

Minimalistic bem code for plane wave scattering from soft targets

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mm-bem contains collection of several source codes for calculating scattering pattern obtained when plane wave scatters from soft targets. It uses boundary element method with piecewise constant discontinuous finite elements in 3D (P0).

Calling conversion depends on the code language but usually it uses four parameters:

1. mesh file name in msh ascii 2.2 format (defaults to sphere-1.905-600.msh representing 1.905cm radius sphere defined with 600 points and 1196 triangles)
2. direction angle (defaults to $\theta = 0$ what means that it travels along x axis)
3. frequency (defaults to $f = 38\text{kHz}$)
4. sound speed (defaults $c = 1480\text{m/s}$)

The most often results are printed into standard output in the form of two-column data containing:

1. scattering angle in degrees
2. absolute value of scattering length.

This output data could be redirected to txt file or piped to plotting software. The polar scattering strength in logarithmic domain could be obtained by gnuplot polar.gp script. The target strength is the value calculated at 180° distance from wave direction angle.

The source codes are in C, Python, Matlab, Julia and FreeFem. The theoretical calculations for a soft sphere are in Gnuplot. The example results are for 38kHz. The use of source codes requires installing its environments or compilers. Only FreeFem version uses Hmatrix approach that allows for faster calculations for large meshes.

The package contains also the demonstration page that do not need any additional installation. The page allows generating sphere, spheroid or ellipsoid meshes and calculate scattering pattern for them. Moreover, it can present the results in polar form of calculated data along with other data file that could be added for comparison.

Shell script

The run.sh script shows software versions used and calling examples generating results for 38kHz (default frequency) on MacBookPro M1 2021 Sequoia 15.5.

```
1  bash-3.2$ ./run.sh
2  #!/bin/bash -v
3
4  gcc --version
5  Apple clang version 17.0.0 (clang-1700.0.13.5)
6  Target: arm64-apple-darwin24.5.0
7  Thread model: posix
8  InstalledDir: /Library/Developer/CommandLineTools/usr/bin
9  julia --version
10 julia version 1.10.7
11 python3 --version
12 Python 3.13.3
13 freefem++-mpi
14 freefem++-mpi - version 4.15 (Fri May  2 13:38:38 CEST 2025 - git v
15 License: LGPL 3+ (https://www.gnu.org/licenses/lgpl-3.0.en.html)
16 ...
17
18 gnuplot --version
19 gnuplot 6.0 patchlevel 2
20
21 gcc src/soft.c -O3 -ffast-math -o bin/soft
22 time ./bin/soft msh/sphere-1.905-600.msh > out/sphere-1.905-0-38-1480
23
24 real    0m0.658s
25 user    0m0.498s
26 sys 0m0.005s
27 time julia src/soft.jl msh/sphere-1.905-600.msh > out/sphere-1.905-0
28
29 real    0m1.881s
30 user    0m2.933s
31 sys 0m1.405s
32 time python3 src/soft.py msh/sphere-1.905-600.msh > out/sphere-1.905
33
34 real    0m4.663s
35 user    0m4.461s
36 sys 0m0.078s
37 time freefem++-mpi -v 0 -f src/soft.edp > out/sphere-1.905-0-38-1480
38
39 real    0m6.452s
40 user    0m6.379s
41 sys 0m0.044s
42 time gnuplot -c src/soft.gp > out/sphere-1.905-0-38-1480-gp.txt
43
44 real    0m0.061s
```

```

45 user    0m0.044s
46 sys 0m0.007s
47
48 cd out
49 gnuplot -p -c ../bin/polar.gp sphere-1.905-0-38-1480*.txt
50 qt.qpa.fonts: Populating font family aliases took 56 ms. Replace use
51 mv polar.svg ../figs/sphere-1.905-0-38-1480.svg
52 mv polar.pdf ../figs/sphere-1.905-0-38-1480.pdf
53
54 gnuplot -p -c ../bin/polar.gp YFT*.txt
55 qt.qpa.fonts: Populating font family aliases took 58 ms. Replace use
56 mv polar.svg ../figs/YFT-0-38-1480.svg
57 mv polar.pdf ../figs/YFT-0-38-1480.pdf
58 cd ..
59 bash-3.2$

