(19) **Octrooicentrum Nederland**

(11) **2028770**

(12) A **OCTROOIAANVRAAG**

(21) Aanvraagnummer: **2028770**

(22) Aanvraag ingediend: **17 juli 2021**

(51) Int. Cl.:
G01V 3/28 (2021.01)

(30) Voorrang:
10 september 2020 CN 202010947615.0

(41) Aanvraag ingeschreven:
9 mei 2022

(43) Aanvraag gepubliceerd:
10 mei 2022

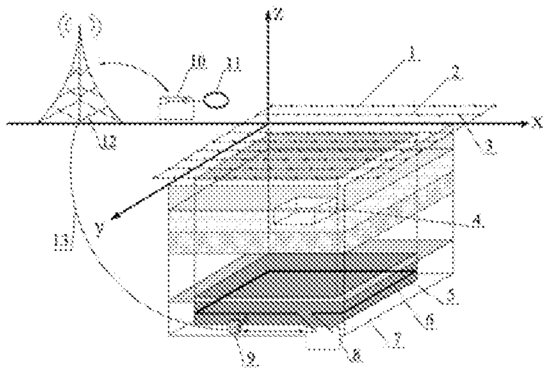
(71) Aanvrager(s):
Anhui University of Science and Technology te Huainan, China, CN

(72) Uitvinder(s):
Xiongwu Hu te Huainan (CN)
Hu Xu te Huainan (CN)
Zhijie Wan te Huainan (CN)
Dan Han te Huainan (CN)
Dangdang Meng te Huainan (CN)
Renjun Chen te Huainan (CN)
Biao Xu te Huainan (CN)

(74) Gemachtigde:
dr. T. Wittop Koning PhD te Delft

(54) 5G+CMFT—R TIME DOMAIN ELECTROMAGNETIC FIELD EXPLORATION SYSTEM AND METHOD

(57) The present invention discloses a 5G+CMFT—R time domain electromagnetic field exploration system and method, applicable to detection and prevention of roof water damage in the process of coal mining. In view of the characteristics of thick roof of coal seam and complicated ground surface in northwest China, with respect to the deficiencies of the existing ground and underground transient electromagnetic detection methods, the present invention implements an electromagnetic field transmission by using the transmitting coil to surround a coalface, and connects an underground signal transmitting system with a ground signal acquisition system to complete the same frequency and synchronization of reception and transmission. A secondary electromagnetic field is received point by point according to arrangement of a survey grid by a receiving coil on the ground. The collected current and voltage data are converted into apparent resistivity data to obtain apparent resistivity images at different layers and conduct anomaly interpretation. The present invention can fully exert the detection advantage of the transient electromagnetic method in the coal mine areas of northwest China to obtain detection results with higher accuracy at lower cost, and can accurately judge the spatial positions of the water-rich regions of coal seam roofs to provide reliable technical parameters for the safety and efficient production of coal mines.



NL A 2028770

5G+CMFT—R TIME DOMAIN ELECTROMAGNETIC FIELD EXPLORATION SYSTEM AND METHOD

Technical Field

The present invention relates to the technical field of detection and prevention of water damage in coal mining, and particularly to a 5G+CMFT—R time domain electromagnetic field exploration system and method.

Background

The early and middle Jurassic coalfield in northwest China has many layers of coal seams, large thicknesses and abundant resources. In recent years, there are many water-sand inrush incidents with intermittent characteristics in soft rocks with weakly abundant water in some coalfields. Large amount of water in a short time seriously threatens the safety production of mines. Therefore, it is necessary to use the geophysical exploration means to find out the abnormal regions with abundant water in coal mines so as to facilitate the formulation of corresponding preventive measures. The transient electromagnetic method has become a preferred method in the current hydrogeological exploration of the coalfields because of its high construction efficiency, pure secondary field observation and sensitivity to low resistance body. The ground transient electromagnetic method is difficult to operate and high in construction cost due to vertical and horizontal ravines and gullies and large topographic relief on the surface in northwest China. In addition, the depth of coal seam roof detection in this region is generally required to be above 150 m. The effective detection distance of the underground transient electromagnetic method is within 100 m, which cannot satisfy the requirements of underground safety production. Moreover, the data value is easily distorted due to the interference of instruments, devices and metal pipes in coal mines to the underground transient electromagnetic method, causing unreliability of detection results. The "detection system based on the stereographic transient electromagnetic data acquisition in upper and lower space of mine" proposed recently can realize stereographic dynamic detection and improve the detection accuracy. However, there are some disadvantages that a transmitting coil is affected by surface relief, receiving regions are only limited to the interior of the tunnel and the water-bearing capability feature of roof strata in a working surface cannot be reflected.

