On the Air

JAN/FEB 2020
ARRL.ORG/OTA



Choosing a Handheld Radio

PREMIERE ISSUE
On the Air
RADIO COMMUNICATIONS
GET ACTIVE GET INVOLVED

Features

JAN/FEB 2020

12
The Big Picture
The Ionosphere: The Great Radio Prism in the Sky

14
Radio Technology
Repeaters—Your Friends in High Places

16
Project Build
Extend Your Handheld's Range with a Simple Ground-Plane Antenna

19
Project Build
One Wire, Many Bands

22
Operating
What Do To With Your Technician License

24
Public Service/ Emergency Communications
A Look at Public Service

25
Equipment
Buying a Handheld Radio

28
Collegiate
What is CARI?

In Every Issue

4 **From the Editor**
4 **Resources**
5 **From Our Readers**
6 **On Frequency**
10 **Up Close**
29 **From the Podcast & Blog**
30 **Hints & Hacks**
32 **US Amateur Radio Band Chart**
33 **The Next Steps**
34 **Last Word**

On the Cover

Be ready for winter storms before they happen. Take a moment on a fair winter day to make sure you can hit the local repeater with your handheld radio.

On this Page

As hams, we love antennas. You can't play radio without them! These towers rising into a wintry mist are commercial antennas, but fundamentally, they're no different from the antennas we use in our amateur pursuits.

See all that ARRL can do for you!

Becoming an ARRL member gives you the resources you need to get active and involved in radio communications.

You get all this:

- Your choice of *QST* – ARRL's official membership journal – or *On the Air* magazine – a bimonthly publication aimed at helping newly licensed and beginner-to-intermediate hams navigate the world of amateur radio
- Answers to all your technical and operating questions through our Technical Information Service (TIS)
- Support and training for public service and emergency communication volunteers
- Access to valuable members-only web services

www.arrl.org/join



From the Editor



It's All About You

Welcome to *On the Air*, ARRL's new magazine for beginner-to-intermediate hams. This magazine got its start in 2017, when a small group of ARRL staff members decided to try getting to the bottom of the challenges that new hams face. The group developed a survey to ask new hams what they were looking for from the amateur radio hobby and service, as well as what they were looking for from ARRL. The survey was accompanied by a package of test material which, for ease of use, we designed to look like a magazine. We called it *On the Air*.

The responses to the survey and the test material led us to do more research and development with new and "newer" hams just like you, and it led to the creation of the magazine you're holding now. We've filled *On the Air* with the knowledge, guidance, and encouragement you said you wanted and needed, all at a level that you can understand.

Every other month, *On the Air* will bring you project builds, operating techniques and know-how, definitions to make you fluent in "hamspeak," stories from the community, wisdom from experienced hams, and much more. And, you can expand your knowledge by listening to the *On the Air* podcast and reading the *On the Air* blog. Visit arrl.org/ota for links to these and other resources.

If you're a new licensee, this magazine is for you. If you've had an amateur radio license for a while, but never got as active as you hoped, this magazine is for you. If you've been a ham for 20 years, and need a refresher or need to fill gaps in your knowledge, this magazine is for you. To sum up, if you flip through these pages and see yourself in them, this magazine is for you regardless of how long you've been a ham.

If you'll be at Orlando HamCation (hamcation.com) in February, come see us at the *On the Air* booth, where we'll be celebrating the arrival of ARRL's newest magazine — its first-ever periodical for new hams just like you.

Again, welcome. We're so glad you're here.

73,

Becky W1BXY

Resources

***On the Air* Information and Archive**
arrl.org/ota

***On the Air* Podcast**
Available through podcasts.apple.com or app.stitcher.com

***On the Air* Blog**
arrl.org/ota-blog

New Ham Group
groups.arrl.org/g/ARRL-New-Hams

Manage Your ARRL Membership
arrl.org/myarrl

Join ARRL or Renew Your Membership
arrl.org/join

ARRL Member Benefits
arrl.org/benefits

Donate to ARRL
arrl.org/donate

Shop with ARRL
arrl.org/shop

Find...
...a Licensing Class
arrl.org/class
...a License Exam Session
arrl.org/exam
...a Radio Club (ARRL-affiliated)
arrl.org/club
...a Hamfest or Convention
arrl.org/hamfests

Facebook: @ARRL.org
Twitter: @arrl, @w1aw, @arrl_ares
Instagram: @arrlhq
YouTube: ARRLHQ
LinkedIn: linkedin.com/company/american-radio-relay-league

On the Air

Howard E. Michel, WB2ITX
Publisher

Becky R. Schoenfeld, W1BXY
Editorial Director

Steve Ford, WB8IMY
Senior Editor

Norm Fusaro, W3IZ
Consulting Editor

David Pingree, N1NAS
Senior Technical Illustrator

Zak Lau, W1VT
Senior Lab Engineer

Janet Rocco, W1JLR
Advertising Sales Manager

Bob Inderbitzen, NQ1R
Product Development Manager

Kathleen Callahan, KC1MBY
Marketing Communications Manager

Yvette Vinci, KC1AIM
Marketing and Sales Manager

David Isgur, N1RSN
Communications Manager

Michelle Bloom, WB1ENT
Production Supervisor

Maty Weinberg, KB1EIB
Production Coordinator

Kolk Design LLC
Graphic Design

John Tomac
Illustration

Chris Zajac
Photos

On the Air is published bimonthly by the American Radio Relay League, Inc., 225 Main St., Newington, CT 06111-1400, USA.

US & Possessions: Membership in ARRL, including a 1-year subscription to *On the Air*, is available to individuals at $49. Other membership rates are available at arrl.org. Membership includes $21 per year for subscription to *On the Air*. Membership and *On the Air* cannot be separated. Single copies $9.95.

Copyright © 2020 by the American Radio Relay League, Inc. All rights reserved. Quedan reservados todos los derechos. Printed in the USA.

QST®, DXCC®, VUCC®, DX Century Club®, ARES®, Amateur Radio Emergency Service®, Logbook of The World®, LoTW®, and ARRL, the national association for Amateur Radio® are registered trademarks of the American Radio Relay League, Inc. ARRL and *On the Air* in no way warrant the products described or reviewed herein.

In order to ensure prompt delivery, we ask that you periodically check the address information on your mailing label. If you find any inaccuracies, please contact the Circulation Department at circulation@arrl.org or 860-594-0200 immediately. Thank you for your assistance.

Reprints and Permissions: permission@arrl.org

Online Privacy Policy: arrl.org/online-privacy-policy

Telephone: 860-594-0200
Fax: 860-594-0259

From Our Readers

When we tested a sample issue of *On the Air* back in 2017, we received a lot of constructive and positive feedback from beginner hams. All of it was carefully considered, to help make the magazine you're holding in your hands (or reading on your screen). Here are just a few of the comments that came in.

Good for New Recruits

I believe that *On the Air* just might be a great recruiting tool. I have sat in on 35-40 VE sessions for ARRL, and it feels like I am only doing half of my job after the congratulations and handshake.

We get people into a test session, they succeed, we give them some club info if they're local, and they walk away. A copy of the new magazine might be a good handout for new folks passing their first exam, and something for folks who are upgrading too.

John Leahy, KK4ITX
Zephyrhills, FL

Thanks, I Needed That

As a senior citizen brand-new to ham radio, thanks for developing a publication for entry-level Technicians. I believe a publication of this type is greatly needed by total newbies. The articles were well written, and, best of all, were not condescending or overly technical in explaining the basics.

I think it should be offered to every new Technician. Not everyone will want it, but I believe for a majority of newbies, this would be helpful for them over the long run.

Tim O'Shaughnessy, KG5OUV
Pflugerville, TX

"I believe a publication of this type is greatly needed by total newbies. The articles were well written, and, best of all, were not condescending or overly technical in explaining the basics."

A Place for the New Guy

I am a Technician with about 3 years experience. I love *QST* and usually find a few articles of interest every month. But I also kind of feel like the "new guy" when reading *QST*. *On the Air* is a perfect fit for me. Every article has some connection to my use of amateur radio.

Mark Rolland, KEØKWX
Lincoln, NE

Talk to us! Send letters and other comments about *On the Air* to ota@arrl.org, arrl.org/on-the-air-magazine-comments, or *On the Air*, ARRL, 225 Main Street, Newington, CT 06111.

Ready to Get *On the Air*?

Join ARRL today and get started!

ARRL is the national association for Amateur Radio in the US, providing resources that help members make the most of their amateur radio license.

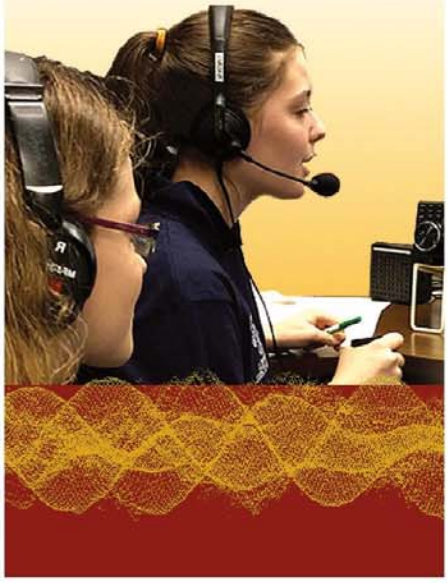
When you join, you'll get *On the Air* every other month, plus many more benefits you need to get active and on the air.

Special *On the Air* Offer!
Join ARRL and select *On the Air* as your print magazine option. You'll get 3 additional months of membership free – **that's 2 extra issues of *On the Air*!**

Go to www.arrl.org/join/OA1 and use web code OA1

All ARRL members can access the digital version of both *QST* – ARRL's official membership journal, and *On the Air*.

Special offer is available only to those who join ARRL and select *On the Air* as their choice of a print magazine. Ends February 29, 2020.





Radio on the Rails

All railroad carriers use radio, mostly on analog FM frequencies that amateurs can easily listen in on. Almost all VHF/UHF amateur transceivers have extended receive capability, and even basic models can usually receive up to 175 MHz, which includes most railroad communication networks. It helps to have an elevated antenna so you can receive over a wide area, but even the "rubber duck" antenna that came with the handheld will work if you're reasonably close to the rail lines.

If you live in a busy Amtrak corridor, such as the West Coast or the Northeast Corridor, you can hear a substantial amount of radio traffic, especially during daytime and early evening. Listen between 160 and 162 MHz. You'll hear onboard personnel, Maintenance of Way crews, and Amtrak's own police force. Check trainweb.org/dispatchoffice/amtrak.htm for a comprehensive list of Amtrak frequencies.

You can hear communication among freight railroads in almost every area of the country, mostly between 160 and 169 MHz, although don't neglect UHF between about 452 and 472 MHz. Find frequencies for everything from the major railroads to small tourist trains at trainweb.org/dispatchoffice/roads.htm. — **Steve Ford, WB8IMY**

On the Air Launch Party February 7 – 9 @HamCation!

We're so excited about *On the Air*, we're celebrating all winter long! Visit the *On the Air* launch party booth at Orlando HamCation, which is also the 2020 ARRL Northern Florida Section Convention, for giveaways, snacks, games, and more.
hamcation.com

Wider Reach for Your Home Wi-Fi



A home Wi-Fi connection that conks out when you're in your garage, basement or yard can be annoying and rack up your data bills. A Wi-Fi extender like this one from Winegard captures high-speed Wi-Fi signals from up to half a mile away while performing seamlessly with 20 devices or more. This compact device uses three amplified, omnidirectional, high-gain antennas that broadcast securely — farther than any main network router can reach. The encrypted security protocol protects your information, and the industrial housing stands up to harsh weather. Winegard Extreme Wi-Fi Extender $349.99, winegard.com.

Protect Your Gear from Stray RF

Giving your indoor radio equipment a ground plane can reduce the amount of stray RF your gear picks up. DX Engineering's Radio RF Ground Plane Kits include a pre-drilled 1/16-inch-thick copper sheet that you place under your HF radios, mics, and other devices. Connect it to the existing grounding bus, and the large metal surface area equalizes the RF electric field around the equipment and attached cables, reducing voltage differences between pieces of equipment and the associated currents that cause RF interference. Various sizes available, $57.99 to $122.99, DXEngineering.com.



ARRL January VHF Contest January 18 – 20

Open to all hams in the US and Canada (and their possessions). Use authorized frequencies above 50 MHz to contact as many stations as possible, in as many different Maidenhead grid squares as possible. Logs are due January 30, by 0359Z. Get the rules at arrl.org/january-vhf.

HAMSPEAK

Maidenhead Grid Square

The grid square system helps specify locations on the Earth's surface. A grid square measures 1° latitude by 2° longitude (about 70 × 100 miles in the continental US) and is denoted by two letters and two numbers, as in FN31, the grid square where ARRL Headquarters is located. Squares can be further broken down into subsquares, designated by two lower-case letters, such as FN31pq for ARRL HQ. The system is named for the town outside London where it was created, and it's used mostly in ham radio activities at VHF and above. See arrl.org/grid-squares for more info, including links to grid search engines and maps.



