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# A SUPPLEMENTAL SYSTEM FOR DETECTION AND MEASUREMENT OF DATA TRANSMISSION RATE IN WIRELESS HF COMMUNICATION

Z. TELATAR

*Ankara University, Faculty of Engineering, Department of Electronic Engineering,*

*06100-Besevler-Ankara-TURKEY*

*E-mail : telatar@eng.ankara.edu.tr*

## ABSTRACT

This paper introduces a new adaptive data transmission rate measurement system for wireless HF digital communication. The system automatically detects and displays the transmission rate of digital data in the presence of FSK modulated signals. For that purpose, a digital phase locked loop (DPLL) and a microprocessor with its peripheral components are used in order to measure the data rates of the digital signals sensed through a receiver and an antenna. After the system is locked to the input frequency, the software run by microprocessor measures the data transmission rate of captured signal within a limited number of data sequence. The detection and the measurement range of the data rate is between 45 Baud and 52000 Baud according to the available standards. The experimental results show that the data rate measurement system can reliably be applied to a communication system whenever the data rate is required for establishing a first connection successfully.

KEYWORDS: Wireless HF communication, Wireless digital data communication, Baud rate, Amateur radio communication, data rate measurement

## 1. INTRODUCTION

Digital data communication has been a great interest over the past years. One of the digital data transmission methods in application is used in amateur radio in HF band with a limited bandwidth. A number of data formats are used in digital HF communication systems based on FCC (Federal Consultative Committee), CCIR (International Radio Consultative Committee) standards. Most commonly used of them are Baudot and ASCII formats. The data transmission rates for these formats vary from 45 Baud to 52000 Baud depending upon the user application.

The most basic problem encountered in digital data communication in HF bands is to establish a first connection between receiver and transmitter, as the different data rate standards are being used in applications. In response to this problem, a reliable data transmission between two stations requires the use of same data standards and rates at the receiver and transmitter site. For example, the data rate can be set to any standard rate at the transmitter and broadcasted for other stations. If the data rate is unknown at the receiver site, the data can not be received correctly and it does not matter for the listener or the computer user. In some stations, the experienced operators might set the receiver and the data receiving device to a proper data rate by listening signal. Otherwise, the unexperienced users at the receiver site try to scan all the common rates to find fitting one [1,2].

A number of studies have been done in literature to contribute the estimation or the measurement of channel characteristics and data rates from the captured signal. Arthur and Maundrell [3] introduced a technique to permit characterization of HF modem performance across a range of possible channel conditions. Abramovich et al., [4] established an experimental system to test modem frame synchronization conditions and multipath resolution in HF channel with standard data rates. Tang et al., [5] analysed the performance of HF serial data transmission system for CW interference rejection by considering the minimum mean square errors of adaptive equalizer in HF serial systems. Chow et al., [6] implemented a working prototype modem and characterized the performance of modem for common data rates with bit rate synchronization. Bernardini et al., [7] presented a method dealing with the optimal choice of the system parameters in an HF digital radio link. Chen et al., [8] introduced a method for improving the carrier tracker and bit synchronizer performance in order to obtain robust communication system. Zhang et al., [9] described a nonlinear short block data estimation technique suitable for HF modem in which the known training symbols are used to track the channel characteristics and to detect the unknown data symbols with an adoption scheme to blocks. Nieto [10] investigated the possible performance improvements of using spatial diversity on modern HF waveforms such as the high data rate waveforms for synchronization conditions of tone based signals.

The methods presented in literature require robust connection links between modem terminals in order to obtain reliable data communications. For that purpose, each modem has to be set for the same data rate to establish a link as explained above. Sometimes, operators in receiver terminals scan all the data rates known to receive the data correctly and blocks of data are lost for such connection. On the other hand, if the data rate of current transmitter station is known at the receiver site, then a connection (with modem) can be established in a short time with minimum loss of data packets. The alternative (and also effective) way to scan all data rates is to measure the data rate of received signal.

In this paper, a robust data rate measurement system has been presented. The system detects the digital signal through a receiver. After locking to the input signal, data transmission rate is computed by microprocessor. Next sections explain the developed system in detail.

