Rajasthan Technical University, Kota
B.Tech. VI Semester ECE
Fiber Optics Communication

Unit 5: Lecture 04
Self Phase Modulation (SPM)
Cross Phase Modulation (XPM)

Chetan Selwal
Assistant Professor
Department of ECE
Mahila Engineering College Ajmer

Contents

Introduction

The origin of SPM and XPM lies in Ultrafast third-order susceptibility $\chi^{(3)}$

- The real part leads to
  - Self Phase Modulation (SPM)
  - Cross Phase Modulation (XPM)
  - Four Wave Mixing (FWM)
- Non-linearities due to Intensity dependent variations in refractive index (Kerr Effect)

Kerr Effect

- The Kerr effect is a phenomenon observed in non-linear optic materials where the refractive index of the material changes in response to an electric field.
- The refractive index n of many optical materials has a weak dependence on optical intensity I (power/A_{eff}) given by

$$n = n_0 + n_2 I = n_0 + n_2 \frac{P}{A_{\text{eff}}}$$

- Here n_0 is the ordinary refractive index of the material and n_2 is the nonlinear index coefficient.
- The value of n_2 is about
  - 2.6 × 10-8 μm^2/W in silica,
  - between 1.2 - 5.1 × 10-6 μm^2/W in tellurite glasses,
- The nonlinearity in refractive index is known as Kerr nonlinearity.
- The Kerr nonlinearity produces a carrier-induced phase modulation of the propagating signals which is called the Kerr Effect.

Self-Phase Modulation (SPM)

- In single-wavelength links, the Kerr effect gives rise to self-phase modulation (SPM).
- This converts light power fluctuations in a wave to spurious phase fluctuations in the same wave.
- The magnitude of non linear effect for SPM is given by

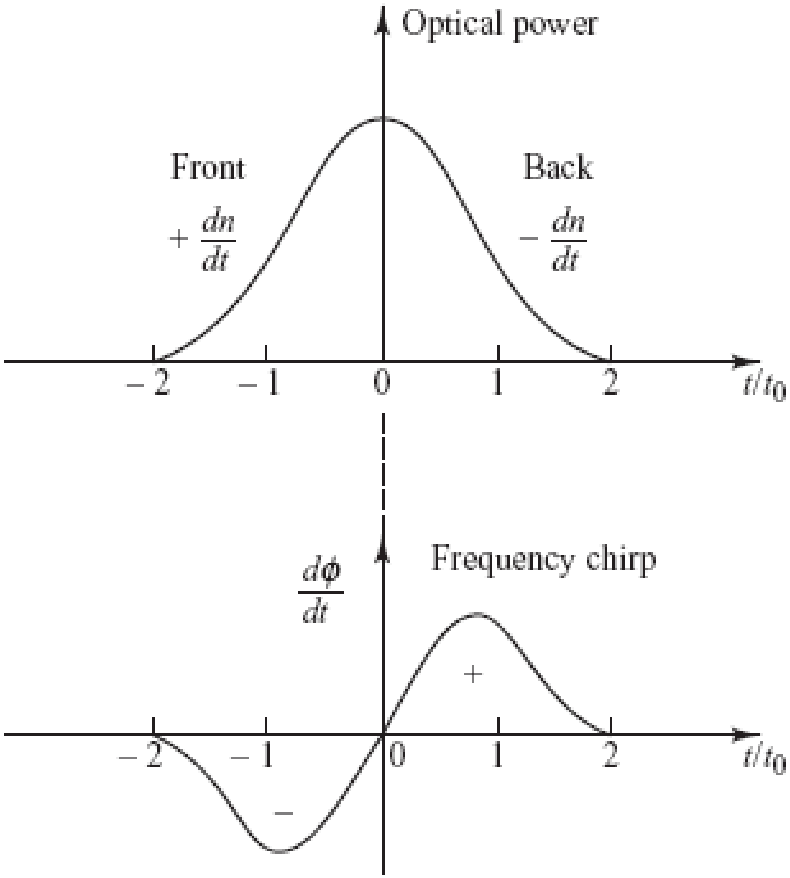
$$\Upsilon = \frac{2\pi}{\lambda}\frac{n_2}{A_{eff}}$$

- The frequency shift arising due to SPM is given by

$$\Delta\varphi = \frac{d\varphi}{dt} = \gamma L_{\text{eff}} \frac{dP}{dt}$$

Self-Phase Modulation (SPM)

- In a medium having an intensity-dependent refractive index, a time-varying signal intensity will produce a time-varying refractive index.
- The leading edge of a pulse will see a positive dn/dt, whereas the trailing edge will see a negative dn/dt.
- This leads to frequency chirping, in that the rising edge of the pulse shifts toward lower frequencies, and the trailing edge toward higher frequencies.



Cross-Phase Modulation (XPM)

- Cross-phase modulation (XPM) appears in WDM systems and has a similar origin as SPM.
- The refractive index nonlinearity converts optical intensity fluctuations in a particular wavelength channel to phase fluctuations in another copropagating channel.
- XPM only appears when the two interacting light beams or pulses overlap in space and time.
- For two copropogating wavelengths the XPM induced phase shift is given by

$$\Delta\varphi = \frac{d\varphi}{dt} = 2\gamma L_{\text{eff}} \frac{dP}{dt}$$

Cross-Phase Modulation (XPM)

- When multiple wavelengths propagate in a fiber, the total phase shift for an optical signal with frequency ω_i is

$$\Delta\varphi_i = \gamma L_{\text{eff}} \left[\frac{dP_i}{dt} + 2\sum_{j \neq i} \frac{dP_j}{dt} \right]$$

First term represents SPM and second term XPM

References

- Optical Fiber Communication, 5 e TMH by Gerd Keiser
- Optical Fiber Communications, 2 e Pearson Education by John M. Senior
- www.google.com

- Note: Author do not claim the originality of contents. The texts referred above have been used for preparation of this lecture for instructional purpose only.

Thank You

For more details please visit

www.chetanselwal.com/learning-resources

Queries may be posted at

www.chetanselwal.com/forum/fiber-optics-comm-forum