Building a Super-Heterodyne Receiver to Observe the 21 cm Line

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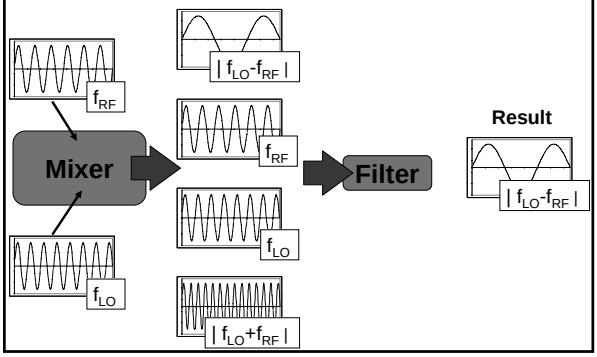
Advisor : Dr. Robert Mutel

How does Super-heterodyning Work?



e-SRT Design Goals

- Reduce a 1420.358 MHz (21 cm) signal to 1 MHz (in the center of a 2 MHz window)
- Build a receiver with low System Temperature and amplify the signal by approximately 120 dB
- Create a “Teaching Device” vs. a “Black Box”

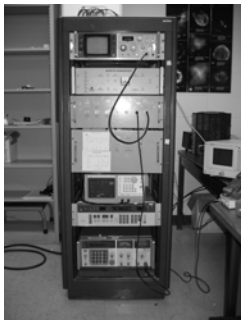
System Temperature

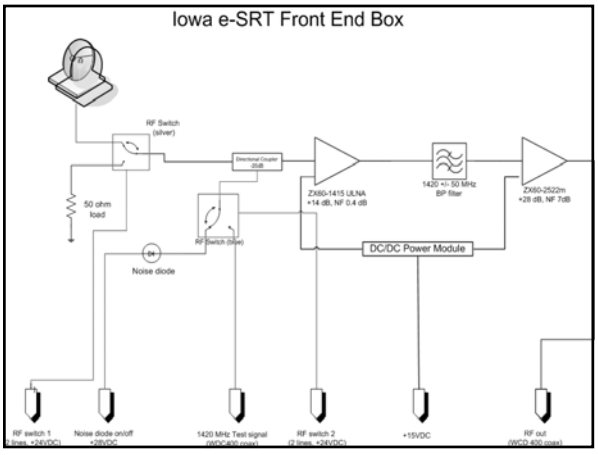
- The System Temperature typically has three parts
- Each component (Amplifier, Splitter, etc.) contributes to the Receiver Temperature T_R

and for multiple Amplifiers …

e-SRT Design

- Antenna and Front End Box
- IF Module
- IF Converter



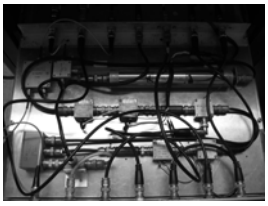


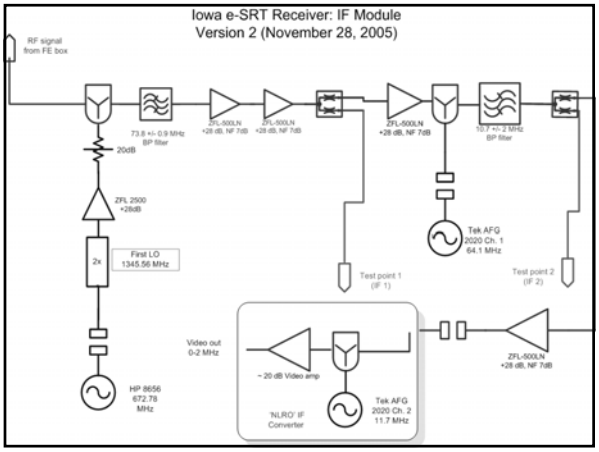
Amplification and System Temperature

Object	T(K)	G (dB)	Total T_{SYS} (K)	Total Gain (dB)
Sky	3	0.0	3.0	0.0
Spillover	50	0.0	53.0	0.0
Coax, Feed to RF Switch (1 ft)	13.7	-0.2	66.7	-0.2
RF Switch	20.7	-0.3	88.4	-0.5
Directional Coupler	20.7	-0.3	111.7	-0.8
1st LNA	27.9	14.0	145.3	13.2
1st BPF	35.4	-0.5	147.0	12.7
2nd LNA	288.6	23.5	162.5	36.2

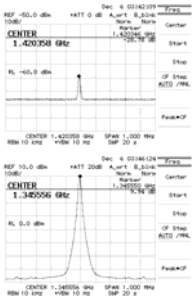
IF Module

- Once the signal leaves the Front End Box, the process of Super-heterodyning begins.
- Design contains signal test points to view the down-converting

