“Optimising airgun signatures for different seismic environments and predicting effects on marine life."

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Overview

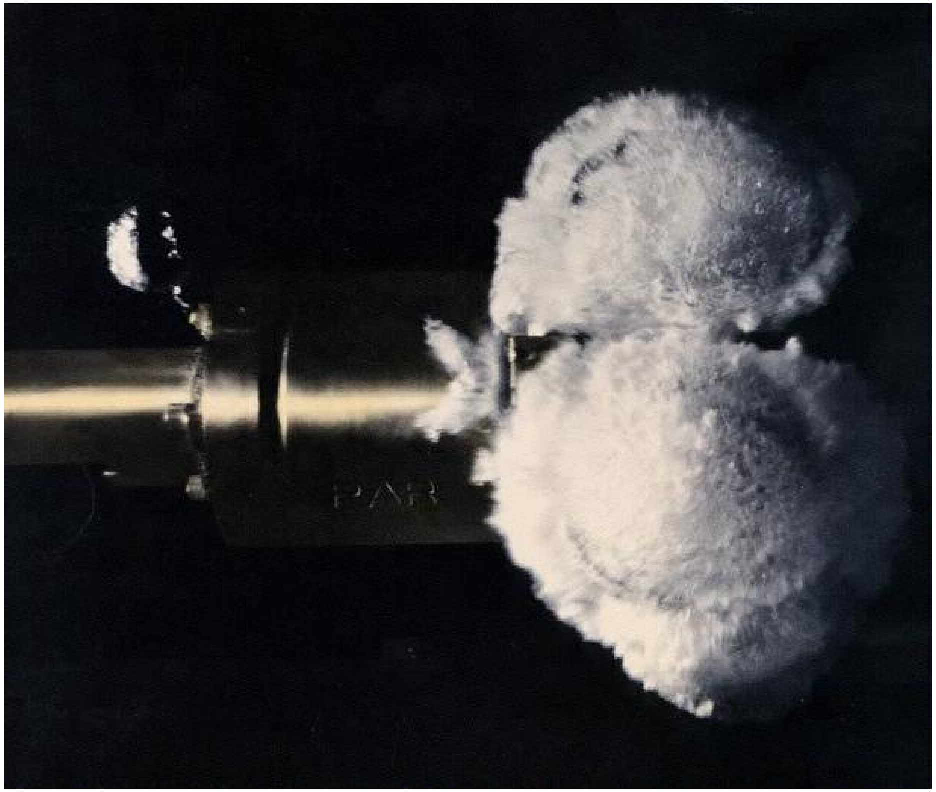
- Introduction
- Optimising airgun signatures
- Effects on marine life
- Conclusion

Introduction

The point of a marine acoustic source

- To introduce into the earth a time-series signature of known spectral behaviour with sufficient signal-to-noise at all desired frequencies in the 0-200ish Hz bandwidth so that we can invert it in the data.
- Commercial seismologists get very hung up on this and like it to be a short duration spike but in truth it can look like a dog's leg providing that you know this.

A Bolt 1500C airgun firing



Introduction

Airgun bubble subtleties

- Modelling is complicated by airgun interaction – guns interact with each other and also with their ghosts
- Internal temperature of a bubble can easily vary by > 200 degrees C whilst oscillating
- The bubble rises whilst oscillating
- The bubble ceases horizontal movement in the water almost immediately from the towing speed
- Nowadays, guns are deployed in very close clusters, perhaps 3 x 200 cu.in. (about 10 litres) within a metre.

