Underwater noise due to marine machinery

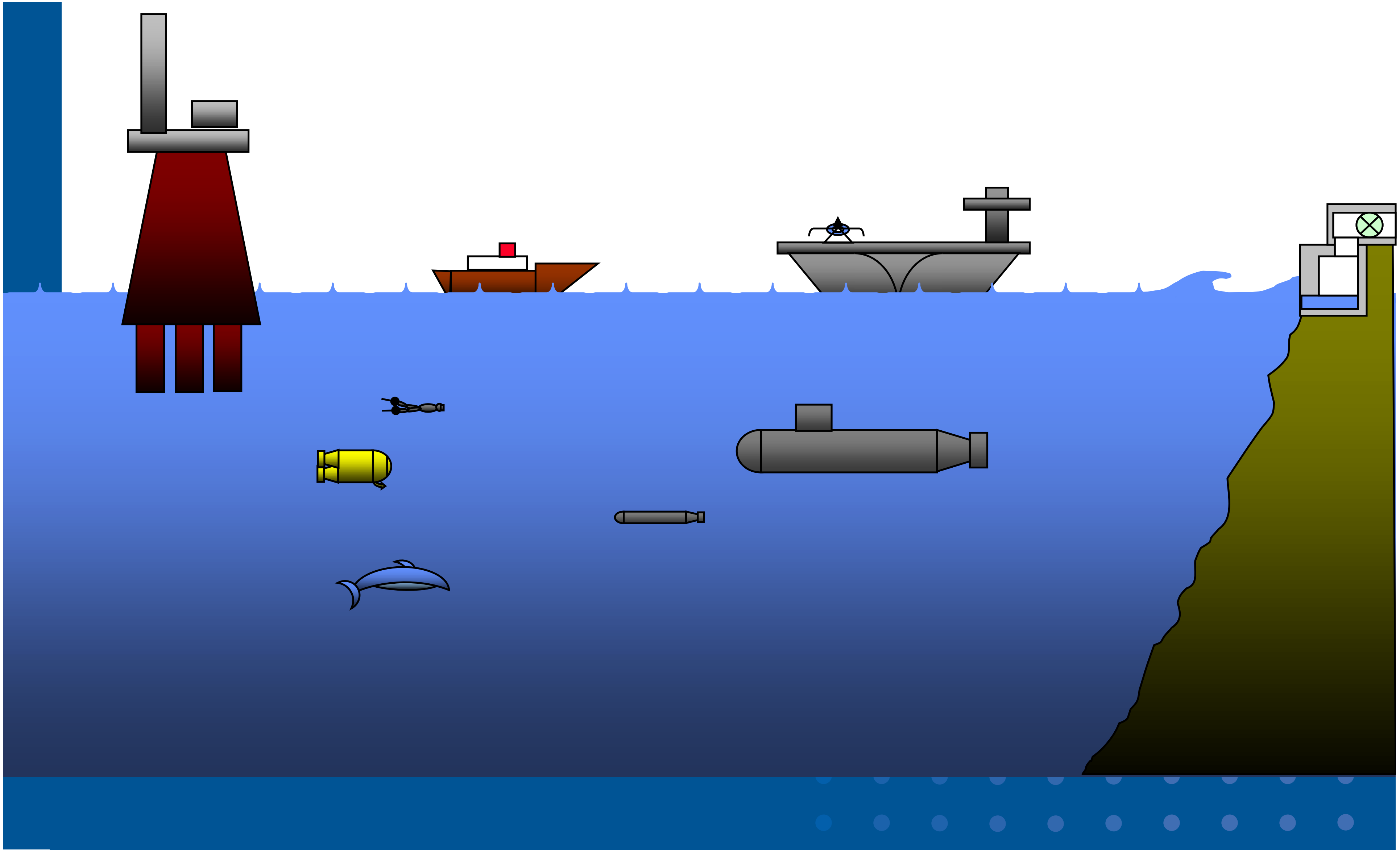
Alistair Mackinnon

Acknowledgements

Richard (Dick) Whitson – NEL

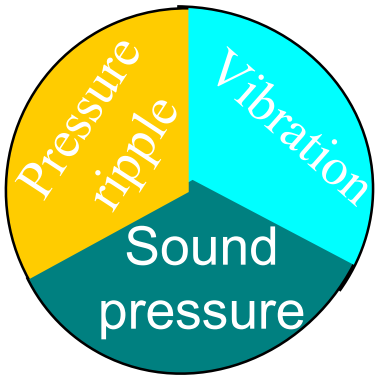
Dr Ken Tease – Wavegen

Overview

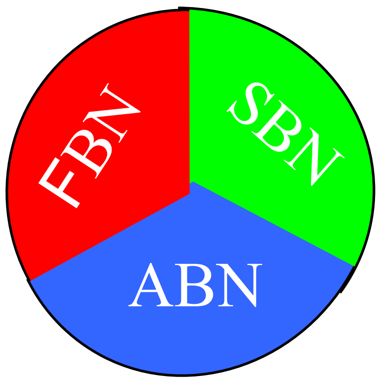


Three types of problem

- Habitation issues (people)
- Self-noise issues (equipment)
- Environment or stealth issues

