VOICES OF TOMORROW
SOLAR POWERED AMATEUR RADIO DIGIPEATER FOR EMERGENCY APPLICATIONS

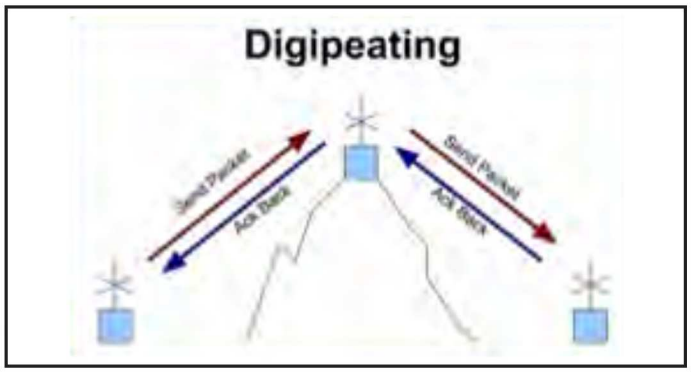
By Tucker J. Dunham

EDITOR'S NOTE: This issue of the Proceedings of the Radio Club of America brings another installment from the next generation of inventors and developers in wireless communications. The Voices of Tomorrow column provides a place for younger people to share their work in a professional setting. RCA is interested in finding students (primarily college- or high-school level) who are interested in writing about their explorations, ideas and contributions to wireless communications. We congratulate Tucker Dunham on his first professional publication, and we encourage submissions by others for future columns. Please contact David Bart, Proceedings editor at jbart1964@gmail.com for further information or to submit draft articles for publication.

After watching the ravages of Hurricane Maria, our team sought to construct an amateur radio digipeater for use by emergency response teams. We presented our results at the Dayton Hamvention and the 2018 Radio Club of America Technical Symposium. This paper outlines our work.

THE NEED

In October of 2017, Hurricane Maria ravaged Puerto Rico. Communication networks were obliterated. People were in need of help, and could not get vital food, water, or medications. In an emergency, under less than ideal conditions, transferring accurate information quickly is key. The solution: a rapid response emergency packet radio network[1]. Over the course of seven months of hard work, research, testing, and troubleshooting, we developed a solar-powered amateur radio digipeater for emergency networking applications. The compact, easily deployable unit can run indefinitely with solar panels and nighttime battery backup. It can be connected with a smartphone or computer to send messages to people miles away, even if there is no cellular service. Our hope is to provide rescue workers an efficient means of communication to help them save lives.



The concept of Digipeating signals.

PROJECT DESIGNS

We knew we could provide something beneficial, and we knew that ham radio would be the key element. Based on our observations from Puerto Rico, we concluded that the unit must have solar capability, because there was no commercial power available. We decided it would be in our best interest to have the digipeater capable of connecting to smart devices to relay information. It also had to be compact, so that it could fit in tight places. The digipeater design consists of low cost parts that all come together and make a self-sustaining unit. Some of the key components are a Raspberry Pi 3 B+, 2 Meter handy talky, folding antenna, solar panels, and a PVC enclosure.

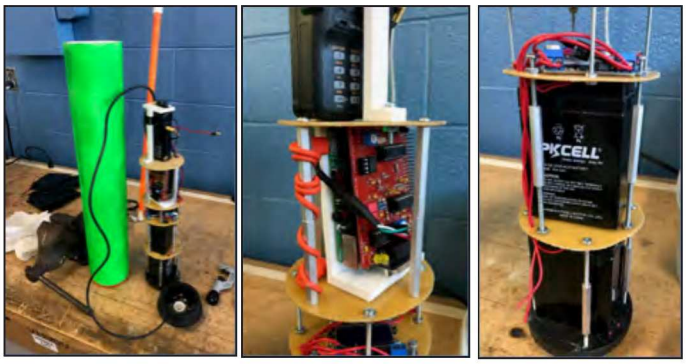
THE HOUSING

First we worked on designing the digipeater housing, or what was it going to reside in. One of the first containers we attempted to use was an ammunition can. The can was promising since it is easily obtainable, opens wide on top to allow easy access for repairs or modifications, and it is waterproof, keeping the electronics dry. After trying to use the ammunition can, we realized that it was not going to work; the steel was difficult to manipulate using the tools available to use, its form was not going work well for it to have solar panels, and the steel was very heavy and susceptible to corrosion. We considered another option, 3D printing a custom container. After careful consideration, we concluded it would take too long and the use of material was not efficient.

[1] See https://en.wikipedia.org/wiki/Packet_radio.

