

# GNU Radio for Exploring Signals Talk Hard

A technical, historical, political, and cultural look at FM

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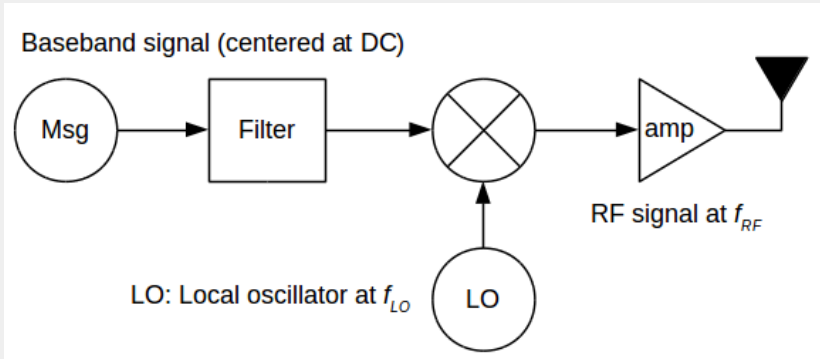
2016-02-01

*"It is proved that the frequency modulation system using a spacing or compensating wave is inferior to the amplitude variation system both as to the width of the frequency band occupied and as to distortion of signal wave form."*

- John R. Carson, "Notes on the Theory of Modulation"



# Amplitude Modulation



*"This superiority will increase as methods of dealing with ignition noise, either at its source or at the receiver, are improved"*

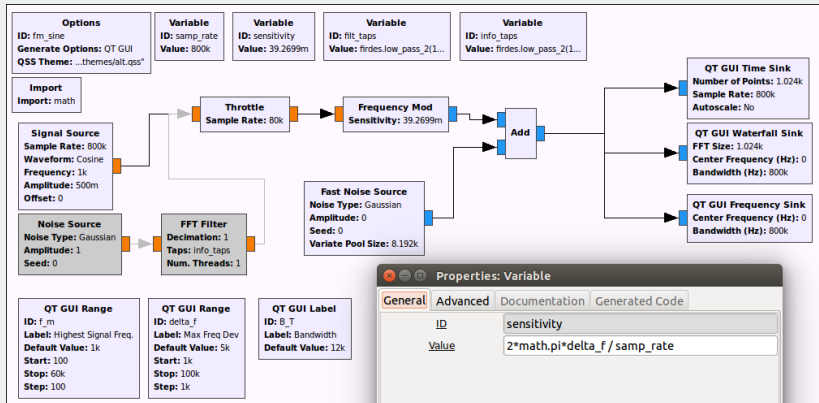
- Edwin H. Armstrong, "A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation"



**E. H. ARMSTRONG**

The discoverer of the "feed-back" circuit, in the uniform of a major in the Signal Corps during the war

# FMing a Sine Wave



# Frequency Modulation:

## Continuous Time

$$y(t) = \cos \left( 2\pi f_{\Delta} \int_0^t x(\tau) d\tau \right)$$

## Discrete Time

$$y[n] = \cos \left( 2\pi \frac{f_{\Delta}}{f_s} \sum x[n] \right)$$

$$y[n] = \cos \left( \eta \sum x[n] \right), \quad \eta = 2\pi \frac{f_{\Delta}}{f_s}$$

We call  $\eta$  the *sensativity*.

# Bessel Functions!

WAT!



No, let's skip that.

Ok, good.





# More practically speaking, what's the signal bandwidth?

## Definitions – Assumes sinusoid input

- $f_{\Delta}$ : maximum frequency deviation from the carrier
- $f_m$ : the highest frequency component in the original signal

