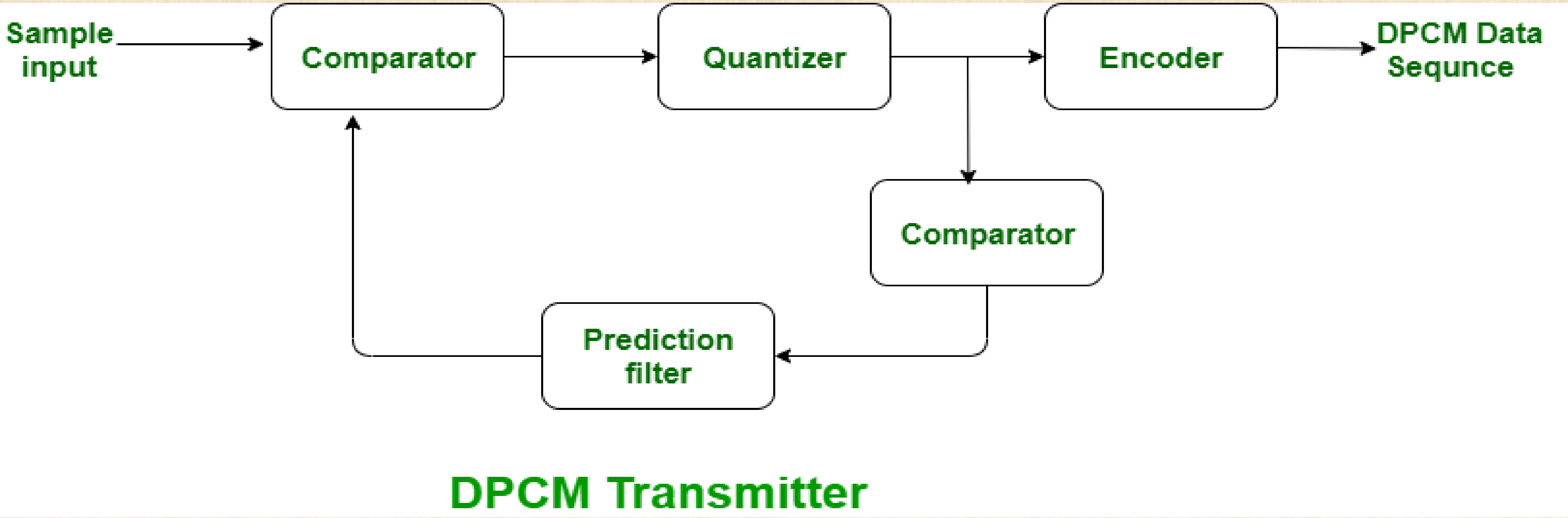
Differential Pulse Code Modulation

Differential Pulse Code Modulation (DPCM)

Differential Pulse Code Modulation (DPCM) is a digital signal processing technique used for encoding analog signals into a digital format. It is a variation of the more common Pulse Code Modulation (PCM) method, offering several advantages in certain applications. DPCM works by encoding the difference between the current signal sample and a prediction of that sample, based on previous samples, rather than encoding the absolute signal value as in PCM.

DPCM is particularly well-suited for encoding signals with high degrees of correlation between successive samples, such as speech, audio, and video signals



Principles of DPCM

Differential pulse code modulation (DPCM) is a variant of standard pulse code modulation (PCM) technology used in digital signal processing and data compression. The basic principle of DPCM is to encode the difference between the current model and the predicted model, rather than encoding the absolute value of the model itself as in PCM.

Predictions are often based on previous examples and can be used in both encoders and decoders. This predictive coding allows DPCM to achieve a higher contrast ratio compared to PCM because the difference between signals tends to have a lower variance and this difference can be achieved using fewer components. The prediction error is quantized and sent along with additional information to allow the decoder to reconstruct the original signal.

1. **Prediction:** DPCM uses a predictive model to estimate the current sample value based on previous samples. Common prediction techniques include linear, adaptive, and non-linear predictors.

2. **Quantization:** The difference between the actual sample and the predicted sample is quantized, reducing the number of bits required to represent the signal. Uniform, non-uniform, and adaptive quantization schemes can be used.