## 2. FORMATS AND DATA RATES IN DIGITAL HF COMMUNICATION

Although the Internet has become most common digital communication media over the world with high data transmission rates, in some cases like natural disasters, Internet might not be reliable for continuous communication because of the damages on the channels. In such cases, an alternative to Internet might be HF radio communication band which is in use for along time. HF uses wireless media between receiver and transmitter.

In general two types of communication formats are used in HF band according to FCC and CCIR standards.

- Baudot RTTY
- ASCII RTTY

Format of Baudot code is as follows,

$$1 Baudot\ packet = 1\ Start + 5\ Data + 1{,}42\ Stop \quad (1)$$

As the Baudot code has 5 data bits, only 32 characters or symbols can be coded and transmitted. This is not enough for all characters and symbols (26 latin character and other symbols). To overcome the character and symbol limit problem, ASCII code with 7 data bits (128 combinations of characters and symbols) has been extensively used in digital data communication. Format of ASCII code is as follows,

$$1\ ASCII\ packet = 1\ Start + 7\ Data + 1\ Parity + 2\ Stop \quad (2)$$

Communication performance of the systems in transmission depends on how many bits are used for a coded format given above and pulse durations of the bits used. On the other hand, pulse durations of the bits and number of bits used in a format are directly related to define the data rate. Most commonly used data rates and pulse characteristics are given in the literature as in Table 1.

In general applications, data rates between 45 Baud and 100 Baud are examined by the Baudot formats and upper rates from 100 Baud are used with the ASCII formats.

**Table 1.** Most common formats and pulse characteristics used in digital HF communication.

| Data Rates (Bits per Sec.) | Duration of Data Pulses | Duration of Stop Pulses | WPM | CPS |
|---|---|---|---|---|
| 45,45 Baud | 22 ms | 22 ms | 65 | |
| 50 Baud | 20 ms | 30 ms | 66,67 | |
| 57 Baud | 17,5 ms | 25 ms | 76,68 | |
| 74 Baud | 13,47 ms | 19,18 ms | 100 | |
| 100 Baud | 10 ms | 15 ms | 133,33 | |
| 110 Baud | 9,091 ms | 18,182 ms | 100 | 10,0 |
| 150 Baud | 6,667 ms | 6,667 ms | 150 | 15,0 |
| 300 Baud | 3,333 ms | 3,333 ms | 300 | 30,0 |
| 600 Baud | 1,667 ms | 1,667 ms | 600 | 60,0 |
| 1200 Baud | 0,833 ms | 0,833 ms | 1200 | 120,0 |
| 2400 Baud | 0,416 ms | 0,416 ms | 2400 | 240,0 |
| 4800 Baud | 0,208 ms | 0,208 ms | 4800 | 480,0 |
| 9600 Baud | 0,104 ms | 0,104 ms | 9600 | 960,0 |
| 19200 Baud | 0,052 ms | 0,052 ms | 19200 | 1920,0 |
| 38400 Baud | 0,026 ms | 0,026 ms | 38400 | 3840,0 |
| 52000 Baud | 0,0192 ms | 0,0192 ms | 52000 | 5200,0 |

Data transmission rates for Baudot and ASCII formats are computed as transmitted character per second (CPS) as follows,

$$CPS = \frac{1}{K + L + M + N} \tag{3}$$

where $K$, $L$, $M$ and $N$ are the number of start bits, the number of data bits, the number of parity bits and the number of stop bits in a pulse sequence for a character. In same manner, transmitted word number in a minute can be computed as,

$$WPM = CPS / 60 \tag{4}$$

Data transmission rate of a digital signal is related to the pulse duration of transmitted signal which are known as mark signal (logic 1) or space signal (logic 0). Some specific data rates (Baud Rates) are given in Table 1. According to the pulse durations in Table 1, Baud Rate (or data rate) computations of the data to be transmitted are formulized as follows,

$$Baud\ Rate = \frac{1}{\tau(ms)} \tag{5}$$

where $\tau$ is the smallest pulse duration of the bits in a sequence.

