Advances in Computer, Signals and Systems (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/acss.2025.090118
ISSN 2371-8838 Vol. 9 Num. 1

A Review of Wireless Electronic Detonator Systems

Zhang Wenyi[1,2,3], Xie Quanmin[1,2,*], Jia Yongsheng[1,2]

[1]State Key Laboratory of Precision Blasting, Jianghan University, Wuhan, Hubei, 430056, China
[2]Hubei Key Laboratory of Blasting Engineering, Jianghan University, Wuhan, Hubei, 430056, China
[3]Jiangsu Police Institute, Nanjing, Jiangsu, 210031, China
**Corresponding author*

Keywords: Wireless Blasting, Mining Technology, Wireless Electronic Detonator, Time Synchronization

Abstract: This review examines the evolution and impact of wireless electronic detonator systems in blasting engineering. Detonators have been pivotal in explosives technology since their invention in 1865, and the introduction of wireless electronic detonators marks a significant advancement. These systems enhance operational safety and flexibility, particularly in challenging environments where wiring is impractical. The article categorizes wireless detonation systems into three main types. The first type uses radio frequency bands but requires exposed antennas to maintain connectivity, complicating automation. The second type ensures safer, quicker operations through wireless communication between devices and control consoles, yet still relies on wired detonator connections. The third type represents a breakthrough with completely wireless operations, utilizing high-power longwave communication to penetrate the ground. However, these systems are complex and expensive, limiting widespread adoption. Despite their benefits, wireless detonator systems face challenges like signal stability and high costs. Ongoing advancements in wireless technology and cost reduction are essential for broader implementation. As the technology matures, wireless detonator systems are poised to revolutionize blasting operations, enhancing safety, efficiency, and automation capabilities in mining, construction, and demolition industries. The future holds promising developments that will further integrate these systems into mainstream blasting practices, driven by continuous technological improvements and increased operator experience.

1. Introduction

Detonators have been invented for nearly 160 years since 1865. In the field of blasting engineering, the emergence of wireless electronic detonators undoubtedly represents a significant technological breakthrough, gradually altering the traditional methods of blasting operations. This article will review and analyze the technical characteristics, application advantages, challenges faced, and future development prospects of wireless electronic detonators [1-3].

The core advantage of wireless electronic detonators lies in their wireless detonation mechanism, making operations safer and more flexible in environments where wiring is difficult or remote

operation is required. With the continuous advancement of wireless communication technology, the precision and reliability of wireless electronic detonators have significantly improved, providing new solutions for blasting operations. In complex blasting tasks, the wireless control capability of wireless electronic detonators is particularly important. It allows operators to precisely control explosions from a safe distance, crucial for enhancing blasting efficiency, reducing risks, and ensuring the safety of personnel. Additionally, the programming function of wireless electronic detonators enables finer control in situations requiring the synchronous detonation of multiple explosive devices[4-6].

Although wireless electronic detonators offer many advantages, they also face some technical challenges in practical applications. The stability of wireless signals is a major technical issue because wireless communication is susceptible to environmental factors and interference from other electronic devices. Additionally, cost is a limiting factor for its widespread adoption, especially in cost-sensitive projects. The future development of wireless electronic detonators will depend on further advancements in wireless communication technology and cost reduction. With technology maturing and costs decreasing, wireless electronic detonators are expected to play a more significant role in blasting engineering. Moreover, as operators gain more experience and understanding of wireless electronic detonators through practice, it will further drive their application in the blasting engineering [7].

So wireless communication is a great technology that brings various benefits when applied to detonation systems. Based on research, there are currently three main types of wireless detonation systems.

2. Wireless Electronic Detonators with Exposed Antennas

The first type involves electronic detonators that have been equipped with wireless communication capabilities, typically using radio frequency bands. However, this frequency isn't very effective at penetrating the ground, which necessitates the use of a long antenna or a communication module that extends above ground to maintain contact with the central control system. A notable example of this type is detailed in the Canadian patent for tunnel wireless detonation (CA 2897582) by Hikone Satoshi and Tasaki Yoji [8].

While this system allows for wireless communication, the main drawback is that the electronic detonators still require a long wire connection to the surface. This limitation hinders the automation of detonator installation operations.

3. Wireless Communication Between Execution Device and Control Console

The second type of system uses wireless communication between the blasting execution device and the main control console, but the execution device itself is connected to the detonators via wires. This setup simplifies and speeds up the blasting process to some extent, and it also enhances the safety of the blasting personnel [9]. However, similar to the first type, it does not facilitate automated installation of detonators. A typical example of this system is the product offered by DetNet.

