# Acoustic Noise Analysis of a 5G Telecom Base Station Design

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## Abstract

Nowadays, new technology tends to consume more and more power than before thus housing, and enclosures are designed to cool thermal energy dissipated by servers which are enclosed with louder fans for the new generation of 5G servers or BTS system. This paper is a collaboration with Viettel R&D and attempts to construct a shroud for reducing acoustic noise of the 5G server unit using fan for cooling system, and the 5G RRU thermal simulation has been implemented. In this study, air ducts are created with different wall impedances to damp an acoustic model of the propagating wave. In order to predict the result, a finite element analysis has been proposed to compute the sound level. Obtained results will be compared with ones of the constructed shroud in Laboratory. The results can be applied for many BTS systems of Viettel to reducing noise for future development. Thermal simulation of 5G RRU has been built with different power levels and experimental result of temperature distribution have been implemented. A new contribution of this study is a comprehensive modeling method for acoustic noise level and thermal management of BTS and RRU 5G.

## Keywords:
**An** Acoustic FEM program, 5G server units, BTS, RRU 5G.

## 1. Introduction
The idea of this paper is to create a housing shroud to reduce acoustic noise of 5G Baseband Telecom Station server. The housing shroud has been designed with different materials (Cremer or rubber) to build silencer for reducing the noise. This silencer is placed in between exhaust air whilst and the server fan which is cooling system of 5G server. This project is solve comprehensive problem both the acoustic and the thermal simulation of 5G BTS telecom base station included server sectors and RRU 5G.
Acoustic noise of the sound pressure is generally noise caused by the blade pass frequency of the fans both the intake and the exhaust. In order to reduce acoustic noise, a silencer was designed as damper which is a form of Cremer damping in ducts in Sack 2016. The modal sound attenuation in ducts has been developed for several decals by J. Tester 1973. However, recently, FEM analytical and simulation methods are useful to investigate acoustic noise performances.

## 2. Analytical Calculation
The construction of silencer of 5G BTS is produced by damping materials and forming in ducts or holes, because thea are very convenient to put them in conventional system. The silencer wall is desinged by a theory method to make the next order duct mode merge with the propagating plane wave, resulting in optimal attenuation of the merged mode pair. The wall impedances are two modes in the complex wavenumber plane. In addition, there is an attenuation peak for these modes traveling in the duct. For such a rectangular duct with negligible flow speeds, a branch point equation can be expressed as:

$$H = (\overline{\beta_1} + \overline{\beta_2})k_y h \cdot khcos(k_y h) + i\left[(k_y h)^2 + \overline{\beta_1}\,\overline{\beta_2}(kh)^2\right]sin(k_y h) = 0, \tag{1}$$

where $\beta_1$ and $\beta_2$ are the normalized admittances for two opposing liner walls with a duct width of $h$

The wall impedance of $Z$ can be then expressed as

$$Z = \frac{-1}{k_y h \tan(k_y h) \cdot kh} \quad (2)$$

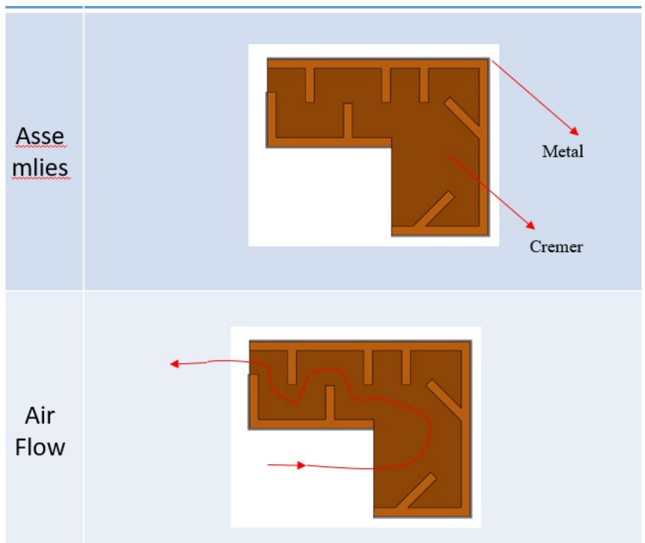


Figure 1. Silencer Design

The silencer is designed by a rectangle chamber and plate to create the Cremer impedance with several frequencies. The total impedance of the wall and chamber can be expressed as :

$$Z_{tot} = Z_{wall} + Z_{chamber} \quad (3)$$

The wall impedance $Z_{wall}$ depends on the wall material of the chamber, such as an rubber or composite sheet. The chamber impedance can be computed as

$$Z_{chamber} = Z_0 \frac{1+e^{ik\times 2h}}{e^{ik\times 2h}-1} \quad (4)$$

where *b* is the height of the duct, and *h* is the depth of the expansion chamber.

