NAVAL GROUP

POWER AT SEA

TARGET ECHO STRENGTH: DESIGN OPTIONS TO REDUCE IT

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ACTIVE SONAR EQUATION

Condition for detection with an active sonar (monostatic):

$$SL - NL + AG + TG - PI - 2LP(r) + TES > 0$$

Threat — Environment — Submarine

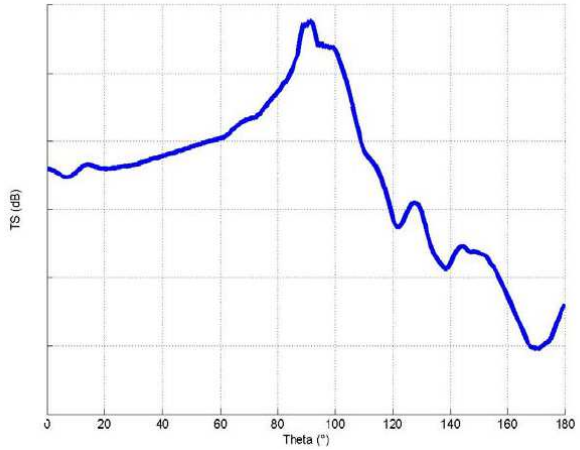
SL : Source Level of the sonar system
NL : Noise Level of the sonar
AG : Antenna Gain (reception)
TG : Sonar Treatment Gain
PI : Performance Index
LP(r) : Loss Propagation at the distance r
TES : Target Echo Strength

TES: the only parameter characterising the ship that we can act upon during design studies

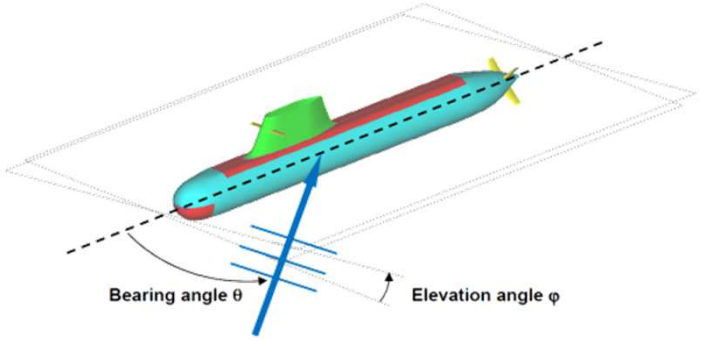
TES PARAMETERS

TES depends essentially on:

- The frequency of emission
- The attitude of the submarine or the angle of incidence of the sound (bearing, elevation)
- The design and shape of the target
- The materials used for the hull and coatings.



Bow Beam Stern

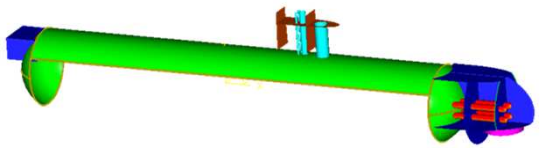


TES CALCULATION

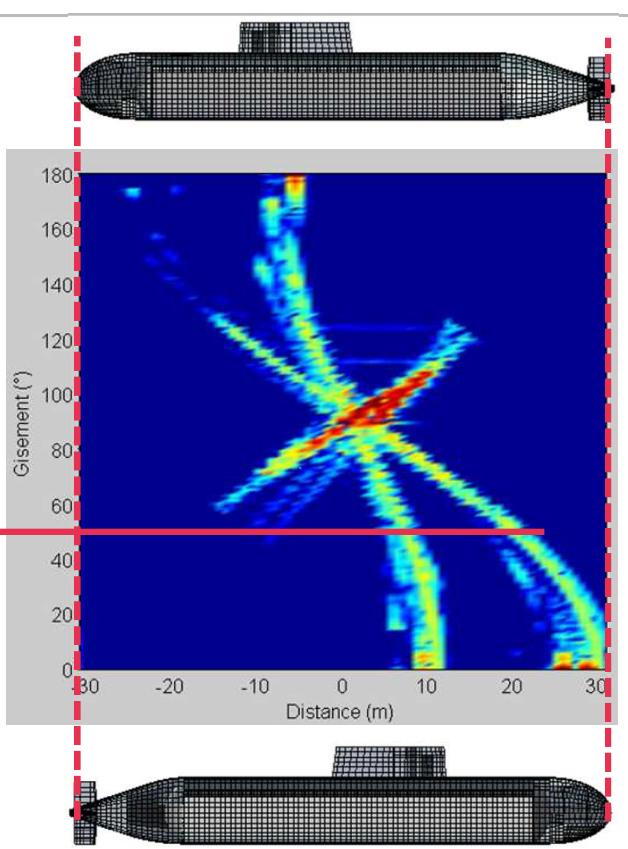
TES of the entire submarine is the result of the sum of TES of each contributor (sail, pressure hull, masts, rudders,…).

