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Description

FIELD OF THE INVENTION

[0001] The invention relates to the field of apparatuses and components thereof, for effecting blasting of rock, which employ wireless communication, and methods of blasting employing such apparatuses and components thereof.

BACKGROUND TO THE INVENTION

[0002] In mining operations, the efficient fragmentation and breaking of rock by means of explosive charges demands considerable skill and expertise. In most mining operations explosive charges, including boosters, are placed at predetermined positions near or within the rock. The explosive charges are then actuated via detonators having predetermined time delays, thereby providing a desired pattern of blasting and rock fragmentation. Traditionally, signals are transmitted to the detonators from an associated blasting machine via non-electric systems employing low energy detonating cord (LEDC) or shock tube. Alternatively, electrical wires may be used to transmit more sophisticated signals to and from electronic detonators. For example, such signaling may include ARM, DISARM, and delay time instructions for remote programming of the detonator firing sequence. Moreover, as a security feature, detonators may store firing codes and respond to ARM and FIRE signals only upon receipt of matching firing codes from the blasting machine. Electronic detonators can be programmed with time delays with an accuracy of 1ms or less.

[0003] The establishment of a wired blasting arrangement involves the correct positioning of explosive charges within boreholes in the rock, and the proper connection of wires between an associated blasting machine and the detonators. The process is often labour intensive and highly dependent upon the accuracy and conscientiousness of the blast operator. Importantly, the blast operator must ensure that the detonators are in proper signal transmission relationship with a blasting machine, in such a manner that the blasting machine at least can transmit command signals to control each detonator, and in turn actuate each explosive charge. Inadequate connections between components of the blasting arrangement can lead to loss of communication between blasting machines and detonators, and therefore increased safety concerns. Significant care is required to ensure that the wires run between the detonators and an associated blasting machine without disruption, snagging, damage or other interference that could prevent proper control and operation of the detonator via the attached blasting machine.

[0004] Wireless blasting systems offer the potential for circumventing these problems, thereby improving safety at the blast site. By avoiding the use of physical connections (e.g. electrical wires, shock tubes, LEDC, or optical cables) between detonators, and other components at the blast site (e.g. blasting machines) the possibility of improper set-up of the blasting arrangement is reduced. Another advantage of wireless blasting systems relates to facilitation of automated establishment of the explosive charges and associated detonators at the blast site. This may include, for example, automated detonator loading in boreholes, and automated association of a corresponding detonator with each explosive charge, for example involving robotic systems. This would provide dramatic improvements in blast site safety since blast operators would be able to set up the blasting array from entirely remote locations. However, such systems present formidable technological challenges, many of which remain unresolved. One obstacle to automation is the difficulty of robotic manipulation and handling of blast apparatus components at the blast site, particularly where the components require tieing-in or other forms of hook up to electrical wires, shock tubes or the like. Wireless communication between components of the blasting apparatus may help to circumvent such difficulties, and are clearly more amenable to application with automated mining operations.

[0005] Progress has been made in the development of apparatuses and components for establishment of a wireless blasting apparatus at a blast site. Nonetheless, existing wireless blasting systems still present significant safety concerns, and improvements are required if wireless blasting systems are to become a more viable alternative to traditional "wired" blasting systems.

[0006] WO 2001/059401 discloses a wireless detonator system wherein a blast initiation signal emanating from a programmable controller is broadcast to individual, remote programmable detonators associated with specific explosive charges. The controller communicates with a programmable RF base transceiver. Upon interpreting the blast initiation signal, the RF base transceiver broadcasts instructions to the detonators. By assigning a single sacrificial detonator to a single charge, a timed blast sequence may be created without the need for time consuming and expensive hand wiring of the charges. However, the system relies on a cable and network infrastructure to carry signals from the controller underground to the base transceiver. Furthermore, the underground wireless connection between the transceiver and the detonators is only suitable in line of sight situations and over a distance up to about 1.6 km.

[0007] US 4,685,396 is directed to the firing of ignition elements by means of remotely generated control signals, particularly to remote control firing systems wherein there is no fixed signal transmission line such as wire or explosive fuse-cord over at least part of the distance between the control site and the ignition elements, for example in blasting detonators used to detonate blasting explosives in rock blasting operations. In this arrangement, the sequential firing of a series of ignition elements is effected by transmitting a timed series of firing control signals to the ignition elements, the signal discriminator
means of each ignition element being arranged to count the firing control signals and to identify predetermined signals of said timed series as the first and second characteristic firing control signals for that particular ignition element.

SUMMARY OF THE INVENTION

[0008] It is an object of the present invention, at least in preferred embodiments, to provide a method of blasting through wireless communication with blast apparatus components such as wireless detonator assemblies and/or wireless booster assemblies.

[0009] It is another object of the present invention, at least in preferred embodiments, to provide a method of synchronizing wireless detonator assemblies and/or wireless electronic boosters for timed actuation of explosive charges associated therewith.

[0010] It is another object of the present invention, at least in preferred embodiments, to provide a blasting apparatus, or a blasting component, suitable for use in achieving timed actuation of explosive charges.

[0011] In one aspect the present invention provides a method for communication between at least one blasting machine of a blasting apparatus and at least one blasting component of the blasting apparatus as specified in the claims.

[0012] It should be noted that the methods of the present invention may be employed to control any type of blasting component, or device forming part of a blasting apparatus, adapted to receive wireless calibration and/or command signals from a remote source such as a blasting machine. The methods may be adapted, at least in selected embodiments, for use in mining operations involving below-ground placement of blasting components. However, the methods may be equally useful for above-ground mining operations for example involving the use of wireless detonator assemblies such as those taught in WO2006/047823 published May 11, 2006.

[0013] In the case of underground mining operations, the methods of the present invention may involve the use of wireless electronic boosters, or wireless booster assemblies, such as those disclosed for example in pending United States patent application 60/795,569 filed April 28, 2006 entitled "Wireless electronic booster, and methods of blasting".

[0014] The invention further encompasses, in a further aspect, a blasting apparatus and a blasting component as specified in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Figure 1 schematically illustrates a preferred method of the present invention.

DEFINITIONS:

[0016] Activation signal: any signal transmitted by any component of a blasting apparatus that causes blasting components to become active components of the blasting apparatus. Typically, in selected embodiments the blasting components may be in an inactive state, but "listen-up" periodically to check whether they can receive an activation signal. In the absence of receipt of such an activation signal the blasting components may fall back into an inactive state. However, upon successful receipt of an activation signal, for example transmitted to all blasting components at a blast site by for example a blasting machine, the blasting components may effectively be caused to "wake-up" fully, and hence become a fully active and fully functioning component of the blasting apparatus.

[0017] Active power source: refers to any power source that can provide a continuous or constant supply of electrical energy. This definition encompasses devices that direct current such as a battery or a device that provides a direct or alternating current. Typically, an active power source provides power to a command signal receiving and/or processing means, to permit reliable reception and interpretation of command signals derived from a blasting machine.

[0018] Automated / automatic blasting event: encompasses all methods and blasting systems that are amenable to establishment via remote means for example employing robotic systems at the blast site. In this way, blast operators may set up a blasting system, including an array of detonators and explosive charges, at the blast site from a remote location, and control the robotic systems to set-up the blasting system without need to be in the vicinity of the blast site.

[0019] Base charge: refers to any discrete portion of explosive material in the proximity of other components of the detonator and associated with those components in a manner that allows the explosive material to actuate upon receipt of appropriate signals from the other components. The base charge may be retained within the main casing of a detonator, or alternatively may be located nearby the main casing of a detonator. The base charge may be used to deliver output power to an external explosives charge to initiate the external explosives charge.

[0020] Blasting component: refers to any device that can receive one or more command signals from an associated blasting machine, process those signals, and if
Blasting machine: any device that is capable of...
the type that is well known, for example in conventional quartz watches and timing devices. Crystal clocks may provide particularly accurate timing in accordance with preferred aspects of the invention. Under specific conditions, however, some clocks such as crystal clocks may be fragile and prone to breakage during use especially if the clock is exposed to blasting forces. Therefore, in preferred embodiments a clock may be protected in a protective shell or casing. Alternatively, a different type of clock may be used that is more robust, and many such clocks are known in the art. For example, simple robust clocks may include for example a simple RC circuit of a type that is known in the art, comprising a resistor and a capacitor. In other embodiments, a clock may form an integral feature of an integrated circuit such as a programmable integrated circuit (PIC) or an application specific integrated circuit (ASIC). Furthermore, such an integrated circuit may for part of, or form, a state machine for any part of a blasting apparatus as described herein, such as a blasting component. In this way, the clock either independently or in combination with processed incoming signals, may cause the blasting component to adopt specific pre-determined states for normal functioning of the blasting apparatus. A 'master clock' refers to any clock as described herein, that furthermore has been designated as the clock to which all other clocks are synchronized either once or more than once during operation of the methods and apparatuses of the invention. For example, a master clock may communicate with another clock either by direct electrical contact (e.g. prior to placement of a blasting component comprising another clock at the blast site), via short-range wireless communication with the other clock (e.g. prior to placement of as blasting component comprising another clock at the blast site), via longer range wireless communication (e.g. after placement of a blasting component comprising another clock at the blast site) or preferably via LF radio waves (e.g. after placement of a blasting component comprising a clock underground at the blast site).

[0028] Clock synchronization signal / further clock synchronization signal: refers to any signal transmitted by a master clock to one or more other components of a blasting apparatus that itself includes a clock, such that receipt and processing of the signal by the other component causes synchronization of its internal clock with the master clock. Typically, but not necessarily, a clock synchronization signal may be a first such signal transmitted by a master clock to achieve initial calibration and / or synchronization of a clock with the master clock. In contrast, a "further" clock synchronization signal refers to any clock synchronization signal subsequent to the initial clock synchronization signal for use e.g. in re-synchronization of clocks to the master clock to correct ‘drift’. A further clock synchronization signal (or a time taken relative to a further clock synchronization signal) may also be designated by a blasting component as a "time zero" to begin counting down a pre-programmed delay time, providing a command signal to FIRE is received by the blasting compo-

[0029] Delineation means: refers to any component that is able to delineate or otherwise decipher the presence of oscillations (or portions thereof) of a calibration signal from all other information, signals, or noise received by a transceiver or receiver. For example, transmission of a calibration signal at a blast site may be carried out via wired or wireless signal transmission over ground, through or around surface objects, or through layers of the ground such as rock. Such signals may be prone to interference, noise, unwanted signal reflections / refractions etc. all of which may contribute to extraneous signals and noise over and above the calibration signal being broadcast. A delineation means aims to aid in the receipt, extraction, and processing of a calibration signal through modification of the received signals and noise. For example, a delineation means may optionally include one or more filters to filter wavelengths or frequencies of received energy other than those expected for the calibration signal, and optionally may include one or more amplifiers to amplify selected portions (e.g. selected frequencies or wavelengths) of received energy. In this way, the calibration signal may be better differentiated from received background noise, extraneous noise, and other signals. Other features and / or components of a delineation means will be apparent to the skilled artisan, and delineation means may include any of such other features and / or components as required to achieve the desired result of delineation of the calibration signal.

[0030] Electromagnetic energy: encompasses energy of all wavelengths found in the electromagnetic spectra. This includes wavelengths of the electromagnetic spectrum division of γ-rays, X-rays, ultraviolet, visible, infrared, microwave, and radio waves including UHF, VHF, Short wave, Medium Wave, Long Wave, VLF and ULF. Preferred embodiments use wavelengths found in radio, visible or microwave division of the electromagnetic spectrum.

[0031] Explosive charge: includes a discreet portion of an explosive substance contained or substantially contained within a booster. The explosive charge is typically of a form and sufficient size to receive energy derived from the actuation of a base charge of a detonator, thereby to cause ignition of the explosive charge. Where the explosive charge is located adjacent or near to a further quantity of explosive material, such as for example explosive material charged into a borehole in rock, then the ignition of the explosive charge may, under certain circumstances, be sufficient to cause ignition of the entire quantity of explosive material, thereby to cause blasting
forms of energy: in accordance with the art.

[0032] Explosive material: refers to any quantity and type of explosive material that is located outside of a booster, but which is in operable association with the booster, such that ignition of the explosive charge within the booster causes subsequent ignition of the explosive material. For example, the explosive material may be located or positioned down a borehole in the rock, and a booster may be located in operative association with the explosive material down or near to the borehole. In preferred embodiments the explosive material may comprise pentolite or TNT.

[0033] Filtering: refers to any known filtering technique for filtering received signal information from noise such as background noise or interference. Is selected examples filtering may employ a device for excluding signals having a frequency outside a predetermined range. In preferred embodiments the filter may be, for example, a band pass filter. However, other filters and filtering techniques may be used in accordance with any methods or apparatuses of the invention. The filter may be passive, active, analog, digital, discrete-time (sampled), continuous-time, linear, non-linear or of any other type known in the art.

[0034] Forms of energy: In accordance with the present invention, "forms" of energy may take any form appropriate for wireless communication and/or wireless charging of the detonators. For example, such forms of energy may include, but are not limited to, electromagnetic energy including light, infrared, radio waves (including ULF), and microwaves, or alternatively make take some other form such as electromagnetic induction or acoustic energy. In addition, "forms" of energy may pertain to the same type of energy (e.g. light, infrared, radio waves, microwaves etc.) but involve different wavelengths or frequencies of the energy.