Winter Field Day January 25 – 26

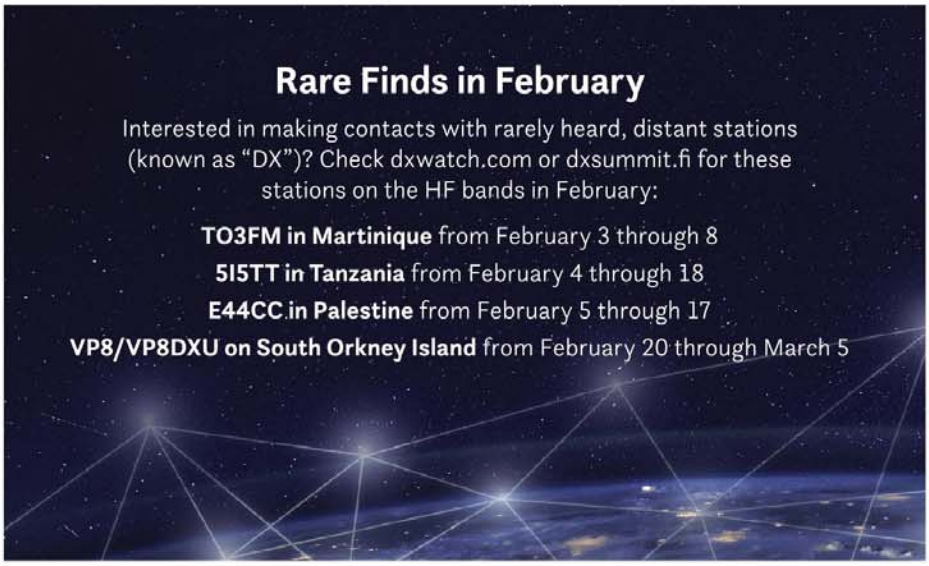
Can you set up an antenna with gloves on? Winter Field Day, January 25 – 26, is the time to find out! Started in 2007 as a training exercise to help hams practice their skills in difficult weather conditions, Winter Field Day is the perfect time to see how you and your station cope with wind, snow, and icy temperatures. The potential for less-than-ideal operating conditions make Winter Field Day a great opportunity to prep for public service/emergency communications operations. Participants have set up in remote parks, a fishing shack on a frozen lake — or have simply stepped into their backyards. Get more information, including the rules, at winterfieldday.com or facebook.com/groups/winterfieldday.

RF Connectors and Adapters

DIN – BNC
C – FME
Low Pim
MC – MCX
MUHF
N – QMA
SMA – SMB
TNC
UHF & More

Attenuators
Loads & Terminations
Component Parts
Hardware
Mic & Headset Jacks
Mounts
Feet – Knobs
Speakers – Surge Protectors
Test Gear Parts
Gadgets – Tools

www.W5SWL.com



Party All Across the Land

State/province "QSO parties" happen all year long. Make as many contacts as possible with stations in the states or provinces in question, and win awards! February QSO parties include:

Vermont QSO Party
Starts February 1 at 0000 UTC. ranv.org/vtqso.html

Minnesota QSO Party
Starts February 1 at 1400 UTC. w0aa.org/docs/mnqp/MNQP%20Contest%20Rules.pdf

British Columbia QSO Party
Starts February 1 at 0359 UTC. orcadxcc.org/bcqp_rules.html

South Carolina QSO Party
Starts February 29 at 1500 UTC. scqso.com

Get On-Air Practice in the School Club Roundup

ARRL's School Club Roundup is a 5-day competition to see how many contacts elementary, middle, high school, and college radio clubs can make in that time. If you're not a student, get on the air and give the kids somebody to talk to — it'll be good practice for you, too! 1300 UTC on February 10 to 2359 UTC on February 14. Get rules and info at arrl.org/school-club-roundup.

Download the ARRL Magazines App!

The perfect companion for members on the go! Includes current and back issues of *On the Air* magazine and *QST*, ARRL's monthly membership journal. Stay up to date on the latest happenings and features right from your mobile device. The ARRL Magazines App is available free for download in Apple's App Store or Google Play, or visit arrl.org/ota for more info.

Hear weak signals clearly with...
...a bhi DSP noise cancelling product!

bhi

ParaPro EQ20 Audio DSP Range with parametric equalisation



- 20W audio and parametric equalisation on all units
- Precise audio adjustment to compensate for hearing loss
- DSP noise cancelling and Bluetooth versions
- Easy to use with simple control of all DSP functions
- Use with passive speakers or headphones
- Greatly improves the clarity of you receive audio
- Four models: EQ20, EQ20B, EQ20-DSP, *EQ20B-DSP

Read the excellent review in December 2019 issue of QST!

High-performance audio processing...
...with first class DSP noise cancelling...
...for a great listening experience

Dual In-Line



Fully featured flexible dual channel DSP noise cancelling unit - 8 Filter levels 9 to 40dB - 3.5mm mono or stereo inputs - Line level input/output - 7 watts mono speaker output - Headphone socket - Suitable for all types of radio incl' SDR - Easy to use controls for quick and easy operation - Enjoy clear intelligble "noise-free"speech from your radio
- Replacement for bhi NEIM1031 In-Line

Compact In-Line



Easy to use in-line DSP noise cancelling unit with simple "real-time" control of audio and functions accross the whole audio bandwidth

- Powerful high-performance audio processor
- Unique DSP noise cancelling technology - Remove noise and interference - Hear weak signals clearly
- Rotary encoders perform all functions
- Easy to use with "real time" adjustment
- Use with headphones or a loudspeaker
- 3.5mm line level and speaker level inputs

Check out our range of extension speakers, headphones and accessories

DSPKR



10W DSP noise cancelling speaker
- Simple control
- 8 filter levels
- Volume control
- Input overload LED
- Headphone socket
- Supplied with user manual and fused DC power lead

DESKTOP

10W Amplified DSP noise cancelling base station speaker
- Easy to use "real-time" control of all functions
- 8 filter levels 9 to 40dB
- Suitable for all radios incl' SDR, Elecraft and FlexRadio products
- Headphone socket
- Speaker level and line level input sockets



DX ENGINEERING
DXEngineering.com -1-800-777-0703 www.bhi-ltd.com

EA&O

VISA PayPal MasterCard

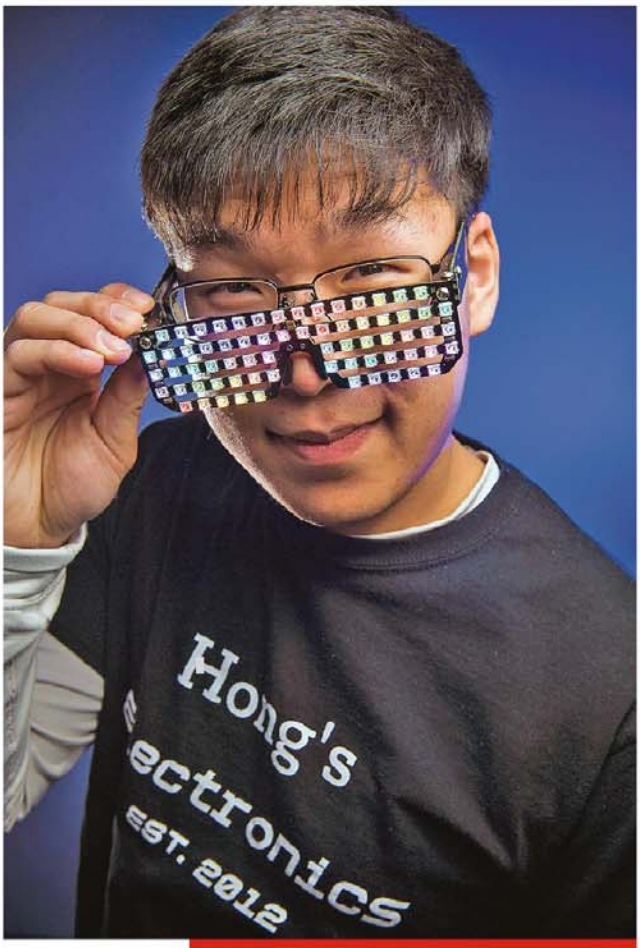
Letting Out the Magic Smoke

UP CLOSE

Jeremy Hong, KD8TUO

Age 25, Fairborn, OH

Credentials: Licensed in 2013, currently holding Amateur Extra (2014)



Q: First ham activities after you got licensed?

Software defined radio (SDR) with the RTL-SDR USB dongle, and using a Baofeng UV-5RA 2-meter/70-centimeter handheld.

Q: What do you currently do with ham radio?

I still work a lot with software defined radio (SDR) as a hobby and now professionally. After getting my first full-time job, I finally bought a Yaesu FT-991A HF rig to use my Extra-class privileges.

Q: Favorite resources for ham radio info and ideas?

1. My local club, Dayton Amateur Radio Association (DARA, w8bi.org), and their homebrew club, the Thursday Night Group.
2. Ham radio groups on Facebook, especially Ham Radio Home Brew Corner (facebook.com/groups/hamradioconstruction/).
3. ARRL and *QST* (arrl.org/qst)
4. Y Combinator Hacker News (news.ycombinator.com/)
5. Hackaday.com
6. RTL-SDR.com

Q: Favorite non-radio activities?

- Camping and hiking
- Information and cyber security (hacking, mostly embedded and IoT devices)
- I also do many non-radio DIY electronics projects

Q: We hear you're a business owner; what do you do?

Hong's Electronics is dedicated to producing open-source hardware and tools for hobbyists. jhongelectronics.org

I also provide consulting services to local aerospace and defense companies in the greater Dayton area.

Q: Biggest ham-related embarrassment?

Despite knowing what shortwave radio was even before I became a ham, for some odd reason I didn't make the connection that HF is included in that part of the spectrum!

Other than that, letting the magic smoke out of DIY boards that I have assembled.

Q: Biggest ham-related success?

1. Getting featured in *QST* (July 2017)
2. DARA Member of the Month (November 2018)
3. DARA Scholarship (2017)

Q: How have you benefited from being an ARRL member?

Through receiving ARRL scholarships and the amazing technical publication that is *QST*.

KD8TUO's top three MUST-HAVE tools for ham radio:

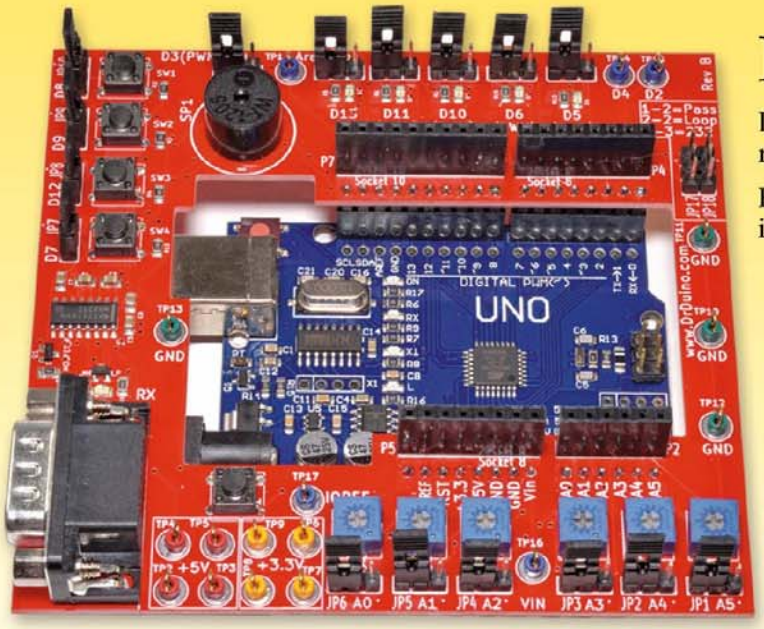
Software defined radio; plenty of options now. I use a HackRF One with PortaPack.

EU1KY Antenna Analyzer, great open-source hardware and software antenna analyzer.

NanoVNA, a nice pocket-sized Vector Network Analyzer (VNA) for debugging and characterizing RF filters and cables.

Become An Arduino® Uno Master Faster!

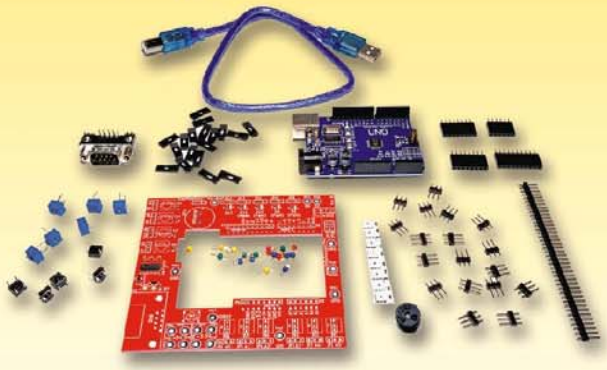
Dr.Duino™ Starter Kit



For Beginners or Pros

It's Perfect for quick prototyping and diving right into Arduino Uno without a breadboard.

Easy to use and insanely powerful, it will become your go to Arduino Uno shield.



As seen in QST Magazine October 2019 | Pg 52 Product Review Section

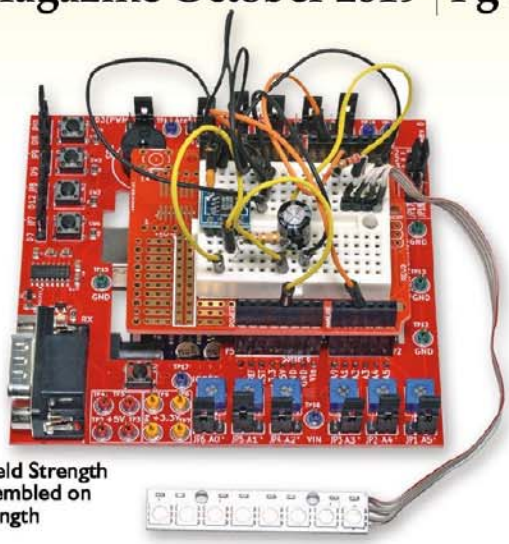


Figure 9 – The Arduino RF field Strength meter project prototype assembled on the Dr.Duino board. (RF strength meter project not included)

"The Bottom Line...

With the included training package, Facebook support group and the Dr.Duino board, this kit is a nice and affordable development platform for both beginning and advanced Arduino hobbyists."

