USER MANUAL

KrakenSDR is a 5-channel coherent RTL-SDR system. With a coherent RTL-SDR, you can expect to set up interesting applications such as direction finding, passive radar and beamforming. It can also be used as five individual radio systems.

This manual explains the device, safety information, its design and provides some information on its operation.

To get the most out of your KrakenSDR, do the following 3 things first:

1. Create an account on the official KrakenRF forum: https://forum.krakenrf.com
2. Register your KrakenSDR to use Kraken Cloud (for free): https://map.krakenrf.com
3. Read the latest documentation on the wiki: https://wiki.krakenrf.com

SAFETY AND ENVIRONMENT

DANGERS

Before using your KrakenSDR, please read these safety instructions.

Electric shock: You can be INJURED OR KILLED if live wires touch an antenna connected to a KrakenSDR. When using external antennas, always keep them away from power lines and other live wires.

EM leakage: The KrakenSDR CANNOT TRANSMIT, but it does contain an internal broadband noise source which is used for phase calibration. Although this noise source is low-power, isolated from the antennas by a high-isolation silicon switch and enclosed in a metal Faraday cage, there may be small amounts of broadband EM leakage that could interfere with very sensitive radio equipment. These leakages have been measured and are well below regulatory compliance thresholds. However, if you remove the housing or modify it for any reason, leakage from the noise source may increase beyond compliance thresholds.

Housing temperature: The KrakenSDR's metal housing can become hot to the touch during operation.

Cooling fan blades : The KrakenSDR contains a cooling fan on the case that operates at high speed. There is finger protection, but small fingers and debris can touch the fan blades. Take care when handling, and always ensure that the fan area is clear of debris before powering up.

Driving hazards: The KrakenSDR can be used in a vehicle for direction-finding. Always pay attention to the road when using the device in a vehicle and when a passenger is performing navigation tasks. Always make sure that antennas on the roof of your vehicle are securely fastened and comply with local laws.

Conflict/war zones or use in or near sensitive areas: Any radio receiver used in conflict or war zones, or near sensitive areas, may not be viewed favorably by the authorities. Use of the KrakenSDR in such areas should be considered with extreme caution.

RECYCLING

The KrakenSDR complies with the RoHs directive and the CE RED standard. The KrakenSDR contains a PCB and electronic components, please do not throw it away. If you need to dispose of a KrakenSDR, please drop it off at an e-waste recycling facility or return it to KrakenRF Inc.

AVOID DAMAGING YOUR KRAKENSDR

NEARBY TRANSMITTERS

The KrakenSDR is a sensitive radio receiver. Like most radio receivers**, all antennas connected to the KrakenSDR MUST be kept away from powerful transmitters in the vicinity**.

The maximum input power allowed at the SMA port is +10dBm. Please take external measures to block or limit if you know you will be working near powerful transmitters. No warranty claims will be accepted in this case.

LIGHTNING DAMAGE

For protection, the KrakenSDR uses ESD diodes, discharge tubes and diode clipping protection.

However, it will not withstand direct or near-field lightning, nor any significant electrostatic discharges caused by events such as snow and dust storms.

Therefore, we suggest that any antenna connected outdoors MUST be protected against lightning and electrostatic discharge (ESD).

OPERATING ENVIRONMENT

The KrakenSDR has been tested to operate in ambient environments up to 50C. However, for best performance, we recommend using it in a cool environment.

THE KRAKENSDR

Material supplied in the package(s) :

1. 1x KrakenSDR
2. (ANTENNA OPTION)
    a. 5x Magnetic whip antennas
    b. 5x SMA Tee's
    c. 5x 2m LMR100 cable approx.

Materials to be supplied :

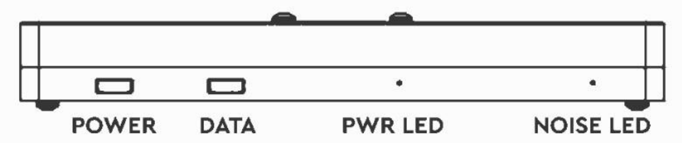
1. Hardware such as at least a Raspberry Pi 4, a Linux Single Board Computer or a Linux PC.
2. A 5 V, 2.4 A USB-C power supply. If you intend to use devices connected to polarizing tees, we recommend a power supply capable of delivering 3A. The official Raspberry Pi USB-C power supply is a good choice.
3. USB-C to USB-A data cable. For connecting data ports to your Raspberry Pi 4, Linux single-board computer or Linux PC.
4. Antennas.
    a. A set of five identical antennas for use with the direction-finding software.
    b. Two directional Yagi antennas for use with passive radar software.

