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Malyi Oleksandr¹, Vlasenko Pavlo²

¹ PhD (Technical Science), associate professor NU «Zaporizhzhia Polytechnic»

² PhD student NU «Zaporizhzhia Polytechnic»

THE NEED OF ADVANCED ANALOG VIDEO SCRAMBLING METHODS FOR MISSION-CRITICAL UNMANNED VEHICLES APPLICATIONS

Unmanned Vehicles are becoming an indispensable tool for critical military operations, both on land, sea and air. Robust and secure real-time video transmission used in these vehicles is fundamental to mission success and safety of the operators. While digital video transmission systems offer high security and image quality, they also have high prices, limited range and can introduce latencies in the video feed, making analog video systems still a relevant option for mission-critical applications because of their:

Low latency: Crucial for real-time decision-making in high-stakes scenarios.

Simplicity and resilience: Superior performance in environments with high interference or weak signal conditions.

Low cost and availability: Can cost a fraction of a similar digital video system, with significantly more options already available in the market to choose from.

However, analog video systems are inherently insecure due to unencrypted transmissions, making them vulnerable to interception and exploitation, thus putting at risk both mission success and personal safety. Existing scrambling methods modify the signal in a way that renders it unintelligible without a compatible decoder, these methods include:

Line and Field Inversion: reverses the polarity of video signal creating a distorted image.

Frequency Shifting: video signal's frequency components (luminance and/or chrominance) are shifted from their original positions to new, offset positions.

Phase Modulation: introduces a phase shift to the luminance/chrominance or syn pulse signals, disrupting synchronization in unauthorized receivers.

Chaotic scrambling: scrambling technique that employs the principles of chaos theory to introduce unpredictable and seemingly random changes to the video signal.

Operating environment onboard unmanned vehicles also offers a number of challenges for such systems, such as:

Signal quality and integrity: for unmanned vehicles operation signal quality is critical for control and situational awareness. Scrambling can degrade the signal's visual quality, which can cause problems in low-bandwidth conditions. For example line and field inversion methods can reduce signal clarity especially in high-noise environments.

Synchronization complexity: accurate synchronization is crucial for scrambled signals, and any misalignment can lead to video decoding failures.

Resilience to Noise and Interference: unmanned vehicles often used in environments with high levels of electromagnetic interference, which complicates the scrambling and descrambling process. Interference may lead to loss of synchronization or introduce noise making the video feed unreliable.

Bandwidth and latency constraints: video scrambling requires additional bandwidth to carry synchronization data. In unmanned vehicles, where bandwidth is often limited, scrambling can increase latency as the signal is processed, transmitted and decoded.

Hardware constraints: size and weight constraints, limited computational and power resources available on most unmanned vehicles, especially in smaller battery-operated models.

While digital systems dominate modern video transmission, analog video remains relevant in specific contexts where cost, simplicity, or latency are priorities. Developing new analog video scrambling methods that can enhance security, improve efficiency, and address real-world challenges in these applications. It also provides an opportunity to innovate, making it a valuable and viable research topic.

REFERENCES

1. N. J. Corron, B. R. Reed, J. N. Blakely, K. Myneni and S. D. Pethel, Chaotic scrambling for wireless analog video. IEEE Southeastcon 2009, pages 38-43
2. Hadjadj, M., Sadoudi, S., Azzaz, M., Bendecheche, H., & Kaibou, R. (2022). A new hardware architecture of lightweight and efficient real-time video chaos-based encryption algorithm. *Journal of Real-Time Image Processing*, 19(6), pages 1049-1062.
3. Zhang, B., & Liu, L. (2023). Chaos-Based Image Encryption: Review, Application, and Challenges. *Mathematics*, 11(11), page 2585.

4. Abuelma'atti, Muhammad & Al Nafisah, Abdullah. (2019). A Memristor-based Chaotic-masking for Analog Spread Spectrum Communication. Indonesian Journal of Electrical Engineering and Computer Science. 14. pages 966-971.