

# PSK31

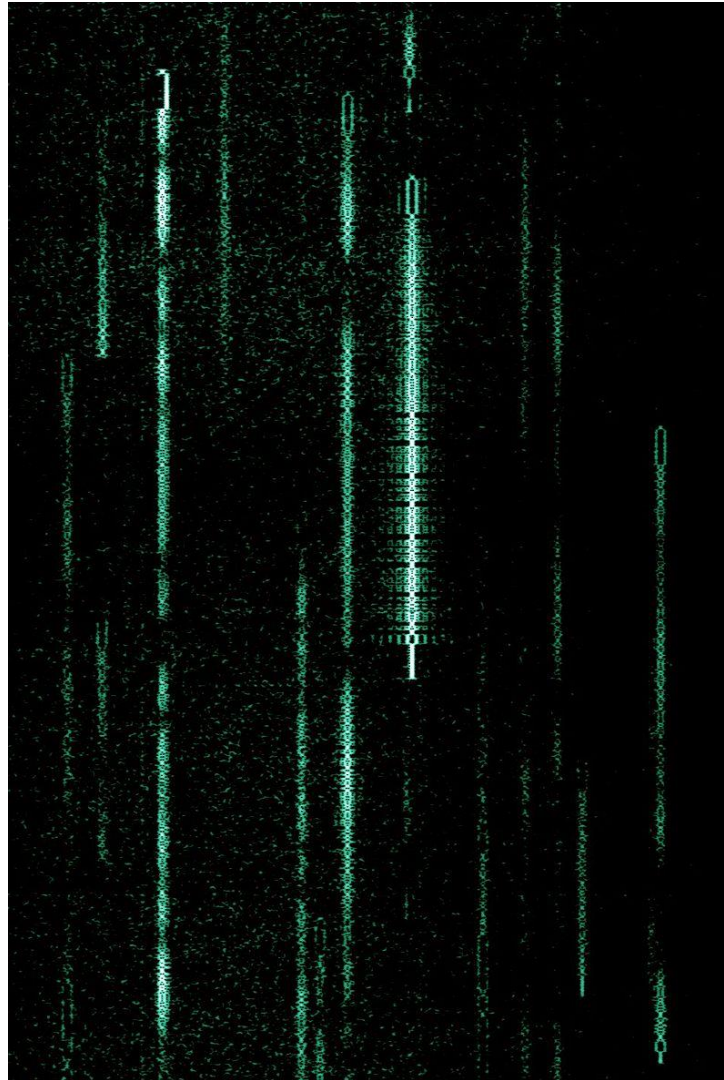
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@0xsh\_

Bsides Canberra 2017

# PSK31 looks like...



# PSK31 sounds like...



PSK31\_sample.ogg

# Amateur Radio Frequencies (RTLSDR Ranges)

- RTLSDR dongle frequency range of 24 – 1766 MHz (frequencies above 1.2 GHz may require cooling/heatsinking)
- PSK31 typical transmit frequencies (in range of RTLSDR dongle):
  - 24.920 MHz 12 meters
  - 28.120 MHz 10 meters
  - 50.290 MHz 6 meters

# Some terms

- **Bit rate (bps):** Speed of data in bits per second. With PSK31 where 1 bit per symbol, baud & bit rates are the same.
- **Baud rate (Bd):** number of symbols transmitted over a line per second.
- **Bandwidth (Hz):** difference between upper and lower frequencies of a given spectrum e.g. can have multiple channels within a bandwidth.
- **Baseband:** signal transmitted without modulation i.e. no shift in the range of frequencies of the signal, and is a low frequency - contained within the band of frequencies from close to 0 hertz up to a higher cut-off frequency or maximum bandwidth.

# What is PSK31?

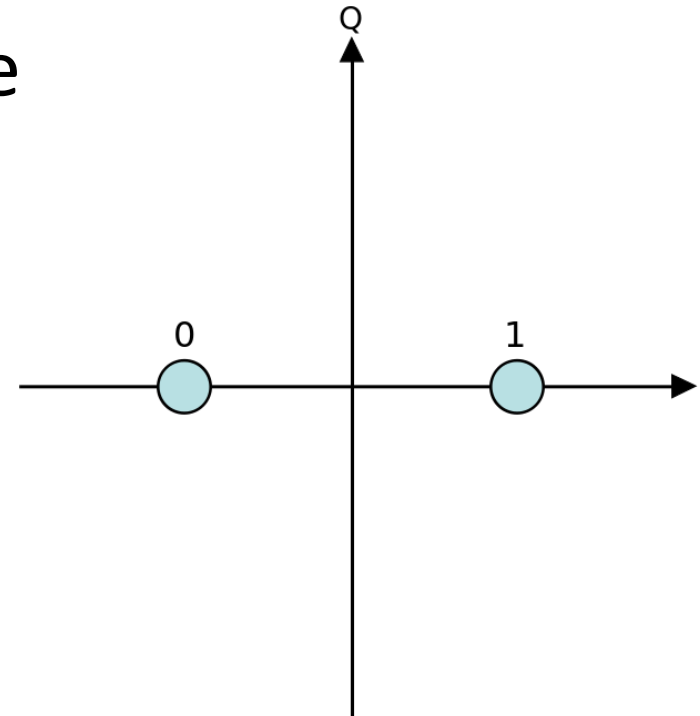
- Created by Peter Martinez (G3PLX)
- Released in 1998
- Used by amateur radio operators for real time chat
- Phase Shift Keying
- 31.25 baud rate & bits per second
- Baud rate matches a typical typing speed of 50 wpm approx.

