

# RFI Team Tool-kit Operation



**AMATEUR RADIO DIGITAL COMMUNICATIONS**



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## Introduction

This ARDC-funded kit is intended for use by ARRL division RFI Teams and should not be loaned out. With an appropriate antenna, the ICOM IC-705 hybrid SDR transceiver can be an effective RFI troubleshooting tool for your RFI team. This portable radio has a wide frequency range with spectrum-scope waterfall display, GPS location logging, audio scope, audio recording, screen capture and a speech synthesizer for visually impaired users. Best of all the radio is compact and is powered by a battery for portable use. The Icom backpack allows one to operate “pedestrian mobile” and have easy access to the radio’s controls using the top flap.

The capabilities of the IC-705, containing D-Star, GPS, Bluetooth and Wi-Fi functionality are far more than you will need to use as an RFI identification and location tool. This document and the training program you are participating in is designed to get you started helping your fellow hams as quickly as possible but the manuals should be referenced for full understanding.

This guide will prepare your team to help find RFI sources. However, this kit is not appropriate for VHF/UHF repeater interference issues. It is best to read the online RFI troubleshooting guide before using this guide.

## Team functions

Assist hams in their sections to locate and eliminate RFI sources.

Use the on-line RFI troubleshooting pages to record the findings of the team as additional information to that provided by the requesting ham. See: [Noise Report to RFI Team – ARRL New England Division](#). In more densely populated areas, one RFI source may account for the interference to multiple hams. Team leaders must have a Google account to access online forms.

Act as facilitators for individual section hams, the ARRL Lab and RFI generating parties like utilities when needed. One goal of the team should be developing and maintaining credibility with the utility. If the utility sees radio amateurs as knowledgeable and good to work with, the team will be viewed as helping to identify power line problems before they cause outages or other failure modes. Teams should understand when the utility isn’t being responsive and be willing to help with contacting the utility.

The Lab will often be involved when you determine that the RFI generating party is unresponsive or unable to respond or needs to redesign a product, like an LED or a solar generating system.

## Guide and Reporting

There are many sources of RFI, and our job is to determine the type and location of the source. RFI is often generated from some non-linear rectification process that causes noise at the fundamental frequency and harmonics of the fundamental that decay as frequency increases, a spark that generates RF on all frequencies or a device that modifies the AC waveform. Examples of the former are some power line faults, poorly filtered switching power supplies, solar energy system inverters, appliance power supplies and poorly designed LED's. Other sources are spark-related such as some power line faults, welding operations and brushes inside motors. Still others are caused by control systems that operate by controlling what portion of an AC signal is used to power a variable speed device. Some devices like dimmer switches and touch lamps can also cause RFI.

Review the report contained in the Google sheet that provides the results of the investigation already done by the amateur radio operator (ham) who has an issue (it is recommended that you obtain a Google ID and password.) You should expect that the main home circuit-breaker has been opened and the RFI still observed on a battery-powered receiver with no power in the residence or (much less frequently) that the RFI is coming from somewhere within the residence and the ham cannot locate it.

When the web-based [RFI troubleshooting guide](#) is exhausted and causes a ham to reach out to the local RFI team for help, the RFI kit can be brought to the ham's QTH and the RFI spectra captured for analysis by the team or the ARRL if required.

RFI that is observed at HF often has weaker harmonics seen at VHF. For that reason, finding RFI seen at HF outside the home is a two-step process:

Use a short antenna (with respect to the wavelength of the HF noise observed, such as a stick or short loop, (optionally amplified) to locate the vicinity of the RFI source. DO NOT use a resonant antenna as this will preferentially receive RFI signals at the resonant frequency and yield a false peak of the noise. Walking around to pinpoint or two people in a car is often effective.

Once in the vicinity, the VHF log-periodic antenna can be used to locate the weaker harmonics can more precisely locate the source.