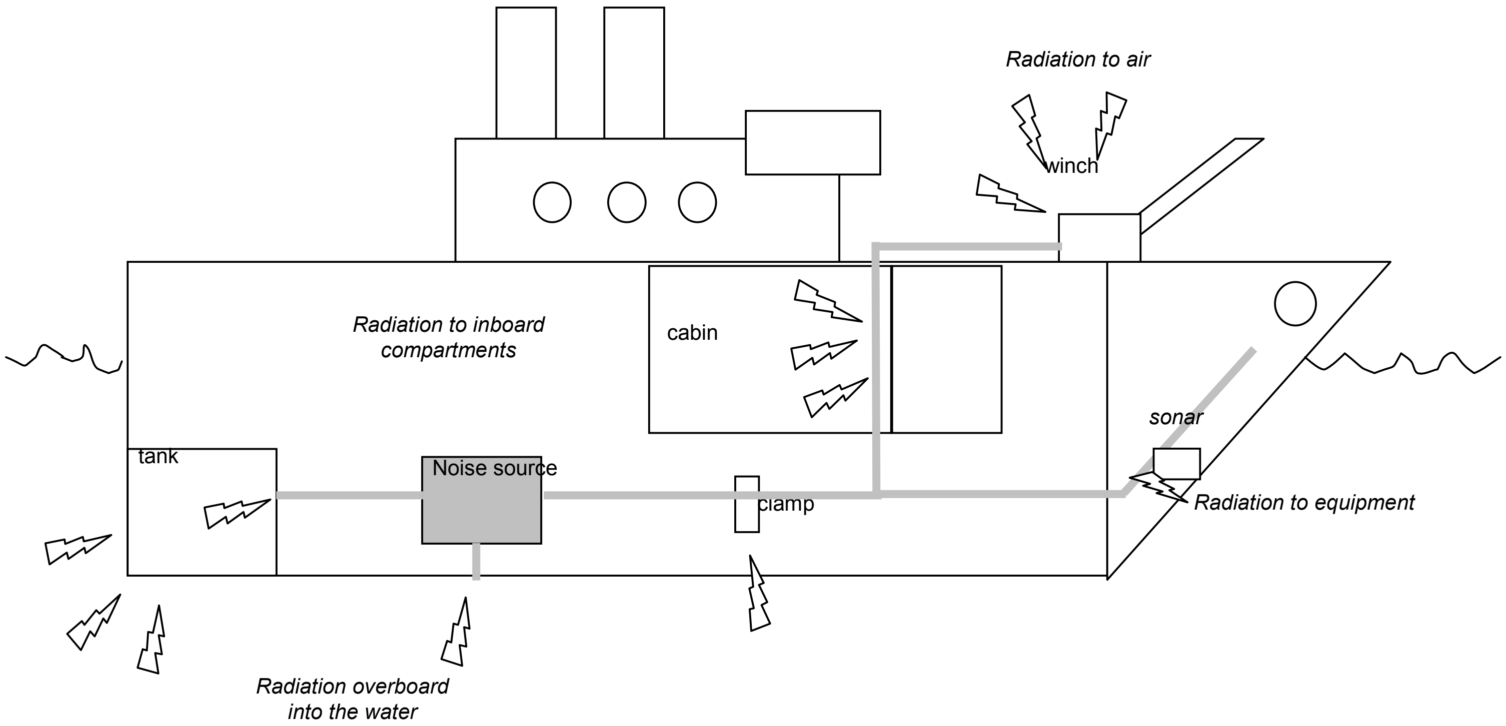


measurement



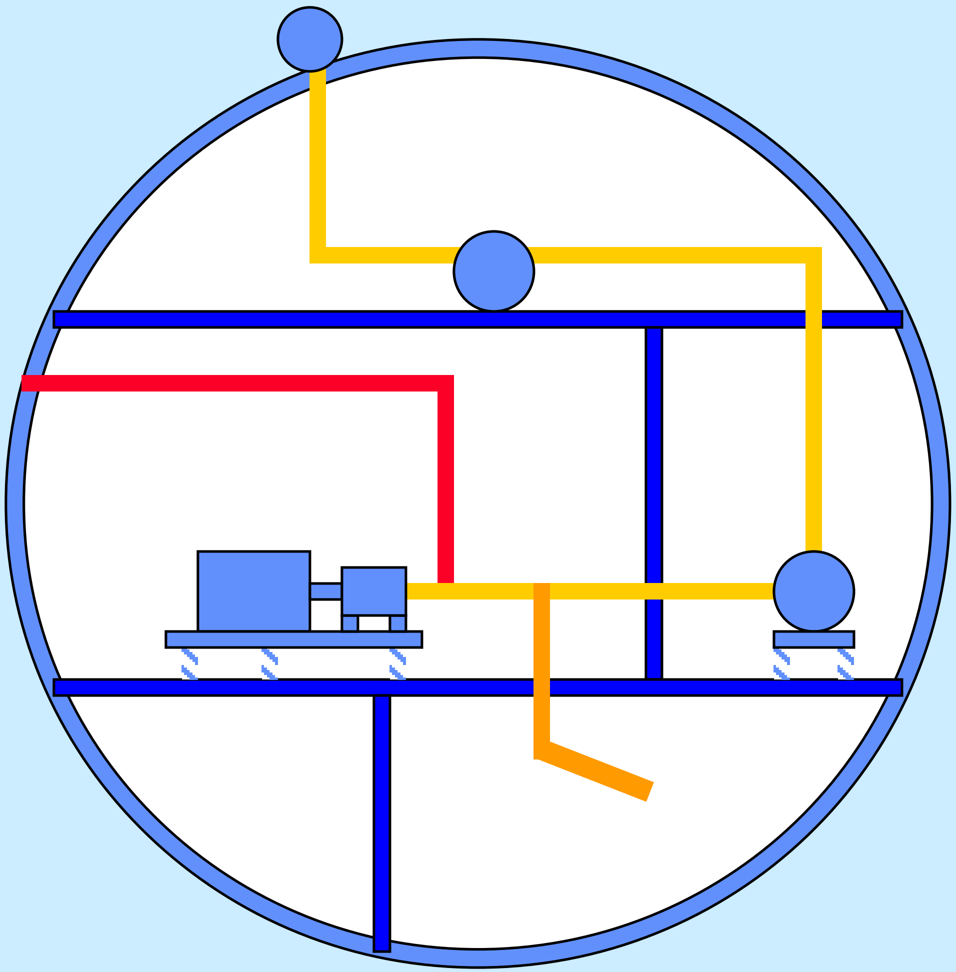
path

What is FBN

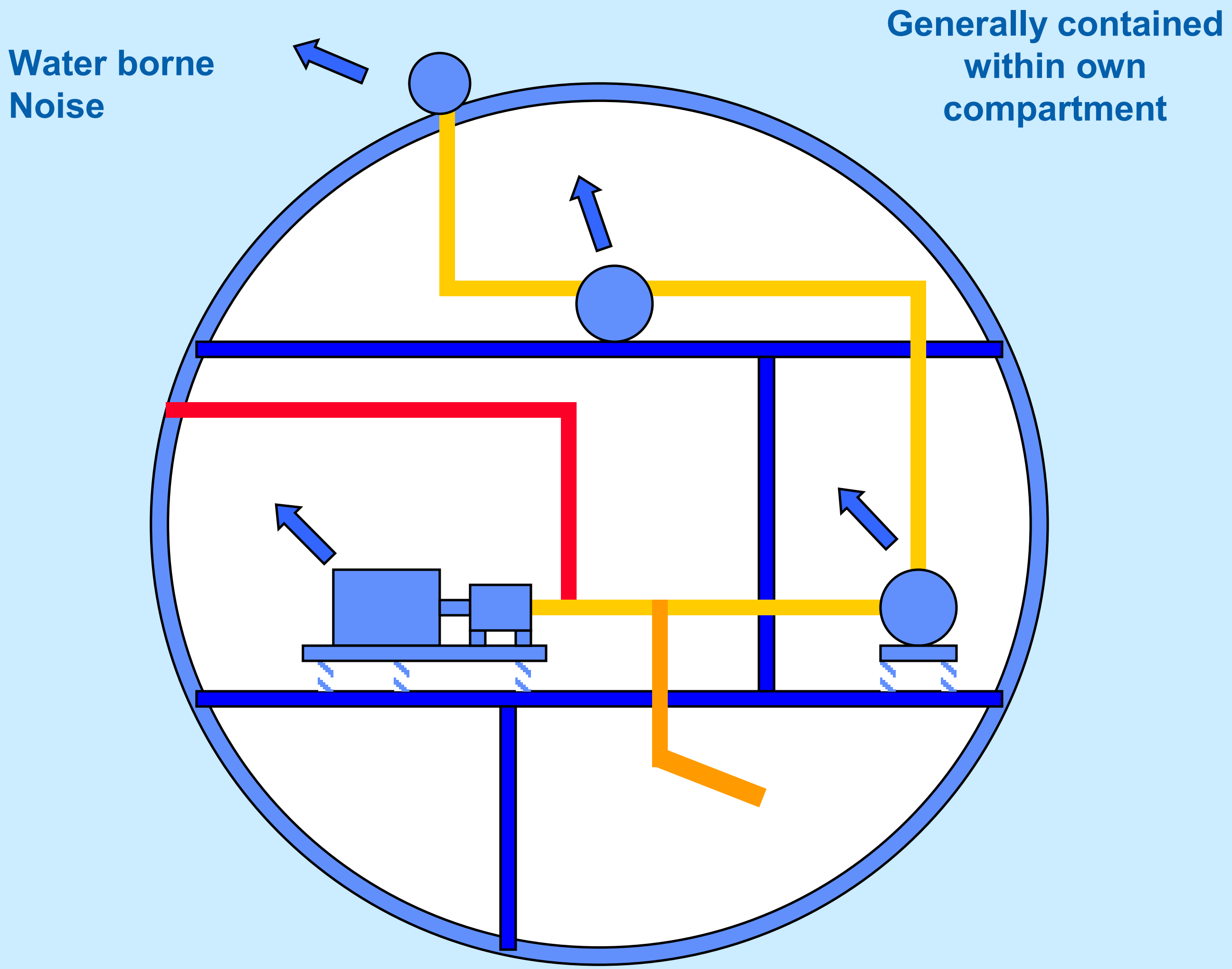


Radiation to air
winch
Radiation to inboard compartments
cabin
sonar
tank
Noise source
clamp
Radiation to equipment
Radiation overboard into the water

Machinery noise

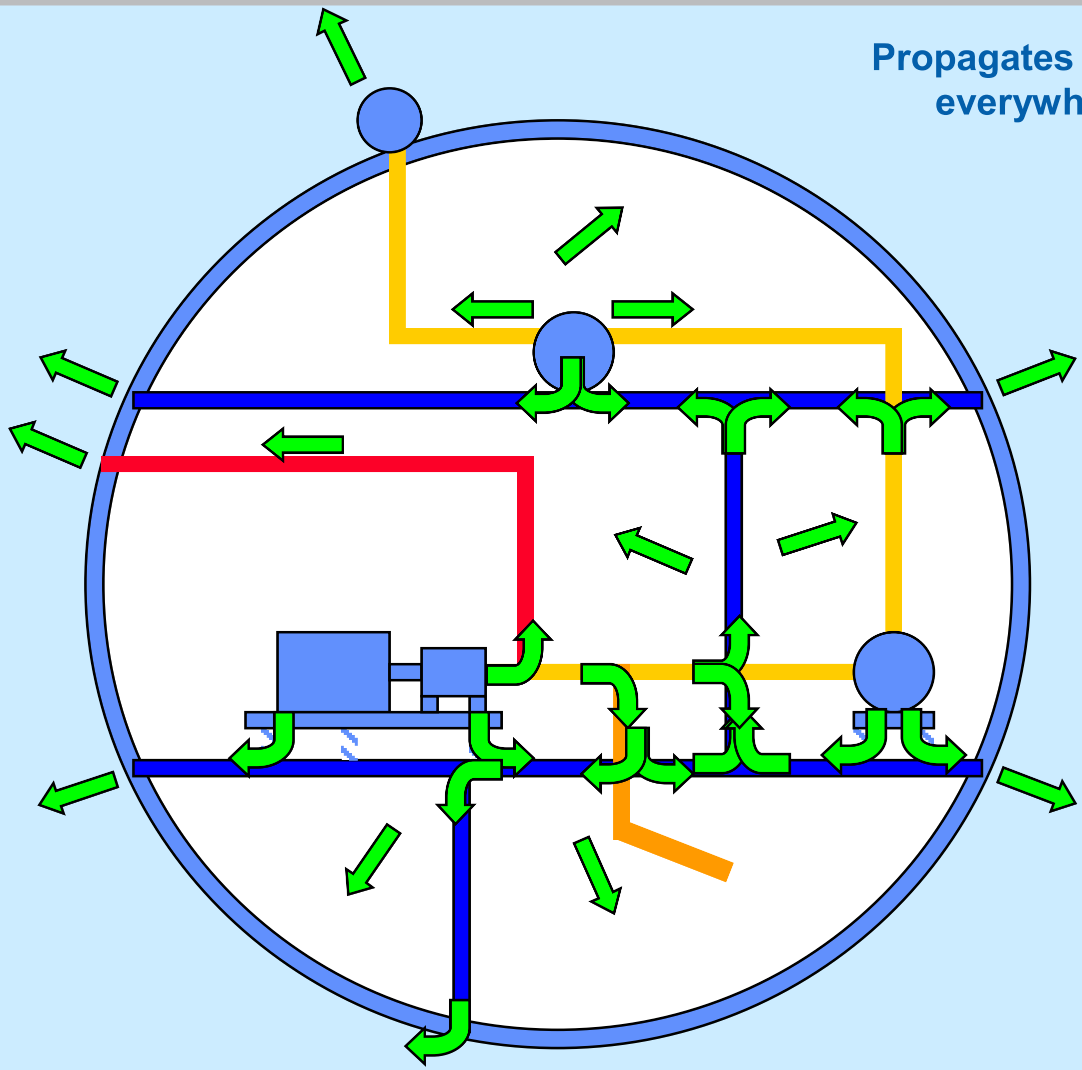


Airborne noise (ABN)