# What is PSK31?

- Phase modulated
- Remember the three main types of modulation are:
  - Amplitude-shift keying (ASK)
  - Frequency-shift keying (FSK)
  - Phase-shift keying (PSK)

# What is PSK31?

- Uses binary phase-shift keying (BPSK/2-PSK)
- Two phases
- 180 degrees apart (anywhere on plane)
- BPSK is most tolerant to noise





# What is PSK31?

- Not packet based
- Modulates in phase an audio signal
- Audio signal then modulates in amplitude a carrier sent over the air
- Can be used by equipment designed for audio

# What is PSK31?

- 0 = phase shift of  $\pi$  radians
- 1 = no phase shift
- Characters = varicode
- Start of character = 00
- Data rate = 31.25 baud

# Varicode

- Includes most of 7-bit ASCII characters
- Start with: 1
- End with: 1
- Never: have 00
- Break between characters: 00
- Prefix with long string of 000s

# Varicode

- BSides Canberra:
- 11101011 1101111 1101 101101 11  
10111 1 1011011101 1011 1111  
1011111 11 10101 10101 1011

```
'a': '1011',  
'b': '1011111',  
'c': '101111',  
'd': '101101',  
'e': '11',  
'f': '111101',  
'g': '1011011',  
'h': '101011',  
'i': '1101',  
'j': '111101011',  
'k': '10111111',  
'l': '11011',  
'm': '111011',  
'n': '1111',  
'o': '111',  
'p': '111111',  
'q': '110111111',  
'r': '10101',  
's': '10111',  
't': '101',  
'u': '110111',  
'v': '1111011',  
'w': '1101011',  
'x': '11011111',  
'y': '1011101',  
'z': '111010101',
```

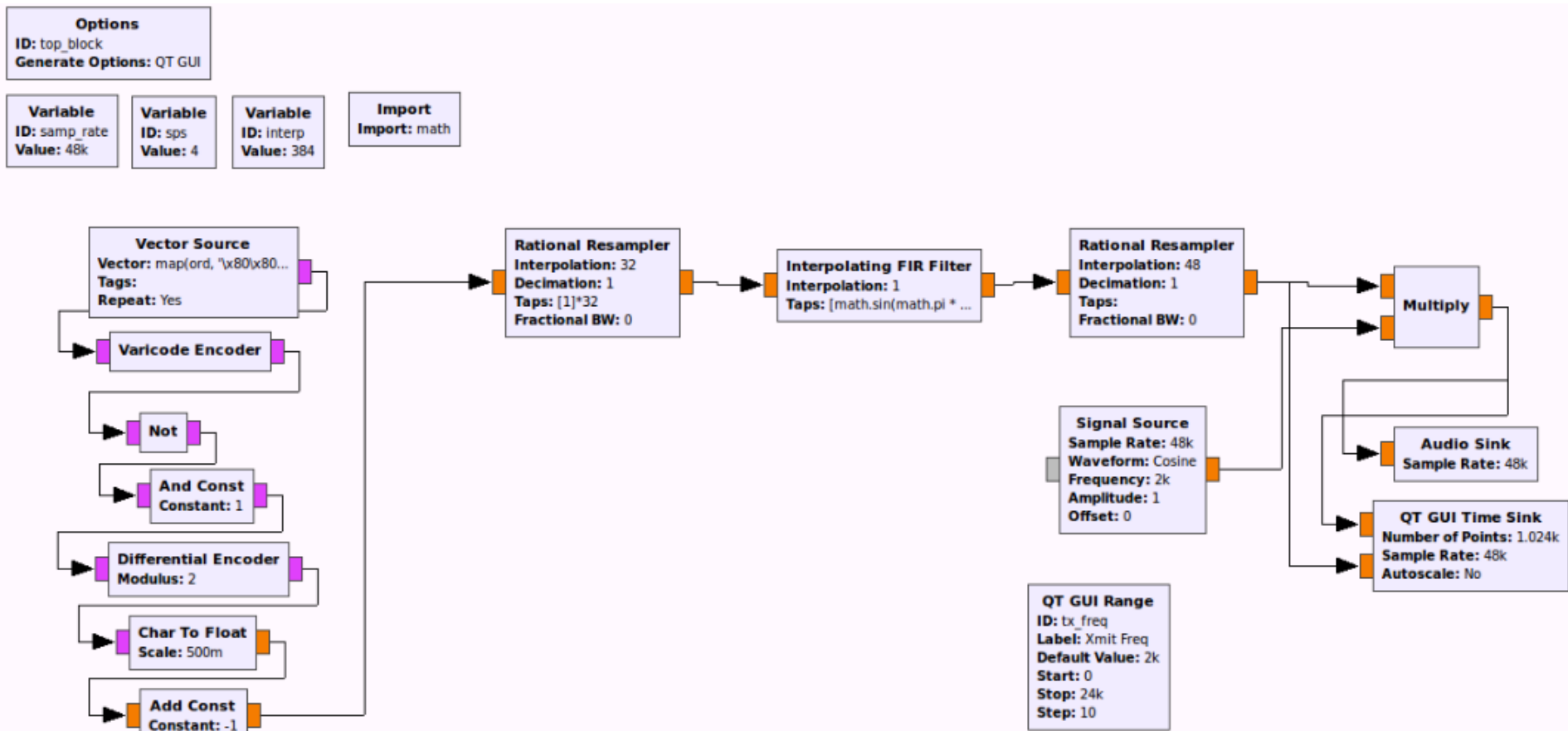
# Generating a message

- Sample rate = 48,000Hz (audio rate)
- 1 channel
- 2 bytes per sample

# Materials

- Using this PSK31 example as a base:  
<https://github.com/tkuester/gr-psk31/>
- All files, install instructions and modifications are described here: <https://github.com/0xsh>

