NASPI North American SynchroPhasor Initiative
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EPRI Charlotte, North Carolina

McEACHERN LABORATORIES INC

GridSweep® - new instrument for grid stability research

An update, and an answer to the question:

"Is it really possible to measure parts-per-million voltages on a distribution grid?"

Acknowledgements

The work presented here initiated in a completed 2-year DOE-funded project “GridSweep” via LBNL Subcontract 7516267,

Sascha von Meier PI, LBNL.

The work presented here continues in DOE-funded project “PROGRESS MATRIX” via LBNL Subcontract 7640617,

Jim Follum PI, PNNL.

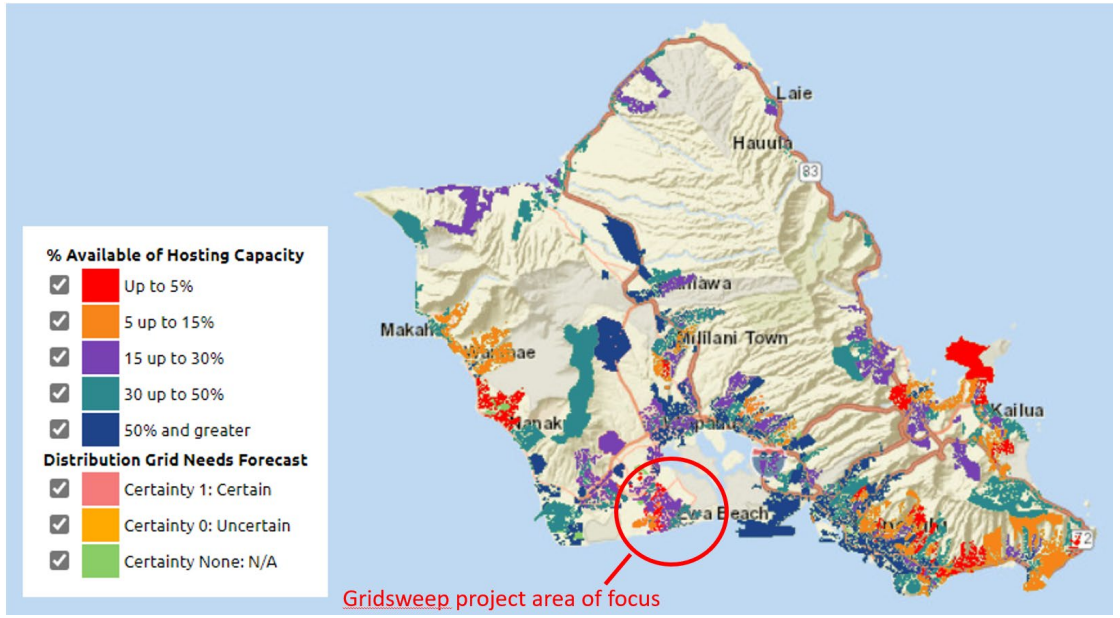
Reassurance about “ppm” and “ppb”

- Power engineers can be slight uncomfortable with “Parts per Million” and “Parts per Billion”
- They’re just fractional units. They are exactly like “percent”.
  - Percent is just Parts per Hundred.
    - 0.1% is the exact same thing as 1,000 ppm.
    - 0.0001% is the exact same thing as 1 ppm, which is the same as 1,000 ppb.
    - 0.0000001% is 1 ppb.
  - The big advantage of ppm and ppb: <u>you don’t have to count the zeros</u>.

- (Fraction, but of what?!)