TECHNICAL SPECIFICATIONS

Dimensions: L: 177mm x W: 112.3mm x H: 25.86mm (+4.7mm height for fan finger protection)
Weight: 670g
Typical power consumption: 5v, 2.2A (11W)
Radio tuner: 5x R820T2
Radio ADC: 5x RTL2832U
ADC: 8 bits
Frequency range: 24 MHz -1766 GHz - Nominal from 100 to 1000MHz
Bandwidth: 2.56 MHz

RX ports: 5 SMA female
Oscillator stability: 1PPM

KRAKENSDR



KRAKENSDR POWER PORT

The KrakenSDR requires a 5V 2.4A USB-C power supply. It is also compatible with the "PD" type USB-C power supplies found in notebook computers.

Cigarette-lighter USB adapters are available for use in vehicles. Make sure they support an output of at least 5V 2.4A. Batteries can also be used, provided they support an output current of 2.4 A or more.

Note Bias-T: The KrakenSDR consumes 2.2A in nominal operation. If you intend to use the BIAS-T function to power external devices, make sure you use a power supply capable of delivering the required power. For example, if you use a 3A power supply, you'll have a current margin of around 800 mA.

Note that the KrakenSDR has no power connection on the data port.

KRAKENSDR DATA PORT

The KrakenSDR requires a USB-C cable to connect the hardware to the data port. Please note that this cable is not connected to the power supply, so you cannot power the device from the data cable. You must use the data cable AND the power cable together.

Be sure to use a high-quality USB-C cable.

KRAKENSDR COOLING

The KrakenSDR is cooled by fins and a fan. Inside, the PCB is thermally connected to the cooled case via a thermally conductive silicone.

KrakenSDR has been tested to operate normally at ambient temperatures up to 50° C.

We recommend keeping your KrakenSDR out of direct sunlight and in a well-ventilated place.

Sudden, large temperature variations can lead to loss of calibration and phase consistency. See below for information on periodic automatic software recalibration.

SMA PORTS

The KrakenSDR has 5 SMA RX IN ports for connecting antennas labeled CH0 to CH4.

TEE BIAS

The KrakenSDR can provide a 4.5V output via a bias tee on each of its SMA ports. This can be used to power external RF components such as LNAs. As mentioned above, your power supply will need to be capable of supplying sufficient current to power external devices.

STATUS INDICATORS

The KrakenSDR features peepholes for several status indicators.

PWR LED: When lit, the white PWR LED to the right of the two USB-C ports indicates that the KrakenSDR is powered by the USB-C POWER port.

NOISE LED: If lit, the white NOISE LED to the right of the PWR LED indicates that the KrakenSDR noise source is active. This LED may flash briefly every few minutes during software execution if automatic calibration/recalibration monitoring is enabled.

CHANNEL LEDS: Five blue channel LEDs are located next to each SMA port. If lit, these LEDs indicate that the channel tuner has been identified by the computing device. They do not indicate whether the drivers are installed or whether the DSP software has connected to the tuners.

KRAKENSDR DESIGN

The coherent design of KrakenSDR consists of

- 5x RTL-SDR tuners (with R820T and RTL2832U)
- 1x single clock source for all RTL-SDRs
- 1x noise source
- 5x antenna port switches
- 1x USB hub

The KrakenSDR is not a naturally coherent system by virtue of its hardware alone, but the design with a single clock source and a noise source with switches allows coherence to be achieved in software through cross-correlation algorithms.

When the software starts up, the noise source is activated and each channel is correlated with the master channel (CH0 by default). All sample timing and phase differences are recorded, and each sample is adjusted in the software.

DIRECTION FINDING

For the latest software updates, we recommend you follow the online software installation guides at www.krakenrf.com.

QUICK START WITH THE ANDROID APP

This quick start guide is designed to help you connect to the Direction Finding Android application as quickly as possible.

However, be sure to read the rest of the manual to understand how direction-finding works.

The first step is to copy the KrakenSDR Direction Finding image to an SD card.

1. Using a PC, download the "Etcher" software from balena.io/etcher
2. Download the latest KrkeanSDR DF Image zip file from krakenrf.com
3. Use Etcher to copy to SD card
4. Insert the SD card into your Raspberry Pi 4 or PI 5.

The following steps show how to run the software and connect to the application.