# Transmit PSK31 with an audio card



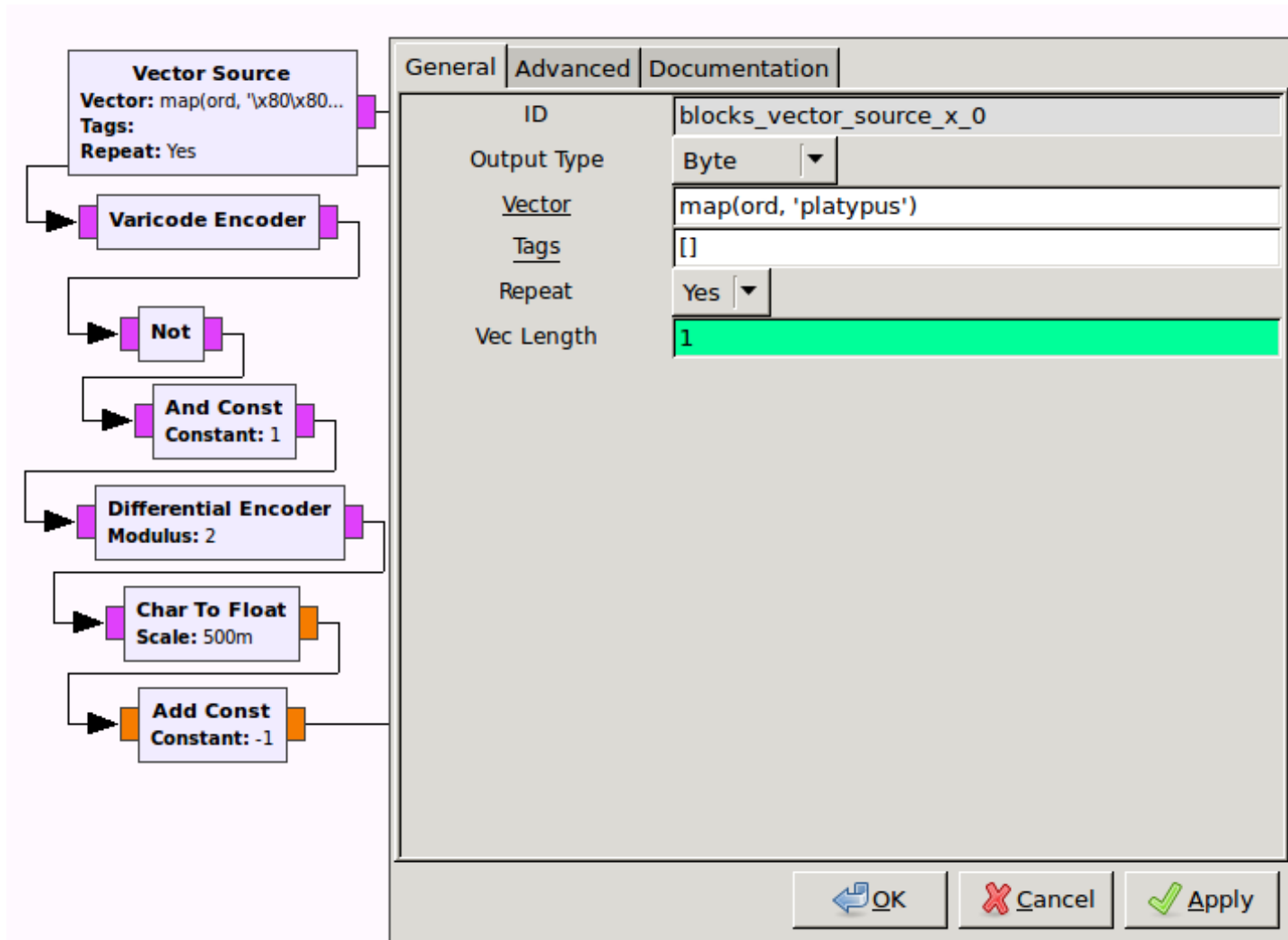
# Transmit Graph: Vector Source

## **Vector source**

- A vector is a dynamically sized sequence of objects (compared to a fixed array)
- Interpreted as list of integers
- Truncated to bytes when output
- Vector: “map(ord, ‘platypus’)”
- Repeat: Yes



# Transmit Graph: Vector Source

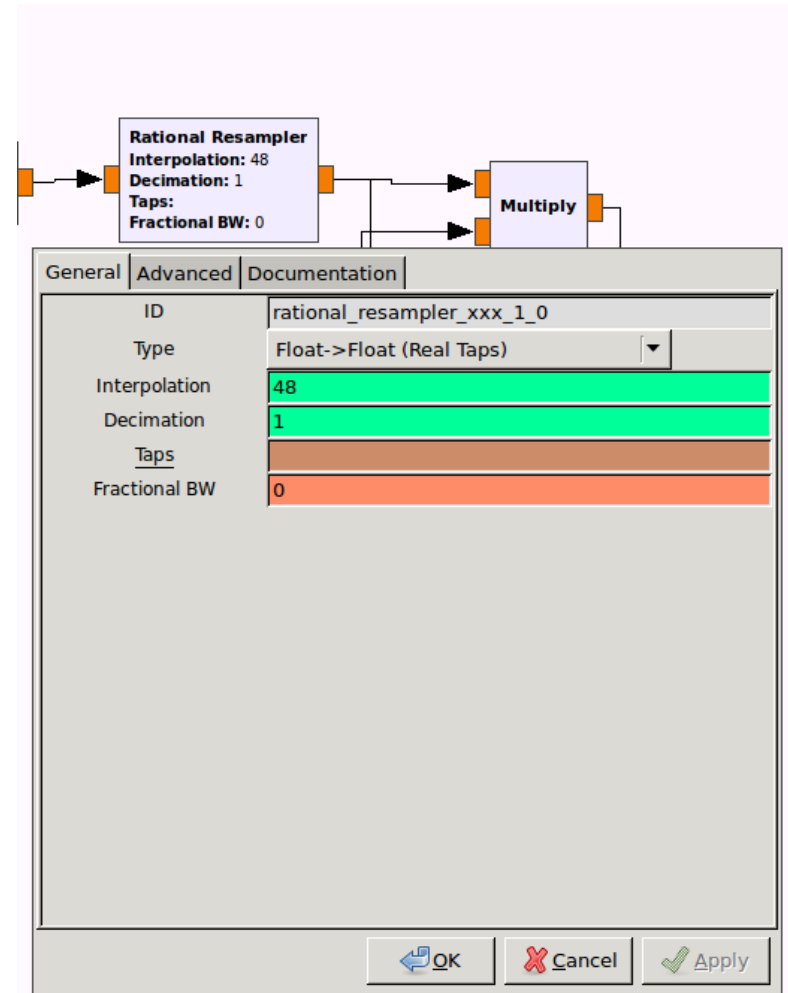
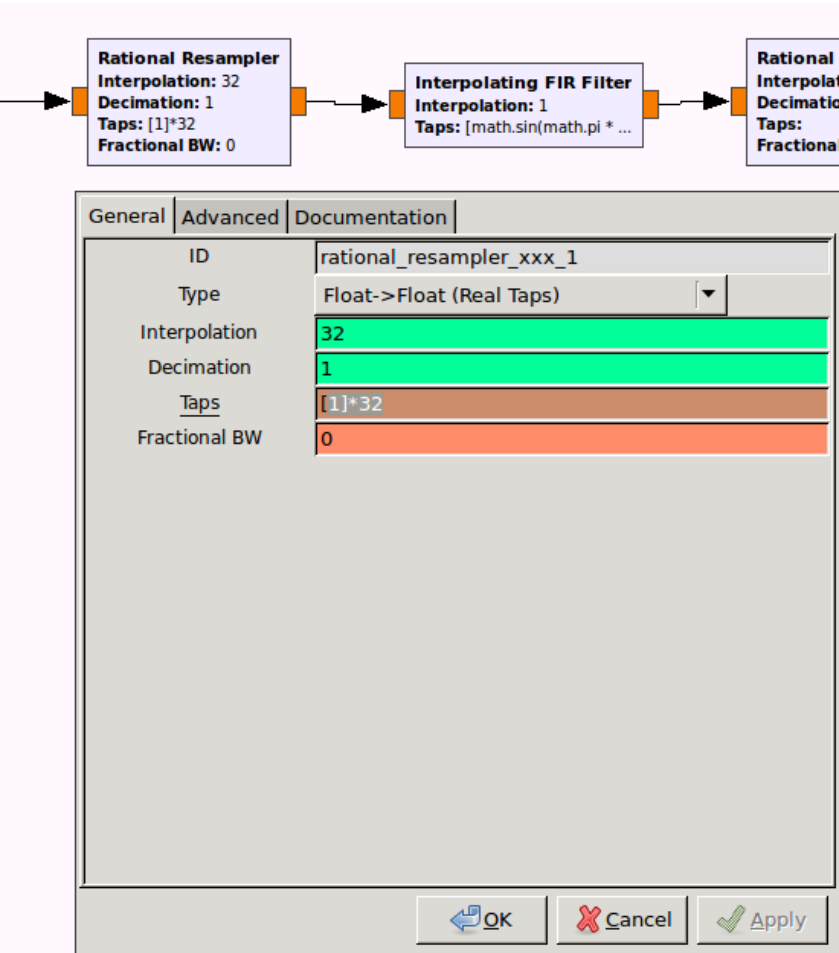


