A wireless Transient Electromagnetic Data Acquisition System based on Virtual Instrument

Yue Li and Xuming Zeng [a]

Faculty of Mechanical and Electronic Information, China University of Geosciences, Wuhan, Hubei, China

Abstract. Electromagnetic survey equipment is widely used in the geophysical field, such as mineral exploration and underground oil detection. To meet the demand of high processing speed and flexible maneuverability, this paper proposes a wireless transient electromagnetic system combined virtual instrument and Wi-Fi technology. Transient electromagnetic receiver and transmitter, Wi-Fi communication links and human operation terminal comprise the whole acquisition system. With the implementation of software programmed by using LabVIEW, the system can process in real-time. This system replaces the old dedicated hardware with compact and flexible device with the same functionality and superior performance.

1 Introduction

Transient electromagnetic method (TEM) is one of the main method which is widely used in mineral exploration, aviation and other fields [1]. At present, Jilin University, Central South University and Chongqing University designed electromagnetic detection equipment which have the slow processing speed, single function, cable transmission and other defects, which cannot meet the actual measurement of the diversity, versatile needs [2-5]. To meet the demand of high processing speed, flexible maneuverability and remote monitoring, a method based on virtual instrument and Wi-Fi technology has been proposed in the transient electromagnetic data acquisition system.

Since the virtual instrument is created by computer technology, it has been became the combination of computer technology and instrument control, test and measurement technology [6]. It is more flexible by establishing the graphical "virtual" panel to realize the instrument's function for measurement, control, transformation, analysis, display [7], etc.

Wireless communication offers lower wiring costs, simple data transfer, and remote monitoring for electromagnetic data acquisition equipment, since the measuring point spatial position is not fixed. Applying virtual instrument and Wi-Fi communication, coupled with computer system's high speed, high precision processing, which can realize data collected under different field environment in real-time display, processing, preservation and analysis of complex algorithms, greatly alleviate the microcomputer in the instrument [8-9].

2 System design

2.1 The main structure of the system

The whole transient electromagnetic data acquisition system is mainly composed of the transmitter and receiver, Wi-Fi communication links and human operation terminal. The transmitter and receiver are used to transmit and receive signals to the underground. The communication between the transmitter and receiver through the communication links, containing the serial and wireless modes. Human operation terminal run the software and user control interface to interact with the transient electromagnetic data receiver via Wi-Fi communication links.

The main structure of this system is shown in figure 1. TEM transmitter consists of control module, the power drive module and system state detection module. All parts are under the unified dispatch of the control module, which can realize a variety of electromagnetic signal waveform synthesis, signal power, large current emission, and fault protection alarm functions.

[a] Corresponding author: zhangh_sun@foxmail.com

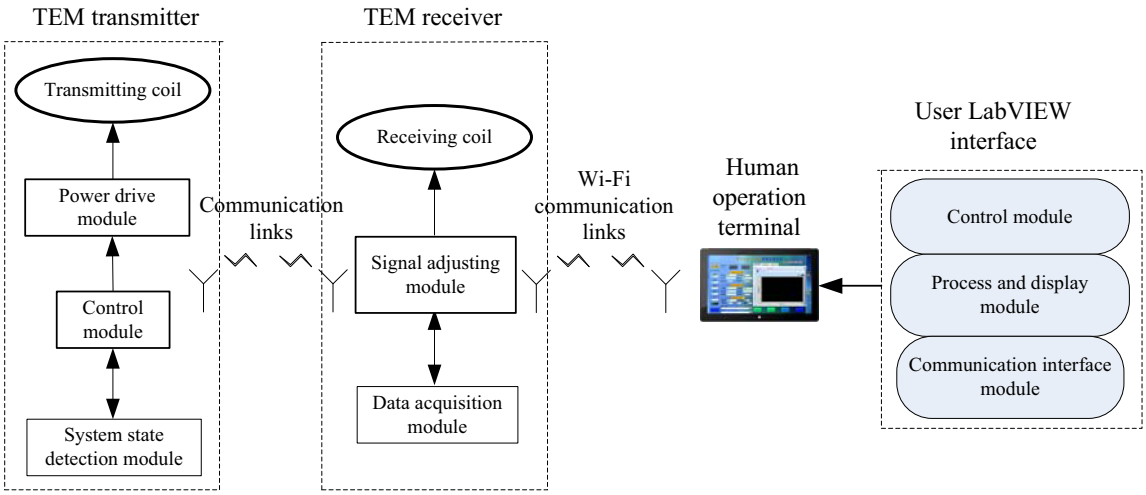

Figure 1. The main structure of the system.