Based on the deficiencies of the detection capability of the existing ground and underground transient electromagnetic methods, with respect to the difficulty of water damage prevention in coal mining areas of northwest China, the present invention proposes a 5G+CMFT—R time domain electromagnetic field exploration system and method, so as to reduce the cost, improve the accuracy of the detection results and satisfy the requirements of safety and efficient production of the mines.

Summary

In view of the problems in the prior art, the present invention provides a 5G+CMFT—R time domain electromagnetic field exploration system and method to solve the problems of limited underground detection distance, poor resolution capability, unreliable data, difficult construction on the ground affected by topography, and high cost in the transient electromagnetic method, enhance the accuracy of detection results and satisfy the requirements of safe and efficient production of mines.

To achieve the above purpose, the present invention adopts the following technical solution:

A 5G+CMFT—R time domain electromagnetic field exploration system comprises an underground signal transmitting system, a ground signal acquisition system, a data transmission control system and a data imaging interpretation system.

The underground signal transmitting system comprises a transmitter module and a transmitting coil module.

The ground signal acquisition system comprises a receiver module and a receiving coil module.

The data transmission control system comprises a mine optical fibre cable, a 5G underground communication base station and a 5G ground communication base station, and both ends of the data transmission control system are respectively connected with the underground signal transmitting system and the ground signal acquisition system.

The data imaging interpretation system is installed in a receiver.

Preferably, a transmitter is a high-power transmitter capable of transmitting large current, is provided with a transmitting power supply and a 5G signal receiving module inside, and generally has explosion-proof performance.

Preferably, a transmitting coil is made of high-quality copper wires and can bear large current and high voltage.

Preferably, the receiver has the built-in 5G signal receiving module which has the characteristics of long standby time and high sampling rate. Generally, the standby time is not less than 8 hours, a sampling interval is less than 1μs and sampling frequency is higher than 1M.

Preferably, a receiving coil is made of high-quality copper wires which can be wound into multiple turns and have the characteristics of wide frequency band and high sensitivity.

A 5G+CMFT—R time domain electromagnetic field exploration method comprises the following steps:

(1) survey grid arrangement: obtaining the geodetic coordinates of a vertical projection of a working surface to be measured on the ground according to the geological data and coal seam mining records of a detection region; extending the projection range of the ground by a certain proportion of n ($1.3 \le n \le 1.5$) in X and Y directions as a survey grid range; and accurately arranging survey lines and survey points within the range of the survey grid according to exploration requirements, with the principle that a line spacing is ≤40m and a point spacing is ≤20m;

(2) system arrangement: firstly, arranging the transmitting coil into a tunnel and surrounding the working surface for one circle; connecting both ends of the coil with a transmitter interface for transmitting electromagnetic waves; connecting the transmitter with the 5G underground communication base station through the built-in 5G signal receiving module; meanwhile, connecting the receiving coil with a receiver interface; connecting the receiver with the 5G ground communication base station through the built-in 5G signal receiving module; connecting and communicating the 5G underground communication base station with the 5G ground communication base station through the mining optical fibre cable; and finally realizing same frequency and synchronization of reception and transmission;

(3) transmission and reception: setting parameters for the underground transmitter according to detection requirements; starting to transmit a pulse magnetic field and record current data; and receiving a secondary electromagnetic field signal point by point according to grid points of the survey grid on the ground and recording voltage data;

(4) data processing and imaging: converting the collected current and voltage data into apparent resistivity data through professional software, obtaining apparent resistivity images at different layers, and analysing electromagnetic wave response characteristics.

