SOP sensing methods and results from live trials

Acoustic Sensing in NORDUnet

SIG-NOC May 2024 Rasmus Lund

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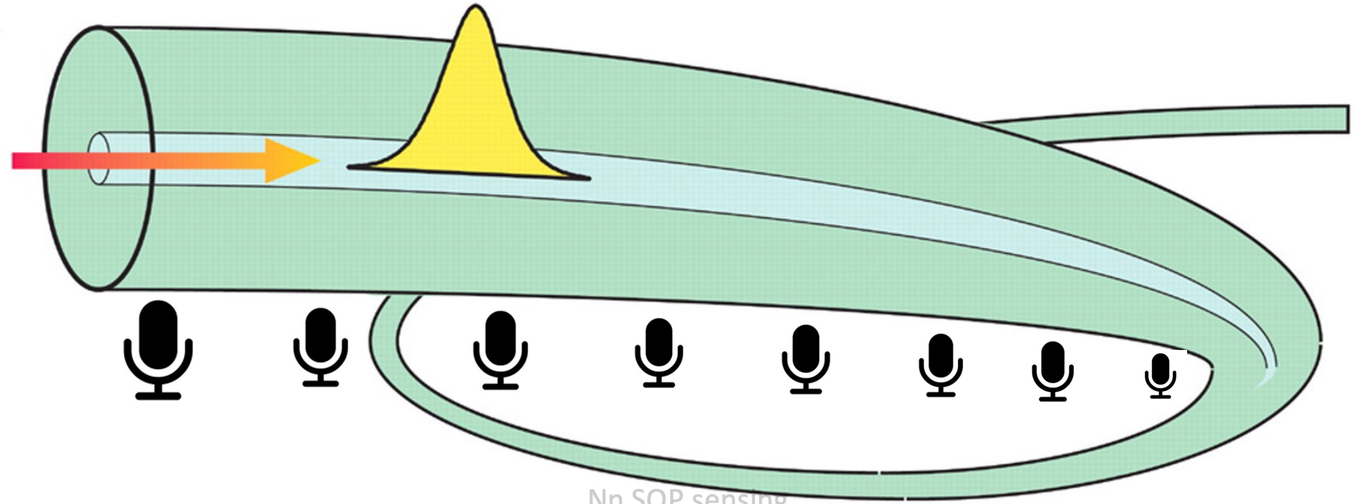
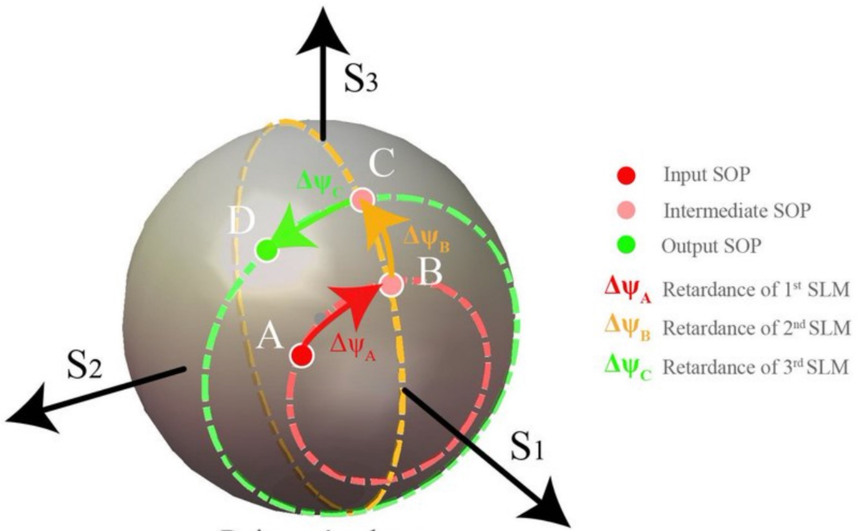
WHAT IS FIBER SENSING

- Fiber optic sensing is detecting changing physical properties of light as it travels along a fiber and thus pickup changes in temperature, stress strain, and other parameters.
- You can think of it as utilising the fiber installation by turning it into distributed acoustic microphones along the whole span.
- NORDUnet are looking at 2 leading technologies for fiber sensing.
  - Distributed acoustic sensing (DAS). ~150km
  - State of Polarisation (SoP). No distance limitations (in theory)

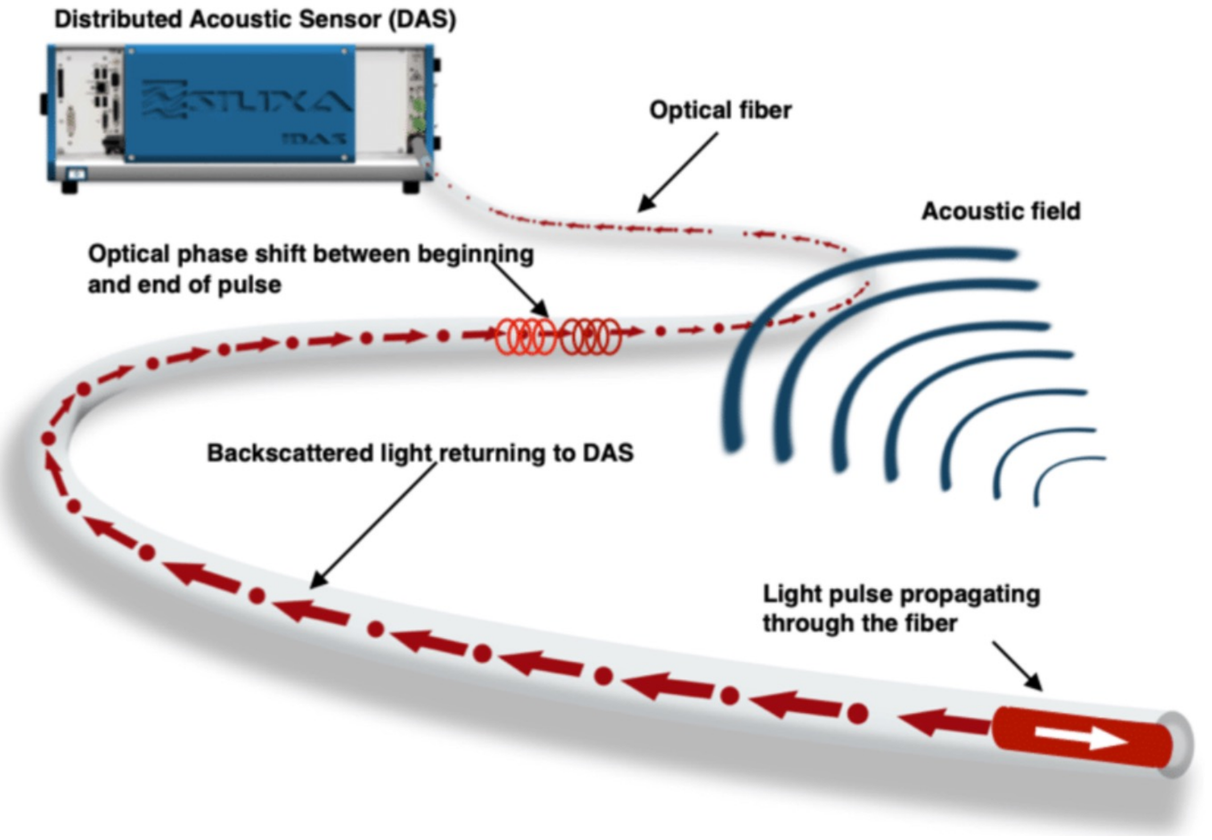


SENSING TECHNIQUES

SoP is looking at abrubt polarisation state changes in the receivced signal, (Phase shifts).

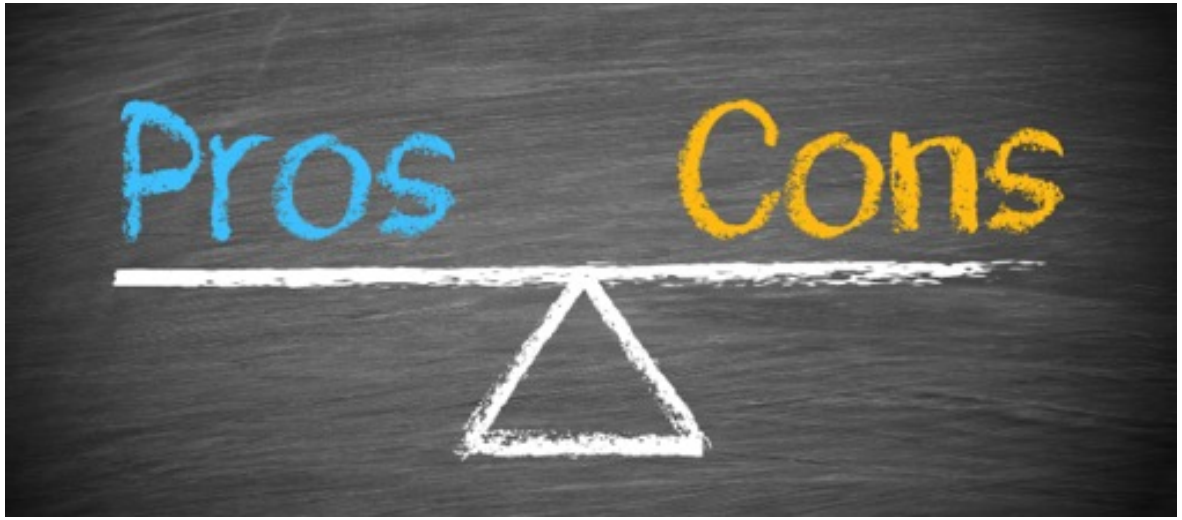


Poincaré sphere



DAS looking for same shifts but from backscattered light. (Hence the distance limitations).

