TAPR PSR #144 Winter 2020

President's Corner

By Steve Bible, N7HPR

HamSCI, the Ham Radio Science Citizen Investigation, is a platform for the publicity and promotion of projects that are consistent with the following objectives:

- Advance scientific research and understanding through amateur radio activities.
- Encourage the development of new technologies to support this research.
- Provide educational opportunities for the amateur community and the general public.

HamSCI serves as a means for fostering collaborations between professional researchers and amateur radio operators. It assists in developing and maintaining standards and agreements between all people and organizations involved. HamSCI is not an operations or funding program, nor is it a supervisory organization.

HamSCI was started by ham-scientists, who study upper atmospheric and space physics. These scientists recognized that projects such as the Reverse Beacon Network, WSPRNet, PSKReporter, DX Cluster, ClubLog, and more are generating big data sets that could provide useful observations of the Earth's ionosphere and related systems. Because of this, HamSCI's initial focus is on these fields of research.

Sounds like something TAPR should be involved with. Well, we are.

TAPR has a hand in the Personal Space Weather Station (PSWS) project that ultimately aims to create a small, multi-instrument system that can make ground-based measurements of the space environment. The observations from this project will not only be useful to the owner of the system, but also aggregated into a central database for space science and space weather research purposes.

Initial work focuses on the development of a scientific-grade HF radio receiver, as well as the necessary software and network infrastructure. TAPR's is working on various aspects of the project:

- Scotty Cowling, WA2DFI – TangerineSDR hardware design and cheerleading.
- John Ackermann, N8UR – GPS and timing
- Dave Witten, KD0EAG – Magnetometer board

TAPR is a community that provides leadership and resources to radio amateurs for the purpose of advancing the radio art.

- Tom McDermott, NE5G – RF board, design documentation and proofreading
- Dave Larsen, KV0S – TangerineSDR webmastering, weekly Teamspeak session moderating and programming
- Bill Engelke, AB4EJ – Building the web-based agitator
- Nathaniel Frissell, W2NAF – Science team and HamSCI meeting leader

TAPR peeps will be attending the HanSCI Workshop at the University of Scranton, March 20-21, which you can read about on page 3.

Hope you can join us there!

73,

Steve Bible, N7HPR, President TAPR

###

NOTICE

Membership-only access of *PSR* will begin with the next issue of the newsletter. In other words, only TAPR members will be able to view the newsletter when it is published. (You can find a membership application on page 31 or visit our membership webpage.)

Past issues of *PSR* will still be available on TAPR's website and membership-only issues will appear there when they are no longer current.

###

TAPR.ORG – The Next Generation

By John Ackermann, N8UR

We're pleased to introduce you to the new TAPR.ORG web site and on-line store. We've completely rebuilt the site using a modern content management system and e-commerce platform, hosted at a well-respected provider that provides automatic security updates.

We'll be updating the front page with new posts regularly, so plan to stop by even if you're not shopping!

There's a lot more content to come as we continue to migrate content from the old site to the new, but for now the on-line store is fully functional and loaded with all current TAPR products. We have removed some very old products from the store; if you need one of those, please contact us and we'll let you know if we still have it available.

We're also integrating our membership management into the new system. All new memberships and renewals are available as products within the store, and there will be special members-only features on the site.

Finally, we'll be changing the way the *Packet Status Register* (*PSR*) is distributed and will be discontinuing the current mailing lists. Before the next *PSR* is published, we'll send a note to those lists explaining the changes, and how to access *PSR* going forward.

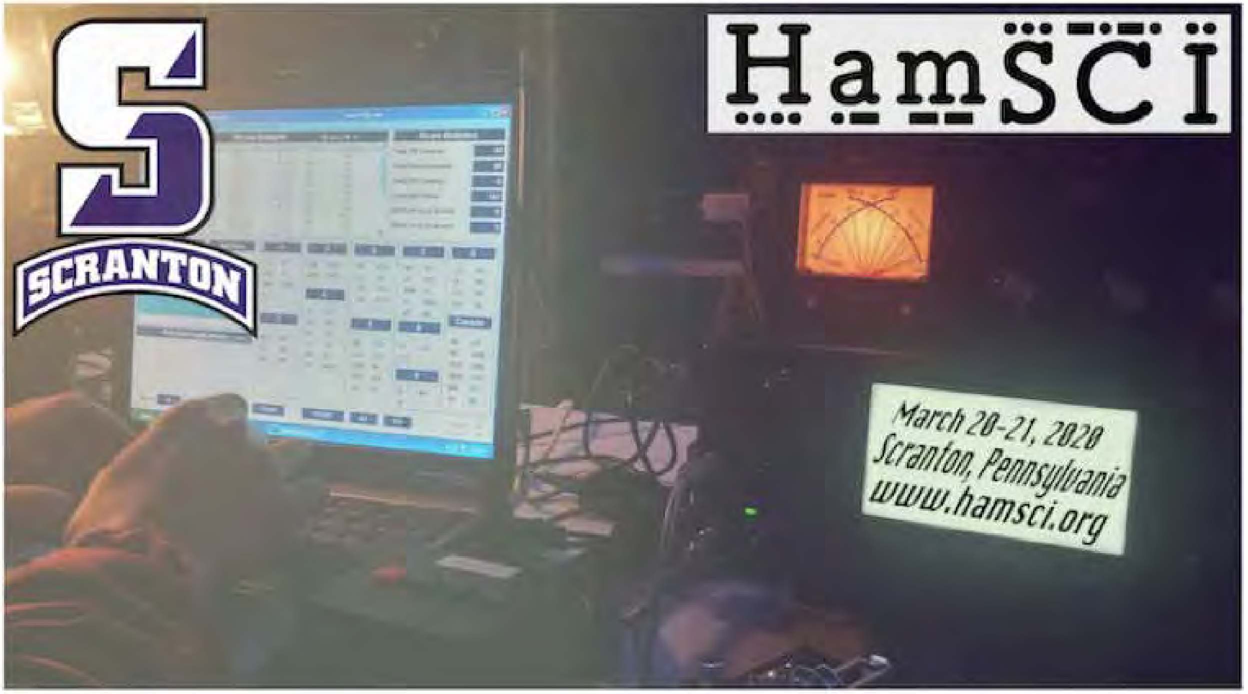
Of course, there may be a few glitches as we get the new site rolling. If you have any problems, or suggestions, please let us know!

###

TAPR Members to Attend 2020 HamSCI Workshop

March 20-21, 2020, University of Scranton

By Nathaniel A. Frissell, W2NAF



TAPR members will attend the 3rd Annual Ham Radio Science Citizen Investigation (HamSCI) workshop March 20-21, 2020 at the University of Scranton in Scranton, Pennsylvania as part of a team meeting for the HamSCI Personal Space Weather Station project. HamSCI is a collective of hams and professional space science researchers working together for the mutual benefit of the ham radio hobby and the advancement of the understanding of ionospheric and space science.

Starting January 1, 2020, TAPR formally became a participant in the National Science Foundation (NSF)-funded project to develop a Personal Space Weather Station (PSWS) in collaboration with HamSCI scientists. TAPR's main role is the development of a new software defined radio (SDR) receiver with specifications that meet the needs of scientists to remotely sense the ionosphere. This collaboration led directly to TAPR's latest project, the TangerineSDR. Additionally, TAPR members are contributing to the development of PSWS ground magnetometer, PSWS software and databases and other critical PSWS systems.

At the HamSCI workshop, all aspects of the PSWS will be discussed. Lead Principal Investigator (PI) from the University of Scranton, Dr. Nathaniel Frissell, W2NAF, will present the overarching PSWS goals and objectives, as well as provide an overall status report on the project. TangerineSDR chief engineer, Scotty Cowling, WA2DFI, will present the latest designs and status for the TangerineSDR data engine (DE). Tom McDermott, N5EG, will discuss his design and progress for the RF board modules, and John Ackermann, N8UR, will present on the precision timing modules. David Witten, KD0EAG, has been leading the development of the ground magnetometer (GMAG) hardware, and plans to provide and update and hardware demonstration, along with GMAG PI from New Jersey Institute of Technology Dr. Hyomin Kim, KC2MCR, and beta-tester Frankie Bonte, KE8GTT. Bill Engelke, AB4EJ, of the University of Alabama is a lead of the control software and database team, and will provide updates on these systems. Finally, the Case Western Reserve University team led by Kristina Collins, KD8OXT, Dr. David Kazdan, AD8Y, and John Gibbons, N8OBJ will discuss the low cost version of the PSWS. And Dr. Phil Erickson, W1PJE, of MIT Haystack Observatory will present methods of ionospheric remote sensing using PSWS capabilities, including FT8 based techniques and signals received from WWV.

In addition to serving as a team meeting for the PSWS project, the 2020 HamSCI workshop also seeks to strengthen ties between the HamSCI and auroral science communities with the overarching meeting theme “The Auroral Connection.”

Saturday morning will feature tutorial talks on optical aurora and citizen science, natural radio emissions from the aurora and using the auroral mode propagation as a ham radio operator. These talks will be given by NASA Scientist and Aurorasaurus lead and founder, Dr. Elizabeth MacDonald, Dartmouth radio physicist Dr. Jim LaBelle, and ham radio operator David Hallidy, K2DH, respectively.

The Friday night banquet will feature, Tim Duffy, K3LR, the world-famous contester and COO and general manager of DX Engineering. Contributed talks, demos, and posters will also be given by members of the ham radio and science communities, as well as the general public. To learn more about the 2020 HamSCI workshop, submit an abstract, or register for the meeting, visit http://hamsci.org/hamsci2020.

###

On the Air with YT7MPB

Miroslav ‘Misko’ Skoric, YT7MPB, has recently started listening for pactor contacts at 20m, 40m, and 80m bands. If anybody can hear YT7MPB-8 node (based on LinBPQ software) calling CQPACTOR or his forwarding partners, new connects are welcomed. As well, possible forwarding over pactor 1-4 and/or robust packet. YT7MPB-8 is usually active from 1330 UTC to 1730 UTC. Due to heavy QRN in the local area and not-so-perfect antennas, without any automatic tuning for direction and SWR, activity is infrequent for now.

From February 3 to 20, Misko YT7MPB will visit India. If a reciprocal license is granted on time, possible VHF packet, APRS experiments will be performed.

###

Donate to TAPR

TAPR is now participating in the AmazonSmile program!

When you shop using the AmazonSmile program, Amazon makes a donation to TAPR equal to 0.5% of the price of your eligible AmazonSmile purchases.

AmazonSmile is the same Amazon you know. Same products, same prices, same service.

Bookmark the TAPR AmazonSmile Program link:

https://smile.amazon.com/ch/86-0455870

That link takes you to a special login portal where you enter your normal Amazon credentials and get redirected at the same Amazon home page except there will now be a notice that you are supporting TAPR.

Other ways to donate to TAPR:

http://www.tapr.org/tapr_donate.html

###

DCC Wrap-Up

By Stana Horzepa, WA1LOU

The 2019 ARRL-TAPR Digital Communications Conference (DCC) is history, but you can read the published DCC papers (listed below) on the TAPR website under the Library > Digital Communications Conference Papers menu.

