ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2010. No. 6(102)
ELEKTRONIKA IR ELEKTROTECHNIKA

ELECTRONICS SCIENCES
ELEKTRONIKOS MOKSLAI

# Educational System to Approach Teaching of Bi-static Noise Radar

**A. V. Alejos, M. Garcia Sanchez, I. Cuiñas**
*Teoría de la Señal y Comunicaciones, University of Vigo,*
*Campus Universitario Lagoas, 36310 Vigo, Spain, phone: +34986812195, e–mail: analejos@uvigo.es*
**M. Dawood, H. U. R. Mohammed**
*Klipsch ECE, New Mexico State University,*
*Las Cruces, 88003 NM, USA, phone: +15756233465, e–mail: dawood@nmsu.edu*

## Introduction

Students usually find some of the basic radar concepts difficult to comprehend without practical experiments. Experimental studies provide valuable teaching tools for almost all disciplines in general, and RF/Microwave engineering courses in particular. Simple experimental tests can facilitate the acquisition of most important concepts that students will need to use and apply as professional engineers after the graduation. Similar experimental systems have been previously developed in the field of electromagnetic teaching as [1-7]. In [1, 5] we can read the importance of the instrumentation in the radio courses curriculum and how the RF instruments can help to emphasize signal and system theory concepts to students. In [6] a cost-effective solution is implemented to design educational modules used in wireless communication courses showing a good performance. This kind of experiences allows the students the acquisition of practical skills in RF design through experimental exploration.

The construction and/or acquisition of radar-related teaching material usually involve specific instruments requiring a large budget. Commercial material exits for radar educational purposes in form of kits, but they, sometimes, limit the experiments to be performed and involve rather cumbersome maintenance, besides a large cost that turn them into a non affordable option.

In this paper we present a solution in terms of using general purpose instruments combined with transmitter and receiver RF front-ends implemented with low-cost components as an alternative to expensive purpose-built kits and hardware. The components used were selected in coaxial version that facilitates the interconnection and accelerates the construction of the system.

For our case, the UHF band was selected, due to availability of low-cost hardware components and RF instruments available in the lab, among other constraints. However, the methods and system presented here are frequency-independent so different frequency bands could be chosen by only selecting the adequate version of the RF front-end components.

The system was completed by programs developed in MATLAB and Labview software that interconnects various instruments allowing the automation of the configuration, as well as the measurement, data storage processes, and data processing.

The described system has been used in the past for ranging estimation experiments in the UHF frequency band with good results [8]. Later it was used by an undergraduate student to accomplish his Master Thesis project who turned into recipient of one IEEE AP Society Graduate Research Award in 2008 [9]. At present it has been dedicated to other undergraduate projects.

But due to the educational potential underlying, it was projected to support the lab experiments development within the context of a radar course at undergraduate or doctorate level. The Problem Based Learning (PBL) methodology is the one selected to apply the developed tool in the laboratory classes. We present here the pilot designed to accomplish this purpose. It is intended to be used as a preliminary stage leading to elaborate the adequate and high-quality course guidance/plan.

The EHEA implantation will require from formers the elaboration of new material with a large content of self-teaching qualities due to the significant percentage of experimental and practical charge that the courses will stipulate within the Bologna process framework.

In this sense, a set of five practices have been designed to be accomplished by the use of the system introduced here. The material presented is in good agreement with the new demands planned by the European Higher Education Area (EHEA) for the imminent future of European universities. But it also provides a high quality material for the teaching system deployed in the American universities.

In the following section, we describe some background details, the system implementation, and the data processing. The PBL-based application plan oriented to undergraduate laboratories is outlined after this. The last section offers the conclusions to this work.

## Automated Bi-Static Radar (AmBAR)

The bi-static radar systems include systems configured such that the radar transmitter and receiver are located in separate positions. According to the transmitted waveform, several radar techniques can be considered [9, 10]. But also depending upon the environment and parameters needed to obtain, different systems can be selected. Among all of them, our system implements the noise technique that consists in the transmission of one random binary code with like-noise characteristics.