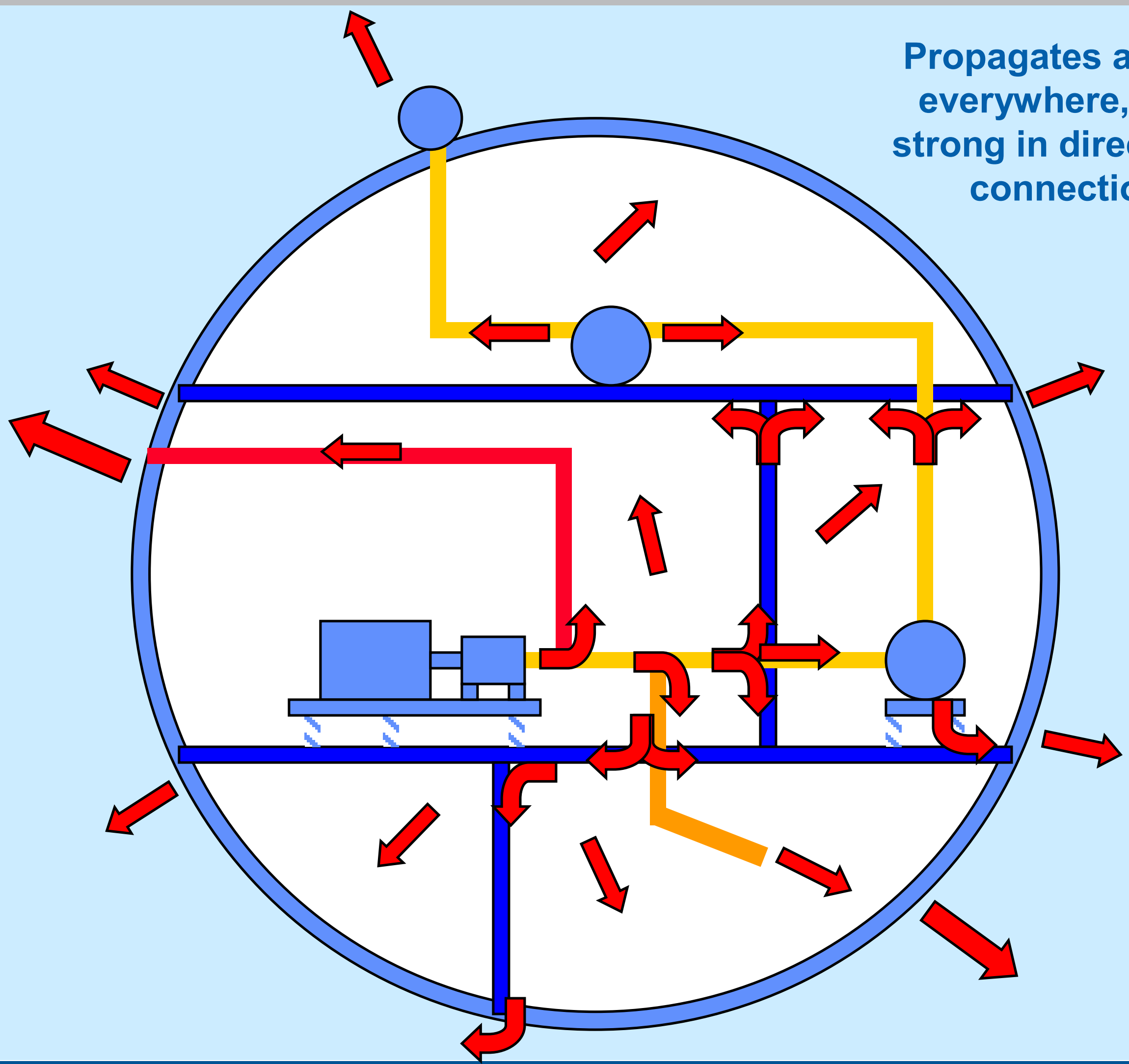


Structure borne noise (SBN)

Propagates almost everywhere

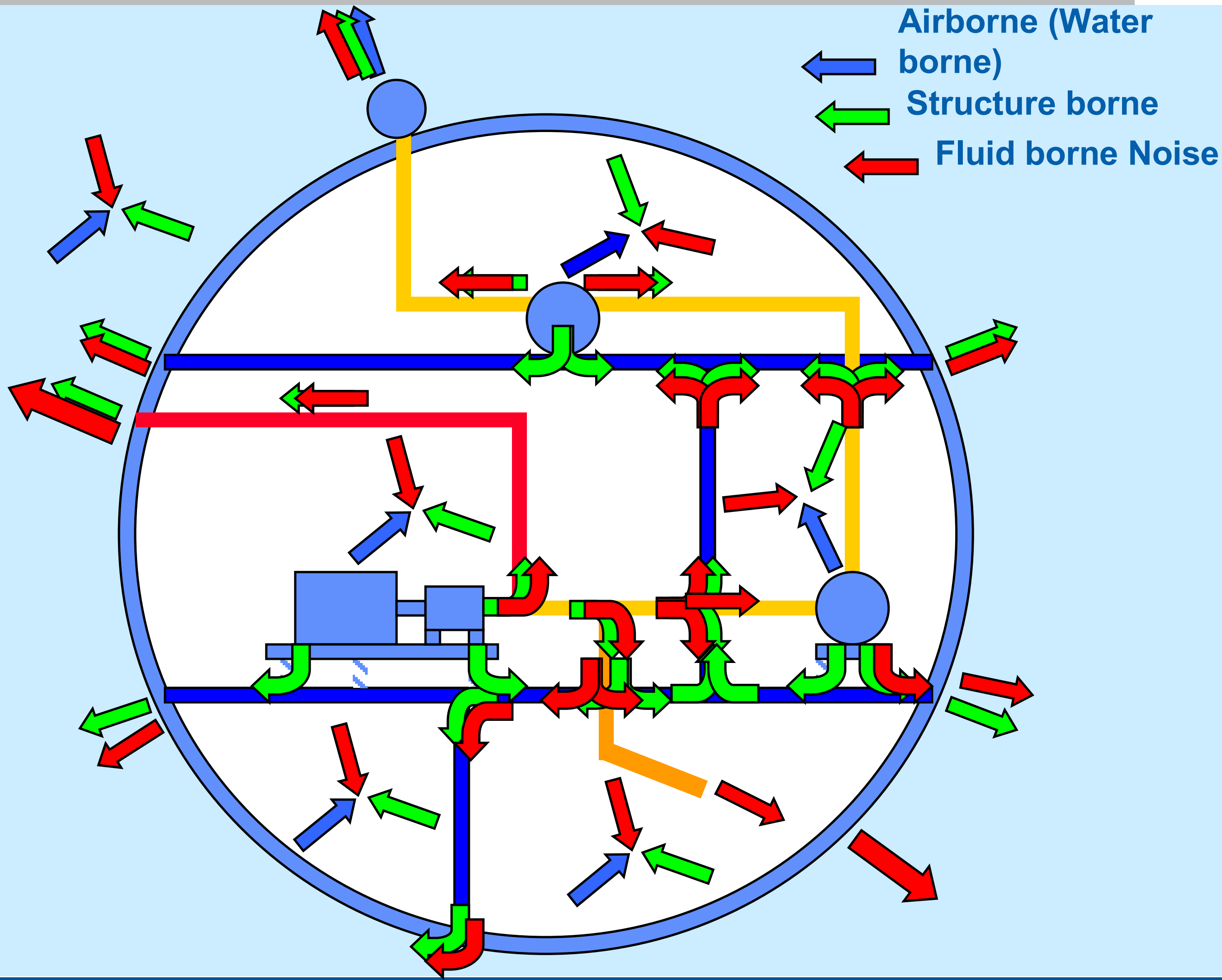


Fluid borne noise (FBN)

