REMOTE UNIT FOR MOBILE-TELEPHONY TELEMETERING FROM DISTRIBUTED ULTRASONIC TRANSDUCERS

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Rodríguez, Miguel A.(1); Sanz, Pedro T.(2); Zaplana, David(1); Ramos, Antonio(2); San Emeterio, José L.(2)

(1) - ETSI Telecomunicación - Universidad Politécnica de Valencia
Camino de Vera s/n, 46022, Valencia, (Spain)
Phone: 34-963879309
E-mail: marodrig@upvnet.upv.es

(2) - Dpto. Señales, Sistemas y Tecnol. Ultrasónicas - Insto. de Acústica, CSIC
Serrano 144, 28006, Madrid, (Spain)
Phone: 34-915618806; Fax: 34-914117651
E-mail: aramos@ia.cetef.csic.es

ABSTRACT

In some ultrasonic inspections, distributed measurements have to be made at different locations, which are distant from the station where the data collected must be checked and analysed. In this paper, the design of a remote unit for such purpose is described. This unit is intended to make ultrasonic measurements and transmit them to a local unit. The involved ultrasonic and telecommunication stages are explained. This development combines low-cost commercial devices with own-designed technologies. The design parameters and the block diagrams of each subsystem are detailed. Additionally, the configuration of a laboratory prototype, developed in order to test the design viability, is presented. This prototype includes a high voltage spike generator for the transducer driving, a broad-band signal amplifier, a multiplexed signal acquisition / A-D card, a mobile telephony system for the ultrasonic data transmission, and the software controlling telemetering aspects in remote and local units.

1. INTRODUCTION

The growing demand for improvements in quality control during the fabrication of materials and structures and also in the periodic “in service” inspection requires the generation of efficient automatic measurement systems. The development of such systems is made specifically for each situation. Thus, the design of general tools allowing to embrace different problems and situations, with small modifications in their structure, is a good solution. The physical dispersion of the elements to be controlled makes necessary the presence of operators in each measure location. This can be avoided by transmitting the measurements to a central station. In this central station, the collected data can be processed with more powerful tools and decisions can be taken using a more complete and global information.

Among the different techniques available to test materials quality, this paper is focused on ultrasonic non destructive testing. Thus, its objective is to explain the main design aspects of a telemetering system devoted to make automatic ultrasonic testing functions with several remote sensors situated at different geographical positions [1]. This geographical dispersion implies the necessity of transmitting the ultrasonic traces obtained from successive acquisitions. The frequency range of these traces is in the most of the applications contained in the frequency interval (0,1 - 10) MHz.

Digital mobile telephony has been selected as telecommunication system. The transmission of ultrasonic information through telephony systems presents a strong limitation due to the great difference on bandwidth between this ultrasonic information (MHz) and the mobile telephone channels (KHz). To solve this problem, the proposed solution is the transmission of the ultrasonic signals frames instead of carrying out a continuous transmission that would result impossible. This makes necessary to dispose of software to control the frames transmission. Additionally, the transmission of high frequency through the digital mobile telephony systems implies an analogue to digital (A/D) conversion.

This paper involves the description of the proposed telemetering system. The hardware is composed by commercial components together with some specific ultrasonic developments. From a functional point of view, it includes three different systems, the central station, the remote units, and an ultrasonic system. The central station software manages the whole system whereas remote unit software controls the ultrasonic signals acquisition and their transmission.

A laboratory test prototype, to check the viability of the proposed telemetering system, is also described. It allowed the development of the control software and the verification of the proposed system. The development of this prototype has involved different techniques, from electronic design of a transceiver of HF ultrasonic pulses, until the software development for communications protocols in data transmission. The efficient and successful combination of these techniques is one of the main contributions of this work.

2. DESIGN OF THE E/R ULTRASONIC SYSTEM

A specifically designed general purpose pulsed ultrasonic transceiver has been developed. Due to this transceiver unit is going to be applied for the excitation and signal detection in each one of the ultrasonic channels present in distributed transduction systems, containing multiple transducers, a simplified scheme for this device has been decided. Thus, the main aim persecuted during this design was the generation of a low-cost device with reduced size and power consumption, as a portable module, capable for broadband driving, with efficiency, different types of non destructive testing probes, and covering the more usual testing frequency range (0,5-20) MHz. The device also would be able of adapting their impedance parameters for an efficient reception of typical echographic traces in a decoupled way from excitation stage.

