



- (51) **International Patent Classification:**
F42B 12/36 (2006.01) *F42B 30/00* (2006.01)
- (21) **International Application Number:**
PCT/GB2024/051375
- (22) **International Filing Date:**
29 May 2024 (29.05.2024)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
2308466.8 07 June 2023 (07.06.2023) GB
23275089.3 07 June 2023 (07.06.2023) EP
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- (81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY,

(54) **Title:** IMPROVEMENTS IN AND RELATING TO LIVE MONITORING OF PROJECTILES

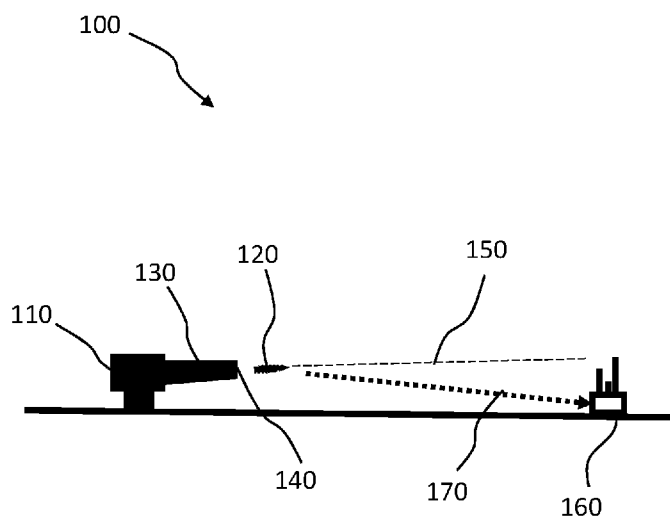


Figure 1

(57) **Abstract:** A data transmission system (200) is provided for use with a projectile (120). The projectile (120) is arranged for firing from an artillery piece (110). The data transmission system (200) comprises at least one sensor (220) arranged to sense at least one parameter. The at least one sensor (220) is configured to produce an analogue voltage output. The data transmission system (200) further comprises a first voltage-controlled oscillator (230), configured to produce an output having a frequency proportional to the voltage output of the at least one sensor (220). The data transmission system (200) further comprises an encoder (240). The encoder (240) is configured to generate encoded data using the output of the first voltage-controlled oscillator (230) by switching between two signal streams having different properties. The different properties are used to encode for different logical states. The data transmission system (200) further comprises a transmitter (250) configured to transmit the encoded data. Also described herein is a method (300) of

MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA,
NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO,
RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH,
TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS,
ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

transmitting data using a data transmission system (200) for use with a projectile (120).

IMPROVEMENTS IN AND RELATING TO LIVE MONITORING OF PROJECTILES

FIELD

5 The present invention relates to a system and method of use thereof for extracting real-time data from sensors that are carried by an artillery round or projectile, thereby removing the need to for expensive and inefficient fire-and-recover methods whilst also reducing the costs associated with the testing of new munitions and firing system components.

10

BACKGROUND

 The development of large calibre munitions and their associated firing systems benefit from live firing trials. During such trials, data can be obtained while a round is in-barrel, and during its subsequent flight to the target. The data
15 obtained during these stages can be used to assess the effectiveness of new components and may further inform future developments.

 Conventional instruments, such as light-barriers, pressure sensors, radar and high speed cameras, are impractical for performing measurements of in-barrel and in-shell behaviour during the firing process and subsequent flight time.
20 Further, wired means are not suitable for tests involving the firing of munitions. As a result, remote sensing and inferred techniques are often used to obtain estimates for quantities including, but not limited to, the barrel port pressure and muzzle velocity. Indirect measurement and modelling approaches are typically used. However, a comprehensive understanding of these systems requires
25 validation through direct measurements. This is especially relevant when considering the safety-related aspects of these systems which may lead to dangerous consequences if improperly assessed.

 Direct measurements can be obtained using embedded sensors and data loggers. A key limitation in using these systems is the incredibly short time
30 periods associated with in-barrel events. For example, the time between a round beginning to move and the round exiting the barrel may be around 10 milliseconds. These sensor systems must also be capable of withstanding the harsh conditions associated with firing and impact. As such, sensor systems intended for this purpose must be capable of acquiring data at a fast rate in the

order of several kilohertz, while also being extremely robust. These requirements have resulted in most suitable sensor systems being relatively, or even prohibitively, expensive. The high cost of these systems can be a significant barrier to their use, particularly during trials where multiple components or combinations are being tested, since costs can quickly begin to spiral.

Another key drawback of using data logging systems is the need to recover the fired rounds to allow the recorded data to be retrieved and analysed. The recovery of fired rounds can reduce the costs associated with using flash memory data loggers and several methods can be used to provide a reasonable probability of successful recovery. Unfortunately, these methods are complex, difficult to access, expensive, or a combination thereof since the round would need to be recovered intact and the interfaces remain unaffected by the physical stresses. Even when using these methods, recovery of the fired round is not guaranteed - leading to the loss of equipment and data, which may be potentially classified. Long turnaround times between firing and recovery typically require multiple data loggers to be used irrespective of whether recovery is successful. In studies investigating multiple variables e.g., different barrels, energetics, masses, and propellants, the need for multiple data loggers can prove to be prohibitively expensive, particularly when considering that each variable may require upwards of 12 rounds to be fired to obtain enough data for valid conclusions to be drawn. In some cases, it may be entirely impractical or impossible to recover the round, for example, when a fired round becomes embedded in the ground or a target.

