Cordless Seismic Data Acquisition System

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***Abstract* — Seismic methods are based on capturing of artificially generated seismic waves that are reflected on different ground layers. Seismic waves are captured using geophones, electro-mechanical sensors specially designed for geophysical exploration. This paper suggests a new system for data acquisition, based on ARM microcontroller, GSM/GPS module used in wireless network, internet technologies and a work station. This seismic system, comparing to older cable realizations, will cost less, greatly reduce the logistics effort, and reduce manpower required to conduct a seismic survey. In this paper are presented hardware and software realization, communicating network and results of data acquisition.**

***Index Terms* — seismic method, geophone, AD conversion, GSM**

I. INTRODUCTION

Nowadays, requirements for oil, natural gas and clean geothermal water are increasing dramatically. One of widely used method for exploration of oil, natural gas and clean geothermal water is seismic method, based on measuring artificially generated seismic waves.

Seismic methods are the most expensive and most effective methods in exploration layered media. Seismic method is based on measuring of seismic waves. Seismic waves carry acoustic energy transmitted by vibration of rock particles [1]. It is basically same method used for earthquake measuring with difference in source of seismic waves. Seismic waves, in their propagation through the various ground surfaces (different types of terrains, holes with natural gas, water or oil), behave same as all other types of waves, reflect or refract on different surfaces, as shown on Fig 1.

Reflection and refraction occur when seismic wave passes trough ground layer with different physical characteristic such as ground density, moisture, etc. Some of energy is reflected and the remainder continues on its way on a different angle, refracted.

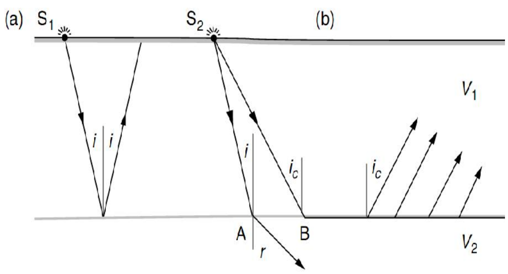

Fig 1. Reflection and refraction of waves

The angle of reflection is equal to the angle of incidence. Refraction is governed by Snell's Law [1]:

$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2}$$

These two phenomena are basis of seismic methods in exploration of oil, natural gas and geothermal water. Information about different layers and their composition is comprised in reflected seismic waves. Reflected seismic waves produce small ground motions detectable with specially designed electro-mechanical sensors called geophones. Geophones are, basically, small generators that produce electrical signal proportional to ground motion caused by reflected seismic wave. In older systems seismic signals are carried from geophones to recorders as varying electric currents, in cables which must contain twice as many individual wires as there are geophones. Wires are packed very closely and not only can external current carries such as power or telephone cables induce currents, but a very strong signal in one wire can be passed inductively to all the others. Cables and plugs are the most vulnerable parts of a seismic system and are most of the problems occurs when they are joined.

II. SEISMIC MEASUREMENT

Seismic measurement starts when the source of seismic waves starts to generate waves. Since depth of investigation with seismic waves depends on their energy, it is essential to use high power sources, maximum power of seismic waves is achieved using explosive charges. Explosives send all of their energy in one moment, which is ideal for this measurement, but is very hard to use and control them, so usually heavy vibration trucks are used instead. Energy which they can produce in one stroke is not adequate, so they usually vibrate for couple of seconds, and when the measurement is made convolution of whole received signal is performed, result of convolution is signal which correspond to response of short, higher power source.

To have accurate information about ground layers it is necessary to use sufficient number of measuring points (as shown in Fig 2).

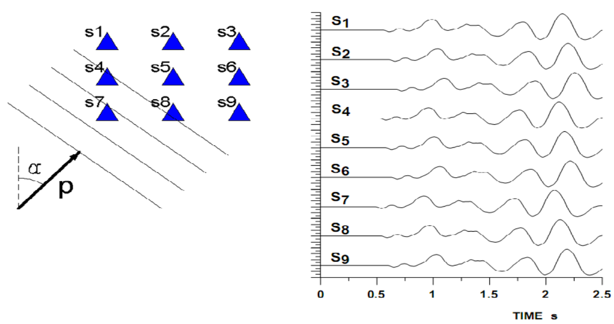

Fig 2. Movement measuring points and signals

Measuring points are placed along so called "line of propagation" which represents side-view of explored part of ground. One set of measuring points gather information from part of the propagation line. Complete information from the propagation line is collected in several successive measuring (as shown in Fig 2). Each measuring point represents a group of geophones, rather than a single geophone. Grouping of geophones has purpose in amplifying signal and cancellation of common errors from one geophone. Geophones are usually grouped in arrays of 6, 12 or 24 geophones. Signals from geophone groups are similar in shape, but geophones groups which are farther from source of signal catches attenuated and delayed signals (as shown in Fig 2).

