

Simulation of Digital Modulation Martin White

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Simulation of digital Modulation

DIGITAL SIGNAL PROCESSING AND COMMUNICATIONS

Martin White | Embedded electronics | 12/11/2024

Abstract

This report looks at the performance of four digital modulation techniques—ASK, PSK, QPSK, and QAM—under noise. It uses MATLAB Simulink to simulate how well they handle various Signal-to-Noise Ratios (SNRs) with an AWGN channel. ASK, which works by varying amplitude, was the most affected by noise, showing a high BER at low SNRs. PSK did better since it relies on phase changes rather than amplitude, making it less sensitive to interference. QPSK improved even more by encoding two bits per symbol, offering better efficiency and lower BER compared to ASK and PSK. QAM was the most efficient in terms of data rates but had a steep rise in BER with higher modulation orders when noise increased. These results help highlight the trade-offs between noise resilience and efficiency for communication systems.

Introduction

Amplitude shift keying (ASK) is a simple and widely used digital modulation technique in which the amplitude of a carrier wave varies between two levels to represent data. This approach minimizes power consumption and circuit complexity, making it ideal for applications that require compact, energy-efficient systems, such as medical or automotive devices. ASK is particularly valued for its low implementation effort and simplicity[1]

Phase shift keying (PSK) is another digital modulation technique that encodes data by changing the phase of the carrier signal. Depending on the number of phase shifts used, PSK can represent multiple bits per symbol, making it more efficient for higher data rates. However, this modulation technique requires a reference carrier signal at the receiver, which increases complexity. PSK is used in long-distance communications with use cases such as satellite and wireless communication systems because it enables robust signal transmission in noisy environments.[2]

Quadrature Phase Shift Keying (QPSK), a variant of PSK, encodes data using four different phase shifts, representing two bits per symbol. These changes can be visualized using a constellation diagram that illustrates the real and imaginary components of the signal. This approach provides a balance between spectral efficiency and noise resilience. [2]

Quadrature Amplitude Modulation (QAM), such as 16-QAM, combines amplitude and phase modulation to encode information. By varying the amplitude and phase of the carrier wave, QAM achieves higher data transmission rates. It is widely used in modern digital communication systems to maximize bandwidth efficiency.[3]

This report investigates the resilience of these modulation schemes to electromagnetic interference through their implementation in MATLAB Simulink.

Simulation Models

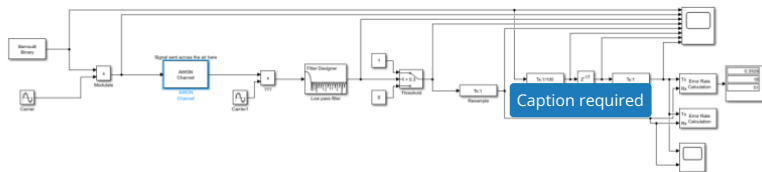
SIMULATION METHOD

The simulations for ASK, PSK, QPSK, and QAM were done similarly to ensure fair comparisons. A Bernoulli binary generator produced random 0s and 1s for data, which were modulated according to the method being tested. Noise was added through an AWGN channel, simulating real-world interference. At the receiver, the signal was demodulated, filtered, and reconstructed, with BER calculated by comparing transmitted and received data. The SNR varied from -25 dB to +10 dB, with 25 tests at each value to allow for more accurate results.

ASK

The Amplitude Shift Keying (ASK) process begins with the generation of a binary signal using a Bernoulli binary source, which creates a random sequence of 0s and 1s to serve as the input message for modulation. This binary signal is then combined with a high-frequency sinusoidal carrier wave, which acts as the basis for modulation. Through the ASK modulator, the carrier's amplitude is altered depending on the binary input: a 1 results in a full-amplitude carrier, while a 0 effectively turns the carrier off. The modulated signal can be visualized in the system's scope as a waveform representing the amplitude variations dictated by the binary data.

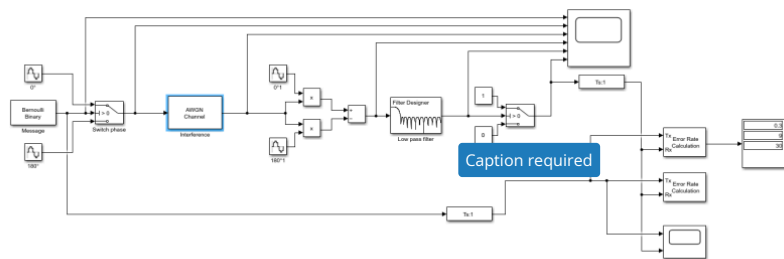
After modulation, the signal is transmitted through an Additive White Gaussian Noise (AWGN) channel to simulate real-world noise interference. At the receiver, demodulation is performed by multiplying the noisy signal with a locally generated carrier of matching frequency and phase. A low-pass filter is then applied to extract the baseband signal. The resulting waveform is passed through a threshold detector, which interprets values above a defined threshold as 1 and those below it as 0, reconstructing the original binary sequence. To ensure synchronization and match the original sequence rate, the demodulated signal undergoes resampling and delay compensation. Finally, the bit error rate (BER) is calculated by comparing the transmitted and received binary sequences, providing a measure of how noise and other impairments affect the transmission.[1]



