The Quantum Periodic Cipher: Merging Elements and Quantum Numbers for Covert Channel

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Abstract

This paper introduces a novel approach to covert communication by encoding messages within chemistry-related posts on Reddit. Using a combination of elemental substitution and quantum number encoding, messages are hidden in plain sight, blending naturally into discussions. The method takes advantage of the public platform's anonymity and diverse content to reduce detection risk. By embedding covert messages into everyday interactions, this approach offers a fresh, effective solution for secure messaging in open environments.

1. Introduction

Covert communication plays a pivotal role in scenarios where the exchange of information must remain concealed, either for secure messaging or safeguarding sensitive data. The primary objective of covert communication is not just to protect the content but to hide the very existence of the communication. If there is no evidence of information being transmitted, onlookers are less likely to suspect or search for hidden messages. This significantly reduces the risk of interception and helps ensure secure messaging. This critical aspect distinguishes it from conventional cryptographic methods.

Covert communication has evolved through a variety of methods, including those based on RF technology and image steganography. These traditional approaches have established a foundation for hidden messaging in various contexts. However, the increasing sophistication of monitoring tools and the growing need for adaptable, flexible methods have highlighted the potential for new approaches. The challenge is not simply improving existing techniques, but creating innovative solutions that can function in diverse environments.

This paper proposes a novel hybrid encoding method that merges principles from chemistry and their quantum numbers. The approach utilizes elemental substitution, where letters are mapped to chemical elements, and quantum number encoding, which incorporates additional parameters such as case sensitivity, priority, and filler detection. This dual-layer encoding system introduces complexity and masking, significantly reducing the risk of pattern detection. This method encodes messages on Reddit, a widely accessible platform for discussing diverse topics, including chemistry. By using Reddit's open structure and anonymity, the method disguises encoded messages as legitimate posts. The complete idea has been implemented successfully and will be explained in detail in the later sections of the paper.

The paper operates under the following assumptions:

- The quantum number rules (e.g., priority, case sensitivity, substitution order, and filler identification) are consistently applied, and the system avoids errors in encoding or decoding.
- The receiver has unrestricted access to the platform and can retrieve posts using automation tools without facing issues like regional restrictions or platform bans. The character limit of the chosen platform (e.g., 10-12 characters for encoded posts) is sufficient for transmitting meaningful messages.
- The sender and receiver have securely exchanged the predefined codebook, which includes the elemental substitution mapping and quantum number encoding rules.

The approach enhances traditional covert communication methods by creating a chemistry-based covert channel with quantum numbers, offering a unique and innovative way to encode messages with increased complexity. This paper explores the design, implementation, and evaluation of this new system, discussing its potential uses and limitations.

2. Related Work

Our paper introduces a novel approach that combines substitution ciphers, quantum number

encoding, and automation to create a covert communication system that not only protects the content but also hides the very existence of the message. This section discusses the foundational concepts of covert communication and highlights how our approach expands on and differs from existing methods.

The field of covert communication has evolved significantly, with various methods and techniques developed to enhance the security and stealth of information exchange. Network-based covert channels have been particularly intriguing. Chen et al. [1] provided a comprehensive survey highlighting the various strategies employed in network communication, demonstrating the complexity of hiding information within existing communication infrastructures. Makhdoom et al. [2] further expanded on these techniques, exploring the nuanced challenges of creating undetectable communication channels.

In addition to network-based channels, steganography has emerged as a powerful tool for covert communication. Embedding messages within images or audio files has been widely studied, as documented by Chen et al. (2023), who review its potential to achieve low detectability through high-capacity embedding. These techniques have inspired us to consider alternative mediums and encoding strategies that disguise information within legitimate content.

