Brilliance
Research of Artificial Intelligence

E-ISSN : 2807-9035
Volume 6, Number 4, November 2026
https://doi.org/10.47709/brilliance.v6i4.9513

Performance Analysis of a Software Defined Radio System Using a Handheld Two Way Radio

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open access

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Article History:
Submitted: 11-08-2026
Accepted: 29-08-2026
Published: 01-11-2026

Keywords:
Software Defined Radio (SDR); Radio Communication System; GNU Radio; Signal-to-Noise Ratio (SNR); Frequency Modulation.

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ABSTRACT

Radio communication systems remain widely used because of their reliability, simplicity, and operational flexibility. The development of Software Defined Radio (SDR) technology has enabled radio signal processing to be implemented in software, providing greater flexibility for signal analysis and system evaluation. This study aims to design and analyze a radio communication system using a Handy Talkie (HT) as the analog transmitter and an RTL2832U Software Defined Radio (RTL-SDR) as the receiver. The received signals were processed using GNU Radio to evaluate transmission performance at different communication distances. System performance was assessed by measuring the Signal-to-Noise Ratio (SNR) and evaluating audio quality using Wideband Frequency Modulation (WBFM) and Narrowband Frequency Modulation (NBFM) demodulation techniques. Experimental results show that at a distance of 10 m, WBFM achieved an SNR of 36.6 dB, while NBFM produced clearer audio with an SNR of 42.5 dB. At 50 m, signal attenuation reduced performance, with WBFM and NBFM achieving SNR values of 31.7 dB and 35.4 dB, respectively. At 100 m, both techniques experienced performance degradation due to increased attenuation and noise; however, NBFM maintained slightly better performance, achieving an SNR of 17.1 dB compared with 16.0 dB for WBFM while preserving more intelligible speech. These results demonstrate that NBFM provides superior transmission performance and audio quality compared with WBFM, making it more suitable for SDR-based analog radio communication systems.

INTRODUCTION

Radio communication systems remain an important wireless communication technology for transmitting voice and data without requiring wired infrastructure. Their flexibility and ease of deployment make radio communication suitable for various communication environments and field applications. Among portable radio communication devices, the Handy Talkie (HT) remains widely used for short-range two-way voice communication because of its portability, simple operation, and ability to provide direct communication without relying on cellular infrastructure.

Recent developments in Software Defined Radio (SDR) have increased the flexibility of radio communication system implementation and experimentation. SDR enables a substantial portion of radio signal processing to be performed through software, allowing communication functions and processing configurations to be modified without extensive changes to dedicated hardware. This flexibility makes SDR suitable for wireless communication research, receiver development, and experimental evaluation (Havinga et al., 2023; Le et al., 2024). Recent SDR-based communication studies have also demonstrated the use of configurable radio platforms for implementing and evaluating wireless communication systems under real transmission conditions (Havinga et al., 2023).

Among low-cost SDR platforms, the RTL-SDR provides an accessible solution for radio-frequency signal reception and software-based processing. Combined with GNU Radio, RTL-SDR can be configured as an FM receiver by setting the center frequency, sampling rate, gain, filtering, and demodulation parameters (GNU Radio Project, 2024). The use of RTL-SDR and GNU Radio for FM signal processing has also been investigated by Dewi (2025), who evaluated FM demodulation performance using SNR as one of the signal-quality parameters. These developments demonstrate the suitability of low-cost SDR platforms for radio signal acquisition, demodulation, spectrum visualization, and signal-quality evaluation.

Several recent studies have demonstrated the application of SDR for configurable wireless communication and signal-processing systems. Havinga et al. (2023) evaluated SDR-based wireless communication and demonstrated the importance of configurable RF platforms for real-world transmission performance. Le et al. (2024) developed an SDR-based receiver architecture for real-time modulation classification and evaluated its performance under real channel conditions. These studies demonstrate the flexibility of SDR for implementing and evaluating communication receivers. However, the evaluation of two-way analog radio communication using an HT transmitter and a low-cost RTL-SDR receiver, particularly through a comparison of WBFM and NBFM at different transmission distances, remains limited.

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Therefore, this study proposes a Software-Defined Radio-based radio communication system using a Handy Talkie (HT) as the transmitter and RTL-SDR as the receiver. The system is designed to compare Wideband Frequency Modulation (WBFM) and Narrowband Frequency Modulation (NBFM) at transmission distances of 10 m, 50 m, and 100 m. GNU Radio is employed for signal acquisition, filtering, demodulation, and real-time spectrum visualization, while SDRangel is used to measure the Signal-to-Noise Ratio (SNR). The performance evaluation focuses on the relationship between transmission distance, SNR, and received audio quality. The results are expected to provide an experimental reference for the use of low-cost SDR platforms in evaluating analog radio communication performance.