TEM receiver includes a receiving coil, signal adjusting module, data acquisition module. Through receiving coil, the electromagnetic signal is carried into data acquisition from underground. It is essential to note that the signal acquired by the receiving coil need to be adjusted before entering into the data acquisition module, which may be too weak to be distinguished and contain lots of electromagnetic noise. Thus amplification and filtering are used in signal adjusting module.

For a desktop computer, it can use the computer's ethernet port for connecting to a Wi-Fi router. Also, if it is a newer laptop computer, such as a windows tablet, it very likely features built-in Wi-Fi capabilities. Based on data acquisition device and computer, the transient electromagnetic data acquisition system user interface is developed by using virtual instrument technology. User interface software is programmed on basis of LabVIEW platform and its usable software packages, including control module, data display module and data processing module, can realize the parameters of the transient electromagnetic data acquisition system setting and electromagnetic data in-real time processing and display.

2.2 The flow chart of the system

The transient electromagnetic data acquisition system based on virtual instrument takes on an orderly structure as figure 2 shows.

At the beginning, it is necessary to build Wi-Fi network connection. After the network connection is established, the computer user interface will be able to send commands to control the working status of the transmitter and receiver. When press the start button, the system starts monitoring. Computer user interface open TCP connection and send data to initial the whole hardware properties. TEM transmitter will transmit the electromagnetic exploration signal waveform and TEM receiver collect transient electromagnetic data. After collected, it will send the digital signal to upper user interface panel. According to the user's choice, the upper computer will display, process or storage the data. If the user does nothing, the procedure will stop monitoring and TCP connection will close. Then the whole system is waiting for next task.

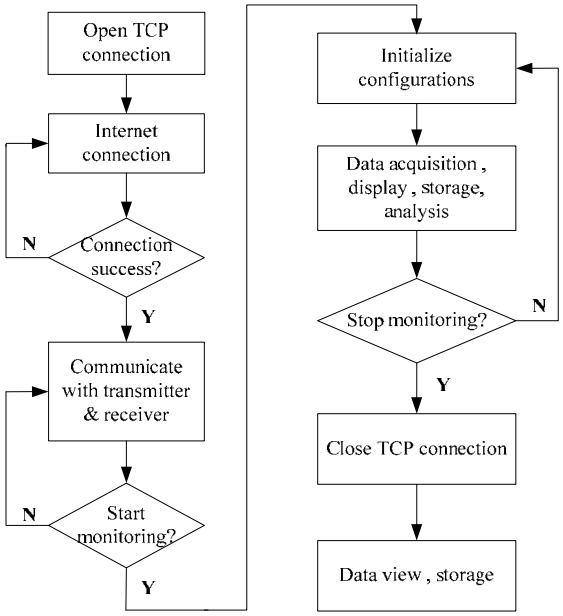

Figure 2. The flow chart of the system.

3 Virtual instrument interface design

Just the virtual instrument software makes the data acquisition device and computer become an integrated system including communication, data processing and display. We use LabVIEW platform written user interface programs. Generally program can be categorized into driver and application program. The driver can directly operate the register of data acquisition device hardware. The benefit is that the users are faced only with more understandable interface. The application program is used to complete display, process, storage and reproduce of the data.

User interface software is composed of three parts: control interface module, data process and display module, communication interface module. Control interface module sends commands to control the equipment and set the parameters of the system. Data process and display module realize data process, dis-play,

storage and reproduce. Communication interface module build the Wi-Fi communication channel.

3.1. Control module

This module is designed for user to control the hardware. Figure 3 shows the control panel of the user interface.

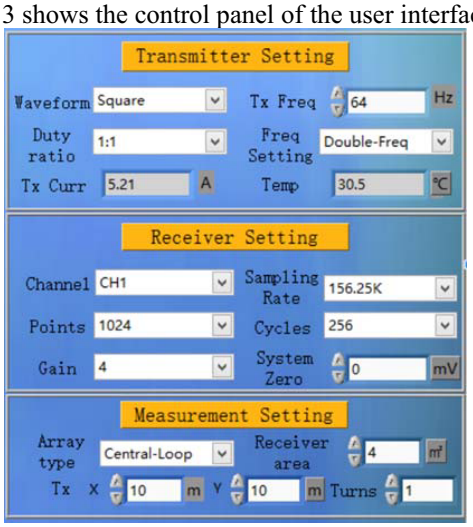

Figure 3. The control panel of the user interface.

