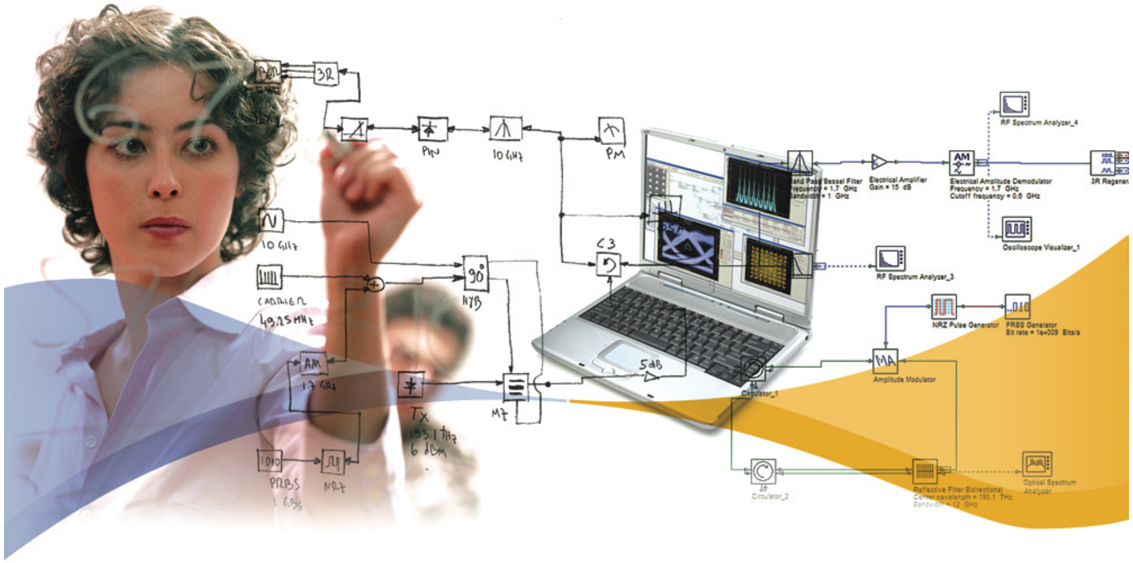

OptiSystem applications:
LIDAR systems design

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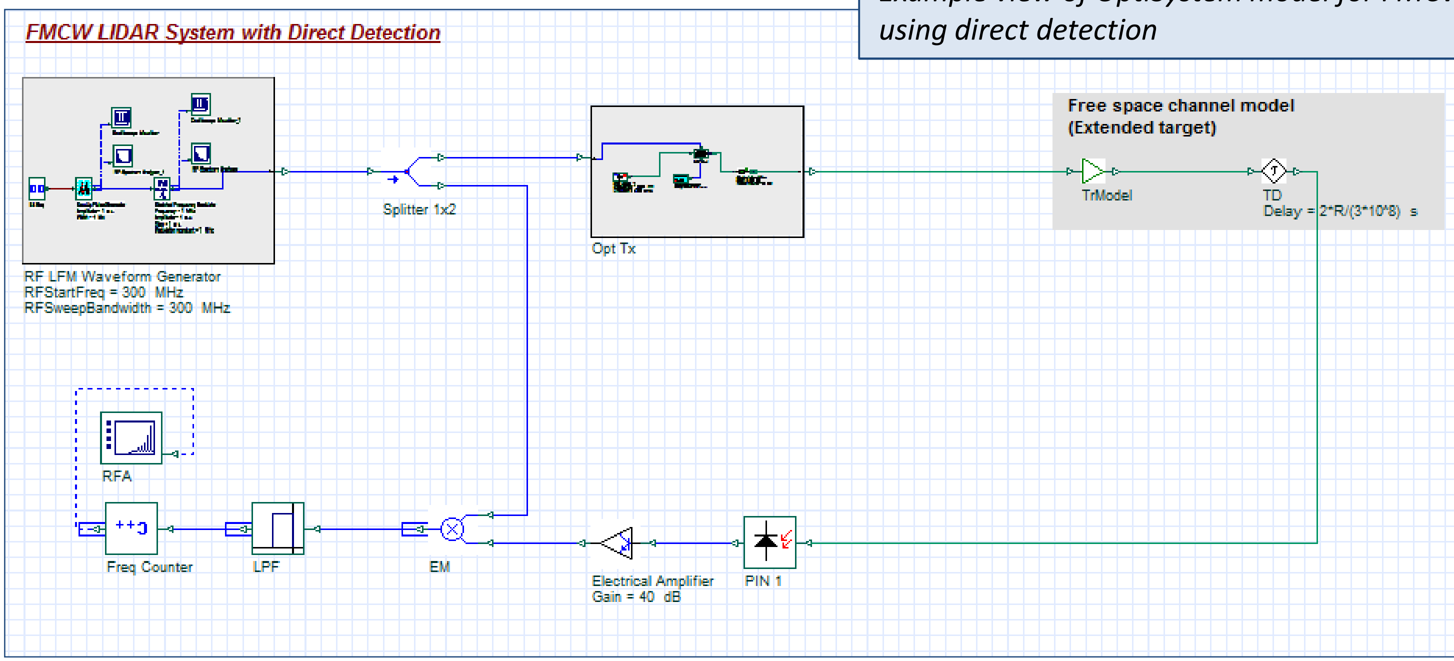
Introduction