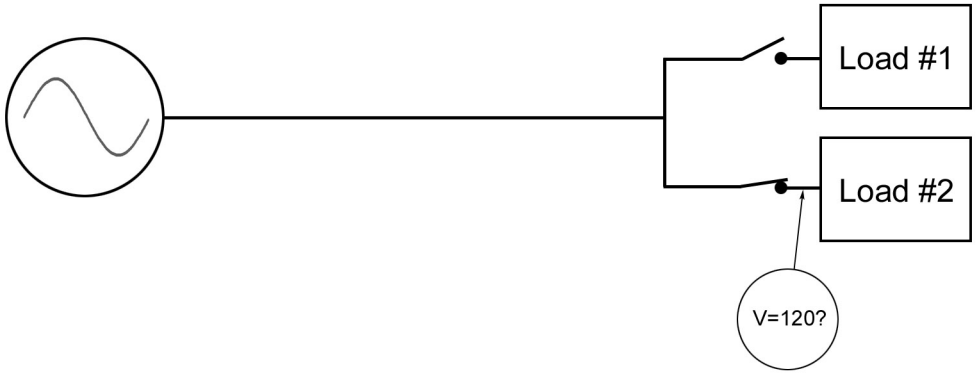
GridSweep instrument motivation

1. "Can we measure <u>incipient</u> instability on power grids?"
2. "Can we do it from 120-volt outlets?"

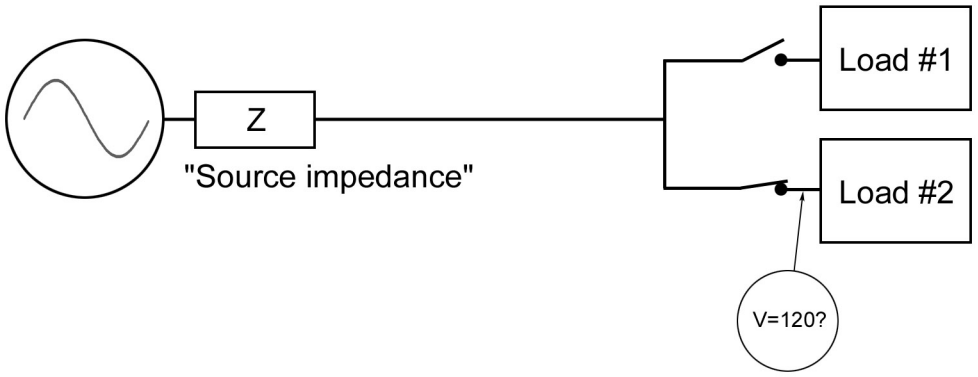


Map & photo acknowledgement: R. China, HECO

Very brief reminders about grid "source impedance"



