In-depth technology for radio engineers

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FUTURE

A flared skirt for Voice of Vietnam

In the country's central highlands, Kintronic Labs designed an unusual 400 kW diplexed medium-wave transmission system.

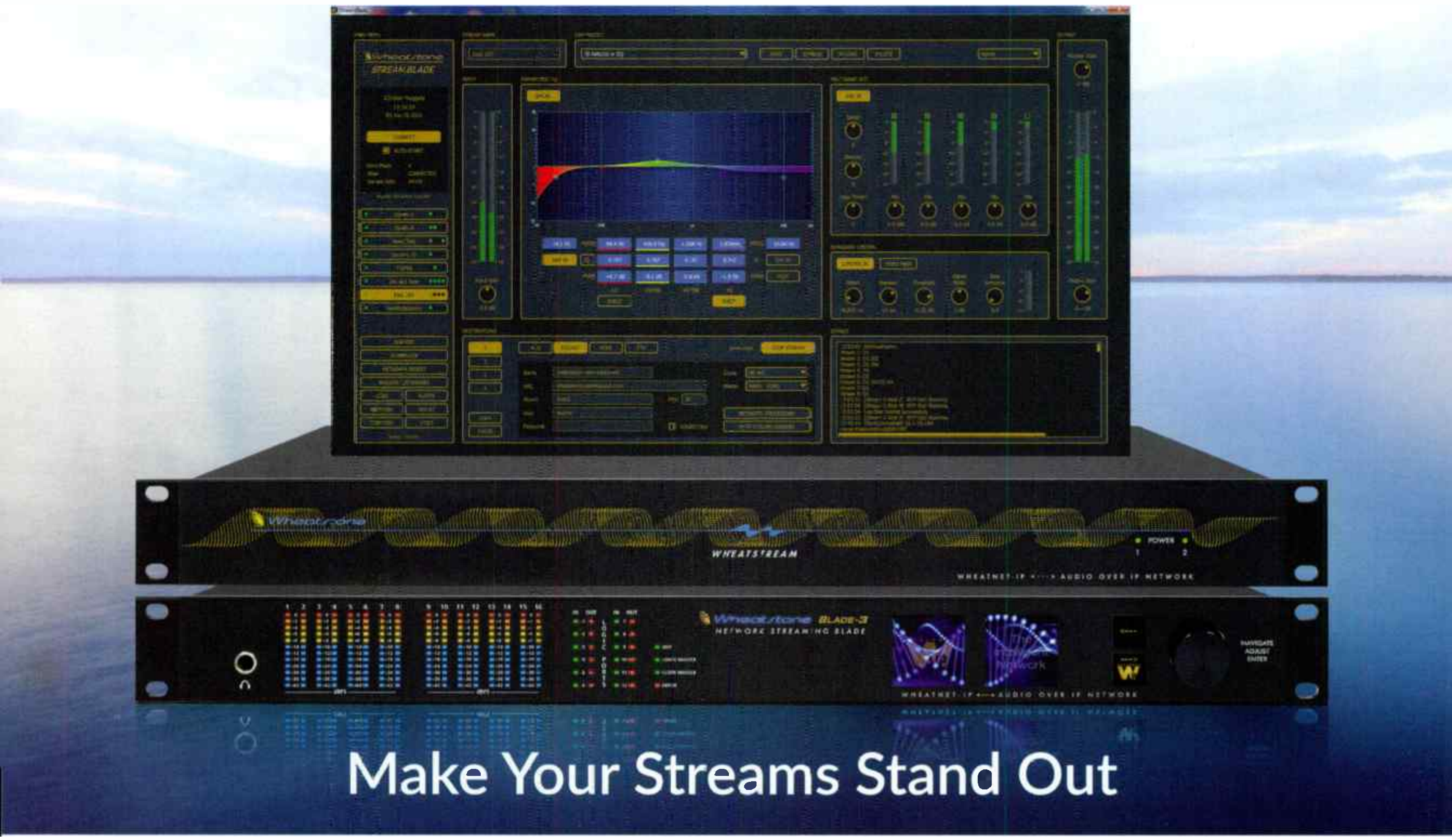
Build a button box

Impress your morning show crew by making them this sound effects gizmo using an Adafruit Audio FX Sound Board.

Thanks, Bob!

We chat with Bob Shotwell as he retires from Spectrum Investigative Services.

IT'S ALL IN WHEATNET IP — THE INTELLIGENT NETWORK



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An opportunity to learn

Cris Alexander
CPBE, AMD, DRB
Technical Editor

I love a good project. Of late, I have been just about inundated with projects, one of which was featured in these pages earlier this year. Since that "ultimate DIY" diplexer job, I've had antenna/line replacements, studio moves and infrastructure upgrades underway in several of our Crawford Media Group markets.

Projects are a great break from the routine of day-to-day broadcast engineering work. They give us the opportunity to show our stuff beyond the mundane, oftentimes designing and building out a new transmitter or studio facility, or perhaps creating a widget to deal with a particular need at a station.

Some of the earliest projects I remember in my broadcast engineering career were remote starts for various pieces of equipment.