IMMEDIATE ADVANTAGE/DISADVANTAGES (SOP)

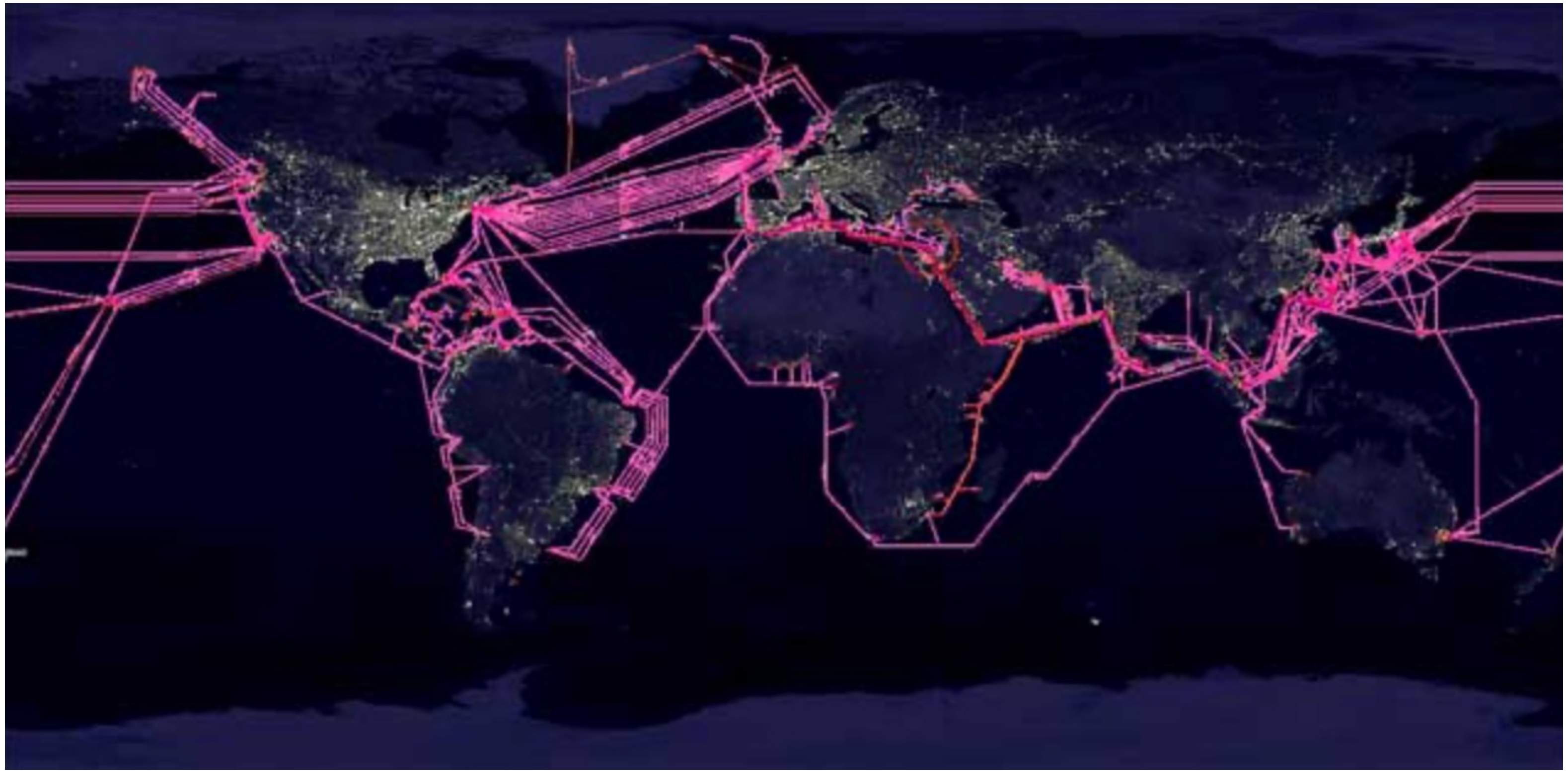


- Easy to implement on existing optical networks
- Can be Imbedded into future silicon photonics
- No distance limitations (senses on entire links)
- Relatively Low cost
- Real time data no “dead zone”

- No distance limitations (senses on entire links and picks up ALL disturbances).
- Lower quality, noisy signals.
- Storage can be cumbersome as real time data @millions of samples/second.
- Less suited for low frequency sensing.

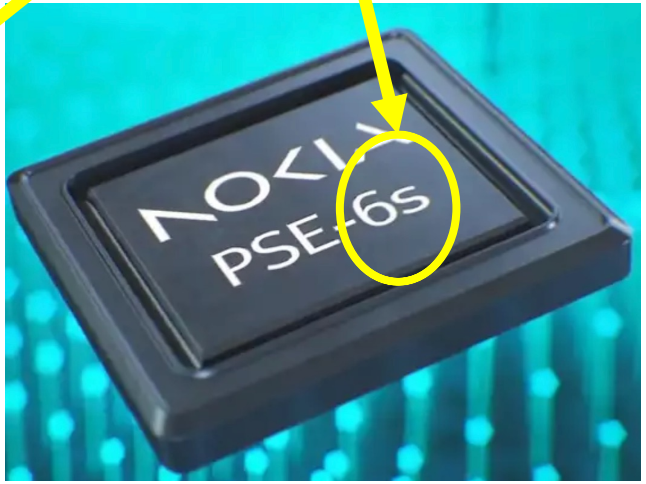
BIG ADVANTAGE ON STATE OF POLARISATION SENSING (SOP)

- In principle, SoP can be implemented on every existing or new fiber plant, all over the world.



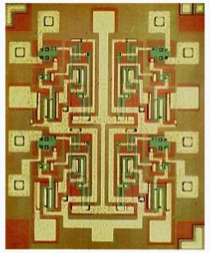
SEMICONDUCTOR EVOLUTION

Apperently 6 is the magic number



Enough compute rescources to populate the data elsewhere than just for internal debugging purposes..

Semiconductor device fabrication



MOSFET scaling (process nodes)

- 10 µm – 1971
- 6 µm – 1974
- 3 µm – 1977
- 1.5 µm – 1981
- 1 µm – 1984
- 800 nm – 1987
- 600 nm – 1990
- 350 nm – 1993
- 250 nm – 1996
- 180 nm – 1999
- 130 nm – 2001
- 90 nm – 2003
- 65 nm – 2005
- 45 nm – 2007
- 32 nm – 2009
- 22 nm – 2012
- 14 nm – 2014
- 10 nm – 2016
- 7 nm – 2018
- 5 nm – 2020
- 3 nm – 2022

Future

- 2 nm ~ 2024

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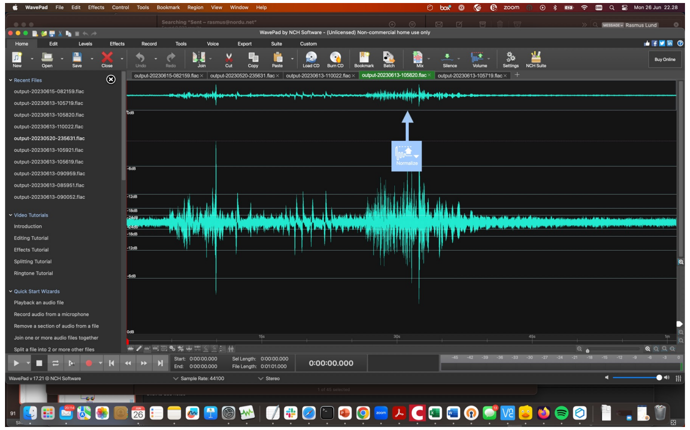
SO BASICALLY (IN NEAR FUTURE) IT COMES WITH THE BOX..

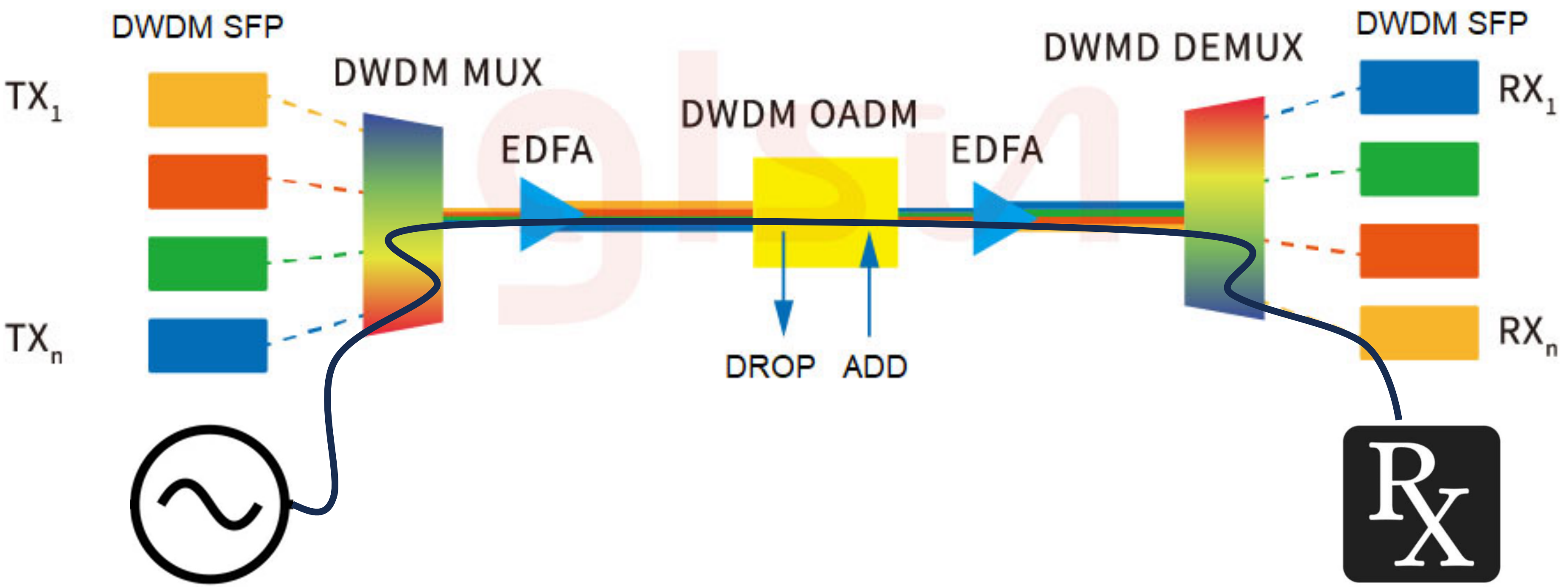
STATE OF POLARISATION SENSING (SOP)

But should we implement everywhere??

Can we use the (relatively large amount), data?
(as operator or scientist)



SOP SENSING DETAILED (PRINCIPLE FROM SOP BOX NN IS USING)



Polarised light
Source. (OOK)

SoP RX detects phaseshifts ”Picked up” on the complete fiber strech. (stokes S0/S1)

SOP TESTING IN NORDUNET

- Study to see the operational potentials of sensing, and the implementation impacts. (financial & design effects, plus implementation affects).

- Can sensing be useful or is it just (again) more data for the operation center's to take care off..?

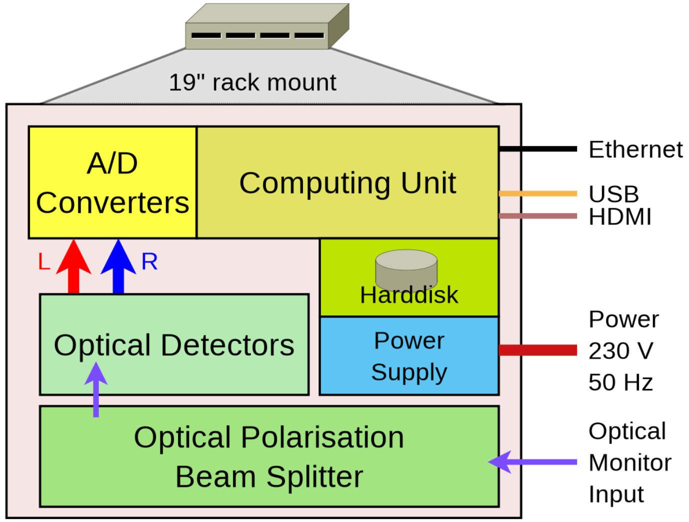
24/7 SURVEILANCE?

Or are we moving more toward machine network operation? (more Automation, pattern recognition, Ai, machine learning SW)?

