Using radio to transmit text and exfil data

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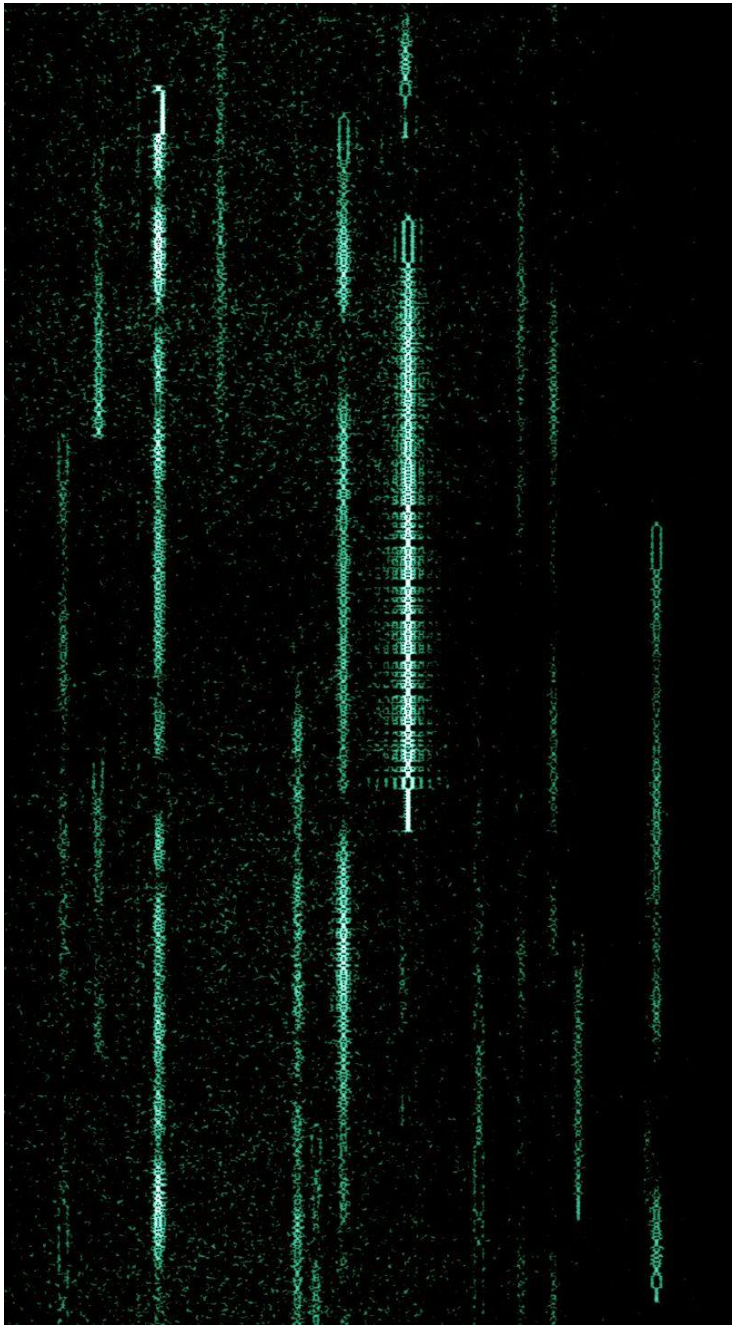
BSides Canberra 2017

This Workshop will…

- Provide an introduction to GNURadio Companion without the need for special hardware
- Provide an introduction to sending text messages over the air
- Get you started with setting up GNU Radio for raspberry pi projects

Happy St. Patrick’s Day!

What does PSK31 look like?



What does PSK31 sound like?

Tell me more about PSK31

What is PSK31?

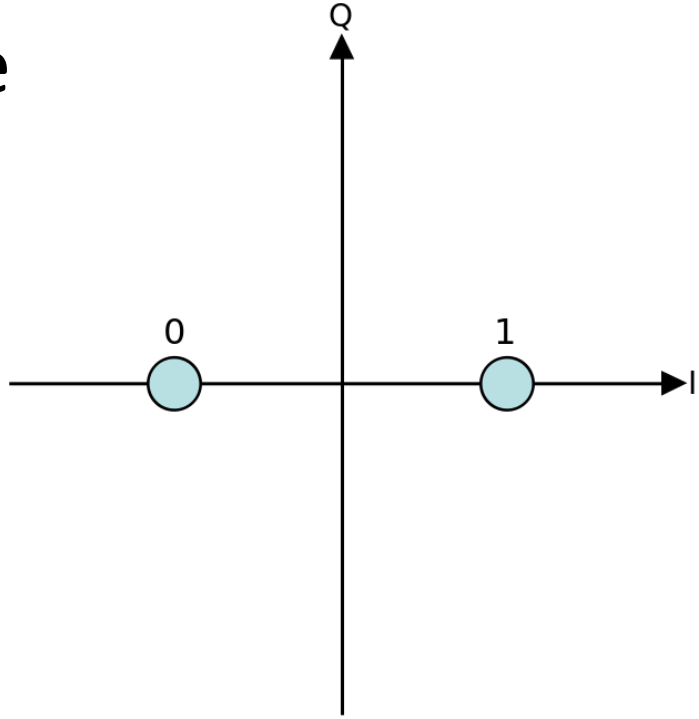
- Created by Peter Martinez (G3PLX)
- Released in 1998
- Used by amateur radio operators for real time chat
- Phase Shift Keying
- 31.25 baud rate & bits per second
- Baud rate matches a typical typing speed of 50 wpm approx.

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 π 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/Workshops/tree/master/BSides-Canberra-2017

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.

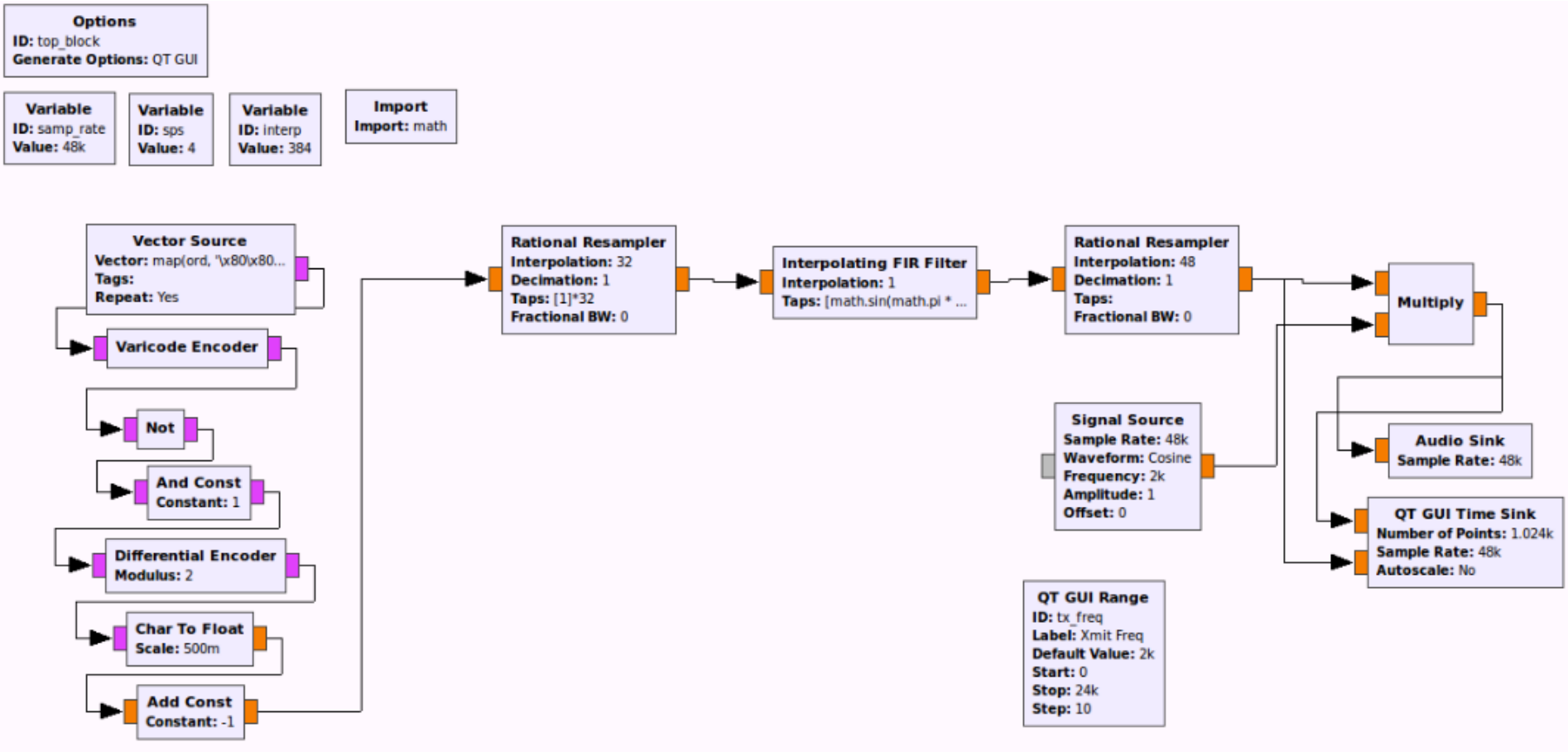
- **Baud rate (Bd)**: number of symbols transmitted over a line per second.