Basic mental model…



Improved mental model…

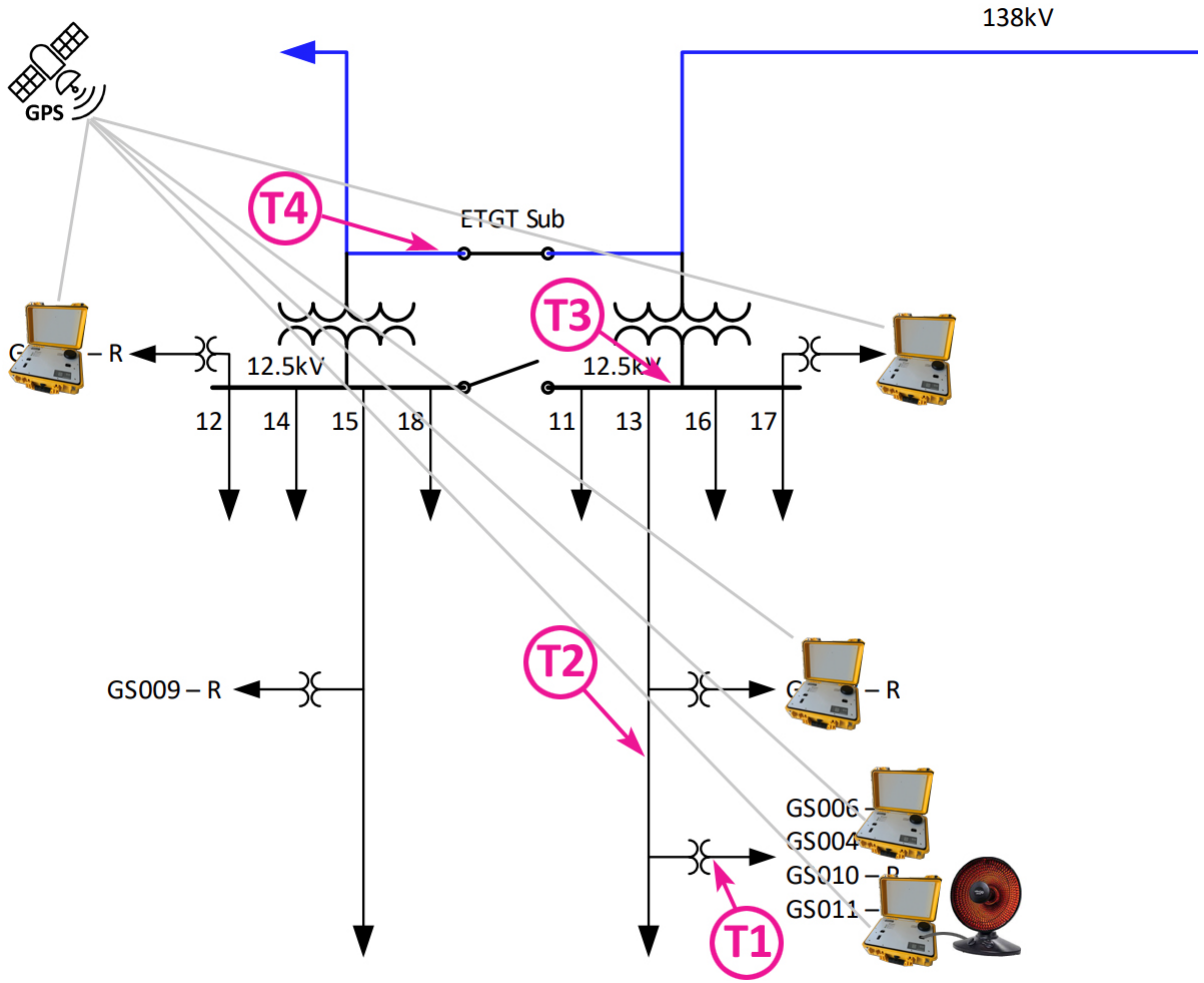
- Z is usually considered only at 60 Hz
- For power line carrier, harmonics, and supraharmonics:
  - Z(f) for 60 Hz < f < 150 kHz
- **For grid stability:**
  - **Z(f) for 0.1 Hz < f < 40 Hz**

GridSweep probing concept: "Shared Thévenin Point"

1. **Inject a subsynchronous varying current (amplitude modulated 60 Hz current) at location T1.**
2. **Measure resulting voltage variation at various locations on the same grid.**
3. **Work your upstream from each location until you find the point where current injection meets voltage measurement: T1, T2, T3, T4**
4. **The voltage measurement tells you the grid source impedance at that meeting point, at the varying frequency.**

Useful rule of thumb
Anywhere on the grid, at rated VA, the voltage decreases by 10%.

Useful rule of thumb
For small changes in VA, that voltage decrease is proportional to the small VA change.



Derived from original drawing by Paul Ortmann, Idaho Power

GridSweep instrument: physical design

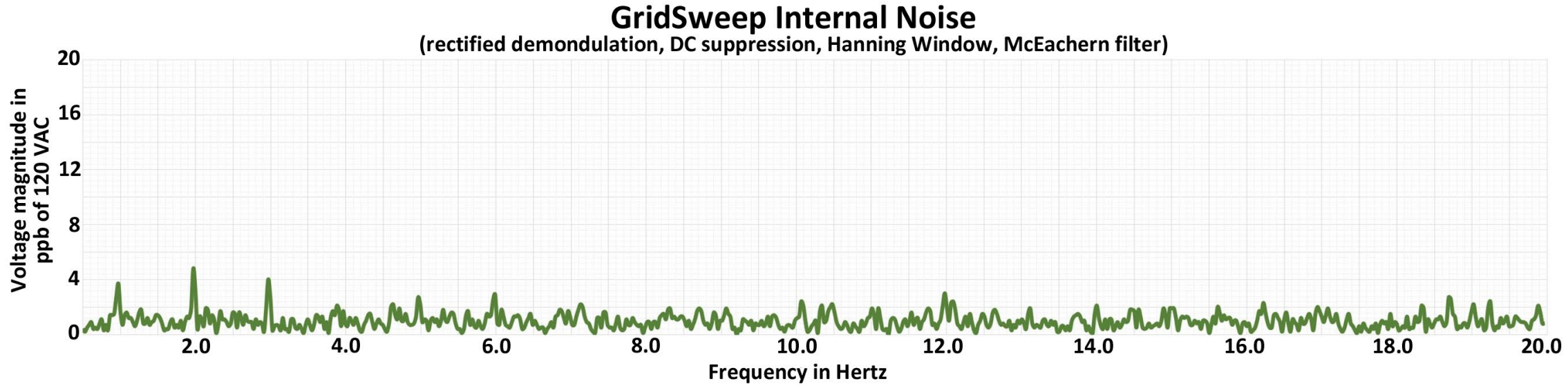
- Use as
  GPS-synced
  1.0 Hz – 40.0 Hz
  1kW probe