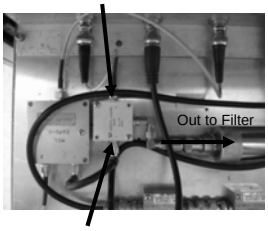




Path of a Test Signal



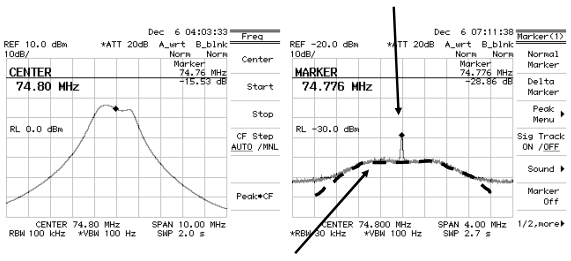
1420.358 MHz RF in from Front End Box



1345.558 MHz LO1 Signal (through Splitter)

Path of a Test Signal

1420.358 MHz – 1345.558 MHz = **74.8 MHz**

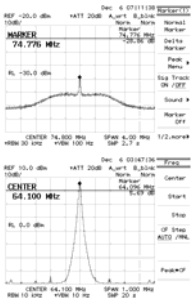


First Filter Response

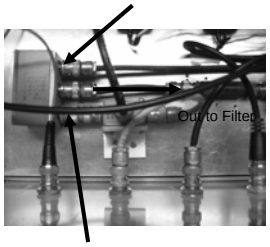
Amplification and System Temperature

Object	T(K)	G (dB)	Total T_{SYS} (K)	Total Gain (dB)
Front End Box			162.5	36.2
1st Mixer	1340.8	-7.5	162.8	28.7
2nd BPF	35.4	-0.5	163.1	28.2
1st IF1 Amp	288.6	28.0	163.3	56.2
2nd IF1 Amp	288.8	28.0	163.3	84.2

Path of a Test Signal



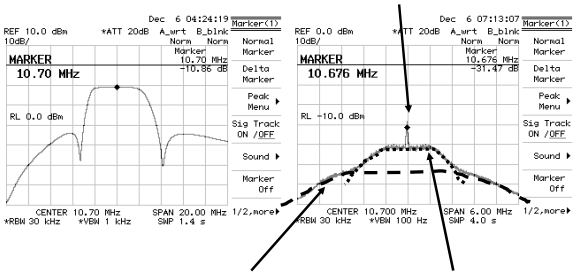
74.8 MHz in



64.1 MHz LO2 (through coupler)

Path of a Test Signal

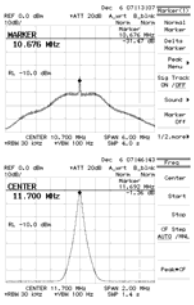
74.8 MHz – 64.1 MHz = **10.7 MHz**



First Filter Response

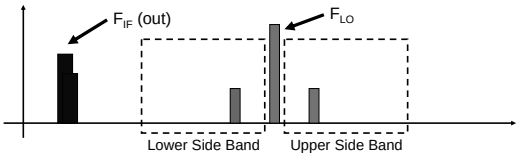
Second Filter Response

Path of Test Signal



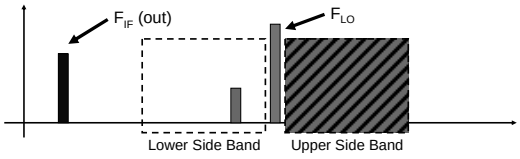
- For the last signal conversion, a different type of mixer must be used

Single Side Mixers



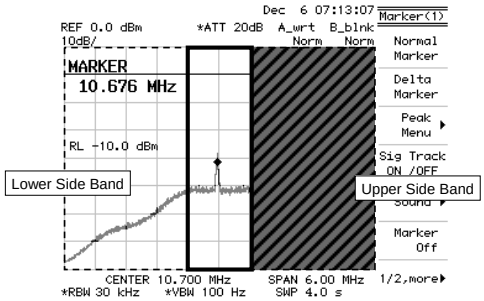
- Super-heterodyning reduces the input signal by mixing with the LO signal, regardless of which side of the LO the input is located.

Single Side Mixers



- Single Side Band Mixers filter out either the LSB or the USB before creating the beat frequency

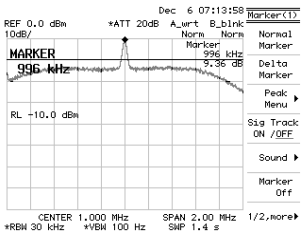
Single Side Mixers



2 MHz "Window" Remaining After Lower Side Band Mixing

Path of a Test Signal

- A test signal of 1420.358 MHz maps to an output signal of 1 MHZ
- Signals between 1395.358 MHz and 1445.358 MHZ also map into this window



Amplification and System Temperature

Object	T(K)	G (dB)	Total T_{SYS} (K)	Total Gain (dB)
Front End Box			162.5	36.2
IF1 Module			163.3	84.7
2nd Mixer	1340.8	-7.5	163.3	76.7
3rd BPF	35.4	-0.5	163.3	76.2
1st IF2 Amp	288.6	28.0	163.3	104.2
1st IF2 Amp	288.6	28.0	163.3	132.2