- **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.

Transmit PSK31 with an audio card

Transmit Graph

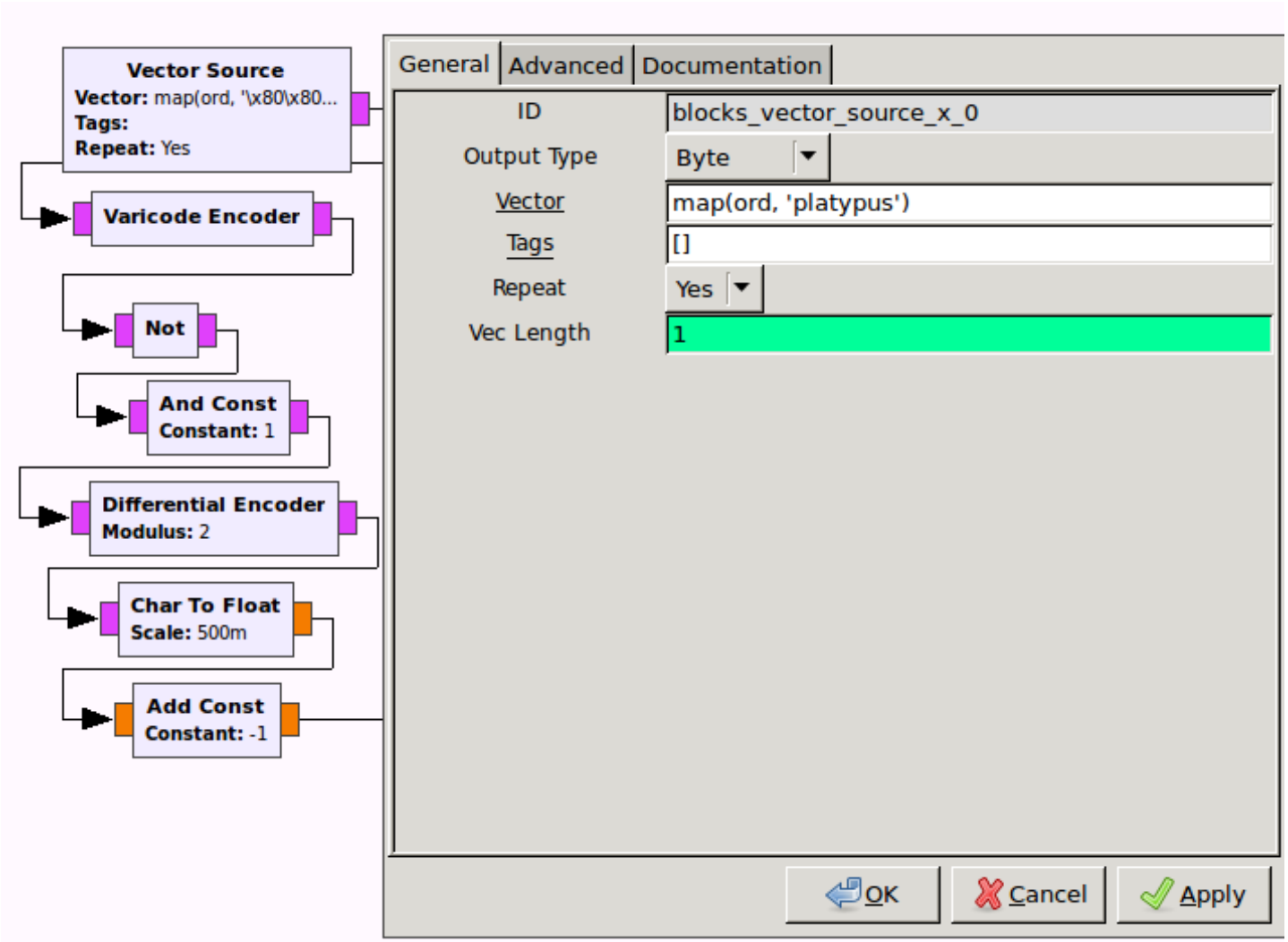


Vector Source

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, ‘BSides Canberra’)”
- Repeat: Yes

