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Physics of the fastest communication

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Abstract. A communication system involves the transmission of information from source to destination and after receiving all the information or a complete signal an acknowledgement is then sent to the source by the destination itself to let the source know that it (destination) has received the signal. In this paper we examine about how to reduce the time of acknowledgement to make the communication faster. In this paper we present a method of sending an acknowledgement signal, in which the last quantum (sample) of the signal is used to compute the time of acknowledgement. The formula for calculating the time of acknowledgement in the case of a continuous time signal and a discrete time signal is also derived in the paper. This technique is applicable for analog communication, digital communication and space communication.

Keywords. Time of acknowledgement; quantum of signal; minimum uncertainty in losing the information; quantum object.

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1. Introduction

1.1 *Motivation and background*

Communication is the process of establishing connection or link between two points for information exchange. It is a process of transferring information from one entity to another. Communication processes are sign-mediated interactions between at least two agents which share a repertoire of signs and semiotic rules. It is commonly defined as 'the imparting or interchange of thoughts, opinions, or information by speech, writing, or signs'. Although there is such a thing as one-way communication, communication can be perceived better as a two-way process in which there is an exchange and progression of thoughts, feelings or ideas (energy) towards a mutually accepted goal or direction (information). Communication is a process whereby information is enclosed in a package and is channelled and imparted by a sender to a receiver via some medium. All forms of

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communication require a sender, a message, and a receiver. Communication requires that all parties have an area of communicative commonality.

In the first information communication revolution, the first written communication began with pictographs. These writings were made on stone, which were too heavy to transfer. During this era, written communication was not mobile, but nonetheless existed. In the second information communication revolution, writing began to appear on paper, papyrus, clay, wax, etc. Common alphabets were introduced, allowing the uniformity of language across large distances. Much later, printing press was invented by Gutenberg. Gutenberg created the printing press in the 15th century. In the third information communication revolution, information can now be transferred via controlled waves and electronic signals. Acknowledgement is an integral part of a successful communication [1]. An acknowledgement is a signal passed between communication processes to signify acknowledgement, or receipt of response. In other words, an acknowledgement signal is a signal which informs the source that message has been received successfully by the receiver.

1.2 *Background and related work*

Transmitted signals may be either continuous or pulse signals. Acknowledgements may be continuous or pulse signals. If pulse signalling is used, the signal may be repeated until it is acknowledged. When continuous signalling is used, signal is sent until the acknowledgement is received and the acknowledgement signal persists until the original has been removed. The present communication engineering involves the release of acknowledgement signal only when all the information sent by the source is received successfully by the receiver. That means a receiver is committed to send an acknowledgement signal to the source if and only if all the information is received by the receiver [2]. In other words, we can say that receiver will not send the acknowledgement signal to the source if some part of the signal that is information is yet to be received. In this paper we aim at optimizing the mechanism of acknowledgement. In our modified technique of acknowledgement, we have reduced the time of acknowledgement by sending the acknowledgement signal when only one quantum of signal is left.

2. Preliminaries

In the most fundamental sense, communication involves the transmission of information from one point to another through the succession of process which is shown in figure 1 [3].

Any process that generates successive messages can be considered as a source of information. A transducer is a device that converts one type of energy to another. The conversion can be to/from electrical, electro-mechanical, electromagnetic, photonic, and photovoltaic or any other form of energy. A transmitter is a device that transmits the signal to the receiver via a specified channel. A receiver is used to receive the signal, and the signal is further sent to the destination. Noise is anything that interferes with a message being transmitted from a sender to a receiver. It results from both internal and external factors.

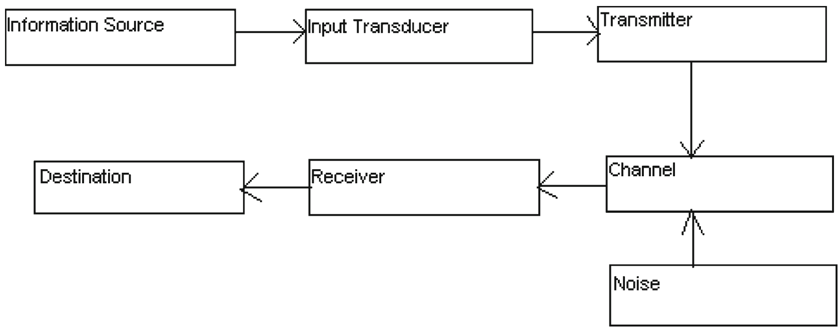

Figure 1. Basic communication system.