[0035] "Keep alive" signal: refers to any signal originating from a blasting machine and transmitted to a blasting component, either directly or indirectly (e.g. via other components or relayed via other wireless detonator assemblies), that causes a charge storage device to be charged by a power source and/or to retain charge already stored therein. In this way, the charge storage device retains sufficient charge so that upon receipt of a signal to FIRE, the charge is discharged into the firing circuit to cause a base charge associated with the firing circuit to be actuated. The "keep alive" signal may comprise any form of suitable energy identified herein. Moreover, the "keep alive" signal may be a constant signal, such that the wireless detonator assembly is primed to FIRE at any time over the duration of the signal in response to an appropriate FIRE signal. Alternatively, the "keep alive" signal may comprise a single signal to prime the wireless detonator assembly to FIRE at any time during a predetermined time period in response to a signal to FIRE. In this way, the blasting component may retain a suitable status for firing upon receipt of a series of temporally spaced "keep alive" signals.

[0036] Logger / Logging device: includes any device suitable for recording information with regard to a blasting component, or a detonator contained therein. For example, the logger may transmit or receive information to or from a blasting component of the invention or components thereof. For example, the logger may transmit data to a blasting component such as, but not limited to, blasting component identification codes, delay times, synchronization signals, firing codes, positional data etc. Moreover, the logger may receive information from a blasting component including but not limited to, blasting component identification codes, firing codes, delay times, information regarding the environment or status of the blasting component, information regarding the capacity of the blasting component to communicate with an associated blasting machine (e.g. through rock communications). Preferably, the logging device may also record additional information such as, for example, identification codes for each detonator, information regarding the environment of the detonator, the nature of the explosive charge in connection with the detonator etc. In selected embodiments, a logging device may form an integral part of a blasting machine, or alternatively may pertain to a distinct device such as for example, a portable programmable unit comprising memory means for storing data relating to each detonator, and preferably means to transfer this data to a central command station or one or more blasting machines. One principal function of the logging device, is to read the blasting component so that the blasting component or detonator contained therein can be "found" by an associated blasting machine, and have commands such as FIRE commands directed to it as appropriate. A logger may communicate with a blasting component either by direct electrical connection (interface) or a wireless connection of any type known in the art, such as for example short range RF, infrared, Bluetooth etc.

[0037] Micro-nuclear power source: refers to any power source suitable for powering the operating circuitry, communications circuitry, or firing circuitry of a detonator or wireless detonator assembly according to the present invention. The nature of the nuclear material in the device is variable and may include, for example, a tritium based battery.

[0038] Passive power source: includes any electrical source of power that does not provide power on a continuous basis, but rather provides power when induced to do so via external stimulus. Such power sources include, but are not limited to, a diode, a capacitor, a rechargeable battery, or an activatable battery. Preferably, a passive power source is a power source that may be charged and discharged with ease according to received energy and other signals. Most preferably the passive power source is a capacitor.

[0039] Power supply (without recitation of the power of the rock. The chemical constitution of the explosive charge may take any form that is known in the art, most preferably the explosive charge may comprise TNT or pentolite.
source being an 'active power source' or a 'passive power source'); refers to a power supply that is capable of supplying a fairly constant supply of electrical power, or at least can provide electrical power as and when required by connected components. For example, such power supplies may include but are not limited to a battery.

Preferably: identifies preferred features of the invention. Unless otherwise specified, the term preferably refers to preferred features of the broadest embodiments of the invention, as defined for example by the independent claims, and other inventions disclosed herein.

Reference times / Further reference times: refers to points in the oscillation of a received signal, such as a low frequency radio signal, more readily calculated by a blasting component of a blasting apparatus of the present invention. For example, such a blasting component may receive an incoming wireless calibration signal (e.g. through rock) from a blasting machine, optionally amplify and/or filter the signal, and determine zero-crossings for the signal, which form the reference times for time calibration. In selected embodiments, further reference times may be calculated from the reference times by determining time points between the reference times, thereby to increase the temporal resolution of the calibration signal.

Time zero: refers to any time from which a delay time pre-programmed into a blasting component begins counting down, such that completion of the count down results in actuation of a base charge of an integrated detonator, and optionally actuation of an associated explosive charge. In accordance with the methods and apparatuses of the invention, a time zero may be established in a synchronous or substantially synchronous manner between blasting components so that pre-programmed delay times can be counted down from a synchronized or substantially synchronized start time (time zero), thereby permitting timed actuation of a blasting event. Typically, but not necessarily, a time zero may coincide with receipt of a further clock synchronization signal, or another time relative to a clock synchronization signal.

Top-box: refers to any device forming part of a blasting component that is adapted for location at or near the surface of the ground when the blasting component is in use at a blast site in association with a bore-hole and explosive charge located therein. Top-boxes are typically located above-ground or at least in a position in, at or near the borehole that is more suited to receipt and transmission of wireless signals, and for relaying these signals to the detonator down the borehole. In preferred embodiments, each top-box comprises one or more selected components of the blasting component of the present invention.

Transceiver: refers to any device that can receive and/or transmit wireless signals. Although the term "transceiver" traditionally encompasses a device that can both transmit and receive signals, a transceiver when used in accordance with the present invention includes a device that can function solely as a receiver of wireless signals, and not transmit wireless signals or which transmits only limited wireless signals. For example, under specific circumstances the transceiver may be located in a position where it is able to receive signals from a source, but not able to transmit signals back to the source or elsewhere. In very specific embodiments, where the transceiver forms part of a booster located underground, the transceiver may be able to receive signals through-rock from a wireless source located above a surface of the ground, but be unable to transmit signal back through the rock to the surface. In these circumstances the transceiver optionally may have the signal transmission function disabled or absent. In other embodiments, the transceiver may transmit signals only to a logger via direct electrical connection, or alternatively via short-range wireless signals. In other embodiments, a transceiver may comprise a memory for storing a delay time, and may be programmable with a delay time (this is especially useful when the detonator and components thereof are not programmable, as may be the case for example with a non-electric electric, or selected pyrotechnic detonator.

Wireless: refers to there being no physical wires (such as electrical wires, shock tubes, LEDC, or optical cables) connecting the detonator or a blasting component, or components thereof to an associated blasting machine or power source.

Wireless booster: In general the expression "wireless booster" or "electronic booster" encompasses a device comprising a detonator, most preferably an electronic detonator (typically comprising at least a detonator shell and a base charge) as well as means to cause actuation of the base charge upon receipt by the booster of a signal to FIRE from at least one associated blasting machine. For example, such means to cause actuation may include a transceiver or signal receiving means, signal processing means; and a firing circuit to be activated in the event of a receipt of a FIRE signal. Preferred components of the wireless booster may further include means to transmit information regarding the assembly to other assemblies or to a blasting machine, or means to relay wireless signals to other components of the blasting apparatus. Such means to transmit or relay may form part of the function of the transceiver. Other preferred components of a wireless booster will become apparent from the specification as a whole.

Zero crossing(s): refers to an instantaneous point at which, for a sine wave, the y-value = zero. In a sine wave or other simple waveform, this normally occurs twice during each cycle. In the case of the present invention, such a sine wave may be derived from a calibration signal in the form of a low frequency radio wave, wherein the zero-crossings occur at the beginning and half-way points of each oscillation in the cycle. However, zero-crossings are not limited to sine-waves. It should be noted that zero-crossings may also be determined under circumstances, for example, where frequency-shift key
modulation generates a binary signal transmission, where zero-crossing analysis may facilitate determination of frequency shifts in the received signal.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0048] The inventors have succeeded in the development of methods for controlling, and optionally calibrating or synchronizing, components of a blasting apparatus that communicate with a blasting machine via wireless communication signals. In selected embodiments, the methods are especially useful for underground mining operations, where wireless electronic boosters positioned underground communicate with one or more blasting machines positioned at or above a surface of the ground. Such wireless electronic boosters are described, for example, in co-pending United States provisional application 60/795,569 filed April 28, 2006 entitled "Wireless electronic booster, and methods of blasting".

[0049] Wireless blasting systems help circumvent the need for complex wiring between components of a blasting apparatus at the blast site, and the associated risks of improper placement, association and connection of the components of the blasting system.

[0050] Through careful investigation, and significant inventive ingenuity, the inventors have developed methods for communicating with and controlling blasting components such as wireless detonator assemblies, or wireless booster assemblies, via wireless communication signals. Such wireless communication signals may include, but are not limited to, command signals derived for example from a blasting machine, as well as calibration signals derived for example from a blasting machine or another component of a blasting apparatus. Most preferably, the methods allow for the control of, and actuation of explosive charges associated with, wireless electronic boosters and wireless booster assemblies located below ground. In this way, wireless through-rock transmission of signals may be achieved. Such as wireless electronic booster is described, for example, in co-pending United States Patent application 60/795,569 filed April 28, 2006 entitled "Wireless electronic booster, and methods of blasting". For example, such a device may include:

- a detonator comprising a firing circuit and a base charge;
- an explosive charge in operative association with the detonator, such that actuation of the base charge via the firing circuit causes actuation of the explosive charge;
- a transceiver for receiving and processing the at least one wireless command signal from the blasting machine, the transceiver in signal communication with the firing circuit such that upon receipt of a command signal to FIRE the firing circuit causes actuation of the base charge and actuation of the explosive charge.

[0051] The present invention encompasses, at least in part, methods of communication between at least one blasting machine of a blasting apparatus, and at least one other component of a blasting apparatus which comprises, or is in operative association with, an explosive charge or quantity of explosive material. Such blasting components may include, but are not limited to, wireless detonator assemblies or wireless booster assemblies. Such wireless detonator assemblies are described, for example, in WO2006/096920 published September 21, 2006.

[0052] Such wireless booster assemblies are described for example in United States patent application 60/795,569 filed April 28, 2006 entitled "Wireless electronic booster, and methods of blasting".

[0053] The methods may involve transmitting from the at least one blasting machine at least one command signal. For example, such command signals may be selected from, but are not limited to, signals to ARM, DISARM, FIRE, ACTIVATE, or DEACTIVATE the blasting component. In preferred embodiments, the wireless signals are transmitted using low frequency radio waves, such as those having a frequency in the range of 20-2500 Hz. In this way, the signals may optionally be transmitted through the ground, through rock or other media and successfully be received and delineated by a blasting component.

[0054] In preferred embodiments, the wireless signals may be modulated via any known technique prior to their transmission, and upon receipt by a blasting component may be demodulated. As is known in the art, such signal processing may help the blasting component to delineate each signal from background noise, or interference caused for example by through rock or through water signal transmission. In other aspects, filters may also be used to reduce a level of noise from received signals. For example, such filters where present may extract only those signals having a frequency that falls within a predetermined range. Increased levels of radio-noise may also be experienced for frequencies of around 50Hz and harmonics thereof, due in part to the local use of electrical equipment operating with a 50Hz A/C current. Optionally, operating frequencies and filters may be employed to avoid such noise-prone frequency ranges.

[0055] In other aspects, the wireless command signals may be transmitted using frequency shift key (FSK) modulation techniques that are well known in the art. FSK is a well known technique for modulating data that uses two frequencies. Frequency shifts between the two frequencies are generated when the binary digital level changes. One particular frequency is used to represent a binary one, and a second frequency is used to indicate a binary zero. Such modulation techniques are especially useful in accordance with the present invention for through-rock wireless signal transmission. For example, more complex wireless command signals such as delay
times may be amenable to through rock transmission using FSK modulation. The binary nature of the received FSK modulated signal may be easier to extract and interpret from signal data received through-rock in comparison to a non-FSK modulated analogue signal.

In preferred embodiments of the methods of the invention, the radio signals comprise 20-2500 Hz, more preferably 100-2000 Hz, more preferably 200-1200 Hz most preferably about 300 Hz. The radio-wave frequency will be selected on the basis of rock penetration and noise considerations. Broadly speaking, lower frequencies will give rise to greater rock penetration. However, very low frequency signals will be limited in terms of complexity, and require very large and expensive transmitters to produce the corresponding radio waves.

In other embodiments of the methods of the invention, each of the blasting components of the blasting apparatus may include a clock, preferably a crystal clock, and a memory for storing a delay time. The clock and memory may optionally form an integral part of an electronic detonator forming part of the blasting component, or may be located elsewhere in the blasting component. The methods of the invention, in selected embodiments, further provide a mechanism for clock calibration and synchronization, even under circumstances where the blasting components are located underground. The blasting machine or any other component of the blasting apparatus located on or near a surface of the ground may transmit to the blasting components a calibration signal preferably comprising LF radio waves in the range of 20-2500 Hz. Following receipt of the calibration signal, each blasting component may analyze the received signal to delineate from the signal reference times for the signal oscillation. Preferably, such reference times may include zero-crossings for the signal, with two zero-crossings for each period (one at the beginning, and one halfway through, an oscillation). In effect, these reference points may serve to provide a "ticking clock" allowing for calibration of each clock or crystal clock of each blasting component.

Often, the blasting components may comprise electronic delay detonators capable of being programmed with delay times of 1ms or less. However, at very low frequencies, zero-crossing reference points may not provide sufficient temporal resolution to allow for delay time programming and synchronization down to 1ms or less. For example, if the calibration signal has a frequency of 30 Hz, there will be only 60 zero-crossings per second, providing a resolution of 1 zero-crossing every 16.67 ms. In other words, the use of a calibration signal having a 30 Hz carrier frequency may provide excellent rock penetration, but on the basis of zero-crossing may provide insufficient temporal resolution for the purposes of clock calibration and delay times. In accordance with preferred aspects of the present invention there are provided further methods for increasing the temporal resolution of the calibration signal. This may be achieved by calculating further reference times between the zero-crossing reference times. In the case of a radio frequency of 30 Hz, each average time spacing between zero-crossing may be equally divided, for example, into 20 equal portions to provide a temporal resolution in the order of 16.67 ms / 20 = 0.838 ms - less than one millisecond. Therefore, the present invention encompasses methods that allow for analysis of a calibration signal by analyzing not only easily attainable reference points (such as zero-crossings), but also further reference points therebetween. In this way, the methods allow for clock calibration and synchronization down to a temporal resolution that at least matches or exceeds the accuracy of electronic detonators known in the art.

