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Enhancing Television Signal Quality Using Advanced Modulation Technique

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Abstract

*The poor broadcasting and telecommunications qualities in our television broadcasting stations were as a result of low bandwidth, high bit error rate and low signal to noise ratio. This poor broadcasting and communication qualities observed in our television stations was overcame by introducing enhancing television signal quality using advanced modulation technique. To vividly achieve this, it was done in this manner, television signal quality was characterized and the causes of poor television signal quality was established. Then a conventional SIMULINK model for television signal quality was designed and Artificial Neural Network (ANN) was trained in the designed advanced modulation rule base to boost the minimization of the causes of poor television signal quality. The algorithm to implement the process was developed, SIMULINK model for Enhancing Television Signal Quality Using Advanced Modulation Techniques was designed and the results obtained were validated and justified. The results obtained were the conventional Bandwidth Efficiency that causes poor television signal quality was 2 bps/Hz. On the other hand, when an Advanced Modulation was integrated into the system, it simultaneously improved to 2.6 bps/Hz, thereby enhancing bandwidth efficiency to 3.3% and the conventional bit error rate that **causes** poor television signal quality was 0.001bits.meanwhile, when Advanced Modulation was imbibed into the system; it instantly reduced it to 0.000867bits. Finally, with these results obtained, it showed that percentage enhancement in Television Signal Quality was 13.3%.*

Keywords: ***Enhancing ,Television, Signal, Quality, Advanced, Modulation ,Technique***

1.0 Introduction

The advent of digital technology has significantly transformed the broadcasting industry, particularly in television signal transmission. As consumer demand for high-definition (HD) and ultra-high-definition (UHD) content grows, maintaining signal quality while optimizing bandwidth utilization has become increasingly challenging. Traditional modulation and compression techniques, though effective, often struggle to balance quality, reliability, and efficiency in modern broadcasting environments. Advanced modulation techniques such as Quadrature Amplitude Modulation (QAM) and Orthogonal Frequency Division Multiplexing (OFDM) have been instrumental in improving signal robustness against noise and interference. However, as the broadcasting ecosystem evolves, integrating intelligent systems into these techniques offers new opportunities for optimizing signal performance. By leveraging artificial intelligence (AI) and machine learning (ML), real-time adaptability to channel conditions and dynamic resource allocation can be achieved, ensuring superior signal quality. Similarly, advanced compression methods like High-Efficiency Video Coding (HEVC) and AV1 have revolutionized the reduction of data rates without compromising visual quality. Incorporating intelligent algorithms into these techniques enables enhanced predictive capabilities, efficient error correction, and reduced latency, which are critical for live and streaming applications. This study explores the integration of intelligent advanced modulation and compression techniques to enhance television signal quality. The research aims to address persistent challenges such as signal degradation, bandwidth constraints, and real-time processing inefficiencies, paving the way for more reliable and high-quality television broadcasting systems in a digital-first era. The quality of television signals is pivotal in delivering clear and reliable content to viewers. Signal degradation can lead to poor reception, resulting in viewer dissatisfaction. To address this, advanced modulation techniques have been developed to enhance signal robustness and quality.Modulation is the process of varying a carrier signal to transmit data effectively.

Common techniques include Frequency Modulation (FM), Amplitude Modulation (AM), and Phase Shift Keying (PSK). Advancements in modulation methods have led to improved signal quality by reducing degradation and errors Digital television standards have evolved to incorporate these advanced techniques. For instance, DVB-C employs Quadrature Amplitude Modulation (QAM) to efficiently transmit digital data over cable networks, ensuring higher data rates and improved signal quality Similarly, DVB-T2 utilizes advanced coding and signal processing algorithms to mitigate signal degradation, enhancing reception quality Incorporating intelligent systems, such as neural networks, into modulation processes has further improved signal quality. These systems enhance channel estimation, leading to better reception of transmitted signals Additionally, hierarchical modulation techniques allow for the multiplexing of multiple data streams into a single symbol stream, providing a fallback signal in weak conditions and enabling graceful degradation instead of complete signal loss In summary, the integration of advanced modulation techniques and intelligent systems plays a crucial role in enhancing television signal quality, ensuring viewers receive clear and reliable broadcasts. Television broadcasting has remained one of the most influential mass communication media, providing entertainment, education, and information to billions of people worldwide. However, the quality of television signals has consistently been challenged by noise, interference, multipath fading, and limited bandwidth, particularly in terrestrial and satellite transmission systems (Kumar & Singh, 2021).

Traditional analog modulation techniques, such as amplitude modulation (AM) and frequency modulation (FM), often suffer from signal degradation during long-distance transmission, thereby reducing picture clarity and audio fidelity (Adeyemi & Olatunji, 2020). With the global transition to digital television broadcasting, the adoption of advanced modulation techniques has become crucial in ensuring improved signal robustness and efficiency. Advanced modulation schemes such as Quadrature Amplitude Modulation (QAM), Orthogonal Frequency Division Multiplexing (OFDM), and Phase Shift Keying (PSK) provide higher spectral efficiency and resilience against channel impairments (Zhou et al., 2019). These techniques enhance television signal quality by optimizing the available bandwidth, mitigating multipath effects, and improving error correction capacity. For example, OFDM, widely applied in digital video broadcasting (DVB-T and DVB-S), combats inter-symbol interference while maintaining reliable data transmission, even under adverse channel conditions (Nguyen & Tran, 2022). This has made advanced modulation techniques central to the success of modern television systems, especially in urban and rural areas where signal distortion is common. Moreover, the increasing demand for high-definition (HD) and ultra-high-definition (UHD) content requires higher data rates and more efficient modulation schemes to deliver superior picture quality (Okafor, 2021). As television networks expand into Internet Protocol Television (IPTV) and satellite-based platforms, modulation plays a critical role in achieving seamless, high-quality transmission with reduced power consumption. Therefore, enhancing television signal quality through advanced modulation techniques not only improves user experience but also ensures efficient utilization of spectrum resources, which are limited and highly contested in the modern telecommunication landscape (Aliyu & Hassan, 2020).