DetNet developed [10,14,15] the CE4 Commander electronic initiation system, the system works by integrating three main components-the CE4 Commande, the 4G detonator, and the CE4 Tagger-to enhance blasting operations. The CE4 Commander serves as the central device, capable of controlling up to 7,200 detonators for a single blast by utilizing long-distance RF communication from a blasting point. Each Commander can connect up to 300 detonators through its four channels, allowing for precise control and coordination during blasting operations. The 4G detonator, a key

component of the system, is a fully programmable device with enhanced memory and durability, featuring a redesigned ASIC with increased memory capacity compared to its predecessor, the 3G detonator. It also includes a new spooled downline wire option designed to withstand impact in deep blast hole applications, with critical information stored in non-volatile memory during detonator assembly. Additionally, the CE4 Tagger interfaces with the 4G detonator, enabling the testing of up to 300 detonators at a time and providing GPS functionality for troubleshooting purposes. DetNet emphasizes that the CE4 Commander system offers advanced capabilities such as fast and simple deployment methods, autonomous detection and testing of detonators, energy monitoring, and high programming speed compared to existing systems on the market . The system is designed to prevent blast delays, speed up deployment, and ensure enhanced blast efficiency and safety standards. Furthermore, the system is fully compatible with blast design software packages like ViewShot and third-party software such as BlastLogic, allowing for seamless integration and efficient operation. In summary, the CE4 Commander electronic initiation system functions by leveraging the capabilities of its components-the CE4 Commander, 4G detonator, and CE4 Tagger-to optimize blast designs, ensure efficient blasting operations, and provide accurate reporting and analysis in mining applications.

4. True Wireless Electronic Detonator System

The third type of system is a truly wireless electronic detonator system that can communicate through the ground. Each electronic detonator is buried underground without any wired connections, offering all the benefits of wireless communication and facilitating automated detonator installation. However, current systems of this type use high-power longwave communication, making the equipment more complex and expensive compared to ordinary electronic detonators. The development of such systems can be traced back to around the year 2000.

In 2005, Dozolme describes DELTADET wireless system had been implemented in various mining applications [6], such as Sishen Iron Mine of Kumba Resources, Rossing Uranium Mines of Potgietersrust Platinum Limited and Konkola Copper Mine etc.. The company BME Delta Caps achieves the first centralized programming, testing and firing system in 1994, and brought the first wireless programming, testing and firing system in 2000, combining it with the existing centralized system. The concept of "centralized and wireless" in blasting refers to the integration of centralized programming and wireless blasting capabilities. This combination offers several benefits in the blasting industry. The centralized aspect allows for remote programming and testing of detonators from a single point, providing convenience, efficiency, and enhanced safety measures. On the other hand, the wireless feature enables blasters to initiate blasts from a safe distance, ensuring a direct and secure view of the blasting area and eliminating the need for physical connection with detonators. Furthermore, the centralized and wireless technology in blasting breaks the limits of traditional wired systems by offering flexibility, capability, reliability, and safety enhancements. It allows for centralized programming, testing, and firing of a large number of detonators, overcoming technical challenges and increasing operational efficiency. This technology also improves site optimization objectives by reducing the need for frequent clearances and enhancing mine scheduling capabilities. It revolutionizes the industry by providing a safer, more efficient, and flexible approach to initiating blasts, ultimately improving operational processes and safety standards. The DELTADET System with wireless technology revolutionizes mining operations, enhancing safety, efficiency, and cost-effectiveness through remote blasting, elimination of traditional blasting wires, and centralized programming and firing [11].

Katelyn Spidle delves into the transformative journey of wireless blasting technology within the mining sector [12]. Initially, Austin Powder unveiled the E*Star wireless remote firing system in

2006, a pioneering solution that faced initial hesitance before gradually gaining traction. In its initial iteration, Austin Powder developed a wireless firing system equipped with two-way radio communication functionality with the blasting machine. However, this system lacked substantial capability to provide the overseeing blaster with real-time feedback regarding the status of the blasting machine throughout the diagnostic and firing procedures [13].

Following suit, Orica, a leading supplier of commercial explosives, embarked on a groundbreaking endeavor, crafting the world's first commercially viable wireless through-the-rock blasting system. This innovative system marked a paradigm shift, eliminating the necessity for wired connections between blasting machines and detonators, thus revolutionizing blasting practices [14].

