APPLICATION NOTE HHAN-022

VIBRATION OF BALANCED ARMATURE RECEIVERS

Understanding the vibration of receivers is critical to controlling feedback in hearing aids. There are tradeoffs between vibration levels and the size and performance of the receivers. Single receivers are widely used for low to medium gain applications where vibration is not an issue, while dual receivers offer the best performance and vibration control for high gain applications. This application note provides a guide to choosing the optimum receiver for different applications.

SIGNIFICANCE & APPLICATION

The primary purpose of the receiver in a hearing aid is to deliver sound to the ear, but some energy leakage is inevitable. Energy leaked from the receiver can vibrate the housing and reach the microphone, leading to feedback-induced instability. Ideally, internal feedback could be eliminated by cutting all vibroacoustic transmission lines, a daunting task after considering all possible paths and hearing aid design constraints. Ultimately, understanding and considering all factors which determine the magnitude of vibration at the receiver level can be a little less daunting.

At the receiver level, receiver configuration, reed type, and vibration isolation are the most common factors which determine the source of magnitude vibration in a hearing aid design. Prior to discussing the effects of these receiver features, a description of basic receiver anatomy as well as the manner in which vibration measurements are executed provides a better context for those who are unfamiliar with receiver vibration.

VIBRATION MEASUREMENTS

Vibration is measured in three directions, Cover-Up (CU), Side-Up (SU), and Tube-Down (TD). This is carried out in order to provide customers information with which to execute design optimization. A cross-section of a single receiver with labelled components and axes with respect to the reed is shown in Figure 1.

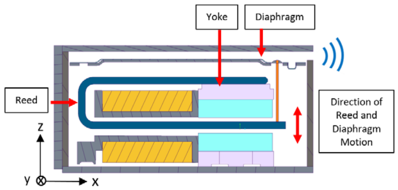

Figure 1: Basic anatomy of a Single U-reed receiver depicting the CU direction in the z-axis, the SU direction in the y-axis, and the TD direction in the x-axis.

The CU, SU, and TD nomenclature was established for standard port placement, but port location can be customized. When modified, the local x, y, and z coordinate system aligned with the reed's orientation is used to maintain consistency, as is shown in Figure 2.

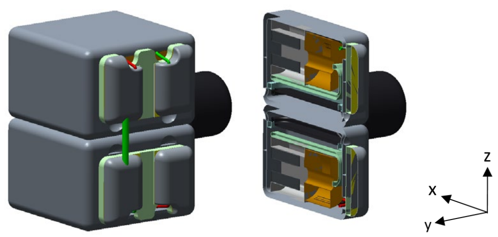

Figure 2: RDH and cross-section, demonstrating use of local x, y, and z axes in place of CU, SU, and TD nomenclature when tube location is shifted

Figure 3 provides additional context for standard axial vibration measurements. Rotational vibration measurements are not routinely carried out as this involves a much more complex setup, but may also play an important role in vibration.

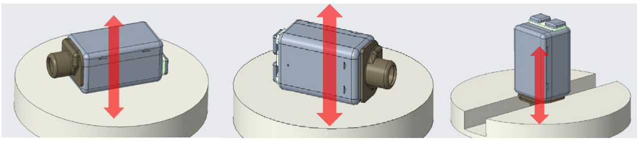

Figure 3: CU (local z), SU (local y), and TD (local x) axes for vibration measurements.

In order to measure the vibration of the receiver within the frequency range of interest, receivers are adhered to a stationary load cell with the measurement axis of interest normal to the plate. A frequency sweep of the desired range is provided as an input to the receiver and the axial force generated by the receiver as a result of the sweep is measured.

Results are presented as force data from the load cell compared to the acoustic output. This provides context for how much vibration will occur when a certain amount of sound is generated and is referred to as the normalized vibration [dB re 1 N/Pa].

