Signal Processing System for Imbedded Transparent Ultrasonic Emitter in Smartphones

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Reference

Plan

Procedure

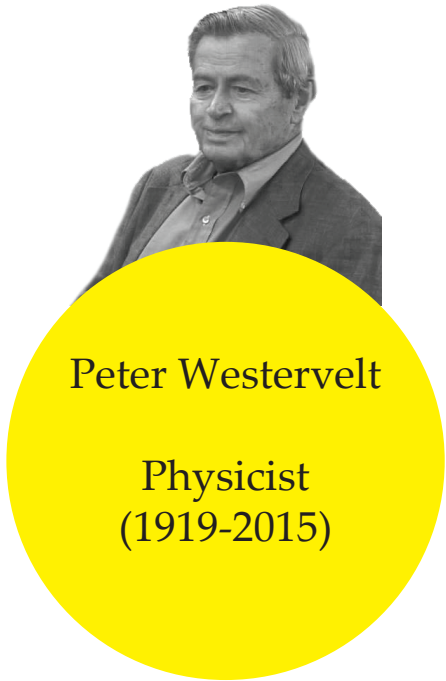
Objectives

Goal / Scope

Background

Background

“Parametric End-fire Array” (Westervelt, 1960)



Peter Westervelt

Physicist
(1919-2015)

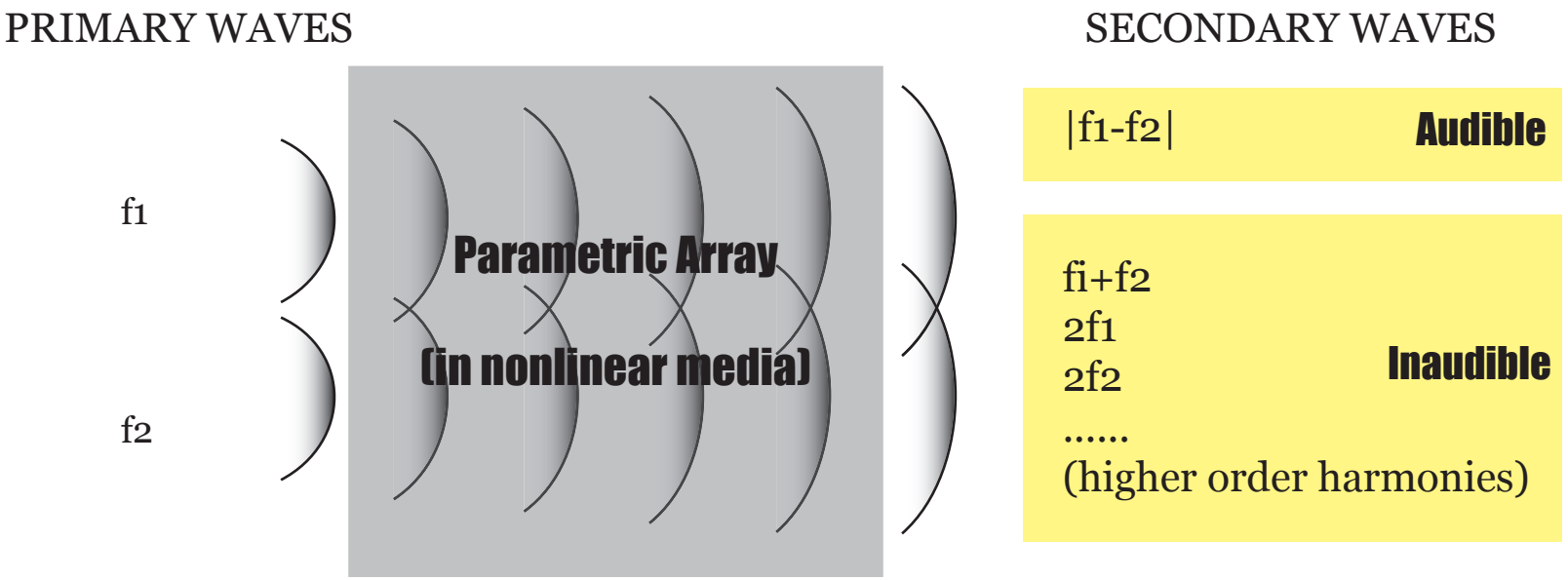


Fig. 1 Brief explanation on ”parametric end-fire array”

1963
Westervelt

Westervelt Equation
Fundamental equation of parametric array

1965
Berktay

Berktay Equation
Simple model on farfield array

1969, 1971
Zabolotskaya, Khokhlov, Kuznetsov

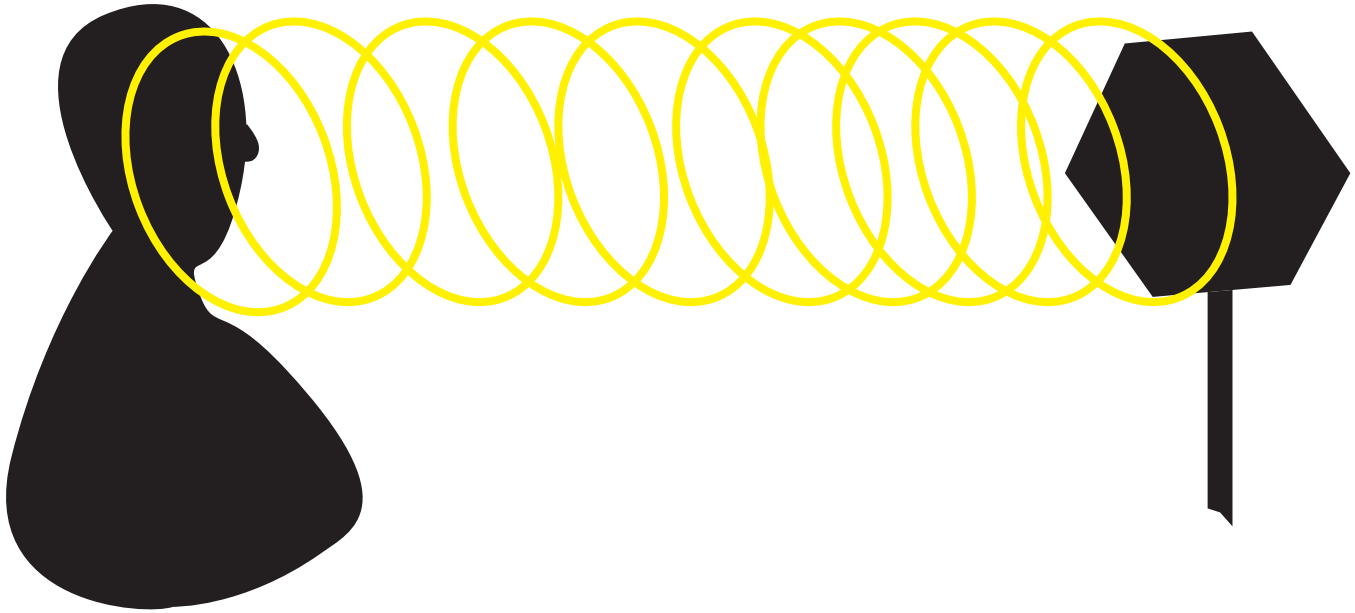
KZK Equation
One of the most efficient models

“Audio Spotlight” (Yoneyama et al., 1983)

Wasahide
Yoneyama

emeritus professor
(1938-)

“Audio Spotlight” (Yoneyama et al., 1983)



Kamakura pointed out three problems to solve
in parctical implement (Kamakura et al., 1984):

- Optimal parameters (e.g. frenquencies of carrier waves)
- Distortion reduction
- Attenuating amplitude of ultrasound

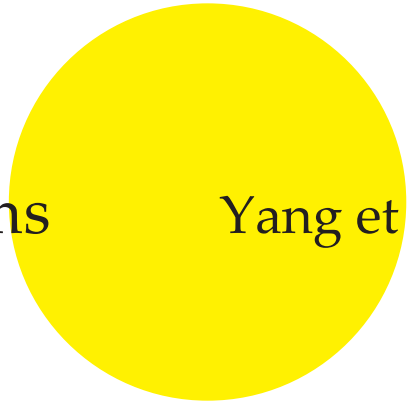
Optimal parameters — Moffett and Mellen,1977; Aoki et al., 1994

Distortion reduction — Kamakura et al., 1984; Kite et al., 1998

Attenuating amplitude of ultrasound — Kamakura et al., 1984

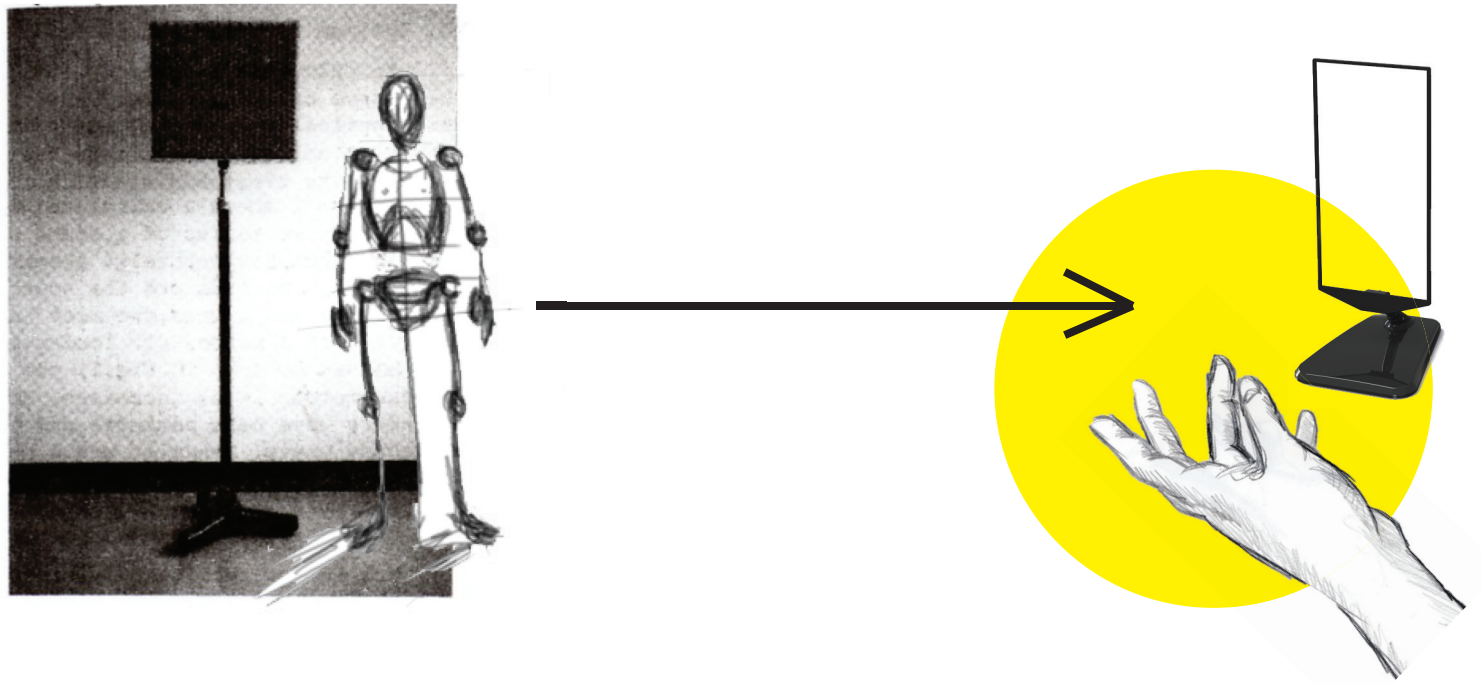
. . . . . .

