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# STUDY ON THE BAFFLED EFFECT OF MOBILE PHONE PANEL

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The aim of this paper was to demonstrate the baffled effect of mobile phone panel at higher frequencies and presents an approach for localizing the optimal position of microphone receiving hole in the mobile phone with the aid of Abaqus commercial software and verification experiment conducted in anechoic chamber. Due to rapid technological development, the mobile phone has not only become a communication device, but also a daily necessity. In addition to the requirement for slim design, improvements are needed in the clarity and quality of sound, especially for the microphone system at higher frequencies. One of the influencing factors is the baffled effect from the panel design, especially in the smart phone. Thus, this paper mainly focuses on the influence of this effect in the mobile phone panel. The results revealed the optimal location of microphone receiving hole using Abaqus software, tested in anechoic chamber. With Abaqus software, the existence of baffled effect in the mobile phone panel can be clearly demonstrated, especially at higher frequencies. Moreover, the variations and relationships of sound field with different sizes and positions of panel can be analyzed. Many commercial mobile phones are also modelled using FEM software, with verification in anechoic chamber. There is perfect agreement between simulated and experimental results. Transferred frequency, in the range of 5 kHz to 6 kHz, causes sound pressure to drastically change and may prove useful in the design process. Finally, all receiving characteristics of microphone system, including the influence of internal components and external baffled effect, had been programmed and integrated in a graphic user interface (GUI) system.

Keywords: condenser microphone, baffled effect, finite element method

## 1. Introduction

With the recent development of technological trends in wearable devices, portable devices, such as mobile phones, smart phones, tablets, and laptops, have dramatically increased in usage and have become a necessity of life. In addition to functionality and appearance, sound quality is an important factor in the design of portable devices. In smart phones and tablets, quality of sound transmission and reception has had to be sacrificed and adjusted to conform to the requirements for wide touch screen, which result in baffled effect. Although baffled effect always exists in such devices and can be approximated with a rough theoretical equation [1], results are only consistent at lower frequencies. With the help of numerical techniques, Swenson presented a very economical and effective system involving a plane reflector under different baffle shapes in 2002 [2]. All the analysis results were limited below 3.5 kHz. In higher frequency range, discrepancies become larger. This is due to the strong directivities of sound at higher frequencies and smaller wavelengths. Any obstacles in the path or in the surroundings easily interfere with the propagation of sound. Higher frequency components are essentially related to sound quality, such as distortion, timbre, and emotion. Without these components, sound is monotonous and dull. For human audio enjoyment and for retaining high fidelity, most portable devices are designed for performance at higher frequencies (100Hz ~7 kHz) instead of at narrowband only, such as 3GGP system [3].

Although the components of higher frequencies are important in terms of sound quality, it is difficult to make predictions or carry out simulations with theoretical equations only. Thus, the aim of this study was to focus on the microphone system in mobile phones to verify the existence of baffled effect. Furthermore, the influence of baffled effect from touch screen and panel were analyzed with commercial finite element software, Abaqus. At the same time, the influences of the hole, used for receiving and transmitting external sound via internal microphone, including the location on panel and thickness of panel, etc., were investigated and verified by testing in anechoic chamber with standard equipment.

## 2. Schematic diaphragm of microphone system

Figure 1 shows sectional view of 6ϕ condenser microphone unit with front waveguide, frequently found in commercial devices. Influences on the parameters of condenser microphone system were based on Pawar et al. [4]. In the theoretical part, two approximated equations expressing baffled-end and free-open-end were referenced from Beranek [1] and listed as Eq. (1). Only flat performance in higher frequency range could be obtained, even under the considerations of equation 1. Thus, these expressions were not strong or powerful enough to predict the baffled effect caused by external panel.

$$l' \simeq \begin{cases} 0.85\times a & \rightarrow \quad Baffled\_End \\ 0.613\times a & \rightarrow \quad Free\_Open\_End \end{cases}. \tag{1}$$