The present invention has the following beneficial effects:

(1) The present invention fully considers the characteristics of the mine environment, encircles the transmitting coil around the whole working surface, and avoids the problems of large topographic fluctuation, difficult operation and high construction cost in the ground transient electromagnetic method.

(2) A high-power transmitter is used to transmit high-magnetic moment transient electromagnetic signals underground, overcomes the problems of short distance, low accuracy and complex construction of the traditional mine small-coil transient electromagnetic detection, and can obtain stronger transient electromagnetic response information, so as to improve the accuracy of judging the water-bearing capability of roof strata of the coal seam and provide reliable technical basis for safety production of the mine.

(3) The present invention adopts the "transmission" operating mode of transmitting the primary electromagnetic field underground and receiving the secondary induced electromagnetic field on the ground, and forms the perspective observation mode of the electromagnetic field for different strata of coal seam roofs. The results of data analysis imaging have higher resolution than the existing transient electromagnetic detection, and especially are more accurate in the determination of the depth of electrical anomaly regions.

(4) In the present invention, the ground detection region is larger than the projection region of the working surface, which can provide more comprehensive and abundant transient electromagnetic data for the actual destruction region of coal seam mining to satisfy the needs of safety production of the mine.

Description of Drawing

Fig. 1 is a three-dimensional schematic diagram of an observation method in the present invention.

In the figure: 1 survey grid; 2 survey line; 3 survey point; 4 water-rich anomaly; 5 coal seam; 6 transmitting coil; 7 tunnel; 8 transmitter; 9 5G underground communication base station; 10 receiver; 11 receiving coil; 12 5G ground communication base station; 13 mining optical fibre cable.

Detailed Description

The present invention is further illustrated through the following embodiments, but the protection scope of the present invention is not limited to the following embodiments.

Referring to Fig. 1, a 5G+CMFT—R time domain electromagnetic field exploration system of the present invention comprises an underground signal transmitting system, a ground signal acquisition system, a data transmission control system and a data imaging interpretation system. The underground signal transmitting system comprises a transmitter module 8 and a transmitting coil module 6. A transmitter 8 is a high-power transmitter capable of transmitting large current, and is provided with a transmitting power supply and a 5G signal receiving module inside. The transmitter 8 generally has explosion-proof performance. A transmitting coil 6 is made of high-quality copper wires and can bear large current and high voltage. The ground signal acquisition system comprises a receiver module 10 and a receiving coil module 11. The receiver 10 has the built-in 5G signal receiving module which has the characteristics of long standby time and high sampling rate. Generally, the standby time is not less than 8 hours, a sampling interval is less than 1μs and sampling frequency is higher than 1M. A receiving coil 11 is made of high-quality copper wires which can be wound into multiple turns and have the characteristics of wide frequency band and high sensitivity. The data transmission control system comprises a mine optical fibre cable 13, a 5G underground communication base station 9 and a 5G ground communication base station 12, and both ends of the data transmission control system are respectively connected with the underground signal transmitting system and the ground signal acquisition system. The data imaging interpretation system is installed in a receiver.

A 5G+CMFT—R time domain electromagnetic field exploration method comprises the following steps:

(1) survey grid arrangement: obtaining the geodetic coordinates of a vertical projection of a working surface to be measured on the ground according to the geological data and coal seam mining records of a detection region; extending the projection range of the ground by a certain proportion of n ($1.3 \leq n \leq 1.5$) in X and Y directions as a survey grid range; and accurately arranging survey lines and survey points within the range of the survey grid according to exploration requirements, with the principle that a line spacing is ≤40m and a point spacing is ≤20m;

(2) system arrangement: firstly, arranging the transmitting coil into a tunnel and surrounding the working surface for one circle; connecting both ends of the coil with a transmitter interface for transmitting electromagnetic waves; connecting the transmitter with the 5G underground communication base station through the built-in 5G signal receiving module; meanwhile, connecting the receiving coil with a receiver interface; connecting the receiver with the 5G ground communication base station through the built-in 5G signal receiving module; connecting and communicating the 5G underground communication base station with the 5G ground communication base station through the mining optical fibre cable; and finally realizing same frequency and synchronization of reception and transmission;

(3) transmission and reception: setting parameters for the underground transmitter according to detection requirements; starting to transmit a pulse magnetic field and record current data; and receiving a secondary electromagnetic field signal point by point according to grid points of the survey grid on the ground and recording voltage data;

(4) data processing and imaging: converting the collected current and voltage data into apparent resistivity data through professional software, obtaining apparent resistivity images at different layers, and analysing electromagnetic wave response characteristics.