Light detection and ranging (LIDAR)

OptiSystem
Optical Communication System and Amplifier Design Suite

- The following four example designs demonstrate how to simulate light detection and ranging systems (LIDAR) using OptiSystem, specifically:
  - Laser pulse time of flight range measurement
  - Phase-shift range measurement
  - Frequency Modulation Continuous Wave (FMCW) range measurement with direct detection
  - FMCW range measurement with coherent detection
- The reference project for this application note is: *LIDAR system designs Version 1_0.osd*.

Example view of OptiSystem model for FMCW LIDAR using direct detection



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Range measurement (Time of flight) (1)

- Using laser pulses, the time of flight range measurement method measures the time it takes for a transmitted pulse to travel from the transmit device to the target and back to the receiver. The range is then calculated from [1]

$$R = \frac{TimeofFlight \cdot c}{2}$$

where c is the speed of light.

- The received signal power is determined based on an extended target model and is calculated as follows [2]

$$P_r = P_t \frac{\rho D^2 (\tau_{opt})(\tau_{atm})^2}{4R^2}$$

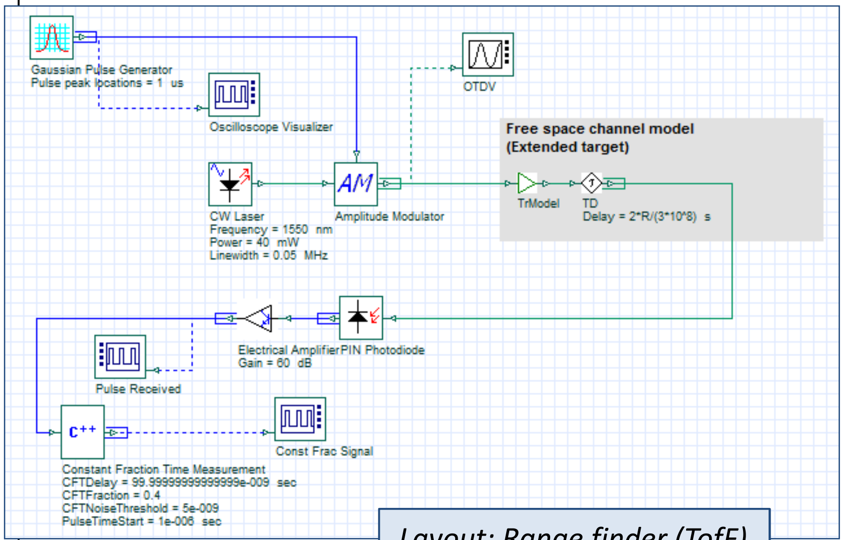
where P_t is transmitted optical power, D is the receiver aperture diameter, ρ is the reflectivity of the target, τ_{atm} is the atmospheric loss factor, τ_{opt} is the optical transmission system loss factor and R is the target range

- To reliably determine the time trigger for the arriving pulse, the Constant Fraction Time Measurement [3] method is used (implemented with our **Cpp Component**).

REF 1: Laser ranging: a critical review of usual techniques for distance measurement, Optical Engineering, Vol. 40, No. 1. (2001), pp. 10-19 by Markus C. Amann, Thierry Bosch, Marc Lescure, Risto Myllylä, Marc Rioux

REF 2: Ahmed H. Elghandour; Chen D. Ren; Modeling and comparative study of various detection techniques for FMCW LIDAR using OptiSystem, Proc. SPIE 8905, International Symposium on Photoelectronic Detection and Imaging 2013: Laser Sensing and Imaging and Applications, 890529 (September 19, 2013)

REF 3: Fast-Timing Discriminator Introduction, Ortec Inc., http://www.ortec-online.com/-/media/ametekortec/other/fast-timing-discriminator-introduction.pdf?la=en (accessed 10 Feb 2017)



Layout: Range finder (TofF)

