

Robbie Young ADSPC ACDA6018

by Robbie Young

Submission date: 22-Jan-2025 02:53PM (UTC+0000)

Submission ID: 249242870

File name: 32858_Robbie_Young_Robbie_Young_ADSPC_ACDA6018_641246_571915852.docx (1.74M)

Word count: 2642

Character count: 13360

Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver Design Using GNU Radio
Name: Robbie Young
Student Number: 2111907

Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver Design Using GNU Radio

Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver
Design Using GNU Radio
Name: Robbie Young
Student Number: 2111907

Contents

- Title Page
- Introduction
- Task one
 - Introduction
 - Background research
 - NBFM Modulation and demodulation
 - Block diagrams
 - Modulation
 - Demodulation
 - Jamming
 - Block diagrams
 - Anti Jamming
 - Block diagrams
 - Analysis and comparison
 - Modulation
 - Demodulation
 - HFSS modulation
 - HFSS demodulation
 - Ethics and impact
- Task two
 - Introduction
 - Setup and design
 - Analysis
 - Ethics and impact

Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver Design Using GNU Radio
Name: Robbie Young
Student Number: 2111907

Introduction

This document details how FM communication systems work in GNU radio. In GNU radio software, Wideband frequency modulation, in turn with an USB output RTL-SDR receiver connected to the software, will be used to demonstrate how a FM Radio system works. Jamming and anti-Jamming techniques will also be used to show the effects both have on performance also covered in this document will be the effects implications of using secure communication methods.

Task One

Introduction

Task one is to simulate a narrowband frequency modulation communication system. Add a jammer then implement anti jamming technique called frequency hopping spread spectrum (FHSS) once completed analysis on the difference's will be done

Background Research

There have been many advances in FM communication techniques allowing for better anti-jamming protocols as using FM communication alongside other communication setups allowing for multiple input and multiple output communication, this means that if one of the two inputs is jammed, then the other communication system can still work and actively talk to the device. Another way is using directional antennas to prevent jamming. FM has also been slowly added to 5G, this is to allow better integration allowing for better communication between different communication networks. Some of the following articles explain how FM modulation works and it applications, [1], [2], [3].

NBFM Modulation and Demodulation

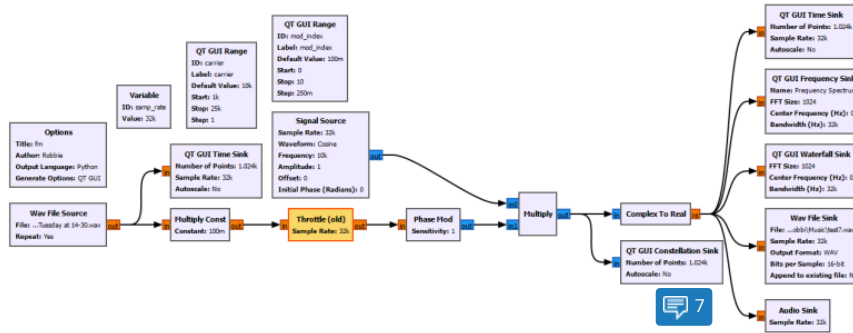
Narrow band frequency modulation is a form of frequency modulation where a narrow bandwidth is used to transmit a signal, the reason a narrow bandwidth is used to transmit is because it can reduce interference, such as noise or jamming. Frequency modulation works by multiplying a sample frequency such as a carrier to the original signal. Thus, the signal is seen floating on the carrier frequency wave.

Frequency demodulation is the inverse of frequency modulation. The modulation frequency is picked up by an antenna, it then is derived by dividing the picked-up signal by the carrier signal, this should remove the carrier part, leaving the original unmodulated signal. However, there are a few problems with this, the main one being noise. Noise can be added to the carrier signal in many different ways, for example another carrier frequency that has a frequency and are very close to modulated frequency can cause interference. This is why governing bodies such as OFCOM [4] exist, to ensure that there is as little interference whilst still being able to use as many frequency bands as possible, they do this by assigning carrier frequencies to ensure that users aren't on the same band. Other noise sources can include environment factors such as solar flares, or electronic devise such as mobile phones. All these factors can create noise effecting the modulated signal. Once demodulated most if not all noise can be removed, this is done by using filters.

Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver Design Using GNU Radio
 Name: Robbie Young
 Student Number: 2111907
 Block Diagrams

Modulation

Before setting up modulation to use, GNU Radio parameter must be set. The first items that need setting are programming language and the option to allow GT GUI. Once set, these allow for the GNU Radio work and function as intended.