Vector Source

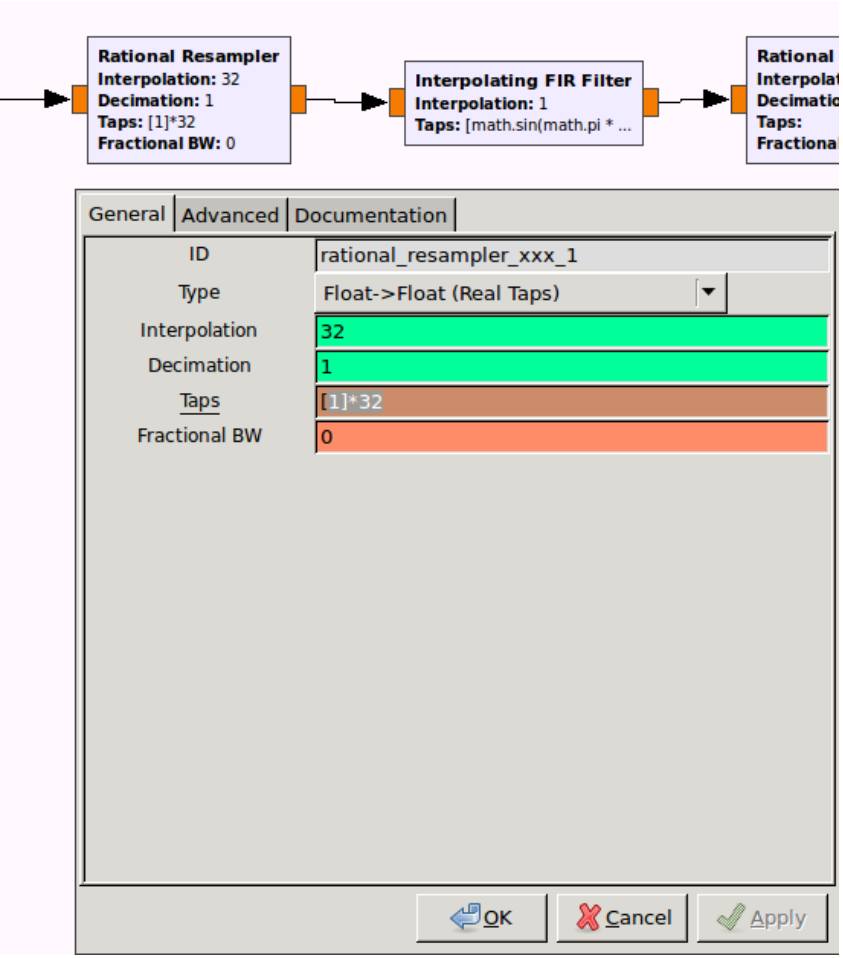


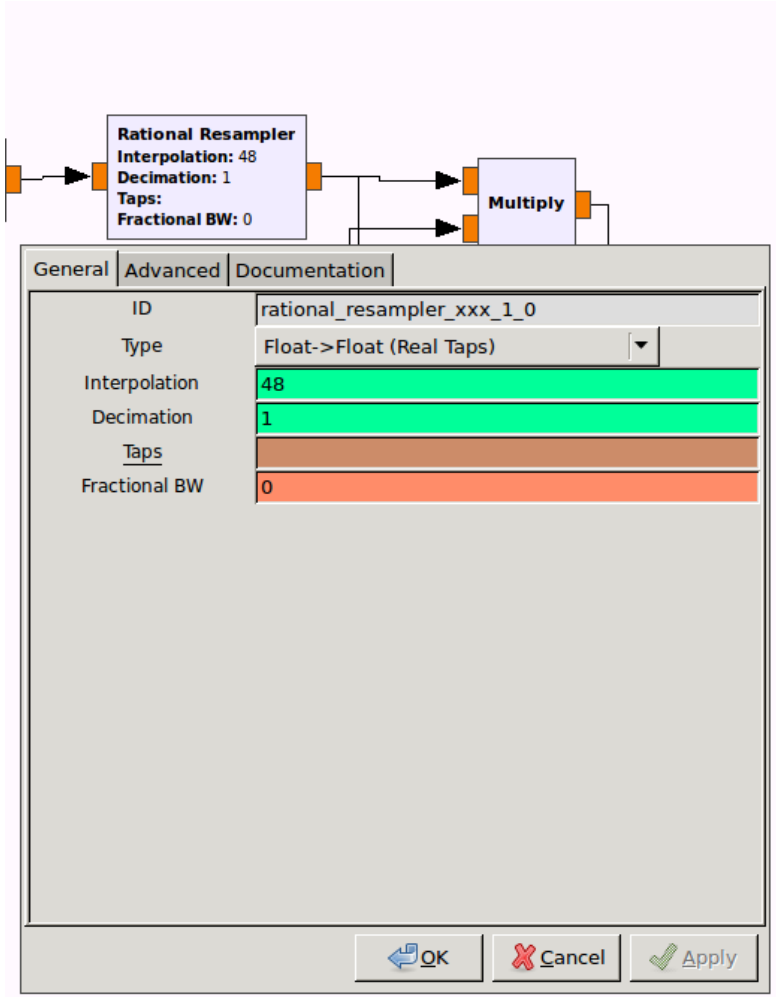
Rational Resampler

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

Rational Resampler



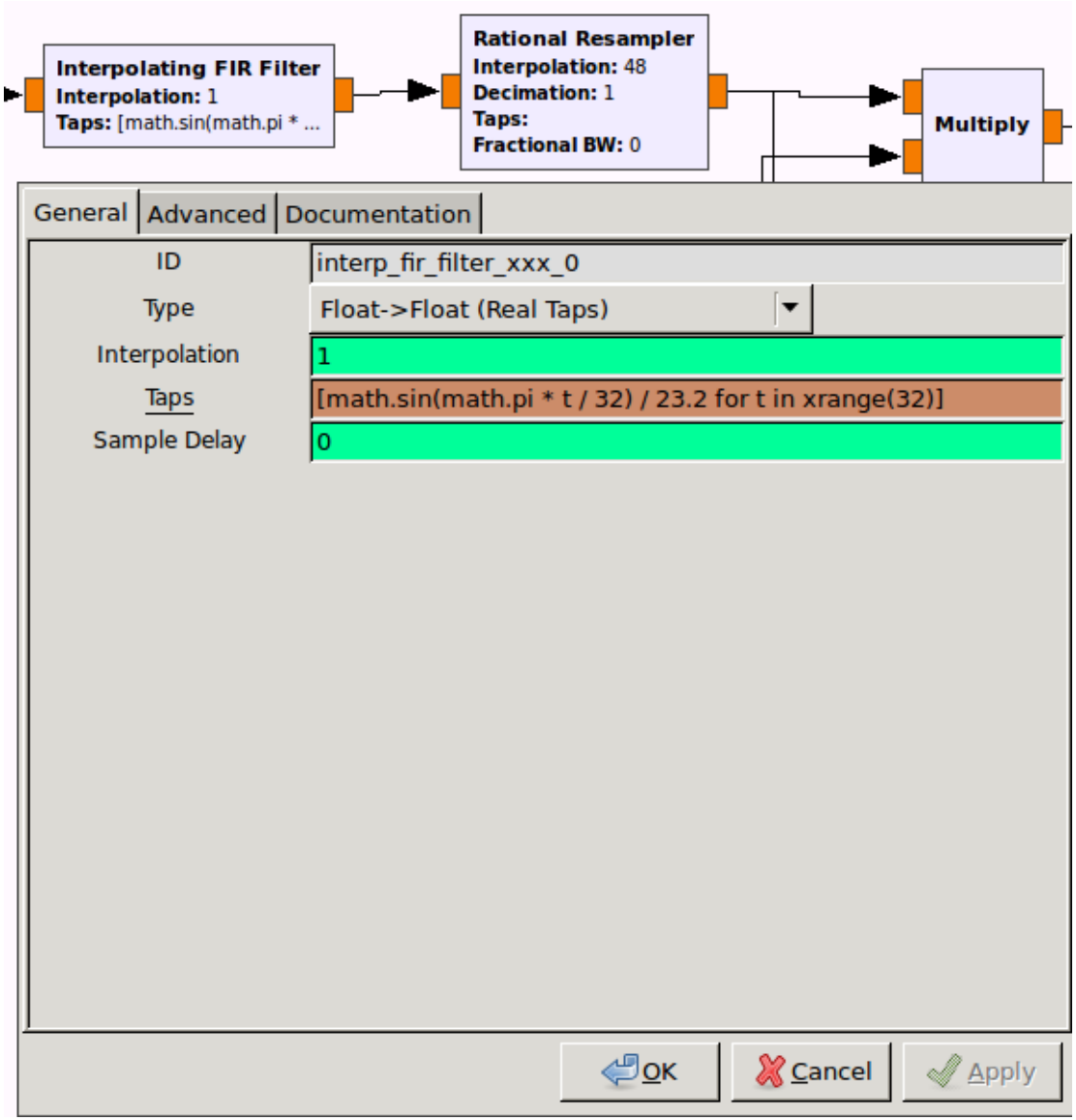


Interpolating FIR Filter

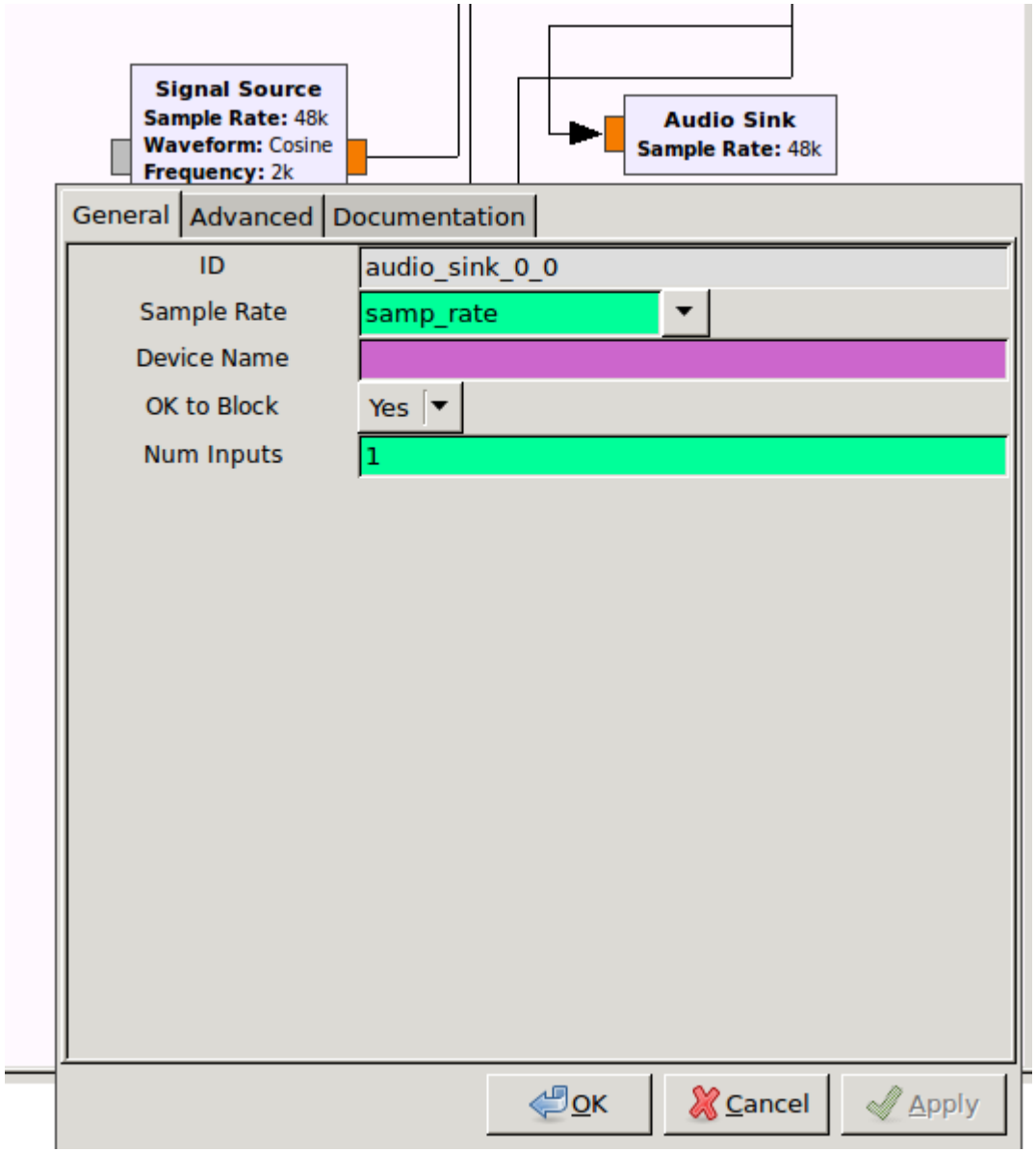
Interpolating FIR Filter

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

