RESEARCH INTRODUCTION

Reducing noise annoyance

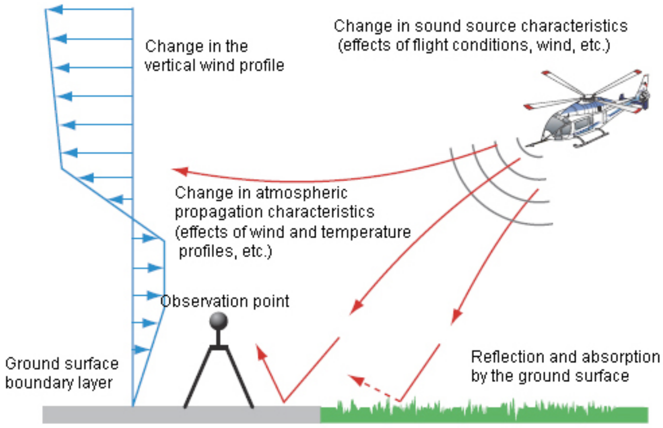
Aircraft noise is a global problem

Aircraft play active roles in various fields, including passenger transportation, physical distribution, and disaster relief and emergency medical services. Though aircraft make life very convenient, the noise impact in communities around airports has become a problem. The Japan Aerospace Exploration Agency (JAXA) is researching technologies to develop quiet airframes and engines, as well as "low-noise flight methods" to fly aircraft quietly.

First, we have to know how sound is emitted and propagated

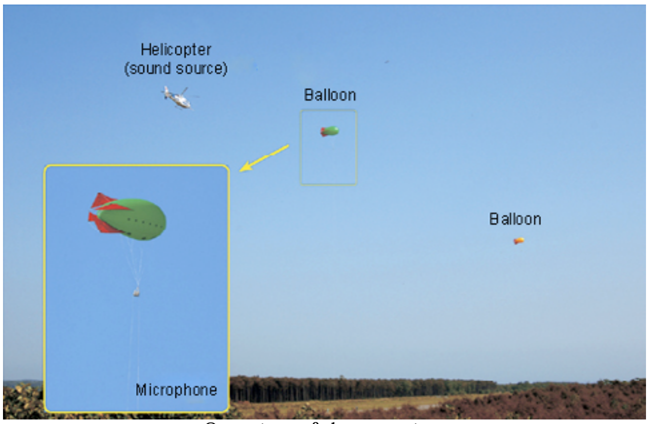
To realize the low-noise flight method, a technology for predicting ground noise with high accuracy is essential. This can be done by accurately modeling "sound source characteristics" to clarify what the noise generated from an aircraft sounds like, and "propagation characteristics" to clarify how the sound is transmitted through the air. These characteristics vary intricately with meteorological conditions, etc. (Fig. 1).

In 2005, our group conducted an experiment to accurately measure "sound source characteristics" using the experimental helicopter MuPAL-ε (See the article entitled "Sora to Sora" in Issue No. 07). The next year, in October, we carried out another experiment to measure "propagation characteristics" using microphones slung from two balloons soaring in the sky at altitudes of 50 m to 200 m (Fig. 2a). Fig. 2b shows the propagation effects of the two microphones for comparison. The red line plots the data obtained with almost no wind; the blue line, the data obtained with a ground wind of about 1 m/s. We see that with only a slight ground wind, the sound refraction produced by changes of the wind velocity in the vertical direction leads to wide variations in the propagation characteristics. The propagation characteristics with no wind agree well with the predicted values. The next challenge will be to develop a model capable of predicting the effects of a wind.

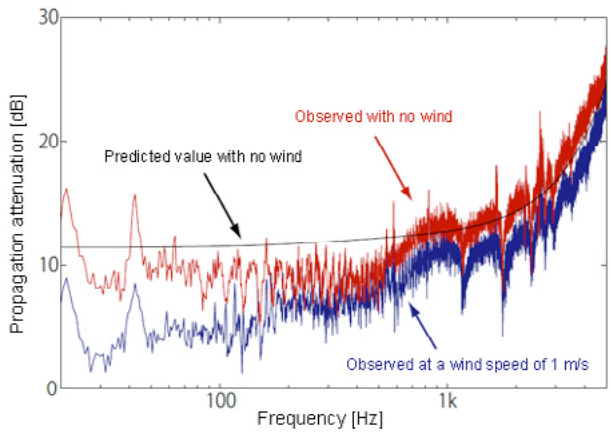


Sound is attenuated and refracted as it travels through the air. These attenuation and refraction effects amplify as the changes in the vertical profiles of wind velocity and temperature increase.