OR

- Use as
  GPS-synced
  10ppb
  POW voltage recorder

Voltage signals will be a few PPM, or less.

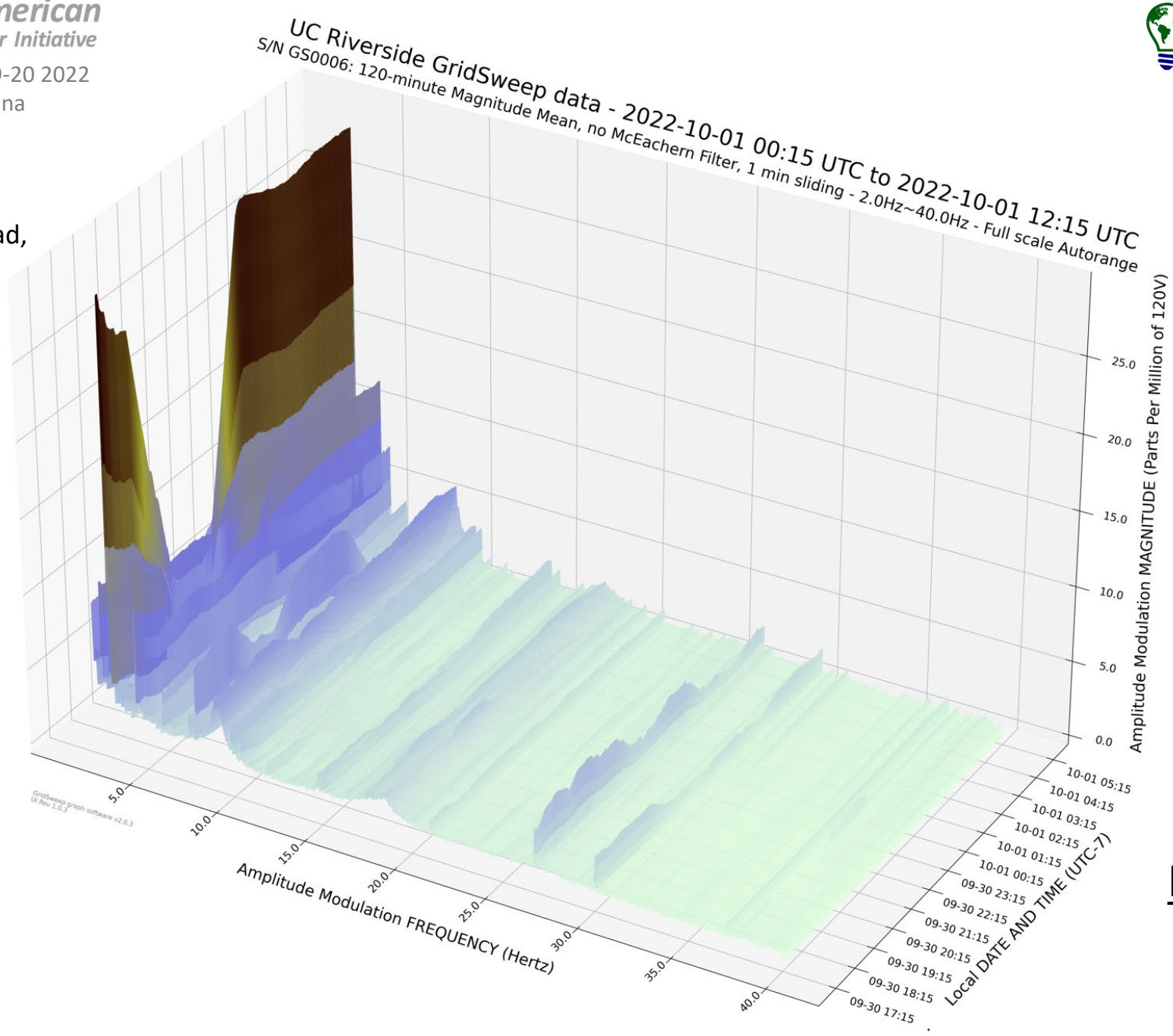
a. Is it possible to construct an instrument that has sufficiently low internal noise in the 2Hz – 40 Hz range? **Yes.**



