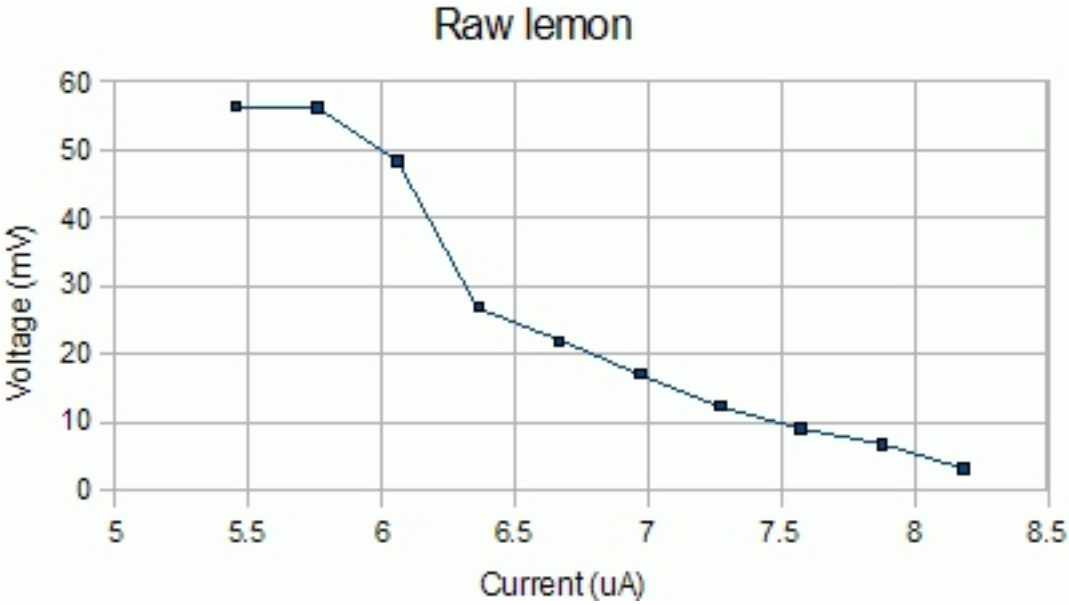
I had lots of fun building radio transmitters powered by natural homebrew power sources. The first

All over the place on the {gallery}battery/lemon{/gallery} classic school science project, sticking two dis

On this page, you can click all thumbnail photographs to get bigger versions. But the graphs are already the full-size versions, so you can't click them.

Simple lemon cell



My first attempt at a lemon battery consisted of a standard lemon, fresh from the supermarket, with a copper wire (solid core household cable with the insulation stripped off) poked in one side and a normal steel bolt pushed in the other side. To test this power generation masterpiece, I rigged up a 10k variable resistor in series with a 330-ohm fixed resistor and my two DVM to measure voltages and currents.

Indeed, when unloaded, the lemon produced around 0.5 Volts. But what about under load? The 10K potentiometer allowed me to vary the load between 10.3k and 330 ohms. The graph to the right shows the resulting battery voltage vs load current. As soon as I connected the load, the voltage dropped to 56mV even though the load was more than 10kOhms. The current was only

5.5 microamps! At the other end of the potentiometer, by the time the load was reduced to 330-Ohms, the current increased to 8uA, but the voltage falls to only 2.6mV. This lemon battery produced only 0.3uW of power across a 10k load! To power my 40m QRSS transmitter I'd need about 30,000 lemons.

Next, I cut a strip of baked bean can tin, maybe 50 x 5mm. I inserted that into the lemon, in place of the steel bolt. The open-circuit voltage was 498mV, dropping to approx 300mV through my 10.3kOhm load. That's a current was of 29uA, for a power of 8.7uW. That's a 28-fold increase in power production! But still, nowhere near the claimed 1mA on some websites. If they lit an LED with some of these in series, then Ok, but it must have been a low-current LED. To power my 40m QRSS transmitter , now I'd only need 1,000 lemons. But that's still a lot of lemons.

In the end, I was so disappointed with the ability of a lemon to produce much current, that I even forgot to take a photograph. So all you get is the graph.

Lemon juice cell

Not quite ready to give up on lemons altogether, however. My next battery cell was made from baked bean tin, soldered into a small cup. The dimensions of the cup are 35 x 23 x 4mm. A small 25 x 25mm square soldered on the bottom keeps it upright. The tin cup is the negative terminal of the battery. To construct the other electrode, I used about 25cm of copper wire, wound into a flat spiral. The copper wire is household lighting cable, with the insulation stripped off. To keep the electrodes apart, I wrapped the copper spiral in a piece of kitchen tissue. Then poured in lemon juice squeezed directly from a lemon. The idea here, is to increase the surface area of the electrodes and decrease the distances involved, to reduce the internal resistance of the battery.