Turntables were always a challenge back in the day. They were started with a push of a top-mounted black-handled toggle switch. The challenge for the jock who was often talking in the mic during a music segue was to get his fingers on that switch and push it without missing and bumping the tone arm!

The fix was to build a box with a pair of latching relays that were actuated by the remote start button below the rotary fader on the board. No more fumbling for the start switch! It was a home run with the air staff.

As the years went by, the projects got bigger. Rebuilding a control room, building out a new tower site, building a studio facility ... then in 1980 I was tasked with building the transmitter facility of a new UHF TV station in Dallas. That was a project, and it took me places I'd never been before.

I had to deal with 8-inch transmission lines, steam weirs, steam pipes and copper water lines. There was something disturbing about making a water connection to a PA tube, in this case a klystron, as big as I was. It was even more disturbing when I first turned on the pump and had a leak. I remember thinking that water and a 25 kV beam supply might not be a good mix!

Then I had to build out a master control room, an audio suite and a 2-inch videotape suite for that station. I had worked in those kinds of facilities before and was familiar with the equipment, but I'd never built any of them out, so it was another new experience for me.

A few years later my project was a new five-tower, two-pattern 10 kW AM directional facility. That was a learning

THIS ISSUE

NEWS

FEATURES

is true of a career in broadcast engineering: It's a license to learn, and learning new things should be a requirement. The SBE's excellent certification program certainly takes that into account.

I've known engineers who got to a certain point and pretty much checked out of learning. Even projects that should have taught them something turned into ordeals to be endured with a lot of help from their friends. In each case, those folks missed an opportunity and really cheated themselves out of some valuable skills. They also lessened their value to their employers and clients in the process.

I hope that our readers don't miss those opportunities when they come along. Projects are often the best route

experience. I was in over my head from day one, but with the patient direction of our consulting engineer Charlie Gallagher, I got it built, tuned up and proofed. I came away from that project with a lot of new knowledge, and that has paid dividends over the years.

There have been many other projects since, including tower, transmitter and studio builds, and not a few AM directional projects. I've enjoyed every one of them.

In more recent years, many of the projects have taken us from analog audio to digital (AES and TDM) to AoIP. Even more recently I have been dragged kicking and screaming into the AES67 world.

My point with all this is that every project has taught me something — often a lot — and given me new skills that have come into play later in my career. It's an ongoing process, and one that never ends.

When I passed my checkride and was licensed as a pilot some 41 years ago, I started hearing from others that a pilot's license is really a "license to learn." That has been true, and all these decades later I'm still learning. The same

Above & Right The author, deep in a directional antenna project.

to new skill sets. They stretch us and boot us out of our comfort zones. They make us think. And when the project is done, we have something to be proud of.

This month's RWEE features a couple of projects. One is a fun "button box," a purpose-built device created by Colorado engineer Michael Baldauf. I think many of our readers will find this device useful and easy to build. It definitely has home-run potential for a morning zoo or other creative daypart.

The other project is no DIY undertaking. It's a 400 kW medium-wave diplex project in Vietnam undertaken by our friends at Kintronic Laboratories. That one makes my 6 kW DIY diplex project of a few months ago look like a church picnic!

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Kintronic Labs Inc.

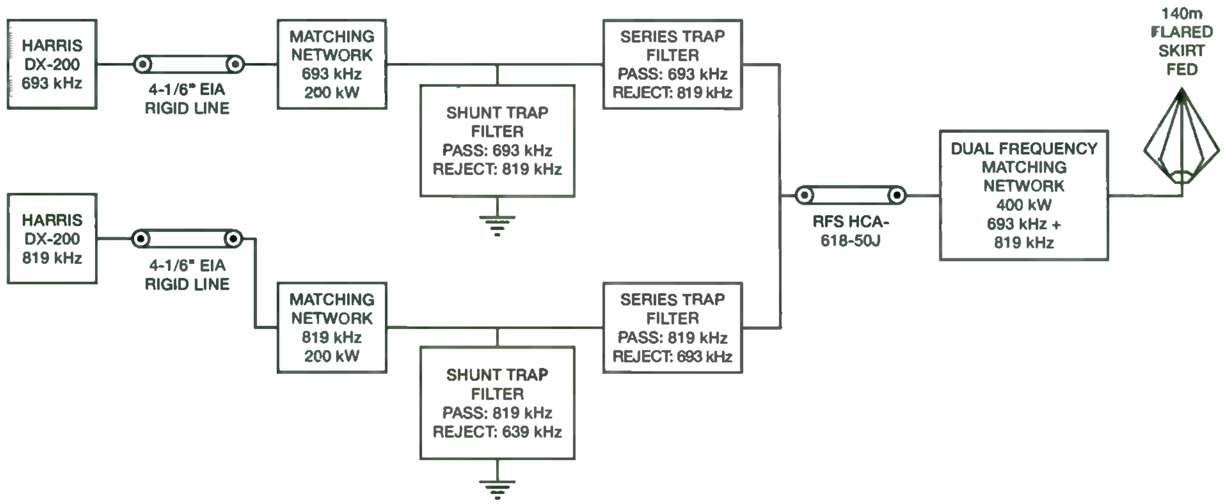
Building a 400 kW diplexer for AM

Kintronic supplies an unusual technical solution for Voice of Vietnam

Kintronic Labs was awarded a contract in 2021 for the design, supply, commissioning and training of a 400 kW diplexed medium-wave radio broadcast transmission system to facilitate the simultaneous operation of a 200 kW transmitter operating on 693 kHz and a 200 kW transmitter operating on 819 kHz into a 140-meter grounded, guyed tower with a flared skirt feed configuration.