LITERATURE REVIEW

Radio Communication System

Radio communication is a wireless communication technology that transmits voice or data through electromagnetic waves without requiring wired infrastructure. Its mobility, flexibility, and ease of deployment make it suitable for various wireless communication applications. Among portable radio communication devices, the Handy Talkie (HT) is commonly used for short-range voice communication because it can provide direct communication between users without relying on wired or cellular infrastructure. In conventional radio systems, signal transmission and reception are primarily performed through dedicated hardware components. The limitations of fixed hardware configurations have encouraged the development of Software Defined Radio (SDR), which provides greater flexibility by implementing radio signal processing through software (Havinga et al., 2023; Le et al., 2024).

Software Defined Radio (SDR)

Software Defined Radio (SDR) is a radio communication technology in which most signal processing functions are implemented through software rather than dedicated hardware. This approach allows communication parameters, including operating frequency, bandwidth, and modulation schemes, to be configured through software, providing greater flexibility for communication system development and experimentation (Havinga et al., 2023; Le et al., 2024). An SDR system generally separates the radio frequency (RF) front-end from the digital signal processing stage, allowing signal processing functions to be implemented and modified according to the required application. This reconfigurability makes SDR suitable for wireless communication research, receiver development, and signal analysis (Le et al., 2024; Demeneghi et al., 2024).

RTL2832U Software Defined Radio and GNU Radio

The RTL2832U Software Defined Radio (RTL-SDR) is a low-cost USB-based receiver that enables radio frequency (RF) signals to be acquired and processed using software. Its low cost and accessibility make RTL-SDR suitable for communication research, signal reception, and educational applications (Pasaribu et al., 2024; Dewi, 2025).

GNU Radio is an open-source software toolkit that provides modular digital signal processing blocks for implementing SDR applications. When integrated with RTL-SDR, GNU Radio can be used for signal acquisition, FM demodulation, spectrum visualization, and audio processing. This combination provides a flexible platform for implementing and evaluating radio receiver systems through software-based signal processing (GNU Radio Project, 2024; Dewi, 2025).

Frequency Modulation (FM)

Frequency Modulation (FM) is an analog modulation technique in which information is transmitted by varying the carrier frequency while maintaining a relatively constant carrier amplitude. FM is widely used for voice communication because of its resistance to amplitude noise and suitable audio quality. FM communication can be implemented using different bandwidth configurations, including Wideband Frequency Modulation (WBFM) and Narrowband Frequency Modulation (NBFM). WBFM uses a wider bandwidth for FM signal transmission, whereas NBFM uses a narrower bandwidth and is commonly applied to narrowband voice communication. These differences result in different receiver bandwidth and demodulation characteristics (Dewi, 2025).

Previous Studies and Research Gap

Several studies have investigated the application of Software Defined Radio (SDR) in wireless communication systems, particularly for signal reception, spectrum monitoring, and receiver implementation. These studies demonstrate the flexibility and cost-effectiveness of SDR platforms, especially when combined with RTL-SDR and GNU Radio. However, differences in research objectives, experimental methods, and performance evaluation indicate that several aspects of analog radio communication systems remain insufficiently explored. A summary of the previous studies related to this research is presented in Table 1.

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Table 1. Summary of Previous Studies

Authors	Focus	Limitation	Novelty of This Study
Pasaribu et al. (2024)	ADS-B Receiver	No analog voice communication	Evaluates HT-based analog communication
Meshram & Kolhare (2019)	FM Receiver	Broadcast FM only	Compares WBFM and NBFM
Akeela & Dezfouli (2018)	SDR Review	No experimental validation	Practical SDR implementation using HT
Goyal & Agrawal (2024)	SDR Review	No communication performance analysis	SNR and audio quality evaluation under different distances

METHOD

This study proposes a Software Defined Radio (SDR)-based radio communication system using a Handy Talkie (HT) as the analog transmitter and an RTL2832U Software Defined Radio (RTL-SDR) as the receiver. The proposed system is designed to evaluate analog radio communication performance by comparing Wideband Frequency Modulation (WBFM) and Narrowband Frequency Modulation (NBFM) under different transmission distances. The HT operates at 166.5 MHz, while GNU Radio is employed for real-time signal acquisition, processing, and demodulation. As illustrated in Fig.1, the transmitted radio frequency (RF) signal is captured by the RTL-SDR and converted into digital in-phase and quadrature (I/Q) samples. The digitized signal is then transferred to a laptop via a USB interface for further processing. GNU Radio performs signal filtering, WBFM and NBFM demodulation, spectrum visualization, and audio processing, whereas SDRangel is used to measure the Signal-to-Noise Ratio (SNR). Finally, the communication performance is evaluated based on spectrum characteristics, SNR, and perceived audio quality. Unlike previous studies that mainly focused on FM broadcast reception, the proposed system evaluates analog two-way radio communication using a Handy Talkie transmitter while comparing WBFM and NBFM receiver configurations.