2.1 *Classification of signals*

2.1.1 *Analog signals.*

Analog signals are continuous electrical signals that vary in time as shown in figure 2. Most of the time, the variations follow that of the non-electric (original) signal. Therefore, the two are analogous hence the name analog.

Not all analog signals vary as smoothly as the waveform shown in figure 4a. Analog signals represent some physical quantity and they are a 'MODEL' of the real quantity.

Example. Telephone voice signal is analog. The intensity of the voice causes electric current variations. At the receiving end, the signal is reproduced in the same proportion. Hence the electric current is a 'MODEL' but not one's voice since it is an electrical representation or analog of one's voice.

2.1.2 *Digital signals.*

In computer architecture and other digital systems, a waveform that switches between two voltage levels representing the two states of a Boolean value (0 and 1) is referred to as a digital signal (figure 3), even though it is an analog voltage waveform, since it is interpreted in terms of only two levels. Digital signals are non-continuous, they change in individual steps. They consist of pulses or digits with discrete levels or values. The value of each pulse is constant, but there is an abrupt change from one digit to the next. Digital signals have two amplitude levels called the nodes, the values of which are specified as one of the two possibilities such as 1 or 0, HIGH or LOW, TRUE or FALSE and so on. In reality, the values are anywhere within specific ranges and we define values within a given range.

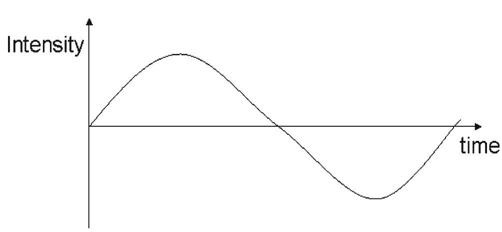

Figure 2. Analog signal.

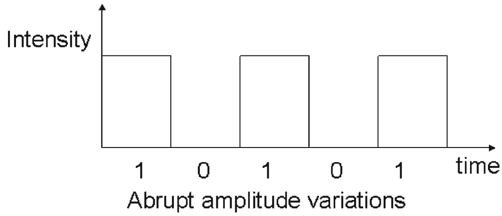

Figure 3. Digital signal.

3. Theory

3.1 *Reduction in the time of acknowledgement*

In the information theory the receiver is the receiving end of a communication channel. It receives decoded messages/information from the sender, who first encoded them. Sometimes the receiver is modelled so as to include the decoder. Any standard receiver has the capability of receiving a signal. Generally, a receiver takes time to receive the complete signal. Sometimes it happens that only some part of the signal is received while the remaining part is either not received or rejected by the receiver [4]. At the instant the receiver receives the signal completely, it sends an acknowledgement to the source to let it know that it (receiver) has received the complete signal and source can send the next signal now. But now the time of acknowledgement is reduced. In this technique the receiver or an external circuit sends the acknowledgement to the source when only one quantum of the signal is left. We have considered only one quantum of the information or signal because it gives the minimum uncertainty in losing the information.

Figure 4 describes best the analogy of reception of a signal by the receiver. On the left-hand side, a wave of length λ is shown and the middle axis represents the barrier of the receiver. Received signal is shown on the right-hand side of the barrier of the receiver in order to understand the quantum by quantum reception of a continuous time signal [5]. Here we have assumed that the acknowledgement is sent to the source when only one quantum of the signal (last sample) is left to be received. This means that when the last quantum of the signal or wave knocks the edge of the barrier of the receiver then at that point of time the acknowledgement is sent to the receiver. Now the source sends the next signal by receiving only one quantum (the first quantum) of the acknowledgement signal. Hence time of acknowledgement is reduced to a great extent.

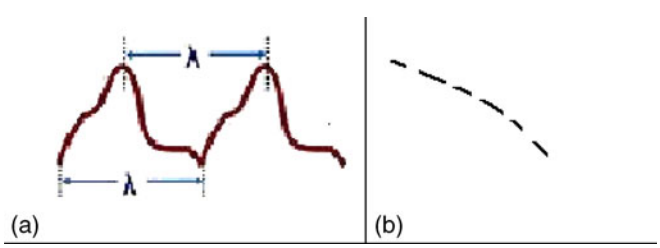

Figure 4. Wave as a signal.