1. Create a WiFi hotspot with your Android device using a krakensdr/krakensdr username and password.
2. Connect your KrakenSDR's power port to a 5V 2.4A power supply, and connect the data port to at least the Raspberry Pi 4.
3. Boot the Raspberry Pi 4 with the KrakenSDR DFing SD card image. Once booted, if the KrakenSDR is detected, the Pi 4 will automatically connect to the hotspot.
4. Via your phone settings, determine the IP address of the connected Raspberry Pi 4 or 5.
5. Open a browser and connect to IP_ADDR:8080
6. Start the KrakenSDR by pressing the 'Start' button
7. Set the desired frequency, antenna configuration and other parameters for the specific signal you're interested in.
8. Open the Android application and enter the RPi's IP address in the settings.
9. Create a log file by pressing the save button.
10. Press the Start DOA button to start recording data and generating the heat map.
11. Drive with your KrakenSDR, either by using the navigation function integrated into the Android app, or by asking your navigator to direct you so that you move in the direction of the bearing.

Otherwise, if you don't create a WiFi access point with your phone :

1. Connect your KrakenSDR's power port to a 5V 2.4A power supply and plug the data port into the Raspberry Pi 4 or 5.
2. Boot the Raspberry Pi 4 with the KrakenSDR DFing SD card image. The Pi 4 will create its own WiFi hotspot.
3. Open the KrakenSDR Android app and use the offline map download function to download maps of the area you'll be working in.
4. Connect to the krakensdr WiFi hotspot on your Android device.
5. In your Android WiFi settings, find the Pi 4's IP address.
6. Enter the IP address in the KrakenSDR Android application settings.
7. You can now repeat steps 5 and following from the previous list.

ORIENTATION RESEARCH CONTEXT

In a direction-finding operation, the aim is to determine the exact location of an RF transmitter. This could be an illegal or interfering transmitter, a fox-hunting beacon, an asset locator, a domestic or wild animal beacon, a search and rescue beacon, or perhaps just a curious unknown signal.

To locate a transmitter, a bearing to the transmitter must be determined from several locations using direction-finding equipment. The bearings are then plotted, and their intersection corresponds to the estimated location of the transmitter.

However, direction finding still has several degrees of inaccuracy when it comes to rolling noise, and results are often poor due to a phenomenon known as multipath. Multipath occurs when the signal can reflect off certain objects such as terrain, buildings or vehicles, and the direction-finding system can "see" this reflection as the source.

This can either distort the bearing relative to the actual source, or provide a totally erroneous reading. The worst case is when the signal source is not in direct view of the antennas, so that only reflections are visible.

Consequently, if we carry out a single survey at a location where the effect of multipath is significant due to the absence of line-of-sight, we risk arriving at an erroneous conclusion as to the direction of the signal source. Therefore, to obtain an accurate location, we need to take several readings at several locations to compensate for incorrect or distorted readings due to the effect of multipath propagation. This can be achieved by having several distributed sites with one KrakenSDR and an antenna array at each site, or by moving a single KrakenSDR onto a vehicle and taking multiple readings.