-Glen Popiel, KW5GP

Dr.Duino is 4 kits in 1! It's a...

Learning Kit
Perfect for getting started with Arduino

Text Fixture
Easily accessible & probe friendly pins

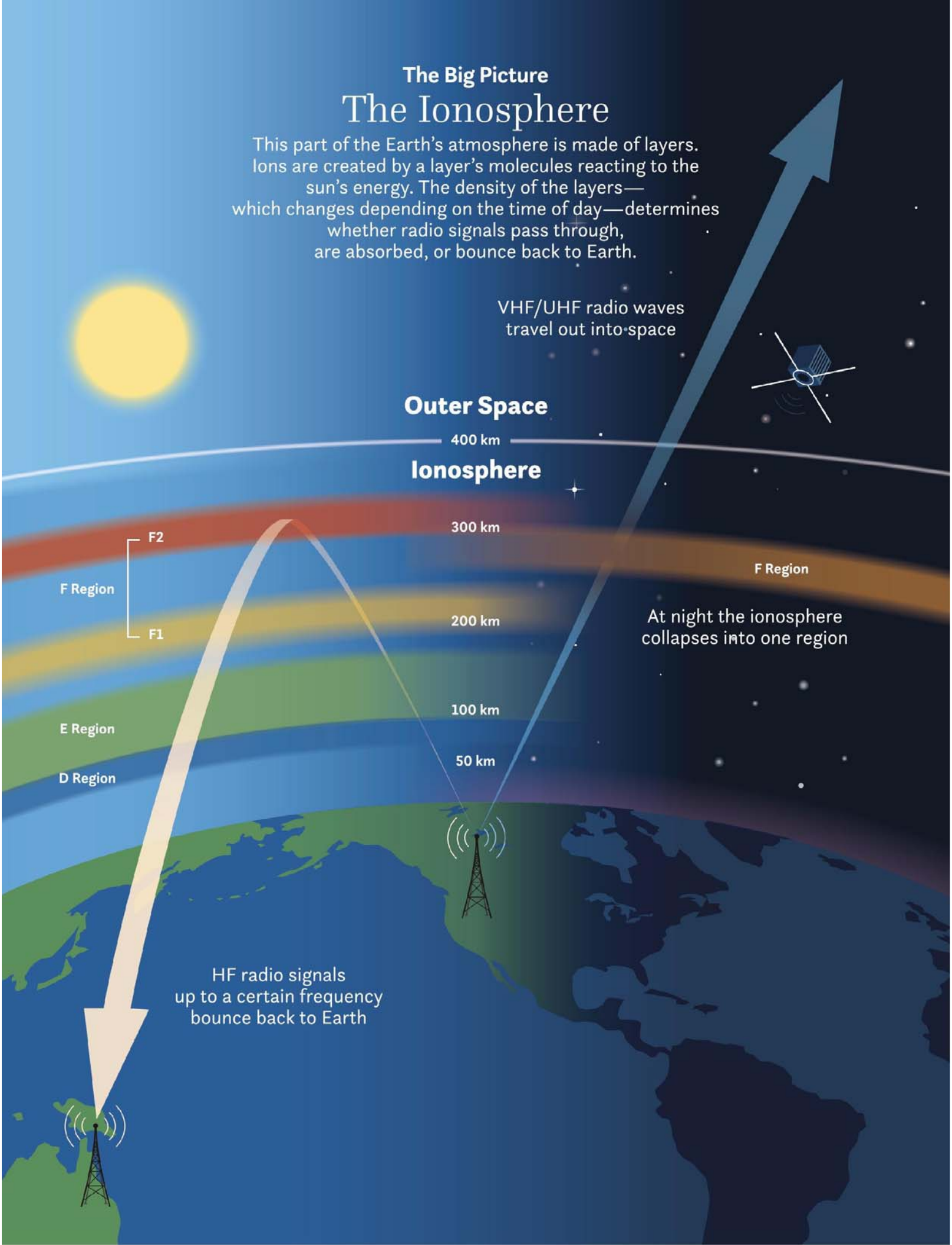
Debugger
Quickly troubleshoot hardware vs. code issues

Simulator
Begin coding even before your hardware arrives

EXCLUSIVE ARRL MEMBER PRICING – ~~$118~~ $59

Available at www.drduino.com/qst

"ARDUINO IS A REGISTERED TRADEMARK OF ARDUINO AG. DR.DUINO IS NOT AFFILIATED OR ENDORSED BY ARDUINO AG."


The Big Picture
The Ionosphere
This part of the Earth's atmosphere is made of layers. Ions are created by a layer's molecules reacting to the sun's energy. The density of the layers—which changes depending on the time of day—determines whether radio signals pass through, are absorbed, or bounce back to Earth.
VHF/UHF radio waves travel out into space
Outer Space
400 km
Ionosphere
300 km
F2
F Region
F1
200 km
F Region
At night the ionosphere collapses into one region
100 km
E Region
50 km
D Region
HF radio signals up to a certain frequency bounce back to Earth

The Ionosphere

The Great Radio Prism in the Sky



The ionosphere is a thin layer of gases — mostly oxygen and nitrogen — that exists at very high altitudes, so high that the International Space Station cruises through its outer reaches.

During the daytime, the intense radiation from the sun strips electrons from the gas atoms and creates charged particles called ions. These ions tend to sort themselves into regions, or layers, in the ionosphere. We call these layers D, E, F1, and F2.

What makes these high-altitude ions special is, if you pack enough of them together in one place, they can act like prisms to radio waves. Just as a prism bends light, the ionosphere can bend radio signals back to Earth — and when that happens, the signals travel great distances. The ionosphere makes long-distance radio communication possible.

The way a radio signal behaves in the ionosphere depends on a number of things, but the frequency of the signal is a major factor. If the frequency is too low, it may be absorbed in the lower regions of the ionosphere, and travel only a short distance. If the frequency is higher, the signal may travel all the way to the F regions, be bent back toward the ground, and then bounce back up again to the ionosphere — and down again, and up again, until suddenly the signal is thousands of miles away from where it originated.

The ionosphere is different at night, though. Without sunlight to create ions, the lower regions disappear and the F1 and F2 regions merge into one region simply called "F." The ionosphere can still bend signals back to Earth at night, but these are usually only signals at frequencies below about 10 MHz.

Regardless of whether it's day or night, if you go higher in frequency, above about 50 MHz, the radio prism effect of the ions stops working. Instead, these signals zoom directly into outer space. That's one of the reasons why spacecraft use VHF, UHF, and microwave frequencies. They need reliable communication paths that won't be blocked by the ionosphere.

Thanks to the ever-changing ionosphere, hams can communicate around the world with just a wire antenna in a tree.

An AM Lesson

Have you ever wondered why the AM radio in your car only receives local stations during the day? That's because those low-frequency signals are being absorbed in the D layer of the ionosphere. The D region is dense, relatively speaking, and it can act like a sponge to lower-frequency signals that aren't energetic enough to punch through.

The next time you're in your car at night, take a spin through the AM signals and you'll hear a big difference. The D and E regions are gone at night, leaving AM broadcast signals free to travel hundreds of miles and even farther. You'll hear one signal after another — so many that they often interfere with each other.

Listen to an AM radio at dawn, and you'll hear an amazing transformation. As the sun rises, distant signals grow weaker as the lower regions of the ionosphere return in the light of the new day. Within an hour or so those lower layers will soak up the AM signals again, until only local stations remain.

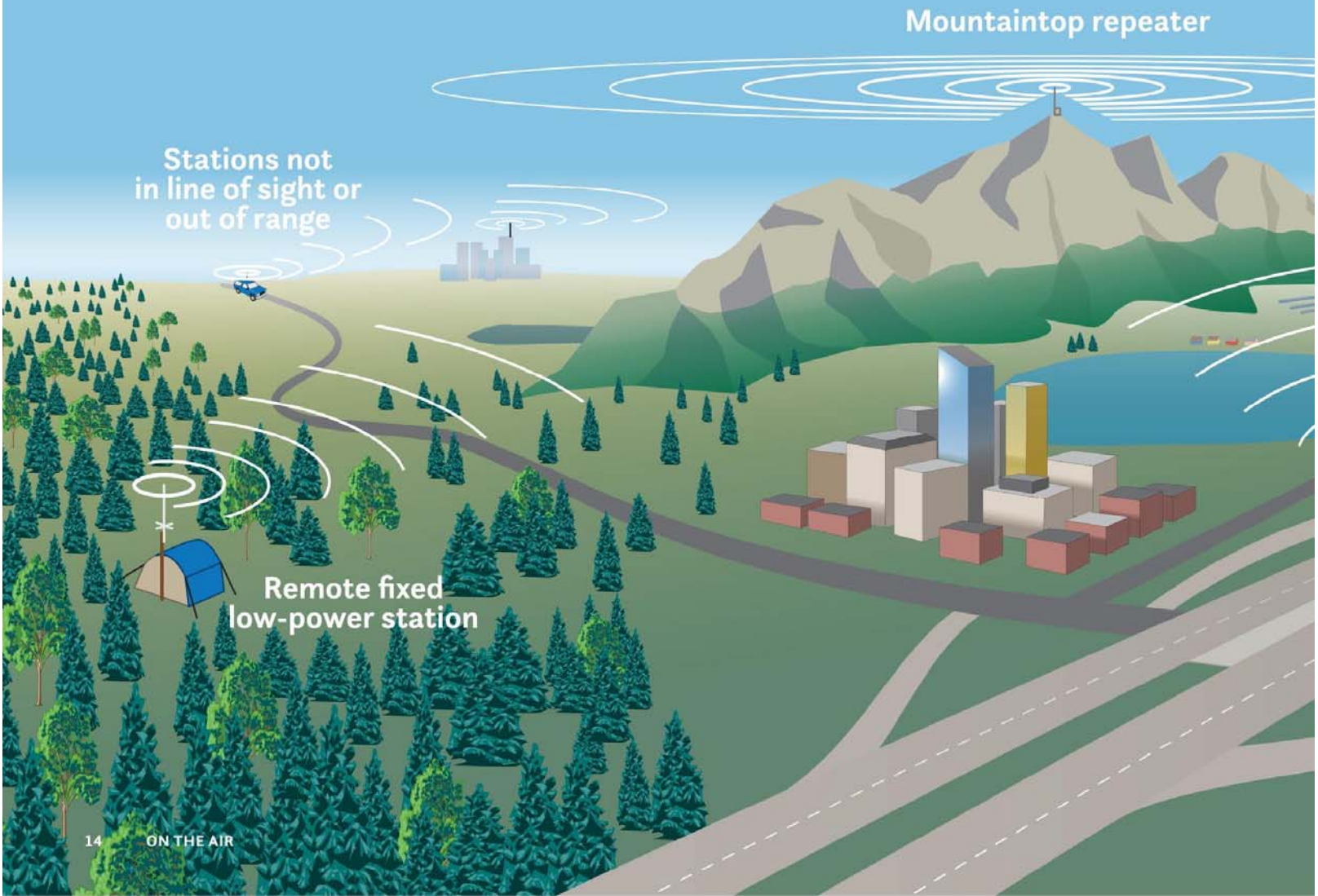
Repeaters — Your Friends in High Places

Mobile radios and handheld transceivers seem cool, until you find out that these little rigs generally have a range of only a few miles. The truth is, you can use a handheld or mobile radio to talk to people tens or thousands of miles away with the help of a device known as a repeater.

When you get down to the basics, a repeater isn't complicated. It simply repeats. It listens for signals on one frequency, known as the input, and repeats whatever it hears on a different frequency, known as the output — all at the same time.

A repeater's receiver is extremely sensitive, and is usually connected to an antenna installed on a tall support tower. In many cases, repeaters and their antennas occupy tall buildings, hills, or even mountaintops. With such a sensitive receiver and tall antenna, a repeater's "big ears" can hear signals over a wide area, including weak ones from handheld transceivers. A friend a couple of miles away may not be able to hear your little handheld radio, but a repeater can hear you very well, even though it may be several miles away or more.

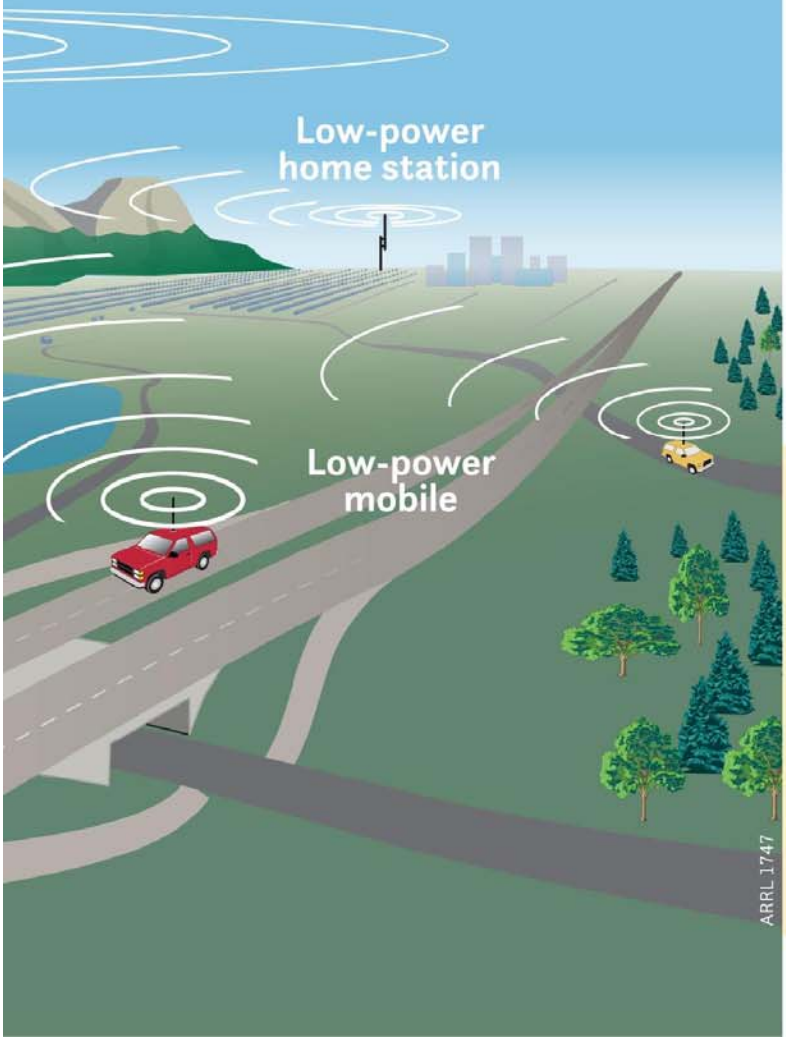
Repeaters expand the coverage area of VHF and UHF stations when low power, distance, or obstructions prevent communication.