➔ Example for BeTSSI* model:

$$TES_{50^\circ} \cong 10log_{10}\left(\left|10^{\frac{TES_{array}}{10}}\right| + \left|10^{\frac{TES_{masts}}{10}}\right| + \dots\right)$$



(*) : BeTSSI : **Be**nchmark on **T**arget **S**trength **Si**mulation
Generic submarine model defined by FWG for TES calculation workshop



Waterfall diagrams of highlights at 10kHz, 0° elevation angle (obtained from IFFT on frequency TES results)

METHODOLOGY FOR REDUCING TES

1/ Plot of TES as a function of bearing angle to quantify contributors weight for the original model

2/ Identification of leading contributors for several frequencies of interest

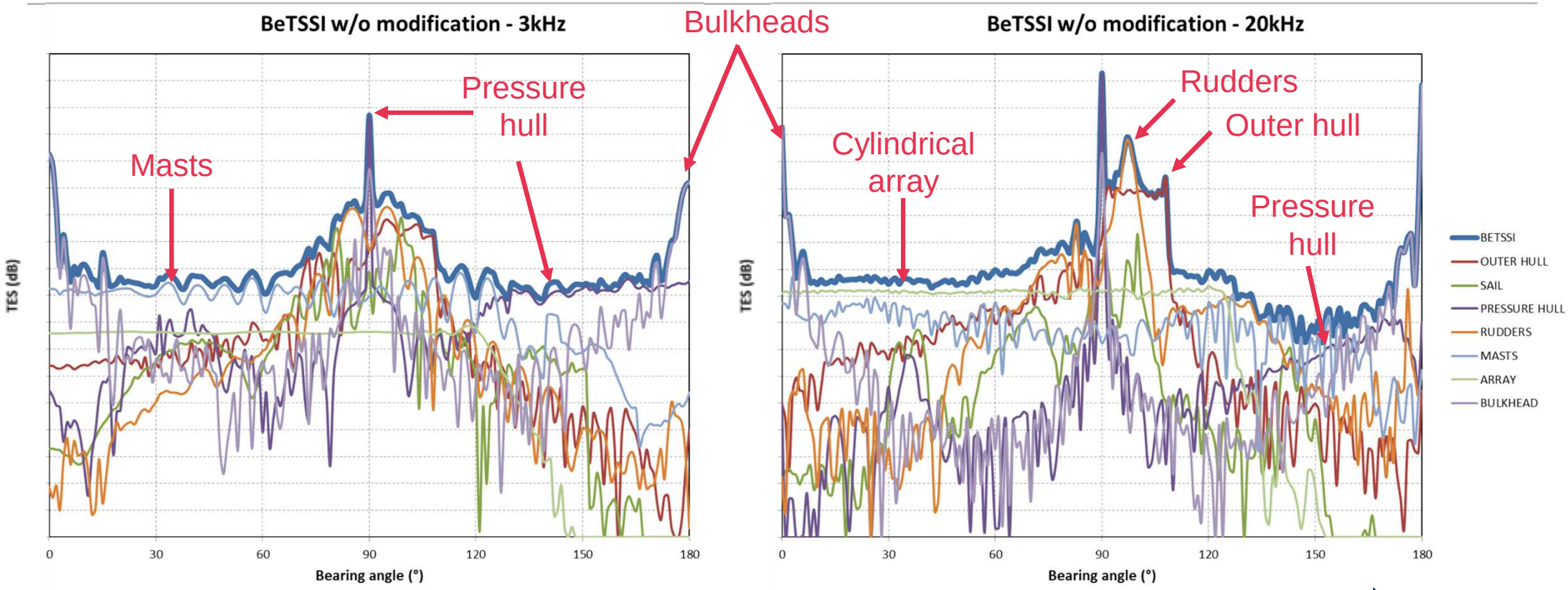
3/ Step by step: taking into account impacts on the WWS performances (Acoustic Discretion, propulsive and hydrodynamic performances,…)