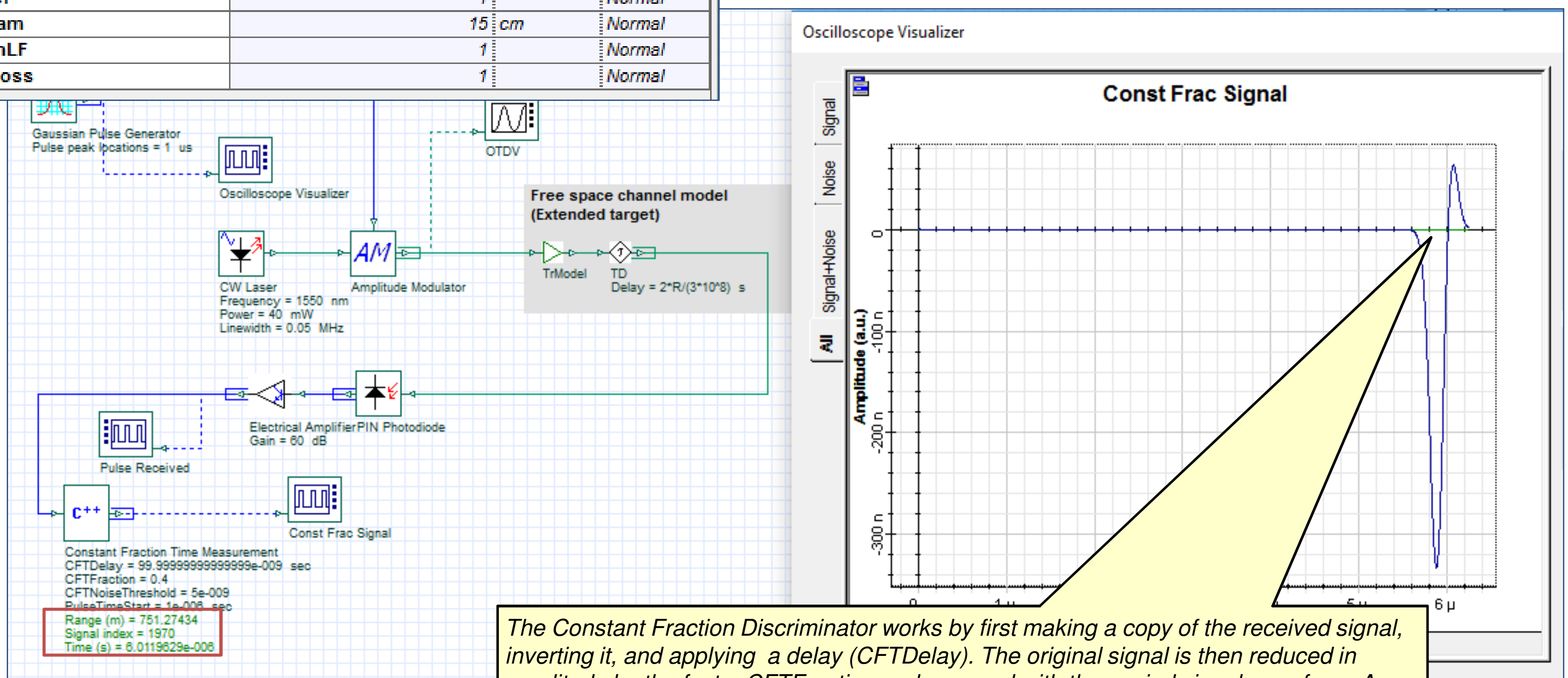
Range measurement (Time of flight) (2)

LIDAR design

- In the example below, a Gaussian pulse (Peak pulse time = 1 us) is transmitted optically and reflected from a virtual target (defined by the Free space channel model (Extended target)). After being subjected to attenuation and delay, the received signal is detected and post-processed by the Cpp Component ***Constant Fraction Time Measurement***.
- The received pulse is time triggered at the time sample 6.02e-06 sec and in turn the range is found to be 751.27 m (compared to the global parameter range setting of 750 m). The sensitivity of the Constant Fraction Discriminator can be modified by changing the input parameters *CFTDelay*, *CFTFraction*, *CFTNoiseThreshold*.

R	750	m	Normal
TRef	1		Normal
RDiam	15	cm	Normal
AtmLF	1		Normal
TrLoss	1		Normal

Global parameter settings for LIDAR system.



The Constant Fraction Discriminator works by first making a copy of the received signal, inverting it, and applying a delay (CFTDelay). The original signal is then reduced in amplitude by the factor CFTFraction and summed with the copied signal waveform. An example of the output waveform is shown here. The zero-crossing point (from negative to positive) is then found and acts as the time trigger to determine the received pulse time.