DCC Papers

PSAT2 DTMF Experiment APRStt – Touchtone® Digital Communications Using any Radio for Data Exchange by Bob Bruninga, WB4APR

Extending D-STAR with Codec 2 by Antony Chazapis

IPV6 for Amateur Radio by Daniel Estévez, EA4GPZ/MØHXM

Synchronization in FT8 by Mike Hasselbeck, WB2FKO

WSPR in an educational Project by Anthony Le Cren, F4GOH

Portable Audio Frequency-Shift Keying Sensors using a Hamshield mini by Nolan Pearce, KE8JCT by Stephen S. Hamilton, KJ5HY, and Kate J Duncan, KB2ZOO

An FPGA Learning Experience: SPI Interface to Max10 FPGA by Gregory Raven, KF5N

Modulation – Demodulation Software Radio by Alex Schwarz, VE7DXW

How to Kill Packet-Radio & APRS? Come to Serbia! (Part 2) by Miroslav “Misko” Skoric, YT7MPB

GPS Watch Technology by Darryl Smith, VK2TDS

DCC Prize Winners

As usual, a wide array of prizes were awarded to DCC attendees at the Saturday evening banquet. The prizes went to the following lucky winners:

WA2DFI photo

Kenwood TH-D74: Kathy, WB0UDN

Icom ID51A Plus 2: Max Yarter

MFJ-1270X - TNC-X Packet Controller: Brian, N8WRL

MFJ-1270DG X-Digi: Brian, N8WRL

Rowetel.com SM1000 FreeDV Adaptor: Al, WA1VHD

ARRL gift certificates: George, K9TRV, Jason, KC5HWB, John, WA8TON, Jonathon, KC3EFX, Mike, KG4DSG, Richard, K3PLR

DX Engineering gift certificate: John, W9DDD

Great Scott Gadgets GreatFET One: Greg, KF5N

Ham Radio Deluxe software CD: Bob, AC8YV

HRO gift certificates: Corey, KB9JHU, Matt, WS8U

TAPR gift certificates: Brannon, KF5WVW, Dan, AD0CQ, Garrett, KD2SAK, Mark, N2OJO, Roland, W9HPX

TAPR GPS Kit (1995): Chris, KF7TUP

West Mountain Radio certificate: Dave, KD0EAG

###

DCC Photos by K9TRV & WA2DFI
Top: N7HPR, K9TRV, N8WRL, WB0UDN, N7HPR, K0PFX
Middle: WB9QZB, K3PLR, AC8ES
Bottom: KA9Q, KB9JHU, AC8YV, W9DDD, WA2DFI, KF7TUP, Max Yarter, N7HPR

2020 ARRL / TAPR Digital Communications Conference

Make your reservations now for three days of learning and enjoyment at the Charlotte Airport Hotel. The Digital Communications Conference schedule includes technical and introductory forums, demonstrations, a Saturday evening banquet and an in-depth Sunday seminar. This conference is for everyone with an interest in digital communications— beginner to expert.

September 11-13
Charlotte, North Carolina

Call Tucson Amateur Packet Radio at: **972-413-8277**, or go online to **www.tapr.org/dcc**

Charlotte Airport Hotel

AX.25 + FEC = FX.25

By John Langner, WB2OSZ

What can you do if your radio signal isn't quite strong enough to get through reliably? Move to higher ground? Get a better antenna? More power? Send data very very slowly with narrow bandwidth?

Sometimes those are not options. Another way to improve communication reliability is to add redundant information so the message will still get through even if parts of it are missing.

In the data communications world, adding additional information, so the receiving end can fix up errors, is known as Forward Error Correction (FEC). This is very common. It is used in all sorts of radio communication, QR codes, DSL, and disk drives. It is even used with CD's and DVD's to work around errors caused by scratches.

AX.25

The AX.25 frame, used by APRS and Amateur Packet Radio, is not very tolerant of low quality radio links. A 16 bit "Frame Check Sequence" (FCS) is computed from the earlier parts. The receiving end recalculates the FCS and discards the frame if there is a mismatch.

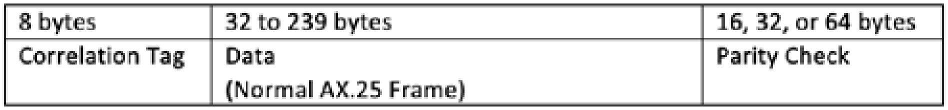
"Flag" pattern	Addresses	Control	Information	Frame Check Sequence	"Flag" pattern

All it takes is a single bad bit to ruin the entire frame. Traditional connected mode packet has automatic acknowledgment of received frames and requests to resend any that are missing. APRS does not use this feature so the information is just gone and nobody knows.

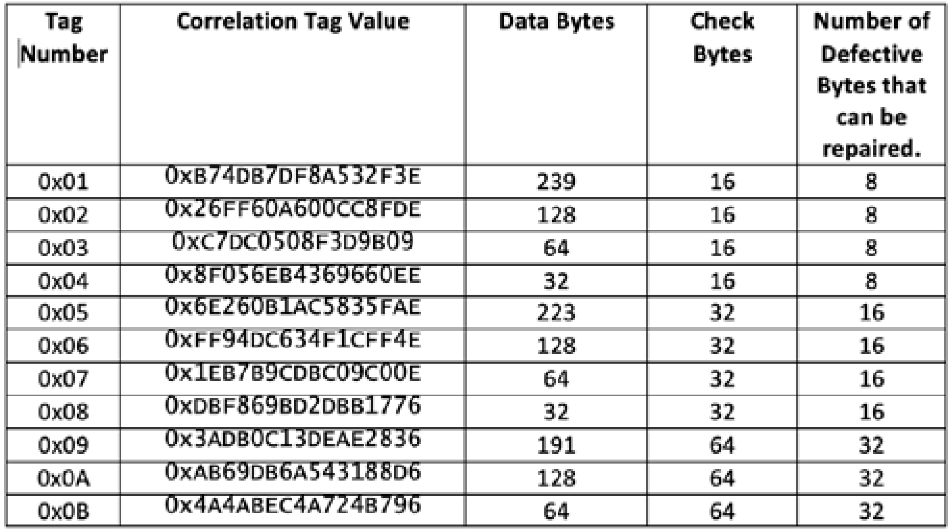
FX.25

Back around 2006, the Stensat Group came up with a clever way to add Forward Error Correction to AX.25 while maintaining complete backward compatibility with existing equipment. A transmission starts with carefully chosen 64 bit patterns to identify the format of the data to follow.

Depending on the Correlation Tag, there are certain numbers of bytes for the "data" and "check" parts. The Reed-Solomon algorithm is used to fix any errors. The number of bytes that can be repaired is one half the number of check bytes.



8 bytes	32 to 239 bytes	16, 32, or 64 bytes
Correlation Tag	Data (Normal AX.25 Frame)	Parity Check



Tag Number	Correlation Tag Value	Data Bytes	Check Bytes	Number of Defective Bytes that can be repaired.
0x01	0xB74DB7DF8A532F3E	239	16	8
0x02	0x26FF60A600CC8FDE	128	16	8
0x03	0xC7DC0508F3D9B09	64	16	8
0x04	0x8F056EB4369660EE	32	16	8
0x05	0x6E260B1AC5835FAE	223	32	16
0x06	0xFF94DC634F1CFF4E	128	32	16
0x07	0x1EB7B9CDBC09C00E	64	32	16
0x08	0xDBF869BD2DBB1776	32	32	16
0x09	0x3ADB0C13DEAE2836	191	64	32
0x0A	0xAB69DB6A543188D6	128	64	32
0x0B	0x4A4ABEC4A724B796	64	64	32

The sender can choose an appropriate correlation tag depending on amount of space required for the AX.25 frame and the desired strength of error correction. The receiver needs to be able to process any of them.

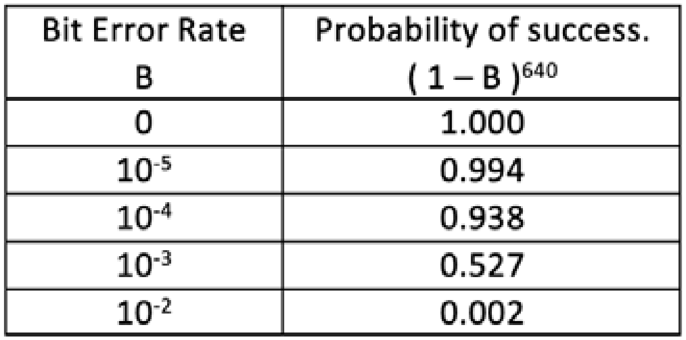
FX.25 has been used for several Amateur Radio Satellites and all of the reception software has been oriented toward that specialized application. Now that FX.25 has been integrated into a general purpose TNC, many new possibilities are now open.

Here are the results of some experiments to see how well it actually works.

Bit Error Rate

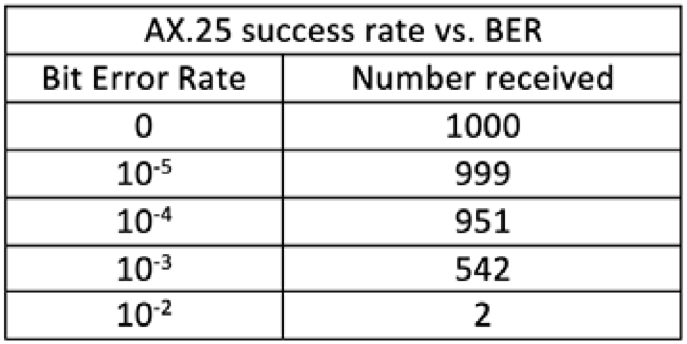
“Bit Error Rate” (BER) is a common measurement of how well a digital communication channel performs. It is simply defined as the number of incorrect bits divided by the total number of bits. Errors can be caused by many factors such as natural random noise, man-made interference, multi-path, fading, low quality modems, incorrect adjustments (e.g. transmit audio level), and distortion added by the radios (e.g. limited bandwidth, pre-emphasis & de-emphasis).

It is easy to compute the impact of different bit error rates. If the probability of any bit getting corrupted is B then the probability of it getting through correctly is (1 - B). The probability of N bits getting though correctly is (1-B)N. Let’s compute the probability of an 80 byte (640 bit) frame getting through with different error rates.



Bit Error Rate B	Probability of success. $(1 - B)^{640}$
0	1.000
10^{-5}	0.994
10^{-4}	0.938
10^{-3}	0.527
10^{-2}	0.002

Now we will try it experimentally. Generate a thousand APRS packets and measure how many are received. The receiving end has an option to introduce a given Bit Error Rate, after the demodulator, using a random number generator.