LETS COME BACK TO THAT AND START BY LOOKING AT THE TAMPERFIGHTER BOX (SOP SENSING)

tampnet

- TAMPNET Operators of worlds largest offshore high capacity communication network.
- In-house development of the "TAMPERFIGHTER" box.
- Low cost, easy to deploy simple solution.
- NORDUnet have been able to borrow 2 boxes. ☺

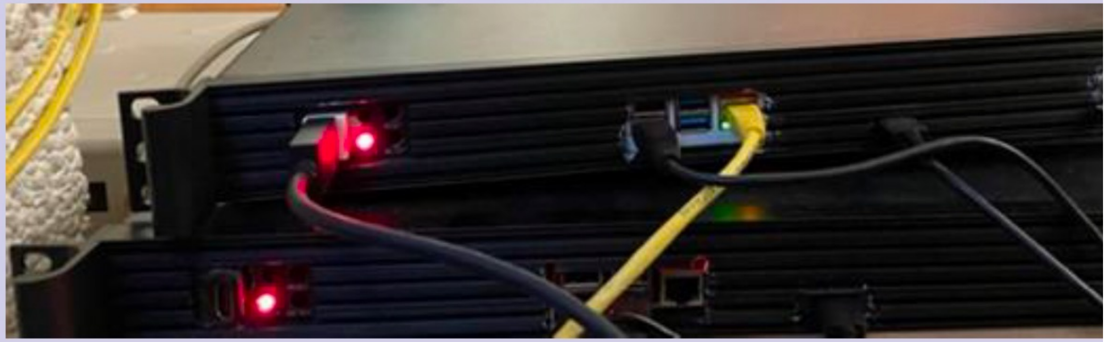


THE TAMPERFIGHTER SOP BOX

Inexpensive, simple and clever.

- The SoP box has 1 year local storage (5 TB) and automatic SSH upload to cloud storage.
- Freq range 10Hz – 20Khz, 44,1Khz 24bit sampling
- Linux Raspberry Pi based
- Produces compressed audio files, 1file ~3-5MB/min. (~2-5TB/year)

THAT'S 10.080 files PER WEEK!



SoP monitoring: Small 1U rack mount

BAND DEPENDANT FFT ANALYSE

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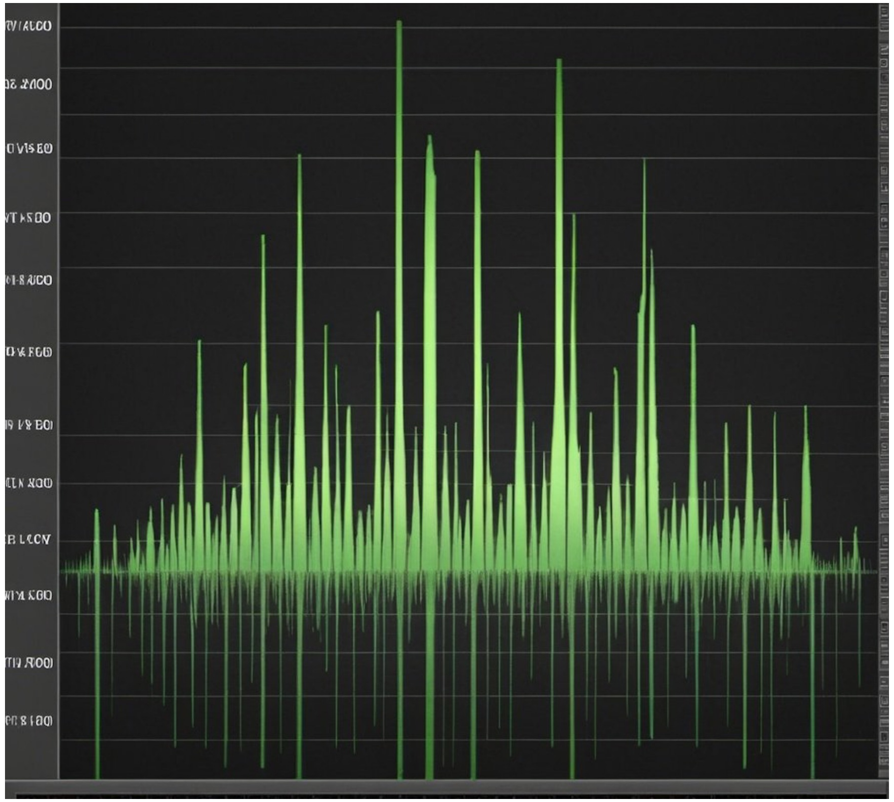
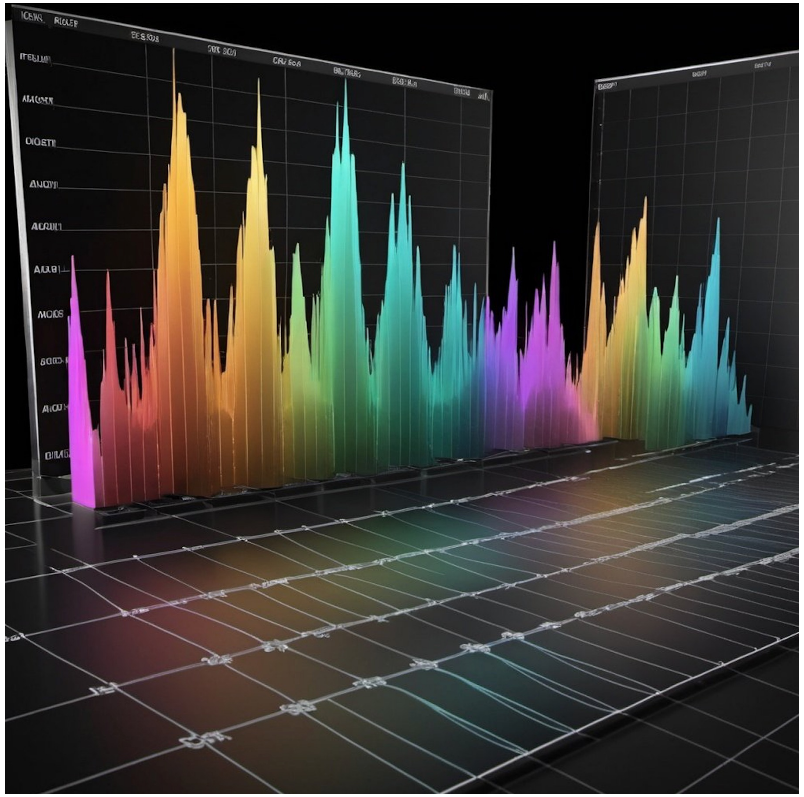


NORMAL FREQ SPEC

Python code

FFT, Peak and RMS finding



BAND DIVISED FREQ SPEC

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AVERAGING AND PEAK FINDING

Name	Date Modified	Size	Kind
data	Yesterday at 19.45	--	Folder
2023	Yesterday at 18.09	--	Folder
06	15 Feb 2024 at 13.27	--	Folder
01	15 Feb 2024 at 13.29	--	Folder
output-20230601-000036.flac	1 Jun 2023 at 02.01	5,5 MB	FLAC
output-20230601-000136.flac	1 Jun 2023 at 02.02	5,6 MB	FLAC
output-20230601-000237.flac	1 Jun 2023 at 02.03	5,5 MB	FLAC
output-20230601-000337.flac	1 Jun 2023 at 02.04	5,6 MB	FLAC
output-20230601-000438.flac	1 Jun 2023 at 02.05	5,6 MB	FLAC
output-20230601-000539.flac	1 Jun 2023 at 02.06	5,6 MB	FLAC
output-20230601-000640.flac	1 Jun 2023 at 02.07	5,5 MB	FLAC
output-20230601-000740.flac	1 Jun 2023 at 02.08	5,6 MB	FLAC
output-20230601-000841.flac	1 Jun 2023 at 02.09	5,6 MB	FLAC
output-20230601-000942.flac	1 Jun 2023 at 02.10	5,6 MB	FLAC
output-20230601-001043.flac	1 Jun 2023 at 02.11	5,6 MB	FLAC
output-20230601-001144.flac	1 Jun 2023 at 02.12	5,6 MB	FLAC
output-20230601-001245.flac	1 Jun 2023 at 02.13	5,6 MB	FLAC
output-20230601-001345.flac	1 Jun 2023 at 02.14	5,6 MB	FLAC
output-20230601-001445.flac	1 Jun 2023 at 02.15	5,6 MB	FLAC

The list goes on and on and on....

