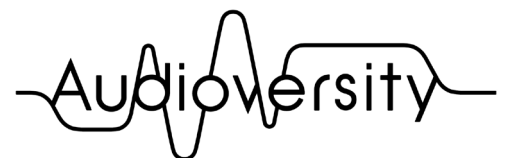# RM-CG Voice Lift System
Ver. 2.00

Version history

2022.09   First Edition

2024.05   Update

Audioversity

by Yamaha Pro Audio

Contents

Introduction

The RM-CG ceiling microphone is equipped with a "multi-beam tracking" function that provides stable tracking to multiple people 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 achieved using an RM-CG by selecting and installing the correct processing options, suitable speakers and by 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 an event with a PA (public address) system that needs a higher sound pressure level than for a normal conversation.

Two Use Cases Where Voice Lift Is Required

There are two main cases where Voice Lift is needed.

① Presentation style (one to many)
② Conference style (many to many)

Both styles require an environment where the participants can listen to the presenter's voice clearly, regardless of the distance between the participants and the presenter.
Please Note that the settings and adjustments for each style differ.

① Presentation style (one to many)
　　To allow all participants to hear a presenter's voice clearly during a presentation:

The RM-CG dynamically detects the direction of a person speaking and picks up and tracks the voice by centering four beams on that person with enhanced directivity. Therefore, when a presenter is moving in front of a whiteboard, screen, or display 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 their 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.

② Conference style (many to many)

To allow all participants to hear each other clearly in a large meeting:

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.

Room Environment for Voice Lift

Size

A small room may not achieve enough sound pressure increment as more sound will be diffracted due to the RM-CG and speakers being 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 may directly reach all the participants in the room and may not need to be amplified.

Background Noise Level

For successful voice lift, 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.)

Acoustics

A room with too much reverberation is not suitable for voice lift 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.

Importance of Microphone and Speaker Placement and Sound Adjustment

A voice lift system with a ceiling array 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 suitable level, you should also keep a sufficient distance between the microphone and the speakers. In addition, this type of system also needs high-precision sound adjustment technology using sound measurement tools (e.g.

a real-time analyzer) to achieve natural amplification.

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.
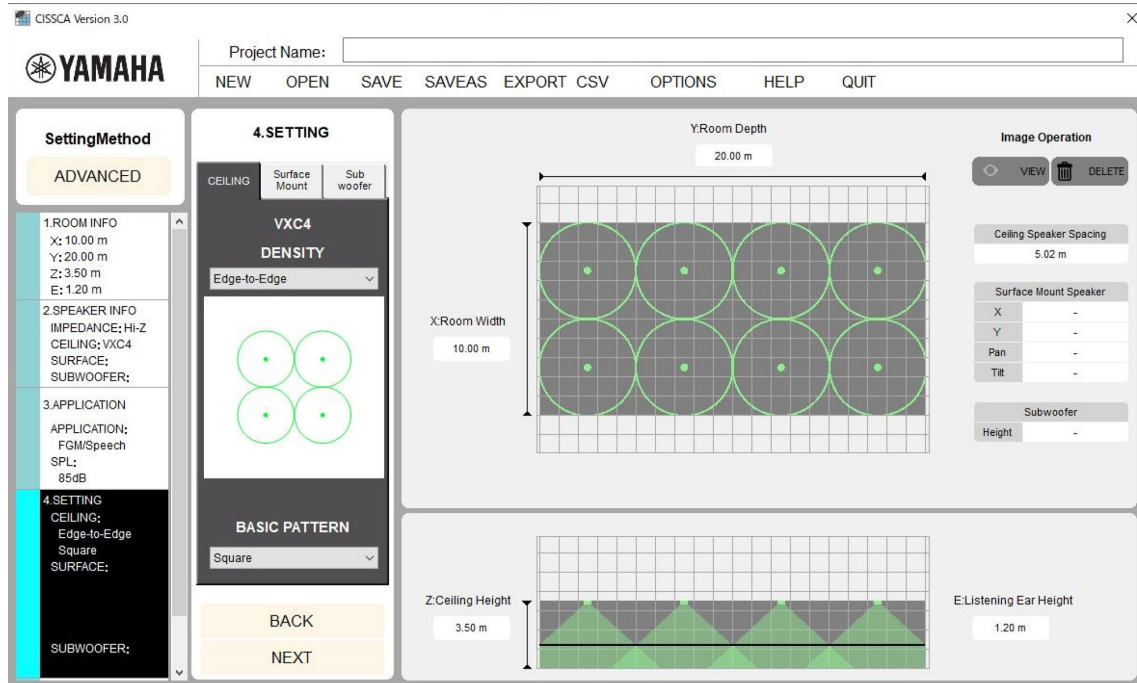
CISSCA's Window of Edge-to-Edge Layout

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. 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, and is better suited for voice lift purposes.