In this regard, the study seeks to explore how advanced modulation techniques can be applied to enhance television signal quality, reduce transmission losses, and ensure a more reliable broadcasting system in both developed and developing regions. Television broadcasting remains one of the most widely used means of information dissemination, entertainment, and education across the world. Despite the rapid growth of internet-based streaming services, terrestrial and satellite television systems continue to play a major role, especially in regions where internet access is limited or costly. However, one of the persistent challenges in television broadcasting is signal degradation, which affects picture and sound quality at the receiver end (Proakis & Salehi, 2008). Signal quality in television transmission is influenced by several factors such as noise, interference, multipath propagation, and limited bandwidth availability. These issues often result in poor reception, ghosting effects, pixelation, and audio distortion. To address these challenges, modern communication systems have increasingly adopted advanced modulation techniques that improve spectral efficiency and enhance signal robustness (Haykin, 2013). Modulation is the process of varying a carrier signal in order to transmit information efficiently over a communication channel.

Traditional analog modulation techniques such as Amplitude Modulation (AM) and Frequency Modulation (FM) were widely used in earlier television systems. However, these methods are more susceptible to noise and channel impairments, leading to reduced signal quality under poor transmission conditions (Carlson, 2010). With the advancement of digital communication, more efficient modulation techniques such as Quadrature Amplitude Modulation (QAM), Phase Shift Keying (PSK), and Orthogonal Frequency Division Multiplexing (OFDM) have been introduced. These techniques provide better resistance to noise, improved bandwidth utilization, and higher data transmission rates, making them suitable for modern digital television broadcasting systems (Stuber, 2017). In particular, OFDM has become a key technology in digital television standards such as DVB-T and DVB-T2 due to its ability to combat multipath interference and improve signal reliability. Similarly, higher-order QAM techniques enable the transmission of more bits per symbol, thereby increasing data throughput without requiring additional bandwidth (Sklar, 2001). Therefore, enhancing television signal quality using advanced modulation techniques is essential for improving viewer experience, reducing transmission errors, and ensuring efficient use of the available frequency spectrum. This study focuses on how these modern modulation techniques can be applied to improve the quality and reliability of television signal transmission systems.

2.0 Methodology

3.3 To characterize and establish the causes of poor television signal quality

Table 3.1 characterized and established Causes of Poor Television Signal Quality

S/N	Parameter	Range That Reduces TV Signal Quality	S.I. Unit	Impact on TV Signal
1	**Signal-to-Noise Ratio (SNR)**	**< 20 dB**	dB (decibels)	High noise, grainy or pixelated video.
2	**Bit Error Rate (BER)**	**> 10^{-3}**	Unitless (fraction or percentage)	Data corruption, video/audio artifacts, freezing.
3	**Modulation Error Ratio (MER)**	**< 25 dB**	dB (decibels)	Poor modulation accuracy, increased error rate.
4	**Received Signal Strength (RSSI)**	**< -85 dBm**	dBm (decibels relative to 1mW)	Weak signal reception, loss of signal.
5	**Carrier-to-Noise Ratio (CNR)**	**< 15 dB**	dB (decibels)	Poor carrier stability, increased noise interference.
6	**Propagation Delay**	**> 50 µs**	Microseconds (µs)	Lag, jitter, and desynchronization in audio and video.
7	**Multipath**	**> 1 µs**	Microseconds	Ghosting effect, double

	Interference		(µs)	images, distortion.
8	**Intermodulation Distortion**	**> -40 dB**	dB (decibels)	Signal distortion, cross-talk, interference with other channels.
9	**Phase Noise**	**> -80 dBc/Hz** at 10 kHz offset	Hz (Hertz)	Blurred video, poor audio synchronization.
10	**Bandwidth Efficiency**	**< 2 bps/Hz**	bits per second per Hertz (bps/Hz)	Low data rate, reduced resolution, signal congestion.

For optimal television signal quality, these parameters should be maintained **above or below the threshold values** depending on the parameter. If they fall within the ranges listed above, significant **signal degradation, video/audio distortion, and loss of transmission quality** can occur.

3.4 To design a conventional SIMULINK model for television signal quality

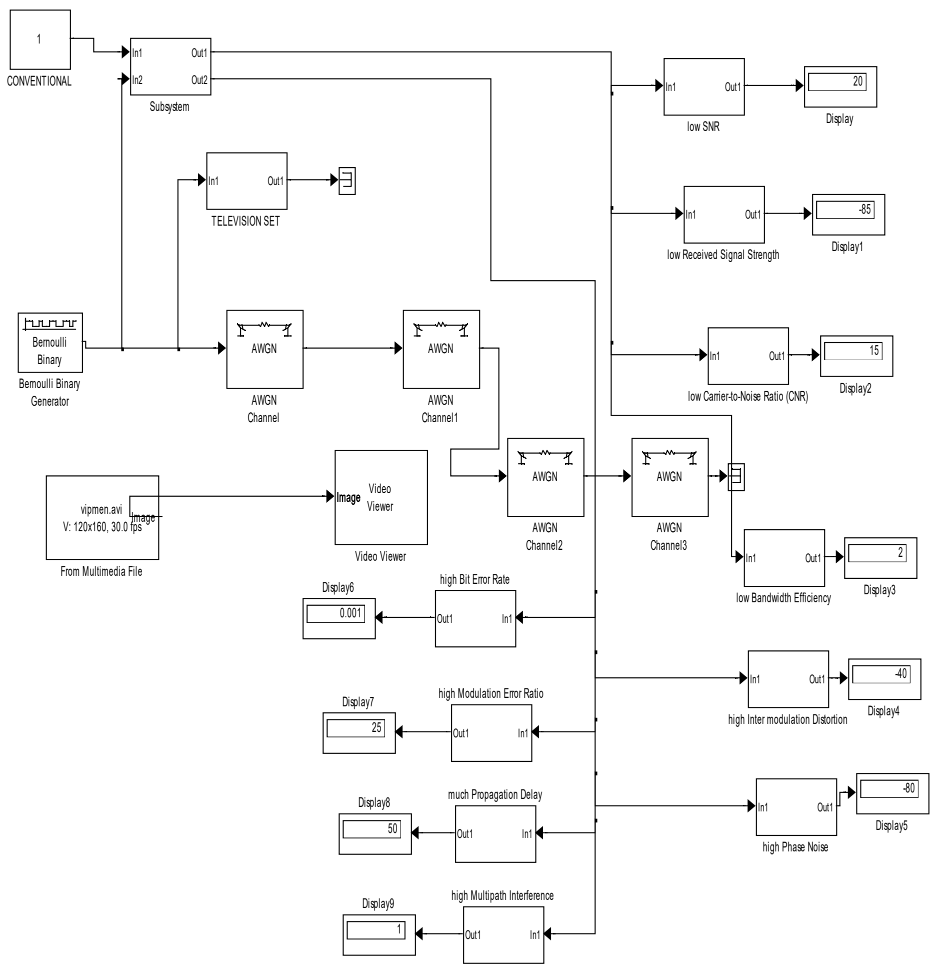

Fig 3.2 designed conventional SIMULINK model for television signal quality

This was done in MATLAB SIMULINK model. The right blocks that were meant to design television signal quality was picked and used to design an ideal television signal quality. The core causes of poor television signal quality were incorporated in the designed model.
The results obtained were shown in the validation and justification and also in figures 4.1 through 4.3