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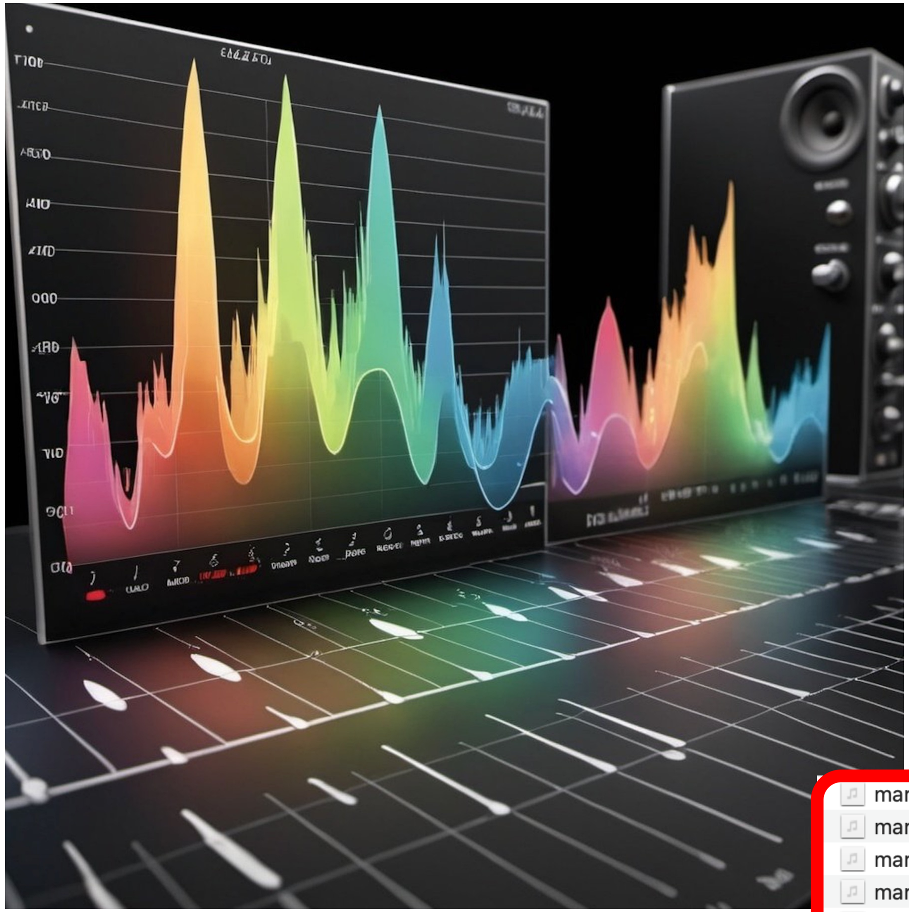
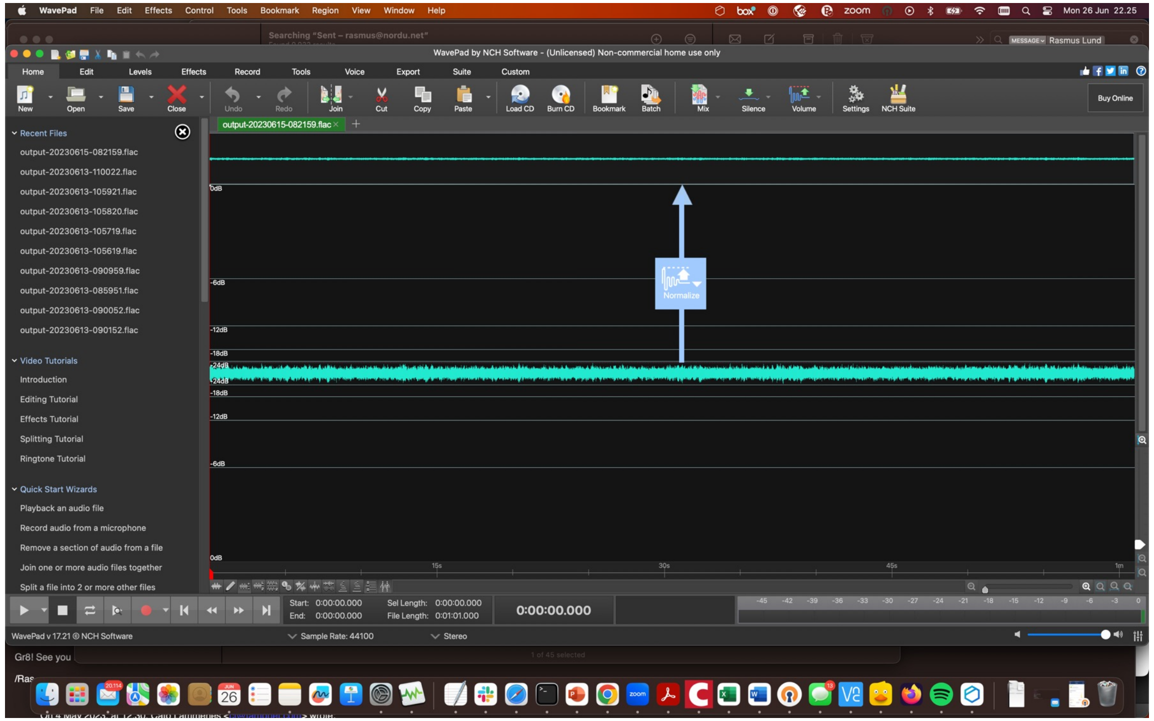


marked_output-20230621-041743.flac	2,6 MB	FLAC
marked_output-20230614-044935.flac	2,9 MB	FLAC
marked_output-20230613-084943.flac	2,5 MB	FLAC
marked_output-20230612-102852.flac	2,8 MB	FLAC
output-20231005-105102.flac	2,1 MB	FLAC
output-20230831-102642.flac	2,4 MB	FLAC
output-20230508-073829_0.flac	2,7 MB	FLAC

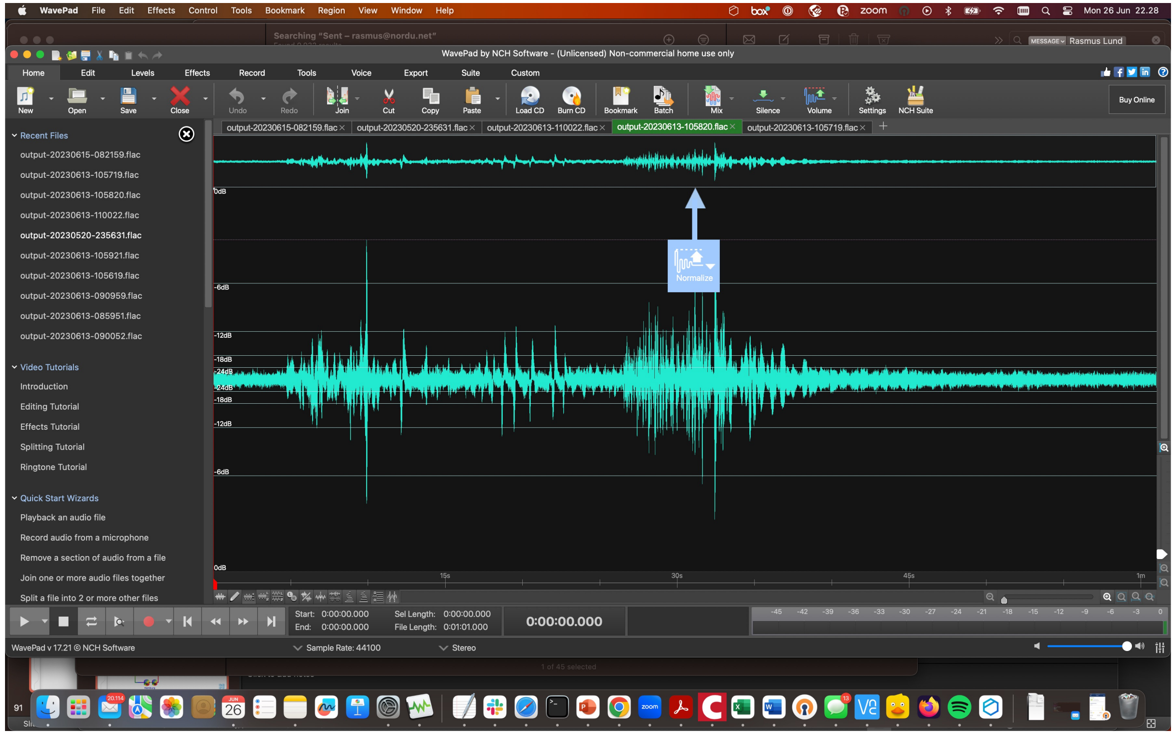
FINDING THE FILES THAT MATTER..

EXAMPLE FROM TESTING

Producing Audio files (.flac):



Normal situation



Bending/pinching fiber at remote site (app.30km)

NETWORK OUTAGES

LOTS OF OUTAGES ARE UNEXLAINABLE AND THE OPERATORS GO LIKE:

NETWORK OUTAGES

- THERES NOT MANY OPTIONS TO CHARACTERISE THE CAUSE OF AN EVENT.
- SUSPISION THAT A WAST MAJORITY IS DUE TO PHYSICAL IMPACT ON CABLE RUNNINGS IN OR OUT OF DC (HUMAN ERROR)
- BEND LOSS ARE THE MOST SENSITIVE FACTOR
- FIBER PINCHES ARE RIGHT NEXT ON THE LIST

NETWORK OUTAGES

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- **The overwhelming majority of human error-related outages involve ignored or inadequate procedures.** Nearly 40% of organizations have suffered a major outage caused by human error over the past three years. Of these incidents, 85% stem from staff failing to follow procedures or from flaws in the processes and procedures themselves.

New research details latest digital infrastructure failure rates, increasing outage costs and impacts, top downtime causes, and more

NEW YORK, NY – June 8, 2022 – The digital infrastructure sector is struggling to achieve a measurable reduction in outage rates and severity, and the financial consequences and overall disruption from outages are steadily increasing, according to Uptime Institute, which today released the findings of its 2022 annual Outage Analysis report.

"Digital infrastructure operators are still struggling to meet the high standards that customers expect and service level agreements demand – despite improving technologies and the industry's strong investment in resiliency and downtime prevention," said Andy Lawrence, founding member and executive director, Uptime Institute Intelligence.

"The lack of improvement in overall outage rates is partly the result of the immensity of recent investment in digital infrastructure, and all the associated complexity that operators face as they transition to hybrid, distributed architectures," said Lawrence. "In time, both the technology and operational practices will improve, but at present, outages remain a top concern for customers, investors, and regulators. Operators will be best able to meet the challenge with rigorous staff training and operational procedures to mitigate the human error behind many of these failures."

* Company Email Address:

* Company Name:

* Job Title:

* Country:

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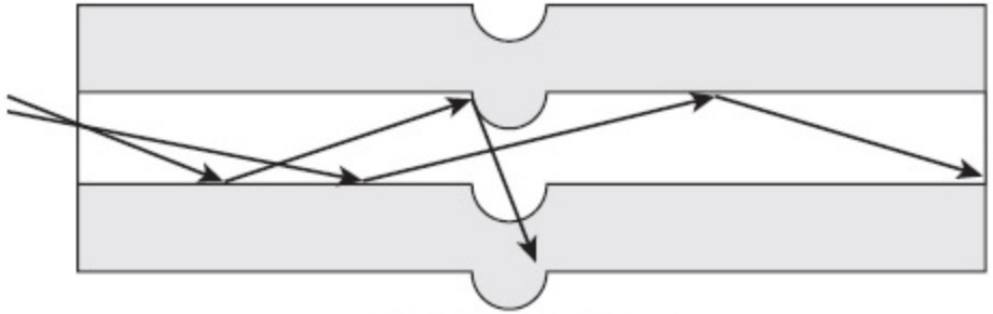
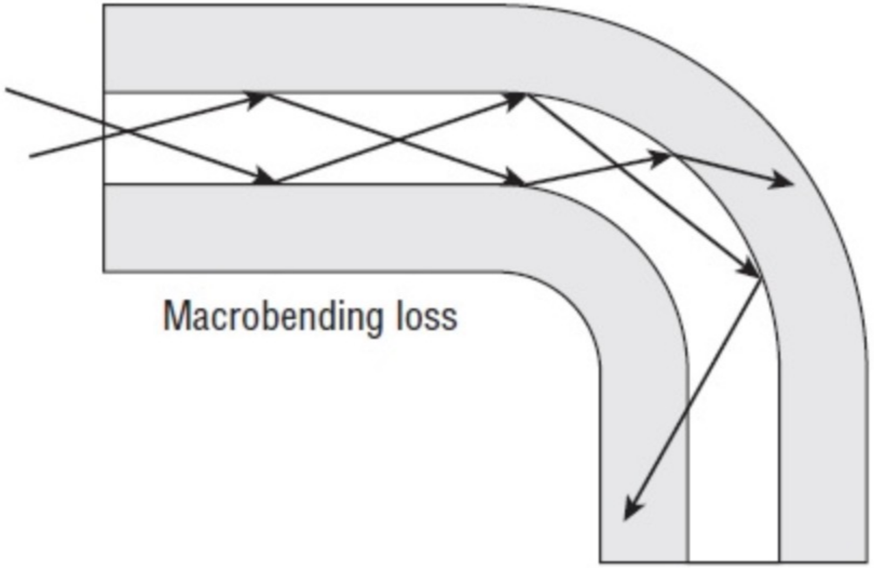
https://www.velir.com/-/media/files/pdfs/uptime-annualoutageanalysis2021.pdf

