B.A.Sc. Thesis Defense

Equalizer Design for Shaping the Frequency Characteristics of Digital Voice Signals in IP Telephony

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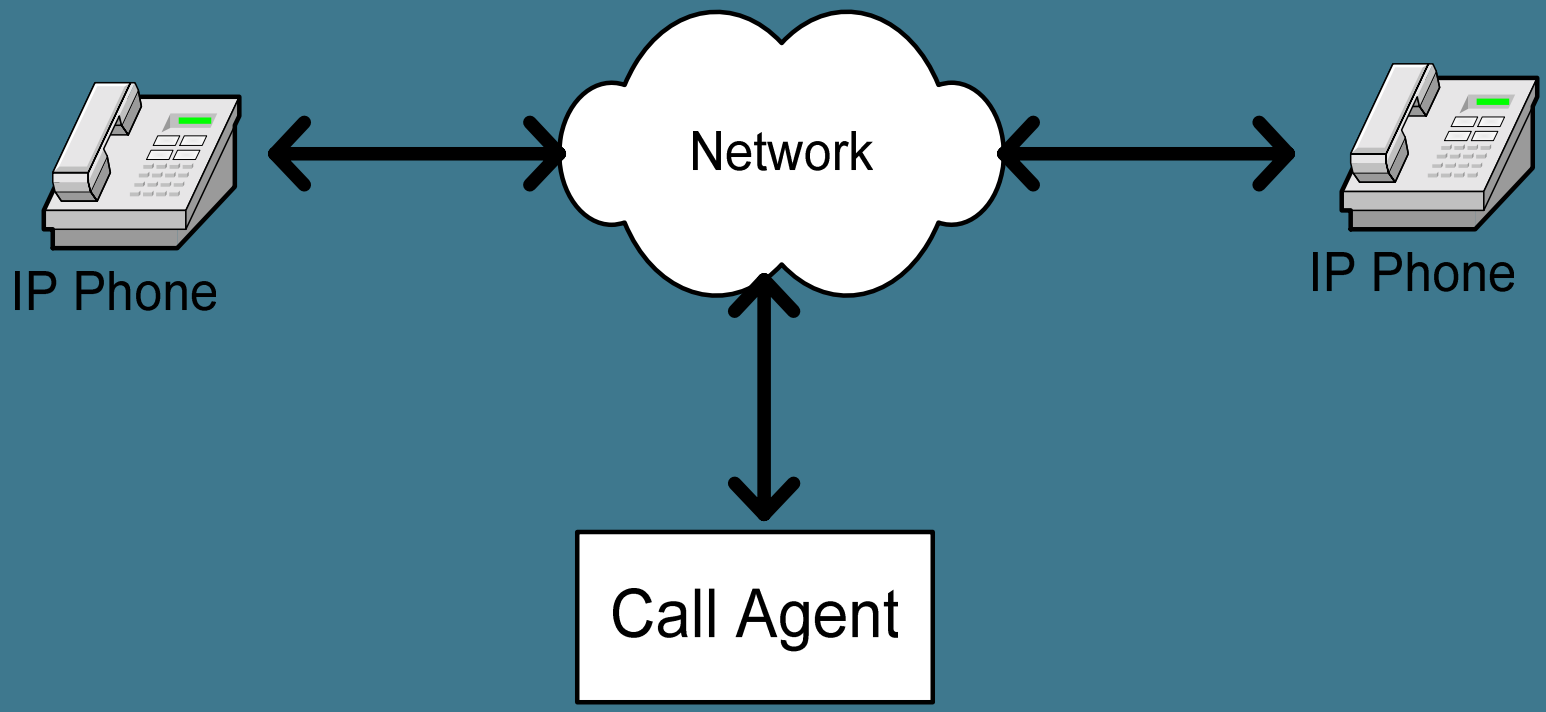
Presentation Overview

- Introduction of Project
- Filter Design Process
- Implementation Overview
- Test Method and Results
- Future Work
- Questions

Voice over IP



Project Objective

- Provide means for IP phone developers to modify signal frequency characteristics