The RF system design in this case is unique in that the matching and filter networks that comprise the diplexer are located in the transmitter building, and the combined 50-ohm output of the diplexer is coupled via a 6-1/8-inch transmission line into a dual-frequency matching unit

Above
The 2 x 200 kW diplexer enclosure is shown installed in the transmitter building.



Right
Fig. 1: Block diagram of the 2 x 200 kW MW diplexer for the Dak Lak station.

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**Assumes a leasing plan successfully negotiated with no upfront payments. Leasing plans under this program only available in the USA but MDCL savings are applicable worldwide. Customer is responsible for existing Tx decommissioning and new Tx installation.

orban

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Left
Fig. 2: A photo of the 140m grounded, flared skirt-fed Dak Lak tower designed for 2 x 200 kW diplexed operation.

located at the base of the tower.

A similar design had been conceived earlier for a station in Vietnam by the late design engineer Ron Rackley P.E., and was the design approach preferred by the Voice of Vietnam (VOV) technical team.

The flared skirt tower feed technique used in this antenna system design yields superior input audio bandwidth for both diplexed stations. The flared skirt consists of six symmetrically located skirt elements that extend out from the top of the tower as a result of associated insulated guy wires at the point where the skirt is directed back into a commoning ring at the base as shown in Fig. 2.

> **“A similar design had been conceived earlier for a station in Vietnam by the late design engineer Ron Rackley.”**

The new MW diplexing system was installed at an existing FM radio broadcast station. All civil works and transmission system equipment installation was accomplished by very capable VOV personnel.

The Kintronic field service team consisted of Senior Field Engineer Rob Elder and President/CEO Joshua King. Their on-site tasks consisted of overall installation inspection and correction as required, final commissioning of the complete transmission system and VOV personnel training.

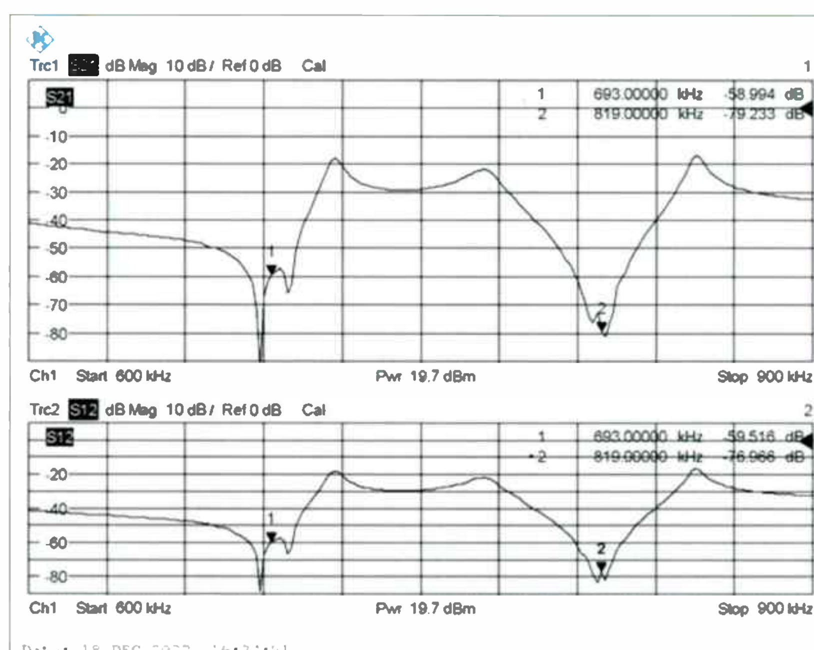
The flared skirt-fed tower was modeled using NEC 4.1 by Jim Moser. The resulting +/- 18 kHz measured drive impedances for the two frequencies as measured at the combined output of the dual-frequency ATU are shown in Table 1. Based on the international 9 kHz channel spacing the measured impedance intervals are +/- 4.5 kHz.

The factory pre-tuned shunt and series trap filter characteristics were individually checked using

Table 1. Measured Tower

Freq. (kHz)	Impedance (Ω)
“Station One”	
Freq. (kHz)	Impedance (Ω)
675	150 + j27.7
679.5	150 + j24.7
684	147 + j15.6
688.5	148 + j19.4
693	**147 + j16.2**
697.5	145 + j14.8
702	144 + j13.7
706.5	143 + j12.6
711	142 + j11.9
“Station Two”	
Freq. (kHz)	Impedance (Ω)
801	138 – j19.9
805.5	135 – j22.8
810	136 – j24.1
814.5	134 – j26.6
819	**132 – j29.3**
823.5	130 – j31.3
828	124 – j34.4
832.5	124 – j36.0
837	120 – j37.7

Below
Fig. 3: Port-to-port diplexer isolation sweeps with the 693 kHz port excited and with the 819 kHz port excited.



a Siglent Model SVA1032X Spectrum and Network Analyzer. Following completion of the matching and filter network adjustments a Rohde & Schwarz two-port network analyzer was utilized to measure the overall port-to-port isolation of –58 dB @ 693 kHz and –76 dB @ 819 kHz. A plot of the port-to-port isolation sweeps is shown in Fig. 3.

