RM-CG Voice Lift System
Ver. 1.00

Audioversity

by Yamaha Pro Audio

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Version history

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Introduction

The RM-CG ceiling microphone is equipped with a "multi-beam tracking" function that provides stable tracking to multiple participants talking at the same time. It also delivers clear sound by making full use of its various audio processing technologies. We have received inquiries about the possibility of realizing a voice lift system in a classroom or meeting room by optimizing these features of the RM-CG. A voice lift system can be made using an RM-CG by selecting and installing the correct speakers and adjusting the audio appropriately. This document explains what to consider when establishing a voice lift system using the RM-CG.

Purpose of Voice Lift

A voice lift system complements the distance attenuation of people's voices by capturing and amplifying them with a microphone and speakers, which provides an environment where even the farthest participant can hear the speaker's voice as if they are close to each other. Therefore, a voice lift system is unsuitable for a room with high reverberation or background noise and an event with a PA (public address) system that needs a higher sound pressure level than for a normal conversation.

Two Use Cases of Voice Lift System

Mainly, there are two cases where a voice lift system is needed. The first is to allow all participants to hear each other clearly in a large meeting (many to many), and the second is to make all participants hear a presenter's voice clearly during a presentation (one to many). Both cases require an environment where the participants can listen to the presenter's voice clearly, regardless of the distance between the participants and the presenter.

Yamaha recommends using the RM-CG for voice lift within a presentation system. The RM-CG dynamically detects the direction of a person speaking and picks up and tracks the sound by centering four beams on that person with enhanced directivity. Therefore, when a presenter is moving in front of a whiteboard to give a presentation, or when several presenters are giving a conversational presentation on a stage, the RM-CG can pick up each speaker's voice clearly by tracking the voice, and it can then amplify it to the audience. Presenters can just concentrate on their presentation without worrying about microphone positioning, and the audience can listen to the presenter with clear sound.

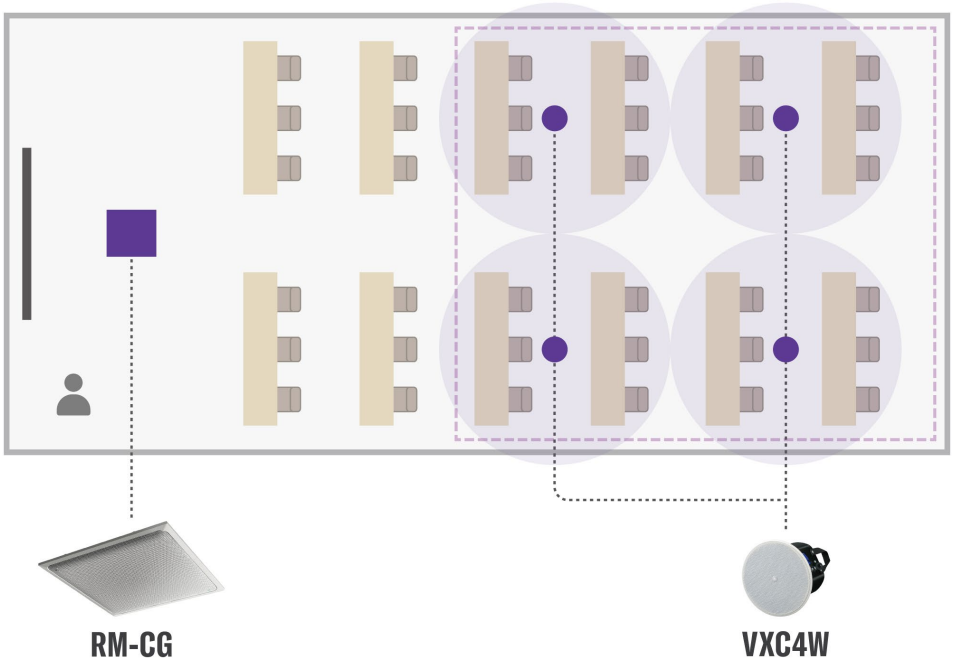
Importance of Microphone and Speaker Placement and Sound Adjustment

A voice lift system with a ceiling microphone can only provide sufficient amplification with advanced design and adjustment technology because the microphone is positioned several meters away from the source it is amplifying (the presenter's voice). To avoid feedback and to increment sound pressure to a certain level, keep a sufficient distance between the microphone and the speakers. In addition, it also needs high-precision sound adjustment technology using sound measurement tools (e.g. a real-time analyzer) to achieve natural amplification.