Propagation model of finite amplitude sound beams — Yang et al., 2005



“Transparent parametric emitter” (Hecht et al., 2005)

“Transparent parametric emitter” (Hecht et al., 2005)



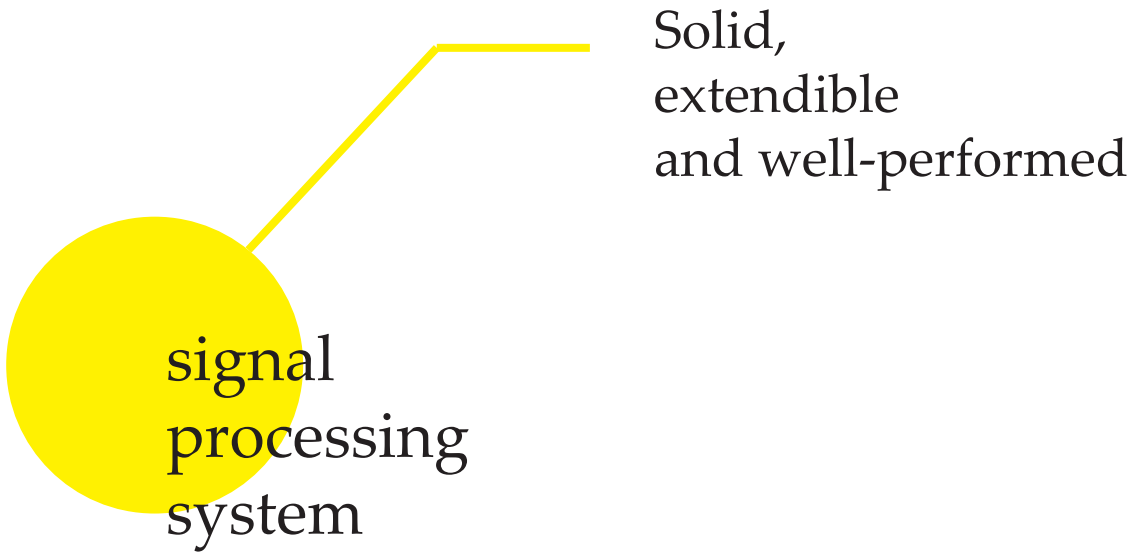
“Transparent parametric emitter” (Hecht et al., 2005)

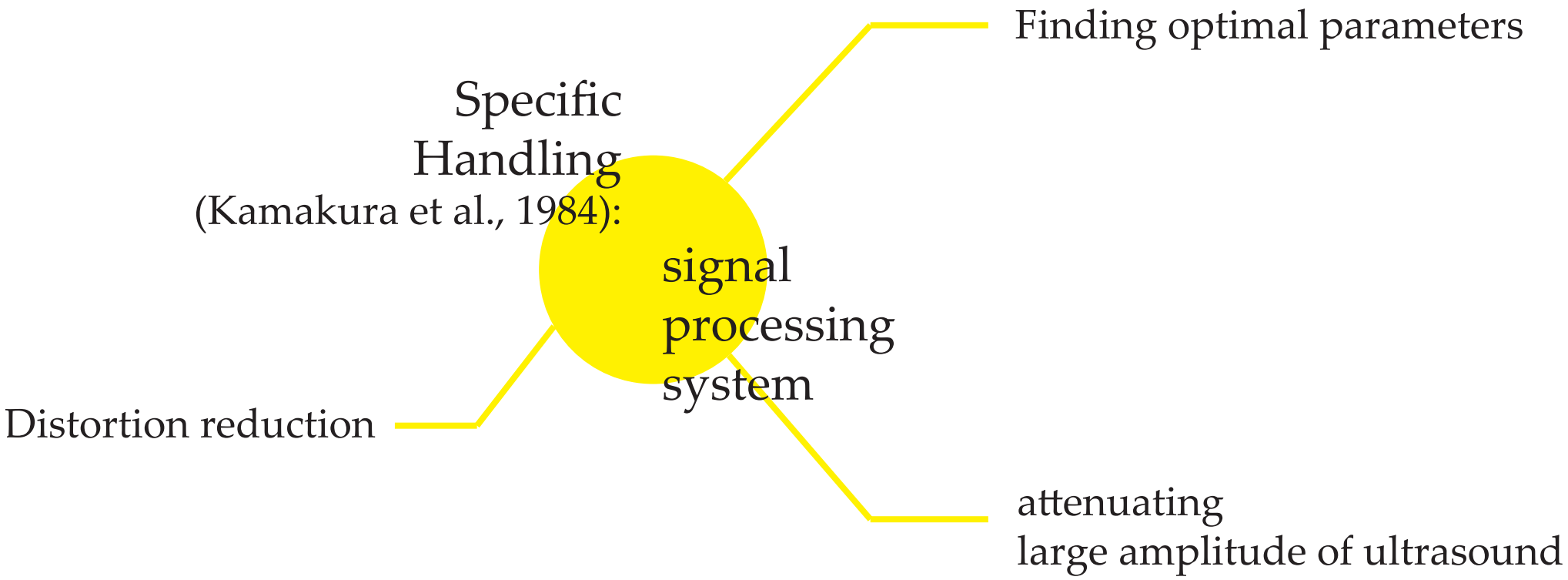
“thin, thiner, ultra thin”

thickness of marketing

Few reports have mentioned the
the detailed design of signal processing system
before the emitting stage.

Goal / Scope


Solid,
extendible
and well-performed
signal
processing
system


Specific
Handling
(Kamakura et al., 1984):
signal
processing
system
Finding optimal parameters
Distortion reduction
attenuating
large amplitude of ultrasound