Table 2. Diplexer Input Port Impedance Sweeps

"Station One"		
Freq. (kHz)	Impedance @ J1 (Tower)	Impedance @ J1 (Transmitter Building)
675	44.8 – j7.2	52.3 – j9.5
679.5	46.2 – j6.6	52.0 – j8.4
684	47.5 – j5.9	52.6 – j6.7
688.5	48.6 – j5.7	53.2 – j5.8
693	**49.5 – j5.4**	**53.3 – j5.2**
697.5	50.1 – j4.8	53.2 – j4.6
702	50.8 – j4.1	53.1 – j3.6
706.5	51.6 – j3.4	53.3 – j2.7
711	52.5 – j2.6	53.5 – j1.9
"Station Two"		
Freq. (kHz)	Impedance @ J1(Tower)	Impedance @ J1 (Transmitter Building)
801	54.2 – j0.9	52.3 – j0.4
805.5	53.2 + j1.6	51.4 + j0.4
810	52.2 + j2.4	50.8 + j1.4
814.5	51.2 + j3.1	50.1 + j2.5
819	**50.1 + j4.0**	**49.5 + j3.7**
823.5	48.9 + j5.1	49.0 + j5.1
828	47.6 + j6.3	48.3 + j7.0
832.5	46.4 + j7.8	48.2 + j9.0
837	45.3 + j9.3	48.4 + j11.1

“These results demonstrate the excellent DRM-compatible wide audio bandwidth that was achievable for both stations with the tower flared skirt feed configuration.”

The RF system adjustment procedure was to obtain a 50-ohm match for both frequencies at the load end of the 6-1/8-inch transmission line, i.e., the input port of the dual-frequency ATU, and then to obtain a 50-ohm match at each input port of the diplexer. Following final adjustment of the dual-frequency ATU at the tower base and the diplexer matching networks in the transmitter room while compensating for any impedance bandwidth impact caused by the diplex filters, the input impedance sweeps were measured at the input of the dual-frequency ATU, i.e. the load end of the 6-1/8-inch transmission line (left column), and at the combined output of the diplexer, i.e. at the input end of the 6-1/8-inch transmission line (right column), as shown in Table 2.

The resulting impedance match measured at the transmitter input port of the antenna/dummy load switch for each station is shown in Tables 3 and 4. These results demonstrate the excellent DRM-compatible wide audio bandwidth that was achievable for both stations with the tower flared skirt feed configuration. A photo of the dual-frequency ATU at the tower base is shown in Fig. 4 on the facing page, and the diplexer matching and filtering system in the transmitter building can be seen in the photo on page 6. The Kintronic Labs Model DL 300WP 618EIA dummy load installed at the Dak Lak station is seen in Fig. 5.

The total 2 x 200 kW MW diplexed broadcast transmission system was power-tested successfully and handed over to VOV for commencing full-time broadcast operation.

The complete site commissioning team is shown at the bottom of the facing page.

Table 3. 693 kHz Transmitter Output Load Impedance Sweep

Freq. (kHz)	Input Z	SWR
675	44.2 – j9.5	1.266
679.5	45.9 – j6.6	1.177
684	47.7 – j4.2	1.102
688.5	49.0 – j2.2	1.051
693	**50.0 + j0.3**	**1.006**
697.5	51.4 + j2.8	1.064
702	53.0 + j5.0	1.121
706.5	54.6 + j6.9	1.173
711	55.9 + j8.8	1.222

Table 4. 819 kHz Transmitter Output Load Impedance Sweep

Freq. (kHz)	Input Z	SWR
801	41.6 – j0.1	1.200
805.5	43.8 + j0.6	1.142
810	46.0 + j1.0	1.088
814.5	48.1 + j0.6	1.041
819	**50.1 + j0.06**	**1.002**
823.5	51.7 – j1.0	1.041
828	52.7 – j2.3	1.076
832.5	52.7 – j4.2	1.103
837	51.8 – j5.5	1.120

Left
Fig. 4: Joshua King stands with the dual-frequency ATU at the tower base.

Above
Fig. 5: Kintronic Labs dummy load installed at the Dak Lak station.

Below
Fig. 6: The Dak Lak 2 x 200 kW MW diplexed broadcast transmission facility commissioning team.

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Writer
Michael Baldauf

The author is a semi-retired independent engineer in southern Colorado. He enjoys supporting small radio operations.

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Got a project idea or tip to share? Email Cris Alexander at *rweetech@gmail.com*.

Build a sound effects box with a little help from Adafruit

You'll also make friends on the morning show team with this fun project

If you're like me, a little project that's mostly for fun can also serve as stress therapy. This one is useful too! It's a classic sound effects button box using modern technology.