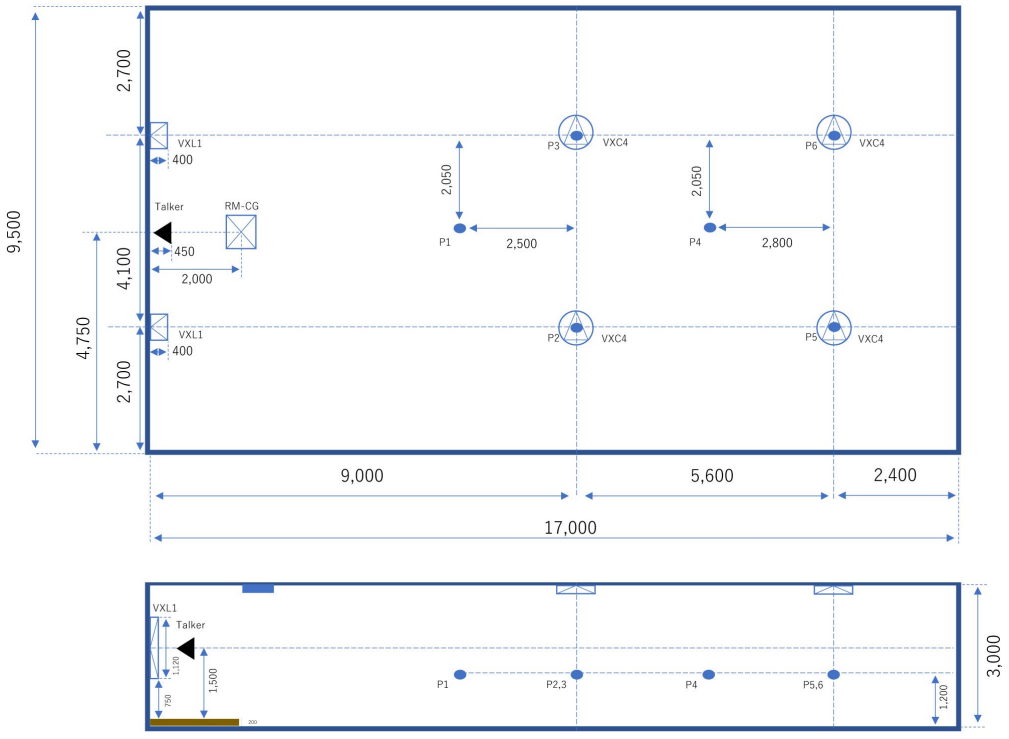
> Amplifying multiple people's voices at different places in a room for all the participants will form many acoustic loops between the microphone and speakers, so the system design and acoustic adjustment will be more complicated than a standard presentation system. As a result, you may not achieve the expected amplification effect from the voice lift system.

Result of Sound Pressure Increment on Voice Lift System with RM-CG and Ceiling Speakers

Sound pressure increment was measured in the following system.



Ceiling speaker layout



When a system needs to increment the sound pressure as high as possible, and is adjusted so each speaker can obtain a similar amount of loop gain, the sound pressure level at each sound receiving point (4.5 meters away from the RM-CG) is incremented by 7dB - 8dB. The further the distance between ceiling speakers and a microphone, the less feedback the speakers produce, as less sound is diffracted. Therefore, greater sound pressure levels can be expected at the back of the room.

System	Distance (RM-CG ⇔ Speaker)			
	4.5m		11.8m	
	SPL	Increment	SPL	Increment
w/o Voice Lift	54.8 dBA		51.8 dBA	
w/ Voice Lift	62.6 dBA	+7.8dB	65.3 dBA	+13.5dB

(Feedback Margin: 6dB)