In further embodiments of the methods of the invention, there are provided methods of blasting rock using a blasting apparatus comprising at least one blasting machine located on or above a surface of the ground for transmitting at least one wireless command signal and at least one blasting component located below a surface of the ground for receiving and optionally acting upon the at least one wireless command signal. Each blasting component may comprise a clock as well as a memory for storing a programmed delay time, and be in operable association with an explosive charge or quantity of explosive material. The steps of the preferred method may include:

- transmitting through rock from each blasting machine or another component of the blasting apparatus a calibration signal having a LF radio wave carrier frequency of from 20-2500 Hz;
- receiving though rock the calibration signal by each blasting component;
- processing the received calibration signal by:
  - optionally filtering the calibration signal;
  - determining from the calibration signal reference times such as zero-crossing times; and
  - optionally calculating further reference times between the reference times thereby to establish a synchronized clock count for each blasting component;
- transmitting through rock at least one command signal having a LF radio wave frequency of from 20-2500 Hz other than the frequency of the calibration signal;
- receiving through rock the at least one command signal by each blasting component; and
- processing the received at least one command signal and acting upon the at least one command signal as required.

If the at least one command signal includes a signal to FIRE, each clock of each blasting component establishes a synchronized time zero and counts down from the synchronized time zero its own programmed delay time, thereby to effect timed actuation of each ex-
The invention encompasses methods in which explosive charge associated with each blasting component, thereby to achieve a desired blasting pattern. In spite of their placement below ground, the blasting components may be optionally programmed with delay times, and the clock may be calibrated and/or synchronized to count down those delay times in response to a command signal to FIRE, all through remote communication with a blasting machine or other devices located above ground.

[0061] The invention encompasses methods in which the blasting components are simply placed as required in underground locations at the blast site, and are subsequently programmed with delay times, firing codes, identification information, and controlled by wireless command signals from above ground after placement.

[0062] The invention also encompasses alternative methods in which the blasting components are placed as required at underground locations at the blast site, programmed in situ with, for example, delay times, firing codes, or identification information through direct electrical or short-range wireless communication with a logger or logging device. Subsequently, the blasting components receive only wireless command signals from an associated blasting machine above ground. This may be especially useful where, for example, there is significant interference in preventing clear through-rock transmission of more complex signals, such as those to program delay times, firing codes, identification information etc. to the blasting components.

[0063] It should be noted that the methods of the present invention may be employed to control any type of blasting component, or device forming part of a blasting apparatus, adapted to receive wireless calibration and/or command signals from a remote source such as a blasting machine. The methods may be adapted, at least in selected embodiments, for use in mining operations involving below-ground placement of blasting components. However, the methods may be equally useful for above-ground mining operations for example involving the use of wireless detonator assemblies such as those taught in WO2006/047823 published May 11, 2006.

[0064] In the case of underground mining operations, the methods of the present invention may involve the use of wireless electronic boosters, or wireless booster assemblies, such as those disclosed for example in co-pending United States patent application 60/795,569 filed April 28, 2006 entitled ”Wireless electronic booster, and methods of blasting”

[0065] The invention will further be described with reference to specific examples, which are in no way intended to be limiting with respect to the appended claims:

EXAMPLE 1 - Method for communication between components of a blasting apparatus

[0066] A preferred method of the invention will be described with reference to Figure 1. In this method there is provided a method of communicating at least one wireless command signal from at least one blasting machine to at least one blasting component comprising or in operative association with an explosive charge. Step 100 involves the transmitting of at least one wireless command signal from the at least one blasting machine to the at least one blasting component using low frequency radio waves. In step 101 there is included the step of receiving the at least one wireless command signal by the at least one blasting component, and in step 102 each blasting component processing the received at least one wireless command signal and optionally acting upon the instructions provided in the at least one wireless command signal as required.

EXAMPLE 2 - Method involving a calibration signal

[0067] A preferred method of the invention will be described with reference to Figure 2. In this method there is provided a method for blasting rock using a blasting apparatus comprising at least one blasting machine or above a surface of the ground, for transmitting at least one wireless command signal, and at least one blasting component located below a surface of the ground for receiving and acting upon the at least one wireless command signal as required, each blasting component including or in operative association with an explosive charge and comprising a clock and a memory for storing a programmed delay time. Step 200 involves transmitting through rock from each blasting machine or another component of the blasting apparatus a calibration signal having a LF radio wave carrier frequency of from 20-2500 Hz. Step 201 involves receiving through rock the calibration signal by each blasting component. Step 202 involves processing the received calibration signal by: optionally filtering the calibration signal; determining from the calibration signal reference times such as zero-crossing times, and optionally calculating further reference times between the reference times thereby to establish a synchronized clock count for each blasting component. Step 203 involves transmitting through rock at least one command signal having a LF radio wave frequency of from 20-2500 Hz other than the frequency of the calibration signal. Step 204 involves receiving through rock the at least one command signal by each blasting component, and step 205 involves processing the received at least one command signal and acting upon the at least one command signal as required. In this way, if the at least one command signal includes a signal to FIRE, each clock of each blasting component establishes a synchronized time zero and counts down from the synchronized time zero its own programmed delay time, thereby to effect timed actuation of each explosive charge associated with each blasting component, thereby to achieve a desired blasting pattern.

EXAMPLE 3 - Binary coding of a calibration signal

[0068] As previously discussed, calibration signals for clock synchronization may be useful if time spacings be-
With reference to Figure 3, there is shown a graph of times between successive zero-crossings received by a blasting component in a test blasting system. It will be noted that for the first 35 zero-crossings detected, a time spacing of an average 48 microseconds is detected. The Figure also shows some experimentation with FSK modulation to generate a binary code for signal transmission as part of the calibration signal. For counts 38 to 43, 48 to 53, 58 to 63, and 68 to 73 a smaller time interval exists between successive zero-spacing: in this case an average time spacing of 32 microseconds is recorded. In contrast, for counts 44 to 47, 54 to 57, 64 to 67, and 74 up there is an average time interval of 48 microseconds. In this way, binary information can be integrated into the calibration signal itself. For example, in Figure 3 the counts 38 to 43 may represent a “0” in binary code, whereas the counts 44 to 47 may represent a “1” in binary code. Nonetheless the binary bits exist for the same amount of time (about 190 ms) due to the smaller time intervals for the “0” readings.

Although Figure 3 is merely exemplary, a person skilled in the art will appreciate the possible integration of command signals into a calibration signal. By altering the frequency of the calibration signal by FSK modulation, binary information may be incorporated into the “ticking clock” of the calibration signal.

EXAMPLE 4 - Radio-frequency variation with distance

Turning now to Figure 4, there is shown a graph comparing a range of radio frequencies for various through-ground signal transmissions. The graph indicates that there is an optimum frequency for any given distance (soil type remaining constant). The benefit of higher frequency in the detector is offset by the exponentially increasing attenuation due to conductivity in the ground. Other ground or rock type may give variance in these results.

EXAMPLE 5 - Method involving a master clock

A particularly preferred method of the invention will now be described with reference to Figure 5. This method extends the method described with reference to Figure 1, to provide a simple alternative means to ensure timed actuation of explosive charges with a high degree of accuracy. In this method, each of the at least one blasting component comprises a clock and a memory for storing a programmed delay time for actuation of the explosive charge, and the method further comprises:

In step 300 transmitting from a master clock, a clock synchronization signal to each of the at least one blasting component, thereby to synchronize all clocks of the at least one blasting component to the master clock; and

In step 301 establishing at least one synchronized time zero relative to transmission of the clock synchronization signal, for all clocks of the at least one blasting component. Receipt by the at least one blasting component of a command signal to FIRE, causes each of the at least one blasting component to wait for a next synchronized time zero and then count down its programmed delay time. Once the delay time has completed its countdown, the expiry of the delay time results in actuation of an associated explosive charge, thereby to effect timed actuation of each explosive charge associated with each blasting component, thereby to achieve a desired blasting pattern. In this way, the master clock functions to keep all other clocks of the blasting apparatus “in line” and synchronized. All blasting components of the blasting apparatus are ready to start a blasting sequence at the next time zero effectively specified by the master clock, so that all blasting components achieve a synchronized time zero for commencing delay time countdown.

The master clock may take any form, and be located either remote from the blast site (for example in an office of a blast operator, perhaps in another location or even another country from the blast site). Alternatively, the master clock may be located at or near the blast site, for example as an integral component of one or more blasting machines. In particularly preferred embodiments, the master clock may be suited for synchronizing the clocks of the blasting components via short range communication at the blast site, for example just prior to or following establishing of the blast apparatus through placement of the blasting components (and associated explosive charges). For example, a master clock may communicate with other components of the blast apparatus, at least for the purpose of initial synchronization, via wired or short range wireless communication. A master clock may, in selected embodiments, be associated with a blasting machine, such that blasting components are brought into close proximity with the blasting machine for clock synchronization with the master clock prior to placement at the blast site. Such a method of synchronization may be especially suited to blasting components that are to be placed underground. Alternatively, the master clock may be associated in some way with a logger device, such that a clock of each blasting component is synchronized with the master clock of the logging device after placement at the blast site, for example during a logging process.

The method of the present example is especially suited for underground explosive operations. Through rock communication typically involves the use of low fre-
EXAMPLE 6 - Method involving re-synchronization to a master clock

Although the methods of the invention involve, least in preferred embodiments, the use of high quality crystal clocks, one of skill in the art will appreciate that all clocks may be prone to a degree of inaccuracy and drift relative to one another, or relative to an absolute standard: Preferred embodiments of the invention allow for correction of such drift. Therefore, in further improvements to the methods of EXAMPLE 5 and other methods described herein, the invention allows for clock re-synchronization or correction following the initial synchronization to the master clock. For example, the methods of the invention may further involve the steps of: transmitting from the master clock at least one further clock synchronization signal to the at least one blasting component; and if required, re-synchronizing each clock of the at least one blasting component, in accordance with the at least one further clock synchronization signal, thereby to correct drift between each clock relative to the master clock. In further selected embodiments, the at least one further clock synchronization signal may be transmitted to the at least one blasting component following placement of the at least one blasting component at the blast site. In this way, initial clock synchronization may be achieved via reliable short range communication with the master clock, whereas correction of drift in blasting component clocks may be achieved via longer range wireless communication, for example through rock. In this way, the maintenance of clock synchrony at the blast site after establishment of a blasting array, may rely upon correction of drift, rather than establishment of absolute synchrony without prior reference to a master clock. Where blasting components are placed underground, post-placement communication with the blasting components need only involve command signals such as a signal to FIRE, and if required at least one further clock synchronization signal, in order to maintain synchronicity and to correct drift.

In especially preferred embodiments, the master clock may transmit a plurality of further clock synchronization signals on a periodic basis. In this way, receipt by a blasting component of a command signal to FIRE will cause the blasting component to begin counting down its delay time upon receipt of a next further clock synchronization signal. In effect, receipt of a command signal to FIRE by the at least one blasting component within a predetermined time period between receipt of two consecutive further clock synchronization signals causes a time zero to be established upon receipt of a second of the two consecutive further clock synchronization signals, thereby causing the delay times to count down from the established time zero.

The further clock synchronization signals may be transmitted on a periodic basis, and each blasting component may correct its own clock on the basis of the further clock synchronization signals thereby to keep in line with the master clock. The further clock synchronization signals may be temporally spaced with any time interval to achieve the desired goal. In preferred embodiments, the further clock synchronization signals are transmitted from 1 to 60 seconds apart. In this way, sufficient time is allowed between the signals for receipt and processing of wireless command signals (to be acted upon at the next further clock synchronization signal), and yet the further clock synchronization signals are not so far apart that the safety of the blast operator(s) is greatly jeopardized. Nonetheless, in preferred embodiments, the further synchronization signals are from 10 to 30 seconds apart, most preferably about 15 seconds apart. The optimum of about 15 seconds is considered most appropriate, since this time period may be long enough for receipt of command signals between further synchronization signals, and yet tolerable to a blasting operator. The applicant appreciates the safety problems that may be presented if the time interval between further synchronization signals (and therefore possible extended delay time between receipt by a blasting component of a command signal to FIRE and a newly established time zero) is greater than 60 seconds. If the delay is too long, a blast operator may consider the blast apparatus to have malfunctioned, and visit the blast site to check the components - this is clearly a scenario to be avoided at all costs, given that the apparatus may still be active for a blasting event. Maintaining a 'small' time interval between further clock synchronization signals is therefore preferred.

In further preferred embodiments, the command signals may only be transmitted by a blasting machine, and / or a blasting component may only be receptive to receive command signals, within a pre-determined time period timed to occur between two consecutive further clock synchronization signals. In this way, a blasting component will know when to "look" for a command signal, or alternatively for a further synchronization signal, to avoid confusion between the two types of signals. Furthermore, the use of such time windows for receipt of command signals may avoid a scenario where a blasting component receives a clock synchronization signal and a command signal to FIRE at, or virtually at, the same time. After all, the blasting component must, at least in preferred embodiments, be in no doubt as to which further
synchronization signal constitutes the "next" synchronization signal from which a time zero is to be established. In other embodiments, the pre-determined time period occurs just prior to or just following receipt of the further clock synchronization signals. If the pre-determined time period for receipt of command signals occurs immediately after receipt of a clock synchronization signal, then any doubt by the blasting component as to which further synchronization signal is the "next" such signal, may be substantially eliminated.