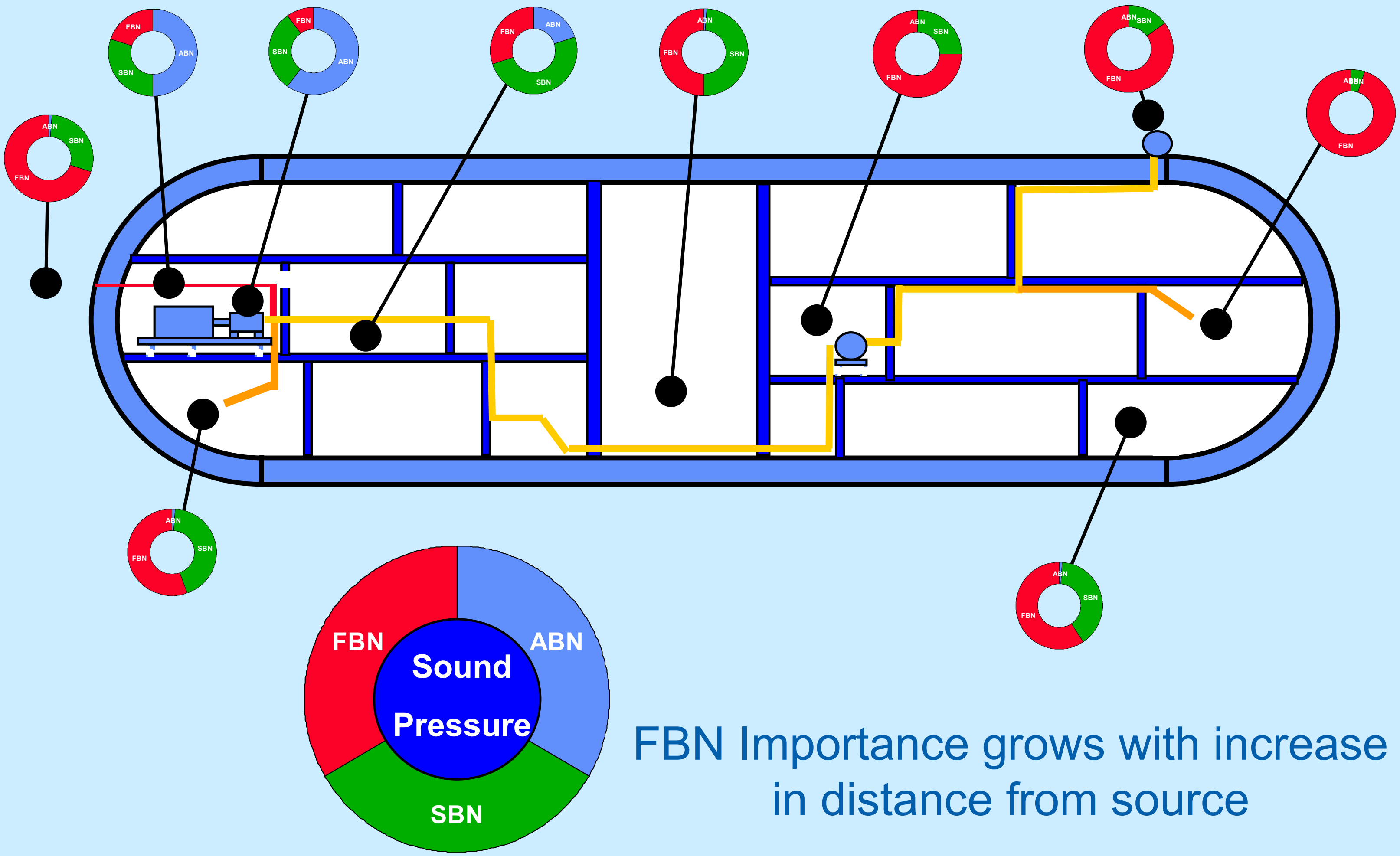


Propagates almost everywhere, very strong in direct sea-connection

Multiple paths

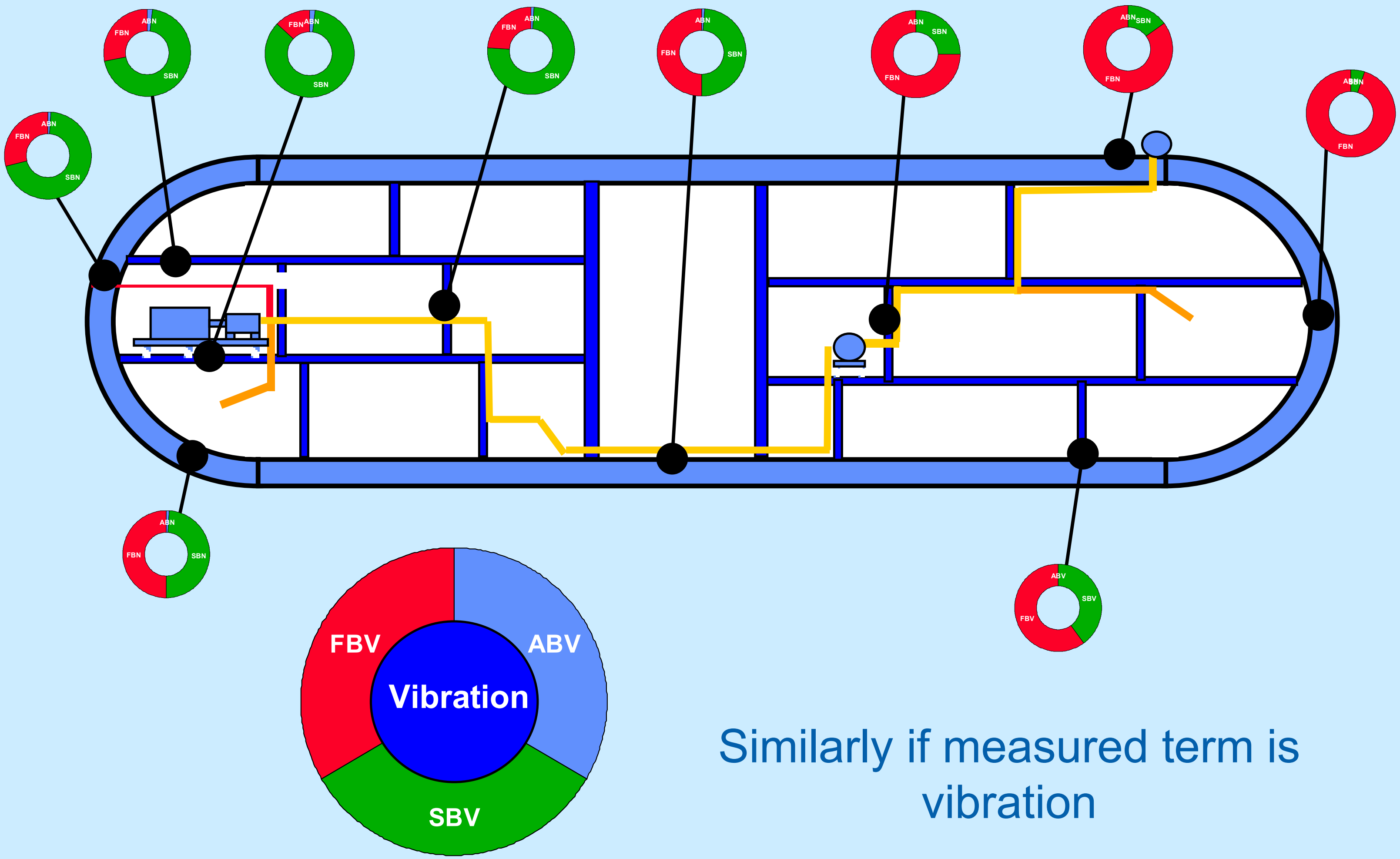


Sound pressure



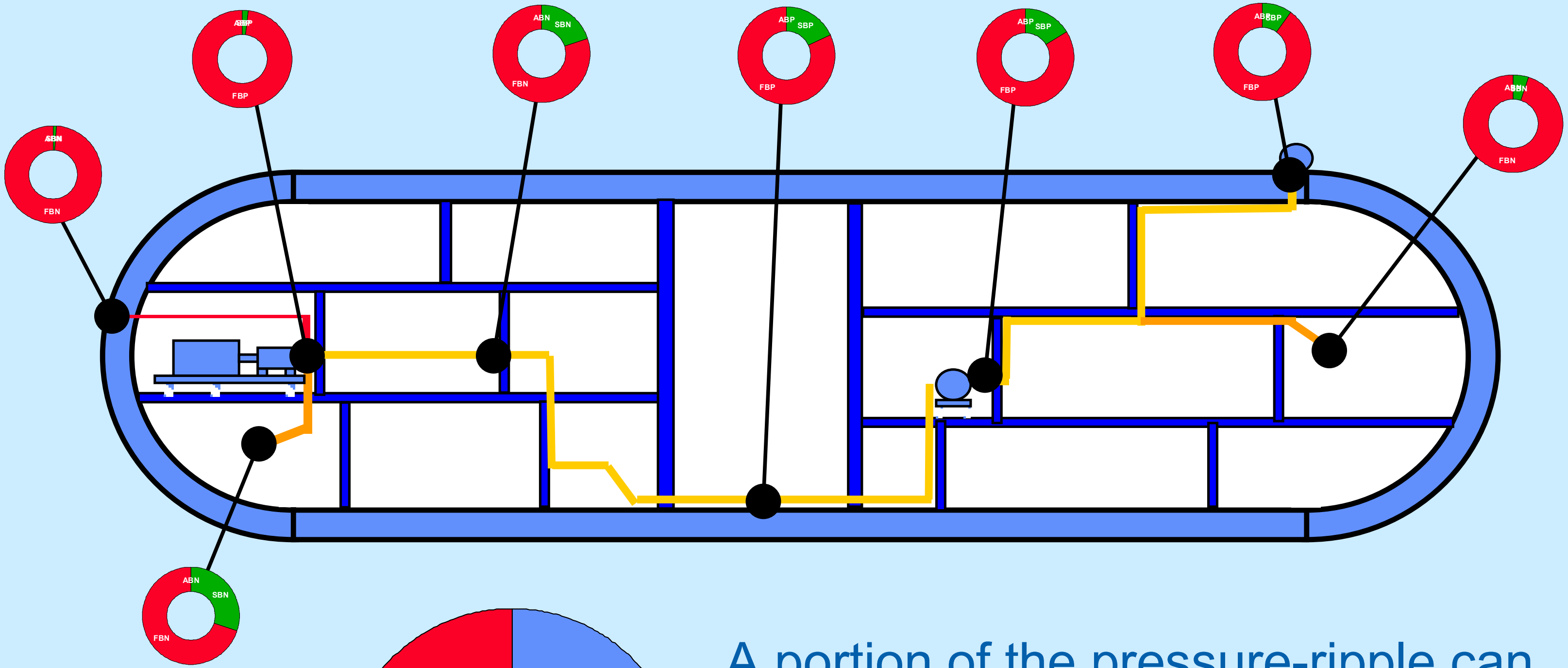
FBN Importance grows with increase in distance from source