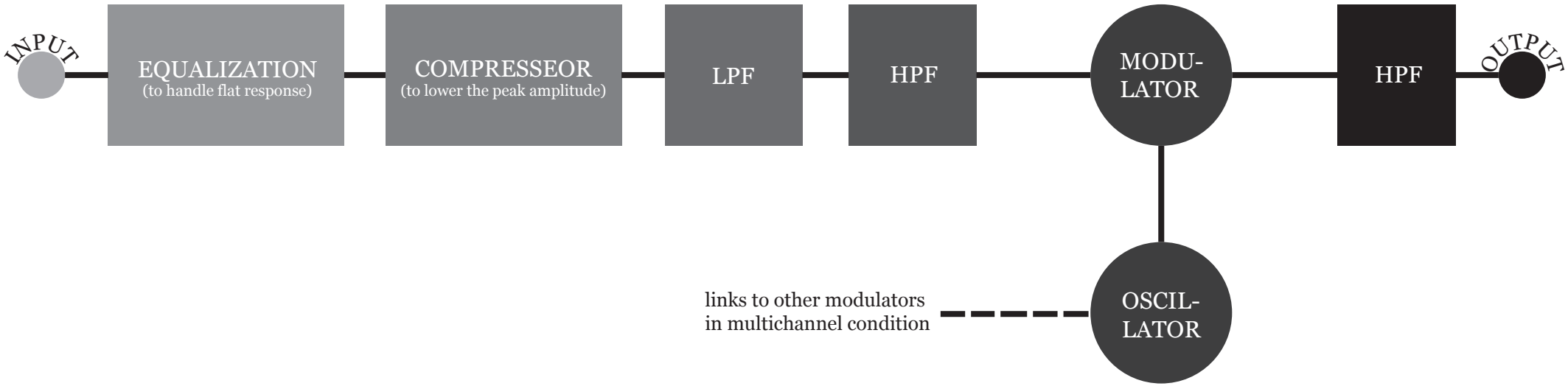
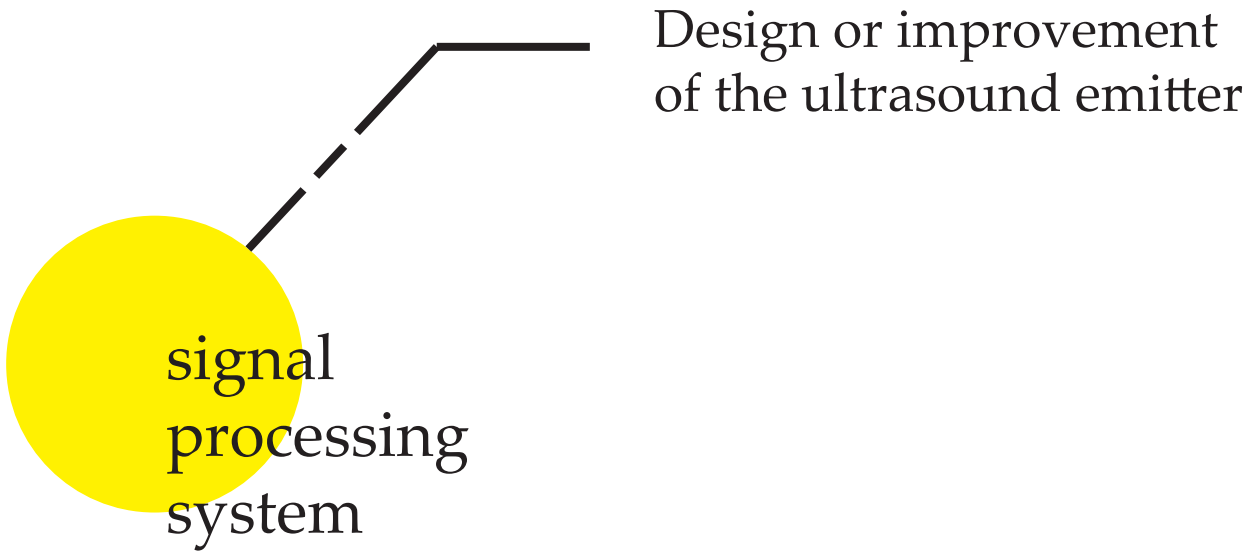
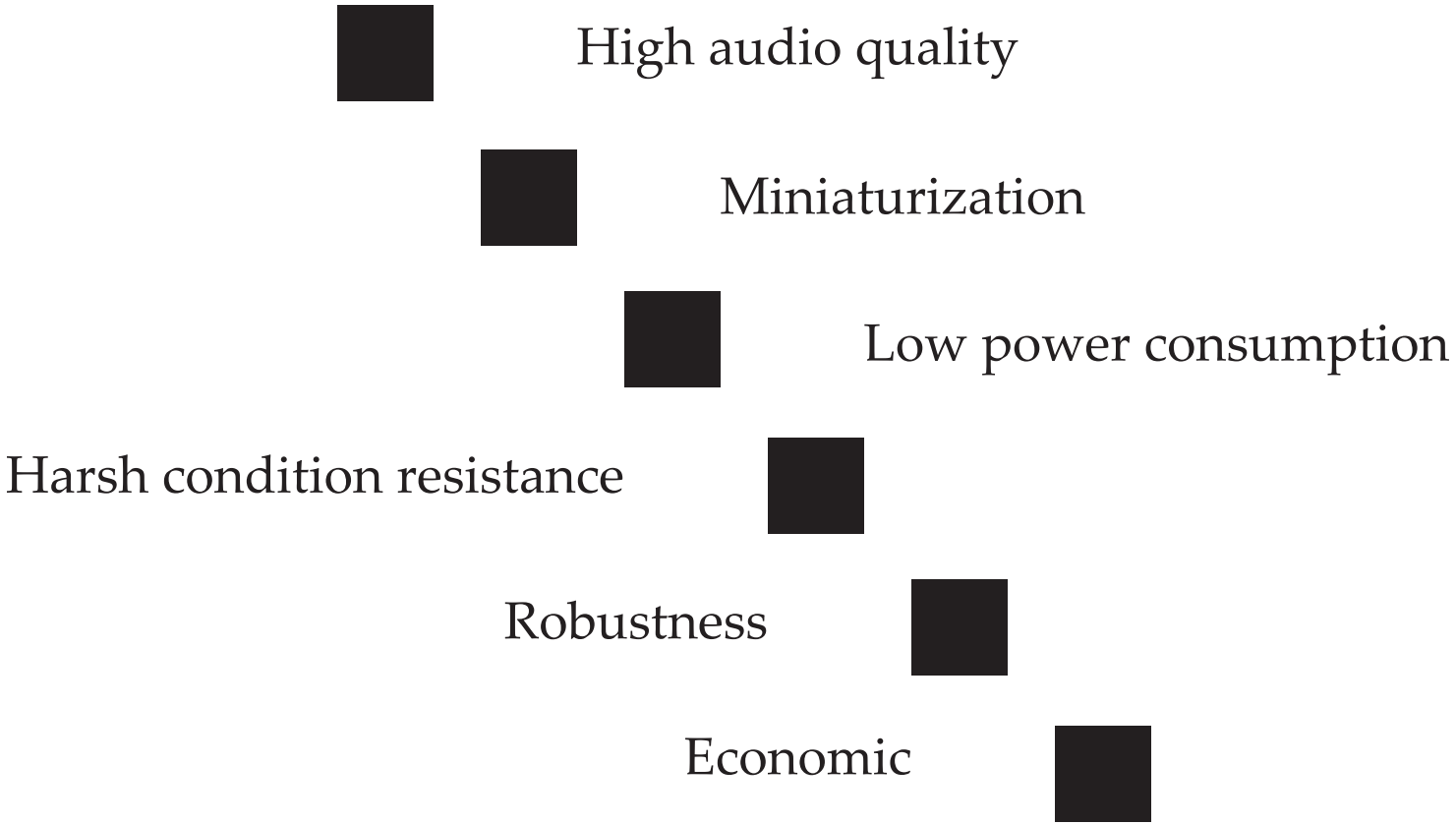


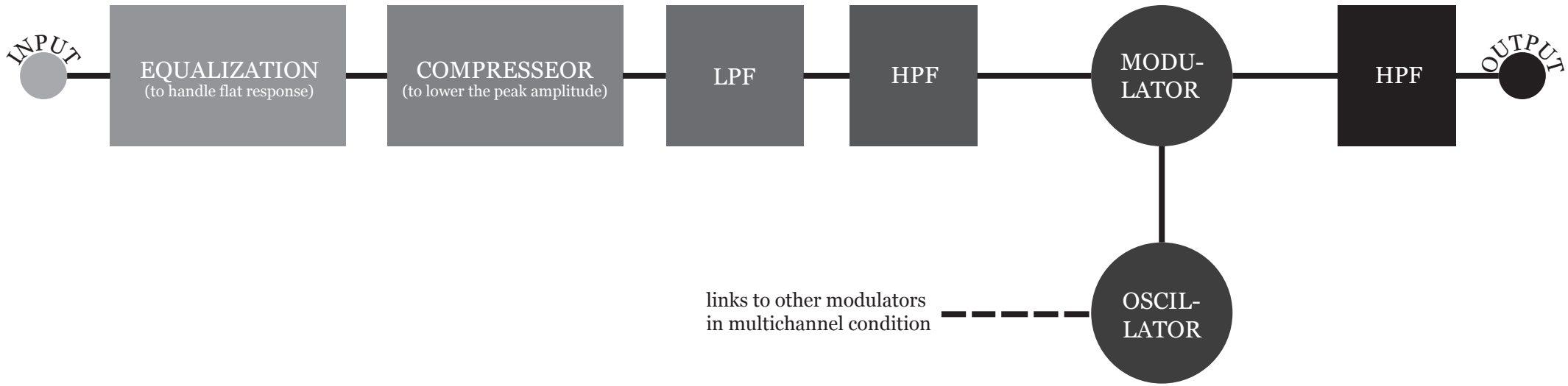
Fig. 2 Prototype of a signal processing system for ultrasound emitter

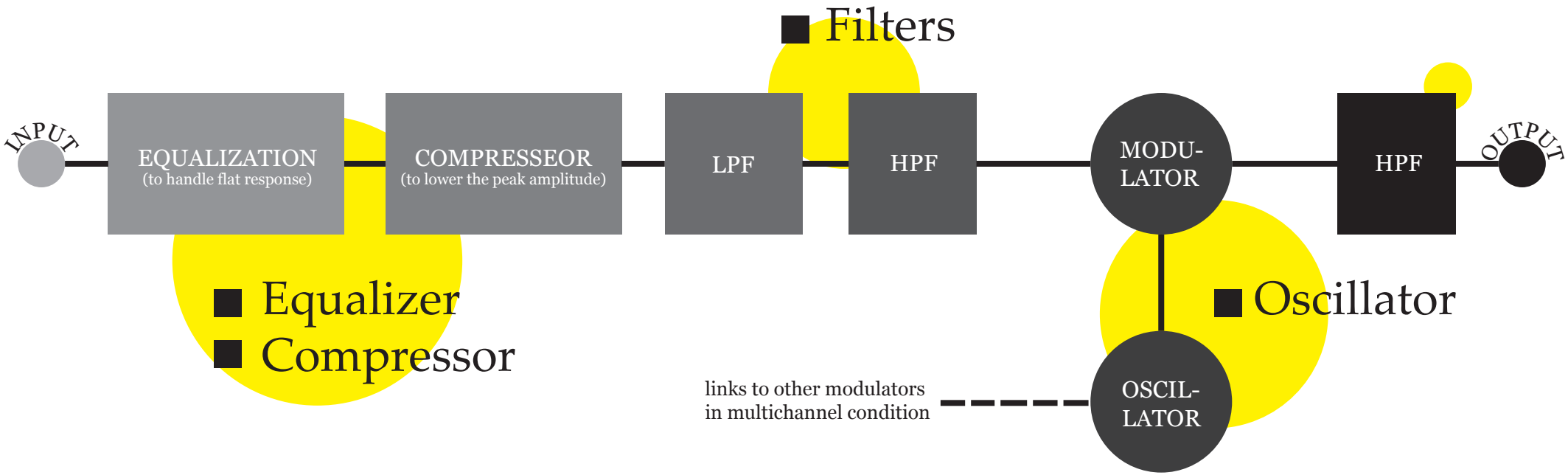

Design or improvement
of the ultrasound emitter
signal
processing
system

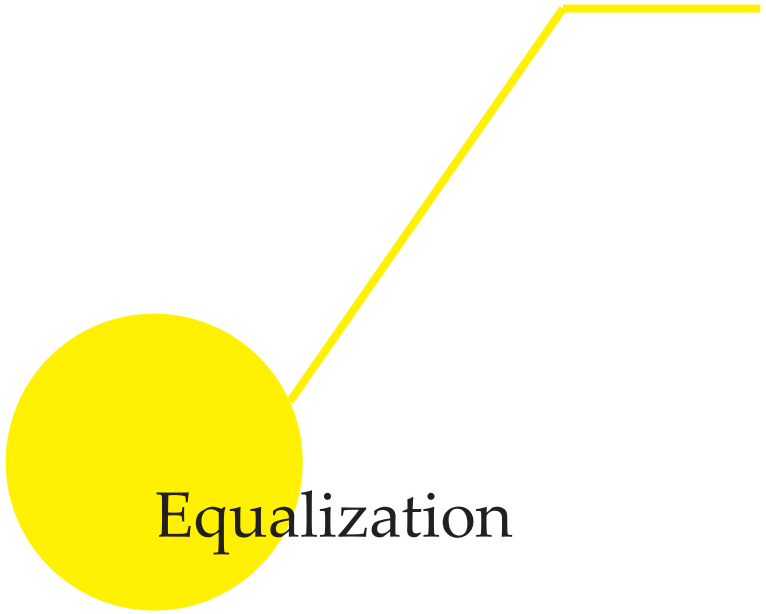
Objectives


High audio quality
Miniaturization
Low power consumption
Harsh condition resistance
Robustness
Economic

Procedure 


INPUT
EQUALIZATION
(to handle flat response)
COMPRESSEOR
(to lower the peak amplitude)
LPF
HPF
MODU-
LATOR
HPF
OUTPUT
links to other modulators
in multichannel condition
OSCIL-
LATOR


Filters
INPUT
EQUALIZATION
(to handle flat response)
COMPRESSEOR
(to lower the peak amplitude)
LPF
HPF
MODU-
LATOR
HPF
OUTPUT
Equalizer
Compressor
Oscillator
links to other modulators
in multichannel condition
OSCIL-
LATOR



[Function]

Converting analog signals
into digital signals;

Adjusting the amplitude of different frequency
by digital filter.