Real-time telemetry systems have recently been produced. For example, General Atomics' BLU-Fuze In-Flight Telemetry System comprises shock-hardened sensors to measure the in-barrel and in-flight performance of missiles, projectiles, munitions, and space systems. The system supports the use of digital and analog sensors. The system allows high-resolution launch data to be streamed in real-time during a flight to allow recovery of the launch while supporting ongoing missions. The associated cost of this system is approximately \$10,000-20,000 per unit. These high costs remain prohibitive for trials which seek to test multiple variables e.g., propellants, projectiles, and other weapon system components.

In addition to the high costs of existing systems, many are products of the United States of America. As such, their shipment and use may be covered by the International Traffic in Arms Regulations (ITAR) regime. This may introduce additional administrative and distributive issues.

5 As outlined above, there is a clear need for a reliable, disposable, and lower-cost alternative telemetry system for use with large calibre munitions and weapon system testing that is suitable for broader scale firing trials and does not require recovery of fired rounds after use whilst still providing empirical evidence to verify modelled data. There is a further need for a system capable of
10 transmitting data in real-time with minimal latency, both while the round is in the barrel of a firing system, and during flight.

SUMMARY

 According to a first aspect of the present invention, there is provided a data
15 transmission system for use with a projectile, the projectile being arranged for firing from an artillery piece. The data transmission system comprises at least one sensor arranged to sense at least one parameter with the at least one sensor producing an analogue voltage output. The data transmission system further comprises a first voltage-controlled oscillator, configured to produce an output
20 having a frequency proportional to the at least one sensor's voltage output. The data transmission system further comprises an encoder, configured to generate encoded data whereby the output of the first voltage-controlled oscillator selects one of two signal streams having different properties. The different properties are configured to encode for different logical states. The data transmission system
25 further comprises a transmitter configured to transmit the encoded data. This system may remove the need for expensive and inefficient fire-and-recover systems, whilst also reducing the costs associated with the testing of new munitions and firing system components.

 According to another aspect of the present invention, the data
30 transmission system may further comprise a receiver. The receiver is arranged to be located proximal to a muzzle of a barrel of the artillery piece. This may allow the transmitted data to be received and makes use of the barrel as a waveguide thereby enabling data to be obtained for in-barrel events.

According to another aspect of the present invention, the different properties of the two signal streams used by the encoder may be based on a different frequency and/or a different phase. This may provide flexibility over the encoding technique that is used.

- 5 According to another aspect of the present invention, the encoder of the data transmission system may be one of a second voltage-controlled oscillator, or a direct digital synthesis driver. This may provide flexibility over the encoded output signals that may be produced.

- 10 According to another aspect of the present invention, the data transmission system may comprise at least one analogue sensor. Analogue sensors may not be subject to clock delays, thereby providing good data resolution and providing benefits over digital sensors.

- 15 According to another aspect of the present invention, the data transmission system may comprise at least one sensor configured to at least one of acceleration, pressure, rotation, strain, temperature, and/or magnetic field. This may allow the projectile to obtain information about a myriad of physical factors that may be used for testing/development.

- 20 According to another aspect of the present invention, the data transmission system may utilise the barrel of the artillery piece as a waveguide for signals transmitted by the transmitter. This may allow information regarding in-barrel events to be recorded.

- 25 According to a second aspect of the present invention is a method of transmitting data using a data transmission system for use with a projectile, the projectile being arranged for firing from an artillery piece. The method of transmitting data comprises the step of detecting information, via at least one sensor, related to at least one parameter and producing a sensor voltage output from the at least one sensor. The method of transmitting data may further comprise the step of passing the sensor voltage output through a voltage-controlled oscillator to produce an output signal with a frequency proportional to
30 the sensor voltage output. The method of transmitting data further comprises the step of generating encoded data, whereby the output of the first voltage-controlled oscillator selects one of two signal streams having different properties. The different properties are configured to encode for different logical states.

The method of further comprises the step of transmitting the encoded data signal.

According to another aspect of the present invention, the method of transmitting data may comprise the step of receiving the encoded data signal, by
5 a receiver.

According to another aspect of the present invention, the method of transmitting data may comprise the step of transmitting and receiving the encoded data signal while the projectile is located within the barrel of the artillery piece. This may allow information about the projectile to be obtained during in-
10 barrel events.

According to another aspect of the present invention, the method of transmitting data may comprise the step of transmitting and receiving the encoded data signal while the projectile is in-flight. This may allow information about the projectile to be obtained during flight without the need to recover the
15 fired projectile.

According to another aspect of the present invention, the method of transmitting data may comprise the step of transmitting the encoded data signal live and then re-transmitting the same encoded data signal following a delay. This may allow the two data sets to be compared.

20 According to another aspect of the present invention, the method of transmitting data may comprise the step of correlating the encoded data signals sent live and after the delay to identify differences. As suggested, this may allow differences and/or errors in the two data sets to be identified, such as the presence of noise or other RF artifacts.

