

LC ADSP Assignment

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

Advanced Digital Signal Processing ACDA6018

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Introduction

Task 1 of this report documents the design, implementation and analysis of a NBFM modulation and demodulation system with frequency hopping capabilities. The system is evaluated through the addition of a jamming signal. Task 2 describes the design and creation of a WBFM receiver using an off the shelf SDR.

Sections for Task 1 include Background Research, a discussion on the Ethics and Impact, followed by Methodologies, Block Diagrams and Flowcharts, Implementation, Simulation Images, Formulas and Expressions, Results and Analysis, Discussion. Task 2 includes sections on the WBFM Methodology, Block Diagrams, Implementation, Signal Analysis and Visualisation of the results, Formulas and Expressions, followed by Ethical and Societal Impacts, and finally a Conclusion covering both tasks.

Task 1: Jammer Techniques Using GNU Radio

Background Research

Low frequency transmissions (300KHz and below [1]) require a huge amount of amplification for transmission and an equally large antenna [2]. To reduce the costs and power consumption the signal is modulated prior to transmission. This involves mixing a source signal with a carrier wave [2]. The main methods of modulation are Amplitude Modulation (AM) and Frequency Modulation (FM), the subject of this report. In FM the waveform is modulated with a carrier wave alternating in frequency with the amplitude of the original signal. Seen in Figure 1 [3] below, the original waveform (b) is mixed with a carrier wave (a) producing an AM or FM signal (c and d). FM is less susceptible to interference than AM, and capable of larger bandwidths [3].

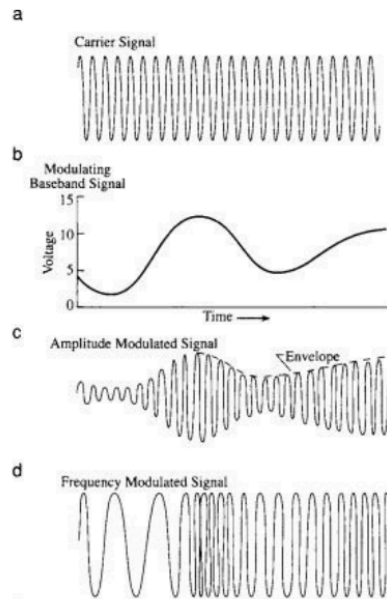


Figure 1: Example of AM and FM

A jammer generates noise or interference on specific target frequencies. There are three types of jammers currently in use; spot, barrage or swept [4]. When using a spot jammer, a single frequency is targeted, concentrating all its power on that frequency. This type of jammer is ineffective against Frequency Hopping Spread Spectrum (FHSS) targets or a networks. Alternately, a swept jammer will sweep across multiple frequencies from one end of its range to the other incredibly fast, making it more effective against FHSS targets. Lastly, barrage jamming transmits interference over an entire frequency range at once. Meaning it is not able to be as powerful as a spot or swept jammer [4].

FHSS is the continuous hopping of the carrier frequency to reduce interference [5]. The concept being that should a frequency be targeted by a jammer or interference of any kind the radio is able to switch onto another carrier frequency to avoid it.

Ethics and Impact

The use of jammers in the UK is illegal under the Wireless Telegraphy Act 2006 [6]. However, specialist use cases may be granted, such as in prisons, by law enforcement [7], or for military experiments [8]. The main reason jamming is illegal is that the effect may be far larger than intended [9]. For example, the transmission may block emergency services channels, either on purpose or through spurious signals [10].

Therefore, the use of jammers should be carefully considered to reduce the impact. For example, Ofcom, the UK Spectrum regulatory body, specify that experiments using jammers should be "*sufficiently remote, shielded, or low power that there is no likelihood of interference external to the test area*" [7].

Non-ethical use of a jammer may be considered the blocking of free-speech or information, GPS services, or Electronic Warfare (EW) attack rather than defence. For example, the Chinese governments use of the FireDrake jammer to block foreign radio stations [11], and the disruption of essential communication services by an aggressor, rather than defending party.

The jammer may also fall into the non-ethical category through poor design. Here the jammer may leak noise over unintentional frequencies, which may affect the emergency services, GPS, or essential communication between two parties.

FHSS allows the party experiencing jamming a technique to continue communication securely. Without FHSS the information could be lost, and important information not relayed, resulting in the loss of resources and time.

NBFM and FHSS Methodologies

This report uses GNU Radio, a free, open-source software toolkit that uses processing blocks to create software radios [12]. Narrow Band Frequency Modulation (NBFM) utilises a smaller bandwidth than with Wide Band FM (WBFM), hence Narrow Band [13].

The input signal is a .WAV audio file. The carrier frequency by default is set to 20KHz, remaining Very Low Frequency (VLF), with a default modulation index of 0.5, able to be altered during the simulation from 0 to 1. The bandwidth of the system is 40KHz.

The FHSS aspect of the NBFM modulator and demodulator is designed so that the carrier frequency is multiplied by the number in the channel selected by the QT GUI Chooser. The jammer functions the same way. The hop is done by the user rather than automatically due to software limitations in GNU Radio.