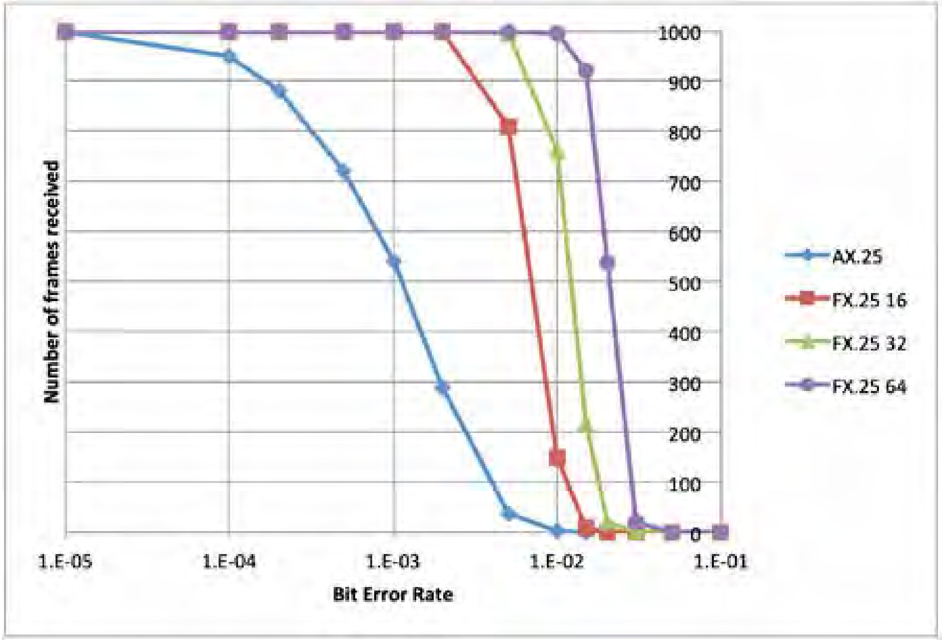


AX.25 success rate vs. BER	
Bit Error Rate	Number received
0	1000
10^{-5}	999
10^{-4}	951
10^{-3}	542
10^{-2}	2

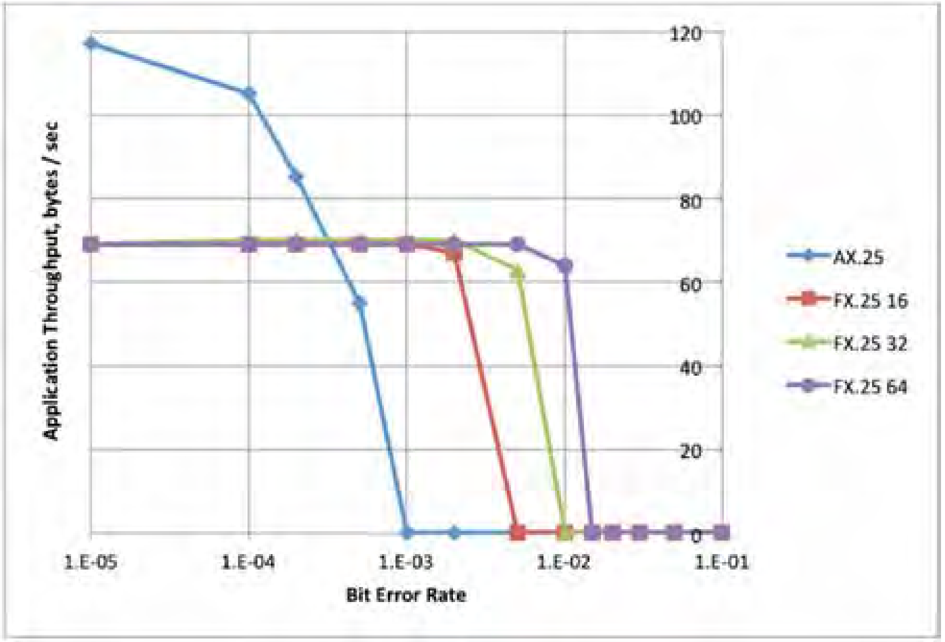
The experimental results are quite similar to the theoretical expectation. Loss of only 1 bit in 1000 (i.e. BER = 10-3) causes almost half of the frames to be lost.

FX.25 Improvement for APRS

The same test will be performed with 1000 frames again, but this time using FX.25. The sender has a choice of 16, 32, or 64 check bytes. Once again, we introduce a controlled Bit Error Rate at the receiving end and count the number of frames received correctly.



FX.25 keeps going strong long after regular AX.25 is completely useless.



FX.25 Improvement for traditional Packet Radio

Connected mode uses the same AX.25 frames but in a different way. Rather than a broadcast to everyone, it is used as a link between two specific stations. The sending TNC assigns sequence numbers to the information frames. The receiving end acknowledges what has been received and asks for fill-ins of missing pieces.

Connected mode AX.25 packet radio is often used, with applications like Outpost PM and WinLink Express, for emergency communications. Temporary antennas and loss of infrastructure make reliable communications more difficult. Anything that can extend range and improve reliability could have a significant impact on people's lives.

This test uses 100 frames each with 128 information bytes.

The total amount of application data transferred, divided by the elapsed time will give us an effective throughput rate, measured in bytes per second here. As the error rate increases, more retries are required, and the throughput decreases. At some point, it just gives up before reaching the end. We give this a score of 0.

Under good conditions, FX.25 is slower because it has more overhead. When conditions deteriorate, FX.25 show little or no degradation long after AX.25 is completely useless.

One could imagine a system where the FX.25 transmission is enabled or disabled based on the error rate detected on the receiving end. It would not have to be symmetrical. Maximum throughput might be achieved by a low power station transmitting FX.25 and a high power station sending regular AX.25.

FX.25 Quick Start Guide

If you got this far, you are probably wondering, "How can I experiment with this?"

The "Dire Wolf" software TNC now has FX.25 built in so it is easy to use with all your favorite APRS and Packet Radio applications.

Some of you might not be familiar with this software.

Dire Wolf is a modern software replacement for the old 1980's style TNC that used special hardware. It uses the computers "soundcard" for audio in and out. The modem is implemented with digital signal processing (DSP) software.

Without any additional software, it can perform as an APRS GPS Tracker, Digipeater, Internet Gateway (IGate), and an APRStt gateway. It can also be used as a virtual TNC for other applications.

It is free open source that runs on Windows, Linux (including Raspberry Pi), Mac OSX, and BSD unix.

It's now very easy to get started with FX.25:

Reception

FX.25 reception is always enabled so you don't need to do anything special. Watching for the special correlation tag sequences adds an insignificant amount of additional overhead when only regular AX.25 is in use.

Transmission

For transmit, simply specify –X (upper case) on the command line followed by 16, 32, or 64, for the desired number of check bytes. The specific correlation tag will be picked automatically based on the frame size. Currently this single option applies to all radio channels.

At the time this is being written, the new functionality is available only in the development ("dev") branch. Not too far in the future, it should be in release 1.6.

That's about all you need to know to get started.

Summary

FX.25 has been used for more than a decade with some Amateur Radio satellites. Receiving implementations were oriented toward that very specialized application. Now that FX.25 is easy to use, integrated into a general purpose TNC, many other AX.25 based applications can gain the benefits while retaining complete compatibility with older equipment.

Recommended Reading

Wikipedia

https://en.wikipedia.org/wiki/FX.25_Forward_Error_Correction

FX.25 FEC extension to AX.25

http://www.stensat.org/docs/FX-25_01_06.pdf

Dire Wolf documentation

https://github.com/wb2osz/direwolf/tree/dev/doc

Most relevant related documents:

- AX.25 + FEC = FX.25 (similar to this but longer)
- AX.25 Throughput: Why is 9600 bps Packet Radio only twice as fast as 1200?
- A Better APRS Packet Demodulator, part 1, 1200 baud

###

TAPR Wear Available

Personalized Land's End clothing with the TAPR logo and your name and call sign are now available from the TAPR Store at

http://business.landsend.com/store/tapr/

Select from the Men's or Women's catalog. (To make shopping easier, there are "TAPR Recommended Shirts" in the Men's catalog including two styles of polo shirts, each available with or without pockets.)

The logo is available in three colors -- red, blue, and white. The name/call sign monogram thread will match the logo color. (We recommend that you use the white logo with dark colored shirts.)

Prices are very reasonable, for example, after adding the logo and monogram, a mesh pocket shirt is $39.85 plus shipping and sales tax where applicable. Processing time is 5-7 days.

###

Automatic Tuner for Small Magnetic Loop Antennas©

By Andrew Cornwall, VE1COR / KB1RSE

According to the 2010 United States Census 80.7% of the population lives in 'urban' regions. Urban residents account for over 90% of the population in seven states. A trend toward urbanization has happened throughout the country. There is considerable leeway in the definition of an urban area, yet the implication is that an increasing number of U.S. hams live in apartments or in houses with lots too small for a full size HF antenna. Many U.S. hams with sufficient land reside in neighbourhoods subject to home owners association rules that do not allow full size HF antennas[1]. Increasing urbanization is also occurring in other countries. According to United Nations data for 2018, 55% of the world's population now lives in urban areas[2]. The implication for hams is there is a growing need for a small footprint, compact, capable HF antenna. Such an antenna might be an autotuned small magnetic loop.

This article is about making a remote automatic tuner for small magnetic loop antennas. The article explains in some detail how the autotuner functions and is used. Implicit in this description is how to make one. I do not provide a parts list here and catalogue numbers. Fortunately, circuit components are standard electronics as identified in the circuit diagram.

A small magnetic loop antenna is relatively compact, easily portable, and does not have radials; it is directional, has some gain, and is suitable for use outdoors, and (within safe antenna proximity power limits) indoors or on a balcony[3]. The antenna consists of two loops, one within the other, interconnected by inductance. The much smaller loop, called the coupling loop, connects to a transmitter/receiver. The larger, transmitting loop (it also receives), about a metre in diameter for popular HF bands, is connected in parallel with a variable capacitor comprising an LC circuit. Tuning happens, with maximum antenna output, when the variable capacitor is turned until the resonate frequency of the LC loop matches the transmitting frequency. At resonance the variable capacitor is subject to very high voltages, up to about 900 volts when the antenna is transmitting 5 watts, and 4,200 volts at 100 watts. The coupling loop does not experience high voltages. Tuning for optimum transmitting concurrently optimizes the antenna for receiving.

There are numerous Internet sites covering small magnetic loop antenna design and construction. Further, there are several small magnetic loop antenna design calculators. The most accurate calculator for my purposes is KI6GD - Glenn Sperry's Magnetic Loop Antenna Calculator, LoopCalc.exe, which can be downloaded from http://www.iw5edi.com/software/magnetic-loop-calculator.

Picture 1 shows the type of small magnetic loop antenna I use. The autotuner is in the box below the antenna. For my antennas I employ good quality coaxial cable to make the transmitter and coupling loops. It operates on the 40, 30, and 20 metre bands. Other bands may be accessed by changing the transmitting loop size and/or the range of the variable capacitor. The antenna's variable capacitor is a high voltage air variable capacitor which can rotate continually 360 degrees[4]. Better amateur radio small magnetic loop antennas have a transmitting loop made of copper pipe or tubing, which is superior because of lower electrical resistance resulting in better performance and lower Q. (The autotuner described here should work well with such a transmitting loop.) Also a costly vacuum variable capacitor[5] may be employed that can withstand much higher voltages, allowing for greater transmission power. Nevertheless, coax based small magnetic loop antennas with air variable capacitors are fairly popular and quite effective. They are also easy to construct.