b. If it is possible to construct the instrument, can those 2 Hz – 40 Hz voltage signals be extracted from the background voltage noise?

Data acknowledgement:
Prof. Hamed Mohsenian-Rad,
U.C. Riverside

Background Noise



Magnitude mean
30 ppm full scale

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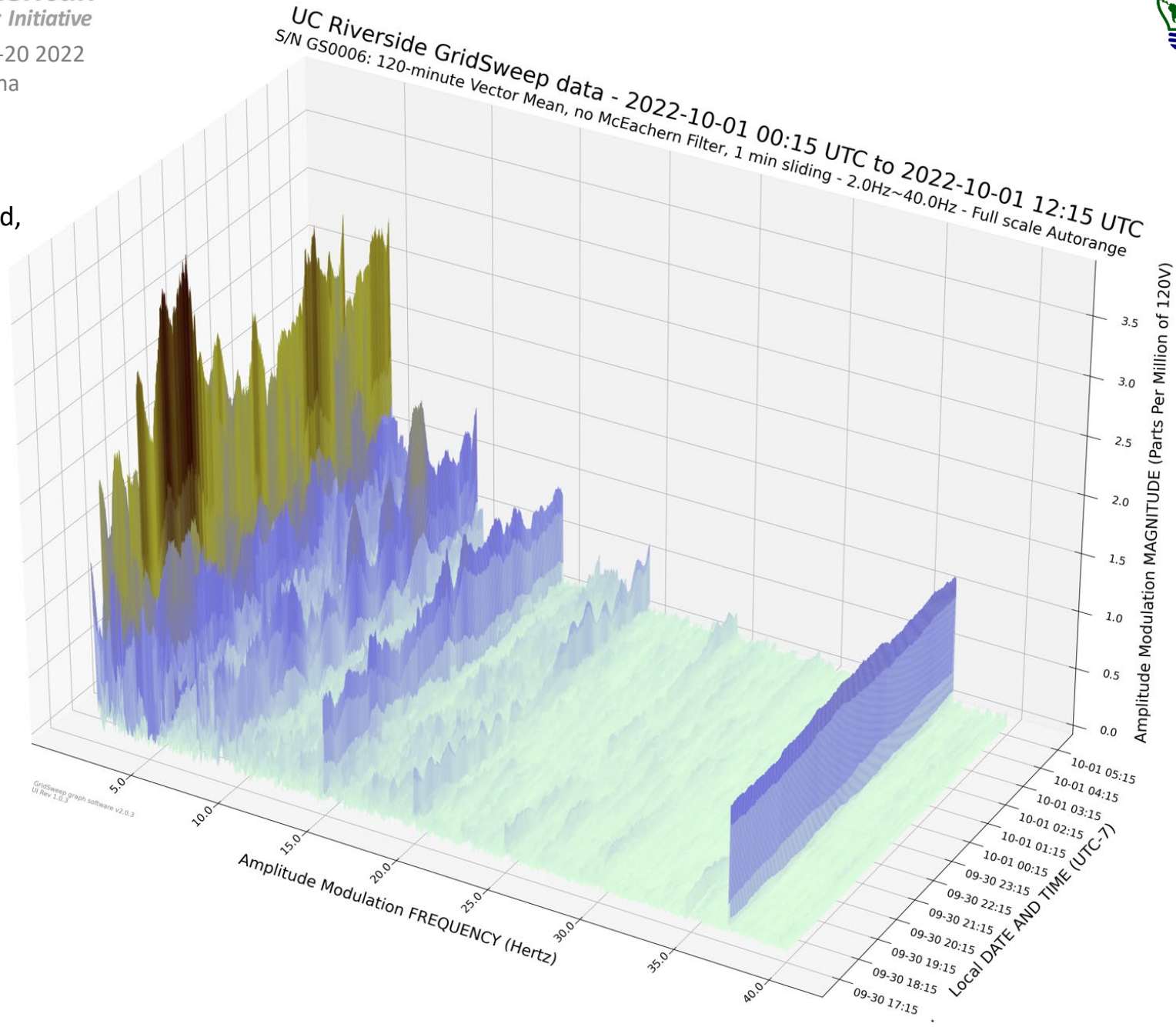
Background Noise



