Performance of LC823455 Echo Canceller

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APPLICATION NOTE

Introduction

This application note describes the performance of LC823455 Echo Canceller.

The canceller enables customers to improve the sound quality of hands free communication in wireless headset or other voice communication products.

The intended audience is customers who are developing audio applications using LC823455.

Overview of Echo Canceller

Figure 1 shows a block diagram of HFP (Hands−Free Profile) signal processing sub−system within LC823455. The sound quality of hands−free communication depends on many processing blocks. However, the performance of the Echo Canceller depends on the AEC (Acoustic Echo Canceller) and NC (Noise Canceller). Those blocks are highlighted with the red dotted box in Figure 1.

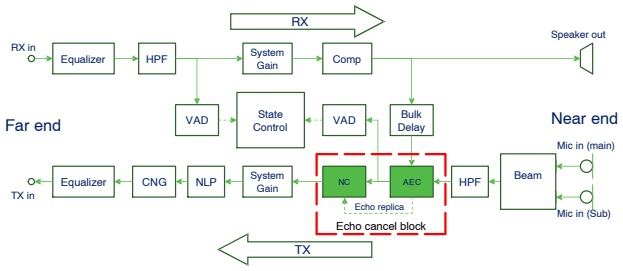

Figure 1. Block Diagram of HFP Program of LC823455

The NC cancels not only the noise signal but also the echo signal that was estimated by the AEC during the echo cancelling process. LC823455 has two types of echo cancelling mode as follows.

a) Time domain mode (Figure 2)

In this mode, the AEC cancels the echo signal in the time domain. After that, NC cancels estimated echo signal by AEC in frequency domain secondarily to improve the performance as secondarily echo cancelation.

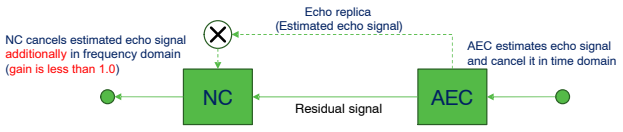

Figure 2. Time Domain Mode

b) Frequency domain mode (Figure 3)

In this mode, the echo cancel process is conducted only by the NC in the frequency domain. The AEC only estimates the echo signal.

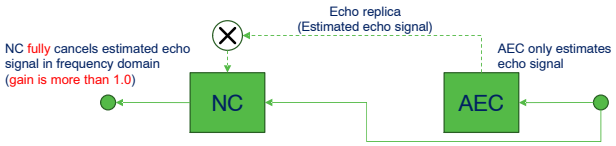

Figure 3. Frequency Domain Mode

Evaluation Environment and Condition

We used the LC823455 HFP GUI running on a Windows PC for this evaluation. Results of this GUI are bit exact with the function implemented in LC823455. We used only the AEC and the NC in the GUI and did not use other blocks. The NC was used only for echo canceling, not for noise cancelling.

Figure 4 shows an overview of this simulation.

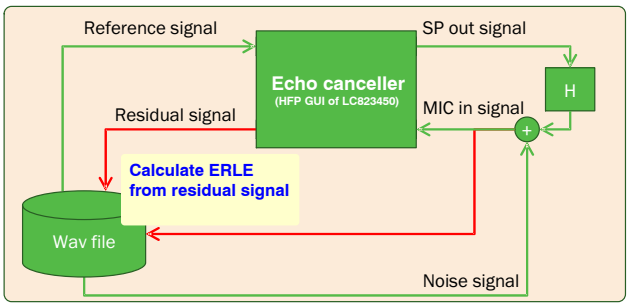

Figure 4. Overview of PC Simulation

We used wav files as the reference input signal and mic in signal (echo signal) going into the of HFP GUI. We used white noise and pink the noise for the reference signal. The Mic in signal is created from the SP out signal by adding echo pass characteristics “H” and ambient noise. The SP out signal is a speaker signal, while the Residual signal is a result of echo cancelling.

We checked the performance of the echo canceller by comparing the difference between the Mic in signal and the Residual signal.

Echo Canceller Setting

We evaluated the echo cancelling function under the conditions as shown in Table 1.