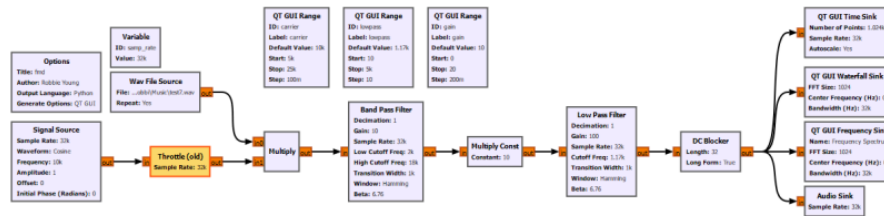
Before block diagrams of how the modulation works the sample, a variable is set which represents the carrier wave must be set. To do frequency modulation for this task it is set at 32KHz. Following this the GT GUI Range parameters are set, these include setting up the carrier frequency, making it a floating value, allowing it to change during the run. Setting it lower and upper limits for the message, starting at 1K and ending at 25KHz. The next step is making the modulation index, doing the same process as before however setting the lower limit to 0 and upper limit to 10. By changing the step count it allows for the number of possible selection options within the range to become bigger or smaller.

The modulation starts with the original message frequency source, in this case it is a WAV file. This feeds out to two different blocks. The first block is a time sink, this allows for the frequency to be shown in the time domain. The time sink also shows multiple frequencies and waveforms, allowing for comparison between different channels not only in real time but also later. The second block is a constant that make the messaged signal smaller allowing for a smaller bandwidth. Next is the throttle which doesn't have any effect on the messaged signal but is used to limit the data rate allowing for real time analysis. The last thing done to the signal before it is multiplied by the carrier frequency is a phase shift, by doing this you keep the amplitudes the same, this helps when trying to use as little bandwidth as possible, this is the idea of a narrow bandwidth frequency modulation. A signal source must be defined before being multiplied with the message signal. The signal source represents the carrier signal; to set up the carrier signal first, the sample rate is set by "variable" block. Other parameters are which waveform is being used in this case it is Cosine, a frequency which is the variable block and finally the amplitude which in this case is set to one. The most important part is the multiplier block. The block multipliers the message and the signal together, this is the final step when doing frequency modulation. The complex to real converts the modulated signal from complex numbers to real, allowing for real time analysis. the analysis blocks are last, the time sink is used to plot amplitude over time showing bandwidth. Waterfall sink shows signal frequency over time allowing analysis to be done

Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver Design Using GNU Radio
 Name: Robbie Young
 Student Number: 2111907
 comparing the before and after modulation. And frequency sink showing frequency vs time giving a better understanding of how everything is being modulated.

GNU Radio does differ from real examples of frequency modulation as it is missing one part of the wider system, an antenna would be used to transmit the modulated frequency across a wide range. Demodulation subsequently would happen by first receiving this data via another antenna set up in a different location allowing for demodulation. This is why frequency modulation happens, as it allows communication between people or equipment without being physically connected, allowing for better distance of communication.