Vector mean
4 ppm full scale

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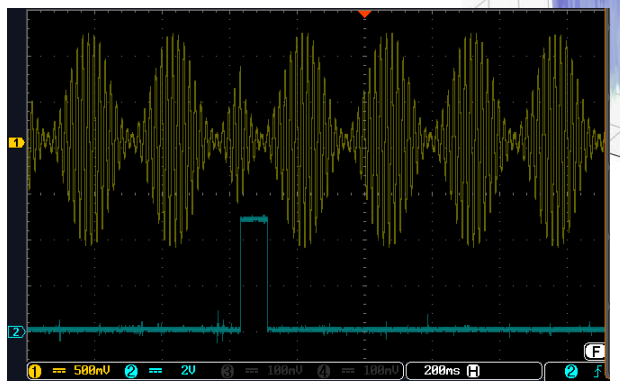
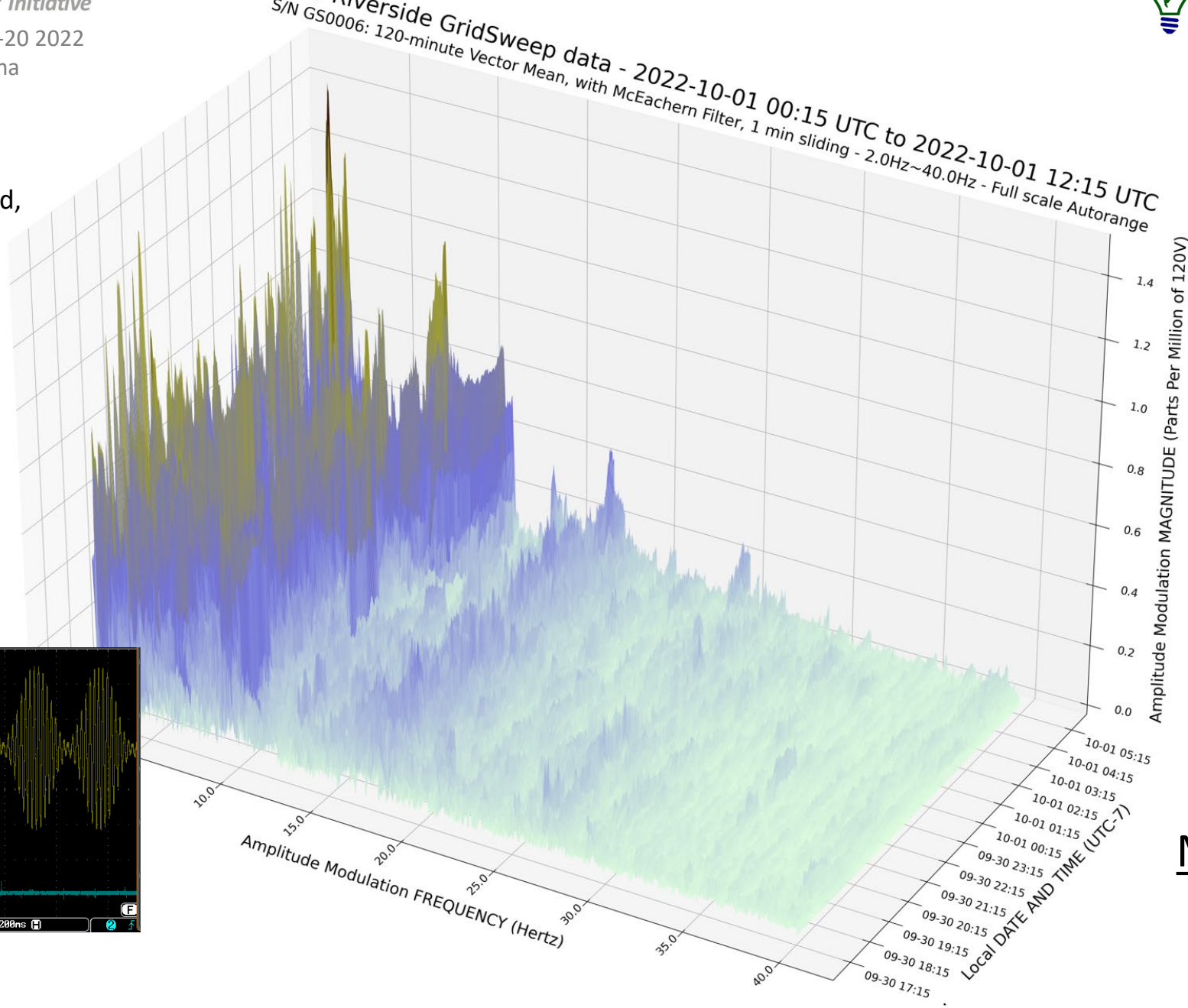
Background Noise





