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Molecular Communication

# Modulation and Transmission of Encoded Binary Data

Reception of data sent between devices is a widespread and important process used in a wide array of current technologies. This data is often encoded as a binary code, due to the fact that electrical circuits can easily process binary signals. Binary signals must be modulated prior to transmission, a process that changes the signal into a form capable of being transmitted through the desired channel (air, water, wire, etc.). One of the major challenges of detecting a signal is noise, which can be generated by the transmitter, in the channel, and by the receiver. The noise can distort the signal, resulting in the data being interpreted incorrectly. There are many techniques to modulate and demodulate a signal, some of which are more susceptible to noise than others. This paper will review current techniques for the detection and demodulation of binary signals sent over the air.

### **Methods of Modulation**

There are currently three basic types of binary encoding. These are amplitude-shift keying, phase-shift keying, and frequency-shift keying. In frequency-shift keying, the data is encoded by a single-frequency sinusoidal wave with changing amplitude. Usually, zero amplitude represents a "0", while a "1" is represented by an amplitude of several volts. In phase-shift keying, the signal is a sine wave with constant amplitude and frequency, but with changing phase. The phase can change by either 90° or 180°, with the 90° shift being more efficient since there are four intervals of 90° in 360°, so each phase can represent two bits. Some systems use more angles than this, and are even more efficient. Frequency-shift keying uses a signal of constant amplitude and phase, but with a changing frequency. In this format, one frequency represents a "0" and the other represents a "1". Phase-shift keying produces by far the fewest errors, with frequency-shift keying outperforming amplitude-shift keying [1].

# **Applications of Digital Signals**

#### **Benefits and Disadvantages**

There are several reasons why one would want to use a digital signal over, say, an analog signal. One major reason is easy integration with digital circuits. Digital circuits can process, manipulate, and store the received signal. This allows for error correction, which can offset the problems caused by noise. This also allows for encryption and secure communication. Another benefit is the simplicity of the signal itself. Since there are only two possible values ("0" and "1"), there is less of a chance that the data will be distorted. Major drawbacks are that the circuits needed to convert the signal into something a computer can use are often complex and the transmitter and receiver need to be synchronized [2].

#### **Current Applications of Digital Signals**

One application of digital signals is in audio systems. Traditionally, audio systems used analog systems, however, digital signals allow interfacing with digital devices such as phones and computers and allows for programming [3].

Another application is removing unwanted portions of the signal. This can be accomplished upon reception of the signal by processing it with a digital circuit [3].

### **Current Technologies**

One current technology is capable transmit 64 terabits per second over a range of 320 km with an efficiency of 8b/s/Hz. This was, however, a proof of concept and is not used commercially. The authors of the paper stated that the purpose of this experiment was to prove that faster signals could be transmitted on current infrastructure, stating that up to 400 Gb/s could be transmitted over current 50GHz lines[4].

Another group was able to transmit 45.2 Tb/s over 240km. They had an efficiency of 10b/s/Hz. The reason that this technology had a lower transmission rate than the previous one is that they were using a much smaller frequency band.

Currently, state-of-the-art commercial data transmission systems operate at around 100 Gb/s. However, standard commercial systems (in the U.K.) operate at around 24Mb/s, which is about a million times slower than the fastest transmitter and about 5,000 times slower than the fastest commercial systems [6]. This demonstrates that data transmission rates can become much faster in the future.

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