Interpolating FIR Filter

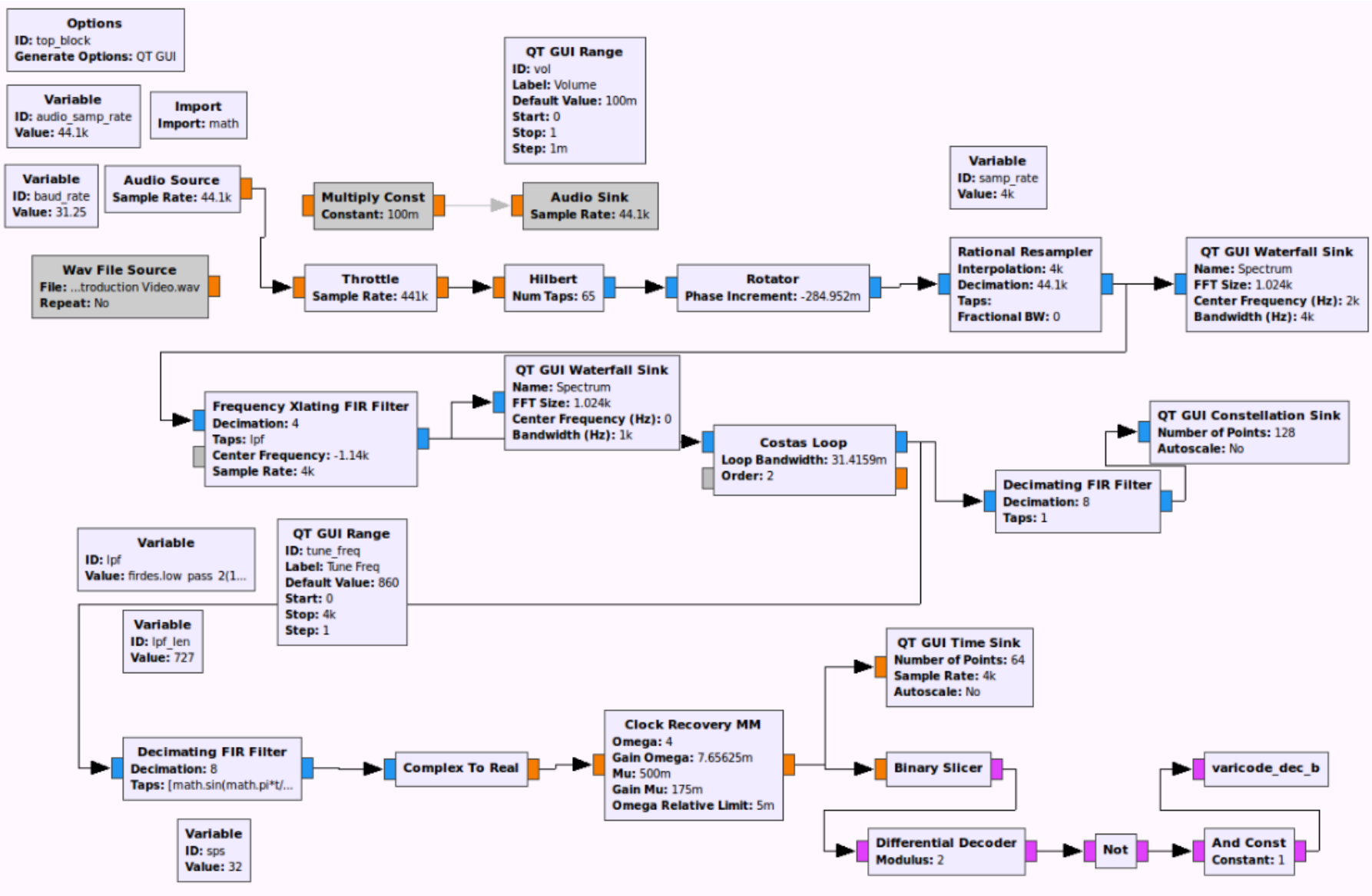


Audio Sink

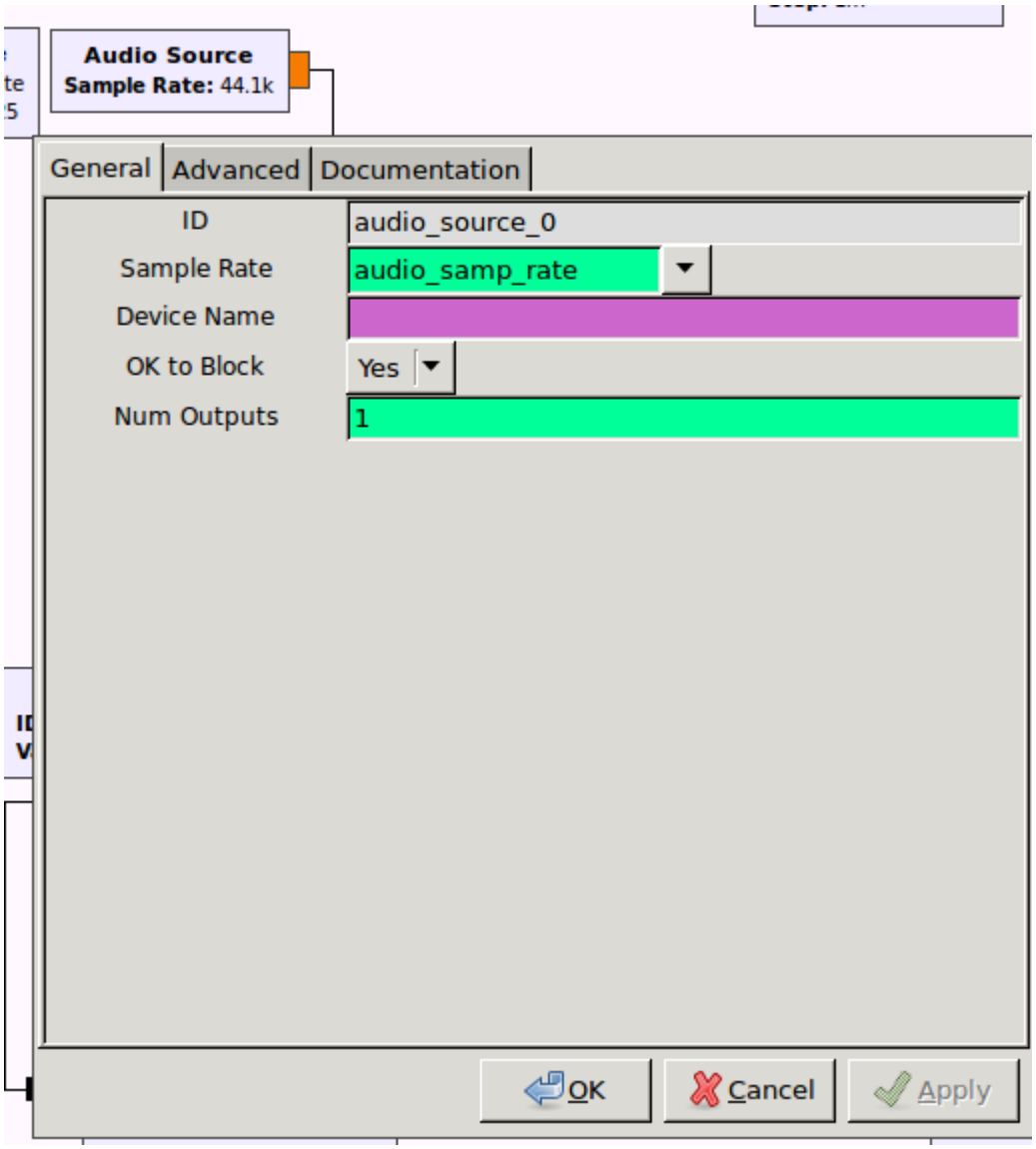

Signal Source
Sample Rate: 48k
Waveform: Cosine
Frequency: 2k
Audio Sink
Sample Rate: 48k
General
Advanced
Documentation
ID
audio_sink_0_0
Sample Rate
samp_rate
Device Name
OK to Block
Yes
Num Inputs
1
OK
Cancel
Apply

