

Lab Manual:  
Communications Principles  
  
Using the EMONA Communications board for NI ELVIS III



Lab 19: Principles of Superheterodyne

List of Updates

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# Lab 19: Principles of Superheterodyne

## Learning Objectives

After completing this lab, you should be able to complete the following activities.

1. Describe the superheterodyne process and its benefit
2. Discuss the purpose of the IF stage
3. Describe the tuning capability of the local oscillator
4. Discuss the necessity of synchronization of carriers

## Prerequisites

You should have completed Lab 1 and Lab 2 and be familiar with the equipment, its use and the handling precautions for the equipment.

## Required Tools and Technology

|  |  |
| --- | --- |
| Platform: NI ELVIS III Instruments used in this lab:   * Oscilloscope-Time * Oscilloscope-FFT * Function and Arbitrary Waveform Generator | * Install Instruments: [http://www.ni.com/documentation/en/ni-elvis-iii/latest/getting-started/installing-the-soft-front-panel/](http://www-preview.ni.com/documentation/en/ni-elvis-iii/1.0/getting-started/installing-the-soft-front-panel/) * Access instruments   <https://measurementslive.ni.com>   * View User Manual   <http://www.ni.com/en-us/support/model.ni-elvis-iii.html>   * View tutorials <https://www.youtube.com/playlist?list=PLvcPIuVaUMIWm8ziaSxv0gwtshBA2dh_M> |
| Hardware: Emona Communications Board Components used in this lab:   * Four BNC to 2mm banana-plug leads * Assorted 2mm banana-plug patch leads * Set of headphones or earbuds | * View User Manual   <http://www.ni.com/en-us/support/model.emona-communications-board-for-ni-elvis-iii.html> |

## Expected Deliverables

In this lab, you will collect the following deliverables:

* Calculations
* Data from measurements
* Observations

Your instructor may expect you complete a lab report. Refer to your instructor for specific requirements or templates.

## Section 1: The Superheterodyne receiver

## Theory and Background

It is the aim of a radio receiver to select one, from many, modulated signals from the radio spectrum, and to recover (demodulate) the message it contains. A tuneable bandpass filter (BPF), tuned to the desired frequency, followed by a demodulator, could achieve this. But tuneable bandpass filters are difficult to design, especially over a wide frequency range. Hence a different approach is preferred.

The superheterodyne receiver avoids this problem. It converts the frequency of the desired input signal to the centre frequency of a **fixed-tuned bandpass filter**. The output of the BPF, still a modulated signal, is then demodulated.

The bandpass filter operates at what was historically called an intermediate frequency (IF) – intermediate between the incoming signal frequency and the desired (audio) output. But this is not necessary – any frequency range of convenience can be used (**either above or below** the incoming frequency). A study of the history of the superheterodyne will reveal the reasons for its early development (circa 1920) and the many compromises then necessary.

[Reginald Fessenden](https://ethw.org/Reginald_A._Fessenden) was the first to apply the “heterodyne” principle, to wireless communications in 1901. The term “heterodyne” was coined by Fessenden from the Greek words for "other" and "force." The heterodyne principle is based on the phenomenon which we have already explored in previous experiments involving demodulation, where the combination of two tones with frequencies A and B results in an oscillation equal to frequency A minus B.

We know that the multiplication of two frequencies fA and fB results in two new components (fA – fB) and ( fA + fB). This results in a **translation** of the original signal in frequency.

In **heterodyne** detection, the local oscillator is frequency-shifted, while in **homodyne** detection it has the same frequency as the radiation to be detected. Using the same frequency results in a direct conversion receiver (meaning the message on RF signal is translated directly to baseband), which is now commonly implemented in Software Defined Radios using very fast sampling ADCs at the antenna stage.

The superheterodyne receiver can be divided into three sub-systems: an RF

amplifier/frequency changer, an intermediate frequency filter/detector, and an audio output amplifier.