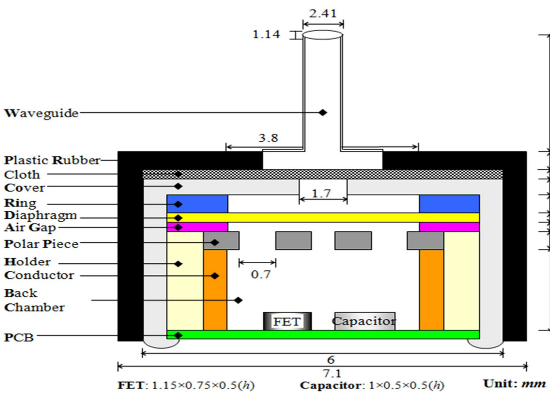



Figure 1: Schematic diagram for the condenser microphone system.

## 3. Measurement

Figure 2 shows the testing equipment used in this study, which included B&K electroacoustic equipment, Tannoy loudspeaker (system 1000), and SoundCheck 8.11 software for signal analysis. The distance between sound source and condenser microphone was limited to 20 cm. All testing was conducted in standard anechoic chamber.

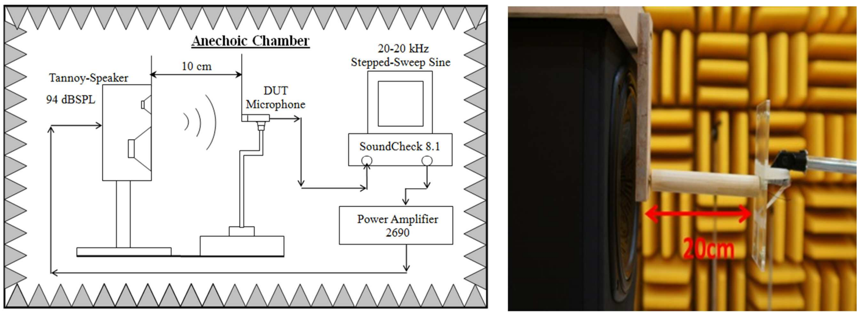



Figure 2: Testing environment and equipment.

Figure 3 shows the testing results for microphone unit with and without external panel. When the frequency was lower than 0.8 kHz, performance was almost the same. The reasons for the observable shifts in the test results were inherent differences in microphones and testing error by inference. With frequency increment above 0.8 kHz, a rapid jump occurred, reaching a maximum of around 1.9 kHz. After that, there were larger variations. This situation was only found with panel and greatly differed from that of microphone unit only. This phenomenon is the so-called baffled effect and is caused by the panel surrounding the entrance hole of microphone. In other words, baffled effect exists in any system with panel at higher frequencies.

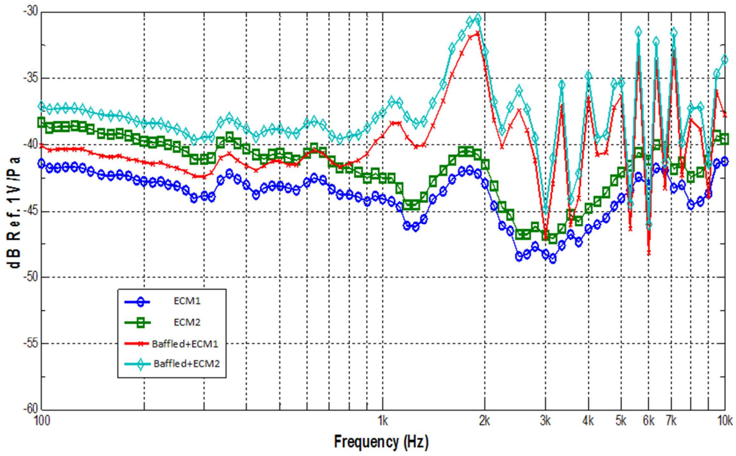



Figure 3: Comparisons of condenser microphone with and without panel.

## 4. Baffle parameters

In order to understand the influence of panel parameters on the baffled effect, three panels of different parameters, shown in Figure 4, were manufactured. Parameters included positions of microphone receiving holes in the panel and thicknesses of panel, and closely imitated the conditions of mobile phones. Furthermore, the influences of panel vibrations at natural frequencies were tested using hammer and accelerometer.