The above is just one preferred embodiment of the present invention. All equal variations and modifications made in accordance with the scope of the application patent of the present invention shall belong to the scope covered by the present invention.

The above shows and describes the basic principles, main features and advantages of the present invention. Those skilled in the art shall understand that the present invention is not limited by the above embodiment. The above embodiment and the description merely illustrate the principle of the present invention. Various changes and improvements can also be made to the present invention without departing from the spirit and scope of the present invention, and shall fall into the protection scope of the present invention.

CONCLUSIES

1. Een 5G + CMFT - R tijddomein elektromagnetisch veldverkenningssysteem, dat een ondergronds signaaloverdrachtssysteem, een grondsignaalacquisitiesysteem, een gegevensoverdrachtscontrolesysteem en een gegevensbeeldinterpretatiesysteem omvat, waarbij het ondergronds signaaloverdrachtssysteem een zendmodule en een zendspoelmodule omvat; het grondsignaalacquisitiesysteem een ontvangermodule en een ontvangstspoelmodule omvat; het controlesysteem voor gegevenstransmissie een optische vezel mijnkabel, een 5G-basisstation voor ondergrondse communicatie en een 5G-basisstation voor grondcommunicatie omvat, en beide uiteinden van het controlesysteem voor gegevenstransmissie respectievelijk zijn verbonden met het ondergrondse signaaltransmissiesysteem en het grondsignaalacquisitiesysteem; en het systeem voor interpretatie van gegevensbeeldvorming geïnstalleerd is in een ontvanger.

2. Het 5G + CMFT - R tijddomein elektromagnetisch veldverkenningssysteem volgens conclusie 1, waarbij de zender een zender met hoog vermogen is die een grote hoeveelheid stroom kan uitzenden, en inwendig is voorzien van een zendvoeding en een 5G signaalontvangstmodule, en over het algemeen explosieveilige prestaties heeft.

3. Het 5G + CMFT - R tijddomein elektromagnetisch veldverkenningssysteem volgens conclusie 1, waarbij een zendspoel is vervaardigd van koperdraden van hoge kwaliteit en een grote hoeveelheid stroom en hoogspanning kan dragen.

4. Het 5G + CMFT - R tijddomein elektromagnetisch veld exploratiesysteem volgens conclusie 1, waarbij de ontvanger de ingebouwde 5G signaalontvangstmodule heeft die wordt gekenmerkt door een lange standby-tijd en een hoge bemonsteringsfrequentie; waarbij de standby-tijd doorgaans niet minder dan 8 uur bedraagt, en het bemonsteringsinterval minder dan 1μs is en de bemonsteringsfrequentie hoger is dan 1M.

5. Het 5G + CMFT - R tijdsdomein elektromagnetisch veld exploratiesysteem volgens conclusie 1, waarbij een ontvangstspoel is vervaardigd van koperdraden van hoge kwaliteit die in meerdere windingen kunnen worden gewikkeld en worden gekenmerkt door een brede frequentieband en hoge gevoeligheid.

6. Een implementatiewerkwijze die is gebaseerd op het systeem volgens willekeurig welke van conclusies 1 - 5, welke werkwijze de volgende stappen omvat:

(1) opstelling van het opmetingsraster:

verkrijgen van de geodetische coördinaten van een verticale projectie van een op de grond te meten werkoppervlak overeenkomstig de geologische gegevens en kolennaadontginningsgegevens van een opsporingsgebied; uitbreiden van het projectiebereik van de grond met een bepaalde verhouding van n ($1{,}3 \leq n \leq 1{,}5$) in X- en Y-richting als opmetingsrasterbereik; en nauwkeurig rangschikken van opmetingslijnen en opmetingspunten binnen het bereik van het opmetingsraster overeenkomstig exploratie-eisen, met als principe dat een lijnafstand ≤ 40 m en een puntafstand ≤ 20 m is;