The idea of through-the-rock communication is firmly established. Twenty-six years ago, MST Global, a company specializing in communications technology infrastructure and application development, spearheaded the utilization of Through-The-Earth (TTE) technology with its PED Emergency Warning System. TTE is a one-way communication system, establishing connections with subterranean devices through the emission of ultra-low frequency radio waves capable of penetrating solid rock at depths ranging from 800 to 1000 meters. Utilizing a large loop antenna positioned either on the surface or underground [12], messages inputted from a remote surface location are transmitted and displayed as messages on cap lamp receivers carried by miners working below ground.

Orica's crowning achievement in this narrative is the culmination of nine years of collaborative effort—a fully realized wireless primer, poised to redefine the blasting landscape. This pioneering system, known as the wireless, through-the-rock blasting system, represents the epitome of innovation in blasting technology, promising unparalleled efficiency and safety in mining operations [15].

Orica Limited [1] released its successful production trials of the WebGen 100 wireless electronic blasting system, highlighting its significance in improving safety and productivity in the mining industry, and it marked a significant advancement in in-hole initiation and a step towards full automation of drill and blast operations. The system allows for wireless initiation of in-hole primers, removing constraints imposed by physical connections and enhancing safety by keeping personnel away from harm's way. The technology was successfully implemented in production trials at the Glencore operated Ernest Henry Mine in Australia and Goldcorp's Musselwhite Mine in Canada, showcasing improved productivity and operational efficiency. The WebGen system obtained a Safety Integrity Level 3 (SIL3) certification, signifying its high safety standards and reliability in commercial blasting products[16].

The WebGen 100 system [17] uses the same technology that allowed the signalling of nuclear submarines even while they were hundreds of meters below the ocean. It eliminates the need for physical connections to each primer in a blast. WebGen uses low-frequency magnetic induction waves for communication, akin to submarine and underground mining emergency device systems. Communication with these personal emergency devices (PEDs) is one-way, from a surface transmitter to underground miners' receivers. The ultra-low frequency magnetic induction wave [9] can travel through water, air, rock, backfill and even bog, it is transmitted by a large loop antenna at around 1800 hertz, and received by disposable receivers in each borehole. With WebGen, signals are transmitted from a transmitter to each primer before a blast. The primers are encoded with their group ID and delay time just before charging, storing this data. After charging, the primer enters standby mode, waking periodically to check for a wake-up signal. Prior to a blast, a wake-up signal is sent to all primers, synchronizing and arming those in the firing group. A unique firing command provides an additional layer of security.

In initial assessments, Musselwhite [9] experienced a remarkable 93% reduction in dilution, 33%

fewer days spent mucking, and a 27% increase in daily mucked tonnes. Additionally, trucks were able to haul 15% more tonnage per load due to improved fragmentation compared to conventional stopes. The technology is a game-changer for the industry, because of its safety improvements [13], enhanced productivity by eliminating wired constraints, and its critical role in fully automated drill and blast for mining [18].

Dyno Nobel Company's [16] CyberDet and BlastWeb using the similar Through the Earth (TTE) signalling where encoded magnetic transmissions propagate through the rock at ultra-low frequencies, it also delivers on its potential to eliminate human presence in hazardous underground mining environments.

The third type of wireless detonation system represents a significant technological advancement in the field of blasting and explosive operations. These systems utilize high-power longwave communication, allowing signals to penetrate through the ground and reach buried detonators without the need for physical wires. This method eliminates many of the logistical and safety challenges associated with wired systems.

Advantages:

Truly Wireless Operation: With no wires required, these systems simplify the setup and reduce the potential for accidental detonation caused by wire damage or misconnection.

Enhanced Safety: The absence of surface wires reduces tripping hazards and makes the site safer for workers.

Automation Friendly: These systems are well-suited for automation, enabling precise and consistent installation and detonation processes. Automated installation systems can place detonators quickly and accurately, improving efficiency and reducing labor costs.

Challenges:

Complexity and Cost: The use of high-power longwave communication requires sophisticated and expensive equipment. The complexity of these systems means that they are currently more costly than traditional electronic detonators.

Power Requirements: High-power communication systems need robust power sources, which can be a limiting factor in remote or off-grid locations.

Development History: The technology for these systems has been in development since around 2000, reflecting nearly two decades of research and gradual improvements. Despite the progress, there is still room for innovation to make these systems more affordable and easier to deploy.

