

A SIMPLE DISTRIBUTED MEASUREMENT SYSTEM BASED ON POWER LINE COMMUNICATIONS

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Abstract – A simple and inexpensive distributed measurement system that uses the common low voltage power line network as a communication medium is presented and discussed. This system is based on a simple low speed FSK PLC modem and its functionalities and ruggedness have been evaluated on a laboratory network in presence of various kind of background noise. A proper Microsoft® Windows® based user interface has been developed both for the client and the server side of the measurement system to simplify its configuration and use. In addition a PC based virtual instrument for the automatic and in-line measurement of the SNR ratio has been developed to evaluate the minimum value of SNR that must be guaranteed on the client side to assure the proper system efficiency.

Keywords: Power Line Communications, Distributed Measurement System, Virtual Instrument

1. INTRODUCTION

Over the last few years the need to interconnect various measurement instruments that interact between them and that receive commands and send measurement data to a remote supervisory console has become more and more important in various fields. The interconnection solutions available nowadays are of various kind, complexity and cost and the choice of the right transmission technology is a fundamental step in the whole design process. Obviously the most important parameters to consider are the required bandwidth and the physical distance between the instruments and the supervisory console.

Nowadays there are tens of possible solutions: starting from the popular Ethernet based networking solutions for the most demanding applications and lasting to the common serial connection for the less ones.

In this work we examine the characteristics of the common low voltage AC power line network as a communication medium between the remote instruments and the supervisory console.

2. BASICS ON POWER LINE COMMUNICATIONS

The power line communications is a communication technology that uses the common low and medium voltage AC network to transmit signal over short to medium

distances. This technology is not a newer one - the first applications go back to 1940s - but has received more and more attention in the last years due to the introduction of new modulation techniques that seems to be very promising in terms of transmission speed and noise immunity. The markets that seem to be more interested to these new technologies is the domestic one (sophisticated home automation applications, sharing of broadband Internet access and multimedia contents, etc.) and also the telecommunications one ("last mile" covering by means of signaling over medium/high voltage power lines). Also various experimental applications in the field of distributed measurement already exist especially in the USA (remote reading of gas and/or energy meters).

However this technology must pay for years of unsuccessful applications and unreliable results; in fact the AC power line is probably one of the most difficult communication medium because it is affected by a strong and unpredictably varying background noise due to the various appliances connected on it; moreover its transfer function is time varying and the signal may be significantly altered by "holes" of attenuation due to the frequency characteristics of these appliances.

The latest advances in the IC technologies with the high integration densities available nowadays, have permitted the design and realisation of advanced chipsets that integrate in hardware all of the functions required to implement a communication node with only a handful of external components; these chipsets use spread spectrum modulation techniques with complex errors correction schemes; an example can be found in [1]. The use of spread spectrum modulation techniques permits remarkable gains in terms of transmission speed and of link ruggedness.

In the last few months various products have been announced that act as bridges between already established and well-known networking or peripherals interconnection standards (like Ethernet and USB) and the AC power line network [2].

However the considerable research costs and efforts that the producers of these chipset and products have supported make them available only to a strict selection of valuable customers (normally only OEMs that can guarantee large businesses).

In the authors' original intentions the present work should have been based on one of these modern high speed

chipset, but it hasn't been furnished by its manufacturer due to the small quantity requested.

3. THE HARDWARE SETUP

For these reasons, this work has been based on a low speed (2400 bps maximum) half duplex FSK modem: the ST7537 Home Automation Modem manufactured by STMicroelectronics [3]; it uses a narrow band modulation scheme that permits good results only on low noise networks.

Due to the experimental characteristics of this work we preferred to use a common Microsoft® Windows® based PC as a control unit and we adopted an RS232 serial link between the latter and the modem; moreover in our design we introduced another parallel I/O port useful to connect the modem to an optional microcontroller based circuitry.

We assembled three modems on an ourselves designed double sided PCB which comprises the power supply unit, the modem itself with its network interface circuitry, the RS232 to TTL logic level translator and the parallel I/O interface; Fig. 1 reports a picture of one of these modems.