```

Results

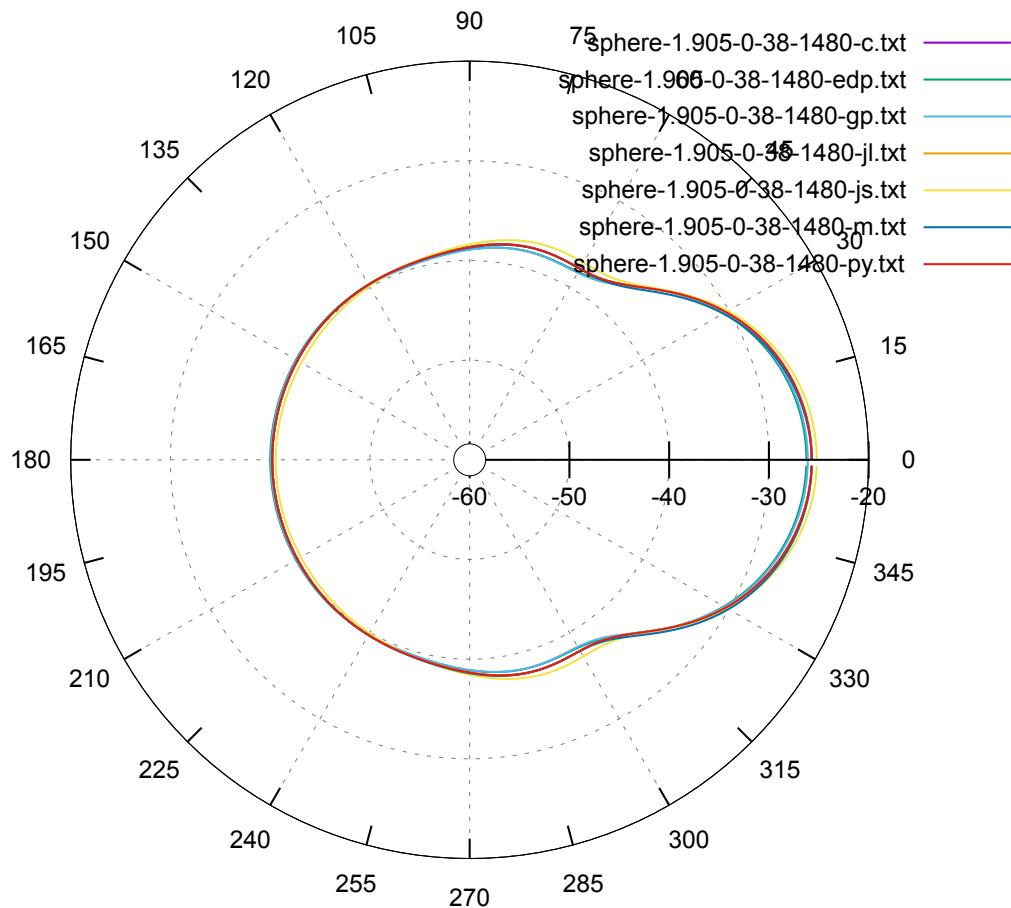


Fig. 1. The results for soft sphere with radius of $a = 1.905$ cm in salt water $c_0 = 1480$ m/s at 38kHz.