Finally, the transceiver must have suitable choices for a reasonably good electrical matching covering a large number of conventional ultrasonic pulse-echo dispositions, but using for this objective only a limited number of adjustment points. In order to satisfies these requirements and assure a portable character, several trade-off solutions have been adopted

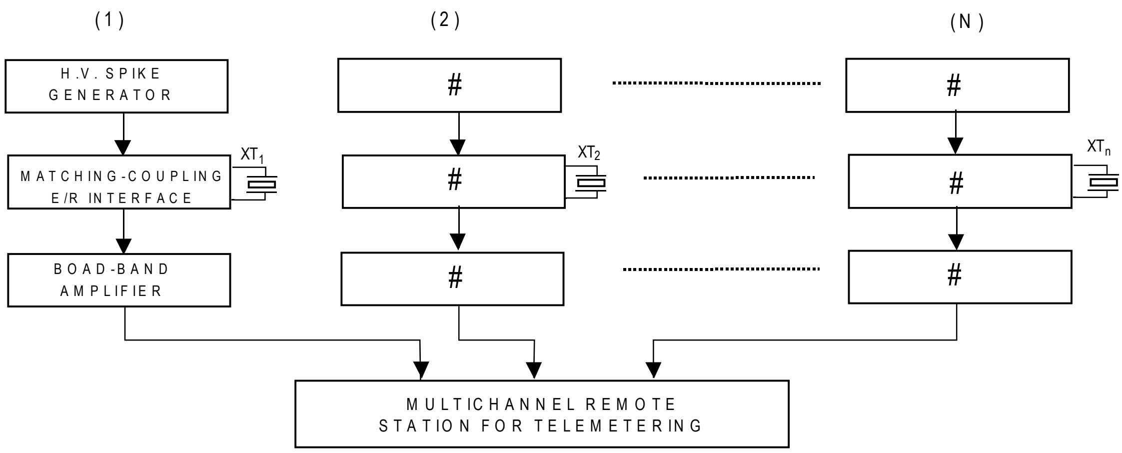


Figure 1. Schematic blocks diagram of ultrasonic stages in the remote unit.

The main electronic stages included in the developed transceiver system are represented in the first column of the blocks diagram depicted in Fig. 1. These general blocks in each channel are the following: a high voltage broadband pulse generator for spike production, a matching-coupling E/R interface, and a broadband ultrasonic signal amplifier.

The developed spike generator is formed by several networks connected in a cascade way:
- a high voltage step generator with a short fall-time.
- a circuit to generate the negative output spikes isolating the high voltage source.
- a network for broadband tuning [2] and a selective pulse damping [3]

A broadband signal amplifier, with 20 Ω in its output impedance, has been developed with three choices for the signal gain, externally selected by the user: 0 dB / 20 dB / 40 dB.
A simple E/R decoupling circuit has been introduced to avoid that the high-voltage driving spikes could damage the chips actuating as signal amplifier in the reception electronics.

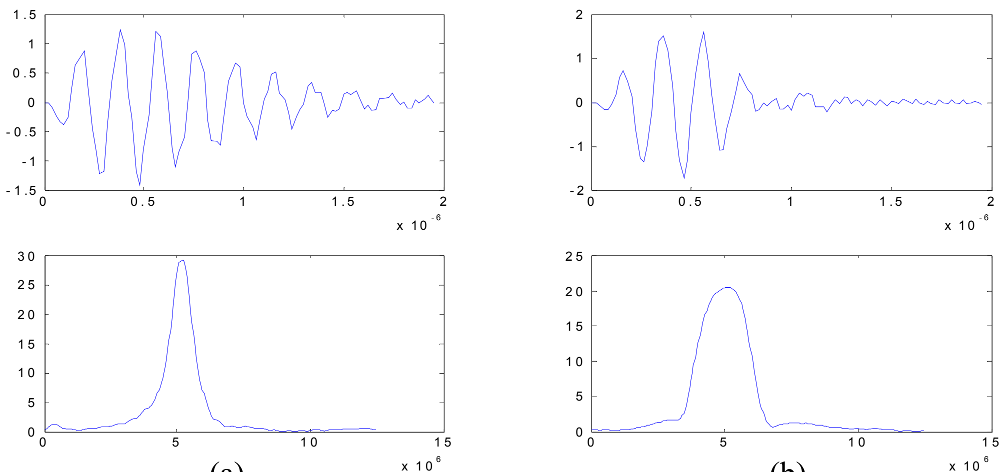
Parameter Setting in Electronic Spike Generation and Emission/Reception Matching