Teams may ask to initially observe the RFI on the ham's own equipment and antenna. While this may be useful to confirm the ham's own observation and make the RFI more recognizable in the field, it should be noted that:

- The profile of RFI as a function of frequency may be skewed by the resonance of the ham's antenna.
- If the RFI isn't continuous, the RFI may not be present when the team visits. The team should plan their visit to coincide with the conditions that were observed and recorded in the report generated by the ham, prior to the team's visit.

The RFI Troubleshooting Guide has more information. **READ THE GUIDE** before starting to help.

In the much less frequent case that the RFI is coming from within the home, but the ham still cannot locate it, there may be battery-backed up devices that are not turning off when power is secured. This can usually be resolved with a phone call but may require a visit in rare cases.

In all cases, upload the spectra captured for the case to the Google drive, with file names: call sign – date - sequence, e.g., W1WBB-012123-1, W1WBB-012123-2, etc. These names would then be entered in the sheet for future reference. Include the latitude and longitude where the spectra were recorded.

Please use descriptive filenames (limit five files, 10 Mb/file)
---

W1WBB-012123-1, W1WBB-012123-2 latitude, longitude
--

The latitude, longitude, altitude can be displayed on the IC-705 screen by touching the GPS icon at the top of the screen and captured for later reference.

## RFI Tool-Kit Items

Icom LC-192 “multi-bag” backpack (note the plastic window for label. We should label these kits with something like “EAST-MASS-1”)

Icom IC-705 transceiver with Basic Manual

Icom HM-243 microphone (recommend you leave disconnected)

BP-272 7.2v 1880mAh battery standard

BP-307 7.2v 3050mAh high-capacity Battery option

OPC-2421 DC power cable with fuses and 2.5mm plug

SanDisk 32GB micro-SD card and adapter

DX Engineering DXE NOISELOOP antenna with DXE-NL-PRE-ATT1 preamp and instructions for assembly and use

ELK Log periodic antenna and carrying bag

6-foot 52-ohm coax cable with BNC connectors

Female BNC to male UHF adapter (for Elk VHF/UHF antenna)

## Initial System Setup Overview

We will refer to the IC-705 *Basic Manual* and *Advanced Manual* for this effort (see references below). You should have a working IC-705 with your choice of antenna and be familiar with the basic operation of the radio. The manuals are available for download on the ICOM web site using the links below. Transmission should be inhibited (Mic Gain to 0, RF Power to 0). The field exploration process may be more effective with an assistant.



Figure 1. Icom IC-705 transceiver

The basic equipment consists of an IC-705 160M – 440 MHz transceiver, a spare battery, the Icom backpack containing the transceiver and auxiliary equipment, a DX Engineering HF loop and preamplifier and an Elk Antenna 2M/440 antenna. Connecting cables, a 32 GB micro HCSD card for the transceiver, a BNC/UHF adapter for the Elk antenna and a 9V battery for the preamplifier are also supplied. Use of the power key for screen capture is discussed in the IC-705 Basic Manual on page 8-7 and in the IC-705 Advanced Manual on page 9-6.

## General Menu and Touch-screen Operation

The IC-705 has a set menu system and a function menu system. The set menu system allows radio configuration that isn't expected to change with operating conditions. The function menu system permits changes to radio operation that may reflect operating conditions, e.g. AGC response selection and pre-amplifier on-off with a momentary touch. There is also a multi-function control that, when depressed, permits power changes, compression levels and microphone gain, depending on the mode selected by touching and changing the displayed value. The multi-function control also changes the value of many function controls when depressed for more than a second. In general, momentary touches turn functions on and off and depressing function buttons for more than a second allows adjusting the function response.

The touch screen also permits band changes by touching the left of the displayed frequency, shifting between memory and VFO modes by touching the screen icon and displaying GPS information by touching the GPS icon.

## Micro-SD-Card Operation

The installed micro-SD card can store data such as GPS coordinates, screen-captures, audio, and the radio's settings. The SD card is formatted in the FAT-32 file-system with a single partition and a root "IC-705" folder (Fig. 2), wherein all data is contained in thirteen sub-folders (Fig. 3).