[0079] In preferred embodiments, each clock of each blasting component may oscillate with a frequency slightly slower than the master clock, such that correction of drift in all clocks of the at least one blasting component requires a positive correction requiring the clocks to gain time to catch up with the master clock. Alternatively, each clock of each blasting component may oscillate with a frequency slightly faster than the master clock, such that correction of drift in all clocks of the at least one blasting component requires a negative correction to cause the clocks to lose time and fall back into line with the master clock. In either scenario, correction of drift in a single direction may facilitate the correction process.

EXAMPLE 7 - Method involving resynchronization to a master clock, with bursts of command signals

[0080] The present example describes further improvements to selected methods described with reference to example 6, and other methods described in the present application. In selected embodiments, the invention presents significant advantages by allowing for the transmission of more than one command signal with the same intended purpose (e.g. a command signal to FIRE), whereby receipt by a blasting component of any one or more of such identical command signals will be sufficient to cause the blasting component to properly act upon the command signal. The transmission of multiple identical command signals may be especially useful where the transmission and receipt of the wireless signals is less than reliable, such as for example though rock signal transmission. Therefore, in selected embodiments, a plurality of command signals to FIRE may be transmitted by a blasting machine, and whereupon receipt of any one or more of the plurality of command signals to FIRE by the at least one blasting component causes establishment of a time zero and countdown of delay times upon receipt of a next further clock synchronization signal from the master clock. In effect, this 'brute force' approach attempts to push many command signals through the rock, in the hope that at least one is properly received and delineated by a blasting component, thereby improving the safety of the apparatus and the possibility of a successful blast. The methods of the invention present an opportunity to send multiple identical command signals, since such command signals will not be acted upon immediately, but rather only when another clock synchronization signal is received.

[0081] Preferably, the plurality of command signals to FIRE are transmitted in a burst of command signals to FIRE transmitted in rapid succession, the burst timed to start and finish between two consecutive further clock calibration signals. In this way, successful receipt by the at least one blasting component of one or more of the plurality of command signals to FIRE, causes establishment of a time zero and countdown of delay times upon receipt of the second of two consecutive further clock synchronization signals. Moreover, receipt of multiple command signals before and after receipt of a clock synchronization signal is substantially avoided. More preferably, each burst lasts not longer than 5 seconds, and is timed to occur between the two consecutive further clock synchronization signals.

EXAMPLE 8 - Blasting components with battery power saving

[0082] In further preferred embodiments of the methods of the invention, each blasting component comprises a battery for providing power thereto, and is switchable between an "active state" for receipt of the clock synchronization signal, the at least one further clock synchronization signal, and optionally the at least one command signal, and an "inactive state" to conserve battery power. More preferably, the at least one blasting component switches from an active state periodically to receive each of the at least one further clock synchronization signals. More preferably, the at least one command signal is transmitted as required to the at least one blasting component within a pre-determined time period relative to a further clock synchronization signal, and the at least one blasting component is adapted to maintain the active state for each of the pre-determined time periods, thereby to ensure proper receipt of the at least one command signal and the at least one further clock synchronization signals. In this way, the blasting component uses battery power to "listen" for incoming signals only when required, and battery power is conserved when no signal is expected.

EXAMPLE 9 - Selected blasting apparatuses of the invention

[0083] The present invention further encompasses blasting apparatuses, and blasting components suitable for use, for example, with the blasting apparatuses of the invention. Such blasting apparatuses, and components thereof, are especially adapted for use in connection with the methods of the invention, but may also be suitable for use with other methods of blasting.

[0084] For example, the invention further encompasses a blasting apparatus designed for conducting the method of any one of claims 7 to 18 (and related embodiments as described herein), but which may also be suitable for use for any other blasting method known in the art. Such a blasting apparatus may comprise:
In other embodiments of the invention, there are provided blasting apparatuses for conducting the method of any one of claims 19 to 31 (and related embodiments as described herein), but which may be suitable for use for any other blasting method known in the art. Such a blasting apparatus may comprise:

- at least one blasting machine for transmitting the at least one command signal;
- a calibration signal generating means for generating a carrier signal having a frequency of from 20-2500 Hz;
- at least one blasting component for receiving the at least one command signal and the calibration signal, each blasting component comprising:
  - a detonator comprising a firing circuit and a base charge, an explosive charge being in operative association with the detonator, such that actuation of the base charge via the firing circuit causes actuation of the explosive charge;
  - a transceiver for receiving and/or processing the at least one wireless command signal from the blasting machine and the calibration signal from the calibration signal generating means, the transceiver in signal communication with the firing circuit such that upon receipt of a command signal to FIRE the firing circuit causes actuation of the base charge and actuation of the explosive charge; a clock; a memory for storing a programmed delay time; and delineation means to delineate the oscillations of the calibration signal, or portions of the oscillations, thereby to allow synchronization of all clocks in all blasting components relative to one another, and establishment of a time zero, such that upon receipt by the at least one blasting component of a command signal to FIRE, the delay times counting down from a synchronized time zero thereby to effect timed actuation of each explosive charge associated with each blasting component, thereby to achieve a desired blasting pattern.

Preferably, the master clock further transmits at least one further clock synchronization signal to each of the at least one blasting component, the clock calibration signal from the blasting machine and the calibration signal from the master clock, the transceiver in signal communication with the firing circuit such that upon receipt of a command signal to FIRE the firing circuit causes actuation of the base charge and actuation of the explosive charge; a clock; a memory for storing a programmed delay time; and delineation means to delineate the oscillations of the calibration signal, or portions of the oscillations, thereby to allow synchronization of all clocks in all blasting components relative to one another, and establishment of a time zero, such that upon receipt by the at least one blasting component of a command signal to FIRE, the delay times counting down from a synchronized time zero thereby to effect timed actuation of each explosive charge associated with each blasting component, thereby to achieve a desired blasting pattern.

Preferably, the at least one blasting apparatus comprises:

- a detonator comprising a firing circuit and a base charge, an explosive charge being in operative association with the detonator, such that actuation of the base charge via the firing circuit causes actuation of the explosive charge;
- a transceiver for receiving and/or processing the at least one wireless command signal from the blasting machine and the calibration signal from the calibration signal generating means, the transceiver in signal communication with the firing circuit such that upon receipt of a command signal to FIRE the firing circuit causes actuation of the base charge and actuation of the explosive charge; a clock; a memory for storing a programmed delay time; and delineation means to delineate the oscillations of the calibration signal, or portions of the oscillations, thereby to allow synchronization of all clocks in all blasting components relative to one another, and establishment of a time zero, such that upon receipt by the at least one blasting component of a command signal to FIRE, the delay times counting down from a synchronized time zero thereby to effect timed actuation of each explosive charge associated with each blasting component, thereby to achieve a desired blasting pattern.
at least one further clock synchronization signal, thereby to correct drift between each clock relative to the master clock.

[0088] In still further embodiments, the invention provides for a blasting component for use in connection with the blasting apparatus of the invention comprising a master clock, the blasting component comprising:

at least one blasting component for receiving the at least one command signal and the clock calibration signal, each blasting component comprising:

a detonator comprising a firing circuit and a base charge, an explosive charge being in operative association with the detonator, such that actuation of the base charge via the firing circuit causes actuation of the explosive charge; a transceiver for receiving and / or processing the at least one wireless command signal from the blasting machine and the clock calibration signal from the master clock, and optionally at least one further clock calibration signals from the master clock, the transceiver in signal communication with the firing circuit such that upon receipt of a command signal to FIRE the firing circuit causes actuation of the base charge and actuation of the explosive charge; a clock; a memory for storing a programmed delay time; and
clock calibration means to delineate the clock calibration signal, thereby to synchronize the clock to the master clock, and establish at least one synchronized time zero, such that upon receipt by the at least one blasting component of an activation signal and / or a clock synchronization signal whilst in the listening state, causes each blasting component to receive an activation signal and / or a clock synchronization signal such as an activation signal or clock synchronization signal. However, to ensure the signals are transmitted during a period “listening” by each blasting component, each activation signal or clock calibration signal is preferably timed or preferably has a duration sufficiently long to ensure proper receipt by each blasting component whilst in a listening state.

[0091] When a blast operator wishes to execute a blasting event, he / she may cause a blasting machine to transmit an activation signal, or a master clock to transmit a clock calibration signal. Either such signals (or indeed other signals) may be suitable to activate all of the blasting components at the blast site fairly quickly. Preferably, the activation signal or the clock calibration signal is transmitted at a time or has a duration sufficiently long for the blasting components to “listen for” and receive the signal during one of their periodic switches to a listening state. Any clock calibration signal may, of course, also serve to calibrate the clocks of the blasting components to a master clock, as required.

[0092] Therefore, the methods of the invention include those in which each blasting component is switchable between a low-power inactive state to preserve battery power, and a listening state to listen for receipt of an activation signal from an associated blasting machine and / or a clock synchronization signal from a master clock. Such methods may further comprising the step of:

EXAMPLE 10 - Methods and apparatuses involving blasting component that conserve battery power

[0089] The methods of the present invention include further embodiments in which the blasting components maintain (for the most part) an inactive state to save battery or other internal power, and which periodically switch to a listening state for a limited time period, with sufficient circuitry active so that they can “listen” for signals from other components of the blasting apparatus (such as a blasting machine or master clock).

[0090] Effectively, the blasting components are “asleep” at the blast site, but they keep checking-in periodically to see whether it is time to “wake-up” and form an active, fully listening part of the blasting apparatus. A blasting machine, master clock or other component of the blasting apparatus, can effectively cause the blasting components to “wake-up” by transmission of a suitable signal such as an activation signal or clock synchronization signal. However, to ensure the signals are transmitted during a period “listening” by each blasting component, each activation signal or clock calibration signal is preferably timed or preferably has a duration sufficiently long to ensure proper receipt by each blasting component whilst in a listening state.

[0093] Such methods may further comprise a step of: periodically switching the blasting component(s) from the inactive state to the listening state for a limited time period, whereupon failure by each blasting component to receive an activation signal and / or a clock synchronization signal whilst in the listening state, causes each blasting component to re-adopt the inactive state, thereby preserving battery power, and whereupon receipt by the blasting component of an activation signal and / or a clock synchronization signal whilst in the listening state, causes each blasting component to adopt an active state suitable for each blasting component to form an active, functional part of the blasting apparatus.
The invention also encompasses correspondingly described above, the blasting component comprising:

- a detonator comprising a firing circuit and a base charge;
- an explosive charge in operative association with the detonator, such that actuation of the base charge via the firing circuit causes actuation of the explosive charge;
- a transceiver for receiving and / or processing the at least one wireless command signal from the blasting machine, if present the clock synchronization signal from the master clock, and if present the activation signal, the transceiver in signal communication with the firing circuit such that upon receipt of a command signal to FIRE the firing circuit causes actuation of the base charge and actuation of the explosive charge if the blasting component is in the active state; a clock;
- a memory for storing a programmed delay time; and switching means for periodically switching the blasting component from the inactive state to the listening state suitable to receive the clock calibration signal or the activation signal.

The invention also encompasses corresponding blasting apparatuses for conducting the methods disclosed in this example. Such blasting apparatus may comprise:

- at least one blasting machine for transmitting the at least one command signal, and optionally the activation signal to switch the blasting components to an active state to form active components of the blasting apparatus;
- optionally a master clock for generating a clock synchronization signal and transmitting the clock synchronization signal to each of the at least one blasting component, thereby to synchronize all clocks of the at least one blasting component to the master clock and / or to switch the blasting components to an active state to form active components of the blasting apparatus; and
- at least one blasting component for receiving the at least one command signal, if present the clock synchronization signal, and if present the activation signal, each blasting component comprising: a detonator comprising a firing circuit and a base charge, an explosive charge being in operative association with the detonator, such that actuation of the base charge via the firing circuit causes actuation of the explosive charge; a transceiver for receiving and / or processing the at least one wireless command signal from the blasting machine, if present the clock synchronization signal from the master clock, and if present the activation signal, the transceiver in signal communication with the firing circuit such that upon receipt of a command signal to FIRE the firing circuit causes actuation of the base charge and actuation of the explosive charge if the blasting component is in the active state; a clock; a memory for storing a programmed delay time; and switching means for periodically switching the blasting component from the inactive state to the listening state suitable to receive the clock calibration signal or the activation signal.

Claims

1. A method for wireless communication between at least one blasting machine of a blasting apparatus and at least one blasting component of the blasting apparatus at a blast site for mining, the at least one blasting component comprising or being in operative association with an associated explosive charge if the blasting component is in the active state; a clock; and at least one blasting component for receiving the at least one wireless command signal and transmitting at least one wireless command signal from the at least one blasting machine, the at least one wireless command signal comprising radio waves having a frequency of from 20 Hz to 2,500 Hz; receiving the at least one wireless command signal by the at least one blasting component; and processing and to reduce noise optionally amplifying/filtering the received at least one wireless command signal;
wherein said at least one blasting machine or another component of the blasting apparatus transmits a calibration signal comprising radio waves having a carrier frequency of from 20-2500 Hz other than the frequency of the at least one wireless command signal, thereby to allow synchronization of all clocks in blasting components relative to each other; and the method further comprising the step of establishing a synchronized time zero for all clocks of said at least one blasting component; such that upon receipt by said at least one blasting component of a command signal to FIRE, said delay time of each of said at least one blasting component counts down from the synchronized time zero thereby to effect timed actuation of each associated explosive charge and achieve a desired blasting pattern.