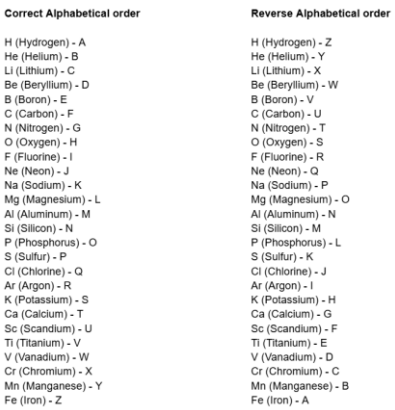
Substitution-based methods have long been a cornerstone of covert communication. Sabonchi and Akay [3] presented an extensive analysis of substitution and transposition ciphers, revealing the intricate methods researchers have developed to encode messages. While traditional substitution techniques offered foundational insights, we recognized an opportunity to introduce a more innovative approach that combines multiple disciplinary perspectives.

The use of chemistry as a medium for information representation is an underexplored area in covert communication. Kennedy et al. (2021) [4] introduce creative methods for secret messaging using endogenous chemistry, showcasing the potential of this field to encode meaningful information within legitimate scientific contexts. Inspired by this idea, we thought of the concept to utilize quantum numbers, using their complexity to enhance the encoding process.

According to Atkins et al. [5], there are four fundamental quantum numbers that characterize electron states in atoms: the principal quantum number (n), which determines the primary energy level and electron shell; the azimuthal quantum number (l), which describes the orbital shape and angular momentum; the magnetic quantum number (m), which indicates the orbital orientation in space; and the spin quantum number (s), which represents the intrinsic angular momentum of the electron. These quantum numbers are essential for understanding atomic behavior, as they collectively define the unique quantum state of an electron within an atom, determining its energy, spatial distribution, and magnetic properties. Recognizing the structure of quantum numbers, we developed a new encoding method that uses their organized nature to build a covert communication channel, turning these scientific principles into a secure way to transmit information. Our approach builds on the existing work, integrating their insights into a system uniquely tailored for stealth, flexibility, and ease of use.

3. Methodology

The idea for this covert communication originated from the concept of using elemental symbol substitution as a cipher to represent the 26 letters of the alphabet. This initial substitution cipher mapped each element on the periodic table to a letter in the English alphabet, following both correct and reverse alphabetical orders as seen in Figure 1. The straightforward substitution was simple to implement but also easy to detect. The primary advantage of this method was its simplicity, while the main disadvantage was the ease with which patterns could be detected, making it vulnerable to brute-force attacks. To improve the security of the communication, an additional layer was introduced using quantum numbers from chemistry.



Correct Alphabetical order	Reverse Alphabetical order
H (Hydrogen) - A	H (Hydrogen) - Z
He (Helium) - B	He (Helium) - Y
Li (Lithium) - C	Li (Lithium) - X
Be (Beryllium) - D	Be (Beryllium) - W
B (Boron) - E	B (Boron) - V
C (Carbon) - F	C (Carbon) - U
N (Nitrogen) - G	N (Nitrogen) - T
O (Oxygen) - H	O (Oxygen) - S
F (Fluorine) - I	F (Fluorine) - R
Ne (Neon) - J	Ne (Neon) - Q
Na (Sodium) - K	Na (Sodium) - P
Mg (Magnesium) - L	Mg (Magnesium) - O
Al (Aluminum) - M	Al (Aluminum) - N
Si (Silicon) - N	Si (Silicon) - M
P (Phosphorus) - O	P (Phosphorus) - L
S (Sulfur) - P	S (Sulfur) - K
Cl (Chlorine) - Q	Cl (Chlorine) - J
Ar (Argon) - R	Ar (Argon) - I
K (Potassium) - S	K (Potassium) - H
Ca (Calcium) - T	Ca (Calcium) - G
Sc (Scandium) - U	Sc (Scandium) - F
Ti (Titanium) - V	Ti (Titanium) - E
V (Vanadium) - W	V (Vanadium) - D
Cr (Chromium) - X	Cr (Chromium) - C
Mn (Manganese) - Y	Mn (Manganese) - B
Fe (Iron) - Z	Fe (Iron) - A

Figure 1. Representation of the encoding scheme.

Quantum numbers are fundamental in describing the unique properties of electrons in atoms. They consist of four numbers: the principal quantum number (n), azimuthal quantum number (l), magnetic quantum number (m), and spin quantum number (s) as viewed in Table 1.