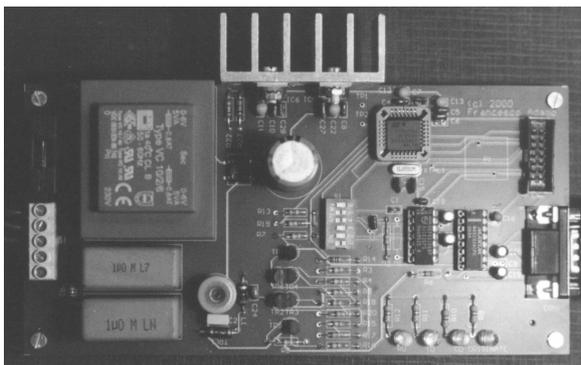


Fig. 1. - Power Line Modem picture

The schematic diagram of the modem is too large to be reported here.

The modems have been installed as interfaces between the power line and three PCs running three copies of the control software; there were two PCs configured as clients and one PC configured as server (supervisory unit). The client PCs were equipped with two National Instruments' DAQ products to be used as measurement equipment.

4. THE SOFTWARE SETUP

The necessary support software has been developed in Object Pascal using the Borland Delphi® 5 IDE from Inprise Corp.; at run time the software can be configured in client or server mode depending on the user's choices. The complete control over the National Instruments' DAQ devices has been obtained using the NI's ComponentWorks® ActiveX class of controls easily integrated in the development environment. Fig. 2 shows the design time aspect of the main window of the software.

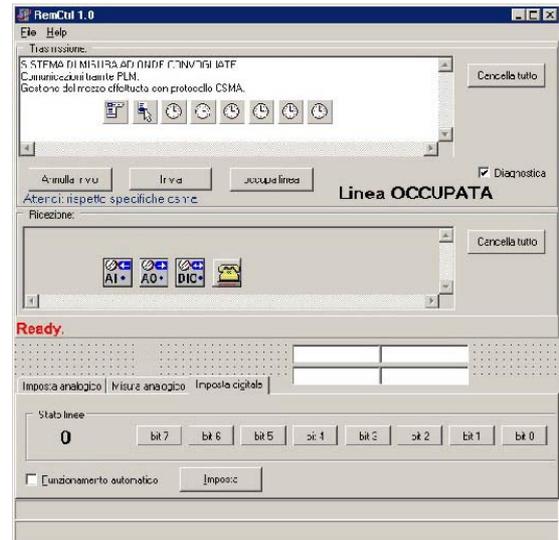


Fig. 2. The main window of the control software at design time

The software permits the remote control from the server side of the basics function of the DAQ devices connected to the client PCs: it is possible to measure an analog input voltage, to generate two independent analog output voltages and to set the status of anyone of the 8 bits of the general purpose digital I/O port.

The access to the communication medium is regulated thanks to the adoption of a simplified form of the well known CSMA/CD protocol with automatic retransmission in case of collision.

5. EXPERIMENTAL RESULTS

Another important part of this work has been the realisation of an instrument for the automatic and in-line measurement of Signal to Noise Ratio obtained over the AC power line in the band of sensitivity of the receiver (12 kHz wide band centred around 132 kHz of the carrier frequency). This instrument has been developed as a virtual instrument in the National Instruments' LabVIEW® environment starting with an example VI available on the support section of the NI's web site. Originally this VI could only show an acquired vector of data both in the time domain and in the frequency domain (DFT based spectrogram of the acquired data weighted by a user selectable window to reduce the negative effects of the finite length of the data).

Due to the complexity of the operations involved in the SNR evaluation we chosen to rely on the powerful computing features of MathWorks MATLAB®; therefore we introduced the MATLAB code directly in a LabVIEW's MATLAB Formula Node function block; this choice allowed us a good analysis of the characteristics of the power line as a communication medium.

An image of the front panel of this VI can be observed in Fig. 3.