[Purpose]

Adding protection to the electric signal;

Compensating the distortion in device;

Restoring the original acoustic signal.

[Implement]

Field—programmable gate array;

System on chip.

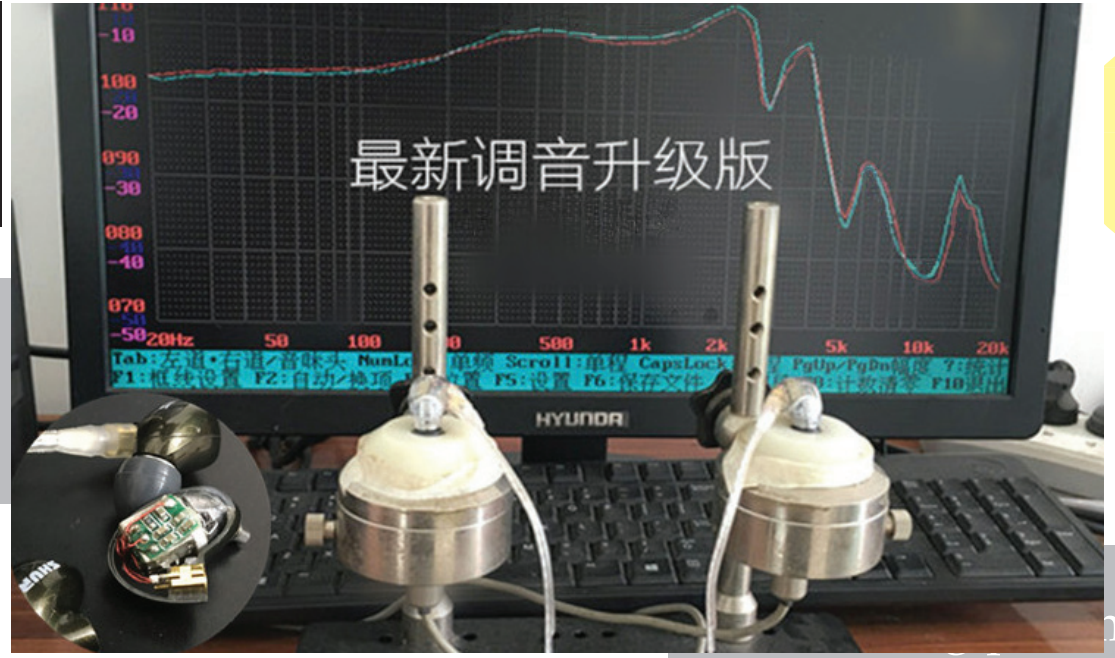
Detecting the test signal and describe the spectrum.

Detailed 3-step

Compared with the range of international standard.

Calculating parameter and design corresponding filters.

Detecting the test signal and describe the spectrum.



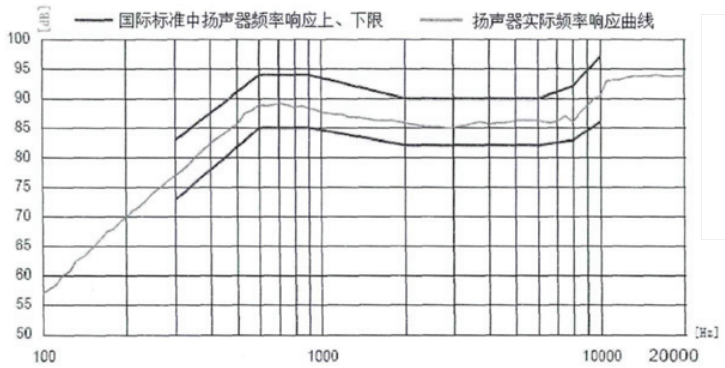
3-step

meter and design corresponding filters.

Detecting the test signal and describe the spectrum.

Detailed 3-step

Compared with the range of international standard.



Calculating parameter and design corresponding filters.

[IIR design]OO

The most common practice is to transform $H_a(s)$ into the desired digital G(z) transfer function

[Methods]

The Impulse Invariance Method
The Bilinear Translation Method

convert the digital filter specification to analog low pass prototype filter specifications

determine the analog low pass filter transfer function meeting these specifications

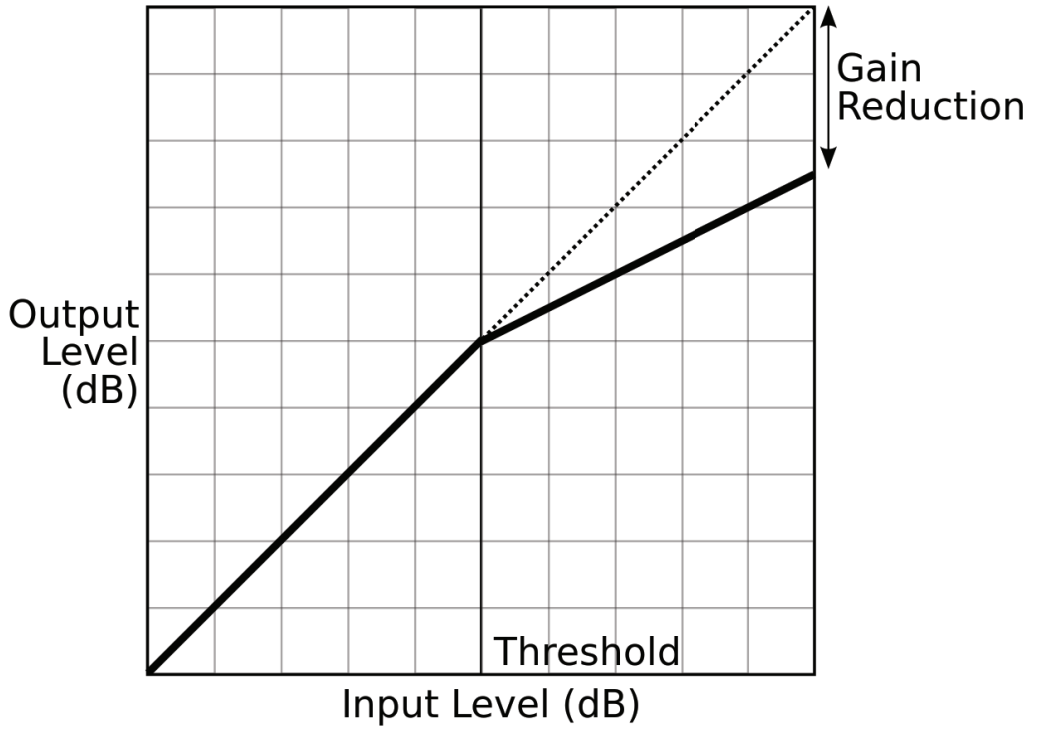
transform the analog filter in to the desired transfer function.

Detailed 3-step

Calculating parameter and design corresponding filters.

Compressor

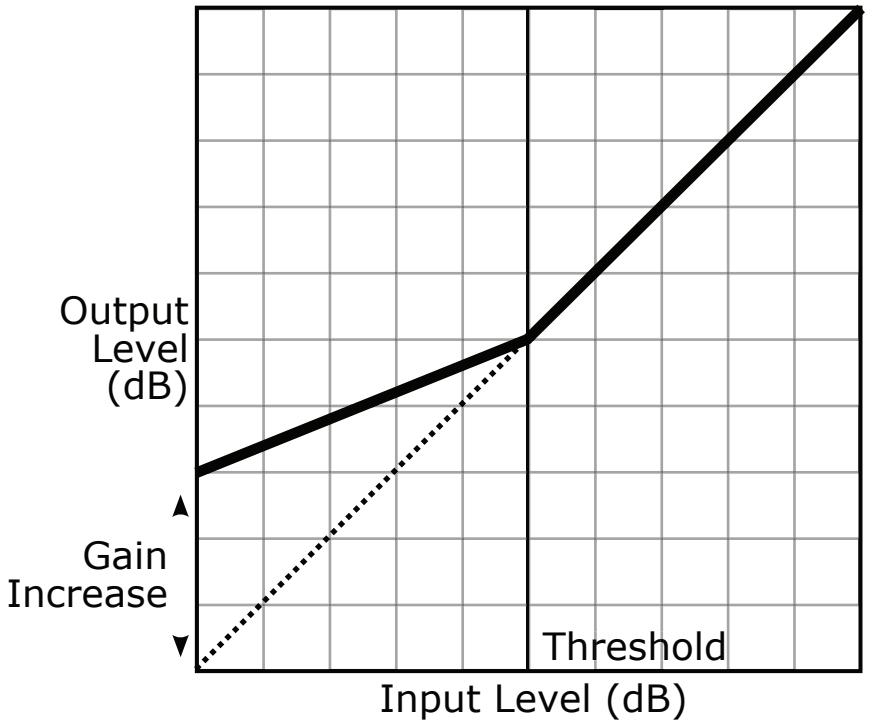
Limit the dynamic range of the signal.