## 3. Methods Acoustic Noise Sound Simulation And Test Result

The sound power values of the housing are evaluated to avoid strong resonances. Moreover, the Cremer dampers is improved to minimize total sound power level. The sound level is calculated by the finite element method (FEM) based on the ANASYS Software.

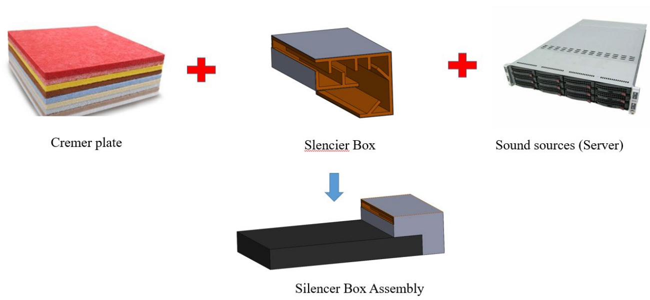


Figure 2. 3D Model of Silencer.

A 3D model of Cremer plate, boxes and total assemblies are built by Solidworks as shown in Figure 2. Moreover, there are still exhaust and housing other parts included together. The 3D simulation was modelled based on 3D model files. The pressure source can be calculated the following equation:

$$\bar{W}/S = \tilde{p}^2/(\rho_0 c), \tag{5}$$

where $c$ is the sound velocity, $\rho_0$ is the air density and S is the area of the surface. The equation (5) is rewritten as:

$$\hat{p}_{intake} = \sqrt{2}\sqrt{\rho_0 c \frac{W_{ref} * 10^{(L_W/10)}}{h_{intake} * b_{intake}}} \tag{6}$$

where $W_{ref}$ is the reference of sound power, $h_{intake}$ and $b_{intake}$ are the height and width of the intake respectively. The measurement devices are recorded by only sound values that do not take the phase parameters into account. The phase can be also estimated by a distance from the fans to the exhaust. In this model, the distance $L$ from fans to exhaust is 120 mm, and the airpath $L_{air}$ along the duct is 300mm. Due to the dipole nature of a fan noise source, the phase has been also shifted $\pi$ radians. The resulting phase shift can be expressed as:

$$\phi = (0.30 - 0.12)\frac{2\pi f}{c} + \pi \tag{7}$$

where $f$ is the frequency. The sound power of both the exhausts are measured in a range of frequency. Thus, the pressure source for each exhaust is written as:

$$\hat{p}_{exhaust} = \sqrt{\rho_0 c \frac{W_{ref} * 10^{(L_W/10)}}{h_{exhaust} b_{exhaust}}} e^{i(0.27-0.09)\frac{2\pi f}{\epsilon} + \pi} \tag{8}$$

The result of both exhausts with the same phase has been calculated above equations. If the server is using multiple fans combined with the interior BBU they will be affected together. In order to be able to realize a solution based on Cremer damping the sound, it has to pass through a cross-section with walls that realizes the Cremer optimum. In order to obtain this, it is decided to perform some sort of duct solution. A duct solution can be presented as follows:

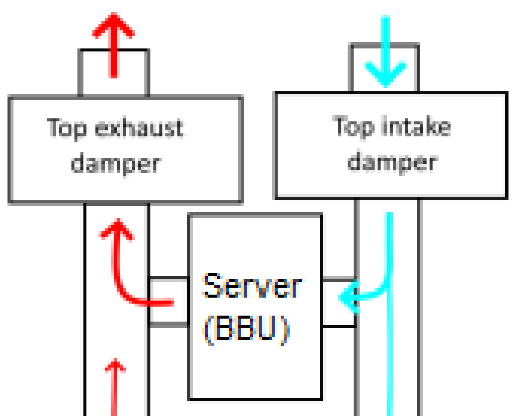


Figure 3. Diagram of BBU with damper.

