

## Radiolocation and Communications on Bill Stone's 2023 Expedition to Systema Cheve in Oaxaca, Mexico

After the 2022 expedition, Cheve was 80.9 km ( 50.3 miles) long and 1531 m ( 5023 ft ) deep, currently the $12^{\text {th }}$ deepest cave in the world.
The known resurgence (by dye trace) is 2445 m ( 8022 ft ) below the main Cheve entrance. If connected, Cheve would become the deepest known cave in the world by a good margin.
It now takes several days of hard caving to reach the limit of exploration. A new entrance is needed. The search is underway.

## Bill is trying to make Sistema Cheve

 the deepest cave in the world

For the 2021 Cheve Expedition I built high performance single wire "Ultraphones" which were used to talk to the surface and between camps


I also built single wire interfaces to allow Topodroid tablets to send survey data digitally to Base Camp. See radiolocation.weebly.com for info on both units.


For the 2023 Expedition I built a custom radiobeacon for a deep radiolocation near the limit of exploration to check the accuracy of the map for the first time.

## B36 9.0 36V BATTERY 36 volt 9.0 ah lithium ion

 For Hilti hammer drill324 watt-hour rated. 300WH is the max for passenger aircraft.


Can only be shipped ground by shipper with HAZMAT training
Can't just go to UPS or FedEx.

Bill wanted to power the beacon with the same hammer drill battery used for bolting


## Several changes were made to the 3496 Hz beacon circuit due to the high DC voltage and ~27W input power. Efficiency is 78\%.



Everything fit on my standard beacon board. The green LED is DC power, red is loop current. Most of the power loss is in the toroid, little in the MOSFET.


I tuned the beacon while it was hanging in my garage. It draws about 0.76 Amps at 36VDC. I later made a 9 hour test run with the battery.


The circuit dissipates about 6 Watts. There was a concern that it might overheat in the plastic box, but it only reached 120 degrees F at 55 F ambient.


The beacon was connected directly to the battery cells without protection (BMS). I added a programmable low voltage cutoff device.


At the end of March 2023 I spent 2 weeks at Cheve where I was able to observe the phones and modems in use, and do the Radiolocation.


## Pleasant camping in a pine forest at 9000 ft elevation



## Clear skies gave 70 degree F days with nights sometimes dropping to the low 20s.



## Some evenings I was in ski pants and a down jacket even with a fire.



## The main Cheve entrance at the bottom of a huge sink that includes Base Camp 1km away



## The upper Cheve entrance

The single wire phone line is 12.7 km ( 7.9 miles) long to it's end at camp 7, including 1 km on the surface to Base Camp where there is a good ground in a stream.

- I got .065uf and 1600 Ohms to gnd at 1 kHz on the OC line. Xc = 2448 Ohms for the capacitance alone. The cap value is suspect (low) due to a known line fault (high resistance connection) between camps 2 and 3.
- I got 0.24VDC and 5-7k Ohms DC to gnd on OC line.
- During the day I got $\sim 25 \mathrm{mv}$ AC on the open circuit line.
- An oscilloscope app showed 120 Hz modulated at 24 Hz and pulsing at $\sim 1.8 \mathrm{~Hz}$ on the Open Circuit line.


## At Base Camp I was able to make a few measurements and observations

- I also made a crude measurement of conductivity on a flat limestone area near Base Camp, limited by a tiny test beacon and a pocket-size receive antenna. My estimate of average rock conductivity was . $0008 \mathrm{~S} / \mathrm{m}$, which was low enough to give hope that this deep radiolocation might be possible.
- Later I repeated this measurement near where the radiolocation point should be and got .00078 S/m, which gave a warm fuzzy feeling.

I also measured the electrical conductivity of the rock, which was very low for limestone


I tested my clip-on mobile phone, which easily worked 1 km from the Cheve entrance to base camp despite the 12.7 km ( 7.9 mile) shunt load

The 12.7 km ( 7.9 mile) phone line acted as a huge antenna that was able to pick up natural atmospheric noise, especially at night.

There was both natural and manmade noise on the phone line

- The phone line had a high resistance fault between Camps 2 and 3. Camp 7, at the end of the line, was strong at camp 3 but much weaker at Camp 2 and Base Camp. Because the phones worked despite the fault, no effort was made to repair it.
- Also because of this fault, the slow but robust Olivia 8-2000 mode was used to transfer survey data \& inventory lists. This used 8 audio tones from $500-2500 \mathrm{~Hz}$ at 125 baud (116WPM)


## The phone line had a problem

This is what the 9AM schedule from camp 7 sounded like. I used acoustic coupling to my mobile Ultraphone, which did not help fidelity


## For the Radiolocation, I moved down to the small mountain town of San Miguel Santa Flor. This was the view from the radiolocation site



The view from Mary's restaurant. At last a real bed, flush toilet, electricity, internet, and Mary's homecooked meals!


The cave passes under the town on it's way north to the resurgence 1100 m ( 3600 ft ) lower. Survey station SNG40 was chosen as the point nearest the surface


## Organizing gear at the Santa Flor fieldhouse. The 3 receivers were last used in Antarctica



## Local officials and others were invited to witness the Radiolocation and try to locate the little test beacon placed down the hill.



Corey Hackey finished assembly of the beacon electronics and teamed with Sean Lewis (photographer) for the radiolocation, which was several days of hard caving from the Cheve entrance

- We were waiting on the hillside near the GPS point for survey station SNG40. The beacon came on strongly only 39 minutes later than scheduled.
- Ground Zero was quickly located only 20.3m ( 67 ft ) on 17 degrees true from the GPS point. The rock seemed to have little effect on the mag field, but due to the hill slope the actual location may be a bit further uphill.
- Due to interference from a power line on the ridgetop, and the great depth, my estimate of Ground Zero location repeatability was $+/-3$ meters (+/- 10 ft ).
- A depth-by-field-angle measurement done at 90 m (295 ft ) horizontal range gave a depth of 250 m ( 820 ft ). This method is known to underestimate depth.


## The Radiolocation went way better than expected!



That's all, folks!