Picture 1. Small Magnetic Loop Antenna with Autotuner

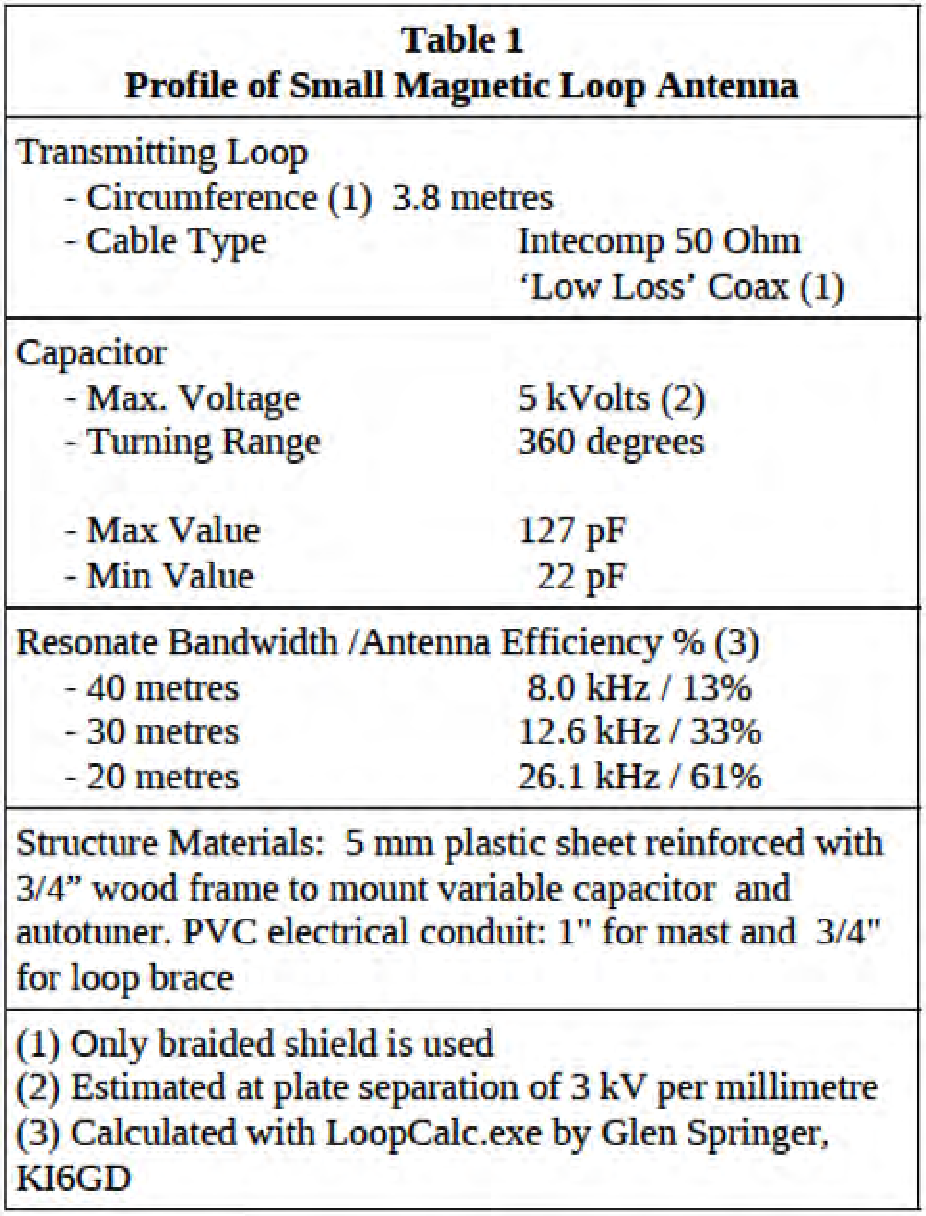


Table 1
Profile of Small Magnetic Loop Antenna

Transmitting Loop	
- Circumference (1)	3.8 metres
- Cable Type	Intecomp 50 Ohm 'Low Loss' Coax (1)
Capacitor	
- Max. Voltage	5 kVolts (2)
- Turning Range	360 degrees
- Max Value	127 pF
- Min Value	22 pF
Resonate Bandwidth /Antenna Efficiency % (3)	
- 40 metres	8.0 kHz / 13%
- 30 metres	12.6 kHz / 33%
- 20 metres	26.1 kHz / 61%
Structure Materials: 5 mm plastic sheet reinforced with 3/4" wood frame to mount variable capacitor and autotuner. PVC electrical conduit: 1" for mast and 3/4" for loop brace	

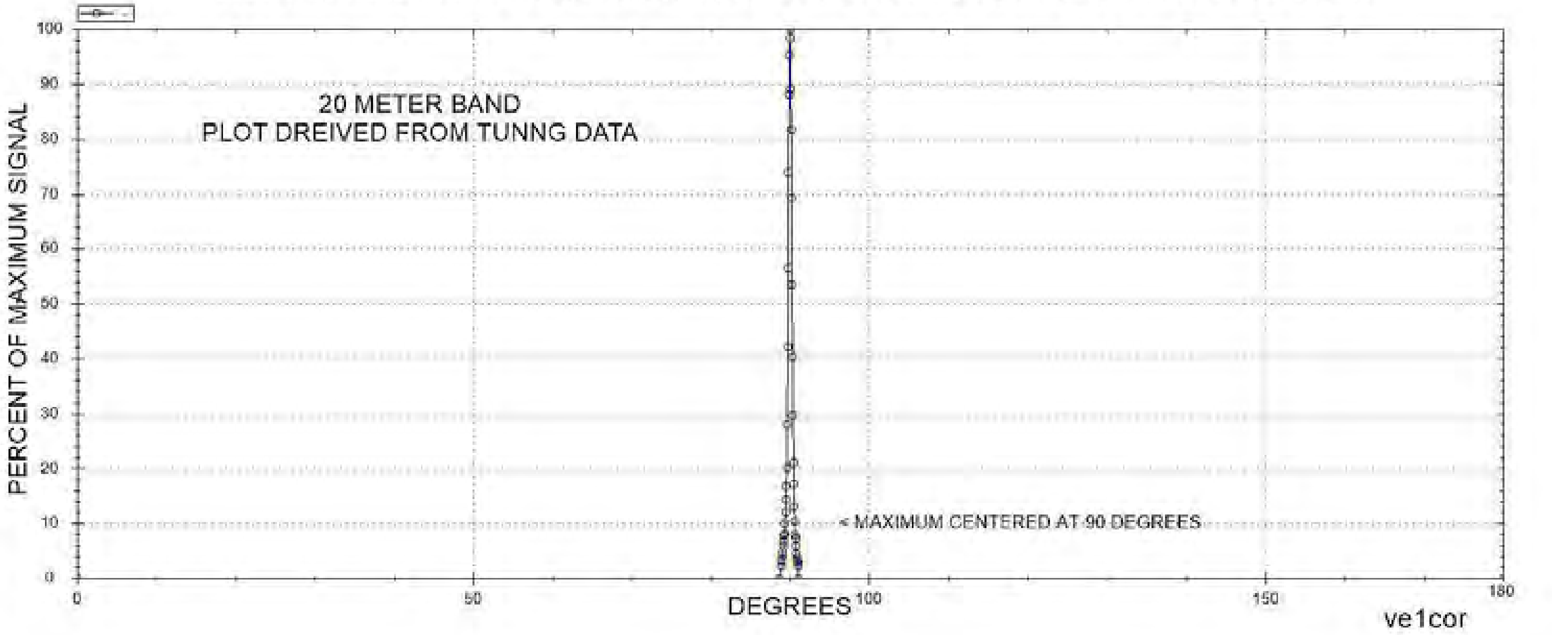
(1) Only braided shield is used
(2) Estimated at plate separation of 3 kV per millimetre
(3) Calculated with LoopCalc.exe by Glen Springer, KI6GD

Table 1 provides the characteristics of the antenna I used for this article.

Except for portable operation small magnetic loop antennas are rarely found in hams' antenna repertoires. The problem is the antenna's extremely high Q making it difficult to accurately tune. Graph 1 illustrates the minute turning range of a traditional air variable capacitor to achieve anywhere near maximum output. The only significant transmitted signal occurs within a two degree portion of the 180 degree (half) rotation of a variable capacitor, and successful tuning is within less than a one-half degree range[6]. (At least this is the situation with my small magnetic loop antenna.)

There is another inherent difficulty with small magnetic loop antennas. If the antenna is not equipped with remote tuning the radio operator has to be able to reach the antenna's variable capacitor to tune by hand, limiting where the antenna can be set up and possibly exposing the operator to significant RF energy. There are commercial and DIY devices that make remote tuning possible. These often utilize a stepper motor or geared down DC motor at the antenna to turn the variable capacitor for minimum SWR at the transmitter. One type has a hand held motor control. Another is a logic based tuner that automatically searches for minimum SWR.

GRAPH 1: PERCENTAGE OF MAXIMUM SIGNAL FOR 180 DEG. TURN OF VARIABLE CAPACITOR



I wanted to make a remote automatic tuner that would be precise, easy to use, and inexpensive. Once I settled on the unique strategy for remote automatic tuning, the design of the autotuner was obvious and extremely simple. It is also inexpensive costing about $50, not including metal box and parts for the small magnetic loop antenna. With my design I confidently autotune a small magnetic loop antenna remotely within a fraction of a dB of best possible. There is a limitation to the autotuner's performance, however, and this is noted later.

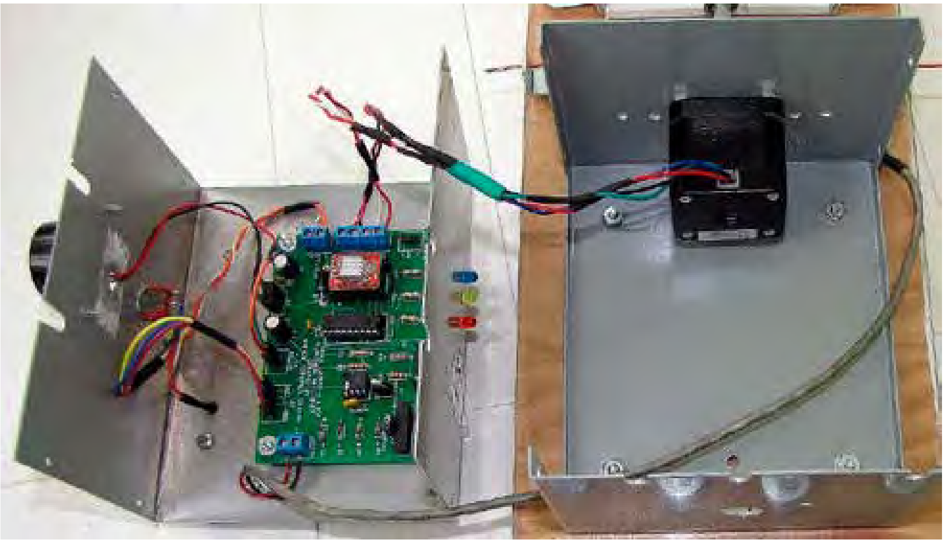
I have constructed several autotuners out of varied parts for the stepper motor, stepper motor driver, and small magnetic loop antenna air variable capacitors. They all did an acceptable job. For guidance, however, specific models of stepper motor and variable capacitor and their suppliers are mentioned in the article. A printed circuit board is available which facilitates assembling the circuit.