Aside from the distance, maybe there's a mountain between the two of you as well. That obstacle makes direct radio communication impossible, but a repeater in the right location will relay your signals around or over that mountain.

And when a repeater repeats your signal, it does it with a big voice. A handheld transceiver may transmit with just 5 watts of power, but a repeater transmits with much greater power — sometimes hundreds of watts. All that power is applied to the same tall, powerful antenna that heard your signal, and the antenna sends that energy over a huge area.

Think of it this way: You started with a little handheld radio, but when you're talking through a repeater, you're effectively controlling that much bigger radio every time you squeeze your handheld's push-to-talk switch. When you speak, your voice is heard over many square miles. When your friend responds, you hear their voice even though they may be far away, and possibly using a tiny handheld of their own.



Types of Repeaters

Most amateur repeaters operate on the 2-meter band (146 – 148 MHz) and the 70-centimeter band (430 – 450 MHz). That's one reason why dual-band transceivers are so popular — they'll work on both bands. You'll also find repeaters on frequencies as low as the 10-meter band (between 29.500 and 29.700 MHz) and as high as the microwave bands. No matter what frequencies they use, all repeaters function the same way.

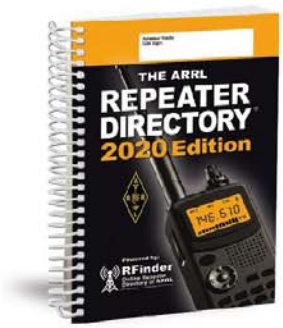
Some repeaters are connected to the internet, enabling you to speak with other amateurs across the globe. Repeaters may also be linked to each other, so that a conversation taking place through one repeater is heard on several repeaters at the same time.

Analog FM repeaters are most popular by far, but you will also find digital repeaters using systems such as DMR (digital mobile radio), D-STAR, and System Fusion (the latter handles conventional FM as well as C4FM digital transmissions, hence the "fusion"). They operate somewhat differently and offer different features, but like their analog cousins, they repeat signals.

Finding Repeaters

Repeaters are almost everywhere. There are more than 20,000 repeaters in the United States alone. Many are operated by groups or clubs, because it can be expensive to maintain repeater equipment and pay rent for a space on a tower, or atop a building.

The best way to find repeaters in your area is to pick up a copy of the ARRL Repeater Directory (arrl.org/shop) or, if you own an iOS or Android smartphone, subscribe to the RFinder app. Regardless of whether you use the app or the book, you'll be able to look up your local repeaters and see their input and output frequencies. You'll also find out whether they are analog FM repeaters, or one of the varieties of digital machines.



Know the Tones

Most analog repeaters use a system called Continuous Tone Coded Squelch, or CTCSS, to prevent interference. CTCSS tones are at low audio frequencies — you won't hear them, because repeaters sharply reduce low-frequency audio after they process the tones.

If you're trying to use a repeater that requires a CTCSS tone, it won't respond unless your transmission is accompanied by the correct tone. Tones for specific repeaters are listed in the ARRL Repeater Directory and the RFinder app. Consult your transceiver's manual to learn how to program your radio for the proper tone.

PROJECT BUILD

Extend Your Handheld's Range with a Simple Ground-Plane Antenna

Parts List

- A female SO239 chassis-mount coaxial connector
- Five feet of #14 electrical house wire
- Heavy-duty wire cutters
- Pliers
- Heavy-duty soldering gun, or a gas torch
- Rosin-core solder
- Coaxial cable
- An adapter to attach the coaxial cable to your handheld transceiver when the antenna is finished.
- PVC pipe
- Hose clamp

TIP **The type of adapter needed will depend on the connector your radio uses. Most use SMA connectors, either male or female. You can find adapters on Amazon or at amateur radio dealers.**



If you're using a handheld transceiver on a VHF or UHF frequency, you've probably learned by now that the radio's small, flexible antenna — sometimes called a *rubber duck* antenna — limits you to a few miles at best, unless you're on top of a mountain or tall building, or if you have a repeater to help relay your signal.

One of the easiest and least expensive ways to extend your range is by using a *ground-plane* antenna. It's called a ground plane because the wires that stick out to the sides — called *radials* — act as ground returns for the energy your transceiver generates. All antennas need ground returns — even the antenna on your car, where the ground plane is the body of the car itself. Many commercial ground-plane antennas have three or four radials. This simple design uses only two.

Step 1

Cut at least three lengths of the #14 wire (remove any insulation), according to the length needed for the frequency you desire. Though this is a single-band antenna that will work on only one frequency, you may be able to it use with a dual-band VHF/UHF transceiver if you cut the wires for the 2-meter band.

Band	Frequency (MHz)	Wire Length (Inches)
2 meters	146	19 1/4
1.25 meters	223	12 1/2
70 centimeters	440	6 1/4

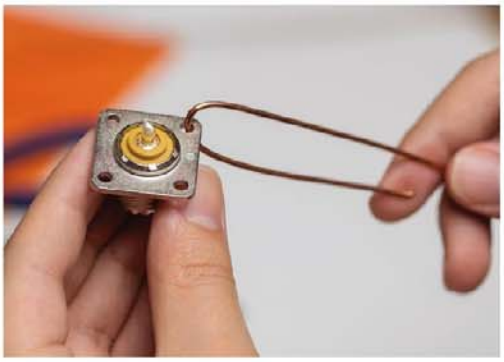
Of the three wires you've created, two will become radials and one will be the radiating element, better known as simply *the element*.

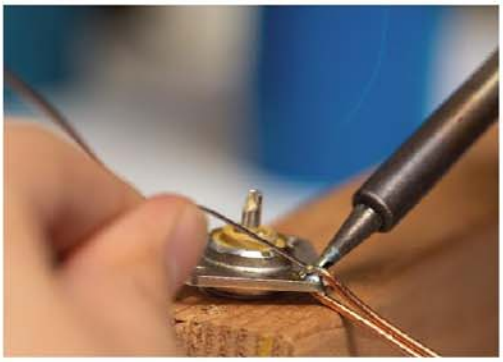
TIP To eliminate sharp ends, bend one end of each wire into a circle.



Step 2

Pass the radial wires through the holes in the chassis mount of the coaxial connector. Choose holes that will place the radial wires are opposite one another. Use your soldering gun or torch to solder them into place.

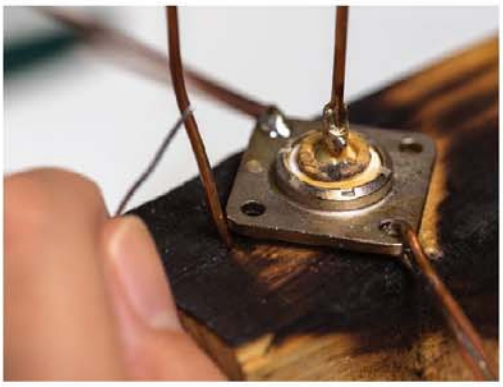




TIP It takes a lot of heat to accomplish this, so sometimes a torch is best.

Step 3

Insert the element wire into the center pin of the connector and solder it into place. This is the pin that is on the opposite side of the threaded part of the connector.



Continues on following page.

What is SWR?

To understand the concept of *standing wave ratio*, or SWR, imagine a small pond with a vibrating motor in the center. Those vibrations make ripples radiate outward in all directions. The ripples strike the soil at the edge of the pond and bounce back in the general direction of the motor. These reflected ripples collide with the "new" ripples being generated by the motor. As they collide, they add or subtract from one another.

If we were to watch from the shore, we'd see the first ripples striking the pond edge and returning, but within seconds we would no longer see moving ripples at all. Instead, we'd see what appeared to be a fixed, non-moving pattern of waves on the pond's surface. All the traveling waves would collide and merge into a series of *standing waves*.

Similarly, the energy your transceiver sends into the coaxial cable, the *forward power*, travels to the antenna. Some of the energy is radiated, but some is reflected. This *reflected power* goes back down the coax toward the transceiver, where it will ultimately bounce back to the antenna. Along the way, it encounters forward power from the transceiver. These waves of energy interact, adding and subtracting. The result is standing waves on the cable.

SWR is important is because it can play an enormous role in determining how much RF energy is lost in a coaxial cable. As the SWR increases, more RF energy is tied up in the standing waves along the cable, and it will be lost as heat. A high SWR can also damage your radio, especially at higher power levels. That's why many transceivers have circuits that automatically reduce their RF output if the SWR rises above 2:1.



Mounting the Antenna

Use a length of PVC pipe as a mast for your antenna. Cut slots into one end to create flexibility in the width of the pipe's opening, and use a hose clamp to squeeze the pipe around the bottom of the coaxial connector to hold it in place inside the end of the pipe.





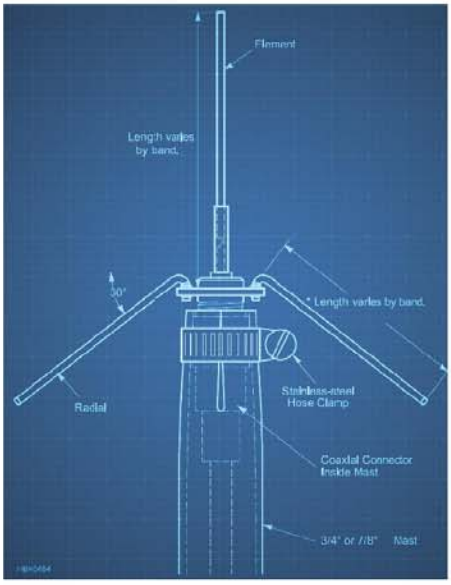
In the drawing at right, note that the coaxial cable is fed through the inside of the pipe where it finally screws onto the connector.

Testing the Antenna

Bend the radial wires down to 30-degree angles (approximately) as shown in the drawing. If you have an antenna analyzer, or know someone who does, attach it to the coaxial cable and measure the standing wave ratio (SWR) at your desired frequency.

If the SWR is greater than 2:1 at your desired frequency, measure above and below the frequency. If the lowest SWR point occurs below the frequency you want, your element wire is too long. Trim the wire by 1/4 inch and measure again. Keep cutting a bit at a time until the lowest SWR occurs at the desired frequency. See the sidebar, "What is SWR?"

On the other hand, if you find the lowest SWR at a frequency higher than the frequency you desire, your element wire is too short. You'll have to remove the wire and replace it with a longer one. Make the replacement wire about an inch longer. In this way, you can trim the wire to bring the low-SWR point exactly where you want it. Once your SWR is under control, you're ready to get on the air with an increased range, thanks to your new ground-plane antenna!



The diagram of our simple ground-plane antenna, using PVC pipe as a support mast.

PROJECT BUILD

One Wire, Many Bands

This easy build uses low-loss feed line and an antenna tuner to give you access to several of the HF bands.

Parts List

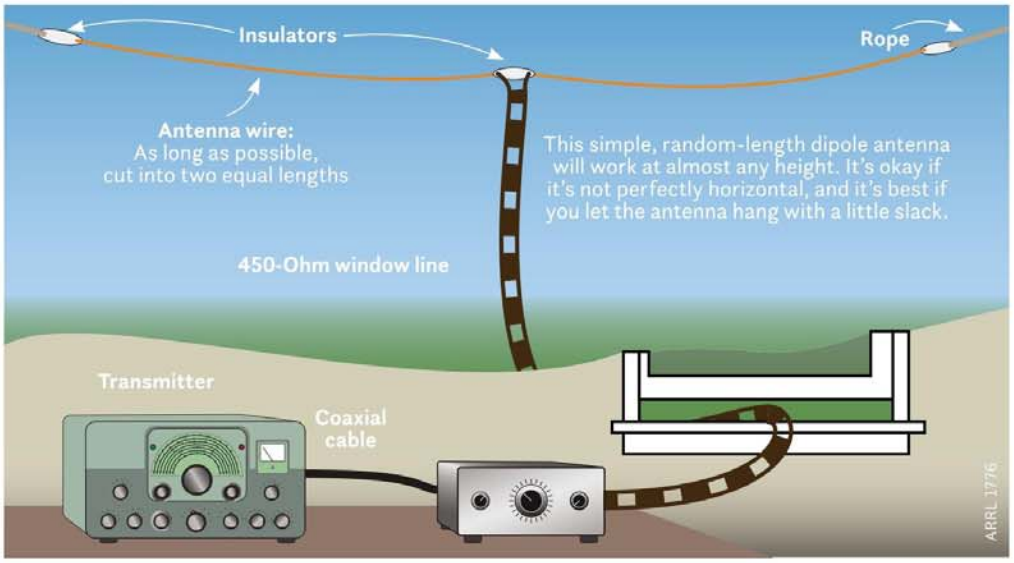
- **Antenna wire.** Almost any type will work, but stranded #14 copper wire is best. Choose something strong, to withstand the ravages of weather. The total length of the wire will depend on the lowest frequency at which you hope to operate (see the table, "Ideal Antenna Lengths"), as well as how much room you have for your antenna.
- **Plastic or ceramic insulators.** Just search online for "antenna insulators," and you'll find lots of choices. For the center insulator, consider a *WA1FFL Ladder-Loc*, which is designed to support windowed line.