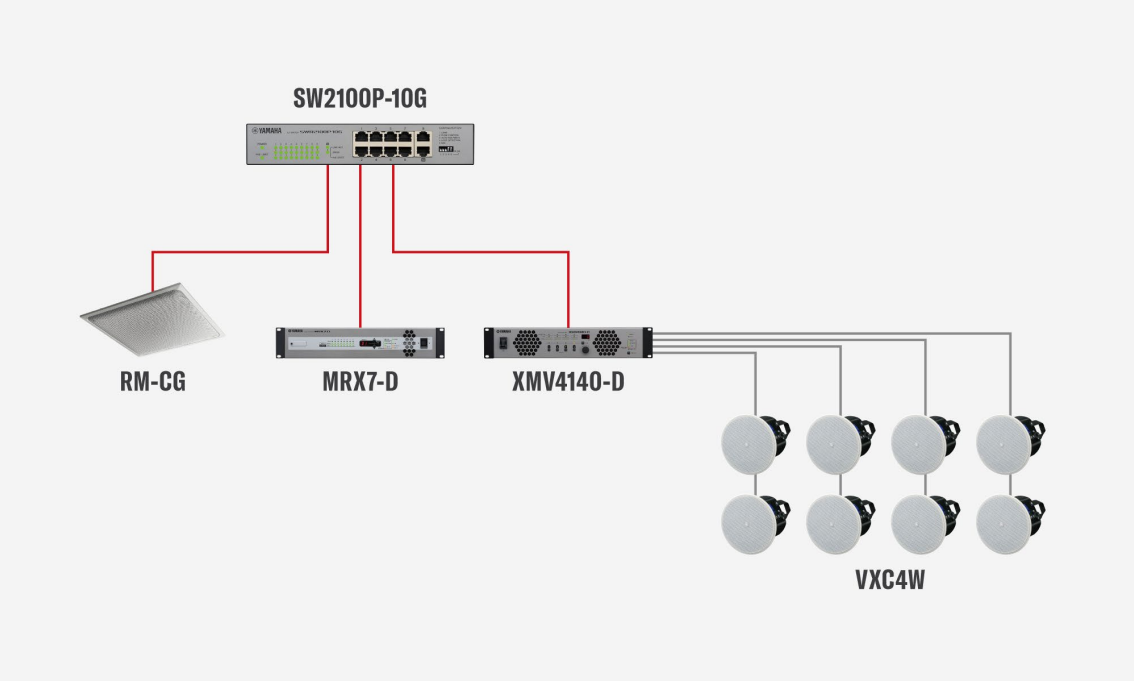
* Results may differ depending on room's acoustic environment.

System Design

Characteristics of Voice Lift System with RM-CG and Ceiling Speakers

This system achieves the highest possible sound pressure by placing each speaker with adequate space between them. A voice lift system can be flexibly adapted to a room with depth by installing additional ceiling speakers. So this system is suitable for large rooms where sound needs to be amplified.

However, there are a few disadvantages. It makes it hard for the participants to know the direction of the presenter as participants will hear amplified sounds from the ceiling. And ceiling speakers cannot be installed close to the listeners sitting in front because they hear the presenter's direct voice and are close to the ceiling microphones. Therefore, depending on their sitting positions, some listeners may mostly hear the amplified sound from the ceiling speakers behind them.



System diagram

RM-CG and Speaker Positions

PAG and NAG

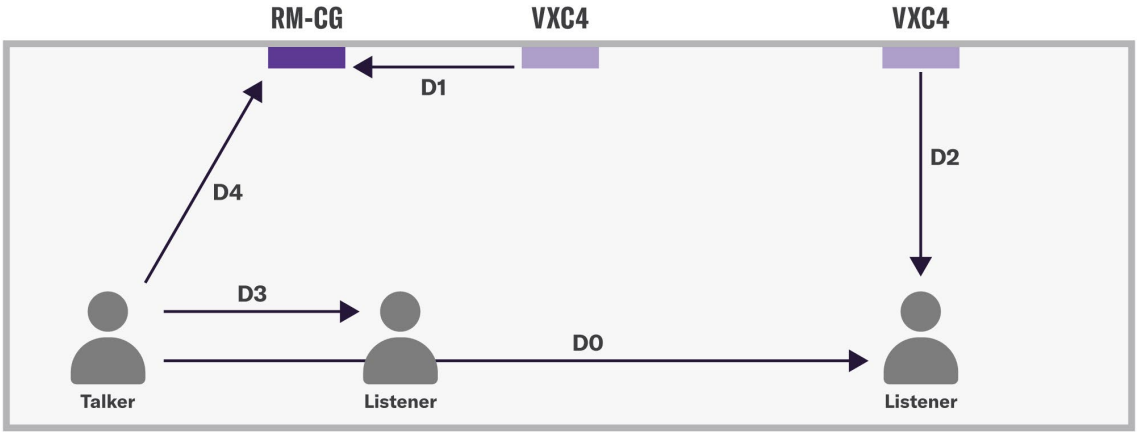
For a voice lift system, install an RM-CG on the ceiling close to a presenter, and install speakers so every participant can hear the presenter's voice. The most challenging thing when designing a voice lift system is to obtain sufficient sound pressure levels without causing feedback. Feedback is usually caused by several factors such as distance between a microphone and speakers, the distance between a microphone and presenter, etc.

