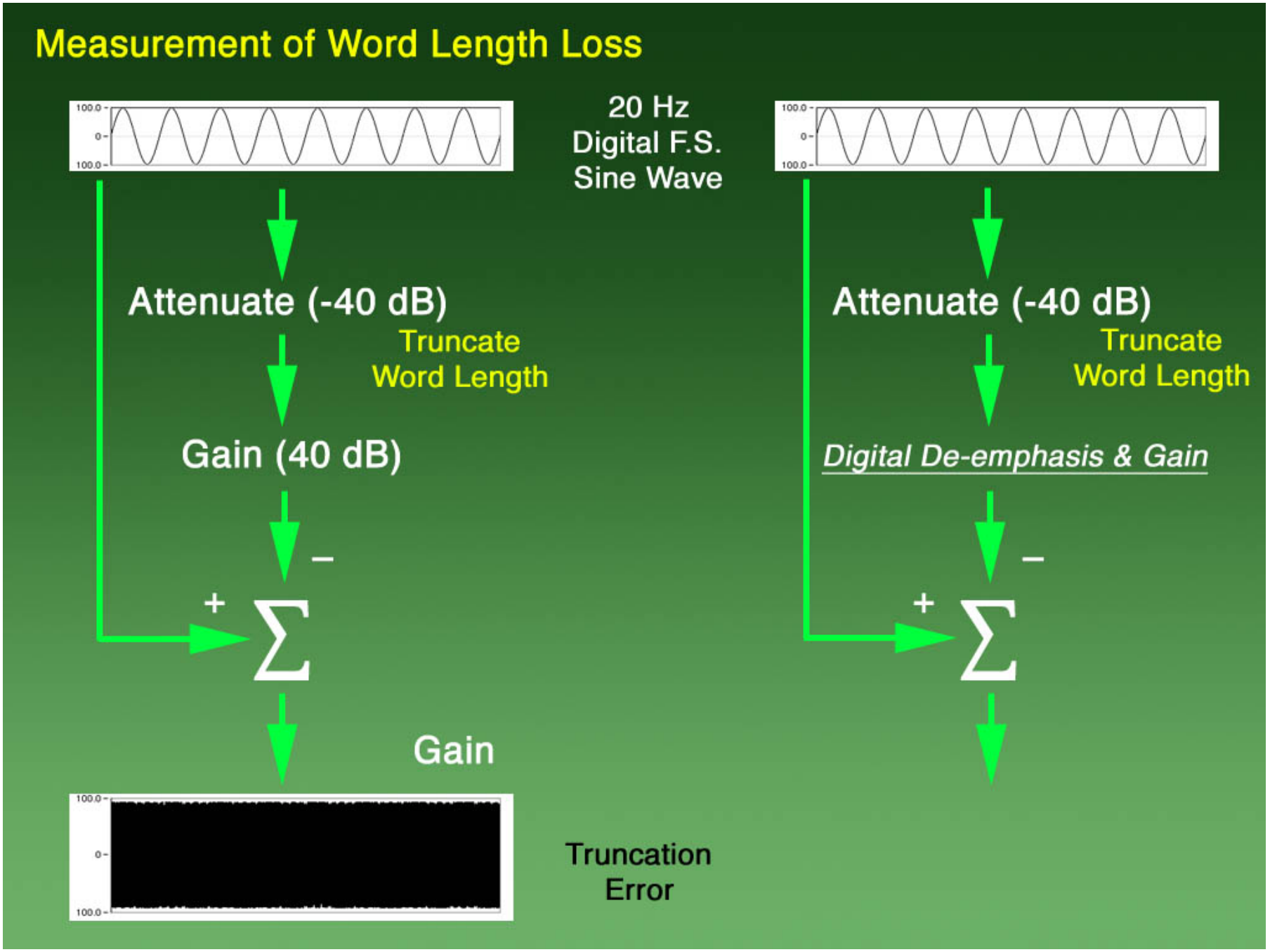
Truncation
Error

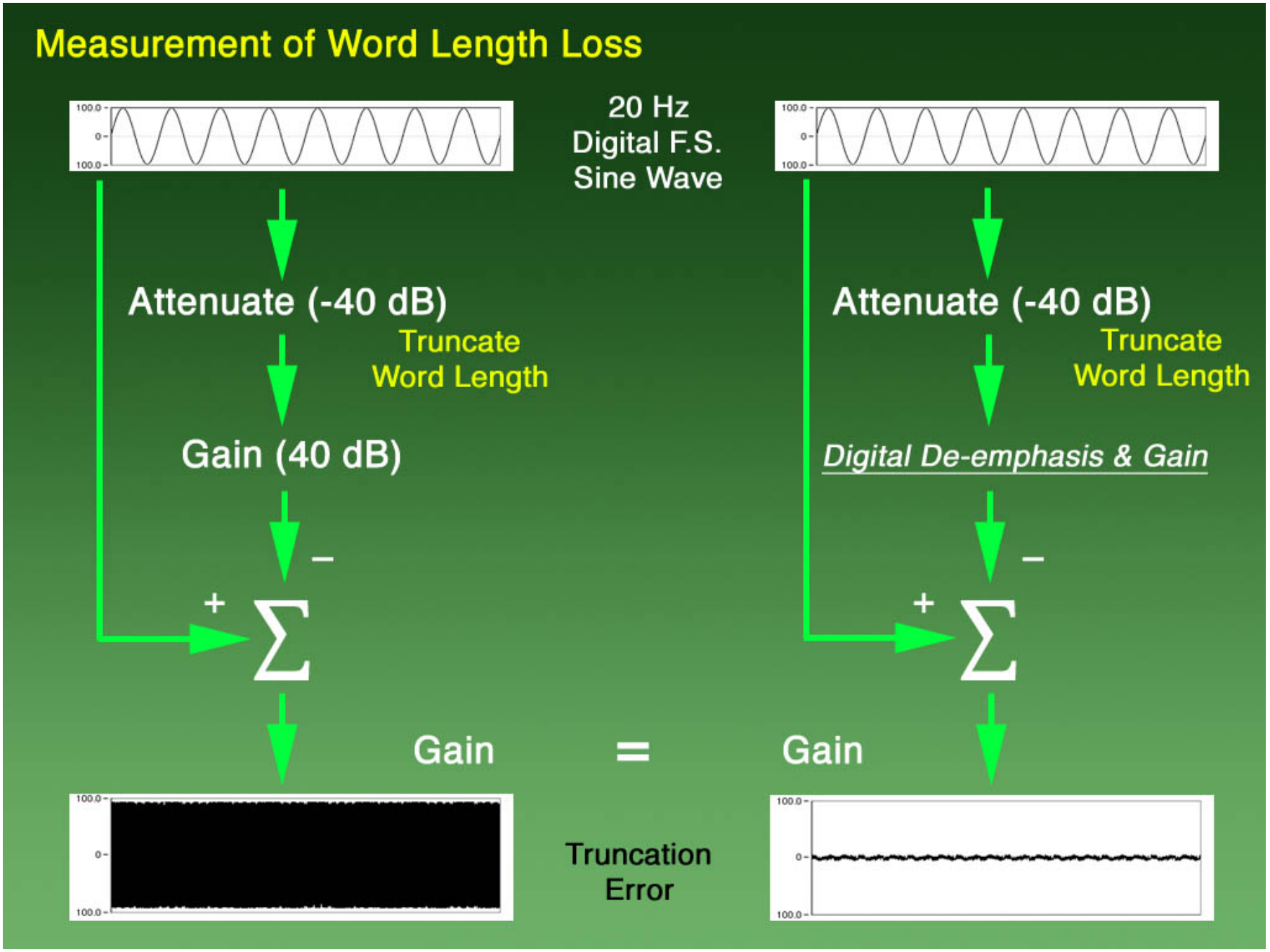
Crests of 16 bit resolution, 