{gallery}battery/smallcell{/gallery}

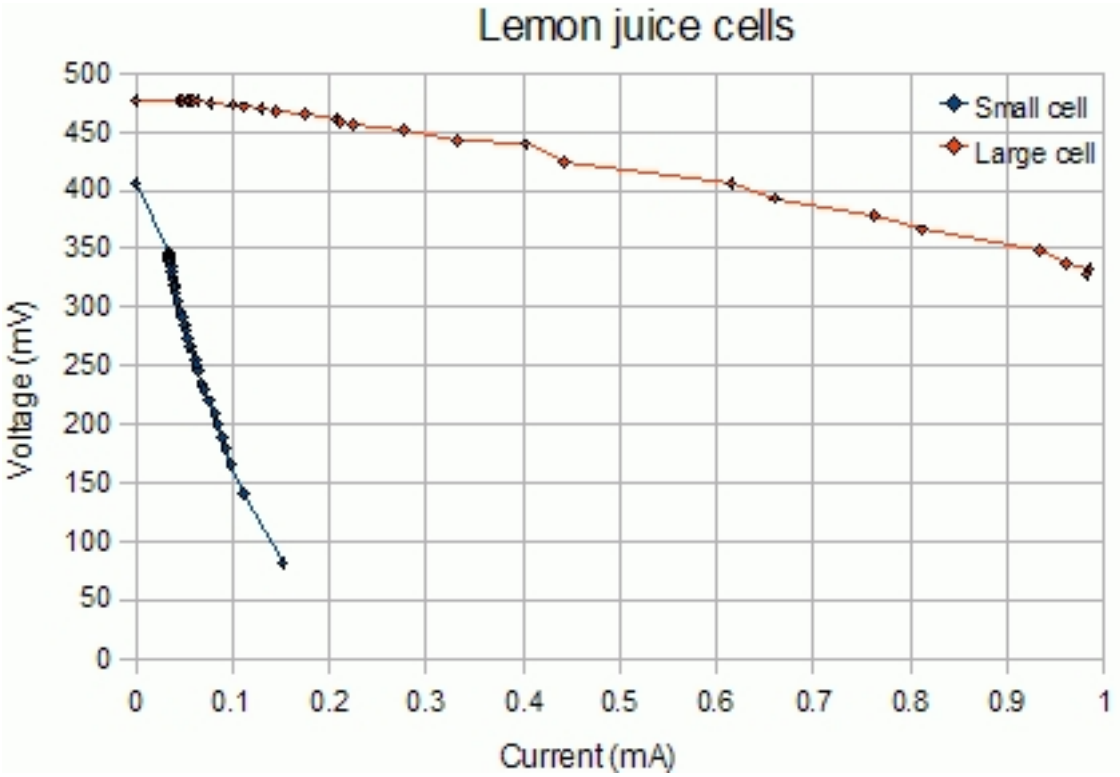
The results of this experiment were a little bit more encouraging. The current at 10.3k load was 34uA, which was only a little bit more than the raw lemon alone. But it coped better with lower resistance loads, and at about 500 ohms load could support a current of 150uA and the voltage dropped to 81mV. Peak power production occured at a little lower current than this, and was 17uW. This cell is therefore about twice as good as my raw lemon (with tin strip electrode).