Demodulation

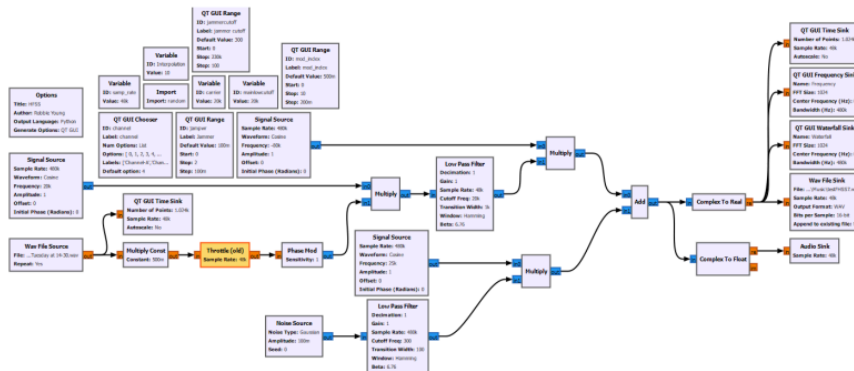


The first step in demodulation is taking the signal and multiplying it by the carrier signal, this will remove the carrier signal from the message signal, thus just leaving the message, this is all that needs to be done in an ideal situation however, it is almost guaranteed that noise will be picked up modifying the signal and leaving audible blips on the message signal, to remove this a band pass filter is used, this removes the blips leaving just the signal. For the block diagram using the same principles as before for modulation. To start the carrier signal is set up along with the saved modulated signal. The band pass filter is set up with the following parameters, gain is set to 10, the sample rate as the carrier waves frequency, the low cut off frequency is 2000Hz the higher being 18000Hz with the filter set to hamming. After passing through the filter the signal is multiplied by 10, making the signal strength stronger, allowing it to pass through a low pass filter removing any last imperfections in the audios signal quality. The low pass filter is set with a gain of 100 (which brings the message back to the same sound level as it was inputted into the modulator) sample rate is the carrier frequency with a cut off set to 1.17KHz, a transition width of 1K and finally a hamming window which is the way it filters the signal. the last thing before analysis can occur is a DC blocker is used this removes any flat lines in the signal making near identical to the original message signal. the last four blocks are all analysis blocks all mentioned in the modulation section.

Jammer

Adding a noise source can act as a jammer. Most jammers add a lot of random noise, this can cause a lot of data loss if not accounted for correctly. By adding noise, extra power is being added to the signal, in most cases for FM communication, it causes frequency disparity and cases the FM signal to be at a different frequency than original signal was sent at, it can also cause a higher bandwidth, making it harder to find the signal and demodulate it correctly.

Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver
 Design Using GNU Radio
 Name: Robbie Young
 Student Number: 2111907
 Block Diagrams



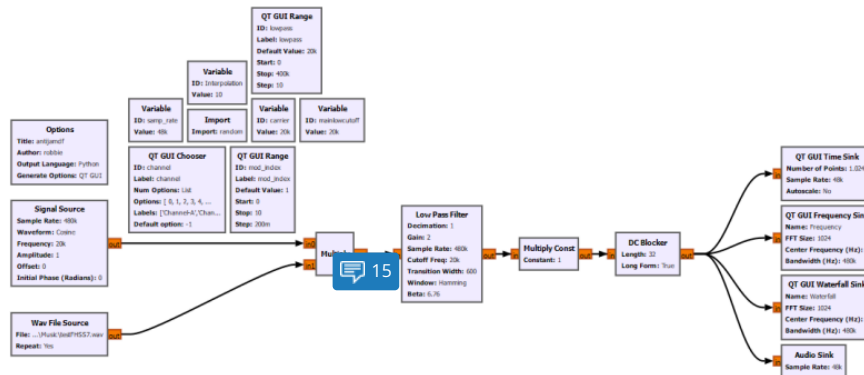
The same modulation operation happens as before, then the noise/ jamming part of the signal is added to the end of the modulated signal, representing how it would happen through the air. All the parameters are set as before, these variable blocks are used across multiple blocks making changes and set up easier.

To add jamming to the signal a noise source is added, it is set quite low as it is easier to generate a lower power signal and then amplify it upwards to the desired signal strength. The noise source is set up by first making a QT GUI range called jammer power, which has value of 100m and a start of 0 with stop being set to 2. This then feeds into the noise source at its amplitude, its noise type is set to gaussian. It then passes through a low pass filter set with the sample rate being the carrier wave times interpolation and the cut off frequency being 300 with a transition width of 100. Next the signal source is set up which will multiply the noise signal a to make it set at the same frequency as the carrier signal. it then gets added to the carrier thus representing noise correctly showing its effects.

Anti Jamming

There are a few anti-jamming techniques, but for the task given, a frequency hopping spread spectrum (FHSS) is going to be used. The benefits of using FHSS is it hops between frequency carriers, this massively reduces interference, as by jumping between frequency the noise factor added to one of the carriers is reduced, as only part of the signal will be jammed, which can be filter out. Another effective reason to use FHSS is it is hard to trace/ intercept making decoding what was sent on the original signal hard, because to intercept the message you would have to listen to each of the carrier frequencies being used and decoding them all at the same time. The last reason to use anti jamming techniques is to reduce signal reflections and fading, as by using FHSS you aren't using the same carrier frequency constantly thus reducing the reflection.

Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver Design Using GNU Radio
 Name: Robbie Young
 Student Number: 2111907
 Block Diagrams

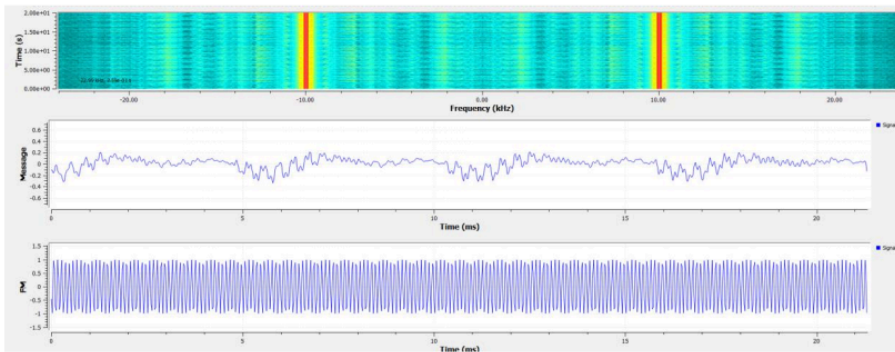


To make FHSS in GNU Radio the same modulation technique happens, but before it is sent out it passes through an extra few steps. First it passes through a low pass filter this ensures that the signal is smooth and that the frequency is constant. Next is the most important step, it is what allows for FHSS. The signal source block is used to multiply the output from the low pass filter. The signal source is set up with predetermine channels in which it randomly chooses from to multiply the signal this crates the FHSS, as it allows for the signal to jump around.

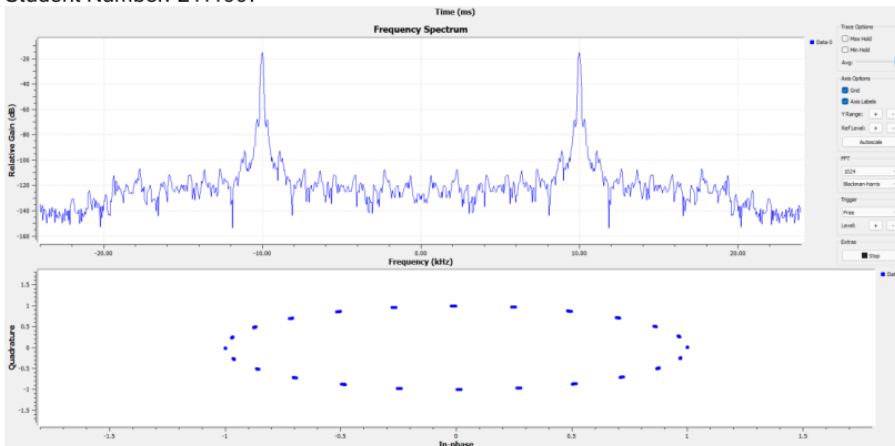
There is also a change when demodulating, the channels are need, so that the signal source can be multiplied and remove the carrier frequency.

Analysis and Comparison

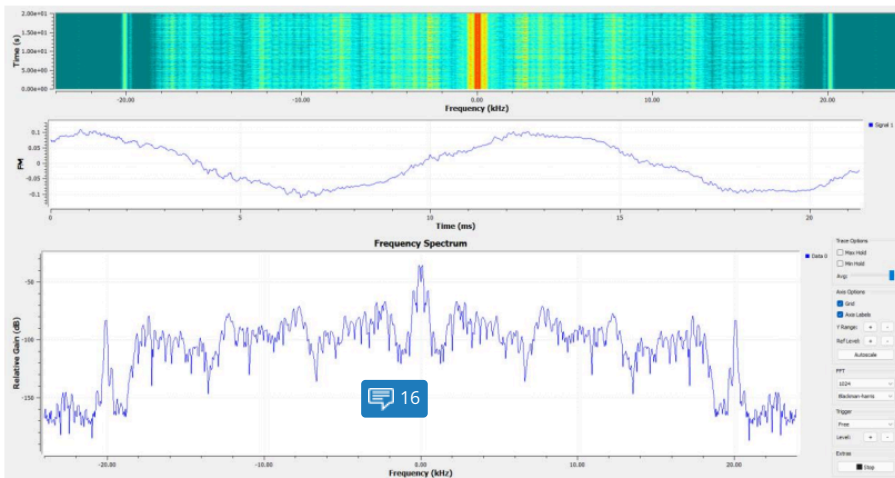
Modulation



Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver Design Using GNU Radio
 Name: Robbie Young
 Student Number: 2111907