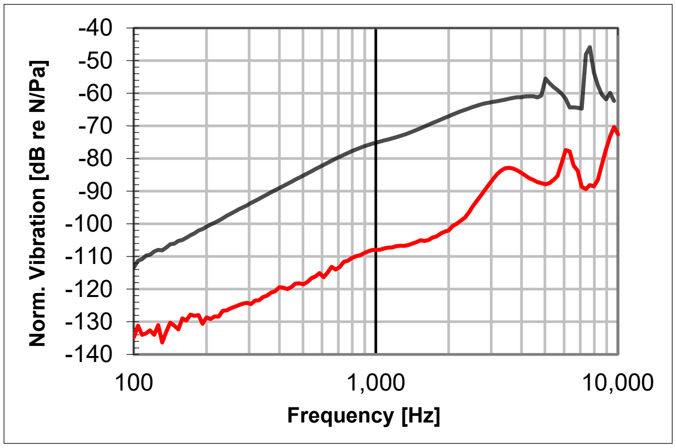

Figure 4: Normalized CU vibration for single (black) vs dual (red) U reed receivers

Figure 4 shows normalized CU vibration data for a dual U reed receiver (red) versus a single U reed receiver (black). These normalized vibration curves rise roughly proportional to the square of the drive frequency for enclosed acoustic loads and are relatively flat for free-field measurements, illustrating the most common possibility of induced feedback at high frequencies. The respective magnitudes of the dual receiver and single receiver illustrate typical behaviors of duals and singles, where the dual generates less vibration than the single. This can be attributed to the vibration forces of the two receivers making up the dual, which are in opposition to one another. The 1 kHz vibration response values for these two curves are used later on in Table 1 to illustrate broad behavioral trends.

RECEIVER CONFIGURATIONS

There are three configurations discussed here that have useful impacts on size and vibration. These are the single receiver, the dual receiver, and the dual-diaphragm receiver.

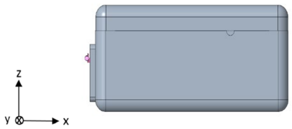

Figure 5: Single receiver

The single receiver shown in Figure 5 will have an anatomy that looks similar to that shown in Figure 1. For single receivers, the CU direction produces the most vibration, since this is the primary direction in which the reed is intended to vibrate in order to produce sound. The TD direction has an intermediate vibration level and is most dependent on reed type, and the SU direction has the lowest vibration level.

Dual receivers like that shown in Figure 6 pair two single receivers, where components mirror one another about the x-axis. Consequently, the dual receiver is roughly twice the volume of a single receiver.

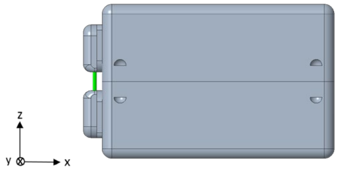

Figure 6: Dual receiver

When compared to the output of a single receiver, this configuration lends itself to a doubling of receiver output pressure and a cancellation of vibration in the CU direction. For dual U reed receivers, vibration adds rather than cancels in the TD direction. However, due to the doubling of output pressure, change in the normalized vibration magnitude is roughly the same as that of a single receiver. The normalized magnitude in the TD direction vibration is negligible for other reed types, as later described. The SU direction is largely unaffected by the addition of the second receiver.

Dual-diaphragm receivers are configured similarly to duals, utilizing a second diaphragm in order to double the output. Figure 7 shows the single receiver portion in dark grey, with the second diaphragm housed in the light grey volume above. These receivers differ from duals in that the second diaphragm is driven by the same motor as the first. Due to this shared motor the two diaphragms move in phase with one another and double receiver output pressure without occupying the full volume of an equivalent dual.

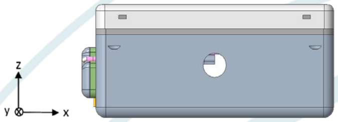

Figure 7: Dual-diaphragm receiver

When comparing the magnitude of vibration for a dual-diaphragm to that of a single, the normalized vibrational response of the dual-diaphragm will be approximately 6 dB less in the CU direction. This is due to the higher acoustic output of the dual-diaphragm relative to the single.

