Holographic Measurement of Sound Radiation Behaviour of Personal Device

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Introduction

In the recent years, the personal devices like smart phones and tablets have been a part of our life. And users are always expecting better sound experience. As is known to all, stereo sound is better than mono sound. Smart phones and tablets that are equipped with 2 or more micro speakers are getting popular. So, the sound radiation behaviour, or directivity, should be seriously considered and measured. However, the widely used far field measurement based on inverse proportional law or 1/r law is not appropriate for the near field performance of those personal devices. In this paper, a practical method based on acoustic holography is introduced for the measurement of the sound radiation behaviour.

Acoustic Holography

Before data analysis, hundreds of points around the DUT (Device Under Test) should be measured with a microphone. In this paper, Klippel Near Field Scanner [1] with a moving microphone is used, as shown in Figure 1.

Figure 1: Klippel Near Field Scanner

The core idea of acoustic holography is to use a modelled sound field to approximate the measured sound field.

The transfer function between sound pressure and input voltage [2] can be expressed in equation (1):

$$H(r,\theta,\varphi,\omega) = \sum_{n=0}^{N}\sum_{m=-n}^{n} C_{mn}(\omega) h_n(kr) Y_n^m(\theta,\varphi) \quad (1)$$

In equation (1), the Hankel function $h_n(kr)$ tells the information of the distance and the spherical harmonics $Y_n^m(\theta,\varphi)$ tells the relationship of 2 angle directions. $C_{mn}(\omega)$ is the weighting coefficient for the spherical harmonics of different orders [3], as shown in Figure 2.

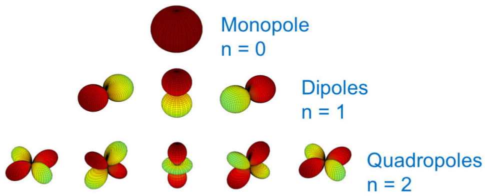

Figure 2: Spherical harmonics

For example, in Figure 3, the target sound field is shown on the left. Monopole (order n=0) is used at first to compare with the target and there are a lot of mismatches.

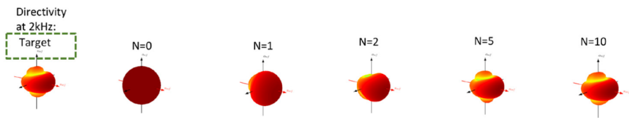

Figure 3: Sound field determination

To minimize the difference between measured sound field and modelled sound field, which is shown in equation (2):

$$e = H_{measured} - H_{model} \quad (2)$$

The problem in measuring a smart phone or other wireless devices is the connection with the computer. Smart phones do not get analog input. Transmission with Wi-Fi or Bluetooth has a variable delay, which can ruin the measurement.

Measurement Process

In this paper, a synchronization method is introduced so that the smart phone can play the test signal itself. As shown in Figure 4, the test signal is played as a loop. In Fast Fourier Transform (FFT) only a period is needed.

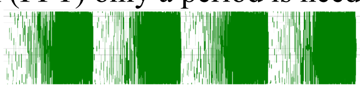

Figure 4: Test signal

As shown in Figure 5, 2 microphones are used. The first microphone scans around the smart phone. The second microphone is fastened closed to the micro-speaker.

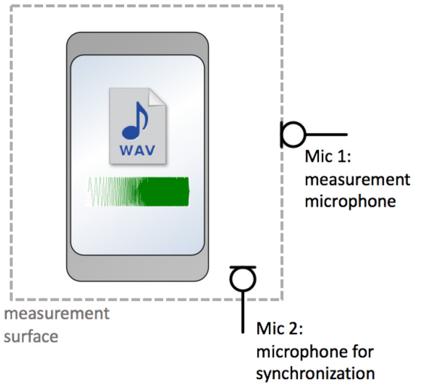

Figure 5: Synchronization Measurement

The second microphone, which is the synchronization microphone, is used to remove the delay from the measurement microphone, as shown in Figure 6.