Receive PSK31 with a microphone

Receive PSK31 with a microphone



Audio Source



Throttle

Throttle

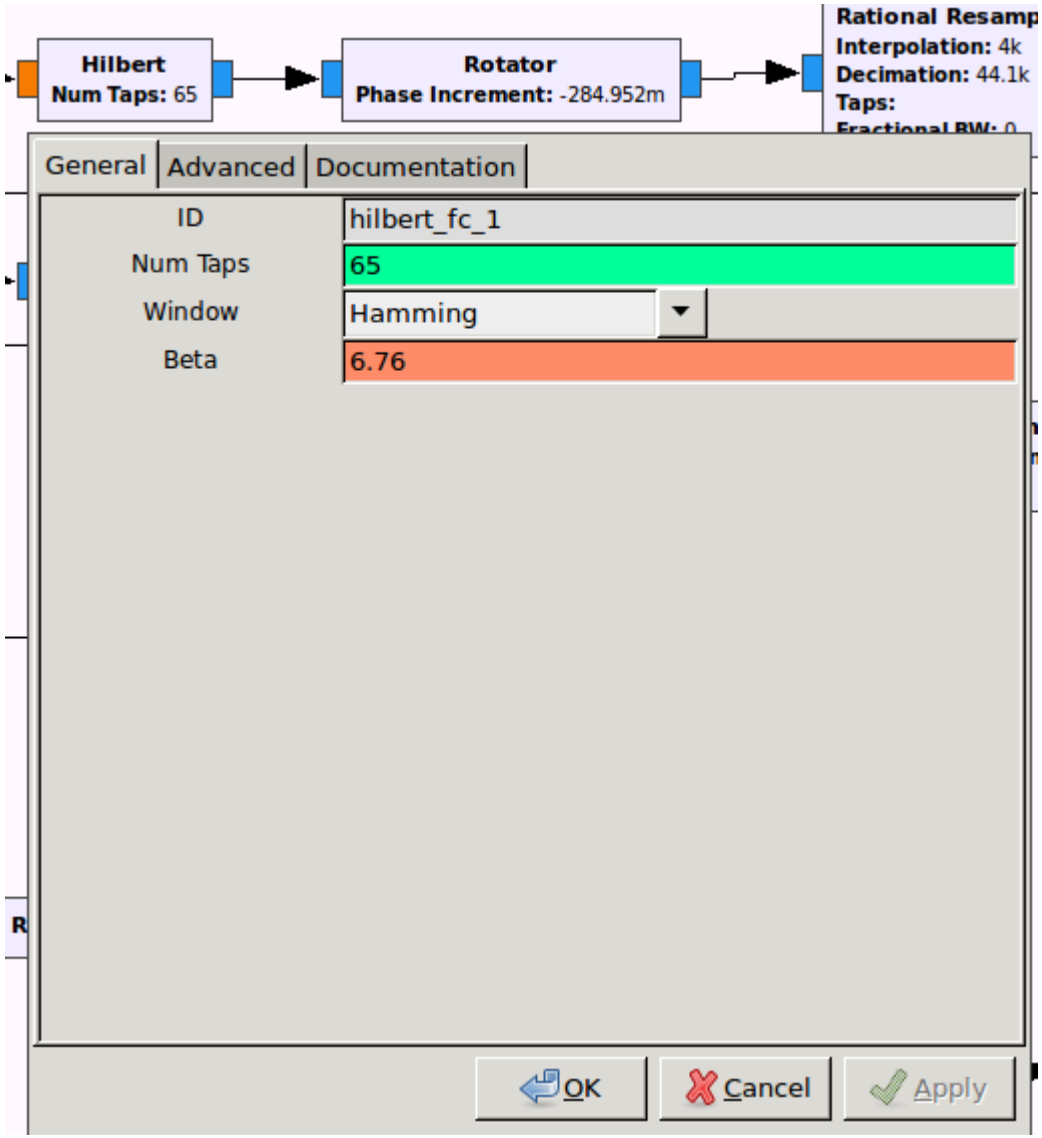
- GNU Radio operates at full speed (when no real hardware in way to slow down)
- Need throttle to <u>control rate</u>
- Don’t use with real hardware (throttle is a bad clock and will end up with timing issues)