It is well known that the pulsed electrical responses of the acoustic systems, used in ultrasonic imaging and non destructive testing applications, are often strongly influenced by some specific electrical parameters of the electronic stages [4]. Bearing in mind that this ultrasonic transceiver is intended to be incorporated in a remote unit, a choice for electrical parameter setting that, not being optimum, at less assures a medium-level performance, was decided. The final design combines certain flexibility in the adjustment of some fundamental electrical parameters with reduced dimensions.

The main specific spike generation parameters (not in common with receiver) that can be configured for distinct applications are the following:
- Spike repetition rate: up to 1 KHz
- Nominal spike amplitude, two values: 120 or 300 Volts
- Pulse energy, two levels: E_L and E_H

Other common emission/reception fitting elements are two external electric components that can be shunt connected across the transducer electrodes, thus being shared in pulse-echo configurations by both E/R transceiver modules:
- An external loading resistance (R_p^{ext}) for E/R transducer matching purposes [5], giving a whole damping value: $R_{Damping} = R_{sh}\, R_p^{ext} \,.\, (R_p^{ext} + R_{sh})^{-1}$.
- An external inductive device, to cancel capacitive loading coming from the transducers, during the E/R processes. The effective parallel inductance will be: $Lp = L_{SH}\, L_p^{ext} \,.\, (L_p^{ext} + L_{SH})^{-1}$

In previous expressions, R_{sh} and L_{SH} are internal spike shaper components.



(a) (b)

Figure 2. Computed pulse-echo responses for two combinations in the damping / inductance values. a) [120 Ω/ 220 µH] and b) [100 Ω/ 22 µH]. Pulse amplitudes are in volts, times in seconds, and frequencies in Hz.

In a bi-directional ultrasonic system, the damping resistance / inductive device combination is quite critical for the whole (emission-reception) bandwidth-amplitude product optimisation. In Figure 2, time (above) and frequency (below) simulation results illustrating this aspect are shown for a 6 MHz backed PZT transducer, and for two particular driving settings in our transceiver. Setting (b) [100 Ω / 22 μH] produces greater pulse-echo amplitude and a clearly better bandwidth than setting (a) [120 Ω / 220 μH]. Equivalent circuital models for the complete ultrasonic transceiver [3] and software based in Spice, were applied to make the simulations.

3. - LABORATORY PROTOTYPE HARDWARE FOR TELEMETERING

To check the viability of the telemetering system, a laboratory prototype has been developed by considering a system with only one remote station. For this prototype, commercial components together with the specifically developed ultrasonic device have been used. The laboratory hardware prototype is composed of the following components: the ultrasonic device (described in section 3), an A/D conversion card Adlink Technology PCI-9810 [6], two Base Stations Xacom 362 [7] with the Modem Wawecom WM02 [8] and two personal computers. A general outline of the system can be observed in Figure 3.