Fig.1 Factors affecting the ground noise emitted by an aircraft



a: Overview of the experiment



b: The effects of propagation(the difference of noise levels between two microphones slung from balloons)

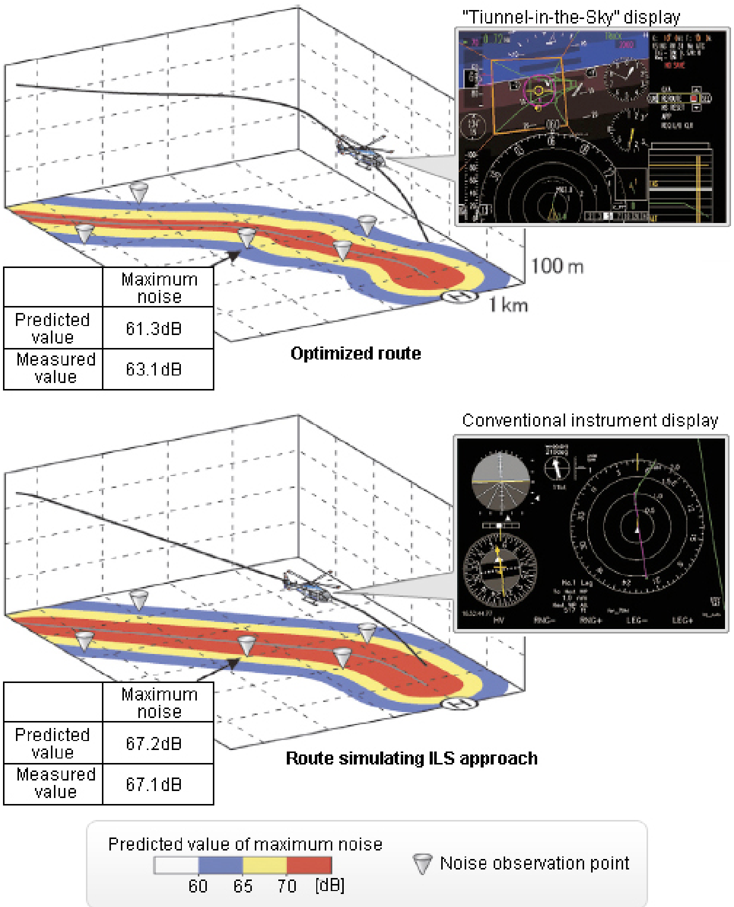
Fig.2 Balloon experiment to study how sound is propagated through the air (Propagation characteristics)

Reducing noise during helicopter flight

Our group is researching a flight method to reduce the ground noise generated by helicopters. The noise emitted from a helicopter varies greatly with the flight conditions. As one strategy for noise control, we have developed an onboard system to minimize the ground noise by optimizing the flight route and flight conditions in real time. Flight tests to demonstrate the feasibility of this system were carried out in July of this year in Taiki-cho, Hokkaido. Fig. 3 shows predicted noise footprints for the flight routes. Fig. 3a shows the optimized route; Fig. 3b, a route simulating a conventional approach using an instrument landing system (ILS). In the optimum route, the range in which ground noise exceeds 70 dB (a level that feels "noisy") is reduced.

An optimized route reduces noise via two strategies: (1) control of flight conditions, such as the angle of descent, to hold down the generation of blade-vortex interaction noise (the annoying slapping noise specific to helicopters); (2) flight along a curved route planned out in consideration of noise propagation changes with wind, etc., to keep noise from concentrating in a particular place. Conventional instruments (e.g. ILS pointers) are incapable of conveying accurate instructions on optimum curved routes for pilots. This can only be done using the "Tunnel-in-the-Sky" display now being developed by JAXA.

In the future we will research practical application by improving the installability of the devices required for this system and demonstrating the noise reduction effect in urban airports and heliports.



Optimized route:

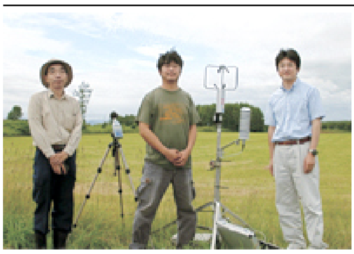
	Maximum noise
Predicted value	61.3dB
Measured value	63.1dB

Route simulating ILS approach:

	Maximum noise
Predicted value	67.2dB
Measured value	67.1dB

Five observation points were set on the ground in this experiment. The noise generated by a helicopter flying an optimum route was reduced by about 4 dB at the observation points shown in the figure, compared with the noise generated by the same helicopter flying a route using a simulated ILS. The error between the predicted and measured noise was within 2 dB.

Fig.3 Flight demonstration in the demonstration experiment on the optimum route for reduced ground noise



[Flight Systems Technology Center]

(from the left) Hiromi Gomi, Hirokazu Ishii, Yoshinori Okuno
At the noise observation point in Taiki-cho, Hokkaido

RESEARCH INTRODUCTION

Predicting the shake of artificial satellites induced by booming roars

Artificial satellites vibrate

An artificial satellite is launched into outer space by a rocket (Fig. 1). The vibration of the rocket during a launch is transmitted to the satellite as "mechanical vibration" through the interface between rocket and satellite. Another phenomenon, so-called "acoustic vibration," also occurs during a launch. Booming roars running through the air reach the satellite and shake it still more.