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Range measurement (Phase shift)

LIDAR design

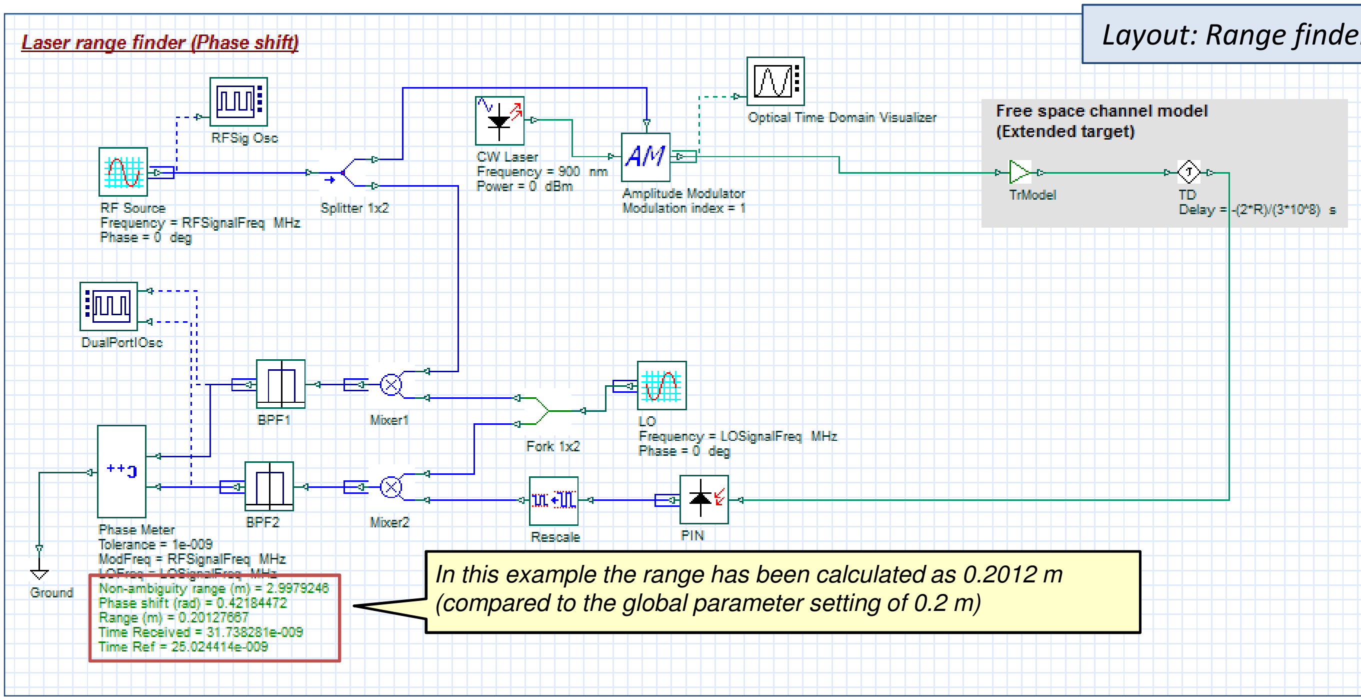
- Another way to measure the range of an object/target is with a phase-shift range finder. With this method, the optical source is modulated at specific frequency R_f and transmitted towards the target. The reflected signal is then detected with a PIN photodiode followed by a heterodyne receiver. The phase shift resulting from the transmission of the optical signal ($\Delta\phi$), relative to the original reference signal, is then measured and used to calculate the range as follows [1]:

$$R = \frac{c\Delta\varphi R_f}{4\pi}$$

- To improve the accuracy of this system, the reference and received modulated signals can be mixed with a local oscillator R_{LO} to down-convert the received waveform to a lower frequency ($R_{LO} - R_f$). These signals are then band-pass filtered (to reduce noise) and processed by a Phase Meter (using our programmable **Cpp Component**)

REF 1: Laser ranging: a critical review of usual techniques for distance measurement, Optical Engineering, Vol. 40, No. 1. (2001), pp. 10-19 by Markus C. Amann, Thierry Bosch, Marc Lescure, Risto Myllylä, Marc Rioux

Layout: Range finder (Phase Shift)



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Range measurement (FMCW)