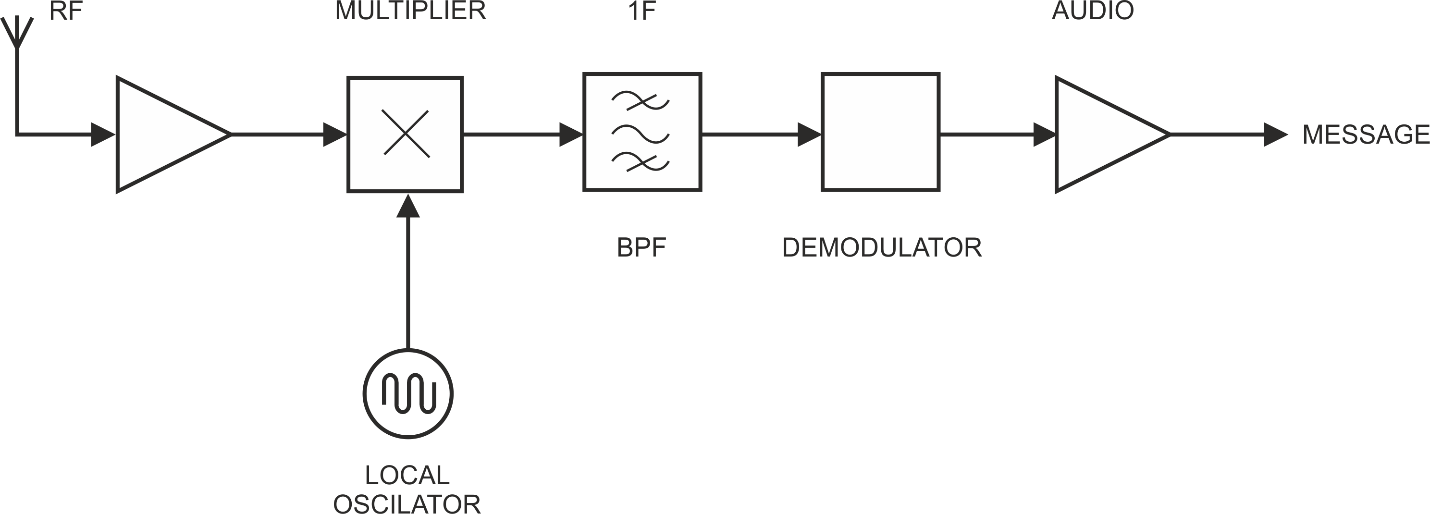


Figure 1: Block diagram of superheterodyne receiver system

## 1.2 Implement: Modeling the RF signal to be recovered

In this experiment we will make use of the blocks we have available to model the “RF” signal which the superheterodyne system will recover.

Since we have a 100kHz BPF module available we will define 100kHz to be the local oscillator frequency. This is in line with the “superhet” principle of translating the RF signal to a frequency at which there is an available, affordable and operational bandpass filter to extract the channel of interest.

For some realism, a double sideband signal with audio message will be used as the RF signal source. Typically an AM signal is recovered using superheterodyne techniques as this has the simplest detection requirements, however in this experiment a DSB-SC signal is simpler and adequate.

Issues to do with rejection of unwanted images, alignment and synchronization of the LO (local oscillator) and filtering requirements are investigated.

It should take you about 45 minutes to complete this experiment.

**Powering up the ELVIS III + EMONA Communications Board**

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| --- | --- |
| 1. | Ensure that the NI ELVIS III Application Board power button at the top left corner of the unit is OFF (not illuminated). |

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| --- | --- |
| 2. | Carefully plug the Emona Communications board (ECB) into the NI ELVIS III ensuring that it is fully engaged both front and back. |

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| 3. | Ensure that you have connected the NI ELVIS III to the PC using the USB cable and that the PC is turned on. |

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| 4. | Turn on the Application Board *Power* button by pressing it once and confirm that it is illuminated. The LEDs on the ECB should also be illuminated. If they are not, then switch the unit off immediately and check for connection or insertion errors. |

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| 5. | Open the Instrument Launcher software in your browser and select and RUN the following instruments. |

Scope Configuration

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| --- | --- |
| Channel Voltage range | 1V/div |
| Horizontal Timebase | 500us/div |
| Trigger | Type: Analog edge, Source: Channel 1 input, Rising |
| Probe Attenuation | 1x |

To create our two sideband DSB-SC (Double Sideband-Suppressed Carrier) signal patch together the system as shown in Figure 2.