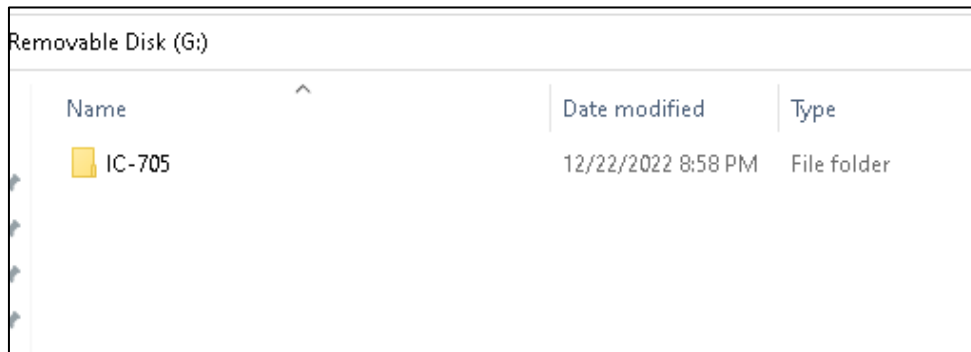


Figure 2. Micro-SD card root level

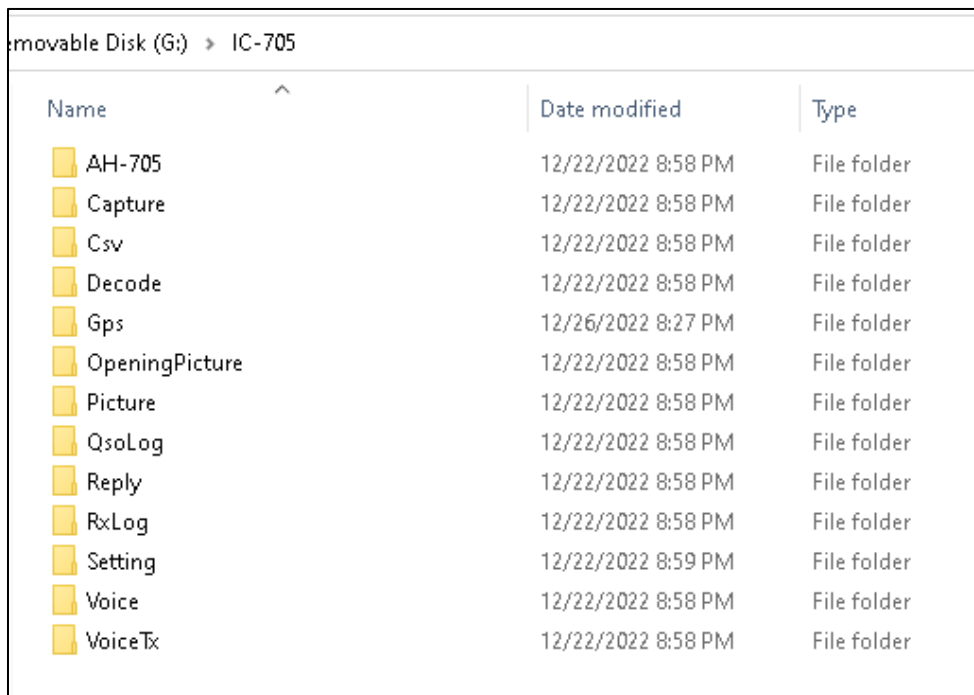


Figure 3. The sub-folders on the SD card

Of interest are the Capture, Gps and Setting folders. When transferring the micro-SD card to a computer for offloading of data, after pressing the SD-card, it is helpful to use a pair of needle-nose pliers or tweezers to extract the micro-SD card from the radio's memory slot. The included

micro to standard SD card adapter may be needed for insertion into a computer. See the Advanced Manual Page 4-6 for further SD-card operation.