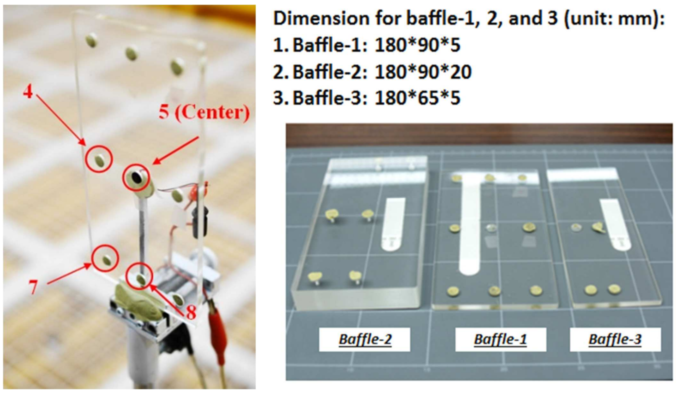
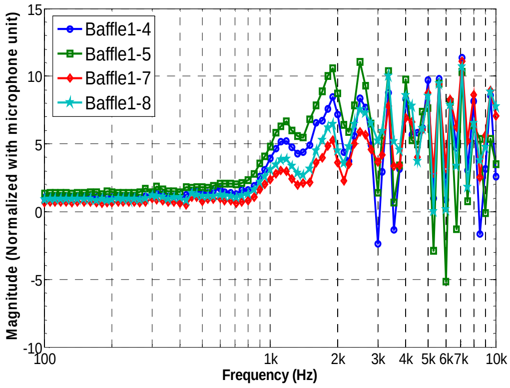



Figure 4: Various parameters of microphone receiving positions and panel thicknesses.

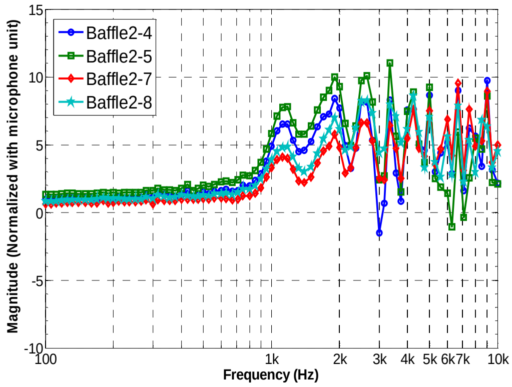
## 4.1 Effects of position

The influences of microphone receiving holes at various positions in the panel were investigated. Based on the considerations of geometric symmetry, four points, numbered 4, 5, 7, and 8, respectively, were defined in advance and used for subsequent testing. Results were normalized with microphone unit only to make the baffled effect clear, as shown in Figure 5. Smaller baffled effect was found at position 7, located in the corner, due to only a quarter of the area surrounding the hole. If the microphone hole surrounded the panel, as in position 5, baffled effect could be predicted to reach the maximum value. For the other two positions, numbered 4 and 8, respectively, these influences were between numbers 5 and 7. Although the same half panel surrounded the receiving hole, baffled effect at position number 4 was more serious than that at position number 8. The reason was that the area of this half panel at number 4 was larger than that at number 8. Thus, it can be concluded that baffled effect is not only due to surrounding panel, but also, and more importantly, to area.

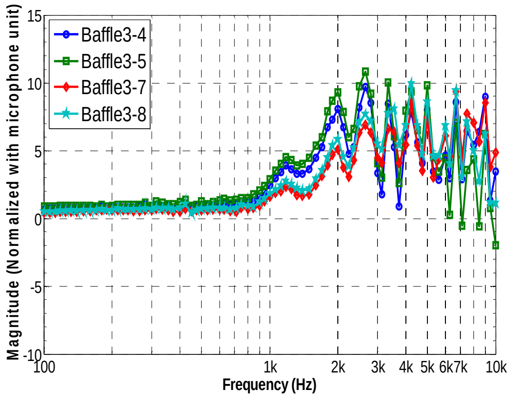
Whatever the changes at these four positions in the panel, the frequency and maximum and minimum values at higher frequencies were almost unchanged. Furthermore, these phenomena and variations at different positions only occurred at below 5 kHz. After that, all of the phenomena and variations were completely reversed. The seriousness of the influence of position number 5 was reduced above this reversed frequency. Independent of the geometries of panel, this reversed frequency was found at around 5 kHz in (a), (b), and (c). This is a much different result than for microphone unit only.