McEachern filter

1.5 ppm full scale

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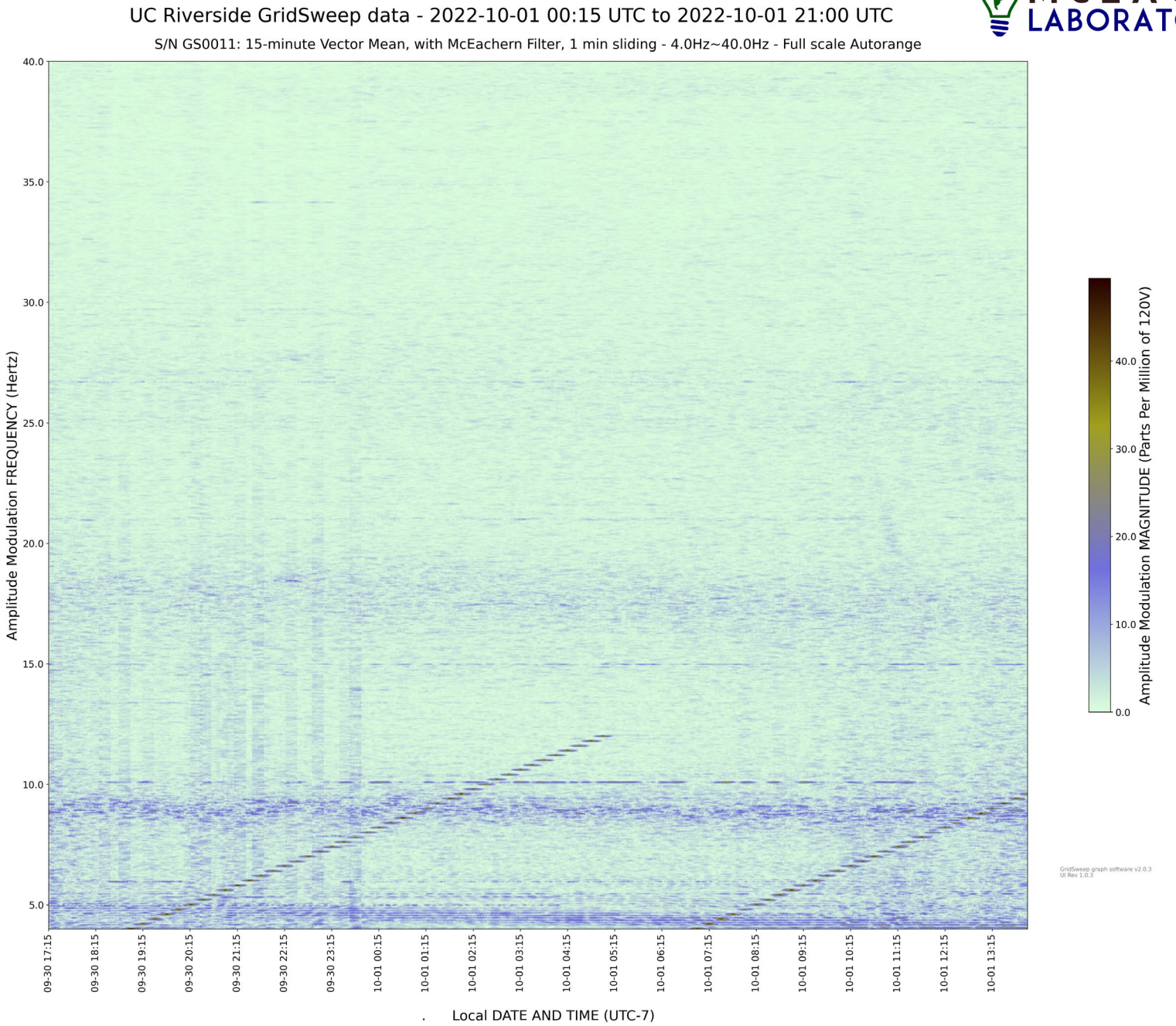
If it is possible to construct the instrument, can those 2 Hz – 40 Hz voltage signals be extracted from the background voltage noise?

