# 2

# IMPLEMENTATION OF SCATTERING ALGORITHM

## 2.1 INTRODUCTION

This chapter describes the methodology of the simulations carried out in this book and the approaches taken to achieve the outlined goals. Mathematical models of the Brillouin and Rayleigh scattering in sensing fiber are clearly described in detail. Additionally, a formula that represents the coherent Rayleigh noise is presented.

## 2.2 OVERVIEW OF ALGORITHM FLOW

The steps shown in the flow chart in Figure 2.1 give an overview about the various procedures that are used in the simulation of the distributed optical fiber sensor. The modeling begins by building a mathematical Brillouin scattering model using the couple mode equations that relate the forward signal with the backscattered signal. These equations govern the nonlinear interaction between the pump and Stokes waves in stimulated Brillouin scattering process, which can be derived rigorously using Maxwell's equation. The dependence on the intrinsic characteristics of the fiber and also its environmental factors are incorporated in these equations. The response of Brillouin scattering to the measurand, such as a change in temperature or strain in fiber, is manifested as a change in both intensity and frequency of the scattered light.

Next, a mathematical formula that describes the Rayleigh scattering component is analyzed. The amount of power of this backscattered light is dependent on the local attenuation coefficient, the backscattering factor and the pulse width [E. Brinkmeyer (1980)]. On the other hand, the backscattering factor depends on the normalized frequency of the fiber, as well as the refractive indices of the fiber core and cladding. Application of strain will modify these quantities, thus the amount of power backscattered, but the Rayleigh signal shows negligible temperature sensitivity [K. De Souza (1997)].

Unfortunately, Rayleigh backscattered radiation inherits a noise feature that is due to the interference among a large number of lightwaves backscattered at different positions in the fiber. This interference, in turn, causes phase-intensity noise conversion manifested as temporal amplitude fluctuations on the backscattered Rayleigh signal, which is named Coherent Rayleigh Noise (CRN). A mathematical model which embraces its dependence on pulse width, source bandwidth and detection bandwidth [K. De Souza (2006)] will be used to model the magnitude of CRN in the Rayleigh backscattered radiation. This is important because this additional noise feature affects the optical signal-to-noise ratio of the detected signals, which primarily influence the temperature resolution.

An attractive technique to determine simultaneously the temperature and strain is by measuring both the Brillouin frequency shift and the spontaneous Brillouin power level. Any variation in the Brillouin power due to fluctuations in the input power, or to fiber attenuation, can be corrected by a rationing the Brillouin signal to the Rayleigh signal, which is known as the Landau–Placzek ratio (LPR) method [J. Schroeder (1973)]. This method is capable to uniquely measure the temperature along the fiber sensor.

Once the temperature of the fiber is spatially resolved, measurement of the Brillouin shifted frequency allows the distributed strain to be computed, and hence the strain may then be determined. The