- **450 Ω windowed line.** Buy only as much as you need to span the distance from the center of the antenna to your transceiver, to minimize energy loss.
- **An antenna tuner (manual or automatic).** If you intend to bring the windowed line directly to the tuner, make sure your tuner has a built-in *balun* (which is short for "balanced-to-unbalanced"), a device that allows a balanced feed line to connect to an unbalanced line. If it doesn't, you'll need to purchase a balun separately (try a 4:1 model) and connect it to the tuner with a short length of coaxial cable (no longer than 10 feet).
- **A soldering iron, solder, pliers and wire cutters.**

Ideal Antenna Lengths

Lowest Desired Frequency (MHz)	Total Length (Feet)
3.5	130
7	66
14	35



This simple wire antenna, known as a *random-length dipole*, works on several HF bands. "Dipole" means "two poles," which, in this case, means the antenna has two wires that function as electrical poles, similar to the plus and minus terminals found on batteries. The "random" length means you don't need to make this antenna a specific length in order for it to work.

The center of the antenna, where the two wires meet, is connected to a type of *feed line* (the wire that carries RF energy between your radio and antenna) known as *windowed line*. Windowed line has very low energy loss, and looks like a brown plastic ribbon about an inch across. Each edge of the ribbon is a wire. The plastic between these parallel wires has slots, or "windows," along the entire length.

To use this antenna with your transceiver, you'll need an *antenna tuner*. Many modern transceivers have built-in antenna tuners, but most of them lack the tuning range to work with the antenna system discussed here. With a wide-range external tuner, however, you should be able load the full output of your radio into the antenna. See the sidebar, "Antenna Tuners," for more information.



Step 1

Measure the antenna wire to the maximum length that will fit on your property. Cut the wire into two *equal* pieces. Place an insulator at one end of each wire. Wrap the wires through the holes in the insulators (1), then solder the wires in place.

Continues on following page.







Step 2

You'll need another insulator, or a WA1FFL Ladder-Loc, to form the center of your antenna. Connect the uninsulated ends of each piece of antenna wire to opposite sides of the insulator or Ladder-Loc.

Carefully cut through the solid plastic portion of the window line until you have separated two 5-inch lengths of the wire (2).

Cut away the solid plastic tabs, and strip away about an inch of insulation from the ends of both wires (3).

Solder one wire to the antenna wire on the left side of the center insulator and solder the other wire to the antenna wire on the right side (4). If you're not using a Ladder-Loc, consider using electrical tape or another insulated material to help keep the windowed line from moving excessively. Too much movement will cause it to eventually fail.

Step 3

Tie ropes to the end insulators and string them over tree limbs (or whatever you're using for supports). Raise your antenna off the ground as high as possible. This antenna will work at almost any height, but higher is better. Don't pull the ropes too tightly; you want your antenna to hang with a little slack, especially if it's being supported by trees. This will reduce stress on windy days.

The antenna doesn't have to be perfectly horizontal. If one end is lower than the other, that's fine.

Step 4

Uncoil the windowed line that's hanging from the center of your antenna and lead it back to your station. *Two important tips:* (1) Do not allow the windowed line to coil into itself or tangle into a ball. (2) Keep the windowed line off the soil and at least 5 inches from metal objects such as gutters, aluminum siding, etc.

Step 5

Connect the windowed line to the balanced terminals on your antenna tuner, or solder the windowed line wires to a balun and connect the balun to your tuner with a short length of coaxial cable.

Time to Test

Set your transceiver output to a low level, such as 10 watts. Select a frequency on the lowest band you hope to operate.

For the next step, you'll need a steady signal for the tuner, so place your transceiver into CW mode and hold down your code key to transmit. Alternatively, use AM or FM mode and hold down your microphone's push-to-talk switch.

If you're using a manual tuner with inductance selected by a switch, usually labeled Inductance, set the Transmitter and Antenna knobs at mid-range. Begin

Antenna Tuners

Just as an electrical transformer converts one voltage to another, an antenna tuner converts one impedance to another. Impedance isn't simple to define because it involves mathematical expressions, but suffice to say that every antenna system (the antenna and feed line together) has an impedance that changes depending on the frequency. We measure impedance in ohms, represented by the omega symbol (Ω).

The goal of an antenna tuner is to convert the antenna system impedance to something close to what your transceiver expects. That is usually 50 Ω. We call this an impedance match, and it allows the transceiver to load all of its output power to the antenna system.

There are many types of antenna tuners on the amateur radio market, and they all have different features.



As the name implies, a manual tuner must be adjusted by the station operator. Most are designed with an internal coil with wires attached to it (called a tapped inductor), as well as two variable capacitors. You turn a switch to select a tap, and then adjust the capacitors for the lowest SWR. Others have a coil that, like the capacitors, can also be adjusted.

transmitting and watch the SWR indicator as you turn the inductance knob. You should see a dip in the SWR reading, although it may be slight. Stop when you find the switch setting that gives the lowest reading. Now turn the Transmitter knob until you lower the reading as far as you can. Next, turn the Antenna knob and try to reduce the SWR even further. Go back to the Transmitter knob and adjust again. You may have to go back and forth between the Transmitter and Antenna knobs several times until you've reduced the SWR to the lowest reading possible.

When you're satisfied, write down the settings for all three knobs. Now go to the next higher frequency band and repeat these steps. Soon you'll have a list of your optimum settings and you can return to them easily.

If your antenna tuner has a variable inductance, the steps are somewhat different. Start by turning the Antenna knob fully clockwise; set the Transmitter knob to the middle of its range. While transmitting, turn the inductance knob and watch for the dip in the SWR reading. Once you've found it, turn the Transmitter knob in either direction and watch for another dip. Go back and forth between the inductor and Transmitter knobs until you reach the lowest SWR reading. Then, adjust the Antenna knob and see if you can lower it further, ideally below 1.5:1. Write down the settings for all three knobs, then go to the next higher frequency band and repeat these steps.



If you're using an automatic antenna tuner, the adjustment process is much easier because the tuner does all the work! Just start transmitting at a low power level (less than 10 watts output) and your tuner should respond by rapidly searching for the lowest possible SWR. You may hear it clattering as it searches, and the SWR indicator may fluctuate wildly. Not to worry! This behavior is entirely normal.

Some automatic tuners require you to press a button before they will begin tuning; others sense the presence of the signal and start tuning on their own. Either way, once the automatic tuner has found the best settings, it will automatically store those settings in its memory so that it can find them quickly again in the future.

You may find that you cannot achieve a low SWR (less than 1.5:1) on all your favorite frequencies. However, you should discover that you can operate on several frequency bands and transmit an effective signal!

When shopping for a manual tuner, look for:

- An SWR/Power meter.
- An internal 4:1 balun (sometimes referred to as a "balanced output" in the sales brochure or advertising).
- A continuous (or CW) power rating of at least 100 watts.

Automatic tuners have become particularly popular because they're so easy to use. Some are designed to work within your station, but there are also models meant to be installed outdoors near your antenna.

When considering an automatic tuner, look for:

- An SWR meter or other indicator. (Indoor models only.)
- A continuous (or CW) power rating of at least 100 watts.

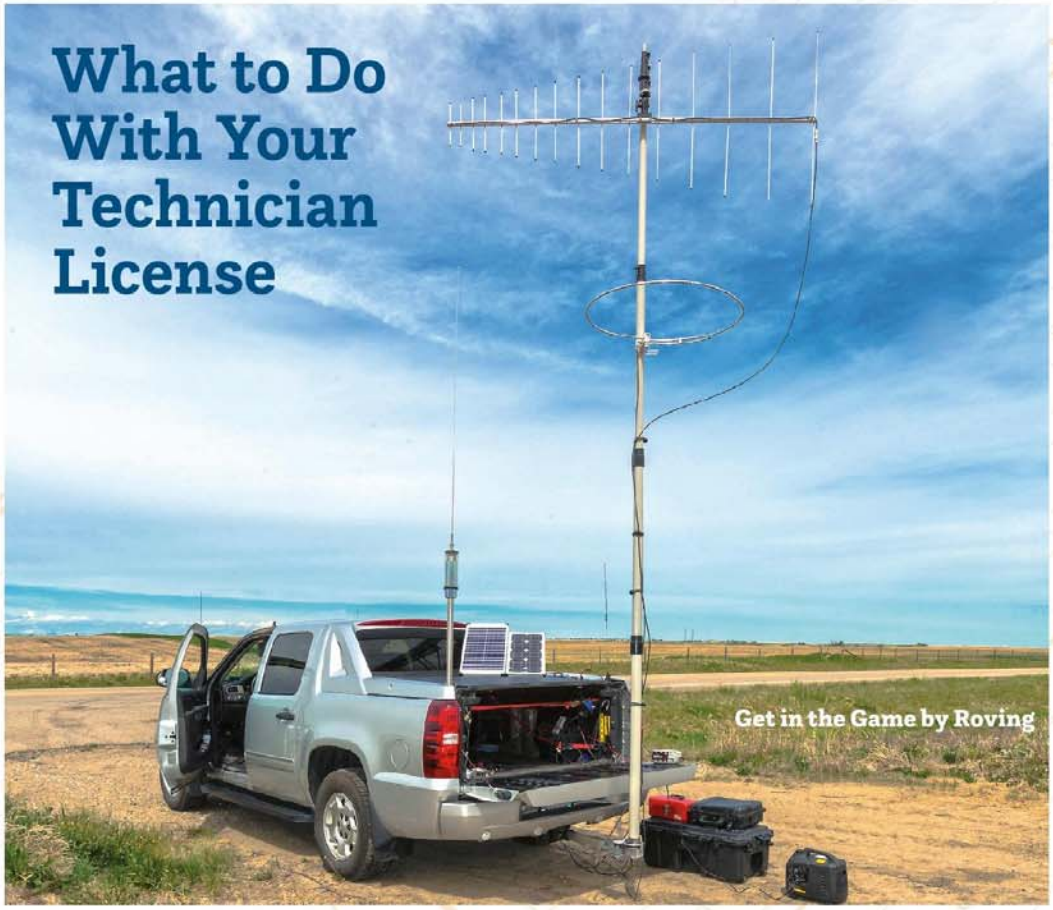
It's rare to find an automatic tuner with a built-in balun, so if you're thinking of using an automatic model with the antenna described in this article, you'll need to buy a 4:1 balun separately. If so, make sure the balun is also rated for 100 watts or more.

Left: A Palstar manual antenna tuner.

Below: An MFJ automatic tuner for indoor use.



What to Do With Your Technician License


Get in the Game by Roving

Amateur radio offers dozens of activities to match your available time and personal interests. Here's a list of just a few of them. Pick your pleasure – or a few! – and get started.

Chase a Fox

Foxhunting, also known as *transmitter hunting*, *radio direction finding*, or *orienteering*, is a radio-based sport where it's your job to track down hidden transmitters. You can organize a foxhunt among your ham friends (one friend can be the fox, or you can buy an automatic fox like the Byonics Micro-Fox byonics.com/mf), or join in larger competitive events around the world. Email ardf@arrl.org for more information.

Get in the Game

The world of radiosport includes many contests on the VHF/UHF bands, where hams compete to see who can contact the most stations in a given amount of time (usually 24 to 48 hours). You can participate from a home station, or from the road in an activity known as *roving*. Check contestcalendar.com to find upcoming events.

HAMSPEAK

HF
High Frequency
Portion of the radio spectrum extending from 3 to 30 MHz, also called shortwave. Includes the 80 – 10 meter amateur bands.

UHF
Ultra High Frequency
Radio frequencies from 300 to 3,000 MHz.

VHF
Very High Frequency
Radio frequencies from 30 to 300 MHz.

FM
Frequency Modulation
The process of applying voice or data information to a radio frequency (RF) carrier by varying the carrier's frequency in a linear fashion, according to changes in the voice or data signal. It is highly resistant to interference from noise.

SSB
Single Sideband
A radio mode also known as "voice" or "phone."