# Transmit Graph: Rational Resampler

## Rational Resampler

- Convert from one sample rate to another
- Combined interpolator (multiply by) & decimator (divide by)
- All following blocks should use newly set sample rate

# Transmit Graph: Rational Resampler

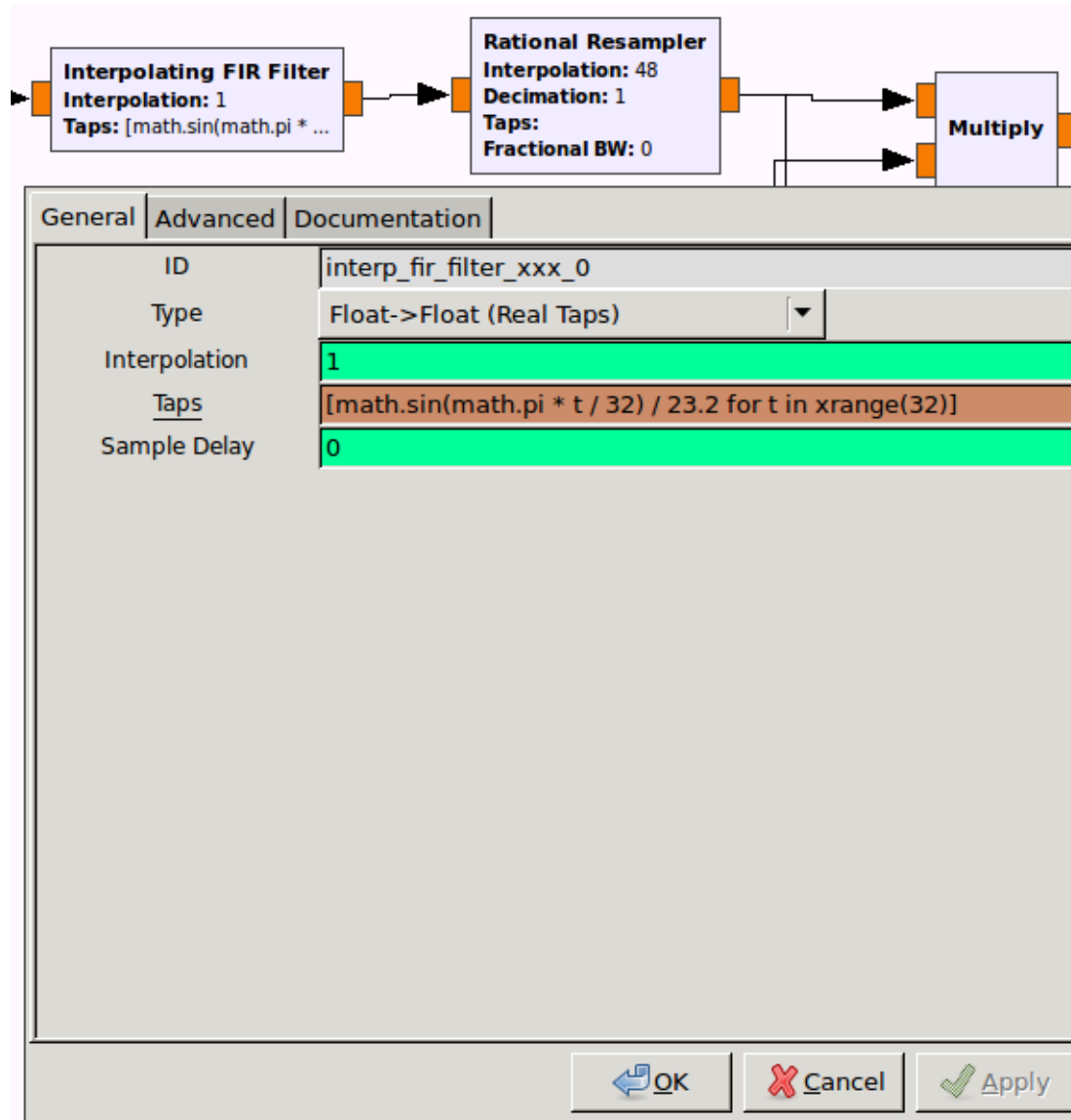


# Transmit Graph: Interpolating FIR Filter

## Interpolating FIR Filter

- FIR = Finite Impulse Response filter
- Settles to 0 in finite time
- Tap = a delay
- More taps = more stopband attenuation, less ripple, narrower filters