Table 1. ECHO CANCELLER SETTING

Item	Condition
Input signal	16 kHz, Sine 16 bit linear PCM
Acoustic echo canceller	Tap size is 128 sample.
Noise canceller	FFT size is 256 sample. Frame shift is 128 sample
Echo cancel level	Time domain mode Echo cancel level 0.0 Echo cancel level 0.05 Echo cancel level 0.2 Frequency domain mode Echo cancel level 1.0 Echo cancel level 1.05 Echo cancel level 1.2

Reference Input Signal

We used white noise and pink noise as reference input signals. White noise is used to evaluate ERLE (Echo Return Loss Enhancement). On the other hand, we used pink noise to evaluate convergence time. Because our echo canceller is tuned to human voice, convergence time of white noise is not appropriate.

Echo Pass

We created echo pass characteristics as follows;

1) Add zero data to the start point of SP output signal wav file as echo pass delay.

2) Attenuate the signal as echo pass return loss.

3) Clip the signal to create distortion with target THD (Total Harmonic Distortion).

The clip level was determined from the 4th harmonics THD of a 1 kHz Sine signal. Table 2 shows the clip levels used in this experiment. The echo signal is clipped as a percentage of the peak signal, as shown in the Table 2.

Table 2. CLIP LEVEL FOR TARGET THD

THD (%)	Clip Level (%)	THD (%)	Clip Level (%)
0.2	99.5	1.8	95.9
0.4	99.1	2.0	95.4
0.6	98.6	2.2	95.0
0.8	98.2	2.4	94.5
1.0	97.7	2.6	94.1
1.2	97.2	2.8	93.6
1.4	96.8	3.0	93.2
1.6	96.3		

Noise Signal

We added noise signal as an ambient noise and double talk.

For ambient noise, we added white noise so that the SNR (Signal−to−Noise Ratio) of echo signal become target SNR as shown in Figure 5.

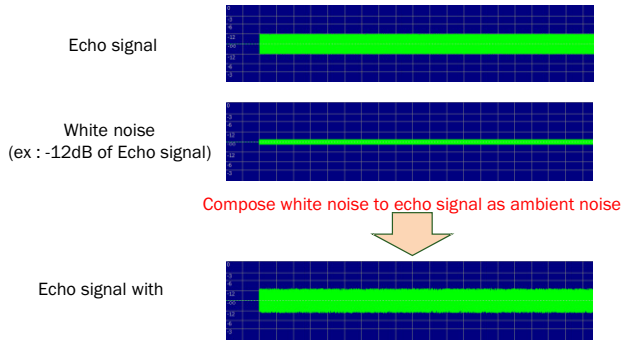

Figure 5. Echo Signal with Ambient Noise

For double talk, we added white noise as double talk. Figure 6 shows an example of the mic in signal with double talk.

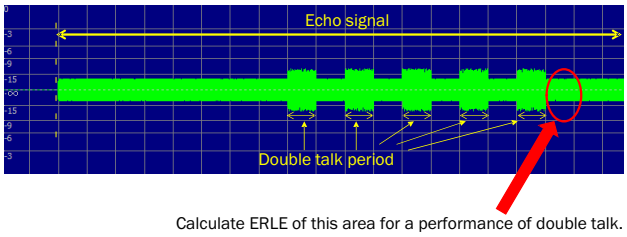

Figure 6. Waveform which White Noise Added to as Double Talk

EVALUATION RESULTS

THD vs ERLE (Echo Return Loss Enhancement)

[Reference signal]
White noise with level of −6dBFS.
[Echo signal]
Delay is 20sample. Echo return loss is −6dB.
THD is from 0.0% to 3.0% with 0.2% step.

If the percentage of THD is increased, there is a tendency that ERLE is decreased due to the influence of THD. The result of frequency domain mode is better than the one of time domain mode.

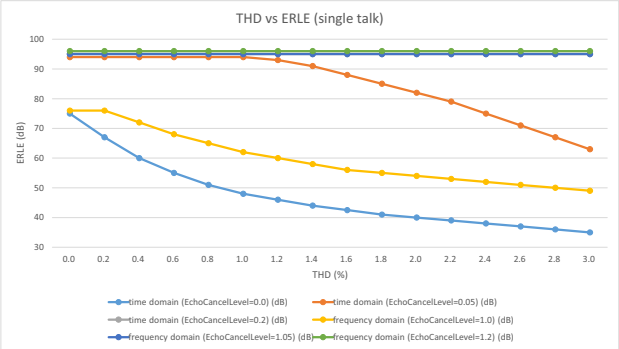

Figure 7. THD vs ERLE (Single Talk)

THD vs ERLE with Double Talk

When double talk occurs, the degradation of ERLE with high THD is smaller than that with low THD. If you use NC for secondarily echo cancellation at the same time in the time domain mode, the degradation of ERLE is improved. It is clear from the comparison of results between Echo cancel level = 0.0 and Echo cancel level = 0.05/0.2.