The indexes called PAG (Potential Acoustic Gain) and NAG (Needed Acoustic Gain) help you to find conditions where a voice lift system can achieve the required sound pressure without feedback. PAG indicates the theoretical maximum value that allows sound pressure increment without causing feedback, while NAG shows the sound pressure needed at a particular listening point.

Elements Required for PAG/NAG Calculation

The following seven elements are needed for PAG/NAG calculation.

	Definitions
D0	Distance between the presenter and the farthest listener
D1	Distance between the ceiling microphone and the closest speaker to the microphone
D2	Distance between a listener and the closest speaker to the listener
D3	Distance between the presenter and the closest listener to the presenter * It can be defined as the maximum distance the presenter's voice can directly reach if nobody can directly hear the presenter.
D4	Distance between the presenter and the ceiling microphone
FSM	Feedback Stability Margin: Estimated fluctuation width of the voice's sound pressure (Fixed at 6dB)
CMM	Ceiling Microphone Margin: Margin for the ceiling microphone (Fixed at 10dB)



PAG/NAG Formulas

PAG: PAG = 20Log((D0 * D1) / (D2 * D4)) - FSM + CMM

NAG: NAG = 20Log(D0 / D3)

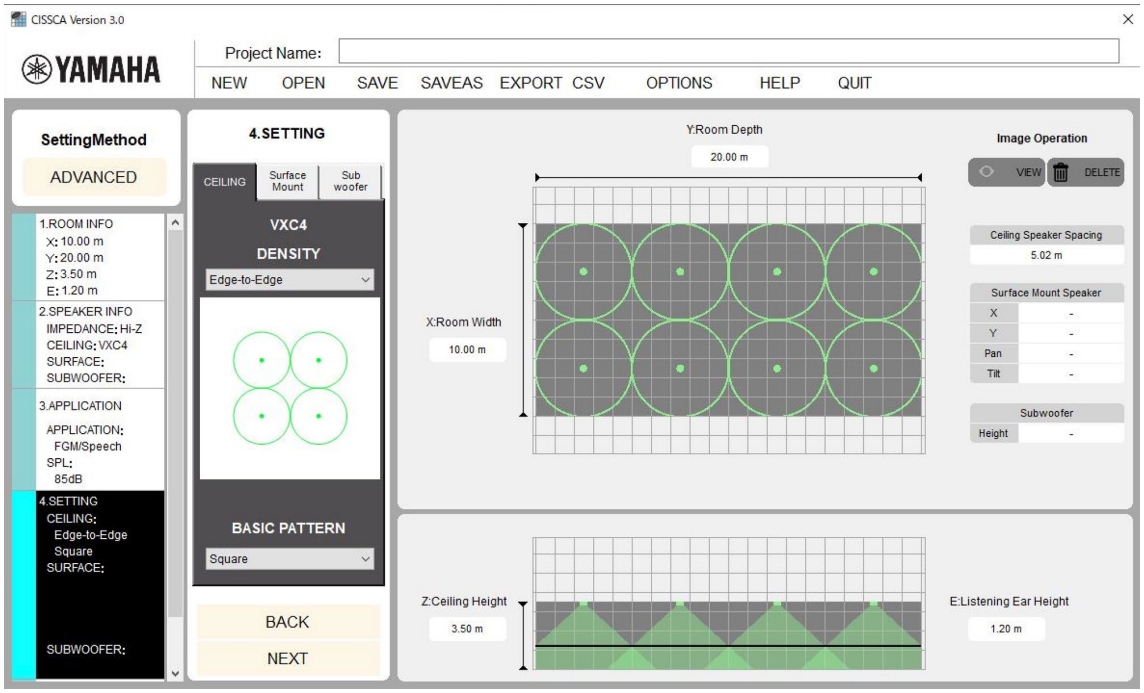
To achieve the required sound pressure without feedback, both PAG and NAG need to meet the following condition:

0 < PAG and NAG < PAG

Addition of CMM to PAG Formula:
CMM is not usually added to the PAG formula because an omnidirectional microphone is commonly used. Since the RM-CG with sharp directivity is less prone to produce feedback, a +10dB margin is added as CMM according to the microphone characteristics. CMM is a margin only for the RM-CG based on the microphone characteristics and an actual measurement value.