# Transmit Graph: Interpolating FIR Filter



# Transmit Graph: Audio Sink

**Signal Source**  
Sample Rate: 48k  
Waveform: Cosine  
Frequency: 2k

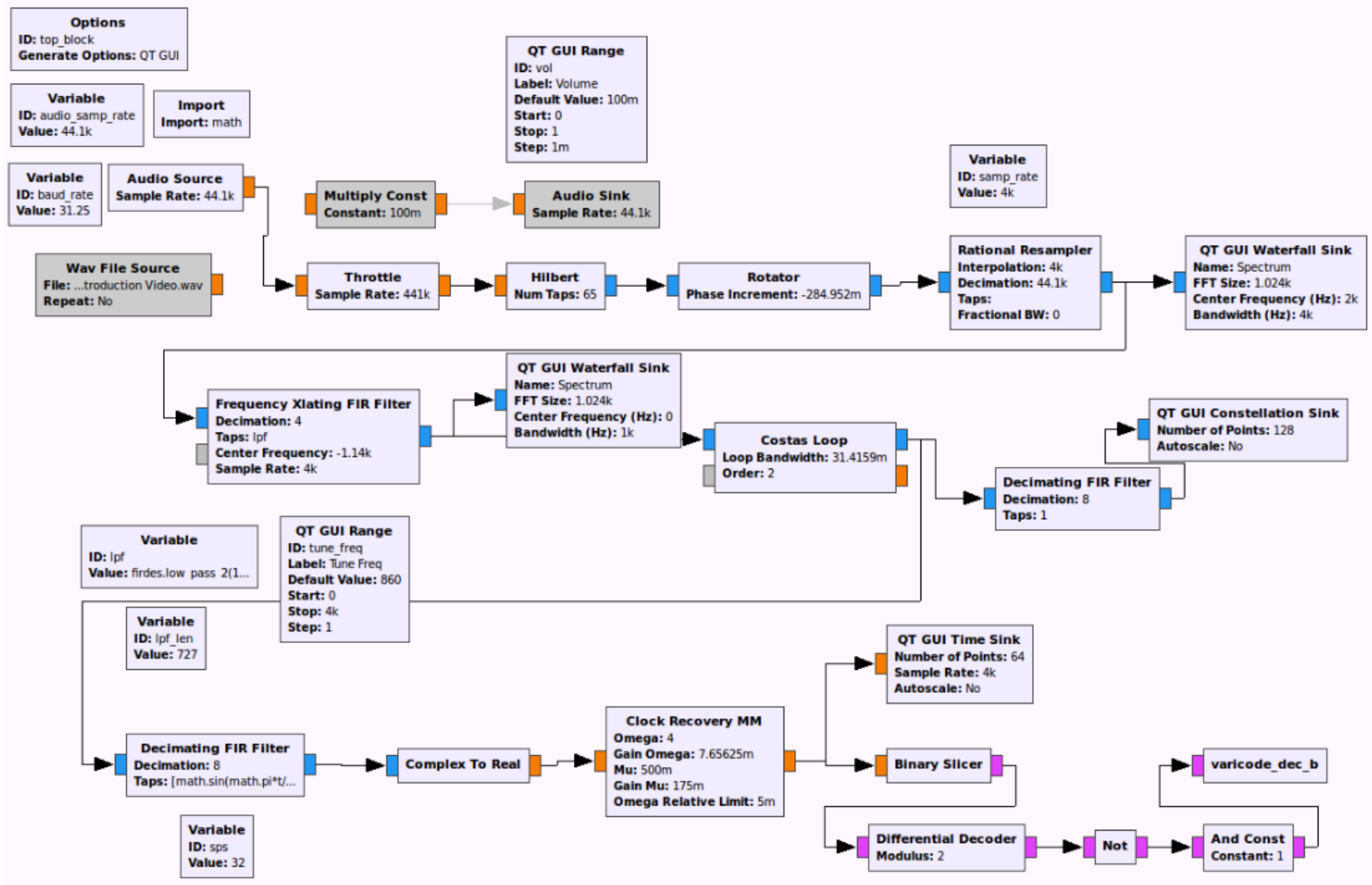
**Audio Sink**  
Sample Rate: 48k

General | Advanced | Documentation

ID	audio_sink_0_0
Sample Rate	samp_rate
Device Name	
OK to Block	Yes
Num Inputs	1

OK Cancel Apply

# Receive PSK31 with an audio card



# Receive Graph: Audio Source

**Audio Source**  
Sample Rate: 44.1k

General | Advanced | Documentation

ID	audio_source_0
Sample Rate	audio_samp_rate ▼
Device Name	
OK to Block	Yes ▼
Num Outputs	1

OK Cancel Apply



# Receive Graph: Throttle

## Throttle

- GNU Radio operates at full speed (when no real hardware in way to slow down)
- Need throttle to control rate
- Don't use with real hardware (throttle is a bad clock and will end up with timing issues)

# Receive Graph: Hilbert Transform

## Hilbert Transform

- Truncates the filter to the number of taps
- Introduces a delay into the signal

# Receive Graph: Hilbert Transform

The image shows a block diagram and a configuration window for a Hilbert Transform block. The block diagram at the top consists of three blocks in series: a Hilbert block (Num Taps: 65), a Rotator block (Phase Increment: -284.952m), and a Rational Resamp block (Interpolation: 4k, Decimation: 44.1k, Taps: , Fractional BW: 0). Below the diagram is a configuration window for the Hilbert block, with tabs for General, Advanced, and Documentation. The General tab is active, showing the following parameters:

ID	hilbert_fc_1
Num Taps	65
Window	Hamming
Beta	6.76

At the bottom of the window are three buttons: OK, Cancel, and Apply.

# Receive Graph: Rotator

## Rotator

- Frequency shifting
- Shift specified as a complex vector (amount of rotation per sample)

# Receive Graph: Rotator

The image shows a software interface for configuring a 'Rotator' block. At the top, a signal flow graph displays the 'Rotator' block with a 'Phase Increment' of -284.952m, followed by a 'Rational Resampler' block with 'Interpolation: 4k', 'Decimation: 44.1k', 'Taps', and 'Fractional BW: 0'.