NBFM Block Diagram

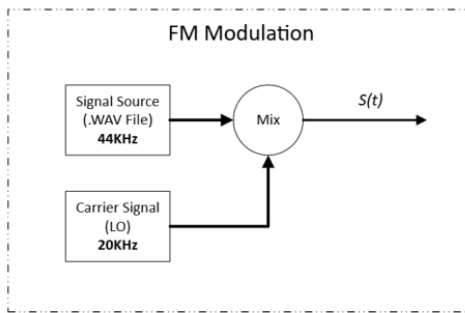


Figure 2: NBFM Modulation Block Diagram

Figure 2 above shows the block diagram for NBFM modulation, producing the transmit signal $S(t)$, followed by the demodulation of $S(t)$ producing the complex signal $Z(t)$, seen in Figure 3 below

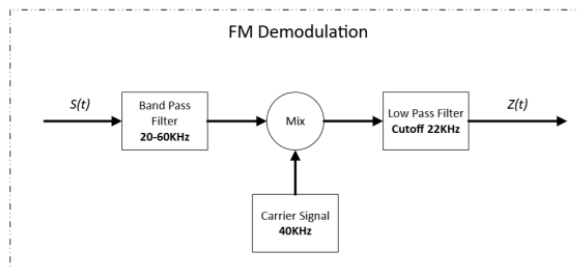


Figure 3: NBFM Demodulation Block Diagram

Figure 4 below is the block diagram for FHSS implementation, which is added to the $S(t)$ signal to add additional frequencies for hopping.

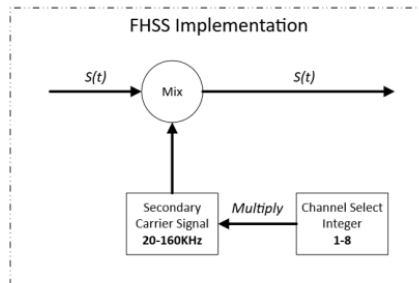


Figure 4: FHSS Implementation Block Diagram

Finally, below in Figure 5 is the jammer signal block diagram which is added to the transmitted $S(t)$ signal as well.

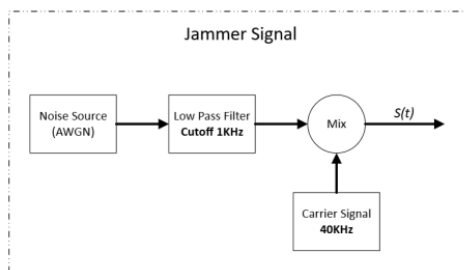


Figure 6: Jammer Signal Block Diagram

To better understand the flow with the two additional elements, the diagram in Figure 6 may be used.



Figure 5: High-Level NBFM Block Diagram

Implementation

The block diagram for the NBFM flow in GNU Radio may be seen below in Figure 7 below (a larger image is in Annex 1).

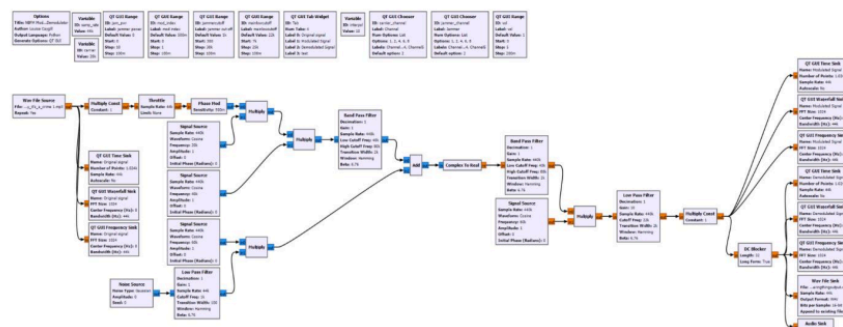


Figure 7: NBFM Modulator and Demodulator With Jamming Element

The signal source is a 44KHz .WAV file, which enters a multiply constant, throttle and phase mod block, before being multiplied by a 20KHz carrier wave for modulation. The resultant signal is multiplied by a second stage carrier wave ranging from 20-160KHz, providing the additional frequencies for FHSS. This signal then enters a band pass filter to filter out unwanted signals and reduce the bandwidth to the desired narrow band of 40KHz. Thus, the signal enters the transmit channel where it encounters a jamming signal. This jamming signal is multiplied by a 40-320KHz carrier signal for modulation, alterable in the same manner as the source signal. This signal enters a second band pass filter, again with a bandwidth of 40KHz to remove any unwanted signals added by the jammer. The remaining signal is mixed

with a 40KHz carrier wave to separate the carrier from the original signal. Finally, it enters a low pass filter to remove unwanted high frequencies, leaving the demodulated signal.

FHSS is implemented by selecting one of 5 channels in the simulation, seen at the top in

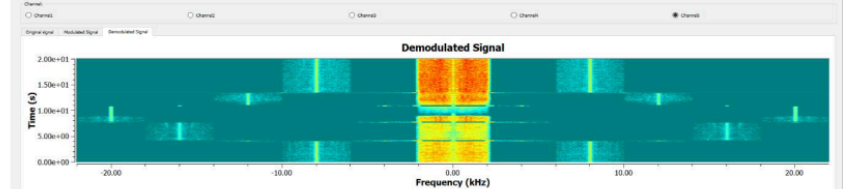


Figure 8: Example of Waterfall Sink with FHSS

Figure 8 above. In each of these channels is an integer of 1, 2, 4, 6, and 8 respectively. This integer is multiplied by the 20KHz starting frequency to provide alternate frequencies for the original source to avoid the jammer. For instance, on Channel 1, the 20KHz carrier is multiplied by 1, whilst in channel 3 it is multiplied by 4. The jammer functions in the same manner and may change channel to jam the signal when it has hopped. This hopping is demonstrated using the waterfall sink of the demodulated message in Figure 8 above, where the channels are selected consecutively, moving the sidebands out and in again.

Simulation Images

Following are images from the simulation in GNU Radio. Figure 10 below shows the original signal.