20 Hz sinusoidal signals



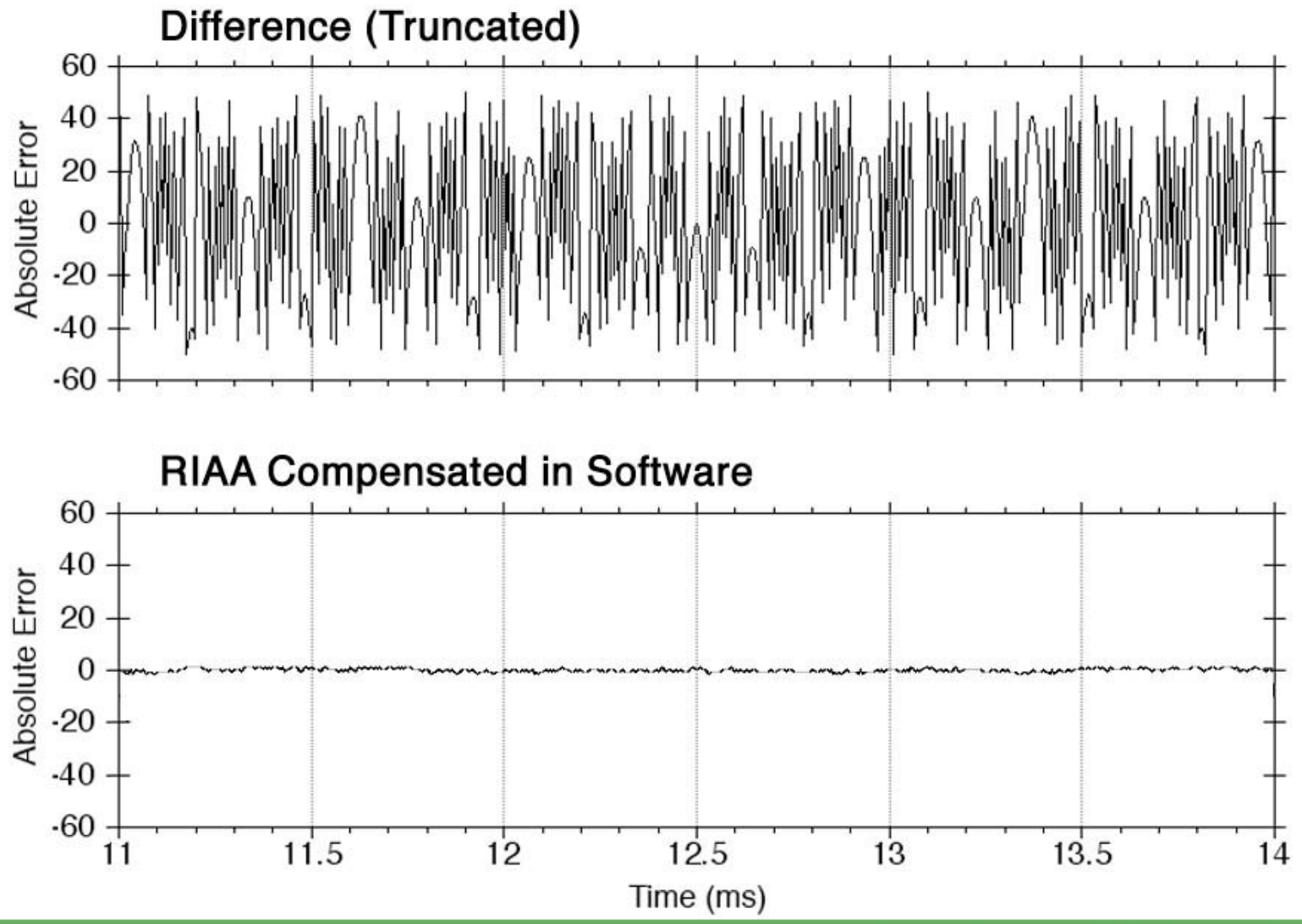
24 Bit Source (20 Hz sine wave) Truncation Error