(2) plaatsing van het systeem:

allereerst het rangschikken van de zendspoel in een tunnel en rond het werkoppervlak voor een cirkel; het verbinden van beide uiteinden van de spoel met een zenderinterface voor het verzenden van elektromagnetische golven; het verbinden van de zender met het 5G ondergrondse communicatiebasisstation via de ingebouwde 5G signaalontvangstmodule; ondertussen het verbinden van de ontvangstspoel met een ontvangerinterface; het verbinden van de ontvanger met het 5G grondcommunicatiebasisstation via de ingebouwde 5G signaalontvangstmodule; het verbinden en communiceren van het 5G ondergrondse communicatiebasisstation met het 5G grondcommunicatiebasisstation via de optische vezel-mijnkabel; en ten slotte het realiseren van dezelfde frequentie van ontvangst en verzending;

(3) transmissie en ontvangst:

het instellen van parameters voor de ondergrondse zender volgens detectievereisten; beginnen met het uitzenden van een puls magnetisch veld; en het ontvangen van een secundair elektromagnetisch veldsignaal punt voor punt volgens rasterpunten van het onderzoeksraster op de grond en het opnemen van gegevens;

(4) gegevensverwerking en beeldvorming:

omzetting van de verzamelde gegevens in klaarblijkelijke weerstandsgegevens met behulp van professionele software, verkrijging van schijnbare resistiviteits klaarblijkelijke weerstandsbeelden op verschillende lagen, en analyse van de responskenmerken van de elektromagnetische golven.

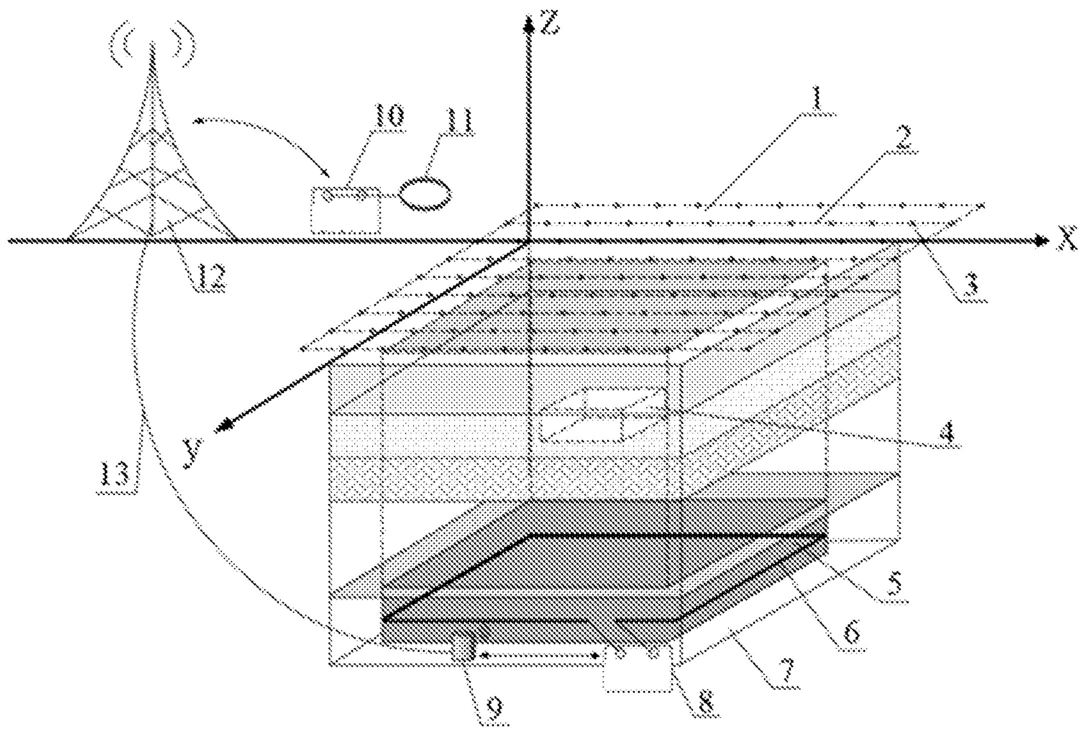


Fig. 1