In our idea, the quantum numbers were modified to introduce additional complexity. For instance, the

principal quantum number (n) was used to define the priority of an element, while the azimuthal quantum number (l) determined whether the letter was uppercase or lowercase. The magnetic quantum number (m) controlled whether the correct or reverse alphabetical order was used for the substitution, and the spin quantum number (s) indicated whether the letter was part of the actual message or a filler to further obscure the message, which can be viewed in Table - 2.

With the addition of quantum numbers, the communication channel became more secure, though it still required a medium that could conceal the messages effectively. We choose Reddit as the medium for this implementation because it provides the right balance of anonymity and flexibility. The platform allows users to post without revealing personal information, making it ideal for covert communication experiments. Unlike traditional chemistry forums, Reddit's moderation is relatively lenient, especially in smaller subreddits, which lets us run test posts without facing strict scrutiny or extensive content reviews. Additionally, Reddit is automation-friendly, making it easy to post and extract content using tools like Selenium. These features make it the best option for achieving our objective of remaining undetected while testing the encoding and decoding process.

Symbol	Definition	Values
n	Principal Quantum Number	1, 2, 3, 4 ....
l	Angular Momentum Quantum Number	0, 1, 2, 3, 4 .... (n - 1)
m	Magnetic Quantum Number	-l ....., -1, 0, 1,..... l
s	Spin Quantum Number	+½ , -½

Table 1. Standard Quantum number Definitions.

Selenium was used as the automation tool to post and retrieve encoded messages on Reddit. Selenium is a powerful tool that automates web browsers, allowing for the automated interaction with web pages. For our idea implementation, Selenium was employed to mimic human behavior when posting messages to Reddit and retrieving them for decoding. This automation eliminated the need for manual interaction and ensured the timely transmission of encoded messages. The encoded messages were posted as normal Reddit comments or posts, and the receiver, using the shared codebook, could automate the decoding process by extracting the elements and interpreting them based on the quantum number modifications. The sender automates the posting process by using a predefined post template that ensures consistency across all communications. The post is structured as follows:

"Hey! I have a doubt. I am a first-year student doing my engineering, and chemistry is a mandatory class for me, and I have no clue what the subject is or how to go about it. I'm just learning more about the quantum numbers of chemistry and all. I have computed a few values, can you guys check and let me know if it is correct or not please?"

$H_2O+NP_3MgBe_2+VFe_3MnB_2$

H -> n = 1 : l = 0 : m = 1 : s = -½
Be -> n = 5 : l = 1 : m = 1 : s = -½
B -> n=11 : l = 0 : m = 0 : s = +½
N -> n = 2 : l = 0 : m = 1 : s = -½
O -> n = 10 : l = 0 : m = 1 s = +½
Mg -> n = 4 : l = 1 : m = 0 : s = -½
P -> n = 3 : l = 1 : m = 1 : s = -½
Mn -> n = 8 : l = 1 : m = 1 : s = -½
Fe -> n = 7 : l = 1 : m = 0 : s = -½
V -> n = 6 : l = 0 : m = 0 : s = -½

Symbol	Definition	Values
n	Priority of the particular element in the chemical equation	1, 2, 3…
l	Uppercase or Lowercase	1 = Lowercase, 0 = Uppercase
m	Correct or Reverse order substitution	1 = Correct order, 0 = Reverse order
s	Filler or actual letter	+½ =Filler , -½ = Actual letter

Table 2. Modified Quantum Number Definitions

This format is used consistently for all posts, ensuring that the receiver can easily identify which posts contain encoded messages. The use of chemical elements and their associated quantum numbers follows a structured pattern, allowing the

receiver to discern the intended covert message from any irrelevant posts. By adhering to this template, the sender ensures that each encoded message is correctly formatted for easy identification and decoding.

The receiver decodes the message by first applying the shared codebook, which contains the mapping between the elemental symbols and their corresponding letters, as well as the quantum number modifications. Using the quantum number values, the receiver identifies whether the letter is in uppercase or lowercase, whether the substitution follows the correct or reverse alphabetical order, and whether the character is part of the actual message or a filler. This methodology ensures that the covert communication remains secure and efficient while utilizing easily accessible platforms like Reddit.