III. CORDLESS DATA ACQUISITION UNIT

In this system long and expensive cables between geophone groups and acquisition unit are not needed any more, because all the data is send by wireless link.

Data is digitalized on the place of acquisition, this is performed in analog block, so that analog signals are not transmitted over great distances. That means that when signal reaches data acquisition unit, there is no more loss in quality of data due to quality of communication link.

Microcontroller, based on ARM7 core, controls and synchronizes all processes. ARM controls AD converter by setting appropriate amplification of the signal and speed of conversion. ARM also collects digital conversion data from AD converter. Synchronization is performed using real-time data gathered from GPS section of Siemens M2M module. GPS also provides physical position of data acquisition unit, which is important for terrain mapping.

Analog digital conversion is critical element in data conversion of seismic recording, since value of reflected signal has very wide dynamic range. Amplitude of signal ranges from very high value (e.g. 1V) for reflection from shallow layers, to very low values in order of micro volts. During measurement, due to multiple reflections and attenuation of seismic waves, useful signal tends to decrease in amplitude exponentially in time.

To fulfill required, A/D converter for this application has to have very high performances with 24-bit resolution. A/D integrated circuit AD1892 is specially designed for seismic application, signal from geophones can be directly connected to this integrated circuits without the need for additional preamplifiers, so that the signal has minimum distortions before the conversion. This converter has internal PGA-programmable gain amplifier, all the manipulations on the signal can be done when the signal is digitalized, so there is no need for hardware amplifiers and filters. Only hardware filter in the system is simple low pass filter, used for filtering over-sampling signals. To obtain maximum resolution, A/D converter has to be isolated from the rest of the system, so noise generated inside the system (from microcontroller and GPRS device) cannot interfere with useful signal. Separate power supply for A/D conversion circuits is used for the same reason.

Fig 3. A/D converter

Data acquisition unit sends data collected from A/D converter to server on remote location by FTP protocol, and at the same time it stores the data locally on SD flash card. The transfer of data is achieved by establishing GPRS connection which is also one of features of Siemens M2M.

Seismic data is uploaded to FTP server. The same PC on which FTP server is working, runs an application that converts uploaded seismic data in SEG Y file.

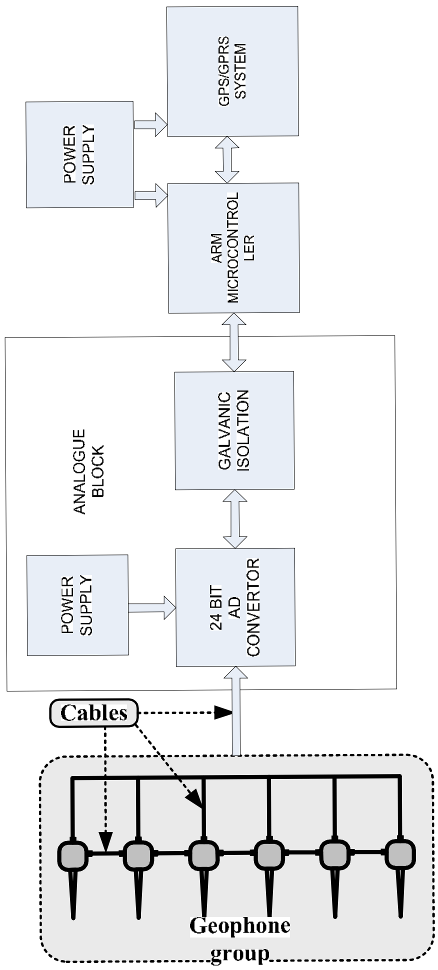

Fig 4. CORDLESS DATA ACQUISITION UNIT

IV. MEASUREMENT METHOD

At every geophone group there is one cordless data acquisition unit, and there can be between ten and few hundred geophone groups.