In order to test the method by using Cremer material, a finite element method is performed to use the Acoustic module. This simulation utilizes the test duct specified where the ducts and expansion chambers used for this model. The simulation is to estimate the sound power spectra of the entire shroud. Another goal is to select damper material to obtain a total sound power level as low as possible. The frequencies are selected based on BBU and RRU 5G operation band. The frequency sweep in the simulation is set to 5000 Hz. The simulation of acoustic sound has been performed by server steps:

**Step 1:** Create model 3D

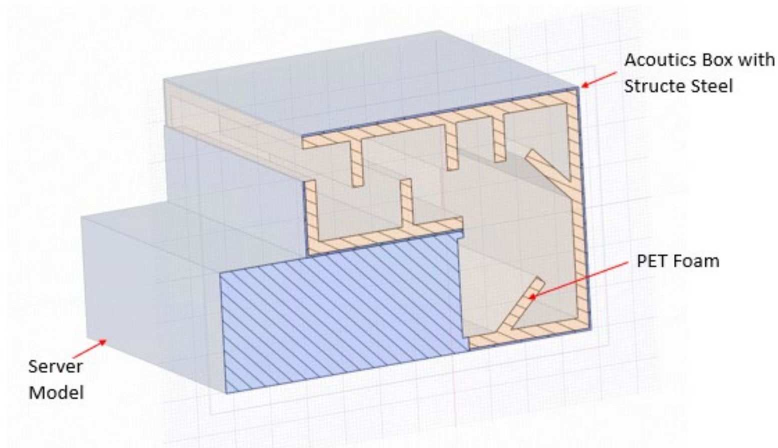


Figure 4. Create Model

The Model 3D drawing was designed with exact dimensions of the server housing.

| | |
|---|---|
| Density | 1.078e-07 kg/mm³ |
| **Structural** | |
| Isotropic Elasticity | |
| Derive from | Young's Modulus and Poisson's Ratio |
| Young's Modulus | 60.78 MPa |
| Poisson's Ratio | 0.3162 |
| Bulk Modulus | 55.114 MPa |
| Shear Modulus | 23.089 MPa |
| Isotropic Secant Coefficient of Thermal Expansion | 0.0001169 1/°C |
| Tensile Ultimate Strength | 2.851 MPa |
| Tensile Yield Strength | 0.6003 MPa |
| **Thermal** | |
| Isotropic Thermal Conductivity | 2.907e-05 W/mm·°C |
| Specific Heat Constant Pressure | 1.198e+06 mJ/kg·°C |
| **Electric** | |
| Isotropic Resistivity | 2.366e+17 ohm-mm |

Figure 5. Added materials and Mass Acoustics Source in Harmonic Acoustics Module of Ansys.

The model has pre-defined material properties and Mass Acoustics Source in Harmonic Acoustics Module of Ansys software as in Figure 5.