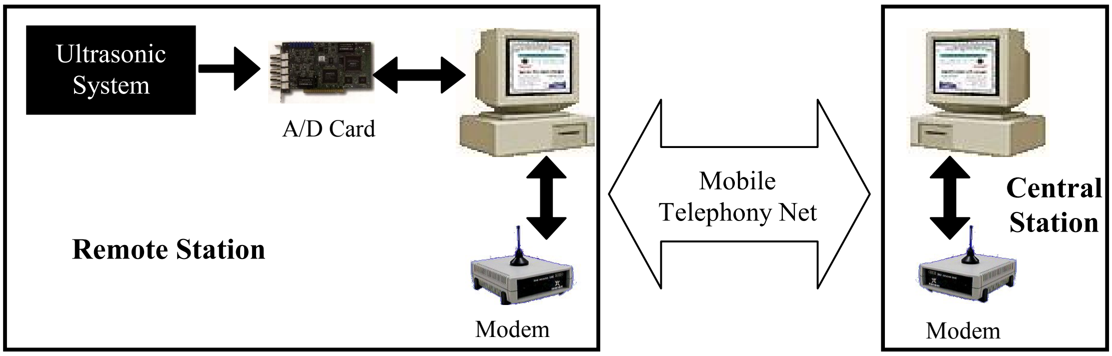


Figure 3. Laboratory prototype for ultrasonic telemetering.

The A/D conversion card PCI-9810 has a 32 bits PCI bus connected to the PC that acts as the mobile station. The most significant characteristics of this card are: maximum value in sampling frequency - 20 MHz (it allows to work with signal bands up to 10 MHz), 10 bits in resolution / sample, 4 simultaneous A/D channels and 32 K-samples of internal memory for data storage.

The main characteristics of the modem Wavecom WM02-G900 GSM are: speed of asynchronous data transmission 2400 to 9600 bits/sec., RS232 V.24/V.28 interface and programmable control by means of AT commands. In order to facilitate the prototype development, the Base Station EBG-362 (that integrates the feeding source and the antenna, with their connections) is used. The used PC´s do not require special characteristics. For the remote station, PC is only the bridge between A/D conversion card and modem. For the central station, the requirements will depend on the processing requirements for ultrasonic signals.

4. SYSTEM SOFTWARE
4.1. CENTRAL STATION SOFTWARE

The software developed for the central station controls the whole system. From central station the programming of the remote stations and the setting of some measurement parameters is allowed. It also decodes the received data generating a standard format. To perform the different tasks, 6 groups of controls have been generated. They can be clearly appreciated in the main screen of the central station (see figure 4): “Menus”, “Current State”, “Measure Programming”, “Connections Programming”, “Control”, “Selected Mobile Stations.”

Menus. In the main screen of central station, 4 menus appear: “Options”, “Summary”, “Data” and “Exit”. “Options” has initialisation functions. “Data” allows the conversion of the received data to ASCII format. “Exit” is the option for leaving the program.

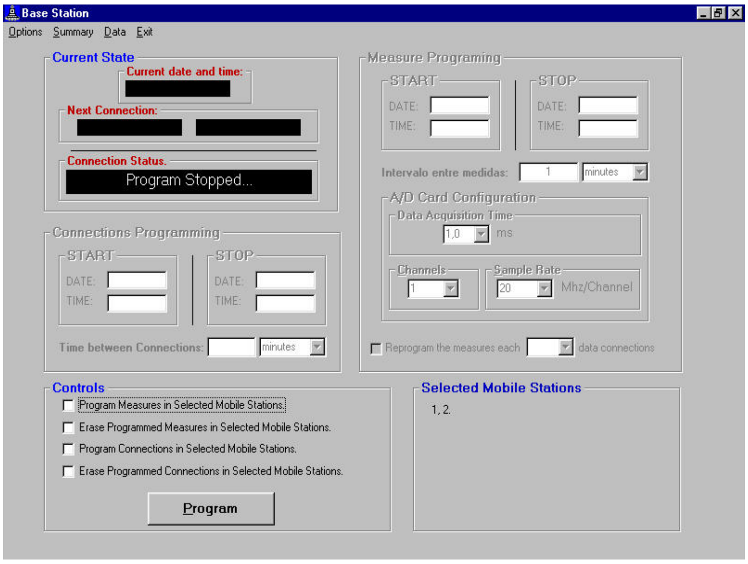


Figure 4. Main screen of base station.

Current State. This record indicates the central station state. It provides three information fields actualised each 200 milliseconds. The fields are "Current Date and Time", "Next Connection" and "Connection Status."