Hilbert Transform

Hilbert Transform

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

Hilbert Transform

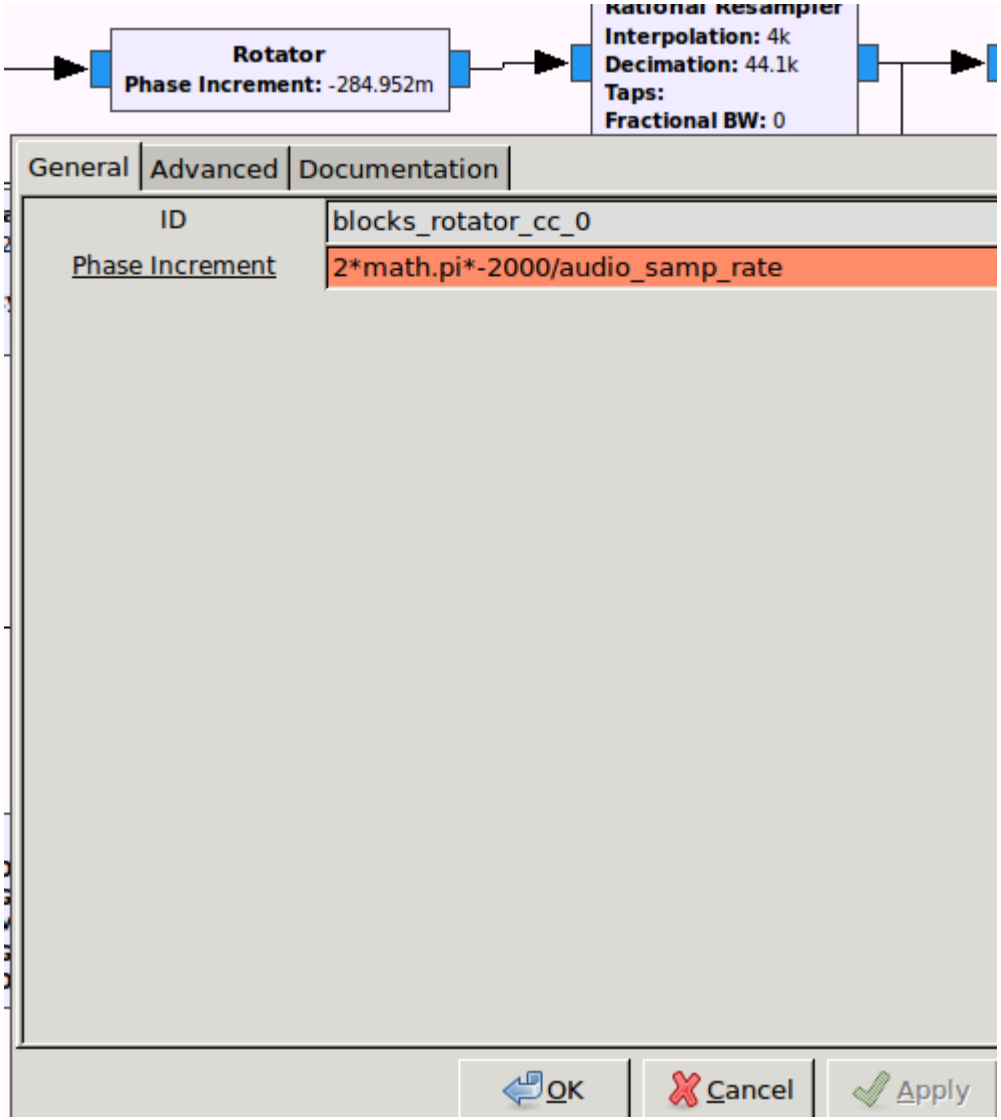


Rotator

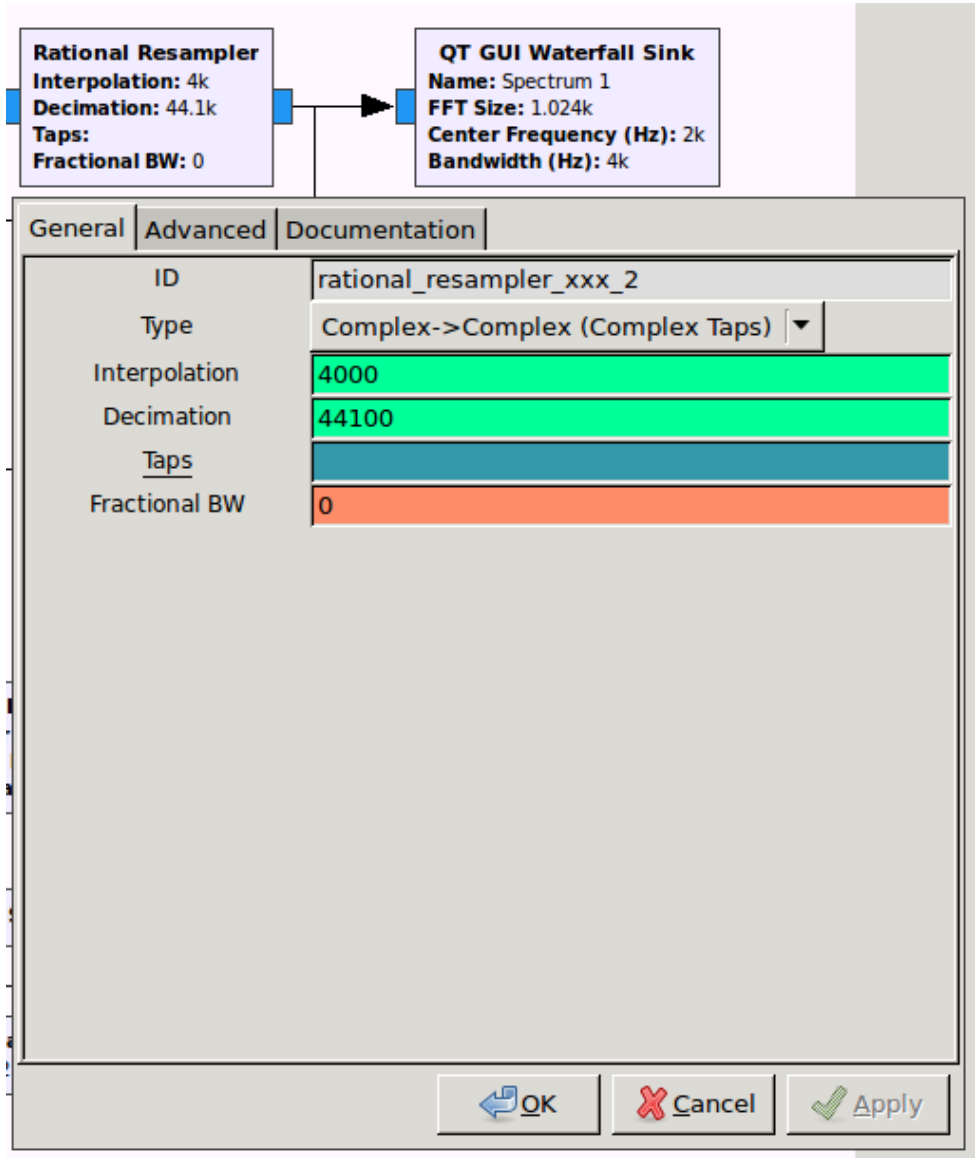
Rotator

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

Rotator


Rotator
Phase Increment: -284.952m
Interpolation: 4k
Decimation: 44.1k
Taps:
Fractional BW: 0
General
Advanced
Documentation
ID
blocks_rotator_cc_0
Phase Increment
2*math.pi*-2000/audio_samp_rate
OK
Cancel
Apply

Rational Resampler

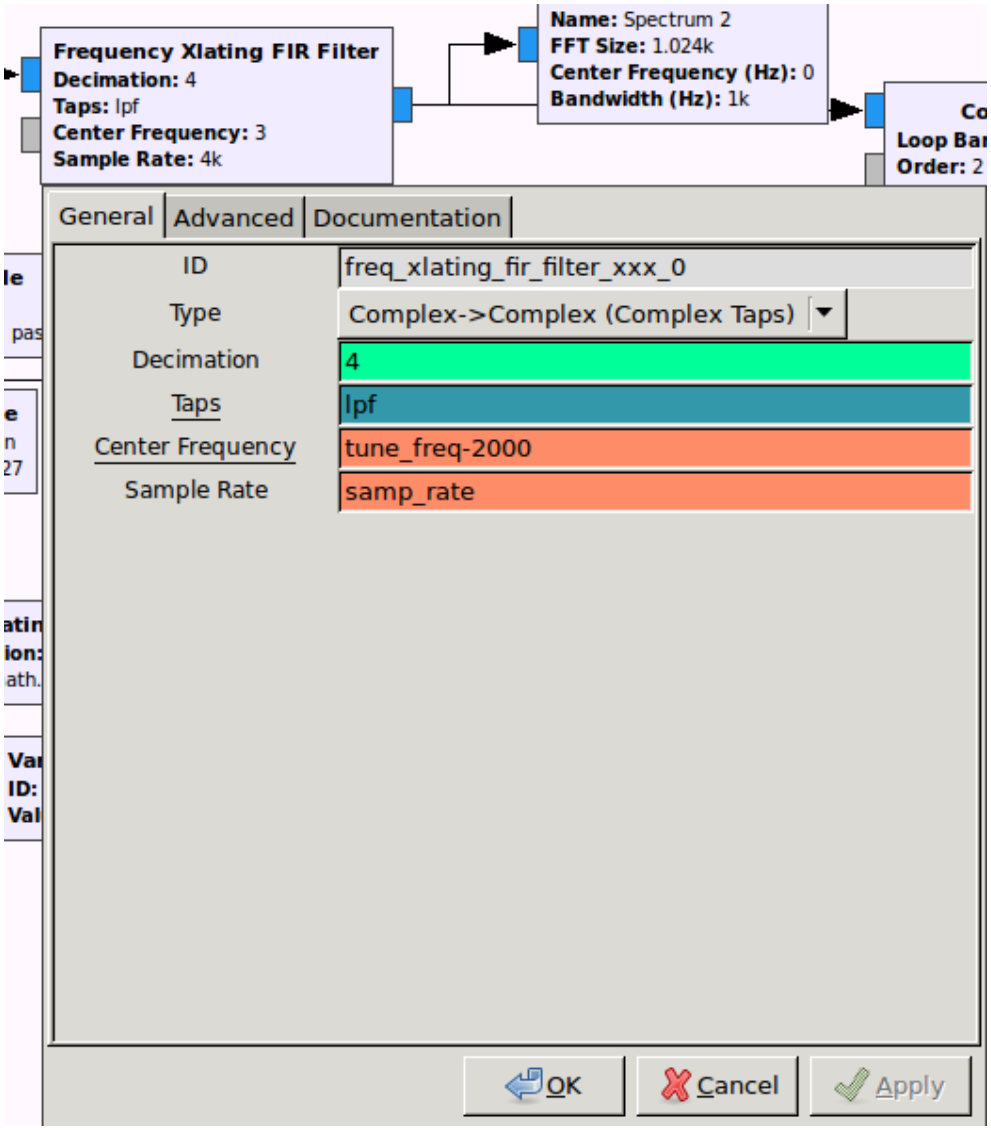


Frequency Xlating FIR Filter

Frequency Xlating FIR Filter

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

Frequency Xlating FIR Filter

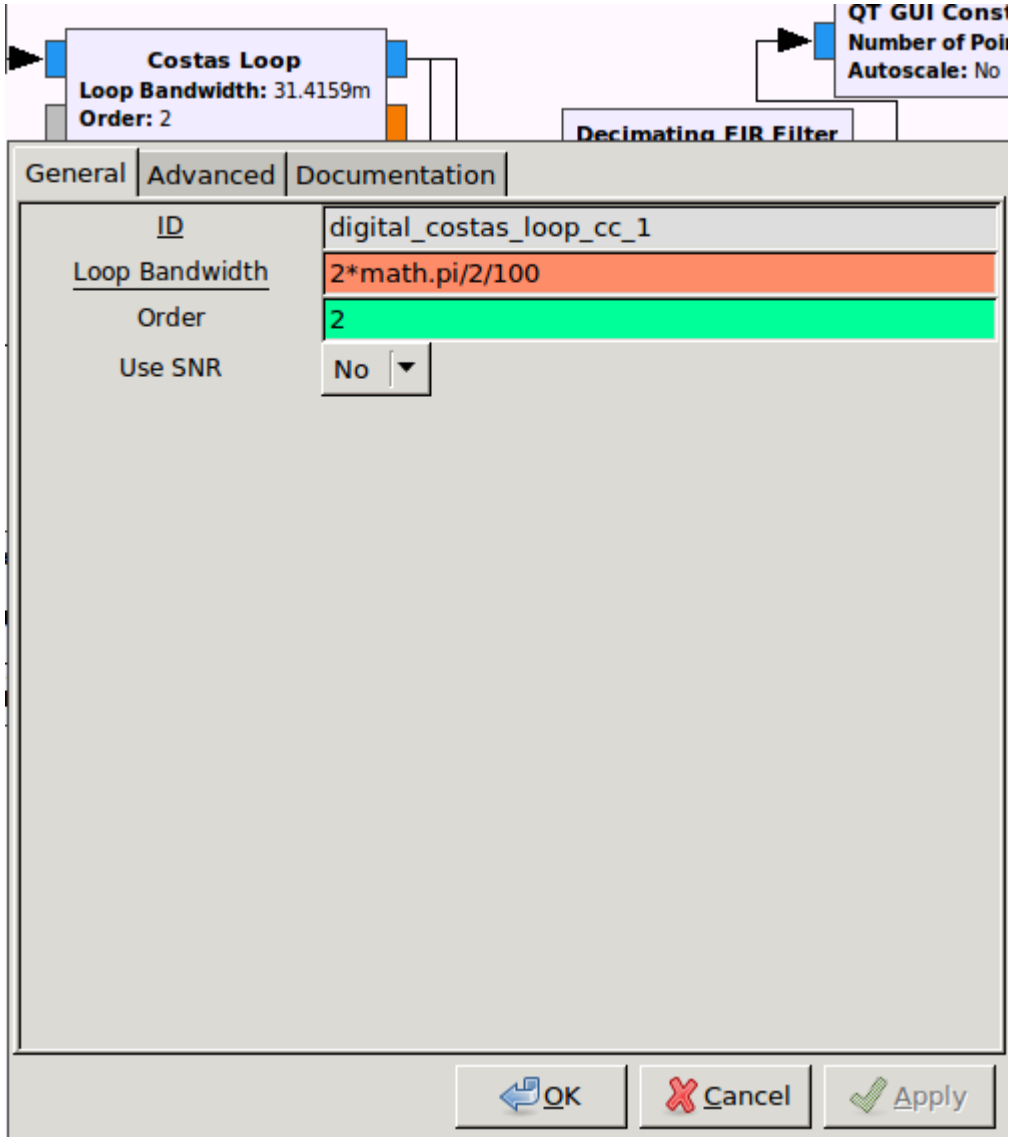


Costas Loop

Costas Loop

- Locks to the centre frequency of a signal and <u>downconverts it to baseband</u>

