# Comparison Of SEA And PFFEA Predictions Of In-Air And Underwater Radiated Noise From A Ring-Stiffened Cylinder

**Layton E. Gilroy**
Defence Research Establishment Atlantic, P.O. Box 1012, Dartmouth, Nova Scotia, B2Y 3Z7

## INTRODUCTION

Both Statistical Energy Analysis (SEA) and Power Flow Finite Element Analysis (PFFEA) have been under investigation at Defence Research Establishment Atlantic (DREA) as methods of predicting high frequency vibrations and radiated noise. PFFEA [1-7] is an analysis method that is based on a conductivity approach in which the flow of vibrational energy is modelled in a similar fashion to heat conduction with convective losses. SEA [8-9] is a more mature method that is based on an energy balance between substructures. DREA has recently performed investigations [10] to both validate the PFFEA software and to compare it against a commercially available SEA code, SEAM [11]. This paper discusses both in-air and underwater experiments performed with a ring-stiffened cylinder with an internal deck. In these experiments, the input mobility to the test model and its response were measured under broadband excitation along with the resulting radiated noise both in-air and submerged in seawater. These data were then compared with both PFFEA and SEA predictions.

PFFEA uses a conductivity model of structural components in which the flow of vibration energy is examined by applying time-averaged and local space-averaged expressions for energy density and power flow to a unit volume of a structural component. This results in a second-order conductivity equation governing the distribution of vibration energy. The basic equations for PFFEA are obtained by spatial discretisation of the differential equation. Energy in each vibration type (e.g. flexural, torsional, etc.) can be modelled separately with PFFEA, with coupling occurring at junctions of components. The PFFEA system, embodied as the software suite SNAP [7], consists of a translator program, which converts a finite element model to a PFFEA model, and a field equation solver, which performs the PFFEA analysis.

Cambridge Collaborative's SEAM software provides a method of analysis that is particularly well suited for studying the dynamic response of complex structures at high frequencies. SEAM includes a complete implementation of SEA. The complex dynamic system being analysed is divided into a set of substructures and acoustic elements. The modes of each substructure and acoustic element form the SEA subsystems. The flow of energy between the different subsystems is proportional to the modal energies of the subsystems and the coupling factors. SEAM calculates all required coupling factors and performs a power balance for each subsystem. The resulting equations are solved for the modal energy and response of each subsystem.

## EXPERIMENTAL PROCEDURE

DREA's ring-stiffened right cylinder is a 9.5mm thick tube, 3m in length, with a nominal diameter of 762mm. It has five internal ring stiffeners welded into the tube at equal intervals of 0.5m each having a square cross-section (38.1mm). The cylinder has 76.2mm thick endcaps with central "hatches" for access. A stiffened deck was welded into the cylinder to simulate a non-symmetric and more complex structure. Figure 1 shows the cylinder on its transport carriage (the painted lines mark the stiffener locations).
A Wilcoxon F4/F7 shaker was used to excite the cylinder over a

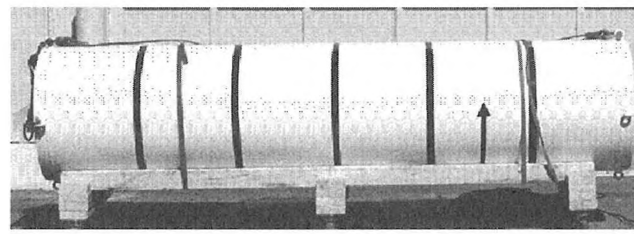

**Figure 1: DREA Ring-Stiffened Cylinder**

frequency range from 0 Hz to 12.8 kHz. The shaker was mounted on the second rib from one end (at the 1/3 point of the cylinder) driving radially (see Figure 2). For the in-air tests, the cylinder rested horizontally on a wooden carriage with contact only at the thick endcaps. For the underwater testing, the cylinder was submerged with the cylinder axis normal to the water surface.

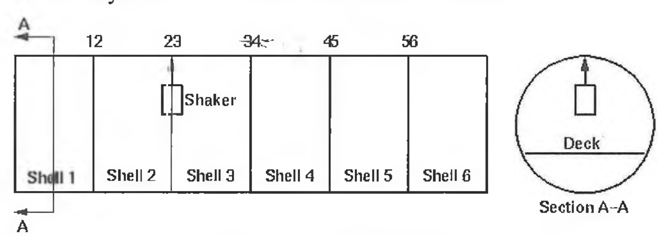


**Figure 2: Schematic of Cylinder with Shaker**

The cylinder was configured with approximately 50 internal mounting blocks for accelerometers located on both the stiffeners and the shell plating as well as several deck locations. For both the in-air and submerged trials, the accelerometer signals, along with a signal from the impedance head (force and acceleration) on the shaker, were fed to a signal analyser. From these signals, narrow band input mobility and transfer mobility were determined. For the radiated noise testing, the signal from either a microphone or a hydrophone was fed to the analyser to determine the sound pressure levels.