Acoustic vibration is one of the main causes for the initial failure of a satellite. If we accurately understand how the booming roars penetrate through the rocket fairing and shake a satellite, we can increase the reliability of a satellite launch.

Detailed analyses of how sound shake objects

To keep balance between reduced weight and high rigidity, the fairing wall is designed with a "honeycomb structure" of hollow hexagons. Sound is considered to penetrate a conventional wall structure differently than it does a honeycomb structure. Figure 2 compares numerical analyses of sound penetration for a conventional wall and a hollow wall with a simply modeled honeycomb structure. From this figure, sound penetrates the hollow wall more intricately than it does the conventional wall.

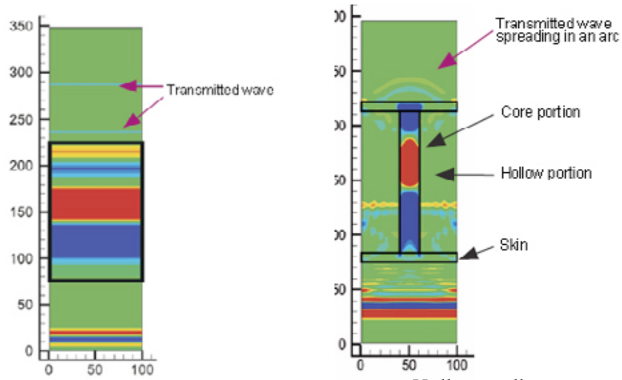
Sounds with various frequencies penetrate through the fairing wall and propagate through a space within the fairing. Every structure has their own natural frequencies, and the high frequencies transmitted into the satellite have the strongest impact on the structures loaded on the satellite. Satellite vibration induced by low-frequency sounds can be analyzed by conventional techniques such as FEM as shown in Fig. 3. It is difficult, however,

Fig. 1 Launch of the H-IIA rocket An artificial satellite loaded at the leading end of a rocket is launched into outer space. The satellite is covered with a fairing to avoid the effects of aerodynamic heating, etc. during flight in the atmosphere.

to analyze propagation and vibration for high-frequency sounds at present. In order to overcome this problem, we are developing a numerical tool applying a new theory capable of predicting high-frequency sound vibrations. Figure 4 shows the results of acoustic field inside of a fairing obtained by the new tool. We can see the difference of acoustic field generated by the low- and high-frequency sounds from the figure.

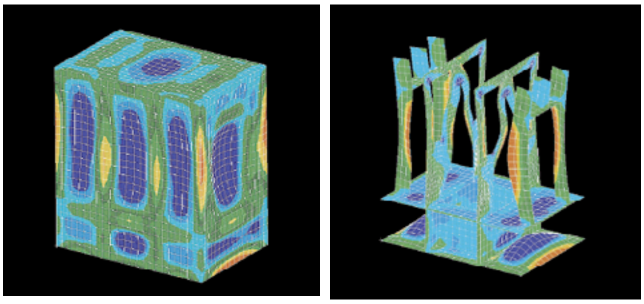
Simulation of acoustic environment during a launch

In order to make good use of analytical results for future satellite development, we need to analyze sounds numerically by a coupling method consisting of the following four elements: (1) sound generation due to launch, (2) sound propagation to the fairing, (3) sound penetration into the fairing, and (4) vibro-acoustics of satellite. These analyses are now being conducted independently because each step requires its own analytical technique. In the future these analyses will be integrated in one chain of procedure.



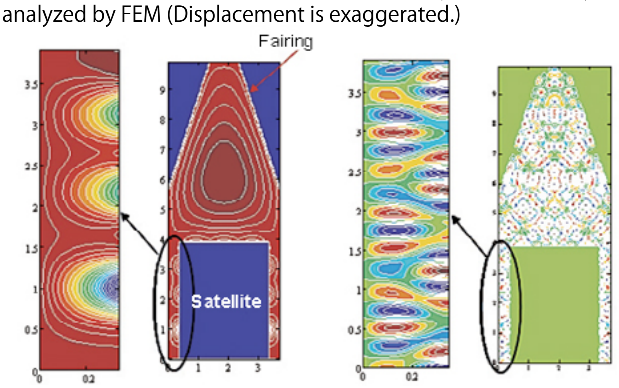
Conventional wall　　Hollow wall

Fig. 2 How sounds penetrate through a conventional wall and through a hollow wall



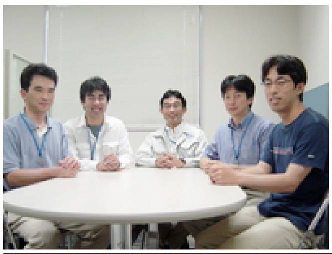
Vibration of skin panel　　Vibration of satellite's interior portionincluding stiffener

Fig. 3 Vibration of satellite structure induced by low-frequency sound analyzed by FEM (Displacement is exaggerated.)