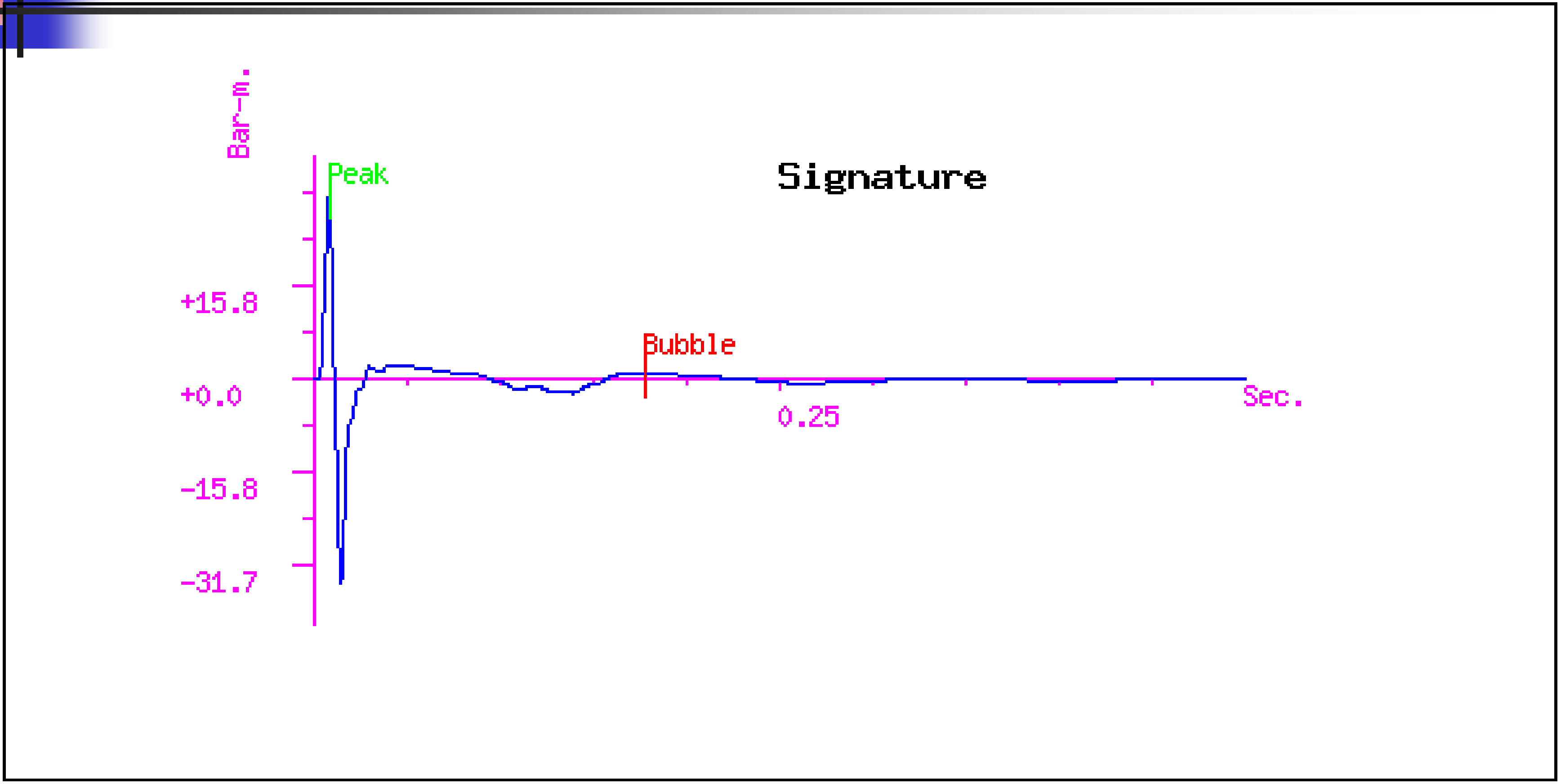
Airgun experimental lab

Introduction

Airgun bubble modelling

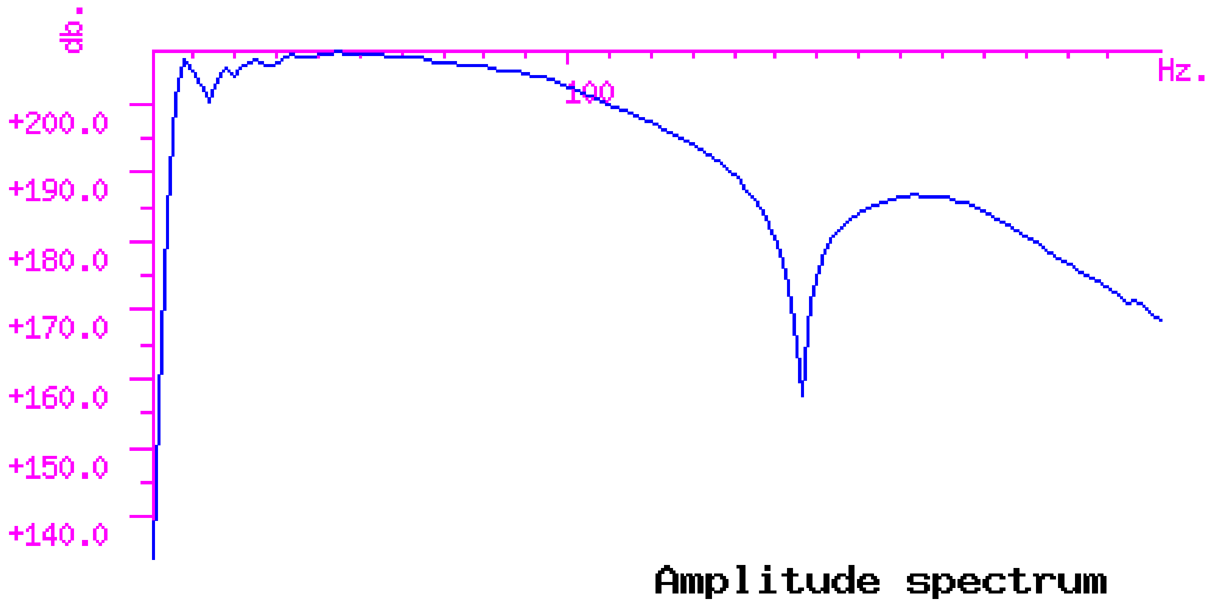
- Early work and solutions done by Ziolkowski and a little later Vaage and collaborators, (1970-1980).
- Notional source replacement done by Ziolkowski, Parkes, Hatton and Haugland (1982)
- Airgun interaction as a turbulent jet for close interaction done by Laws, Hatton and Haartsen (1990)
- ‘Super-foam’ modelling for very close interaction done by Hatton in the late 90s
- High frequency extension done by Hatton (2003).