MACROBEND & MICROBEND



Microbending loss



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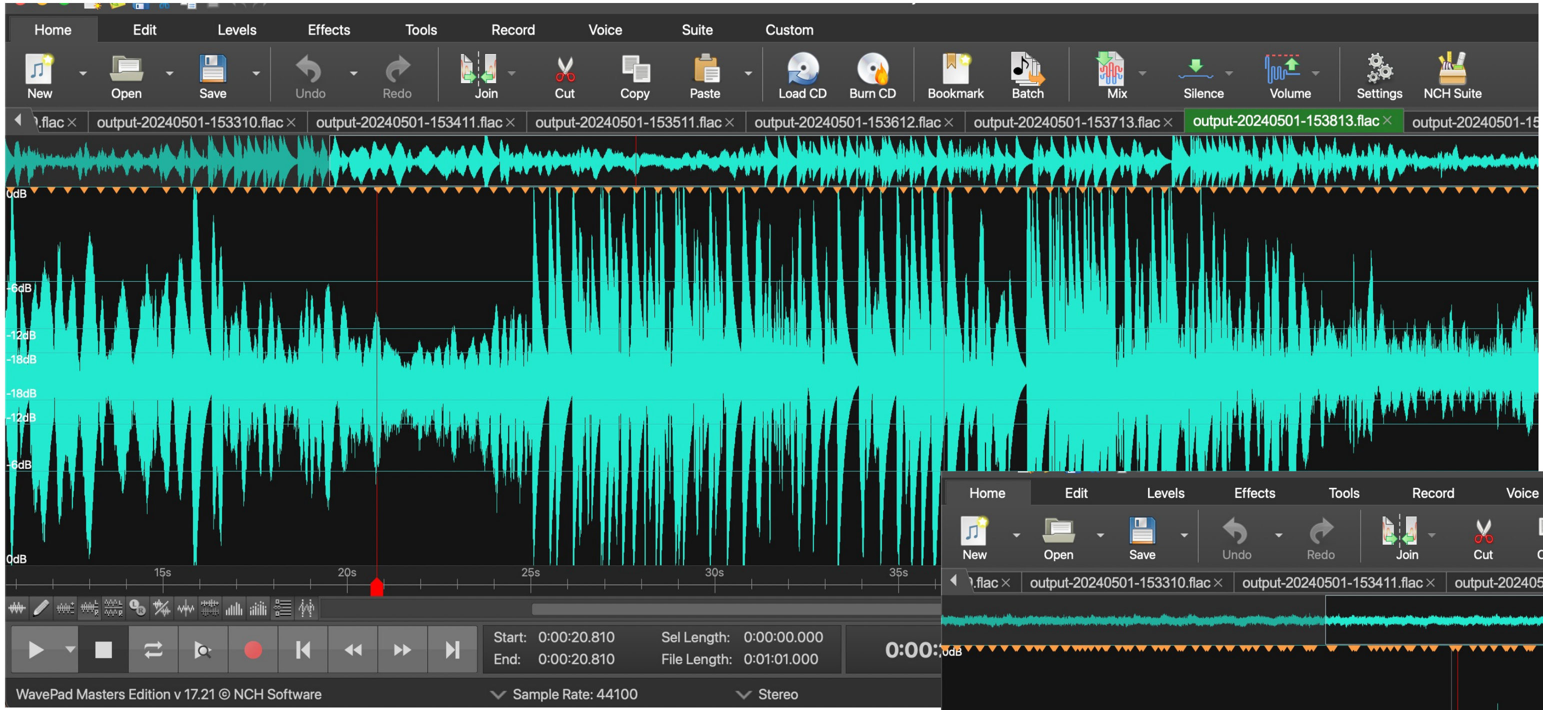
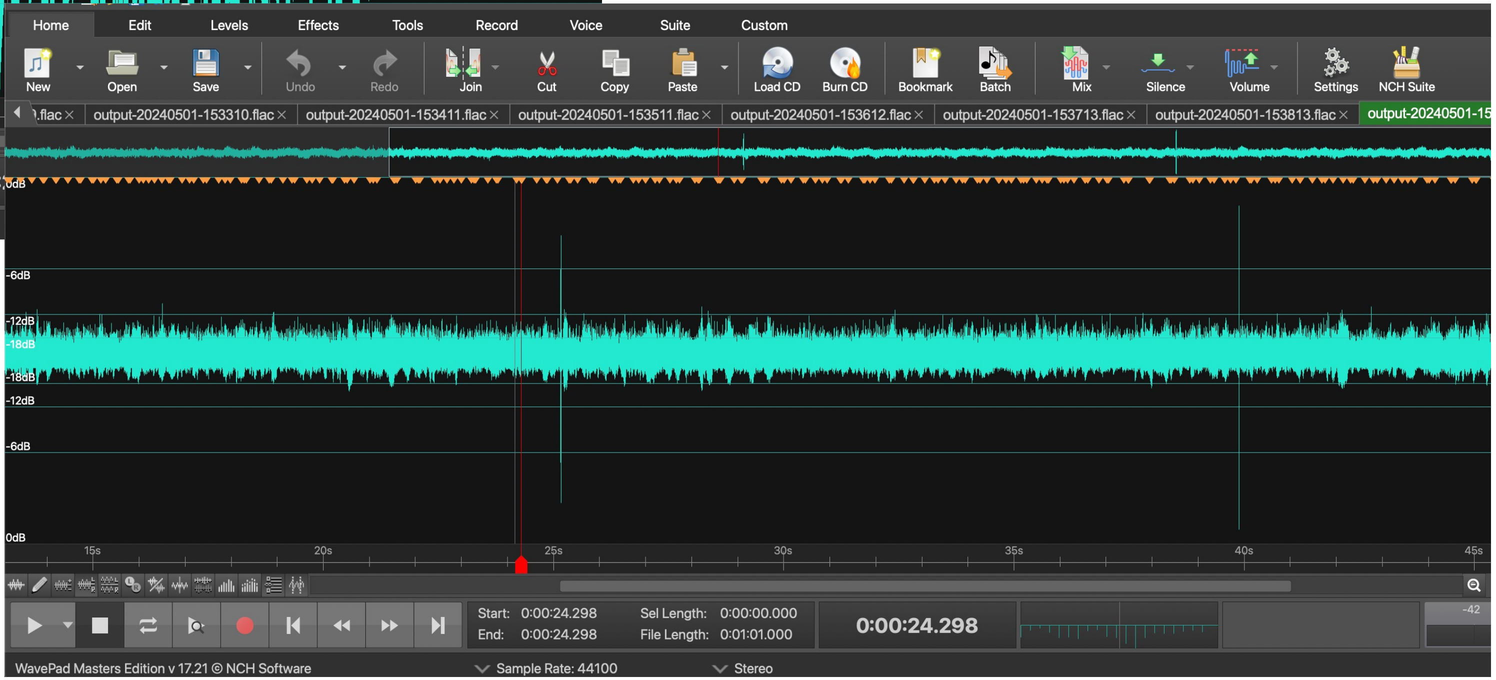
SOP SENSING FIBER PINCH & FIBER BENDS?