Hit the Satellites

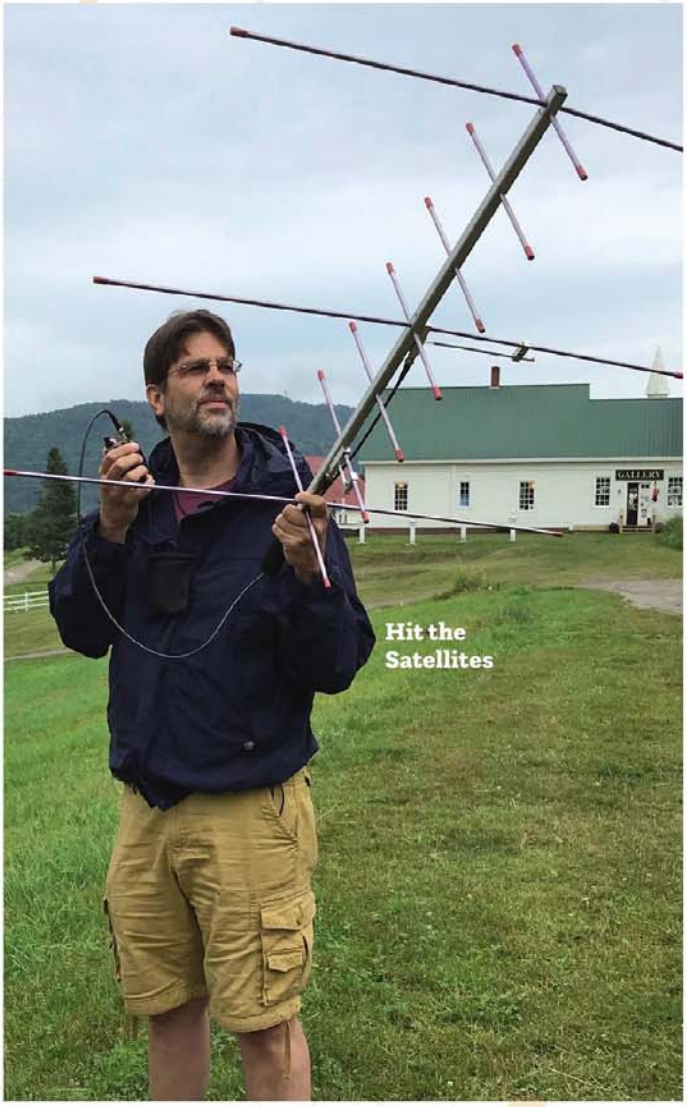
Talk through one of the many ham radio satellites with a 2-meter/70-centimeter dual-band radio, a dual-band antenna, and the help of apps like GoSatWatch, ProSat, and others. A satellite works like a flying FM repeater, relaying your signal hundreds of miles away. The action is often fast, furious and fun as hams try to make contact during a satellite's short window of availability (called a *pass*). The good news is, if you if don't make it onto one pass, there's always another.

State Your Position

Connect a GPS receiver to your 2-meter FM transceiver and send your position coordinates and other information using the Automatic Packet Reporting System (APRS). It's a terrific tool for public service, and many FM transceivers have GPS and APRS capability built in. You can also add APRS to an FM transceiver with a GPS receiver and a tracker (also known as a *Terminal Node Controller* [TNC]) — see byonics.com/tinytrak4.

Use Your HF Privileges

Technicians have CW (Morse code) privileges on the 80, 40, and 15-meter bands — learn the code and hone your skills on the air. Techs also have SSB (single sideband) voice and digital privileges on the 10-meter band — despite solar conditions making this band a bit lackluster, string up a simple wire antenna and give 10 a listen once in a while. You never know what you might find!





Tap Into a Phenomenon

If you have a radio with capability for the 6-meter band, you have a window into a genuine mystery called *sporadic E*, a type of radio wave propagation that appears suddenly and without warning, and allows for long-distance communication over hundreds, or even thousands, of miles. No one really knows what causes sporadic E, but we do know that the occurrences (called *openings*) are usually in spring and early summer, and sometimes in December and January. Sporadic E sometimes shows up on the 2-meter band, but it's famous for occurring on 6, giving 6 meters the nickname, "the Magic Band."

Take a Hike

Hit the trail and bring a handheld or portable radio — a directional antenna can add to the fun. Head to a high-elevation area and see who you can contact. Bring a friend with a radio of their own, split up and use the radios to keep in touch on your adventures.

The Right Antenna for the Job

For hikes and other outdoor activities, the so-called rubber duck antenna that came with your handheld transceiver will let you communicate over several miles, depending on the surrounding terrain. If you want greater range in all directions, consider a larger antenna, such as the ground-plane design described on page 16.

For radiosporting on VHF and UHF, including foxhunting, you'll want a directional antenna, such as a Yagi. Directional antennas focus your signal like a flashlight beam, maximizing your power and bringing in weak signals you wouldn't otherwise hear.

Satellite communication is best with directional antennas. Satellites are hundreds and even thousands of miles away, so you'll need a dual-band (VHF/UHF) directional antenna to concentrate your power.

On the HF frequencies, wire antennas such as the multiband dipole antenna described on page 19, are good choices. There are directional antennas for HF frequencies as well, but they are large and expensive. If you're not ready for that, a wire antenna will do just fine.



A Look at Public Service

Many of us get an amateur radio license in the hope of serving our communities in times of emergency. Here's some insight into public service radio from a newer ham who walks the walk.

The amateur radio community engages in public service activity for many reasons, including a desire to give back to society, to be part of a team, or for excitement, adventure, and a way to make new friends. It's done all of that for Lisa Neuscheler, KC1YL, of Clearwater, FL. Public service was part of Lisa's life before amateur radio was. She started out as an EMT then switched to serving on a Community Emergency Response Team (CERT) when family obligations prevented her from being on call. CERT hams got Lisa hooked on radio about 4 years ago. She joined a club and was fortunate to find mentors. "Whatever you needed help with, there was somebody there to help," Lisa said. Now, as part of the St. Petersburg Amateur Radio Club and the Upper Pinellas Amateur Radio Club, she's part of an "antenna team" that helps local hams with setup and repairs, and she serves as net control for several on-air nets.

Practice Makes Perfect

Because emergencies and disasters don't happen every day, it's important for hams to find ways to keep their skills sharp. "There are plenty of charity bike rides, boat races, motorcycle rides, marathons, and street fairs that use volunteer amateur radio operators to help with crowd control, sweep vehicles, and reporting incidents," Lisa said. "Being familiar with your radio equipment during these non-emergency events will prepare you for an actual emergency. A radio doesn't help if you can't program it, or if the battery is dead because you never use it!"

Finding Training and Mentors

Public service operating is performed in concert with others, many of whom are veteran operators who can serve as mentors for those of us who are new to amateur radio technology and communications. We can learn from them as apprentices until at some point in the future we have enough training and qualifications to work side by side with them as peers. When asked how to get started in public service, Lisa said, "Contact local amateur radio clubs and local chapters of organizations that use amateur radio volunteers, such as the American Red Cross, Salvation Army Team Emergency Radio Network, SKYWARN, and ARES. All these organizations have information and training on becoming a volunteer."

There are also more formal training opportunities, such as online courses from ARES and FEMA, that can put you on the path to gaining new knowledge and skills.

Eventually, when we've got some training and experience behind us, it will be our turn to mentor someone new. Paying it forward is a responsibility that can be just as rewarding as acquiring the knowledge in the first place.

For More Info

Right now, however, you're at or near the beginning of your experiences in the Amateur Radio Service. Here's some basic information on serving your community with amateur radio.

General Resources

ARRL Amateur Radio Emergency Service: arrl.org/ares

Public service: arrl.org/public-service

Training

ARRL training courses: arrl.org/emergency-communications-training

FEMA National Incident Management System: fema.gov/national-incident-management-system

Red Cross training: redcross.org/take-a-class

SKYWARN training: weather.gov/SKYWARN

Major Amateur Radio Emergency Communications Nets

Hurricane Watch Net: hwn.org

Maritime Mobile Service Net: mmsn.org

Salvation Army (SATERN) Net: qso.com/satern

VoIP SKYWARN/Hurricane Net: voipwx.net

Waterway Net: waterwayradio.net

Served Agencies and Partners

ARRL Served Agency Memoranda of Understanding: arrl.org/served-agencies-and-partners

Above left: Lisa Neuscheler, KC1YL, uses amateur radio to serve her community, as well as for enjoyment.

Hams Help in Many Ways

Sometimes, the ways that hams serve don't have anything to do with communications. We've delivered water to disaster areas and given out blankets at shelters. No matter what we're tasked with, a positive, professional attitude and appearance, as well as the breadth and depth of our training and experience, can go a long way toward making a positive impact and a favorable impression.



Buying a Handheld Radio



The ICOM ID-31A is a dual-band D-STAR handheld that also receives and transmits analog FM.



The Yaesu FT-3DR is a System Fusion handheld that operates analog FM as well.



The Kenwood TH-D72 is an example of a feature-rich analog-only transceiver.

Why Handhelds Are Called HTs

Many people think handheld transceivers are known as "HTs" because "HT" stands for "Handheld Transceiver," but that's actually not the case.

"HT" is an abbreviation referring to Motorola's "Handie Talkie" radios, which had their roots in Motorola's "Walkie Talkies," military transceivers that debuted in 1940 at the beginning of World War II.

Motorola trademarked "Handie Talkie"—along with the abbreviation "HT"— in 1951 and has guarded it jealously ever since, which is why amateur radio publications often refer to handheld radios as "handheld transceivers."

Check the Reviews

For in-depth information about specific models of handheld transceivers, check the *QST* Product Review archive at arrl.org/product-review.

Most amateurs own more than one handheld transceiver. Different radios can have different uses — public service, AM/shortwave, digital protocols, and so on. Plunging prices make it easier to have a handheld for each of your radio interests. Today you can buy a single-band handheld for less than $40, and a dual-band for less than $100. Not all handhelds are created equal, though. Here are several key aspects to consider before making a purchase.

Single Band or Multiband

This seems like a no-brainer. Who wouldn't want a handheld that can be used on more than one band? But multiband capability also means a more expensive radio, so unless money is no object, you need to ask yourself if you really need those extra bands.

The most common multiband combinations are:

- 2 meters and 70 centimeters (146 and 440 MHz)
- 6 meters, 2 meters, and 70 centimeters (52, 146 and 440 MHz)
- 2 meters, 1.25 meters, and 70 centimeters (146, 222 and 440 MHz)

In terms of activity, the most active bands, listed here from most to least active, are:

2 meters 70 centimeters 1.25 meters 6 meters

You'll get plenty of use out of 2 meters, less on 70 centimeters, and much less on 1.25 and 6 meters. With that in mind, it's easy to understand why 2 meters/70 centimeters is the most popular multiband handheld configuration.

The sticking point with 1.25 meters is that it's not a worldwide amateur radio allocation. Only amateurs in the US and a few other countries have access to the band. As a result, transceiver manufacturers are understandably reluctant to make equipment for this limited market. This factor has suppressed activity on 1.25 meters since the beginning.

As for 6 meters, this band is occasionally available (or *open*, in ham radio-speak) for direct communication over hundreds and even thousands of miles — a feat that led to its nickname, "the Magic Band." However, FM on 6 meters just never caught on and manufacturers have had little incentive to market FM products for this band.

This doesn't mean that you should avoid multiband handhelds that offer 6 or 1.25 meters. Just keep your budget and your local resources in mind. Get a copy of the *ARRL Repeater Directory* or download the RFinder smartphone app to see how many 6- or 1.25-meter repeater systems are available in your area — and then check with local hams to determine whether those systems are active. Being listed in the *Repeater Directory* doesn't guarantee that a repeater system is consistently active.

How Much Output Power

The maximum RF output power you're likely to find in a handheld FM transceiver is 5 watts (W). Many radios offer the ability to adjust the output power, typically from 1 to 5 W in steps. At the opposite extreme, you'll find handhelds with a maximum output of only a few hundred milliwatts (mW).

When it comes to effectiveness, you can rarely go wrong buying as much RF output as you can afford. This is especially true for handhelds, because you're often limited to using the so-called rubber duck antennas that are included with the radio.

There are a few downsides to buying maximum RF output, however:

- More power means more money. A 5-watt radio is more expensive than, say, a 1-watt radio.
- Higher output power drains batteries faster.
- Higher output power requires more components inside the radio, so the radio will be physically larger.
- Higher output power often results in more heat being generated during long transmissions. Some 5-watt handhelds can become uncomfortably warm.

Milliwatt output handhelds are inexpensive, but at that level of RF output you need to have a sensitive repeater close by to relay your signal. Without that, these otherwise fine radios can be disappointing.

So long as the transceiver offers the ability to select different RF output levels, the battery drain issue isn't a serious consideration. In most instances, cost is the main factor.

Expanded Reception

This popular handheld feature often adds to the cost of the radio. A bargain handheld may only allow you to receive signals that fall within the transmitting spectrum of the radio. On 2 meters, for instance, that means 144 to 148 MHz in models intended for the US market.

As price increases, reception range begins to expand. It's common to see 2-meter handhelds offering expanded reception above 148 MHz, often as high as 170 MHz. That may give you access to a fair amount of public service and commercial radio activity, including NOAA Weather Radio between 162.400 and 162.550 MHz — a must-have feature for amateurs interested in public service work.

Many police and fire departments have yet to make the jump to digital communications and you're likely to run into their transmissions above 148 MHz, along with a host of other transmissions from railroads to tow truck operators.

Above the high end of the amateur 70-centimeter band (450 MHz), you'll hear more commercial and public service activity, including the Family Radio Service.

All these transmissions use FM modulation. Climb the price ladder higher still and you'll find radios that offer expanded reception on other frequencies as well as other modulation methods. Some handhelds allow you to eavesdrop on AM transmissions from aircraft at 108 to 137 MHz. You'd be astonished at how much aircraft chatter you may hear, regardless of your location.

Some handhelds offer *Wide FM* reception (WFM), which allows you to listen to broadcast stations from 88 to 108 MHz, although not all handhelds include the ability to receive in stereo.

At the very top tier are handhelds that include general-coverage MF/HF receivers. You can use these radios to listen to AM broadcasts, shortwave transmissions, and even HF amateur activity—in addition to expanded VHF/UHF coverage.

The ability to listen to shortwave sounds like a fine feature to have, and it is, but be sure to calibrate your expectations. Performance on the AM broadcast and shortwave bands is often adequate at best. With the small antennas that accompany these radios, you'll only be able to hear big powerhouse stations. Attaching a longer antenna may improve reception, but keep in mind that these receivers are designed to be used with the small antennas that are sold with them. The receiver can easily overload if you couple it to a longer antenna.