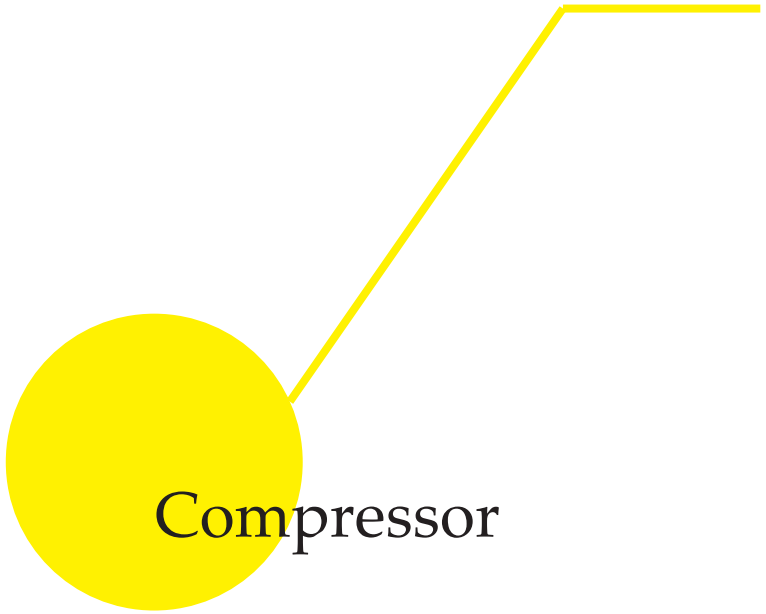
Downward Compression

Compressor

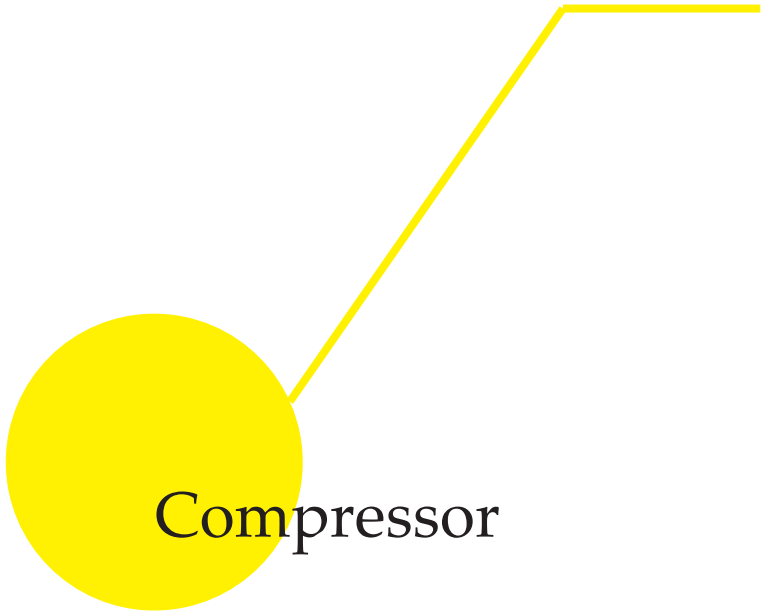
Limit the dynamic range of the signal.



Upward Compression



Two major benefits:
Free membrane protection;
Audio quality improvement.

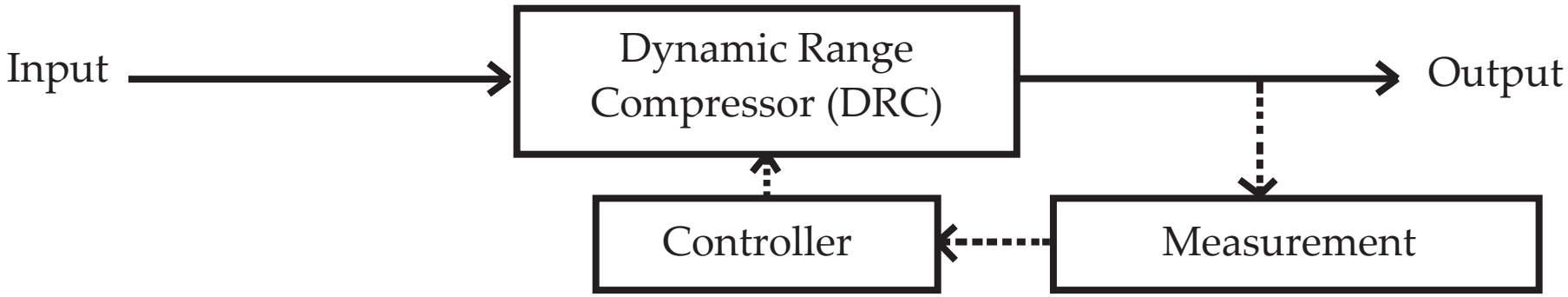


Two major benefits:
Free membrane protection;
Audio quality improvement.

Two common implementations:
Feedback design;
Feedforward design.

Adaptive, based on DSP techniques.

Different advantages and disadvantages.



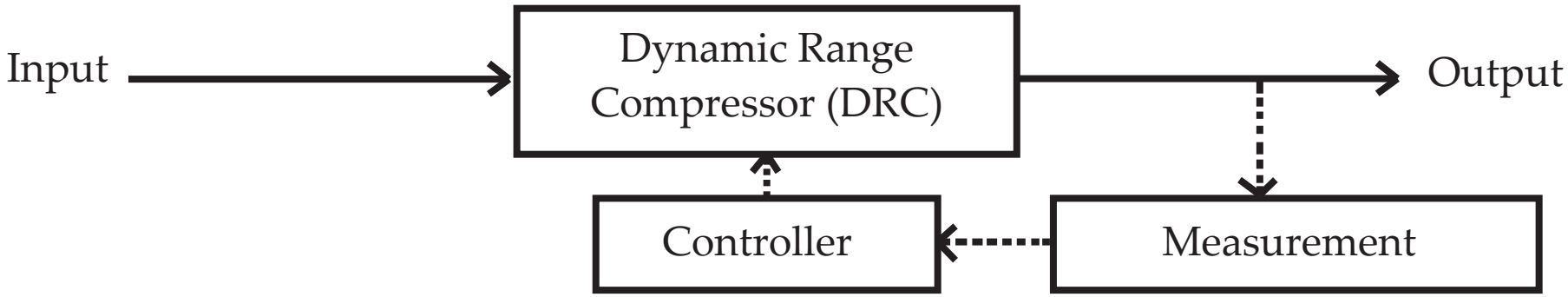
A Feedback Design (REF)

Compressor

Feedback approach

Dynamic range compressor (DRC);

Feedback control loop.



Compressor

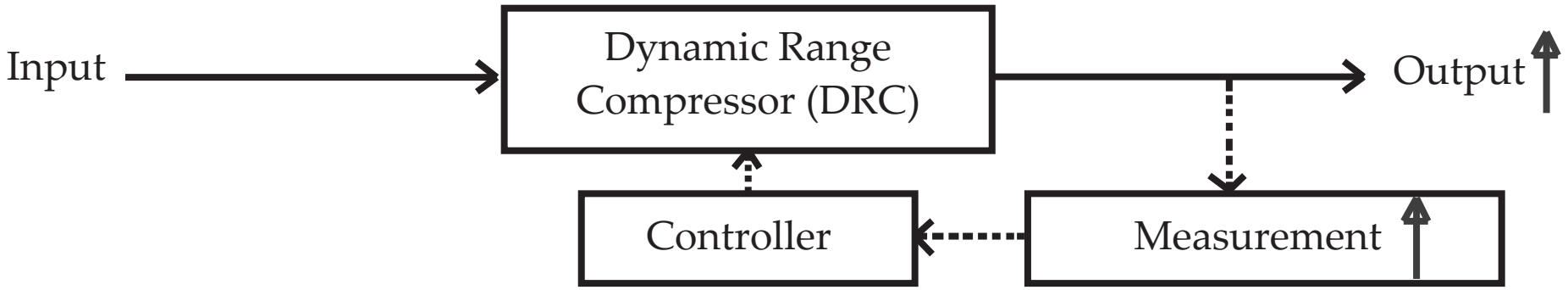
A Feedback Design (REF)

Feedback approach

Dynamic range compressor (DRC);
Feedback control loop.

Function

Measurements at output port;
Controller adjusts DRC parameters;
DRC adapts to the current signal.



A Feedback Design (REF)