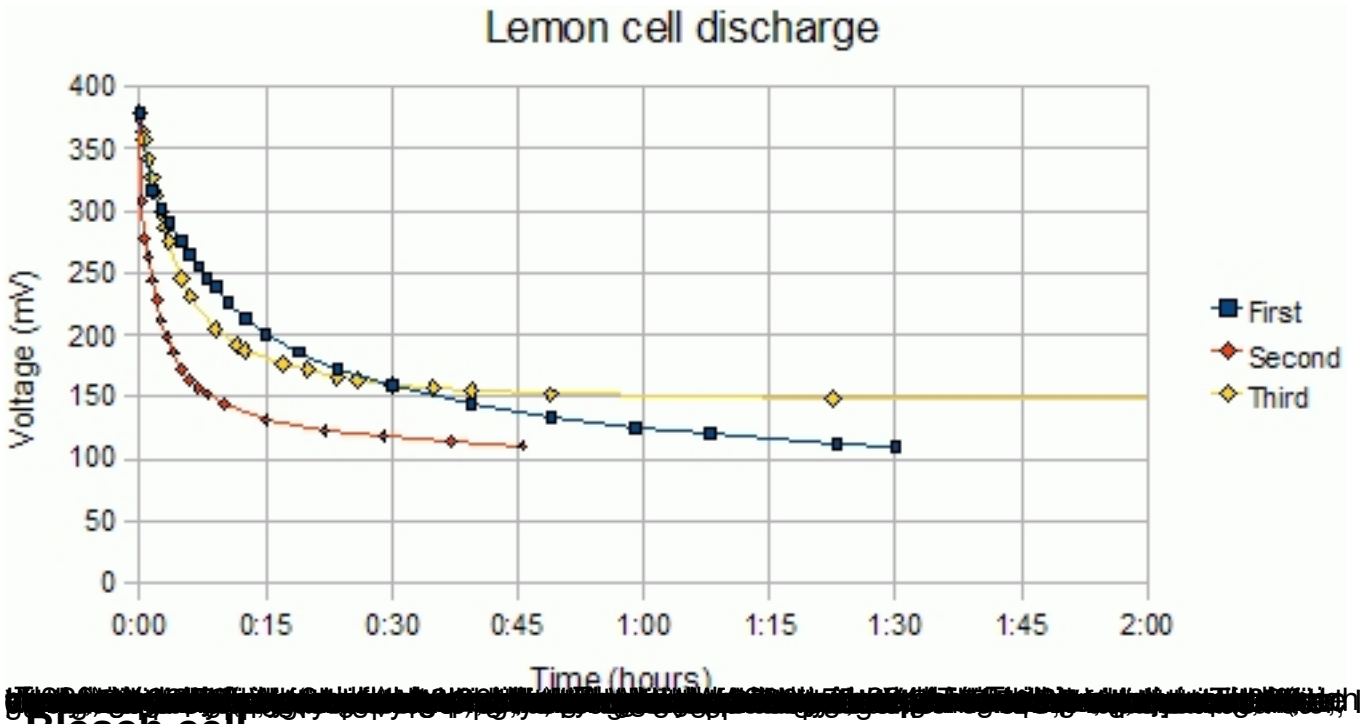
Improved lemon juice cell

I was encouraged by this result and decided to build a bigger version of the same cell, incorporating larger electrodes and keeping the electrode separation as small as possible. For this larger cell, I used a whole 400g baked bean can. I cut the wall of the can into two pieces, folded together such that I produced a cell having three compartments. A piece of tin strip from the offcuts completed this small tank. All soldered together (baked bean can tin solderes very nicely). The size of this cell was about 70 x 50 x 20mm. The flat spiral coil is in this case still made from copper wire, but a longer length of it. Three such spirals are used in this battery. Each one was wrapped in a piece of kitchen tissue to stop it touching the tin electrode. Finally, lemon juice was poured into the cell. One lemon produces enough juice to fill the cell. The three compartments weren't sealed from each other; the only reason for the three compartments was to keep as much tin and copper as close together as possible.

{gallery}battery/bigcell{/gallery}

Well, the results from this cell were much better than previous attempts, as might be expected:

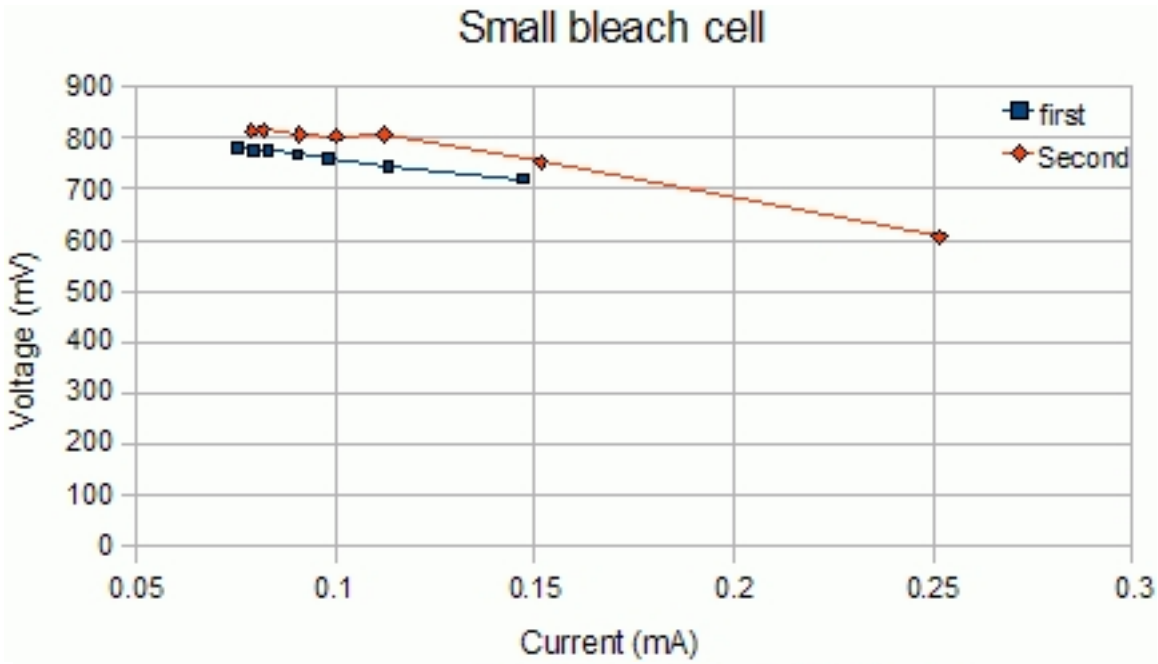


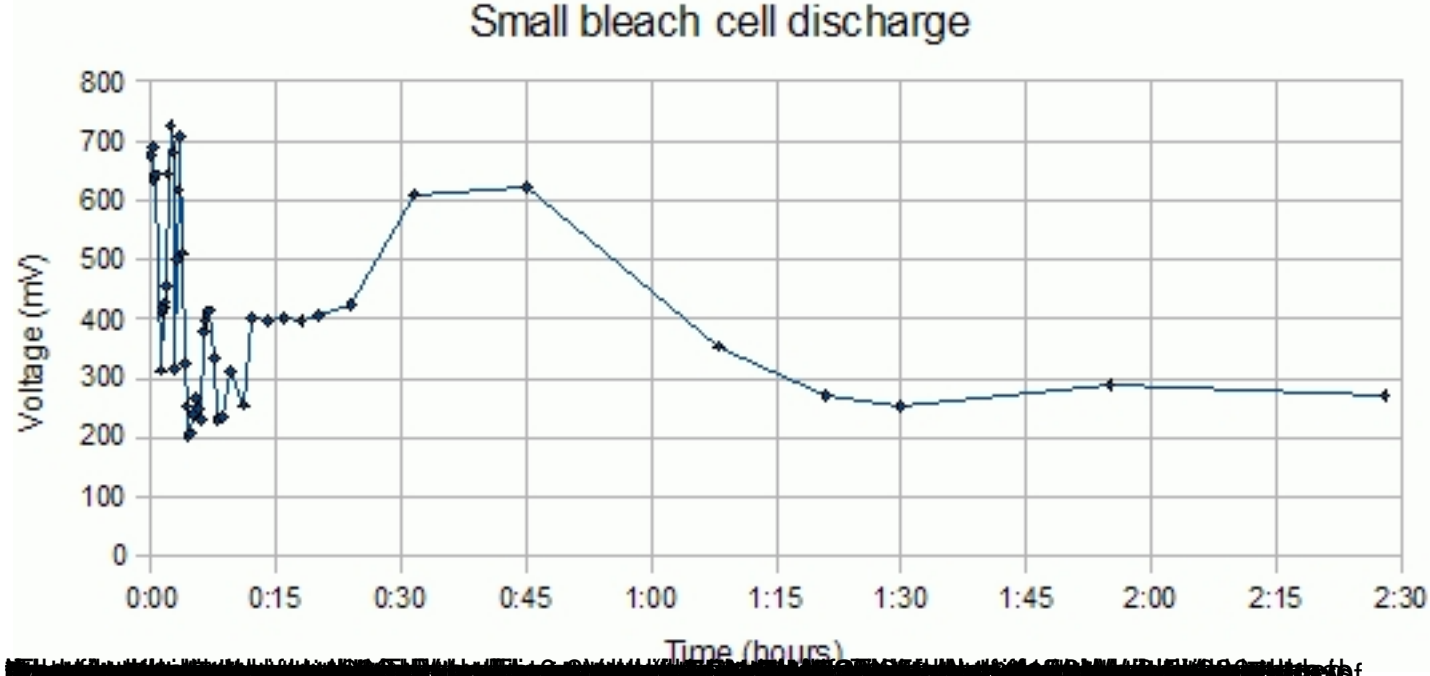


Bleach cell

A little bit more internet research. I read somewhere of a fellow who put bleach into an ice cube tray, with electrodes separated by kithen tissue and connecting "cells" made from each ice cube's hole, in series. So I decided to have a go with bleach. I cleaned the original "small" lemon juice cell to get rid of all the lemon juice, used a new piece of kitchen tissue to separate the electrodes, and filled it up with undiluted bleach.

Now here's a REALLY much more impressive result! Forget about lemons. Keep them for your cooking. Try bleach instead! It's cheaper than lemons, and it works MUCH better. In fact, it even SMELLS better, and less strong! You'd think not, but it's true. Too much lemon juice and the room will really start to smell. Bleach smells strong when it's been spread over a large area, but not so bad when the exposed surface area is small.



