Acoustic Transfer Function of the Anjok: A Bridge of the Korean Traditional String Instruments

PACS: 43.75.-z

Hyun-Woo Koh; Jung Uk Noh; Sangha Park; Koeng-mo Sung
Institute of New Media and Communications, School of Electrical Engineering, Seoul National Univ. Shillim-dong, Kwanak-gu, Seoul, South Korea; kenshin@acoustics.snu.ac.kr; junoh37@acoustics.snu.ac.kr; bosetom@acoustics.snu.ac.kr; kmsung@acoustics.snu.ac.kr

ABSTRACT
The Anjok is a common name of the bridges of several Korean traditional string instruments, such as the Gayageum, the Geomungo and the Ajaeng. It, like the bridges of the violin family, plays a role in boundary of string and supports tension of string. Also, as compared with the bridges of the violin family, the Anjok has some unique characteristics. In the case of the violin family, a bridge supports all strings and is located on fixed place. However, one Anjok supports only one string. And it can be moved along the string in order to tune the string. We once studied on the acoustic characteristics of the Gayageum Anjok in the year 2006. We have measured some impulse responses of the Anjok on two kinds of boundary conditions, one was a rigid boundary (stone plate) and the other was Gayageum body. In this paper, we measured some impulse response transfer functions of the Gayageum Anjoks again with our new and more precise measurement equipments (B&K PULSE with B&K Force transducer and Accelerometer), and could acquire more significant results.

INTRODUCTION
The Anjok is a common name of the bridges of some Korean traditional string instruments, such as Gayageum, Geomungo, and Ajaeng. Like the bridges of the other string instruments, the Anjok plays a role in both a boundary and a support that supports tension of a string. Also, it transfers the vibration from a string to the body [1]. The name, Anjok, is a Chinese word that means a foot of a wild goose, because the shape of the bridge is similar to that. (Figure 1)

As compared with the bridges of the violin family as well as guitar family, the Anjok has some unique characteristics. In the case of the violin family, a bridge supports all strings and is located on fixed place. However, one Anjok supports only one string. And it can be moved along the string on the body in order to tune the string. (Figure 2)
With its tall but well-stabilized shape (Figure 1), the mobility of the Anjok makes it easy not only to tune the string immediately but also to play the Nong-hyun technique dynamically (which is similar to vibrato technique). With his (or her) left hand, a player can make various types of movements such as pressing, shaking, bending and vibrating the strings. The Nong-hyun technique of the Gayageum has very slow rate (0.3~0.4 seconds in period) and wide pitch variation (80~130 cents).

Generally, a string instrument can be regarded as the combination of string, bridge and body. The timber of a string instrument is determined by the acoustical characteristics of these parts and of the auditory space which the instrument is played. The bridge (the Anjok) plays a role in delivering vibration from a string, which is excited by a player, to the body, which radiates sound to the auditory space, with its unique transfer characteristics [2], [3].

In this paper, we studied on the acoustic characteristics of the Anjok by measuring impulse responses of several Anjok samples.

**MEASUREMENT**

When a Gayageum is played by a player and radiates its sound, there are some boundary conditions that would interact with Anjok, such as player, string or body. To obtain acoustic characteristics of the Anjok only, we need to exclude these boundary conditions as much as possible. In order to eliminate the coupling effects between the Anjok and body and to regularize boundary conditions on measurement, we replaced Gayageum body to rigid boundary; in this paper, we used a flat marble stone [4]. (Figure 3) And we muted all strings on the Gayageum body with some pieces of felt cloth.
We mounted a small accelerometer on one foot of Anjok (the position of F out, see Figure 1(b) and Figure 3) and hit on the head of an Anjok with a small force-transducer in the two directions, one is on the accelerometer’s side and the other is on the opposite side (the position of F in, see Figure 1(b) and Figure 3). All measurement signals from both an accelerometer and a force-transducer are acquired through B&K PULSE front-end and calculated to obtain frequency response functions (FRF). Table I shows the measurement equipments we used.