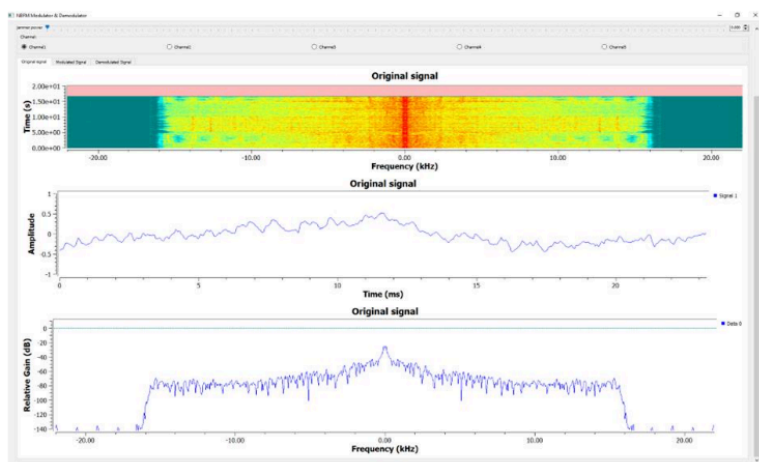


Figure 10: Source Signal Visualisation – NBFM

Figure 9 below shows the modulated transmission signal. It may be seen that the bandwidth has been reduced, and two side bands added.

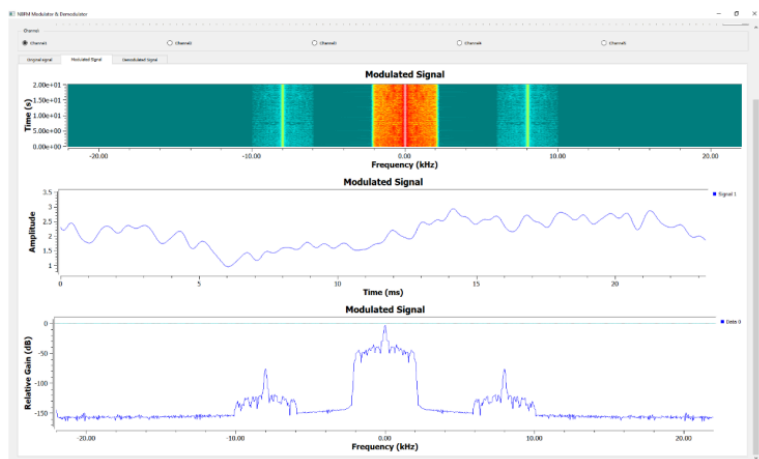


Figure 9: Modulated Signal Visualisation - NBFM

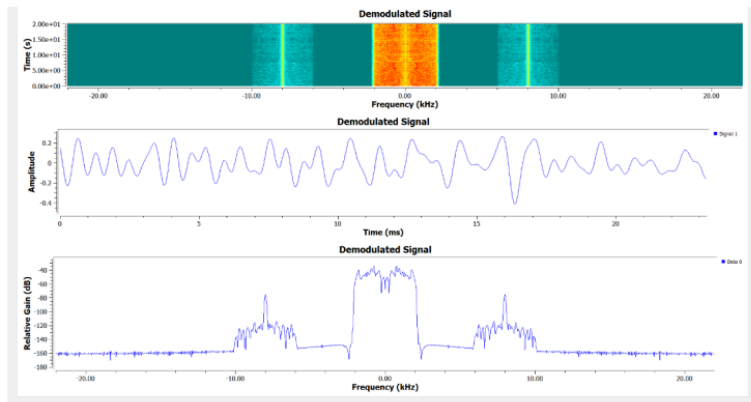


Figure 11: Demodulated Signal Visualisation - NBFM

Figure 11 above shows the demodulated signal. It may be seen that the signal has noise, but still a good Signal to Noise Ratio (SNR).

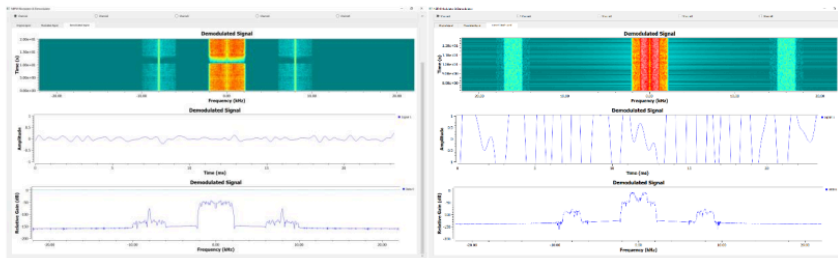


Figure 12: Channel 1 With (right) and Without Noise (left)

Figure 12 above and Figure 13 below show the effects of the jammer on the demodulated signal. The left-hand images show the clear modulated signal on Channel 1 and Channel 4, and the right-hand images show the demodulated signal with the jammer active on the same channel. It may be seen on the amplitude graph that the signal has been overwhelmed, and the original signal lost.

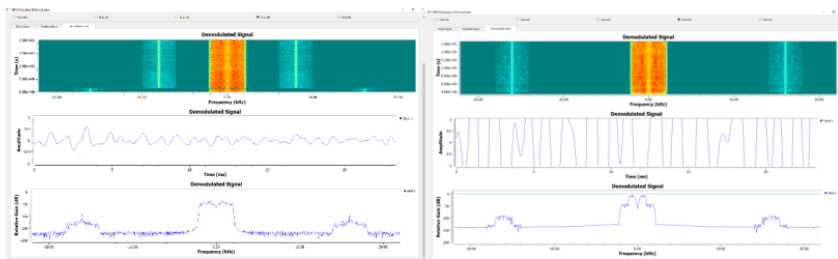


Figure 13: Channel 4 With (right) and Without Noise (left)

NBFM Formulas and Expressions

For FM application the following formula for WBFM is used

$$S(t) = A_c \cos [2\pi f_c t + \beta \sin 2\pi f_m t]$$

Equation 1: WBFM Transmission Formula

To obtain a narrow band, the β must be small compared to a radian [14]. Therefore, after expansion and simplification becomes

$$s(t) \approx A_c \cos(2\pi f_c t) - \beta A_c \sin(2\pi f_c t) \sin(2\pi f_m t)$$

Equation 2: NBFM Expression

Which will produce the approximate form of NBFM wave [14].