Modelled far-field signature



Example airgun signature

and its amplitude spectrum



Example amplitude spectrum

Introduction

The position today …

- For single and clustered airguns deployed anywhere in the range 3-30m depth, the modelling problem is effectively solved
- Current research work is getting the anelastic surface response correct for very shallow deployment (1-3m).

Calibration

Overview

- Introduction
- <u>Optimising airgun signatures</u>
- Effects on marine life
- Conclusion

Optimising airgun signatures

Why ?

- Different targets might require different spectral properties, (for example the current interest in sub-basalt imaging, requiring an emphasised low frequency content)
- Airgun interaction means that it is non-intuitive so some automated way of searching for optimal behaviour is highly desirable

Optimising airgun signatures

What can you optimise ?

- Primary to bubble ratio, bubble period (lengthen or shorten), average spectral response in a band, peak spectral response, most deconvolvable signature …

What can you vary ?

- Volume, gun type, gun delays, pressure, gun (x,y) positions, gun depth (individually or by sub-array)

How do you do it ?

- Mixed annealing / genetic solutions – the snuggling phase because of the discrete gun inventory.

Optimising airgun signatures

Two examples …

- Optimising a typical 7 gun array for its primary to bubble …
- Optimising a typical 7 gun array for its low-frequency content …

Overview

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Effects on marine life

Units ?

- 20 $\log_{10}$ (P2/P1) so dimensionless on its own
- Many ways of measuring sound amplitude but thanks to Fricke et. al. (1985) we have standardised on amplitude spectral units of microPascals/Hz. at 1m. which is independent of duration or sample interval.
- Marine seismologists like BIG noises (you should try their parties) so a typical airgun array might peak at 210 db. referenced to 1mPa/Hz at 1m.

Effects on marine life

How mammals hear:-

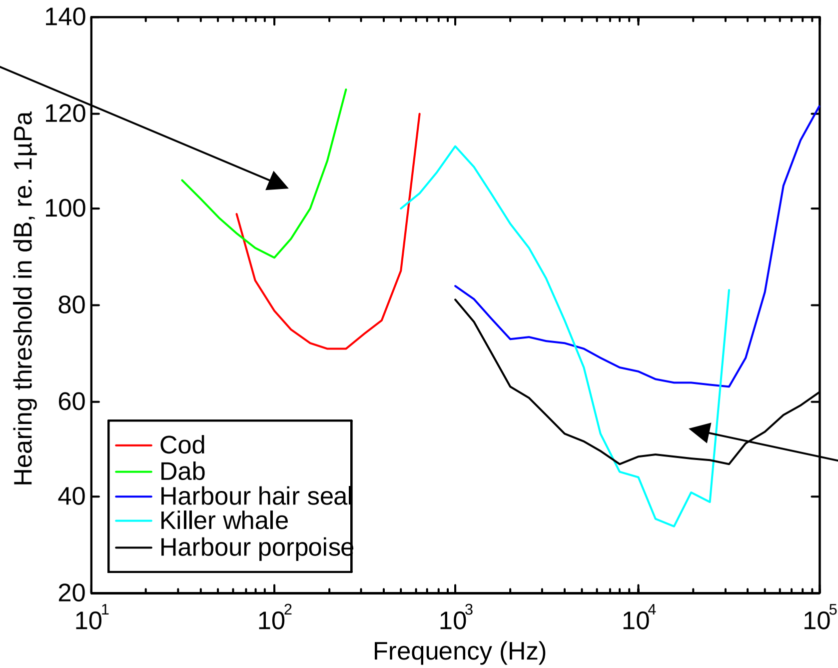
- There is evidence (c.f. Richardson et. al. (1995) and others), that the complex filtering done by the auditory system effectively admits a bandwidth of around 1/3 octave centred on frequencies of peak sensitivity
- We must therefore integrate over this to estimate mammalian impact