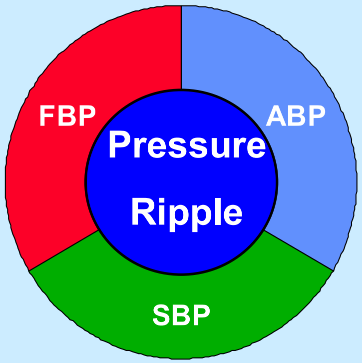
Vibration



Similarly if measured term is vibration

Pressure ripple



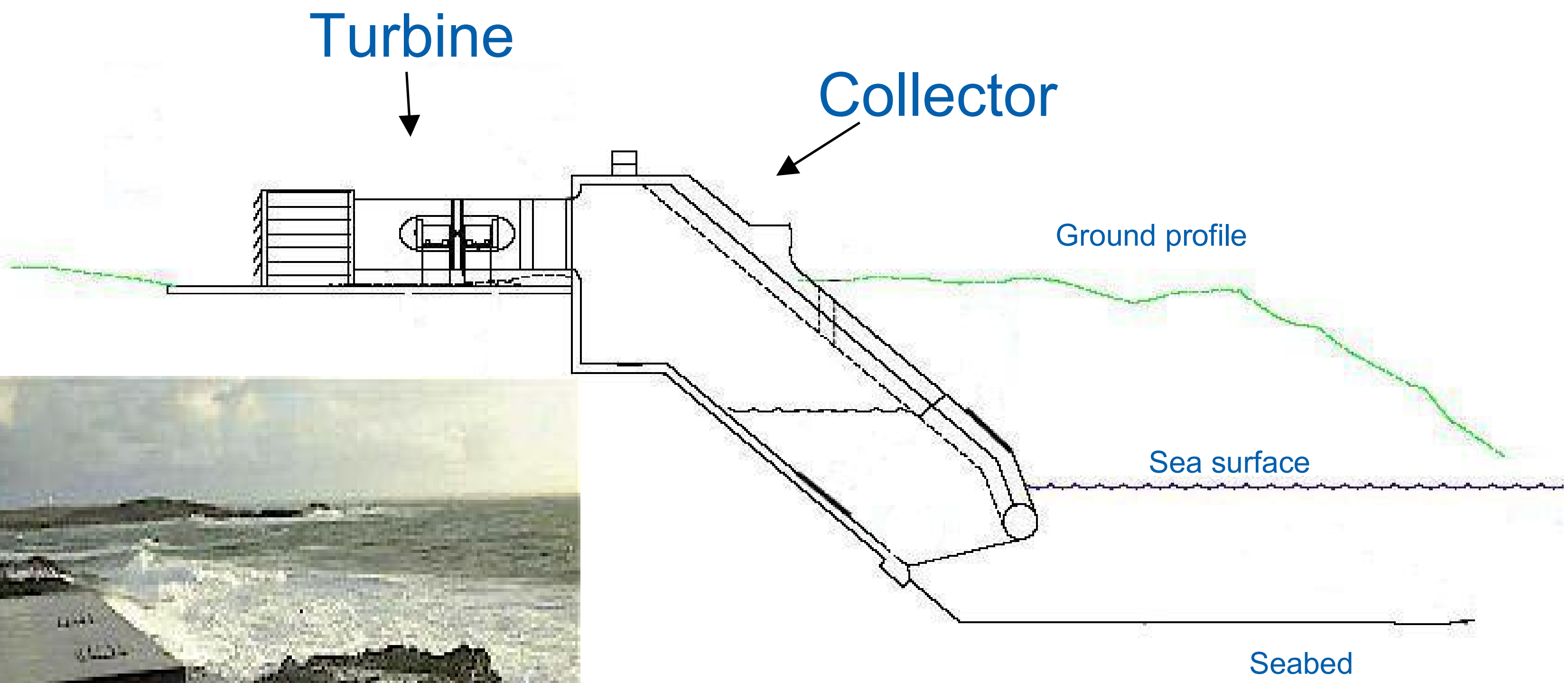


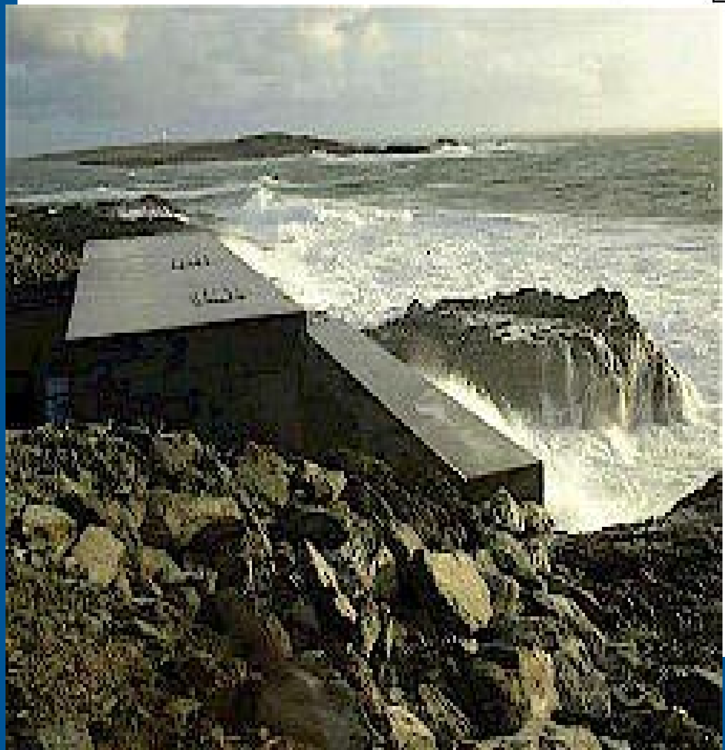
A portion of the pressure-ripple can be due to fluid-structure-fluid energy exchange. This can be important downstream of attenuators and valves

Machinery noise

- In-pipe pressure-ripple measurement and measurement of FBN
- Fluidborne noise attenuators
- Non-invasive measurement using PVDF
- Pump Noise
- Valve Noise

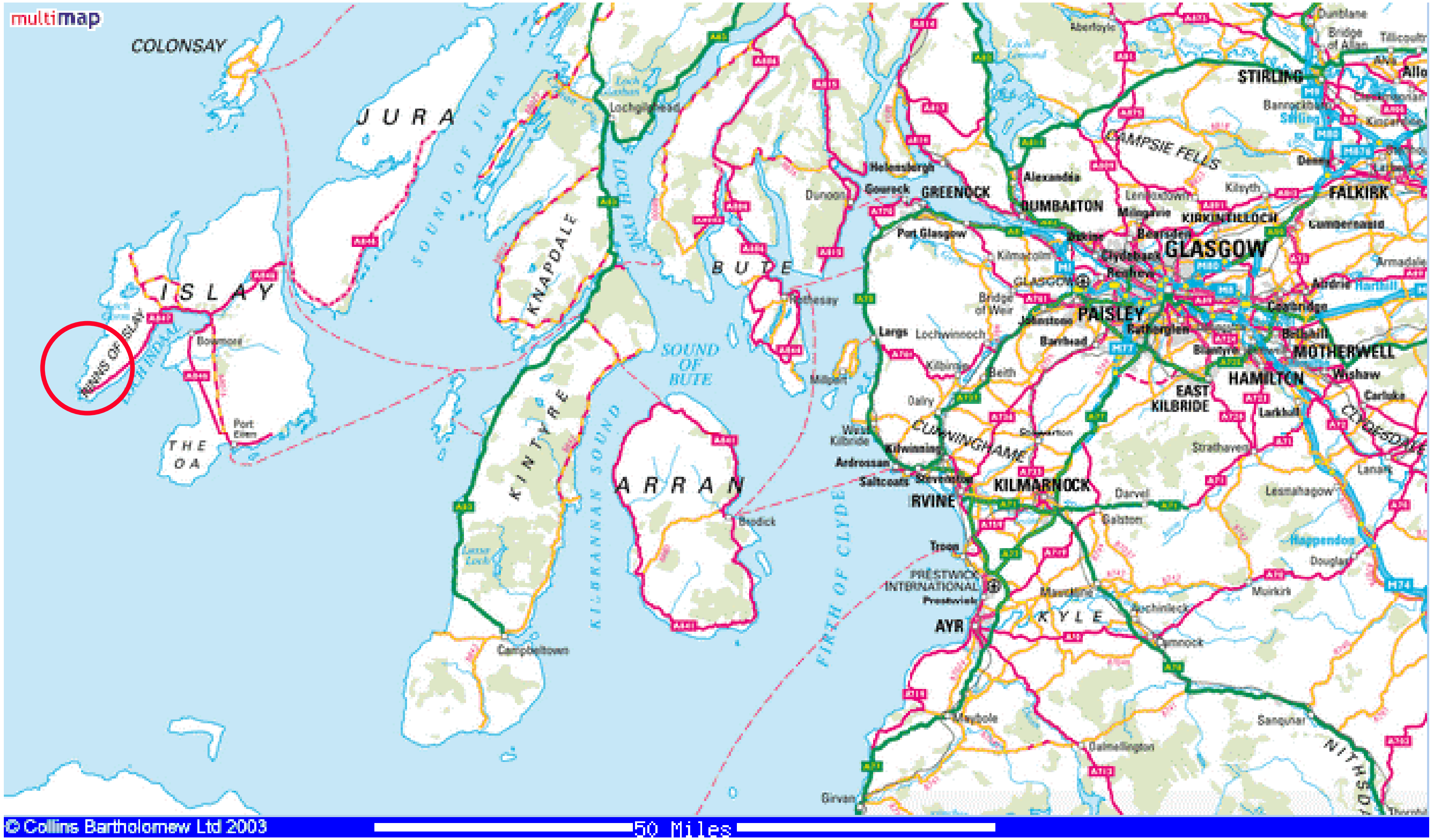
WAVEGEN 'LIMPET'