3.5 To Design Advanced Modulation Rule Base that will Minimize the Causes of Poor Television Signal Quality

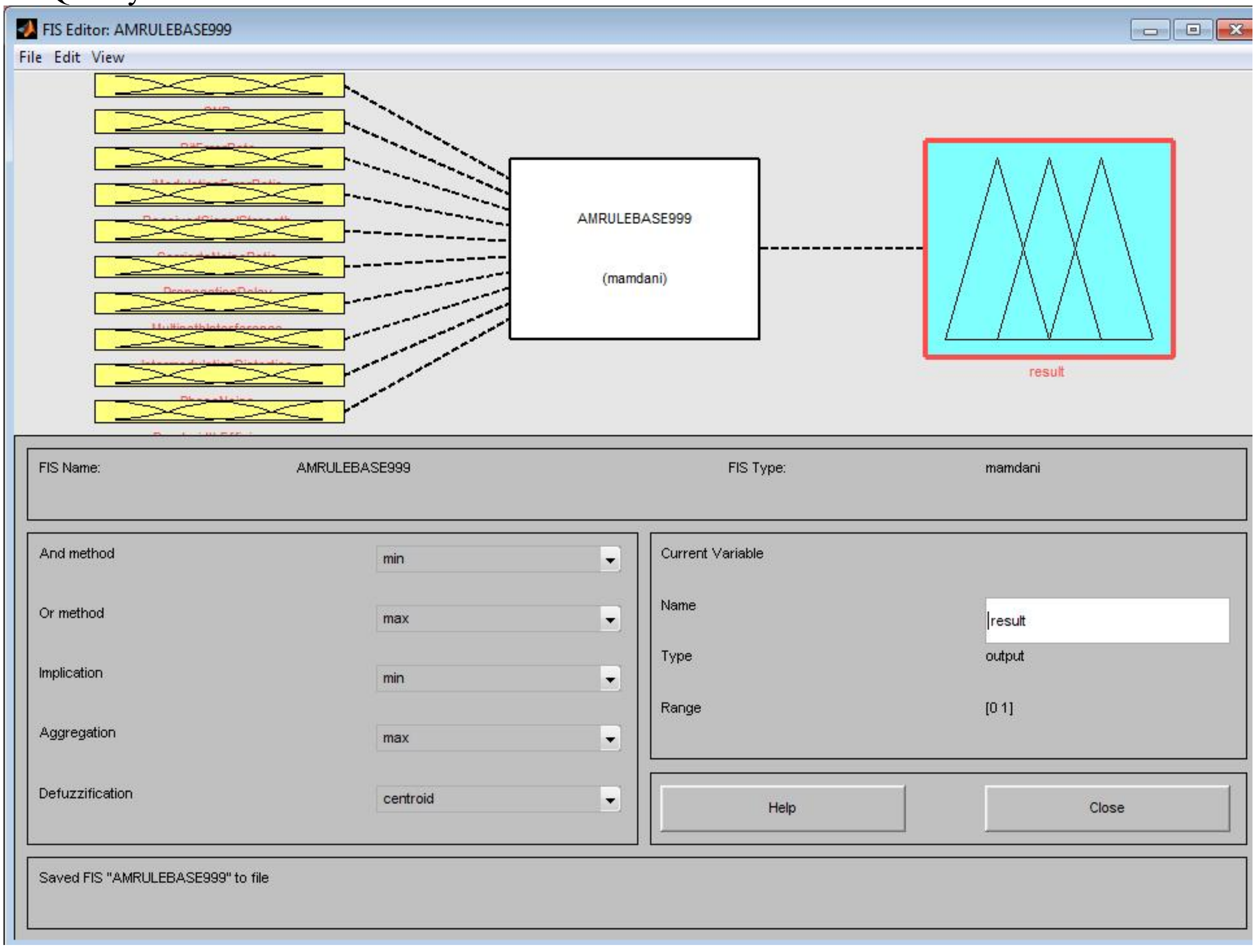

Fig 3.3 designed advanced modulation fuzzy inference system that will minimize the causes of poor television signal quality

This was designed in Fuzzy logic tool box in MATLAB environment

It has ten inputs of **Signal-to-Noise Ratio (SNR), Bit Error Rate, Modulation Error Ratio, Received Signal Strength, Carrier-to-Noise Ratio, Propagation Delay, Multipath Interference, Inter modulation Distortion, Inter modulation Distortion, Phase Noise and Bandwidth Efficiency. It also has an output of results.**

