Effective Voice Warning for Drivers at Open Section

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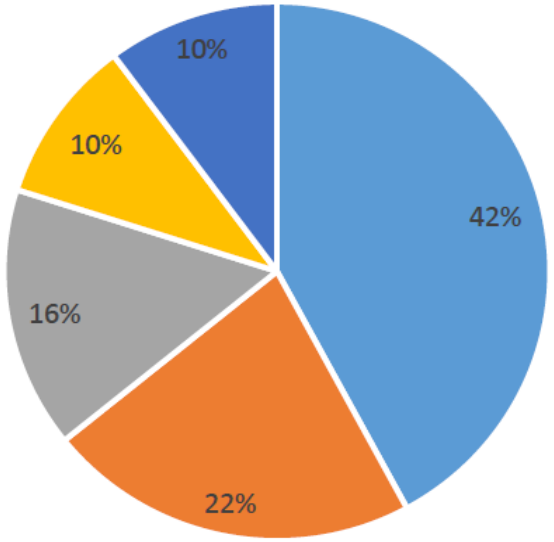
1, Introduction

Introduction



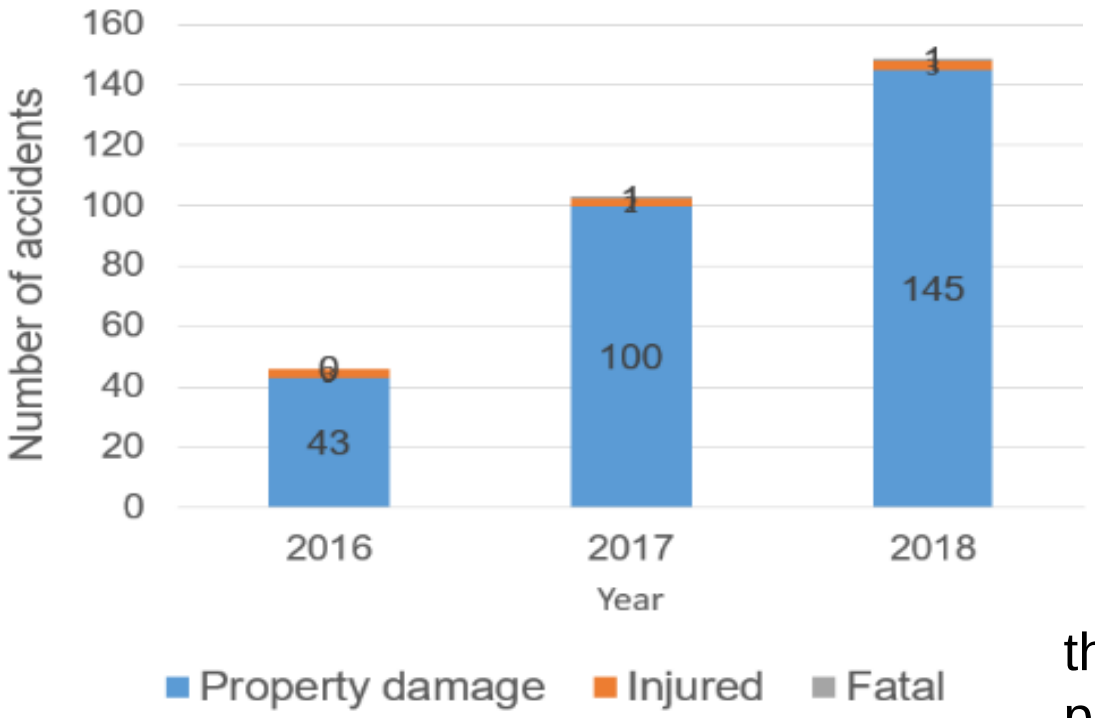
Violation trend of traffic accident on expressway

National Police Agency of Japan 2021

Drivers who caused a traffic accident, did not pay attention to the front, or did not try to look forward, or was low wakefulness.

Almost all safety measures appeal to the driver's eyesight, so the current traffic safety measures are not sufficiently effective.

Introduction



Number of accident entering the restriction area on expressways in NEXCO central

The case was increasing that the vehicle run into the lane restricted area for an operation on expressways in spite of installing the enough regulation signs and the enough attention attracting devices.

NEXCO Central decided to develop the direct warning and information provision system to a driver using acoustic sense at an open space.

The warning system is expected to work directly with the driver as an effective traffic safety measures.