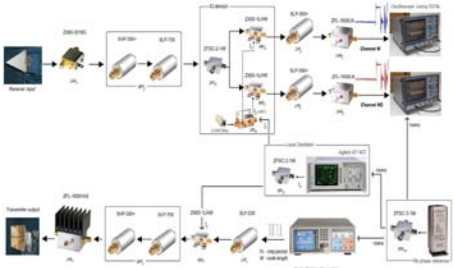


**Fig. 1.** Diagram block in the AmBAR sounder [8]

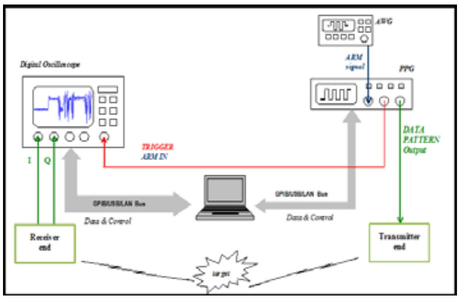


**Fig. 2.** Automated configuration for pulsed transmission mode

These codes are generated and selected to offer the best possible autocorrelation properties. The goal is to minimize the sidelobe levels of the autocorrelation functions without affecting the peaks in order to obtain a large dynamic range. If possible, the codes will also help in obtaining better Doppler range resolution [9].

A classical hardware used to implement noise radar is the known as swept-time delay cross correlation (STDCC) system. The STDCC radars are based on correlation of pseudo-noise sequences. It is a pulse compression technique based on the correlation principle to estimate the channel impulse response [11-13].

The scheme of a STDCC system consists in a transmitter end that modulates a binary sequence, and a receiver end based in a super-heterodyne branch with one or two down-conversions to an intermediate-frequency or directly to baseband. Following the analogue RF receiver, a digital stage can be placed consisting in an A/D converter and a storage unit.

After this a digital processing is off-line applied to obtain cross-correlations functions providing channel information. Although this technique with off-line cross-correlation implies a non real time sounding, it provides some advantages as simplicity in the understanding, from educational points of view.

The measurement system is composed of a hardware subsystem and a software program described in the following subsections. The acronym AmBaR (<u>A</u>uto<u>m</u>ated <u>B</u>i-st<u>a</u>tic <u>R</u>adar) designates the set of the hardware and software elements.

*Hardware subsystem.* The hardware subsystem is composed by a BPSK transmitter and a zero-IF super-heterodyne receiver with an in-phase (I) and quadrature-phase (Q) outputs. The system operates at a carrier frequency ($f_c$) of 500MHz and with a baseband waveform from DC-250MHz.

The main goal of this system is the cost-effective implementation of the required large bandwidth bandpass filters and also a large bandwidth I/Q demodulator. Salient system parameters include a noise figure of 3.11dB and dynamic range of 80.84dB at room temperature (290K).
The block diagram of the hardware radar subsystem is shown in Fig. 1.

The A/D stage consists of a four channel high speed sampling digital storage oscilloscope, which captures the *I/Q* baseband waveforms. The rest of the process is performed by software. The data on the oscilloscope is digitally collected, analyzed and processed based on the sliding correlation technique. The digital processing is explained in section *C*.

The system can operate in two modes: with CW or pulsed transmission. For the second case, extra elements are required. A pulsed signal from HP33120A arbitrary waveform generator (AWG) has to be utilized to trigger the pulse pattern generator (PPG). The PPG is software controlled and when the armed signal from the AWG is detected by the PPG, it sends burst of coded signals and the trigger output is enabled. When the oscilloscope receives this trigger it detects the coded signal coming from the PPG. Fig. 2 shows the interaction of all the involved systems for a pulsed transmission working mode.

*Generation, Configuration and Acquisition SW Tool.* The data acquisition and stored data format should allow minimizing post-processing. Also, the impulse response snapshot must be measured in a time short enough to remain the channel response essentially constant during acquisition and sampling.