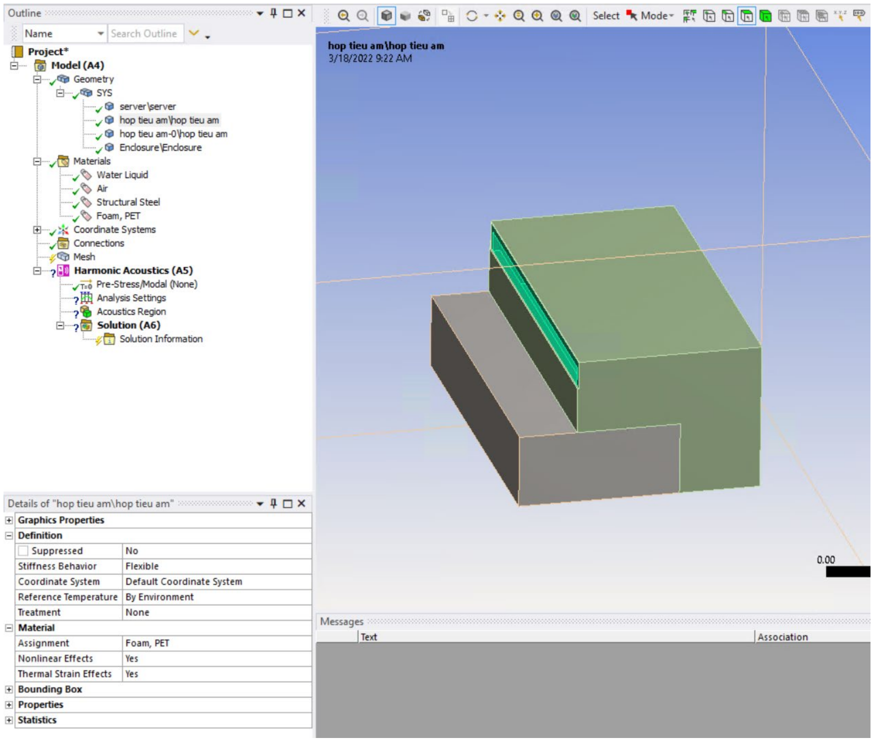

Figure 6. Detail material setup for Model

The Cremer material for acoustic sound model has been detailed in Figure 6. The BC is also presented as

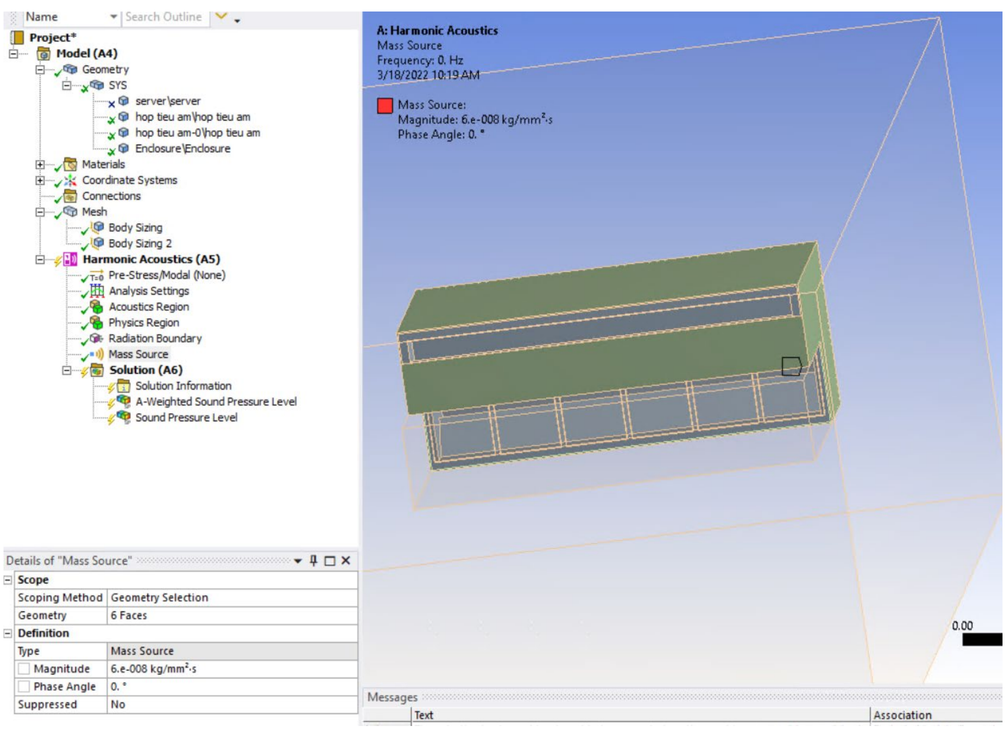


Figure 7. Mass source setup.

The mass source has been per-determined with 6 positions of fan (0.05 -0.06 Kg/m2.s). The equivalent with 110 dBA is measured from the real fan.