While usage of a single receiver is most cost effective, it may lead to issues with stability. The maximum stable gain before feedback instability onset ocurrs functions as a limit to the usable gain and provides a loose guide for receiver configuration selection given a desired output gain. A single receiver is well-suited to applications with an output gain less than 40dB, or 60dB with suspension design. A dual receiver is typically recommended for greater output gain. When space is at a premium but lower vibration than a single provides is needed, consider using a dual-diaphragm receiver.

Receiver Configuration	Reed	Cover-Up	Side-Up	Tube-Down
Dual	E	-107	-116	-102
	M	-108	-120	-106
	U	-110	-117	-85
Dual-Diaphragm	E	-79	-112	-90
	U	-78	-121	-87
Single	E	-71	-89	-92
	U	-72	-97	-79

Table 1: Heat map of normalized receiver vibration [dB re N/Pa] at 1kHz

Table 1 shows typical vibration levels for all combinations of receiver configuration, reed type, and vibration axis. Lower values correspond with lower magnitudes of vibration and are shown in green, while intermediate magnitudes are shown in yellow, and higher magnitudes are shown in orange.

When vibration is considered a principal design criterion, receiver selection should begin with the initial evaluation of desired gain in order to find the appropriate receiver configuration. After the receiver configuration is determined, consideration for reed type will aid in the receiver selection process.

REEDS

The vibration force of a receiver mainly comes from the armature, often referred to as the reed. There are three commonly used reed shapes, referred to as the U, the E, and the M shapes. Small variations within each reed type exist, but reed shapes are not switchable between receiver series. A list of receiver series and their respective reed shapes is available in the appendix.

While the vibration force in the primary direction of motion (CU) is similar for all reed types, the vibration along the long axis of the reed types (TD) is quite different.

The reed shown in Figure 8 is a long U shaped reed, where one side of the U is anchored to a stationary yoke and the other end moves driven by the magnetic field of the input signal. This motion drives the diaphragm, creating acoustic pressure. A single U reed receiver generates more vibration along the TD direction as compared to other reeds, due to flexure of the U-reed bend.

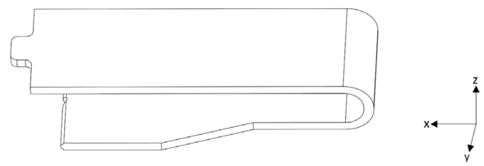

Figure 8: U reed design

The E Reed in Figure 9 was designed for a receiver with a flat and wide housing shape. The center tine of the reed is connected to a vertical back wall which is bent to form two members that fasten to the sides of the yoke. The low profile shape and low TD direction vibration make this an excellent candidate for use in dual receivers.

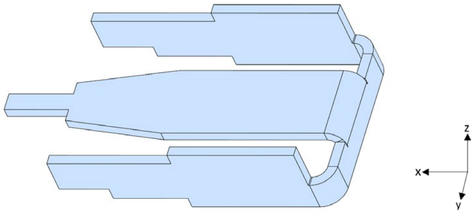

Figure 9: E reed design

The M reed functions similarly to the E reed design. The center tine is connected to the outer tines with a structure designed to be especially rigid in the TD direction, as shown in Figure 10. Due to this design, vibrations along the TD direction of the M reed are well-controlled and often too small to measure.

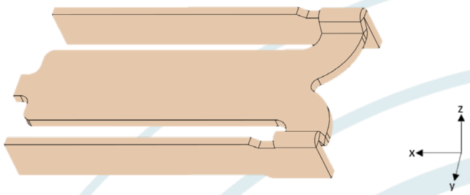

Figure 10: M reed design

The combination of reed type and receiver configuration will allow for appropriate receiver selection, but additional considerations for vibration isolation will optimize a receiver for use within a design.

VIBRATION ISOLATION

Features of modules, suspensions, cabling materials, and microphone directionality can all affect the potential gain before feedback occurs.

Rubber suspensions and modules act as spring-damper systems in order to attenuate vibration and prevent transmission to the hearing aid shell and microphone. This is a common feature in all high gain designs and is particularly important for achieving high gain with a single receiver.