In the case of low-frequency sounds　　In the case of high- frequency sounds

Fig. 4 Acoustic field inside of fairing analyzed by the new analytical technique



[Computational Science Research Group]

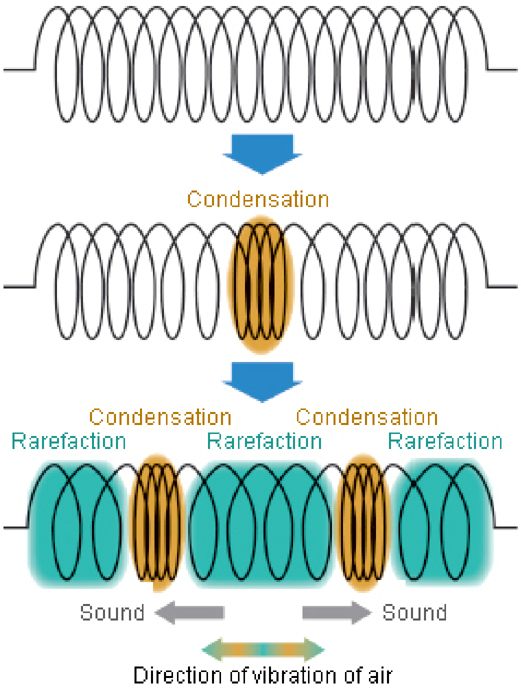
(from the left) Yoshinobu Inada, Atsushi Hashimoto, Takashi Aoyama, Keiichi Murakami, Takashi Takahashi

Sound — Its properties

Sound is the vibration of air. Vibration occurs when the pressure of a portion of air changes relative to the reference pressure (atmospheric pressure). Describing the concept of "sound" in this way may make it kind of difficult to understand. But making sounds is easy. We vibrate air and emit sound whenever we speak language, for example, or clap our hands. When air pressure changes, two portions are created, a thin air portion (rarefaction) and a dense air portion (condensation). The movement of air as it reverts from this rarefaction-condensation condition to its original condition generates vibration, which itself runs through the air (Fig. 1).

Sound runs not only through air, but also various other substances. The speed at which sound runs through a substance varies with the modulus of elasticity (hardness) and density (weight) of the substance. The harder and lighter a substance is, the faster sound runs through it. In air near the ground, sound runs through at about 340 m/s. In the water, sound runs through at about 1,480 m/s. In solid objects, sound travels much faster. In the case of iron, for example, it travels at a speed as high as 5,290 m/s (Table 1). The speed of sound also varies with the temperature: usually it's faster at higher temperatures. At an altitude of 10,000 m (near the cruising altitude for large passenger aircraft), where the air is cooler and less dense than the air on the ground, sound travels at about 300 m/s.

The properties of sound depend on the "loudness" and "musical interval." The loudness of a sound, expressed in "dB" (decibel) *, refers to the magnitude of a pressure change relative to the atmospheric pressure (Table 2). The musical interval depends on the number of vibrations of a substance per second. The number of vibrations per second is referred to as the "frequency" [unit: Hz (hertz)]. A sound with a higher frequency has a higher pitch; a sound with lower frequency, a lower pitch. Humans can hear sounds in a wide frequency range of 20 to 20,000 Hz. But at the very high and very low frequencies within this range, the sensitivity of our ears declines. Even when we hear sounds of the same loudness within these ranges, our perception of the loudness will vary as the frequency changes. This is why we need to make corrections to account for the sensitivity of human ears when measuring noise.



Sound (sound wave) is a longitudinal wave in which the direction of vibration is the same as the direction of vibration transmission. Sound is composed of both a "rarefaction" portion and a "condensation" portion. It can therefore also be described as a "wave of condensation and rarefaction."

Fig.1 Image of sound

Table1 Speed of sound transmission

	speed of sound (m/s)
Air	340
Helium	970
Water	1480
Mercury	1380
Ice	3940
Iron	5290
Glass	4000 ～ 5500
Wood	3500 ～ 4500

*The speed of sound varies with the temperature, etc.

Table2 Loudness of sound

	Minimum audible sound (dB)
Minimum audible sound	0
Whisper (1m)	20
Conversation (1m)	60
Crowded streets	80
Inside a subway car	90
Jet engine (50m)	120

*dB : A value determined by multiplying the magnitude of a pressure, expressed as a number of digits relative to the minimum sound pressure humans can hear, by a factor of 20