Below the graph is a configuration dialog box with three tabs: 'General', 'Advanced', and 'Documentation'. The 'General' tab is active, showing a table with the following data:

ID	
blocks_rotator_cc_0	
<u>Phase Increment</u>	$2 * \text{math.pi} * -2000 / \text{audio\_samp\_rate}$

At the bottom of the dialog are three buttons: 'OK' (with a blue arrow icon), 'Cancel' (with a red X icon), and 'Apply' (with a green checkmark icon).

# Receive Graph: Rational Resampler

The image shows a software interface for configuring a Rational Resampler block. At the top, a block diagram shows the Rational Resampler connected to a QT GUI Waterfall Sink. The Rational Resampler block has the following parameters: Interpolation: 4k, Decimation: 44.1k, Taps, and Fractional BW: 0. The QT GUI Waterfall Sink block has the following parameters: Name: Spectrum 1, FFT Size: 1.024k, Center Frequency (Hz): 2k, and Bandwidth (Hz): 4k.

Below the block diagram is a configuration window for the Rational Resampler. The window has three tabs: General, Advanced, and Documentation. The General tab is selected. The configuration table is as follows:

ID	rational_resampler_xxx_2
Type	Complex->Complex (Complex Taps) ▼
Interpolation	4000
Decimation	44100
Taps	
Fractional BW	0

At the bottom of the configuration window are three buttons: OK, Cancel, and Apply.

# Receive Graph: Frequency Xlating FIR Filter

## Frequency Xlating FIR Filter

- Frequency-translating FIR filter
- Often used for channel selection block
- Performs frequency translation, channel selection and decimation in one step

# Receive Graph: Frequency Xlating FIR Filter

The screenshot displays a software interface for configuring a **Frequency Xlating FIR Filter**. The top section shows a block diagram with the filter block connected to a **Spectrum 2** block. The filter block's parameters are: Decimation: 4, Taps: lpf, Center Frequency: 3, and Sample Rate: 4k. The **Spectrum 2** block's parameters are: Name: Spectrum 2, FFT Size: 1.024k, Center Frequency (Hz): 0, and Bandwidth (Hz): 1k. Below the block diagram is a configuration window with three tabs: **General**, **Advanced**, and **Documentation**. The **General** tab is active, showing the following settings:

Parameter	Value
ID	freq_xlating_fir_filter_xxx_0
Type	Complex->Complex (Complex Taps)
Decimation	4
Taps	lpf
Center Frequency	tune_freq-2000
Sample Rate	samp_rate

At the bottom of the configuration window are three buttons: **OK**, **Cancel**, and **Apply**.