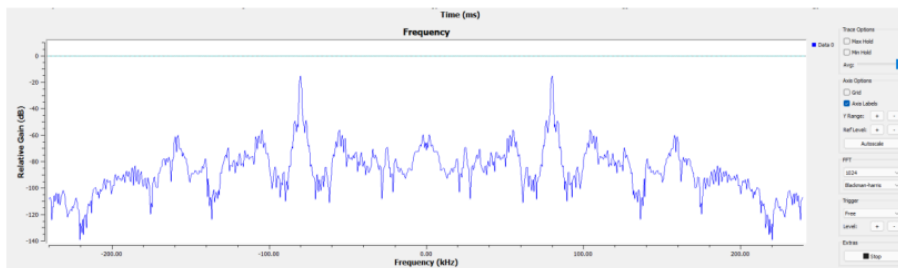


Demodulation

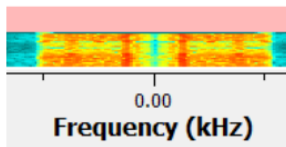


Before jamming and anti-jamming were introduced modulation and demodulation worked after demodulation the message was clear. However, when adding the jamming and anti-jamming after demodulation the message could still be heard but wasn't as clear as before, a lot of noise was present and interpreted the message. Looking at graphs produced in real time it is clear where the noise is and what happened.

HFSS modulation



HFSS demodulation



Before noise was added the message signal looks the same, the up and down of the sine wave along can be seen. Also visible is the narrow band from the demodulated waterfall

Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver Design Using GNU Radio
Name: Robbie Young
Student Number: 2111907

graph showing that the system worked effectively before noise was added. Looking at the second anti jammed waterfall graph, there is a visible difference between the two, the anti-jamming has a lot wider band, this would explain the noise as it is capturing and displaying the noise when running. The wider band would come from filtering, if the low pass filter were tuned this could cause the noise to go away as it would make it a narrower band. Overall, there is a slight difference between the two but the anti-jamming technique used wouldn't affect the audio signal so can be used as an effective technique.

Ethics and Impact

There is a big ethical impact to jamming signals, as it could cause disruption to vital services or just general communication between people. This can be considered as being very bad public safety.

Jamming also causes security concerns as it can interfere with security systems that are set up not just for public safety but also private property or corporate property, which could cause data leaks, risking the public once again.

One possible ethical reason to jam signals is for personal safety or safety of the public. For example, if a drone was flying on personal property, it could be considered ethical, as whom ever is in control of the drone is invading your personal space/ information and collecting data on you without your consent.

There are also less but still ethical concerns when using anti jamming techniques in certain situations because anti jamming can be considered as passive encryption which could be considered unethical as it is less transparent.

Task Two

18

Introduction

Task two is to design an RTL-SDR receiver using the GNU Radio software. After choosing a frequency, analysis of the signal and its quality will take place at different stages. Once again ethical considerations should be considered.

Setup and design

The set up would involve using a wideband frequency modulator along with a low pass filter and a rational re sampler, this would allow for a local radio station to be heard when an antenna is used and set to the right frequency. The local radio station is set to Which means the carrier needs to be set to the same allowing for it to be heard.

Analysis

Title: Implementation and Analysis of NBFM Jamming Techniques and RTL-SDR Receiver Design Using GNU Radio
Name: Robbie Young
Student Number: 2111907

After building the block diagram and running some tests, the local station was heard, however it was rather quite meaning the gain would have to increase. However, when the gain was increased the block diagram broke and wouldn't play the audio correctly, meaning that other parameters need changing. If the constant was increased, it could make the audio louder and more understandable.

Ethical impact

There are ethical concerns with software defined radio, the best example of this is right to privacy/ information. The problem with software defined radio is that in theory you can listen in to radio communication such as walkie talkies or blue tooth. The reason for the concern is that personal information can be sent/ spoken about over these communication systems, if someone is using software defined radio, they could in theory gain access to this information and potential exploit it. Another way of miss using it is setting up a transmitter that could send false information to the devices, thus causing a jam or miss guiding public services therefore effecting public safety.