The final design for the housing was as follows:

- We used a 4 inch wide PVC pipe for the housing. This worked very well, because it was a plastic material that is easily worked, and it can be sealed from the outside.
- We used the 3D printer to make a top cap, which seals the digipeater from the elements and protects the electronics. Since the cap is made of soft plastic, we can attach any accessory into the cap, such as the currently installed power connectors for the solar panels and a PL259 connector for use with many antennas.
- The unit has a 3D printed threaded bottom, allowing the digipeater to be put on a broom handle, allowing the user to hoist it higher for better signal transmission and reception.
- Finally, we constructed the antenna from PVC so that it could be collapsible and waterproof, similar to the actual digipeater itself.



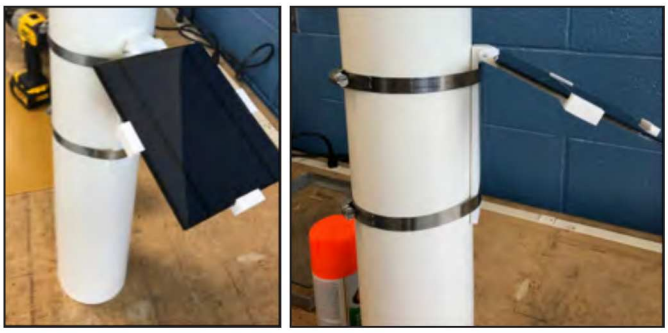
Interior of the Digipeater assembly.

SOLAR PANELS AND POWER

The PVC's round shape was perfect for mounting solar panels that would power the system since they could receive sunlight from any direction. There are 12 solar panels mounted around the 4 inch PVC pipe. Each solar panel is specified at 5V at 500mA, but after real life testing, our results fell short of those specifications. In an ideal situation and in their current configuration, the solar panels should provide 2A at 15V. Even though the solar panels did not provide as much power as the specification sheet indicated, it was enough power to keep the batteries charged.

We designed a simple, three-part bracket and 3D printed the component to attach the solar panels to the PVC pipe. It is a minimalist design that grabs the edges of the panel and hinges at the top. The back of the bracket sits flat against the pipe, while it is fastened using two 5 ½" hose clamps. The hinge on the bracket allows the solar panels to be adjusted to any angle for best sunlight reception. The bracket and panels can be moved around the surface of the digipeater simply by loosening the hose clamps, repositioning the solar panels for optimal sunlight coverage, and then tightening them.

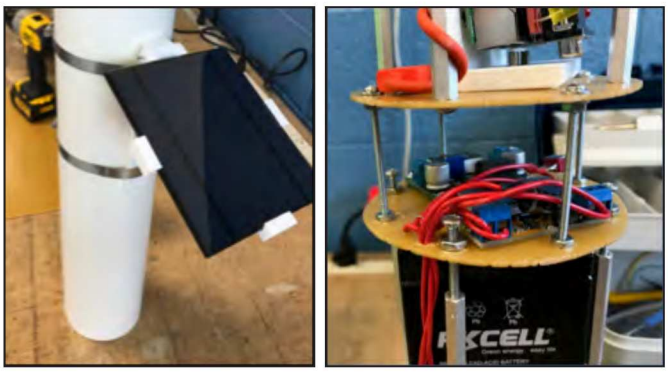
Next, we had to decide which battery to use for nighttime battery backup. Lithium-ion batteries, although very high energy density, are relatively difficult to charge and can react explosively if they are overcharged, so we eliminated this option. Alkaline batteries only provide one-time use, so they were not seriously considered. Nickel cadmium (Ni-Cad) batteries are rechargeable, but they are expensive and have a "memory-effect," where it loses maximum capacity if a battery is re-charged before it is completely discharged. Finally, we experimented with sealed lead acid batteries. We discovered that they were easy to maintain a charge using the solar panels, were tolerant to being overcharged and undercharged, and they did not have the "memory-effect" that afflicted the Ni-Cad batteries.



Mounting assembly for the solar panels.

THE RADIO

Finally, we faced the hardest problem: selecting the right radio. During initial testing, we used an inexpensive import brand radio. We identified the biggest problem, after hours of troubleshooting: the receiver on the radio was distorting incoming transmissions and was not able to transmit a usable digital signal. As a backup, we considered using a 60 watt Kenwood TM-271, but for simple digital transmissions, we decided this too much of an overkill and would draw too much power. After a few hours of searching online, we found the Yaesu FT-60, a radio that is well designed, did not distort digital signals, and did not draw too much power or deplete the batteries. In addition to the radio's great engineering, it is very affordable at $150.