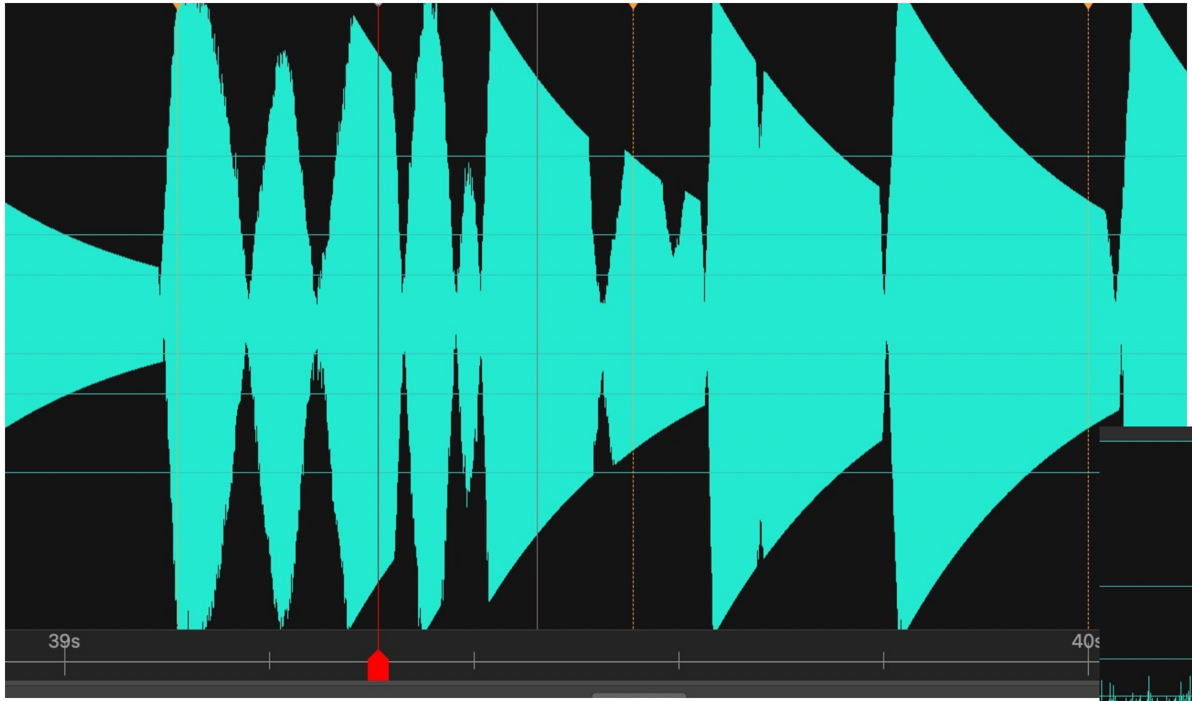


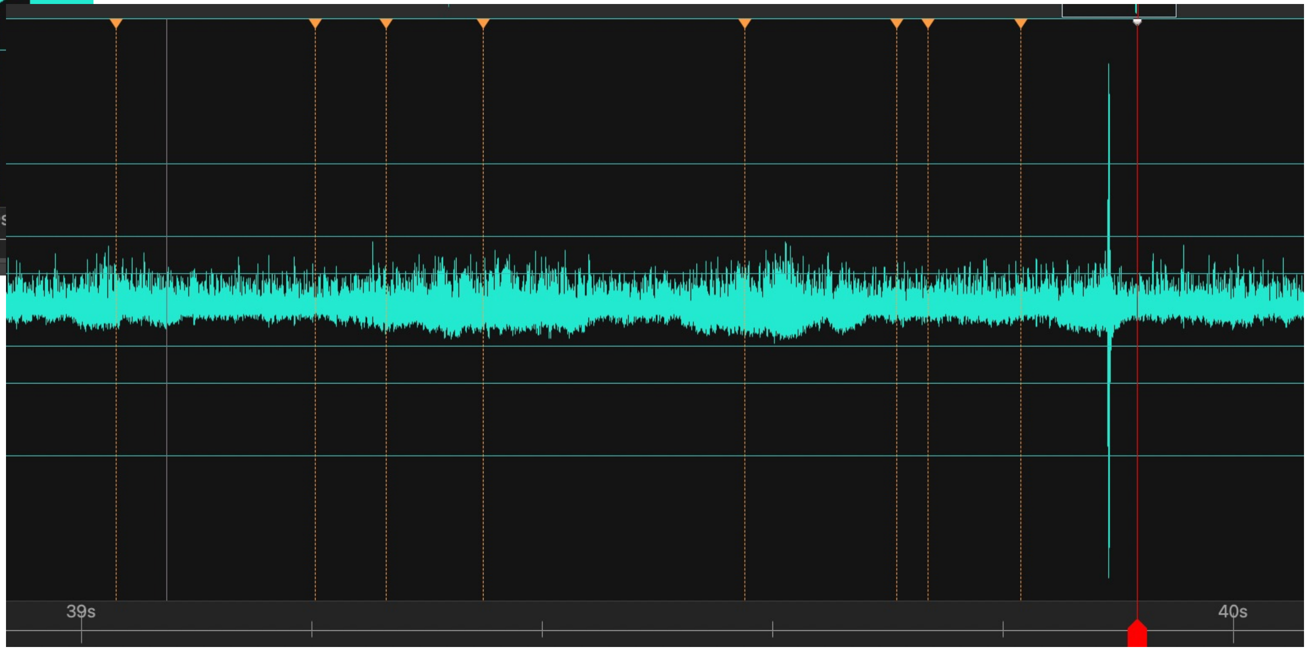
FIBER BEND



FIBER PINCH

SAME ZOOM





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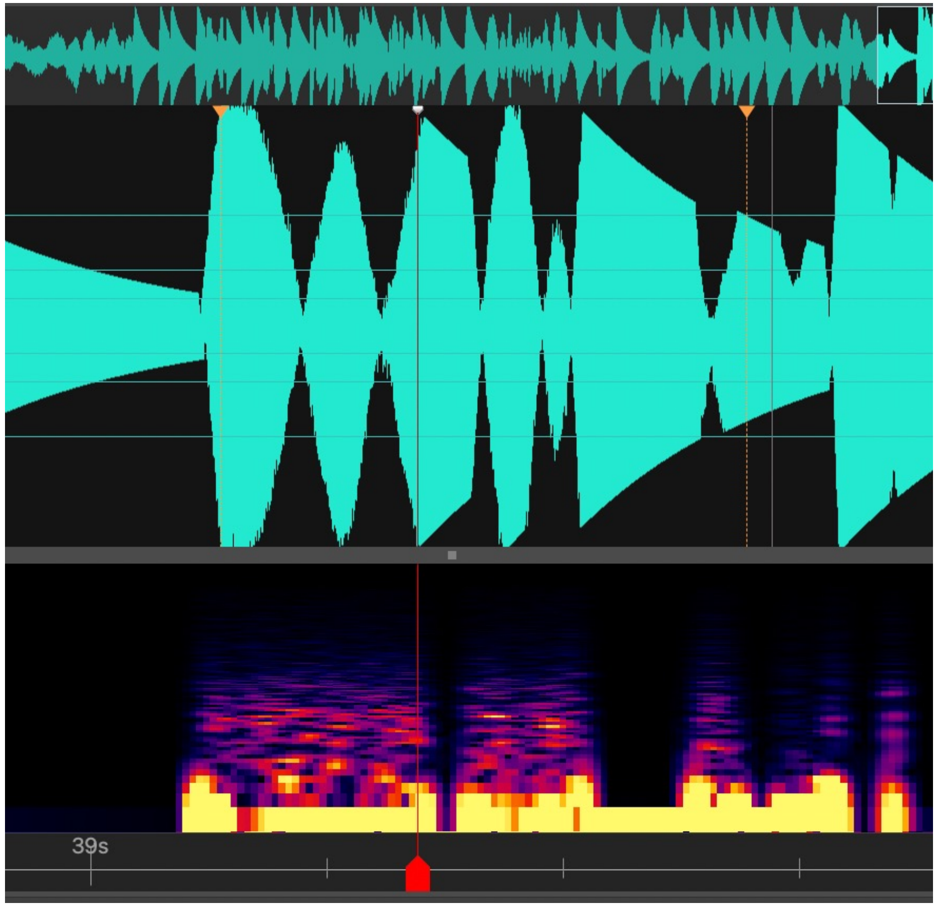
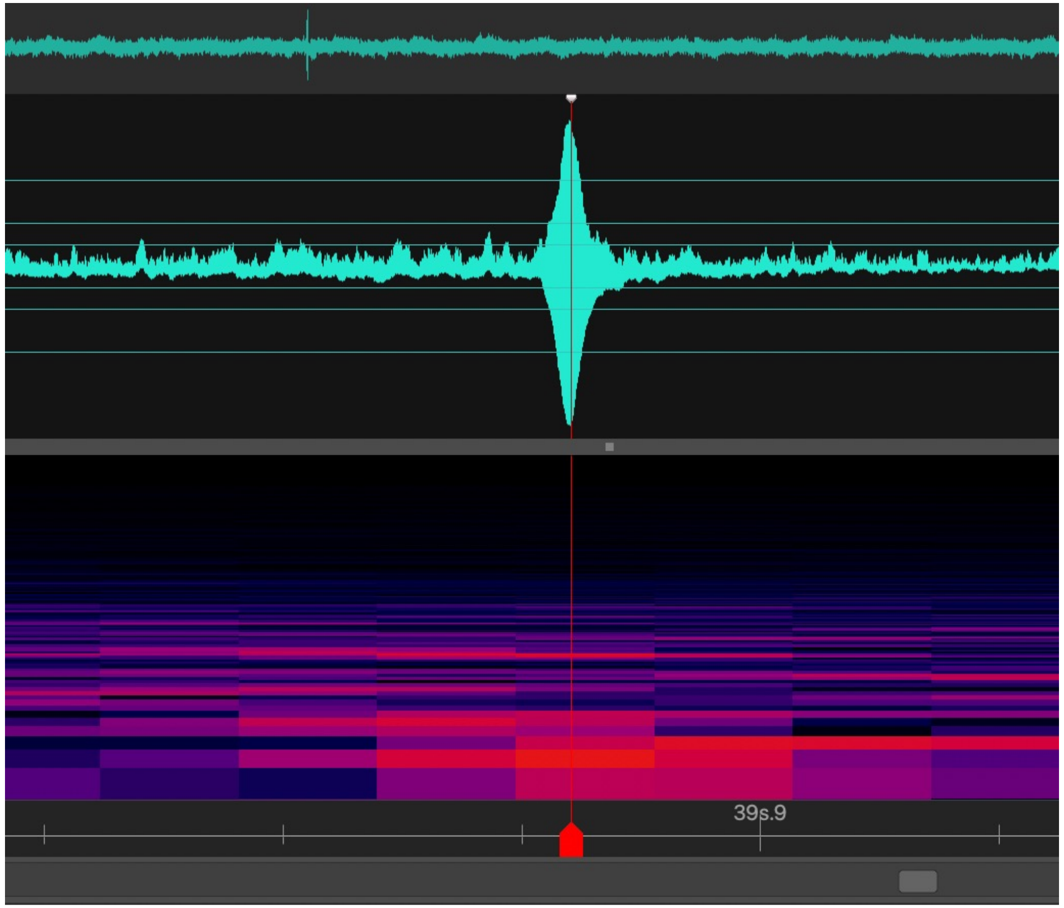
VERY DIFFERENT FREQUENCY COMPOSITIONS