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 style system, set the tracking area only to the point where the presenter is standing.
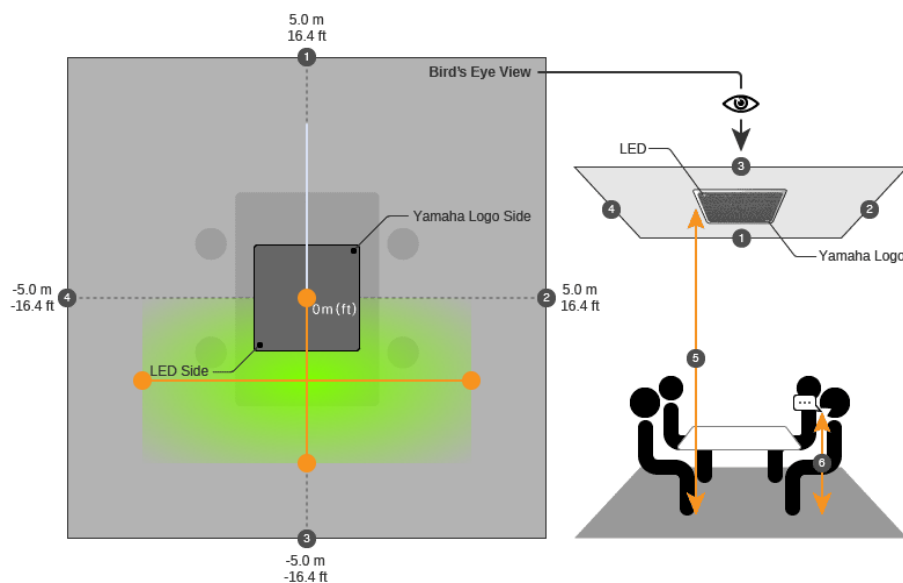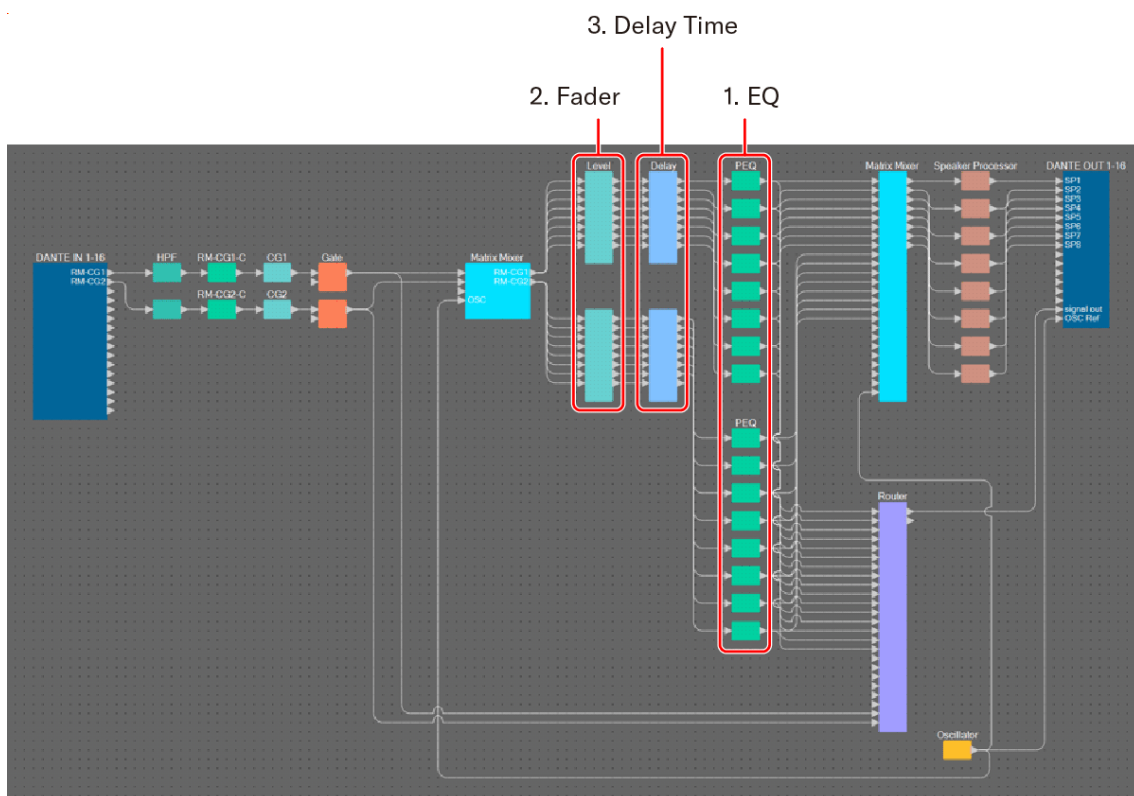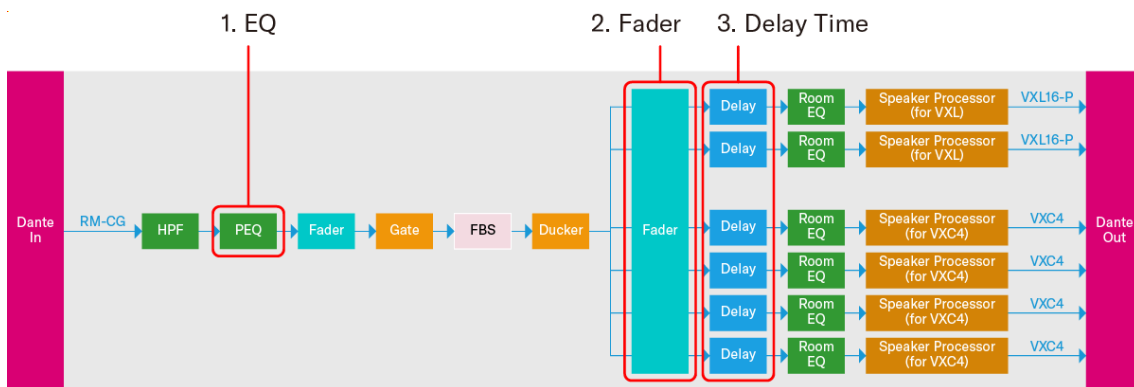