PSK

Bernoulli Binary Generator that produces a random binary data sequence (0s and 1s) as the input message. This message undergoes PSK modulation, where binary 0 is mapped to a 0° phase shift and binary 1 to a 180° phase shift, creating the modulated signal. To simulate real-world interference, Additive White Gaussian Noise (AWGN) is introduced, enabling the assessment of the system's resilience to noise under various Signal-to-Noise Ratios (SNRs).

The noisy signal is demodulated by multiplying it with reference carrier signals (0° and 180° phases) to extract phase information. A low-pass filter removes high-frequency noise, leaving the baseband signal. Decision-making logic compares the demodulated signal to a threshold, identifying whether the received bit is a 0 or 1. Finally, an Error Rate Calculator (ERC) measures the system's accuracy by calculating the Bit Error Rate (BER), which compares the transmitted and received messages. A lower BER reflects better noise resistance and overall performance.[2]

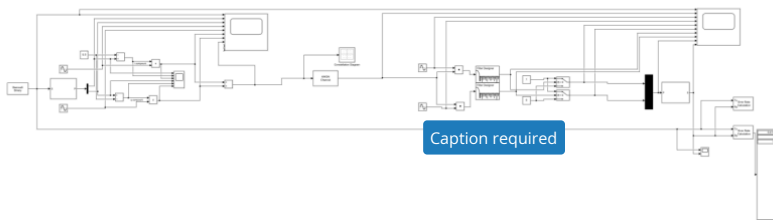


QPSK

The Quadrature Phase Shift Keying (QPSK) process begins with the generation of a random binary sequence of 0s and 1s using a Bernoulli binary generator. This digital data is divided into pairs of bits, which QPSK maps to four distinct phase shifts (e.g., 0° , 90° , 180° , and 270°). The binary stream is split into two parallel paths: the In-phase (I) component, which encodes the first bit of each pair, and the Quadrature-phase (Q) component, which encodes the second. These paths are modulated using cosine and sine carrier signals, respectively, and then combined to produce the QPSK-modulated signal. This signal is efficient in bandwidth utilization, encoding two bits per symbol, and can be observed in the scope outputs.

The QPSK signal is transmitted through an Additive White Gaussian Noise (AWGN) channel to simulate real-world interference, adding noise that distorts the signal. At the

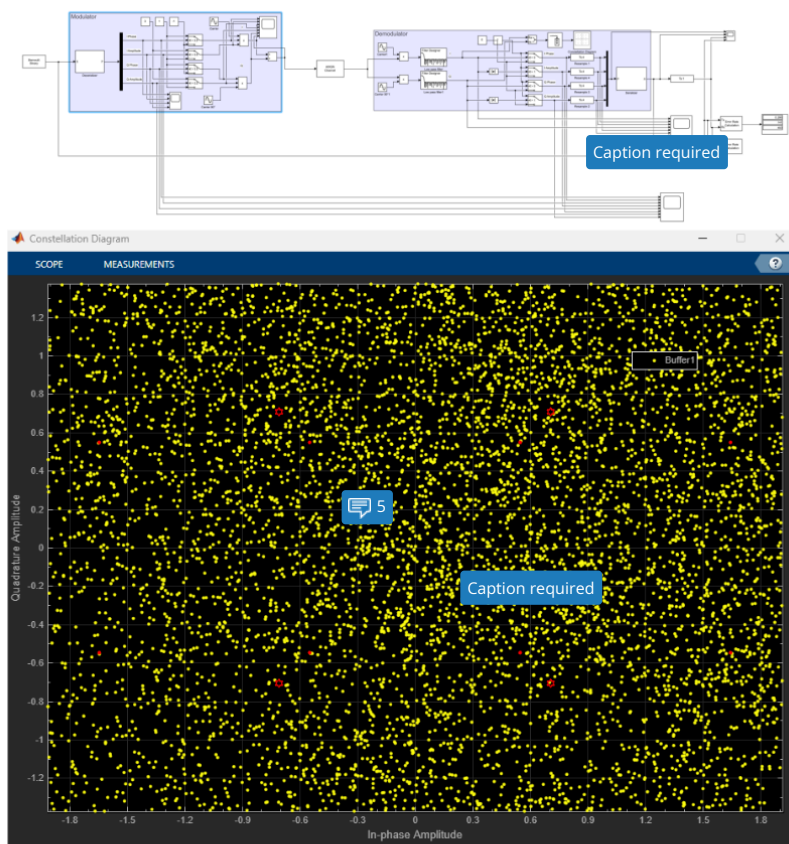
receiver, the noisy signal is demodulated by separating it into the I and Q components using synchronized cosine and sine carriers. Low-pass filters remove high-frequency noise, yielding baseband signals for both components. Threshold detectors then classify the amplitude of each component to reconstruct the binary data stream. The system's constellation diagram illustrates the phase positions of the received symbols; ideally, they cluster around four distinct points, but noise causes scatter. Finally, the transmitted and received binary sequences are compared to calculate the Bit Error Rate (BER), which evaluates the system's performance and reliability under noisy conditions[2]