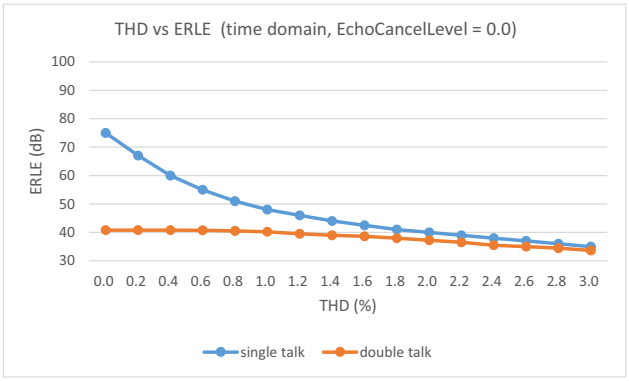

Figure 8. THD vs ERLE (Time Domain, Echo Cancel Level = 0.0)

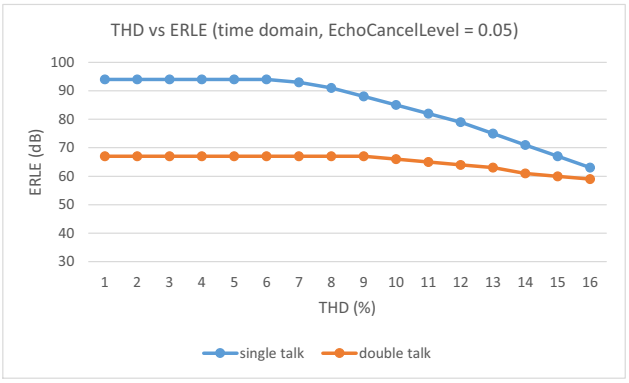

Figure 9. THD vs ERLE (Time Domain, Echo Cancel Level = 0.05)

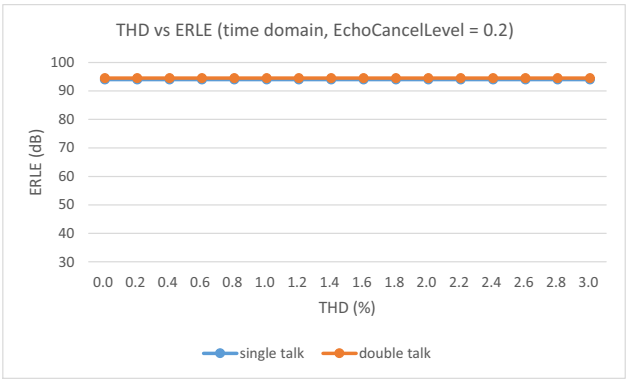

Figure 10. THD vs ERLE (Time Domain, Echo Cancel Level = 0.2)

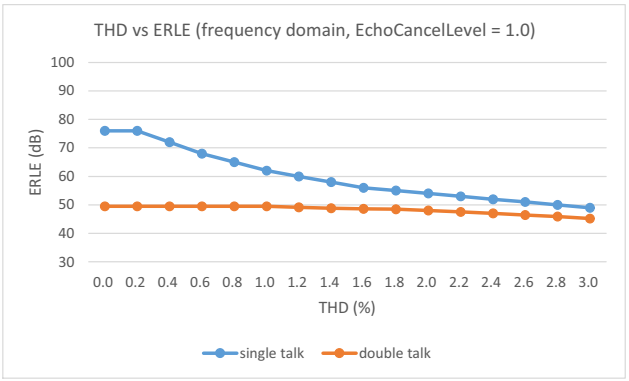

Figure 11. THD vs ERLE (Frequency Domain, Echo Cancel Level = 1.0)