Before the whole system starting to collect data, measurement parameters are required for the transmitter and receiver settings. In the middle of the user interface panel, the user-defined parameters can be configured. Drop-down menu contains parameters to choose, according to the needs, the user can select the appropriate parameters. The user-configured transmitter parameters include waveform selection, transmitting frequency and duty ratio, frequency setting, etc. As to receiver parameters, it is needed to configure the parameters of channel selection, sampling, cycle times, signal gain, the system zero. For channel selection, the channel number of the channel used for sample need to be determined. At most three channels can be selected. For the sample, the users can define sample frequency and the number of sample points per channel. For the cycle times, signal gain, it can enhance the signal amplitude and reduce noise. After all parameters finished setting, they all form in a unified command and then sent to the transmitter and receiver.

3.2 Process and display module

Data process and display module can easily display and process transient electromagnetic data in real-time, at the same time can finish to storage and view historical data.

After all parameters are determined and the system acquisition task is started, the electromagnetic acquisition equipment begins collecting data automatically. The original collected data from the communication interface are 16 bits integer number. Data process and display module calculates transient electromagnetic data into real voltage value. The waveform of voltage is displayed on the right of the user interface panel, then press the “save” button to save the results and parameter settings into text file with the test time. Our design is unique in that we display data in three ways, including one-dimensional arrays, two-dimensional waveform, called MATLAB logarithmic coordinate. When we need to analysis the historical data, it is convenient to view the settings and waveforms just choose the right file.

3.3 Communication interface module

According to the actual needs of communication with the transient electromagnetic data acquisition systems, communication interface module supports wireless communication modes, including Bluetooth and Wi-Fi mode. Bluetooth can realize the short-range wireless communications between user interface and the device, which is suitable for the test the performance of the device in lab environment. Using Wi-Fi mode can realize the data transportation over a long distance in the field [10], it is the resolution of processing collected data in real-time.

The wireless communication function of Wi-Fi mode is mainly to achieve by LabVIEW comes with TCP functions and VI. Run LabVIEW, create a new VI, added a block diagram "Open TCP Connection" function, and defined IP address, remote port and other terminals. The IP address and port number configured here must the same with the setting of the TEM receiver. User interface communicate with transient electromagnetic equipment via this channel. If TCP network connect success, the "successful connection" indicator will light. Figure 4 shows the TCP parameter setting of the user interface.

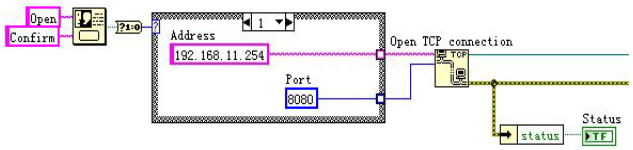

Figure 4. TCP parameter setting.

3.4 Analysis module

In order to obtain the stratigraphic information of the survey area, the data collected by the receiver is mainly use for data inversion. The analysis module call MATLAB Script node to inversion, which use improved damping least squares fitting algorithm. The input data of VI node is the response value after de-noising. After obtained inversion formation parameters by the inversion algorithm, using a forward inversion can get inversion of transient response value. In order to compare the effectiveness of the inversion algorithm, the analysis module output original voltage and inversion formation response curve. Figure 5 shows the part diagram of data inversion analysis module.

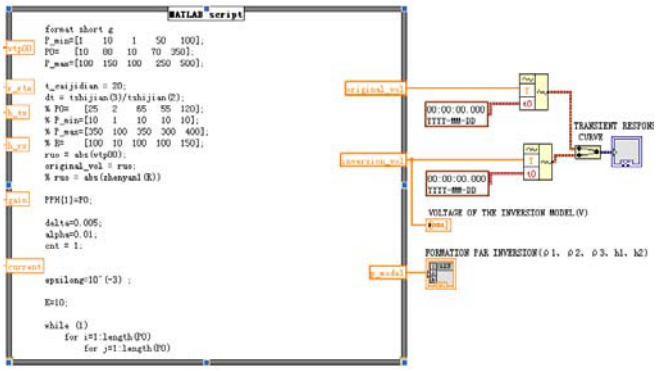

Figure 5. Diagram of data inversion analysis module.