## GPS coordinate information

The IC-705 records GPS data in a comma delimited text file with the date as a filename, e.g., *20221222\_205842.txt*. In this file are multiple entries in NMEA standard format such as:

```
$GPRMC,015941.00,A,4142.9756,N,07012.9844,W,0.5,71.4,231222,14.5,W,A*33
```

See Advanced Manual Page 12-31 for explanation.

Coordinate format: Latitude 00'.00.00'N, Longitude 000'.00.00'E, Altitude 00 feet. To save your current position, push Quick, the Add to GPS memory. See Advanced Manual section 12 for further information. GPS Logger information starts on Page 12-28.

## Capturing data to the SD-card

Noting the specific parameters of the spectral recoding, e.g., IC-705 settings when recorded will help in reproducing the same settings for analyzing new cases. Section 3 of the IC-705 Advanced Manual lists the specific settings available. Section 4 of the IC-705 Advanced Manual describes the folder structure in the memory card. Captured screen data is contained in the "capture" folder.

The setup dialogue permits the momentary pressing of the power button to function as a screen capture button. This will be the default setting.

Once the radio is properly set-up, we can proceed to detect unwanted noise. In this document, we will search for power line noise, non-power-line sources and examine antenna techniques.

## Initial IC-705 Setup Configuration

The IC-705 when delivered to the teams will be setup with power out set to zero on all bands and the low-end frequencies for each band stored in memory in the AM mode with the preamp on above 20 meters. The power button will be set up to capture the screen contents when depressed momentarily. Battery charging will be set up to charge the battery when the IC-705 is connected to a power supply. **WARNING!** If connecting to a power supply the white striped lead is positive and the solid black lead negative. The leads are marked with a small + and - but they are hard to read. The setup menu permits the storage of many frequencies and modes that can be selected in groups, e.g. by mode or by frequency range. Two batteries are supplied and replacing them will display a menu that permits selecting the correct battery. When replacing a battery, always insert the bottom first and check that the latches at the top of the battery are engaged.



## IC-705 Scanning Operation

Press the Memo/VFO icon to the right of the frequency display until in the Memo mode. Once scanning groups are set up, scanning with a dwell that enables capture at sequential frequencies is accomplished with the scan button just to the left of the main tuning knob. Selecting all memory scan or scanning within a group determines the particular frequencies that are swept. The VFO/Break-in key has been configured to switch between VFO and memory modes.

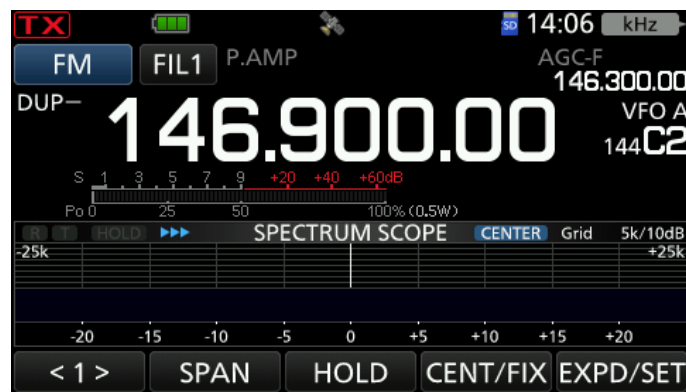


Figure 4. An IC-705 screen capture

## Power-Line noise

Power line interference has a few common signatures. The procedure to capture scope screens is contained in ICOM IC-705 *Advanced Manual* page 9-6. The SD card file system description is contained on page 4-6. The file system on the 32 GB SD card can record scan images as well as any scan information, band edges, receive audio capture files, transmit audio files, GPS location data, etc. Power line noise is typically seen as a set of interference bands spaced eight milli-seconds (120 Hz) apart representing the peaks of a 60 Hz AC signal. Power line noise is rarely generated by less than a few thousand-volt systems so 220–240-volt lines downstream of pole transformers are not usually RFI sources.

For power-line noise, listening to the noise on an open frequency range above the AM broadcast band such as 1750KHz can be helpful. Once located and recorded, the utility company should be contacted by the reporting ham and a case number obtained and forwarded to the team.