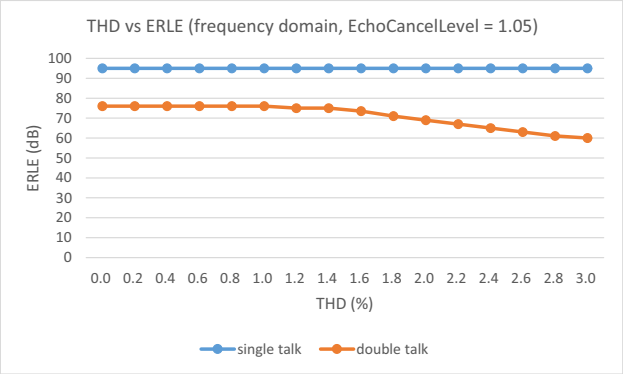

Figure 12. THD vs ERLE (Frequency Domain, Echo Cancel Level = 1.05)

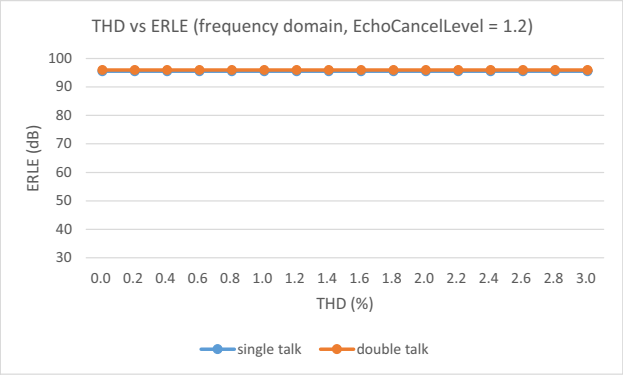

Figure 13. THD vs ERLE (Frequency Domain, Echo Cancel Level = 1.2)

ERL vs ERLE

[Reference signal]

White noise with level of −6 dBFS.

[Echo signal]

Delay is 20 sample. Echo return loss is from 0 dB to 39 dB with 3 dB step. THD is 0.4%.

Total echo return loss is ERL plus ERLE. Therefore, If ERL is increased, there is a tendency that ERLE is decreased. The result of frequency domain mode is better than the one of time domain mode.

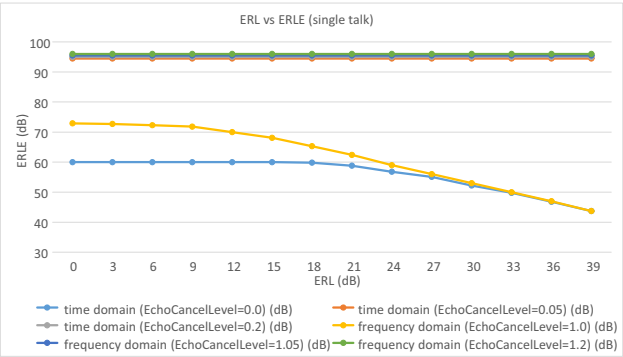

Figure 14. ERL vs ERLE (Single Talk)

ERL vs ERLE with Double Talk

When double talk occurs, ERLE is degraded about 20 dB without noise canceller as the secondarily cancellation in the time domain mode. To avoid this degradation, you can use NC for secondarily echo cancellation. In this case, the degradation becomes small as shown by the comparison of results between Echo cancel level = 0.0 and Echo cancel level = 0.05/0.2.

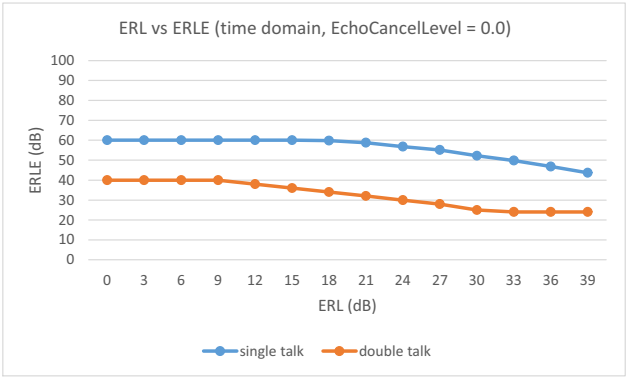

Figure 15. ERL vs ERLE (Time Domain, Echo Cancel Level = 0.0)