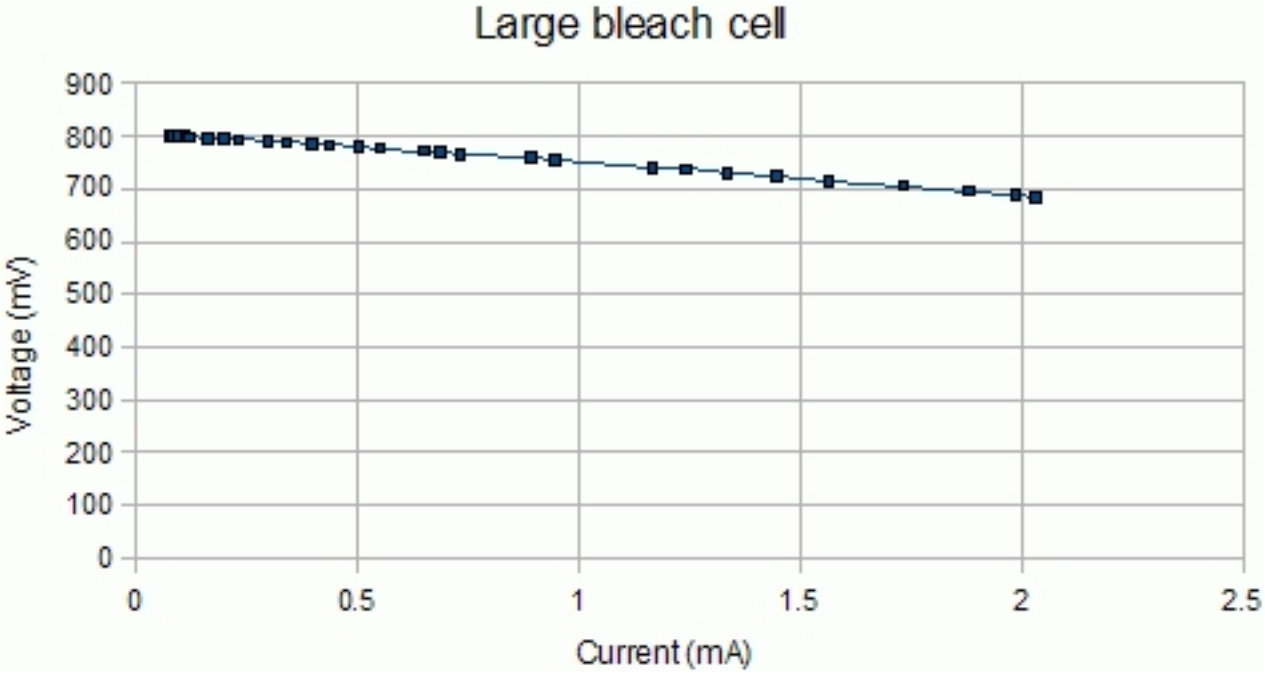


LARGE bleach cell

Right. Enough of the research, now I want a practical cell that I can use to power my 40m QRSS transmitter
. The kitchen tissue dissolving problem meant it isn't suitable as a means to keep the two electrodes apart. Bleach is fierce stuff and it is difficult to think of suitable separating materials which would let the bleach through, but not be rapidly degraded. On the other hand, I wanted to get as much copper and tin as close together as possible. I thought long and hard about this and the solution I came up with is effective yet very simple to make.

{gallery}battery/construction{/gallery}

Above, the construction process. One cell uses one baked bean can. I liked baked beans, and anyway I have a collection of baked bean cans because they are great as shielding material, or as circuit substrate for "ugly" construction. Next comes the "other" electrode, for which I used copper wire again. The copper wire is from a bit of old house lighting cable, left over on a reel. I have grey and white coloured ones (on the bottom and top respectively, in the picture). I used the white wire because the copper was thicker - over 1mm diameter of copper. Stripping off the red and black insulation was a big task and I got blisters on my hands.



Each cell uses two 7-foot lenths of copper wire joined end-to-end. The join is brought OUT of the cell and soldered outside, so as to avoid corrosion breaking the contact if the wires were just twisted together. The wire is wound on a 250ml Johnson's orange juice bottle. I drink one of these at lunchtime so collected them over the course of a week. I filled the orange juice bottle with water, so that 1) it was less compressible than it would have been if it was air-filled and 2) so that it was heavy enough to rest firmly on the bottom of the can when the bleach was poured in, rather than trying to float. The third-from-left photo above shows three cells in various stages of construction. I like the orange juice bottle idea. The separation between the copper wire and tin walls is about 7mm, but no material is required between the two to keep them apart, as long as the cell is placed carefully on a horizontal surface. Furthermore, the orange juice core means that much less bleach is required, limiting it to about 150ml per cell.

The far right photo above, shows the test setup where I am characterising one bleach cell.