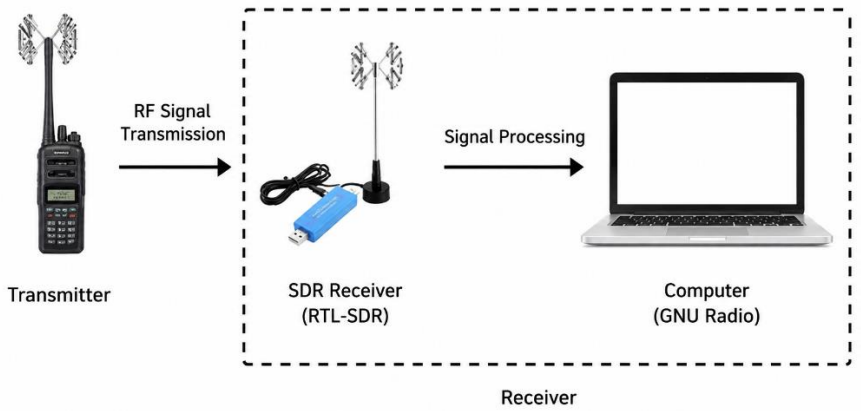


Figure 1. Proposed SDR-Based Radio Communication System.

The research methodology adopted in this study is presented in Figure 2. The process begins by configuring the operating frequency of the Handy Talkie (HT) transmitter and the RTL-SDR receiver to ensure communication on the same frequency. Subsequently, a GNU Radio flowgraph is developed to perform signal acquisition, filtering, and both Wideband Frequency Modulation (WBFM) and Narrowband Frequency Modulation (NBFM) demodulation. The received signals are then analyzed through spectrum visualization, Signal-to-Noise Ratio (SNR) measurement using SDRangel, and audio quality evaluation. Finally, the performance of WBFM and NBFM is compared under different transmission distances to determine the effectiveness of the proposed SDR-based radio communication system.

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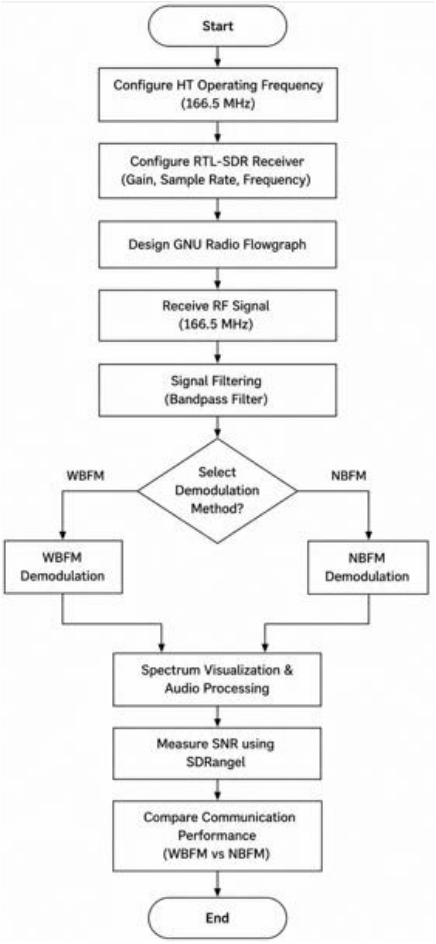


Figure 2. Flowchart of the Proposed Research Methodology.

GNU Radio was employed to implement two receiver configurations for processing the radio signals captured by the RTL-SDR. Both receiver configurations use the same RTL-SDR source, operating frequency, sample rate, and signal processing stages. The only difference lies in the demodulation block, allowing a direct performance comparison between Narrowband Frequency Modulation (NBFM) and Wideband Frequency Modulation (WBFM). The received RF signal is filtered, demodulated, and converted into an audio signal while simultaneously displaying the signal spectrum in real time. Fig.3 shows the receiver configuration using the NBFM demodulation block, whereas Fig. 4 presents the receiver configuration using WBFM. These flowgraphs provide the basis for evaluating the communication performance of both demodulation techniques under identical operating conditions.