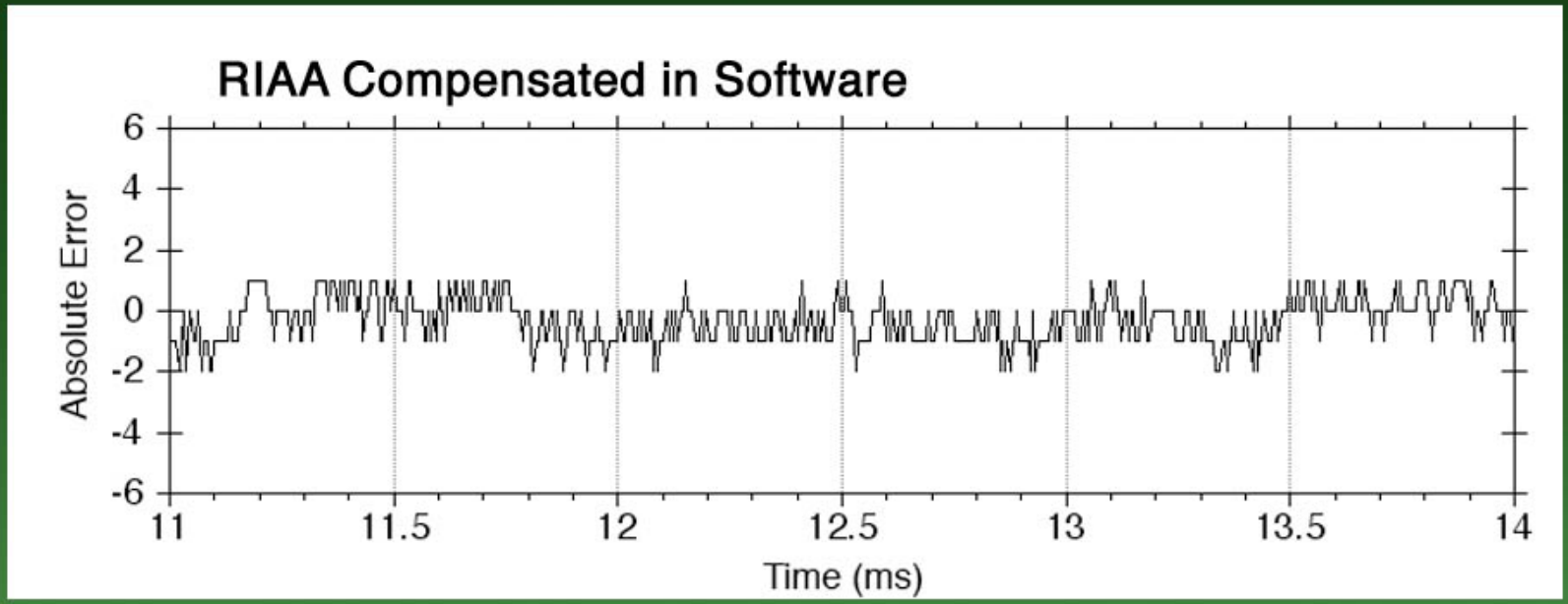




24 Bit Source (20 Hz sine wave) Truncation Error

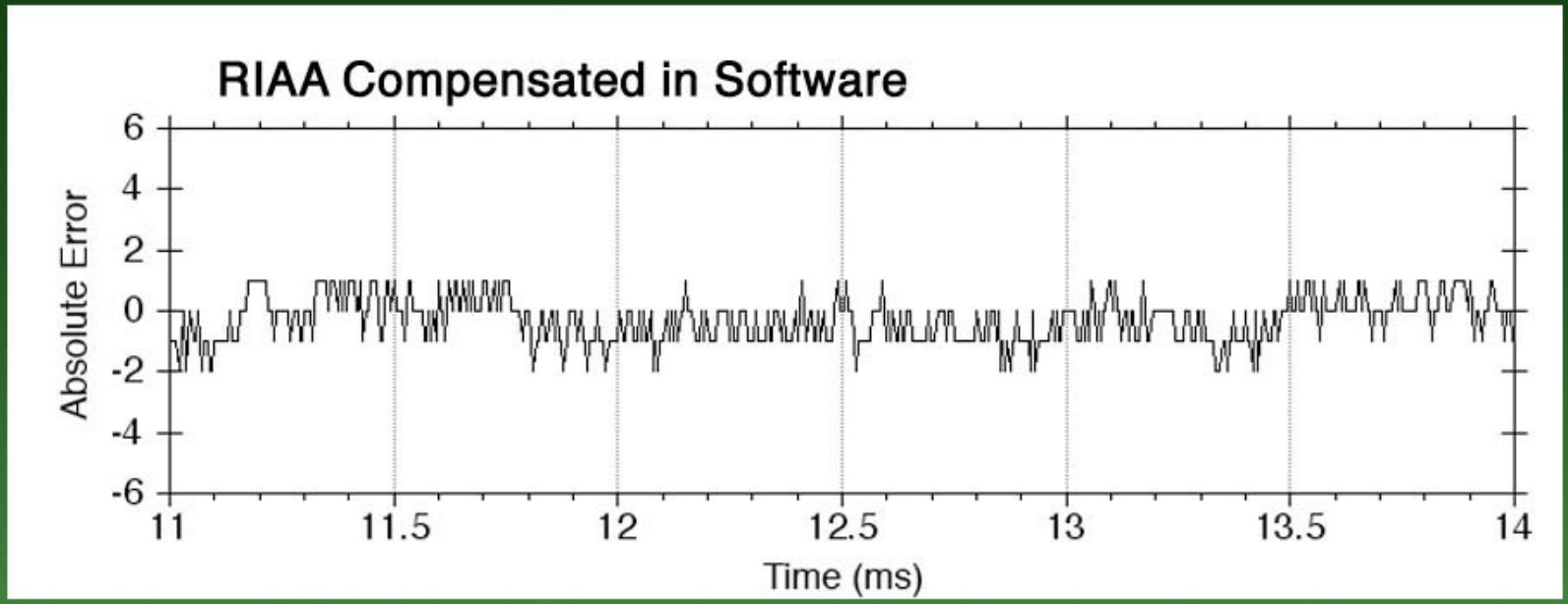


24 Bit Source (20 Hz sine wave) Truncation Error (Magnified)