Costas Loop

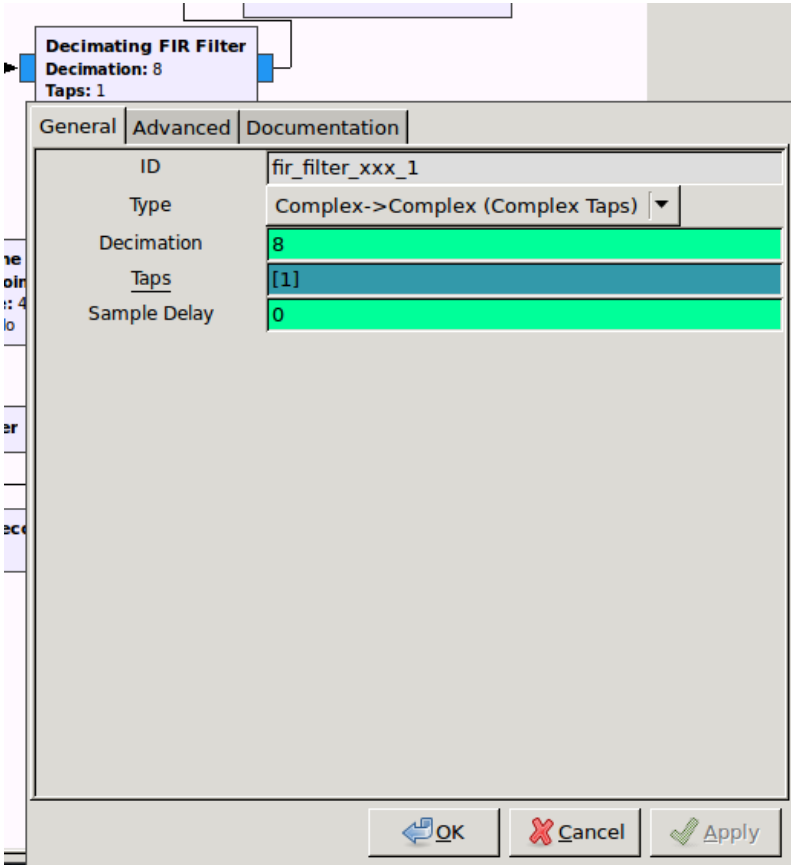

Costas Loop
Loop Bandwidth: 31.4159m
Order: 2
QT GUI Const
Number of Poi
Autoscale: No
Decimating FIR Filter
General
Advanced
Documentation
ID
digital_costas_loop_cc_1
Loop Bandwidth
2*math.pi/2/100
Order
2
Use SNR
No
OK
Cancel
Apply

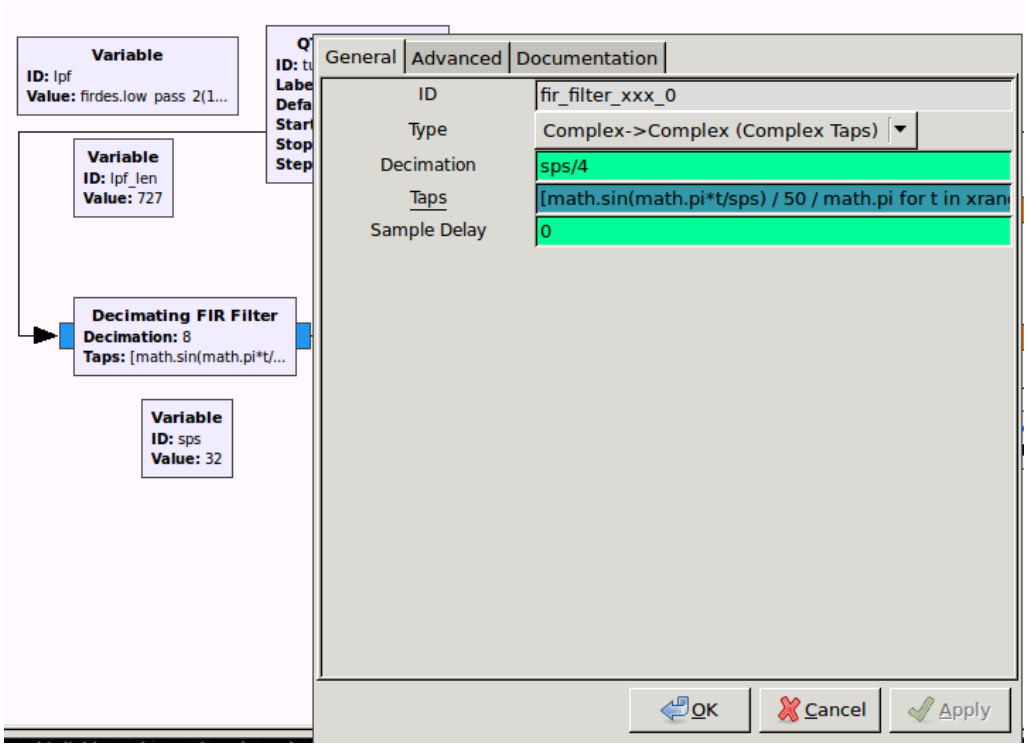
Decimating FIR Filters

Decimating FIR Filters

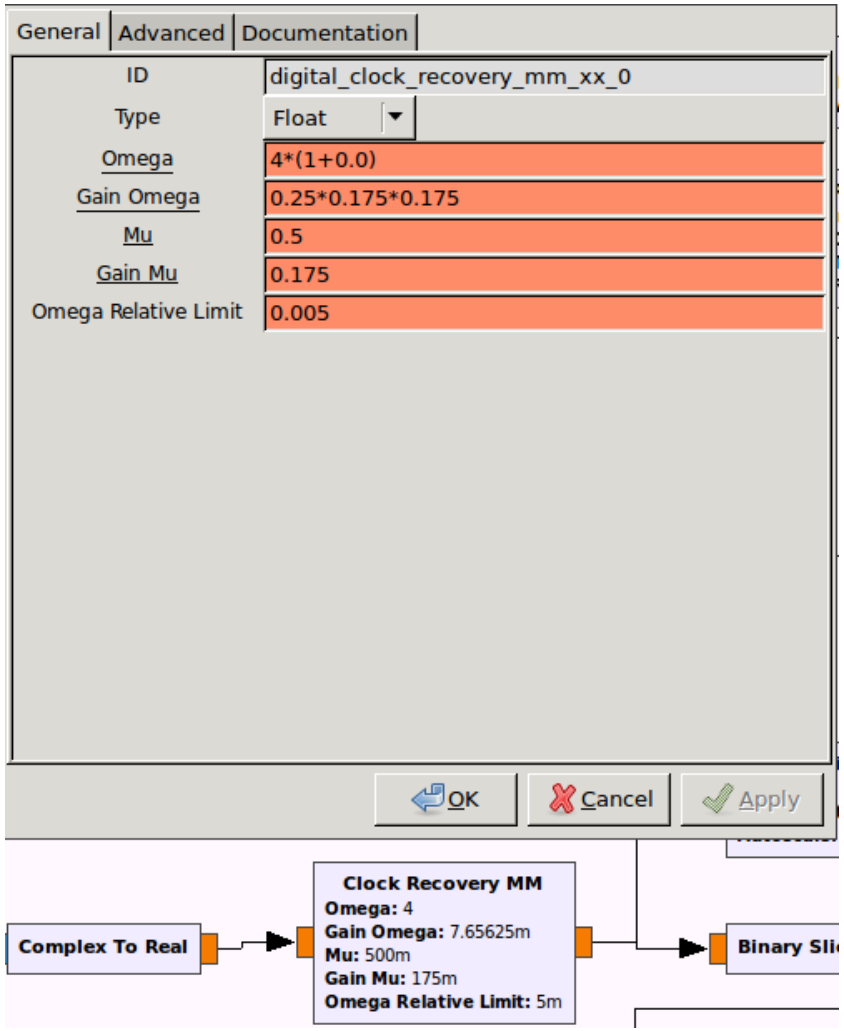
- Decimation is reducing the output sampling rate by ignoring all but every Nth sample

Decimating FIR Filters





Clock Recovery



Workshop time!