160M reception: Set the radio to VFO mode, the frequency above the AM broadcast band to around 1.750MHz.

Use a receiving loop or other directional antenna.

Set the preamp or attenuator for a signal below S9. Make sure OVF (overflow) is never indicated on the radio.

Set the IF bandwidth to a wider setting (6 or 9 KHz) with soft shape factor so that the noise is most easily heard.

Make sure the noise blanker and noise reduction are off.

Set the spectrum scope to Center mode and set the span to 50KHz. Optionally, the audio scope can also be turned on.

If the noise level is strong, switch in the receive antenna attenuator to reduce the level to below S9. The log-periodic VHF/UHF antenna can be rotated to take advantage of polarization effects to attenuate the noise as well.

Mark the direction, then relocate the test system and again mark the direction. Do this at (least) a third location to triangulate the source.

Often power-line noise can be located to a particular utility pole. Once a pole where the RFI is coming from is located, that should be reported to the utility and a case number determined. Identify the pole by location (e.g., GPS coordinates, intersection, or street address, as well as ID number. Note that the power lines are not the only potential generators on a power pole, and often have a different signature. Leaky cable lines are an example of another service that may cause RFI from a power pole, but the power company will deal with other utilities if needed. If the noise is not power related, different signatures should be sought. Note that weather can also be a factor – wind can cause intermittent sources and rain can fill in gaps that are noisy when dry.

## Non-Power Line RFI Sources

The techniques for identifying these sources are the same as for the power line situation but do not involve utilities. These sources can be poorly designed RFI generators either in a neighbor's home or in a nearby business. Spectral recordings are especially important as they can provide important clues regarding the nature of the RFI, especially if the type of spectra has been previously documented.

Pay particular attention to the frequency spacing of the RFI, as this is often an important clue. Also note the change in amplitude of the RFI with frequency and at what frequency it is first observed. The HF loop is particularly effective for this search as it is short with respect to HF wavelengths. This eliminates any resonant antenna effects that distort the observations, as can happen with longer antennas in use by hams.

## The loop antenna

In the kit is a DX Engineering DXE-NOISELOOP terminated flag receiving antenna (designed by Don WD8DSB) with preamp. Loop antennas are useful for finding the general vicinity of an RFI source, as they are electrically short relative to a noisy HF wavelength and therefore unaffected by resonance effects and are useful for hunting. This loop covers 1.8-30MHz and has a cardioid pattern with a 30dB null in the rear direction (See fig. 5). The front of the antenna is the direction of the balun transformer. The terminating resistor is in the rear and will provide a deep null. Also available for use is the optional preamp.

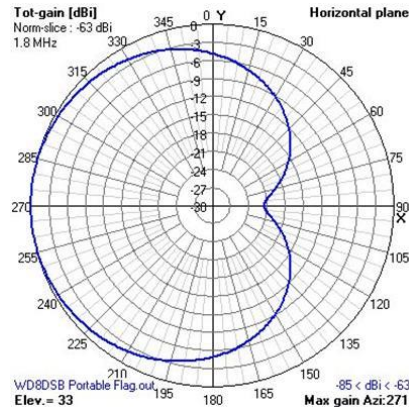


Figure 5. NOISELOOP pattern. The null is in the direction of the terminating resistor.

The included DXE-NL-PRE-ATT1 loop preamplifier covers 100KHz to 30MHz with an average gain of 30dB, a noise figure of 4.5dB and is operated from an internal 9V battery. In the field we found that the preamp was most effective below 14MHz. Attenuation of 10-30dB is available by switch selection, as is an AM broadcast band filter. **WARNING! Leave the transmitter power set to zero and do not transmit into the antenna or preamp. It will damage them!**



Figure 6. DXE-NL-PRE-ATT1 receiving preamp for NOISELOOP

## Loop techniques

Once the loop, preamplifier and IC-705 are operational, establish the general direction of strongest signal by searching for a null of the noise that is more precise than searching for a signal peak. The RFI source will be in the direction of the null. You may have to walk or ride around to find a null. Once the first null is found, make additional measurements with a large a baseline as practical. A map for creating intersecting lines and/or a GPS may be useful (a GPS is built into the IC-705). Once the RFI source vicinity is determined, it is time to use the weaker VHF harmonics to locate the source more precisely. Before looking for noise it is advantageous to look at AM broadcast-band signals, especially if you know the direction of the transmitter. With an AM-station, a null is easily seen, whereas power-line noise can be emitting from multiple locations. When close to a noise signal, use the preamplifier attenuator to improve the response.