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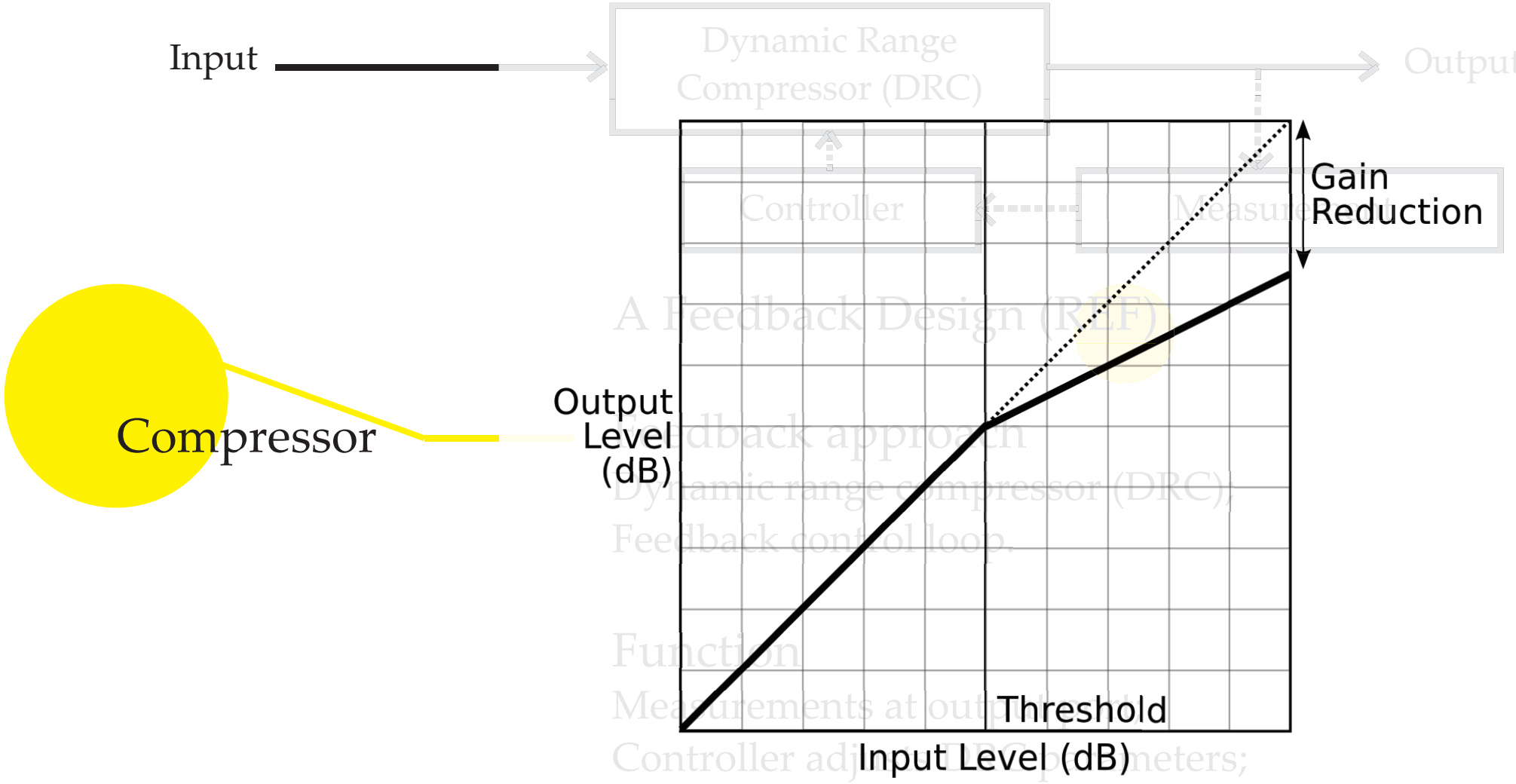
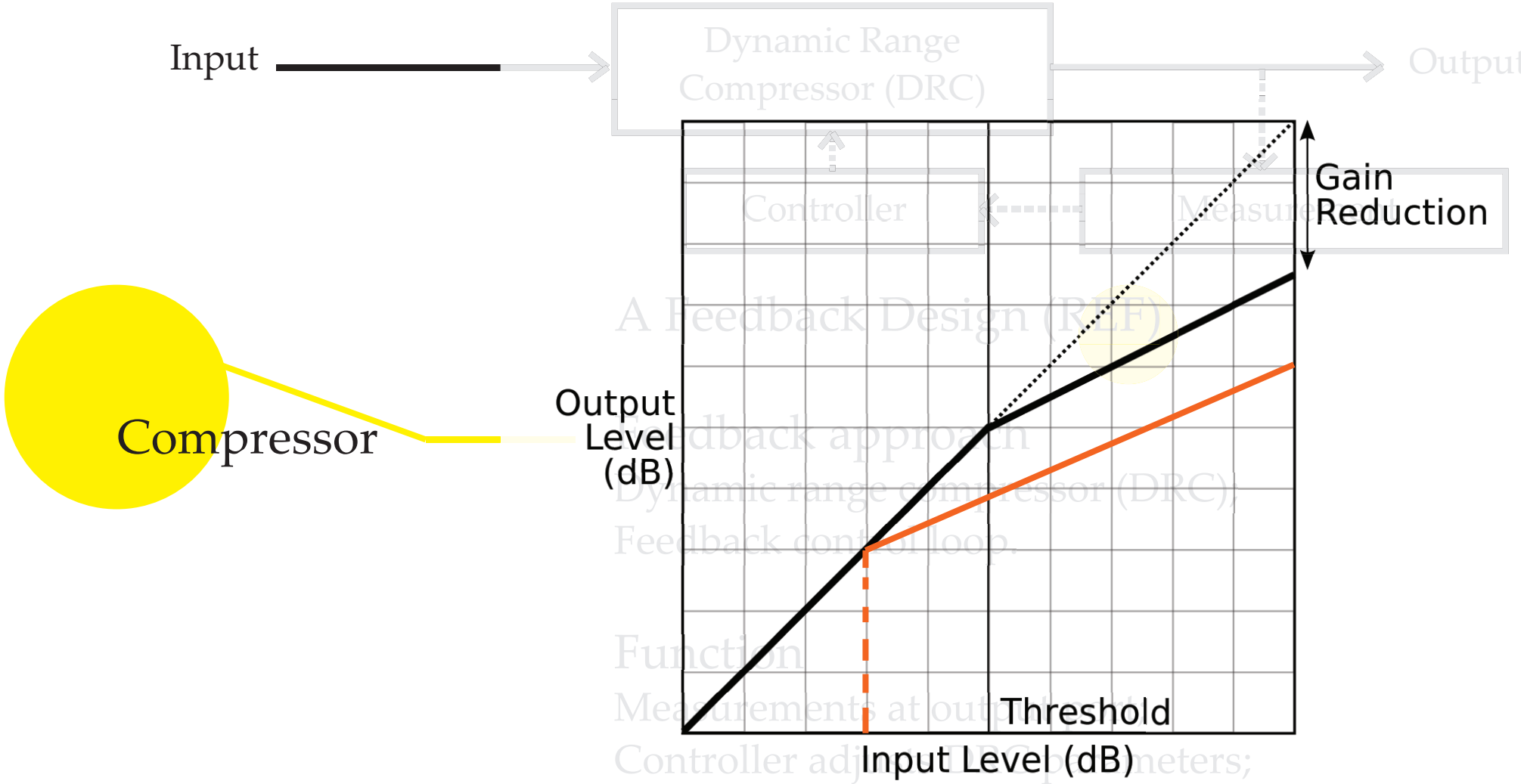

Input
Dynamic Range
Compressor (DRC)
Output
Controller
Measurement
Gain
Reduction
Compressor
Output
Level
(dB)
Threshold
Input Level (dB)


Input
Dynamic Range
Compressor (DRC)
Output
Controller
Measurement
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Output
Level
(dB)
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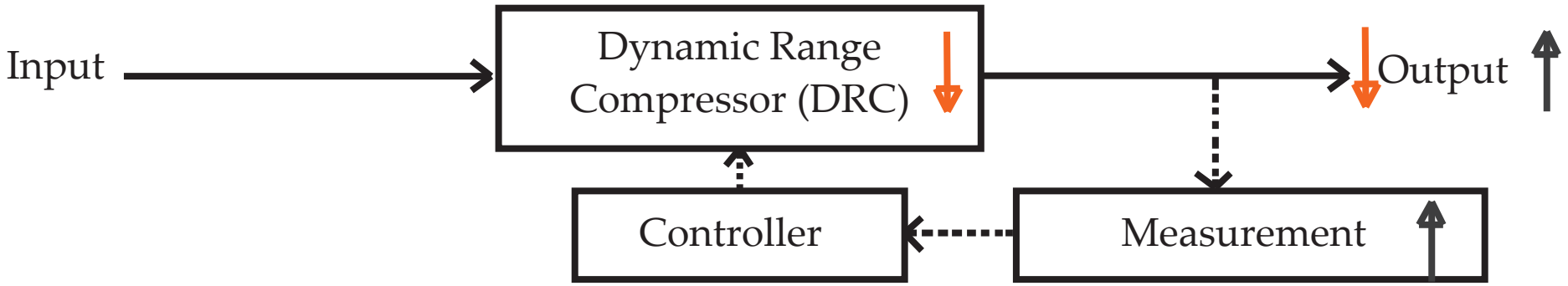
Input Level (dB)



Compressor

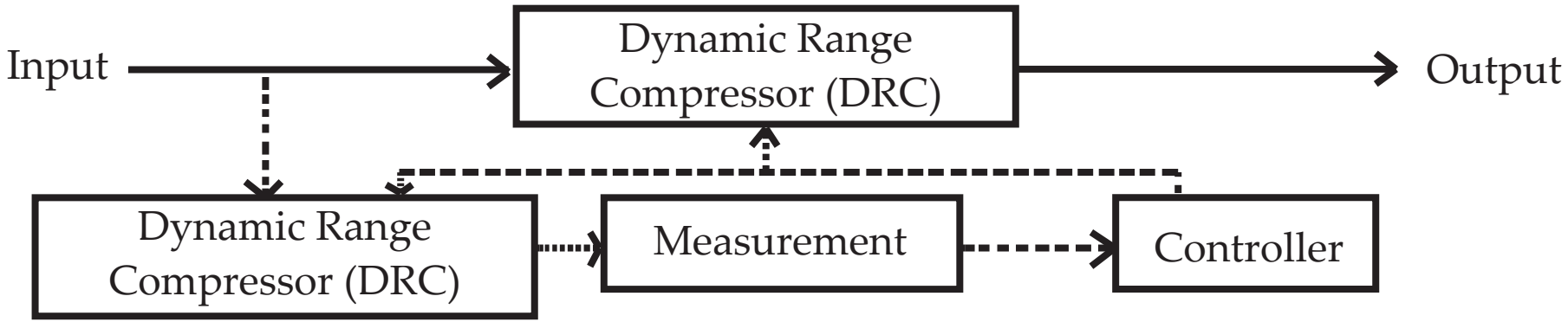
A Feedback Design (REF)

Feedback approach

Dynamic range compressor (DRC);
Feedback control loop.

Function

Measurements at output port;
Controller adjusts DRC parameters;
DRC adapts to the current signal.



A Feedforward Design (REF)

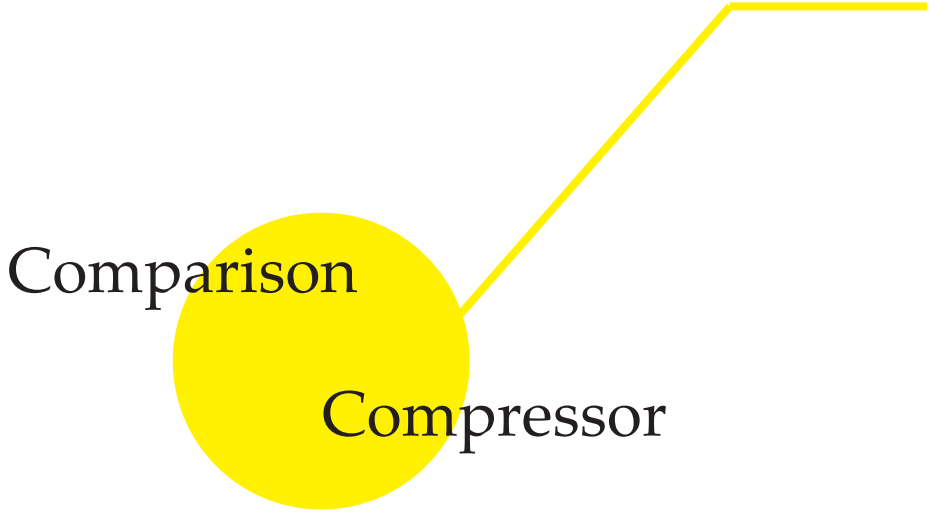
Compressor

Feedforward approach

Dynamic range compressor (DRC);
Feedforward control loop.

Function

Measurements at output port in loop;
Information directly sent to controller;
Controller adjusts parameters of both DRCs.