Installation Distance between Ceiling Speakers

It is recommended to use the “edge-to-edge” layout to align the ceiling speakers if we consider both the effect of sound pressure increment and the number of speakers to be used. The “edge-to-edge” layout is an installation method in which each speaker is aligned at a point where sound pressure of adjacent speakers attenuates by -6dB. Distance between speakers for the “edge-to-edge” layout can be easily calculated using CISSCA (Commercial Installation Solutions Speaker Calculator) provided by Yamaha. CISSCA is free software that can be downloaded from the Yamaha website. VXC4 ceiling speakers are used for every verification in this document.



CISSCA's Window of Edge-to-Edge Layout

Installation Environment

Room Size

A small room may not achieve enough sound pressure increment as more sound will be diffracted due to the RM-CG and speakers that are placed closer to each other. Therefore, if you are designing a system for a room with less than 10m depth, please reconsider if a voice lift system is really needed as a presenter's voice can directly reach all the participants in the room and may not need to be amplified.

Background Noise Level

For a successful voice lift system, the background noise level must be low enough compared to the sound to be picked up. If the background noise is loud, the microphone will also pick up the noise; so the sound will be unclear. Please make sure that background noise is low enough in the room before designing a system. Also, avoid installing the RM-CG close to a device that produces background noise such as an air conditioner and projector as the beamforming arrays will pick up the noise. (* The RM-CG has a Noise Reduction function, but Output 2 - used for voice lift purposes - does not have this function.)

Acoustic

A room with too much reverberation is not suitable for a voice lift system as such rooms are prone to generate feedback. To use a voice lift system in a room with a lot of reverberation, reduce reverberation by installing suitable acoustic absorbing materials prior to installing microphones and speakers.

RM-CG Settings

Low Latency Mode

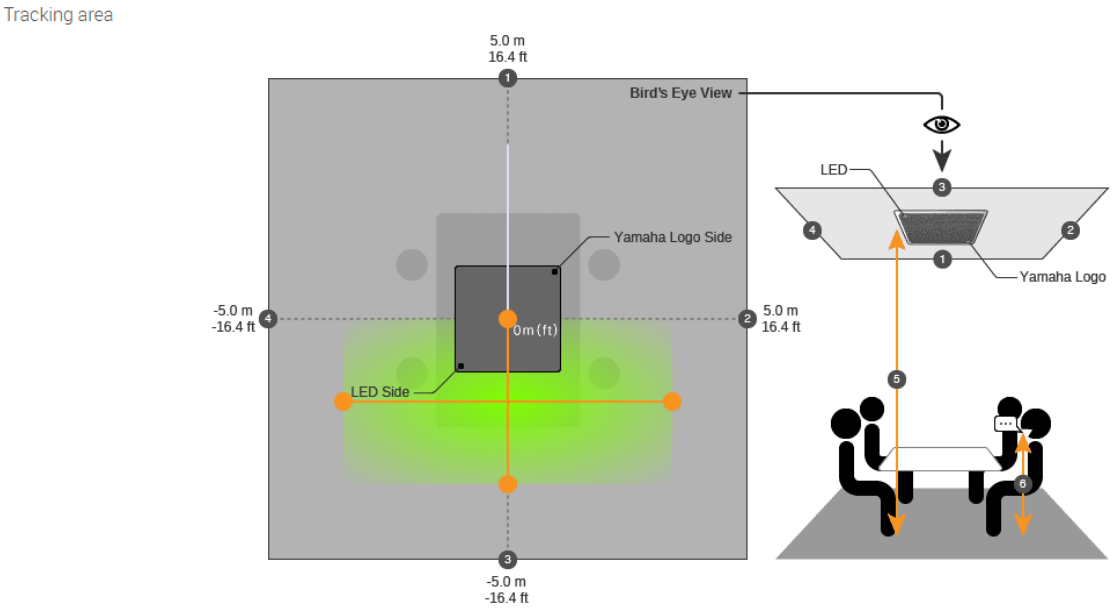
To obtain clear sound, it is important to make the latency of amplified sound as low as possible.