25 According to another aspect of the present invention, the method of transmitting data may comprise the step of decoding the received encoded data signal by means of a Fast Fourier Transform. This may allow the encoded data to be retrieved for analysis.

30 BRIEF DESCRIPTION OF THE FIGURES

The invention will now be described by way of example only with reference to the figures, in which:

Figure 1 shows a schematic of an artillery firing system;

Figure 2 shows a schematic of a data transmission system, according to an embodiment of the invention; and

Figure 3 shows a schematic of a data transmission system, according to another embodiment of the invention; and

5 Figure 4 shows a flowchart for a method of preparing and transmitting a signal, according to an embodiment of the present invention.

DETAILED DESCRIPTION

Figure 1 shows an artillery system 100 as may be used in conjunction with
10 the data transmission disclosed herein. The artillery system 100 comprises an artillery piece 110 configured to fire a projectile 120, round, or shell. The projectile 120 may be a high-calibre projectile with a diameter of e.g., 81mm, 105 mm or 155 mm. The skilled person will appreciate that the system described herein may be similarly applicable to other relatively large-calibre projectiles.

15 The artillery piece 110 may be a gun, cannon, howitzer, mortar, or the like. The artillery piece 110 comprises a barrel 130. The barrel 130 may further comprise a muzzle 140 located at the tip of the barrel 130. Upon firing, a projectile 120 is passed along the barrel 130, expelled through the muzzle 140, and passes along a flight path 150. The flight path 150 of the projectile 130 may be adjusted
20 by altering the elevation of the artillery piece 110, by increasing or decreasing the amount of charge used to accelerate the projectile 120, or by changing the size and/or weight of the projectile 120 used.

 The barrel 120 may comprise rifling configured to impart a spin upon a projectile 120 to improve the stability of the projectile 120 during flight. The spin
25 rate of the projectile 120 may be approximately 200-300 radians per second (1900 – 2800 revolutions per minute). Fired projectiles 120 may leave an artillery piece 110 with a muzzle velocity of up to 1100 m/s. Of course, the spin rate and the muzzle velocity of the projectile 120 may vary depending on the rifling arrangement, the type of projectile 120 used, the charge used, and various other
30 factors that will be known to those skilled in the art.

 The artillery system 100 may further comprise a receiver 160 configured to receive a signal 170 transmitted from the projectile 120. The encoded data signal 170 may be transmitted by the projectile 120 to convey information about the fired projectile 120.

Figure 2 shows a schematic of a data transmission system 200 to provide live telemetry data of a projectile 120. The projectile 120 is arranged to be fired from an artillery piece 110 as described in relation to Figure 1. The data transmission system 200 may be contained within a fuse body 210 of the projectile 120. The projectile 120 may be inert/non-lethal, in that it may not contain a primer, propellant, explosive charge, or a combination thereof. A projectile 120 as described herein may be used for training and/or testing purposes. For example, inert projectiles 120 may be useful in the development of new or modified projectiles 120.

The data transmission system 200 comprises at least one sensor 220. The at least one sensor 220 may be configured to sense information relating to at least one parameter. The at least one sensor 220 may be a plurality of sensors arranged within a sensor module (not shown). The at least one sensor may be configured to monitor environmental and physical factors or parameters including, but not limited to, acceleration, rotational rate, displacement, velocity, pressure, strain, temperature, and magnetic field. The skilled person will appreciate that this is a non-exhaustive list and that one or more other sensors may be included according to the specific requirements of the test or training exercise being undertaken. The at least one sensor 220 is configured to produce an analogue voltage output. The voltage output of the at least one sensor 220 may contain information relating to the detected information relating to at least one parameter. The at least one sensor 220 may be a digital sensor. The digital sensor may be configured to generate a digitally oscillated square wave instead of using a first VCO.

The at least one sensor 220 may be configured to provide appropriate temporal resolution with a sampling rate in the kilohertz frequency range, in that the at least one sensor 220 is capable of obtaining data relating to events occurring over short time scales. For example, firing of the projectile 120 typically occurs over the span of a few milliseconds. The at least one sensor 220 may preferably be at least one analogue sensor. Analogue sensors may provide a wide output bandwidth compared to comparable digital sensors. Analogue sensors may not be subject to clock delays, thereby providing good data resolution.

The data transmission system 200 further comprises a first voltage-controlled oscillator 230 (VCO). The first VCO 230 is configured to produce an output signal with a frequency that is proportional to the voltage output of the at least one sensor 220. The variability in the output frequency of the first VCO 230 directly represents the parameter information as detected by the at least one sensor 220. The output signal produced by the first VCO 230 may be a square pulse-frequency modulation (PFM) wave.

The data transmission system 200 further comprises an encoder 240. The encoder 240 is configured generate encoded data. The output of the first VCO 230 selects one of two signal streams having different properties. The different properties are configured to encode for different logical states. The different properties may include frequency, phase, and other quantities as may commonly used for shift keying purposes, as will be known to those skilled in the art. The defined logical states may be, for example, a 0 or a 1.

The encoder 240 may generate an encoded data signal comprising different frequencies. The different frequencies may be based on the output signal received from the first VCO 230. Each of the different frequencies may be associated with a defined logical state. Defined logical states may be, for example, a 0 or a 1.