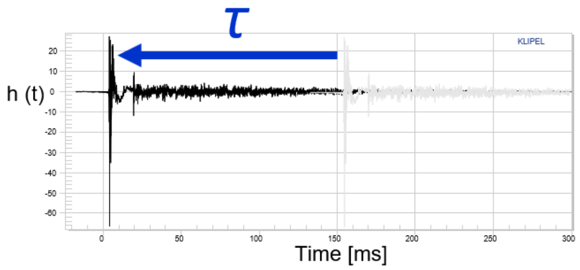

Figure 6: Synchronization

Measurement Result

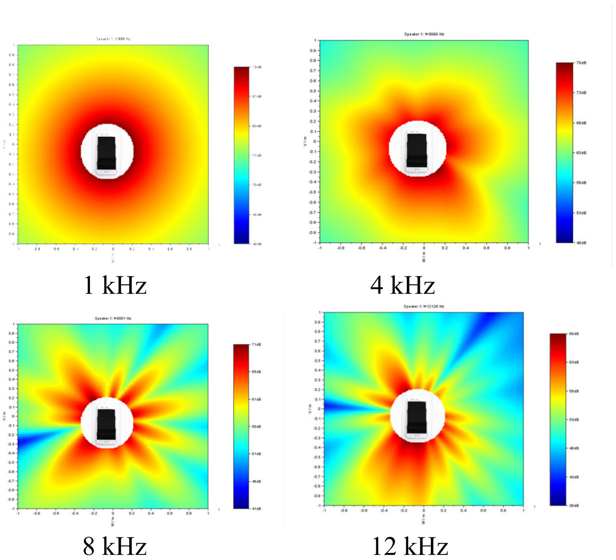

Figure 7: Sound pressure distribution

In Figure 7, the sound pressure distributions at different frequencies are displayed. This smart phone has only one micro-speaker at the bottom. At 1 kHz, the smart phone is almost omnidirectional. But when the frequency increases, the smart phone becomes quite directional.

As shown in Figure 8, the sound power at 1 kHz decreases until 15 cm. Since 15 cm, the sound power is constant. So 15 cm is the boundary of the near field and far field at 1 kHz.

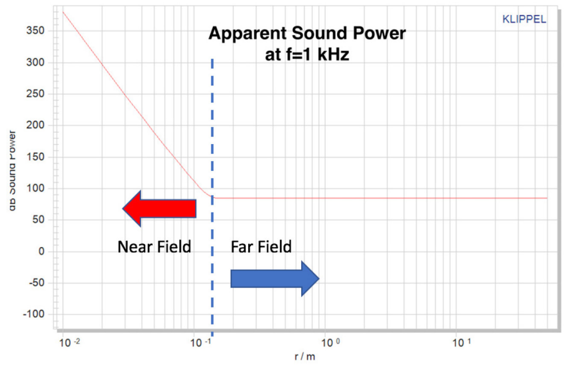

Figure 8: Near field vs. far field.

Additionally, the micro-speaker can be measured individually. As shown in Figure 9, the micro-speaker is mounted on a large plate to simulate a baffle measurement.

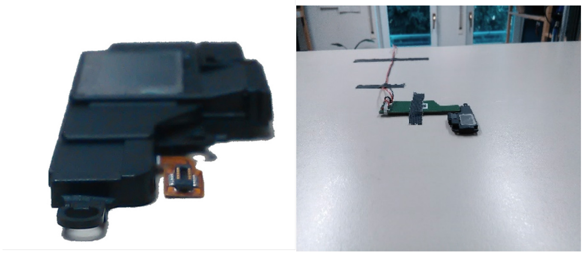

Figure 9: Measurement of micro-speaker

As shown in Figure 10, the micro-speaker becomes more directional when frequency increases.

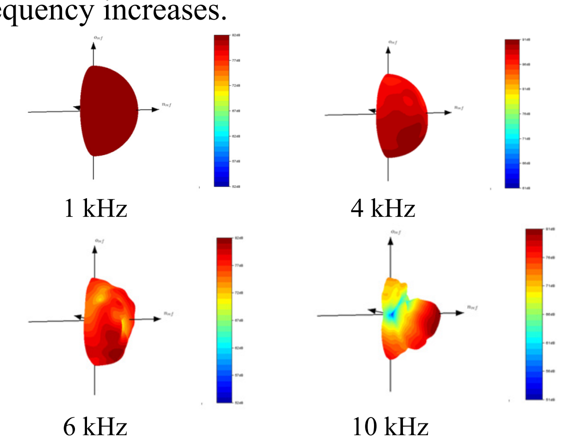

Figure 10: Sound field of micro-speaker

The sound field of the micro-speaker can be integrated with the shape design of smart phones or tablets to simulate the final sound field.

Conclusions

The measurement of the sound radiation behaviour is based on acoustic holography. The synchronization method with 2 microphones can be used to measure smart phones and tablets. The measurement result has covered 360° sound field and can be used for the optimization of the acoustic experience of mobile devices.

References:

[1] Klippel GmbH, "Near Field Scanner 3D(NFS)," Nov. 2015.
[2] C. Bellmann, "Separierung von Direktschall und Raumreflexionen mit Hilfe holografischer Methoden ," Dec. 2012.
[3] Klippel GmbH, "NFS - Safety Instructions," pp. 1–30, Oct. 2015.