Controls. Allows the definition and modification of the operating mode of the system. The actions that it can carry out include to program and erase measures in the stations and to program or deprogram the connections of the central station with the mobile stations.

Measures Programming. Allows the introduction of the parameters of measurements to be performed at each remote station. These parameters are divided into two subsets: A/D conversion and temporisation. The A/D conversion parameters are the sampling frequency, the number of channels and the signal duration. The temporisation parameters are date and hour of starting and stopping measures together with the time interval between two consecutive measures.

Connections programming. In this record, the connections are programmed with the Mobile Stations selected to receive data from them. These connections programming would be carried out taking into account the measures carried out by the mobile stations. However the system has the possibility of making a smaller number of connections than measurements. Therefore, in each connection each mobile station can transmit several measures simultaneously. The parameters programmed in this part are initial and final dates together with the connection times.

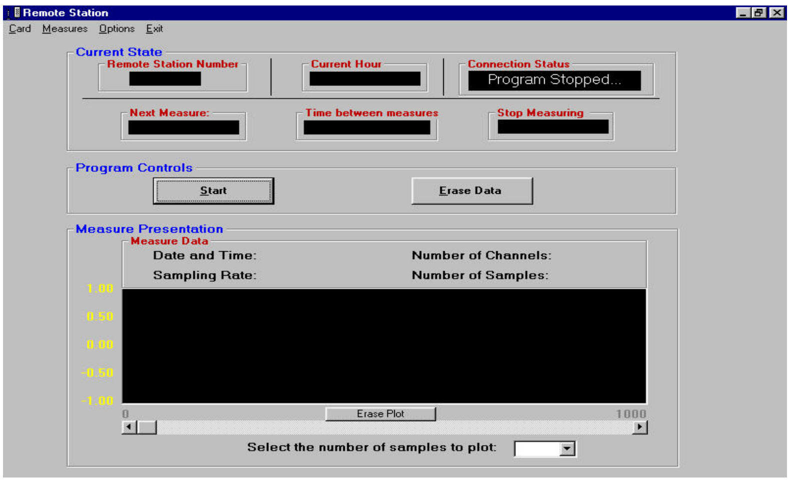


Figure 5. Main screen of remote unit.

4.2. REMOTE TERMINALS SOFTWARE

The remote terminals software allows these terminals to work as subsystems dependent of the central station or as independent measurement units. Figure 5 represents the main screen of the remote station program where 4 groups of controls are shown: “Menus”, “Current State”, ”Program Controls” and “Measures Presentation.

Menus. There are 4 menus “Card”, “Measures”, “Options” and “Exit”. By means of menu “Card” adjustments and maintenance of the A/D conversion card can be performed. The menu “Measures” allows the modification of the remote unit parameters without the central station intervention. This allows the modification of measurement parameters when the system is working in dependent way together with the use of each mobile system in an independent way. The menu “Options” make the initialisations of the remote unit.

Current State. In this record, the remote station information is actualised each 200 milliseconds. The fields contained in this record are: “Mobile Station Number”, “Current Hour”, “Connection Status”, “Next Measure”, “Time between Measures”, “Stop Measuring.”

Program Controls. This option allows to start or to stop the mobile station. It also allows making the reset of several parameters, by making an initialisation.

Measure Presentation. The following information is represented: the name of the file that contains the measure, date and hour of the measure, number of channels used by the A/D conversion card, sampling frequency, number of taken samples and a graphic representation of the last taken measure (up to 4 simultaneous, 1 for channel)

5. CONCLUSIONS

The design of a novel and flexible automatic system for remote ultrasonic measurements, using piezoelectric distributed transducers, has been described. The development of the system has involved different techniques, including software and hardware designs, have been used. The hardware contains commercial components and an ultrasonic transceiver designed for this application. The software for central and remote stations has been developed in Visual Basic.

Communications among remote and central stations have been performed by means of mobile telephony. To avoid the impossibility of the transmission of ultrasonic signals in a continuous way through telephony channels, a protocol allowing the transmission of complete frames of ultrasonic signals has been implemented. The hardware/software developed on a laboratory prototype has permitted the verification of the viability of the proposed objective.

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