The encoder 240 may comprise a second voltage-controlled oscillator or a direct digital synthesis driver (DDS). The encoder 240 may be configured to output one of two different frequencies using frequency shift keying at each logic level. Amplitude shift keying (ASK) or phase shift keying (PSK) may be used. However, frequency shift keying (FSK) is preferable because it is generally easier to create with a VCO and it is generally easier to detect in the resulting signals. When using a DDS, phase shift keying (PSK) is preferable since it uses less bandwidth which the skilled person would understand could lead to an improved signal recovery.

The use of DDS may be preferable since it employs a continuous phase transition and the internal sine wave lookup table needs no additional computation. The output frequencies may be designed to centre around a channel frequency with sufficient bandwidth deviation to overcome the Doppler shift incurred by the fired projectile 120. For example, a Doppler shift of 45 kHz may be expected. In this example, a centre frequency of 1 ± 0.05 MHz may

ensure that the keys do not overlap, thereby ensuring a clear differentiation between low and high logic states. In arrangements where an appropriate DDS is used as the FSK generator, sine lookup tables and accumulators may be used to switch between frequency keys. This approach is also applicable to an
5 appropriate DDS whereby the phase accumulator may be switched or reversed.

The data transmission system 200 may further comprise a mixer (not shown). The mixer may combine signal channels with different centre frequencies with appropriate band spacings. The combined frequency signal may then be modulated onto a carrier signal for transmission at industrial, scientific, and
10 medical (ISM) radio band frequencies. ISM band frequencies may range from 6.5 kHz to 250 GHz. The ISM band frequency used may preferably be approximately 2.45 GHz, but this will be confined to the bore of the barrel since the waveguide cut-off frequency will vary with bore diameter. For example, a 105mm diameter bore will have a lower cut-off frequency for the TE₁₀ mode at 1.67 GHz. Higher
15 frequencies may be chosen to negate background noise and increase the gain of the signal, or for smaller calibre rounds; conversely, lower frequencies can be used for larger calibre rounds.

Using this arrangement, the reaction time of the at least one analogue sensor 120 may be as short as one cycle of the VCO changing/switching
20 frequency. The bandwidth of the entire signal may be narrow, particularly if a Doppler profile is calculated first. This can be applied to the recorded signal using digital signal processing (DSP) to reverse Doppler. Doing so may reduce the deviation and channel spacing that is required.

The data transmission system 200 further comprises a transmitter 250.
25 The transmitter 250 is configured to transmit the encoded data signal 170. The transmitter 250 may be configured to transmit the encoded data signal 170 live or in real-time. The transmitter 250 may be further configured to re-transmit the same encoded data signal 170 following a delay. The delay may be brief, for example, on the order of 10-30 milliseconds. This arrangement may be used by
30 an operator to assess the correlation between the original (live) and delayed signals. This can improve the reliability of the decoding process to recover the transmitted data. The delay would be chosen to negate any RF or magnetic influence of the barrel, muzzle or hot ionised gasses produced as a result of the firing. In addition, the delayed data could allow a smaller calibre round to use a

lower ISM band frequency for transmission, such that the barrel allows for the TE₁₁ waveguide mode.

The barrel 130 of the artillery piece 110 may act as a waveguide to aid transmission of the encoded data signal 170 while the projectile 120 remains
5 confined within the barrel 130 of the artillery piece 110.

The fuse body 210 comprising a majority of the components of the data transmission system 200 may be disposable, in the sense that the components used are relatively inexpensive. This enables a fire-and-forget approach to be used, thereby removing the need to physically recover the fired projectile 120 to
10 obtain the measured data. An advantage of this approach is that the cost and time associated with firing tests may be reduced.

Figure 3 shows a schematic of a data transmission system 200 to provide live telemetry data of a projectile 120, as described above in relation to Figure 2. The data transmission system 200 may further comprise a receiver 260. The
15 receiver 260 may be configured to receive an encoded data signal 170 from a transmitter 250 within the fuse body 210 of a projectile 120. The receiver 260 may comprise components necessary for decoding and storing the data obtained from the encoded data signal 170. The receiver may be configured to record data obtained from encoded data signal 170 live or in real-time. This live recording of
20 transmitted data may remove the need for the fired projectile to store the data itself and be recovered.

The receiver 260 may be configured to obtain an encoded data signal 170 from the projectile 120 while the projectile 120 is still confined within the barrel 130 of the artillery piece 110. The barrel 130 of the artillery piece 110 may act as
25 a waveguide to facilitate the transmission of the encoded data signal 170 to the receiver 260. For example, a transmission frequency of 2.45 GHz may be optimal for signal transmission from an 81 mm mortar projectile 120.

The receiver 260 may be positioned proximal to the muzzle 140 of the barrel 130 of the artillery piece 110 to improve reception of the encoded data
30 signal 170.