You will need to use a 180kHz sinewave signal from Channel 1 of the FUNCTION GENERATOR on ELVIS III.

Function and Arbitrary Waveform Generator Configuration

|  |  |
| --- | --- |
| Channel 1 | Sine |
| Frequency | 180kHz |
| Amplitude | 2Vpp |
| DC Offset | 0V |

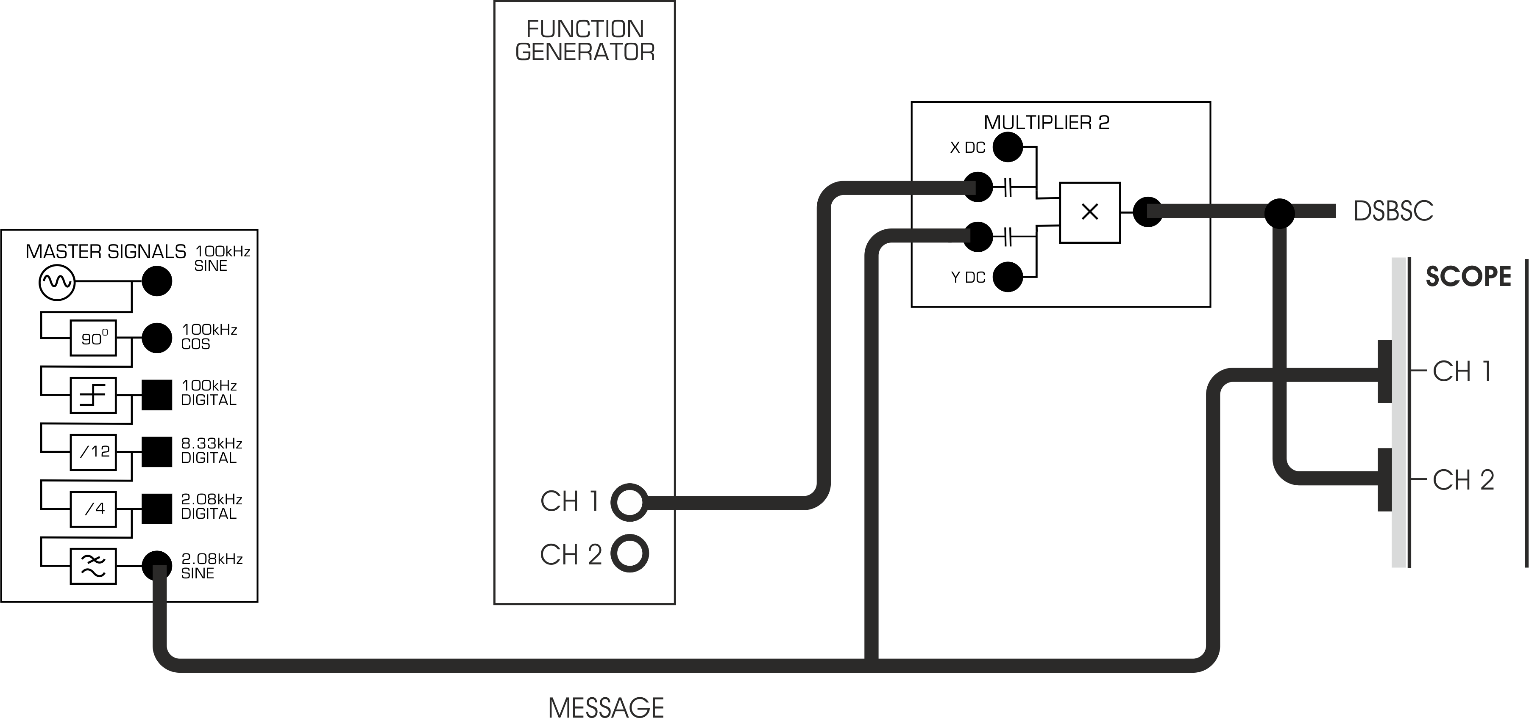


Figure 2: Patching to create DSBSC signal

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| --- | --- |
| 6. | View both the 2kHz message and the DSB signal using Channels 1 and 2 of the scope. |