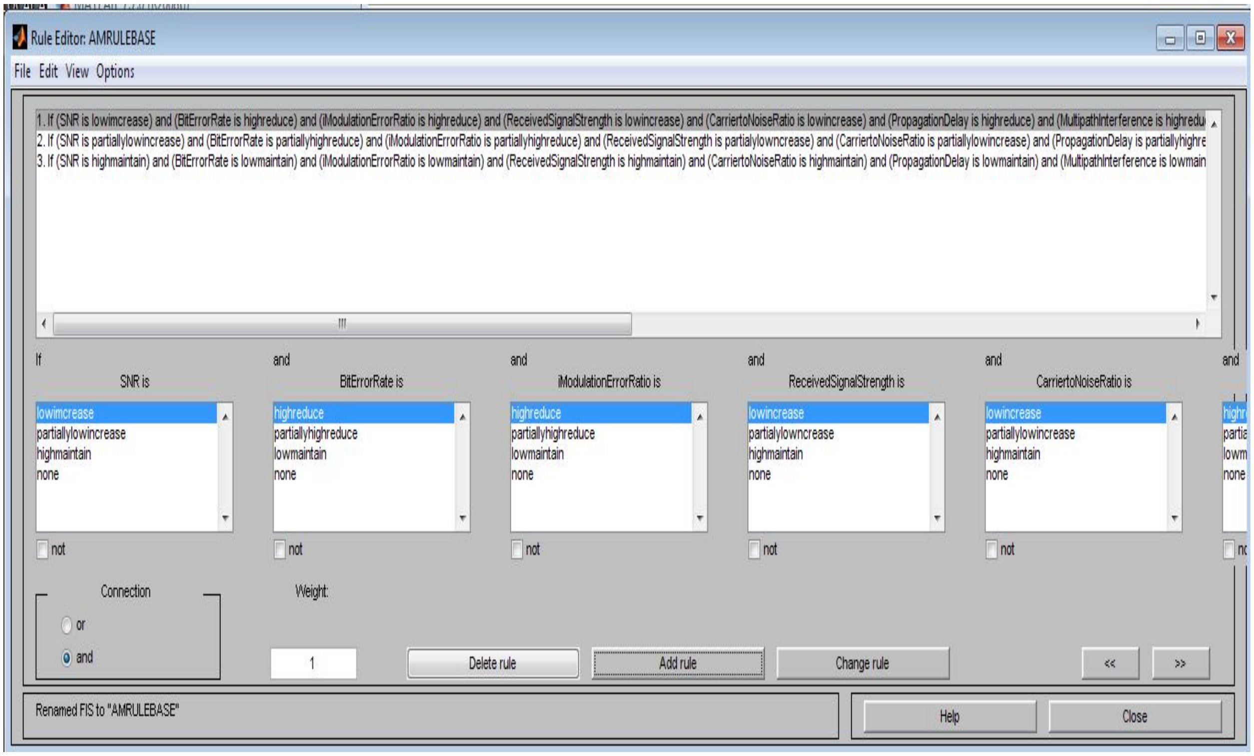

Fig 3.4 designed advanced modulation rule base that will minimize the causes of poor television signal quality

The comprehensive details were shown in table 3.3

Table 3.3 comprehensive details of designed advanced modulation rule base that will minimize the causes of poor television signal quality

1	**IF** SIGNAL-TO-NOISE RATIO (SNR) IS LOW INCREASE	**AND** BIT ERROR RATE IS HIGH REDUCE	**AND** MODULATION ERROR RATIO IS HIGH REDUCE	**AND** RECEIVED SIGNAL STRENGTH IS LOW INCREASE	**AND** CARRIER-TO-NOISE RATIO ISLOW INCREASE	**AND** PROPAGATION DELAY IS HIGH REDUCE	**AND** MULTIPATH INTERFERENCE IS HIGH REDUCE	**AND** INTERMODULATION DISTORTION IS HIGH REDUCE	**AND** PHASE NOISE HIGH REDUCE	**AND** BANDWIDTH EFFICIENCY IS LOW INCREASE	THEN RESULT IS UNENHANCING TELEVISION SIGNAL QUALITY
2	IF SIGNAL-TO-NOISE RATIO (SNR) IS PARTIALLYLOW	AND BIT ERROR RATE IS PARTIALLYHIGH REDUCE	AND MODULATION ERROR RATIO IS PARTIALLY	AND RECEIVED SIGNAL STRENGTH IS PAR	AND CARRIER-TO-NOISE RATIO IS PARTIALLYLOW INCRE	AND PROPAGATION DELAY IS PARTIALLYHIGH REDUC	AND MULTIPATH INTERFERENCE IS PARTIALLY HIGH REDU	AND INTERMODULATION DISTORTION IS PARTIALLY	AND PHASE NOISE PARTIALLYE HIGH REDUCE	AND BANDWIDTH EFFICIENCY IS PARTIALLYLOW INCRE	THEN RESULT IS UNENHANCING TELEVISI

	INCREASE		HIGH REDUCE	TIALLY LOW INCREASE	ASE	E	CE	HIGH REDUCE		ASE	ON SIGNAL QUALITY
3	IF SIGNAL-TO-NOISE RATIO (SNR) IS HIGH MAINTAIN	AND BIT ERROR RATE IS LOW MAINTAIN	AND MODULATION ERROR RATIO IS LOW MAINTAIN	AND RECEIVED SIGNAL STRENGTH IS HIGH MAINTAIN	AND CARRIER-TO-NOISE RATIO ISHIGH MAINTAIN	AND PROPAGATION DELAY IS LOW MAINTAIN	AND MULTIPATH INTERFERENCE IS LOW MAINTAIN	AND INTERMODULATION DISTORTION IS LOW MAINTAIN	AND PHASE NOISE LOW MAINTAIN	AND BANDWIDTH EFFICIENCY IS HIGH MAINTAIN	THEN RESULT IS ENHANCING TELEVISION SIGNAL QUALITY