Modulation of RIAA compensated error significantly (24.6 dB) smaller than expected (based on headroom requirement)

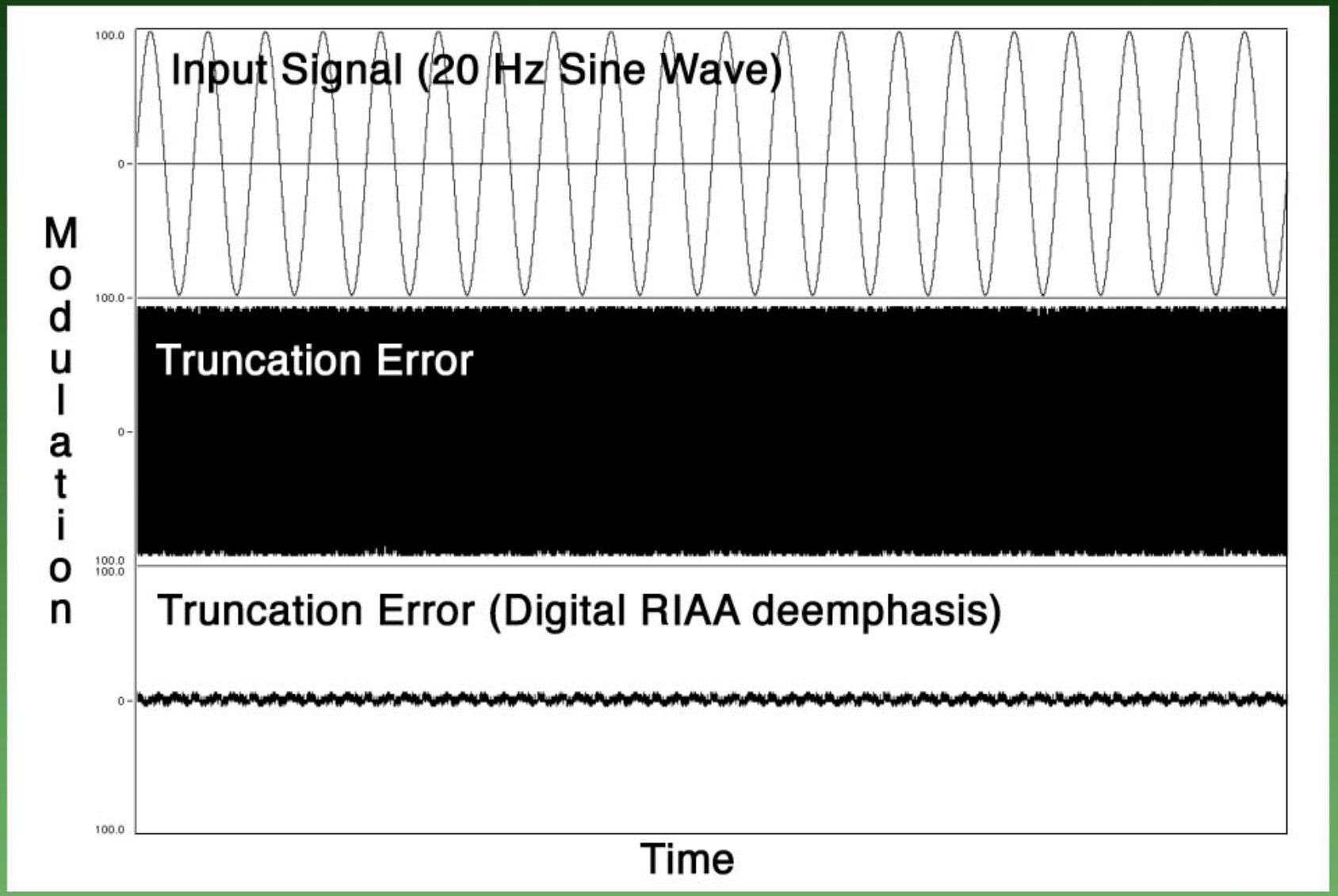
24 Bit Source (20 Hz sine wave) Truncation Error (Magnified)