Because of these reasons, a *Configuration and Acquisition Software (SW) Tool* was developed in Labview graphical programming language. This control SW allows ensuring a correct configuration of the involved instrumentation, as well as performing the real-time impulse response snapshots acquisition and storing.

Screen shots of the program are shown in Fig. 3. The program functionalities can be grouped in three modules: one is related to the PN generator configuration, other one is used in the configuration of the oscilloscope, and the third one configures the options to store the snapshots.

*Data processing.* A stand-alone Matlab program allows basic processing for the stored snapshots (Fig. 4). This off-line processing can be performed according to two methods related to the working mode selected for transmission: CW or pulsed.

*Method 1* (time-of-arrival (ToA)). This method basically allows determining the range or the round trip length travelled by a random binary sequence from the transmitter to the receiver via a reflection on the target. Once the snapshot is recorded, the time of arrival is obtained by the number of samples $N$ registered until the sequence starts.

We observe that this method can be applied in pulsed transmission mode, but if CW is required then it will be necessary to measure at least two snapshots to observe a correct range value.

*Method 2* (cross-correlation function (CCF) estimation). By performing the cross-correlation between each one of the acquired snapshots and the replica of the transmitted sequence, the result is an ensemble of impulse responses $<h(t,\tau)>$ [14].

## Application in the lab

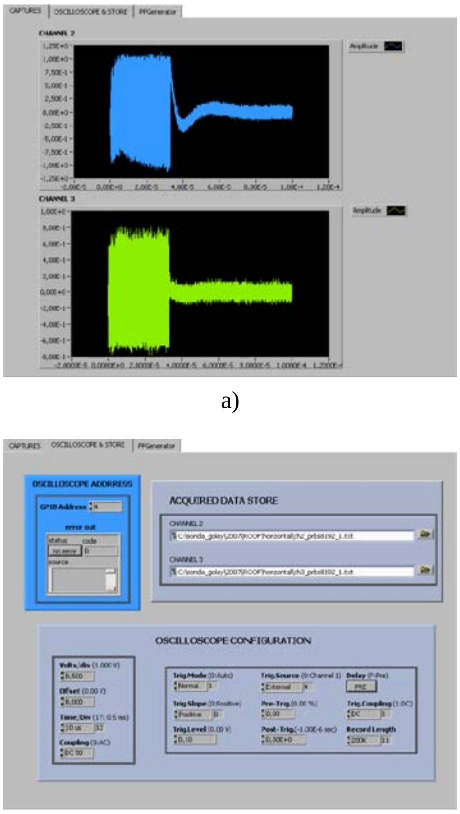
The tool described in this paper offers a wide variety of experimental lab practices that can be developed. As examples of this variety, we have selected five possible experiments. All of them are conceived to take place under controlled conditions in order to ensure a quasi-static channel behavior. These ideal conditions occur inside an anechoic chamber, but also can be found in a room with proper dimensions and also ensuring that the ground reflection is not affecting the results.

The PBL methodology has been estimated as an optimal solution to introduce the involved concepts. Students are provided with material via an e-learning platform. A set of four short practices introduce the different objective concepts. The methodology is completed with one final practice that summarizes all the learned concepts and is valid to put in practice the skills learned and developed by the students. If the software tools have been correctly fitted, and a comprehensive cognition has taken place, the students will pass this challenge with less effort that if it is planned as a single practice.

*Experiment #1* (range measurement). The goal of this test is to obtain the round trip length travelled by a random binary sequence from the transmitter to the receiver via a reflection on the target.

*Experiment #2* (averaging as improvement technique against noise). The ensemble of resulting impulse responses $<h(t,\tau)>$ will be averaged along variable $t$, $\overline{h(\tau)}$. From this averaged impulse response an average range value is obtained, $\overline{R}$. Otherwise, from the ensemble of impulse responses $<h(t,\tau)>$, a time variable range $R(t)$ can be obtained and averaged, $\overline{R}$. This procedure helps to identify possible fluctuations in the range estimation and their possible causes.