The jammer signal may be defined broadly by the following [15]

$$r(t) = x_j(t) + x_{tg}(t) + n(t)$$

Equation 3: Jamming Signal Expression

Where $r(t)$ is the received signal, $x_j(t)$ the jamming signal, $x_{tg}(t)$ the target signal and $n(t)$ the AWGN. $x_j(t)$ is expanded as

$$x_j(t) = A_j \cos [2\pi(f_c t + \Delta_j)t + b_j(t - n_j) \frac{\pi(t - n_j)}{2T} + \varphi_j]$$

Equation 4: Expansion of $X_j(t)$ Expression

With $x_{tg}(t)$ having the same formula, simply replacing j values with tg values. In the above expression φ_j is the phase of the signal, f_c the carrier frequency, Δ_j the jammer frequency and n_j the timing offset.



For this report, the additional frequencies that the signal is able to hop to through FHSS may be represented simply by

$$F_{HOP} = f_{ca} * x_{ch}$$

Equation 5: FHSS Expression

Where f_{ca} is the frequency of the carrier wave, and x_{ch} the integer held by the chosen channel. The jammer hopping may be represented by the same formula, with the carrier frequency being replaced by the jammer frequency.

Results and Analysis

Without jamming the system functions well, the audio quality could be improved, but the original signal elements are present, and the correct information conveyed. With jamming introduced, depending on the jammer power, the original signal becomes overwhelmed and no longer discernible, as seen in the right-hand images of Figure 12 and Figure 13 previously.

SNR is the ratio of signal power to noise power, the formula for which is as below[16].

$$SNR = \frac{\text{Signal Power}}{\text{Noise Power}}$$

Equation 6: SNR Formula

The system displays a good SNR without jamming. The signal is able to be heard and understood. However, it could be improved in clarity. When adding the jammer, the SNR rapidly decreases as the jammer power is increased, eventually overwhelming the original signal. A good SNR is able to be regained by frequency hopping to a different channel.



Discussion

As demonstrated in this report, FHSS is an effective anti-jamming method, it gives the signal agility and the ability to change frequency to avoid being jammed, whilst retaining source signal information. During simulation a new channel may be selected by the user for the modulated signal and the jammer. This channel selection works well, and there is no bleed from the jammer into the next channel, signifying appropriate filtering and that the frequency hopping is implemented correctly with no additional loss of signal clarity.

In real-life applications frequency hopping is done automatically, with multiple hops happening per second [17]. It is a design limitation of GNU Radio that this is not able to be implemented automatically and must be done by manually switching the channel.

Task 2: Design and Analysis of an RTL-SDR Receiver in GNU Radio

WBFM Methodology

A Software Defined Radio (SDR) is an electronic, wireless device configurable through software, capable of RF transmissions from FM radio to 5G plus [18]. This report uses a Nooelec NESDR Mini SDR [19] as a receiver.

The design for the WBFM is done so as to be as simple as possible to ensure the clearest signal quality utilising the RTL-SDR. Again, the design makes use of GNU Radio with global variable block; samp_rate set to 2.048MHz. The working frequency is set by the range GUI and by default is set to 9.59MHz, Andover FM (later altered to 96.2 for signal clarity), able to be tuned between 85-110MHz encompassing all commercial radio stations.

Block Diagram

The block diagram for the WBFM operation may be seen below in Figure 14.

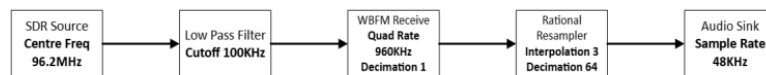


Figure 14: WBFM Block Diagram

Implementation

The design of the receiver is seen below in Figure 15 (a larger image is in Annex 2), which represents the following.

$$s(t) = i(t) + jq(t)$$

Equation 7: RTL-SDR Signal Equation

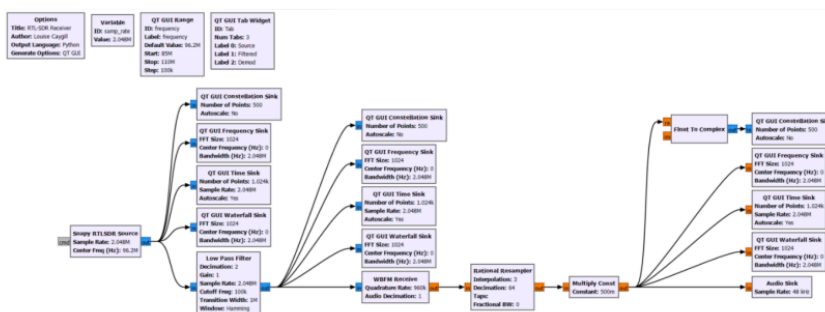


Figure 15: RTL-SDR Programme

The global variable for sample rate is seen in Figure 16 overleaf.

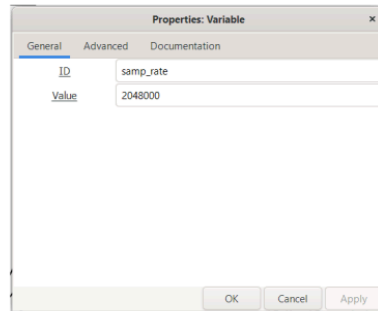


Figure 16: Sample Rate Global Variable

The signal is introduced by the Soapy RTLSDR block on the left of Figure 15, which reads the input from the SDR USB. The properties for this block are seen in Figure 17 below.