Measurement is started when trucks generates vibrations, in the same moment seismic receivers must start to record signals from geophones. To achieve that, synchronization between truck and acquisition units is necessary. In older systems, this has been achieved by sending start signal to truck and acquisition units at the same time, but unfortunately this is impossible to do directly GPRS communication, because of the network lag. To overcome this, all the cordless acquisition units are synchronized prior to measurement. All units are equipped with real time clock (RTC). In the initial phase, after the units are switched on, they are connected one by one to a central unit via serial port, in order to synchronize the clocks. This way, all the units have the same system time. After the units are deployed in the field where the measurements are to be performed, a central unit informs them about the exact time when the measurement starts. At that precise moment, the central unit initiates the vibrations of the truck, while all the other units start recording seismic data. The units store recorded data on SD flash cards, which is very important because this way the loss of data is prevented even in the case of network failure or some other undesired event. When the measurement is finished and all the data is stored on flash memory cards, the units establish GPRS connection with FTP server and upload the raw data which is later processed by the application, which is described in the next section. Summary, the procedure of measurement is performed as follows:

- After powering on the units, each of them is connected to a central unit via serial port in order to synchronize the real time clocks
- The units are physically deployed in the field where the measurement is performed. Each of them obtains its geographical coordinates by using embedded GPS device, which simplifies the terrain mapping.
- Central unit makes decision about the time when the measurement is going to begin and it notifies the other units about it by using GPRS communication. At the same time, it sends other important information such as duration of recording, sample rate, etc.
- At the exact time which is determined in previous step, central unit initiates the seismic vibrations, while all the other units start acquisition and record the data on SD flash cards.
- When the recording is finished, the field units upload seismic data to FTP server by GPRS, after which the data is ready for further processing.

V. CLIENT APPLICATION

Data acquisition unit sends data collected from A/D converter to server on remote location by using FTP protocol, but at the same time it stores the data locally on SD flash card. The transfer of data is achieved by establishing GPRS connection. This is a crucial advantage of our solution in comparison with existing solutions. Long and expensive cables are not needed any more, because now we sent all the data by wireless link. Also, it is important to mention that contrary to existing systems, we digitalize data on the place of acquisition, so we don't transmit analog signals over great distances any more. That means when signal reaches data acquisition unit, there is no more loss in quality of data due to quality of communication link. However, one drawback of our approach is that we need to have GSM/GPRS network coverage in the whole area where we conduct seismic measurements.

Seismic data is uploaded to FTP server. Client application could be located anywhere, as long it is connected to internet access, this application converts uploaded seismic data in SEG Y file.

Client GUI application (Fig. 5), designed for personal computers, was developed in order to receive and interpret recorded signals. Client machine has to be connected to a distant FTP server. Files uploaded at the server side are displayed after click on a button named "FTP". Files are listed in a list box so a user is able to choose a file by clicking on it, after client can download file with a click on a button "FTP Preuzmi". Received file is a binary file with raw data samples and some additional information: sample rate used, number of samples, etc. Upon downloading file, raw data samples are processed and SEG-Y file is created. At the end, recorded signal is displayed on a graph, providing additional testing of the data acquisition unit.

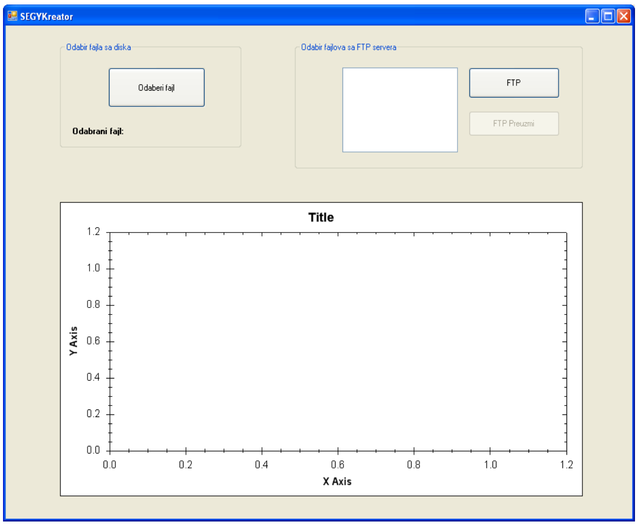

Fig 5. Client application for data collection

Additional option is to read data file from local disk. This can be done by pressing on a button named "Odaberi fajl". User is able to select file to be opened when File-open dialog appears. The same procedure for converting raw data from a binary file to SEG-Y file format is performed and recorded signal is displayed on a graph.