2. The method of claim 1, wherein each of the at least one blasting component is selected from a wireless detonator assembly, and a wireless electronic booster.

3. The method of claim 1, wherein said at least one command signal is modulated, and the step of receiving includes demodulation of the at least one command signal.

4. The method of claim 3, wherein the at least one command signal undergoes frequency shift key (FSK) modulation, and the step of receiving includes FSK demodulation to reconstruct the at least one command signal.

5. The method of claim 1, wherein the at least one command signal comprises radio waves having a frequency of from 100-2000 Hz, more preferably from 200-1200 Hz, more preferably about 300 Hz.

6. The method of claim 1, wherein the at least one wireless command signal comprises radio waves having a frequency other than about 50 Hz or harmonics thereof, thereby to avoid interference of said at least one command signal by sources of noise operating at 50 Hz or harmonics thereof.

7. The method of claim 1, wherein the at least one command signal is transmitted from said at least one blasting machine to said at least one blasting component through rock.

8. The method of claim 1, which further comprises delineation of the oscillations of the calibration signal, or portions of said oscillations by the at least one blasting component, thereby to allow said synchronization of all clocks in the blasting components relative to one another.

9. The method of claim 8, wherein each oscillation of the calibration signal comprises zero-crossing times at a beginning and a half-way time for each oscillation, said zero-crossing times establishing reference times to assist in delineation by each of said at least one blasting component of the calibration signal over noise, and wherein further reference times are optionally calculated between the zero-crossing times thereby to increase a temporal resolution of the calibration signal as received by the at least one blasting component.

10. The method of claim 1, wherein the calibration signal has a resolution of less than 1 ms.

11. The method of claim 1, wherein the calibration signal is transmitted continuously.

12. The method of claim 1, wherein the at least one command signal is integrated into the calibration signal by varying the frequency of the calibration signal periodically between at least two frequencies, thereby to introduce binary coding into the calibration signal.

13. A method for blasting rock using a blasting apparatus comprising at least one blasting machine located on or above a surface of the ground for transmitting at least one wireless command signal, and at least one blasting component located below a surface of the ground for receiving and acting upon said at least one wireless command signal, each blasting component including or being in operative association with an explosive charge and comprising a clock and a memory for storing a programmed delay time, the method including a method for wireless communication according to claim 1 and further comprising the steps of:

   processing the received calibration signal by:

   optionally amplifying and/or filtering the calibration signal to reduce low frequency noise;

   determining from the calibration signal reference times such as zero-crossing times; and

   optionally calculating further reference times between the reference times,

   thereby to establish a synchronized clock count for each blasting component;

wherein if said at least one command signal includes a signal to FIRE and on receipt by the at least one blasting component of the at least one command signal, each clock of each blasting component establishes a synchronized time zero and counts down from said synchronized time zero its own programmed delay time, thereby to
effect timed actuation of each explosive charge associated with each blasting component and achieve the desired blasting pattern.

14. The method of claim 13, wherein each of the at least one blasting component is selected from a wireless detonator assembly, and a wireless electronic booster.

15. The method of claim 13, wherein said at least one command signal and/or the calibration signal is modulated, and each step of receiving includes demodulation of the signal(s).

16. The method of claim 15, wherein the at least one command signal undergoes frequency shift key (FSK) modulation, and the step of receiving includes FSK demodulation to reconstruct the at least one command signal and/or the calibration signal.

17. The method of claim 13, wherein the at least one command signal comprises radio waves having a frequency of from 100-2000 Hz, more preferably from 200-1200 Hz, more preferably about 300 Hz.

18. The method of claim 13, wherein at least one wireless command signal and/or the calibration signal comprises radio waves having a frequency other than about 50 Hz or harmonics thereof, thereby to avoid interference by sources of noise operating at 50 Hz or harmonics thereof.

19. The method of claim 1, wherein each of said at least one blasting component comprises a clock and a memory for storing a programmed delay time for actuation of the explosive charge, the method further comprising the steps of:

transmitting from a master clock, a clock synchronization signal to each of said at least one blasting component, thereby to synchronize all clocks of said at least one blasting component to said master clock; and

establishing at least one synchronized time zero relative to transmission of said clock synchronization signal, for all clocks of said at least one blasting component; such that upon receipt by said at least one blasting component of a command signal to FIRE, each of said at least one blasting component waiting for a next synchronized time zero and then counting down its programmed delay time resulting in actuation of an associated explosive charge, thereby to effect timed actuation of each explosive charge associated with each blasting component, thereby to achieve a desired blasting pattern.

20. The method of claim 19, wherein at least the step of transmitting said clock synchronization signal occurs via short range communication involving either direct electrical contact or short range wireless communication between the master clock and said at least one blasting component, optionally prior to placement of said at least one blasting component at the blast site.

21. The method of claim 19, wherein said placement of said at least one blasting component comprises placement below ground, and said at least one wireless command signal is transmitted from said at least one blasting machine through rock.

22. The method of claim 19, further comprising the steps of:

transmitting from said master clock at least one further clock synchronization signal to said at least one blasting component; and if required, re-synchronizing each clock of said at least one blasting component, in accordance with said at least one further clock synchronization signal, thereby to correct drift between each clock relative to said master clock.

23. The method of claim 22, wherein said at least one further clock synchronization signal is transmitted to said at least one blasting component following placement of said at least one blasting component at said blast site below ground, such that at least both said at least one wireless command signal and said at least one further clock synchronization signal are transmitted through rock via radio waves having a frequency of 20-2500 Hz.

24. The method of claim 22, said at least one further clock synchronization signal comprising a plurality of further clock synchronization signals transmitted by said master clock periodically, and receipt of at least one command signal to FIRE by said at least one blasting component within a predetermined time period between receipt of two consecutive further clock synchronization signals causes a time zero to be established upon receipt of a second of said two consecutive further clock synchronization signals, thereby causing said delay times to count down from said time zero causing subsequent actuation of explosive charges associated with said at least one blasting component, thereby resulting in a desired blasting pattern.

25. The method of claim 24, wherein said further clock synchronization signals are transmitted from 1 to 60 seconds apart, preferably from 10 to 30 seconds apart, more preferably about 15 seconds apart.
26. The method of claim 22, wherein said at least one command signal to FIRE comprises a plurality of command signals to FIRE transmitted in a burst of command signals transmitted in rapid succession, said burst timed to start and finish between two consecutive further clock calibration signals, such that successful receipt by said at least one blasting component of one or more of said plurality of command signals to FIRE, causes establishment of a time zero and countdown of delay times upon receipt of said second of said two consecutive further clock synchronization signals.

27. The method of claim 22, wherein each of said at least one blasting component comprises a battery for providing power thereto, and is switchable between an active state for receipt of said clock synchronization signal, said at least one further clock synchronization signal, and optionally said at least one command signal, and an inactive state to conserve battery power.

28. The method of claim 27, wherein said at least one blasting component switches from an active state periodically to receive each of said at least one further clock synchronization signals.

29. The method of claim 28, wherein said at least one command signal is transmitted as required to said at least one blasting component within a pre-determined time period relative to a further clock synchronization signal, and said at least one blasting component is adapted to maintain said active state only for each of said pre-determined time periods, thereby to ensure receipt of said at least one command signal and said at least one further clock synchronization signals, and thereby to conserve battery power when no signal is expected.

30. The method of claim 22, wherein each clock of each blasting component oscillates with a frequency slightly slower than said master clock; such that correction of drift in all clocks of said at least one blasting component requires a positive correction to cause said clocks to gain time to catch up with said master clock.

31. The method of claim 22, wherein each clock of each blasting component oscillates with a frequency slightly faster than said master clock, such that correction of drift in all clocks of said at least one blasting component requires a negative correction to cause said clocks to lose time and fall back into line with said master clock.

32. The method of claim 1, wherein each blasting component is switchable between a low-power inactive state to preserve battery power, and a listening state to listen for receipt of an activation signal from an associated blasting machine or other component, and/or a clock synchronization signal from a master clock, the method further comprising the step of:

periodically switching the blasting component(s) from said inactive state to said listening state for a limited time period, whereupon failure by each blasting component to receive an activation signal and/or a clock synchronization signal whilst in said listening state, causes each blasting component to re-adopt said inactive state, thereby preserving battery power, and whereupon receipt by said blasting component of an activation signal and/or a clock synchronization signal whilst in said listening state, causes each blasting component to adopt an active state suitable for each blasting component to form, an active, functional part of said blasting apparatus.

33. The method of claim 32, the method further comprises a step of:

transmitting an activation signal from a blasting machine or other component and/or a clock synchronization signal from a master clock at a time or for a time period sufficient to activate each blasting component of the blasting apparatus, thereby to bring each blasting component into an active, functional state suitable for forming an active component of said blasting apparatus.

34. The method of claim 33, wherein said activation signal and/or said clock synchronization signal has a duration longer than a time period between said periodic switching, thereby to ensure each blasting component is in a listening state suitable for receiving said activation signal and/or said clock synchronization signal before each blasting component reverts back to an inactive state.

35. A blasting apparatus for conducting the method of any one of claims 1 to 34, the blasting apparatus comprising:

at least one blasting machine for transmitting the at least one command signal comprising radio waves at a frequency of from 20 Hz to 2500 Hz;
a calibration signal generating means for generating a carrier signal comprising radio waves having a frequency of from 20-2500 Hz other than the frequency of the at least one wireless command signal;
at least one blasting component for receiving said at least one command signal and said calibration signal, each blasting component comprising: a detonator comprising a firing circuit and a base charge, an explosive charge being
in operative association with said detonator, such that actuation of said base charge via said firing circuit causes actuation of said explosive charge; a transceiver for receiving and/or processing said at least one wireless command signal from said blasting machine and said calibration signal from said calibration signal generating means, said transceiver being in signal communication with said firing circuit such that upon receipt of a command signal to FIRE said firing circuit causes actuation of said base charge and actuation of said explosive charge; a clock; a memory for storing a programmed delay time; and means to process the calibration signal to allow synchronization of all clocks in the blasting components relative to one another, and establishment of a time zero, such that upon receipt by said at least one blasting component of a command signal to FIRE, said delay times counting down from the synchronized time zero thereby to effect timed actuation of each explosive charge associated with each blasting component, thereby to achieve the desired blasting pattern.

36. A blasting apparatus according to claim 35, wherein the means to process the calibration signal comprises delineation means to delineate the oscillations of the calibration signal, or portions of said oscillations.

37. A blasting apparatus according to claim 35, wherein the calibration signal generating means comprises:

- a master clock for generating the calibration signal as a clock synchronization signal and transmitting the clock synchronization signal to each of said at least one blasting component, thereby to synchronize said clock; and
- a memory for storing a programmed delay time; and
- a transceiver for receiving and/or processing said calibration signal from said blasting machine and said calibration signal generating means.

38. A blasting apparatus according to claim 37, wherein the master clock further transmits at least one further clock synchronization signal to said at least one blasting component, said clock calibration means resynchronizing each clock of said at least one blasting component if required, in accordance with said at least one further clock synchronization signal, thereby to correct drift between each clock relative to said master clock.

39. A blasting apparatus according to claim 35, wherein the at least one blasting machine transmits an activation signal to switch said at least one blasting component to an active state to form active components of the blasting apparatus, each of the at least one blasting component receiving and/or processing said activation signal through the transceiver and further comprising switching means for periodically switching each blasting component from an inactive state to a listening state suitable to receive said activation signal.

40. A blasting apparatus according to claim 35, wherein the clock synchronization signal generated by the master clock switches each of said at least one blasting component to an active state to form active components of the blasting apparatus, each of the at least one blasting component further comprising switching means for periodically switching each blasting component from an inactive state to a listening state suitable to receive said clock calibration signal.

41. The blasting apparatus of claim 36, whereby the blasting component comprises:

- the said detonator;
- the said explosive charge;
- the said transceiver;
- the said clock;
- the said memory; and
- the said delineation means to delineate the oscillations of the calibration signal, or portions of said oscillations, thereby to allow synchronization of all clocks in the blasting components of the blasting apparatus relative to one another, and establish a synchronized time zero, such that upon receipt by said blasting component of a command signal to FIRE, said delay times counting down from the synchronized time zero thereby to effect timed actuation of the explosive charge associated with the blasting component.

42. The blasting apparatus of claim 37, whereby the blasting component comprises:

- the said detonator;
- the said explosive charge;
- the said transceiver;
- the said clock;
- the said memory; and
- the said clock calibration means to delineate the clock synchronization signal, thereby to synchronize said clock to said master clock, and establish at least one synchronized time zero.
43. The blasting apparatus of claim 39 or 40, whereby the blasting component comprises:

the said detonator;
the said explosive charge;
the said transceiver for receiving and/or processing said at least one wireless command signal from said blasting machine, and said clock synchronization signal from said master clock or said activation signal, said transceiver being in signal communication with said firing circuit such that upon receipt of a command signal to FIRE said firing circuit causes actuation of said base charge and actuation of said explosive charge if said blasting component is in an active state;
the said clock;
the said memory; and
the said switching means for periodically switching said blasting component from an inactive state to a listening state suitable to receive said clock calibration signal or said activation signal to change the blasting component into its active state.