LIDAR design

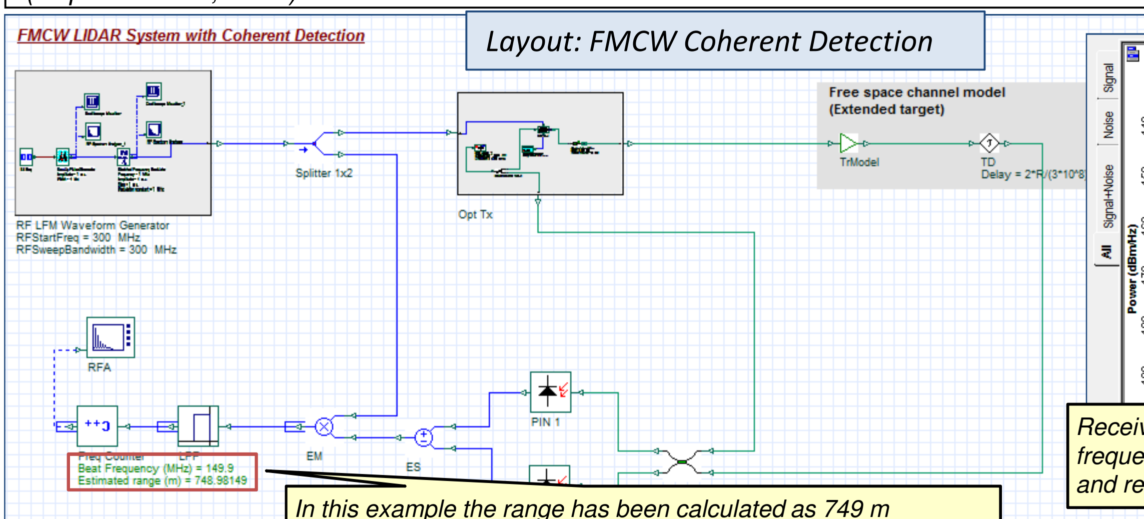
- The last method to be presented is the frequency modulated continuous wave (FMCW) LIDAR. Two models have been developed: *FMCW LIDAR with Direct Detection* and *FMCW LIDAR with Coherent Detection*. Both models work on the same principle. A frequency modulated optical transmitter is sent out towards the target and the reflected signal is detected (by a photodetector) and mixed with the original linear frequency modulated (LFM) signal. As the received signal is time-delayed, an intermediate frequency signal is produced. Using a frequency counter (implemented with our **Cpp Component**) the detected R_f signal is measured and then used to calculate the range as follows [1]:

$$R = \frac{R_f \cdot c \cdot RampPeriod}{2 \cdot DeltaFreq}$$

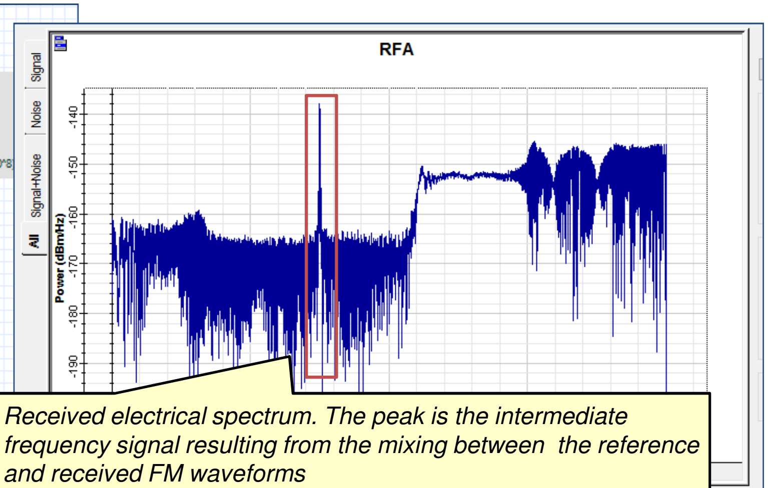
  where the *RampPeriod* is equal to the global parameter ***Time window*** and the *DeltaFreq* is equal to the parameter ***RFSweepBandwidth*** (set within the component parameters of the Subsystem **RF LFM Waveform Generator**)

- The only difference between both detection systems is that one uses square law detection whereas the other uses a coherent homodyne detector to recover the incoming optical signal before mixing (the latter thus provides a higher sensitivity as the detection process is shot-noise limited)

REF: Ahmed H. Elghandour; Chen D. Ren; Modeling and comparative study of various detection techniques for FMCW LIDAR using OptiSystem, Proc. SPIE 8905, International Symposium on Photoelectronic Detection and Imaging 2013: Laser Sensing and Imaging and Applications, 890529 (September 19, 2013)



In this example the range has been calculated as 749 m (compared to the global parameter setting of 750 m)



Received electrical spectrum. The peak is the intermediate frequency signal resulting from the mixing between the reference and received FM waveforms

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