Unique Tuning Objective

Usually antenna tuning strives to achieve the lowest SWR measured at the transmitter or the antenna feedpoint. My autotuner's objective, however, is to achieve the highest possible output at the antenna from the power delivered to it. Maximum transmitted power might not occur at the antenna's lowest SWR, because the impedance of an optimally tuned small magnetic loop antenna may not be 50 ohms, typical transmitter output and transmission line impedances. Tuning the antenna for lowest SWR does not guarantee absolutely highest antenna radiation. Fortunately, in my experience, the highest radiated power of a small magnetic loop antenna is consistent with acceptably low SWR. If this were not the situation high SWR at the antenna can be managed by adding a traditional antenna tuner probably at the transceiver.

Picture 2. Autotuner - Sampling Antenna Below Variable Capacitor Protector

Picture 2 shows the autotuner and variable capacitor mounted together on a platform that clamps to the mast of the small magnetic loop antenna. The variable capacitor is housed in a white shield made from PVC pipe, and the autotuner is in the metal box. (The extra holes in the box relate to a former autotuner.) Picture 3 shows the placement of parts inside the box, and Figure 1 shows the circuit of the autotuner. The circuit has five sections: sampling antenna, wide band receiver, microcontroller, stepper motor driver, and stepper motor. They are described below.



Picture 3. Inside the Autotuner Box

Sampling Antenna

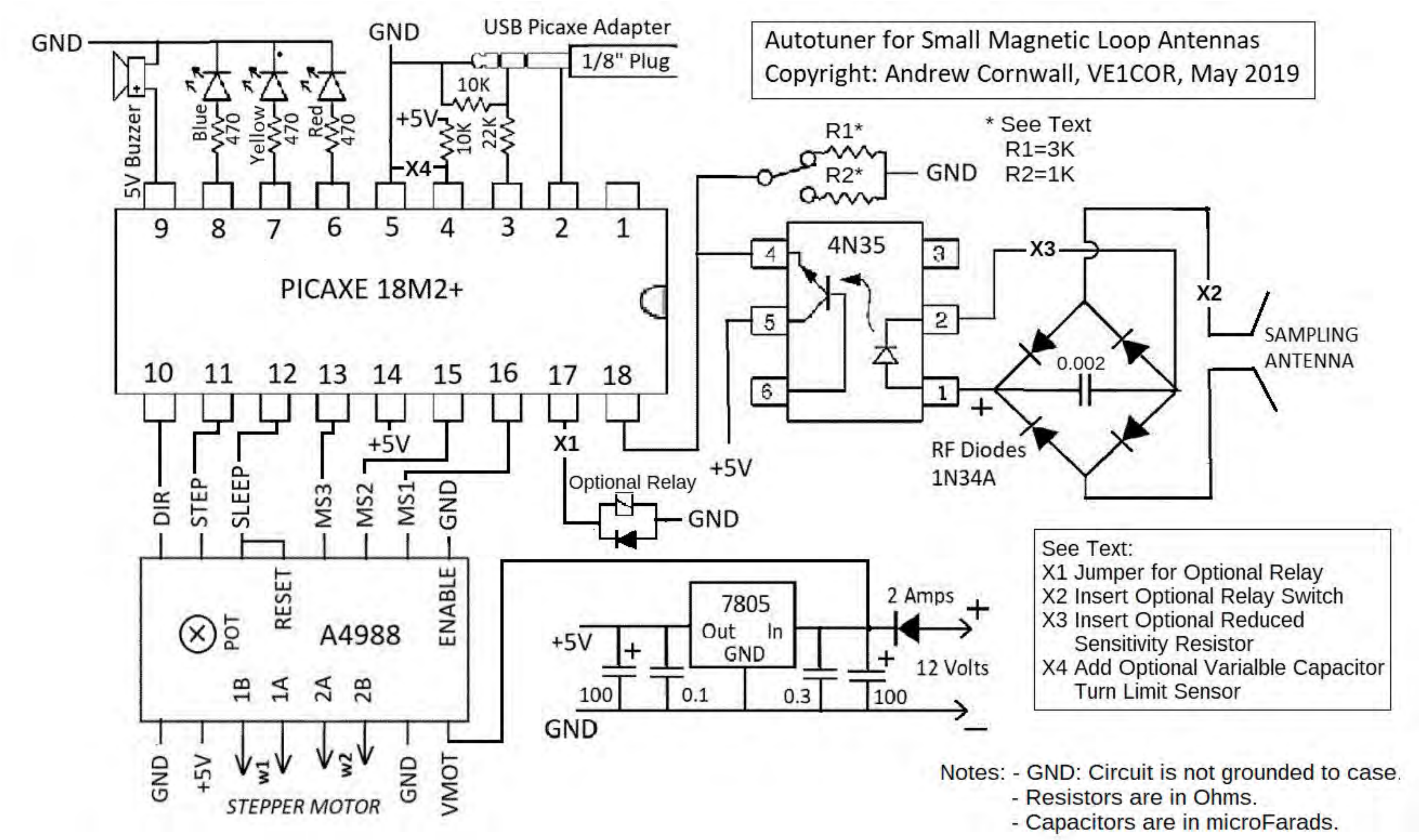
The perceived sensitivity of the sampling antenna increases with frequency. This is mostly because small magnetic loop antennas of a given size are more efficient at higher frequencies, as shown in Table 1 for the prototype antenna.

The sampling antenna has one important limitation. It can pick up a signal from a nearby relatively high power transmitter and mislead the autotuner[7]. Although infrequent I have had the embarrassment of demonstrating the autotuner at a transmission laden hamfest with unsatisfactory results. Computer monitoring of the automatic tuning process or autotuner manual mode, described later, can reveal where outside RF is likely to throw off autotuning. Also, extraneous RF interference can be reduced by using a shorter sampling antenna in conjunction with higher tuning power, e.g. 5 watts.

Receiver

The receiver is very wide band, consisting of four 1N34A RF diodes in a bridge rectifier. A 0.002 uF capacitor suppresses non-DC output from the receiver. Indeed, the combination of sampling antenna and receiver comprise a field strength meter.

Linking the receiver to the microcontroller is a 4N35 optocoupler which provides a non-inverting path, signal isolation, and limits the voltage to the microcontroller input to 5 volts, its maximum safe level. Output from the bridge rectifier is connected to the LED inside the optocoupler. The optocoupler functions in the linear mode, where current passing through its output transistor varies in conjunction with the amount of current going to the internal LED. Too much current at the LED results in transistor saturation - this is the optocoupler's switching


Autotuner for Small Magnetic Loop Antennas
Copyright: Andrew Cornwall, VE1COR, May 2019

See Text:
X1 Jumper for Optional Relay
X2 Insert Optional Relay Switch
X3 Insert Optional Reduced
Sensitivity Resistor
X4 Add Optional Varialble Capacitor
Turn Limit Sensor

Notes: - GND: Circuit is not grounded to case.
- Resistors are in Ohms.
- Capacitors are in microFarads.

Figure 1. Autotuner Circuit

mode. The optocoupler's linear mode sensitivity (before saturation) varies with the value of the output transistor emitter resistor, switchable between R1 and R2 in the circuit diagram. Voltage across the emitter resistor is applied to pin 18 of the microcontroller. A high value for the resistor results in high sensitivity but also early saturation. Conversely, a low value decreases the optocoupler's sensitivity but allows for a greater range for linear operation. In the circuit R1 is 3.0 K-ohm for 'High Sensitivity' and R2 is 1 K-ohm for 'Low Sensitivity', resulting in a scale range of 3:1. By changing the sensitivity setting the autotuner may operate with a tuning signal that is neither too high nor too low, covering several bands given the length and position of the sampling antenna.

There is the opportunity for further autotuner sensitivity adjustment at the two point gap at X3 in the circuit diagram. Placing a resister here reduces the current going from the diode bridge to the optocoupler LED. A resistor may be needed if tuning wattage is relatively high and cannot be accommodated by shortening or moving the sampling antenna. Otherwise the ends of the gap are connected.

Even when the autotuner is turned off the receiver via the sampling antenna is exposed to the full power being transmitted by the small magnetic loop antenna. There is the possibility that transmitting high power will cause the current handling capacity of the 1N34A bridge rectifier diodes, 50 mA, and the 4N35 optocoupler input LED, 60 mA, to be exceeded, destroying them. The circuit provides for an optional SPST, normally open, relay to disconnect the sampling antenna when the autotuner is not tuning or not in manual mode. It is likely, however, that transmitting high power will arc the variable capacitor before creating sufficient current to damage the receiver diodes or optocoupler LED. A procedure for estimating how much full transmitting power the autotuner can tolerate is described in a short article that may be downloaded from my website. If a relay is not installed then there would be no connections at X1 on pin 17 of the microcontroller, and the gap in the sampling antenna connection, at X2, would be closed. The autotuner program assumes that a relay is present, if not there is no effect.

Microcontroller

The brains of the autotuner is an inexpensive Picaxe 18M2+ microcontroller. Picaxe microcontrollers are entirely self-contained and simple to implement. Support components consist of only two resistors. The built in oscillator can run up to 32 MHz. Most pins are programmable for input or output, with many having the input option of 10 bit analogue to digital conversion. There is a resident BASIC interpreter having a wide range of built-in functions, including 5 and 10 bit integer mathematics. Program creation in BASIC and uploading it to the 18M2+ is done by means of the Picaxe Development Program; versions of which are downloadable free to work with Windows, Mac, and Linux. For programming and serial data communications the 18M2+ connects to a computer via a serial to USB port adaptor cable made for the Picaxe. A Picaxe chip can be reprogrammed more than 100,000 times - necessary for experimentation.

The circuit diagram shows the digital I/O pin assignments of the 18M2+ connecting to the A4988 stepper motor controller module, three tuning status LEDs, 5 volt status buzzer, and optional 5 volt sampling antenna relay. The LEDs, buzzer, and relay must each draw less than the 20 mA, the per pin I/O current limit of the 18M2+. In the circuit diagram there is also an optional capability at pin 4, with pair of connections at X4 and a 10 K ohm pull-up resistor, for adding a turn-limit sensor to accommodate an 180 degree turn variable capacitor; a modified program is needed for this.

Stepper Motor Driver

The autotuner employs an A4988 modular stepper motor driver that powers and controls a two phase bipolar stepper motor. Input voltage to the A4988 can range from 8 to 30 volts; my autotuner power source is approximately 12 volts. The A4988 can provide up to one amp (two amps with external heat sink) to each of the two phase coils of the stepper motor. The A4988 has an on-board adjustable current limiting control to tailor power to the requirements of the stepper motor.

Driving a stepper motor can be complex, and the A4988 module handles this task. Specific pins on the module receive instructions from the microcontroller. Moving a step occurs when the 'Step' pin receives a pulse. Other pins are set high or low to control stepper motor direction, fractional step size, and motor power on or off.

Stepper Motor

The autotuner stepper motor is two phase bipolar type that is commonly available. The stepper motor turns the small magnetic loop antenna's variable capacitor. As the name implies, a stepper motor moves in discrete increments. The motor can start, stop, and go forward and backward. The stepper motor receives power from the A4988 driver through four wires, two for each phase coil (in the circuit diagram these are labelled W1 and W2).