Patentansprüche

1. Verfahren zur drahtlosen Kommunikation zwischen mindestens einer Sprengmaschine eines Sprenggeräts und mindestens einer Sprengkomponente des Sprenggärts an einem Sprengstandort für Bergbau, wobei die mindestens eine Sprengkomponente eine zugeordnete Sprengstoffladung umfasst, wobei die mindestens eine Sprengmaschine oder eine andere Komponente des Sprenggeräts ein Kalibrationssignal überträgt, welches Radiowellen umfasst, die eine Trägerfrequenz von 20-2500 Hz haben, die verschieden von der Frequenz des mindestens einen Befehlssignals ist, um derart die Synchronisation aller Zeitgeber in Sprengkomponenten relativ zueinander zu ermöglichen; und
wobei das Verfahren weiterhin den Schritt umfasst: Bestimmen einer synchronisierten Nullzeit für alle Zeitgeber der mindestens einen Sprengkomponente; sodass, als Relation auf Erhalten eines ZUNDUNGS-Befehlssignals, durch die mindestens eine Sprengkomponente, die Verzögerungszeit von jeder der mindestens einen Sprengkomponente von der synchronisierten Nullzeit herunterzählt, um derart zeitabgestimmte Betätigung jeder zugeordneten Sprengstoffladung zu bewirken und ein erwünschtes Sprengmuster zu erhalten.

2. Verfahren nach Anspruch 1, wobei jede der mindestens einen Sprengkomponenten ausgewählt wird aus einer drahtlosen Detonationsanordnung und einem drahtlosen elektronischen Booster.

3. Verfahren nach Anspruch 1, wobei das mindestens eine Befehlssignal moduliert ist und der Schritt des Empfangs Demodulieren des mindestens einen Befehlssignals beinhaltet.

4. Verfahren nach Anspruch 3, wobei das mindestens eine Befehlssignal einer Frequenz-Shift-Key (FSK) Modulation unterzogen wird und der Schritt des Empfangs FSK-Demodulation beinhaltet, um das mindestens eine Befehlssignal zu rekonstruieren.

5. Verfahren nach Anspruch 1, wobei das mindestens eine Befehlssignal Radiowellen mit einer Frequenz von 100-2000 Hz, vorzugsweise von 200-1200 Hz, vorzugsweise von ungefähr 300 Hz umfasst.

6. Verfahren nach Anspruch 1, wobei das mindestens eine drahtlose Befehlssignal Radiowellen mit einer Frequenz, die verschieden von 50 Hz oder Harmonischen davon ist, umfasst, um dadurch Interferenz des mindestens einen Befehlssignals mit Rauschquellen, die bei 50 Hz oder Harmonischen davon arbeiten, zu vermeiden.

7. Verfahren nach Anspruch 1, wobei das mindestens eine Befehlssignal von der mindestens einen Sprengmaschine zu der mindestens einen Sprengkomponente durch Stein hindurch übertragen wird.

8. Verfahren nach Anspruch 1, welches weiterhin umfasst: Abgrenzen der Oszillationen der Kalibrationsignale oder von Abschnitten der Oszillationen durch die mindestens eine Sprengkomponente, um derart die Synchronisation aller Zeitgeber in den Sprengkomponenten relativ zueinander zu ermöglichen.

9. Verfahren nach Anspruch 8, wobei jede Oszillation
des Kalibrationssignals Nulldurchgangszeiten an einem Anfang und einer halben Zeit für jede Oszillation umfasst, wobei die Nulldurchgangszeiten Referenzzeiten bestimmen, um dabei zu helfen, durch jede der mindestens einen Sprengkomponente das Kalibrationssignal gegenüber Rauschen abzugrenzen, und wobei optional weitere Referenzzeiten zwischen den Nulldurchgangszeiten berechnet werden, um dadurch eine Zeitauflosung des Kalibrationssignals, wie es von der mindestens einen Sprengkomponente empfangen wird, zu erhöhen.

10. Verfahren nach Anspruch 1, wobei das Kalibrationsignal eine Auflösung von weniger als eine Millisekunde hat.

11. Verfahren nach Anspruch 1, wobei das Kalibrationsignal kontinuierlich übertragen wird.

12. Verfahren nach Anspruch 1, wobei das mindestens eine Befehlssignal in das Kalibrationssignal durch periodisches Variieren der Frequenz des Kalibrationssignals zwischen mindestens zwei Frequenzen integriert wird, wodurch eine Binärcodierung in das Kalibrationssignal eingebracht wird.

13. Verfahren zum Sprengen von Gestein unter Verwendung eines Sprengeräts, das mindestens eine Sprengmaschine, die sich auf oder oberhalb einer Oberfläche des Bodens befindet, zum Übertragen mindestens eines drahtlosen Befehlssignals, und mindestens eine Sprengkomponente, die sich unterhalb einer Oberfläche des Bodens befindet, zum Empfangen des mindestens einen drahtlosen Befehlssignals zum daraufhin Tätigwerden umfasst, wobei jede Sprengkomponente eine Sprengstoffladung beinhaltet oder in operativer Zuordnung mit dieser steht und einen Zeitgeber und einen Speicher zum Speichern einer programmierten Verzögerungszeit umfasst, wobei jede Sprengkomponente eine Sprengstoffladung beinhaltet oder in operativer Zuordnung mit dieser steht und einen Zeitgeber und einen Speicher zum Speichern einer programmierten Verzögerungszeit umfasst, wobei das Verfahren eine drahtlose Kommunikation gemäß Anspruch 1 beinhaltet und weiterhin die Schritte umfasst:

Verarbeiten des empfangenen Kalibrationssignals durch:

optional Verstärken und / oder Filtern des Kalibrationssignals, um niederfrequentes Rauschen zu reduzieren;

Bestimmen von Referenzzeiten, so wie Nulldurchgangszeiten, aus dem Kalibrationssignal; und

optional Berechnen von weiteren Referenzzeiten zwischen den Referenzzeiten; um dadurch einen synchronisierten Zeitgeberzähler für jede Sprengkomponente zu bestimmen;

wobei, wenn das mindestens eine Befehlssignal ein ZÜNDUNGS-Signal beinhaltet und als Reaktion auf Erhalten des mindestens einen Befehlssignals durch die mindestens eine Sprengkomponente hin, jeder Zeitgeber jeder Sprengkomponente eine synchronisierte Nullzeit bestimmt und von der synchronisierten Nullzeit seine eigene programmierte Verzögerungszeit herunterzählt, um dadurch zeitabgestimmte Betätigung jeder Sprengstoffladung, die jeder Sprengkomponente zugeordnet ist, zu bewirken und das erwünschte Sprengmuster zu erhalten.

14. Verfahren nach Anspruch 13, wobei jede der mindestens einen Sprengkomponente ausgewählt wird aus einer drahtlosen Sprenganordnung und einem drahtlosen elektronischen Booster.

15. Verfahren nach Anspruch 13, wobei das mindestens eine Befehlssignal und / oder das Kalibrationssignal moduliert ist und wobei jeder Schritt des Empfangens Demodulieren des Signals (der Signale) beinhaltet.

16. Verfahren nach Anspruch 15, wobei das mindestens eine Befehlssignal einer Frequenz-Shift-Key (FSK) Modulation unterzogen wird und der Schritt des Empfangs FSK-Demodulation beinhaltet, um das mindestens eine Befehlssignal und / oder das Kalibrationssignal zu rekonstruieren.

17. Verfahren nach Anspruch 13, wobei das mindestens eine Befehlssignal Radiowellen mit einer Frequenz von 100-2000 Hz, vorzugsweise von 200-1200 Hz, vorzugsweise von ungefähr 300 Hz umfasst.

18. Verfahren nach Anspruch 13, wobei das mindestens eine drahtlose Befehlssignal und / oder das Kalibrationssignal Radiowellen umfasst, die eine Frequenz haben, die verschieden von ungefähr 50 Hz oder Harmonischen davon ist, um derart Interferenz mit Rauschquellen, die bei 50 Hz oder Harmonischen davon arbeiten, zu vermeiden.

19. Verfahren nach Anspruch 1, wobei jede der mindestens einen Sprengkomponente einen Zeitgeber und einen Speicher zum Speichern einer programmierten Verzögerungszeit zum Betätigen der Sprengstoffladung umfasst, wobei das Verfahren weiterhin die Schritte umfasst:

Übertragen von einem Masterzeitgeber eines Zeitgebersynchronisationssignals zu jeder der mindestens einen Sprengkomponente, um dadurch alle Zeitgeber der mindestens einen Sprengkomponente mit dem Masterzeitgeber zu synchronisieren; und

Bestimmen von mindestens einer synchroni-
Verfahren nach Anspruch 22, wobei das mindestens zwei Zeitgebersynchronisationssignale, die durch den Masterzeitgeber periodisch übertragen werden, umfasst, und wobei Erhalten des mindestens einen ZÜNDUNGS-Befehlssignals durch die mindestens eine Sprengkomponente innerhalb einer vorgegebenen Zeitdauer zwischen Erhalten von zwei aufeinanderfolgenden weiteren Zeitgebersynchronisationssignalen bewirkt, dass als Reaktion auf Erhalten eines zweiten der zwei aufeinanderfolgenden weiteren Zeitgebersynchronisationssignalen eine Nullzeit bestimmt wird, wodurch bewirkt wird, dass die Verzögerungszeiten von der Nullzeit heruntergezählt werden, was darauf folgende Betätigung von Explosionsladungen, die der mindestens einen Sprengkomponente zugeordnet sind, bewirkt, was in einem gewünschten Sprengmuster resuliert.

Verfahren nach Anspruch 24, wobei die weiteren Zeitgebersynchronisationssignale zwischen 1 bis 60 Sekunden voneinander getrennt übertragen werden, vorzugsweise getrennt um 10 bis 30 Sekunden, besonders vorzugsweise ungefähr 15 Sekunden getrennt voneinander.

Verfahren nach Anspruch 22, wobei jedes der mindestens zwei Sprengkomponenten eine Batterie enthält, die periodisch von der Nullzeit heruntergezählt werden, was in einem gewünschten Sprengmuster resuliert.

nen weiteren Zeitgebersynchronisationssignals zu empfangen.

29. Verfahren nach Anspruch 28, wobei das mindestens eine Befehlssignal, wenn benötigt, zu der mindestens einen Sprengkomponente innerhalb einer vorgegebenen Zeitdauer relativ zu einem weiteren Zeitgebersynchronisationssignal übertragen wird, und wobei die mindestens eine Sprengkomponente eingerichtet ist, um den aktiven Zustand nur für jede der vorgegebenen Zeitdauern aufrecht zu erhalten, um dadurch Erhalten des mindestens einen Befehlssignals und des mindestens einen weiteren Zeitgebersynchronisationssignals sicherzustellen und um durch Batterieenergie zu schonen, wenn kein Signal erwartet wird.

30. Verfahren nach Anspruch 22, wobei jeder Zeitgeber von jeder Sprengkomponente mit einer Frequenz, die geringfügig kleiner als der Masterzeitgeber ist, oszilliert; sodass Korrektur eines Drifts in allen Zeitgebern der mindestens einen Sprengkomponente einer positiven Korrektur bedarf, um derart zu bewirken, dass die Zeitgeber Zeit gewinnen, um zu dem Masterzeitgeber aufzuschließen.


32. Verfahren nach Anspruch 1, wobei jede Sprengkomponente zwischen einem Niederenergie-inaktiven Zustand zum Aufsparen von Batterieenergie und einem Horchzustand zum Hören auf Erhalten eines Aktivierungssignals einer zugehörigen Sprengmaschine oder anderen Komponenten und / oder eines Zeitgebersynchronisationssignals von einem Masterzeitgeber geschaltet werden kann, wobei das Verfahren weiterhin die Schritte umfasst:


33. Verfahren nach Anspruch 32, wobei das Verfahren weiterhin die Schritte umfasst:

Übertragen eines Aktivierungssignals von einer Sprengmaschine oder einer anderen Komponente und / oder eines Zeitgebersynchronisationssignals von einem Masterzeitgeber zu einem Zeitgeber oder für eine bestimmte Zeitdauer, die ausreicht, um jede Sprengkomponente des Sprenggeräts zu aktivieren, um dadurch jede Sprengkomponente in einen aktiven funktionalen Zustand zu bringen, der geeignet ist, um eine aktive Komponente des Sprenggeräts auszubilden.

34. Verfahren nach Anspruch 33, wobei das Aktivierungssignal und / oder das Synchronisationssignal eine Dauer hat, die länger als eine Zeitspanne zwischen dem periodischen Schalten ist, um dadurch sicherzustellen, dass jede Sprengkomponente in einem Horchzustand ist, der zum Empfangen des Aktivierungssignals und / oder des Zeitgebersynchronisationssignals geeignet ist, bevor jede Sprengkomponente zurück in einen inaktiven Zustand fällt.