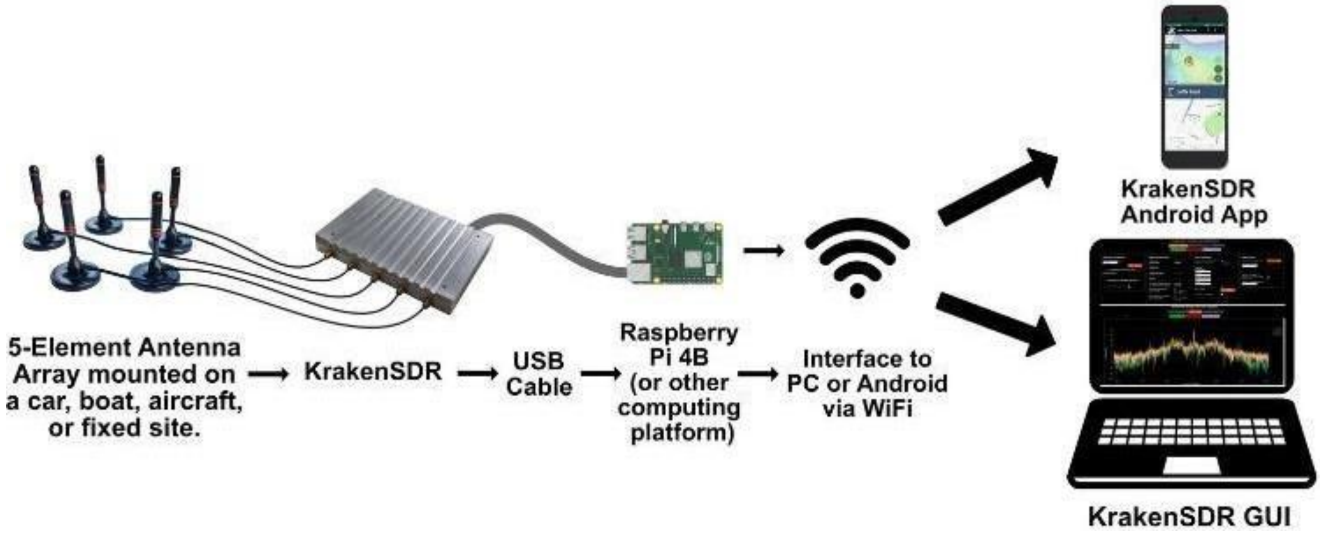
THEORY OF MOBILE VEHICLE OPERATION

In many simple direction-finding systems, the user has to drive to different locations, take a manual reading and plot this bearing on a map. With the KrakenSDR system, we use modern smartphone technologies, such as mapping, GPS and compass sensors, to take hundreds of readings automatically.

The system records the KrakenSDR's bearings with the current position as the vehicle moves. Over time, the system generates an average intersection of these readings, essentially locating the transmitter. We use the MapBox mapping service for smartphones to display this data on a constantly updated map.

Advanced: The KrakenSDR application does something a little smarter than calculating simple bearing line intersections. It uses the 360 degrees of data provided by the correlative interferometry system.

These 360 degrees of data also include multipath data. It then superimposes this data on a grid, activating each cell on which the bearing data lies. Over time, the cell with the highest number of activations is considered the transmitter location.



KRAKENSDR DOA WEB INTERFACE

INTERFACE

Configuration: The configuration page contains all the parameters for modifying center frequency and gain, and for adjusting DoA parameters such as network size and algorithm type.

Spectrum : The spectrum page displays an RF spectrum and a cascade graph of the currently tuned frequency.

DOA estimate: The DOA estimate page displays a graph of data relating to the currently estimated direction of arrival.

PARAMETER CONFIGURATION PAGE

Center frequency: The frequency at the center of the active bandwidth.

Receiver gain: The gain setting for all 5 tuners. Check SNR in the spectrum plot screen and adjust gain to achieve high SNR and avoid spectrum overload.

Any changes to the receiver's center frequency or gain are only applied when the "Update Receiver Parameters" button is pressed.

Antenna configuration: Choose the type of antenna array you are using, either a linear "ULA" or circular "UCA" antenna configuration.

Antenna radius/Element spacing : Define array size here (in meters)

Wavelength multiplier: Indicates the spacing multiplier as a function of frequency and network size.

Activate DoA estimation: Activate direction-finding algorithms

DoA algorithm: Choose between different direction-finding algorithms. In most cases, you'll want to use MUSIC.

Activate F-B averaging: When using a linear ULA network, this function can be activated to improve direction-finding performance.

DoA graph type: Choose between linear, polar or compass graphs for displaying DoA readings. If you use the compass graph, you can define a compass offset to compensate for the orientation of your network.

BASIC DAQ PARAMETERS

The DAQ code can also be controlled via the web interface. However, we recommend that only experienced users modify the DAQ settings.

Preconfigured DAQ files: Choose a DAQ file configuration from a preset.

Data block length: integrated time for each block processed. Larger blocks mean greater processing gains, at the expense of slower update rates.

Decimated bandwidth: system bandwidth after decimation. Decimation may be necessary to keep the update rate fast enough for intermittent signals.

Recalibration interval: number of minutes the system waits before checking consistency calibration and recalibrating if calibration has been lost for any reason.

Advanced DAQ parameters are not described here. For these parameters, please refer to the code's technical documentation.

Any changes to the basic or advanced DAQ parameters can be applied by pressing the "Reconfigure and restart DAQ chain" button. This restart process may take a few minutes.

THE ANDROID APPLICATION KRAKENSDR

The KrakenSDR Android application can be downloaded from Google Play. Just search for "KrakenSDR".

The app is free and can be installed on any modern Android device with an internet connection and GPS. We recommend that you install a phone or tablet holder for your vehicle, so that you can view the map without compromising driving safety.