## 3. SYSTEM IMPLEMENTATION

Data rate detection and measurement system presented here have three functional blocks as shown in Figure 1. The controller block which consists of a DPLL (Digital Phase Locked Loop) and a digital counter circuits is for locking to the input signal captured by a receiver and for updating the system control parameters on a basis of the results coming from MDM (Modification, Decision and Measurement) block if necessary. Identifier block compares the input signal and output of controller block and detects the lock condition. When identifier block locked to the input signal, it sends a control signal to MDM block. MDM block evaluates the output of the identifier and decides whether an update is necessary for measurement parameters in controller block. A microprocessor (8052 AH BASIC) is run by software in MDM block to realize identification, decision and measurement purposes. The clock rate of the microprocessor has been chosen as 11.059.200 Hz (100 nanoseconds) which is enough for measurement of pulse length of received data. The clock required for DPLL in controller block has also been obtained by dividing microprocessor clock to synchronize the blocks.

The microprocessor in the MDM block continuously reads the output of controller block after DPLL is locked to the input signal and scans all the mark pulses in packets by 100 nanoseconds clock. After scanning two or more packet block depending on data format, MDM block decides the data rate by finding the smallest pulse length in the sequence.

Mathematical representation of Figure 1 can be given according to functionality of each block as follows,

Reference (input) frequency : $w_{in} = w_0 + \Delta w_{in}$ (6)

DPLL output frequency : $w_{out} = N w_0 + \Delta w_{out}$ (7)

Input-output frequency error : $w_e = w_{in} - w_{out}/N$ (8)

where $w_0$ is the center frequency inwhich input frequency alternates around the center frequency. The relationship between input and output frequencies of DPLL circuit is as follows,

$$w_{out} = K_{PD} * K_{DCO} * F(w) * w_e \quad (9)$$

$$w_{out} = \frac{K_{PD} * K_{DCO} * F(w)}{1 + K_{PD} * K_{DCO} * F(w)/N} * w_{in} \tag{10}$$

where $K_{PD}$, $K_{DCO}$, F(w) and N are phase detector gain, digital controlled oscillator (DCO) gain, filter response and number of bits in counter respectively. Controller block is locked to the input signal and follows it with a minimized error given in equation (8).

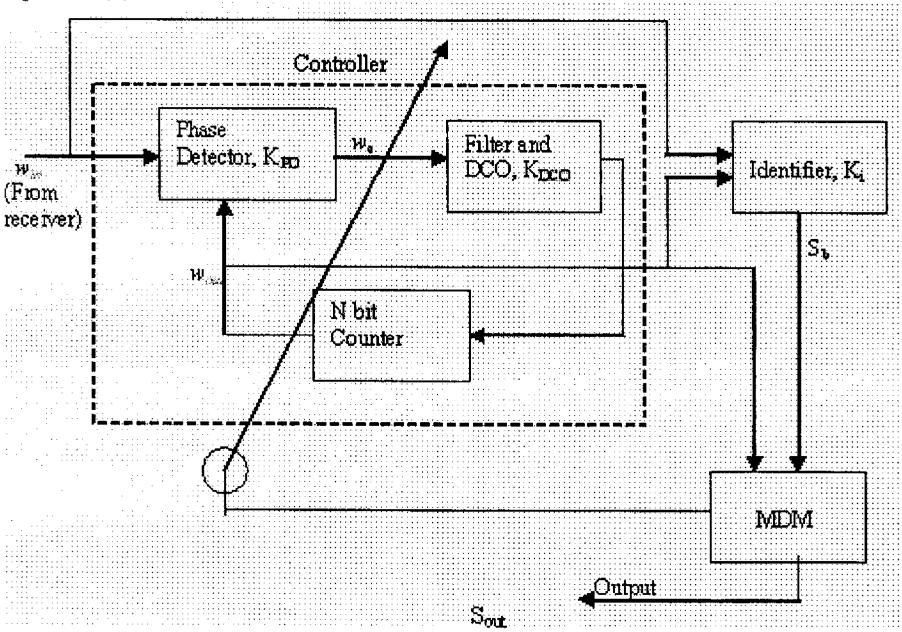


**Figure 1.** Block diagram for the proposed data rate measurement system

As the input data to the system is sometimes analog, a zero crossing detector circuit has been used in the identifier block to convert the input continuous signal to discrete form in order to digitally processing the data in microprocessor.Output of the identifier block can be computed as follows,