35. Sprenggerät zum Durchführen des Verfahrens gemäß einem der Ansprüche 1-34, wobei das Sprenggerät umfasst:

mindestens eine Sprengmaschine zum Übertragen des mindestens einen Befehlssignals, das Radiowellen bei einer Frequenz zwischen 20 Hz und 2500 Hz umfasst;

ein Mittel zum Erzeugen eines Kalibrationssignals zum Erzeugen eines Trägersignals, das Radiowellen mit einer Frequenz von 20-2500 Hz, die verschieden von der Frequenz des mindestens einen drahtlosen Befehlssignals ist, umfasst;

mindestens eine Sprengkomponente zum Empfangen des mindestens einen Befehlssignals und des Kalibrationssignals, wobei jede Sprengkomponente umfasst: einen Detonator, der einen Zündschaltkreis und eine Basisladung umfasst, sodass Betätigung der Basisladung über den Zündschaltkreis bewirkt; einen Sendeempfänger zum Empfangen und / oder Verarbeitung des mindestens einen drahtlosen Befehlssignals von der Sprengmaschine und des Kalibrationssignals von dem Mittel zum Er-
zeugen des Kalibrationssignals, wobei der Sen-
deeempfänger in Signalkommunikation mit dem Zündschaltkreis auf eine solche Art und Weise steht, dass, auf Erhalten eines ZÜNDUNGS-Befehllsignals, der Zündschaltkreis Betätigung der Basisladung und Betätigung der Sprengstoffladung bewirkt; einen Zeitgeber; einen Speicher zum Speichern einer programmierten Verzögerungszeit; und ein Mittel zum Verarbei-
den des Kalibrationssignals, um Synchronisati-
on aller Zeitgeber in den Sprengkomponenten rela-
v zu ihrer und Bestimmen einer Nullzeit zu ermöglichen, sodass als Reaktion auf Erhal-
ten eines ZÜNDUNGS-Befehllsignals durch die mindestens eine Sprengkomponente hin die Verzögerungszeiten von der synchronisierten Nullzeit herunterzählen, um derzeit eine zeitab-
gestimmte Betätigung jeder Sprengstoffladung, die zu jeder Sprengstoffkomponente gehört, zu bewirken, wodurch ein gewünschtes Sprengmuster erhalten wird.

36. Sprenggerät gemäß Anspruch 35, wobei das Mittel zum Verarbeiten des Kalibrationssignals ein Mittel zum Abgrenzen umfasst, um die Oszillationen des Kalibrationssignals oder Abschnitte der Oszillationen abzugrenzen.

37. Sprenggerät gemäß Anspruch 35, wobei das Mittel zum Erzeugen des Kalibrationssignals umfasst:

- einen Masterzeitgeber zum Erzeugen des Kalibrationssignals als ein Zeitgebersynchronisationssignal und zum Übertragen des Zeitgeber synchronisationssignals zu jeder der mindestens einen Sprengkomponente, um damit alle Zeitgeber der mindestens einen Sprengkomponente mit dem Masterzeitgeber zu synchronisieren, und wobei die mindestens eine Sprengkomponente ein Mittel zur Zeitgeberkalibration umfasst, um den Zeitgeber mit dem Ma-
sterzeitgeber zu synchronisieren und die min-
destens eine synchronisierte Nullzeit zu bestim-
men.

38. Sprenggerät gemäß Anspruch 37, wobei der Master-
zeiger weiterhin mindestens ein weiteres Zeitge-
bhersynchronisationssignal zu der mindestens einen Sprengkomponente überträgt, wobei das Mittel zur Zeitgeberkalibration jeden Zeitgeber der minde-
stens einen Sprengkomponente, wenn benötigt, er-
neut synchronisiert, in Übereinstimmung mit dem mindestens einen weiteren Zeitgebersynchronisationssignal, um dadurch einen Drift zwischen jedem Zeitgeber-relativ in Bezug auf den Masterzeitgeber zu korrigieren.

39. Sprenggerät gemäß Anspruch 35, wobei die minde-
stens eine Sprengmaschine ein Aktivierungssignal überträgt, um die mindestens eine Sprengkompo-
nente in einen Aktivzustand zu schalten, um aktive Komponenten des Sprenggeräts auszubilden, wobei jede der mindestens einen Sprengkomponente das Aktivierungssignal durch den Sendeempfänger empfängt und / oder verarbeitet und weiterhin ein Mittel zum Schalten umfasst, um jede Sprengkom-
ponente periodisch aus einem inaktiven Zustand in einen Horchzustand zu schalten, der geeignet ist, um das Aktivierungssignal zu empfangen.

40. Sprenggerät gemäß Anspruch 35, wobei das Zeit-
gebersynchronisationssignal, das durch den Ma-
sterzeitgeber erzeugt wird, jede der mindestens ei-
en Sprengkomponente in einen aktiven Zustand schaltet, um aktive Komponenten des Sprenggeräts auszubilden, wobei jede der mindestens einen Sprengkomponente weiterhin ein Mittel zum Schal-
ten umfasst, um jede Sprengkomponente periodisch aus einem inaktiven Zustand in einen Horchzustand zu schalten, der geeignet ist, um das Zeitgeberkalibrationssignal zu empfangen.

41. Das Sprenggerät nach Anspruch 36, wobei die Sprengkomponente umfasst:

den Detonator;
die Sprengstoffladung;
den Sendeempfänger;
den Zeitgeber;
den Speicher; und
die Mittel zum Abgrenzen, um die Oszillationen des Kalibrationssignals oder Abschnitte der Oszillationen abzugrenzen, um dadurch Synchronisierung aller Zeitgeber in den Sprengkomponenten des Sprenggeräts relativ zueinander zu ermöglichen, und um eine synchronisierte Nullzeit zu bestimmen, sodass, als Reaktion auf Erhalten eines ZÜNDUNGS-Befehllsignals durch die Sprengkomponente hin, die Verzögerungszeit von der synchronisierten Nullzeit herunterzählt, um dadurch zeitabgestimmte Betätigung der Sprengstoffladung, die der Sprengstoffkomponente zugeordnet ist, zu bewirken.

42. Das Sprengstoffgerät nach Anspruch 37, wobei die Sprengstoffkomponente umfasst:

den Detonator;
die Sprengstoffladung;
den Sendeempfänger;
den Zeitgeber;
den Speicher; und
das Mittel zum Zeitgeberkalibrieren, um das Zeitgebersynchronisationssignal abzugrenzen, um dadurch den Zeitgeber mit dem Masterzeitgeber zu synchronisieren und zumindest eine
synchronisierte Nullzeit zu bestimmen, sodass, als Reaktion auf Erhalten eines ZÜNDUNGS-Befehlssignals durch die Sprengkomponente hin, die Sprengkomponente auf eine nächste synchronisierte Nullzeit wartet und dann ihre programmierte Verzögerungszeit herunterzählt, was in Betätigung der zugeordneten Sprengstoffladung resultiert, wodurch zeitabgestimmte Betätigung der Sprengstoffladung, die der Sprengkomponente zugeordnet ist, bewirkt wird.

43. Das Sprenggerät nach Anspruch 39 oder 40, wobei die Sprengkomponenten umfasst:
- den Detonator;
- die Sprengstoffladung;
- den Sendeempfänger zum Empfangen und oder Verarbeiten des mindestens einen drahtlosen Befehlssignals von der Sprengmaschine und des Zeitgebersynchronisationssignal von dem Masterzeitgeber oder des Aktivierungssignals, wobei der Sendeempfänger auf eine solche Art und Weise in Signalkommunikation mit dem Zündschaltkreis steht, dass, als Reaktion auf Erhalten eines ZÜNDUNGS-Befehlssignals hin, der Zündschaltkreis Betätigung der Basisladung und Betätigung der Sprengstoffladung bewirkt, wenn die Sprengstoffkomponenten in einem aktiven Zustand ist;
- den Zeitgeber;
- den Speicher; und
- die Mittel zum Schalten, um die Sprengkomponente periodisch aus einem inaktiven Zustand in einen Horchzustand, der geeignet ist, um das Zeitgeberkalibrationssignal oder das Aktivierungssignal zu empfangen, um die Sprengkomponente in ihrem aktiven Zustand zu ändern, zu schalten.

Revendications

1. Procédé de communication radioélectrique entre au moins un explosif d’un dispositif de tir et au moins un organe de tir du dispositif de tir dans une zone de tir d’exploitation minière, ledit au moins un organe de tir comprenant ou coopérant avec une charge explosive correspondante et comprenant une horloge et une mémoire pour mémoriser une durée de temporisation programmée pour le déclenchement de la charge explosive, le procédé comportant les étapes de :
- émission d’au moins un signal radioélectrique de commande par le/les explosif ou une des sources de bruit fonctionnant à 50 Hz ou à des harmoniques de cette fréquence.

2. Procédé selon la revendication 1, dans lequel ledit au moins un organe de tir est choisi entre un détonateur radioélectrique et une amorce électronique radioélectrique d’appoint.

3. Procédé selon la revendication 1, dans lequel ledit au moins un signal de commande est modulé et l’étape de réception comprend une démodulation dudit au moins un signal de commande.

4. Procédé selon la revendication 3, dans lequel ledit au moins un signal de commande subit une modulation par déplacement de fréquence (FSK) et l’étape de réception comprend une démodulation FSK pour reconstruire ledit au moins un signal de commande.

5. Procédé selon la revendication 1, dans lequel ledit au moins un signal de commande comprend des ondes radio à fréquence de 100 à 2 000 Hz, de préférence de 200 à 1 200 Hz, de préférence encore d’environ 300 Hz.

6. Procédé selon la revendication 1, dans lequel ledit au moins un signal radioélectrique de commande comprend des ondes radio à fréquence différente d’environ 50 Hz ou d’harmoniques de celle-ci pour ainsi éviter un parasitage dudit au moins un signal de commande par des sources de bruit fonctionnant à 50 Hz ou à des harmoniques de cette fréquence.

7. Procédé selon la revendication 1, dans lequel ledit
au moins un signal de commande est émis par ledit au moins un explosif, à travers la roche, vers ledit au moins un organe de tir.

8. Procédé selon la revendication 1, comportant en outre une délimitation des oscillations du signal d’étalonnage, ou de parties desdites oscillations par ledit au moins un organe de tir, pour permettre de la sorte ladite synchronisation de toutes les horloges les unes avec les autres dans les organes de tir.

9. Procédé selon la revendication 8, dans lequel chaque oscillation du signal d’étalonnage comprend des instants de passage par zéro à un début et à mi-période pour chaque oscillation, lesdits instants de passage par zéro établissant des instants de référence pour faciliter la délimitation, par ledit/chaque organe de tir, du signal d’étalonnage par rapport au bruit, et dans lequel d’autres instants de référence sont éventuellement calculés entre les instants de passage par zéro pour ainsi accroître une résolution temporelle du signal d’étalonnage reçu par ledit au moins un organe de tir.

10. Procédé selon la revendication 1, dans lequel le signal d’étalonnage a une résolution inférieure à 1 ms.

11. Procédé selon la revendication 1, dans lequel le signal d’étalonnage est émis en continu.

12. Procédé selon la revendication 1, dans lequel ledit au moins un signal de commande est intégré dans le signal d’étalonnage en faisant périodiquement varier la fréquence du signal d’étalonnage entre au moins deux fréquences pour ainsi introduire un codage binaire dans le signal d’étalonnage.

13. Procédé pour faire exploser de la roche à l’aide d’un dispositif de tir comportant au moins un explosif disposé au sol ou au-dessus d’une surface du sol pour émettre au moins un signal radioélectrique de commande, et au moins un organe de tir situé sous une surface du sol pour recevoir ledit au moins un signal radioélectrique de commande et agir sur ce dernier, chaque organe de tir comprenant ou coïncidant avec une charge explosive et comprenant une horloge et une mémoire pour mémoriser une durée de temporisation programmée, le procédé comportant un procédé de communication radioélectrique selon la revendication 1 et comportant en outre les étapes de :

   traitement du signal d’étalonnage reçu en :
   amplifiant et/ou filtrant éventuellement le signal d’étalonnage afin de réduire le bruit à basse fréquence ;
   déterminant, à partir du signal d’étalonna-
Procédé selon la revendication 19, comportant en outre les étapes de :

- émission, depuis une horloge principale, d’un signal de synchronisation d’horloges vers chaque dit au moins un organe de tir, pour synchroniser de la sorte toutes les horloges dudit au moins un organe de tir avec ladite horloge principale ; et
- établissement, pour toutes les horloges dudit au moins un organe de tir, d’au moins un instant zéro synchronisé par rapport à l’émission dudit signal de synchronisation d’horloges ; de telle sorte qu’à la réception, par ledit au moins un organe de tir, d’un signal de commande de MISE A FEU, chaque dit au moins un organe de tir attende un prochain instant zéro synchronisé, puis compte à rebours sa durée de temporisation programmée se traduisant par un déclenchement d’une charge explosive correspondante, pour ainsi réaliser un déclenchement synchronisé de chaque charge explosive associée à chaque organe de tir, afin d’obtenir une combinaison de tir voulu.

20. Procédé selon la revendication 19, dans lequel au moins l’étape d’émission dudit signal de synchronisation d’horloges s’effectue à l’aide d’une communication à courte portée impliquant soit un contact électrique direct soit une communication radioélectrique à courte portée entre l’horloge principale et ledit au moins un organe de tir, éventuellement avant que ledit au moins un organe de tir ne soit disposé dans la zone de tir.

21. Procédé selon la revendication 19, dans lequel ladite disposition dudit au moins un organe de tir comprend une disposition sous le sol et ledit au moins un signal radioélectrique de commande est émis à travers la roche par ledit au moins un explosif.

22. Procédé selon la revendication 19, comportant en outre les étapes de :

- émission, par ladite horloge principale, d’au moins un autre signal de synchronisation d’horloges vers ledit au moins un organe de tir ; et si nécessaire, resynchronisation de chaque horloge dudit au moins un organe de tir, conformément audit au moins un autre signal de synchronisation d’horloges, pour ainsi corriger la dérive entre chaque horloge par rapport à ladite horloge principale.