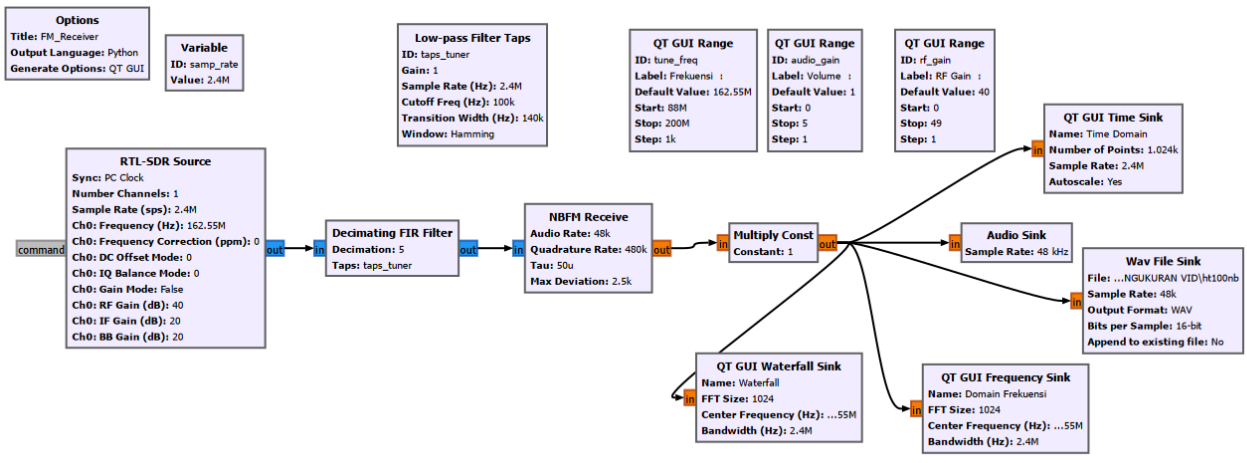


Figure 3. GNU Radio Flowgraph for NBFM Receive

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Figure 3 shows the GNU Radio flowgraph configured for the NBFM receiver. The RF signal captured by the RTL-SDR is first processed using the Decimating FIR Filter with a center frequency of 166.5 MHz and a sampling rate of 2.4 MS/s. The filtered signal is then demodulated using the NBFM Receive block to recover the audio information. The demodulated signal is passed through the Multiply Const block before being sent to the Audio Sink for real-time playback. The Frequency Sink, Time Sink, and Waterfall Sink are used to observe the received signal in the frequency, time, and waterfall domains, respectively, while the WAV File Sink is used to record the resulting audio.

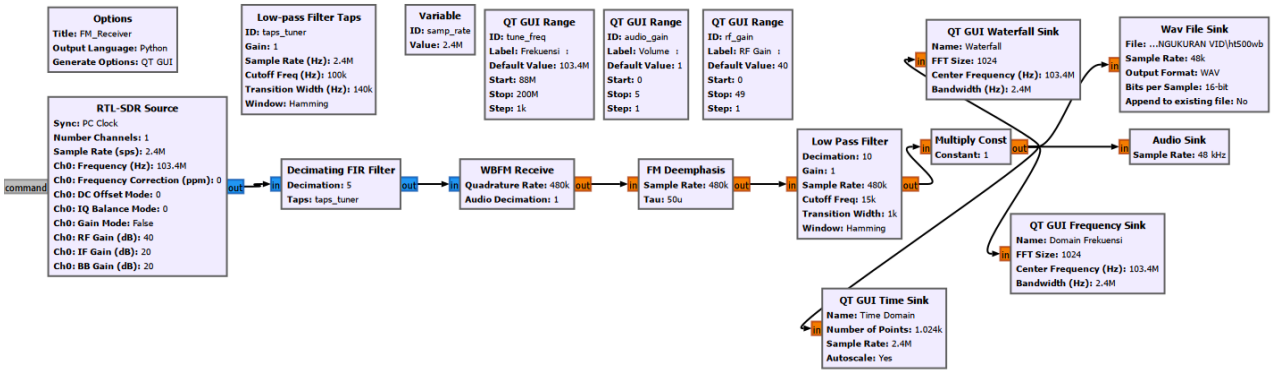


Figure 4. GNU Radio Flowgraph for WBFM Receiver

Figure 4 shows the GNU Radio flowgraph configured for the WBFM receiver. Similar to the NBFM configuration, the RF signal is acquired by the RTL-SDR at a center frequency of 166.5 MHz and a sampling rate of 2.4 MS/s, followed by filtering using the Decimating FIR Filter. The filtered signal is then processed by the WBFM Receive block and further processed using the FM Demod and Low Pass Filter blocks before being passed through the Multiply Const block to the Audio Sink. The Frequency Sink, Time Sink, and Waterfall Sink provide real-time visualization of the received signal, while the WAV File Sink records the demodulated audio.