4 Result

In order to verify the performance of this design, we do the test in the lab environment.

Once initialized, the electromagnetic acquisition equipment and user interface panel turned into the default settings. If the users are not familiar with the procedure of the whole transient electromagnetic data acquisition system, "help" button will gives user a brief introduction of how to operate the system, which makes the system easy to use.

4.1 Parameter settings and waveform display

At the beginning of the procedure, it is necessary to initialize hardware properties such as waveform selection, duty ratio, channel selection, sampling, etc. For the case of transmitter, the waveform is set as square wave, the duty ratio is 1 to 1, and the frequency mode is selected to double frequency. For the case of the data acquisition, the channel is chose channel one, the sampling frequency is set as 156.25K/s, acquisition points is 1024, the current system adjustment is zero. After entering the acquisition procedure, the measurement parameters such as device type and magnetic torque for receiving are all need to be configured firstly. The rest of configuration parameters are kept default. Then the acquisition system begins acquiring signal from channel one. The acquisition procedure would quit if there is no synchronization signal within 30 seconds.

Figure 6 shows hardware parameter settings and the waveform data. As is shown in the figure, the horizontal axis represents the acquisition time, the unit is millisecond. The longitudinal axis represent the actual voltage value, which is limited to between 0 and 1 after logarithmic coordinate transformation.

4.2 View results

In order to compare the different results in different fields, the previously saved data can be shown in figure 7 to view the data and parameters.

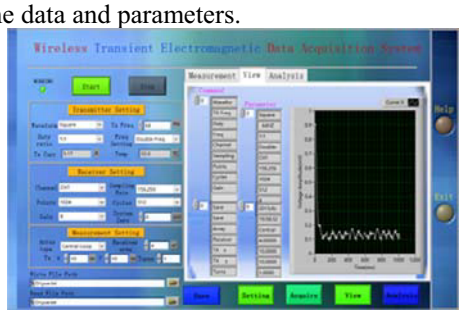

Figure 7. The view results of previously saved data file.