23. Procédé selon la revendication 22, dans lequel ledit au moins un autre signal de synchronisation d’horloges est émis vers ledit au moins un organe de tir à la suite de la disposition dudit au moins un organe de tir sous le sol dans ladite zone de tir, de façon qu’au moins ledit au moins un signal radioélectrique de commande ainsi que ledit au moins un autre signal de synchronisation d’horloges soient émis à travers la roche à l’aide d’ondes radio à fréquence de 20 à 2500 Hz.

24. Procédé selon la revendication 22, ledit au moins un autre signal de synchronisation d’horloges comprenant une pluralité d’autres signaux de synchronisation d’horloges émis périodiquement par ladite horloge principale, et la réception d’au moins un signal de commande de MISE A FEU par ledit au moins un organe de tir dans un délai prédéterminé entre la réception de deux autres signaux de synchronisation d’horloges consécutifs, ce qui lance un compte à rebours de ladite durée de temporisation à partir dudit instant zéro, induisant un déclenchement ultérieur de charges explosives associées audit au moins un organe de tir, ce qui se traduit par une combinaison de tir voulu.

25. Procédé selon la revendication 24, dans lequel les-dits autres signaux de synchronisation d’horloges sont émis de 1 à 60 secondes les uns après les autres, de préférence de 10 à 30 secondes les uns après les autres, de préférence encore 15 secondes les uns après les autres.

26. Procédé selon la revendication 22, dans lequel ledit au moins un signal de commande de MISE A FEU comprend une pluralité de signaux de commande de MISE A FEU émis dans une salve de signaux de commande émis en une succession rapide, ladite salve étant synchronisée pour débuter et s’achever entre deux autres signaux d’étalonnage d’horloges consécutifs, de façon que la réception réussie d’un ou de plusieurs de ladite pluralité de signaux de commande de MISE A FEU par ledit au moins un organe de tir provoque l’établissement d’un instant zéro et un compte à rebours de durée de temporisation à la réception dudit second desdits deux autres signaux de synchronisation d’horloges consécutifs.

27. Procédé selon 1 revendication 22, dans lequel chaque dit au moins un organe de tir comprend une batterie servant à lui fournir de l’électricité et peut être commuté entre un état actif pour la réception dudit signal de synchronisation, dudit au moins un autre signal de synchronisation d’horloge et éventuellement dudit au moins un signal de commande, et un état de repos pour économiser le courant de la batterie.

28. Procédé selon la revendication 27, dans lequel ledit
au moins un organe de tir quitte périodiquement un état actif pour recevoir chaque dit au moins un autre signal de synchronisation d’horloge.

29. Procédé selon la revendication 28, dans lequel ledit au moins un signal de commande est émis lorsque nécessaire vers ledit au moins un organe de tir pendant un laps de temps prédéterminé par rapport à un autre signal de synchronisation d’horloge, et ledit au moins un organe de tir est apte à maintenir ledit état actif uniquement pendant chacun desdits laps de temps prédéterminés, afin d’assurer de la sorte la réception dudit au moins un signal de commande et dudit au moins un autre signal de synchronisation et ainsi d’économiser le courant de la batterie quand aucun signal n’est attendu.

30. Procédé selon la revendication 22, dans lequel chaque horloge de chaque organe de tir oscille à une fréquence un peu plus lente que celle de ladite horloge principale, si bien que la correction de la dérive dans toutes les horloges dudit au moins un organe de tir nécessite une correction positive pour amener lesdites horloges à regagner du temps pour rattraper ladite horloge principale.

31. Procédé selon la revendication 22, dans lequel chaque horloge de chaque organe de tir oscille à une fréquence un peu plus rapide que celle de ladite horloge principale, si bien que la correction de la dérive dans toutes les horloges dudit au moins un organe de tir nécessite une correction négative pour amener lesdites horloges à perdre du temps pour rattraper ladite horloge principale.

32. Procédé selon la revendication 1, dans lequel chaque organe de tir peut passer d’un état de repos à faible puisance pour économiser le courant de la batterie à un état d’écoute pour écouter la réception d’un signal d’activation émis par un exploseur ou autre organe correspondant, et/ou un signal de synchronisation d’horloges émis par une horloge principale, le procédé comportant en outre l’étape de :

- passage périodique du/des organe(s) de tir dudit état inactif audit état d’écoute au cours d’un laps de temps limité, à la suite de quoi un échec de réception, par chaque organe de tir, d’un signal d’activation et/ou d’un signal de synchronisation d’horloges pendant qu’il est dans ledit état d’écoute amène chaque organe de tir à revenir dans ledit état de repos, ce qui économe le courant de la batterie, et à la suite de quoi la réception, par ledit organe de tir, d’un signal d’activation et/ou d’un signal de synchronisation d’horloges pendant qu’il est dans ledit état d’écoute amène chaque organe de tir à passer dans un état actif qui permet à chaque organe de tir de constituer une partie active, fonctionnelle dudit dispositif de tir.

33. Procédé selon la revendication 22, le procédé comportant en outre l’étape de :

- émission d’un signal d’activation par un exploseur ou un autre organe et/ou d’un signal de synchronisation d’horloges par une horloge principale à un instant ou pendant un laps de temps suffisant pour activer chaque organe de tir du dispositif de tir pour ainsi mettre chaque organe de tir dans un état actif, fonctionnel lui permettant de constituer une partie active, fonctionnelle dudit dispositif de tir.

34. Procédé selon la revendication 33, dans lequel ledit signal d’activation et/ou ledit signal de synchronisation d’horloges a une durée plus longue qu’un laps de temps entre ladite commutation périodique pour ainsi assurer que chaque organe de tir se trouve dans un état d’écoute permettant de recevoir ledit signal d’activation et/ou ledit signal de synchronisation d’horloge avant que chaque organe de tir ne repasse dans un état de repos.

35. Dispositif de tir pour mettre en œuvre le procédé selon l’une quelconque des revendications 1 à 34, le dispositif de tir comportant :

- au moins un explosif destiné à émettre ledit au moins un signal de commande comprenant des ondes radio à fréquence de 20 Hz à 2 500 Hz ;
- un moyen de production de signal d’étalonnage pour produire un signal de porteuse comprenant des ondes radio à fréquence de 20 à 2 500 Hz différente de la fréquence dudit au moins un signal radioélectrique de commande ;
- au moins un organe de tir destiné à recevoir ledit au moins un signal de commande et ledit signal d’étalonnage, chaque organe de tir comprenant un détonateur ayant un circuit de mise à feu et une charge de base, une charge explosive coopérant avec ledit détonateur, de façon que le déclenchement de ladite charge de base par l’intermédiaire dudit circuit de mise à feu provoque le déclenchement de ladite charge explosive ;
- un émetteur-récepteur destiné à recevoir et/ou traiter ledit au moins un signal radioélectrique de commande émis par ledit explosif et ledit signal d’étalonnage émis par ledit moyen de production de signal d’étalonnage, ledit émetteur-récepteur échangeant des signaux avec ledit circuit de mise à feu de telle sorte qu’à la réception d’un signal de commande de MISE A FEU ledit circuit de mise à feu provoque le déclenchement de ladite charge de base et le déclen-
chément de ladite charge explosive ; une horloge ; une mémoire pour mémoriser une durée de temporisation programmé ; et un moyen pour traiter le signal d’étalonnage afin de permettre la synchronisation de toutes les horloges présentes dans les organes de tir les unes avec les autres, et l’établissement d’un instant zéro de façon qu’à la réception, par ledit au moins organe de tir, d’un signal de commande de MISE A FEU, le compte à rebours de ladite durée de temporisation débute à partir de l’instant zéro synchronisé afin de réaliser un déclenchement synchronisé de chaque charge explosive associée à chaque organe de tir, afin d’obtenir de la sorte la combinaison de tir voulue.

36. Dispositif de tir selon la revendication 35, dans lequel le moyen pour traiter le signal d’étalonnage comprend un moyen de délimitation pour délimiter les oscillations du signal d’étalonnage ou des parties desdites oscillations.

37. Dispositif de tir selon la revendication 35, dans lequel le moyen de production de signal d’étalonnage comprend :

une horloge principale pour produire le signal d’étalonnage en tant que signal de synchronisation d’horloges et émettre le signal de synchronisation d’horloges vers chaque dit au moins un organe de tir pour ainsi synchroniser toutes les horloges dudit au moins un organe de tir avec ladite horloge principale et ledit au moins un organe de tir comprend un moyen d’étalonnage d’horloges pour synchroniser ladite horloge avec ladite horloge principale et établir ledit au moins un instant zéro synchronisé.

38. Dispositif de tir selon la revendication 37, dans lequel l’horloge principale émet en outre au moins un autre signal de synchronisation d’horloges vers ledit au moins un organe de tir, ledit moyen d’étalonnage d’horloges resynchronisant chaque horloge dudit au moins un organe de tir, si nécessaire, en fonction dudit au moins un autre signal de synchronisation d’horloges, pour ainsi corriger la dérive entre chaque horloge par rapport à ladite horloge principale.

39. Dispositif de tir selon la revendication 35, dans lequel ledit au moins un exploseur émet un signal d’activation pour faire passer dans un état actif ledit au moins un organe de tir afin de former des organes actifs du dispositif de tir, chaque dit au moins un organe de tir recevant et/ou traitant ledit signal d’activation à l’aide de l’émetteur-récepteur et comprenant en outre un moyen de commutation pour faire périodiquement passer chaque organe de tir d’un état de repos à un état d’écoute permettant de recevoir ledit signal d’activation.

40. Dispositif de tir selon la revendication 35, dans lequel le signal de synchronisation d’horloges produit par l’horloge principale fait passer chaque dit au moins un organe de tir dans un état actif afin de former des organes actifs du dispositif de tir, chaque dit au moins un organe de tir comprenant en outre un moyen de commutation pour faire périodiquement passer chaque organe de tir d’un état de repos à un état d’écoute permettant de recevoir ledit signal d’étalonnage d’horloge.

41. Dispositif de tir selon la revendication 36, l’organe de tir comprenant :

ledit détonateur ;
ladite charge explosive ;
ledit émetteur-récepteur ;
ladite horloge ;
ladite mémoire ; et
ledit moyen de délimitation pour délimiter les oscillations du signal d’étalonnage, ou des parties desdites oscillations, pour ainsi permettre la synchronisation de toutes les horloges présentes dans les organes de tir du dispositif de tir les unes avec les autres et établir instant zéro synchronisé, de telle sorte qu’à la réception, par ledit organe de tir, d’un signal de commande de MISE A FEU, le compte à rebours dudit durée de temporisations débute à l’instant zéro synchronisé pour ainsi réaliser un déclenchement synchronisé de la charge explosive associée à l’organe de tir.

42. Dispositif de tir selon la revendication 37, l’organe de tir comprenant :

ledit détonateur ;
ladite charge explosive ;
ledit émetteur-récepteur ;
ladite horloge ;
ladite mémoire ; et
ledit moyen de délimitation pour délimiter le signal de synchronisation d’horloges, pour ainsi synchroniser ladite horloge avec ladite horloge principale et établir ledit au moins un instant zéro synchronisé, de façon qu’à la réception, par ledit organe de tir, d’un signal de commande de MISE A FEU ledit organe de tir attende un instant zéro synchronisé suivant et commence à compter à rebours sa durée de temporisation programmée, ce qui induit un déclenchement de la charge explosive correspondante, pour ainsi réaliser un déclenchement synchronisé de la charge explosive associée à l’organe de tir.
43. Dispositif de tir selon la revendication 39 ou 40, l’organe de tir comprenant :

   ledit détonateur ;
   ladite charge explosive,
   ledit émetteur-récepteur pour recevoir et/ou traiter ledit au moins un signal radioélectrique de commande émis par ledit explosif et ledit signal de synchronisation d'horloges émis par ladite horloge principale ou ledit signal d'activation, ledit émetteur-récepteur échangeant des signaux avec ledit circuit de mise à feu de telle sorte que, à la réception d’un signal de commande de MISE À FEU ledit circuit de mise à feu provoque le déclenchement de ladite charge de base et le déclenchement de ladite charge explosive si ledit organe de tir est dans un état actif ;
   ladite horloge ;
   ladite mémoire ; et
   ledit moyen de commutation pour faire périodiquement passer ledit organe de tir d’un état de repos à un état d’écoute permettant de recevoir ledit signal d’étalonnage d’horloges ou ledit signal d’activation pour faire venir l’organe de tir dans son état actif.
Transmitting at least one wireless command signal comprising LF radio waves

Receiving the at least one wireless command signal by the at least one blasting component

Processing and optionally acting upon said at least one wireless command signal

Fig. 1
Transmitting through rock at least one calibration signal comprising LF radio waves

Receiving through rock the at least one calibration signal by the at least one blasting component

Processing the calibration signal

Transmitting through rock at least one command signal comprising LF radio waves

Receiving through rock the at least one command signal by the at least one blasting component

Processing the at least one command signal

Fig. 2
Length of gaps between successive zero crossings in 40 microsec units.

SD of Noise: $s_{dn} = 0.7$  RMS signal: 0.707

Fig. 3
Trying different distances shows that there is an optimum frequency for any given distance (soil type not changing). The benefit of higher frequency in the detector is offset by the exponentially increasing attenuation due to conductivity in the ground.

Fig. 4
transmitting from a master clock, a clock synchronization signal to each of said at least one blasting component

establishing at least one synchronized time zero relative to transmission of said clock synchronization signal, for all clocks of said at least one blasting component

Fig. 5
REFERENCES CITED IN THE DESCRIPTION

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