Abstract

[1] <https://resources.system-analysis.cadence.com/blog/msa2022-designing-for-the-future-with-5g-new-radio-technology>

[2] [https://www3.advantest.com/documents/11348/7898f05e-0a52-4e68-9221-3b8b75595436#:~:text=Frequency%20modulation%20\(FM\)%20has%20a,to%20be%20tested%20in%20production](https://www3.advantest.com/documents/11348/7898f05e-0a52-4e68-9221-3b8b75595436#:~:text=Frequency%20modulation%20(FM)%20has%20a,to%20be%20tested%20in%20production)

[3] https://www.rcet.org.in/uploads/academics/rohini_98541852915.pdf

[4] <https://www.ofcom.org.uk/about-ofcom/>

FINAL GRADE

GENERAL COMMENTS

35/100

Feedback on A4HEP Learning Objectives

B1: Lacks sufficient application of knowledge in problem-solving. You have not met the requirements for this learning outcome. Improvement is needed.

B2: Inadequate analysis, leading to weak or unsupported conclusions. You have not met the requirements for this learning outcome. Improvement is needed.

B3: Incorrect or ineffective use of computational and analytical techniques. You have not met the requirements for this learning outcome. Improvement is needed.

B6: Successfully applies a systems approach to problem-solving. You have successfully met the requirements for this learning outcome.

B8: Lacks ethical awareness and fails to make reasoned choices. You have not met the requirements for this learning outcome. Improvement is needed.

B12: Effectively applies laboratory and workshop skills in investigations. You have successfully met the requirements for this learning outcome.

PAGE 1

PAGE 2

PAGE 3



Comment 1

A
very brief introduction is provided in the background study.



Comment 2 | Engagement with Lit (20)

A
very brief introduction is provided in the background study.



Comment 3 | Knowledge & Understanding (20)

The
explanation of the concept is limited and provides minimum information about NBFM.



Comment 4 | Engagement with Lit (20)

It is commendable that the overall effect of adding noise is mentioned, the fundamental ideas of NBFM modulation and demodulation are lacking.



Comment 5 | Knowledge & Understanding (20)

Good. Some
noise disturbances are mentioned.



Comment 6 | Knowledge & Understanding (20)

Essential conceptual block diagrams and equations related to FM, such as the modulation index and frequency deviation, are missing.

PAGE 4



Comment 7 | Practical Skills (25)

The GNU Radio blocks for NBFM are correctly designed. However, the sample rate for audio signal sampling is usually 44 kHz or 48 kHz, while the blocks in the report are designed with a sample rate of 32 kHz, which is unusual. At this rate, the audio levels will be insufficient for producing sound through speakers.



Comment 8 | Cognitive Skills (20)

The explanation of each block is given with limited concepts.



Comment 9 | Knowledge & Understanding (20)

It could be better if the findings on frequency deviation, bandwidth usage, and filtering are not thoroughly discussed.

PAGE 5



Comment 10 | Knowledge & Understanding (20)

The description of the physical connection lacks clarity because real-time applications typically involve different SDR components.



Comment 11 | Knowledge & Understanding (20)

The basic idea of demodulation is addressed, which is commendable.

PAGE 6



Comment 12 | Cognitive Skills (20)

Some fundamental techniques for handling signals are included, which is appreciable.



Comment 13 | Knowledge & Understanding (20)

The concept of using a jammer is well explained. The working of the blocks is described in terms of how the signal is processed as it passes through them.



Comment 14 | Knowledge & Understanding (20)

The idea of using FHSS is mentioned, but traditional block diagrams should be included to explain the concept more effectively.

PAGE 7



Comment 15 | Practical Skills (25)

The blocks presented do not accurately depict the FHSS concept.

PAGE 8



Comment 16 | Practical Skills (25)

The sink screenshots provide insight into the original and noise-added signals.

PAGE 9

PAGE 10



Comment 17 | Knowledge & Understanding (20)

Ethical considerations, such as public safety, security, privacy, and the misuse of anti-jamming techniques like passive encryption, are briefly discussed, which is good.



Comment 18 | Practical Skills (25)

Task 2 is incomplete. There are no clear findings or structured procedures followed in Task 2.

PAGE 11



Comment 19 | Cognitive Skills (20)

The ethical impact of SDR is not effectively conveyed.



Comment 20

It is 'References'



Comment 21 | Transferable Skills (15)

Only a few references are used. While the report has a good flow and structure, it lacks mathematical representations of signals in both Task 1 and Task 2.

GRADING FORM: ADSP_GRADING_TEMPLATE

ROBBIE YOUNG

35.20

ENGAGEMENT WITH LIT (20)

Task 1: Demonstrate understanding of NBFM, jamming effects, and FHSS. Citations and research on related topics. Task 2: Show understanding of SDR receiver principles and signal representation. Evaluate research on SDR technology and related topics.