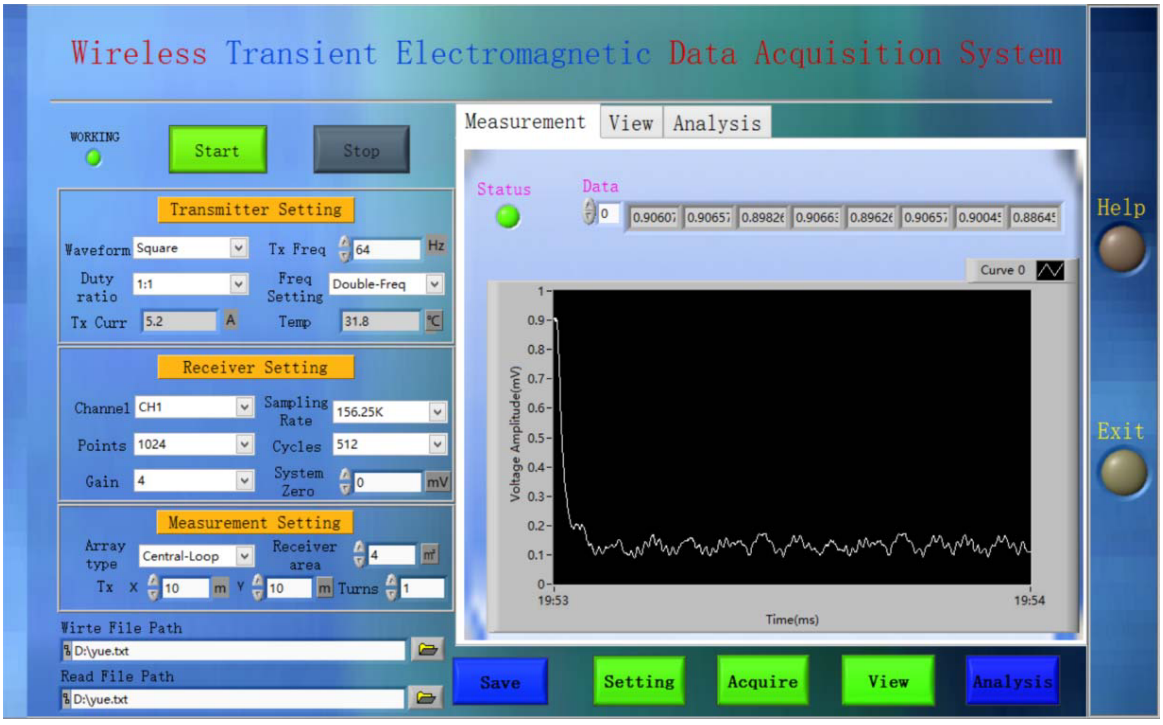

Figure 6. The result of the whole user interface.

Waveform		TX Freq		Duty ratio		Freq setting		Channel		Sampling Rate		Points		Cycles		Gain		System-zero
Square		64HZ		1:1		Double-Freq		CH1		156.25k		1024		512		4		0.0000
Save time		Save time		Array type		Receiver area		TX x		TX y		Turns						
2015/6/20		19:58:32		Central-Loop		4.000000		10.0000		10.0000		1.0000						
0.906	0.907	0.898	0.907	0.896	0.907	0.900	0.886	0.847	0.805	0.767	0.724	0.689	0.650	0.611	0.570	0.530	0.495	0.463
0.436	0.411	0.384	0.356	0.336	0.320	0.309	0.299	0.287	0.276	0.265	0.254	0.244	0.236	0.228	0.220	0.209	0.201	0.197
0.196	0.195	0.193	0.191	0.190	0.190	0.193	0.199	0.204	0.206	0.204	0.202	0.203	0.203	0.201	0.197	0.192	0.188	0.187
0.190	0.196	0.201	0.202	0.200	0.196	0.194	0.193	0.190	0.184	0.174	0.165	0.156	0.151	0.149	0.147	0.143	0.138	0.132
0.134	0.135	0.137	0.137	0.134	0.129	0.125	0.122	0.119	0.114	0.107	0.102	0.099	0.099	0.102	0.106	0.112	0.118	0.122
0.124	0.126	0.127	0.125	0.120	0.114	0.109	0.105	0.103	0.103	0.106	0.111	0.115	0.118	0.122	0.126	0.128	0.127	0.125
0.123	0.122	0.122	0.123	0.126	0.129	0.130	0.131	0.133	0.135	0.135	0.133	0.130	0.128	0.127	0.127	0.128	0.129	0.133
0.135	0.138	0.142	0.146	0.148	0.150	0.151	0.152	0.152	0.149	0.144	0.139	0.132	0.128	0.120	0.114	0.110	0.107	0.106
0.106	0.108	0.107	0.106	0.103	0.103	0.100	0.100	0.098	0.101	0.104	0.108	0.111	0.113	0.114	0.111	0.106	0.100	0.096
0.092	0.089	0.089	0.094	0.101	0.109	0.117	0.122	0.125	0.126	0.124	0.119	0.113	0.108	0.103	0.102	0.102	0.100	0.105
0.110	0.115	0.122	0.130	0.138	0.144	0.145	0.144	0.141	0.138	0.135	0.131	0.128	0.128	0.130	0.134	0.140	0.147	0.155
0.161	0.165	0.167	0.168	0.168	0.162	0.153	0.144	0.138	0.134	0.133	0.135	0.139	0.143	0.146	0.149	0.152	0.153	0.152
0.149	0.143	0.132	0.125	0.117	0.113	0.112	0.112	0.116	0.120	0.125	0.129	0.131	0.131	0.127	0.119	0.112	0.106	0.102
0.100	0.100	0.101	0.102	0.106	0.113	0.121	0.127	0.127	0.124	0.116	0.114	0.110	0.106	0.105	0.105	0.105	0.105	0.109
0.115	0.121	0.126	0.128	0.128	0.130	0.134	0.137	0.139	0.141	0.141	0.142	0.143	0.146	0.148	0.149	0.148	0.147	0.147
0.148	0.149	0.152	0.154	0.153	0.151	0.153	0.157	0.159	0.159	0.158	0.156	0.154	0.151	0.149	0.147	0.143	0.137	0.129
0.125	0.124	0.125	0.126	0.129	0.131	0.133	0.134	0.134	0.132	0.128	0.121	0.113	0.107	0.104	0.104	0.108	0.113	0.117
0.120	0.123	0.125	0.128	0.127	0.122	0.115	0.109	0.104	0.101	0.099	0.098	0.099	0.100	0.104	0.110	0.118	0.124	0.125
0.122	0.119	0.115	0.112	0.110	0.109	0.108	0.110	0.115	0.122	0.131	0.140	0.146	0.148	0.152	0.149	0.143	0.139	0.132
0.131	0.128	0.127	0.129	0.134	0.141	0.148	0.154	0.157	0.157	0.154	0.151	0.146	0.141	0.135	0.130	0.127	0.126	0.130
0.135	0.140	0.142	0.141	0.141	0.142	0.141	0.138	0.136	0.136	0.136	0.137	0.140	0.143	0.146	0.147	0.145	0.144	0.146
0.147	0.148	0.146	0.143	0.138	0.132	0.134	0.134	0.133	0.132	0.132	0.132	0.131	0.129	0.125	0.120	0.113	0.106	0.100