Effects on marine life

Audiogram data

- What we hear depends on our aural sensitivity

Fish



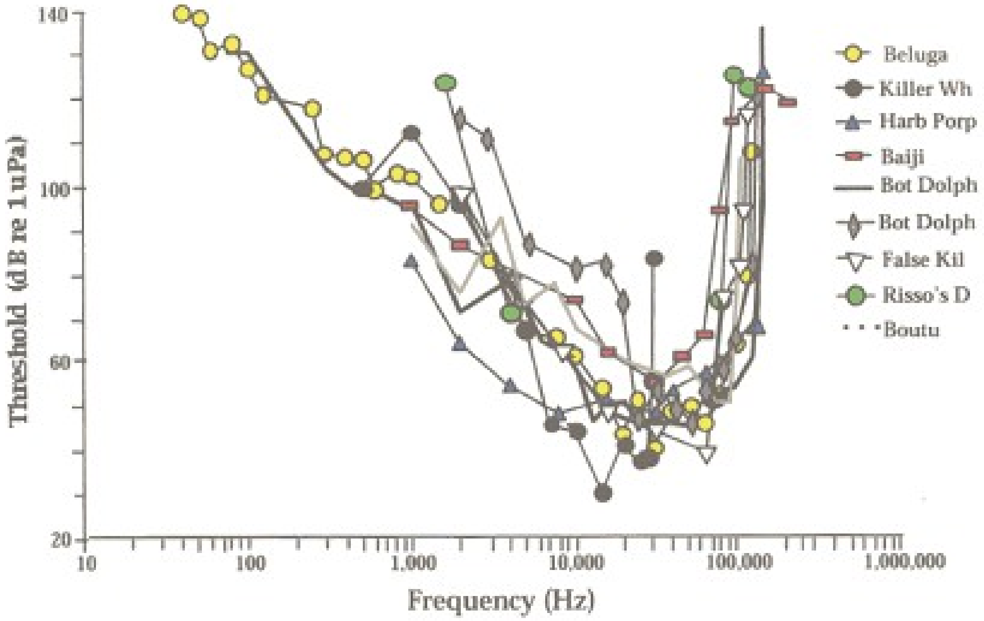
Mammals

Source: Nedwell, Needham, Turnpenny and Hampson (2004)

Effects on marine life

More audiogram data for a wide range of mammals

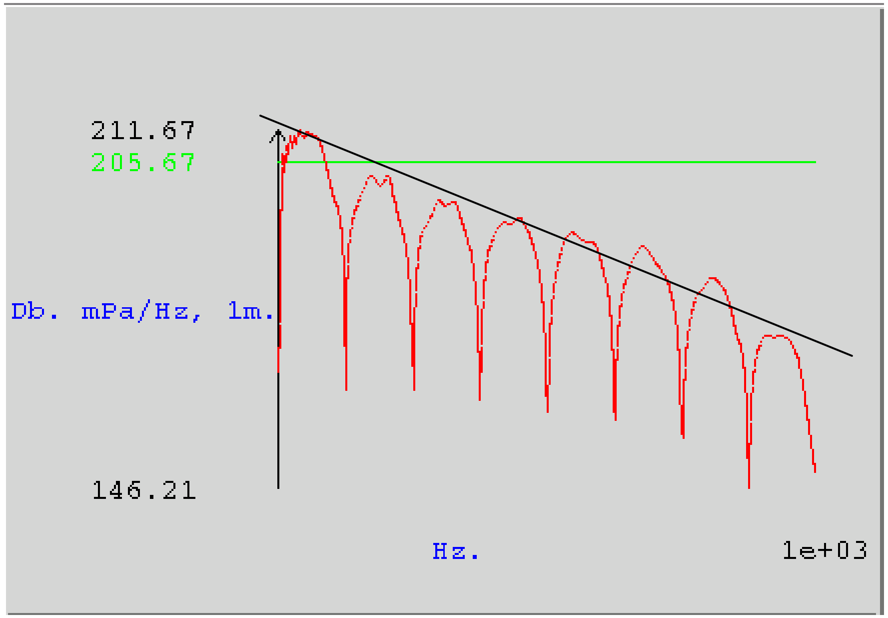
- What we hear depends on our aural sensitivity

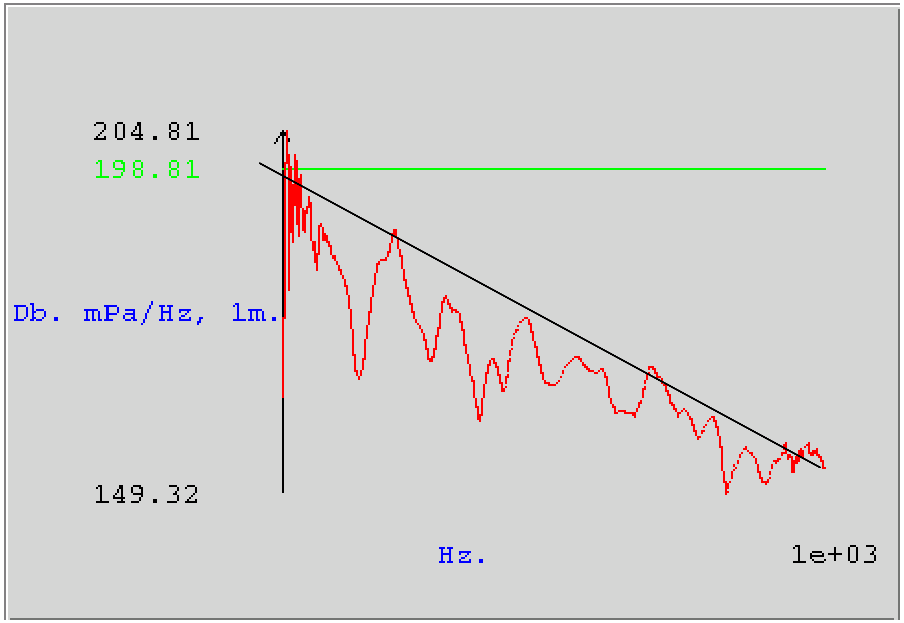


Source: Fontana (2004)

High-frequency calibration

Where are the high frequencies in an airgun signature ?