*Experiment #3 (*noise sequence kinds and length influence analysis). Two main noise sequences can be generated by using AmBaR tool: pseudo binary random (PRBS) and Golay complementary codes. The influence of the sequence length in the dynamic range can be stated. From this experiment it can be confirmed the autocorrelation properties offered by the different codes in dynamic range terms.



a)

b)

**Fig. 3.** SW tool for the Acquisition Process control

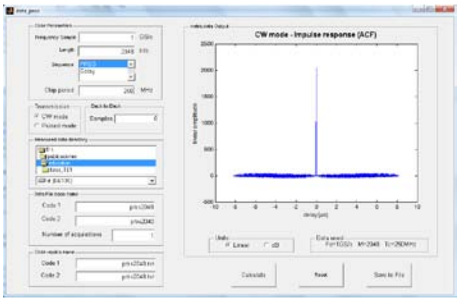


**Fig. 4.** Influence of the used sequence on the range estimation

*Experiment #4* (sidelobe level analysis). From the outcomes of the experiment #3, the sidelobe influence can be also observed. For this, the values of the Peak-SideLobe (PSL), Secondary-SideLobe (SSL) and Integrated-SideLobe (ISL) levels have to be determined. The influence of the sequence length in these parameters can be checked.

*Experiment #5* (material dielectric properties estimation). This experiment is perhaps one of the most interesting from a strictly radar point of view. It consists in obtaining the relative dielectric constant $\varepsilon_r$ corresponding to a target.

## Evaluation methodology

It is essential to collect information in the cognitive and in the affective dimension. This information has to be analyzed to evaluate a classical trade-off: the satisfaction level and the effective cognitive learning.

The evaluation of the subject is planned to be divided in two parts. The evaluation of the theoretical contents will follow a method based on online surveys provided via the web eLearning and eWorking platform *Claroline*. The surveys will include short questions regarding the theoretical part.

For the evaluation of the other practical contents a traditional method usually extended in engineering is intended to be used, consisting in the elaboration of reports regarding the lab practices. In order to evaluate the cognitive level, for each practice a set of questions must be included in the memory to be solved and answer individually and by the group.

## Conclusions

An automated system has been introduced as an approach for teaching bi-static radar courses and topics with special emphasis on the technique using coded sequences. Among the capabilities of this system we can mention the range estimation and the target identification. It results a powerful teaching tool in the radar teaching field. It has been demonstrated also to be a valid tool in past research works.

One of the main benefits of the system is the low-cost implementation and the facility to change the frequency range covered by the system. Some experimental tests have been designed to demonstrate the potential application of this tool in lab practices. We present the methodology to be developed and the material needed to carry out this pilot. The experience showed a large level of enthusiasm and satisfactory feeling among Master Thesis students.

## References

1. **Carlosena A., Cabeza R.** A course on instrumentation: The signal processing approach // IEEE Trans. Education. – IEEE, 1997. – No. 40. – P. 297–304.
2. **Camps A.J.** A radar course at undergraduate level: an approach to systems engineering // IEEE Transactions on Education. – IEEE, 2003. – No. 4(46). – P. 497–501.
3. **Jensen M.A., Arnold D.V., Crockett D.E.** System-level microwave design: radar-based laboratory projects // IEEE Trans. on Educ.. – IEEE, 2000. – No. 4(43). – P. 414–419.
4. **Solano M.A., Ipina J.S., Zamanillo J.M., Perez-Vega C.** X-band Gunn diode oscillator for a multiple-frequency continuous-wave radar for educational purposes //IEEE Trans. on Educ. – IEEE, 2002. – No. 4(45). – P. 316–322.
5. **D'Alvano F., Badra R.E.** A simple low-cost laboratory hardware for noise generation // IEEE Transactions on Education. – IEEE, 1996. – No. 2(39). – P. 280–281.
6. **Lopez-Martin A.J.** Teaching random signals and noise: an experimental approach // IEEE Transactions on Education. – IEEE, 2004. – No. 2(47). – P. 174–179.
7. **Zhang J. Z., Adams R. A., Burbank K.** The design of RF labs using Mini-Circuit modules to improve the quality of teaching in a course on wireless communications and systems // World Transactions on Engineering and Technology Education. – IEEE, 2005. – No. 1(4).
8. **Vazquez Alejos A., Garcia Sanchez M., Cuiñas I.** Low Sidelobe Level Radar Techniques Using Golay Based Coded Sequences // Proceedings APS-2008. – San Diego, 2008. – P.
9. IEEE Antennas and Propagation Magazine. – IEEE, 2008. – No. 2(50).
10. **Levanon, N., Mozeson, E.** Radar Signals. – John Wiley & Sons, 2000.
11. **Mahafza B. R.** Radar systems analysis and design using Matlab. – Chapman and Hall CRC, 2005.
12. **Parsons J. D., Demery D. A., Turkmani M. D. A.** Sounding techniques for wideband mobile radio channels: a review // Communications, Speech and Vision, IEE Proceedings I. – IEEE, 1991. – No. 138. – P. 437–446.
13. **Vazquez Alejos A., Garcia Sanchez M., Cuiñas I.** Improvement of wideband radio channel swept time crosscorrelation sounders by using Golay sequences // IEEE Transactions on Vehicular Technology. – IEEE, 2007. – No. 1(56). – P. 362–368.
14. **Bello P. A.** Characterization of randomly time-variant linear channels // IEEE Trans. Communications Systems. – IEEE, 1963. – No. 4(11). – P. 360–393.