For this project I experimented with stepper motors having full-step turning increments of 1.8 degrees, 0.9 degrees, and a geared stepper motor with the equivalent of about 0.25 degrees. The tuning increment of the stepper motor can be further reduced by half-stepping, quarter-stepping, eighth-stepping, and sixteenth-stepping with potentially reduced motor torque. I have had the most success with 0.9 degree stepper motors. The remainder of this article generally assumes the use of a 0.9 degree stepper motor, but a 1.8 degree stepper motor may be easily accommodated by a small change in the program. The present autotuner has a 0.9 degree NEMA 17 cube stepper motor, 'Steperonline' model 17HM15-0904S, shown mounted to the box in Picture 3. This and comparable stepper motors may be obtained from Amazon.com or Ebay, and other on-line sources..

Two phase bipolar stepper motors have three power input specifications: voltage, amps per phase, and resistance per phase. For example the present autotuner's stepper motor specifications are 5.4 volts per phase, 0.9 amps rated current per phase, and 6.0 ohms phase resistance. My experience is that voltage is not an issue when amperage is at or below the stepper motor phase coil rating.

The turning force provided by the stepper motor is related to the amperage it draws. The variable capacitors I've used are fairly easy to turn by hand (i.e. able to turn the bare shaft with fingers without a knob) and can be rotated (even with partial stepping) by a stepper motor drawing 0.9 amps.

Although the stepper motor turns in very small increments the chances of the stepper motor positioning the variable capacitor at exactly maximum radiated power is statistically hit or miss. Near resonance there are substantial changes in radiated power per increment of the stepper motor, as displayed in Graph 1. While landing the variable capacitor exactly on maximum radiated power is never certain, using partial stepping improves the odds that near miss tuning yields an acceptable result. Sixteenth-stepping, with 3200 increments per one-half turn of the variable capacitor, is employed by the present autotuner. The success of this strategy is evident in the test results shown at the end of this article. However, with earlier autotuners I have had reasonably satisfactory tuning results with even quarter step tuning.

Microcontroller Automatic Tuner Logic

The autotuner has two modes of operation, 'manual' and 'autotuning'. In both modes the microcontroller can send data through its serial port (converted to USB by the Picaxe connecting cable) to a connected computer[8].

For the manual mode to be useful a computer must be connected to the autotuner. Manual mode is engaged by letting the autotuner run without any tuning power to the antenna during the reconnaissance sweep, described below. After not finding any signal upon which to target tuning, the autotuner reverts to manual mode. Power to the stepper motor is turned off and the variable capacitor can be turned by hand. Then measurements of any radiated power are sent to the computer about three times per second. This data is useful for understanding the nature of the small magnetic loop antenna. Without a transmitted tuning signal, manual mode can be used to assess ambient RF energy from nearby transmitters.

If a computer is connected while in autotuning mode, autotuning information on levels of antenna radiated power and variable capacitor position is communicated after each increment of the stepper motor. (Insignificant measurements, less than '10', are not sent to the computer.) This information is important for understanding autotuning and for experimenting. Autotuning data is the basis of Graph 1. When automatic tuning in the field computer data are not usually needed, and the autotuner is happy to work without a computer connection.

The task of the microcontroller program in autotuning mode is to maximize the small magnetic loop antenna's radiated power at a given frequency. While a low level tuning signal is being transmitted to the antenna and the stepper motor incrementally turns the variable capacitor, the microcontroller tracks power being radiated until the maximum is achieved. This does not seem complicated, but I've tried several autotune algorithms with varied success. For the present combination of autotuner and small magnetic loop antenna I use the 'direct method' - my terminology.

Direct method autotuning starts with a reconnaissance sweep of the entire turning range (i.e. a full turn) of the variable capacitor to identify a probable maximum signal level. Next one or more active tuning sweeps commence where the objective of the autotuner is to turn the variable capacitor until a signal level is produced that is close to or exceeds the reconnaissance maximum. Because the reconnaissance sweep could have been very lucky in encountering the maximum, its value may not be matched during active tuning. The initial active tuning objective, therefore, is to turn the variable capacitor until a signal level is achieved that is at least 95% of the reconnaissance maximum. Occasionally a 95% value is not encountered whereupon a new active tuning sweep is attempted using a 90% threshold. Before giving up a third and forth active tuning sweep will be attempted using 85% and 80% thresholds. If tuning is not achieved after the fourth tuning sweep there is likely something wrong that does not involve autotuner operation. Perhaps there is a loose antenna connection, or there may be a high power ham rig nearby adding its transmitted signal to the autotuner sampling antenna.

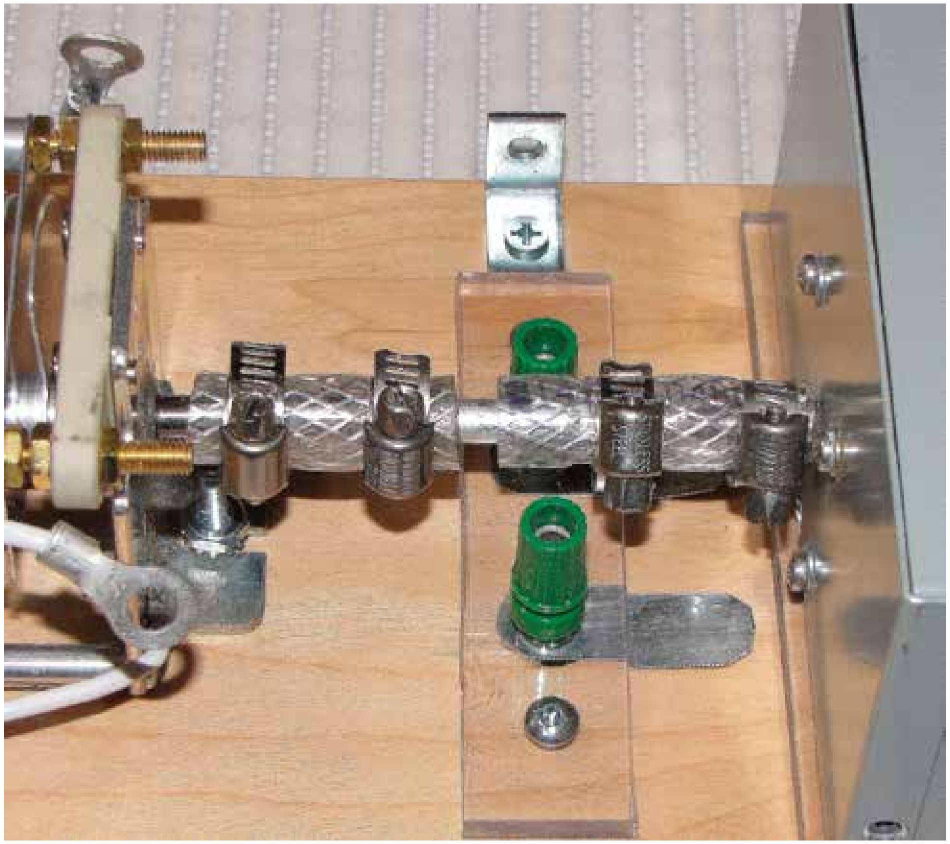
The autotuner has to deal with variations in transmitted tuning power when the transmitter's foldback circuit responds to large changes in SWR. Encountering high SWR may cause the foldback function to reduce transmitter tuning power. As tuning approaches antenna resonance SWR declines significantly and the foldback function allows tuning power to increase to the specified level. To give the foldback circuit time to catch up to declining SWR, the stepper motor slows down turning the variable capacitor. In the present program, to speed up the tuning process, the stepper motor turns at half-step until antenna resonance is approached then slows down to sixteenth step.

The autotuner visually and audibly communicates its operating status by means of a buzzer and three LEDs on the box. Table 2 outlines the Buzzer and LED indications.

Mechanical and Shielding Considerations

I suggest two mechanical shortcuts that I found helpful with prototype construction. First, evident in Picture 2, is fastening the two ends of the transmitting loop to the variable capacitor by 1/4 inch stainless steel bolts extending from the variable capacitor protective housing, by means of small hose clamps. The coax braid at the ends of the transmitting loop are stripped for an inch, or so, and tinned to make a firmer connection. Although not elegant the connection is physically and electrically secure. Also, the transmitting loop is easy to set up and take down.

The second shortcut, in Picture 4, is using two short lengths of 1/4 inch PVC, reinforced, flexible hose to attach the stepper motor to the variable capacitor by means of a 1/4 inch aluminum rod drive shaft.