The receiver 260 may utilise frequency-modulated receiver blocks (either software or physical) to receive the encoded data signal 170 data at audio frequencies (assuming the sensors gather data at a rate where the encoder transitions <1MHz). This may improve the efficiency of data storage and

processing. The received data may be decoded and thereby recovered by means of a Fast Fourier transform (FFT) approach. Those skilled in the art will appreciate the subsequent analysis steps associated with using such means. It is important that the shortest transition of keyed data and the frequency bandwidth are taken
5 into consideration when digitally capturing RF for use in an FFT. The receiver will need to capture enough data so that the order of FFT will produce discrete frequency bins that will discriminate FSK keying (where FSK is used), and have the desired temporal dwell time so that all transitions are captured. For example, a 50 MSPS sample rate might be used to capture data from the sensor with a
10 maximum VCO frequency of 1 MHz or 1 μ s resolution between transitions; this would imply that the mark and space frequencies need to be at least 1 MHz apart.

Figure 4 shows a flowchart for a method 300 of preparing and transmitting a signal for use with a projectile 120. The method may be compatible with the data transmission system 200 described in relation to Figures 2-3.

15 The method 300 comprises the step 310 of detecting, via at least one sensor 120, information related to at least one parameter. The at least one sensor 120, as described in relation to Figures 2 and 3, may be configured to monitor environmental and physical factors or parameters including, but not limited to, acceleration, rotational rate, displacement, velocity, pressure, strain,
20 temperature, and magnetic field. The skilled person will appreciate that this is a non-exhaustive list and that various other sensors may be included according to the specific requirements of the test or training exercise being undertaken. The at least one sensor 220 then produces an analogue voltage output.

The method 300 further comprises the step 320 of passing the at least one
25 sensor 220 voltage output through a voltage-controlled oscillator 230 to produce an output signal with a frequency that is proportional to the voltage output of the at least one sensor 220.

The method 300 further comprises the step 330 of generating encoded data whereby the output of the first voltage-controlled oscillator 230 selects one
30 of two signal streams having different properties. The different properties are configured to encode for different logical states. For example, the defined logical state may be a 0 or a 1. The encoded data signal may comprise different frequencies based on the output signal of the voltage-controlled oscillator 230

such that each of the different frequencies is associated with a defined logical state.

The method 300 further comprises the step 340 of transmitting the encoded data signal 170. In the case that the projectile 120 is confined within the
5 barrel 130 of the artillery piece 110, the barrel 130 may be utilised as a waveguide to aid transmission of the encoded signal 170.

The method 300 may further comprise the step of receiving the encoded data signal by a receiver 260.

The method 300 may further comprise the step of transmitting the encoded
10 data signal 170 while the projectile 120 is located within the barrel of the artillery piece 110.

The method 300 may further comprise the step of transmitting and receiving the encoded data signal 170 while the projectile 120 is in-flight.

The method 300 may further comprise the step of transmitting the encoded
15 data signal at a first time that is live, and subsequently re-transmitting the same encoded data signal at a second time point following a delay. The method may further comprise the step of correlating the live and delayed encoded data signals to identify differences and/or errors.

Experimental work has identified that the rotational rate and orientation of
20 a fired projectile 120 can be inferred by measuring the polarisation mismatch loss at the receiving antenna when the projectile 120 is configured to emit linearly polarised microwaves. The encoded data signal 170 amplitude may be greatest when the receiving antennas are aligned, and weakest when the antennas are perpendicular to one another. Using this information may allow the angle of the
25 fired projectile 120 to be determined at a given point in time. If the projectile 120 is spin-stabilised i.e., the barrel 130 of the artillery piece 110 is rifled, this information may be related to the displacement of the projectile 120, which would negate the need for high-speed cameras when combined with velocity information from the signal's apparent Doppler shift. The acceleration of the
30 projectile 120 may then be determined by comparing this data at two points in time. It may be preferable to use circularly polarised antennas in order to obtain a more consistent signal amplitude.

Further experimental work has revealed that using a planar circuit board for low-flying direct fire can inductively couple with the ground and is capable of

causing the detuning of oscillators. This has been observed where a carrier wave that is being emitted from a rotating projectile 120, produces an oscillation in frequency (akin to frequency modulation). This may allow the angle of the shell to be determined at a position in time when outside the barrel 130 of the artillery
5 piece 110, which would negate the need for high-speed cameras when combined with velocity information from the signal's apparent Doppler shift.

CLAIMS

1. A data transmission system for use with a projectile, the projectile being arranged for firing from an artillery piece, the data transmission system comprising:
 - at least one sensor arranged to sense at least one parameter, the at least one sensor producing an analogue voltage output;
 - a first voltage-controlled oscillator, configured to produce an output having a frequency proportional to the at least one sensor's voltage output;
 - an encoder, configured to generate encoded data signal whereby the output of the first voltage-controlled oscillator selects one of two signal streams having different properties, wherein the different properties are configured to encode for different logical states; and
 - a transmitter configured to transmit the encoded data signal.
2. The data transmission system of claim 1, further comprising a receiver, wherein the receiver is arranged to be located proximal to a muzzle of a barrel of the artillery piece.
3. The data transmission system of claims 1 or 2, wherein the different properties of the two signal streams used by the encoder are based on a different frequency and/or a different phase.
4. The data transmission system of claims 1 or 2, wherein the encoder is one of a second voltage-controlled oscillator, or a direct digital synthesis driver.
5. The data transmission system of any preceding claim, wherein the at least one sensor is at least one analogue sensor.
6. The data transmission system of any preceding claim, wherein the at least one sensor is configured to measure at least one of acceleration, pressure, rotation, strain, temperature, and magnetic field.