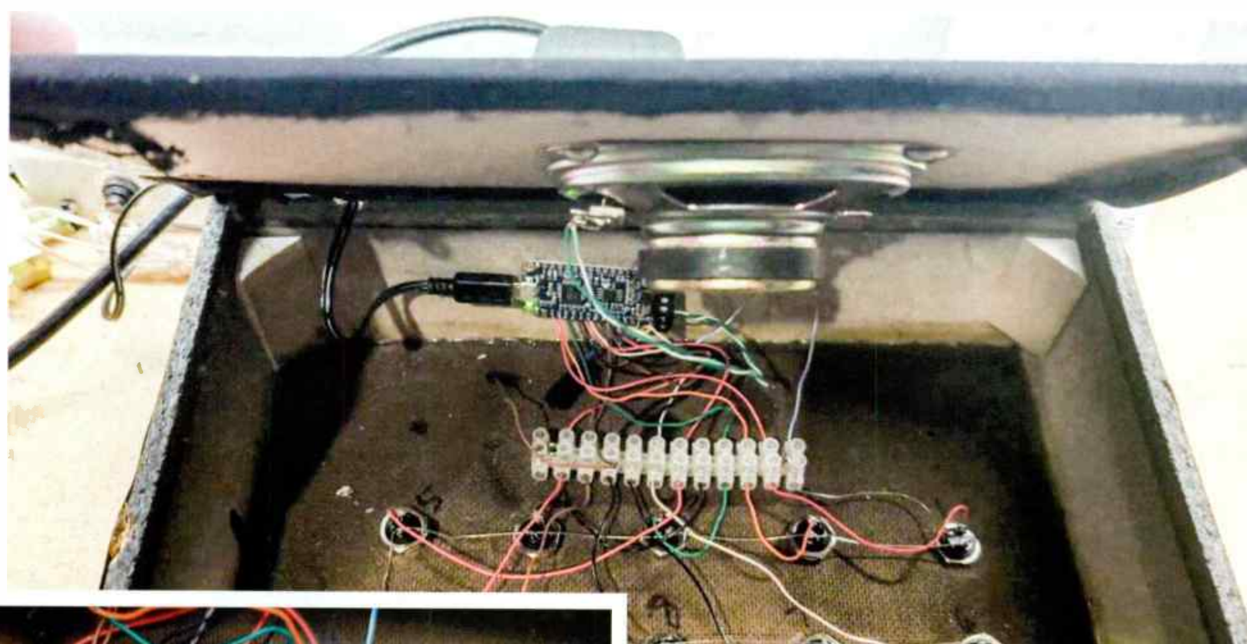
The heart of the button box is the Adafruit Audio FX Sound Board. You can learn about it at *learn.adafruit.com*, type "audio FX" in the search field. They're sold on Amazon and other online retailers.

For this application, choose either the board with built-in amplifier that allows "cue" speakers, or just the basic board that provides only a line out.

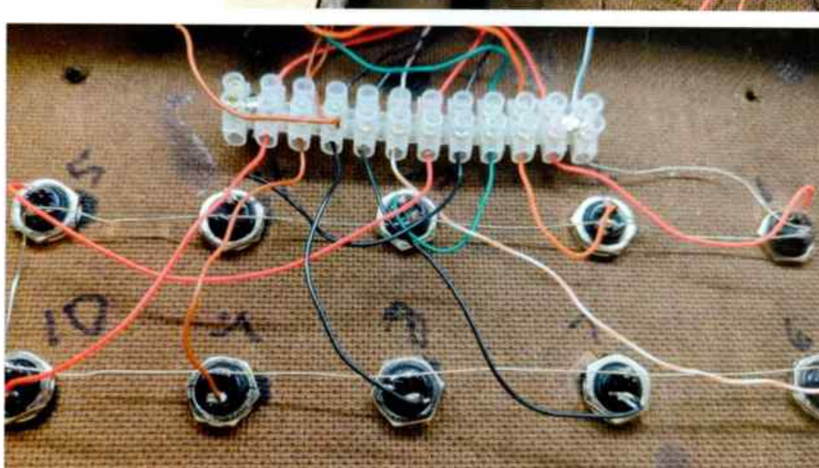
There are two options: One supports eight sound effect buttons, the other allows 11. (Notice that one board has pins 0–7 while the other has pins 0–10.) For applications where sound effects are only a few seconds each, the on-board memory is sufficient.

If you have basic tools, a USB cable and soldering skills, the rest is easy.

The board has a micro-USB connector, which means the power and programming connections are all complete in one common plug. When the USB line is connected to the computer, the Adafruit acts like an external drive; when the USB is connected to a power block, the Adafruit acts like a button box. The only other external connection will be the audio line out cable, which depends on the user's connection needs.



Right
Fig. 1: The front face and speaker will become the back of the button box.



Below
Fig. 2: The back of the speaker box becomes the front of the button box.

For this project, it is easy to use any small speaker enclosure that can be opened by prying off the front face. The front face and speaker will become the back of the button box (see Fig. 1). The pushbutton switches are mounted into the back of the speaker box, which becomes the front (Fig. 2).