The receiver configurations were designed using identical signal acquisition and processing settings to provide a consistent basis for performance evaluation. Table 3 summarizes the principal GNU Radio receiver parameters employed in the experiments.

Table 2. GNU Radio Receiver Parameters

Parameter	NBFM	WBFM
Center Frequency	166.5 MHz	166.5 MHz
Sample Rate	2.4 MS/s	2.4 MS/s
RF Gain	40 dB	40 dB
FIR Decimation	5	5
FIR Cutoff Frequency	100 kHz	100 kHz
Audio Rate	48 kHz	48 kHz*
Quadrature Rate	480 kHz	480 kHz
Maximum Frequency Deviation	2.5 kHz	Default WBFM
Audio Decimation	–	10
De-emphasis (Tau)	50 µs	50 µs

The experimental evaluation was conducted in an open outdoor environment located on Jl. Lubuk Ipuh, Pisang, Pauh District, Padang City, West Sumatra, Indonesia. The selected location provides a clear line-of-sight (LoS) communication path with minimal physical obstructions, allowing radio signals to propagate with limited interference. The test site is located at approximately 0.943623° S latitude and 100.398684° E longitude. Communication performance was evaluated at transmission distances of 10 m, 50 m, and 100 m along a straight measurement path. During each experiment, the Handy Talkie transmitted voice signals at 166.5 MHz, while the RTL-SDR received the transmitted signals for further processing using GNU Radio. The received signals were evaluated in terms of Signal-to-Noise Ratio (SNR), spectrum characteristics, and perceived audio quality to compare the performance of the WBFM and NBFM receiver configurations.

RESULT

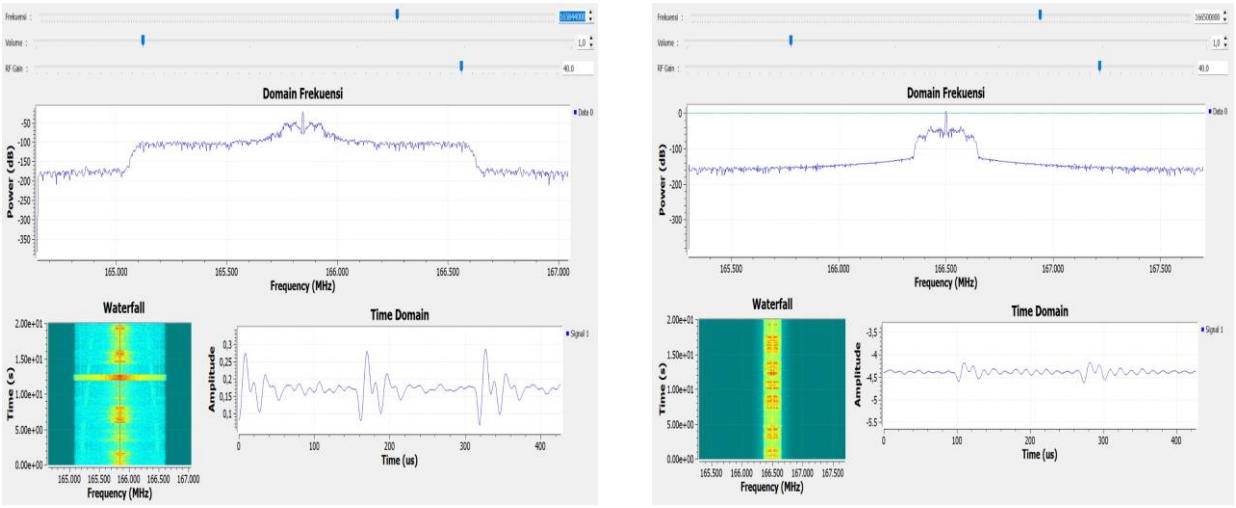
In this section, the researcher will explain the results of the research obtained. Researchers can also use images, tables, and curves to explain the results of the study. These results should present the raw data or the results after applying the techniques outlined in the methods section. The results are simply results; they do not conclude. This section presents the received signal characteristics obtained from the proposed radio communication system using