The RM-CG has two Dante output channels. To make the latency low, use Dante Output CH2 which is set to the Low Latency mode. Dante Output CH1 outputs audio picked up by the RM-CG after being processed by AEC, etc. Because of this, Output Ch1 has higher latency. Dante Output CH2 outputs sound picked up by the RM-CG without audio signal processing except for the internal beam control processing if it is set to the Low Latency mode. Therefore, Dante Output CH2 can keep the RM-CG's latency to around 21 msec.

For a voice lift system, set the RM-CG to Low Latency mode and use Dante Output CH2 to get the best results.

Tracking Area Settings

Since a voice lift system amplifies sounds picked up by the RM-CG, the RM-CG must be set so the sound will not be picked up again. The RM-CG has a function to narrow down the pickup area by specifying the tracking area of the microphone. For a presentation system, set the tracking area only to the point where the presenter is standing.

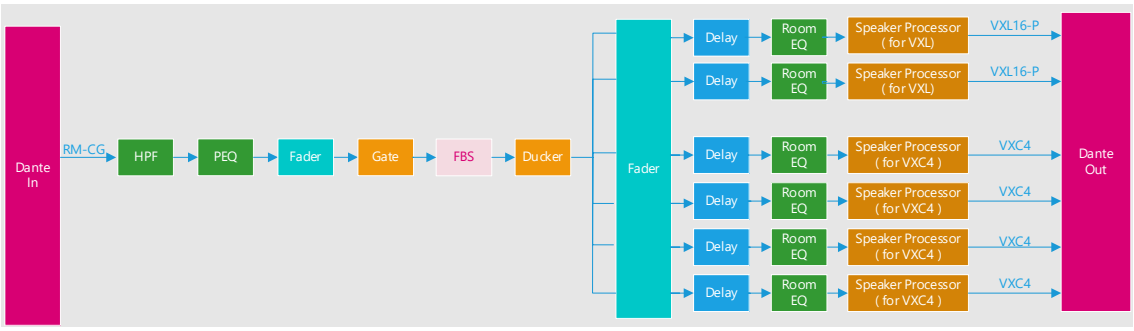


Acoustic Adjustment

Digital Signal Processor

For a voice lift system with the RM-CG, use the MRX7-D digital signal processor to adjust EQ and other fine adjustments because MRX7-D allows flexible settings.

The following is a configuration example of the MRX7-D used for a voice lift system.



The following are the four important elements when designing and adjusting a voice lift system.

1. **Room EQ settings to flatten the frequency response in the room**
   Use an acoustic adjustment tool such as a real-time analyzer as well as a room EQ to flatten the system's frequency response as much as possible according to a room's acoustic character. The flatter the frequency response is, the more feedback margin can be achieved.

2. **Output level setting for each speaker using the output fader**
   Since the audio output from a speaker close to the microphone can easily be diffracted, set the output level low to minimize feedback. And the output level can be set higher as a speaker gets farther from the microphone. Set each speaker's output level properly using each output fader.

3. **Delay time setting according to the system latency and the time when the audio reaches the listeners**
   The latency between the direct voice and the amplified voice from the speakers can affect the sound quality, especially clarity.
   Set the delay time properly by referring to the latencies below and considering the time when the sound output from each speaker reaches the listeners.

   RM-CG's latency: Approx. 21msec (when set to the Low Latency mode)
   MRX7-D's latency: Approx. 4 to 5 msec*
   Dante's latency: Approx. 1msec
   * The latency varies according to the configuration of the MRX7-D.