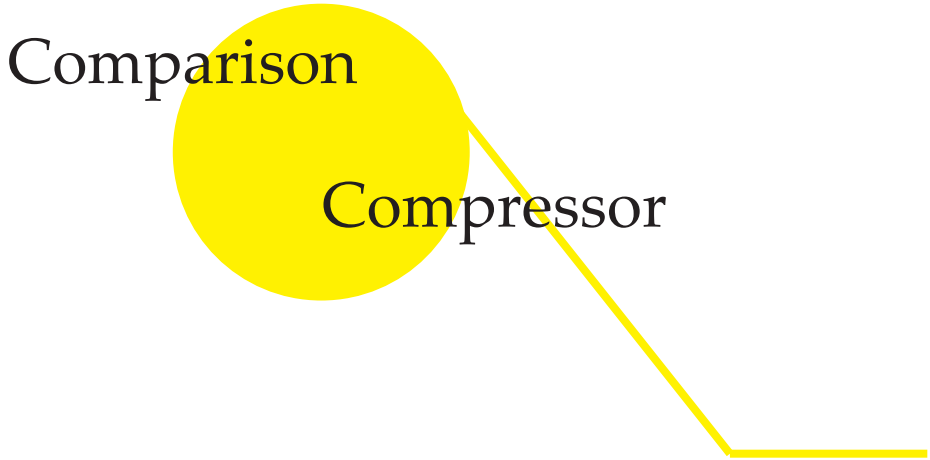


Feedforward:

Instantaneous parameter adjustment;
Requires duplicate DRCs.

Feedback:

Small delay;
Single DRC.



Feedforward:

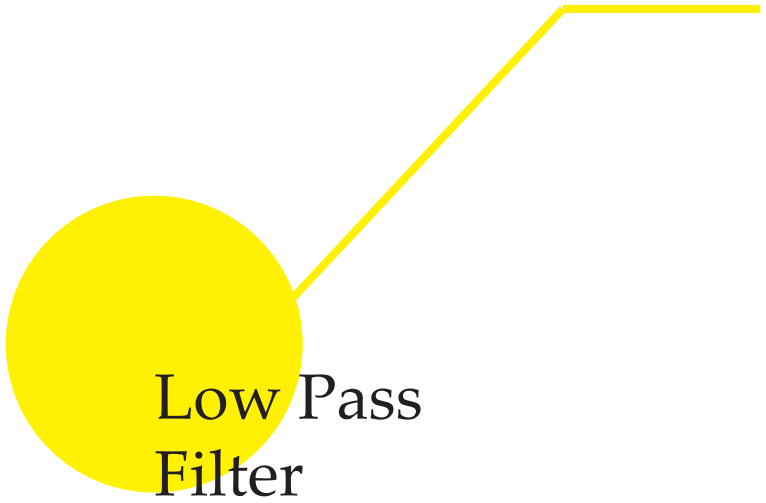
Instantaneous parameter adjustment;
Requires duplicate DRCs.

Feedback:

Small delay;
Single DRC.

Choice:

Performance vs. Power consumption



[Purpose]

Eliminate the sound out of people's hearing range;
Eliminate audible beat signal.

[Parameter]

Passband: 11kHz;
Stopband: 20kHz (<24kHz).

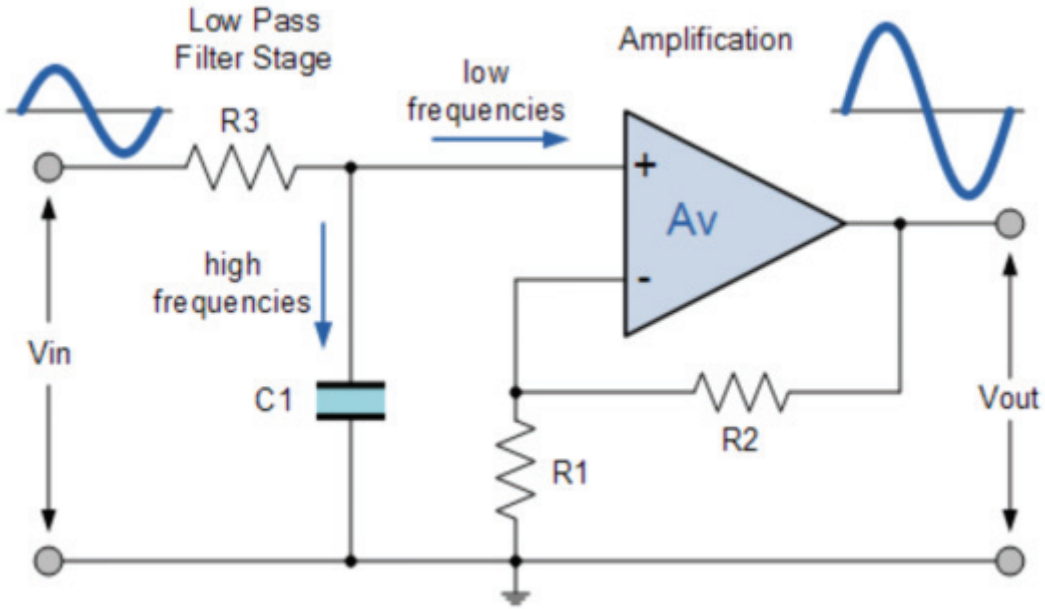
Low Pass Filter

[Active low-pass filter]

Steep roll-off and low noise;

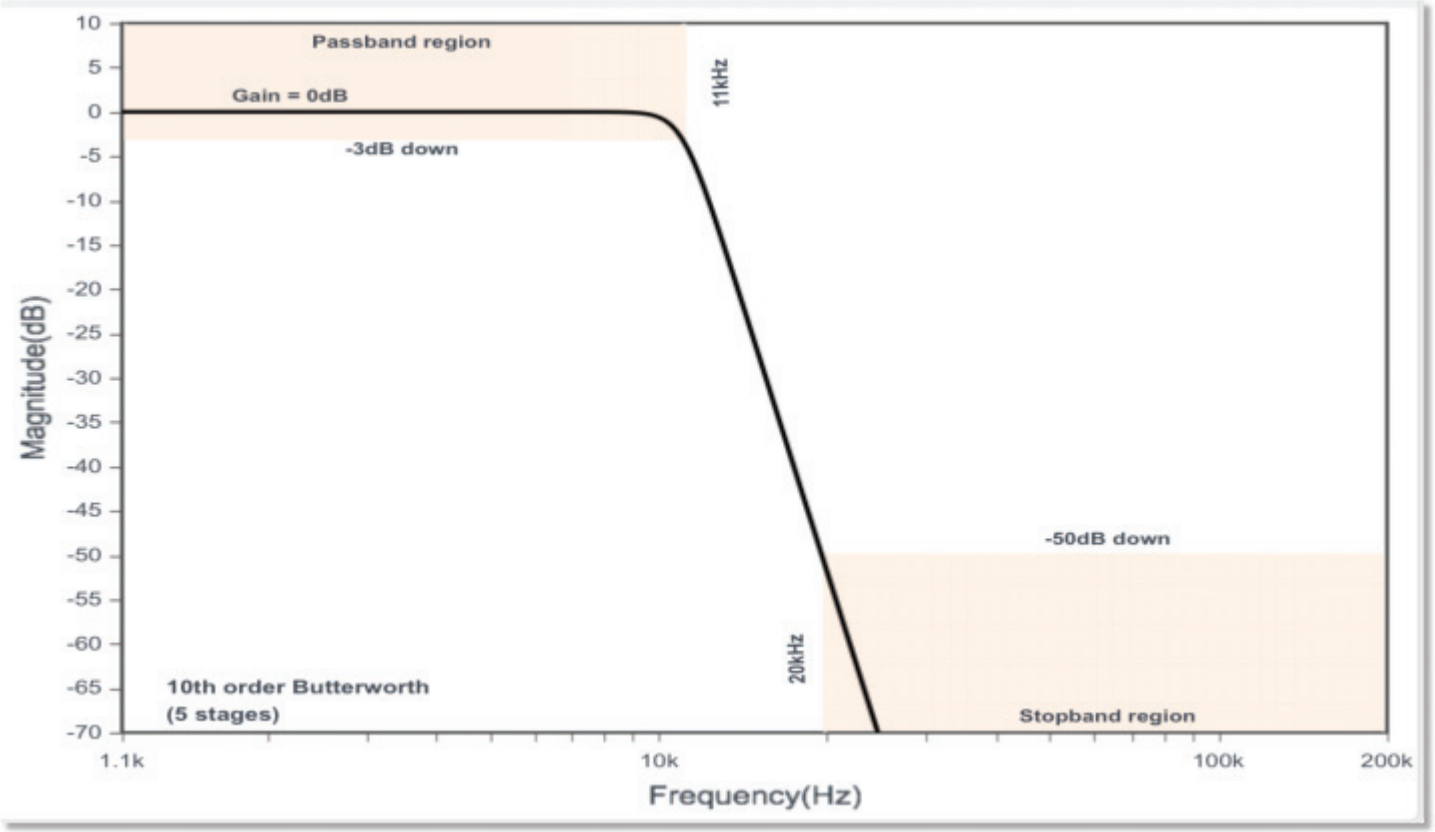
Easy to be integrated;

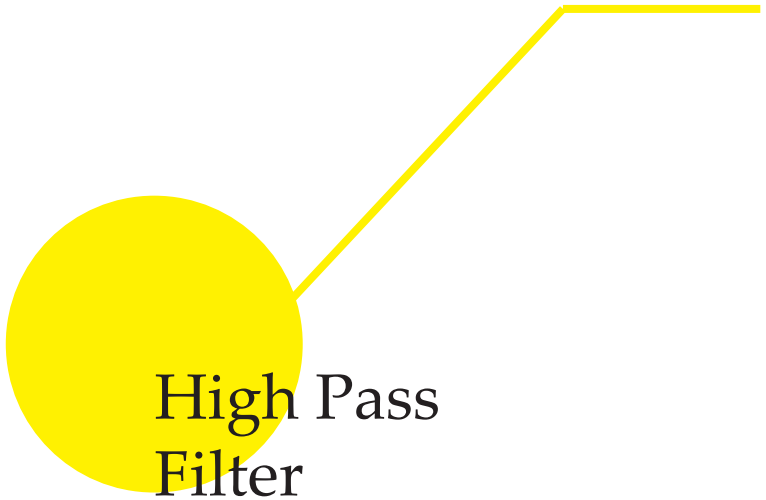
No attenuation.



Frequency Response

Low Pass Filter





[Purpose]

Eliminate the sound out of people's hearing range;
Eliminate audible frequencies.