Let the instant of time at which the acknowledgement is sent to the source be $T_{\mathrm{K^{th}}}$. Time of acknowledgement is given by the following relationship:

$$\int_0^k \mathrm{d}t_k = \int_0^n \mathrm{d}t_n - \int_0^{\lambda_s/N_s} \frac{\mathrm{d}\lambda}{C}. \quad (1)$$

On solving the integrals and by applying the limits, we get

$$T_{\mathrm{K^{th}}} = T_{\mathrm{N^{th}}} - \frac{\lambda_s}{N_s C}, \quad (2)$$

where $T_{\mathrm{K^{th}}}$ is the time of acknowledgement, $T_{\mathrm{N^{th}}}$ is the instant of time at which the signal is received completely, λ_s is the wavelength of the signal, N_s is the total number of quantums in the signal and C is the speed of light.

The wave (quantum object) and the classical electromagnetic wave analogy. The term 'quantum object', although regularly used in physics, is really an oxymoron. An 'object' is something that lives completely in the paradigm of classical physics: It has an independent reality in itself, it behaves deterministically, and it has definite physical properties, such as occupying a well-defined spot in time and space. For the 'quantum' all those seemingly self-evident truths become false: Its reality is one that is relative to the observer, the principle of causality is violated, and other features of materiality such as clear boundaries in space and time, objective locatedness or even identity, do not pertain. 'A quantum object can show either a wave-like behaviour or a particle-like behaviour, but not both at the same time'. Nevertheless, the quantum object is both wave and particle at the same time. The fact that we can see only one or the other is our limitation. According to the wave-particle duality, light behaves like a particle (as explained by Einstein) as well as a wave (quantum mechanics).

In this paper, stress is given on the very last quantized part (λ or τ) of a wave packet in order to formulate the time at which the acknowledgement could be sent. So we just need the very last quantum of the signal that could be a complete wave itself or a small part (quantum) of it, depending on the length of the signal [6]. So the last quantum of the signal itself could be called a quantum object of finite width. For example, electrons and neutrons serve as the quantum objects. 'So in a communication system in which electrons are used as the communication tools, an equivalent wavelength (λ) of an electron (quantum object) can serve as the quantum of the signal having wavelength (λ')'.

The idea of quanta, energy, had been thought to be a phenomenon of continuous flow – basically waves. Quantum theory describes energy as separate, discrete 'particles'. An analogy you could use to explain the wave/quantum idea might be that of analog versus digital. In the analog sense, energy flows in continuous streams or waves, having no specific inherent quantity – in other words, an energy wave could be of any size. The quantum idea says that energy is a 'digital' flow, that what appears to be a continuous wave is actually broken down into discrete, individual 'bits'. The name 'photon' is used for these individual energy particles. Photons contain a specific amount of energy. For example, if you have a pure red light (like a laser), it can be thought of as a stream of photons all having a specific energy (the units for measuring this energy are usually electron-volts). The more photons, the brighter the light – but all the photons individually have the same amount of energy. In fact, these individual particles of energy can be detected discretely, or counted. Now, at the same time, the light has the properties of a wave. The wave can be described by its wavelength and frequency. Experiments can be devised that show light (or other electromagnetic energy) to act as a wave or a particle. So the same mechanics can be applied in case of an optical communication channel where light quanta (photons) are used as the communication tools.

3.2 *Validity of the above technique in the digital communication engineering*

Data transmission, digital transmission or digital communications, is the physical transfer of data (a digital bit stream) over a point-to-point or point-to-multipoint transmission medium. Examples of such media are copper wires, optical fibres, wireless communication media and storage media. The data are often represented as an electromagnetic signal, such as an electrical voltage signal, a radio wave or microwave signal or an infrared signal [7]. Data transmitted may be digital messages originating from a data source, for example a computer or a keyboard. It may also be an analog signal such as a phone call or a video signal, digitized into a bit-stream, for example using pulse-code modulation (PCM) or more advanced source coding (analog-to-digital conversion and data compression) schemes [8]. This source coding and decoding is carried out by codec equipment.

For some applications we do need to convert an analog signal to a digital signal. With the help of sampling and quantization, an analog signal can be converted into a digital signal (figure 5). We know that after sampling we get the sampled signal. So the same technique can be applied to the digital communication as well.