Acoustical Adjustment

Digital Signal Processor

For voice lift 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 voice lift.

1. **EQ setting to flatten the frequency response in the room**

   With an acoustic adjustment tool such as a real-time analyzer, adjust the EQ to flatten the frequency response for the loop gain as much as possible according to the speaker and microphone positions and room 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, and speech intelligibility.

Refer to the latencies below for the time it takes for the sound from each speaker to reach the listeners and also use your own hearing to identify if the system is performing as needed.

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 an FBS (Feedback Suppressor), unexpected feedback can be avoided.

Gate:

By inserting a Gate, noise can be cut when no voice is present.

Ducker:

By inserting a Ducker, the output from the speaker can be kept below a specified level even if an unexpected amount of feedback occurs.
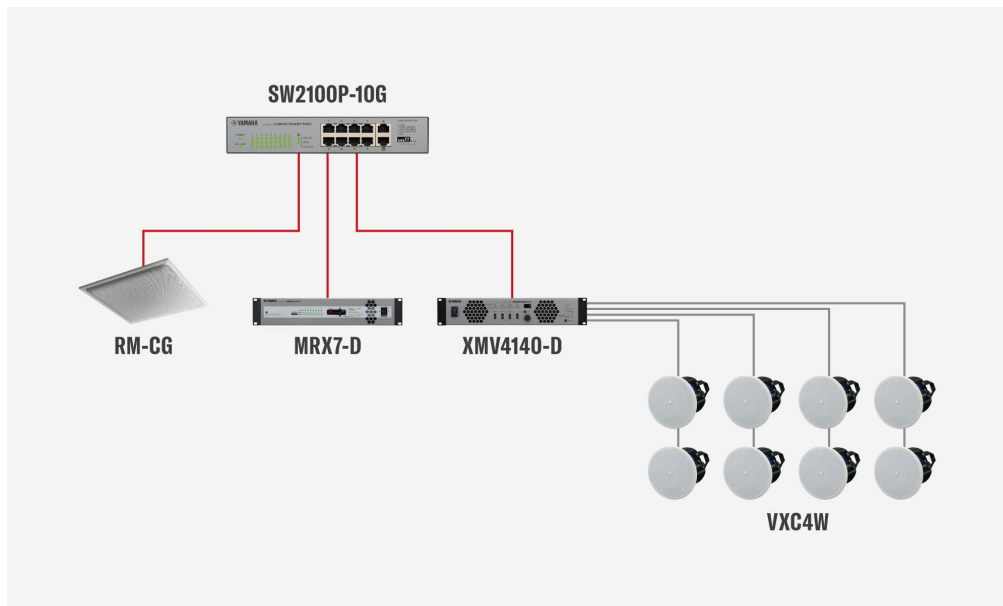
System Design [Presentation Style]

Overview

Presentation style voice lift achieves the highest possible sound pressure by placing each speaker with adequate space between them. It can be flexibly adapted to a deeper room 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 presentation style voice lift, 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 can achieve the required sound pressure without feedback. PAG indicates the theoretical maximum sound pressure level that can be achieved without causing feedback, while NAG shows the sound pressure that is needed at a particular listening point, to allow for good intelligibility.