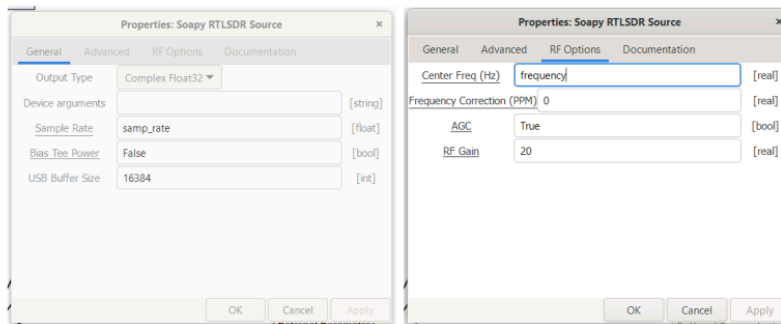


Figure 18: Soapy RTLSDR Source Properties

The signal passes through a low pass filter to remove noise and interference, seen in Figure 18 below. It has a decimation level of 2, gain of 1, cut off frequency of 100KHz, and a transition width of 1MHz. Decimation in this case meaning to the reduce the sampling rate, also known as down-sampling [20], reducing the bandwidth and removing unwanted high frequency noise. The gain is set to 1, meaning the input and output of this block are of the same power.

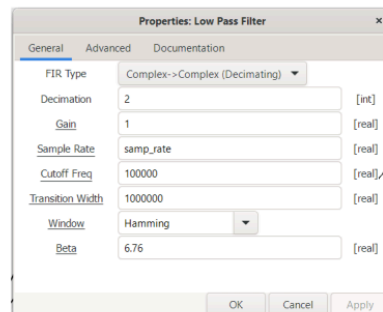


Figure 17: Low Pass Filter Settings

Here the signal enters a WBFM Receive block, seen in Figure 19 below. This demodulates the received signal, removing the carrier wave. The quadrature rate is the input sample rate, in this case 960KHz, and the decimation rate is set to 2, here meaning how much the quadrature rate is decimated [21].

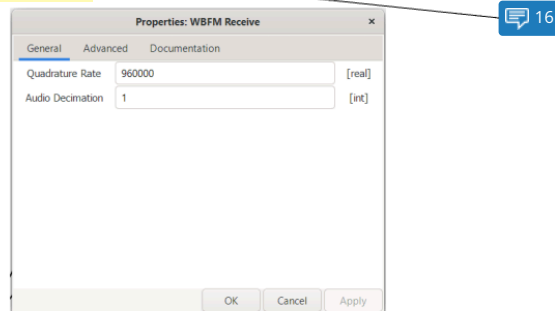


Figure 19: WBFM Receive Block Settings

Next, the signal enters a Rational Resampler Block, altering the sample rate by interpolating (multiplying) and decimating (dividing) the signal. The 960KHz received is interpolated by 3 and decimated by 64, producing a sample rate of 45KHz.

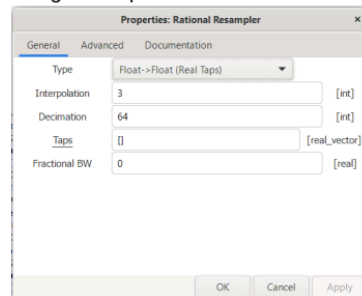


Figure 20: Rational Resampler Settings

Finally, the signal is passed through a multiplication block, forming the modulation index. In this case it is multiplied by a constant of 0.5, meaning the signal is halved.

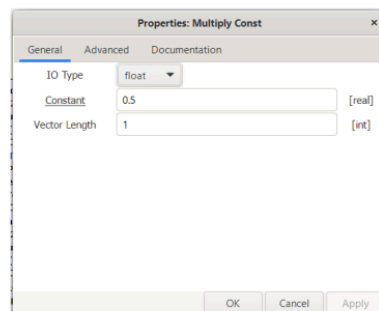


Figure 21: Multiply Constant Settings

Signal Analysis and Visualisation

Figure 22 below shows a visualisation of the source signal. It is seen that there are two signals, the source and carrier signal.

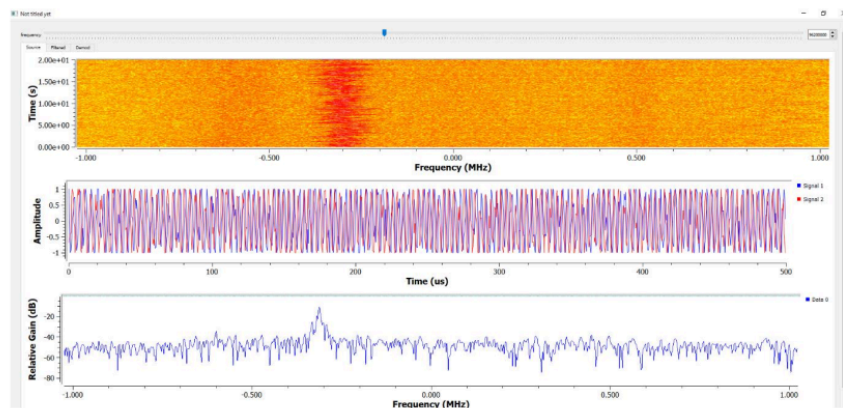


Figure 22: Source Signal Visualisation: 96.2 - Andover FM

Figure 23 below is post filtering, the bottom graph demonstrates that the signal is more linear, and the signal peak has shifted slightly in frequency by ~ 0.75 MHz. The amplitude also appears tighter and less uniform.