2. Former Research

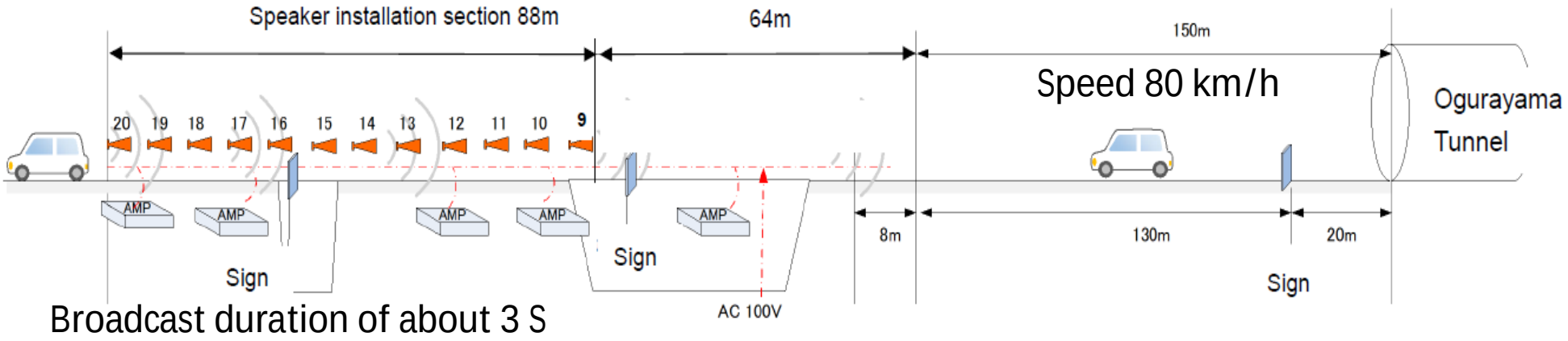
We already identified following items.

1. Suitable voice frequency to propagate into the cabin with windows closed ----- 500Hz~4kHz

2. Best speaker angle to transmit the voice warning into the cabin with windows closed ----- about 23 degree

3, Voice Warning System at Open Space

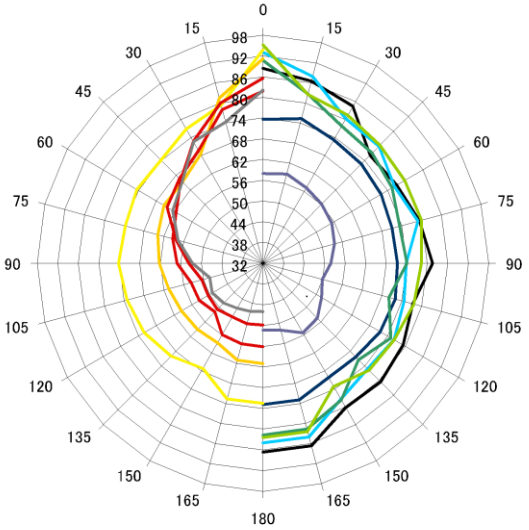
Voice Warning Trials at Open Space



Broadcast duration of about 3 S

Actual Test at Ogurayama tunnel

High directional and high flexibility flat speaker's sound pressure distribution chart and photo

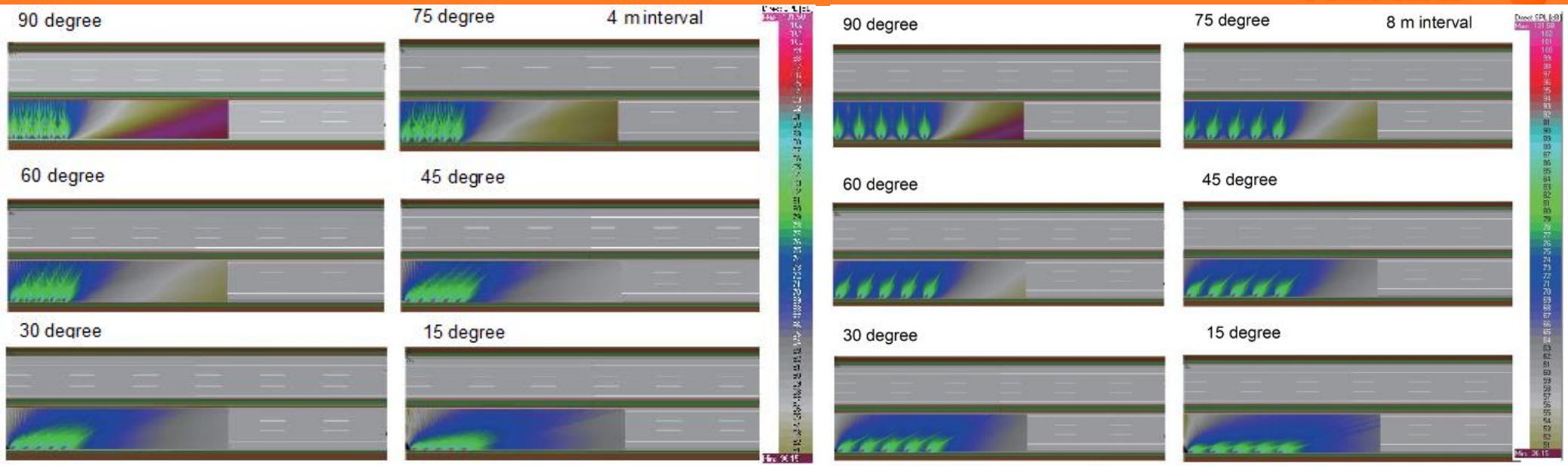


Measurement day :
2014/10/23
Place :
FPS Tokyo
Input :
1W
Distance :
100cm
Box:

Equipment :
Etani ASA-2

100Hz
200Hz
400Hz
630Hz
800Hz
1kHz
2kHz
4kHz
6.3kHz
8kHz
10kHz

Speaker Arrangement, Computer simulation



Sound pressure distribution by computer simulation (Left: 4 m interval, Right: 8m interval)

Two different speaker spacing and six different speaker angles were simulated.

The suitable interval is 8 m as following reasons.

1, Sound pressure distribution will not be extremely uneven.

2, Suitable sound pressure area can cover over 2 lanes.

3, Reasonable cost

The Suitable angle is 20 degrees as following reasons.

1, Less non-uniform sound pressure distribution

2, Cover more than 2 lanes

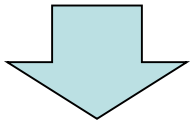
3, Former researches

Result while Driving

The subject of audition: Drivers traveling on the driving lane at 80 km/h
Text: Please cooperate with good parking manners at Atsugi rest area.

Drivers could be heard less than twice in the vehicle with windows closed.
Almost all drivers could hear the voice information.

The system was found to be sufficiently weather resistant and durable.

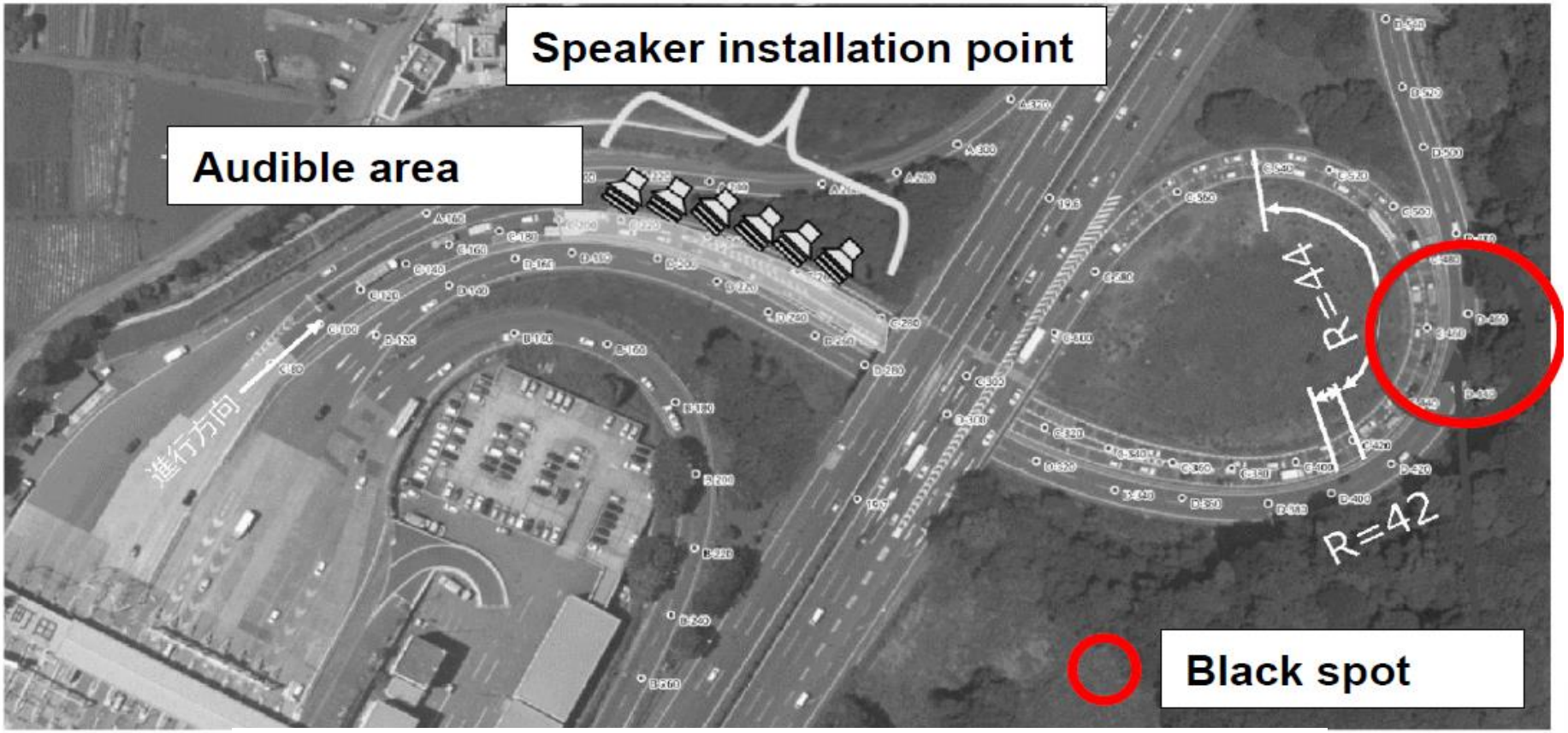


The appropriate system was able to be built at a reasonable cost.

4, Application as Accident Countermeasure

Application as an Accident Countermeasure

This system was installed into the curved section of approach ramp at Yokohama-Machida IC as an accident mitigation measure, as 18 lane departure accidents occurred during FY 2018. They are caused by excessive speed due to the downhill gradient and the subsequent left curve, and resulting in improper steering operation.



Outline of test area (C ramp at Yokohama-Machida IC)

Speaker Arrangement and Sound Pressure Level

Speaker Arrangement

1, 6 speakers 6 m apart ------- To secure more than 3 s, target speed 40 km/h.

2, With reflective plates -------- Sound go directly to the car.

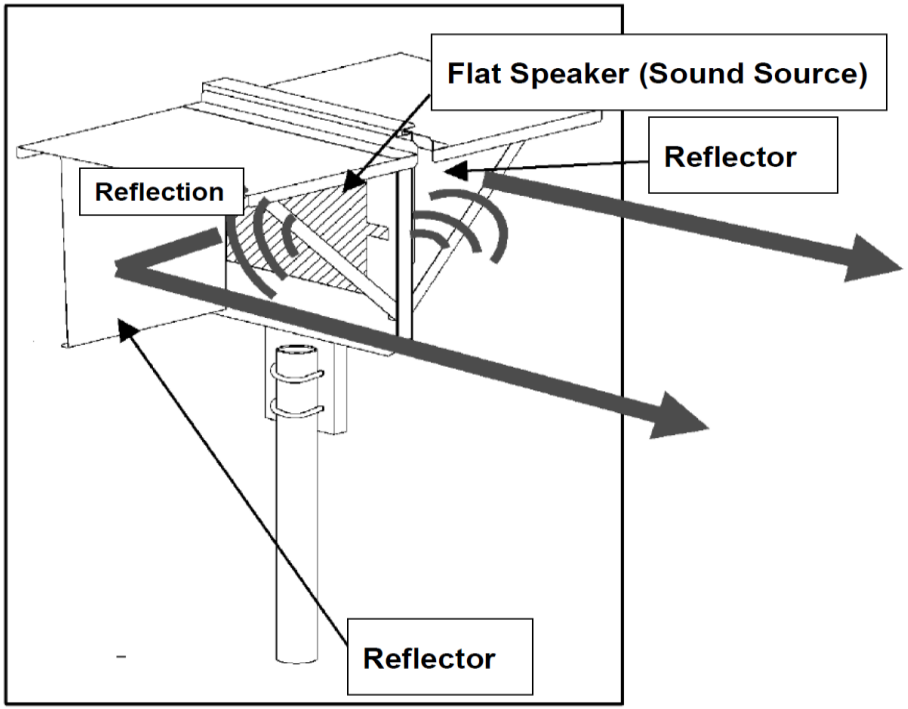
3, Speaker angle relative to vehicles ------- about 20 degrees

Sound Pressure Level

1, Radiated sound pressure: 95 dB (A) ------ 90 dB (A) inside a cabin

Warning statement:

Sharp curve ahead !