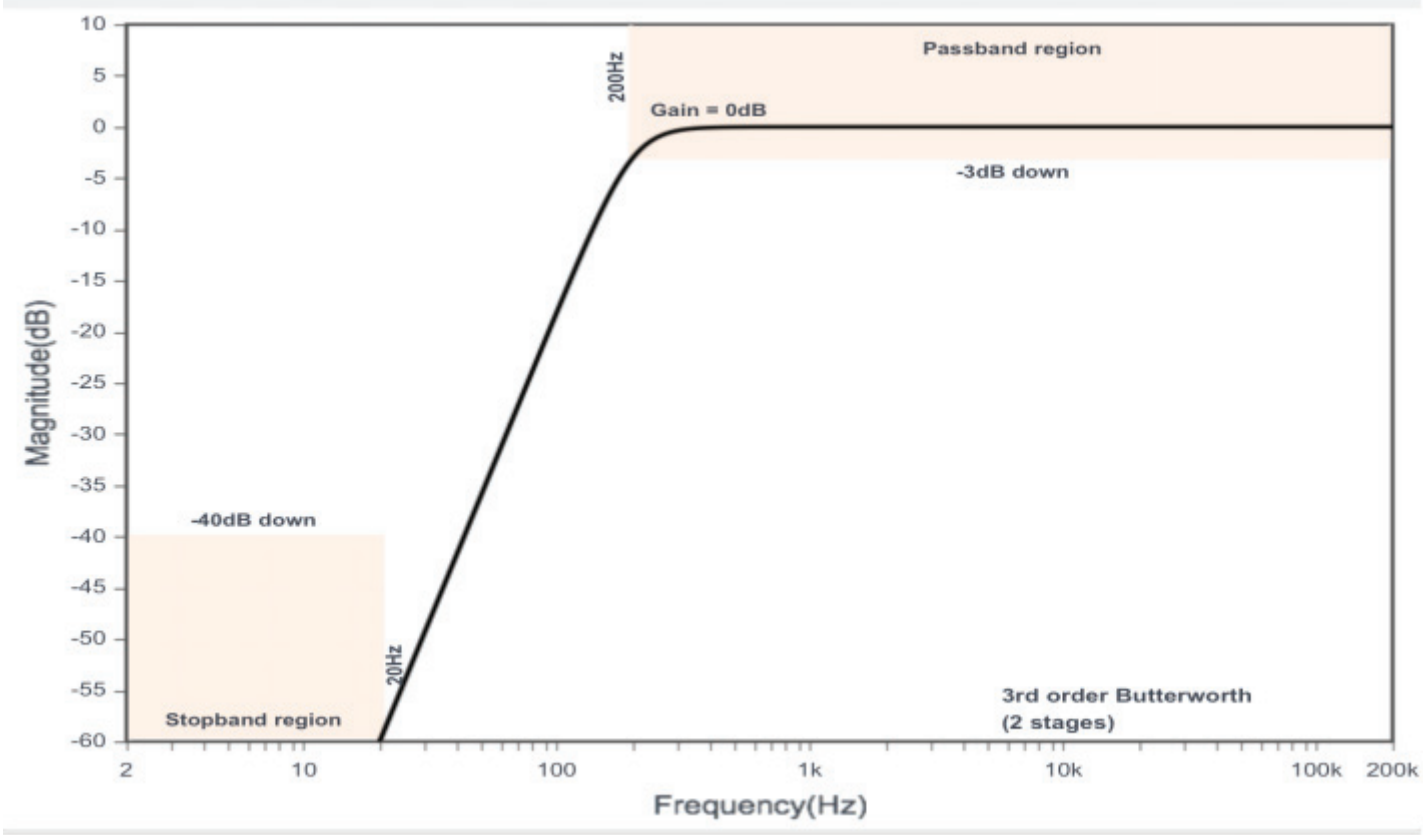
[Parameter]

Passband: 200Hz(before modulation),
26kHz(after modulation);
Stopband: 20kHz(before modulation),
23kHz(after modulation).

[Active high-pass filter]
Steep roll-off and low noise;
Easy to be integrated;
No attenuation.

Frequency Response

High Pass Filter



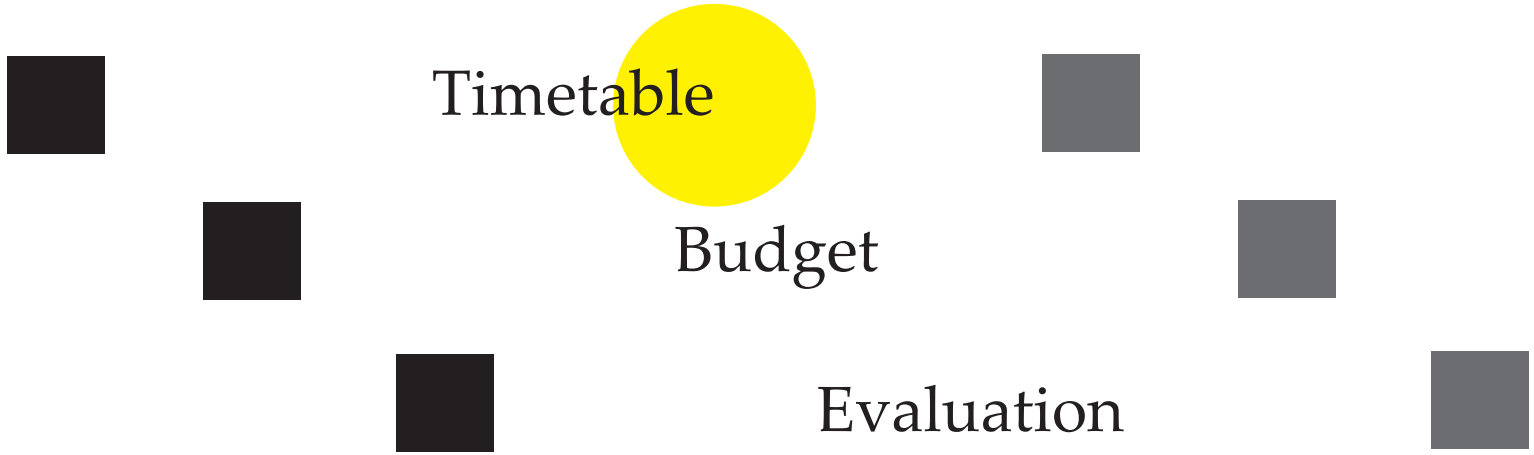
[Function]
Combining the signal with ultrasonic carrier wave.

[Purpose]
Finding the optimal frequencies of carrier wave, such that the directionality of the loudspeaker is improved and the sound received by audience is clearer.

The optimum frequency of the primary wave is dependent on (Aoki et al., 1994):

The transmitter radius,
The source pressure,
The location of the observation point.

Plan 


Timetable
Budget
Evaluation

Timetable

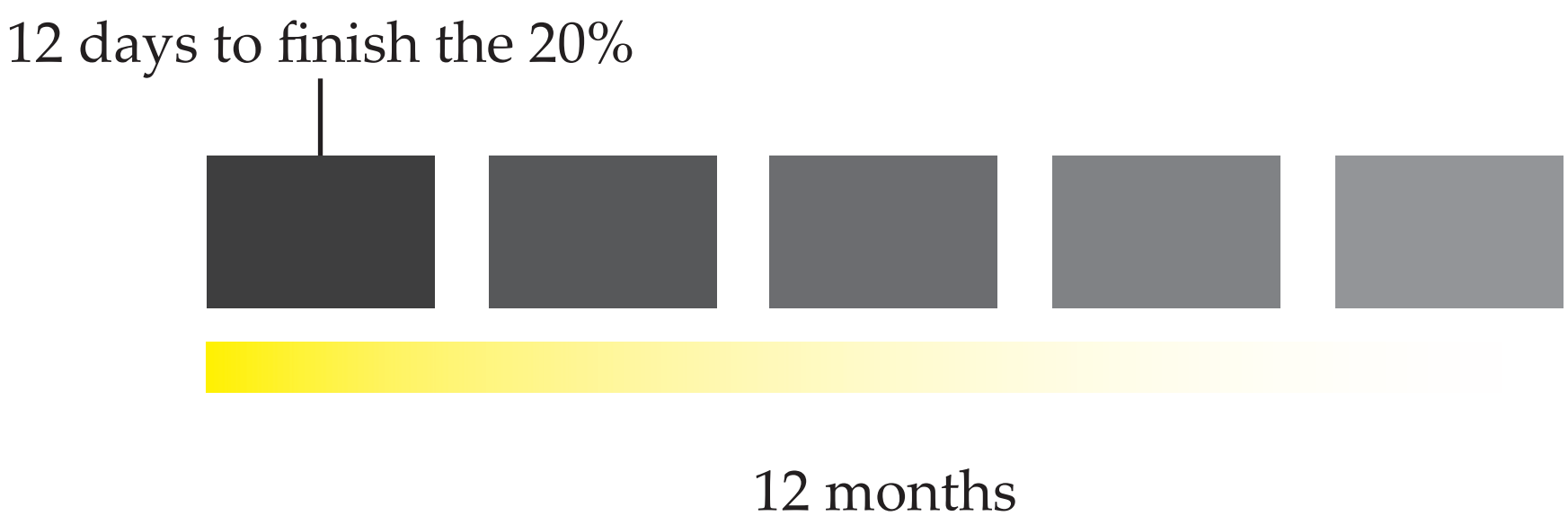
	Description of Work	Start & End Dates
Phase 1	Personnel recruitment, needs assessment, field study, materials preparation.	Apr. 1st to Apr.30th
Phase 2	(i)System Design, Prototype Building, (ii)Testing and enhancement.	(i) May. 1st to Jun. 30th (ii) Jul. 1st to Aug. 31st
Phase 3	Feedback, Productization (including miniaturization), Product Training.	Sep. 1st to Oct. 15th

Budget

	Description of Budget	Start & End Dates
Phase 1	Labor costs: $13000 Materials preparation: $15000	Apr. 1st to Apr.30th
Phase 2	(i) Labor costs: $ 26000 Supplies: $ 1000 (ii) Labor costs: $ 26000 Additional material: $ 5000	(i) May. 1st to Jun. 30th (ii) Jul. 1st to Aug. 31st
Phase 3	Labor costs: $ 26000 Productization cost: $ 20000	Sep. 1st to Oct. 15th

Evaluation

Objectives	Indicators
High audio quality	Distortion less than 1%
Miniaturization	Imbeded into a smartphone (e.g. iPhone)
Low power cosumption	Power under 3w
Harsh condition resistence	Temperature range of 0~40 ℃
Robustness	More than 4 years.


12 days to finish the 20%
12 months


Thanks