Modulation of RIAA compensated error significantly (24.6 dB) smaller than expected (based on headroom requirement)

Complete word length recovery (and word length *enhancement*) from digitally applied RIAA compensation curve

Comparison of "Expected" and Actual Digital RIAA Filtered Truncation Error



Factors Mitigating Word Length Loss

- Signal Reconstruction from Low-Pass Filtering

  RIAA de-emphasis curve *is* a low-pass filter

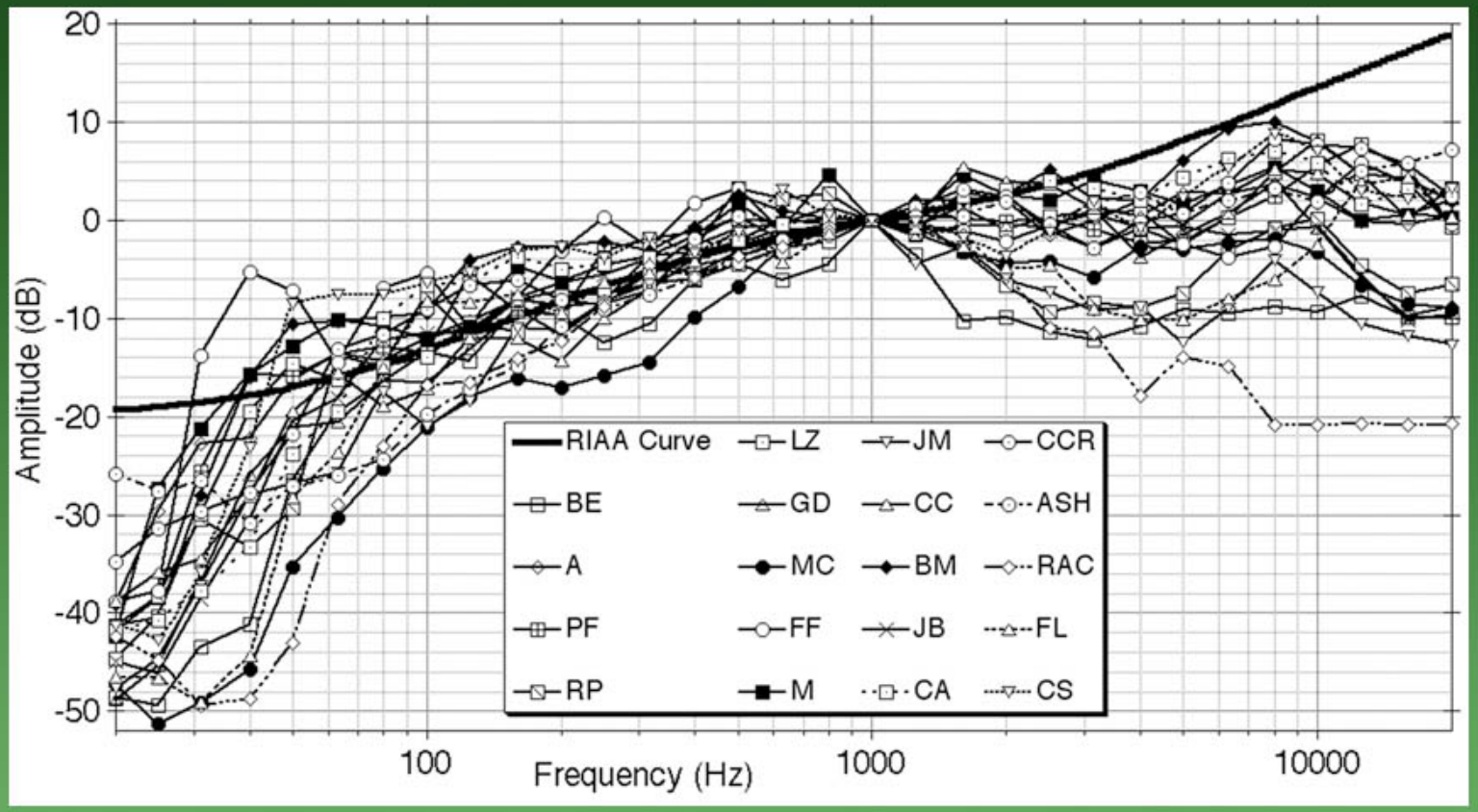
- Program Material Frequency Balance

  (High Frequency Content)