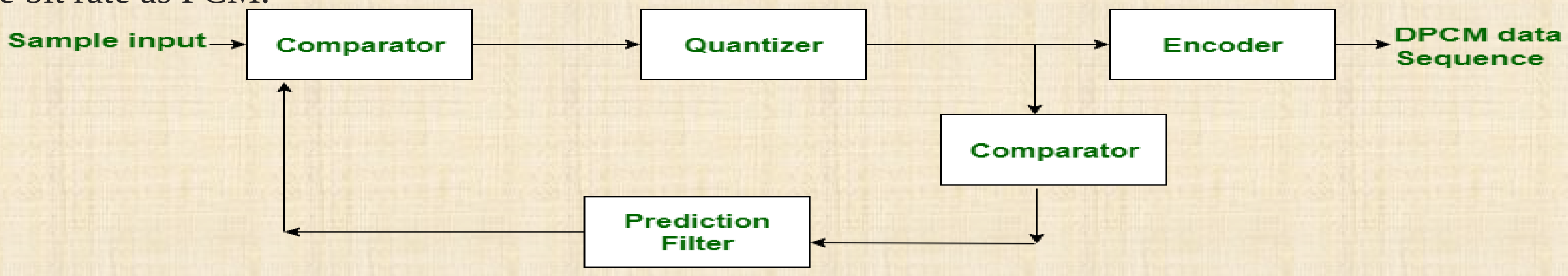
3. **Encoding and Decoding:** The quantized prediction error is encoded and transmitted. The decoder uses the same prediction model to estimate the current sample, then adds the received prediction error to reconstruct the original signal.

Advantages of DPCM over PCM

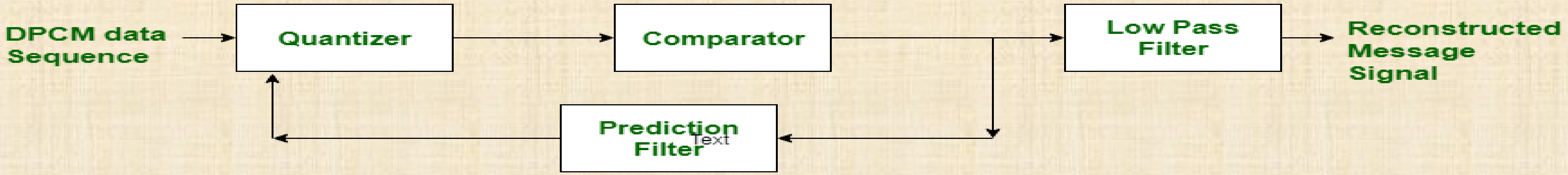
Differential Pulse Code Modulation (DPCM) offers several key advantages over the traditional Pulse Code Modulation (PCM) technique.

Firstly, DPCM is more efficient in its use of bandwidth by transmitting only the difference between the current sample and the predicted sample, rather than the full sample value as in PCM. This allows for a lower bit rate while maintaining similar quality, making DPCM particularly suitable for applications with limited bandwidth availability.

Another significant advantage of DPCM is its improved signal-to-noise ratio (SNR) compared to PCM, especially at lower bit rates. This is because DPCM focuses on encoding the differences between samples, which tend to have a smaller dynamic range than the original signal. This results in more efficient quantization and a better overall signal quality, even at the same bit rate as PCM.