Full: 40db / 1000 Hz from 212 db

No onset: 50db / 1000 Hz from 205 db

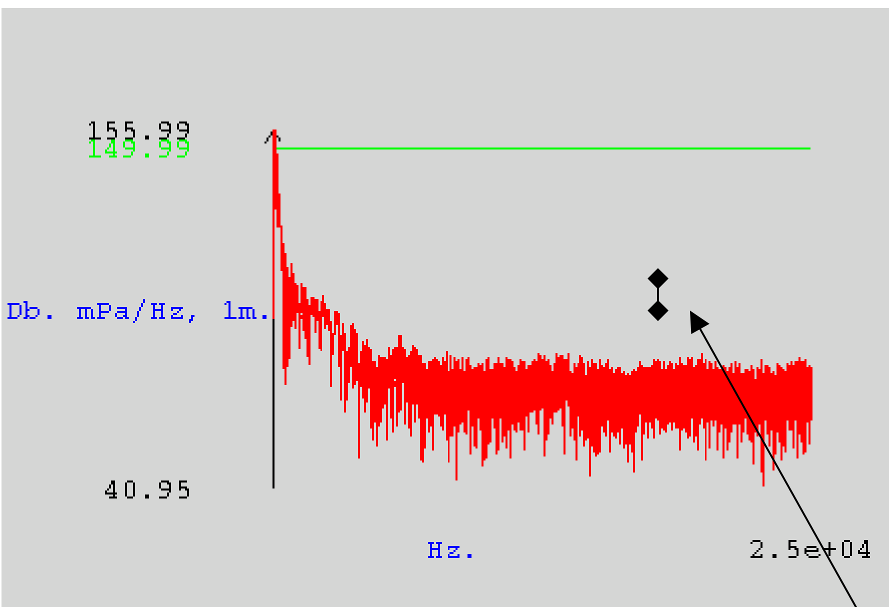
High-frequency calibration

IFRC experiment

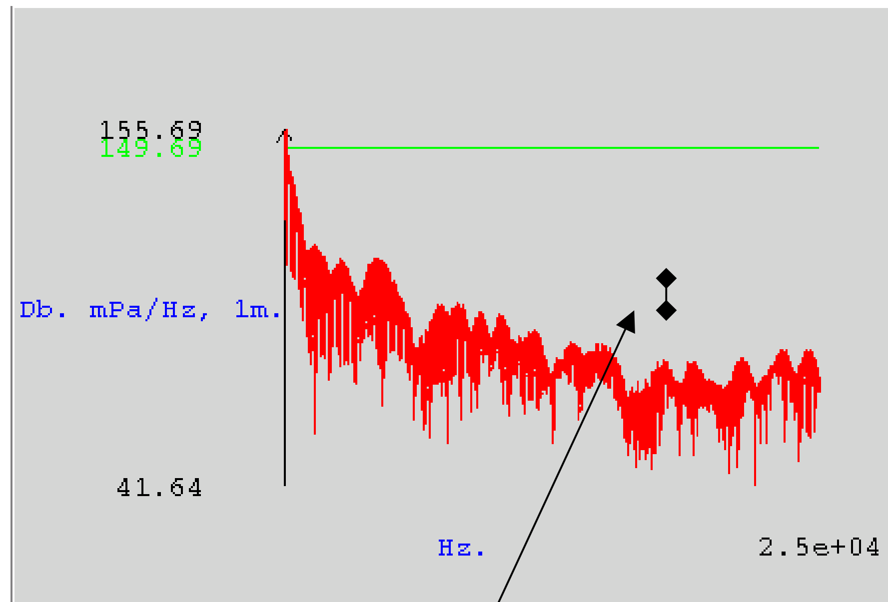
- Industry Funders Research Committee, (BP, ChevronTexaco, ConocoPhilips, Exxon,Shell)
- 3590 cu.in array measured with calibrated 5Hz.-25kHz. phone at various positions
- Data kindly supplied with permission by Phil Fontana, VeritasDGC.

High-frequency calibration

Comparison against IFRC data



Data: hydrophone at 739m



Model: 4^0 offset, gun jitter 0.0005ms

18kHz Depth Transponder

High-frequency calibration

Comparison against IFRC data, (Fontana 2004)

Source	Amplitude spectral value at 18kHz. db ref 1mPa/Hz at 1m.
Depth transponder	95.57
Measured 3590 cu.in array	74.0 +/- 3.0
Gundalf modelled 3590 cu.in array	76.7 +/- 3.0

Implementation

We can use the models to produce:-

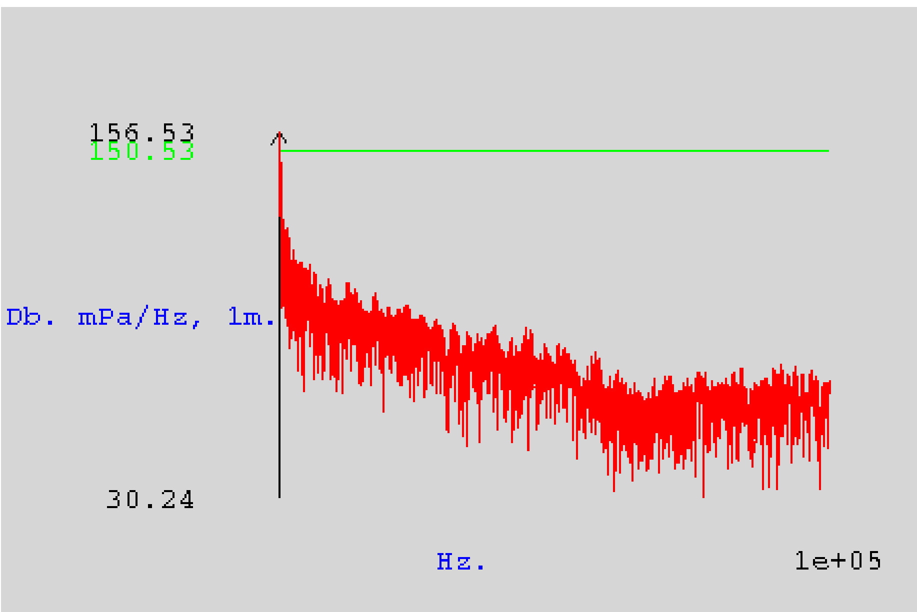
- Amplitude spectral prediction out to 100kHz.
- Radial directivity distributions in significant parts of the spectrum integrated over 1/3 octave
- Closest safe approach