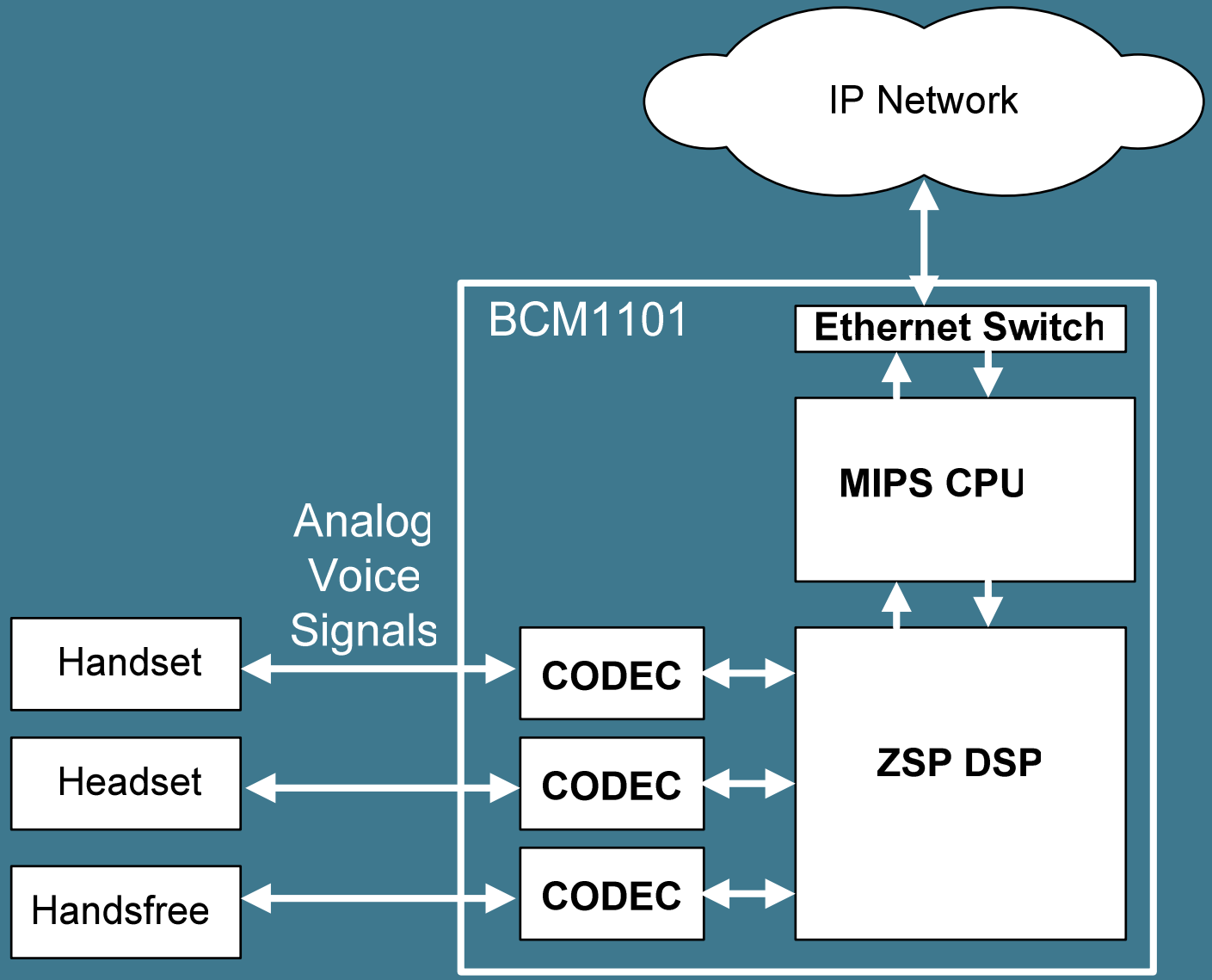
  Why?

  - Industry standards
    - TIA-EIA 810-A: Transmission Requirements for Narrowband Voice over IP and Voice over PCM Digital Wireline Telephones
  - Compensate for frequency response of audio device transducers

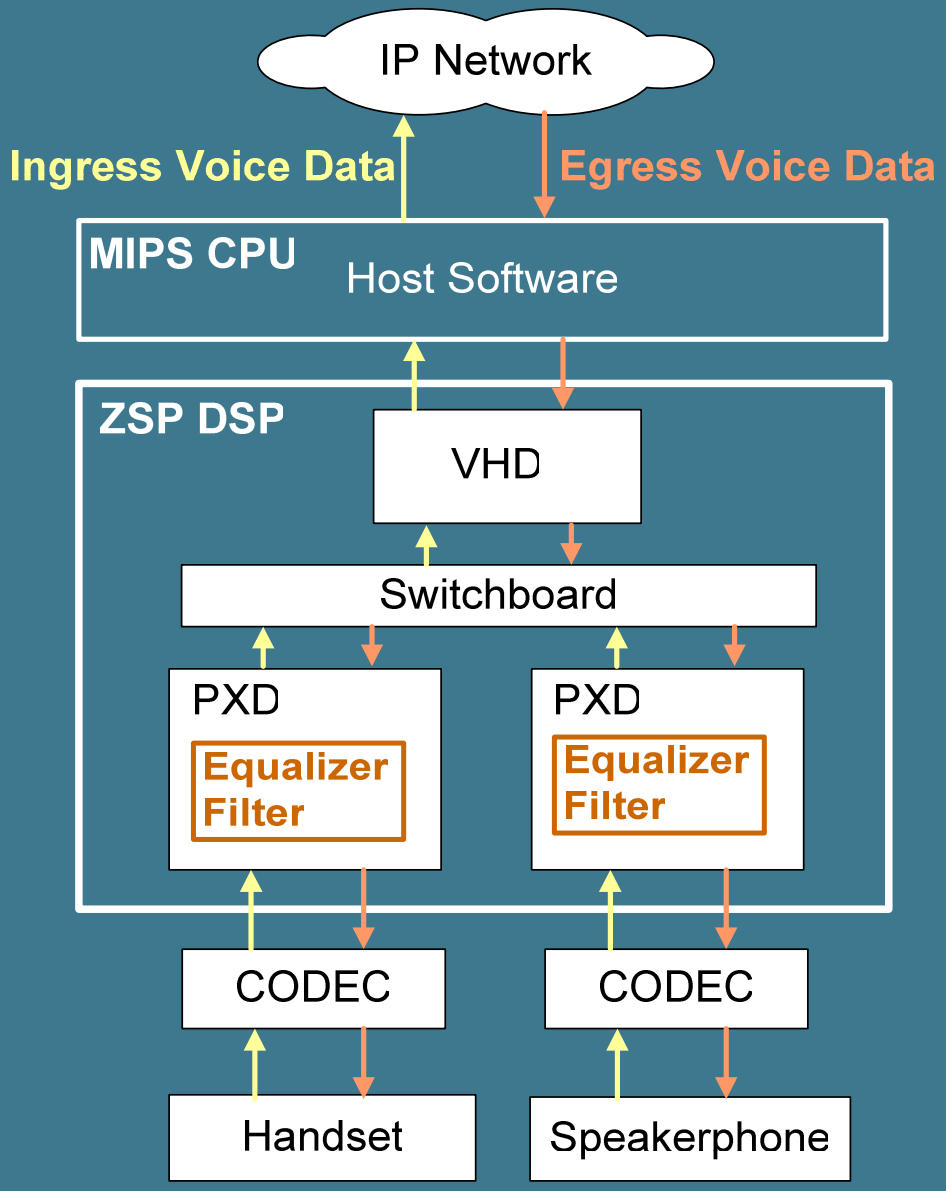
Solution

- Equalizer filter:
  - Integrated into existing IP phone architecture
  - Implemented in software
  - Programmable filter parameters
- Equalizer User = IP Phone developer