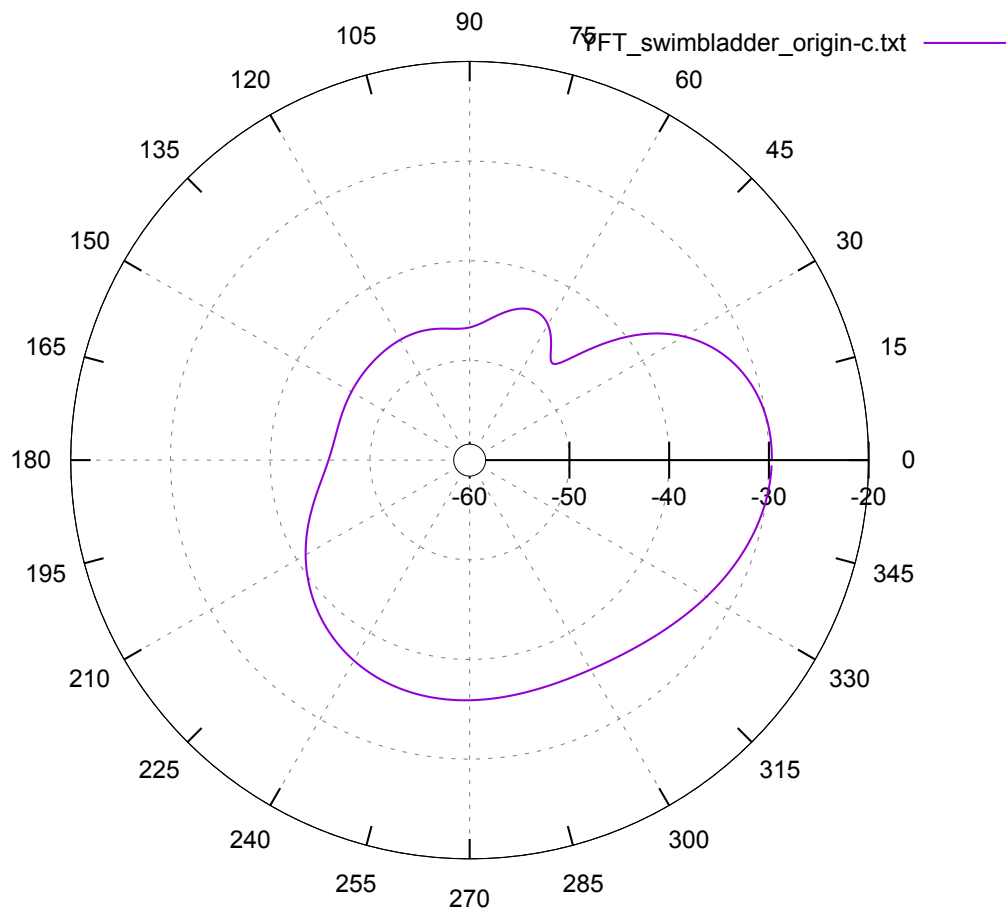


Fig. 2. The results for vacuum filled YFT swimbladder in salt water $c_0 = 1480$ m/s at 38kHz

mm-bem - scattering from soft target ([readme](#), [download](#)) MM 29.7.2025

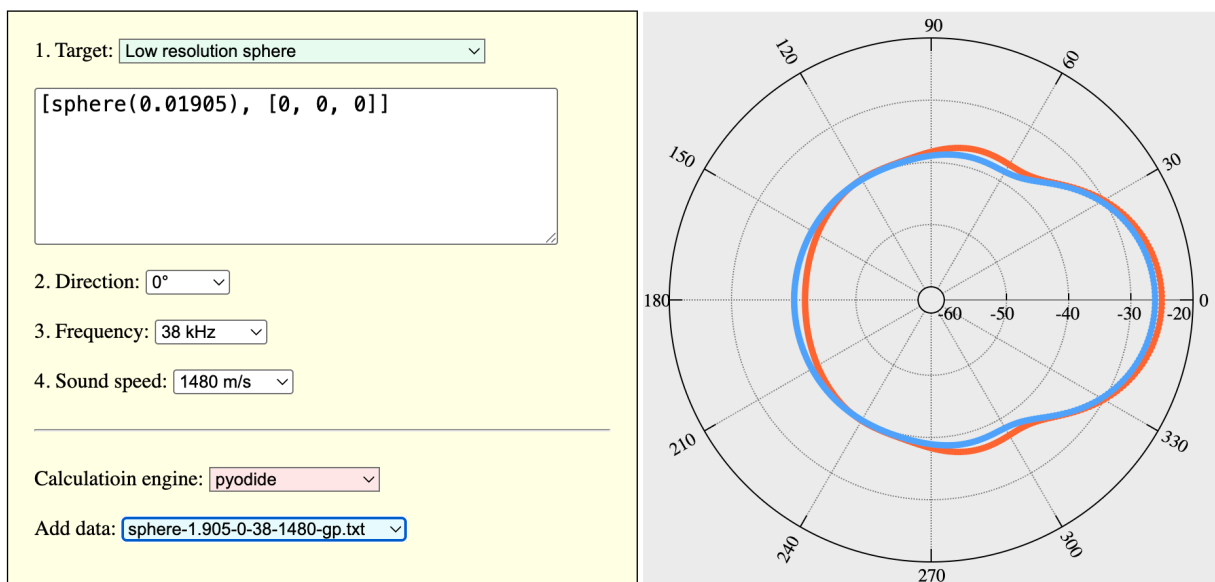


Fig. 3. The screendump from mm-bem web-page for low resolution mesh of 1.905 cm radius sphere along with theoretical curve for soft sphere in salt water $c_0 = 1480$ m/s at 38kHz.