Internal wiring

A sound effect is triggered when the pin number of the hole on the Adafruit board is grounded. For example, the audio file stored in position zero will play when the wire soldered into hole zero is momentarily connected to

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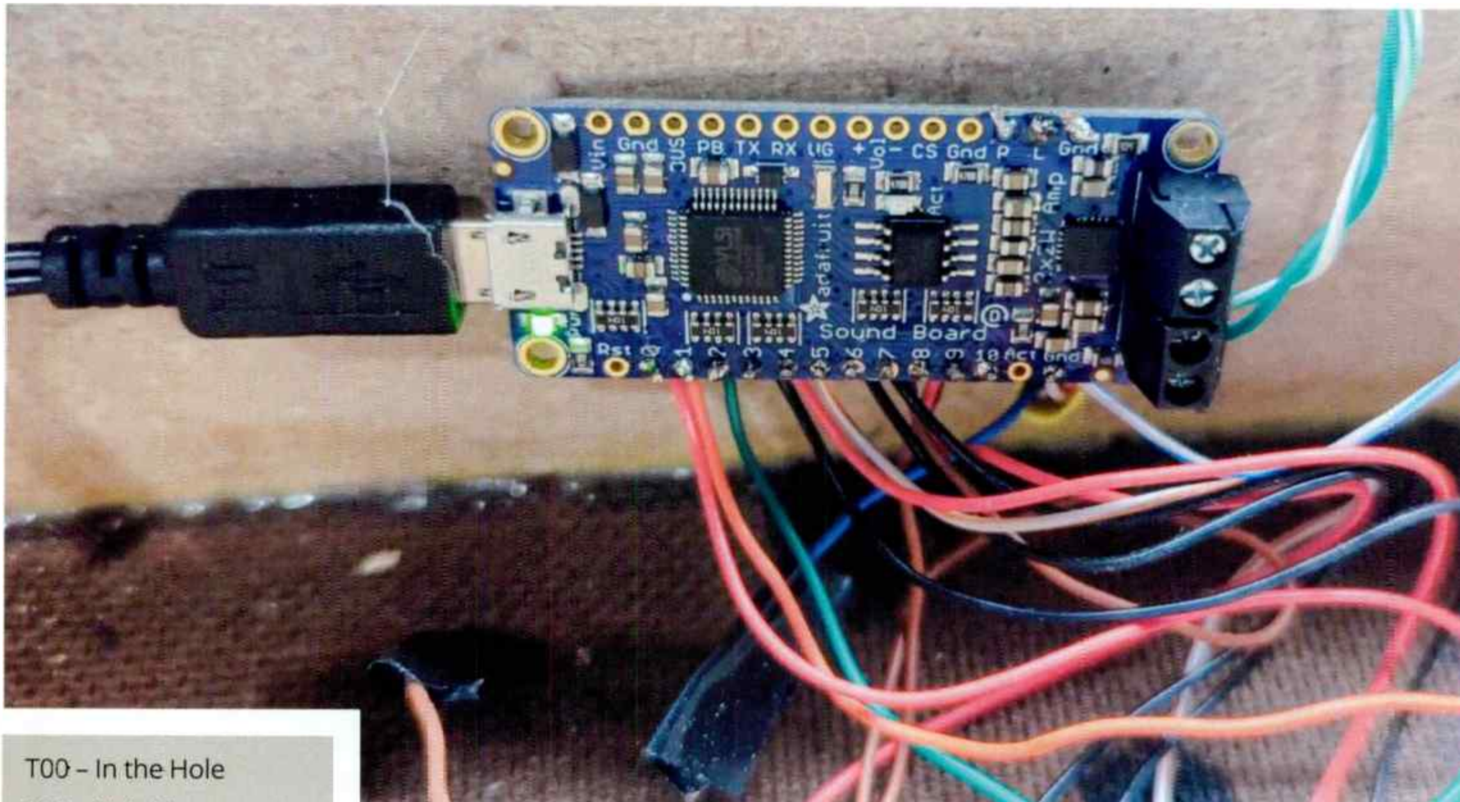

T00 – In the Hole
T01 – He's Nuts
T02 – Mission from God
T04 – Bart Laugh
T05 – Stupid Political
T06 – No Soap
T07 – Woohoo
T08 – Facebook Joke
T09 – Birthday Beatles

Above
Fig. 3: Adafruit board connections

Left
Fig. 4: Sound file nomenclature. All files are .ogg format.

ground. The way this is accomplished is that the momentary pushbutton switch for playing audio file zero will have one pin wired to hole zero on the sound board and one pin soldered to ground. The same process applies to all the switches ... hole one tied to switch one, etc. and the other side of all the switches tied to ground. (This project used a terminal strip between the switches and the Adafruit Board).

Fig. 3 shows all the connections on the Adafruit board. The switch connections are shown across the bottom on holes 0 to 10, and also the ground connector (the ground wire common to all switches).

The top of the Adafruit board has the line out connections: left, right and ground. The end of this board has the left and right speaker connections. Only one speaker is connected in the photo. Obviously, this board can be used in many other applications with other interconnections.

There is usually a test audio file that will play when button zero is pushed (hole zero is grounded momentarily). It is very short, but it's a good way to test connections prior to loading audio into the unit.