Figure 8. The example of storage file.

4.3 Data storage

In consideration of further analysis, it is necessary to store the transient electromagnetic data to a text file. Not only the collected electromagnetic data, but also the acquisition parameter configurations and time are all packed into the text file.

Figure 8 shows a text file of data storage. The example of storage file contains data and parameters.

Through the interface of select previously saved data file, it is easy to view the older parameters and data, which facilitates the experimental comparison.

5 Conclusion

A wireless transient electromagnetic data acquisition system is developed based on virtual instrument and Wi-Fi technology. The system combined the electromagnetic equipment and virtual instrument technology has the advantage of flexible maneuverability and real-time processing. Transient electromagnetic receiver and transmitter, Wi-Fi communication links and human operation terminal comprise the whole system, which is controlled by virtual instrument panel. The collected data can be easily stored, displayed and analysis in the computer. Furthermore, we have made the whole user interface into an application with the suffix of .Exe, which indicates that any computer can run the interface just use the .Exe.

Human operation terminal using the portable terminal, such as tablets, which facilitates fast moving when working in the field. We hope that the paper will help the process of research and development in this field, and we also welcome comments and suggestions for improvement.

Acknowledgement

This paper is sponsored by the Fundamental Research Funds of the Institute of Geophysical and Geochemical Exploration CAGS (GN: WHS201305); the Teaching Laboratory Opening Funds, China University of Geosciences, Wuhan (GN: SKJ2015220); the Key New Products and New Technology Research and Development Funds of Hubei Province of China (GN: 2012BAA06007).

References

1. Defu Cheng, Jun Lin, Shengbao Yu, etc, *Study on TEM weak signal detection techniques*, J. Jilin. U. Techno. Ed, **20**, 2(2002)
2. Zhong Wang, Yue Huang, Jun Lin, etc, *Development of high speed and large dynamic range transient electromagnetic receiver*, Chin. J. Sci. Instrum, **27**, 7(2006)
3. Qiyun Jiang, *Study on the key technology of wide field electromagnetic sounding instrument*(CSU, Chang Sha, 2010)
4. Jing Pei, Qiyun Jiang, *Wide-field electromagnetic receiver acquisition design based on AD7762*, PG, **25**, 3 (2010)
5. Zhihong Fu, Junli Zhao, Luowei Zhou, etc, *WTEM fast turn-off transient electromagnetic detection system,* Chin. J. Sci. Instrum, **29**, 5 (2008)
6. C.J. Kalkman, *LabVIEW: A software system for data acquisition, data analysis, and instrument control*, JCMC, **11**, 1 (2005)
7. Hu Liu, Shili Lu, Cangwen Jiao, *Virtual instrument techniques and their application to development of electromagnetic imaging system*, UG, **21**, 6 (2005)
8. Jie Xu, Benyue Lou, Jianying Zhang, *Collection and pretreatment of transient electromagnetic data based on LabVIEW*, Ind. Mine. Autom, **12**, 6 (2011)
9. Tao Lv, *Study on the key technology of wide field electromagnetic sounding instrument*(J. Jilin. U, Ji Lin, 2004)
10. L.W. Couch, *Digital & Analog communication systems* (Prentice Hall, Upper Saddle River, 2007)