The Best of Both Worlds

Analog Advantages

- Less expensive than comparable digital transceivers.
- Features and functions are easier to learn.
- Analog repeater systems are much more common. In fact, of the roughly 23,000 repeaters in existence today, only about 18% are digital.
- Will still provide audio—albeit noisy—even as the signal weakens beyond the point where a digital transceiver could decode it. (A digital radio will just fall silent —a phenomenon known as the *digital cliff*.)

Digital Advantages

- Send text and other information, in addition to your voice.
- Display the call signs of those you are communicating with and use this information for selective calling features.
- Greater audio clarity — 100% noise free.
- Flexible group calling capability.
- Automatic routing through repeater networks and the internet. (With D-STAR networks, for example, a person with a 2-meter handheld transceiver in Orlando, Florida can communicate with a 70-centimeter handheld operated by a person in Olympia, Washington.)



At the low end of the price range you'll find analog-only FM transceivers like these. Beware, that some of the least expensive transceivers have reliability issues. Some also have problems meeting FCC requirements for signal purity.

Analog or Digital

Until relatively recently, all amateur FM transceivers were analog. You pressed the push-to-talk button, began speaking, and your speech was converted to electrical signals and used to shift the transmitting frequency of the radio. When you received, the process occurred in reverse.

But the early 2000s saw the birth of *D-STAR*, a digital communications protocol developed by the Japan Amateur Radio League (JARL). A D-STAR radio transforms the sound of your voice into bits of data, which are then transmitted and decoded on the receiving end.

A D-STAR transceiver can communicate more than just your voice. The data stream transporting your voice is also carrying your call sign, which appears on the display of the receiving radio, along with the call sign of the D-STAR repeater you may be using. There's a second data stream that can carry more information such as your location (as latitude and longitude coordinates supplied by an attached GPS receiver). Most commonly used D-STAR transceivers are designed for operation on the 2-meter or 70-centimeter bands, and are made by Icom or Kenwood.

Another contender in the digital arena is Yaesu with their *System Fusion* transceivers, which use an entirely different approach to digital communication, and are not compatible with D-STAR.

Another popular digital transceiver is *DMR* — Digital Mobile Radio. DMR began as a system for commercial use, but amateurs adapted it to their purposes and it's now the second-most-popular amateur digital communications mode, behind D-STAR. However, DMR is incompatible with both D-STAR and System Fusion.

Despite the gradually increasing popularity of digital transceivers, analog-only FM radios still comprise the vast majority of amateur radio FM transceivers. Digital radios tend to be more complex than analog transceivers, and each digital system has its own peculiarities. The functional differences between analog and digital hardware are so great, books have been written for the owners of digital transceivers. In the ARRL online store (arrl.org/shop), for example, you'll find books such as the *Nifty E-Z Guide to D-STAR Operation*.

It's worth noting that some digital transceivers are capable of operating as analog FM rigs as well, so you get two modes of communication in the same package.

Happy Shopping

These guidelines can help you set your priorities and standards as you start shopping around. There's a handheld to fit every amateur radio pursuit. Before long, you may find yourself with a collection!

FM Handheld Transceiver Features

Feature	Must Have	Good to Have	Limited Use
5 Watts Output	X		
CTCSS	X		
DTMF Keypad		X	
Illuminated Keypad		X	
Extended Receive Frequencies			X
Wide/Narrow FM		X	
GPS/APRS			X
Time-Out Timer			X
Tone Burst		X	
Switchable Attenuator		X	



The Collegiate Amateur Radio Initiative

If you're in a college amateur radio club, or are wondering what it takes to start one, the College Amateur Radio Initiative (CARI) offers resources to help college hams start, manage, and promote clubs and activities.



Launched in 2016 as an ARRL program, CARI is based at facebook.com/groups/ARRLCARI, where a growing community of more than 900 students, alumni, faculty members, and other interested hams discuss everything from advice on equipment and operating techniques, to perspective on issues unique to college clubs. The Facebook group also maintains a collection of files for download, including a master list of college radio clubs.

CARI hosts exhibit booths and forums at popular ham gatherings like HamCation in Orlando, Florida and Hamvention in Xenia, Ohio. Forum topics center on challenges that college clubs face, like funding the club and its station, finding and maintaining a location for the station, and recruiting and retaining members. Forum speakers have also extolled the benefits of being a college ham — namely the leg up it can give you when applying for jobs, in terms of the range of practical experience the hobby affords, and in terms of the professional network of hams that you gain as you become active in amateur radio. CARI often organizes a dinner meetup at ham conventions, to give college hams an opportunity to build that network and make friends.

In 2018, the Collegiate QSO Party, an on-air event just for college hams, made its debut. Run by the Gator Amateur Radio Club (GARC) at the University of Florida, W4DFU, this event is a way for college clubs to engage with each other on the air, in the spirit of amateur radio contesting — and the spirit of CARI. The most recent running of the Collegiate QSO Party was in September 2019. Information can be found at gatorradio.org/collegiate.html.

If you're looking for ways to make your college club more vibrant, whether you're a current student or an alumnus, check out what CARI has to offer.

Learn Even More With the *On the Air* Podcast and Blog

Get more info that helps you engage with ham radio the way you want to.

Podcast

Every month, the editors of *On the Air* will release a companion podcast that extends the features, projects, and experiences presented in the magazine. Hosted by *On the Air* Editorial Director Becky Schoenfeld, W1BXY, the 15-minute podcast takes a deeper dive into an issue of *On the Air* to offer additional resources, techniques, and hints to help you get the most from the magazine's content.

For example, if you want to learn how to make the hands-free jig pictured in this issue's project build article, "Extend Your Handheld's Range with a Simple Ground-Plane Antenna" — or if you're not sure what a "hands-free jig" is in the first place — the first episode of the *On the Air* podcast will tell you everything you need to know. We'll also talk with an experienced public service ham who'll offer more insight into this issue's article, "A Look at Public Service."

You can subscribe to the *On the Air* podcast in Apple iTunes (podcasts.apple.com) or on Stitcher (app.stitcher.com).

Blog

We're also launching an *On the Air* blog to enhance your experience of the ham radio community. Updated monthly, the *On the Air* blog will feature curated stories from the communicators and makers who, like you, are the driving force of today's ham radio hobby and the Amateur Radio Service.

Amateur radio is an adventure, and the aim of the *On the Air* blog is to encourage more hams to try new things. Like most blogs, the intent is to have a conversation — we want you to talk to us! The *On the Air* blog welcomes contributions from both new licensees and more-experienced hams. You can share your stories and experiences by emailing ota-blog@arrl.org.

To read the *On the Air* blog, visit arrl.org/ota-blog.

West Mountain RADIO

Three great ideas for your new ham radio station!

1



Power your station the safe & easy way with a RIGrunner!

2



Hear the weak ones with an amplified PWRspkr

3



Connect to the Winlink system for radio email!

Check out the link below for tips on DC Power, Winlink Email and MORE!

westmountainradio.com/OTA120

262-522-6503 EXT 35
sales@westmountainradio.com

Hints & Hacks

Share your hints (or hacks) with fellow hams by sending them to ota@arrl.org or *On the Air*, ARRL, 225 Main St., Newington, CT 06111.

HACK

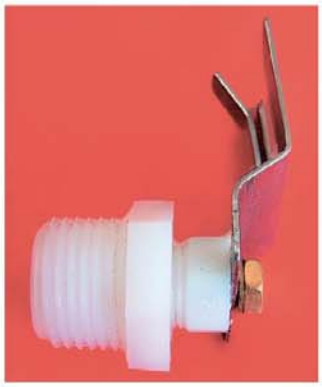
Car Mic Holder — No Drilling Required

Here's a way to install a microphone holder in your car without drilling holes. I start with a 1/2-to-1/4-inch nylon bushing. Screwed into the bushing is a ¼-inch nylon hex-head plug. These parts are available from many sources, including Ace Hardware (see links below).

Drill a hole in the head of the plug to fit a small brass screw (your choice) that will hold the mic clip to the plug. Now drill a hole in the bottom-center of the mic clip to pass the screw. I use this instead of using the two existing holes; it keeps the clip centered. Finally, fasten the clip to the plug/bushing assembly.

The 1/2-inch bushing fits in a car lighter socket. Twist it a little to tighten it.

David Quam, WØCIA



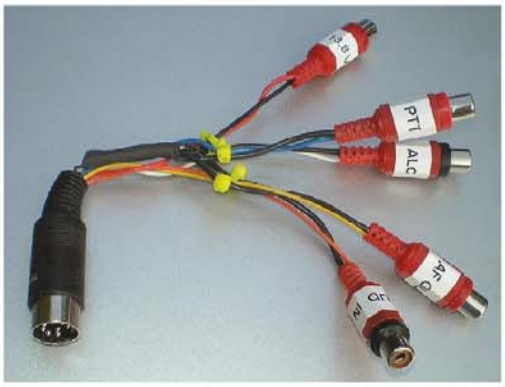


A side view of the lighter-plug mic holder.

WØCIA's lighter-plug mic holder at work.

Find the bushing:
acehardware.com/departments/plumbing/pipe-fittings/plastic-fittings/48737

Find the nylon hex-head plug:
acehardware.com/departments/plumbing/pipe-fittings/plastic-fittings/48732



A simple homemade adapter for the accessory DIN socket found on most transceivers.

HACK

Don't Rewire DIN Jacks; Adapt!

Many transceivers have multipin DIN jacks for accessory functions, such as using the radio with an external modem for digital communications. It can be a hassle, however, to wire one plug for a given application, only to have to rewire it when your needs change.

I came up with an "octopus" adapter that makes the process more versatile. Wire pairs from several female RCA connectors are soldered to the appropriate pins on a male DIN connector, with all the black wires soldered together to the ground pin. Each RCA connector is labeled, for example, ALC, PTT, 13.8 V, audio in, audio out. If only a couple of them are needed, the others dangle harmlessly, but remain available for future use.

Carl Solomon, W5SU

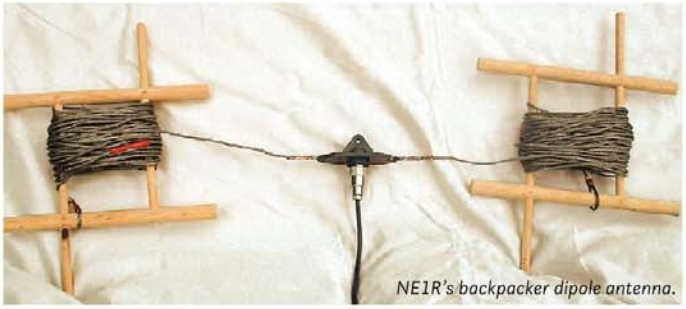
It can be a hassle to wire one plug for a given application, only to have to rewire it when your needs change.

Experiment before leaving home to determine the proper length of the antenna for each desired band.

HACK

Make a Portable HF Antenna

Whether you're backpacking, vacationing, or assembling a "go kit" for emergency service, it's a good idea to have an easily transportable antenna for the HF bands. This one is a half-wave dipole, and the length is adjustable so it can be used on almost any frequency.



NE1R's backpacker dipole antenna.

The key to this adjustability is the use of bare, stranded wire and open reels made from wooden dowels. When wire is accumulated on the reels, that wire no longer acts as part of the length of the antenna. For example, if the antenna is made long enough for the 40-meter band, but about half of it is wound onto the reels, the antenna will resonate at 20 meters instead. Later, the wire can be unrolled from the reels until the antenna is long enough to be used on 40 meters — or shortened to work on 15 meters.

Each reel consists of two 9-inch long 5/8-inch diameter hardwood dowels joined together, about 4 inches apart, by two 9-inch long 3/8-inch dowels about 4 inches apart. The 3/8-inch dowels pass through the larger dowels and extend outward to serve as crank handles for rolling the wire on or off of the reels. This speeds up the work of laying out the antenna, and avoids kinking of the antenna wire. The feed point is a center insulator.

Experiment before leaving home to determine the proper length of the antenna for each desired band. Once you know the lengths that work best, the wires on each side can be marked with paint or tape to speed adjustments.

Proximity to the ground will affect the resonant frequency. So, if you're going to install the antenna 10 feet off the ground when you're out in the field, experiments at home should simulate that height.

To deploy the antenna, string the support lines over tree branches or some other supports. Unroll the wire from each reel to the desired lengths, which should be approximately equal. Gather the remaining wire in a bunch on each spool, and tie it with one end of the support line. Then raise the antenna by pulling the support lines.

The version shown in the photo contains approximately 100 feet of bare wire on both reels and resonates from approximately 5 MHz to 54 MHz. The antenna, 30 feet of coax, and some nylon support line weighs less than 5 pounds. The weight of the assembly could be reduced by using thinner antenna wire.

Thomas Carrigan, NE1R

HINT

Caring for Soldering Iron Tips

To maximize the lifespan of an iron-plated tip, wipe it on the sponge *before* soldering — never after. When shutting down the iron, clean the tip on the sponge, shut off the power, then apply solder to the tip and let it cool down. Never shut down an iron with an iron-plated tip dry; always wet it with solder.

Dennis R. Murphy, KØGRM



US Amateur Radio Bands

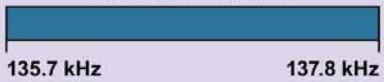
Operator license classes: **E** = Amateur Extra **A** = Advanced **G** = General **T** = Technician **N** = Novice
CW operation is permitted throughout all amateur bands. Except as noted, all frequencies are in megahertz (MHz).