Broadcom IP Phone System



Software Architecture



Equalizer Specifications

- User defined magnitude response:
  1. User measures transducer frequency response of telephone device (e.g. Speakerphone)
  2. User compares the frequency response to the requirements/standards
  3. User determines compensating frequency response equalizer filter needs to have to satisfy requirements/standards

Equalizer Specifications

- Finite impulse response (FIR) filter
- Advantages of FIR filters:
  - Stable
  - Linear phase response possible
- Filter order chosen by user based on requirements

Equalizer Specifications

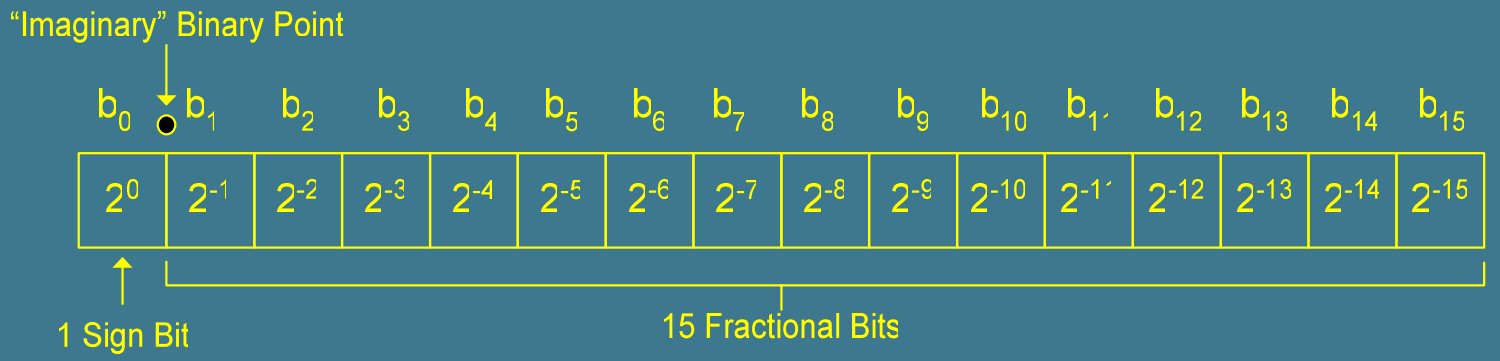
- Filter phase specifications
  - No requirement for linear phase response
  - Want to minimize overall filter delay for real time applications such as Voice over IP
- Implemented equalizer as minimum phase filter
  - Minimizes group delay

Equalizer Design

- Design decisions driven by user requirements
- Tradeoffs involved with all decisions
  - Example: Choosing the filter order
    - Larger filter => more accurate frequency response
    - Smaller filter order => requires less memory and processor usage

Equalizer Design

- Equalizer user generates coefficients using our filter design method
- Window filter design method
  - Hamming window
  - Implemented in Matlab
  - Q15 format coefficients



Software Implementation

- Equalizer filter module
  - Generic interface
  - Optimized for memory/processor usage
  - Reusable software function
- Equalizer PxD Function Module
  - Software ‘wrapper’
  - Conforms to existing software architecture