4. Implementation

The implementation was carried out in Python and involved three main components: encoding the input message, automating the posting and retrieval process on Reddit, and decoding the extracted content to reconstruct the original message. Below, we detail each component of the process, along with the challenges and measures taken to ensure the covert nature of the channel.

4.1. Encoding Process

The encoding process begins by taking a plain text message as input and converting it into a chemical equation combined with quantum number definitions. The goal is to disguise the message while ensuring the output looks like legitimate chemistry data. The algorithm processes the input message character by character. Each character is mapped to a chemical element based on its position in the alphabet. For example, A corresponds to Hydrogen (H), B to Helium (He), and so on. To add an extra layer of complexity, the algorithm randomly decides whether to use the periodic table in the correct order (e.g., A = H, Z = Fe) or reverse order (e.g., Z = H, A = Fe). Once an element is selected, quantum numbers are assigned to it to make the output look scientifically accurate. These include:

- Principal quantum number (n): Represents the position of the character in the message, capped at 12 to stay realistic.
- Azimuthal quantum number (l): Determines whether the original character was uppercase or lowercase (l=0 for uppercase, l=1 for lowercase).
- Magnetic quantum number (m): Indicates whether the mapping follows the correct or reverse order of the periodic table.
- Spin quantum number (s): Set to −0.5 for actual characters and +0.5 for filler elements.

To make the equation less predictable, filler elements such as Xenon (Xe) and Argon (Ar) are randomly inserted at various positions. These fillers don't carry any meaningful data but help disguise patterns in the encoded message. Finally, the elements in the equation and their quantum number definitions are shuffled independently. This step ensures the output doesn't follow the order of the original message, making it even harder to detect.

4.2. Reddit Automation

The encoded chemical equation and quantum number details are posted on Reddit using Selenium, which automates the process of logging in, navigating the subreddit, creating a post, and extracting content. Reddit serves as the medium for transmitting the covert message while maintaining a realistic and legitimate appearance.

- Posting the Encoded Message: The automation begins by logging into Reddit with predefined credentials. Selenium is used to navigate to the target subreddit and create a new post. The post contains the encoded equation and quantum number definitions, along with an introductory message to make it look like a genuine query. This ensures the post blends into the community's theme and avoids drawing unnecessary attention.
- Retrieving the Post for Decoding: Once the post is live, Selenium is used to locate the post using its title or specific content. The program then extracts the raw text, including the encoded message and quantum details, and stores it for decoding. This retrieval process is automated to ensure seamless extraction without manual intervention.

4.3. Decoding Process

The decoding process reconstructs the original message by reversing the steps of the encoding algorithm. Once the encoded post is retrieved from

Reddit, the program extracts the chemical equation and quantum number definitions. These are then processed to decode the hidden message character by character. The extracted content contains two key components:

- Encoded Chemical Equation: This represents the disguised message.
- Quantum Number Definitions: These provide the mapping details required for decoding.

The program separates these two parts and processes them individually. It breaks down the quantum number definitions into structured data, mapping each element to its corresponding quantum properties (n, l, m, s). Once the mapping is complete, the program iterates through the chemical equation to decode each character:

- Character Mapping: Based on the m value, the program determines whether the periodic table's correct or reverse order was used.
- Quantum Numbers: The n value indicates the character's position in the message, while l determines its case (uppercase or lowercase).
- Ignoring Fillers: Elements marked with s=+0.5 are identified as fillers and skipped during decoding.

After processing all elements, the decoded characters are combined to form the original message, with empty slots replaced by spaces.

5. Analysis

The evaluation of the proposed covert channel includes key characteristics such as mechanism, type, throughput, robustness, detection probability, and prevention strategies, based on Brown's framework for covert channel assessment [6].