Elements Required for PAG/NAG Calculation (Distances shown in Meters)

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 feedback loop (Fixed at 6dB)
CMM	Ceiling Microphone Margin: Margin for the ceiling microphone (Fixed at 10dB)
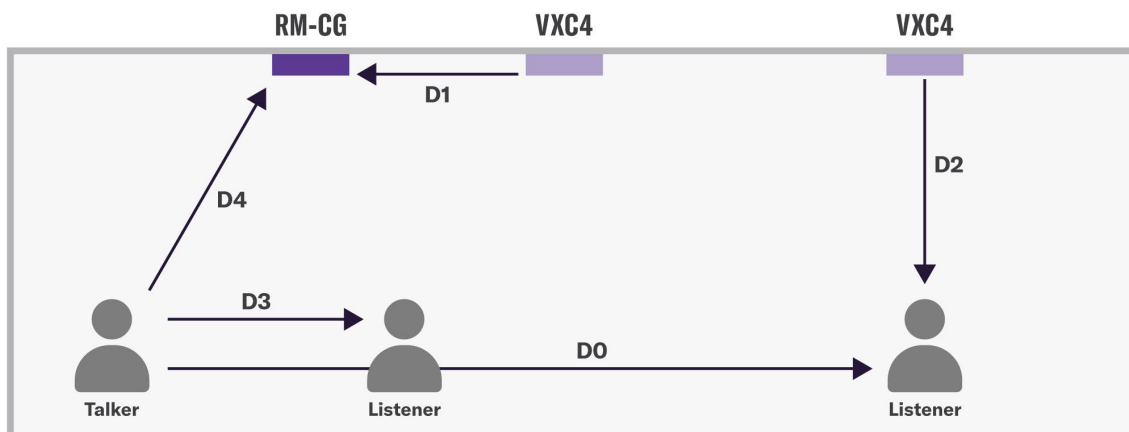
PAG/NAG Formulas

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

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

> **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.