Loading the audio files

Loading up the Adafruit with sound files requires a few simple steps: resaving the files as .ogg files; renaming the files to fit the format for the Adafruit board; and dragging the files into the Adafruit folder.

Step 1: Locate the audio files to be loaded into the button box and place them on a computer. The files will need to be converted into .ogg files. This can be done at no cost through various online or downloadable programs. One app in common use in radio stations that can do this is Audacity (*www.audacityteam.org/download*). Open

> **"With just a few dollars in parts and whatever old speaker or other enclosure you have lying around, you can make a sound effects button box that will liven up the morning zoo or other live show."**

Above
Fig. 5: Wrap it up with labels and colored pushbuttons.

Audacity and drag one of the sound files into the Audacity workspace. Once opened, use the process File | Export | Export as Ogg. The file will be saved under the original file name with a different icon and the .ogg suffix. Convert all of the files to be used in the button box.

Step 2: Rename the .ogg files for the button box. This is a simple process. If there are 11 sound effects to go to 11 buttons, they must be renamed as T00, T01, T02 through T10 before they can be loaded into the Adafruit board. Decide which effects go to which button and rename them accordingly (see Fig. 4).

Step 3: Connect the Adafruit board to the computer through the USB cable. It should behave like any USB drive. The workspace may show the test file, usually listed as "T00 Left/ Right." Delete file T00 and drag in the files that are renamed in Step 2 above. The buttons should now be active and play the audio files as configured.

Wrap it up

There is some planning required to decide where to drill a hole in the box to run the wires, possibly painting the back of the box, and how to lay out the switches (Fig. 5). Use colored pushbuttons if you wish, and affix labels to identify the various cuts.

With just a few dollars in parts and whatever old speaker or other enclosure you have lying around, you can make a sound effects button box that will liven up the morning zoo or other live show. It, and you, will be a big hit with the air staff!

Writer

Elle Kehres
Content Producer, Radio World

A chat with Bob Shotwell upon his retirement

He departs Spectrum Investigative Services, the company he has owned since 2004

Radio World recently learned from Bob Shotwell, who conducted the Alternative Broadcast Inspection Program in the six New England States, that he would be retiring from Spectrum Investigative Services, the company he has owned since 2004, and that Chip Morgan and Maria Slattery would take over.

Spectrum Investigative Services has the distinction of having pioneered the ABIP concept before there was an ABIP program.

Radio World contacted him to learn more and to ask him to reflect on his career, including his role in helping the industry stay compliant, interference-free and operating on schedule.

It was in 1971 that Shotwell was hired by his first radio station, AM outlet WROL (formerly WRYT) in Boston. "I'm convinced the events which seem the least critical or important in your life have the possibilities to be life-changing," he said of meeting life-long inspiration and mentor Ken Carberry and beginning his career at the station. "This was mine."

The career that ensued has included roles as announcer, chief engineer, corporate director of engineering, consultant, corporate officer and station owner.

50 percent initially pass

But it was in 2003 that Shotwell had another profound moment when he began working with the founder of Spectrum Investigative Services, Larry Hardy.

As a retired FCC investigative agent in the Boston office, Hardy founded the company for two purposes, Shotwell said: to investigate and resolve RF interference issues, and to propose to the FCC and New England state broadcast associations that a wide-reaching, voluntary radio and TV inspection process be put in place.

Spectrum had started in 1991 as an engineering firm that investigated RF interference issues between radio stations, cell carriers, CB, ham radio, police and other land mobile services. In the early days, the company also conducted marine bridge-to-bridge and Communications Act

Above
Along with all things engineering, Shotwell is an aviator, shown here with his wife, Laurie, and their Cherokee Warrior aircraft.

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inspections for small- and medium-sized boats and ships.

Today Spectrum conducts more than 120 ABIP inspections annually. Shotwell helped spearhead the effort.

"The program is really quite simple," he said. "I come to the radio or TV station with an FCC compliance inspection checklist and methodically work through all the items on that list," he said, which could include public files, EAS compliance and logging, technical and tower compliance, among other related items. The difference is that Shotwell is not an FCC agent, so he can neither cite nor fine a station.

"Our goal is to certify those stations which are found to be in compliance; and for those which are not, to work with them, to the extent we are able, to bring them back into compliance," he said.

The initial pass rate is about 50 percent, Shotwell said. After working with other stations, identifying areas where violations and lapses were found, stations are given direction to solve the problems. The company helps a station raise the pass rate to well over 80 percent. For those stations that do not eventually pass, he said, "If we can take a station with 10 or more violations and through working with the staff reduce that to three or four, we've still accomplished something worthwhile."

After identifying FCC violations and helping station staff to resolve them, he and the state association would then report this successful "pass" to the local FCC field office, giving them a heads-up as to which stations were independently found to be in compliance and which were not.

The program started in just New Hampshire and Massachusetts, but it soon spread to all New England and then across the country.

Not all stations choose to participate in the program, although in New England the participation rate is about 90%. And for those who do not participate, having an unannounced FCC field compliance inspection is not necessarily automatic, although when a station participates in the program and passes, "they are removed from the list of stations available for an unannounced field inspection," Shotwell said.

The VERY public file

Some changes have occurred over the years.