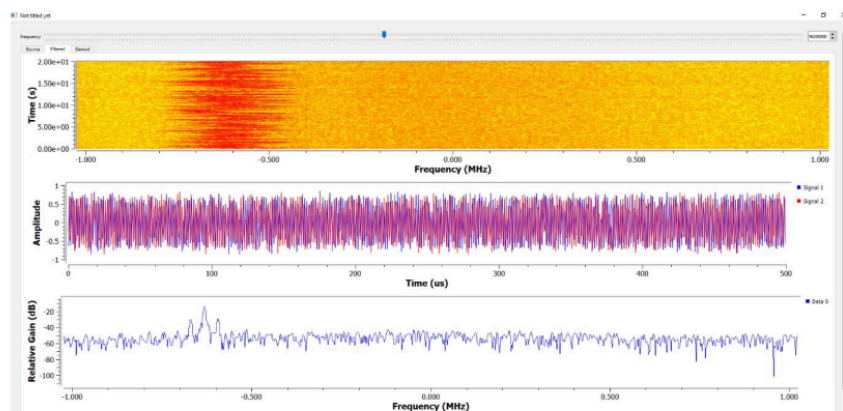


Figure 23: Filtered Signal Visualisation: 96.2 - Andover FM

Finally, in Figure 24 overleaf is the demodulated signal. The signal is clean, with minimal noise, appearing uniform, and peaking at the centre frequency. Also shown is that there is no second signal in the middle graph, demonstrating that the carrier wave has been removed.

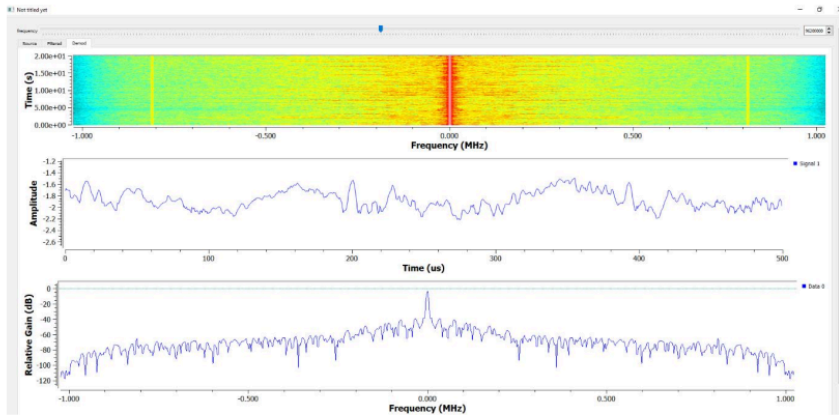


Figure 24: Demodulated Signal Visualisation: 96.2 - Andover FM

To discuss the SNR constellation diagrams have been used, seen below in Figure 25 for the source, filtered and demodulated signal. It is seen that the source (top), has poor SNR, causing the constellation loop to be loose and poorly defined. Whilst after filtering (middle) the loop is tighter and more defined, demonstrating that the filter has removed interference. Lastly, after demodulation (bottom) it is seen that the phase has shifted, and the diagram is represented in a straight, tight line, demonstrating a strong SNR.

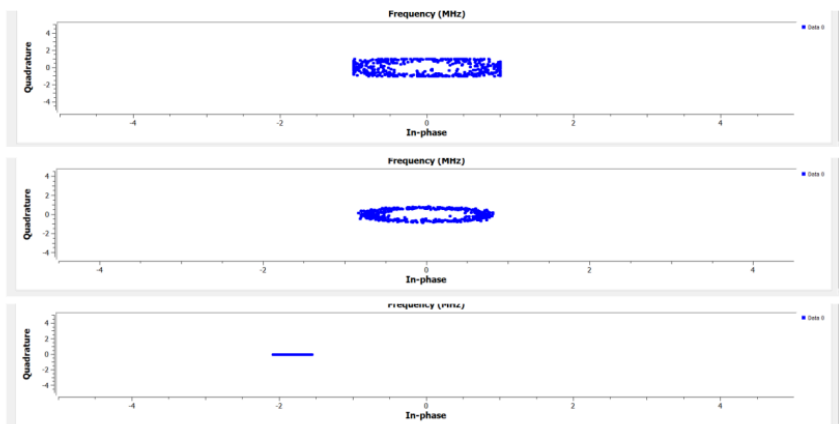


Figure 25: Constellation Diagram of Source, Filtered and Demodulated Signal

Formulas and Expressions

The formulas in this section comprise of the expressions after the low pass filter, creating a complex signal $Z(t)$. The expression for $Z(t)$ is as follows [22]

$$Z(t) = I'(t) + jQ'(t)$$

Equation 8: Complex Baseband I/Q Expression

Where $I'(t)$ is expressed as

$$I'(t) = \frac{A}{2} [\cos 2\pi(f_m - f_o)t + \varphi]$$

Equation 9: I'(t) Expression

And $Q'(t)$ is expressed as

$$Q'(t) = -\frac{A}{2} [\sin[2\pi(f_m - f_o)t + \varphi]]$$

Equation 10: Q(t) Expression

Which when substituted into the original formula becomes

$$Z(t) = \frac{A}{2} \{(\cos 2\pi(f_m - f_o)t + \varphi) + j\sin(2\pi(f_m - f_o)t + \varphi)\}$$

Equation 11: Expanded Z(t) Expression

Here f_o is the frequency of the local oscillator, f_m the frequency of the mixer and φ the phase.

Ethical and Societal Impacts

SDRs may be purchased for ~£30 [23], and easily used through free software such as GNU Radio. Meaning it is widely available to the general public with no conditions of purchase. This also means that they may be used for a variety of purposes which may raise ethical concerns. For example, purchasing an SDR kit to build a radio does not raise any ethical concerns by itself. However, using that radio to listen in to conversations or broadcasts that are not expecting to be overheard is unethical. Additionally, the use of an SDR to transmit becomes unethical when doing so illegally or with ill intent, for example, when used to transmit propaganda or misinformation. It may also interfere with or listen to emergency services communications, which in itself is unethical, as there may be sensitive or identifying information.