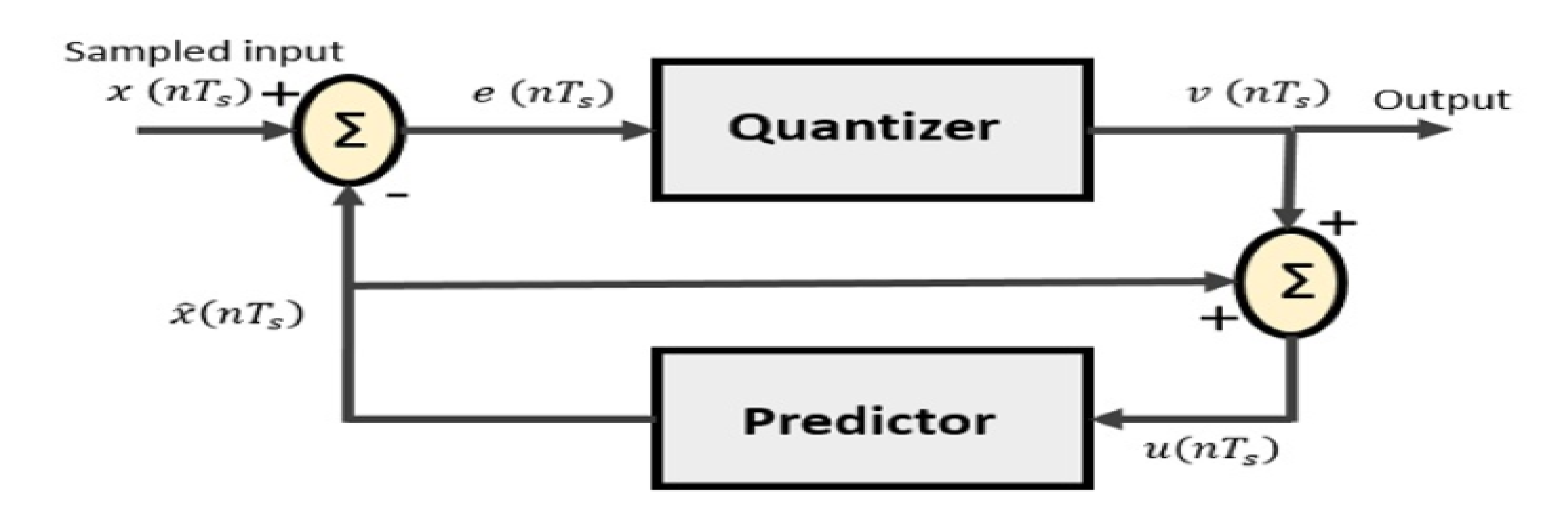
DPCM Transmitter



DPCM Receiver

DPCM Transmitter

The DPCM Transmitter consists of Quantizer and Predictor with two summer circuits. Following is the block diagram of DPCM transmitter.



The signals at each point are named as −

- $x(nT_s)$ is the sampled input
- $\widehat{x}(nT_s)$ is the predicted sample
- $e(nT_s)$ is the difference of sampled input and predicted output, often called as prediction error
- $v(nT_s)$ is the quantized output
- $u(nT_s)$ is the predictor input which is actually the summer output of the predictor output and the quantizer output

Predictor input is the sum of quantizer output and predictor output,

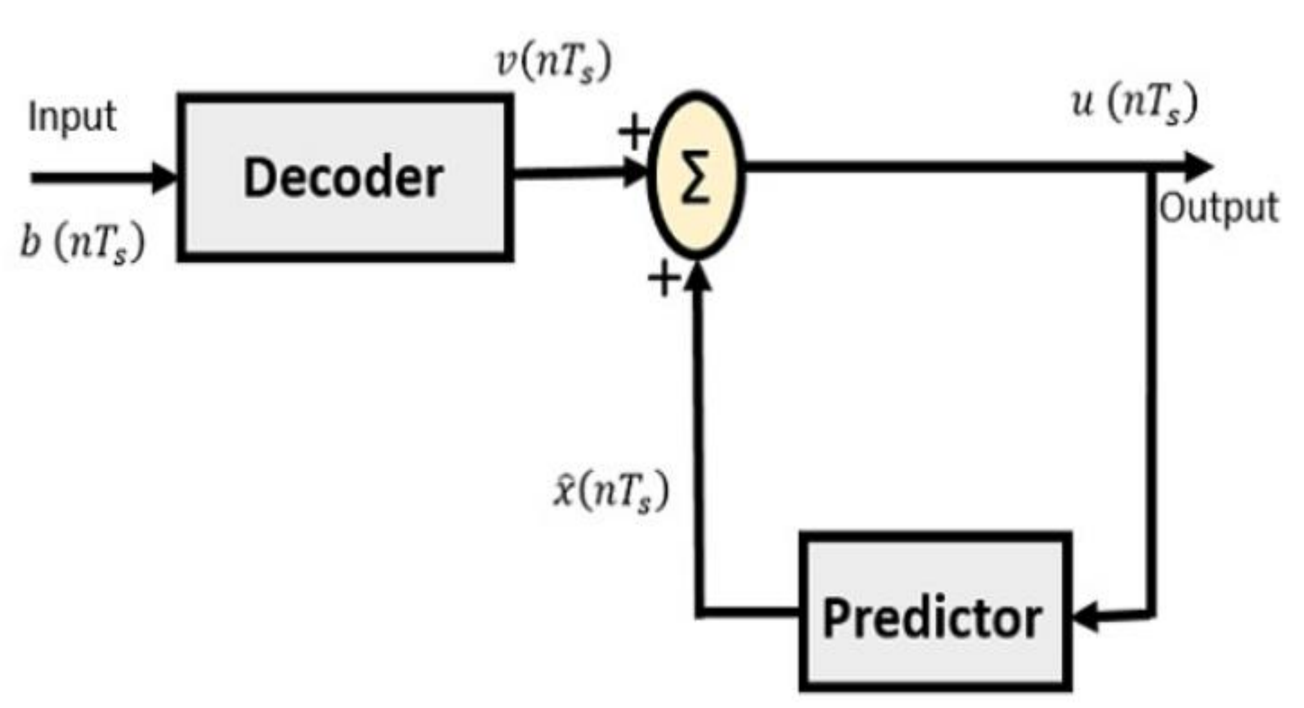
$$u(nT_s) = \widehat{x}(nT_s) + v(nT_s)$$
$$u(nT_s) = \widehat{x}(nT_s) + e(nT_s) + q(nT_s)$$
$$u(nT_s) = x(nT_s) + q(nT_s)$$

The same predictor circuit is used in the decoder to reconstruct the original input.

DPCM Receiver

The block diagram of DPCM Receiver consists of a decoder, a predictor, and a summer circuit. Following is the diagram of DPCM Receiver.