➔ Definition and implementation of design options to reduce the importance of leading contributors

Note about elevation angle:

- The following results are given as examples to 0° (Y axis: 5dB/div)
- Others elevation angles have been studied to optimize the TES performance versus different elevation angle of the incident wave.

TES REDUCTION ON BETSSI MODEL
CONTRIBUTORS WEIGHT FOR THE ORIGINAL MODEL



Initial BeTSSI

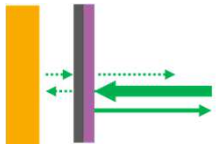
Step 1: Masts + CA | Step 2: Hull | Step 3: Bulkheads | Step 4: Rudders

Optimised BeTSSI

TES REDUCTION ON BETSSI MODEL
STEP 1: MASTS + CA

General principles to reduce TES:

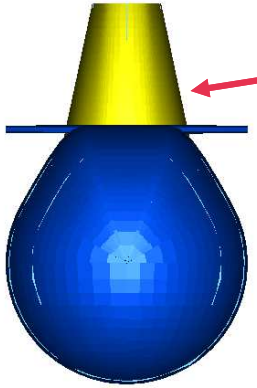
Absorption with anechoic coating



Deflection with TL coating

Application to sail and its inner structure:

Anechoic coating specified in BeTSSI workshop



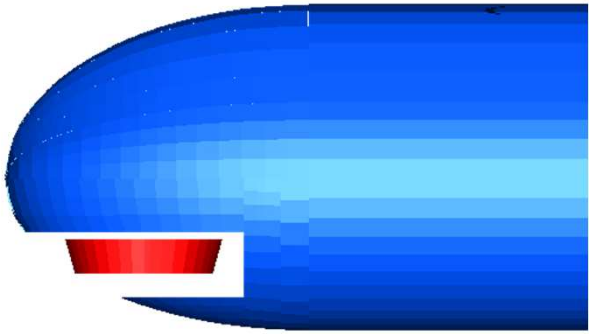
TL coating specified in BeTSSI workshop

Impact on:
- Acoustic Discretion (flow degradation in front of the propeller)
- Drag and propulsive performance

Initial BeTSSI → Step 1: Masks + CA

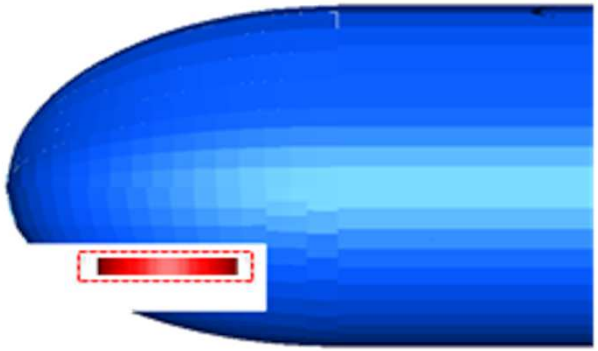
TES REDUCTION ON BETSSI MODEL
STEP 1: MASTS + CA

Application to bow array:



Deflection principle: conical shape

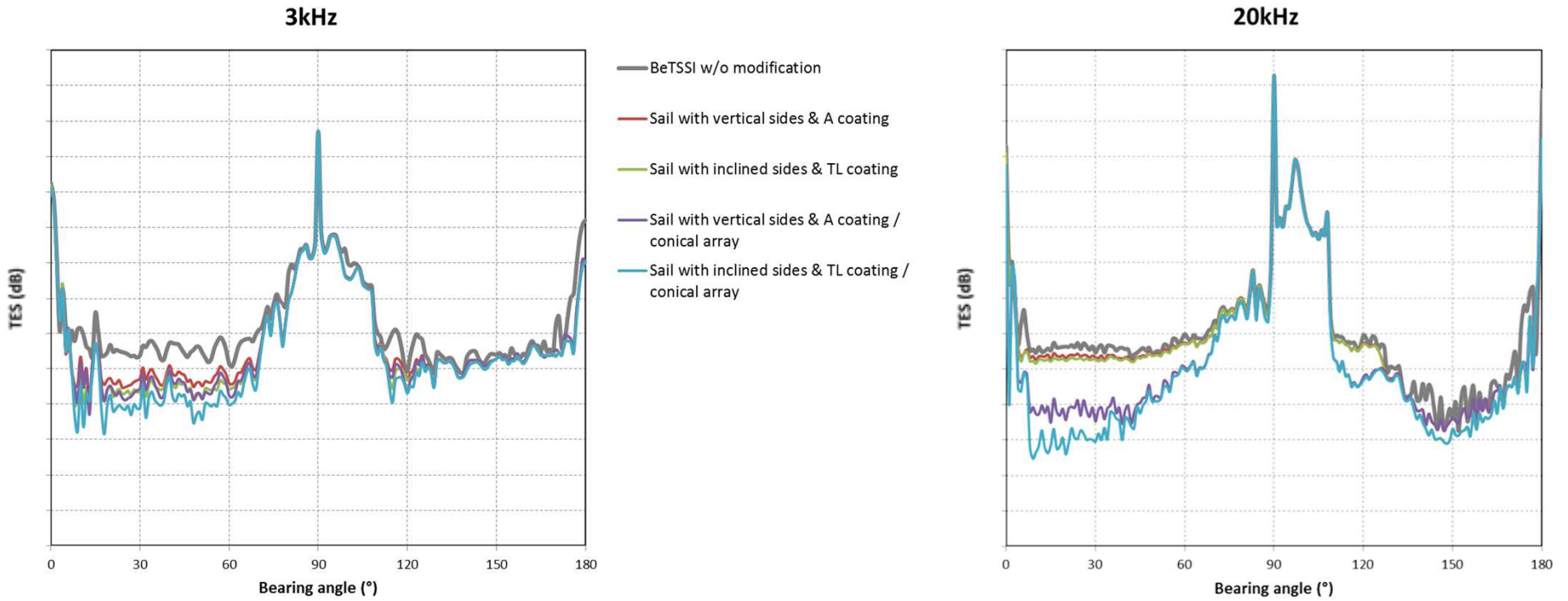
Impact on development cost!



Other solution: size reduction of the array but impact on sonar detection performance…