Sound pressure increment was measured in the following system.
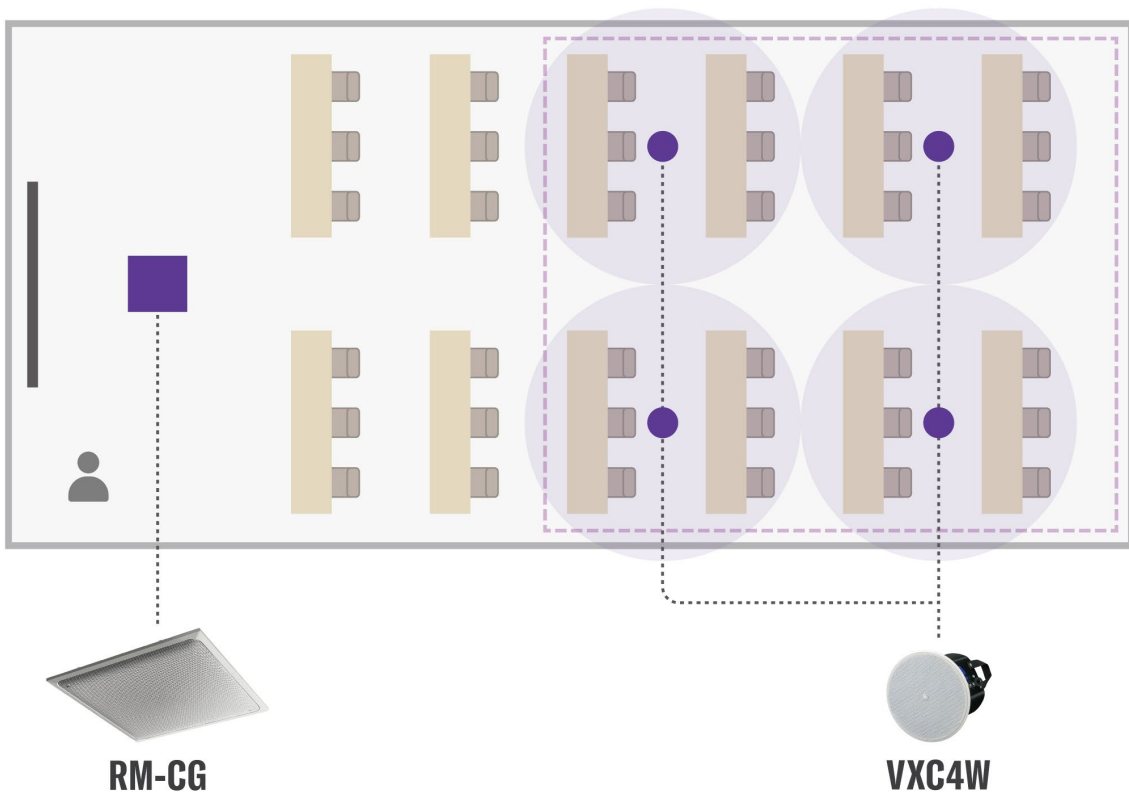
Ceiling Speaker Layout
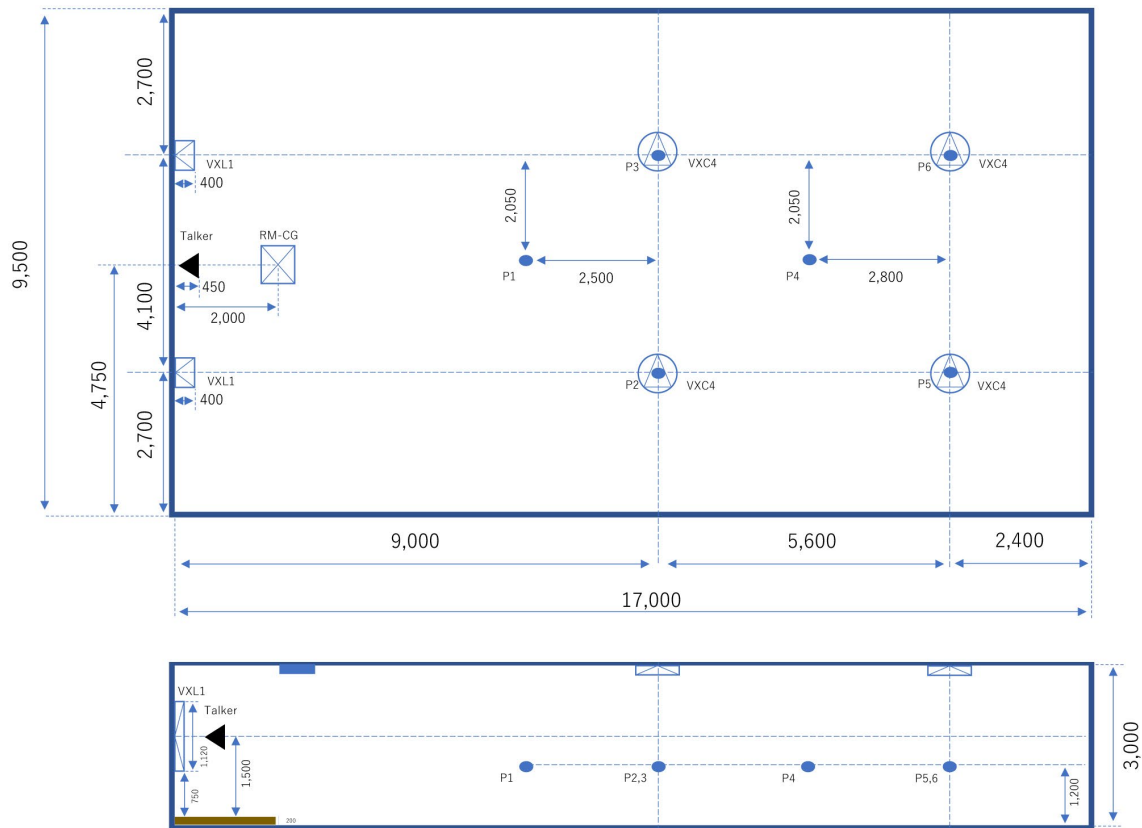
When both systems are adjusted so each speaker can obtain a similar amount of loop gain, the sound pressure level at the sound receiving point (4.5 meters away from the RM-CG) is incremented by 7dB - 8dB. The further the distance between ceiling speakers and a microphone, the less feedback the speakers produce, as less sound is diffracted. Therefore, greater sound pressure levels can be expected at the back of the room.

   *Loop gain is the difference in gain between the microphones and speakers where the audio signal is sent from the input to the output and back into the input.

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 [Conference Style]

Overview

A conference style voice lift system is designed to increase the output level of the speakers as the distance from the person speaking increases when the ceiling microphone close to the person picks up his/her voice. The system can be flexibly adapted to a room with a large depth by installing additional ceiling speakers. Zoning makes it possible to deliver the speaker's voice to the entire room with a system that uses two ceiling microphones and multiple ceiling speakers.