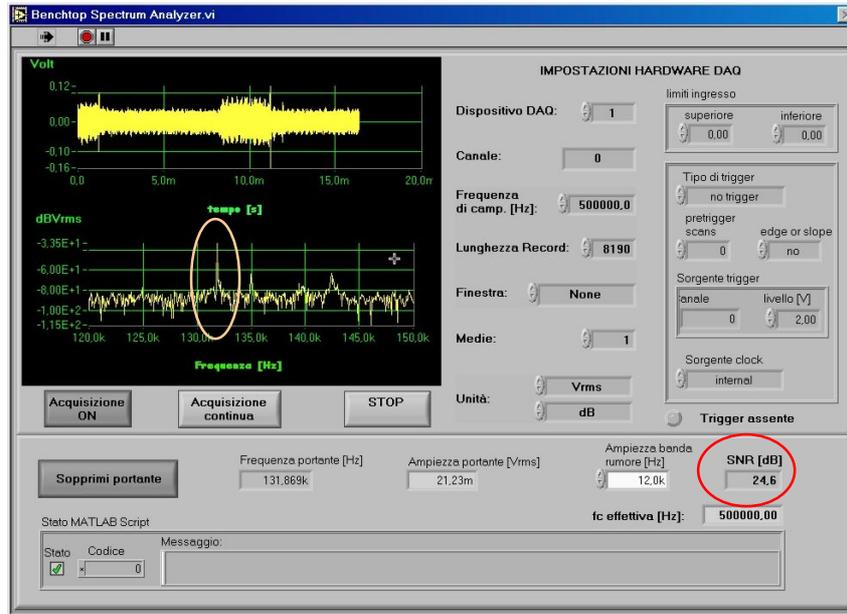


Fig. 3. An image of the front panel of the VI used to study the characteristics of the modem; the indicator circled on the lower right-side of the image shows the computed SNR

The MATLAB code developed for this work uses a frequency interpolation algorithm ([4]) to compute an accurate estimate of the frequency of the carrier signal (circled on the spectrogram of Fig. 3) and a common three parameters sine-fit algorithm to obtain a good estimate of the amplitude of this signal. We use the estimate of the carrier frequency to digitally filter out this signal from the acquired data; subsequently we compute the total noise power in the receiver's band of sensitivity (12 kHz) and use it to compute the SNR with the formula

$$SNR = 10 \cdot \log_{10} \left(\frac{P_c}{P_n} \right) = 10 \cdot \log_{10} \left(\frac{V_{c,rms}^2}{\sum_{RBS} V_{n,rms}^2} \right)$$

where:

- P_c is the power of the carrier signal
- P_n is the total noise power in the receiver band of sensitivity (referred as RBS)
- $V_{c,rms}$ is the RMS value of the carrier signal

We observed that the simple FSK modulation scheme used by our modem is very sensitive to the noise injected on the line by domestic appliances like light dimmers or brush-motor equipped ones; in fact, as can be seen from Table 1, in presence of these type of appliances, the SNR ratio suddenly falls under the minimum value required by the receiver section of the modem to extract the carrier. Obviously this situation causes the loss of link between the server and the client.

Table 1. SNR measured at the client side with various types of electric appliances

Noise Source	Operating Mode	SNR [dB]
None	-	32,6
Light dimmer	max brightness	32
	1/6 max brightness	30
	1/3 max brightness	26
	1/2 max brightness	21
	2/3 max brightness	25
	5/6 max brightness	29
	off	31
hand-held drill (750W)	on-off switching	11 (max)
	1/3 max speed	29
	2/3 max speed	27,5
	full speed	27
Motor no. 1	max speed	31
	1/2 max speed	28
Motor no. 2	max speed	31
	1/2 max speed	24
Motor no. 3	normal	30
Motor no. 4	normal	29
	on-off switching	27 (peak)

Another important interference is also caused by the switching regulators circuitry of the various appliances (PCs, printers, etc.).

6. CONCLUSIONS

In this work the authors present an experimental analysis of the characteristics of the common low voltage AC power line network as a communication medium for the transmission of measurement data. In the authors' opinion the FSK modulation technique is not suited for critical applications due to its relatively high sensitivity to the noise produced by the common appliances. The new sophisticated spread spectrum modulation schemes seems to be very promising in achieving the necessary noise immunity; however this is a relatively new technology and the necessary evaluation hardware is not available to customers different than OEMs which can guarantee large businesses.

7. REFERENCES

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