We will include:-

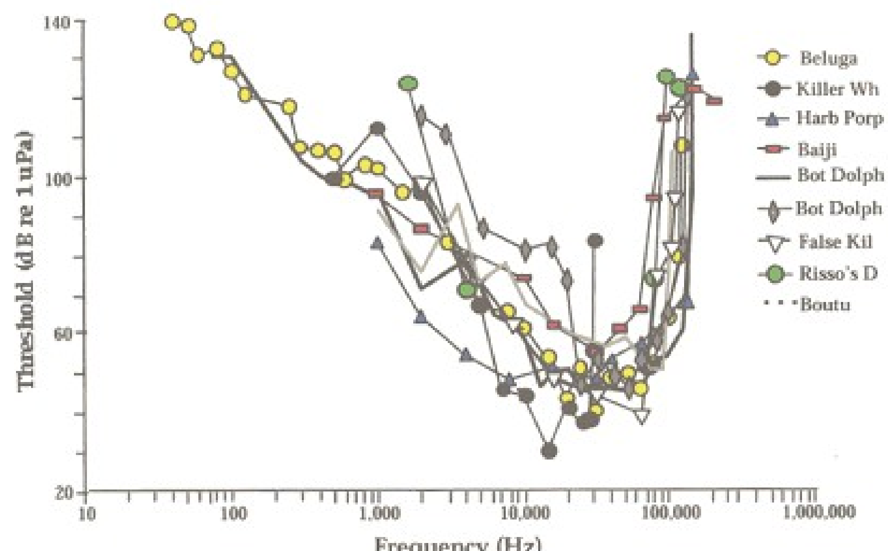
- Audiogram data, (Nedwell et. al. (2004))
- Attenuation data, (Richardson et. al. (1995))

Implementation

Modelling out to 100kHz.



Audiogram data



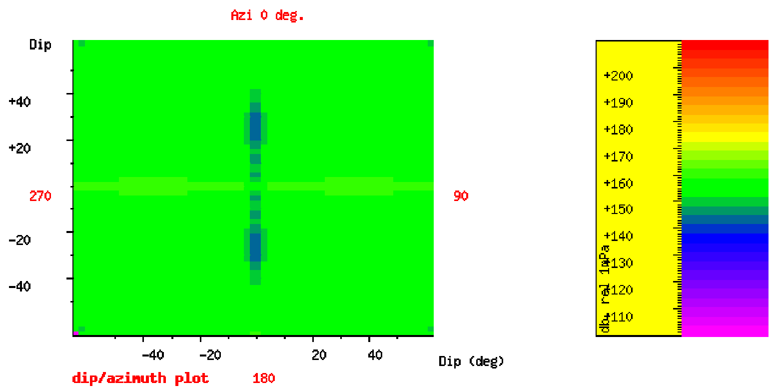
Implementation

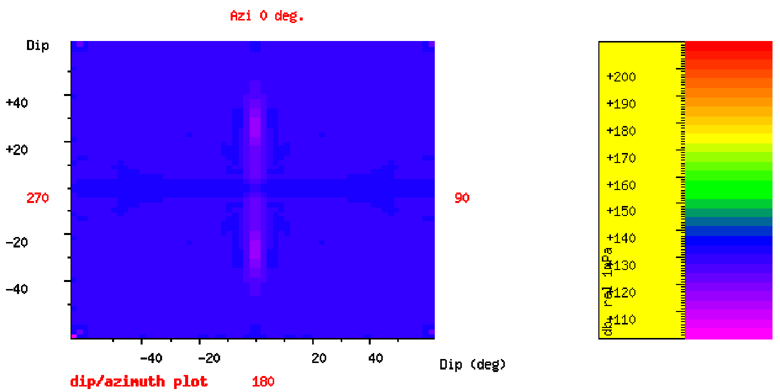
What spreading should we use for directivity and safe range computation ?

- Exceptionally complex problem which is very locale dependent
- In Gundalf, we compute everything for pure cylindrical to pure spherical spreading and allow supra-spherical or sub-cylindrical under option.