However, there are a few disadvantages. It makes it hard for the participants to identify the direction of the presenter as participants will hear amplified sounds from the ceiling. And participants may feel discomfort because participants close to the presenter hear the presenter's direct voice while participants far from the presenter hear amplified sound from the speakers. This discomfort can be reduced by setting a delay to allow for the time that it takes for the presenter's direct voice to reach the participants.
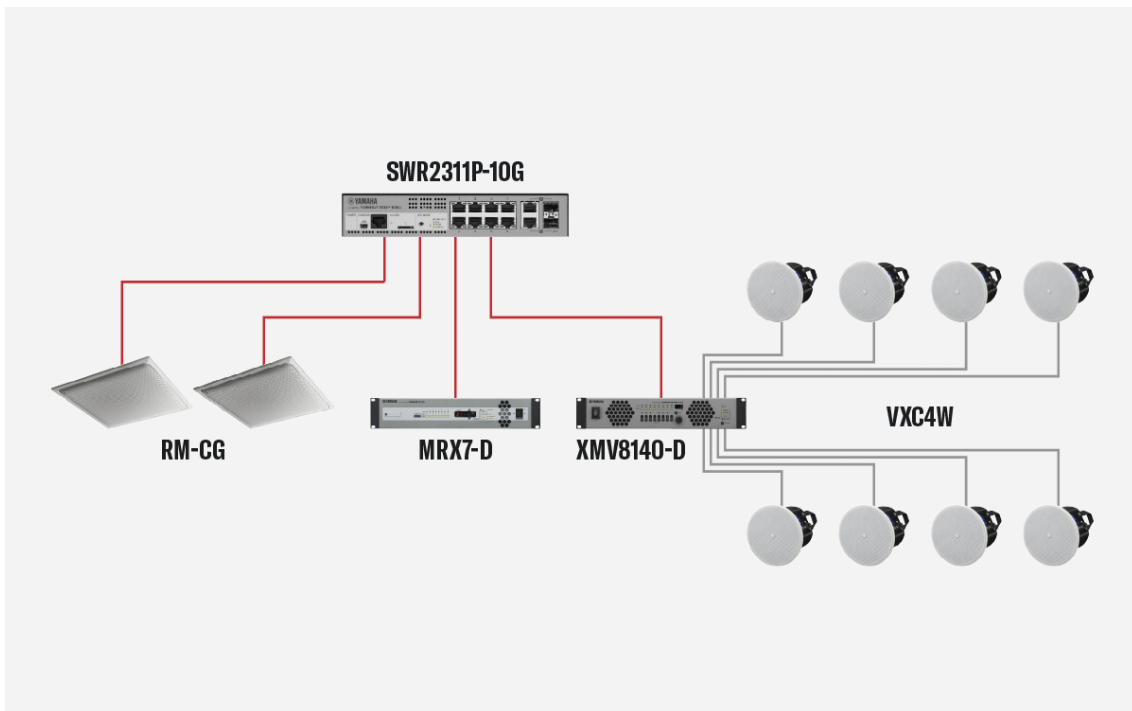
System Diagram

RM-CG and Speaker Positions

System Configuration

For this conference-style voice lift example, two RM-CGs and eight ceiling speakers are installed to cover the all of the participants. An important setting in designing a conference-style voice lift is the maximum loop gain between the microphones and the speakers.
In this verification, the maximum loop gain value for each speaker was determined so that the maximum loop gain value is -6 dB when all speakers are turned on.

Maximum Loop Gain Setting

Set the gain parameter for all speakers so that the maximum loop gain is -6dB when all speakers are turned on. It is recommended to set each gain according to the positional relationship between the microphone and the speaker.

The table below shows the verification of the sound pressure increment at the specified points by measuring the equivalent noise level with a sound level meter under the condition that voice lift is turned on or off and pink noise is played from a speaker instead of a person speaking.

System	Distance (Speaker - Listener)			
	4.5m		6.5m	
	SPL	Increment	SPL	Increment
w/o Voice Lift	55.2 dBA		53.7 dBA	
w/ Voice Lift	61.8 dBA	+6.6dB	65.0 dBA	+11.3dB