|  |  |
| --- | --- |
| 7. | Open the FFT window in the scope panel and view the DSB signal in the frequency domain. Remember, to have a high resolution frequency display you must view MORE of the signal in the time domain ie set the timebase to 500us/div. |

|  |  |
| --- | --- |
| 8. | You will need to set the frequency range of the FFT window from 0Hz to 200kHz as the RF signal is at 180kHz. |

The FFT is derived FROM the time domain signal so it stands to reason that more time domain signal viewed and captured gives a higher resolution FFT display.

1-1 At what frequency are the sidebands of the DSB signal ?

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1-2 Are there any other components of this signal that perhaps we did not expect ?

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Figure 3: Scope display for DSBSC "RF" signal

## 1.3 Implement: Translate the RF signal to IF (Intermediate Frequency)

As mentioned in the introduction, we have a 100kHz BPF (Band Pass Filter) at 100kHz available on the EMONA Communications board. For this reason we will treat 100kHz as the IF.

We wish to translate the DSB sidebands centered at 180kHz to the 100kHz region. To do this we will exploit the heterodyne principle that multiplying two frequencies results in two new components: sum and difference frequencies.

We will use a local oscillator frequency of 80kHz. This will come from Channel 2 of the FUNCTION GENERATOR.

Function and Arbitrary Waveform Generator Configuration

|  |  |
| --- | --- |
| Channel 2 | Sine |
| Frequency | 80kHz |
| Amplitude | 2Vpp |
| DC Offset | 0V |

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| 1. | Set up the FG to output 80kHz from Channel 2. |

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| 2. | Patch up the additional translation circuit as shown in Figure 3 |

1-3 what are the two center frequencies that the translation circuit will create ?

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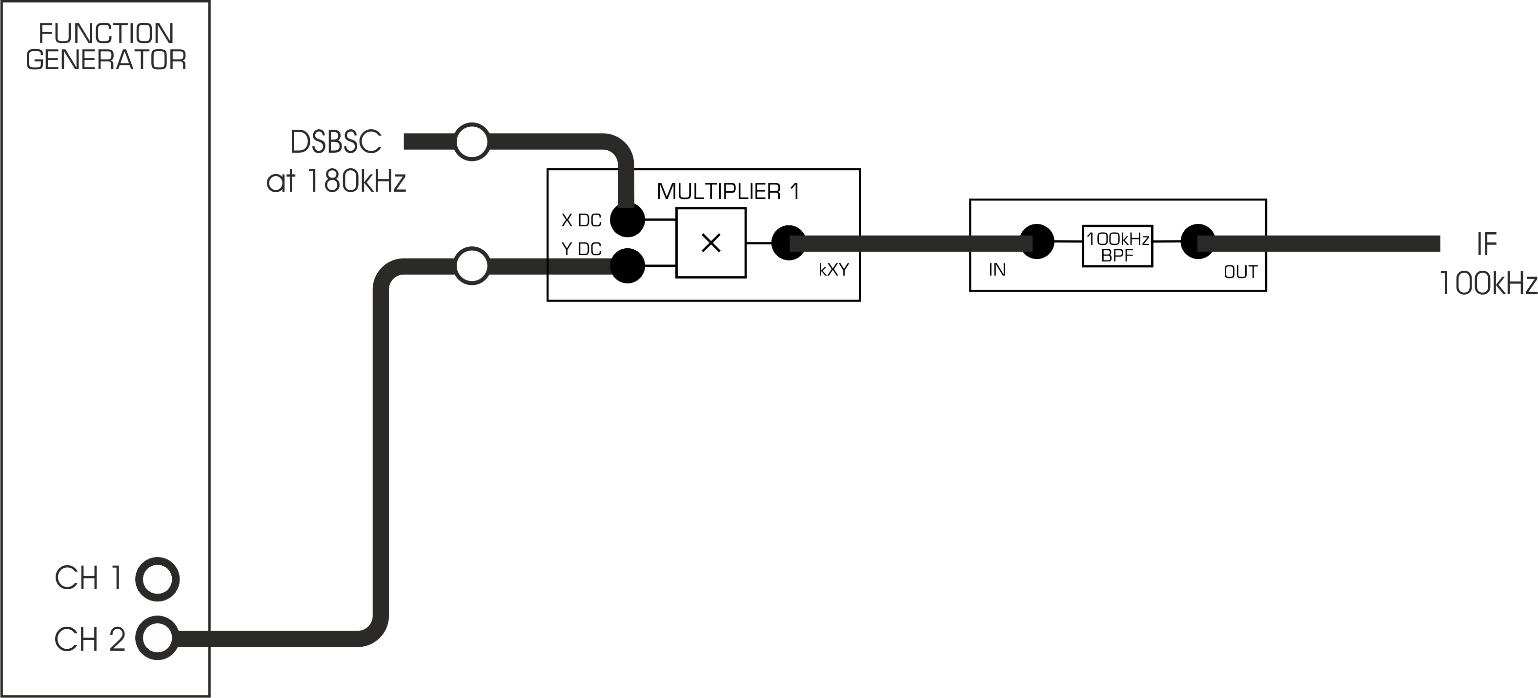