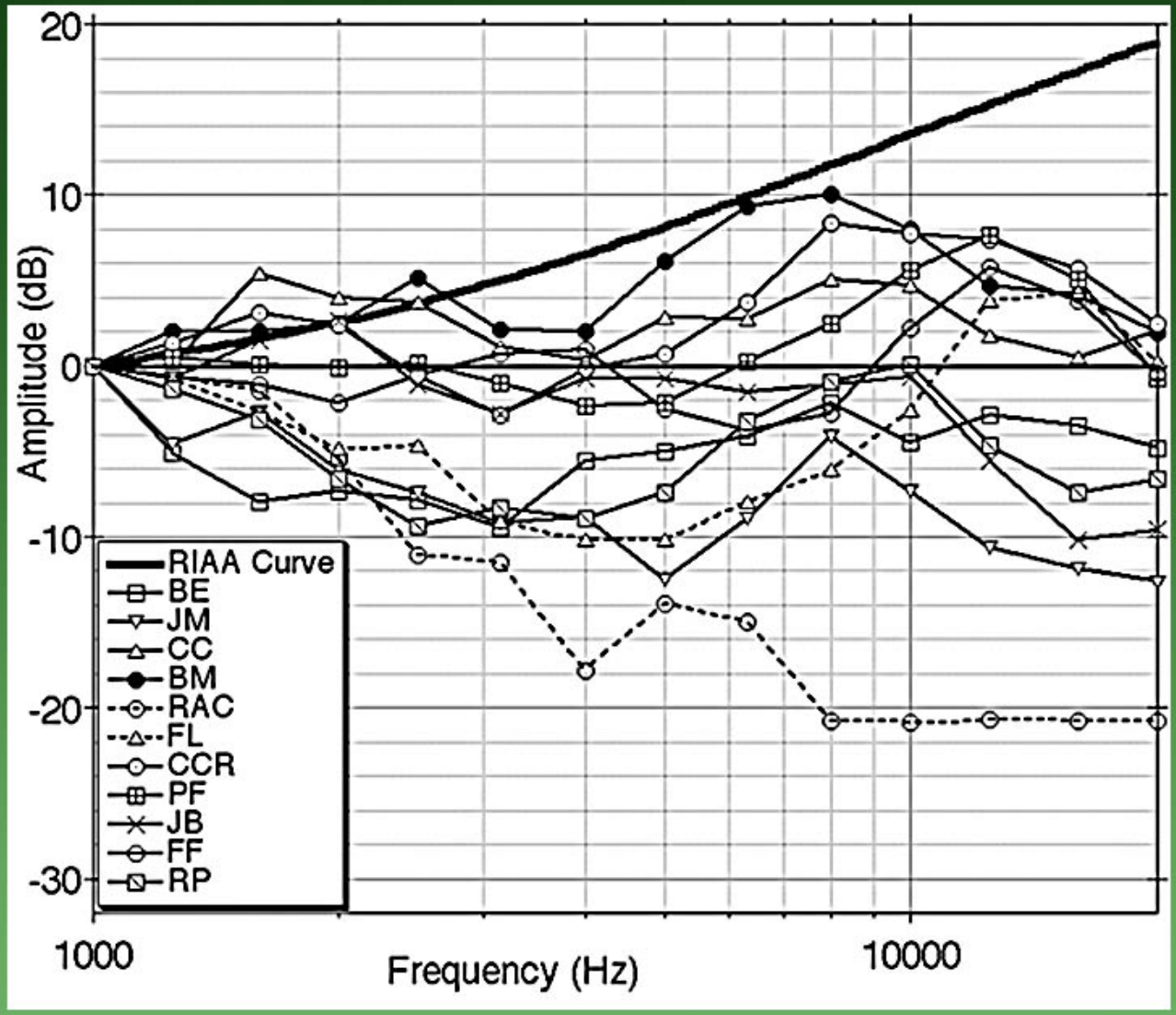
Vinyl LP Recordings Used For Frequency Balance Analysis

Artist	Album	Label
Bill Evans	Live at the Village Vanguard	Riverside (reissue)
Ambrosia	Ambrosia	20th Century
Pink Floyd	Wish You Were Here	Columbia
Rebecca Pidgeon	The Raven	Chesky
Led Zeppelin	Houses of the Holy	Classic (reissue)
Grateful Dead	Workingman's Dead	Warner Brothers
Maria Callas	Lucia di Lammermoor	Angel
Frederick Fennell	Holst Handel Bach / Cleveland Symph.	Telarc Digital
Magazine	Secondhand Daylight	Virgin (U.K.)
Joni Mitchell	Blue	Rhino (reissue)
Clifton Chenier	Clifton Chenier's Very Best	Blue Thumb
Bob Marley & the Wailers	Natty Dread	Island
Jeff Beck	Blow By Blow	Epic
The Cars	The Cars	Elektra
Creedence Clearwater Rev.	Cosmo's Factory	MFSL (reissue)
Ash	1977	Infectious (Germany)
Svatioslav Richter	Rachmaninoff (Op. 23 & 32 Preludes)	MHS
Nicholas Zumbro	Liszt Piano Con. No.1 in E-flat Major	MHS
Cat Stevens	The Teaser and the Firecat	Universal (reissue)