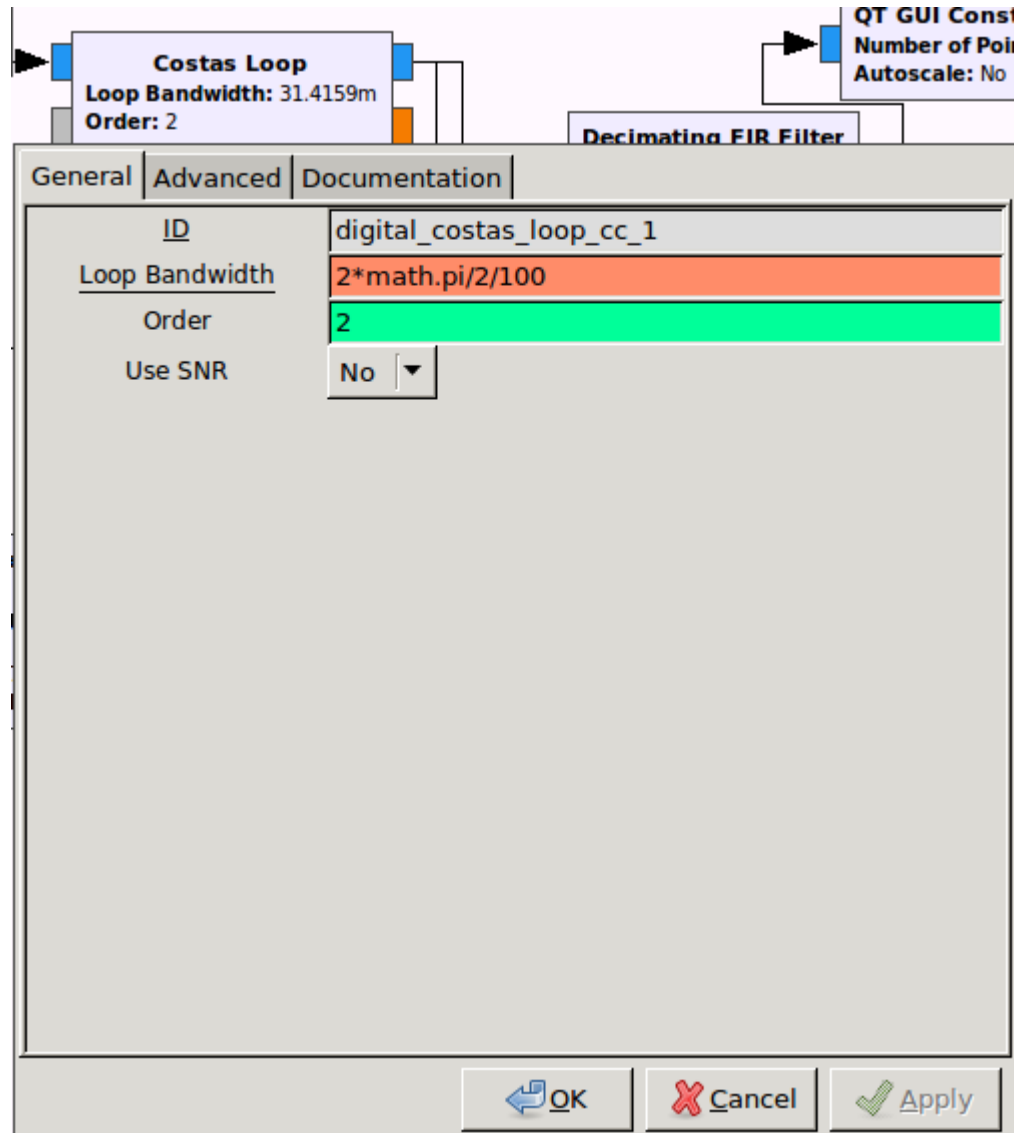


# Receive Graph: Costas Loop

## Costas Loop

- Locks to the centre frequency of a signal and downconverts it to baseband

# Receive Graph: Costas Loop

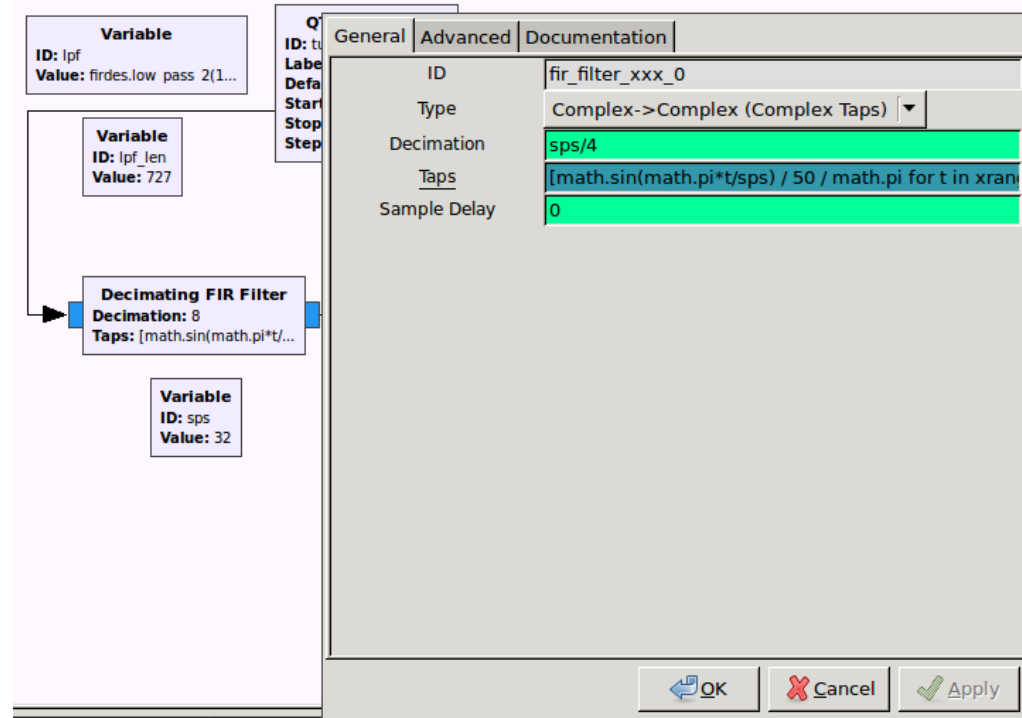
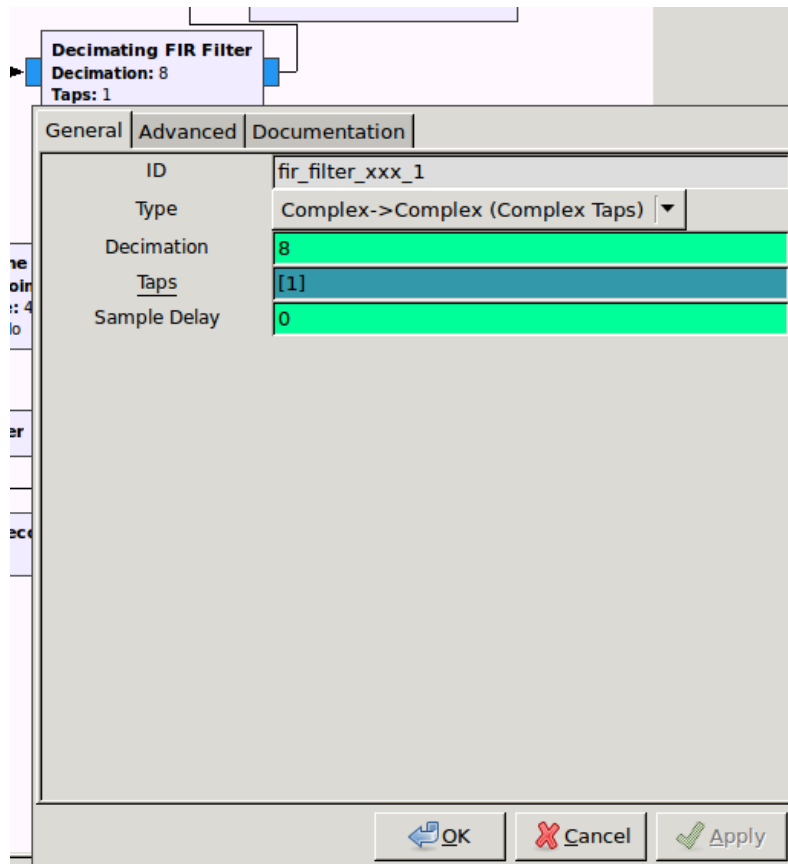


# Receive Graph: Decimating FIR Filters

## Decimating FIR Filters

- Decimation is reducing the output sampling rate by ignoring all but every  $N$ th sample

# Receive Graph: Decimating FIR Filters



# Receive Graph: Clock Recovery

The image shows a configuration window for a 'Clock Recovery MM' block. The window has three tabs: 'General', 'Advanced', and 'Documentation'. The 'Advanced' tab is selected, displaying a table of parameters. Below the table are 'OK', 'Cancel', and 'Apply' buttons. Below the window, a block diagram shows the 'Clock Recovery MM' block connected between a 'Complex To Real' block and a 'Binary Slicer' block. The block diagram also displays the parameter values for the 'Clock Recovery MM' block.