<table>
<thead>
<tr>
<th>Measurement Equipments</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>B&amp;K PULSE System Type 3560C</td>
<td>I/O Front-end</td>
</tr>
<tr>
<td>B&amp;K Force-Transducer Type 8203</td>
<td>Force Transducer</td>
</tr>
<tr>
<td>B&amp;K Accelerometer Type 4517</td>
<td>Accelerometer</td>
</tr>
<tr>
<td>B&amp;K Conditioning Amplifier Type 2626</td>
<td>Conditioning Amplifier</td>
</tr>
</tbody>
</table>

We measured five mid-grade Anjok samples, two of them are made of cherry tree, the other two are made of pear tree, and another is made of walnut tree.

**TRANSFER FUNCTIONS OF THE ANJOK**

We measured transfer functions (or frequency response functions) of five Anjok samples using impulse response method. For each Anjok sample, we measured on two measurement positions, one is on the accelerometer’s side and the other is on the opposite side (the position of F in, see Figure 1(b) and Figure 3).

Figure 4 show how we obtained the transfer functions of the Anjok samples. As we hit the head of Anjok sample with force-transducer, we got the frequency responses of each signal from both force-transducer (F in, [N]) and accelerometer (F out, [m/s²]). (Figure 4(a) and (b)) Then we could finally obtain the transfer function of the Anjok sample by compensating the frequency response of accelerometer signal with that of force-transducer signal. (Figure 4(c))

![Figure 4](image)

**Figure 4.** Frequency responses of the force-transducer (input) signal [N] (a), the accelerometer (output) signal [m/s²] (b), and a compensated frequency response function of the output signal with input signal [dB] (c)

Compared these results to that of our former study [4], in the year 2006, we could obtain improved measurement data that bears wider data in frequency range, over 3 kHz and up to 5 kHz, while we could obtain only up to 1 kHz in former study. And frequency responses at low-frequency range, which are about from 70 Hz to 200 Hz, are more accurate than that of former’s Figure 5 ~ 9 shows the frequency response functions of five Anjok samples.
Figure 5.- Frequency response functions of the cherry tree Anjok 01 on the accelerometer’s side (a) and the opposite side (b)

Figure 6.- Frequency response functions of the cherry tree Anjok 02 on the accelerometer’s side (a) and the opposite side (b)

Figure 7.- Frequency response functions of the pear tree Anjok 01 on the accelerometer’s side (a) and the opposite side (b)

Figure 8.- Frequency response functions of the pear tree Anjok 02 on the accelerometer’s side (a) and the opposite side (b)
From the results shown above, we could reconfirm that the frequency responses tend to increase as frequency increase up to 1 kHz on rigid boundary, as we reported in former study [4]. Above 1 kHz, each Anjok sample has unique characteristics in frequency response. However, we could find common features that two main peaks appear around 1.5 kHz and 4 kHz. These peaks seem to be main resonances due to structure of the Anjok. For the samples made of the same material, the frequency response functions in low frequency range look alike, but not identical. (Figure 5 and 6, 7 and 8) These differences would be due to the differences in texture of wood, in other words, the inhomogeneity of wood. For the input (hitting) sides of the Anjok’s head, the frequency responses change not only in magnitude level but also in response characteristics.

CONCLUSIONS
In this paper, we studied on the acoustic transfer function of the Anjok by measuring frequency response function with impulse response method. In succession our former research on the Anjok, we measured the Gayageum Anjok samples again with our new and more precise measurement equipments, and could acquire much improved results than that of former's. This work is only the beginning of the research on the Anjok. We will measure more samples of the Anjok as much as possible. Also, study on the factors that would be related to the frequency response characteristics of the Anjok, such as geometric structure or mechanical properties of the wood, will be continued.

ACKNOWLEDGMENTS
This work was supported by The National Center for Korean Traditional Performing Arts (NCKTPA).