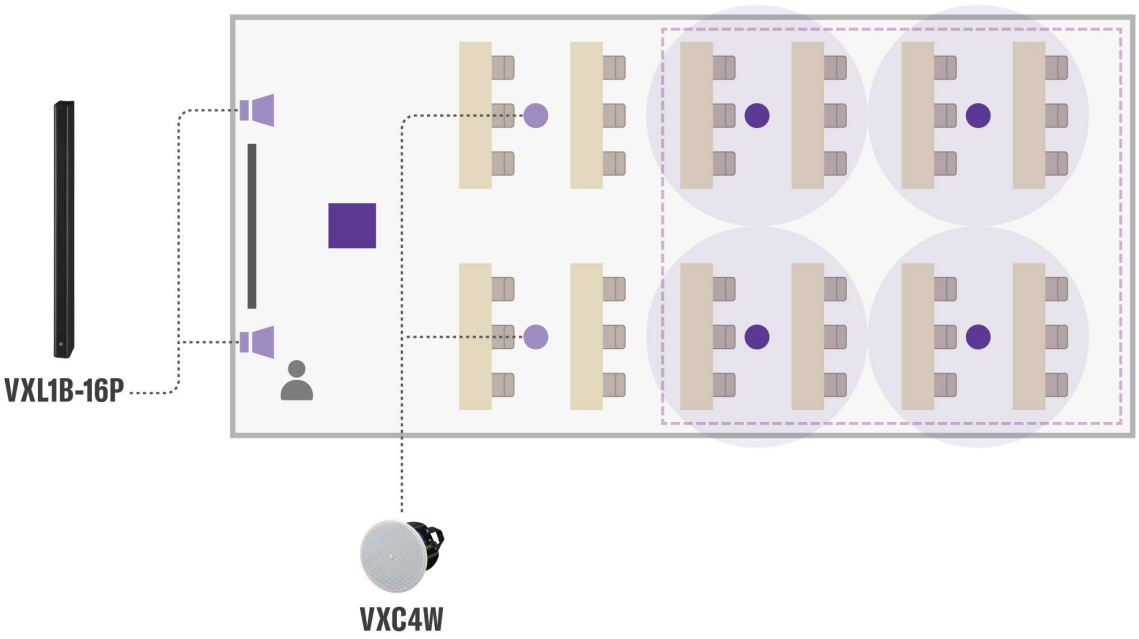
4. **Additional information**
   FBS (Feedback Suppressor):
   By inserting FBS (Feedback Suppressor), unexpected feedback can be avoided.

   Gate:
   By inserting Gate, noise can be cut when no sound is produced.

   Ducker:
   By inserting Ducker, the output from the speaker can be kept below a specified level even when an unexpected amount of feedback occurs.

Supplementary Audio

Installation of Sub-speakers in Front



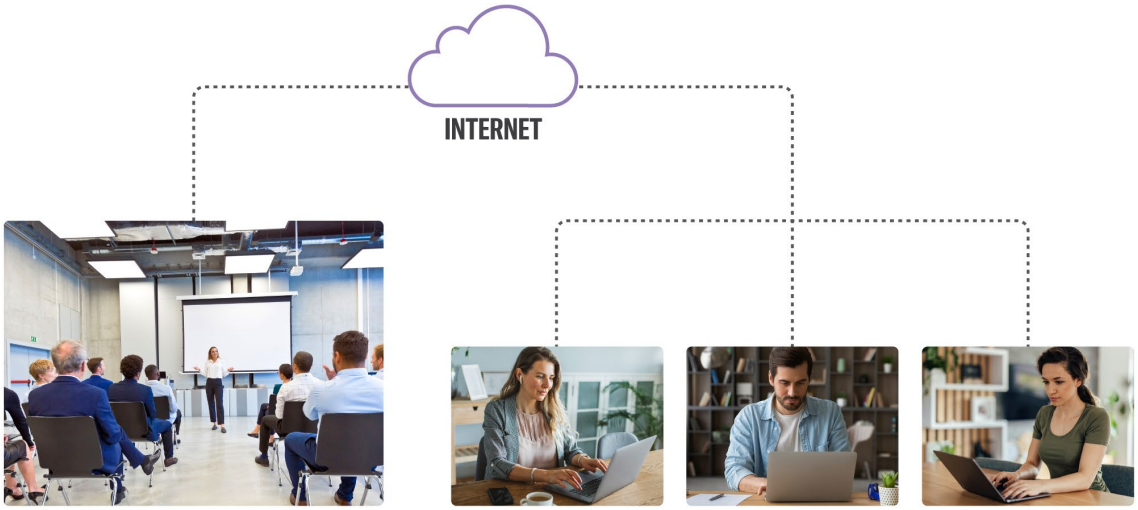
A voice lift system with the RM-CG and ceiling speakers may not deliver sound at a sufficient volume level to the listeners in front. Ceiling speakers or VXL1-16-Ps installed in front for supplementation (see the figure above) can resolve an unusual situation where the listeners in front hear the presenter's voice from behind. Though those speakers cannot achieve sound pressure increment as much as other ceiling speakers can, the farther the sub-speakers are installed from the RM-CG, the higher the system can make sound pressure.