QAM

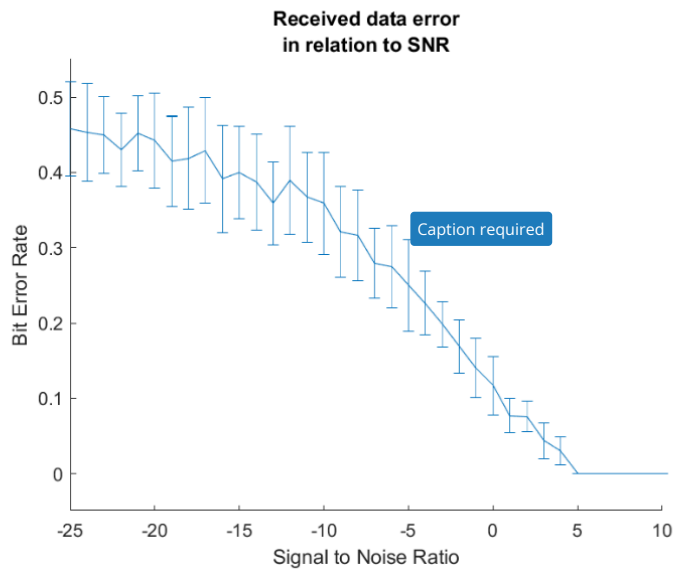
Quadrature Amplitude Modulation (QAM) begins with binary signal generation, where a Bernoulli binary generator produces a random sequence of 0s and 1s. These binary streams are grouped into symbols, with each symbol representing a combination of bits—for instance, 4 bits per symbol in 16-QAM or 6 bits per symbol in 64-QAM. Each symbol is then mapped to a unique combination of amplitude and phase as defined by the QAM constellation diagram. The binary stream is divided into two parts: the in-phase (I) component, which determines the horizontal position in the constellation, and the quadrature (Q) component, which determines the vertical position. These components are modulated separately using cosine (I) and sine (Q) carriers, and their modulated signals are combined to form the final QAM signal.

The QAM signal is transmitted through an Additive White Gaussian Noise (AWGN) channel to simulate real-world conditions, where noise is introduced. At the receiver, the noisy QAM signal is demodulated by splitting it into its I and Q components using synchronized carriers, and low-pass filters remove unwanted high-frequency noise. The amplitude and phase of the demodulated signals are then compared to thresholds in the constellation diagram to identify the closest symbol, enabling the recovery of transmitted symbols. These detected symbols are converted back into binary data, reconstructing the original sequence. A constellation diagram visualizes the received symbols, showing how noise impacts their clustering around expected positions. Finally, the Bit Error Rate (BER) is calculated by comparing the received binary sequence to the original, quantifying the system's performance under noisy conditions.[3]