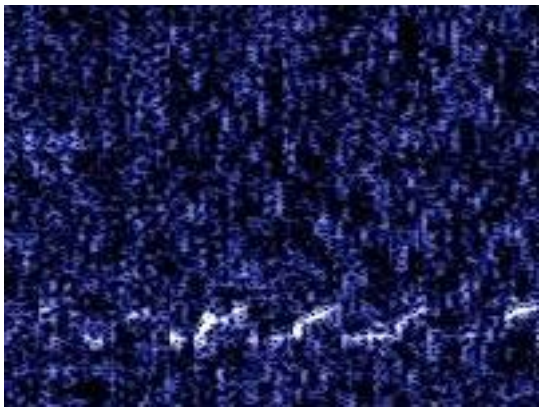
The results for this battery cell are at last good enough for it to be seriously considered for powering my 40m QRSS transmitter . Across my usual 330 ohm load, it produces 2mA current, dropping the cell voltage to nearly 700mV and producing 1.4mW of power.

Bleach battery

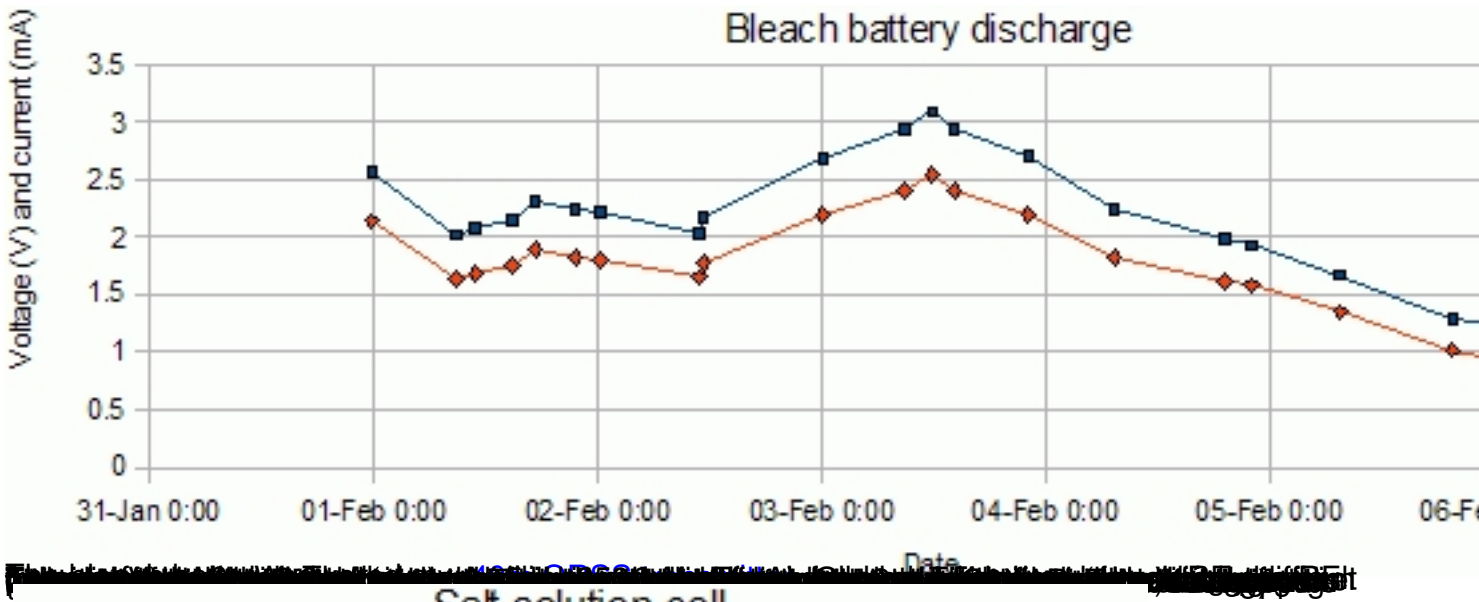
{gallery}battery/bleach{/gallery}

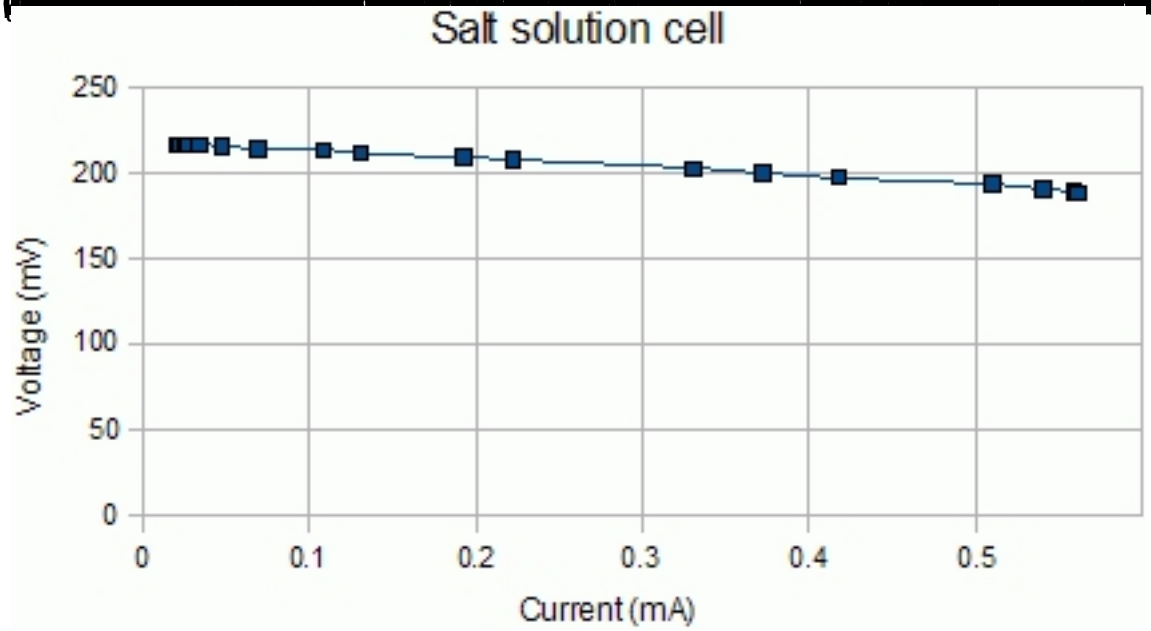
I built FOUR of these bakeo bean cans, and connected them in series. One 750mV or the photo, 3

SUCCESS! With this battery powering the TX, it produced an output of about 3mW (into 50 transmitter .



Demise of the bleach battery



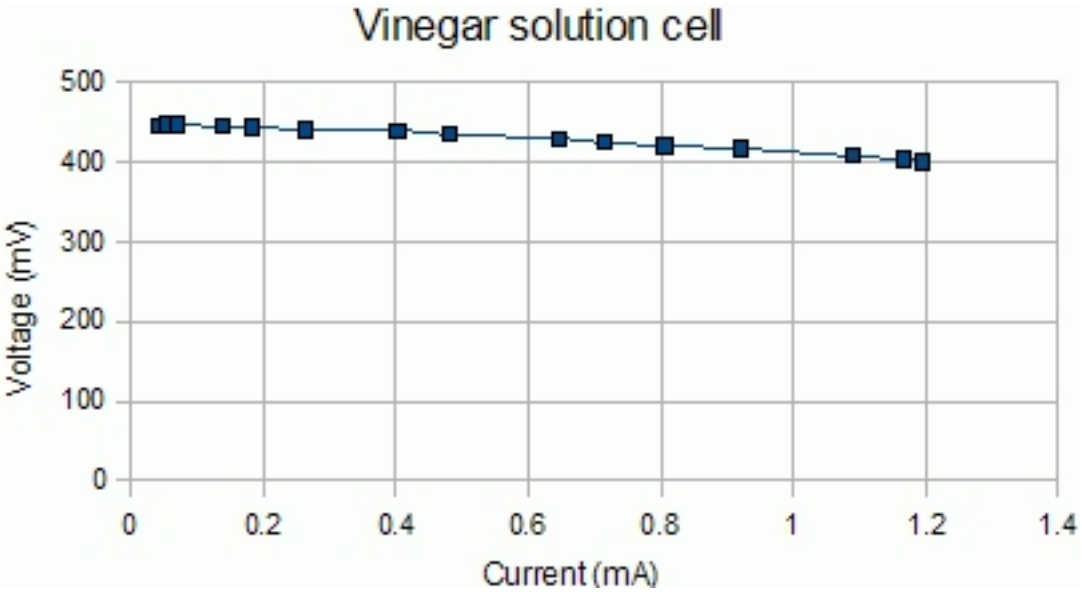


Salt cell

Considering the acceptable state of the copper electrodes following the bleach battery experiment, and also encouraging reports of salt and vinegar experiments from Anders Sandstrom, I decided to try a salt cell. I dissolved a large amount of salt into boiling water, until I could dissolve no more. This ensures a saturated salt solution. I used fresh baked bean cans but the same bottle with copper wire wound around.

My measurements on the salt cell are shown in the graph on the right. The same standard set-up was used as for evaluation of previous cells. It seems capable of supplying a good current but the voltage is rather low, which is consistent with what Anders found.

Vinegar cell



Next comes my vinegar cell. Balsamic vinegar, to be exact, since I had no plain vinegar. I covered the bottom of a new baked bean can with a few mm of balsamic vinegar, put in the orange juice bottle with wire wound around, and filled up with water.