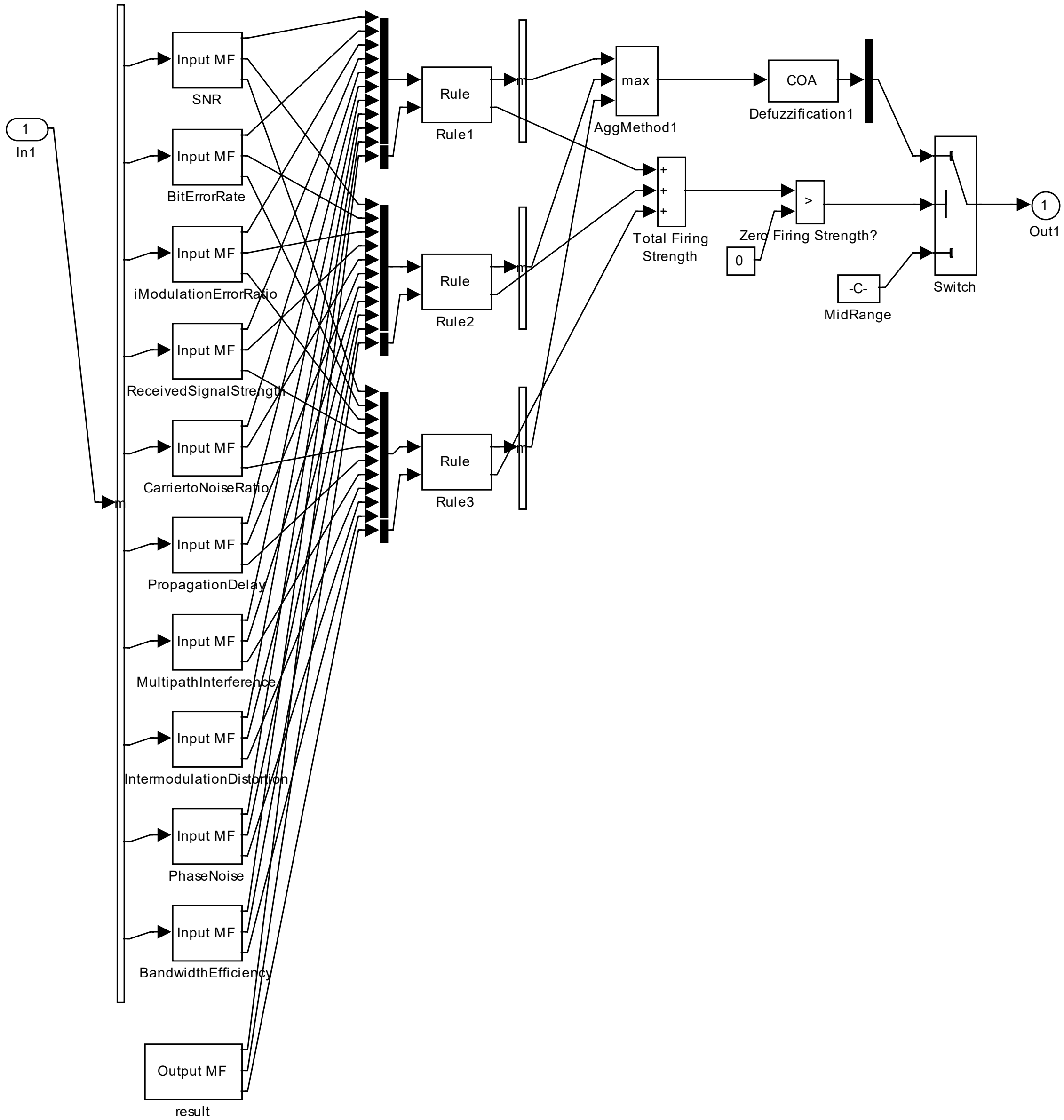

Fig 3.5 the operational mechanism of the rules

3.6 To train Artificial Neural Network (ANN) in the designed advanced modulation rule base to boost the minimization of the causes of poor television signal quality

