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Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "The development and test research of multi-channel Synchronous transient electromagnetic receiver" *by* Fanqiang Lin et al.

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Dear Anonymous Referee: Thank you for your time and very useful comments! According to your advice, we revised this manuscript. All of the changes are made in the supplement files, which are a marked-up manuscript version and a clear revised version.

1. Comment from Reviewer: "PPS", "FPGA", "ARM" should be explain for ïňĄrst mention. Author's response in manuscript: In Page 8 Line 7, the abbreviation of PPS means pulse per second, and in Page 2, Line 15, FPGA means Field Programmable Gate Array, and ARM means Advanced RISC (reduced instruction set computer) Machine.

These explanations were provided in the marked-up manuscript version.

2. Comment from Reviewer: There are minor type errors: Page1 Line7 change "128 k" to "128 kHz" Page 5 Line 11, change "second pulse signal" to" pulse per second", Page 8 change "40mS" to "40 ms". Author's response in manuscript: We have modified the typing errors in the manuscript. In Page 1 Line 7: 128k refers to the sample rate, and it should be changed to 128k SPS (Sample Per Second). In Page5 Line 11: the PPS means Pulse Per Second. In Page 13, Figure 15: the period of the emitting signals is 40mS, and the "S" in "40mS" should be lowercase. 40mS was changed to 40ms.

3. Comment from Reviewer: Section 4 presents some results of the performance on the ïňĄeld. However, it would be interesting to see some ïňĄeld work photo and instrument picture. Author's response in manuscript: we added photos of the instrument and the field work, which are shown in Figure 21, the photo of the receiver, Figure 22 T-4, photo of the transmitter in operation and Figure 23, the field working photo of exploration area. Those pictures were inserted after the conclusion.

4. Comment from Reviewer: the lab test is too simple, the main performance of the receiver contains band width, signal to noise ratio, self-noise level, input full scale, power consumption, linearity, et al. and the table 1 ,table 2, ïňĄgure 2, ïňĄgure 3, ïňĄgure 4 are not the key performance test. Author's response in manuscript: we have given the following statements in response to the reviewer's comment. (1) In Page 5, Line 4, the band width of the receiver is DC to 12.8k SPS, (2)In Page 11, Line 1: SNR=20*log (Full Scale Value/Root-Mean-Square Noise Voltage, and the signal-to-noise ratio of 6 channels is approximately 100dB by calculating. (3)In Page 4, Line 3: the multi-channel receiver has a wide voltage input range, which varies from -5V to +5V, and the amplitude of the signal in actual test is at the millivolt level. In Page 4, Line 9, the dynamic range of analog-digital converter is up to 144dB, because the resolution of the analog to digital convertor is a 24-bit resolution. (4) In Page 7 Line 6, since all chips are low-powered, and the overall power consumption of the receiver is lower than 10 watts. (5) In the manuscript, Table 1 and Table 2 show the amplification

ratios of each channel under the same input condition. From table 2 we can see the average error is less than 2.2μV. All of these changes were made in supplemented file. (6) In Page 12 Line 3: the noise of the circuit itself is collected when each channel of the receiver is connected to zero. And Figure 14 was added to present it. The figure can be seen in supplement file.

5. Comment from Reviewer: field test used Phoenix T-4 transmitter, the authors should at least mention the performance of V8 receiver. And it may show the advantage of multi-channel TEM receiver. Author's response in manuscript: In Page 12 Line 5: we added the following description. Phoenix T-4 transmitter is a small power transmitter. This transmitter powered by battery group can launch up to 40A current, and it can launch many kinds of waveforms, such as TD50 (named by Phoenix), which has a duty ratio of 50%. V8 receiver is the eighth generation of receiver technology developed by Phoenix since 1975. The sample rate is 96k, while the memory card used in V8 receiving system is only 512M bytes, which can't store all received data. V8 system is synchronized by GPS time. But the sample rate of the multi-channel TEM receiver proposed in the manuscript is 128k SPS, and synchronization mechanism is realized by GPS module and 28-bits counter. The synchronization accuracy can be improved greatly, and all the time information and data information are stored in SD card simultaneously.

6. Comment from Reviewer: in "introduction" and "Literature review" sections, there are too many words to describe the status in china, but it should be compare with international peer, and ïňĄnd the disadvantage of current instrument. The background and methodology and design have not been captured in detail. Author's response in manuscript: we have modified the part of "introduction" and "literature review", and the two parts were merged into one part named "Introduction". "Transient electromagnetic (TEM) method belongs to the active field source method of time domain electromagnetic. J.R.Wait firstly proposed the use of transient electromagnetic method to search for conducting ore bodies in 1951. In recent decades, the TEM re-