Implementation

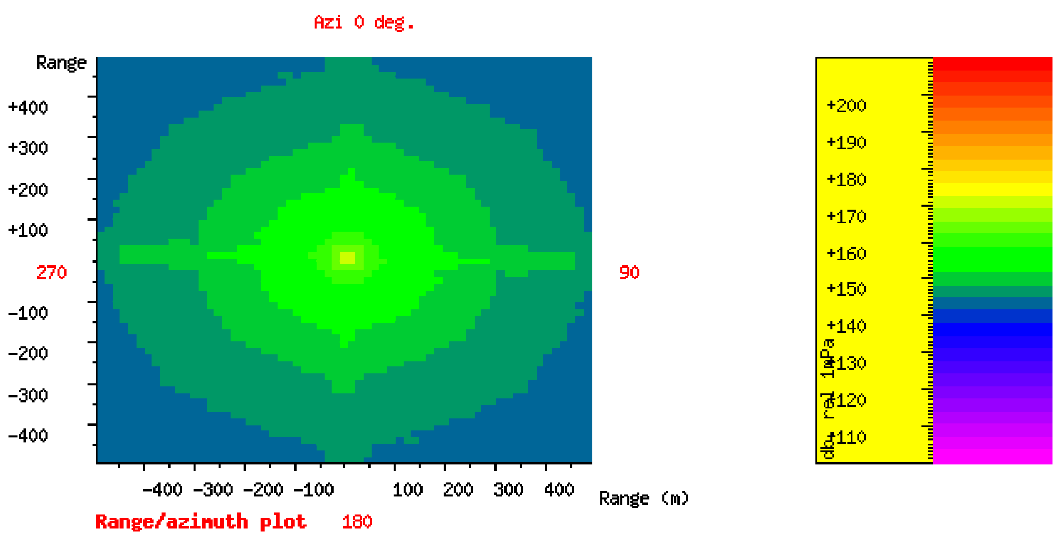
Cylindrical | **Spherical**





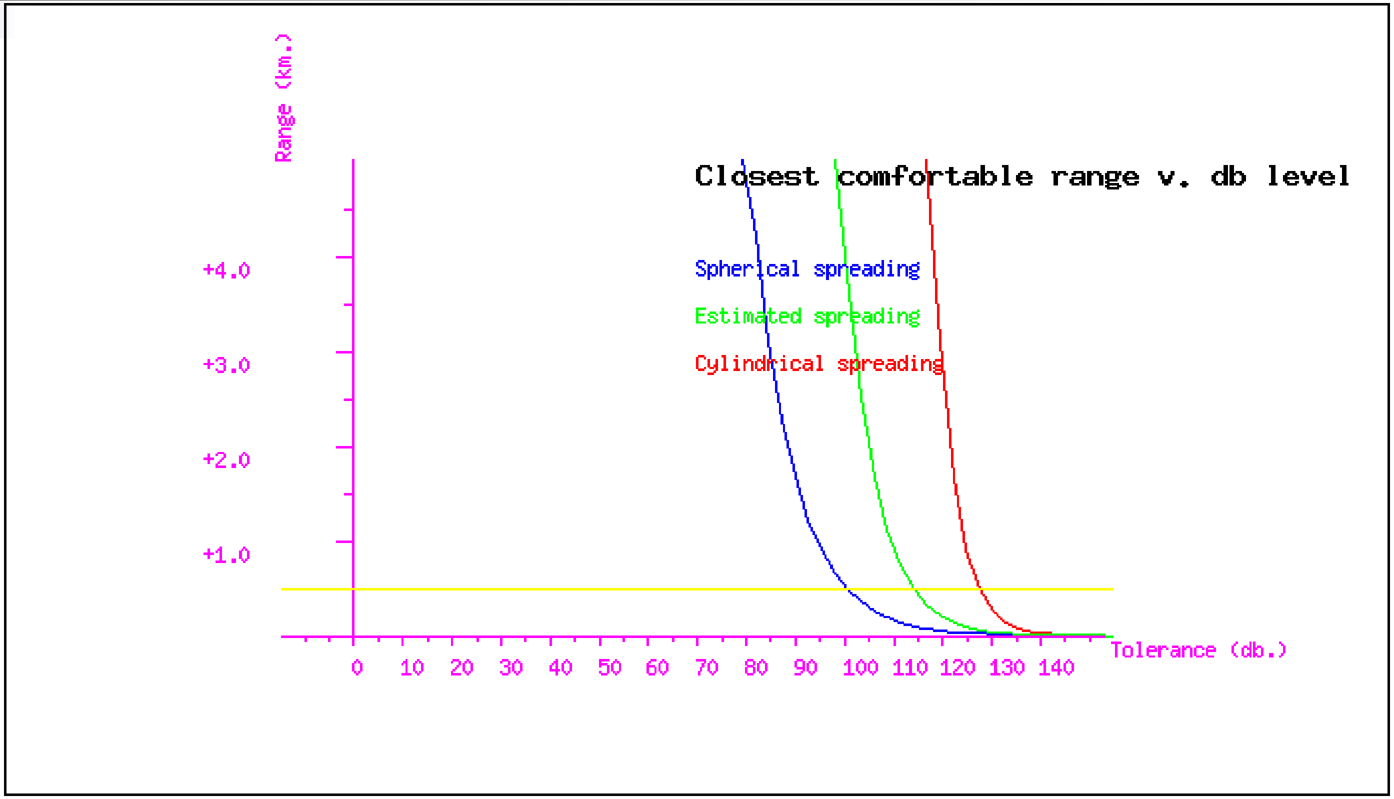
1/3 octave centred on 20kHz.