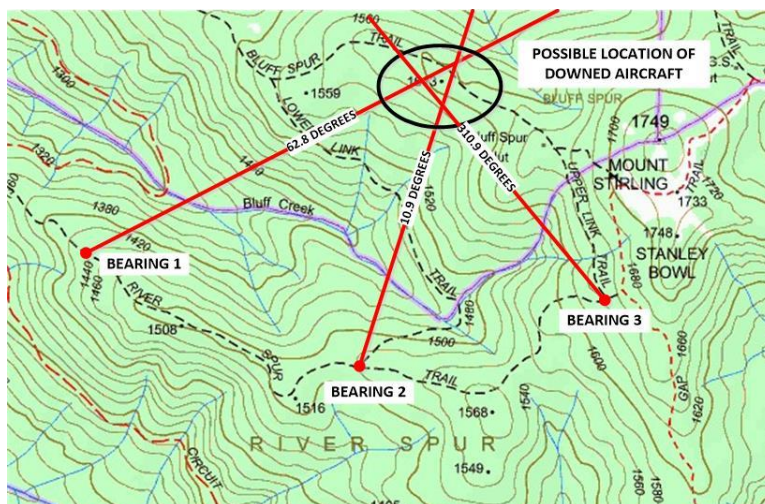


Figure 7. A triangulation map (from <https://www.sarcnet.org/amateur-radio-direction-finding.html>)

## VHF/UHF antenna techniques

Supplied in the kit is an ELK 2M/440L5 dual-band log-periodic antenna (Fig. 8). The antenna is delivered partially disassembled in a carrying case. Element assembly on the boom using the color-coded boom and elements is a matter of a few minutes. The antenna uses one SO-239 connector for both vhf and uhf and is directional towards the end of the antenna containing the coax fitting. The included adapter will be needed to adapt from the BNC connector on the supplied RG-58 coaxial cable to the SO-239 socket on the antenna. This antenna is resonant at 144 and 440MHz, but has wide-range reception. The ELK 2M/440L5 has 8.7dBi gain on 2M and 9dBi on 440MHz.

For certain types of interference, it may be easier to listen for the offending noise at VHF. Here the Aircraft band (108-137MHz) can be used as many receivers (including the IC-705) will receive the AM mode on this frequency range, making detection of noise easier. The included hand-held log-periodic antenna can be used here.

Jim W6LK, the designer of the antenna notes:

*The beam-width of the Elk 2M/440L5 is 70 degrees (35 degrees per side). The front lobe is a teardrop shape and works in both horizontal and vertical polarization. There is a much smaller lobe from the rear. It will not produce the same gain from the back, but it is not deaf either. I recommend pointing the Elk towards really distant or challenging stations to work, and use the rear to pick up closer in stations. You will find a null at 90 degrees on the antenna. This can be useful for direction finding - especially when you are close to your source target. The front to back ratio of the Elk 2M/440L5 is 20 dB. (From email 2022-January 6)*