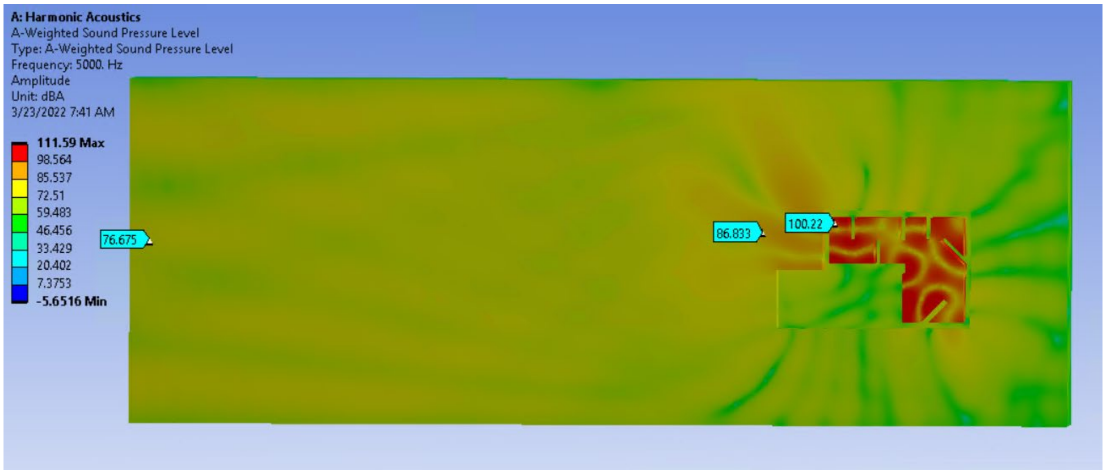


Figure 8. Solve and results.

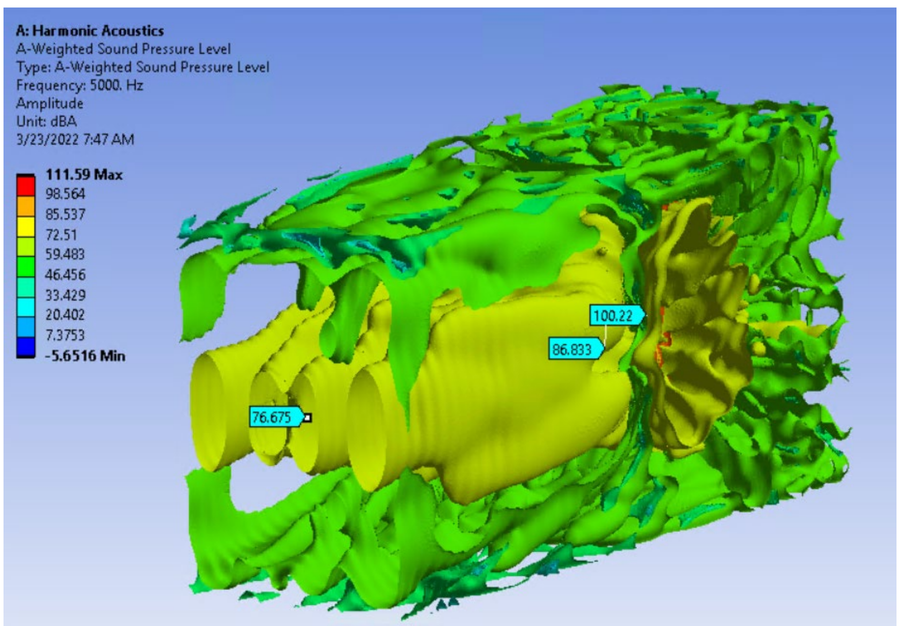


Figure 9. Simulation results with Silencer Box.

As can be seen in figures 8 and 9, the sound results are 100dB in the fan location and 76 dB in exhaust. It can be confirmed 23 dB reduced by silencer. To evaluate the noise level in the server with and without silencer, the sound instrument was set up and measured in Viettel as in Figure 10.


a. Without silencer b. With silencer

Figure 10. Sound values without/without Silencer Box.

The sound values are 98.1 dB without and 76.3 with silencer boxes. To validate the resulting simulator, the shroud values of the server with silencer in fig 8 good agreement with fig 9.b. The sound level between before and after applied the shroud or silencer is about 22dB. The fan has been operated with full load power of BBU and 5G RRU. In practice, the separating board was constructed. To avoid vibrations from the other devices, the sound instrument was placed about 1m from the server. The difference of sound power level between the intake and the exhaust is for relevant frequencies about 23 dB being higher than the exhaust. The conclusion is shown that both the intake and the exhaust need noise reduction.

## 4. Conclusion

This paper has been successfully developed by the FEM. The obtained results have also been checked to be close the experiment methods for Telecom server coupling to RRU 5G with different power and losses. The resulting shroud has quite noticeably reduced the emitted sound from the server. The average sound power level is about 23 dB, which fulfills the scope of this project of at least 20dB sound power level reduction. This paper has also illustrated that the temperature of 5G RRU and sound level of Telecom 5G will increase with the load power. Thermal and acoustic noise simulations have been carried out and compared with sound measure devices and thermal image results in the laboratory by supporting Viettel High Technology Industries Corporation, Vietnam.

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## Biographies

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