Yes.



Next steps in the GridSweep project:

- Additional deployments beyond Alameda Power, Idaho Power, Hawaiian Electric, U.C. Riverside, Dominion
- Data analysis – converting probing + voltage measurements to impedances and stability
- Open source release of raw data
- Publication: methods, circuits, algorithms, filters

Opportunities for you?

- Small fleet of loaner GridSweep instruments at LBNL:
  - Do you have ideas for research/experiments?
    - 4.1kHz sampling, ppb resolution, continuous 1-minute GPS-synced POW voltage files.
    - Optional GPS-synced AM (amplitude modulation) of 1kW resistive heater
    - 120-volt outlet. Fully UL listed, FCC compliant, CE marked.
    - No internet connection, no IT department approval required.
- Or deployment together with LBNL GridSweep team?

McEACHERN LABORATORIES INC

Alex McEachern

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- Life Fellow, IEEE, for “contributions to power quality measurements and immunity”
- Visiting Scholar, U.C. Berkeley Dept of Electrical Engineering & Computer Science
- Affiliate, Lawrence Berkeley National Lab
- Founder & CEO/CTO:
- Basic Measuring Instruments (1980-2000)
- Power Standards Lab (2000-2019)
  - Grid instruments – $300 million in cumulative revenue – 50% North America, 50% international
  - Led technical development and commercialization: **PowerScope** instrument, **PQube** instrument, **Grid Thumper** for DARPA, **µPMU** for ARPA-E
  - Close working partnership on many projects with Prof. Sascha von Meier
  - Close working partnerships globally: North America, South America, Asia (Japan, China, Vietnam, Thailand, Malaysia, Singapore), Western Europe, most of Eastern Europe
  - Chair & Principal Author of many International Standards: IEC 6100-4-30, IEC 61000-4-11, IEC 61000-4-34, IEEE 1159.1, IEEE 519, SEMI F47
  - Sold Power Standards Lab, then “retired” in 2019. McEachern Laboratories Inc.
- 2020-2021: Developed GridSweep® instrument for DOE SETO/OE (LBNL, LLNL)
- 2022: Active in PROGRESS MATRIX follow-on project for DOE (PNLL, LBNL, NREL, ORNL)

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