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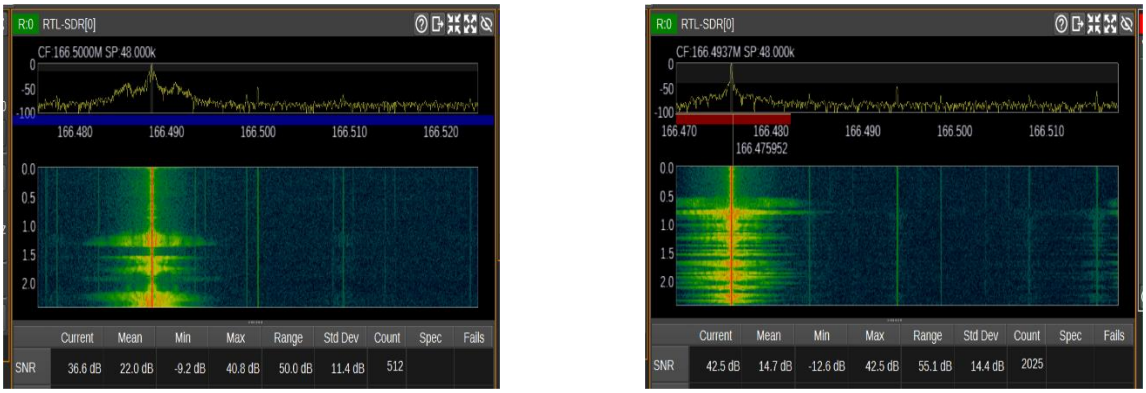
E-ISSN : 2807-9035
Volume 6, **Number** 4, November 2026
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Wideband Frequency Modulation (WBFM) and Narrowband Frequency Modulation (NBFM) at transmission distances of 10 m, 50 m, and 100 m. The received signals were observed through the frequency spectrum, time-domain waveform, and waterfall display generated by GNU Radio and show at Figure 5.



a b

Figure 5. Received Signal Characteristics (a) WBFM Receiver and (b) NBFM Receiver.



a b

Figure 6. Received Signal Characteristics: (a) WBFM Receiver and (b) NBFM Receiver.

Figure 6 presents the received signal characteristics at a transmission distance of 10 m. For the WBFM receiver, the received spectrum extends approximately from 165.5 MHz to 167.3 MHz, with the carrier located at 165.844 MHz. The measured peak signal level is approximately −30 dB, while the noise floor is around −170 dB. The corresponding time-domain waveform exhibits repeated burst patterns associated with voice transmission, and the waterfall display shows a dominant signal concentrated around the carrier frequency. The measured SNR under this condition is 36.6 dB. For the NBFM receiver, the received spectrum is concentrated within 166.35–166.65 MHz, with the carrier frequency located at 166.5 MHz. The maximum signal level reaches 0 dB, while the noise floor is approximately −120 dB. The time-domain waveform remains relatively stable, and the waterfall display indicates that the strongest signal energy is concentrated around the carrier frequency. The measured SNR is 42.5 dB.

At a transmission distance of 50 m, the NBFM receiver achieved an SNR of 35.4 dB, while WBFM recorded 31.7 dB, resulting in a difference of 3.7 dB. The higher SNR obtained by NBFM is related to its narrower bandwidth, which limits the noise entering the demodulation process compared with WBFM. Compared with the 10 m measurement, the SNR decreased from 36.6 to 31.7 dB for WBFM and from 42.5 to 35.4 dB for NBFM. This decrease indicates a reduction in received signal quality as the transmission distance increased. Although the displayed noise floors were different, approximately −180 dB for WBFM and −122 dB for NBFM, these values were not used as the primary basis for comparison because they are affected by the respective receiver and visualization configurations. SNR was therefore used as the main parameter for comparing WBFM and NBFM performance.

At a transmission distance of 100 m, the measured SNR decreased to 16.0 dB for WBFM and 17.1 dB for NBFM. Compared with the measurements at 50 m, the SNR decreased by 15.7 dB for WBFM and 18.3 dB for NBFM. The received signal characteristics also show greater amplitude fluctuations and reduced signal activity in the time-

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E-ISSN : 2807-9035
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domain waveform for both demodulation configurations. The NBFM receiver still recorded a slightly higher SNR than WBFM, with a difference of 1.1 dB. The narrower bandwidth of NBFM limits the noise entering the demodulation process, resulting in a slightly higher SNR under the 100 m test condition. However, the SNR values for both configurations were substantially lower than those measured at 10 m and 50 m, indicating a considerable reduction in received signal quality at the maximum testing distance. The displayed noise floor at Figure 11 was approximately −155 dB for WBFM and −110 dB for NBFM. As in the previous measurements, these noise-floor values are not used as the primary basis for comparing the two demodulation techniques because they are affected by the respective receiver and visualization configurations. The SNR values are therefore used as the main parameter for evaluating the change in signal quality with increasing transmission distance.