Speaker detail

Speaker Arrangement

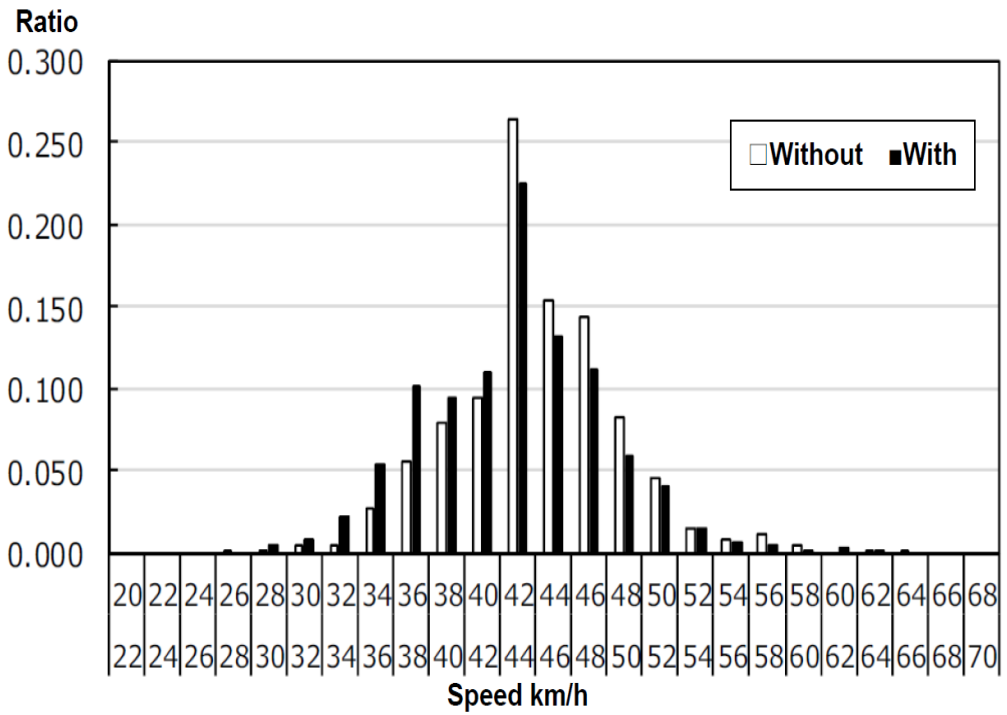
Voice Warning at Yokohama-Machida IC

Investigation

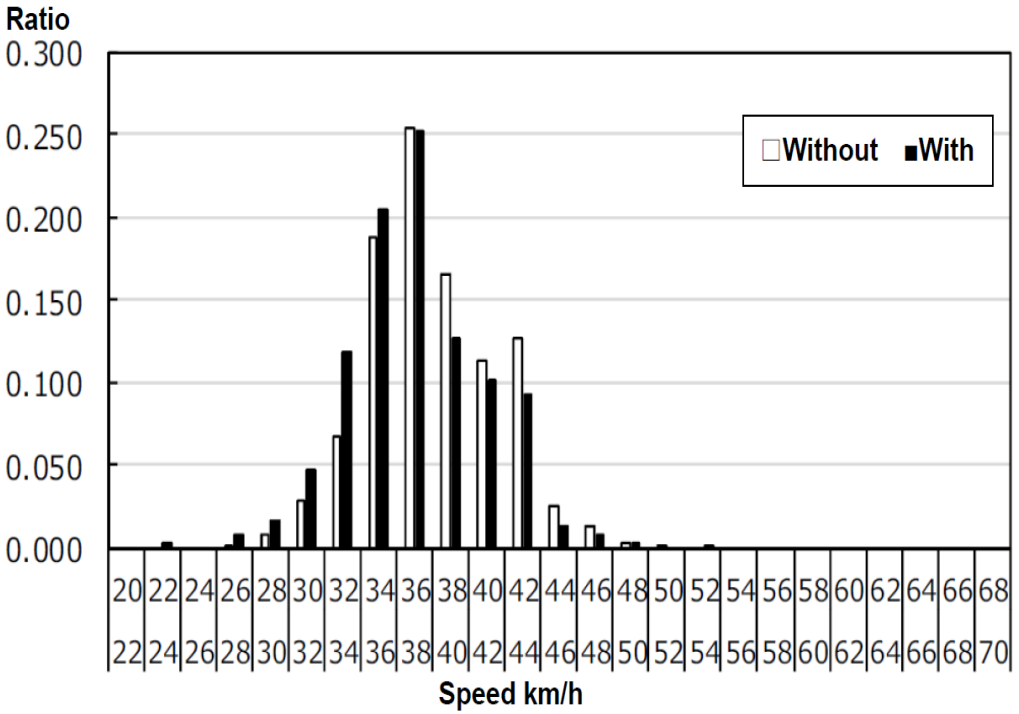
Data:
Before: 1 H (5-6 PM) July 28-30, August 2, 2019 ------2414 samples
After: 1 H (5-6 PM) August 30, September 4-5, 2019 ----- 1763 samples

Average speed ------- 35 m period around the tightest plane alignment
------ the vehicle with an interval of 3s or more from the vehicle in front

Results --- Small car and large car



Speed distribution (Small car, All lanes)