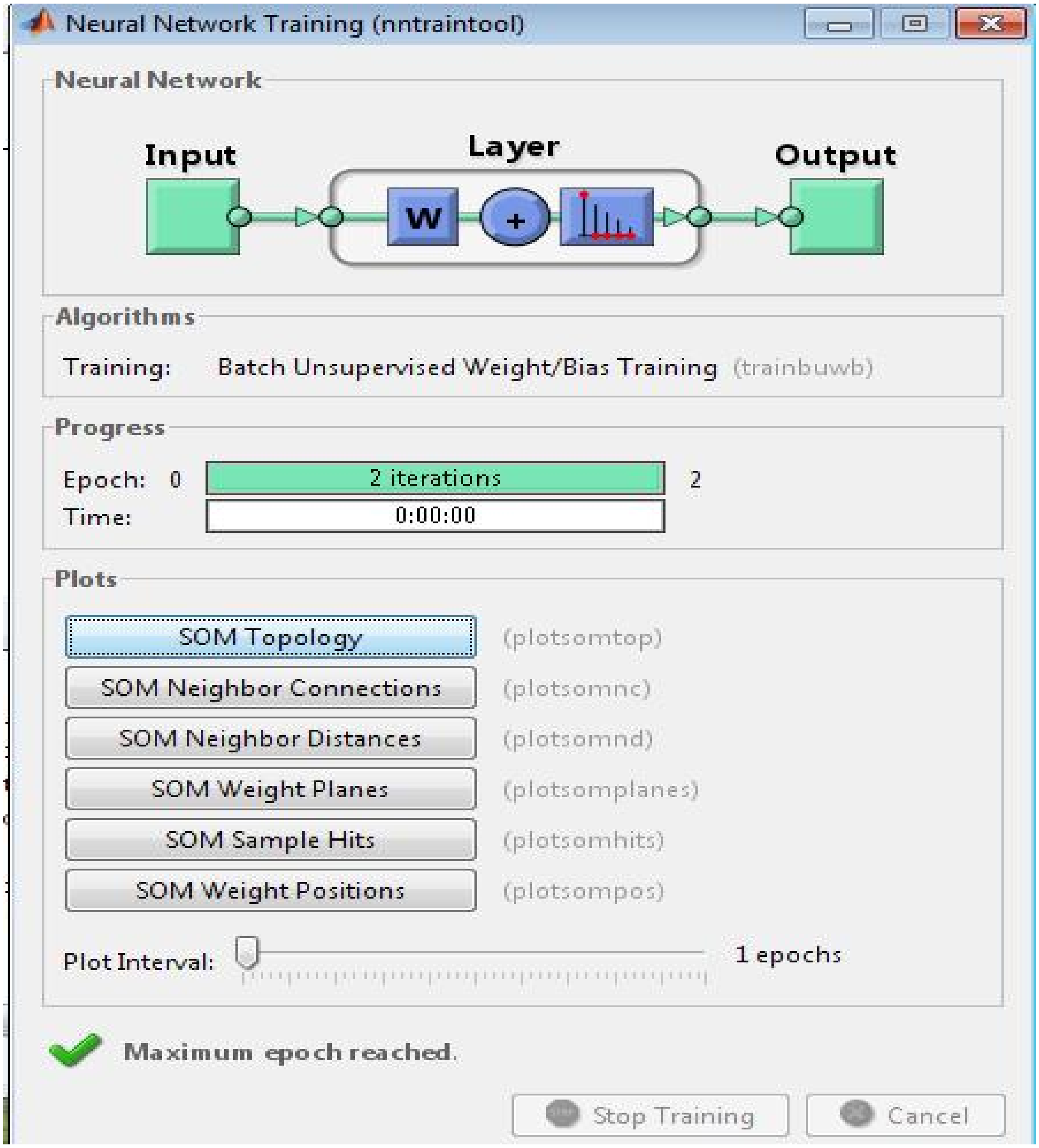

Fig 3.6 ANN training tools

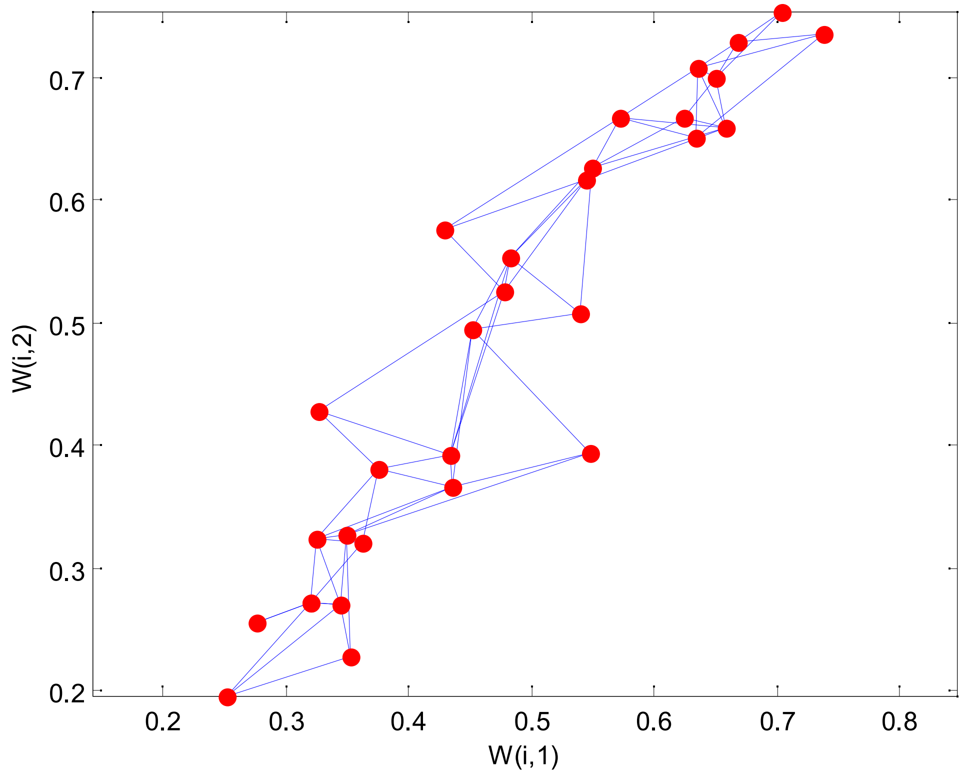

Fig 3.7 trained Artificial Neural Network (ANN) in the designed advanced modulation rule base to boost the minimization of the causes of poor television signal quality

The three rules were trained ten 3 x 10 = 30 to have thirty neurons that looks like human brain and executes what it was instructed to do. In this case ANN was trained ten times in the advanced modulation three rule base to minimize the causes of poor television signal quality. This training took place in ANN tool box in MATLAB environment to explain objective 3.

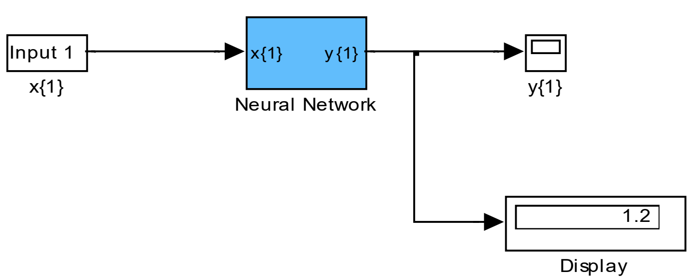

Fig 3.8 result obtained during the training

3.7 To develop an algorithm that will implement the process

1. Characterize and establish the causes of poor television signal quality.
2. Identify low SNR
3. Identify high **Bit Error Rate**
4. **Identify high Modulation Error Ratio**
5. **Identify low Received Signal Strength**
6. **Identify low Carrier-to-Noise Ratio (CNR)**
7. **Identify much Propagation Delay**
8. **Identify high Multipath Interference**
9. **Identify high Inter modulation Distortion**
10. **Identify high Phase Noise**
11. **Identify low Bandwidth Efficiency**
12. design a conventional SIMULINK model for television signal quality and integrate 2 through 11
13. Design advanced modulation rule base that will minimize the causes of poor television signal quality.
14. train Artificial Neural Network (ANN) in the designed advanced modulation rule base to boost the minimization of the causes of poor television signal quality
15. Integrate 13 and 14
16. Integrate 15 into 12
17. Did low SNR, **low Received Signal Strength, low Carrier-to-Noise Ratio and low Bandwidth Efficiency increase when 15 was integrated into 12?**
18. **IF NO go to16**
19. **IF YES go to 23**
20. Did high **Bit Error Rate, high Modulation Error Ratio, much Propagation Delay, high Multipath Interference, high Inter modulation Distortion and high Phase Noise reduce when16 was integrated into 12?**
21. **IF NO go to16**
22. **IF YES go to 23**
23. Enhanced Television Signal Quality
24. Stop
25. End

3.8 To design a SIMULINK model for Enhancing Television Signal Quality Using Intelligent Advanced Modulation and Compression Techniques

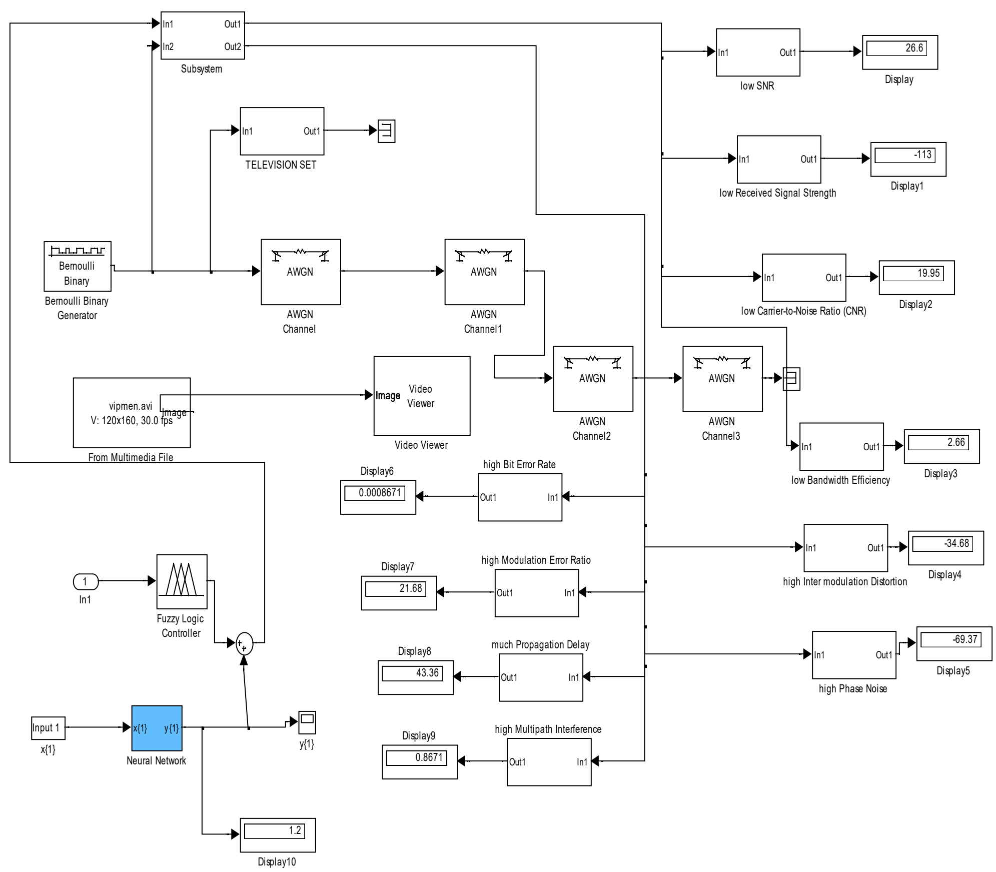

Fig 3.9 designed SIMULINK model for Enhancing Television Signal Quality Using Advanced Modulation Techniques