Initial BeTSSI → Step 1: Masts + CA

TES REDUCTION ON BETSSI MODEL
STEP 1: MASTS + CA

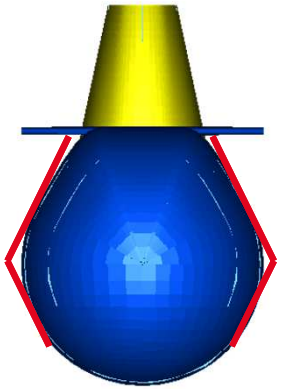


Initial BeTSSI

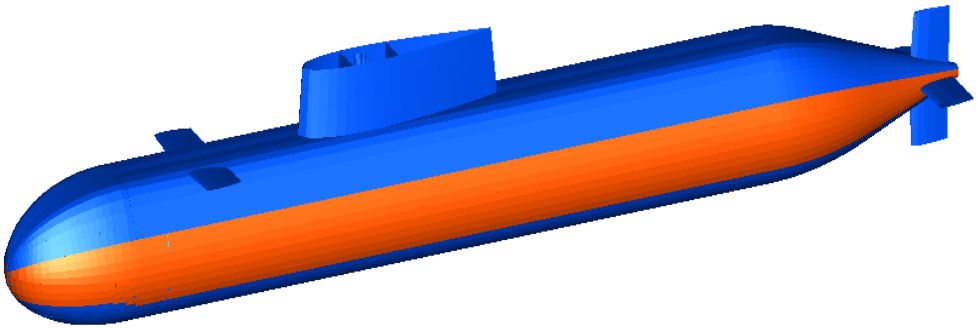
Step 1: Masts + CA

TES REDUCTION ON BETSSI MODEL
STEP 2: HULL

Application to hull (pressure hull & outer hull):



Deflection principle: flank deflectors



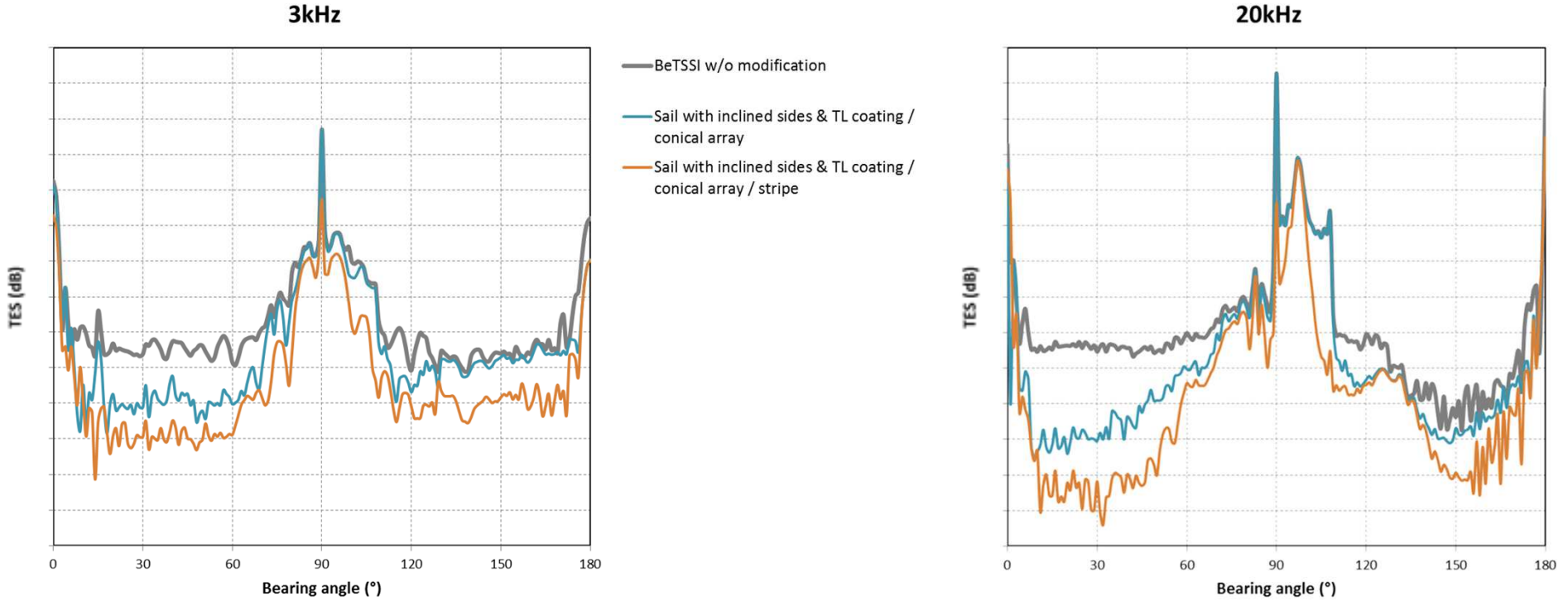
Absorption principle: anechoic stripe on the flanks (« belt »)

Impacts on:
- Hydrodynamic and Acoustic Discretion performances (flow noise)
- Drag and propulsive performance