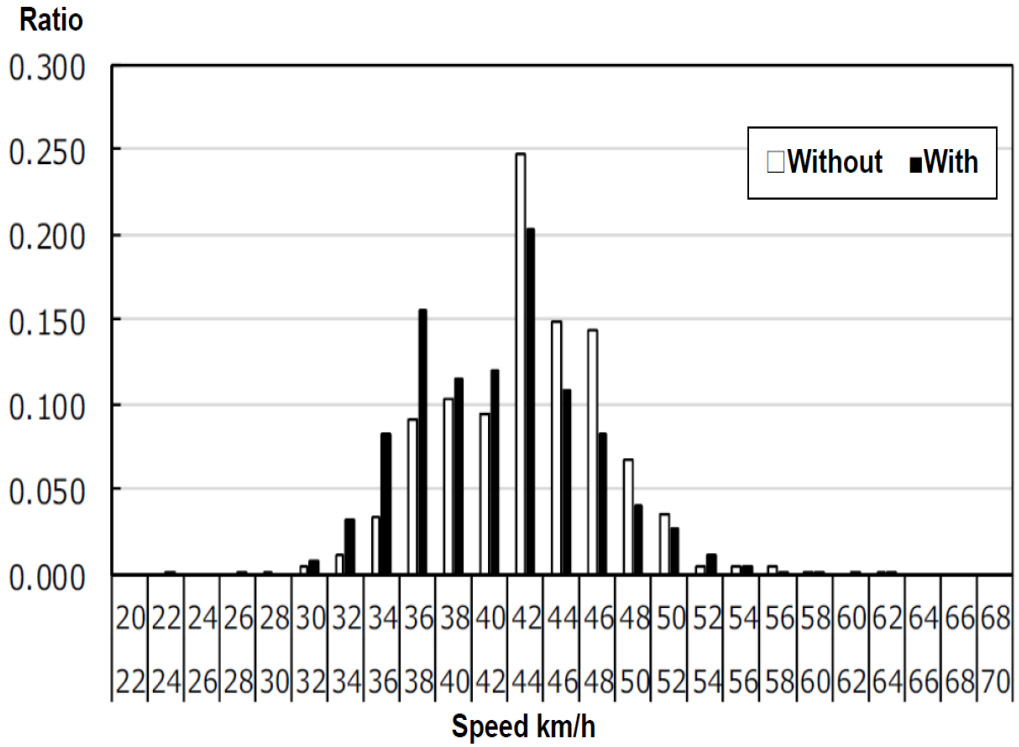
(Large car, All lanes)

Small car: Mode is same. Above the mode decreased, below increased.
Average speed decreased by 3.1%.**

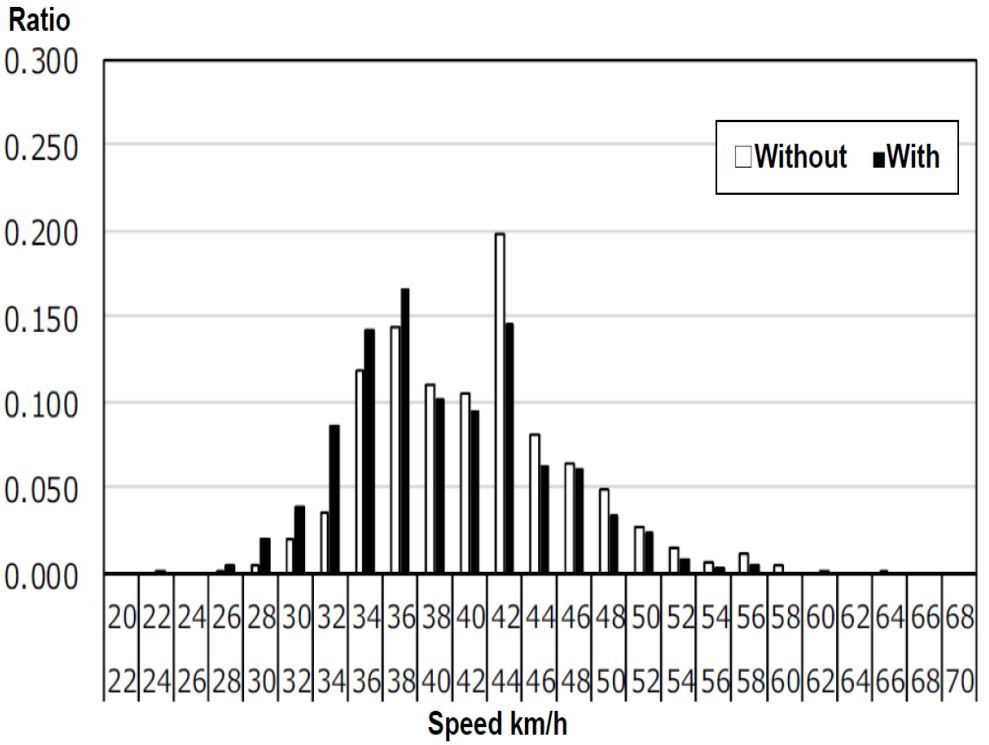
Large car: Mode is same. Above the mode decreased, below increased.
Average speed decreased by 2.8%.**

**Significant at the 1% level.

Results --- Left (Cruising) and Right (Passing) Lane



Speed distribution (All cars, Left lane)



(All cars, Right lane)

Vehicle speed in left lane (close to the speaker) (4.3 %, from 41.2 to 39.5 km/h) was higher than that in the right lane (3.8 %, from 43.2 to 41.5 km/h). **

Speed of μ+σ were reduced by -3.7% in left lane and -2.5 % in right lane.**

Rate of speed reduction is greater in left lane.