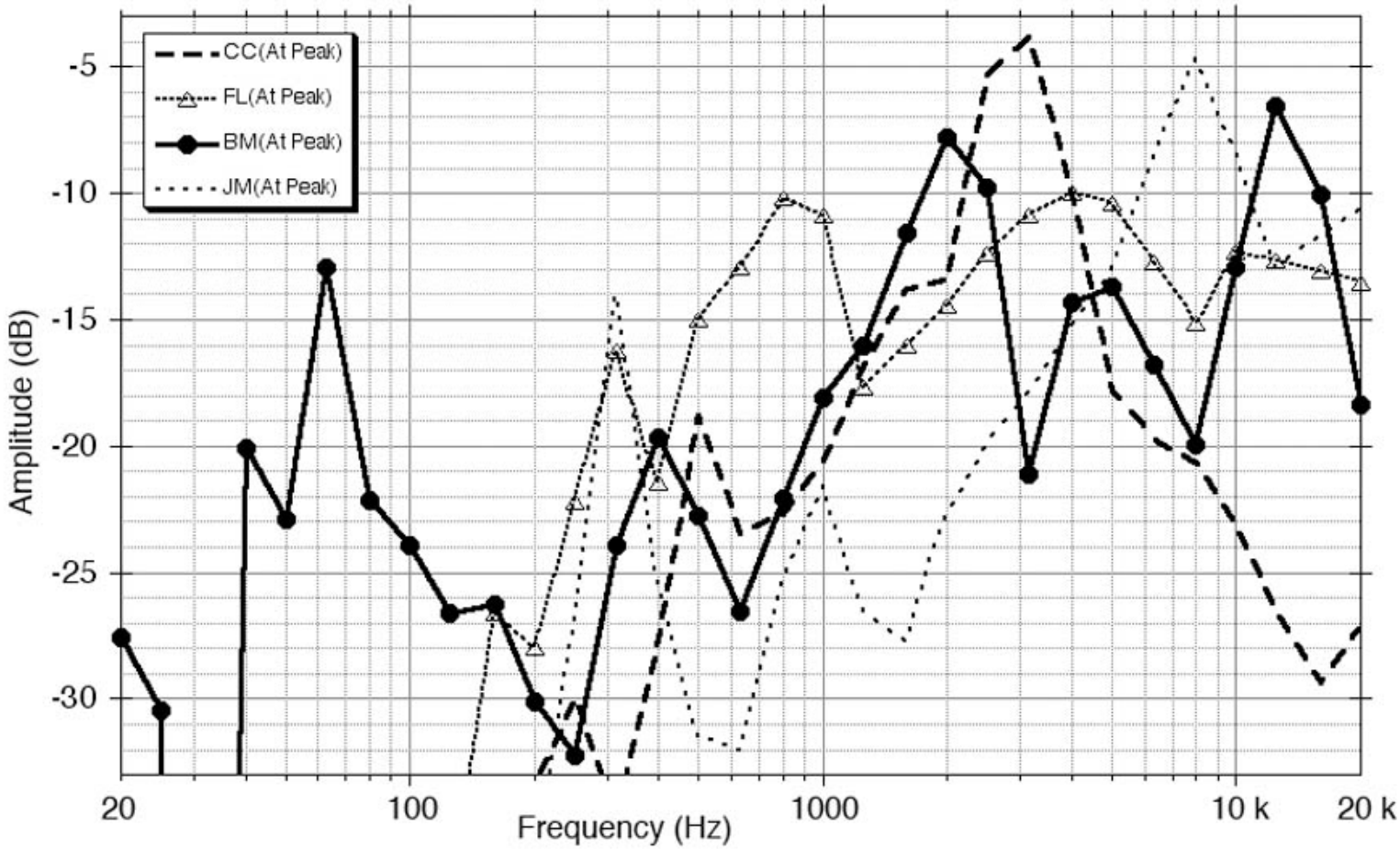
Normalized peak-responding, peak-hold third-octave frequency balance of selected vinyl LPs (without applying RIAA deemphasis)



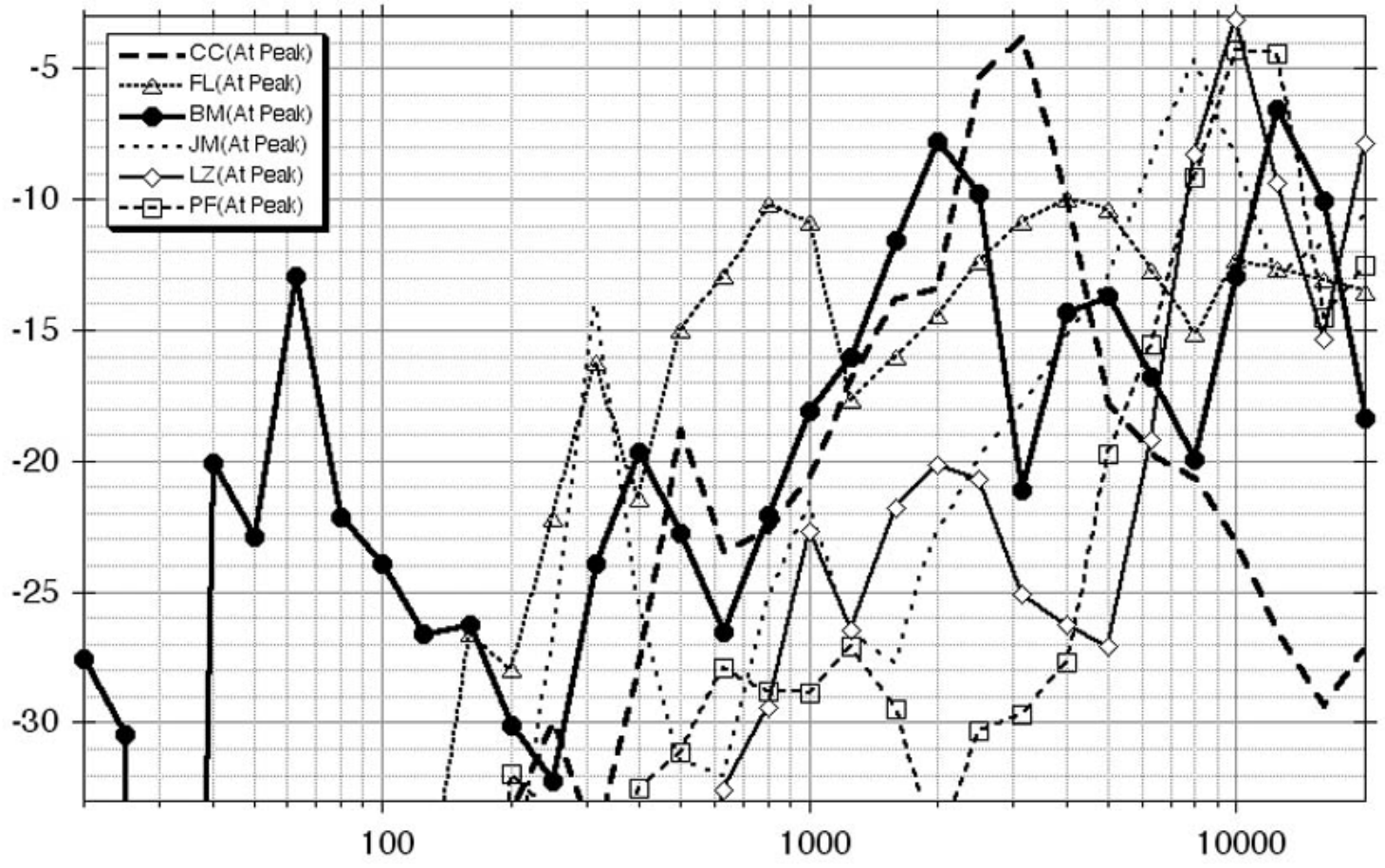
Peak-responding, peak-hold third-octave frequency balance (> 1 kHz)