5.1 Mechanism

The mechanism defines how the covert channel is constructed and how it hides and carries information. The proposed channel employs elemental substitution and quantum encoding, embedding messages within chemistry-related discussions on Reddit. This dual-layer approach provides obfuscation through natural content (chemistry queries) and complex encoding schemes, making it difficult for adversaries to distinguish covert messages from regular content. Unlike timing-based or network-level covert channels, the mechanism relies on human-readable text disguised in a benign context, effectively minimizing suspicion.

5.2 Type

Covert channels are commonly classified into storage, timing, or behavioral-based types. The proposed channel falls under storage-based channels, as it encodes information within static textual data. The encoded messages are concealed in plain sight, using the chemistry-related context to minimize suspicion.

5.3 Throughput

Throughput refers to the data transmission rate of the channel. In the proposed system:

- Capacity: The character limit per Reddit post (10–12 characters) restricts the throughput, making it suitable for transmitting short, discrete messages rather than large datasets.
- Tradeoff: This limited throughput enhances the covert nature of the channel, as shorter messages are less likely to trigger detection mechanisms.

5.4 Robustness

Robustness measures the channel's ability to survive disruptions, such as content moderation or platform restrictions. The use of Reddit, an open platform with diverse and dynamic content, makes the channel resilient against random deletions or moderator actions. Posts appear as legitimate queries, blending into natural user behavior.

5.5 Detection

Detection probability evaluates the likelihood that the covert channel will be discovered. The integration of chemistry-based fillers and quantum parameters obfuscates patterns, making it challenging for automated detection tools or machine learning algorithms to identify the encoded messages.

5.6 Prevention

Prevention assesses the difficulty of identifying or disrupting the covert channel, and several mitigation strategies were implemented to enhance its resilience. While automation played a critical role, manual posting was incorporated to reduce reliance on scripts and avoid detection by automated

moderation systems. Automation scripts were carefully designed to replicate human behavior, incorporating delays and random intervals between actions like typing, posting, and navigating the platform. Additionally, a mix of manual and automated activity created a natural flow of interactions, making the subreddit appear as an authentic and active community. To further reduce suspicion, encoded posts were framed as legitimate student questions related to chemistry, seamlessly blending into the platform's context and minimizing the likelihood of detection or disruption.

6. Limitations

One of the main limitations of the system is the need for a shared codebook between the sender and receiver. If this codebook is lost or mismatched, the encoded messages cannot be decoded, compromising the system's security. Using Reddit as the communication medium also presents challenges. The platform's anti-bot systems may flag frequent automated posts, leading to potential bans. To mitigate this, we manually added unrelated posts and randomized the timing of automated actions to appear more natural. Additionally, the system is limited by the quantum number n, which cannot exceed 12, restricting the length of messages that can be transmitted. While longer messages can be split into parts, this increases the risk of detection. Overall, these limitations highlight the need for further improvements to enhance security, reduce the risk of detection, and improve scalability.

7. Future Work

To enhance the security and functionality of the covert communication system, expanding the encoding to include numbers and special characters would be a significant improvement. Previously, the system was limited to sharing only words covertly, restricting its scope. By incorporating numbers and special characters into the encoding, the system gains versatility, allowing a broader range of messages to be transmitted.

In addition to extending the character set, more advanced obfuscation techniques could be employed to further disguise the true nature of the communication. For example, introducing randomness into the quantum number assignments (such as varying the values of n, l, m, and s within certain limits) could make it more difficult for an observer to decode the message without the exact codebook.

One key challenge in the current system is the sharing of the codebook. As it stands, the codebook must be securely exchanged between the sender and receiver, which can be a potential vulnerability. Future work could involve the development of secure methods for distributing the codebook without compromising security. This might include using a public-key cryptography system to encrypt the codebook during transmission or implementing a key exchange protocol that ensures both parties can securely obtain the codebook without revealing it to third parties.

8. Conclusion

Our paper presents a creative approach to covert communication by combining elemental substitution with quantum number encoding. By embedding messages in seemingly ordinary scientific discussions on platforms like Reddit, the system ensures secure and undetectable communication. While this method offers a promising solution for hidden communication, there is still much to be done, with plenty of room for further development and improvement. The approach holds significant potential for enhancing covert communication in diverse online environments.

9. References

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