- Land Integrated Marine Power Extraction Turbine

Location



multimap
COLONSAY
JURA
ISLAY
RHINNS OF ISLAY
Bowmore
Port Ellen
THE OA
SOUND OF JURA
KNAPDALE
KINTYRE
Campbeltown
LOCH FYNE
BUTE
Rothesay
SOUND OF BUTE
ARRAN
Brodick
KILBRANNAN SOUND
FIRTH OF CLYDE
Dunoon
Helensburgh
Gourock
GREENOCK
Port Glasgow
DUMBARTON
Alexandria
GLASGOW
PAISLEY
Clydebank
Renfrew
Largs
Ardrossan
Saltcoats
Stevenston
IRVINE
KILMARNOCK
Troon
PRESTWICK INTERNATIONAL
Prestwick
AYR
KYLE
Maybole
Girvan
STIRLING
FALKIRK
KIRKINTILLOCH
CAMPSIE FELLS
Cumbernauld
MOTHERWELL
HAMILTON
EAST KILBRIDE
Wishaw
Lanark
Carluke
Strathaven
Lesmahagow
Douglas
Muirkirk
Cumnock
Sanquhar
Dalmellington
CUNNINGHAME
Dalry
Beith
Barrhead
Coatbridge
Airdrie
Dunblane
Bridge of Allan
Alloa
Denny
Kilsyth
Lennoxtown
Milngavie
Bearsden
Lochgilphead
Aberfoyle
Millport
© Collins Bartholomew Ltd 2003
50 Miles

Objectives

Assess challenges in measurement of:

- Audible noise
- Ground borne vibration
- Underwater noise

Working towards a simple means of quantifying Emission and Immission levels from shore based wave power plant

Measurement approach

<u>Measure</u> source strength (Emission)

- Variation with available power (sea-state) & generated power

<u>Measure</u> background (ambient) noise at source & receiver

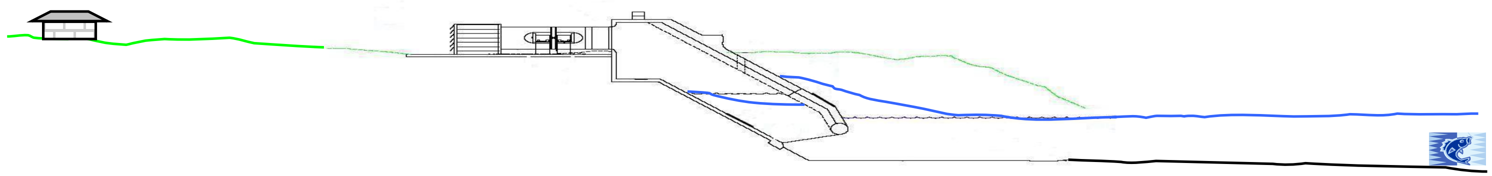
- Variation with available power (sea-state)

<u>Predict</u> levels at a distance (Immission)

- Hemisherical propagation for audible noise (ü) and vibration (?)
- Hemicylindrical propagation from inlet mouth for underwater noise

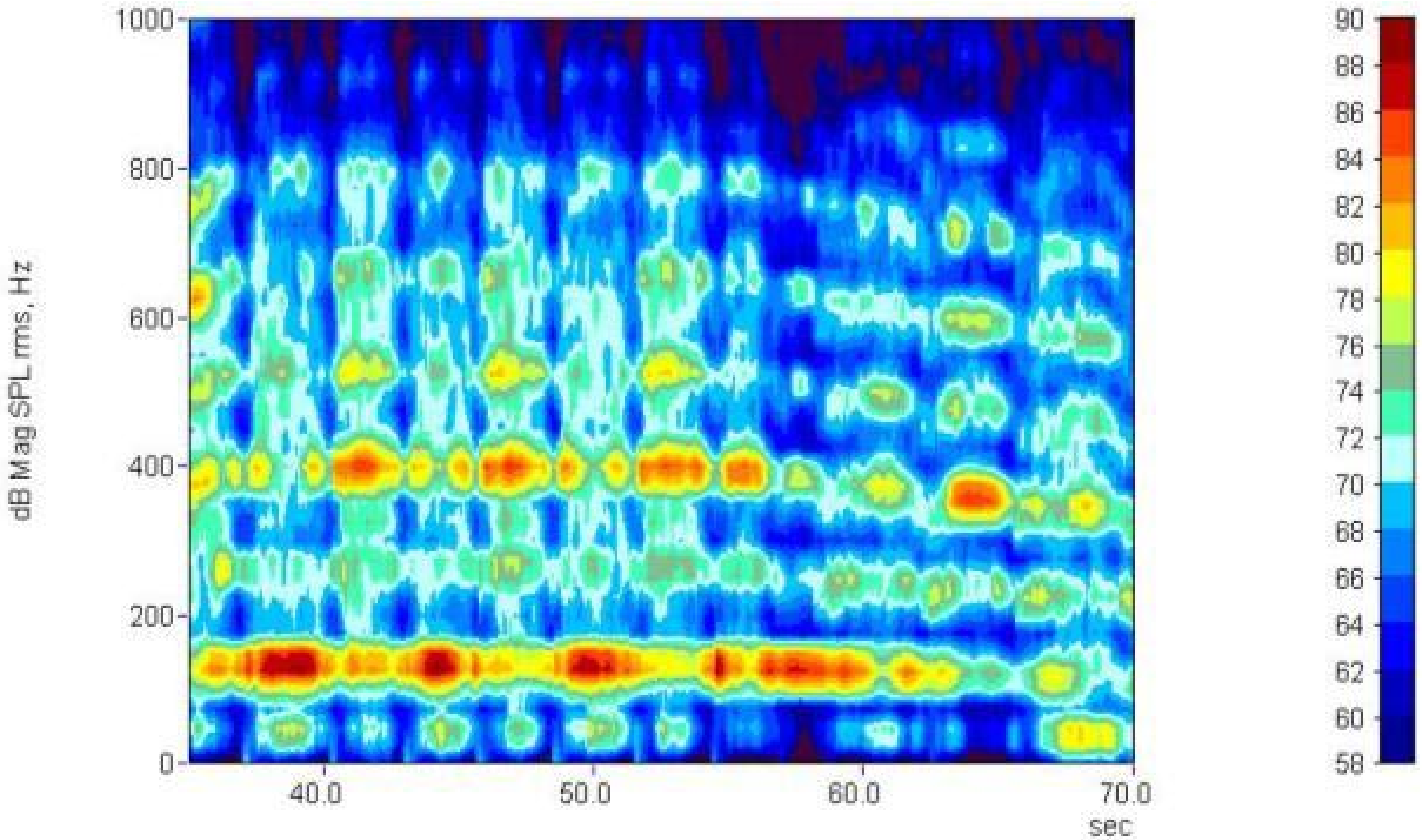
<u>Compare</u> against local background (ambient) noise & targets (?)

<u>Quote</u> at reference positions (e.g. plant boundary, shore edge, gulley mouth)