The closer to the speaker, the more effective.

Speed change, with/without system

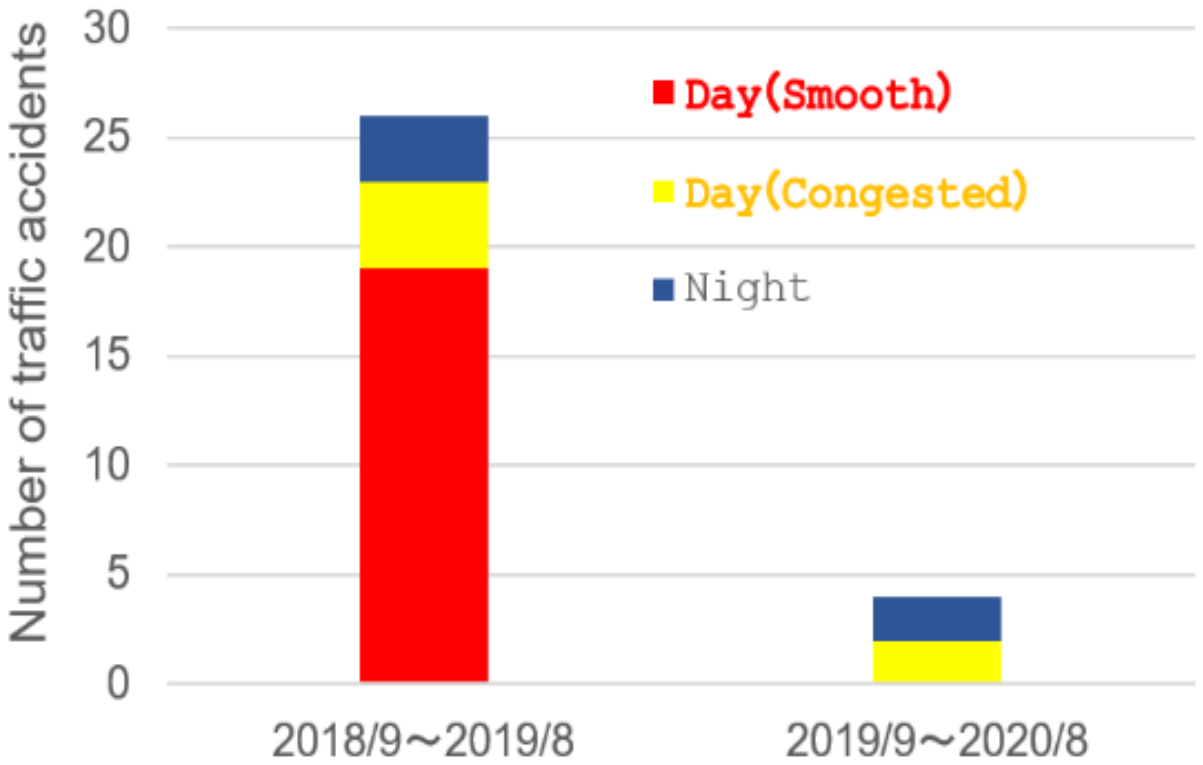
Speed change, with/without system (Vehicle type, All lane)

	Small Car			Large Car		
	Without	With	With/Without	Without	With	With/Without
Maximum value	65.1	62.9	-3.4%	50.4	52.4	4.0%
Average value μ	44.1	42.8	-3.1%	38	36.9	-2.8%
Standard deviation σ	4.7	5.1	8.8%	3.6	3.8	6.6%
$\mu + \sigma$	48.8	47.9	-1.9%	41.6	40.8	-1.9%
$\mu - \sigma$	39.4	37.6	-4.5%	34.4	33.1	-3.7%
Minimum value	27.8	28.2	1.4%	26.4	22.6	-14.4%
Sample	1,644	1,066		770	697	

Speed of μ+σ were reduced by -3.7% in left lane and -2.5 % in right lane.**
Rate of speed reduction is greater in left lane.
The closer to the speaker, the more effective.

NEXCO CENTRAL

Number of Traffic Accidents



Number of traffic accidents with and without voice warning

19 cases occurred before, but not after, when compered during the daytime non-jammed period. 17 occurred on wet surfaces and 2 on dry surfaces.

5, Summary

Summary

1, We have developed the system that broadcasts voice warning in an open space to give effective information directly to drivers in a traveling car cabin with windows closed.