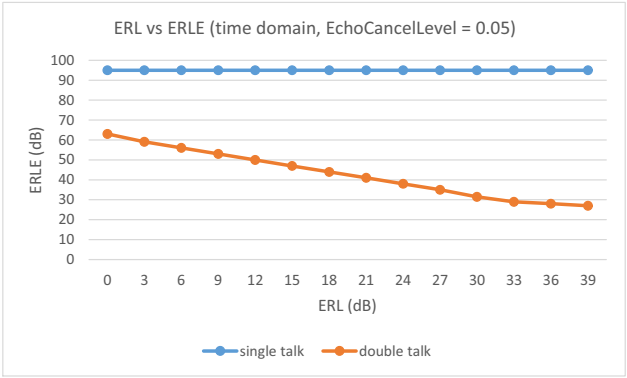

Figure 16. ERL vs ERLE (Time Domain, Echo Cancel Level = 0.05)

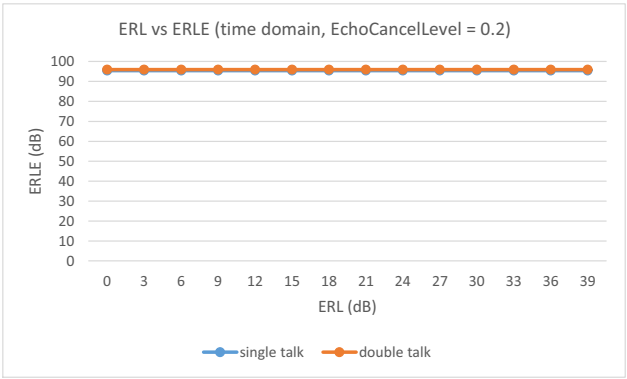

Figure 17. ERL vs ERLE (Time Domain, Echo Cancel Level = 0.2)

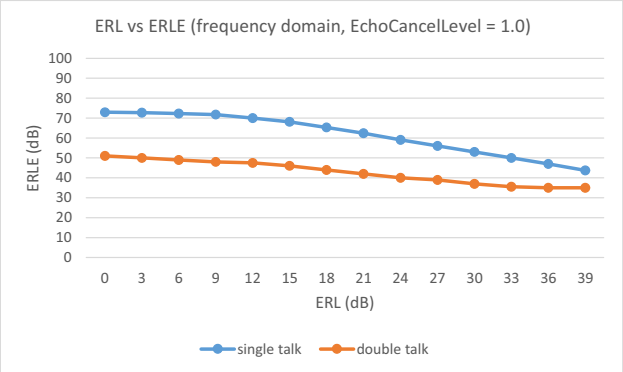

Figure 18. ERL vs ERLE (Frequency Domain, Echo Cancel Level = 1.0)

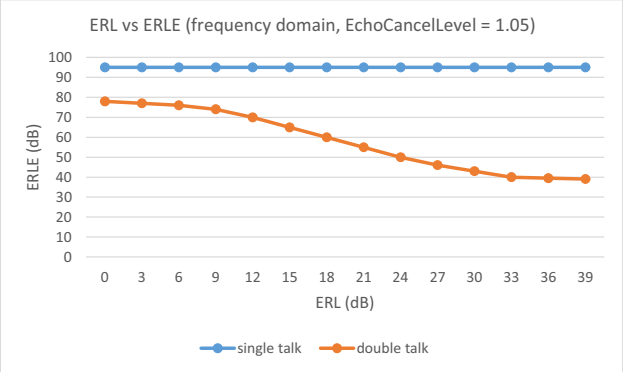

Figure 19. ERL vs ERLE (Frequency Domain, Echo Cancel Level = 1.05)

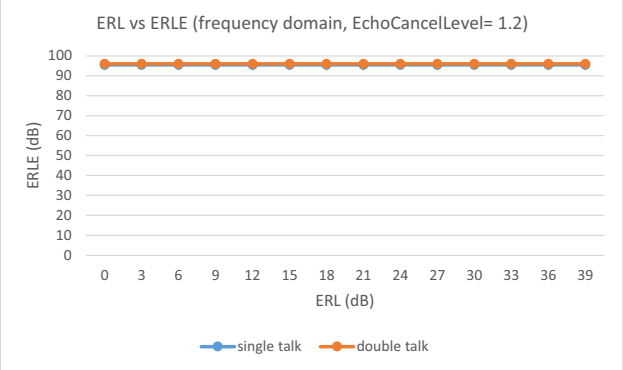

Figure 20. ERL vs ERLE (Frequency Domain, Echo Cancel Level = 1.2)

Ambient Noise vs ERLE

[Reference signal]

White noise with level of −6dBFS.