The results obtained were detailed in validation and justification. It was fully detaied in figures 4.1 through 4.3 in chapter four.

3.9 To validate and justify percentage improvement in the minimization of the causes of poor television signal quality with and without Intelligent Advanced Modulation and Compression Techniques

To find percentage improvement in low **Bandwidth Efficiency** causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques

Conventional **Bandwidth Efficiency =2 bps/Hz**

Advanced Modulation and Compression Techniques **Bandwidth Efficiency**

=2.66 **bps/Hz**

%improvement in low **Bandwidth Efficiency** causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques =

IAM **Bandwidth Efficiency** - Conventional **Bandwidth Efficiency** x 100%

Conventional **Bandwidth Efficiency** **1**

%improvement in low **Bandwidth Efficiency** causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques =

$$\frac{2.66\ \mathbf{bps/Hz} - 2\text{dbps/Hz}}{2\text{bps/Hz}} \times \frac{100\%}{1}$$

%improvement in low **Bandwidth Efficiency** causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques =3.3%

To find percentage improvement in low SNR causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques

Conventional SNR =**20 dB**
Intelligent Advanced Modulation and Compression Techniques SNR =26.6dB

%improvement in low SNR causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques =

$$\frac{\text{IAM SNR - Conventional SNR}}{\text{Conventional SNR}} \times \frac{100\%}{1}$$

%improvement in low SNR causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques =

$$\frac{26.6\text{dB} - 20\text{dB}}{20\text{dB}} \times \frac{100\%}{1}$$

%improvement in low SNR causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques =33%

To find percentage improvement in reduction of high bit error rate causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques

Conventional bit error rate =0.001bits
Intelligent Advanced Modulation and Compression Techniques bit error rate =0.000867bits

%improvement in reduction of high bit error rate causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques =

$$-\frac{\text{Conventional bit error rate - IAM bit error rate}}{\text{Conventional bit error rate}} \times \frac{100\%}{1}$$

%improvement in reduction of high bit error rate causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques =

$$\frac{0.001\text{bits} - 0.000867\text{bits}}{0.001\text{dbits}} \times \frac{100\%}{1}$$

%improvement in reduction of high bit error rate causes of poor television signal quality with intelligent Advanced Modulation and Compression Techniques =13.3%

3.0 Results and Discussion

Table 4.1 comparison of conventional and Advanced Modulation **Bandwidth Efficiency that causes** poor television signal quality

Time(s)	Conventional Bandwidth Efficiency that causes poor television signal quality (bps/Hz)	Advanced Modulation Bandwidth Efficiency that causes poor television signal quality (bps/Hz)
1	2	2.6
2	2	2.6
3	2	2.6
4	2	2.6
10	2	2.6

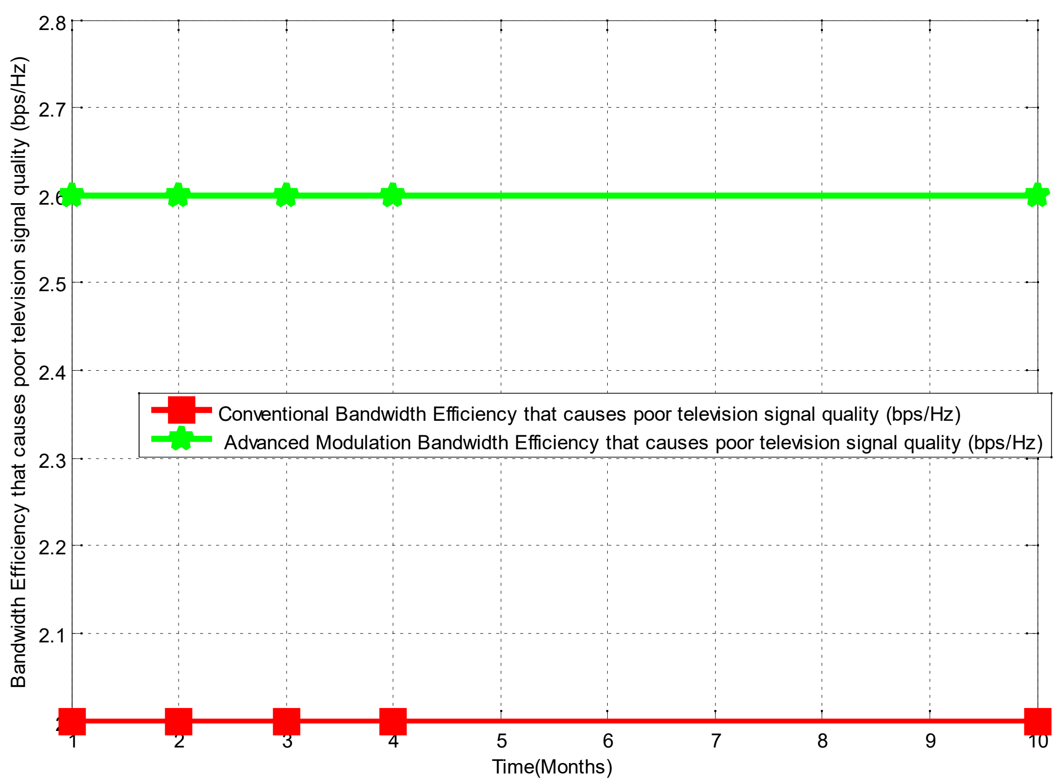

Fig 4.1 comparison of conventional and Advanced Modulation **Bandwidth Efficiency that causes** poor television signal quality

The conventional **Bandwidth Efficiency that causes** poor television signal quality was **2 bps/Hz. On the other hand, when an** Advanced Modulation was integrated into the system, it simultaneously improved to **2.6 bps/Hz, thereby enhancing bandwidth efficiency to** 3.3%.

