FIBER OPTIC RECEIVER & MEASUREMENTS

This chapter covers:

- Fundamental & operation
- Pre-amplifier
- Emission features
- IR config
- Probability & Bias
- Quantum limit
Fundamental by operation

- The design of optical Rx is much more complicated than that of an optical Tx.

- Because the Rx must first detect weak signal, distorted signal, and then make decisions on what type of data was sent based on an amplified version of the distorted signal.

- When the optical data are incident on the APD, higher current pulses flow through the circuit.

- The photon current is amplified by the preamplifier:

  ↓

  It converts the current pulses to have adequate voltage levels.
The peak amplitude of the voltage pulse are maintained at constant by the AGC circuit.

The signal from the output of AGC amplifier is fed back to the AGC amplifier via a peak amplitude detector.
A compensation is made below the IP 4 reference rejection level.
A log amp 1dB is generated with red. The gain of the AFC amplifier.

Fig: Optical Rx

Fig: Optical Tx

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Threshold level:

- It compares the signal from each time slot with a certain reference voltage known as the threshold level.

  - If the signal is greater than the threshold (\( \text{signal} > \text{threshold} \))
  - If the signal is less than the threshold (\( \text{signal} < \text{threshold} \))

If the received signal is greater than the threshold, in some cases, an optical amplifier is placed ahead of the photodiode to boost the optical signal level before photo detection.

An optical preamplifier provides a larger gain factor by broadening the frequency bandwidth. However, this process also introduces additional noise to the optical signal.
but now:

3) The transmission of a 1 or 0 binary data stream consisting of either 0 or 1 in a time slot of duration T is referred to as bit period.

4) One of the simplest techniques for sending binary data is amplitude shift keying, wherein a voltage level is switched between two values, which are usually on or off.

5) The optical is converted to electrical via an optical to electrical converter. An electrical current (if) can be used to modulate an optical source to produce an optical pulses (if).

6) An optical pulse "p" is equivalent to 1 is pulse of optical power "p" dur ing to "p". It's direction. The optical pulse will attenuate as it propagates in the fiber.
A p-n or avalanche photodiode at the anode converts the optical signal into an electrical signal. Amplified, this signal is compared with a decision criterion to determine whether it has crossed the threshold value.

Error Sources

It can arise from various causes, such as noise and disturbances associated with the detection system.

- Photon detection
  - Quantum noise
  - Thermal noise
  - Dark current
  - Surface leakage current
  - Gain
Noise:

- Noise sources can be either external or internal to the system.

\[ \text{Noise} \]
\[ \text{\hspace{1cm} Internal} \]
\[ \text{\hspace{1cm} External} \]
\[ \text{\hspace{1cm} \text{\hspace{1cm} Internal}} \]
\[ \text{\hspace{1cm} \text{\hspace{1cm} External}} \]
\[ \text{\hspace{1cm} \text{\hspace{1cm} \text{\hspace{1cm} Shot}} \}
\[ \text{\hspace{1cm} \text{\hspace{1cm} \text{\hspace{1cm} Thermal}}} \]

Internal noise:

1. It is caused by the spontaneous fluctuation of current or voltage in electric circuits.

2. Two types

   a) Shot noise
   b) Thermal noise
shot noise arises in electronic devices because of the

discrete nature of current flow in the device.

Thermal noise arises from the random motion of

particles in a conductor.

1. Random arrival rate of all photons produces a quantum

noise at the photodetector.

2. For APD, photodetectors additional shot noise

arises from the statistical nature of the multiplication

process.

Increasing avalanche gain $G$,$\uparrow$

the noise level also $\uparrow$

3. Dark current and surface leakage current now also

induced by the electrons. Thermal noise also

arises from the detector load resistance $R$.

Increasing the resistance $R$,\,$\uparrow$
The primary photocurrent generated by the photocathode is a time-varying current produced when the incident light strikes the surface of the photocathode.

If the photocathode is illuminated by optical power $P$, then the area $A$ of the (e-h) pairs is generated in a time $\tau$.

$$\tilde{N} = \frac{A}{hv} \int_0^\tau P(t) \, dt$$

$$\tilde{N} \frac{hv}{E}$$

$\frac{E}{hv}$ selects quantum $\tilde{N}$.

$E = \phi$ is the photoelectron energy.

$E = \phi_0 + \frac{hv}{e}$ is the energy loss and in a time interval $\tilde{N}$. 
The actual rate of carrier recombination in that are generated is fluctuated from the average according to the Poisson distribution:

\[ P(n) = \frac{N_0 e^{-z}}{n!} \]

The fraction of \( n \) carriers are emitted in an interval of

The random nature of the annihilation and the recombination process, similar to a type of shot noise.

A detector with mean vulnerability \( S_0 \) in the absence \( \alpha \) and with a detection rate \( \beta \), the excess noise factor \( F \) is given by

For \( \alpha \) injection it is

\[ F(\alpha) = \frac{kM - (2 + \frac{1}{\alpha})}{(1-\alpha)} \]
Ix.

Indicator of Intelligence

1. When the pulses appearing in the output
   channel will be occur.

2. When a pulse is fed in a certain time slot, most of the pulses will
   occur in the corresponding time slot at the receiver.

   However, because of pulse overlapping induced by the
   receiver, some of the test energy will necessarily
   appear in the next channel time slot on the
   pulse backscatter channel. With the above
   the presence of the excess in an
   adjacent time slot will indicate an
   interference signal.

   This called an "Interference Interference"
An: Pulse width of the optical signal that leads to T12.

Receiver configuration:

The three basic stages are:

1. Photo detector
2. An amplifier
3. An equalizer

The PD can be either an avalanche photodiode or a PIN PD with an amplifier.
The noise function is represented by the voltage
load current source which is characterized by a
bias conductance \( g_m \).

Two additional noise sources are here:

1. Thermal noise due to resistor \( R_2 \).
2. Noise voltage source \( E_{n(0)} \).

These noise sources are assumed to be white in
the frequency range of interest, hence known as
white noise.
Expression for mean MP from PD

Binary pulse train incident on the photodiode

is given by

\[ P(E_t) = \sum_{n=-\infty}^{\infty} b_n h_p(t-nT_b) \]  \hspace{1cm} (1)

- \( P(E_t) \): Net optical power
- \( b_n \): Amplitude of \( n \)th message digit
- \( T_b \): bit Period
- \( h_p(t) \): Real pulse shape

\[ \int_{-\infty}^{\infty} h_p(t) dt = 1 \]  \hspace{1cm} (2)

- Non-negative, \( PD \) input pulse normalized to have unit area

The mean MP current drawn by the PD at time \( t \) due to pulse train \( \{ b_n \} \) is given by

\[ \langle I(t) \rangle = \frac{\eta_0 M_0 e}{h} \]  \hspace{1cm} (3)
\[ r(t) = \sum_{n=0}^{\infty} b(n) \delta \left( t - nT_{0} \right) \]

\[ \therefore r(t) \sim \frac{nq}{h} \]

where \( \eta \) = quantum \#.

\( r_{0} \) = responsivity of the detector.

\text{quantum limit}

For an idee site, which has unique quantum \( \eta \)

\( r_{0} \) which produce no dark current \( 1 \) no electron hole generated.

So, in this condition, it is possible to find the minimum

\text{and spectral power required in a specific bit error rate}

\text{reconstruction in a digital sense}

\[ P_{0}(0) = \frac{N}{N} \]

\( \downarrow \)

There which we can find quantum limit