Case 1: *When the digital pulse is sampled*

Let us consider that we have N number of samples of a digital pulse and each sample has a width equal to τ. We know that signal is defined at the specified time instants only [9]. So we can consider τ as the quantum of the sampled signal. In this case the acknowledgement is sent to the source when the time equal to τ/C is left for the signal to be received completely. So the formula for the time of acknowledgement can be given by the following relation:

$$T_{\mathrm{K^{th}}} = T_{N^{\mathrm{th}}} - \frac{\tau}{C}, \qquad (3)$$

where τ is the width of a quantum or sample of the signal.

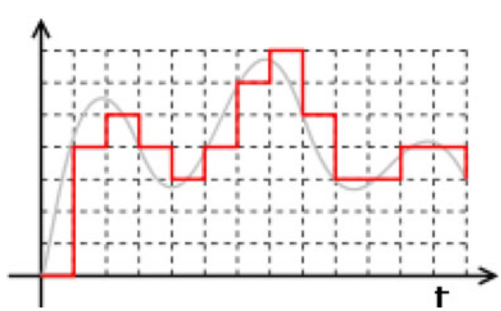

Figure 5. Digital signal (sampled, quantized): discrete time, discrete values.

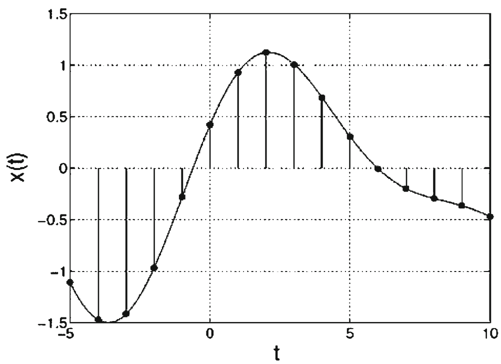

Figure 6. Quantization.

Case 2: *When the digital pulse is not sampled*

Let us consider a digital pulse which is not sampled. So we can say that a bit is transferred as pulse and this pulse is continuous over a specified interval of time (figure 6). If the width of a complete pulse is equal to τ then a set of $\mathrm{d}\tau$ completely represents the signal [10]. Then in this case the acknowledgement is sent to the source when the time equal to τ/C is left for the signal to be received completely. So the time of acknowledgement can be given by the following relationship:

$$\int_0^k \mathrm{d}t_k = \int_0^n \mathrm{d}t_n - \int_0^{\tau_s/N_s} \frac{\mathrm{d}\tau}{C}, \tag{4}$$

$$T_{\mathrm{K^{th}}} = T_{\mathrm{N^{th}}} - \frac{\tau_s}{C}, \tag{5}$$

where τ is the width of the pulse.

For an undisturbed digital pulse, eq. (5) can be represented as follows:

$$\int_0^k \mathrm{d}t_k = \int_0^n \mathrm{d}t_n - \frac{1}{C}\sum_{N=0}^{1}(\tau)\,. \tag{6}$$

3.3 *Consideration of single quantum and clarification on the signal loss*

The acknowledgement signal is sent when only one quantum ($\mathrm{d}\tau$) of the signal is left to be received. Now, sending the acknowledgement signal before the last quantum is received gives the lowest probability of losing the signal during the transmission process because it is quite obvious that the receiver has received all the parts except $\mathrm{d}\tau$ and the confirmation about the last quantum can be retrieved by setting the transmission at a constant frequency [11]. If we send the acknowledgement signal before two or more quantum parts are received, it will increase the probability of losing the signal because more parts of the signal are still left to be received and it makes the process quite uncertain. This is the reason behind considering only one single quantum of the signal.

However, signal loss may occur due to the following common factors for which the stated technique to send the acknowledgement signal cannot be held responsible at all.

(1) Multiphoton absorption occurs when two more photons simultaneously interact to produce electric dipole moments with which the incident radiation may couple. These dipoles can absorb energy from the incident radiation, reaching a maximum coupling with the radiation when the frequency is equal to the fundamental vibrational mode of the molecular dipole in the far infrared or one of its harmonics.
(2) The selective absorption of infrared light by a particular material occurs because the selected frequency of light waves matches the frequency at which the particles of the material vibrate. Since different atoms and molecules have different natural frequencies, they will selectively absorb different frequencies of infrared light.

4. Conclusion

It is hence concluded that by the application of the above-derived results, a significant reduction in the time of acknowledgement can be achieved. This method makes the communication faster. This technique is universal in nature because it can be applied to any kind of communication. In future, if any communication system would be designed for faster communication, then it will surely have to include the stated technique to make the process least uncertain.

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