5. Conclusion

As the technology continues to evolve, future advancements are expected to address these challenges, making truly wireless electronic detonator systems more accessible and widely adopted in various industries, including mining, construction, and demolition. These improvements will likely focus on reducing costs, enhancing the reliability of wireless communication, and further simplifying the deployment and operation processes.

Truly wireless electronic detonator systems, capable of penetrating the ground with longwave communication, represent a major step forward in blasting technology. While they offer numerous benefits such as enhanced safety and suitability for automation, their complexity and high costs remain challenges to broader adoption. Continued advancements are expected to make these systems more practical and cost-effective, revolutionizing the field of explosive operations.

Acknowledgement

This work was supported by State Key Laboratory of Precision Blasting and Hubei Key

Laboratory of Blasting Engineering from Jianghan University under Grant No. PBSKL2023A11

References

[1] Andrew Valler, 2017, Improving safety and productivity with the world's first wireless electronic blasting system, Orica Limited News & Media, September 27, 2017, https://www.orica.com/ news---media/improving-safety-and-productivity-with-the-world-s-first-wireless-electronic-blasting-system.
[2] Chalnot M., Coustou, A., Aubert, H., Pons, P. Lavayssiere, M. Lefrancois, A., Luc, J., 2021, Wireless Transmission of Friedlander-Type Signals for the Dynamic Measurement of Blast Pressure, Propellants Explosives Pyrotechnics, 2021, Vol. 46, pp 563–571.
[3] Chi, H., 2020, Research on Underground Remote Control Detonation System, Journal of Physics: Conference Series 1682 012076, 2020 International Conference on Machine Learning and Computer Application.
[4] Dirk Hummel, Michael J. McCann, Charles Michael Lownds, Erich Nicol Meyer, 2010, Orica Explosives Technology Pty Ltd, Data Communication in Electronic Blasting Systems, US Patent 7791858 B2, 2010.
[5] Dirk Hummel, Michael J. McCann, Ronald F. Stewart, 2009, Orica Explosives Technology Pty Ltd, Wireless Detonator Assembly and Methods of Blasting. US Patent 7568429 B2, 2009.
[6] Dozolme P.H., Bernard T., 2005, Wireless programmable blasting-3 year track record, Brighton Conference Proceedings 2005, European Federation of Explosives Engineers. Section 14. pp 465–469.
[7] Dozolme P.H., Bernard T., 2006, Ultimate Technological Combination in Electronic Blasting-A Conclusive Contribution to Blasters' Health & Safety, International Society of Explosives Engineers, 2006G Volume 2.
[8] Hikone, Satoshi & Tasaki, Yoji, 2020, Wireless Detonation System Wireless Detonation Method and Detonator and Explosive Unit Used In Same, Canadian Patent CA 2897582, 2020.
[9] Ian Ewing, 2018, No wires New ideas, CIM Magazine, November 2018 issue, Vol. 13, No. 7, pp 36–37.
[10] Johann Smit, 2017, New electronic initiation system from Detnet is a game-changer, Modern Mining, April 2017, pp 18–21.
[11] Kara, S., Adamson, W. R., Reisz, W. J., Trousselle, R., 2014, The Latest Generation of the Electronic System Enhanced Safety and Productivity. Procedia Engineering, 83, pp 432–440.
[12] Katelyn Spidle, 2016, Cutting the strings, CIM Magazine, February 05 2016.
[13] Mark Alfred Clarkson, 2022, Fully Automated Drill and Blast for Mining, PhD Thesis, Faculty of Engineering and Built Environment, University of Southern Queensland, Australia.
[14] Muller E. L., Botha M. C., Meyer T. C., 2023, Wireless Detonator System, US PATENT: US 2023/0057631 A1, 2023-02-23.
[15] Muller E. L., Meyer C. T., Liebenberg A. J., 2022, Wireless Detonator Assembly, US PATENT: US 2022/0357141 A1, 2022-11-10
[16] Nickolas Zakharia, 2021, Improved safety and production with wireless initiation and centralized blasting, Australian Mining, September 2, 2021, https://www.australianmining.com.au/ improved-safety-and-production-with-wireless-initiation-and-centralised-blasting/
[17] Noel Dyson, 2017, Going Wireless, Australia's Mining Monthly, October 2017, pp 28–32.
[18] Singh, J. K., Mandal, S. K., Banerjee, G., 2021, An Empirical Modeling and Evaluation Approach for the Safe Use of Industrial Electric Detonators in the Hazards of Radio Frequency Radiation, Journal of Scientific & Industrial Research, Vol. 80, January 2021, pp. 27–33.