However, also means that it is more widely accessible, allowing a wider variety of users from different backgrounds. This again may be a "double edged sword" in that by allowing a wider user base through reduced costs, it also increases the likelihood of bad actors (whether intentionally or through lack of knowledge) purely by increasing the number of users the system is available to.

Conclusion and Future Recommendations

In conclusion it may be seen through this report that FHSS is a potent antijamming technique allowing the signal to be agile and avoid being jammed effectively. There are some design limitations inherent within GNU Radio, which mean that some aspects of FHSS are unable to be implemented, such as speed and automation. However, it is still an effective solution to the addition of noise-based interference.

The WBFM Receiver produces a clean and clear signal, showing that inexpensive SDRs may be used to create receiver radios, able to be tuned to any frequency. They may also be used to create personal radio stations, or personalised jamming systems, making the ethics surrounding the ownership and use of SDRs unclear.

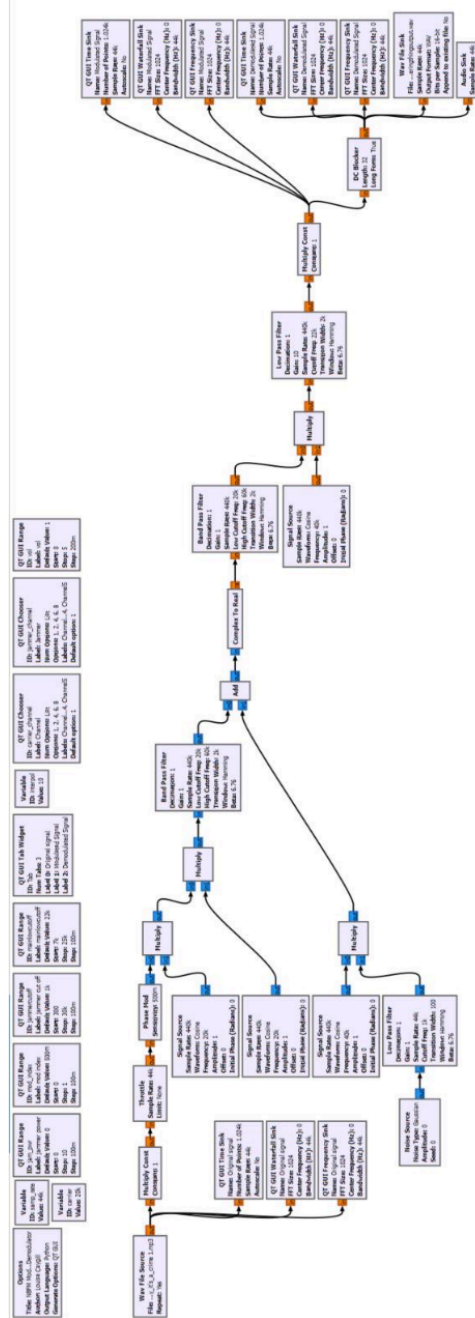
In the future it may be pertinent to analyse the SDR with different antennas to evaluate the performance. It may also be beneficial to implement an automatic version of FHSS utilising a different software toolkit. Additionally, the channel selection may be randomised, so that the user must find an open and clear channel. Similarly, the user may be using the jammer to find and block the transmitted signal.

References

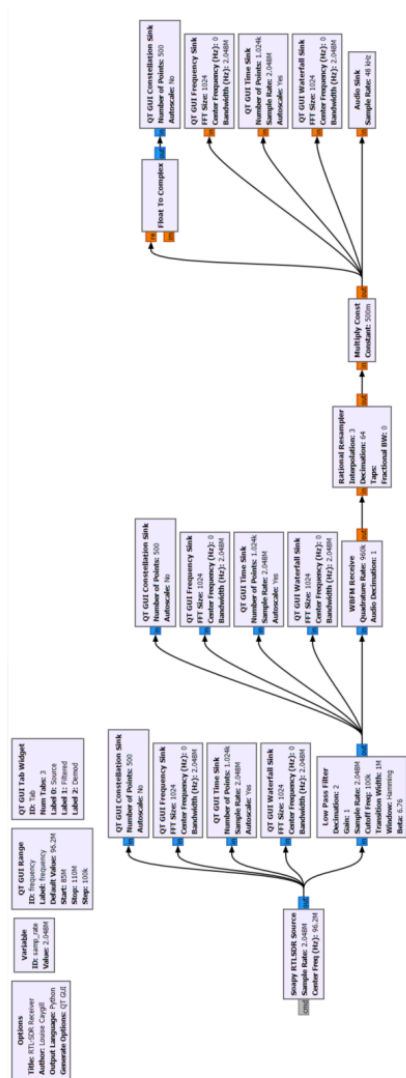
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Annex 1



Annex 2



LC ADSP Assignment

GRADEMARK REPORT

FINAL GRADE

78/100

GENERAL COMMENTS

B1: Demonstrates a good application of knowledge in problem-solving. You have successfully met the requirements for this learning outcome.

B2: Effectively analyses problems and reaches logical conclusions. You have successfully met the requirements for this learning outcome.

B3: Proper selection and application of computational and analytical techniques. You have successfully met the requirements for this learning outcome.

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

B8: Demonstrates strong ethical analysis and informed decision-making. You have successfully met the requirements for this learning outcome.

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

PAGE 1

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Comment 1 | Engagement with Lit (20)

The basic concepts of signal transmission and its modulation techniques are presented.



Comment 2 | Engagement with Lit (20)

The effects of jamming are briefly explained, and the discussion on different types of jamming is commendable.