$$S_b = \{K_i (w_{in} - w_{out})\}_{min} \tag{11}$$

If $S_b$ exceeds limit value defined, then MDM block makes a decision to update the running parameters of controller. In that case, controller or DPLL will search new frequency component to lock the input signal. When the system is locked to the input frequency, MDM block tries to compute the data rate of input signal. Finally, output of the measurement system is obtained as follows,

$$S_{out} = Measurement\{S_b, w_{out}\} \tag{12}$$

## 4. RESULTS

The measurement system developed here was tested by real HF signals obtained from ICOM receiver. For that purpose, first, a transmitter station was established nearby the receiver station having different antenna location. Most common data rates given in Table 1 were transmitted by this station and the captured signals by ICOM station were tested our system. Measurement period of

one packet is between 164 milliseconds for 45,45 Baud and 0,2112 milliseconds for 52000 Baud depending on data rate of transmitted signal. All computed data rate durations have been given in Table 2 and Figure 2. Note that, only the pulse lengths of data in packets have been examined in this work, not interested in involvement of data packets.

**Table 2.** Data rate measurement performance statistics of the system

| Measured Data Rates (Bits per sec.) | Measurement Duration for one data packet (ms) | Total time for measuring the data rate (ms) | Required packet number for the measurement of data rate | |
|---|---|---|---|---|
| | | | Noise free channel | Noisy channel |
| 45,45 Baud | 164 | 492 | 3 | 5 |
| 50 Baud | 150 | 450 | 3 | 5 |
| 57 Baud | 130 | 390 | 3 | 4 |
| 74 Baud | 100 | 300 | 3 | 4 |
| 100 Baud | 75 | 225 | 3 | 4 |
| 110 Baud | 118,183 | 236,366 | 2 | 4 |
| 150 Baud | 73,337 | 146,674 | 2 | 3 |
| 300 Baud | 36,663 | 73,326 | 2 | 3 |
| 600 Baud | 18,337 | 36,674 | 2 | 3 |
| 1200 Baud | 9,163 | 18,326 | 2 | 3 |
| 2400 Baud | 4,576 | 9,152 | 2 | 3 |
| 4800 Baud | 2,288 | 4,576 | 2 | 3 |
| 9600 Baud | 1,144 | 2,288 | 2 | 3 |
| 19200 Baud | 0,572 | 1,144 | 2 | 3 |
| 38400 Baud | 0,286 | 0,572 | 2 | 3 |
| 52000 Baud | 0,2112 | 0,4224 | 2 | 3 |