- Minimal knowledge. Little effort in research or citations, with significant inaccuracies.
- Minimal knowledge. Little effort in research or evaluation, with significant inaccuracies.

7

KNOWLEDGE & UNDERSTANDING (20)

Task 1 (i) Understanding NBFM, modulation, and demodulation. Exploring bandwidth, frequency deviation, and impact on signal quality. Task 1 (ii) Analysing jamming effects by studying noise sources and interference. Observing impact via frequency, time domain, and constellation diagrams. Task 1 (iii) Investigating FHSS to reduce interference and evaluating its effectiveness. Task 1 (iv) Comparing

original, jammed, and FHSS signals. Studying Signal-to-Noise Ratio (SNR), clarity, and system efficiency. Task 1 (v) Understanding ethical issues in jamming. Discussing legal aspects and FHSS benefits for security. Task 2 (i) Designing a WBFM receiver using RTL-SDR and GNU Radio. Studying block functions and sampling. Task 2 (ii) Visualising signals via waterfall plots, frequency sinks, and time-domain analysis. Studying SNR, stability, and filtering. Task 2 (iii) Evaluating privacy and interference issues. Analysing societal benefits like improved efficiency and technology.



- Basic understanding of NBFM. Descriptions are incomplete or unclear, with noticeable gaps in coverage.
- Satisfactory understanding with basic explanations, but limited detail.
- Basic understanding. Explanations of FHSS are incomplete.
- Limited grasp. Vague signal descriptions.
- Satisfactory understanding. Basic descriptions, but lacking clarity.
- No understanding of GNU Radio flow or associated concepts.
- Sinks, SNR, and stage comparisons are not addressed.
- Ethical considerations of SDR are limited.

7.1

COGNITIVE SKILLS (20)

Task 1 (i) NBFM Modulation and Demodulation: Understands modulation, demodulation, bandwidth, and clarity. Task 1 (ii) Add a Jammer: Evaluates noise, interference, and signal impact in frequency, time, and constellation domains. Task 1 (iii) Implement FHSS for Anti-Jamming: Applies FHSS to reduce interference and compare signal stability. Task 1 (iv) Analysis and Comparison: Compares original, jammed, and FHSS signals using frequency and time-domain tools. Task 1 (v) Ethics and Impact: Assesses legal and societal effects of interference in secure communication. Task 2 (i) Setup and Design of WBFM Receiver: Designs WBFM receiver, focusing on setup, bandwidth,

and stability. Task 2 (ii) Analysis and Visualisation: Examines signal analysis, error detection, and filtering techniques. Task 2 (iii) Ethics and Impact: Reviews interference impact and decision-making in WBFM technology.



- Basic setup with unclear reasoning.
- Satisfactory analysis, limited clarity.
- No understanding of FHSS.
- No understanding of signals.
- Minimal effort, significant inaccuracies.
- No evidence of receiver setup or understanding of signal demodulation.
- No signal analysis or understanding of parameters like SNR or modulation index.
- Minimal effort in discussing ethics and societal impact.

4.1

PRACTICAL SKILLS (25)

Task 1: Hands-on experience in transmitter and receiver setup, understanding signal bandwidth and frequency deviation. Implementing noise sources and analysing interference effects using frequency, time, waterfall, and constellation sinks. Applying FHSS techniques for anti-jamming and evaluating signal clarity through SNR analysis and stage comparisons. Developing an awareness of secure communication and legal implications. Task 2: Practical implementation of RTL-SDR receiver setup, signal representation, and processing. Understanding block functionality, decimation factors, and performing signal analysis using waterfall and frequency sinks. Visualising constellation diagrams and evaluating signal stability through SNR measurements. Comparing different demodulation stages for performance optimisation.



Task 1: Displays satisfactory practical skills with basic NBFM modulation, jammer introduction. Signal analysis is present but lacks detail in SNR and system performance. Lacks in displaying

10

FHSS.

Task 2: No evidence of practical skills or understanding of the task requirements. Setup and analysis are absent with RTL SDR.

TRANSFERABLE SKILLS (15)

Enhancing mathematical integration and simulation skills using GNU Radio and RTL-SDR. Developing ethical reasoning and effective communication for teamwork and professional interactions. Practising systematic reporting, structured problem-solving, and clear presentation skills.



Basic transferable skills shown with incomplete setups and limited documentation. Analysis is vague, and ethical considerations are minimally addressed.

7