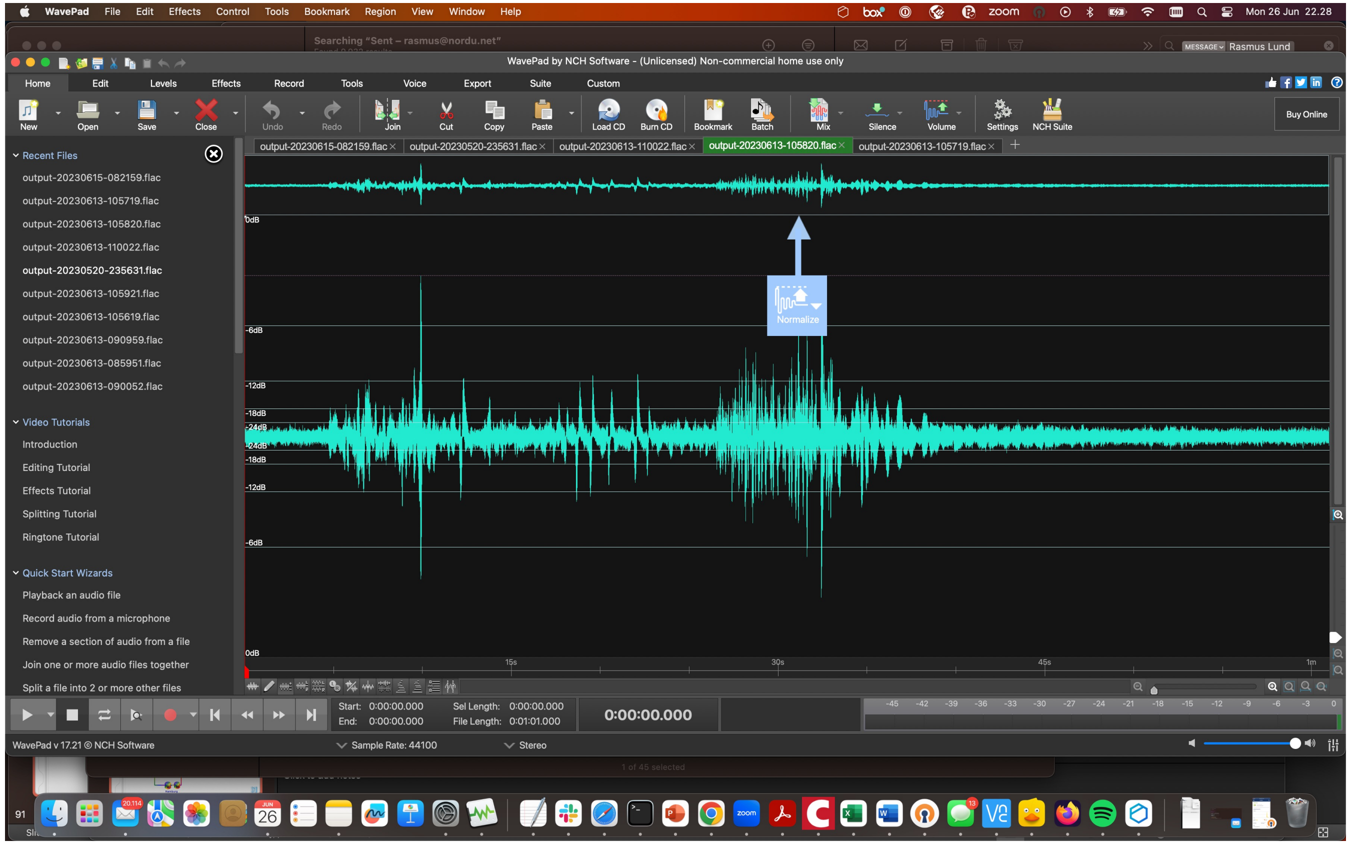


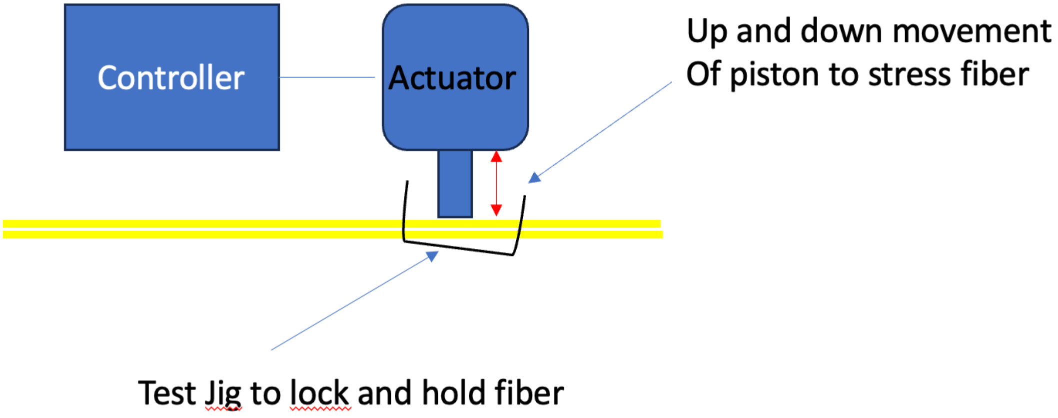
BEND



PINCH

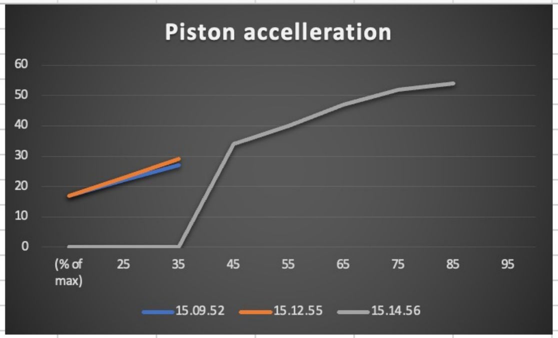
USING ACTUATOR TO SIMULATE PINCH

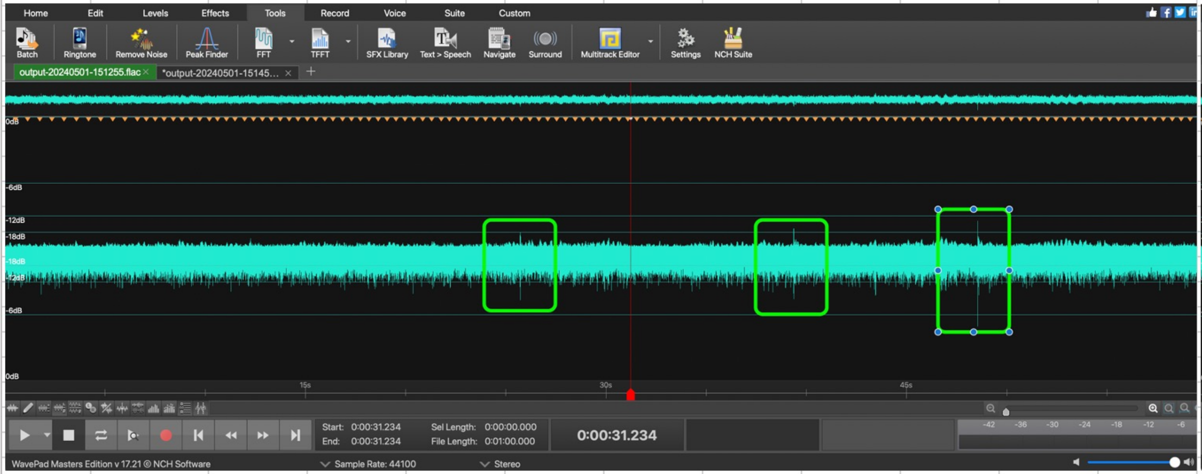


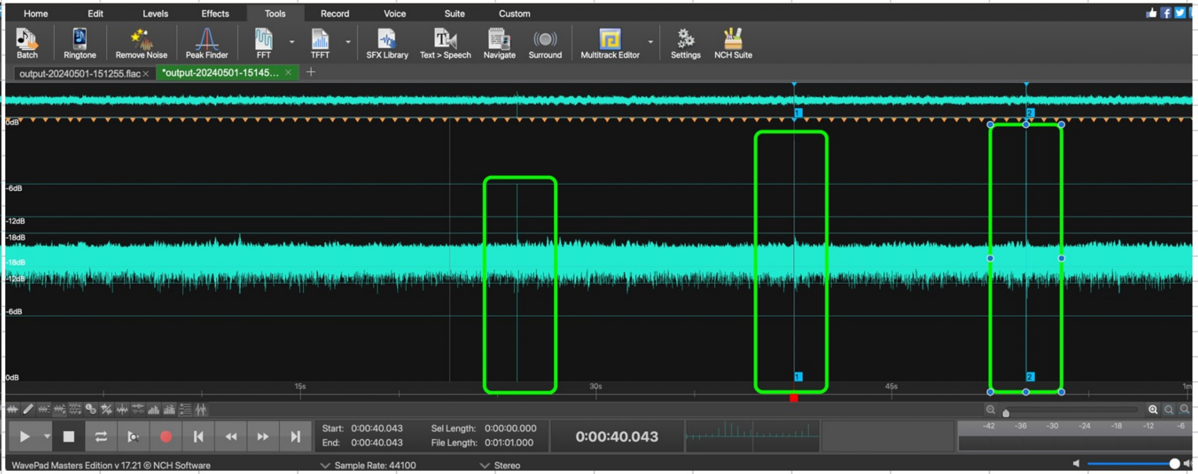


IMPORTANCE OF CABLE ROBUSTNESS

	Std cable 60km		
	Timestamp		
(% of max)	15.09.52	15.12.55	15.14.56
25	17	17	-
35	22	23	-
45	27	29	-
55			34
65			40
75			47
85			52
95			54
100			





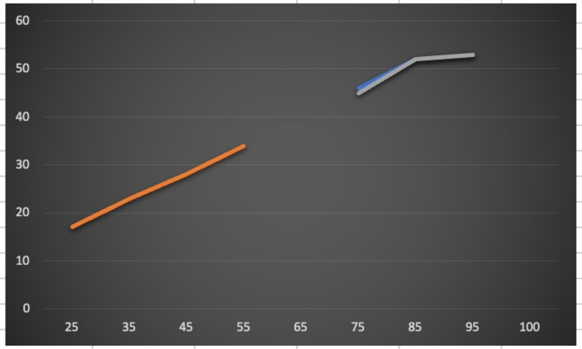


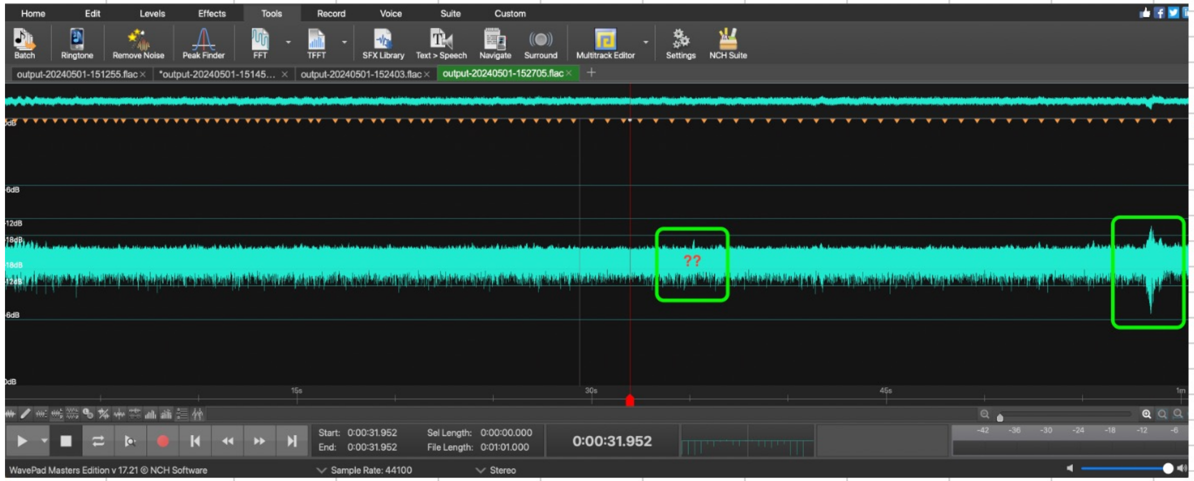
Standard patch cable 60km | Ruggedised patch cable 60km | Thick cable 0km

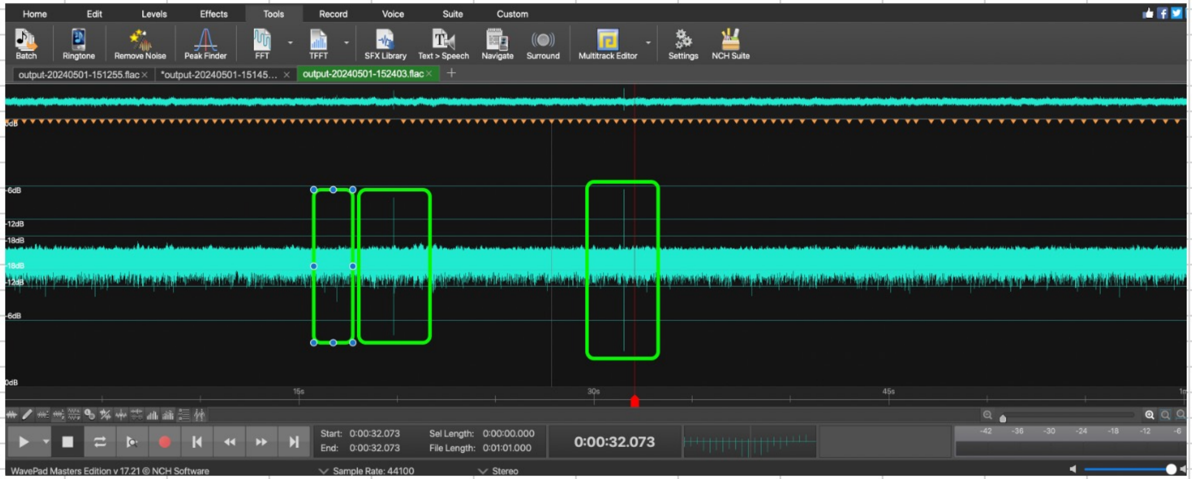
FIBER PINCHES (Standard patch)

FIBER PINCHES (RUGGEDISED PATCH)

	Thick cable 60km		
	Timestamp		
	15.24.03	15.27.05	15.30.07
Acc (% of max)			
25		17	
35		23	
45		28	
55		34	
65			
75	46		45
85	52		52
95	53		53
100			