= RTTY, data, phone, image = USB phone, RTTY, data and CW = RTTY and data = phone and image
= SSB phone = CW only

LF – Low Frequency band

2200 Meters (135 kHz) E,A,G

1 W EIRP maximum



MF – Medium Frequency bands

630 Meters (472 kHz) E,A,G

5 W EIRP max, except in Alaska within 496 miles of Russia where the limit is **1 W EIRP**



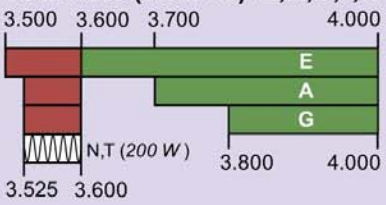
160 Meters (1.8 MHz) E,A,G



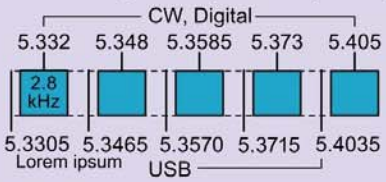
Amateurs wishing to operate on **2200 or 630 meters** must first register with the Utilities Technology Council online at **https://utc.org/plc-database-amateur-notification-process/.** You need only register once for each band.

HF – High Frequency bands

80 Meters (3.5 MHz) E,A,G,T,N

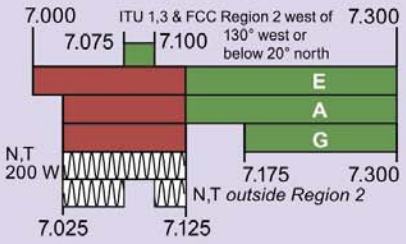


60 Meters (5.3 MHz) E, A, G (100 W)



Gen, Adv, and Extra licensees may operate on a secondary basis with a maximum ERP of 100 W maximum.

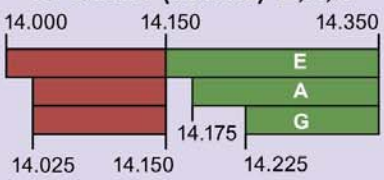
40 Meters (7 MHz) E,A,G,T,N



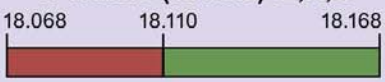
30 Meters (10.1 MHz) E,A,G



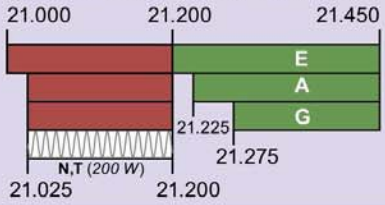
20 Meters (14 MHz) E,A,G



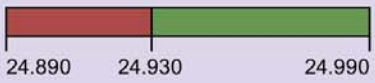
17 Meters (18 MHz) E,A,G



15 Meters (21 MHz) E,A,G,T,N



12 Meters (24 MHz) E,A,G

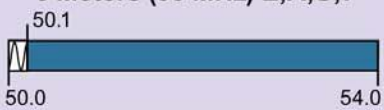


10 Meters (28 MHz) E,A,G,T,N

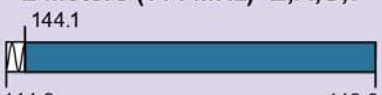


VHF – Very High Frequency bands

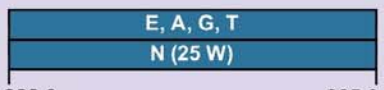
6 Meters (50 MHz) E,A,G,T



2 Meters (144 MHz) E,A,G,T

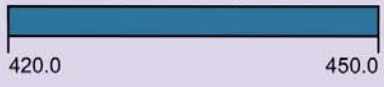


1.25 Meters (222 MHz) E,A,G,T,N

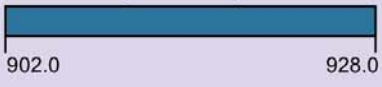


UHF – Ultra High Frequency bands

70 cm (420 MHz) E,A,G,T



33 cm (902 MHz) E,A,G,T



23 cm (1240 MHz) E,A,G,T,N



SHF&EHF – Super and Extremely High Frequency bands

All licensees except Novices are authorized all modes on the following frequencies:

2300-2310 MHz	3300-3500 MHz	10.0-10.5 GHz	47.0-47.2 GHz	122.25-123.0 GHz	241-250 GHz
2390-2450 MHz	5650-5925 MHz	24.0-24.25 GHz	76.0-81.0 GHz	134-141 GHz	All above 275 GHz

See www.arrl.org/band-plan for detailed band plans.

Copyright © ARRL 2019
OTAbands **rev. 11/8/2019**

The Next Steps

If you're thinking about upgrading your amateur radio privileges, try your hand at a couple of questions you may encounter on your next exam. These questions and answers appear in the current official question pools from the National Conference of Volunteer Examiner Coordinators.

General Class

Question G2B02

What is the first thing you should do if you are communicating with another amateur station and hear a station in distress break in?

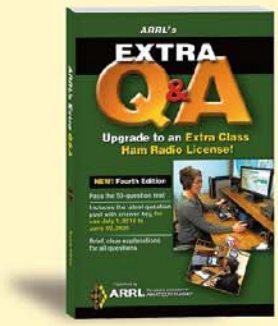
A. Continue your communication because you were on the frequency first

B. Acknowledge the station in distress and determine what assistance is needed

C. Change to a different frequency

D. Immediately cease all transmissions

The correct answer is B, although no doubt there are some hams who may think A is appropriate! Changing frequency or ceasing all transmissions isn't particularly helpful either. You are a federally licensed communicator and it is your job to acknowledge the station, ask where they are located and what assistance he or she needs.



Amateur Extra

Question E7F17

What do the letters I and Q in I/Q Modulation represent?

A. Inactive and Quiescent

B. Instantaneous and Quasi-stable

C. Instantaneous and Quenched

D. In-phase and Quadrature

The correct answer is D. So-called I/Q Modulation is the bedrock of modern software-defined radios (SDRs). Thanks to I/Q Modulation, an SDR can demodulate any signal and extract voices, data, images and much more.

For Further Study

For the entire General or Amateur Extra question pools, along with simple answers like the ones shown here, pick up a copy of ARRL's *General Q&A* or *Extra Q&A*. For in-depth explanations of the answers, get a copy of *The ARRL General Class License Manual* or *Extra Class License Manual*. These resources are available from the ARRL online store (arrl.org/shop), Amazon, or your favorite ham radio dealer.

As you're studying, take free practice exams at arrl.org/exam-practice.

Level Up!

Whether you're looking to advance your emergency communications skills or get more enjoyment from your ham radio hobby, *ARRL License Manuals* are a great place to start.

ARRL License Manuals provide:

- All the exam questions with answer key so there are no surprises on exam day
- An expert approach to studying that breaks down difficult concepts
- Detailed answers that make studying more efficient
- A complete glossary for quick reference of new terms

Level 2 – General Class
Enjoy the entire range of operating modes and extensive HF privileges.
The ARRL General Class License Manual
Only $32.95

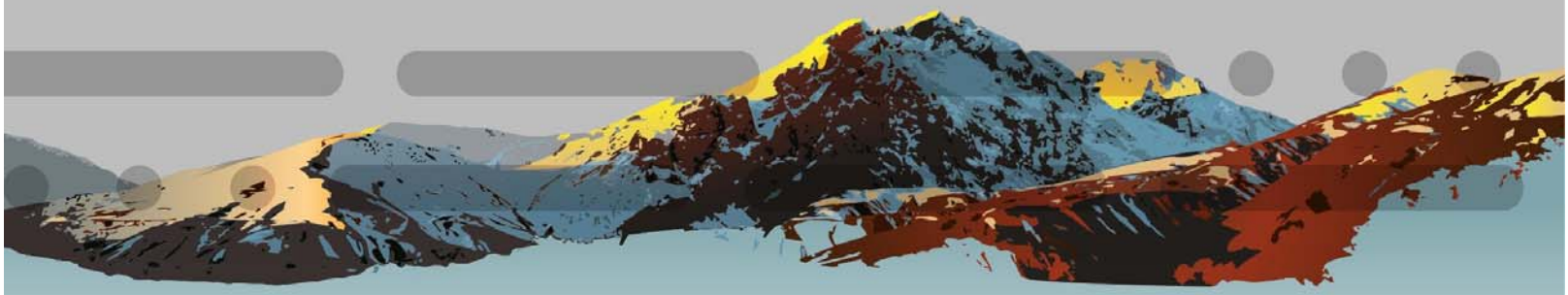
Level 3 – Amateur Extra
Your ticket to every privilege granted to amateur radio operators.
The ARRL Extra Class License Manual
Only $32.95

www.arrl.org/shop



Enjoy the Journey

Amateur radio is such a vast collection of sub-hobbies (electronics, contesting, and building, to name a few) that it's easy to get overwhelmed or distracted. Choosing a path and setting goals can help you hit the heights.



73 LAST WORD

Stuart Thomas, KB1HQS

I combine my passion for radio with hiking by participating in the Summits on the Air (SOTA, www.sota.org.uk) program. This activity involves hiking summits throughout the world with your radio, making on-air contacts and collecting points for completed activations. It's a competition against yourself — I need to complete personal goals to be proficient in portable radio operation on mountain summits while dealing with a variety of elevations and weather conditions. Evaluating my past radio accomplishments and setting future goals is a way of staying on track in this pursuit.

When I started in SOTA, my first goal was to complete a summit. At that time I was using a handheld, and I knew the stock antenna and 5 watts wouldn't work very well. I found a VHF Yagi antenna project using piano wire and plastic tubing, and scrounged my parts bin for the parts. Adding coaxial cable gave me a lightweight high-gain antenna for less than $5. I climbed a SOTA summit in northwest Maine and made contacts. It wasn't a durable solution — the antenna fell apart after a few activations — but it got the job done, and more importantly, I had fun.

Wanting to reach farther than VHF line of sight, I sold the HF radio I had at the time, and purchased a lightweight Elecraft KX3 that consumed less power and was easier to pack. After several 10-mile trips with high elevation gains, I realized I needed an even lighter radio. However, the major roadblock was CW (Morse code). Super-lightweight QRP (low power) radios predominantly are CW rigs, and while I had learned CW for my General license exam, I hadn't used it since.

My next goal was to become proficient in CW, but it didn't come easily. I spent countless hours listening to ARRL Code Practice Files, decoding CW. Becoming a better CW operator is still a goal I am working on.

My final goal is reaching "SOTA Goat" status. This status (which comes with a trophy) is achieved after completing 1,000 points in SOTA activations, and is a well-deserved recognition for those who put in the effort to operate radio under less-than-ideal conditions. I've accumulated more than 500 points and still have a long way to go. On the way to that goal, I keep in mind something my friend and mentor, Steve Galchutt, WGØAT (a two-time SOTA Goat himself) says: "Enjoy the radio journey."

While doing portable radio from summits may not appeal to you, the process is the same for whatever you might be interested in. Set goals to help keep the hobby interesting and prevent yourself from becoming overwhelmed. Use amateur radio in the way that works best for you. Remember, there are many different paths to the summit, so select one and enjoy the journey!

"Use amateur radio in the way that works best for you. Remember, there are many different paths to the summit."



Stuart Thomas, KB1HQS, lives in the Washington, DC metro area and enjoys hiking when he's not on the radio.

ALINCO®

Quality. Style. Performance!

ALINCO.com



440MHz FM MOBILE TRANSCEIVER
DR-435TMkⅢ

220MHz FM MOBILE TRANSCEIVER
DR-235TMkⅢ

144MHz FM MOBILE TRANSCEIVER
DR-135TMkⅢ

50MHz FM MOBILE TRANSCEIVER
DR-06T

29MHz FM MOBILE TRANSCEIVER
DR-03T





144 / 430MHz FM DUAL BAND HANDHELD TRANSCEIVER
DJ-500T/DJ-VX50HT



* With optional EDS-17 separate cable.

HF 100W SSB/CW/FM/AM
DESK-TOP TRANSCEIVER
DX-SR8T



SSB/AM/FM/CW and I/Q
LW/MW/SW 150KHz to 30MHz
DESK-TOP RECEIVER
DX-R8T

With a wide selection of easy-to-operate, multi-band desktop, handheld and mobile radios, Alinco delivers maximum value for your amateur radio enjoyment.



VHF/UHF DUAL BAND, DUAL MODE
DMR TRANSCEIVER
DJ-MD5T/TGP
Part 90 certified LAND MOBILE



144/440MHz
FM FULL-DUPLEX MOBILE TRANSCEIVER
DR-735T



30A SWITCHING POWER SUPPLY
DM-330MVT



30A SWITCHING POWER SUPPLY
DM-430T



30A SWITCHING POWER SUPPLY
DM-30TR



144/440/1200MHz
FM FULL-DUPLEX
HANDHELD TRANSCEIVER
DJ-G7T

222/902 MHz FM
FULL-DUPLEX
HANDHELD TRANSCEIVER
DJ-G29T

REMTronix, Inc.
17508 Murphy Parkway, Lathrop, CA 95330
Ph: (209) 900-1296 Fax: (209) 624-3153 Website: http://www.remtronix.com
Email: alinco@remtronix.com Service: alincosupport@remtronix.com

Distributed in North America by REMTRONIX

Products intended for properly licensed operators. Required products are FCC part 15/IC certified. Specification subject to change without notice or obligation. ALL warranty claims and requests for repair/technical assistance for Alinco products should be sent to REMTronix regardless of contact information found on the warranty certificate packed with the product.

Quicksilver Radio

Quality, Service & Value!

DC Power Cables



Meters



Crimpers & Tools



Soldering Equipment



Power Connectors



Antennas



Go-Kits & Supplies



Coax Cables



Connectors & Adapters



Outdoor Antenna Supplies



Power Supplies & Batteries



Audio



The Best in Ham Radio Products from Quicksilver Radio. Safe and Secure Ordering at:

www.qsradio.com

Follow us on Facebook