Picture 4. Connection Between Variable Capacitor and Stepper Motor

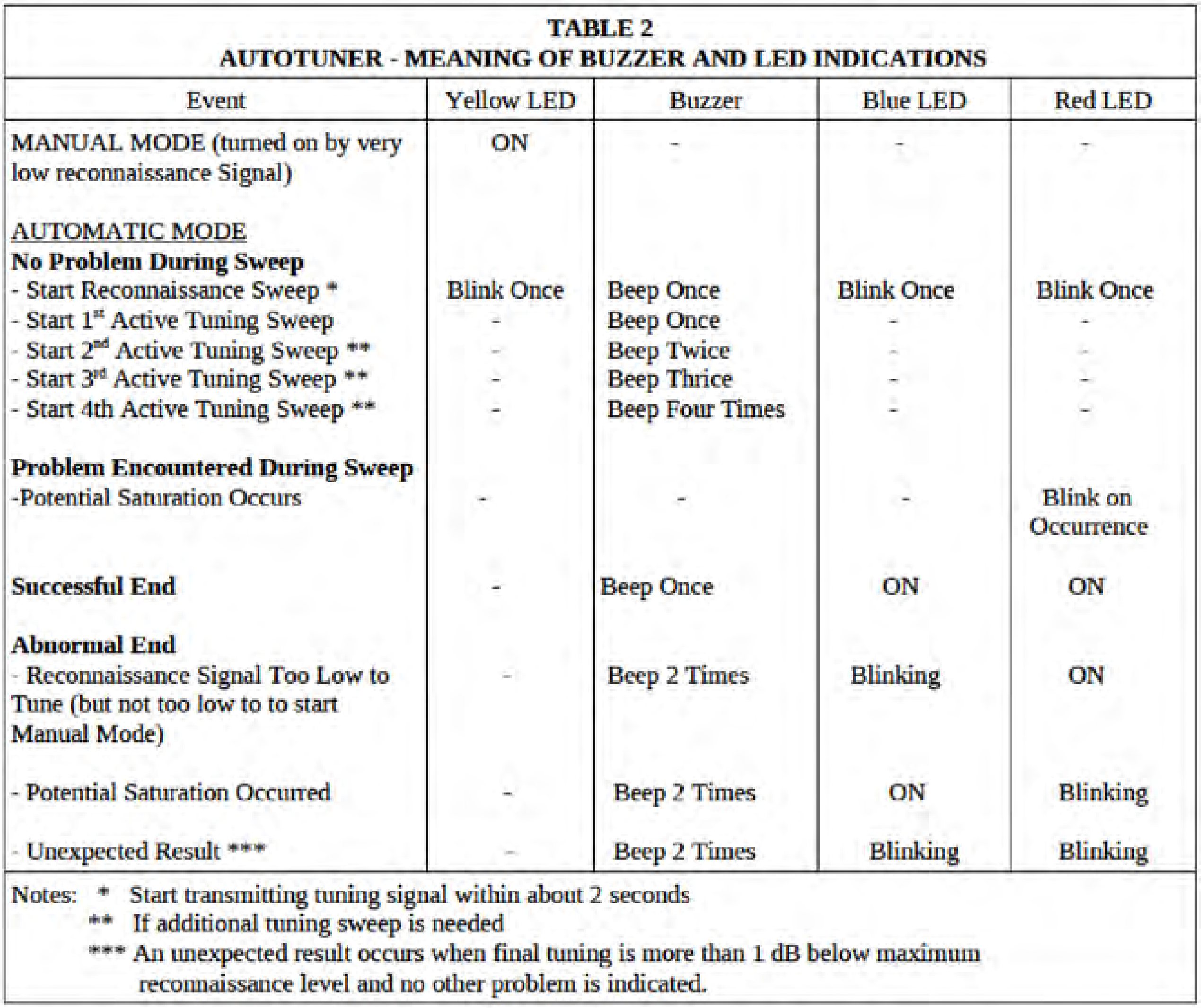


TABLE 2
AUTOTUNER - MEANING OF BUZZER AND LED INDICATIONS

Event	Yellow LED	Buzzer	Blue LED	Red LED
MANUAL MODE (turned on by very low reconnaissance Signal)	ON	-	-	-
AUTOMATIC MODE **No Problem During Sweep**				
- Start Reconnaissance Sweep *	Blink Once	Beep Once	Blink Once	Blink Once
- Start 1st Active Tuning Sweep	-	Beep Once	-	-
- Start 2nd Active Tuning Sweep **	-	Beep Twice	-	-
- Start 3rd Active Tuning Sweep **	-	Beep Thrice	-	-
- Start 4th Active Tuning Sweep **	-	Beep Four Times	-	-
Problem Encountered During Sweep				
-Potential Saturation Occurs	-	-	-	Blink on Occurrence
Successful End	-	Beep Once	ON	ON
Abnormal End				
- Reconnaissance Signal Too Low to Tune (but not too low to to start Manual Mode)	-	Beep 2 Times	Blinking	ON
- Potential Saturation Occurred	-	Beep 2 Times	ON	Blinking
- Unexpected Result ***	-	Beep 2 Times	Blinking	Blinking

Notes: * Start transmitting tuning signal within about 2 seconds
** If additional tuning sweep is needed
*** An unexpected result occurs when final tuning is more than 1 dB below maximum reconnaissance level and no other problem is indicated.

The hose is tightly clinched to the shaft's of the stepper motor, variable capacitor, and rod by four small hose clamps. The shafts of the stepper motor, variable capacitor, and ends of the rod are roughened to enhance holding power. At each end of the rod there is about a 3 mm gap inside the hose to electrically isolate the stepper motor from the variable capacitor. If the variable capacitor turns relatively easily and the four hose clamps remain tight there is no slippage nor twisting evident with this linkage. Further the flexible hose can accommodate the somewhat different diameters of the shafts of the variable capacitor, aluminium rod, and stepper motor; and overcome minor misalignment.

Although more expensive than the jury rigged approach described above, stepper motor (CNC) shaft couplers work well to connect the stepper motor and variable capacitor. A coupler must be specified to conform to the diameters of the shafts it is connecting. If electrically conductive (i.e. made of metal) then two couplers are needed, one at the stepper motor and the other at the variable capacitor with a non-conductive drive shaft in between to electrically isolate the variable capacitor from the autotuner. I have used one-quarter inch, stiff plastic rod for a drive shaft.

The autotuner's circuitry must electrically float inside the metal box. There is no electrical nor power connection between the circuit's components and the box. The metal box shields the autotuner electronics from the potentially significant RF field surrounding the small magnetic loop antenna. Shielding also occurs at the transmission cable from the sampling antenna to the autotuner receiver. (Initially I used RG-174 coax, but the outer braid became part of the sampling antenna.) I use a transmission cable made of shielded audio cable with the two inner wires carrying the signal from the two legs of the sampling antenna. The cable's shield is grounded to the metal box. (The stepper motor is mounted to the box but the motor's coils are insulated from it.)

The method of wiring the electronics and stepper motor is not critical, although a printed circuit simplifies assembly.

Autotuner Platform - Rigidity Rules

A lesson I've learned in building four autotuners with different variable capacitor and autotuner mounting strategies is the variable capacitor and autotuner have to be mutually mounted on a very rigid structure. If there is any flexing a torque will build up during tuning between the variable capacitor and stepper motor which results in the variable capacitor continuing to turn slightly when autotuning is completed. Previously I've finagled this problem by programming the microcontroller to turn the stepper motor backwards a small amount as autotuning finishes. The prototype autotuner now employs a 3/4 inch plywood (16" x 6"). The rigidity this provides allows both the stepper motor and variable capacitor to stop the instant tuning is complete.

Variable Capacitor Considerations

Small magnetic loop antenna air variable capacitors able to withstand high voltage can be expensive to purchase new. This is an issue with small magnetic loop antennas regardless of tuning mechanism. My primary source for high voltage variable capacitors has been ham flea markets. The 27-127 pF variable capacitor used with the small magnetic loop antenna for this article is a flea market find; plate spacing suggests it maybe able to withstand 90 watts. Previously I extensively used an available 10-260 pF high voltage variable capacitor, double the capacitance range warranted for the desired bands. This made tuning twice as demanding (i.e. for each stepper motor increment the change in capacitance is double). Despite the added challenge the autotuner consistently tuned within one dB (80%) of optimum. I mention my variable capacitor experience to give heart to small magnetic loop antenna builders who face a compromise when using less than ideal variable capacitors.

Recently I successfully tried a variable capacitor from RF Parts (www.rfparts.com), model 73-175-23, 14pF-145pF, 3.2Kv ($60 US). Based on LoopCalc.exe calculations, the 3.2Kv voltage rating allows my small magnetic loop antenna to handle about 65 watts on 40 meters, and 50 watts on 30 meters and 20 meters. I had to reduce the variable capacitor's turning resistance by slightly loosening the screw (with locking nut) holding the rotor shaft rear pivot point. Once turning resistance was lessened, the 'Steperonline' model 17HM15-0904S stepper motor, specified previously, readily turned the variable capacitor.

Operating the Autotuner

A small magnetic loop antenna is attached to a transceiver with ordinary 50 ohm coax transmission cable. I tend to insert an RF isolator in the transmission line near the antenna. A 12 volt DC power source (a small gel cell will do) with a switch at the operator's position, connects to the autotuner by two conductor hookup wire. The coax and DC power wire may be as long as needed to achieve a satisfactory antenna position. If computer connection to the autotuner is desired it is done by means of the Picaxe serial to USB adapter cable (at the computer) and lengths of stereo headphone extension cables having 1/8 inch female and male end connectors. I've chained together over 30 ft. of headphone extension cables. If there is a traditional tuner between the transceiver and the small magnetic loop antenna, it should be in by-pass mode while the autotuner is actively tuning and in manual mode[9].

My autotuner on average draws somewhat over one amp when tuning; while 'on' at other times (e.g. manual mode) the draw is less than 20 ma.

Autotuning commences when 12 volt power is switched on. The autotuner beeps once as a reminder to commence transmitting a small, constant tuning signal, which may be an AM or CW carrier, or tone modulated SSB. While tuning progresses the transceiver's SWR indicator dips and rises several times. This is normal. At the end of tuning the SWR meter most likely will be relatively low. The time to complete autotuning with one active tuning sweep is about 50 seconds. Subsequent active tuning sweeps, if needed, add another 20 to 30 seconds each. The tuning signal should not interfere with other hams, because of the antenna's high Q it is effectively transmitting only a few seconds. Once tuning is done, there is a final beep, the stepper motor stops turning, and the red and blue LEDs light up steadily indicating that tuning was successful. Table 2 refers to the LED and buzzer indications for non-successful tuning outcomes. Afterwards 12 volt power to the autotuner can be turned off. Turning the autotuner off before tuning is finished does no harm.

Very infrequently the autotuner misses acceptable tuning within four active tuning sweeps. When miss-tuning occurs, tune again. Repeated failure confirms that there is something wrong operationally with the autotuner, the small magnetic loop antenna, or the antenna's connection with the transceiver.

In manual mode the setup is the same as autotuning except a computer must be attached to the autotuner. Manual mode is activated by turning on 12 volt power but not transmitting any signal to the antenna. After a reconnaissance sweep without any radiated signal the autotuner goes into manual mode and starts providing continual radiated signal data to the computer. Manual mode status is indicated by the yellow LED turned on. Twelve volt power is kept on as long as manual mode operation is desired. No power goes to the stepper motor and the antenna's variable capacitor can be turned by hand.

Autotuning Results

To illustrate the capability of the autotuner for this article I conducted a total of fifteen trails. The small magnetic loop antenna was set up in the driveway of my home in Nova Scotia. An MFJ-915 RF isolator was inserted in the coaxial cable near the antenna. My operating position was 25 feet away in the garage which had AC power, and a Yaesu FT-897 transceiver and a laptop computer on a makeshift table. The afternoon was sunny with ambient temperature of 68 deg. F.

Table 3 presents the tuning results of fifteen trials. There were five consecutive trails in three groups for frequencies in the 40, 30, and 20 metre bands. The criteria for the frequencies were that they were not special use, not for CW code, and not busy. The Yaesu FT-897 transmitted a CW tone at 5 watts, the lowest possible output[10].

Three parameters were recorded for each trial: SWR, number of tuning sweeps, and percentage of highest signal achieved. SWR was measured by an MFJ-813 QRP, SWR meter. The number of tuning sweeps is the count of 360 degree active tuning turns the autotuner took to (nearly) match the highest signal level found in that trial's reconnaissance sweep. As is typical only one tuning sweep was needed.

"Percent of Highest Signal for the Frequency Group" compares, in percentage terms, the signal level measured at the conclusion of each trial with the highest signal occurring among all five trials in the frequency group. The highest group signal level is that encountered collectively among the five trial reconnaissance maximums and the five autotuned results. The theory is that the highest among these ten values reasonably estimates the maximum signal possible for the frequency group. Also shown in parenthesis in Table 3 is the percentage of 'local' maximum power achieved for just that trail.