Received 2010 04 16

**A. V. Alejos, M. Garcia Sanchez, I. Cuiñas, M. Dawood, H. U. R. Mohammed. Educational System to Approach Teaching of Bi-static Noise Radar // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 6(102). – P. 71–74.**

In this paper an experimental radar system is introduced as an aid in teaching an introductory radar system course. The developed radar system is an automated bi-static radar system that has adjustable general features, including the use of pulsed or continuous wave (CW) transmissions, and both coded and uncoded sequences. Additionally, the system is implemented using off-the-shelf low cost components, general purpose laboratory instrumentation, and easy to use software program. We have designated the system with the acronym AmBaR (AutoMated Bi-stAtic Radar). This tool is also used to facilitate the accomplishment of Master Thesis projects with an excellent degree of success. The Problem Based Learning methodology was selected to apply this system in the lab classes. It is intended to be used as a preliminary stage leading to elaborate the adequate and high-quality course guidance/plan. An evaluation methodology is also proposed to measure the the satisfaction level and the effective cognitive learning. Ill. 4, bibl. 14 (in English; abstracts in English, Russian and Lithuanian).

**А. В. Алеюос, М. Гарциа Санхез, И. Цуинас, М. Давоод, Х. У. Р. Мохаммед. Исследование системы подготовки кадров для двустороннего стационарного радара шума // Электроника и электротехника. – Каунас: Технология, 2010. – № 6(102). – С. 71–74.**

Описывается экспериментальная радарная система в качестве учебного процесса. Предложенная система является автоматической и би-стационарной, в которой использованы лабораторные устройства и программные средства. Для повышения эффективности обучения рекомендуется использовать методологию эволюции. Ил. 4, библ. 14 (на английском языке; рефераты на английском, русском и литовском яз.).

**A. V. Alejos, M. Garcia Sanchez, I. Cuiñas, M. Dawood, H. U. R. Mohammed. Sistemos, skirtos mokymui apie bistacionarųjį triukšmo radarą, tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 6(102). – P. 71–74.**

Pristatoma eksperimentinė radarų sistema, kaip pagalbinė priemonė dėstant įvadinį radarų sistemų kursą. Ši radarų sistema yra automatinė, bi-stacionari, galinti keisti bendrus savo parametrus. Sistema sukurta naudojant bendros paskirties laboratorinę ir programinę įrangą. Jai pavadinti parinktas akronimas AmBaR. Parengiamojoje studijų stadijoje numatyta naudoti šią sistemą. Efektyviam pažintiniam mokymuisi užtikrinti siūloma taikyti evoliucijos metodologiją. Il. 4, bibl. 14 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

DOI: 10.5755/j02.eie.9357