(a)




(b)

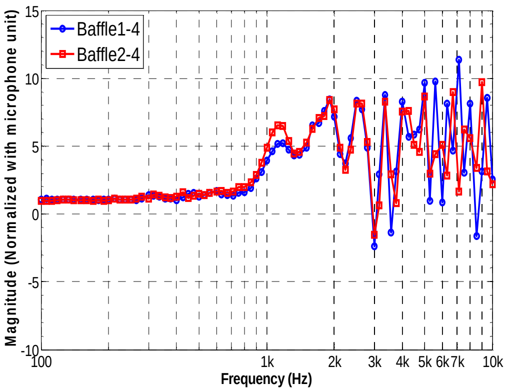



(c)

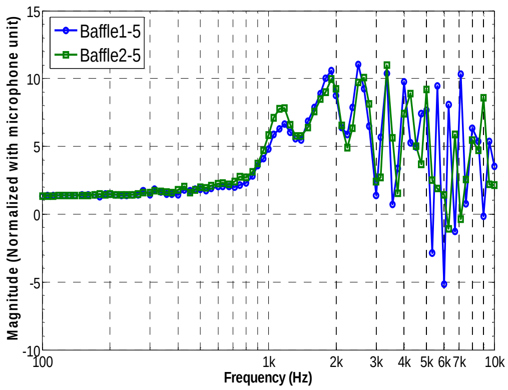
Figure 5: Comparisons of 4 different positions normalized with microphone unit only; (a) Baffle-1; (b) Baffle-2; (c) Baffle-3.

## 4.2 Effects of thickness

Baffled effect under various panel thicknesses was investigated, as shown in Figure 6. Before the occurrence of the reversed frequency discussed above, there was no obvious difference in level or performance. However, once the frequency became larger than the reversed frequency, the influence of thickness appeared. However, there was no regular or clear variation in the influences of panel thickness above the reversed frequency




(a)




(b)

Figure 6: Comparisons of various panel thicknesses; (a) position 4; (b) position 5.

## 4.3 Contribution of panel vibrations

To determine if panel vibrations contribute to the corresponding frequencies, we determined the natural frequencies of Baffled-2 using B&K hammer with accelerometer and executed signal processing with PULSE 3560C. Figure 7 shows the simplified testing structure, and Figure 8 shows the results. Natural frequencies of Baffled-2 were around 3.5 kHz, 4.8 kHz, 7 kHz, and 9 kHz, respectively. Moreover, we found higher frequencies than adjacent frequencies. Thus, we believe that panel vibrations also affect microphone reception at panel vibrating frequencies.

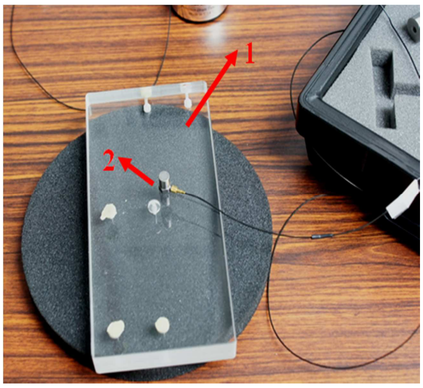



Figure 7: Vibration testing structure of panel with B&K facilities.

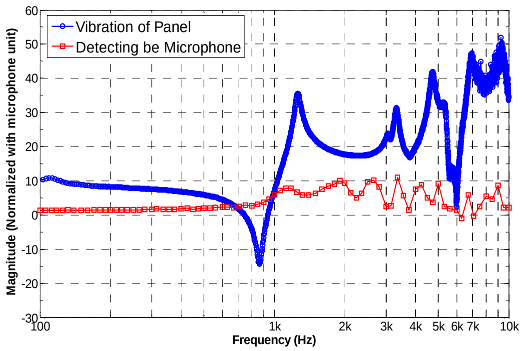



Figure 8: Comparisons of panel vibration and microphone reception.