ceiver has been widely used in metal mineral, petroleum, natural gas exploration and other fields (Danielsen et al., 2003; Haroon et al., 2015), so many kinds of TEM receiver have been developed and manufactured, such as V8 receiver from Phoenix Geophysics(Phoenix Geophysics, 2017), ADU-07e from Metronix (Metronix, 2017), KMS-820 from KMS(KMS, 2017), which are easy to use and have good performance. Meanwhile, the TEM detection theories have also been developed. In 2010, internationally renowned geophysicist Zhdanov proposed the following directions for future electromagnetic exploration instruments and methods in the 75th anniversary of "Geophysics": Multi-component emission, Multi-channel reception and Pseudo-seismic data collection (Qi et al., 2015, Ayuso et al., 2016). Xue Guoqiang proposed short offset transient electromagnetic (SOTEM) method (Xue et al., 2013, Chen et al.,2016, Chen et al.,2017), and the reduction of transceiver distance can both greatly enhance the exploration depth and improve the signal to noise ratio (SNR). Because of the need for deeper exploration depth, and the need to obtain more diverse subsurface geological information, multi-channel number, low SNR and high synchronization are the key elements for TEM receiver development, which are useful to obtain more abundant underground geological information and improve the accuracy of detection. Therefore, we propose a multi-channel synchronous transient electromagnetic receiver, which has the characteristics of multi-channel synchronous parallel acquisition, large capacity (64G) storage function with full time synchronization and the sampling rate up to 128k SPS, while the sampling rate of V8 receiver is 96k only. The main purpose of this paper is to introduce a receiver system for synchronous acquisition of multiple electromagnetic signals in transient electromagnetic prospecting to achieve multi-parameter and multi-channel synchronous reception. High-speed programmable logic devices are used to achieve high-level synchronization between channels. Transmitting current waveform acquisition and multi-channel reception can be synchronized by using high-precision Global Position System(GPS) timing unit which is controlled by serial port of micro controller, while a programmable high-precision counter is used to store another data information synchronously, which is adopted to further improve the synchronization

accuracy when the receivers work in distributed mode."

7. Comment from Reviewer: the main innovation is multi-channel, add the result of ïňĄeld test for supporting the advantage. Author's response in manuscript: The receiver has the following innovations: firstly, the channel number of the receiver can be flexibly configured as even number. In laboratory testing, the receiver is configured as six-channel receiving system, and Figure 12 and 14 display signal data that is collected synchronously. Secondly, the high precision synchronization method is realized by GPS module and high resolution counter together. Thirdly, the receiver has high ripple rejection ratio, which is up to 82dB, and low power consumption by the application of high performance LDO devices. Fourthly, the receiver implements real time information storage, and the synchronization sampling rate is as high as 128k SPS. But in mine testing, due to the inconvenience of the layout of multi electrode pairs and coils, the data receiver and current waveform receiver are configured as two channels, while one channel of current waveform receiver is used to receive currents. Three waveform figures are shown in Figure 17. The first sub-figure is about the change rate of magnetic field(dB/dt), and the second one is about the electric field intensity Ex, and the third one is about the transmitting current waveform. Synchronous receiver with 32 channels can be realized, according to the bandwidth of the storage speed of SD card.

8. Comment from Reviewer: the description in the article is useful if the English is somewhat unclear. The English can be improved. Author's response in manuscript: We have tried our best to improve the English expression and corrected the grammatical errors in the manuscript. And the changes will be seen in the supplement file.

9. Comment from Reviewer: could the authors discuss synchronous method in more detail? Author's response in manuscript: In Page 13 Line 10, the high-precision synchronization mechanism is implemented with a high reliability GPS module and a 28-bit counter in FPGA. The receiver's time information is refreshed every two seconds by PPS of GPS module. The 28-bit counter is used to record the pulse, which come from 25MHz clock in FPGA board. The 28-bit counter value and collecting data and

time information are packaged and stored in SD card. The error for each count value is 40ns. Each sample data point can be tracked by the stored time information and data information in SD card. After data collection, no matter how many receivers work in mine area at the same time. The full-time range store technology supplied a valuable method to enhance the accuracy of the synchronization.

We look forward to hearing from you regarding our latest submission. We would be glad to respond to any further questions and comments that you might have. Thanks again for your valuable suggestions!

Please also note the supplement to this comment:
https://www.geosci-instrum-method-data-syst-discuss.net/gi-2018-6/gi-2018-6-AC2-supplement.pdf

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Fig. 1. Figure 21 Receiver

Fig. 2. Figure 22 T-4 transmitter

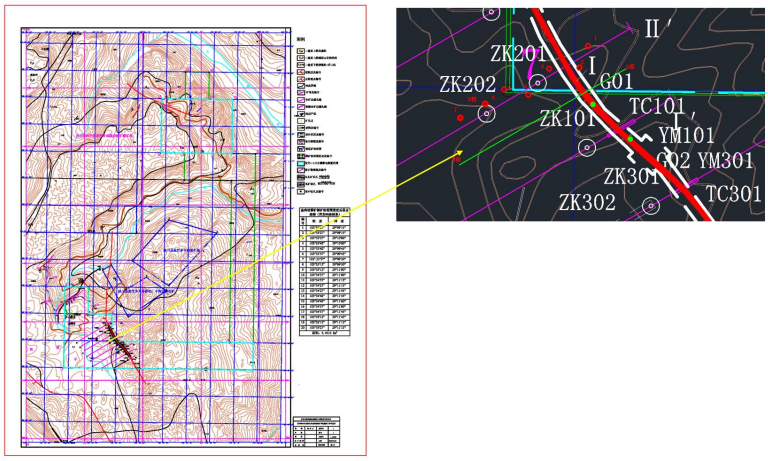

Fig. 3. Figure 23 Mine Picture