Parameter	Value
ID	digital_clock_recovery_mm_xx_0
Type	Float
<u>Omega</u>	$4 \cdot (1 + 0.0)$
<u>Gain Omega</u>	$0.25 \cdot 0.175 \cdot 0.175$
<u>Mu</u>	0.5
<u>Gain Mu</u>	0.175
Omega Relative Limit	0.005

**Clock Recovery MM**  
Omega: 4  
Gain Omega: 7.65625m  
Mu: 500m  
Gain Mu: 175m  
Omega Relative Limit: 5m

# Materials

- Next, follow the Step1, Step2 & Step 3 instructions here: <https://github.com/0xsh>

# Other work you can play with...

- **GoodPSK** “is a tool for generating PSK31 audio recordings, sometimes with strange or clever attributes” & check out the lectures!: <https://github.com/travisgoodspeed/goodpsk>
- <https://sdradventure.wordpress.com/2011/10/15/gnuradio-psk31-decoder-part-1>
- <https://sdradventure.wordpress.com/2011/10/15/gnuradio-psk31-decoder-part-2/>
- <https://github.com/JasonBens/PSK31-transceiver>
- <https://github.com/tkuester/gr-psk31>
- <https://github.com/christophL/gr-digimodes>
- <https://github.com/argilo/sdr-examples>

# References

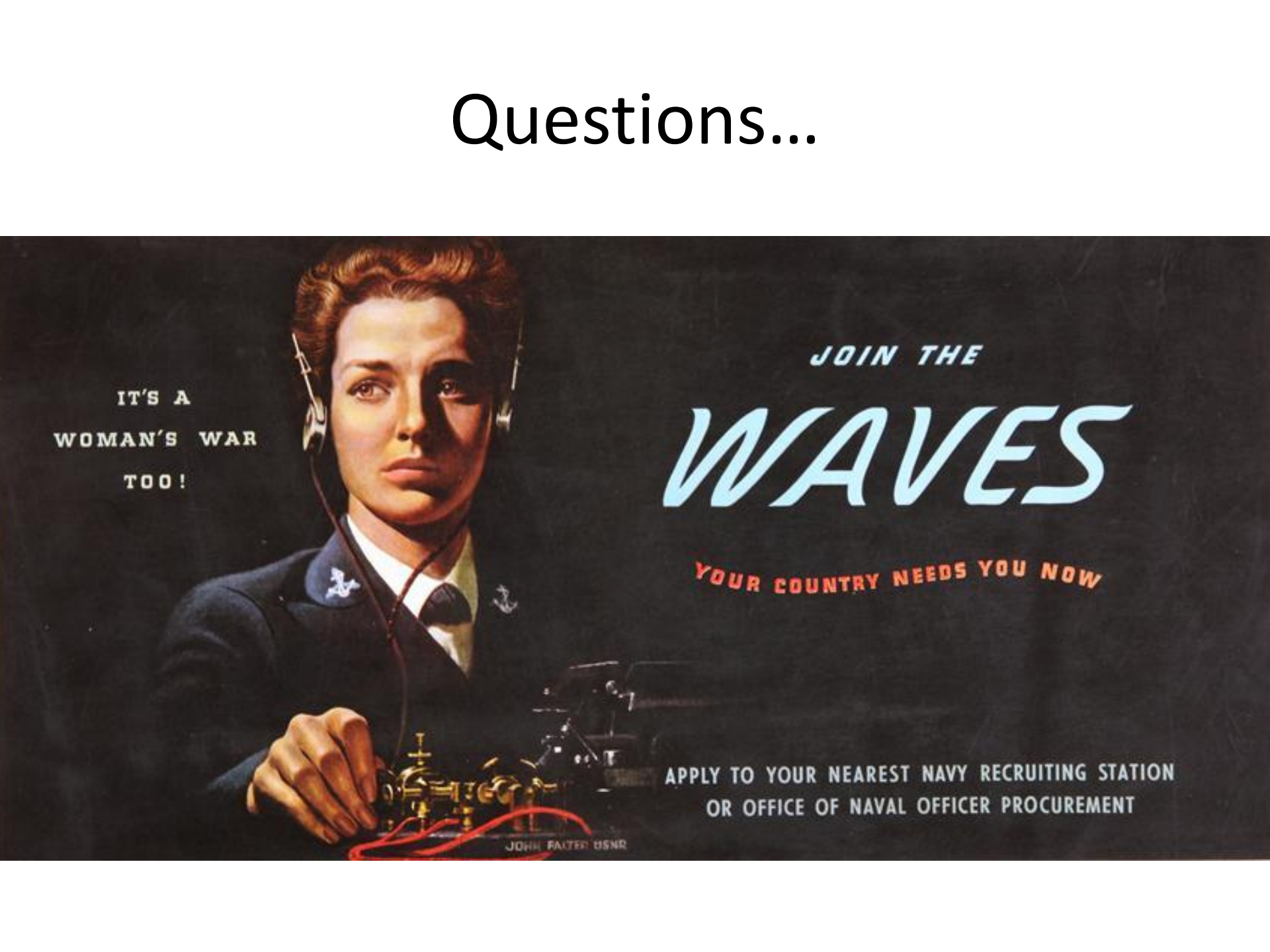
- <http://aintel.bi.ehu.es/psk31theory.html>
- <http://www.arrl.org/digital-data-modes>
- [https://en.wikipedia.org/wiki/Phase-shift keying](https://en.wikipedia.org/wiki/Phase-shift_keying)
- <https://en.wikipedia.org/wiki/PSK31>
- <https://en.wikipedia.org/wiki/Baud>
- <http://people.scs.carleton.ca/~barbeau/SDRCRBook/Content/chapter09.pdf>
- <https://github.com/travisgoodspeed/goodpsk>
- <https://github.com/tkuester/gr-psk31>
- <http://www.w1hkj.com/FldigiHelp/index.html>



# Glossary

- FIR Filter: Finite Impulse Response Filter
- PSK: phase shift keying
- SPS: samples per second

# Questions...

A woman with short, wavy brown hair is wearing a dark blue Navy uniform jacket with white anchor insignia on the lapels. She is wearing a headset with a microphone and is looking intently at a piece of electronic equipment, possibly a radio or a cipher machine, which has various knobs, switches, and red wires. The background is dark and textured.

IT'S A  
WOMAN'S WAR  
TOO!

JOIN THE  
*WAVES*

*YOUR COUNTRY NEEDS YOU NOW*

APPLY TO YOUR NEAREST NAVY RECRUITING STATION  
OR OFFICE OF NAVAL OFFICER PROCUREMENT

JOHN FASTER USNR

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Meetup

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Blog

<http://randomkeystrokes.com/category/sdr/>

Github

<https://github.com/sdr-melbourne>

YouTube

<https://www.youtube.com/channel/UCLBloqxOXEj4fH7s>  
ULA (SDR Melbourne Channel)