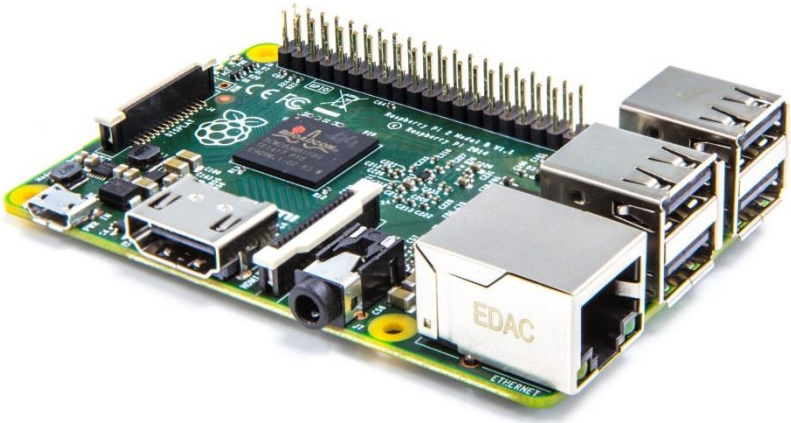
- Now it's your turn to follow steps 1, 2 & 3 here: https://github.com/0xsh/Workshops/tree/master/BSides-Canberra-2017

- Please collect a live USB Stick
  - Boot "Persistence Kali" menu option, this has GNURadio installed for you

Porting to a Raspberry Pi

Raspberry Pi – Data Exfil POC

- Raspberry Pi + USB Microphone + 4G Dongle



Raspberry Pi – Data Exfil POC

- Tutorial with GNU Radio: http://randomkeystrokes.com/2017/03/13/data-exfiltration-via-psk31-with-gnu-radio/

- Tutorial without GNU Radio: http://randomkeystrokes.com/2017/03/13/data-exfiltration-via-psk31-without-gnu-radio/

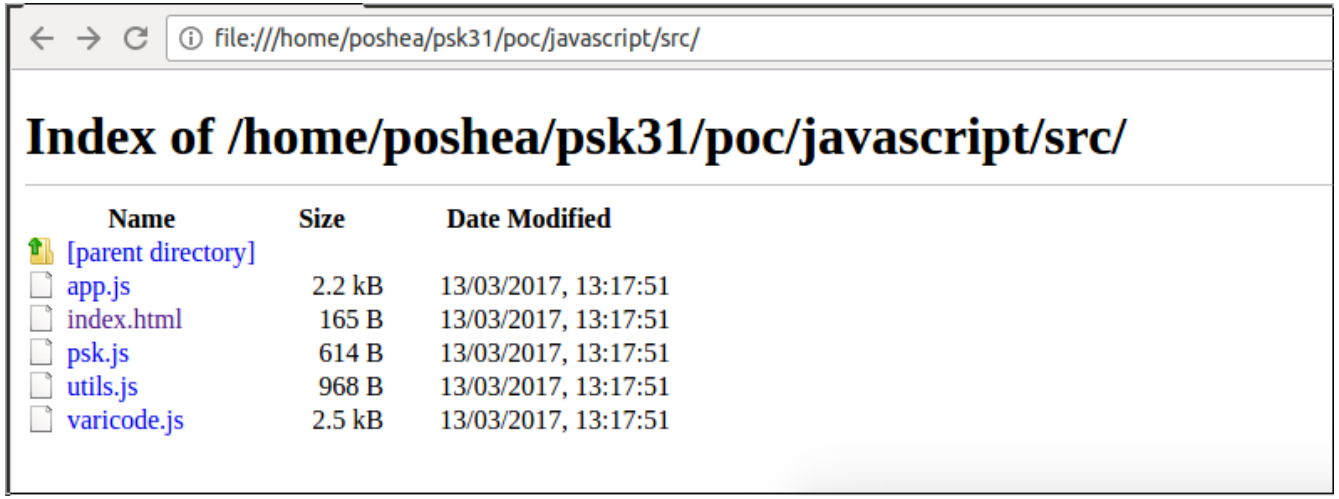
Raspberry Pi – Data Exfil POC

- Try out the JavaScript for transmitting PSK31 here: https://github.com/0xsh/Workshops/tree/master/BSides-Canberra-2017/JavaScript

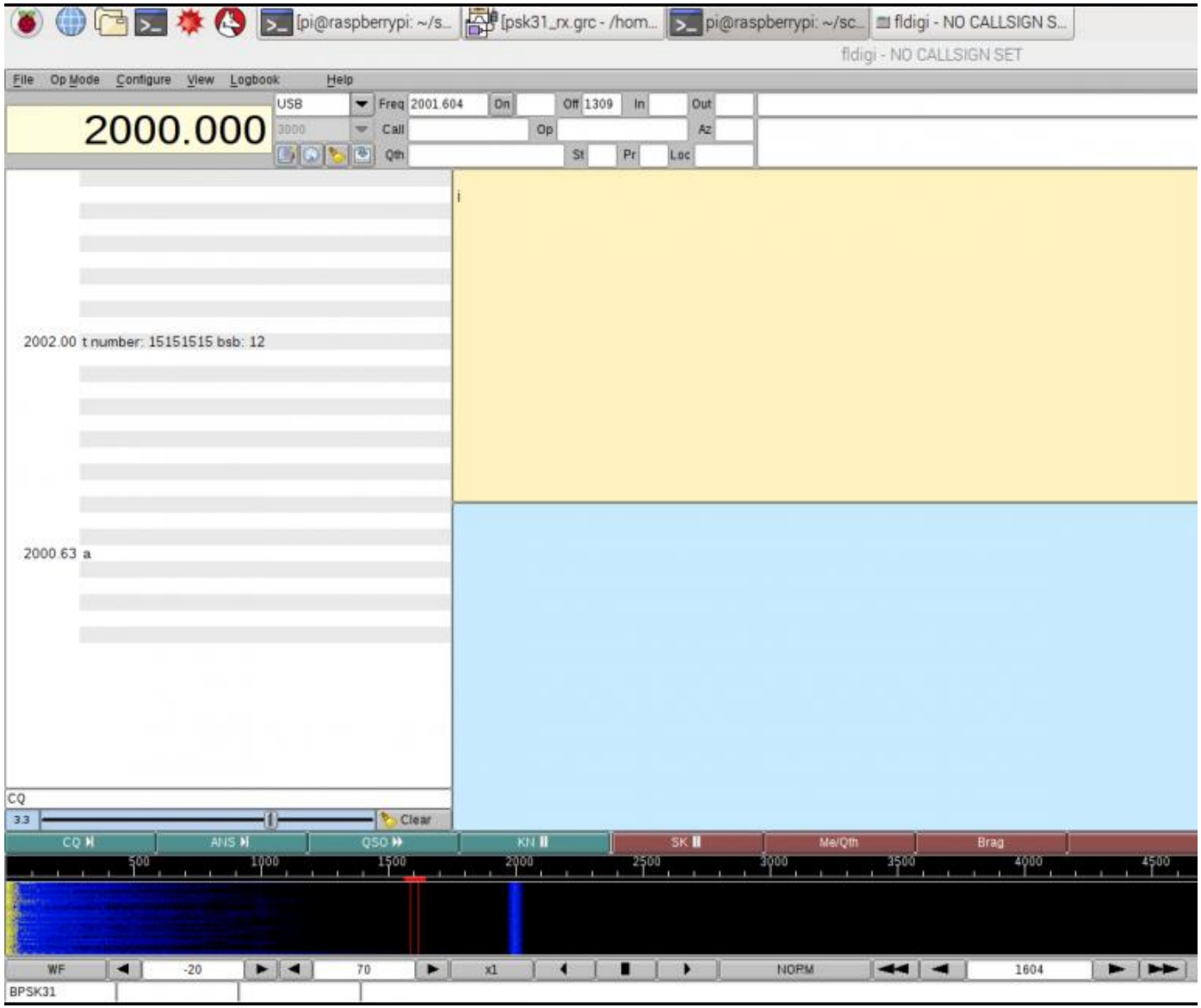
- You can keep the same GNU Radio receive graph to test it out on your laptop – but this also works on a Raspberry Pi with a USB microphone

- Can also use tools like Fldigi instead of GNU Radio for receiving or even more JavaScript!

JavaScript for transmitting



Raspberry Pi – Receiving with Fldigi



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/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

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Meetup	https://www.meetup.com/Cyberspectrum-Melbourne
Blog	http://randomkeystrokes.com/category/sdr/
Github	https://github.com/sdr-melbourne
YouTube	https://www.youtube.com/channel/UCLBloqxOXEj4fH7s ULA (SDR Melbourne Channel)

Please return the USB sticks…

or kitteh haz cry…