Table 4.2 comparison of conventional and Advanced Modulation SNR **that causes** poor television signal quality

Time(s)	Conventional SNR that causes poor television signal quality (dB)	Advanced Modulation SNR that causes poor television signal quality (dB)
1	20	26.6
2	20	26.6
3	20	26.6
4	20	26.6
10	20	26.6

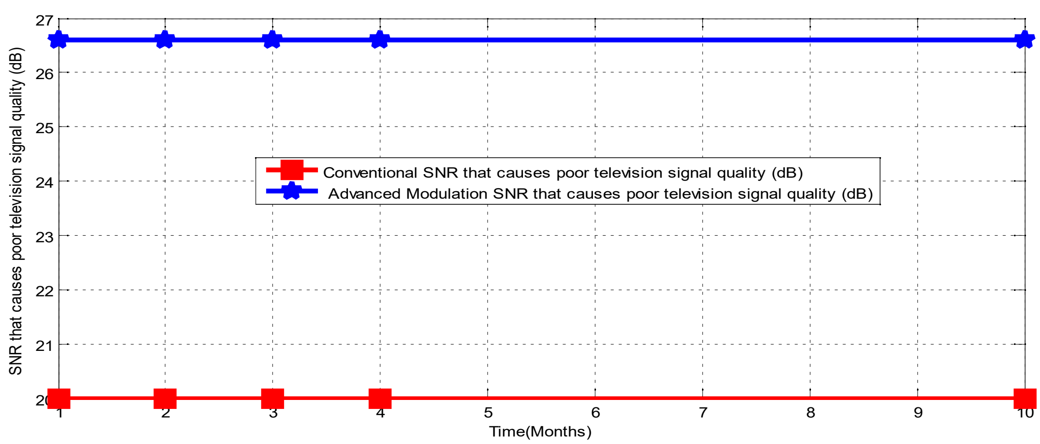

Fig 4.2 comparison of conventional and Advanced Modulation SNR **that causes** poor television signal quality

The conventional SNR **that causes** poor television signal quality was 20dB. However, when an Advanced Modulation was input into the system, it concurrently increased it to 26.6dB.

Table 4.3 comparison of conventional and Advanced Modulation bit error rate that **causes** poor television signal quality

Time(s)	Conventional bit error rate that causes poor television signal quality (bits)	Advanced Modulation bit error rate that causes poor television signal quality ((bits)
1	0.001	0.000867
2	0.001	0.000867
3	0.001	0.000867
4	0.001	0.000867
10	0.001	0.000867

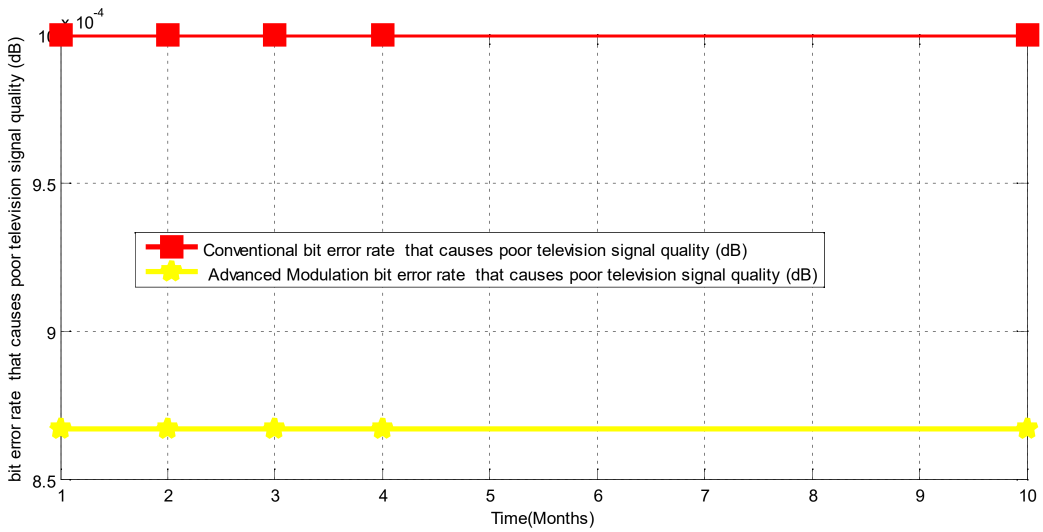

Fig 4.3 comparison of conventional and Advanced Modulation bit error rate that **causes** poor television signal quality

The conventional bit error rate that **causes** poor television signal quality was 0.001bits.meanwhile, when Advanced Modulation was imbibed into the system; it instantly reduced it to 0.000867bits. Finally, with these results obtained, it showed that percentage enhancement in Television Signal Quality was 13.3%.

4.0 Conclusion

The study has clearly demonstrated that the adoption of advanced modulation techniques is a highly effective strategy for enhancing television signal quality. Techniques such as QAM, OFDM, and PSK not only improve signal robustness against noise and interference but also ensure higher spectral efficiency and lower bit error rates. These benefits directly translate to better picture and sound quality for end-users, especially in environments prone to signal degradation such as urban and rural areas with challenging topographies. Furthermore, the compatibility of these modulation methods with modern digital broadcasting standards like DVB-T2 and ATSC 3.0 highlights their relevance in the ongoing transition to digital television systems. The use of adaptive and intelligent modulation techniques also presents a scalable and cost-effective solution for broadcasters seeking to optimize signal transmission without extensive infrastructure overhaul. In conclusion, advanced modulation techniques represent a critical advancement in modern broadcast technology, ensuring reliable, high-quality television transmission and significantly improving viewer satisfaction. The conventional **Bandwidth Efficiency that causes** poor television signal quality was **2 bps/Hz. On the other hand, when an**

Advanced Modulation was integrated into the system, it simultaneously improved to **2.6 bps/Hz, thereby enhancing bandwidth efficiency to** 3.3%, the conventional SNR **that causes** poor television signal quality was 20dB. However, when an Advanced Modulation was input into the system, it concurrently increased it to 26.6dB and the conventional bit error rate that **causes** poor television signal quality was 0.001bits.meanwhile, when Advanced Modulation was imbibed into the system; it instantly reduced it to 0.000867bits. Finally, with these results obtained, it showed that percentage enhancement in Television Signal Quality was 13.3%.

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