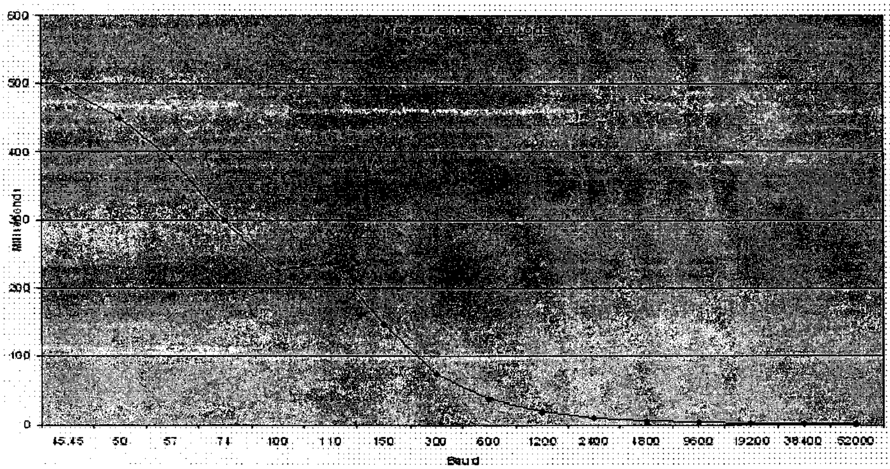


**Figure-2.** Data rate (Baud rate) measurement statistics

The system requires more than one packet for reliable and robust data rate measurement computation depending upon data formats handled. For example, while the system needs to three data packets for Baudot format because of the long time duration of data pulses, two data packets are required for ASCII formats. These packet numbers used in data rate computations define the required maximum data transmission rate measurement periods. Measurements were made for noise free and noisy channel. These measurement periods have been given in Table 2. The measurements in the case of noise free channel are required 2 or 3 packets of data, while measurements in noisy case are required 3 to 5 packets of data. The error measurements depending on received signal levels in dB are given in Figure 3. The error computations is realized by considering noisy and noise free conditions of the channel and compared with the computer simulations. The error for measuring the data rate depends on signal level received and it decreases for higher SNR levels as shown in Figure 3.

Then, digital signals in HF Bands broadcasted by different local, regional or international stations were captured by the receiver and then data rates were computed by presented system. The similar results with our test results were obtained for noise free and noisy channels. The measurement periods of the received data depends on which data rate was used in transmitter and the noise level in channel. It has been observed from the experiments that lower data rates are more sensitive to noise level in order to erroneous measurement of the data rate.

## 5. CONCLUSIONS

In this paper, a new robust data rate measurement system was presented. This system is required for data receiving site to establish a reliable and fast connection to the data transmitter station as the different data rates are in use. The system automatically detects the data rate of transmitter station on a basis of noise free and noisy conditions in a short time with an HF modem through a digital phase lock loop circuit. This system can be applied to all digital data communication devices communicating through different computer terminals

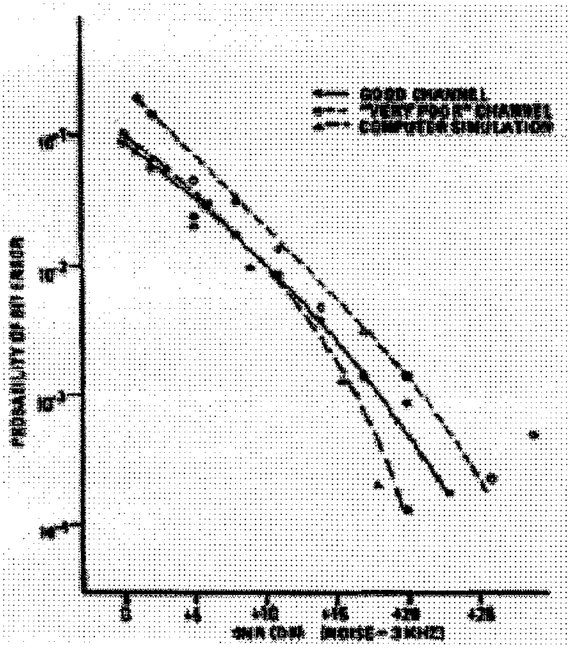

**Figure-3.** Error rates via channel conditions


## ÖZET

Bu makalede kablosuz HF sayısal haberleşme için yeni bir adaptif veri iletim hızı ölçüm sistemi tanımlanır. Sistem FSK modüleli sinyallerdeki sayısal verinin iletim hızını otomatik olarak ölçer ve gösterir. Bu amaçla, bir anten ve bir alıcı cihaz ile algılanan sayısal sinyallerin veri hızlarını belirlemede bir sayısal faz kilitli döngü (DPLL) ve bir mikroişlemci kullanılır. Sistem giriş frekansına kilitlendikten sonra, belirli bir veri grubunu kullanarak mikroişlemci ve üzerindeki yazılımı yardımıyla sinyalin veri iletim hızını ölçer. Veri hızı algılama ve ölçme aralığı mevcut standardlara uygun olarak 45 Baud ve 52.000 Baud olarak belirlenmiştir. Deneysel sonuçlar geliştirilen sistemin, herhangi bir istasyona başarılı bir ilk bağlantı kurulabilmesi için gerekli olan veri hızına ihtiyaç duyulan haberleşme sistemlerinde güvenli bir şekilde kullanılabileceğini göstermiştir.


**ANAHTAR KELIMELER:** Kablosuz HF haberleşme, Kablosuz sayısal veri haberleşmesi, Baud hızı, Amatör radyo haberleşmesi, Veri hızı ölçümü.

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