2, This system is expected to provide information and reminders to all drivers, including those who are not aware of traffic safety.

3, Such a system, which is given by voice, is expected to be more effective in reducing accidents and secondary accidents, since the information can be given to drivers individually and directly.

4, With a highly directional, water-resistant speaker and the ability to determine the proper radiation angle and placement of sound, we were able to develop an audio warning system for open space.

5, Until autonomous vehicles and vehicle equipped with next- generation driving support systems become widespread, the newly developed system has made it possible to transmit voice warning to vehicles inside traveling in open spaces. Then, this system is an extremely effective safety measure in an open space.

Thank you for your attention

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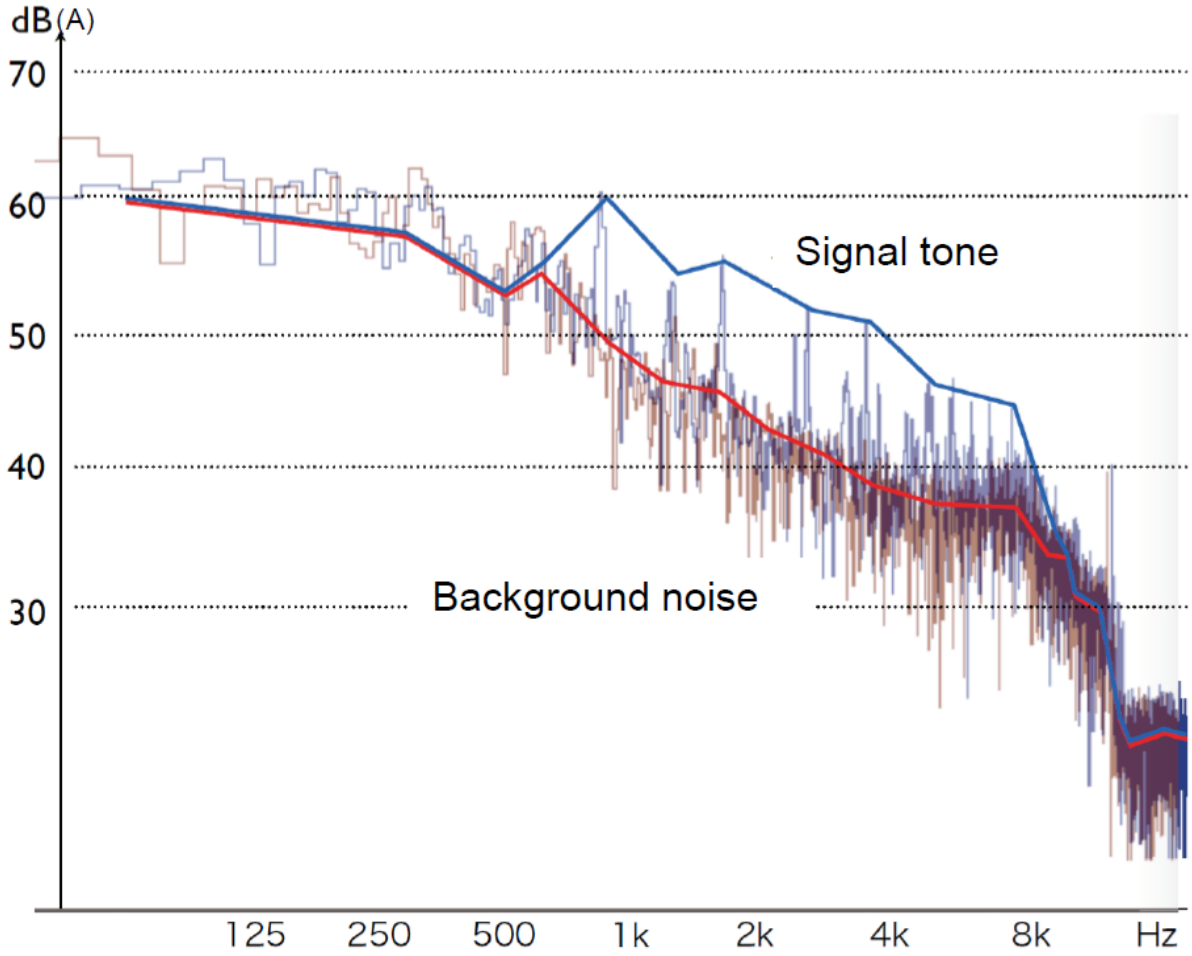
Optimal in-vehicle transmission frequency



Considering the background noise in a cabin and the sound transmission property of car window glass confirmed that the suitable voice frequency to propagate into a cabin is from 500 Hz to 4 kHz, as a result of measuring the sound pressure in a cabin with window closed running 100 km/h on an expressway, making a sound from flat speakers on the road shoulder. Kamekawa 2017