DISCUSSION

The experimental results show a clear decrease in Signal-to-Noise Ratio (SNR) as the transmission distance increases for both WBFM and NBFM. The WBFM SNR decreases from 36.6 dB at 10 m to 31.7 dB at 50 m and 16.0 dB at 100 m, while NBFM decreases from 42.5 dB to 35.4 dB and 17.1 dB, respectively. As shown in Figure 7, the most pronounced reduction occurs between 50 m and 100 m, with decreases of 15.7 dB for WBFM and 18.3 dB for NBFM. This trend is associated with the reduction in received signal strength as the propagation distance increases, resulting in a lower signal-to-noise ratio.

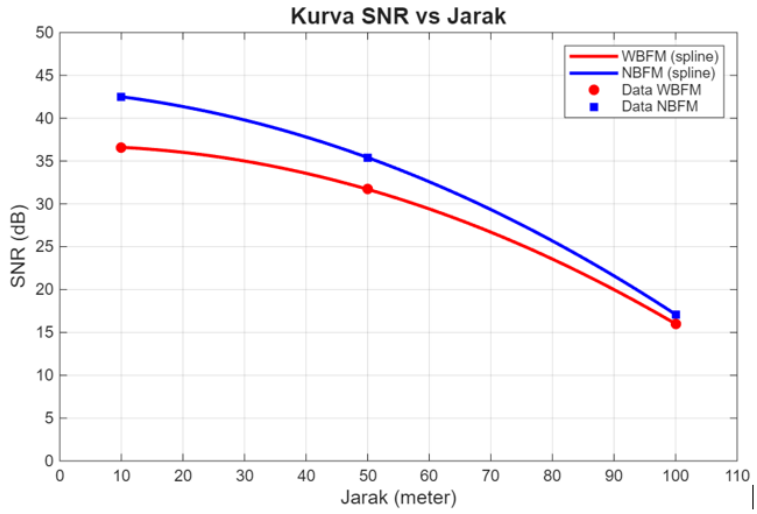


Figure 7. SNR Performance of WBFM and NBFM at Different Transmission Distances.

Across all measurement distances, NBFM records a higher SNR than WBFM, with differences of 5.9 dB at 10 m, 3.7 dB at 50 m, and 1.1 dB at 100 m. The higher SNR observed in NBFM can be associated with its narrower bandwidth, which limits the amount of noise entering the demodulation process. In contrast, the wider bandwidth of WBFM accommodates a broader range of frequency components and can consequently include more noise in the received signal. However, the difference between the two configurations becomes smaller at 100 m, indicating that the effect of propagation distance becomes increasingly dominant as the received signal weakens. The SNR measurements are also reflected in the observed audio quality. At 10 m, both configurations provide strong and clear audio, although a slight high-pitched background sound is observed in WBFM. At 50 m, the audio remains clear for both configurations, with occasional reduction in WBFM audio level and slight background noise in NBFM. At 100 m, both configurations exhibit noticeable degradation, with increased noise and weaker WBFM audio, while NBFM remains audible but becomes intermittent. These observations indicate a relationship between the reduction in SNR and the degradation of perceived audio quality at longer transmission distances. Environmental conditions may also have contributed to variations in the received audio, particularly during the longer-distance measurements. Wind was observed at the test location during the experiment; however, its individual contribution was not separately measured. Therefore, the observed SNR reduction is primarily discussed in relation to transmission distance, while environmental effects are considered as additional experimental conditions rather than quantified causes. Overall, the results demonstrate that NBFM consistently achieves a higher measured SNR than WBFM under the tested conditions, while both demodulation techniques experience substantial performance degradation at 100 m. The results also show that increasing transmission distance has a greater influence on signal quality at longer ranges, as reflected by the sharp SNR reduction and corresponding changes in audio quality.

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CONCLUSION

This study successfully designed and implemented an SDR-based radio communication system using a Handy Talkie (HT) as the transmitter and RTL-SDR as the receiver, with GNU Radio used for signal acquisition, filtering, demodulation, and real-time signal visualization. The system was implemented using both WBFM and NBFM receiver configurations and evaluated at transmission distances of 10 m, 50 m, and 100 m. The experimental results show that the SNR decreased as the transmission distance increased for both demodulation techniques. NBFM consistently produced higher SNR values than WBFM, with values of 42.5 dB, 35.4 dB, and 17.1 dB at 10 m, 50 m, and 100 m, respectively, compared with 36.6 dB, 31.7 dB, and 16.0 dB for WBFM. The decrease in SNR was accompanied by a reduction in perceived audio quality, particularly at 100 m. Under the tested conditions, NBFM provided a higher SNR and more stable audio reception than WBFM, while both configurations remained capable of receiving the transmitted signal up to 100 m. These results demonstrate the applicability of low-cost SDR technology for analyzing and evaluating analog HT communication systems.