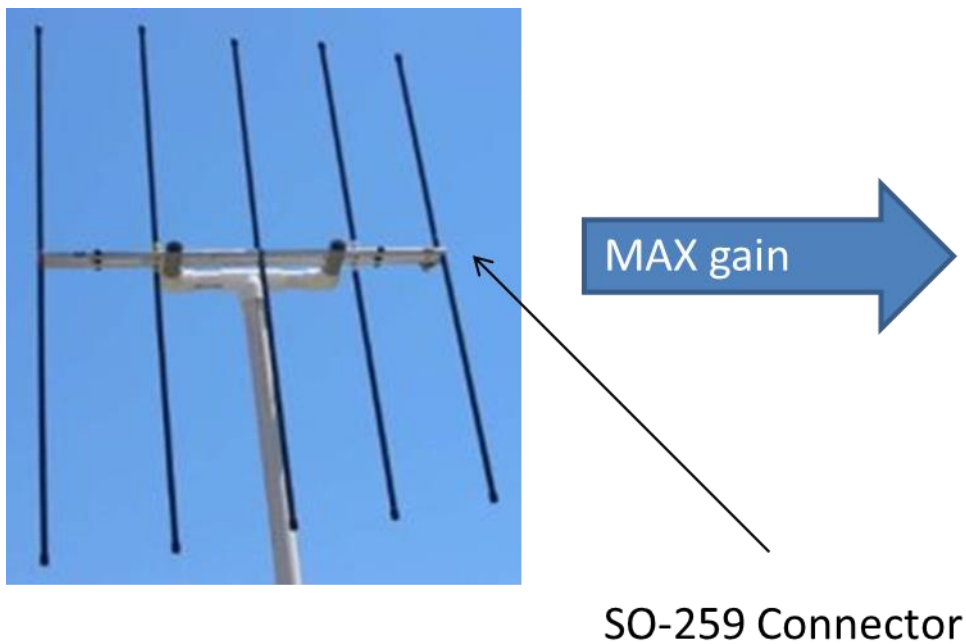


Figure 8. ELK 2M/440L5 antenna

Set the receiver to VFO mode, set to 136MHz and AM mode

Near the noise source as determined using the HF loop, note the direction of the loudest signal and the null.

Repeat at least three times from different directions with the longest possible baseline (but close enough that the signal is still detectable) to triangulate.

## GPS logging

See Basic Manual Section 7 (Page 52) for use of this feature. Recording the GPS position for recorded spectra will make the work of locating the signal easier. This information will become part of the RFI data stored for later reference by other teams.

## Audio recording

See Advanced Manual Section 5 (Page 42) for use of this feature. Recording the audio sound of the RFI will help in diagnosing its source. This information will become part of the RFI data stored for later reference by other teams.

## Spectrum Scope Operation

See the Basic Manual (Pages 5-2) and the Advanced Manual Section 3 (Page 2-3 through 3-7) for use of this feature. Recording the spectrum of the RFI will help in diagnosing its source. This information will also become part of the RFI data available for later reference by other teams. There are three modes, Center, Fixed and Scroll. Scroll, that follows frequency may be most useful at first, then the other modes may prove useful for a more detailed investigation. Momentarily depressing the Power button will capture the screen (in .PNG format) and the GPS screen can then be captured to identify the location the spectrum was observed.

## Use of Radar Engineers Equipment

The Radar Engineers Model 243 includes both an amplified loop stick (for HF) and a 10-element VHF Yagi. The Model 243 is specifically designed to detect low-level power line noise. This is a professional tool available for loan from the New England Division. The older model 240, available on loan from the ARRL Lab, is of similar design. These will be useful when the RFI is coming from a power line fault, based on its spectral signature, but is too weak to be located otherwise.

## Stowing away the kit

Upon completion of a search, please clean, test and verify that all kit items are once again in the kit, and that the batteries are charged ready for the next deployment. Make sure your team lead

has the equipment. If the loop antenna preamp 9V battery needs to be replaced, let the team lead know.

## Appendix 1, Icom IC-705 addenda

1. IC-705 current draw: 300ma in standby, 500ma receive. Estimated battery life: probably 7 hours 39 minutes for receive with BP-272 battery:  
(<https://swling.com/blog/2020/10/icom-ic-705-lets-see-how-long-itll-receive-with-supplied-bp-272-li-ion-battery-pack/>).
2. There are ways to extend the battery life by turning off features you may not need such as Bluetooth and GPS.
3. The clips at the top of the battery need to be moved into the locked position manually, depending on the battery. If the clips aren't in position properly, the charge light doesn't come on.
4. OPC-2421 DC power cable's white stripe is +12VDC. The 2.5mm plug's tip is positive. OBSERVE POLARITY! This cable can be connected to a regulated 12V-13.8VDC power supply to charge a battery through the radio.