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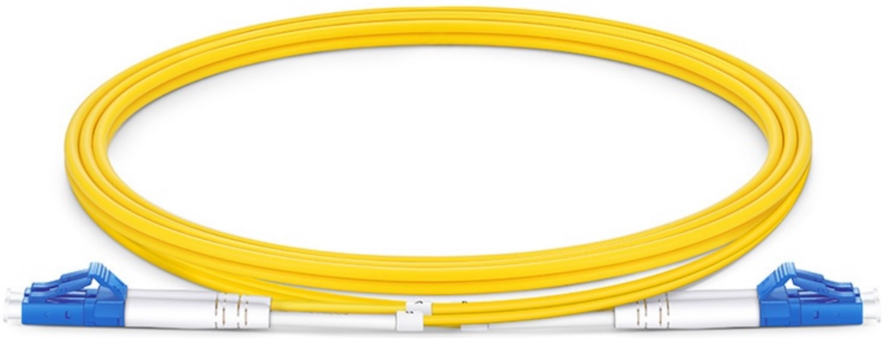
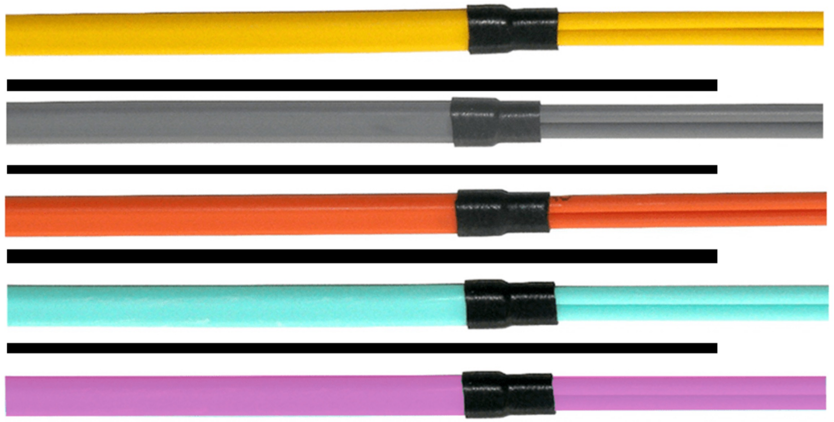
PATCH CABLES

FIRST RESULTS OF STUDY SHOW 30% LESS SENSITIVE TO PINCHES (armoured cable even better)



Standard

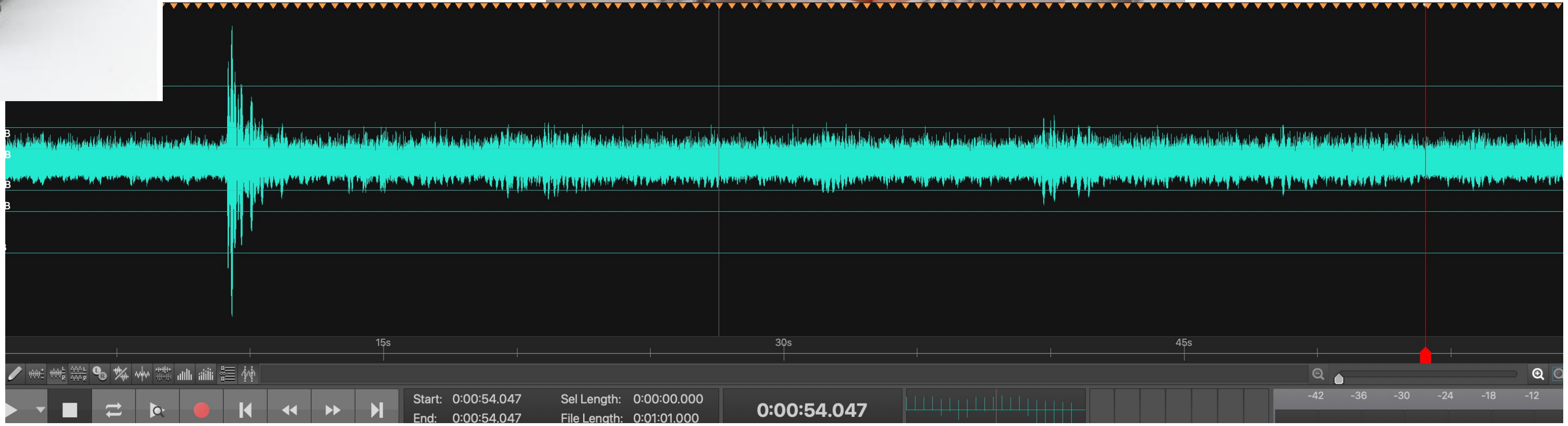


Ruggedised

Performance Parameter	Ruggedised Fibre Patch Leads	Standard Patch Cables
Materials	Reinforced connectors, robust outer jackets	Standard connectors and outer jackets
Design Features	Additional protective layers, armored design	Standard design
Environmental Resistance	Enhanced resistance to moisture, dust, and chemicals	Standard resistance to environmental factors
Torsion	Standard: IEC-60794-1-2-E7 and TIA/EIA-455-85 Length of fiber optic cable tested: 4 m Tension load: 30 N (according to the diameter of the fiber optic cable) Rotation frequency: 1 turn per minute for a total of 10 turns Duration: 5 minutes	Standard: IEC-60794-1-2-E7 and TIA/EIA-455-85 Length of fiber optic cable tested: 4 m Tension load: 15 N (according to the diameter of the fiber optic cable) Rotation frequency: 1 turn per minute for a total of 10 turns Duration: 5 minutes
Impact Resistance	Standard: IEC-60794-1-2-E4/TIA/EIA-455-25 Hanging hammer weight: 2 Kg Impact frequency: 30 times / min Duration: 5 minutes Suspension height: 150±5mm	Standard: IEC-60794-1-2-E4/TIA/EIA-455-25 Hanging hammer weight: 1 Kg Impact frequency: 30 times / min Duration: 5 minutes Suspension height: 150±5mm
Min Static Bend	10D	10D
Min Dynamic Bend	20D	20D
Tensile Load (long term)	150N	150N
Crush (long term)	2000N/100MM	1000N/100MM
Crush (short term)	3000N/100MM	1500N/100MM
Operating Temperature	-20°C to 75°C	-20°C to 75°C

AND YES….
WE PICK UP ACOUSTIC SIGNALS WITH FIBER SENSING

Screaming at a patch 30km away:



CONCLUSIONS?

- With SoP we CAN discriminate on certain events in our Network.
- We can find these events by using, (relatively simple), automation sw.
- We can use machine learning and Ai on known or solved events. They can be characterised with a propabilliy score, for recognition of similar data at later stage. (We **don’t** need more NOC rescources).
- This can be useful for the NOC operators in identifying outages and disturbances. (bend, pinch, lightning strikes, truck rolls etc..)
- Easy to implement on existing infrastructure
- Relatively cheap.

SOP EXPERIMENTS IN NORDUNET (NEW CABLE LULLEÅ-BERLIN (VIA BORNHOLM).

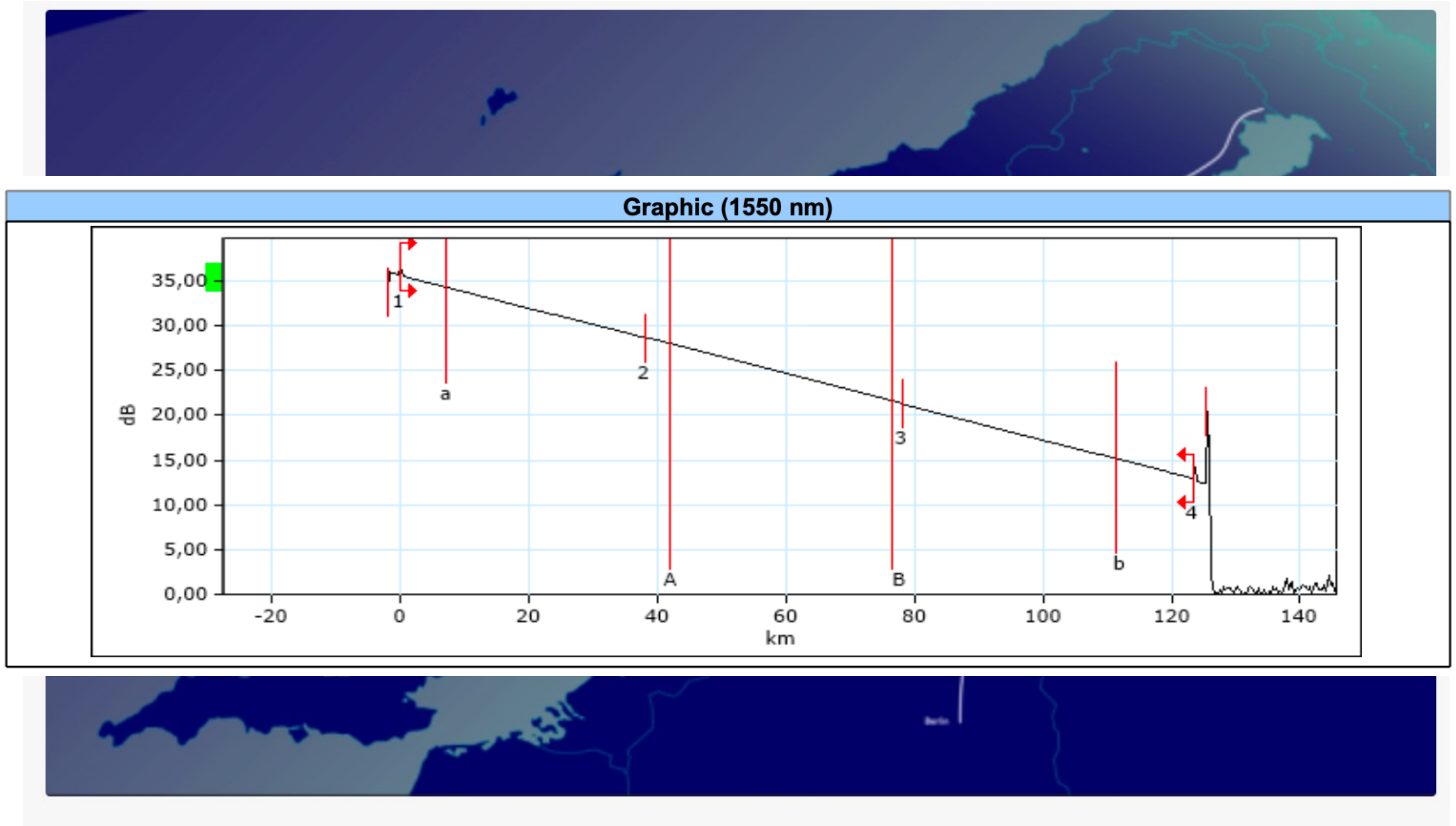


Illustration: GlobalConnect.

GEUS DAS SENSING

G E U S

De Nationale Geologiske Undersøgelser for Danmark og Grønland

- Utilise NN Xtra fiber pair from Bornholm to Germany
to calibrate and compare to normal seismographs

- Eventually to make probable the data collected during
CCS (CARBON CAPTURE AND STORAGE projects). Plus supplement
The existing seismic monitoring systems.

- Expected to start sensing end May.

Thank you.

THE END

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