Implementation



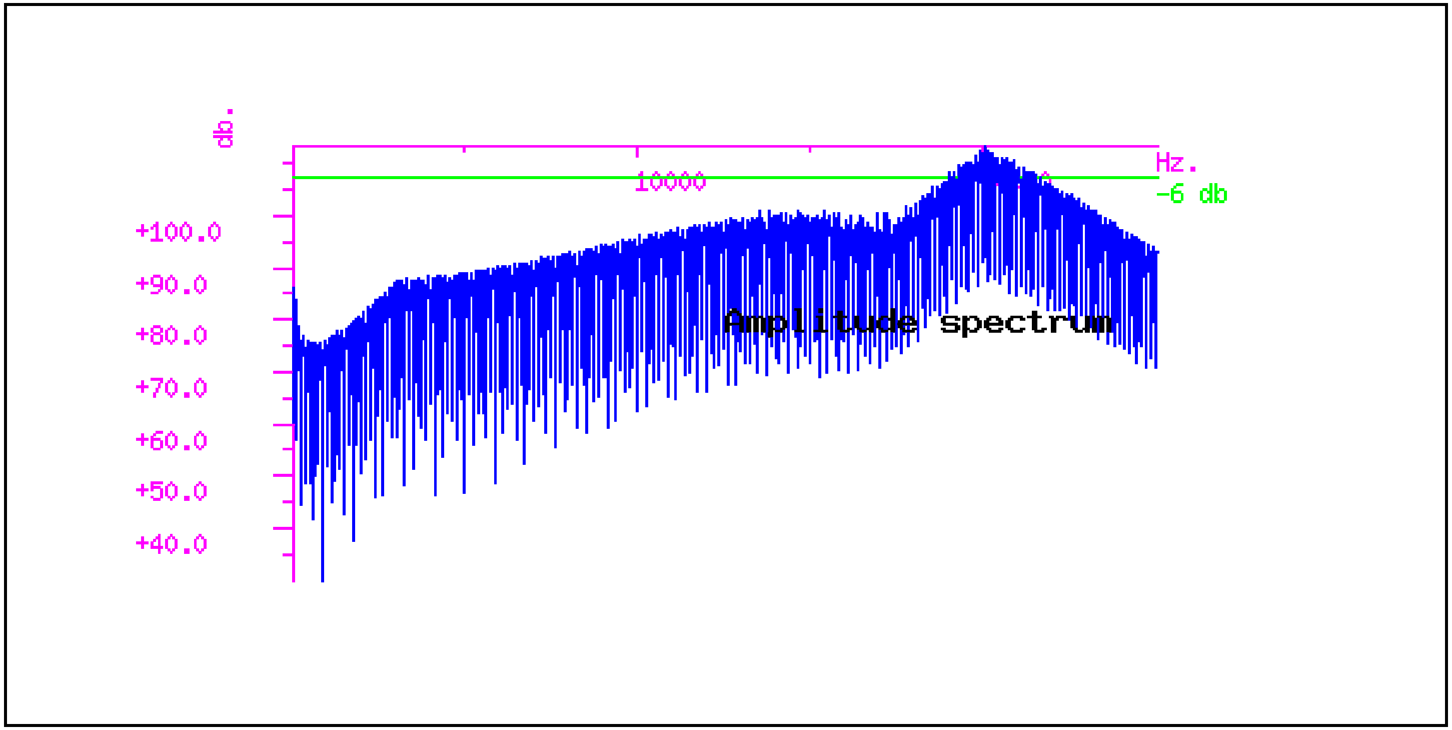
1/3 octave at 20kHz. down to 20m.

Implementation



Closest comfortable range at 20kHz.
Audiogram corrected for killer whale

Implementation



Amplitude spectrum audiogram corrected for killer whale.

Conclusions

The conclusions are:-

- Airgun arrays are not particularly rich in the frequencies at which marine mammals are most sensitive and are at least 20db. down on a depth transponder at 18kHz.
- Without modification, the *Gundalf* modelling engine gives excellent predictions out to 25kHz. (+/- about 2db at 18kHz.) compared with high quality wide band data.
- Taking audiogram data and attenuation into account, an excellent estimate of the characteristics, directivity and closest safe approach for a given model of spreading and intrusion level can be made.

Postscript

How to avoid being eaten by a killer whale:

- A short burst of Chicago Blues

Postscript

How to avoid being eaten by a killer dab:

- You can’t, they’re deaf as a post

Acknowledgements

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- Phil Fontana of VeritasDGC for help and many useful suggestions
- Mike Saunders of Bolt for high quality airgun data in the seismic band.
- The IFRC science sub-committee for very kindly making their high quality broad band data set available.

References and further reading

- http://www.leshatton.org/
- Have a look at Penny Barton's excellent SEG presentation,

  "Seismics in the environmental spotlight: counting the cost", Barton P.J. et. al. 75th SEG, Houston, Texas 2005.