REFERENCES

Agasti, R., Kim, E., Ruyle, J., Onwuchekwa, C. C., Azizi, S., & Rahaim, M. (2023). Implementation of software-defined antenna and radio test system for congested spectral environments. *Proceedings of the GNU Radio Conference, 8*(1).

Demeneghi, J. A., Kaur, J., Tan, K., & Abbas, H. (2024). Sub-6 GHz beamforming with low-cost software-defined radio: Design, testing, and performance evaluation. *Physical Communication, 65*, 102391. https://doi.org/10.1016/j.phycom.2024.102391

Dewi, I. T. (2025). Evaluasi kinerja demodulasi FM berbasis RTL-SDR dan Raspberry Pi 4: Perbandingan desain modular dan blok dasar pada GNU Radio. *Telekontran: Jurnal Ilmiah Telekomunikasi, Kendali dan Elektronika Terapan, 13*(2). https://doi.org/10.34010/telekontran.v13i2.16558

Dzhezyan, G., Kulhandjian, M., & Kulhandjian, H. (2022). Implementation of faster-than-Nyquist signaling using software defined radios. *Proceedings of the GNU Radio Conference, 7*(1).

Grigoriev, V., Komissarov, A., Ryutin, K., & Fokin, G. (2024). Software-defined radio wireless communication technology design: LibreSDR board validation. In *2024 Systems of Signals Generating and Processing in the Field of On Board Communications*. https://doi.org/10.1109/IEEECONF60226.2024.10496728

Havinga, T., Jiao, X., Aslam, M., Liu, W., & Moerman, I. (2023). Improved TDD operation on software-defined radio platforms towards future wireless standards. *Computer Communications, 209*, 178–187. https://doi.org/10.1016/j.comcom.2023.06.026

Herrera Ramos, M. C., Capacho Valbuena, L. M., & Londoño Cano, A. (2025). Modular communication systems based on spread spectrum modulation techniques using GNU Radio. *Revista Ingenierías Universidad de Medellín, 24*(47). https://doi.org/10.22395/rium.v24n47a1

Joosens, D., BniLam, N., Berkvens, R., & Weyn, M. (2025). Software-defined radio-based Internet of Things communication systems: An application for the DASH7 Alliance protocol. *Applied Sciences, 15*(1), 333. https://doi.org/10.3390/app15010333

Le, Q. N., Huynh, T. Q., Ta, H. Q., Vo Tan, P., & Nguyen, L. L. (2024). Modified receiver architecture in software-defined radio for real-time modulation classification. *EURASIP Journal on Advances in Signal Processing, 2024*, 77. https://doi.org/10.1186/s13634-024-01176-6

Lin, N., Yun, Z., Zhou, S., & Han, S. (2025). GR-WiFi: A GNU Radio based WiFi platform with single-user and multi-user MIMO capability. *Physical Communication, 72*, 102812. https://doi.org/10.1016/j.phycom.2025.102812

Lyshevski, S. E., Buckley, R., & Feuerstein, C. (2025). Resilient communication for software defined radio: Machine reasoning and electromagnetic spectrum evaluation. *Sensors, 25*(6), 1826. https://doi.org/10.3390/s25061826

Mitsuishi, N. Y., Ma, Y., & Coder, J. (2024). 5G NR and LTE downlink coexistence measurements using software-defined radios. In *Proceedings of the IEEE International Conference on Communications (ICC 2024)*. National Institute of Standards and Technology.

Narayana, N., & Sure, P. (2023). Performance of a software defined radio based non-coherent OFDM wireless link. *International Journal of Electronics and Telecommunications*.

Onwuchekwa, C. C., AminuMukhtar, M., Martinez, L., Lemus, A. D., Berkhout, C., Semash, F. Y., et al. (2023). Design and implementation of a multi-node optical wireless communication testbed for centralized configuration and adaptation of system parameters using GNU Radio's XML-RPC and ZMQ modules. *Proceedings of the GNU Radio Conference, 8*(1).

Siauciulis, M., Crockett, L. H., & Stewart, R. W. (2023). Ultra-wideband SDR architecture for AMD RFSoCs and PYNQ based GNU Radio blocks. *Proceedings of the GNU Radio Conference, 8*(1).

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