Comment 3 | Engagement with Lit (20)

The advantages of using Frequency Hopping Spread Spectrum (FHSS) are well articulated, and the impact of jamming is thoroughly discussed.

PAGE 8



Comment 4 | Knowledge & Understanding (20)

The ethical concerns regarding the misuse of jammers are also highlighted, which is commendable. Additionally, the report explains how effective communication can be disrupted due to jamming.

PAGE 9

PAGE 10



Comment 5 | Knowledge & Understanding (20)

The conventional block diagrams for Narrowband FM (NBFM), jamming, and FHSS are included, along with signal representations within these blocks. However, a more detailed explanation of how these blocks operate would improve clarity.



Comment 6 | Knowledge & Understanding (20)

It would be beneficial to include blocks with added noise and explain how the signal is processed in Task 1(i) and Task 1(ii).

PAGE 11



Comment 7 | Cognitive Skills (20)

The NBFM blocks with and without noise are missing, which is a critical aspect that should be included. Additionally, key parameters such as bandwidth, frequency deviation, and modulation index are not explicitly mentioned.



Comment 8 | Knowledge & Understanding (20)

The GNU Radio blocks for NBFM modulation/demodulation with FHSS concepts are well explained, particularly in detailing how the signal is processed at each stage, which is commendable.

PAGE 12



Comment 9 | Cognitive Skills (20)

The sink analysis is clear and effectively explains the signals with and without noise, which is commendable.

PAGE 13



Comment 10 | Cognitive Skills (20)

Comparisons between the original, jammed, and FHSS-processed signals are observed. However, including SNR values would enhance the analysis, allowing for a more quantitative conclusion.

PAGE 14



Comment 11 | Cognitive Skills (20)

Mathematical expressions for NBFM and FHSS techniques are provided. However, certain calculations on parametric values applied within the blocks are not linked to the formulas.

PAGE 15



Comment 12 | Cognitive Skills (20)

SNR expressions are mentioned, the actual calculations are missing, which should be addressed for a more thorough analysis.

PAGE 16

PAGE 17



Comment 13 | Knowledge & Understanding (20)

The conventional block diagram for Wideband FM (WBFM) is provided, and the block settings with proper values are mentioned, which is good.



Comment 14 | Knowledge & Understanding (20)

A brief introduction to the SDR receiver is included, which is commendable.

PAGE 18



Comment 15 | Cognitive Skills (20)

The parameter values for designing the SDR receiver blocks are carefully set, which is also well executed.

PAGE 19



Comment 16 | Cognitive Skills (20)

It would be better to show the calculations for the re-sampler and decimation factors rather than just specifying the values.

PAGE 20



Comment 17 | Practical Skills (25)

The analysis of the SDR receiver is clean and detailed, with observations made at different stages such as the source, demodulation, and post-filtering actions.

PAGE 21



Comment 18 | Cognitive Skills (20)

The constellation graphs effectively illustrate how filtering enhances signal clarity, which is commendable. Mathematical representations of complex expressions are provided.

**Comment 19** | Cognitive Skills (20)

Ethical concerns are well discussed, particularly regarding overhearing private conversations. The concept is aptly described as a "double-edged sword", which is a strong representation of the issue.

**Comment 20** | Transferable Skills (15)

The report maintains a strong flow, organization, and structure, which enhances readability. Additionally, it covers a wide range of references, demonstrating thorough research, which is commendable.

GRADING FORM: ADSP_GRADING_TEMPLATE

LOUISE CAYGILL

77.60**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.



• Comprehensive understanding of topics with appropriate citations and research, though some areas could be enhanced.

16

- Good understanding of SDR principles with relevant research, though certain aspects in citations or depth could be improved.

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.



- Strong knowledge of NBFM, with well-explained concepts, though additional depth could further enhance understanding.
- Good understanding of jammer effects, with scope for added depth.
- Sound knowledge of FHSS application, though certain areas in explanation could be refined.
- Strong grasp of signals, with clear explanations, but some aspects in SNR or performance analysis require improvement.
- Good understanding of ethics and societal benefits, with scope for more detailed insights.
- Comprehensive knowledge of GNU Radio flow and block functions, though some areas could be elaborated further.
- Well-developed understanding of signal analysis, with clear explanations, but stage comparisons and SNR details could be refined.

14.8

- Basic understanding. Explanations of ethics and benefits are incomplete or unclear.

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.



- Satisfactory setup, limited interpretation of parameters.
- Good analysis of jammer effects, with clear use of visual tools, though some aspects could be refined.
- Effective application of FHSS for jammer mitigation and signal comparison, though with some scope for improvement.
- Satisfactory comparison, limited clarity.
- Satisfactory discussion, limited depth.
- Displays satisfactory skills with limited clarity in receiver setup or signal demodulation.
- Displays good analytical skills in interpreting signal parameters like SNR and modulation index, with appropriate use of visualisation tools, though some refinements could enhance clarity.
- Basic discussion with limited reasoning about societal benefits or interference management.

13.3

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: Demonstrates excellent practical skills in setting up NBFM modulation and demodulation, introducing a jammer, and implementing FHSS for anti-jamming. Provides detailed and accurate analysis using Frequency, Time, Waterfall, and Constellation sinks. Strong comparisons of original, jammed, and anti-jammed signals, clarity, and system performance.

Task 2: Demonstrates excellent practical skills with precise setup and effective configuration of the RTL-SDR receiver. Utilises Waterfall, Time, and Frequency sinks effectively for analysis.

22.5

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.



Shows strong transferable skills with good application of GNU Radio tools and solid understanding of signal processing concepts. Minor gaps in analysis depth or documentation.

11

Ethical considerations are discussed but need more detail.