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

Sound pressure increment was measured in the following system.
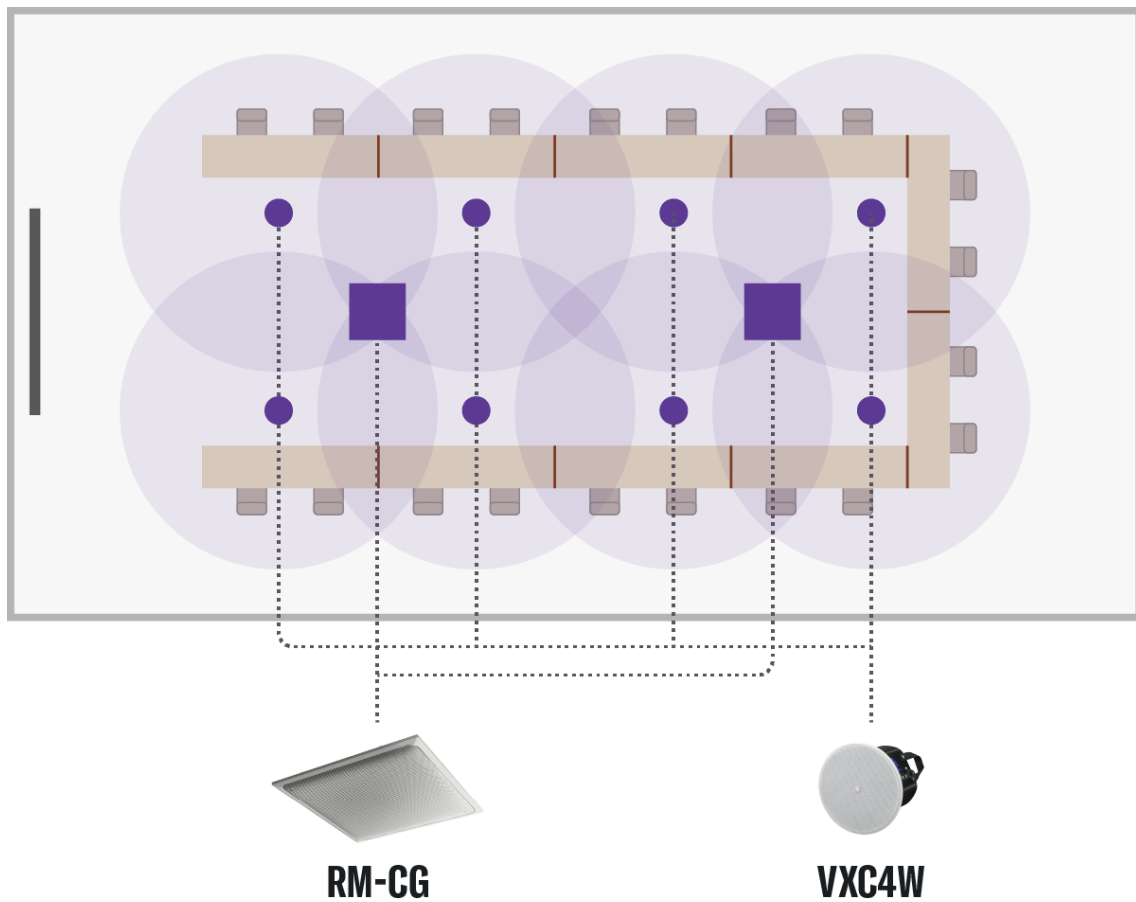
Ceiling Speaker Layout

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 is incremented by a maximum of about 6dB. 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 with appropriate settings according to the room environment.
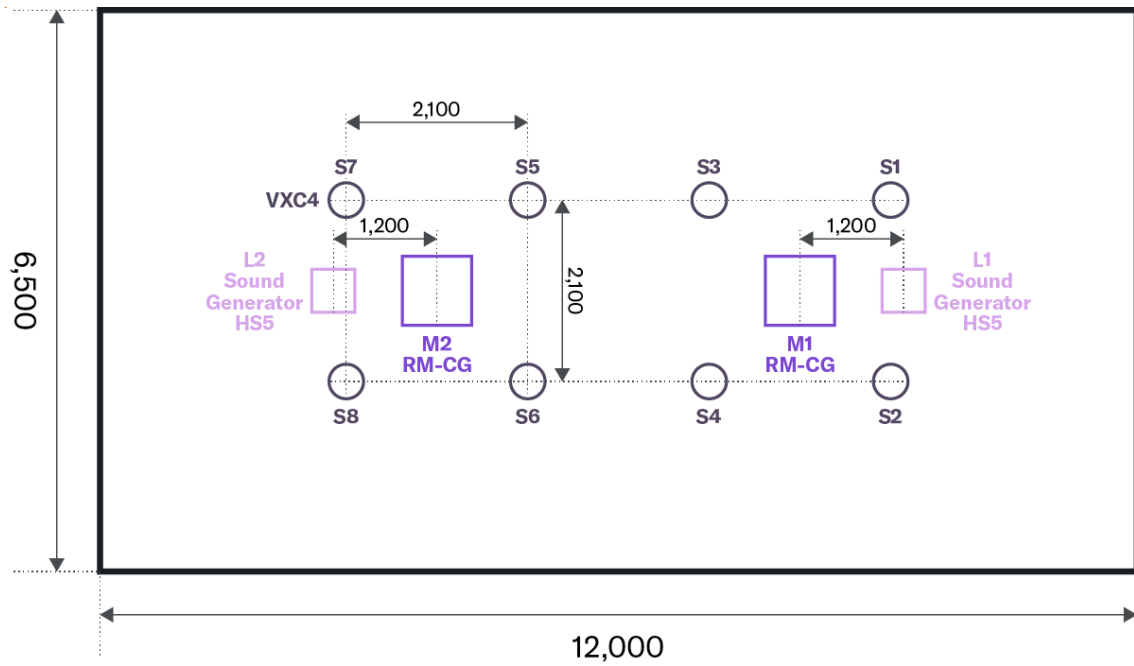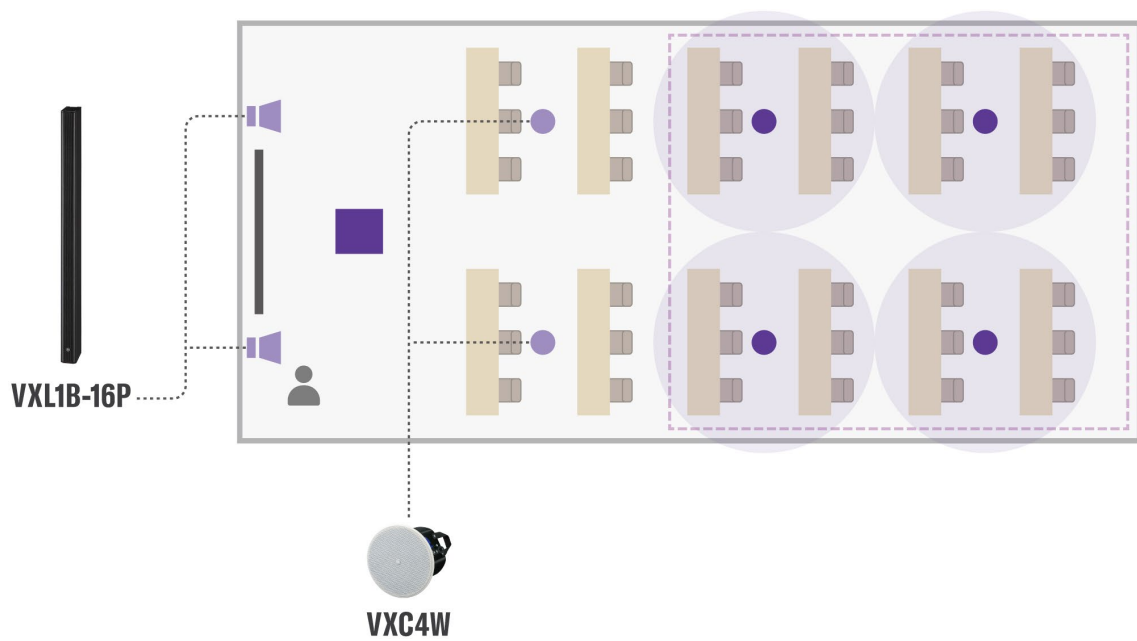
Layout of Ceiling Speakers and Microphones