Figure 4: Additional patching to translate RF to IF stage

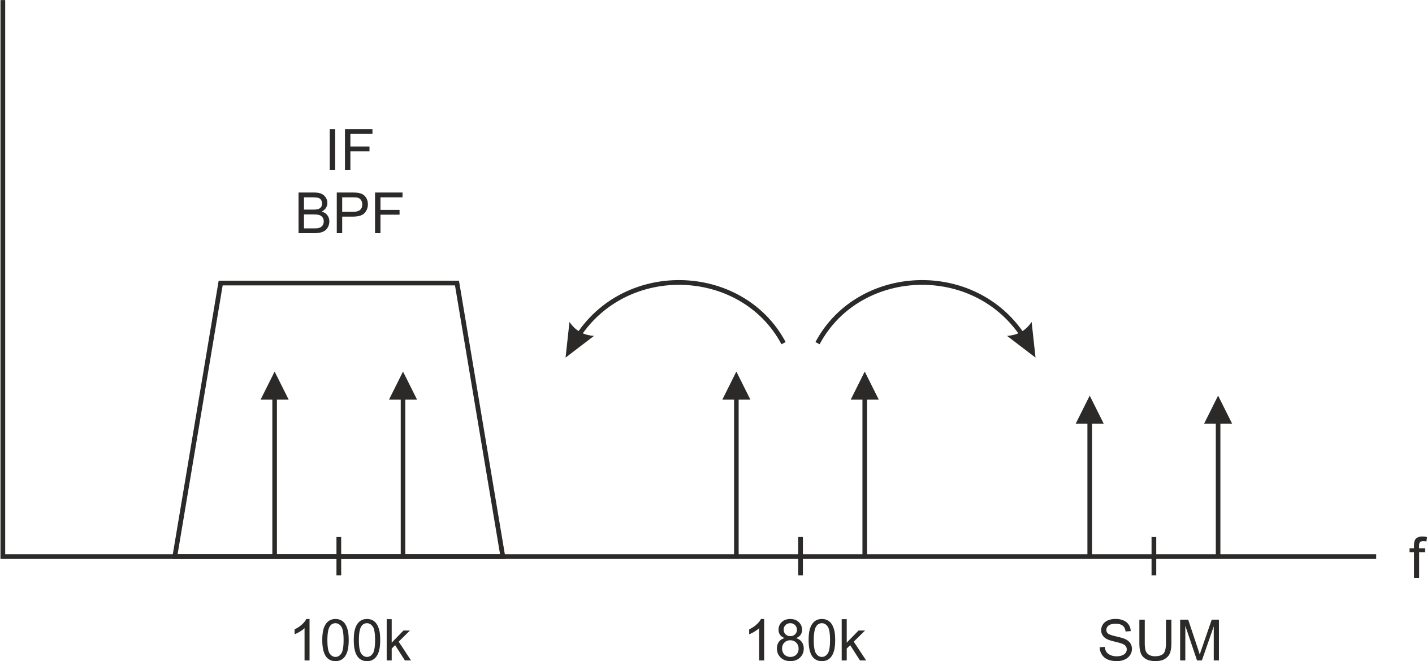


Figure 5: Translation of frequencies to from RF to IF

You now have 2 BNC leads to the scope and two BNC leads from the FUNCTION GENERATOR.