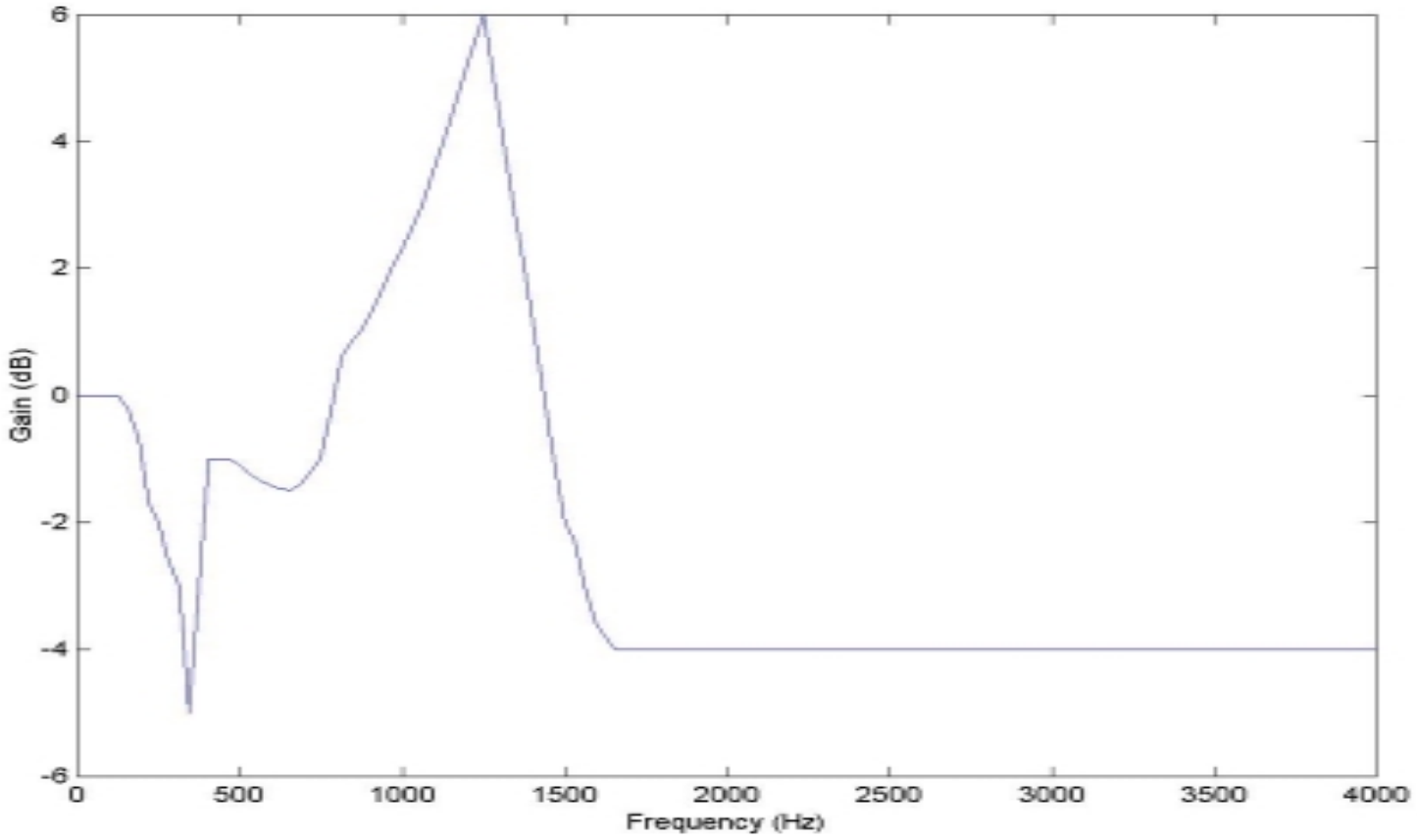
Software Testing

- Broadcom IP Phone reference platform
- LSI Logic ZSP Software Development Kit
- Unit Test Application
  - Verify filter module functionality
  - Characterize filter response

Software Testing

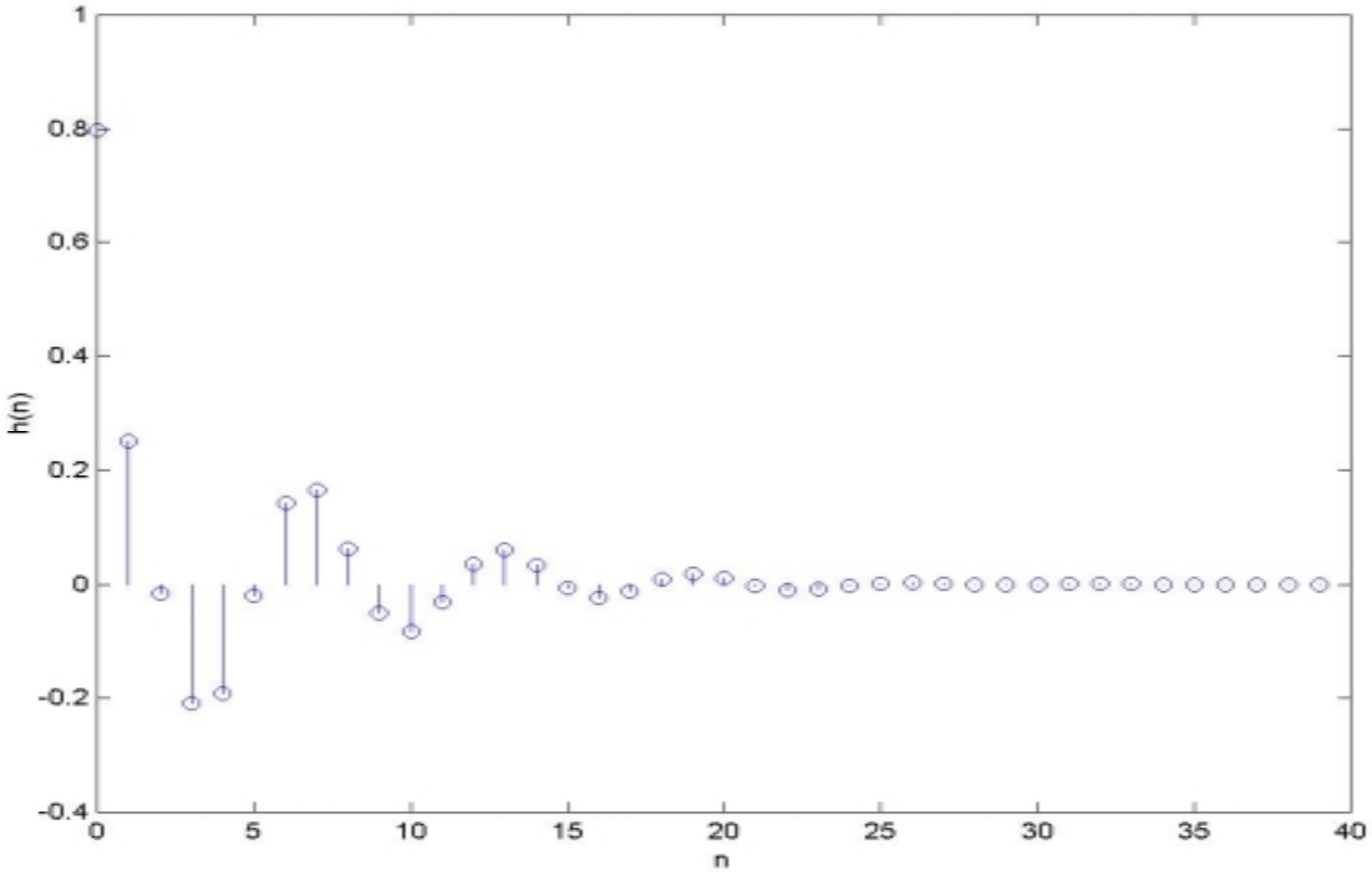
Example Test Case

Plot of User Specified Frequency Response:



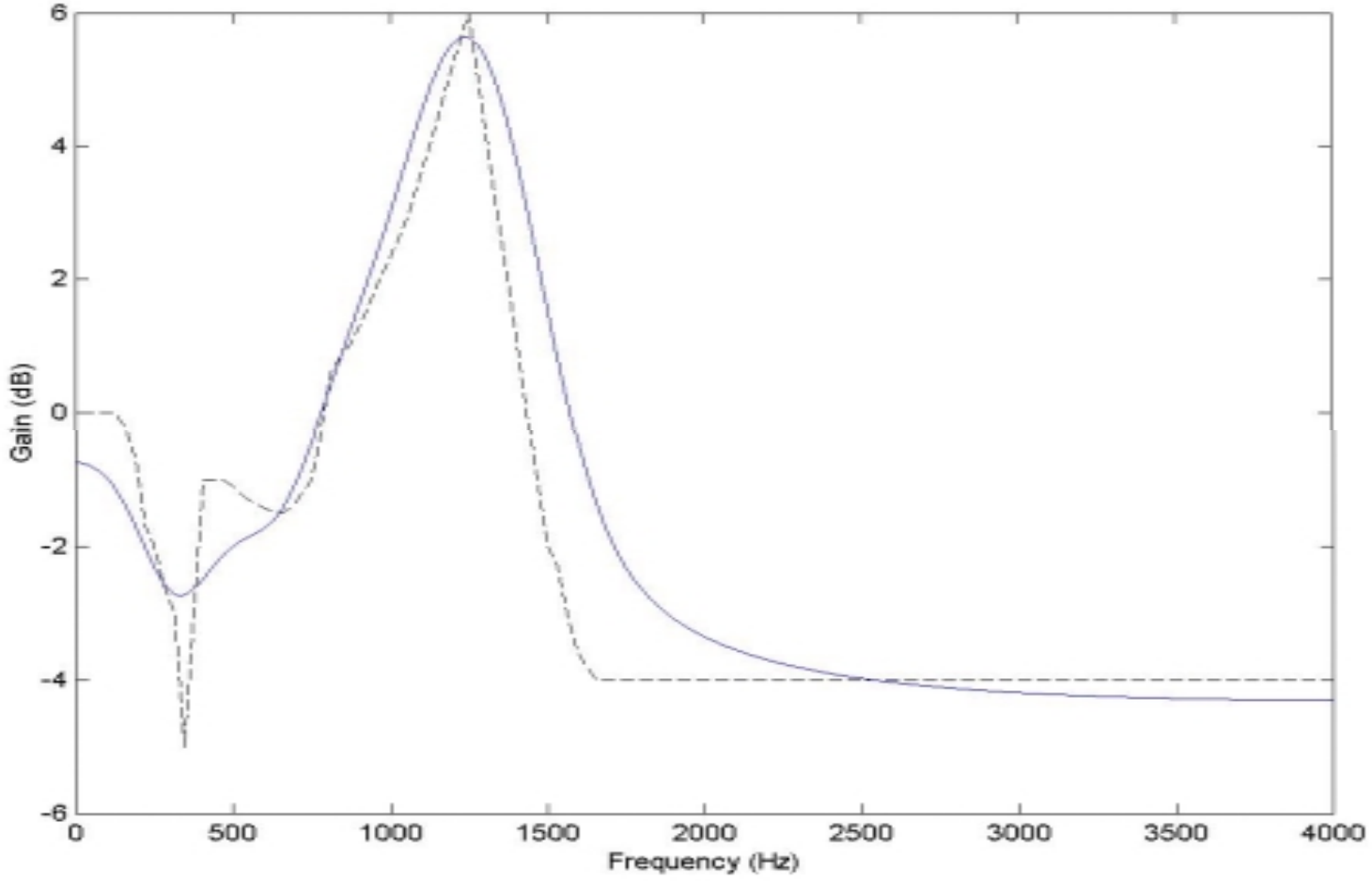
Software Testing

Example Filter Coefficients for N=40:



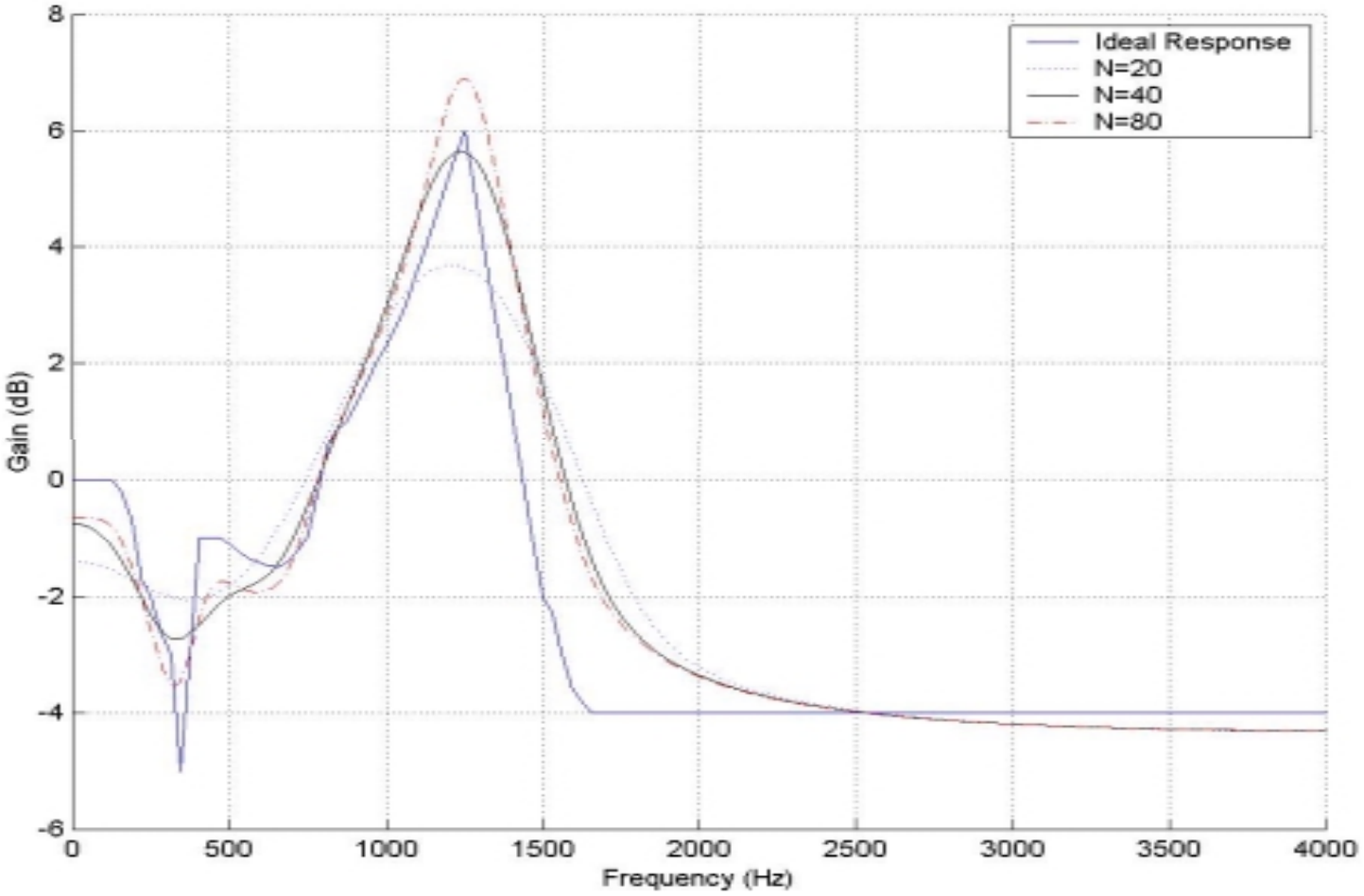
Software Testing

Example Filter Response for N=40:



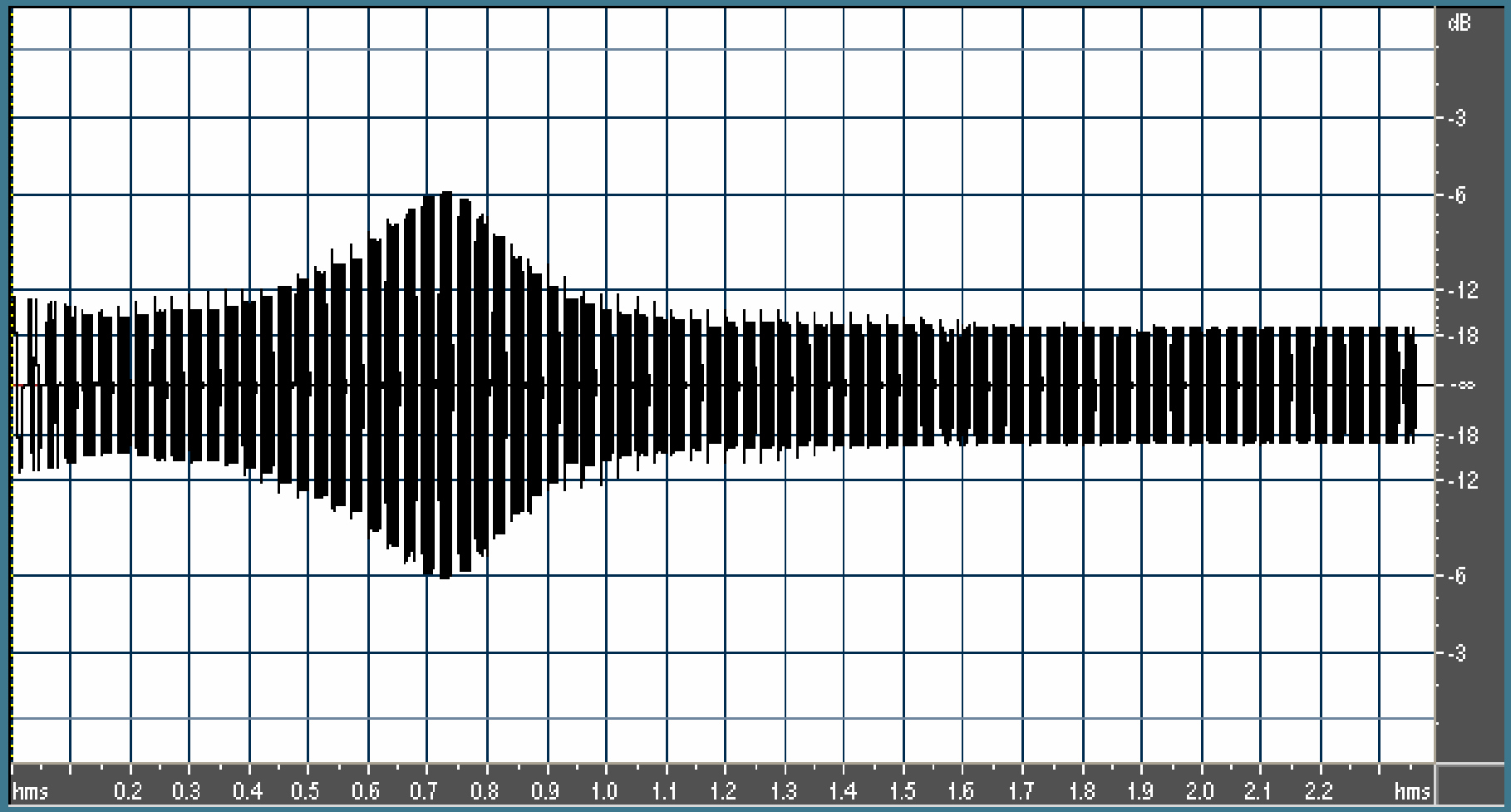
Software Testing

Comparison of Different Filter Orders:



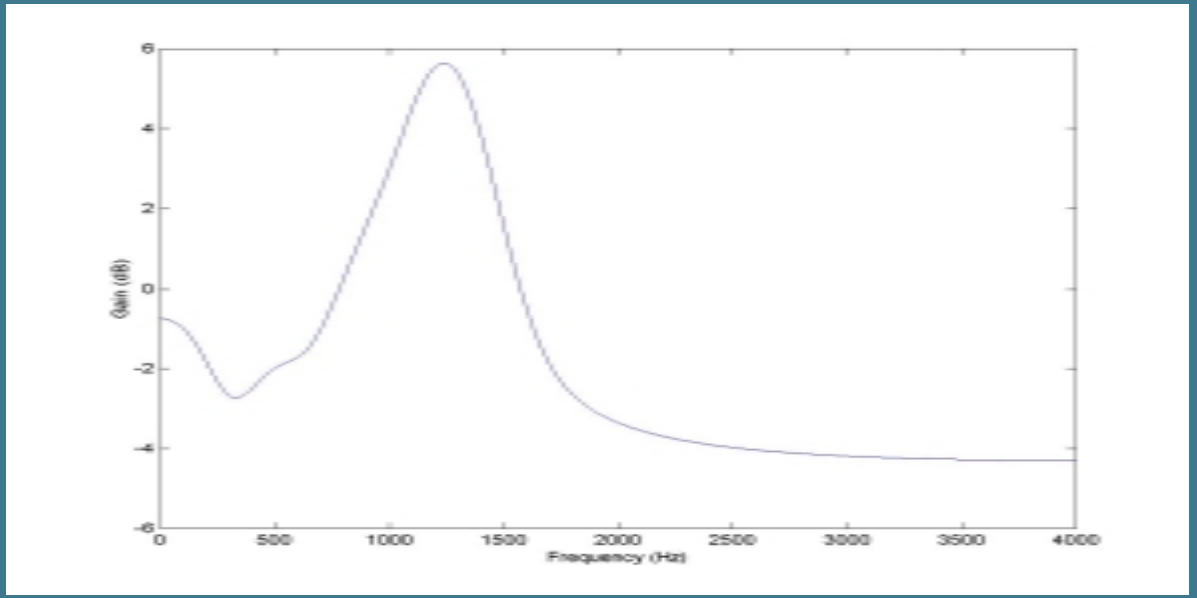
Software Testing

Example Unit Test Case Output

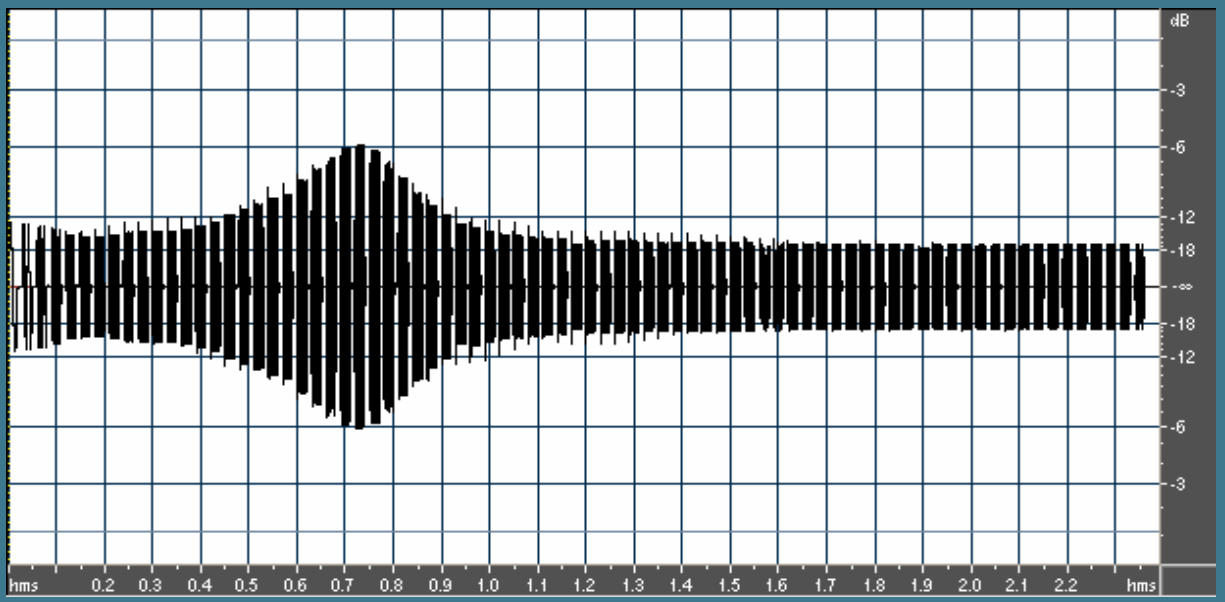


Software Testing

Filter Frequency Response

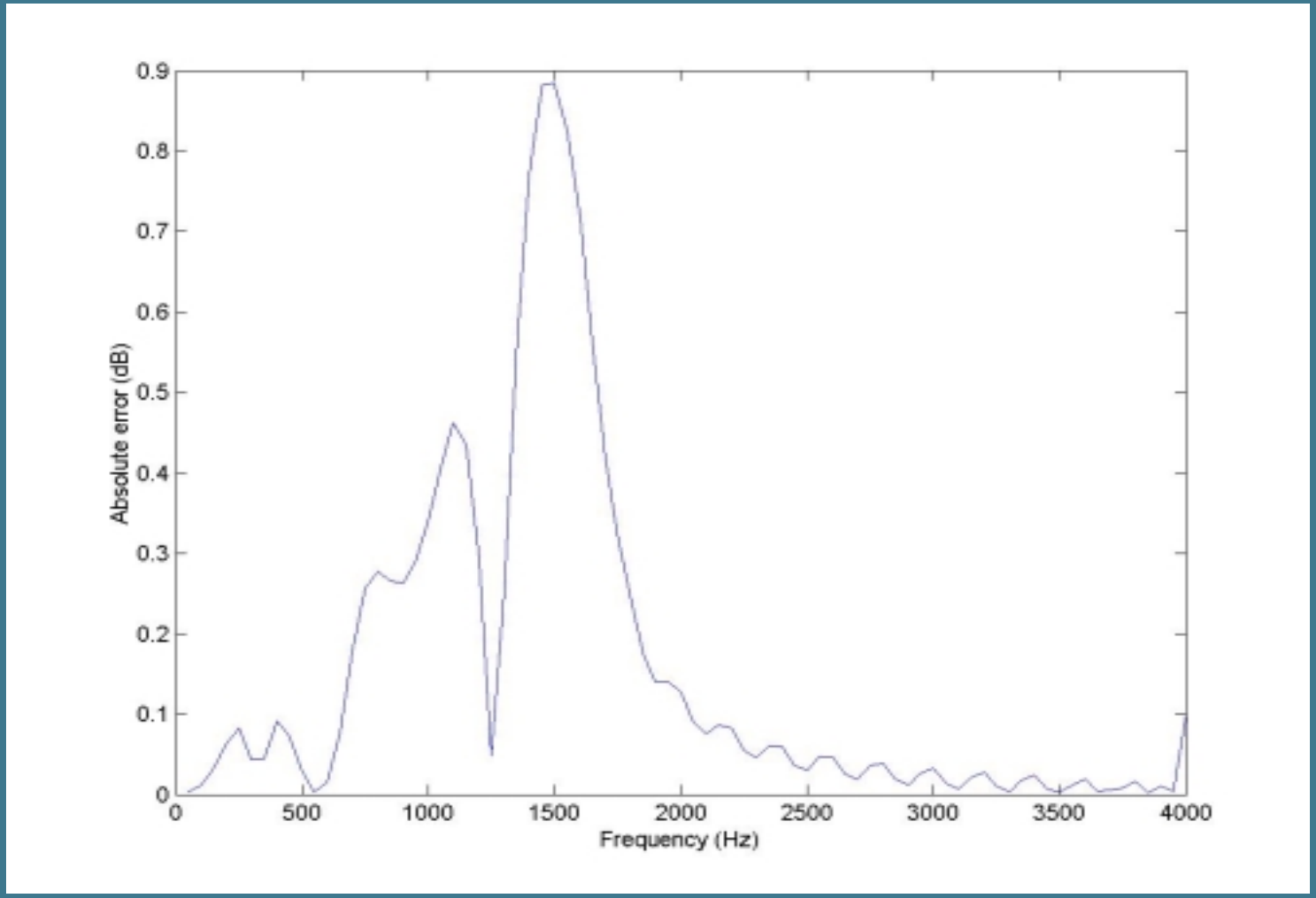


Response to Input Frequency Sweep



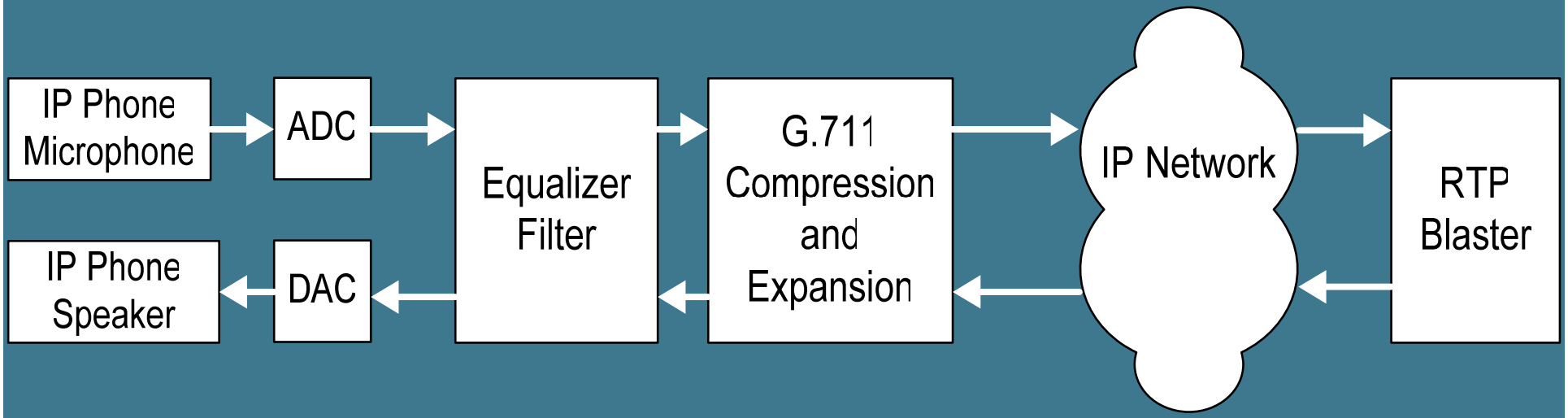
Software Testing

Error between expected and actual filter gains:



Software Testing

- System Testing
  - Verify behaviour after integration
  - Test equalizer PxD function API



Future Work

- Software enhancements
  - Cascade FIR with IIR filter
  - Implementation improvements
- Silicon implementation

Acknowledgements

- Broadcom Design Engineers
  - Taro Umezawa
  - Andy Fung
  - …and other co-workers for their technical support and advice
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Questions?