## NUMERICAL MODELS

The numerical model used in the PFFEM analysis consisted of 13 structural elements with or without fluid loading, as required. Radiated noise predictions were made with a boundary element based post-processing software. The material properties used are those of mild steel (Young's modulus of 200~GPa, Poisson's ratio of 0.3, density of 7600 kg/m$^3$, and a loss factor of 0.005).
The SEAM model consisted of 16 structural elements (also with fluid loading as required), 2 acoustic elements and 27 structural and structural-acoustic connections and used similar material properties

to the PFFEA model. As the software does not explicitly support radiated noise predictions that vary with distance from the source, corrections were made to the acoustic space element at each distance to predict an appropriate sound pressure level.

## RESULTS

Figure 3 shows the in-air input mobility measurements and predictions. Experimentally there was virtually no difference between the submerged and in-air input mobilities and this was also reflected in both the SEAM prediction, which was reasonably accurate, and the SNAP prediction, which, while roughly correct in level, did not correctly reflect the trend of the experimental data.

A typical response measurement and prediction is shown in Figure 4. This figure shows the underwater response of the shell adjacent to the input location (shell 3). As can be seen SEAM and SNAP accurately predicted the response. This was typical of the underwater shell and stiffener responses in general. The structural response predictions in the in-air case were typically slightly less accurate than the submerged responses.

Figure 5 shows the in-air radiated noise measurement and predictions. As can be seen, the predictions were fairly accurate, with SEAM underpredicting the exterior noise and SNAP underpredicting the interior noise (not shown) by about 10 dB. Finally Figure 6 shows a typical underwater radiated noise comparison in which SNAP gives a more accurate prediction and better represents the general trend of the data.

## CONCLUSIONS

Both SEAM and SNAP accurately predicted the input mobility to the ring-stiffened cylinder and gave reasonable predictions for structural response. SEAM typically underpredicted exterior radiated noise while SNAP underpredicted interior noise. This may be due in part to the lack of free-field radiated noise prediction capabilities in SEAM and the lack of a true reverberent acoustical space element in SNAP.

## REFERENCES


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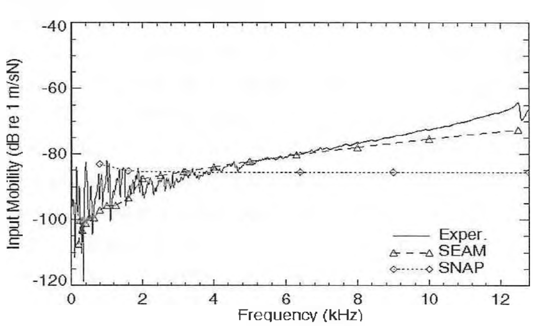


**Figure 3: In-Air Input Mobility**

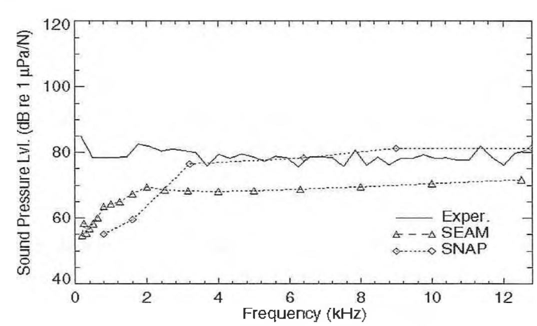


**Figure 5: Exterior Radiated Noise**

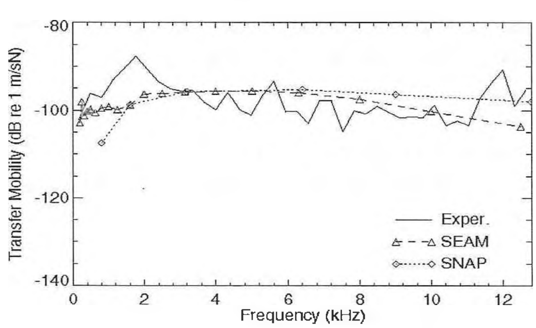


**Figure 4: Underwater Response in Shell 3**

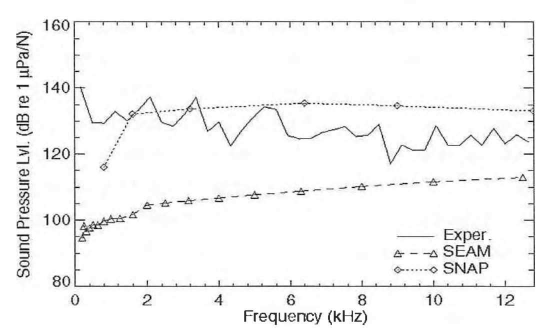


**Figure 6: Underwater Radiated Noise**