Sound pressure increment verification result when sub-speakers are installed

System	Distance (RM-CG ⇔ Speaker)			
	4.5m		11.8m	
	SPL	Increment	SPL	Increment
w/o Voice Lift	54.8 dBA		51.8 dBA	
Voice Lift	62.6 dBA	+7.8dB	65.3 dBA	+13.5dB
Voice Lift with sub speakers	60.4 dBA	+5.6dB	62.6 dBA	+10.8dB

To Stream Presentation to Remote Participants

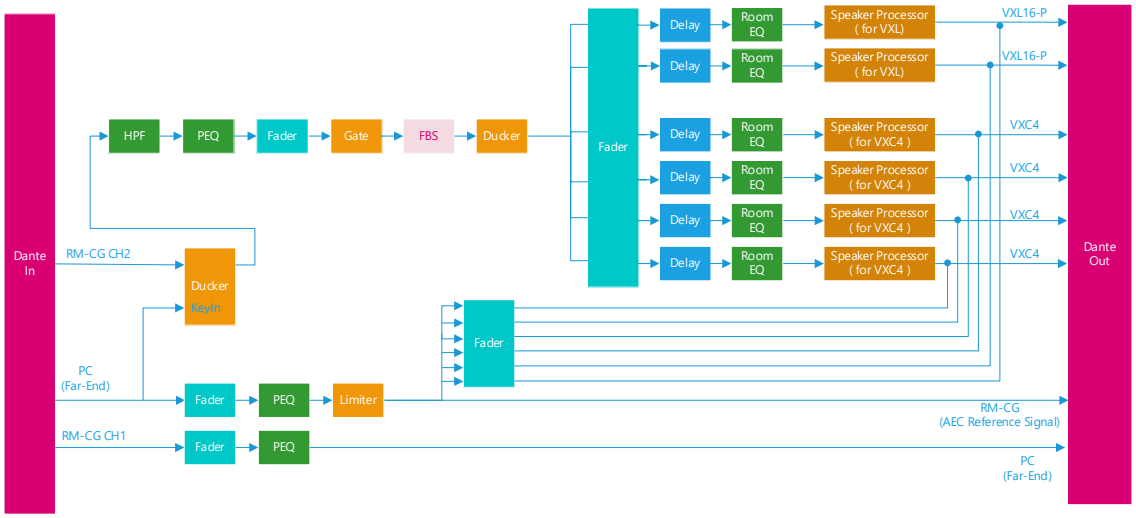
A voice lift system that can deliver presentations to remote locations requires more advanced design and adjustment techniques but with some limitations. The following are the elements that need to be considered.



- Use the RM-CG's internal AEC that is optimized for the RM-CG.
- Since RM-CG's Dante CH1 outputs audio with AEC processed, route audio from Dante Output CH1 to remote locations.
- Return only the reference signal of the far-end signal to AEC.
  (Make sure not to include signals amplified by the voice lift system.)
- The sound quality of far-end*1 and near-end*2 will decrease because AEC's echo cancellation performance will drop by the diffraction of amplified near-end/far-end audio from the ceiling speakers to the RM-CG.
  - *1
    Near-end voice amplified by the voice lift system will again be picked up by the RM-CG. This loop will decrease the sound quality, and the degraded sound will be delivered to the far end.
  - *2:
    Far-end voice amplified at the near end will again be picked up by the RM-CG. This loop will decrease the sound quality, and the degraded sound will be amplified at the near end.

- Ducker can reduce audio deterioration mentioned above as it stops amplifying voice lift with the trigger of audio signals from the far end. However, there is the following limitation.
  - When a double-talk occurs (when both near-end and far-end speakers are speaking at the same time), for example when a near-end speaker starts speaking while a far-end speaker is speaking, the near-end speaker's voice will not be amplified by the voice lift system. Therefore, we need to set a rule in which a far-end speaker should not speak while a near-end speaker is speaking.

The following is the simplified diagram of the MRX7-D configuration.



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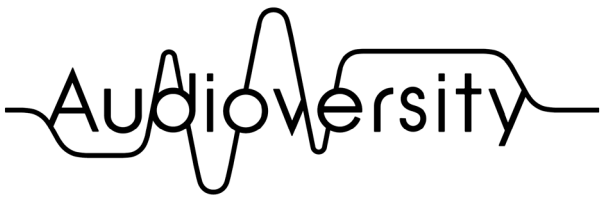

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