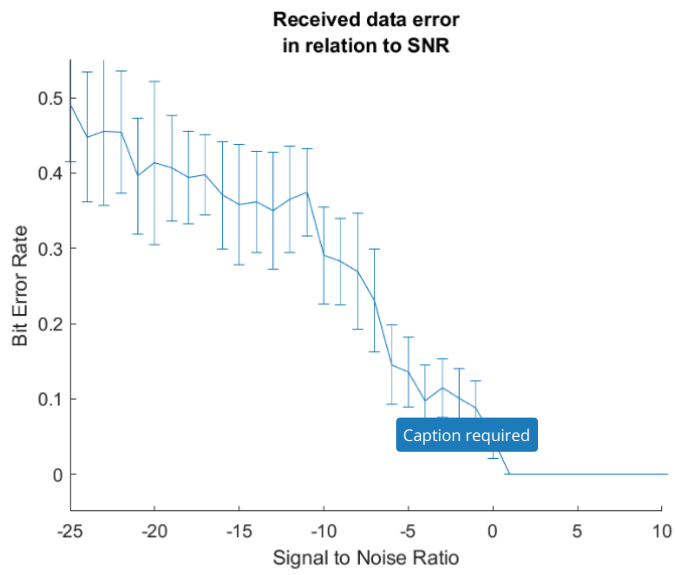


Results

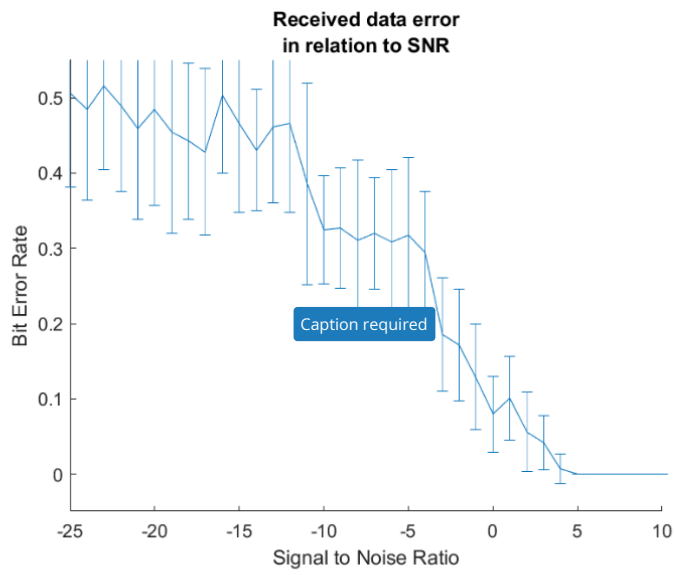
ASK



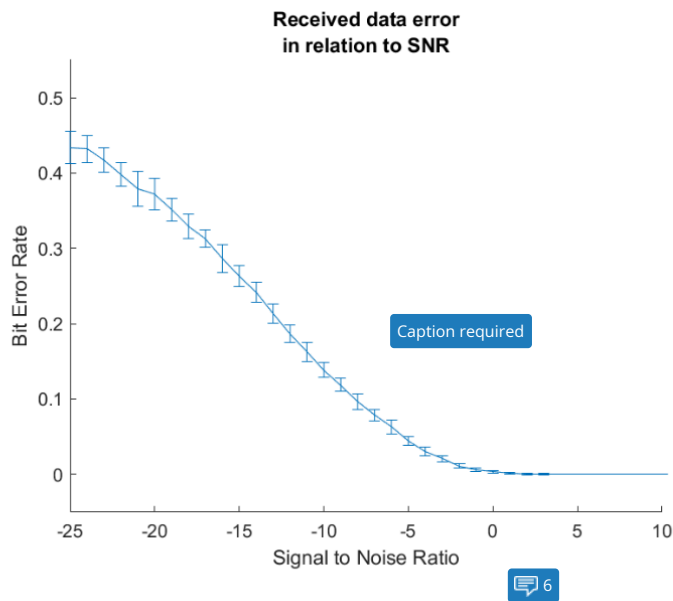
PSK



QPSK



QAM



Discussion

The simulations showed clear differences in how these modulation techniques handle noise. ASK was the worst performer, with BER increasing rapidly as noise grew. This is because it relies entirely on amplitude, which is easily affected by interference. While it is simple and low-cost, its lack of robustness makes it unsuitable for noisy environments.

PSK improved on this by encoding data in phase, making it less sensitive to amplitude noise. This resulted in a slower BER increase at lower SNRs, showing its effectiveness for moderate noise conditions.

QPSK provided a good balance. By encoding two bits per symbol and using both in-phase and quadrature components, it achieved higher efficiency while keeping noise resilience. The BER was lower than ASK and PSK for most SNRs, though it still increased at very low SNRs due to symbol scatter.

QAM achieved the highest data rates by combining amplitude and phase modulation. However, its performance depended on the modulation order. Lower-order QAM was more robust, while higher orders became too sensitive to noise at low SNRs. This trade-off makes QAM suitable for high-SNR environments but challenging in noisy conditions.

Conclusion

ASK is the simplest modulation technique, changing the amplitude of the carrier signal to represent data. This simplicity makes it energy-efficient and easy to implement, but it also makes ASK highly vulnerable to noise. When noise levels increased, the amplitude changes were harder to detect, causing a sharp rise in BER. Because of this, ASK works best in situations with low noise, where complexity and power usage need to stay low, like in simple, short-range communication systems.