7. The data transmission system of any preceding claim, wherein a barrel of the artillery piece is configured to act as a waveguide for the transmitter.
- 5 8. A method of transmitting data using a data transmission system for use with a projectile, the projectile being arranged for firing from an artillery piece, comprising the steps of:
- detecting information, via at least one sensor, related to at least one parameter and producing a sensor voltage output from the at least one sensor;
- 10 passing the sensor voltage output through a first voltage-controlled oscillator to produce an output signal with a frequency proportional to the sensor voltage output;
- generating encoded data, whereby the output of the first voltage-controlled oscillator selects one of two signal streams having different
- 15 properties,
- wherein the different properties are configured to encode for different logical states; and
- transmitting the encoded data signal.
- 20 9. The method of transmitting data of claim 8, further comprising the step of receiving the encoded data signal, by a receiver.
10. The method of transmitting data of claim 9, wherein the encoded data signal is transmitted and received while the projectile is located within the
- 25 barrel of the artillery piece.
11. The method of transmitting data of claim 9, wherein the encoded data signal is transmitted and received while the projectile is in-flight.
- 30 12. The method of transmitting data of claim 9, wherein the transmitter is configured to transmit the encoded data signal live and then re-transmit the same encoded data signal following a delay.

13. The method of transmitting data of claim 12, comprising the step of receiving and correlating the encoded data signals sent live and after the delay to identify differences and/or errors.
- 5 14. The method of transmitting data of claim 9, further comprising the step of decoding the received encoded data signal by means of a Fast Fourier Transform.
- 10 15. The method of transmitting data of claim 11, further comprising the step of inferring the rotational rate and orientation of the fired projectile by measuring a polarisation mismatch loss at the receiver.
- 15 16. The method of transmitting data of claim 15, wherein an angle of the shell is determined at a position in time when the projectile is located outside of the barrel of the artillery piece based on an oscillation in a frequency of a carrier wave emitted from the projectile.

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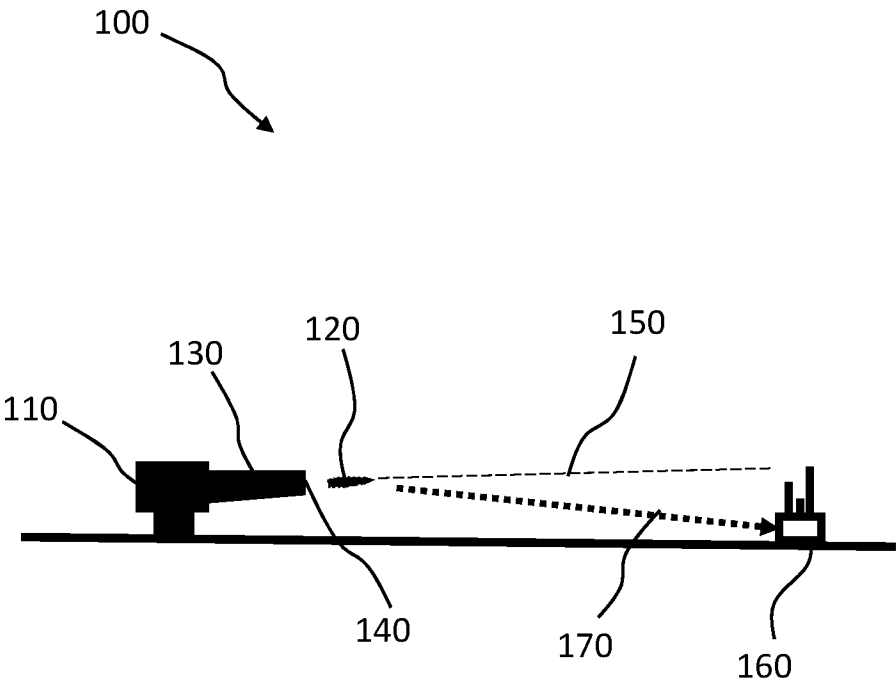