My measurements on this vinegar cell are in the graph on the right. It produces about twice the voltage of the salt solution, but half the voltage of the pure bleach. The toxicity of this weak solution of vinegar is considerably less than the bleach. The current provision ability is good, like the salt. I decided to connect four of these vinegar cells in series and try them on the 40m QRSS transmitter
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Finally - click here for the spreadsheet containing raw data (Open Office format)

Ideas and comments from Anders Sandstrom

Anders writes: *After I read the page about homemade batteries on your website I decided to try to make some batteries myself.*

I had some good results with using a steel can and copper wire, with vineager essence and caustic soda between. I could only get 600 mV and 3 mA of short circut current with only the vineager essence, but after i pored in some caustic soda I got over one volt from a single cell and over 60 milliamperes of short circut current! I tried to make another one, but the second one I only got 700 mV from, but still the same high current. There was also some salt in the first one from another experiment, but I found that poring salt into the soloution actually decreases the voltage, but increses the maxium current. I had also good results with using copper and zink, but my only source of zink were nails with zink on the outside (I don't know what they are called in English). However, I have no idea for how long the battery cells can last.

{gallery}battery/anders{/gallery}

I have now made 2 new cells, using copper pipe and sheet metal. I used water and drain opener as electrolyte. First i took a piece of copper tube, about 6-7 cm long and wrapped it in paper as insulation. I cut some sheet metal and wrapped it around it to form another tube. I put it in a small glass jar and poured in water (about 0,75 dl) and a spoon (15 ml) of caustic soda. The voltage was almost 1,2 volts for a new cell, but i decreases fast to about 1 volt and then stays there. I measured the current of a cell when it was places in a short circut and it was over 100 mA.

I tried to recharge the cells when they were almost empty, and it worked. I used a car battery charger set to 6 V and the current was about 300 mA, probably to much because bubbles started to form and after one hour the caustic soda solution was bubbling over the jar. But it worked and cell voltage was increased to 1,1 V and I could power a mp3 player for almost 3 minutes with 2 cells in series.

I have attached 2 photos of the cells in this email. The cells were about 1 day old when they where taken.

Ideas and comments from John Beech G8SEQ

John writes: *I had a look at your batteries and I'm not sure I agree with your calculations (though they might be true for your batteries). Way back in the early 1970's (which was probably before you were born) we had what was called the "Three Day Week" where everyone (except me!) worked a three day week because the power workers went on strike and we had electricity cuts left, right and centre.*

People were making oil lamps that run on smoky, smelly cooking oil and animal fat, but I thought I could do better and made a battery out of houseold materials (People had panic-bought all the dry cells and most of them had gone flat by then). I used an aluminium 35 mm film can, some copper wire and household bleach.(I tried cooking salt first) This gave enough energy to light a 1.5 v torch bulb to full brightness for about 2 hrs. I then progressed to aluminium foil and jam jars, but these used up too much bleach, so I filled the jam jars with marbles (later quarz pebbles) as inert displacers. Later I used aluminium drinks cans. I have made loads since as demos to school kids and at Amateur Radio Rallies. The design was published in RadComm TT many years ago. At one rally I actually used one cell to re-charge some Nicads and then had a QSO on 2m using a 2W handheld. I did a test using a Coca Cola Can and a jumbo LED (about 40 mA) - it lit it for a fornight continuously. Then the experiment was stopped because it was end of term and the lab techs wanted to clear up!

These cells work better if you use a carbon rod as the positive electrode. The off load terminal voltage is about 2 v. Salt will produce this sort of voltage, but the cell quickly polarizes, reducing the current. By using chlorate bleach, the hydrogen produced is oxidized to water and current is maintained. Chorate bleaches also contain sodium hydroxide which attacks aluminium whether you are drawing current or not, but this soon gets used up. However, it has the effect of etching the aluminium surface increasing its area and increases the current generating capability. Several of these cells would definitely work a QRP TX directly in an emergency.

Incidentally, I wrote to Guiness in the 70's to ask them to change the design of their cans. I tried theirs and was dissapointed with the results until I found that their cans were steel with aluminium tops. I explained that this was the worst possible combination of metals from the re-cycling point of view. They did change the design and they are now all aluminium. Whether or not I had any influence on it I don't know, but I would like to think so. Conerting aluminium metal back to electricity is NOT the most efficient way of recycling aluminium, Re-melting and re-processing is the most energy efficient and therefore money efficient way.

I have been toying with the idea of making a cell which uses seawater as the electrolyte. This would be flushed with fresh seawater every time a wave came up the beach. I reckon there might be enough oxygen in the sea water to depolarize the cell. Just the job if you are stuck on a desert island with only a pile of coke cans or bits of aircraft!.