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M. Bramanti - F. Denoth

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M. Bramanti - F. Denoth
Istituto di Elaborazione della Informazione, C.N.R. - Pisa

Introduction

The problem of trasmission of biomedical signals by means of radio waves or by telephon lines has received in past years the attention of several researchers and industrial organizations [1,2]. The need of such aids in medical field was confirmed by international communication committees and at present a set of rules exists for such transmission systems [3]. This paper reports the activity recently undertaken at IEI-CNR of Pisa in the field of biomedical telemetry via switched telephon lines. In this first part of the work the transmission of ECG signals was principally considered; nevertheless the trans-receiver system was structured in such a way that it can be easily adapted to transmit other biomedical signals as electroencephalograms (EEG), peripheral pulses (PP), arterial blood pressures (BP) and, by reducing the number of channels, signals with broader bandwidth, such electromiograms and phonocardiograms.

Methods for multichannel telephone telemetry.

Designing a telemetric system via common switched telephone lines firstly requires a choice between analog and digital transmission. Transmission of signal in a digitalized form undoubtly offers high noise immunity and allows to use modem systems commercialy available. By this transmission method, however, the whole telephone band (300 ÷ 3400 Hz) is almost saturated by only one signal source with a bandwidth of 100 Hz. Therefore, in the case of a multichannel system, the transmission of signals in analog form is convenient. Input signals are transposed into the telephone band by means of an opportune frequency domain multiplexing technique. This information processing is essentially obtained by modulating a number of carriers, and the adopted modulation methods are normally AM or FM type. When a small frequency modulation index is adopted in order to reduce the bandwidth of each channel, the performances of the two modulation types, in the respect of signal to noise ratio, are substantially equal from a theoretical point of view: the final choice is greatly conditioned by the characteristics of the available circuitry. Another important problem relative to the use of common telephone lines for multiplexed analog signals, concerns the coupling between the modem and the transmission system. Generally an acoustic or a magnetic coupling of the multiplexed signal to the line is adopted. In this paper experiments on both these methods are reported. Also a third method was successfully experimented in which the multiplexed signal feeds the microphone terminals at the transmitter and it is picked up from the earphone terminals at the receiving end. In the following paragraphs the adopted solution and the experimental results are reported.

Description of the system

On the basis of technical literature and industrial realizations in the field (e.g.: OTE Mod. 1181 and 1182, HP Mod. 1515A) a trans-receiver system was designed with a capacity of four ECG channels and an auxiliary phone channel. Band requirements of the four channels may

be changed and fitted to particular needs by simply replacing the low-pass and band-pass filters board of the modem. Input channels are transposed in the telephone band by frequency domain multiplexing technique, based on FM modulation of suitable allocated carriers and on successive band limiting filtering. FM modulation was estimated to be better than AM modulation, respect to S/N ratio, even in case of a low modulation index, as required to reduce modulation spectrum. FM modulators were easily implemented by the use of integrated voltage to frequency converter (V/F) circuits with good linearity and stability performances. The four channel carrier are allocated in the 1000-3000 Hz frequency range, while the phone channel is transmitted untransposed through a low pass bidirectional passive filter with an upper cut-off frequency of about 800 Hz. At the receiving end, demodulation is achieved by means of a phase locked loop F/V converters. Valuable performances of the adopted solution are: high value (>40 dB) of AM rejection ratio, useful against amplitude noise of line, and high immunity from adjacent channel interference, due to the tracking mode of PLL system which diseregards much lower amplitude interfering signals due to other channels; the last feature greatly simplifies filtering problems.
Fig. 1 shows a simplified block diagram of the implemented system.

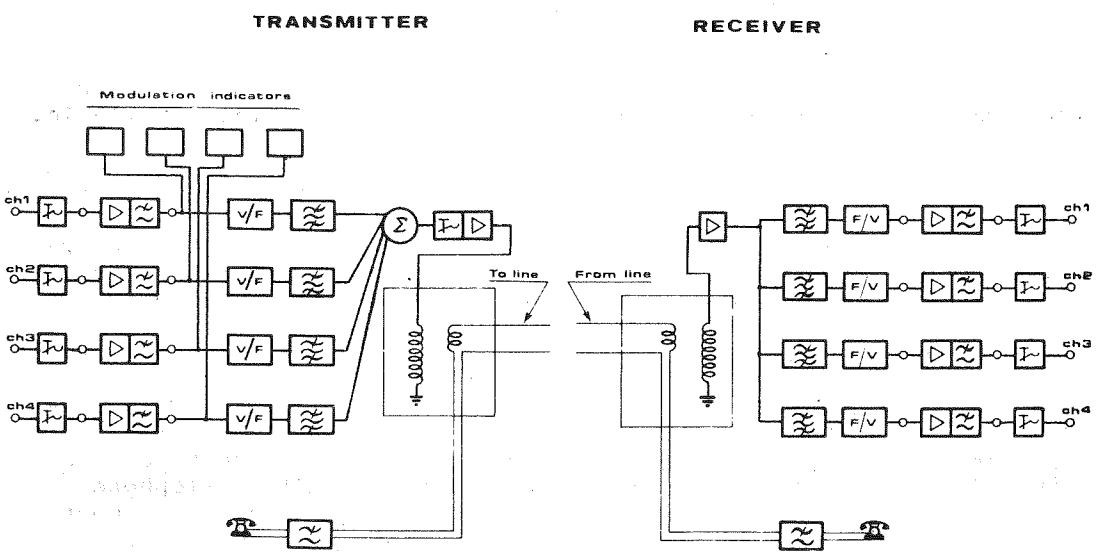

Fig. 1 - Black diagram of the telemetry system.