Supplementary Audio

Installation of Sub-speakers in Front

Voice lift with the RM-CG and ceiling speakers may not deliver sound at a sufficient volume level to the listeners in front. Additional 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 a 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 far-end signal to AEC as the reference signal.

  (Make sure not to include signals amplified by the voice lift.)

- 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.

- A Ducker can reduce audio deterioration mentioned above as it stops amplification by 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.
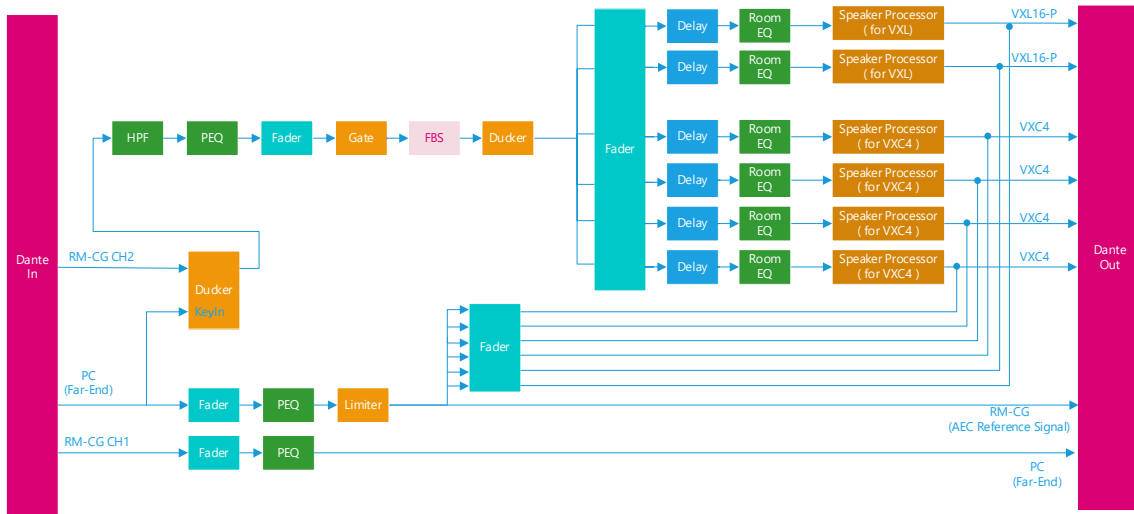
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