When designs include cabling, as is common in Receiver-in-Canal (RIC) devices, the cabling may function as another possible path for vibration transmission. Here, softer mounts will provide weaker coupling for all frequencies above resonance, which is illustrated in Figure 11. The addition of damping will attenuate vibration at the resonance frequency.

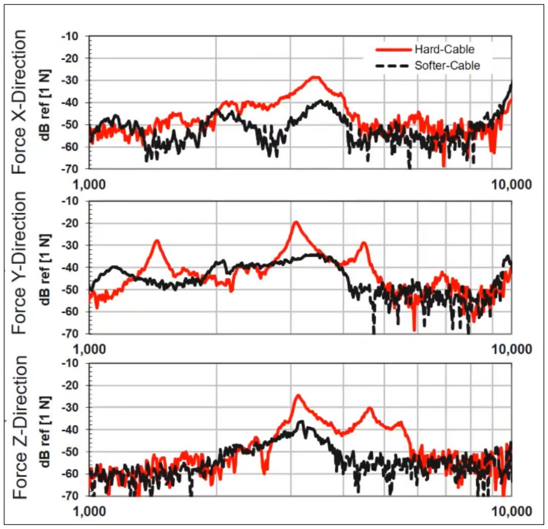

Figure 11: Vibration of a receiver with hard cabling (red) versus vibration of the same receiver with soft cabling (black).

Control of vibration can be further improved by adjusting the orientation of the receiver with respect to the microphone. Vibration of a receiver couples with the housing, which in turn couples with the microphone. Changing the orientation of the receiver may alter how the hearing aid housing is excited, reducing the sound presented to the microphone.

MEMS microphones are most sensitive orthogonal to the port direction, while the balanced armature vibration varies as shown in Table 1. Understanding a given receiver's vibrational profile will allow a designer to orient the two appropriately within the enclosure in order to minimize force transmitted from the receiver to the microphone.

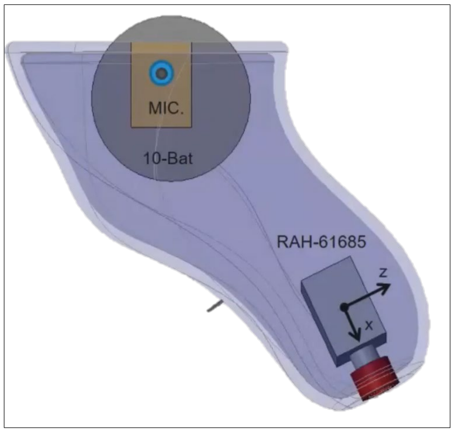

Figure 12: Microphone and receiver placement in an In-The-Ear (ITE) device.

As shown in Figure 12, microphone and receiver positioning is not always flexible. When the two cannot be oriented in an enclosure in such a manner which minimizes transmission, Knowles allows for customization of both the MEMS microphones and the receivers to reorient spouts and meet customer needs.

Vibration isolation is most imperative for high gain hearing aids, and is necessary for stabilizing the system when operating near the upper limit of the usable gain. All of these mechanisms are secondary to appropriate receiver selection, however. Dual receivers are very effective in reducing vibration, with dual M-reed receivers providing the lowest vibration. Dual-diaphragm receivers can prove useful when there is not enough room for a dual receiver. Single receivers offer a space and size advantage when vibration does not limit the system performance. Altogether, proper consideration for the featured vibration factors will yield optimum vibration performance and promote a stable and feedback-free system.

REVISION HISTORY

Revision	Description	Date
A	Active	2/2/2022

APPENDIX

Receiver Configuration	Dual			Dual-Diapragm		Single	
Reed	E	M	U	E	U	E	U
Series	DTEC EJ HODTEC HODVTEC RDI	GD GR	DBK DFK RDB RDD RDH RDJ SRDD SWFK	RLI	RLQ	ED EF FEF HOTEC RAI TEC	BK EH FC FEH FFC FFH FFK FH FK HC PHF RAB RAD RAF RAH RAJ RAN RAQ RAU WBFK WBHC

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Model/Reference Number:
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