[Echo signal]

Delay is 20sample. Echo return loss is −6 dB. THD is 0.4%.

Ambient noise is added so that SNR becomes from −12 dB to −39 dB.

If ambient noise is added to echo−signal, echo canceller cannot reduce ambient noise. Therefore, residual signal includes ambient noise and ERLE is limited by them.

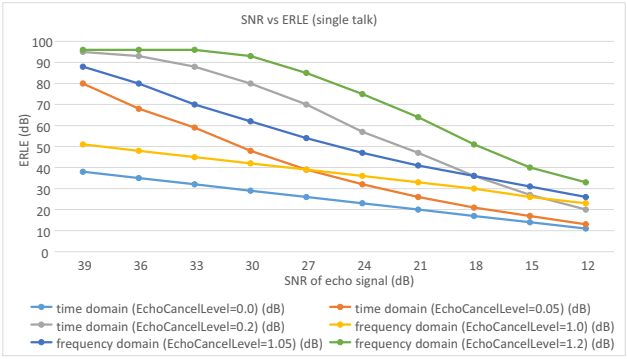

Figure 21. Ambient Noise vs ERLE (Single Talk)

Ambient Noise vs ERLE with Double Talk

When double talk occurs, ERLE is slightly degraded without the noise canceller as the secondarily cancellation in the time domain mode. If you use the noise canceller for secondarily echo cancellation, you can improve the performance of echo cancelling in double talk period. It is clear from the comparison of results between Echo cancel level = 0.0 and Echo cancel level = 0.05/0.2.

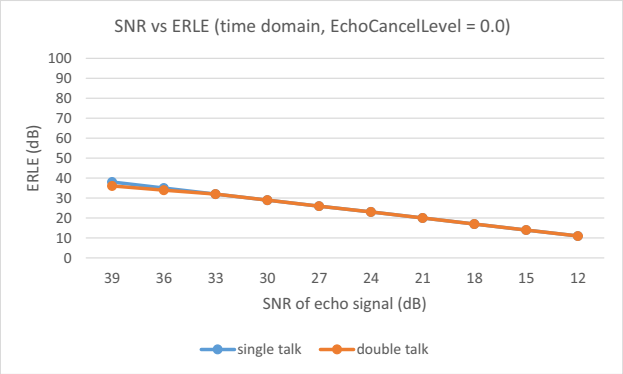

Figure 22. Ambient Noise vs ERLE (Time Domain, Echo Cancel Level = 0.0)

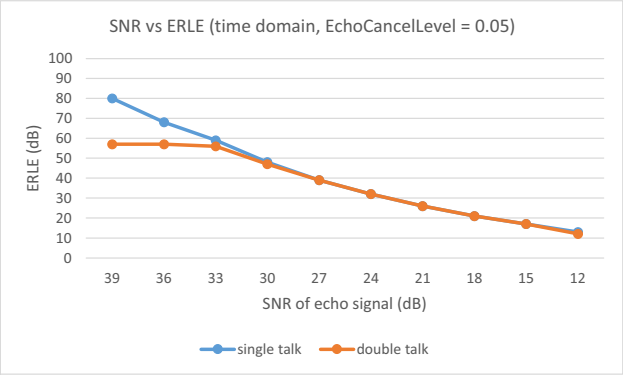

Figure 23. Ambient Noise vs ERLE (Time Domain, Echo Cancel Level = 0.05)

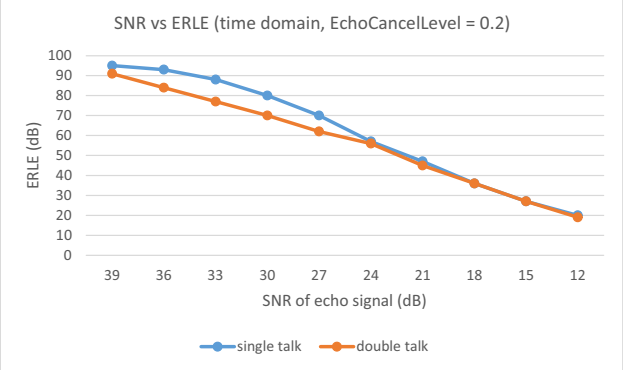

Figure 24. Ambient Noise vs ERLE (Time Domain, Echo Cancel Level = 0.2)