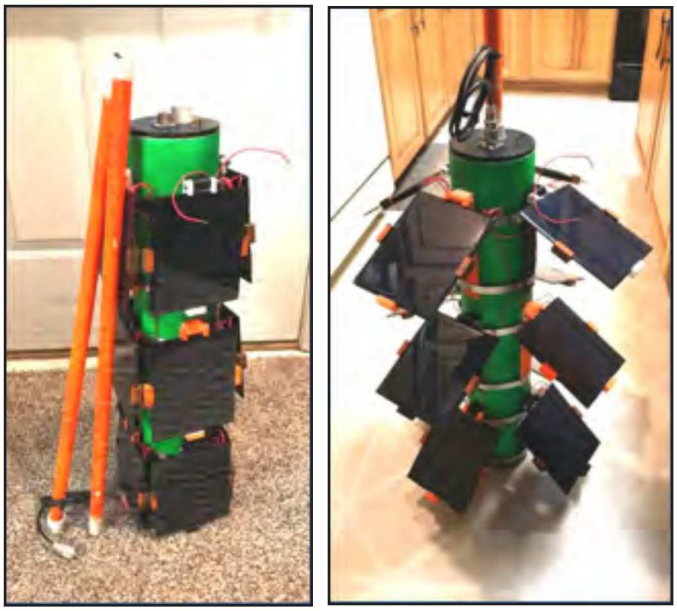
Digipeater radio mounting (left) and Raspberry Pi 3 (right).

DIGITAL CONNECTIONS

We wanted our digipeater to connect with smart devices, such as a smartphone or laptop. We used a Raspberry Pi 3 B+. A Raspberry Pi[2] is a low cost ($35) credit card sized computer capable of running Linux to process and move data. We placed a TNC-Pi "hat" on top of the Raspberry Pi as an add-on board that can interface with the Linux operating system. The TNC-Pi[3] is a low cost card ($40) that enables the Raspberry Pi to act as a terminal node controller to send, receive and repeat AX.25 Packets using the 2 Meter handy talkie.

Our device can also be used as a packet radio endpoint in addition to a digipeater. The Raspberry Pi 3 has an onboard wireless adapter. We configured the wireless adapter to serve as a WiFi access point. A user local to the digipeater can connect to the access point using a laptop or smartphone capable of common wireless access. Using a basic "telnet" program messages can be originated or received on the packet network. This access mode can also be used to configure or monitor the health of the digipeater.

We built a self-sustaining digipeater that can support itself indefinitely, and is safe from the elements. The digipeater is portable and can easily be placed on a tall building or hilltop to relay packet radio messages between several endpoints. If the need arises, additional digipeater nodes can be added to further extend the range of the network.



Digipeater closed for transport (left) and open for use (right).

[2] See https://www.raspberrypi.org/products/raspberry-pi-3 model-b-plus/.

[3] See https://tnc-x.com/TNCPi.htm.

RESULTS AND USE

After we finished construction, we brought the digipeater outside and left it outdoors for a whole weekend in the backyard. During that time, local hams were able to connect to the digipeater and to send messages through it. Over the course of the weekend, with the use of the solar panels, the whole unit remained powered the entire time. At the conclusion of the weekend, the batteries still remained adequately charged.

The team learned many things while building and testing this digipeater. The primary lesson was to make certain the transceiver is well designed and did not distort outgoing or incoming packets. We also learned that solar panels may not always provide the amount of power initially claimed. Everyone learned that under load, solar panels have a voltage curve, and when more current is drawn, less voltage appears on the panels. Given these important discoveries, adjustments were made, and the final result was successful transmission.

I thank my classmates for their help and support with this project. I also acknowledge Abigail Heim, KD2PUA, for her help on the project, in particular for her help on the antenna assembly, and finally, the members of the 721st Mechanized Contest Battalion for their guidance and mentoring.

PROJECT PARTICIPANTS

Tucker Dunham, KD2JPM, is 18 and a senior electronics student at Warren County Technical School in New Jersey. Originally licensed in October 2015, he upgraded to General Class in June 2018. Tucker is also an Associate Certified Electronics Technician. He is a member of the WC2FD and W3OK radio clubs and enjoys participating in multiple events with each club. Tucker was accepted to Rochester Institute of Technology where he will study microelectronics, fulfilling his goal is to pursue an Electronics Technology career and hobby. As a Boy Scout, he has earned the Radio Merit Badge and has achieved his Eagle Scout Award. Tucker received the Radio Club of America Young Achiever Award in November 2018.

Abagail Heim, KD2PUA is 16 and currently a third year student at Warren County Technical School in New Jersey. She earned her Amateur Radio license this year and is a proud member of the 721st Mechanized Contest Battalion radio club. In her free time, she trains in kickboxing and Brazilian Jiu Jitsu, She also likes to read, loves spending time outdoors and is an avid photographer. Abagail received the Radio Club of America Young Achiever Award in November 2018.

Demonstrating the Digipeater assembly at the 2018 RCA Technical Symposium.

Don't forget to register for the 2019 RCA Technical Symposium at:

www.radioclubofamerica.org

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