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| --- | --- |
| 3. | Move the scope leads to view the input and output of the 100kHz BPF as well as the FFT display of the input. Vary the timebase so that the components are well resolved. |

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| 4. | Set the FFT range to display from 0Hz to 300kHz. |

1-4 What frequency components are visible?

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1-5 Are there any unexpected components? Why do they exist?

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| 5. | View the output of the BPF on the FFT display. |

1-6 What major frequency components are visible, and why?

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## 1.4 Implement: Tuning the IF

The output of the 100kHz BPF is effectively our channel select output. Any RF channel we wish to recover has to pass through this narrow “keyhole” in frequency.

What happens if out LO is not set correctly to recover the “RF channel” signal at 180kHz.

Whilst using the FFT display on the scope to view the output of the 100kHz BPF, vary the frequency of the LO using the FG control panel. Try changing the 80kHz both up and down in frequency. Pay attention to the signal in the time domain as well.  
NOTE: The Frequency display is auto-ranging so pay attention to the vertical dB range whilst doing this.

1-7 What happens to the components out of the BPF?

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1-8 What are the implications of not having the LO set to say 81kHz?

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## 1.5 Implement: Translate the IF to baseband

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| 1. | Reset the IF to exactly 80kHz and confirm the output of the BPF is as expected.  Now introduce the circuits for translating from IF to baseband. Patch together the additional modules as per Figure 5. |