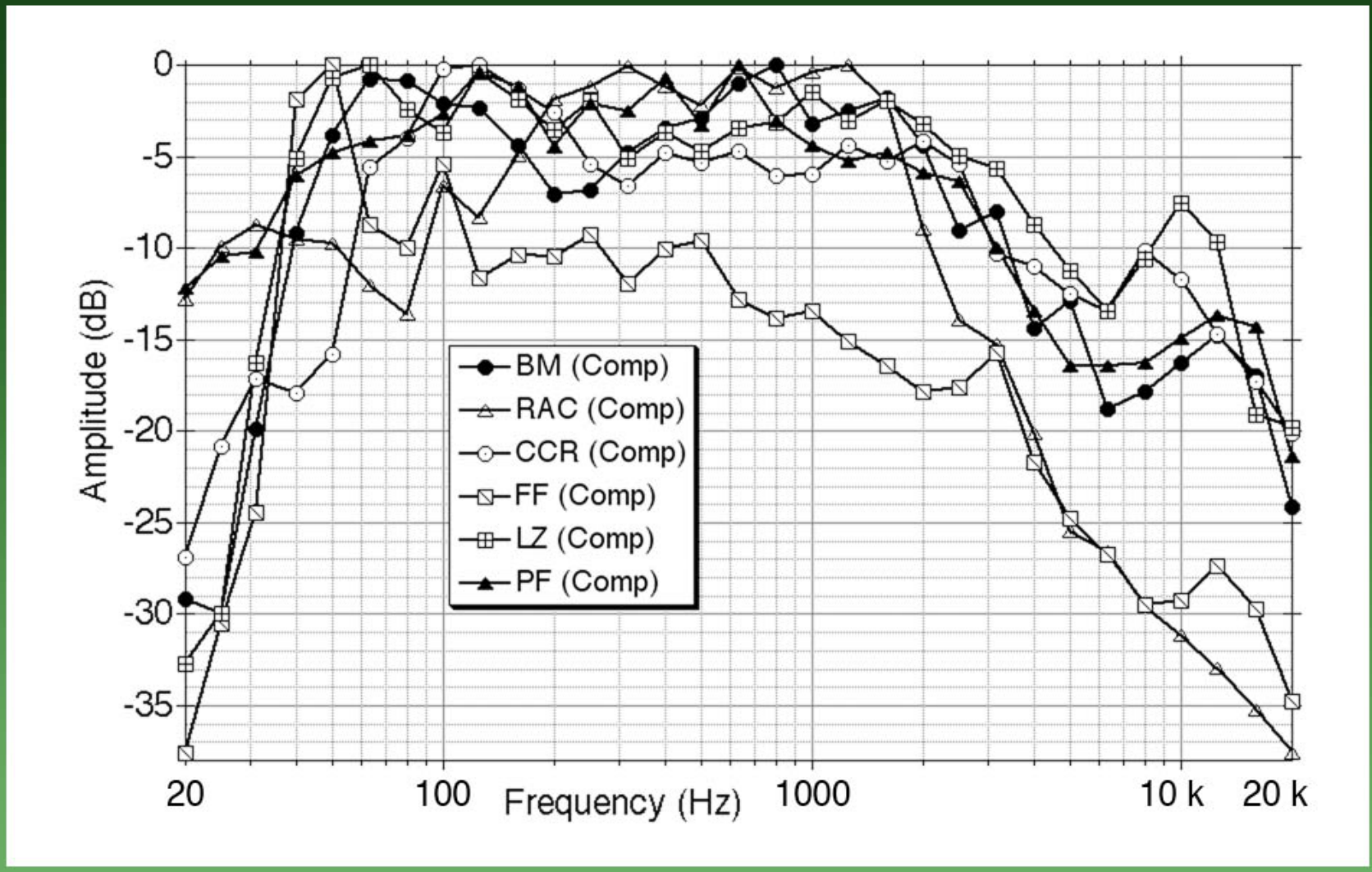
Frequency balance at time offset of overall peak signal amplitude (amplitudes normalized to overall peak signal amplitude value)



Frequency balance at time offset of overall peak signal amplitude (amplitudes normalized to overall peak signal amplitude value)



Frequency balance of LPs (after applying RIAA deemphasis)



Conclusion

Digital De-emphasis Filtering Recovers Bass Word Length

Conclusion

Digital De-emphasis Filtering Recovers Bass Word Length

Typical Musical Program Content: < 1 bit Reduction in Bass

Other side of the coin:

- Bass Word Length Reduction = Increased Effective Treble Word Length
  - (Pre-emphasis of Input Signal)


CHANNEL D
D
DIGITAL
stands for
TM