The Android app receives bearing data from the KrakenSDR software via WiFi. We use the Android device's built-in GPS and compass sensors to determine our true direction of movement, then the app calculates the actual bearing to the transmitter. The actual bearing is then plotted on a map from the current GPS position.

MAIN MAP SCREEN BUTTONS

RIGHT EDGE BUTTONS

Save: Create a log file to record bearing and GPS tracking data. If you have recorded data without first creating a file and press save, a log file will be created with temporary data saved.

Load: Load a previously saved log file.

Close: Close any open log files or reset temporary data.

Navigation: Start turn-by-turn navigation.

Start recording: Connect to KrakenSDR and start recording data.

Center location: centers the map on the current GPS position.

TOP BAR BUTTONS Magnifier: Find a location

Download: Download maps of the currently zoomed-in area

SETTINGS PAGE

Server address: The IP address or host name of the KrakenSDR server (the Pi 4 or the computer running the KrakenSDR software).

Interrupt data collection: If you're using GPS bearing mode, you can interrupt data collection when you're stationary to avoid obtaining incorrect vehicle bearing results.

Logging Period: Frequency with which the application polls the KrakenSDR server for data. Faster polling may give better results, but may result in very large log files if the total number of data is less than or equal to 1,000. Logging time is long. There is no point in polluting faster than the KrakenSDR server software update rate.

Skip each X point: Skip all X recording points. Useful if your Android device is a bit slow and has trouble plotting many points.

Minimum confidence required: The confidence value is an estimate of the "quality" of a bearing result. Trial and error with this value can help reduce data size by discarding the poorest results. But it is generally not necessary.

Minimum power requirement: Values below a certain power level are not taken into account.

Total grid size: total distance of the direction-finding grid

Number of grids per axis: defines the size of each grid cell. A greater number of grids per axis results in smaller grids and better resolution. At the expense of computation time.

Grid estimation mode: You can choose to use the full 360 degrees of data supplied by KrakenSDR with the grid system, to use a single bearing for maximum bearing with the grid system, or to use a single bearing with an intersection calculation algorithm. In general, the full 360-degree method gives the best results.

Track length: length of bearing tracks displayed on the map.

Use Kalman filter for displayed bearing: Direction finding is a noisy process, and the bearing can jump around a lot, which can be difficult for a human being to follow. Here you can activate Kalman filtering, which will eliminate bearing line noise.

Map settings: Choose between a road map and a satellite map.

Camera mode: Choose between free mode and automatic mode. Free mode allows the user to manually position the map camera. The automatic camera automatically follows the vehicle's location.

Zoom mode: Choose between free zoom mode and automatic zoom mode. The free zoom mode allows you to zoom in manually. The automatic camera automatically zooms in on the active area between the vehicle's location and the estimated location.

Bearing Mode: The mapping system uses either the GPS sensor or the compass to determine the direction of movement. In general, the GPS sensor is the most accurate, as long as the device is in motion. If compass mode is used, you'll need to pay attention to the direction in which the Android device is pointing. For fixed sites, the antenna array, forward bearing and coordinates can also be set manually.

Speedometer units: Choose between metric and imperial speed units, or deactivate the speedometer.

Antenna array type: Define in the application the type of antenna array used by the direction-finding system.

Linear network layout direction: If you're using a linear network, decide whether you want to layout the bearings in the forward or reverse direction, or both.

Counter-clockwise antenna: the standard convention is to arrange antennas in clockwise order. If you have arranged them counter-clockwise, select this option to invert the network in the software.

ANTENNA CONFIGURATION

For standard direction finding, you'll need five identical omnidirectional antennas. (You can use fewer antennas, but for best performance we recommend all five). These are usually magnetic-mounted whip antennas or dipoles.

Note that when mounting antennas, the convention is to mount them clockwise. So, antenna 1 is the first antenna pointing to bearing zero, antenna 2 is at the coordinate to the right of antenna 1, and so on.

The explanations below provide some details of the mathematics behind antenna spacing. In practice, however, all you need to do is decide what type of array you want to use, then use an Excel spreadsheet to calculate the required spacing. Please see krakenrf.com for the link to the excel sheet.

UNIFORM CIRCULAR NETWORK

If you want to determine radio sources over 360 degrees, the antennas must be arranged in a uniform circular array (UCA. The spacing between elements (the distance between the end of each antenna element in the array) must be designed specifically for an interested frequency range.

You need to design your network so that the spacing betweenI_e elements is less than half a wavelength λ of the highest frequency of interest.

$$I_e = s\lambda$$

where s is the wavelength spacing multiplier, which must be <= 0.5, and λ is the wavelength in meters.