Figure 1

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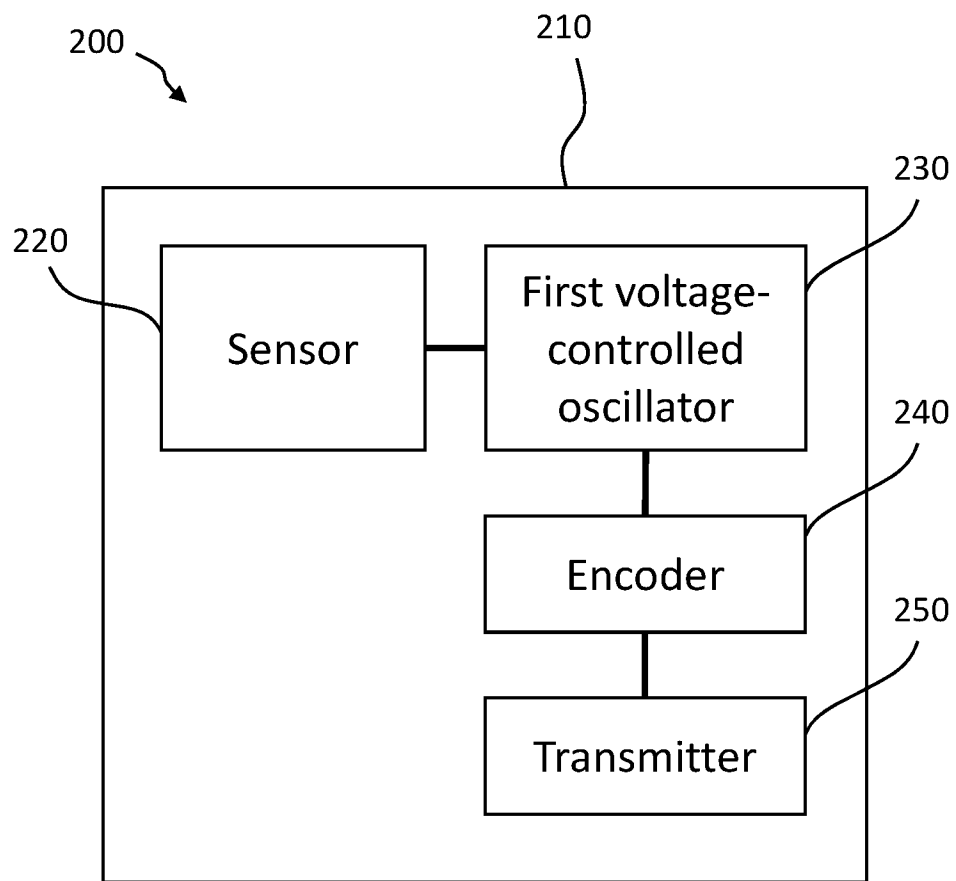


Figure 2

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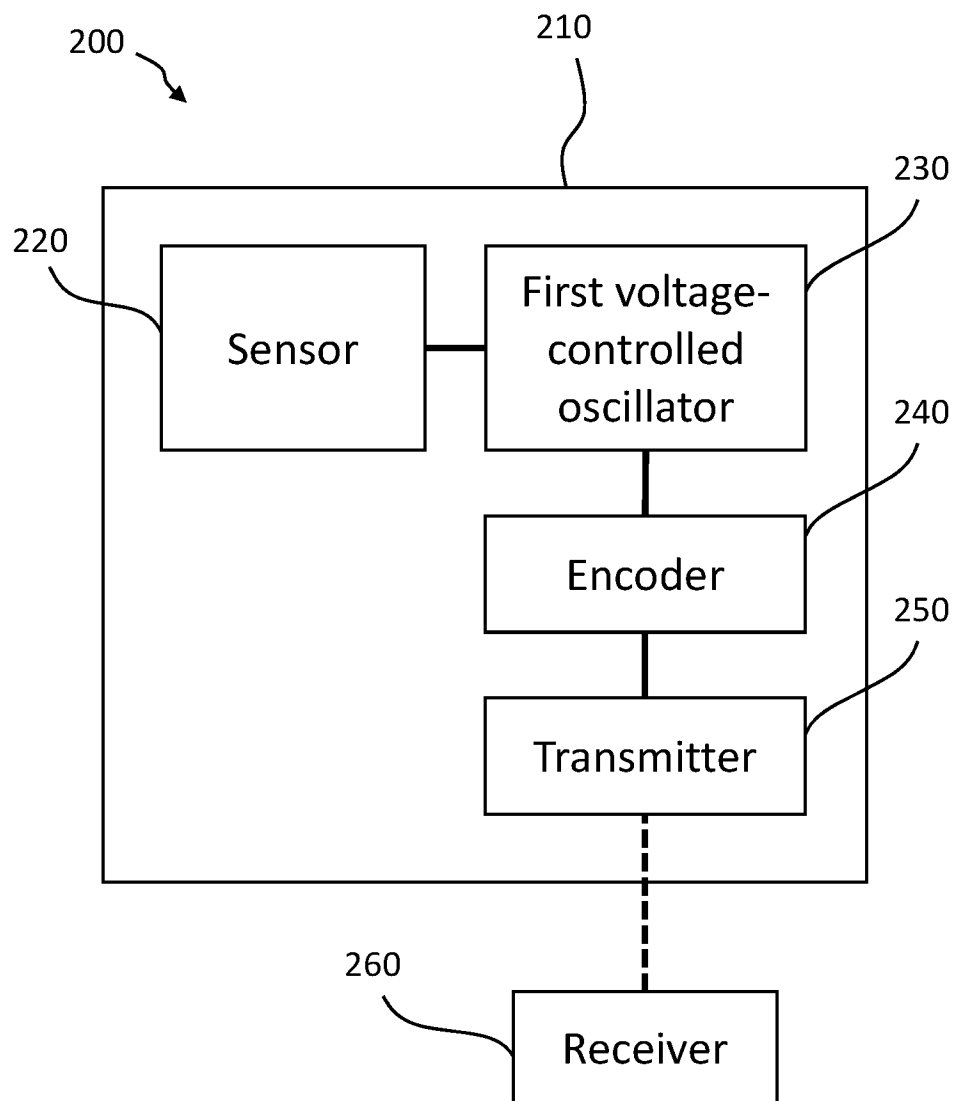