The results in Table 3 are self evident. The individual trial signal values are very close to the probable highest signal value for their frequency group. The lowest are 92% for the second trial in the 40 metre band and 92% for the fourth trail the in the 20 metre band; these trails are bolded in the table. To put this percentage into perspective, 92% is only 0.36 dB (less than one-half dB) below the highest probable signal value. Regarding each trail's local maximum, the autotuned percentage is 96% or higher. These autotuning results

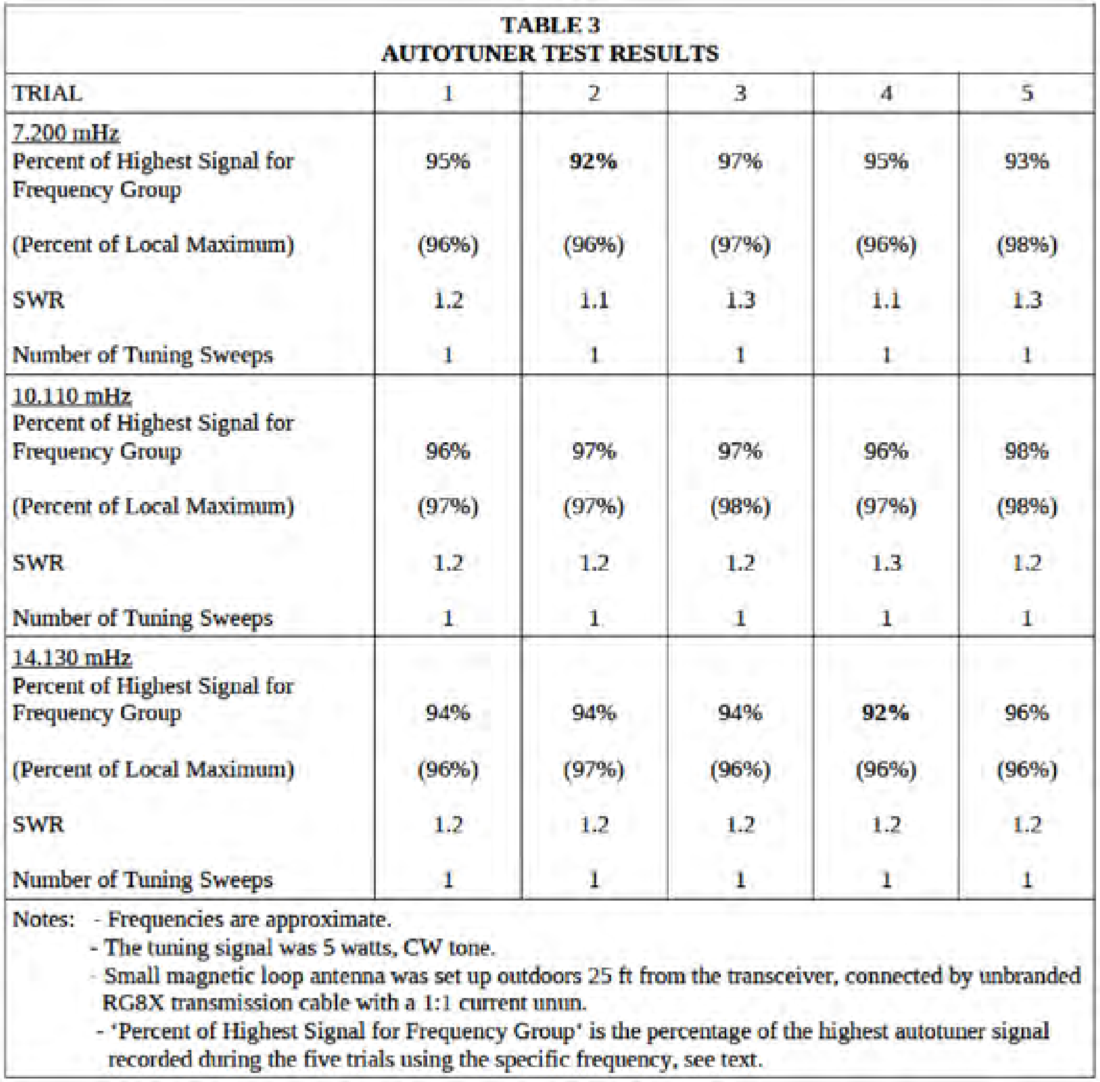


TABLE 3
AUTOTUNER TEST RESULTS

TRIAL	1	2	3	4	5
7.200 mHz					
Percent of Highest Signal for Frequency Group	95%	**92%**	97%	95%	93%
(Percent of Local Maximum)	(96%)	(96%)	(97%)	(96%)	(98%)
SWR	1.2	1.1	1.3	1.1	1.3
Number of Tuning Sweeps	1	1	1	1	1
10.110 mHz					
Percent of Highest Signal for Frequency Group	96%	97%	97%	96%	98%
(Percent of Local Maximum)	(97%)	(97%)	(98%)	(97%)	(98%)
SWR	1.2	1.2	1.2	1.3	1.2
Number of Tuning Sweeps	1	1	1	1	1
14.130 mHz					
Percent of Highest Signal for Frequency Group	94%	94%	94%	**92%**	96%
(Percent of Local Maximum)	(96%)	(97%)	(96%)	(96%)	(96%)
SWR	1.2	1.2	1.2	1.2	1.2
Number of Tuning Sweeps	1	1	1	1	1

Notes:
- Frequencies are approximate.
- The tuning signal was 5 watts, CW tone.
- Small magnetic loop antenna was set up outdoors 25 ft from the transceiver, connected by unbranded RG8X transmission cable with a 1:1 current unun.
- 'Percent of Highest Signal for Frequency Group' is the percentage of the highest autotuner signal recorded during the five trials using the specific frequency, see text.

are typical. Tuning any antenna to this degree would be considered a success. The relatively low SWRs are encouraging by any standard, but they relate to this particular antenna. It is comforting, never the less, to know that after autotuning with this small magnetic loop antenna no further signal treatment is needed to protect the transceiver from high SWR.

Where to Obtain Autotuner Picaxe Programs and Additional Information

I am adding to my website program files and additional information to complement the description in this article. There are two program files. One is a circuit tester that verifies all functions of the circuit are operating correctly. This can be run before the circuit is installed in the autotuner. The second program controls the autotuner. Picaxe programs may be opened in the Picaxe Development Program or any text editor to look at (and edit) the code. Picaxe BASIC is easy to follow and the code tends to be self documenting. Other information on the website includes a circuit parts list, assembly tips involving the printed circuit board, how to estimate highest tolerable transmitting power, and some project history.

I leave many details of autotuner assembly to the reader. My platform, 3/4" plywood board about 6" x 18", is suitable for the variable capacitors and autotuner boxes that I have used. The shortcuts described above have facilitated construction, and the way of mounting the autotuner on the mast of a small magnetic loop antenna has worked well. Other than a requirement for rigidity between the stepper motor and variable capacitor, there is nothing vital about my approaches. What they accomplish can be achieved in other ways. Indeed most aspects of the autotuner are still amenable to experimentation.

Availability of a Printed Circuit Board

To simplify assembling the autotuner circuit I have a printed circuit board, shown in Picture 3. The board was designed to professional standards by Ed Thompson, then a student at the Institute of Technology Campus of the NSCC (Nova Scotia Community College). Ed's ability and diligence are commendable, and he recommended changes that significantly improved the prospective board.

I am planning to have a small supply of printed circuit boards available for sale by February 2020, when this article is scheduled to be published in the 'Packet Status Register'. How to order the board will be posted on my website. If demand exceeds the initial supply of boards, I will attempt to source more.

Acknowledgements

An earlier article of mine describing the experimental nature of this project was published in the May-June 2018 edition of the Radio Amateurs of Canada magazine, TCA (The Canadian Amateur). I wish to acknowledge the assistance I received from the TCA editor and reviewers of the earlier article. Many of their suggestions helped my approach to the project and writing about it. Since then I have refined the autotuner to make a good device even better. With the present article I was pleased to have the advice of the TAPR reviewer Bruce Raymond, ND8I. Any and all problems associated with the autotuner, however, are entirely my fault.

There remains the need to demonstrate the autotuner's capabilities with a wide range of small magnetic loop antennas used by other hams. Also, the autotuning approach described in this article should be applicable for other kinds of antennas.. There are always opportunities for experimenting.

About the Author

Andrew Cornwall resides in Nova Scotia, Canada where he has Basic with Honours amateur radio certification. He was first certified in 1992 and retains the call sign VE1COR. He spends considerable time in the United States and has had a General license since 2008 with call sign KB1RSE. He is retired from careers in economics analysis and in information technology system group management.

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Footnotes

1. The website www.hoa-usa.com claims that there are 351,000 such home owners associations in the United States. Commonly home owners associations ban full size HF antennas.

2. United Nations Department of Economic and Social Affairs, 2018 Revision of World Urbanization Prospects.

3. I have not used a small magnetic loop antenna on a balcony, but others have, for instance: www.qsl.net/kp4md/balconyloop.htm

4. The autotuner circuit design allows for variable capacitors that have an 180 degree turning limit. This requires the addition of a turn limit sensor and a modified microcontroller program.

5. The adjusting mechanism of a vacuum variable capacitor is not suitable for my autotuner mechanism.

6. Some of the peakiness of the small tuning range is due to the very high SWR outside of the vicinity of antenna resonance. This results in transmission line loss and also causes the transmitter's foldback function to reduce power output.

7. There is the possibility of measuring the output signal of the antenna other than a sampling antenna, which would not be subject to extraneous transmissions. The autotuner circuit and logic would not be altered.

8. Measurements of signal strength are relative and range from 10 to about 1000 (anything below 10 is meaningless and not reported). A value of 1000 corresponds to nearly 5 volts from the optocoupler to the microcontroller.

9. The data signal from the autotuner to a computer can be garbled when a fairly high tuning signal (sometimes as low as 5 watts) is being transmitted and the small magnetic loop antenna is close to the computer, or the radio transmission line is in the proximity of the data cable. The solution is to move the antenna, separate the transmission and data cables, and/or lower the power of the tuning signal.

10 Running sequential trials is not as simple as it might seem. Even with the tuning signal reduced to 5 watts, from a 100 watt capable transceiver, holding the key down repeatedly for about a minute heats up the transmitter notably. This eventually reduces tuning power by a small amount. While autotuning is accurate for the trail, the results are not comparable to other trails. The solution for consistency is to allow time for heat to dissipate between trials.

###

Write Here!

Your *PSR* editor is working on the next issue of *PSR* and hopes to find a few good writers, particularly ham radio operators working on the digital side of our hobby, who would like to write about their activities and have them published here in *PSR*.

You don't have to be Hiram Percy Maxim to contribute to *PSR* and you don't have to use *Microsoft Word* to compose your thoughts.

Your *PSR* editor can handle just about any text and graphic format, so don't be afraid to submit whatever you have to wa1lou@tapr.org --- she can handle it!

The deadline for the next issue of *PSR* is April 1, so write early and write often.

###

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By Mark Thompson, WB9QZB

Facebook

As you may know, TAPR has a Facebook page, www.facebook.com/TAPRDigitalHam.

However, I also created a TAPR Facebook Group, www.facebook.com/groups/TAPRDigital/.

If you have a Facebook account, "Like" the TAPR Facebook page and join the TAPR Facebook Group.

If you join the group click on the Events link and indicate you're Going to the events.

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Also on YouTube

TAPR now has its own channel on YouTube: the TAPR Digital Videos Channel: www.youtube.com/user/TAPRDigitalVideo.

At this time, there are a slew of videos on our channel including many from the TAPR-ARRL Digital Communications Conference (DCC) that you may view at no cost, so have at it!

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TAPR is always interested in receiving information and articles for publication. If you have an idea for an article you would like to see, or you or someone you know is doing something that would interest TAPR, please contact the editor (wa1lou@tapr.org) so that your work can be shared with the Amateur Radio community. If you feel uncomfortable or otherwise unable to write an article yourself, please contact the editor for assistance. Preferred format for articles is plain ASCII text (OpenOffice or *Microsoft Word* is acceptable). Preferred graphic formats are PS/EPS/TIFF (diagrams, black and white photographs), or TIFF/JPEG/GIF (color photographs). Please submit graphics at a minimum of 300 DPI.

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