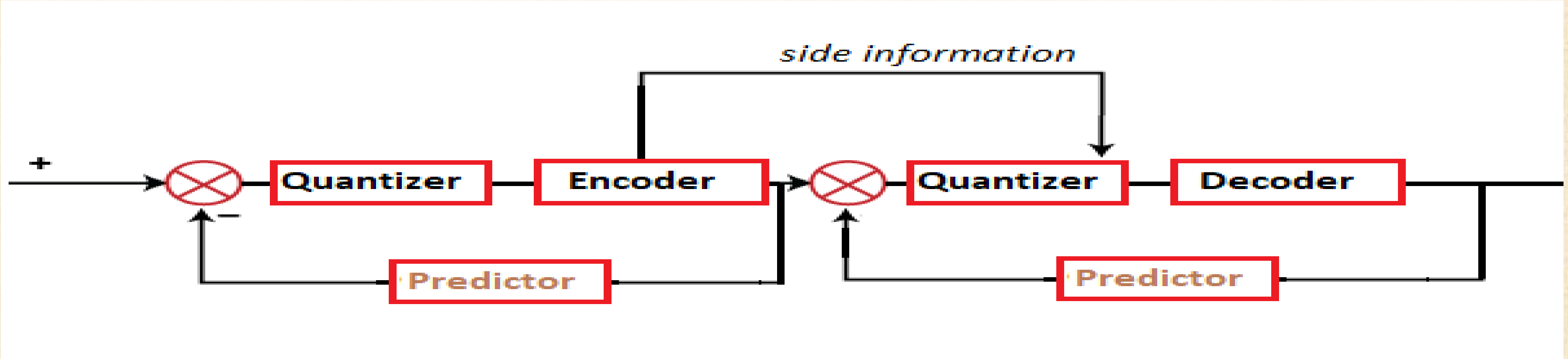
The notation of the signals is the same as the previous ones. In the absence of noise, the encoded receiver input will be the same as the encoded transmitter output.



Adaptive DPCM (ADPCM)

Adaptive Differential Pulse Code Modulation (ADPCM) is an enhanced version of the basic DPCM technique. In ADPCM, the quantization step size is adjusted dynamically based on the input signal characteristics, unlike the fixed step size in DPCM. This allows ADPCM to better adapt to the changing nature of the input signal, leading to improved performance in terms of coding efficiency and noise reduction.

The key idea behind ADPCM is to use a prediction filter with a variable step size quantizer. The step size is continuously updated based on the past samples, allowing the system to track changes in the signal amplitude and adjust the quantization accordingly. This adaptive quantization helps to reduce the quantization noise and improve the overall signal-to-noise ratio (SNR) compared to standard DPCM.



Applications of DPCM

Telecommunications

Differential Pulse Code Modulation (DPCM) has found widespread use in telecommunications applications, particularly in voice and audio transmission. DPCM's ability to effectively encode and transmit speech signals with reduced bandwidth requirements makes it a popular choice for telephone networks, mobile communication systems, and voice-over-IP (VoIP) technologies.

Digital Signal Processing

DPCM is extensively used in digital signal processing (DSP) applications, such as image and video compression. Its efficient encoding capabilities and the ability to capture the differences between consecutive samples make it a valuable tool for reducing the storage and transmission requirements of multimedia data, without significantly compromising quality.

Medical Imaging

DPCM finds applications in the field of medical imaging, where it is used for the compression and transmission of medical data, such as x-rays, CT scans, and MRI images. By leveraging the inherent similarities in adjacent pixels, DPCM can significantly reduce the file size of these images, enabling faster data transfer and more efficient storage in healthcare environments.

Data Storage

The efficient encoding capabilities of DPCM make it a useful technique for data storage applications, particularly in situations where storage space is limited. DPCM can be employed to compress various types of digital data, such as audio, video, and sensor measurements, without sacrificing the essential information, thereby optimizing the utilization of available storage resources.

Comparison of DPCM with other Modulation Techniques

DPCM vs. PCM

Differential Pulse Code Modulation (DPCM) offers several advantages over traditional Pulse Code Modulation (PCM). While both techniques digitize analog signals, DPCM encodes the difference between the current sample and a predicted sample based on previous samples. This results in a more efficient use of bandwidth, as DPCM can transmit the same information using fewer bits per sample. DPCM also exhibits better noise resilience, as the quantization noise is reduced due to the differential encoding.

DPCM vs. ADPCM

Adaptive DPCM (ADPCM) is an extension of DPCM that further improves efficiency by dynamically adjusting the quantization step size based on the signal characteristics. ADPCM can adapt to changes in the input signal, resulting in better overall performance and lower bit rates compared to standard DPCM. The adaptive nature of ADPCM allows it to handle a wider range of signal types and environments more effectively.

Thank You