A network whose element spacing is greater than this value exhibits what is known as "ambiguity". In other words, the system can see the signal source coming from several directions, and we have no way of knowing which is the true direction. This situation is obviously not ideal, which is why the multiplier should always be less than 0.5.

Using a spacing multiplier of less than 0.5 may allow you to design a smaller network, at the expense of some accuracy. In general, a value of less than s=0.2 is acceptable.
However, it is important to note that the accuracy of the direction finding result becomes much poorer with smaller spacing multipliers.This calculation shows that the lower the frequency, the larger the array size.

This shows that this type of direction-finding method can be impractical for long-wave frequencies, as the arrays take up a lot of space. For HF and VHF frequencies with long wavelengths, other direction-finding methods such as TDoA, Watson-Watt and Yagi may be more appropriate. It may be more useful to work with a radius based on the spacing between elements. The formula for calculating the radius for a given spacing multiplier and wavelength is given by :

$$r = \frac{s\lambda}{\sqrt{2\left(1 - cos(\frac{360}{n}\right)}}$$

where s= spacing multiplier, λ= wavelength in meters and n = number of antenna elements

UNIFORM LINEAR NETWORK

The other way to set up an array is to use a uniform linear array, which simply involves aligning the antennas in a straight line. The disadvantage of this arrangement is that you can only receive signals at 180 degrees, and there's no way of knowing whether the signal is coming from the front or the back of the array.

The advantage is much more precise resolution, thanks to the larger aperture possible. As above, the spacing between elements is calculated using the same formula

$$I_e = s\lambda$$

RESOLUTION THEORY RESOLUTION

The resolution of the system is in fact the accuracy. If the resolution is 10 degrees, we can say that the actual bearing is somewhere within an arc of 10 degrees.

If you're interested, we'll briefly explain the theory behind the type of resolution we can expect from this system. With a circular array of 5 elements spaced 0.5 λ apart, we can expect a resolution of around 8 degrees. With a linear array of 5 elements, we can expect a resolution of around 3.4 degrees.

To estimate it, we used the Rayleigh resolution calculation in physics. Rayleigh's formula is.22λ/D where D is the aperture of the antenna array. For a circular array, the aperture is equivalent to the diameter, and for a linear array it is equal to the total length. So, using the above formula to calculate the radius, then multiplying by two to obtain the diameter, we obtain for a circular antenna array n=5 elements with spacing s=0.5 an aperture of D=0.85 λ . Consequently, the Rayleigh equation reduces to θ=1.22/0.85 = 1.44rad = 83 degrees. For a 5-element linear array, the aperture is given by the total length of the array, which is given by D= (n-1) * s. If we have n=5 elements and spacing s=0.5, then.= 0.61 rad= 34 degrees. The use of "super-resolution" algorithms such as MUSIC improves Rayleigh's resolution by a very approximate factor of 10. We thus obtain a resolution of 83/10 = 8.3 degrees for the circular grating and 34/10 = 3.4 degrees for the linear grating.

APPENDIX

CONNECT TO AN ESTABLISHED WIFI NETWORK

If you're using Kraken DF or Kraken PR software on a fixed WiFi network, rather than via hotspots, you'll need to add your WiFi network details. To do this, you'll need to temporarily connect your Pi 4 to a monitor and keyboard, or connect your Pi 4 via Ethernet and SSH into it.

The default connection IDs for terminal and SSH are pi/krakensdr.

To add your network, edit the wpa_supplicant.conf file

sudo nano
/etc/wpa_supplicant/wpa_supplicant.conf

Add your own network by adding the following text

network={

ssid="MY_WIFI_SSID"

psk="MY_WIFI_PASSWORD"

}

Then press "CTRL+X", "Y" to close and save the file.

HELP

Please visit the forum at: https: https://forum.krakenrf.com/

And the documentation on the wiki: https: https://github.com/krakenrf/krakensdr_docs/wiki

GUARANTEE

The KrakenSDR is guaranteed for 2 years against manufacturing defects.

The warranty does not cover damage caused by external events such as lightning strikes, electrostatic discharges or high-power emissions in the vicinity.

DECLARATION OF CONFORMITY

KrakenSDR equipment is declared by the manufacturer KrakenRF to be CE RED compliant according to Directive 2014/53/EU. The complete CE RED declaration of conformity can be downloaded from :

https://www.passion-radio.com/sdr-receivers/kraken-2996.html

This material must be recycled and not thrown away.

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