"For example, we used to spend quite a bit of time at the station reviewing the public files, before the FCC began the online program," he said. "It has made things easier from an inspection standpoint, but the consequence of this file being online is that now anyone can see it at any time without ever having to ask. In effect, it has become the 'Very Public File.' In my opinion, this makes an independent review of the public file all the more important and valuable."

Looking back, one of Shotwell's favorite career memories came after applying for an FM station license in 1988 when he was finally awarded the grant "through a very contentious comparative hearing," he said. "Eventually building and operating it in 1994 has to be my top career event."

Above
Bob Shotwell

Shotwell is also a senior member of the Society of Broadcast Engineers, a charter member of the National Association of Radio and Telecommunications Engineers, a ham radio licensee and a licensed pilot and flight instructor, sharing his passion for flying with his wife Laurie. His bio is at *https://amfmtech.com/bobbio.html*.

The industry has undergone so much change since the day he walked into a station more than 50 years ago.

"Some things good, some not so much," he said. "The one thing I'd like to see is more interest in engineering. This is something that both the industry, the NAB and the SBE have been lamenting. There are more and more engineers retiring, or simply leaving the industry, and fewer coming in.

"The reasons are multifold and the answers are not simple. But something needs to be done to not only attract new blood into broadcast engineering — I'd say as early as high school — and then to keep this talent in the industry."

One thing that is clear, however, is that after 52 years in the industry, Shotwell has never regretted a day working in broadcasting. "I have done announcing, engineering, tower climbing, IT, traffic, production, accounting and even court collections," he said. "For anyone who is ever looking for an industry that answers the call — find something you love to do and you will never work a day in your life. The broadcast industry, both radio and TV, answers that call. There is an almost endless variety of career paths, and all of them are fun.

"So many people dread the weekend ending because it means going back to work," he said. "For me, the end of the weekend meant I could go back to work. Yay!"

A station's main channel is usually the most profitable

So make sure you've maximized it, even if exploring exotic options

A Radio World ebook, available at *http://radioworld.com/ebooks*, explores "Maximizing RF Coverage." This is an excerpt.

Bob Weller is responsible for developing and implementing spectrum policy for the National Association of Broadcasters. Prior to joining NAB, he was chief of technical analysis at the FCC and worked for 14 years as a consulting engineer.

Above
Bob Weller

What strategies have stations been using to maximize FM coverage or expand their presence?

Bob Weller: Broadcasters and their engineering consultants are very creative at finding ways to gain listeners. A station's main channel is usually the most profitable and the one that brands the station. So, getting the best possible coverage from the main transmitter is usually the most cost-effective strategy.

That could mean ensuring you're getting the most out of your present site and studying alternative transmitter sites to see how they compare. Translators and single-frequency networks can improve coverage but those options are very location-dependent. SFNs can only serve areas within your existing coverage contour, so it's important to be sure that contour is maximized. SFNs can also create self-interference so it's important to do detailed studies and testing.

Translators are less restrictive than SFNs in terms of location, but finding channels for translators is increasingly challenging.

What advice would you give to an broadcaster who came to you and asked how they might go about maximizing coverage, expand their signal footprint or maximize existing spectrum?

Weller: The first step is to know where your listeners are. Once you know that, ask whether the station is at the best site to serve them. Then ask whether you can improve at your existing site by increased power or maybe a better tower position.

If not, consider whether there is a better site. A site close to the city center is not always the best choice. Commuters are usually a target audience, and you need to understand where they live and where they work and try to serve as much of that route as possible.

What about strategies to deal with coverage gaps and other signal challenges?

Weller: It's important to know where the coverage problems are geographically, and what those problems are. Are you dealing with a weak signal, interference from another station, multipath distortion? Each of those problems usually requires a different approach. Terrain-obstructed areas are usually the best case for SFNs since the extent of interference is inherently limited. SFNs, a.k.a. boosters, are becoming increasingly sophisticated and can help fill in coverage gaps due to terrain.

Know your competitors. If your station has coverage gaps, your competitors probably do too. So there may be an opportunity for several stations to jointly develop a fill-in site and share costs. Or the fix that a competing station did might be a good choice for your station.

What modeling tools are available to help?

Weller: There are lots of terrain-sensitive propagation modeling tools available today, and most consultants have a go-to favorite. An experienced consulting engineer will understand the limitations of the propagation model and understand what features are important to include (or exclude).

Longley-Rice is a popular model because it's free and because the FCC uses it. Saying "I use Longley-Rice" doesn't really tell you the whole story, though. What terrain database are you using? Are you considering clutter and morphology? How are you handling out-of-range errors? Do you have measured data for the antenna being studied? Are you considering interference from other stations?

All of those things affect the accuracy of the results, and there is no "right" choice for every station.

You mentioned single-frequency networks; what should we know about them?

Weller: SFNs can create self-interference problems if they are not carefully engineered. It doesn't take much time for a listener to become annoyed and tune away, so it's important that you be certain that an SFN isn't creating new problems. Even well-engineered SFNs don't match real-world conditions, so field testing is often an important step prior to committing to an SFN design. An SFN means paying rent at multiple sites, so it's important to test.

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