PSK performed better in noisy environments because it uses changes in phase rather than amplitude. This makes it less sensitive to interference, as noise affects phase less than amplitude. As a result, PSK's BER increased more slowly when noise levels rose. However, PSK is slightly more complex to implement, as it requires a reference signal at the receiver. Even so, its ability to handle moderate noise makes it useful for systems like satellite and wireless communication.  7

QPSK improved on PSK by sending two bits of data per symbol. By using both in-phase (I) and quadrature (Q) components of the signal, QPSK achieved higher data rates while still handling noise well. Although very low SNRs caused errors due to noise spreading the signal, QPSK provided a good balance between data rate and reliability. This makes it a strong choice for systems like mobile networks that need moderate speeds and reliability.

QAM, which combines amplitude and phase changes to send data, showed the highest efficiency in terms of data rates. Lower-order QAM (like 16-QAM) managed noise well and provided reliable communication. Higher-order QAM (like 64-QAM) sent more data per symbol but was much more sensitive to noise because the data points were closer together, making errors more likely in low-SNR conditions.  8. QAM works best when noise is minimal, such as in high-quality connections, where its ability to transmit large amounts of data can be fully used.

In summary, each modulation method has specific strengths depending on the situation. ASK is a good choice for simple, low-cost applications with minimal noise. PSK offers better noise resistance for systems in moderate environments. QPSK provides a good mix of speed and reliability for many modern communication needs. QAM is ideal for high-data-rate systems where noise levels are low. This study shows how these techniques can be matched to different needs, helping to optimize communication systems for various tasks, from small devices to high-speed networks.

References

[1]

S. and VKS, "Amplitude Shift Keying (ASK) Modulation MATLAB Simulation, With MATLAB Code." <https://www.divilabs.com/2013/12/amplitude-shift-keying-ask-modulation.html>

[2]

Ref Qual Ref Qty Refs missing info

"Phase Shift Keying : Types, Advantages, Disadvantages and Applications," *ElProCus - Electronic Projects for Engineering Students*, Sep. 30, 2019.
<https://www.elprocus.com/phase-shift-keying-psk-types-and-its-applications/>

[3]

A. Zola, "What is QAM and how does it work?," *SearchNetworking*.
<https://www.techtarget.com/searchnetworking/definition/QAM>

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

59/100

PAGE 1

PAGE 2



Comment 1

Very good abstract, although you should quantify your results. What level of noise did they reach before failing?



Comment 2

They all require this.

PAGE 3



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 4



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

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PAGE 5



Comment 3

as shown in figure.....?



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

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Comment 4

You need to put captions on your figures and refer to them in text like this paragraph. Then you can direct the reader to a diagram of what you are trying to describe. Doing this would vastly increase the information content in your work without overly increasing word count.

e.g. if you numbered the blocks in your diagram, you could say "The QAM system is shown in figure 4. The random data to be transmitted is generated by 1, this is then multiplied by the carrier wave 2 by the multiplier 3.".. etc.

PAGE 6



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 5

What does this noisy constellation diagram show?



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

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PAGE 7



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PAGE 8



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PAGE 9



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PAGE 10

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

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Comment 6

A graph with all the data together would allow a direct comparison to be made between them. The way you have presented the data, it is difficult to see exactly how well they compare to each other.

PAGE 11



Comment 7

They all require this.



Comment 8

You didn't simulate higher order QAM so how can you comment like this?

PAGE 12

QM

Ref Qty

I was hoping for more references

QM

Ref Qual

You should try to use more high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.

QM

Refs missing info

Some of your references are missing information. To understand what information should be included, see the university IEEE referencing handbook on the library website.

https://uwtsd.ac.uk/media/uwtsd-website/content-assets/documents/library-and-learning-resources/infoskills/IEEE-eng_v.1.2.pdf

GRADING FORM: SMU GENERIC_SMOSEY

MARTIN WHITE

59.30

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty

-  "References to a limited range of mostly relevant sources. Some omissions and minor errors. Referencing conventions evident though not always applied consistently."
"

4

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.

-  Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.

12.4

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.

-  While you have presented some good results, you haven't done much more than describe them. At level 5 you should be trying to explain the reason behind all of your results.

19.5

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.

-  "A good and appropriate application of standard methods, materials, tools and/or techniques. Good appreciation of the context of the application, with some use of examples, where relevant."
"

17.4

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



"Can communicate well, confidently and consistently in a suitable format.

Can work very well as part of a team, with very good contribution to group activities.

Work is coherent and fluent and is well structured and organised.

"

6