The basic system of fig. 1 has been also modified in order to feed the telephone line by directly switching the microphone terminals (fig. 2a) or by an acoustic coupling (fig. 2b). In both cases at the receiving end the signal was picked up at the earphone terminals by a differential balanced amplifier.

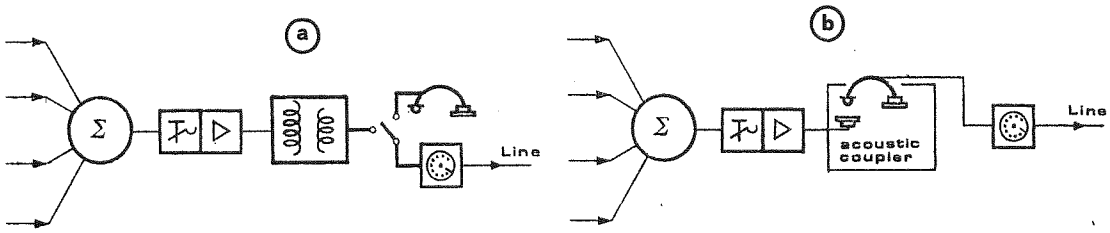

Fig. 2 - Different ways of feeding the telephone line: a) by switching the microphon terminals; b) by acoustic coupling.

Experimental results and development

The trans-receiver systems of fig. 1, fig. 2a and fig. 2b were tested by transmitting square wave, sinusoidal signals and true ECG signals.

Fig. 3 shows an example of transmission and reception of four signals over an urban path. ECG modulating signals were obtained from an actual ECG recorded an a FM magnetic tape.

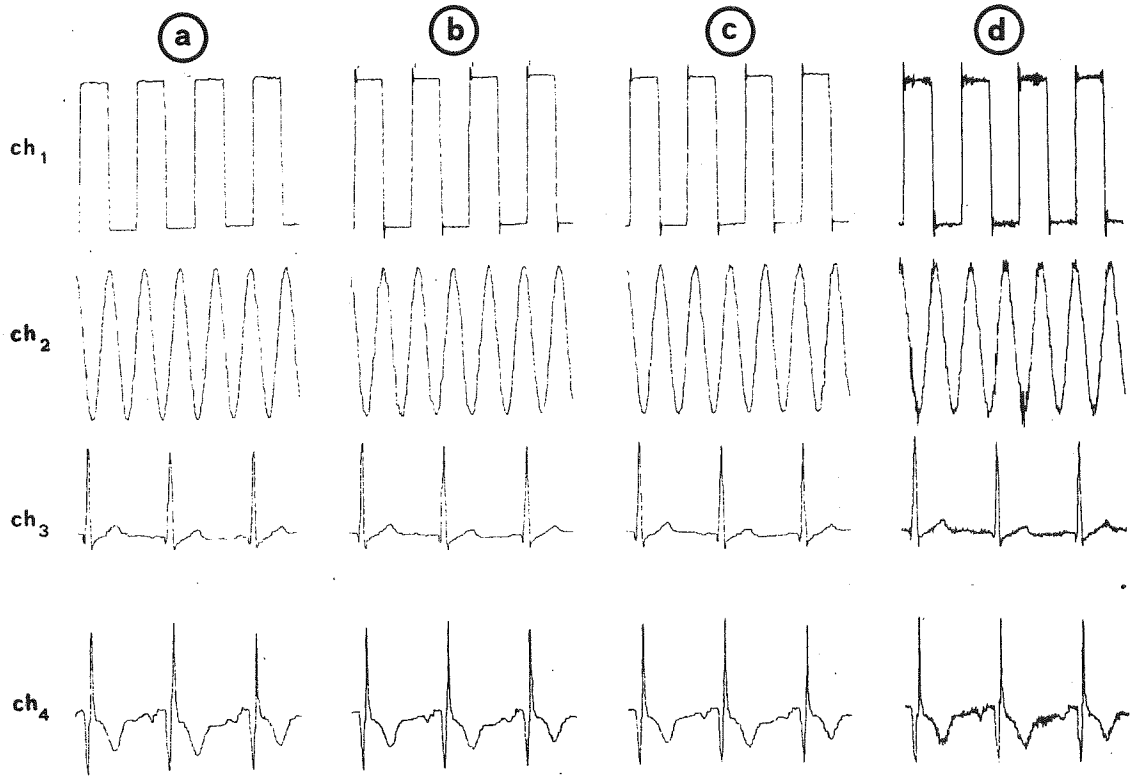

Fig. 3 a) transmitted signals; b) received signals with the system of fig. 1; c) received signals with the modification shown in fig. 2a; d) received signals with the modification shown in fig. 2b.

Very interesting are the results obtained by the method of fig. 2a which allows good quality transmission and has the possibility of phonic conversation, achieved by a simple switching operation. The results obtained by the method of fig. 2b) show the difficulty of employng acoustic couplers for large band multichannel transmission, essentially due to a poor signal to noise ratio.
At present experiments of transmission of two indipendent signals by means of AM and FM modulation of the same carrier are under investigation, by using a new generation of PLL demodulators with FM and AM output: by this way the transmission capacity of the system will be barely doubled.

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- R E F E R E N C E S -

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