## 4.4 Finite element simulation by Abaqus

Finite element simulation is a convenient and popular way to predict the performance of a target in a diversity of fields. If there is good agreement between finite element simulation and testing, simulation techniques can be used in subsequent works for comprehensive investigation and discussion of parameters of interest. We selected Abaqus software to simulate sound reception of microphone system in finite space with and without finite panel. The influences of the parameters discussed above were simulated. Figure 9 shows the simulated model. Results of simulation and testing are shown in Figure 10. Good agreement in performance, level, and frequency locations was obtained. The discrepancy between the two methods was low and resulted from testing error or the simulation settings by inference. Moreover, simulation with finite element commercial software, Abaqus, satisfied simulation results for the predictions of microphone reception. We believe that it can be efficiently applied to advanced analysis and control of finite sound field in the future.

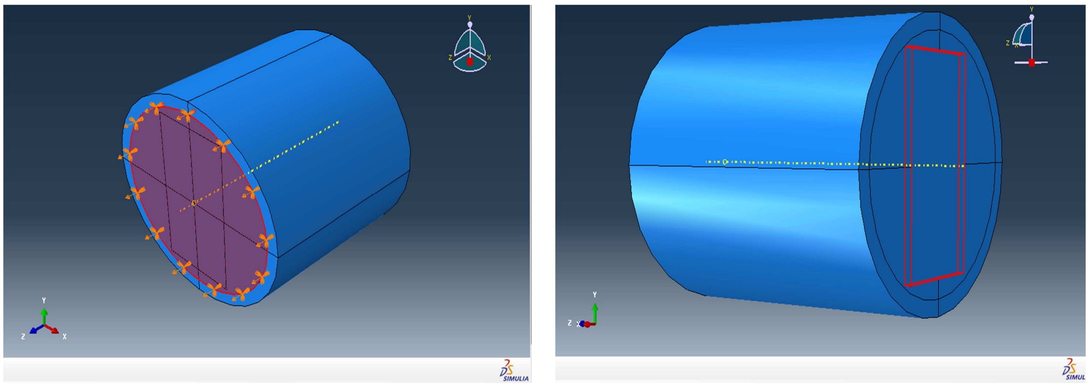


Figure 9: Simulation of microphone reception in finite field. (a) sound source; (b) finite panel.

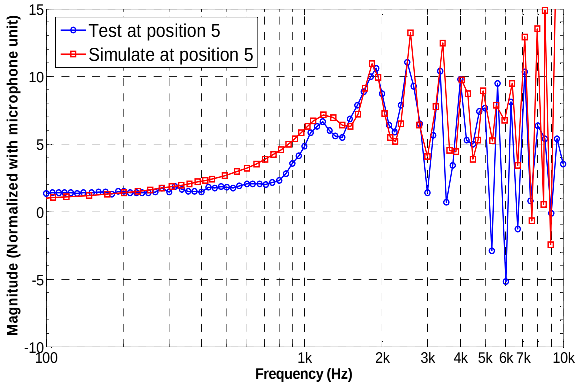



Figure 10: Comparisons of baffled effect by testing and simulation.

## 5. Conclusion

We investigated the baffled effect on microphone reception from the panel by testing and simulation with finite element. Baffled effect has no influence at lower frequencies. With frequency increment, its influences appear abruptly and increase dramatically above 1 kHz, which is large enough to take into account in product design. Furthermore, the conditions surrounding the microphone receiving holes on the panel are another important factor in baffled effect. A reversed frequency at around 5 kHz existed in all cases. All of the characteristics were reversed above this frequency. This may provide a reference for panel design and position selections of microphone reception holes in the future. We also found that natural frequencies of panel promote and increase the capability of microphone reception. Finally, simulated baffled effect showed close results with those obtained through testing. Thus, more complicated characteristics of propagation or receiving with diverse transducers in finite space can be directly predicted and controlled with Abaqus in the future.

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