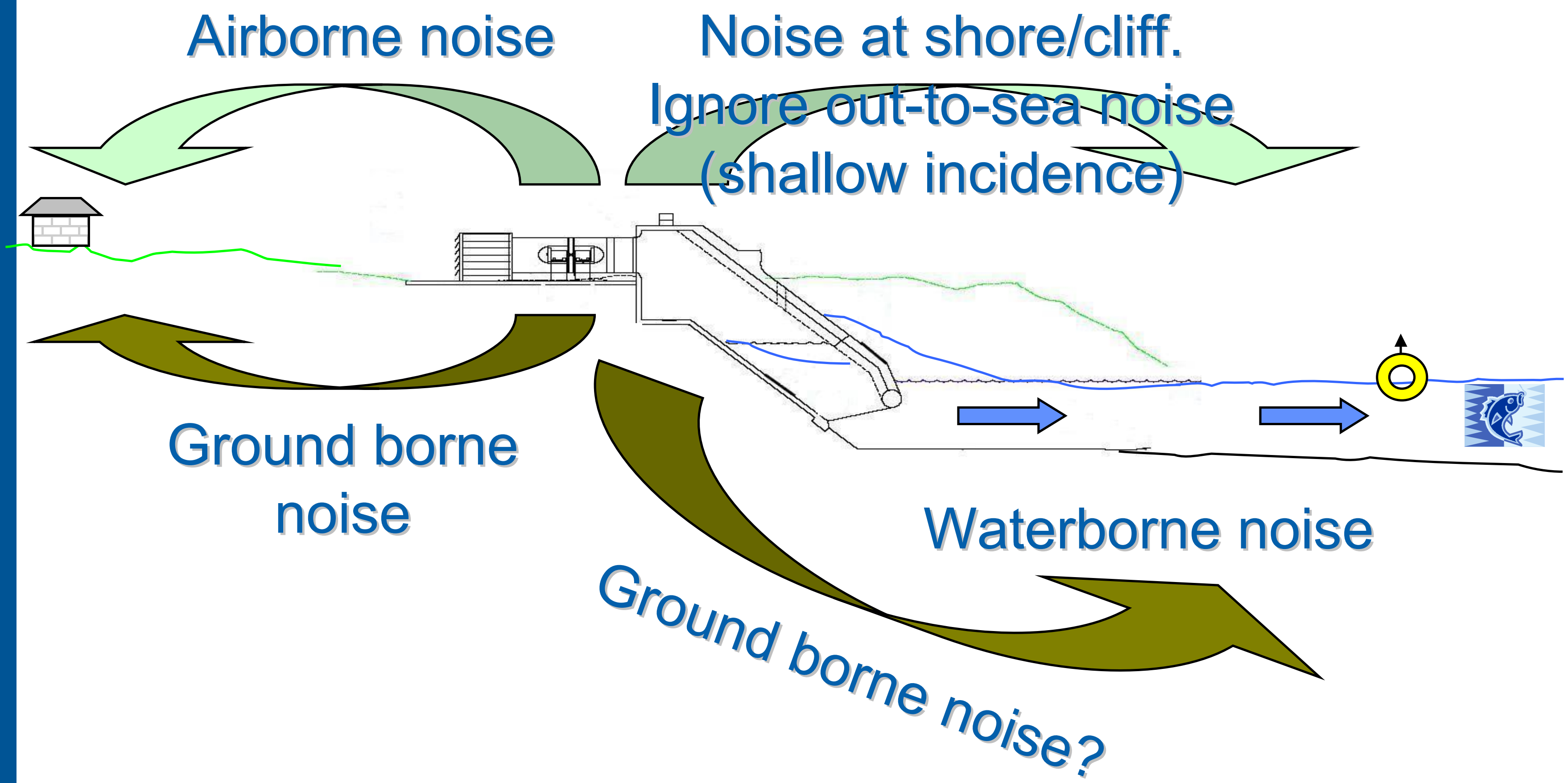


Random cyclic variation

Audible noise variation with time 3 m from bell-mouth



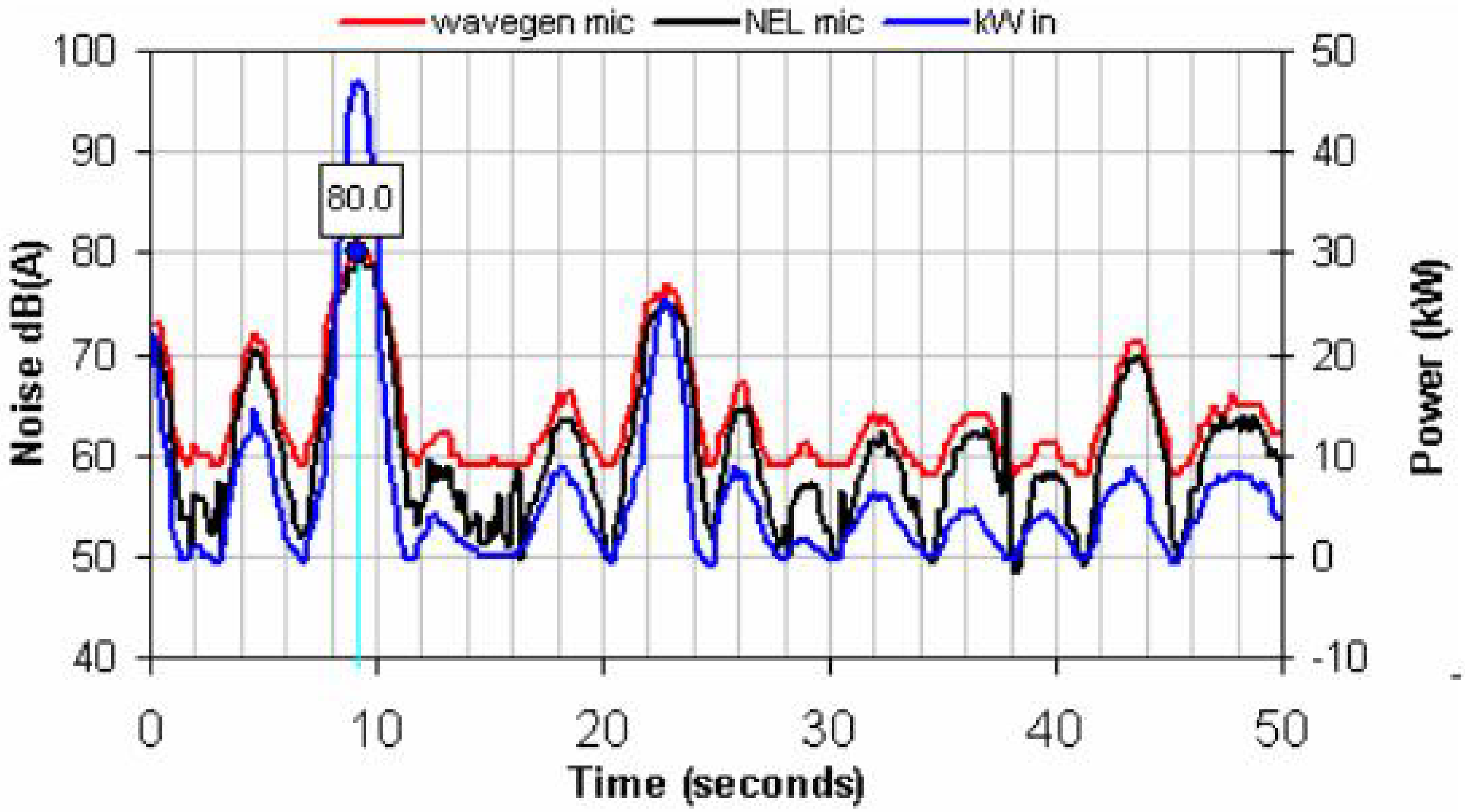
LIMPET Device



Audible noise & wave power

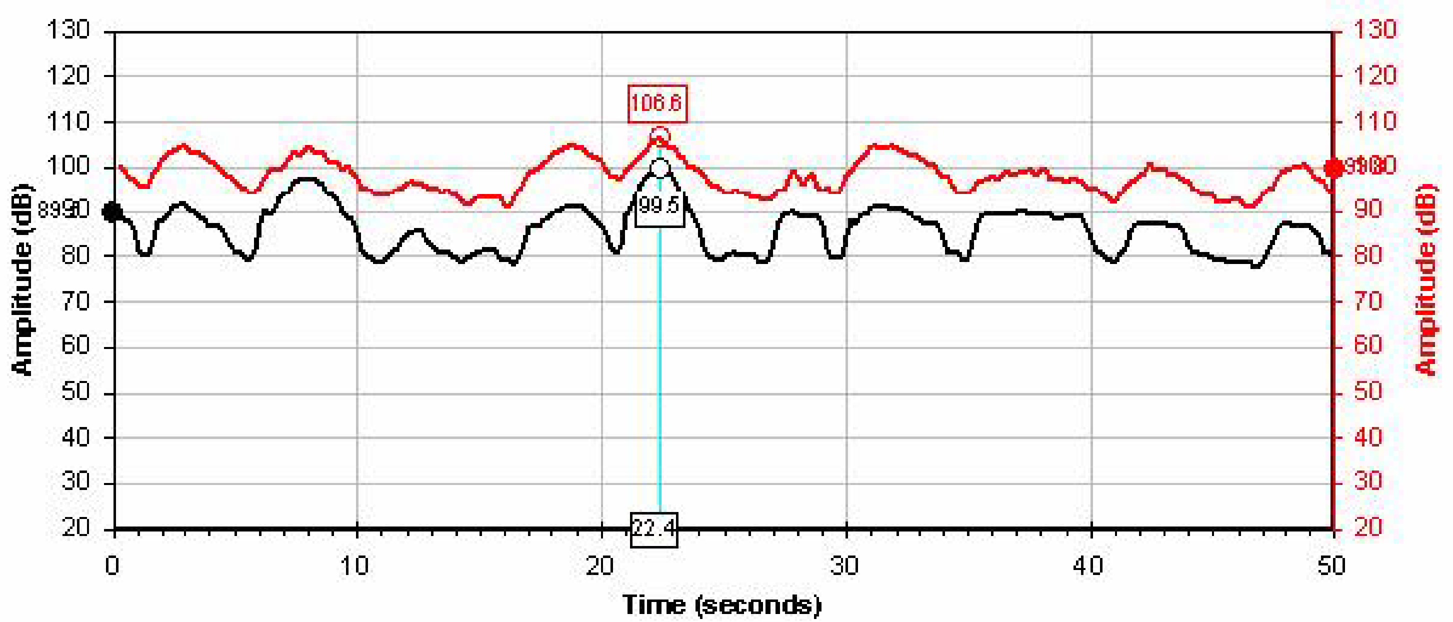
Use audible noise at a fixed position as a 'reference' position

Plot variation against a 'roving' measurement position



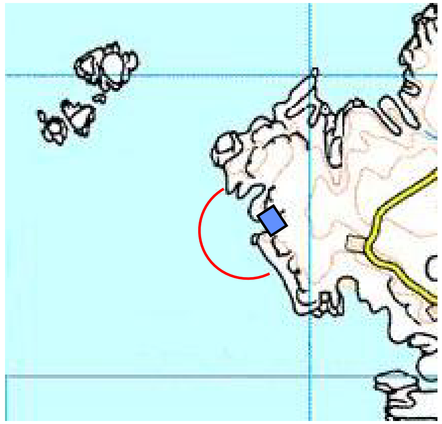
Audible noise inside & out

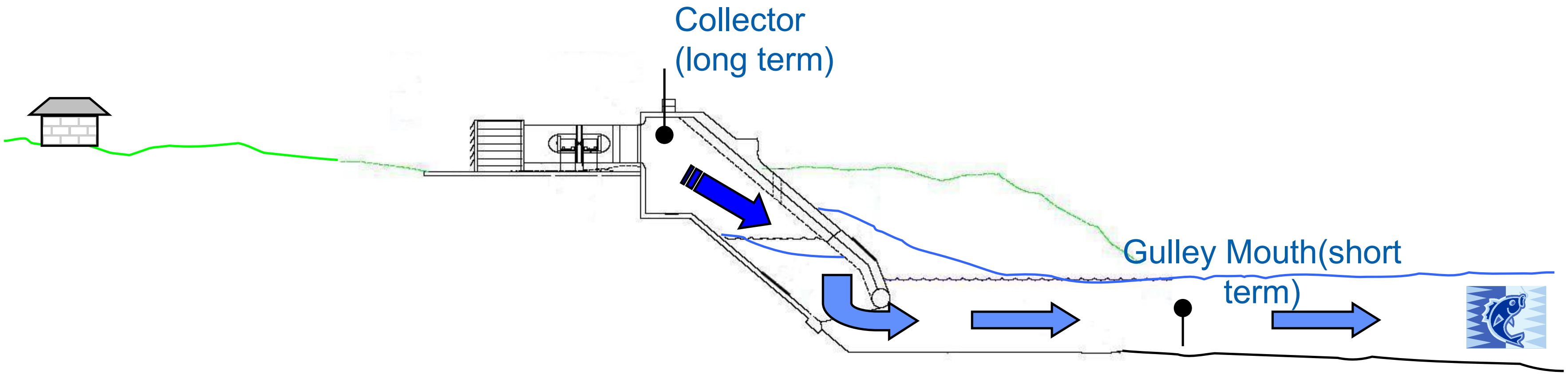
- Plan to use a hydrophone inside the collector air space for long-term monitoring due to deployment and reliability issues
- Good agreement between Audible noise at reference position and hydrophone inside collector



- Agreement between hydrophone at gulley mouth and inside collector still to be shown

Measurement underwater





Waterborne noise

Measurement – underwater

Emission (generated noise)

Machinery Noise

- Lp in collector (Hydrophone)
- Lp at gulley mouth (Hydrophone)
- Show relationship between two (possibly $L_{p,m} = L_{p,c} + 6dB$)
- Derive Ls, Source Level dB(/Hz?) re 1µPa at 1m

Sea-slap/wave

- Different from background ?