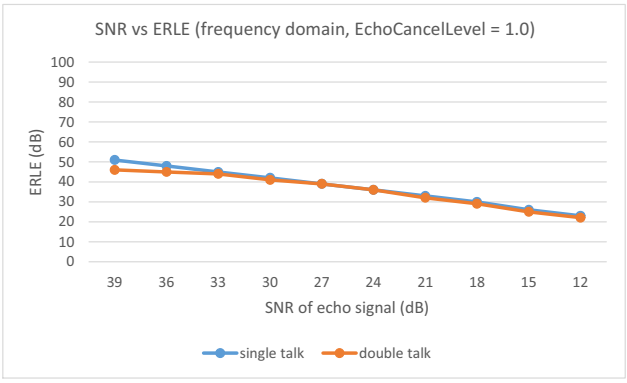

Figure 25. Ambient Noise vs ERLE (Frequency Domain, Echo Cancel Level = 1.0)

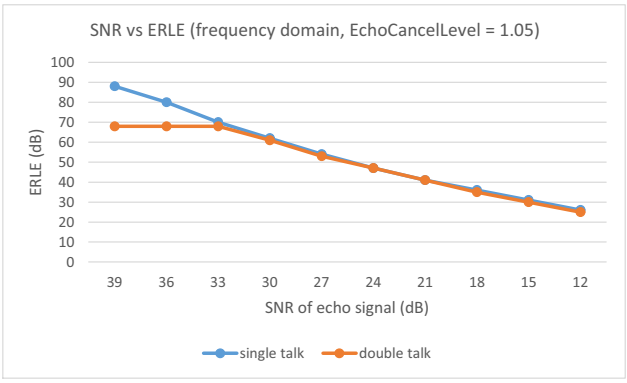

Figure 26. Ambient Noise vs ERLE (Frequency Domain, Echo Cancel Level = 1.05)

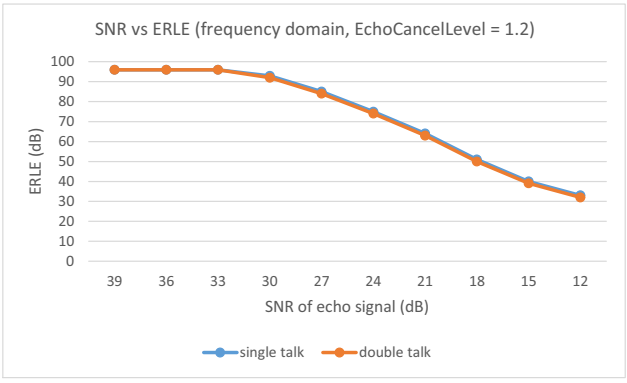

Figure 27. Ambient Noise vs ERLE (Frequency Domain, Echo Cancel Level = 1.2)

Convergence Time

[Reference signal]
White noise with level of −6 dBFS
Pink noise with level of −6 dBFS
[Echo signal]
Delay is 20 sample. Echo return loss is from −6 to −12 dB with −3 dB step. THD is 0.0%

Table 3 and 4 show convergence time. Our echo canceller is tuned to human voice. Therefore, convergence time of pink noise is shorter than that of white noise.

Table 3. CONVERGENCE TIME WITH WHITE NOISE

Test Signal is White Noise	ERL		
	0 dB	−6 dB	−12 dB
Convergence time to obtain 24 dB ERLE	700 ms	580 ms	400 ms
Convergence time to obtain 54 dB ERLE	1300 ms	1300 ms	1300 ms

Table 4. CONVERGENCE TIME WITH PINK NOISE

Test Signal is White Noise	ERL		
	0 dB	−6 dB	−12 dB
Convergence time to obtain 24 dB ERLE	300 ms	280 ms	260 ms
Convergence time to obtain 54 dB ERLE	325 ms	305 ms	285 ms

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