# ONS Problem Set 8

Wednesday, January 30, 2018

**Problem 1: Self-Homodyne Detection**

Self-homodyne detection refers to the reception of a coherently modulated carrier on a single-ended photodiode. Therefore, the modulated signal is transmitted along with its carrier on the same fiber

a) Describe how to practically transmit the carrier itself along with the data signal. Determine if the phase information of the optical signal can be extracted for self-homodyne detection.

b) Self-homodyne detection, besides being impeded by thermal noise is inherently affected by the signal-to-signal-interference. Derive the signal-to-interference-and-noise power ratio (SINR) for homodyne detection in dependence of the carrier-to- signal power ratio (CSPR).


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How to transmit carrier with Data signal?

⇒ Slighty de-tune the modulator's operating point from the Null-point. Thereby, there is a constant signal component ⇒ DC carrier.

$$\cancel{E_{DC} = 2|E_{DC}| e^{j\omega t}}$$

$$\underline{E}_{DC} = E_{DC}\, e^{j\omega t}$$

$$\underline{E}_{sig} = E_{sig}\, e^{j[\omega t + \phi_{sig}]}$$

In - Self - Homodyne detection, the signal is received by direct detection.

$$|E_{Rx}|^2 = |\underline{E}_{DC} + \underline{E}_{sig}|^2$$

$$= |E_{DC}|^2 + |\underline{E}_{sig}|^2 + 2\,\mathrm{Re}\{E_{DC} E_{sig}^*\}$$

$$= |E_{DC}|^2 + |E_{sig}|^2 + 2\, E_{DC} E_{sig} \exp[-j\phi_{sig}]$$

$$= |E_{DC}|^2 + |E_{sig}|^2 + 2\, E_{DC} E_{sig} \cos(\phi_{sig})$$



**For questions and suggestions on the ONS tutorial, please contact:**
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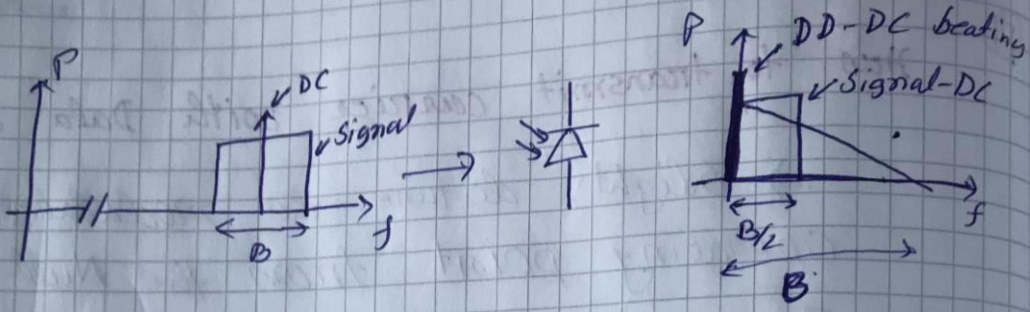
b)




↳ Here, Signal-Signal Beating overlaps with DC-signal Beating

↳ We can consider it as Signal Distortion

Here, consider only the Real signal

$$E_{DC} = b$$

$$E_{sig} = a \cdot \underbrace{P(t)}_{\text{signal. Actual.}}$$

Sending Signal.

$$x(t) = a\,p(t) + b$$

In Rx

$$r(t) = |x(t)|^2 + \underbrace{n(t)}_{\text{thermal noise in electrical Rx Signal.}}$$

$$= |a|^2 |P(t)|^2 + |b|^2 + 2ab\,P(t) + n(t)$$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We use a DC block @Rx

$$r(t) = a^2 p^2(t) + 2ab\,p(t) + n(t)$$

$$= 2ab\left[p(t) + \frac{a^2 p^2(t)}{2ab} + \frac{1}{2}\frac{1}{ab}\,n(t)\right]$$

$$= 2ab\left[p(t) + \tfrac{1}{2}\,\tfrac{a}{b}\,p^2(t) + \tfrac{1}{2}\,\tfrac{1}{ab}\,n(t)\right]$$

$$\approx p(t) + \tfrac{1}{2}\left[\tfrac{a}{b}\,p^2(t) + \tfrac{1}{ab}\,n(t)\right]$$

$$\text{CSPR} \rightarrow c^2 = b^2/a^2 \qquad \frac{c^2+1}{c} = \frac{b^2/a^2+1}{b/a} = \frac{b^2+a^2}{a^2}\,\frac{a}{b}$$

$$\Rightarrow a/b = c \qquad \cancel{1/ab =} \qquad = 1/ab$$

$$1/ab = \frac{c^2+1}{c}$$

$$r(t) \approx p(t) + \tfrac{1}{2}\left[\frac{p^2(t)}{c} + \frac{c^2+1}{c}\,n(t)\right]$$

$$P_{sig} \approx \sigma_p^2 \sim p^2(t)$$

$$P_n \sim \sigma_n^2 \sim n^2(t)$$

$$SINR = \frac{P_{sig}}{P_{in} + P_n} = \frac{\sigma_p^2}{\frac{\sigma_p^4}{4c^2} + \frac{c^2+1}{4c^2}\,\sigma_n^2}$$


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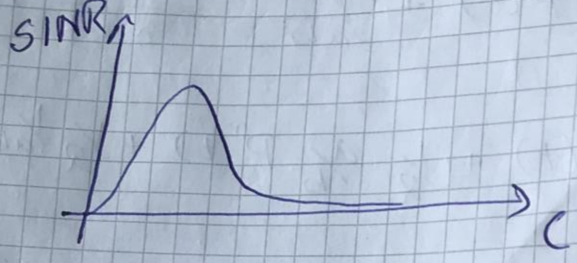
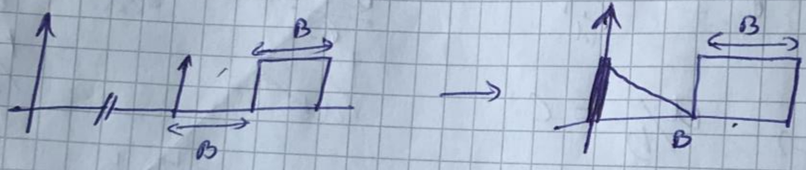
$$= 4 \frac{c^2}{\sigma_p^2 + (c^2+1)\frac{\sigma_n^2}{\sigma_p^2}}$$




iii) self hetrodyne.




iv) ~~Sign~~ Single Sideband (SSB) modulation can be achieved by driving a IQ modulator with the signal and its Helbert tranform

$$u_1(t) = \cos(\Omega t)$$

$$u_2(t) = \mathcal{H}\{\cos(\Omega t)\} = \sin(\Omega t)$$

$$E_{out} = e^{j\omega t}\left[\cos(\Omega t) + j\sin(\Omega t)\right]$$

$$= e^{j\omega t} e^{j\Omega t}$$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