VI. SEG-Y DATA EXCHANGE FORMAT

Earlier solutions require magnetic tapes as storage memory. Nowdays, more flexible approach is needed in accordance with progress of modern technique. Modern solutions certainly have at least one common point in realization. That is standard digital record format known as SEG format (Society of Exploration Geophysicist – SEG). Several recording formats have been defined in the past to accommodate the previous changes of instrumentation. They were: SEG's A, B, C, and Y. SEG Y, revision 1 is the latest improvement of this format. Fig 4 shows file header in SEG-Y format [3] for one group of geophone. By using these records in high equipped and specialized laboratories, geophysicist gather picture of ground layers.

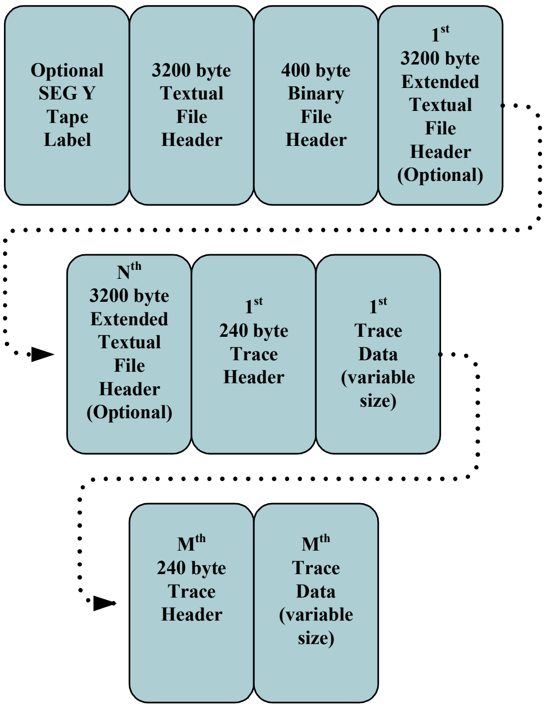

Fig 3. Byte stream structure of SEG Y file

As it could be noticed from figure 3, SEG-Y file format is quite complex standardized format for creating records with sampled data. Since creation of SEG-Y files has been required, correspondence between gathered data samples and specific bytes written to SEG-Y files was determined. During SEG-Y file creation we focused on a problem of defining the smallest possible set of data written to SEG-Y file, which still provides enough data required by software for ground structure analysis. Thus, part of the software for SEG-Y files creation were:

- omits 3200 bytes of optional Textual File Header
- writes values of Binary File Header:

-Data for identifying group of geophones (job identification number, line number, reel number);

- Data considering measurements (number of data traces per ensemble and number of auxiliary traces per ensemble);
- Sample interval in microseconds;
- Number of samples per data trace
- Data sample format code (IEEE or IBM floating point number format).

Values in Trace header:

- Trace sequence number within line;
- Original field record number;
- Trace number within the original field record;
- Trace identification code;
- Number of samples in the trace and
- Sample interval in microseconds for the trace.
- Write Trace data.

Since expensive software used for analysis in geophysical laboratories was not available during system development, *SegyView* (free software tool) was used. During development of the software module for SEG-Y file creation, we've noticed that SegyView required IBM floating point number format in order to graphically display data sampled, although SEG-Y file format specification allows data samples to be written in IEEE floating point number format. Thus, additional efforts were made in order to create SEG-y files containing samples written in either IEEE or IBM floating point number format. IBM floating point number format, comparing to default IEEE floating point number format, has exponent of 7 bits (not 8), representing power of 16 (not 2). Exponent offset is set to 64 (not 128 like in IEEE number format). Also, fractional part of a number represents number with value between 0 and 1 (not between 1 and 2 as in IEEE floating point number format).

VII. CONCLUSION

This paper presents the hardware realization of data acquisition unit for exploration of oil, gas and geothermal water sources using seismic method. In this paper solution for avoiding problem caused by cables and connectors is given. Proposed solution is proven to be cost efficient and also brings required manpower to its minimum. System is developed as prototype and tested in laboratory condition.

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