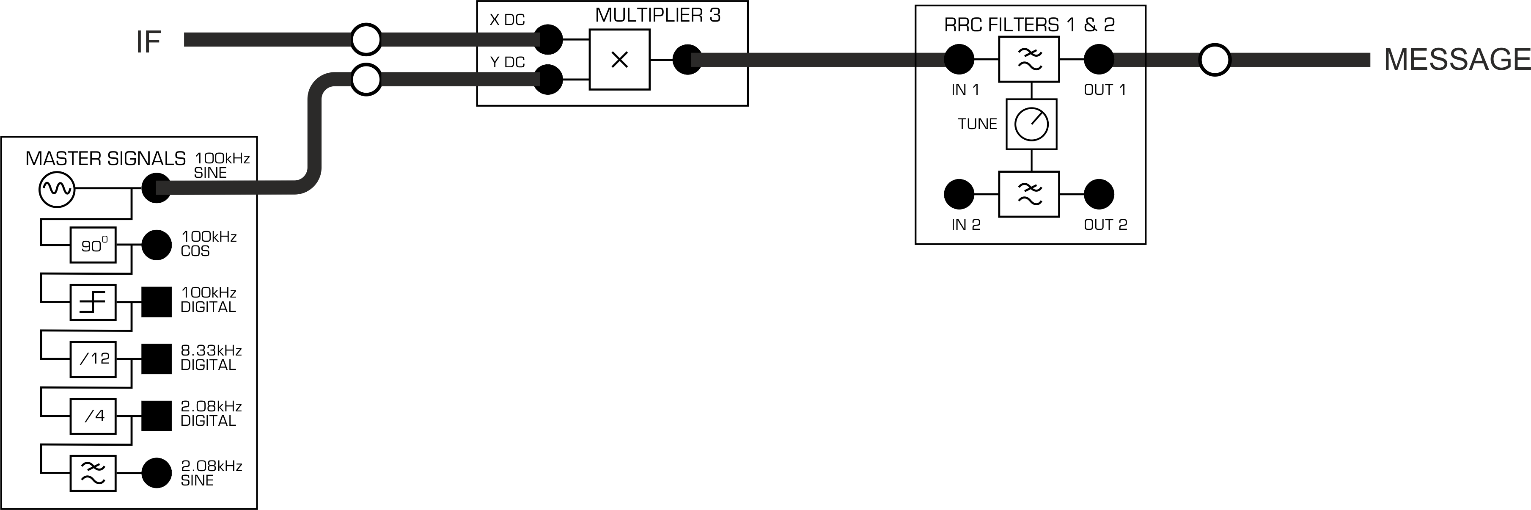


Figure 6: Additional patching for IF to baseband stage

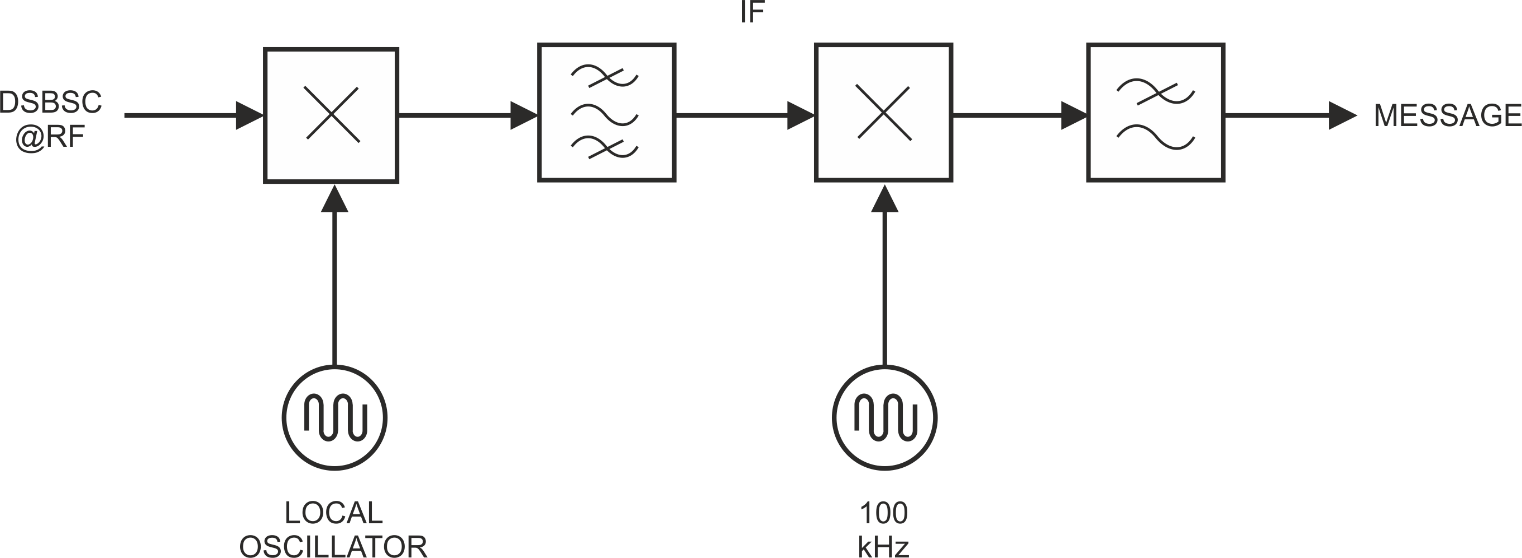


Figure 7: Block diagram for superheterodyne receiver implementation

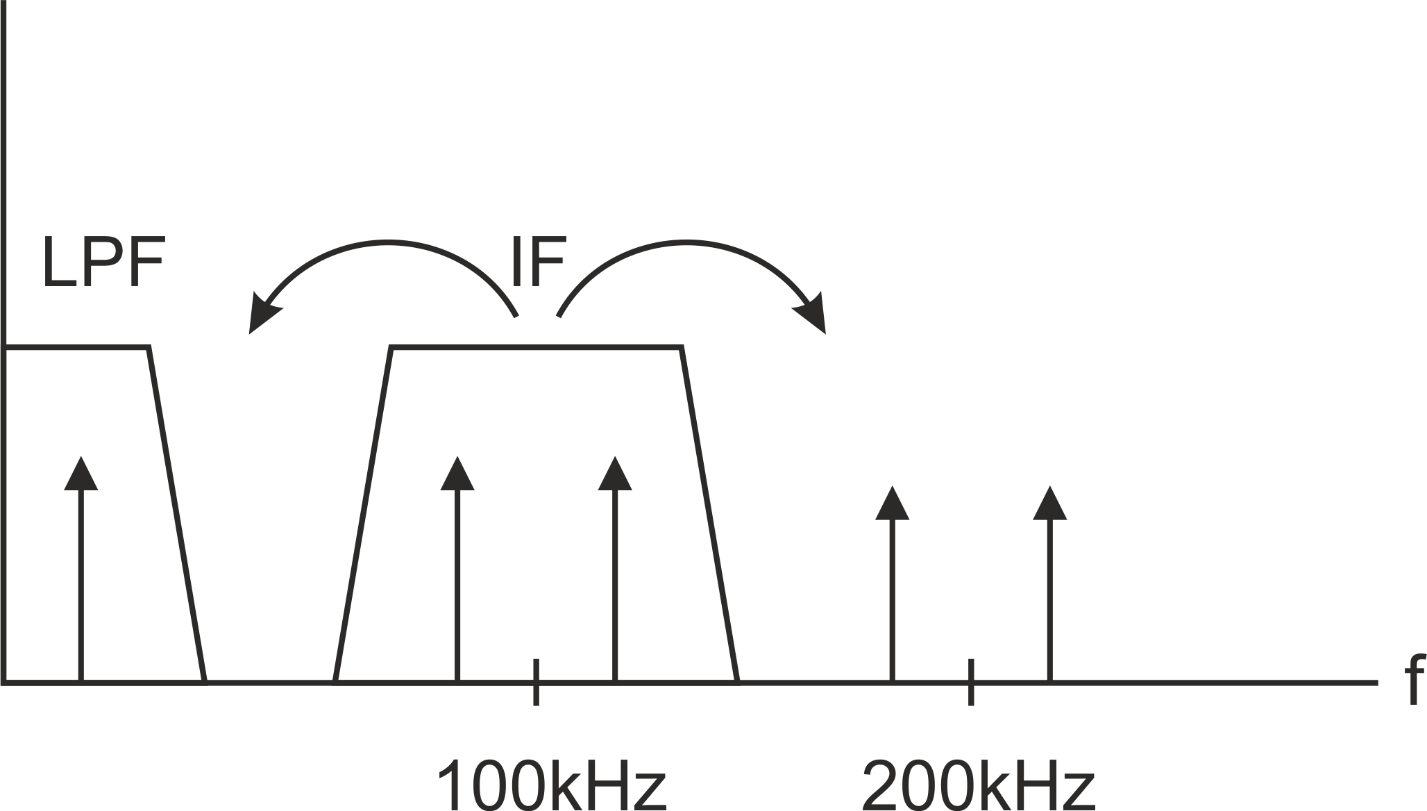


Figure 8: Translation of frequencies from IF to baseband

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| 2. | Tune the RRC FILTER 1 to maximum cutoff frequency. It only serves to eliminate the 200kHz components so no need to tune it specifically. |

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| --- | --- |
| 3. | View the input and output of the RRC FILTER 1 module with Channels 1 & 2 of the scope. As well view the input on the FFT display.  Set the frequency range to 0Hz to 220kHz. |

1-9 Are there any unexpected components ?

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| 4. | View the original 2.08kHz message signal at MASTER module and trigger the scope on this signal. View the recovered 2.08kHz signal out of the RRC FILTER 1 module. |

1-10 Why is the recovered 2.08kHz sinewave varying in amplitude constantly?

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Although the recovered signal is necessarily varying in amplitude we can see that the process of signal translation has indeed been successful.

Try varying the LO on Channel 2 of the FUNCTION GENERATOR again as you did in Section 1.4.

1-11 What happens to the recovered message signal and why?

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