Impacts on:
- Thermal balance
- And then hotel load balance and propulsive performance

Initial BeTSSI → Step 1: Masts + CA → Step 2: Hull

TES REDUCTION ON BETSSI MODEL
STEP 2: HULL



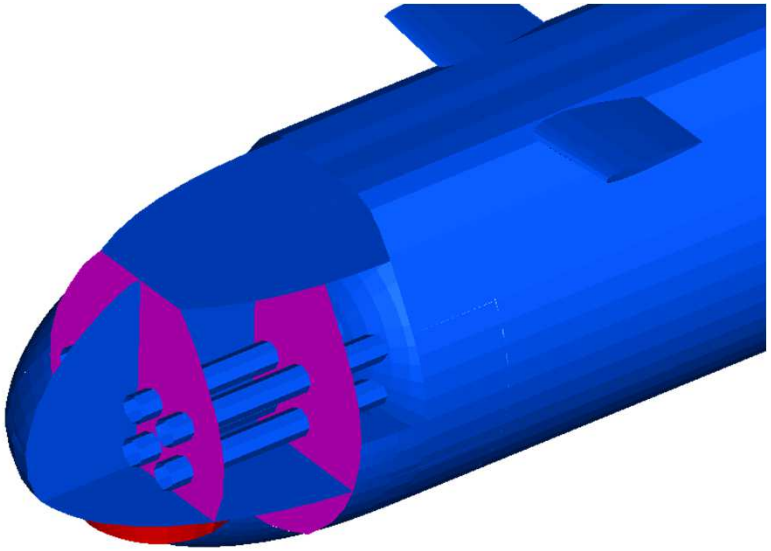
Initial BeTSSI

Step 1: Masts + CA

Step 2: Hull

TES REDUCTION ON BETSSI MODEL
STEP 3: BULKHEADS

Application to bulkheads:

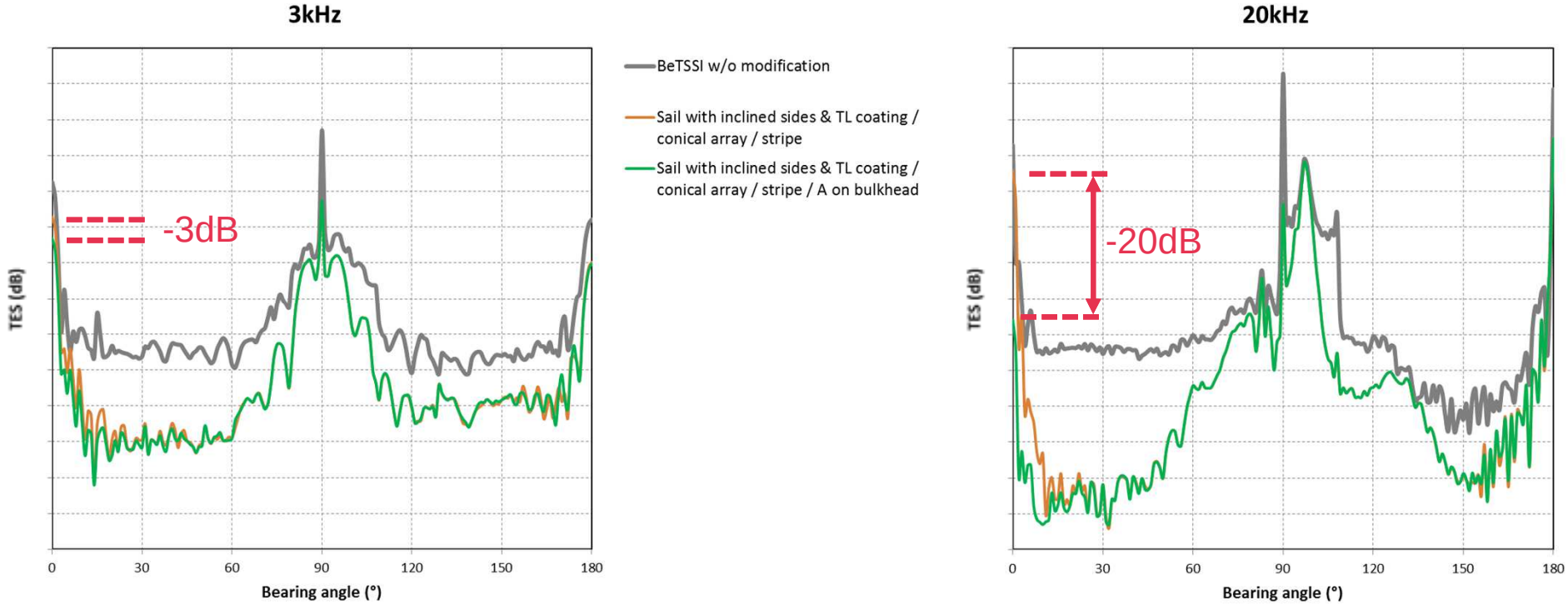


Absorption principle: anechoic coating on the front bulkhead

Reflection principle is also possible (shaping and/or inclined surface) but anechoic coating may be usefull to reduce reverberation noise and improve self noise on bow array.

Initial BeTSSI → Step 1: Masks + CA → Step 2: Hull → Step 3: Bulkheads

TES REDUCTION ON BETSSI MODEL
STEP 3: BULKHEADS

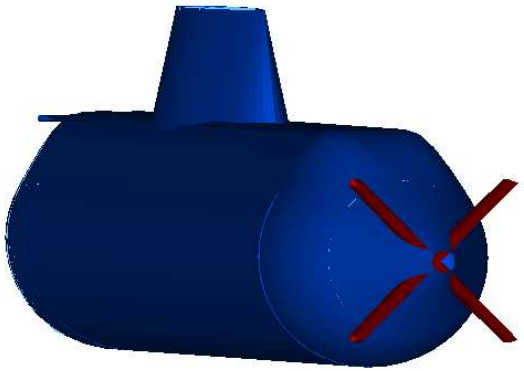


Initial BeTSSI → Step 1: Masts + CA → Step 2: Hull → Step 3: Bulkheads

TES REDUCTION ON BETSSI MODEL
STEP 4: RUDDERS

Application to rudders:

- Reflection principle

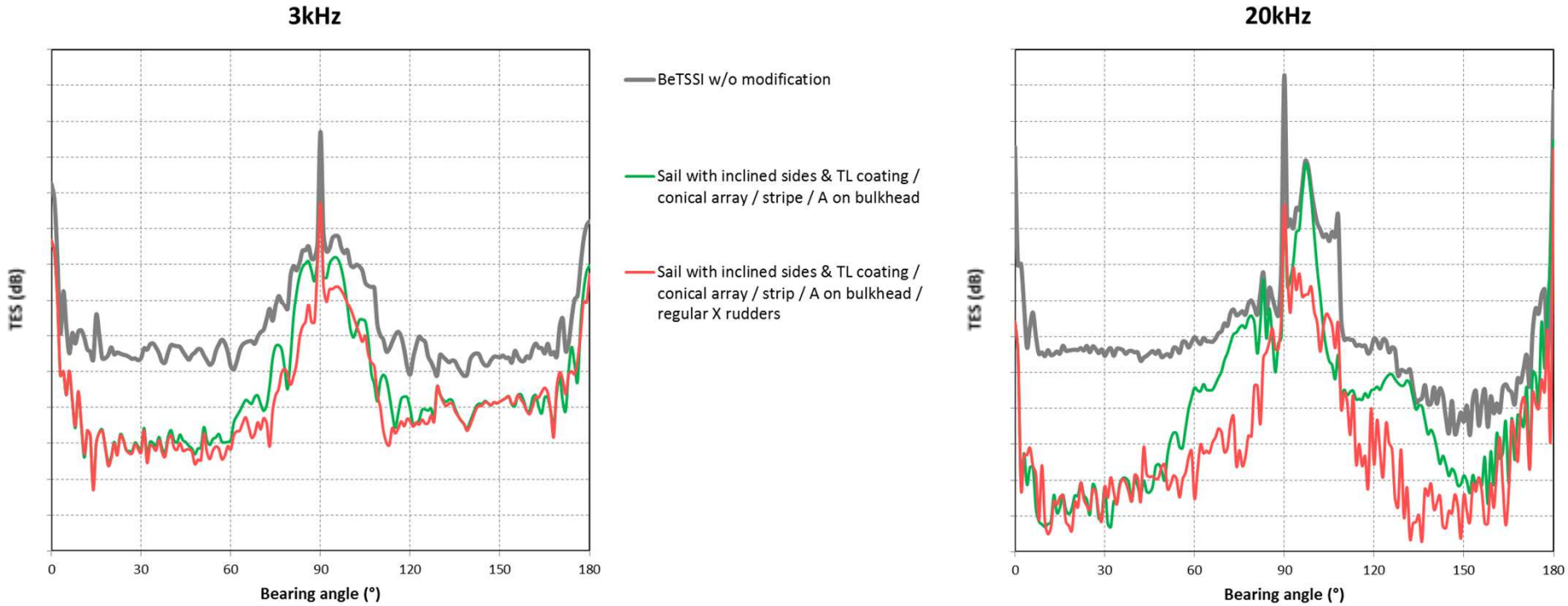


Regular X rudders

Manoeuvring performances define the hydroplane size and have therefore an impact on TES rudders contribution
➔ trade off between manoeuvring and TES performances

Initial BeTSSI → Step 1: Masts + CA | Step 2: Hull | Step 3: Bulkheads | Step 4: Rudders → Optimised BeTSSI

TES REDUCTION ON BETSSI MODEL
STEP 4: RUDDERS



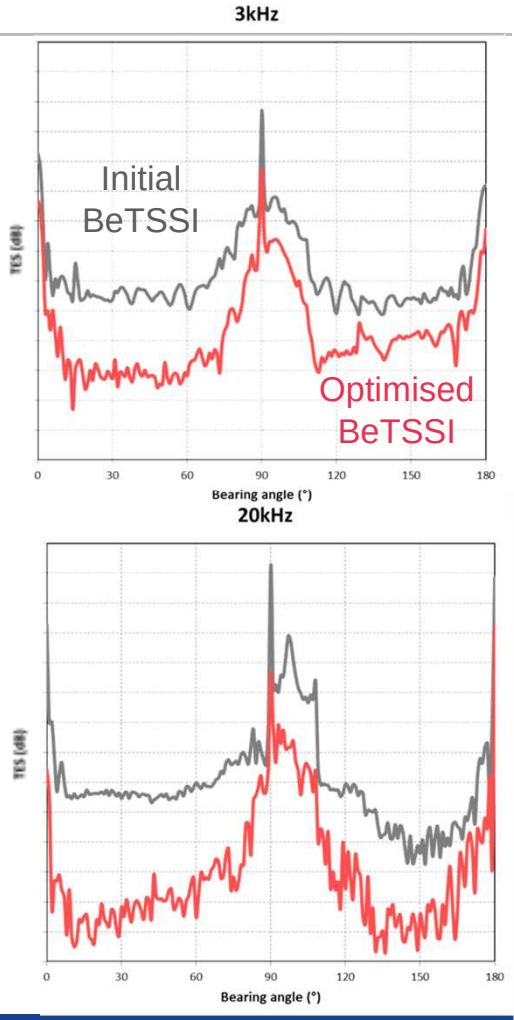
Initial BeTSSI → Step 1: Masks + CA → Step 2: Hull → Step 3: Bulkheads → Step 4: Rudders → Optimised BeTSSI

CONCLUSION

- TES optimization is possible by taking architectural options during the design process.

- But TES options must take into account impacts on:
  - Acoustic Discretion
  - Propulsive and manoeuvring performances
  - Sonar detection performance
  - Cost for development of specific technologies

- Submarine TES optimisation is an incremental process implemented by Naval Group regarding necessary trade off with whole war ship performances required to propose the best submarine compromize against threats.



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