## Appendix 2. IC-705 Basic Settings

Function:

Preamp: on

AGC: slow (can be set to off by holding, then configuring fast, med or slow response to zero.)

Notch: off

NB: off

NR: off

Split: off

Vox: off

Tone: off

Moni: off

Dup: 0.600

Screen capture file type: PNG

Screen capture power switch: ON

Max TX PWR (batt): 5W (preset to zero on all bands. **This should remain at 0 at all times, for safety.**)

The VOX/break-in front panel button has been configured to switch between VFO and memory modes.

The Autotune front panel button has been configured to skip selected frequencies when scanning.

## SET

Bluetooth: off

WLAN: Off

IC-705 configuration and frequencies in memory have been saved to the micro HDSC card. If changes to the frequencies or configuration are necessary, the **starting** configuration can be restored by loading this file from the MENU-SET-SDCARD-LOAD sequence. **Do not overwrite the file provided. If you wish to store another configuration, do so with a different name.**

## Appendix 3. CS-705 Icom Software

Windows software to program the IC-705 is available from Icom free of charge at [CS-705 | Firmware / Software | Support | Icom Inc. \(icomjapan.com\)](#). The Icom drivers must also be downloaded from the Icom website at ([IC-705/ID-52A/ID-52E | Firmware / Software | Support | Icom Inc. \(icomjapan.com\)](#)). The CS-705 software version used must be compatible with the firmware in use on the IC-705, currently version 1.26. The latest version of the software is compatible with version 1.3 so the older software version is downloaded until the firmware is upgraded. The software creates configuration files that can be shared between users via email. The software is especially useful for defining scan groups and their member frequencies, mode and filter settings. Call frequencies can also be programmed, together with mode and filter settings. A micro-USB to USB-A cable is required to connect the IC-705 to a PC. The IC-705 battery is also charging when connected with the PC on.

## Resources

ARDC: <https://www.ampr.org/>

NEDIV ARRL RFI Troubleshooting Guide: <https://nediv.arrl.org/rfi-troubleshooting-guide/>

NEDIV RFI Toolkit: <https://nediv.arrl.org/rfi-team-toolkit/>

NEDIV Antenna Suggestions: <https://nediv.arrl.org/equipment-you-can-buy-or-build/>

ICOM-IC-705 Basic Manual: <https://www.icomjapan.com/support/manual/3060/>

ICOM IC-705 Advanced Manual: <https://www.icomjapan.com/support/manual/3063/>



DXE NOISELOOP: <https://www.dxengineering.com/parts/dxe-noise-loop#overview>

Noise-loop QST article: [https://static.dxengineering.com/global/images/technicalarticles/dxe-noise-loop\\_ct.pdf?gl=1\\*13mx58i\\*ga\\*ODQwNjA4NTM2LjE2NzI2OTMwNjA.\\*ga\\_NZB590FMHY\\*MTY3MjY5MzA2MC4xLjAuMTY3MjY5MzA2MC42MC4wLjA](https://static.dxengineering.com/global/images/technicalarticles/dxe-noise-loop_ct.pdf?gl=1*13mx58i*ga*ODQwNjA4NTM2LjE2NzI2OTMwNjA.*ga_NZB590FMHY*MTY3MjY5MzA2MC4xLjAuMTY3MjY5MzA2MC42MC4wLjA).

Noise-loop YouTube video: <https://www.youtube.com/watch?v=yIWY2KwoZ8w>

DXE-NL-PRE-ATT1 Preamp: <https://www.dxengineering.com/parts/dxe-nl-pre-att-1?rrec=true>

ELK 2M/440L5 antenna: <https://elkantennas.com/>

Rev 9

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