Figure 3

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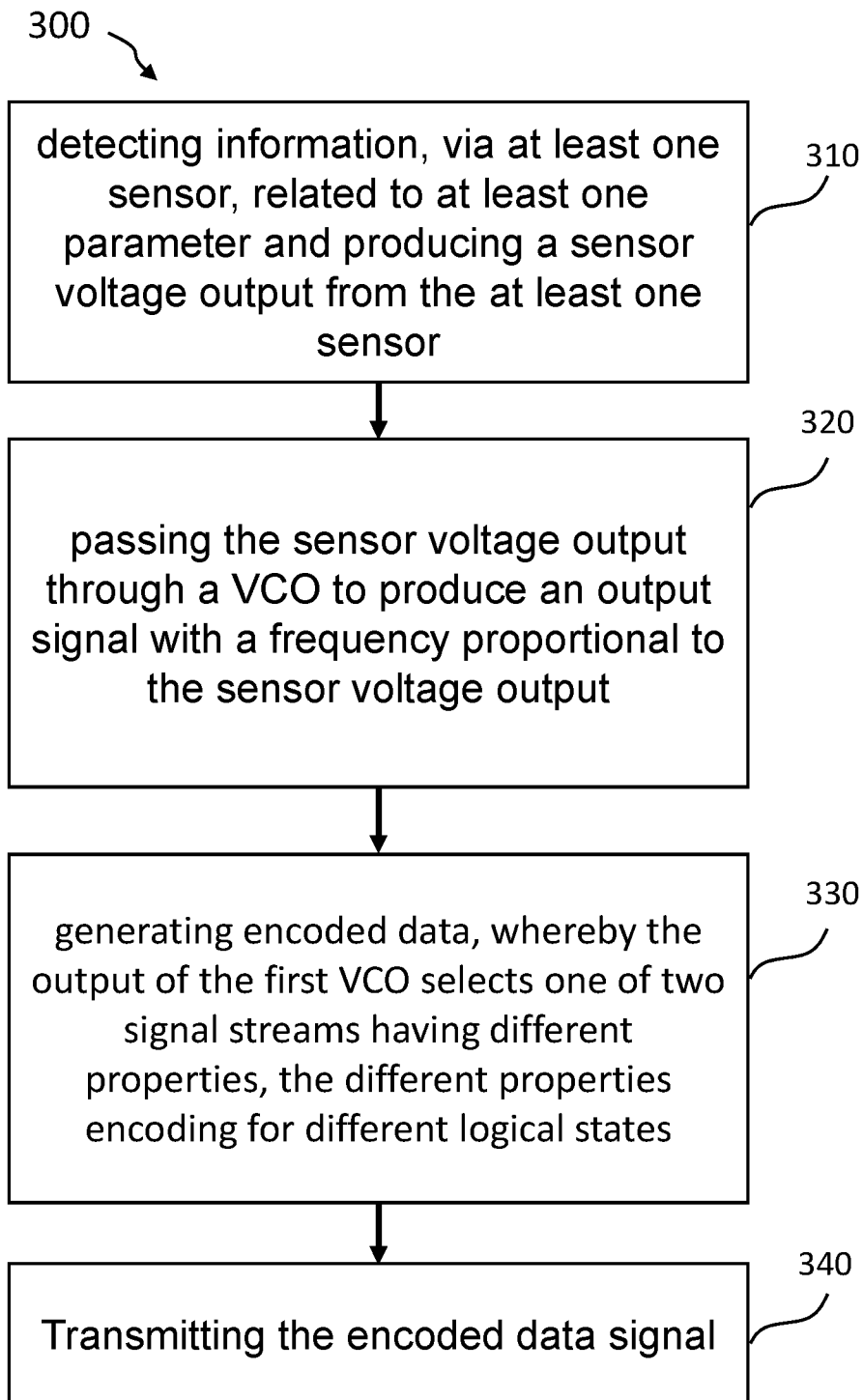


Figure 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2024/051375

A. CLASSIFICATION OF SUBJECT MATTER INV. F42B12/36 ADD. F42B30/00		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) F42B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 108 955 427 A (UNIT 63850 OF PLA) 7 December 2018 (2018-12-07) the whole document -----	1 - 16
A	US 2010/107915 A1 (GESWENDER CHRIS E [US] ET AL) 6 May 2010 (2010-05-06) paragraphs [0022] - [0026]; figures 1-4 -----	1 - 16
A	US 7 600 421 B1 (HOLLIS MICHAEL [US] ET AL) 13 October 2009 (2009-10-13) column 2, line 54 - column 3, line 12 column 3, line 43 - line 47 column 3, line 57 - column 4, line 10 figures 1,3,4 ----- - / - -	1 - 16
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 7 August 2024		Date of mailing of the international search report 13/09/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Seide, Stephan

INTERNATIONAL SEARCH REPORT

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PCT/GB2024/051375

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 349 652 B1 (HEPNER DAVID J [US] ET AL) 26 February 2002 (2002-02-26) column 2, line 43 - column 3, line 30 column 4, line 25 - line 51 figures 1-4 -----	1 - 16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2024/051375

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
CN 108955427	A	07-12-2018	NONE	
US 2010107915	A1	06-05-2010	NONE	
US 7600421	B1	13-10-2009	NONE	
US 6349652	B1	26-02-2002	NONE	