## Carson's Rule

$$B_T = 2(f_{\Delta} + f_m)$$

Generally assumed to under-represent the signal bandwidth

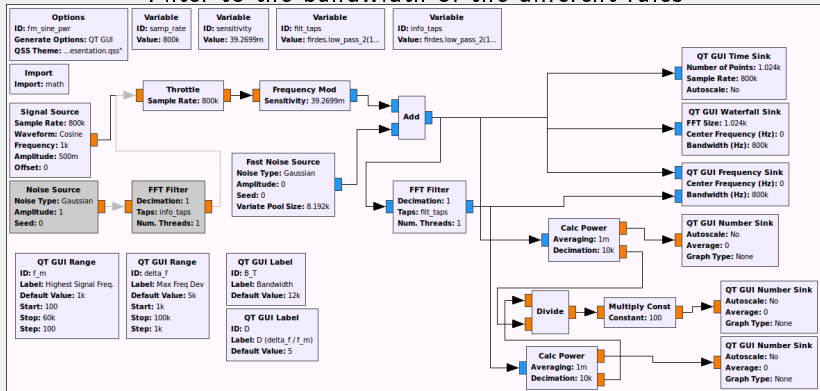
## Carlson's Rule

$$B_T = 2(f_{\Delta} + 2f_m)$$

More realistic calculation of the bandwidth

# What's the practical difference?

## Filter to the bandwidth of the different rules



*"The thrill, believe me, is as much in the battle as in the victory."*

- David Sarnoff

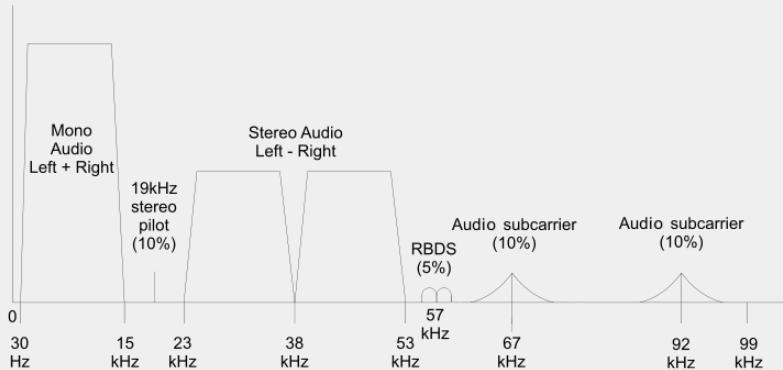




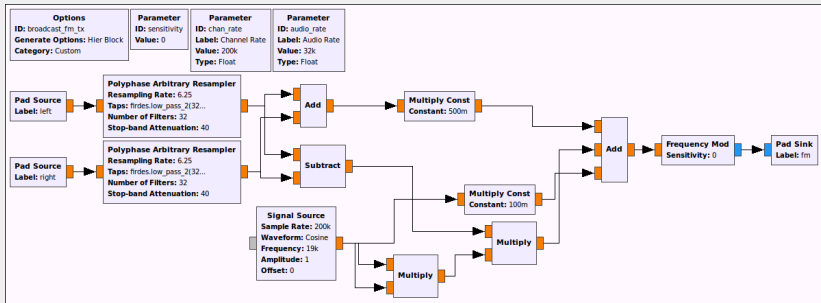
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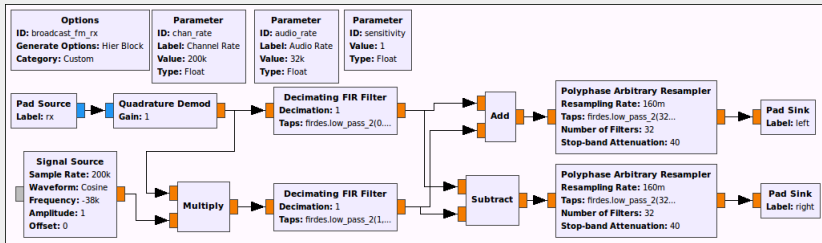
# FM Spectrum and Information Composition



# Modulating Stereo FM

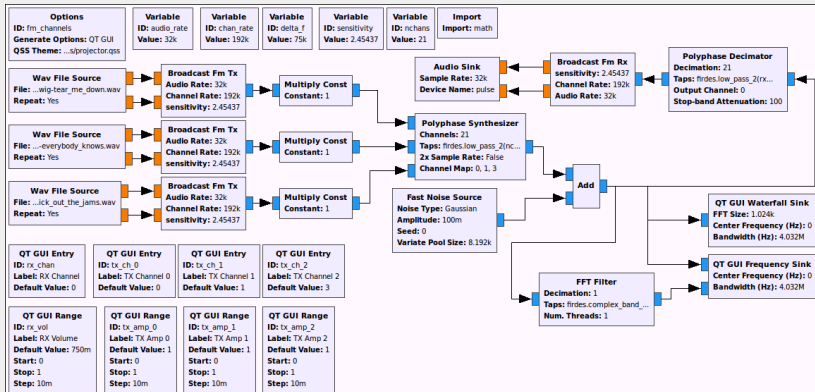


# Demodulating Stereo FM





# Channelizing FM



*"Welcome to radio free America."*  
- Happy Harry Hardon (Christian Slater), *Pump Up the Volume*



# Pirates on the airwaves



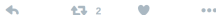
**Brooklyn PirateWatch** @BkPirateWatch · 24 Nov 2015

Listeners can hear 2 competing pirates each at 95.9 & 96.1: In each case 1 is Haitian, the other an Engl.-lang. Caribbean or hip-hop pirate.



**Brooklyn PirateWatch** @BkPirateWatch · 24 Nov 2015

...plus Haitian pirates at 90.9, 91.3, 95.3, 97.5, 104.7, and others. 91.3 has a strong signal in downtown Newark.



**Brooklyn PirateWatch** @BkPirateWatch · 24 Nov 2015

After more scans in Newark, from a higher elevation than before, we've heard: long-standing illegal mainstay [@ROADBLOCKKRADIO](#) at 90.1 FM....



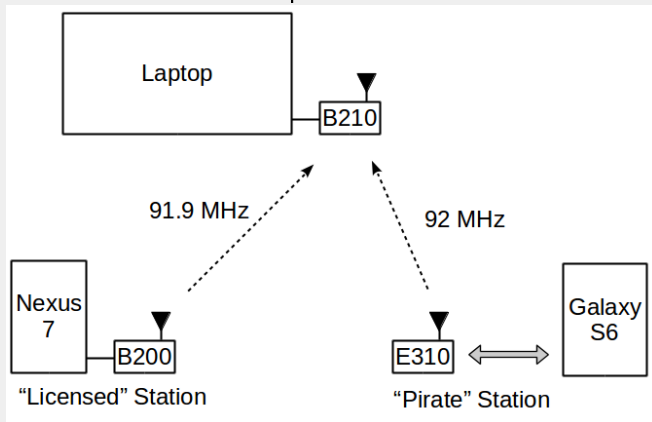
**Brooklyn PirateWatch** @BkPirateWatch · 24 Nov 2015

More visits to Newark NJ: Piracy seems to have increased significantly in Newark in recent years. Even weekday daytimes, many can be heard.



# What's the issue?

- High demand for spectrum.
- Interference and the FM Capture Effect.



# Questions?

*So be it.*

