Pulse Modulation

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Pulse Analog Modulation

1. **Pulse amplitude modulation (PAM):** The amplitude of pulse is varied in accordance with the height of the modulating signal keeping the width and the position of the pulse constant.
2. **Pulse width modulation (PWM):** The width of the pulses is varied in accordance with the height of modulating signal keeping amplitude and position of pulse constant.
3. **Pulse position modulation (PPM):** The position or the location of the pulses is varied in accordance with the height of the modulating signal keeping the amplitude and the width of the pulses constant.

Note:

- Speed control of DC motor is done using PL/m.
- PWM is generated using 555 timer in monostable multivibrator mode.
- PPM is generated using 555 timer by using PWM as a trigger signal in monostable multivibrator mode.

Comparison of various pulse modulation signals

	Circuit Complexity	BW	SNR
PAM	Minimum	$\sim 2\omega_m$	Minimum
PWM	↓	$\sim 10\omega_m$	↓
PPM	Maximum	$\sim 1/t_r$	Maximum

where, t_r = Rise time of each pulse

Note:

- PPM is most effective pulse analog modulator scheme in forms of SNR.
- SNR should high, it is an advantage.
- The aperture effect occurs only when flat topped sampling is used. This error voltage is acceptable since the generation of flat top sampling is least complex.

Time Division Multiplexing (TDM)

1. In TDM entire time interval into smaller time slots and corresponds to each time slot, the sample from a specified signal is transmitted over a common communication channel.
2. A common sampling frequency is use for transmission of various signal.
3. Simplex circuit and less costly.
4. Used for discrete signals such as pulse modulated signals or pulse code modulated signals (PCM).

Frequency Division Multiplexing (FDM)

1. In FDM entire frequency band available is divided into smaller frequency bands and corresponding to each frequency band the signals are transmitted with different carrier frequencies at all times.
2. A separate transmitter is require for the transmission of each signal.
3. Complex circuit and therefore more costly.
4. FDM system is used for continuous signals such as AM and FM signals.

Pulse Digital Modulation

Sampling Theorem

In order to recover the original modulating signal from its sampled version the signal must be having a sampling frequency of greater than or equal to twice of highest modulating frequency component contain in the given signal i.e.

$$\boxed{f_s \geq 2f_m} \quad ; \quad \boxed{\omega_s \geq 2\omega_m}$$

where, f_s = Sampling rate

The Nyquist rate of sampling represents the minimum rate sampling so that the original signal can be recovered from its sampled version.

$$\boxed{f_{s(min)} = f_{s(Nyquist)} = 2f_m} \text{ Samples/sec}$$

where, f_m = Maximum modulating frequency component

Pulse Code Modulation (PCM)

1. The signal to noise ratio of PCM signal is very high.
2. Only two level signal and therefore the noise can always be minimise by passing the PCM signal through a limiter circuit.
3. For detecting the PCM signal a threshold level is fixed and incoming voltage is detected on the basis of whether the incoming voltage is more than or less than this threshold level. The detection does not depend upon the absolute value of the voltage receive but depends only upon the relative voltage receive with reference to the threshold value.
4. Very low probability of error. Error in the detection takes place only when
   (a) The noise exceeds the threshold value.
   (b) The signal is detected at the time instant where the nose exceeds the threshold value.

Note:

The PCM signal cannot be transmitted through antenna since the sampling is done at a rate comparable to highest modulating frequency component. Therefore the PCM signal is transmitted through a transmission line or co-axial cable and therefore the range transmission is limited.

- Quantization levels

$$\boxed{L = 2^n}$$

where, n = Number of bits/sample
L = Number of quantization levels

- Step size

$$\boxed{\delta = \frac{2V_m}{L} = \frac{2V_m}{2^n}}$$

where, V_m = Maximum amplitude of sinusoidal signal

- Quantization Noise

$$\boxed{N_q = \frac{\delta^2}{12}}$$

- Signal to Noise Ratio (SNR)

$$\boxed{\frac{S_0}{N_q} = \frac{3}{2}L^2 = \frac{3}{2}2^{2n}} \quad ; \quad \boxed{\left(\frac{S_0}{N_q}\right)_{dB} = 1.76 + 6n}$$

- Bit rate

$$\boxed{R_b = nf_s}$$

where f_s = Number of samples per sec.

- Min-bandwidth

$$\boxed{BW_{min} = \frac{1}{2}R_{b(min)} = nf_m}$$

Note:

The bit coading parameter 'n' is adjusted depending upon.

- Availability of B.W. of transmission.
- Required value of the signal to noise ratio.
- The complexity of circuit which we can afford for the transmission of given signal.

Delta Modulation

As the bit coding parameter increases the number of quantization level of the quantizer will increase. Therefore design of the quantizer becomes more complex.

The use of quantizer is avoided in the delta modulation system. It has much simpler circuit and SNR of the delta modulation system is comparable to the PCM system since both are digital modulation system.

Error Signal

$$\boxed{\Delta(t) = f(t) = \tilde{f}(t)}$$

where, $f(t)$ = Present sample value of the input signal

$\tilde{f}(t)$ = Latest approximation to $f(t)$

Remember:

$$\boxed{f_s|_{DM\ system} > f_s|_{PCM\ system}}$$

f_s = Sampling Frequency

$$\boxed{BW|_{DM\ system} > BW|_{PCM\ system}}$$

Noise in DM system

1. Granular noise
2. Slope overload noise

(a) To minimize granular noise:

(i) Step size 'δ' should be decreased to limit the range of transmission.

(ii) Sampling frequency increased, $f_s \sim$ 3 to 4 times of f_s.

(b) To avoid slope overload noise

$$\boxed{\delta \cdot f_s \geq 2\pi f_m A} \;;\; \boxed{A_{max} = \frac{\delta f_s}{2\pi f_m}}$$

To avoid or minimize slope overload noise, the above mention condition must be satisfied and it is controlled by solving 4 parameters.

(i) Maximum amplituce of the modulating signal.

(ii) Frequency of the modulating signal.

(iii) Step size 'δ'.

(iv) The sampling frequency f_s.

Note:

If these conditions are specified, still the slope overload noise will always occur. To minimise the slope overload noise under this condition a delta modulator with variable step size is used. Such delta modulator is then called, adaptive delta modulator (ADM).

Adaptive Delta Modulation (ADM)

- In adaptive delta modulation, step size is chosen in accordance with message signal sampled value to overcome slope overload error and hunting.
- If message is varying at a high rate then step size is high and if message is varying slowly the step size is small.

Note:

- In case of ADM and DM bandwidth required is almost same.
- The PCM and DM signal cannot be transmitted through antenna, since the sampling is done at the rate f_s or Δf_s, therefore such signals are then transmitted through a transmission line so that the range of transmission is limited.
- To transmit such signals through antenna, a high frequency carrier is modulated using the PCM or DM signals as the modulating signals, therefore a low pass signal is converted to a band pass signal and is then transmitted through antenna for long distance communication.

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