  Assume it is not ?

Immission (received noise)

Based on simple hemi-cylinder propagation calculation to 100m from gulley mouth:

$L_{p,100m} = L_{p,m} - 13.5$ dB

(based on an average depth of say 15m)

Or, simply based on Lp,m at gulley mouth

Thresholds underwater

Health of Fauna **Nuisance to Fauna** **Significant Biological Impact**

- Actual discomfort, damage or death
- Interference with the use of hearing for feeding or communication reducing viability
- Disturbance of breeding behaviours reducing viability

Emission & Immission concepts are still relevant:

- Emission is given by Source Level, L_s, in dB(/Hz?) re 1μPa at 1m
- Immission is received Sound Level in dB(/Hz?) re 1μPa
- **SPECTRAL DENSITY ? Not 1/3rd OCTAVE: Big difference at high f. Need to take care when source consists of tones.**

MarLIN Benchmark (for "received" pressure level i.e. Immission):

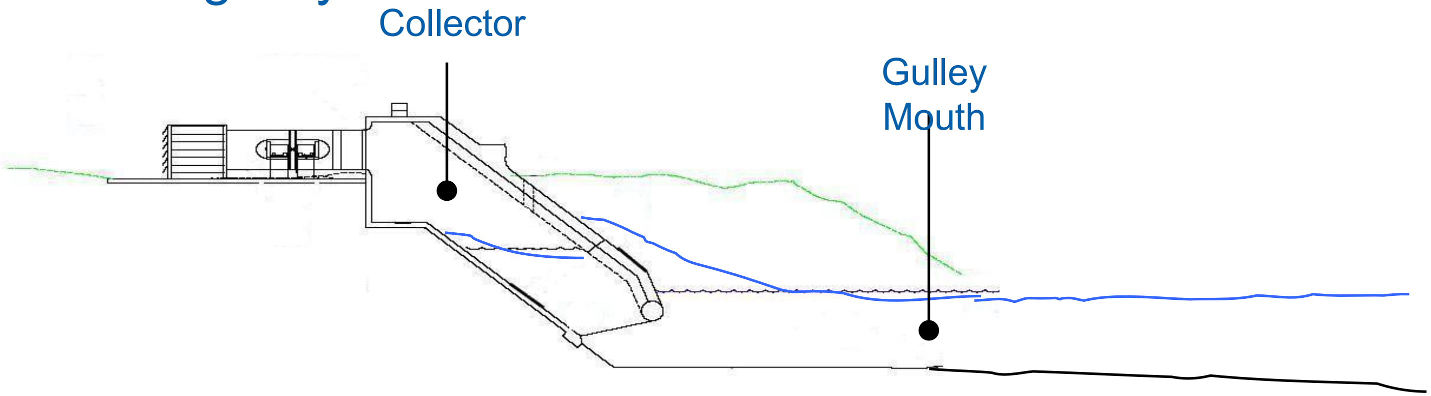
- 130 dB(/Hz?) re 1μPa at 100m, 45-7100 Hz

ICES levels (for radiated noise of fisheries research vessels) 1Hz-100kHz, 11 knots

- 135 dB/Hz re 1μPa at 1m at 10Hz, 130 dB/Hz at 1kHz, 93dB/Hz at 50 kHz

Simplified target?

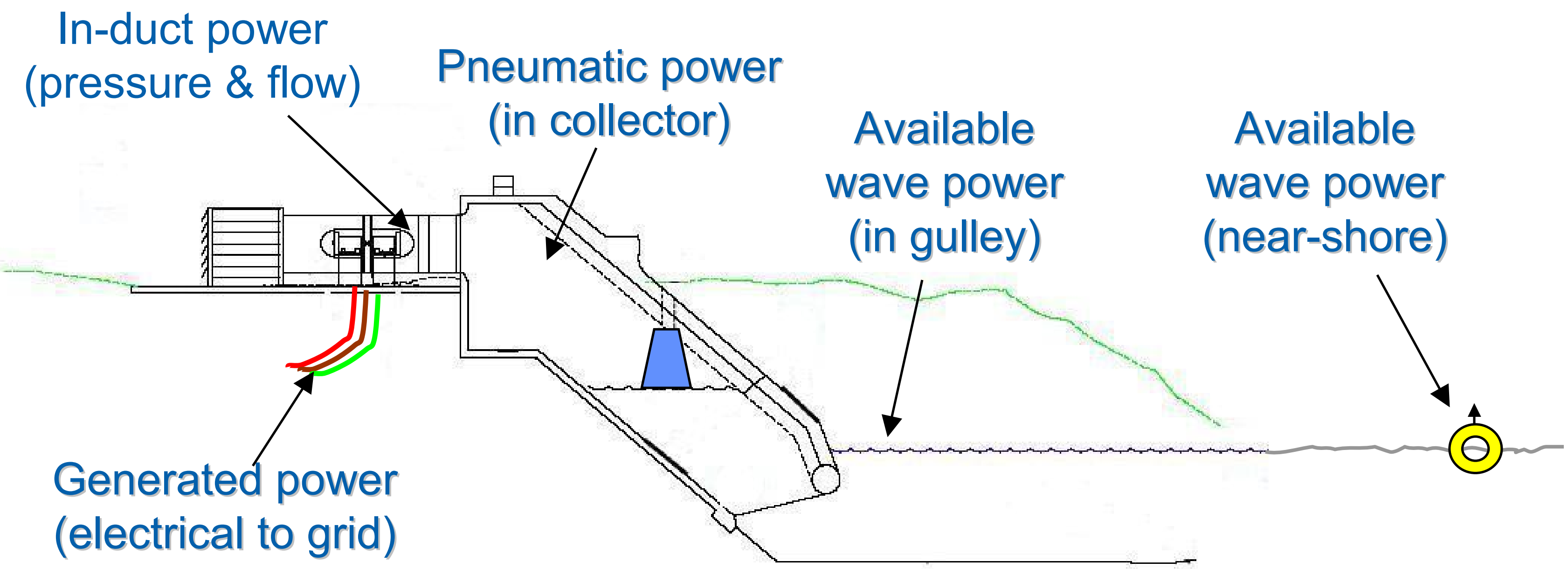
- Take 130 dB re 1µPa as the underwater target at the mouth
- This equates to 130-32 = 98 dB re 20µPa as the target for the sound pressure level in the Collector. This assumes the collector area = the gulley mouth inlet area



- 32 dB correction calculated from simple acoustic theory for an air-water interface (6dB) plus change to dB re 20 µPa
- Note: These are band levels; if these are in dB/Hz then a significant increase in level will be allowed if 1/3rd Octaves are used. Safest route is to use 98 dB re 20 µPa as the band total

Measurement - Power

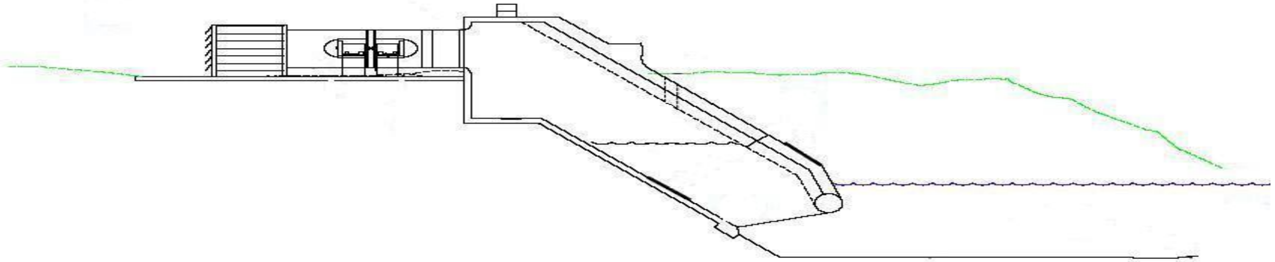
Four (or 5?) forms of power



•Audible noise, vibration and underwater noise all need to be compared against some form of background versus an independent parameter

•Available wave power (near-shore or gulley?) is obvious choice since background noise and vibration will be most closely related to this

Overview – Long Term



- Standardise on 10 minute (?) averages of:
  - ❑Audible noise, underwater noise and vibration at reference positions
  - ❑Generated power and turbine speed
  - ❑Sea-state, available wave power, wind speed & direction
  - ❑Background noise (audible, vibration and underwater) with turbine stopped
- 10 min averages can be made up from numbers of shorter averages
- L_{eq}, L_{10} and L_{90} with occasional 1/3rd Octave spectra may be of benefit
- This will allow plotting of parameter against available power