At each simulation step t and for each ι, the path length reflected by the ι-th scatter $l_t^{(\iota)} = |(x_t^\iota, y_t^\iota) - (0,0)| + |(x_t^*, y_t^*) - (x_t^\iota, y_t^\iota)|$ and its derivative with respect to time $\frac{d}{dt} l_t^{(\iota)}$ are computed. The corresponding transmission delay time $\sigma_t^{(\iota)}$, the constant phase offset $\theta_t^{(\iota)}$, and the Doppler frequency $f_{D_t}^{(\iota)}$ caused by the ι-th scatterer following the rules $\sigma_t^{(\iota)} = l_t^{(\iota)}/c_0$, $\theta_t^{(\iota)} = ((-l_t^{(\iota)} f_{\text{carrier}}/c_0) \bmod 1) \cdot 2\pi$, and $f_{D_t}^{(\iota)} = -\frac{d}{dt} l_t^{(\iota)} f_{\text{carrier}}/c_0$, respectively, as well as the received signal amplitude $a_t^{(\iota)}$ computed using the free-space propagation model $a_t^{(\iota)} = c_0/(4\pi f_{\text{carrier}} l_t^{(\iota)})$ (cf.) are recorded for each scatterer ι. (Here, c_0 refers to the speed of light in vacuum.) In a setting without line of sight, using linearisation of the phase offset with respect to the Doppler frequency, the time-variant channel impulse response evaluated at time $t+\tau$ for each simulation step t and small τ resulting from the multipath transmission simulated using the above parameters can be approximated by

$$h(\cdot, t+\tau) = \frac{1}{\sqrt{\sum_{\iota=0}^{255} (a_t^{(\iota)})^2}} \sum_{\iota=0}^{255} a_t^{(\iota)} \exp(i\theta_t^{(\iota)} + i2\pi f_{D_t}^{(\iota)} \tau) \delta_{\sigma_t^{(\iota)}}(\cdot).$$

For any signal $\{S_\tau\}_{0 \le \tau < T}$ being transmitted in the block beginning at time step t through the simulated channel, this consideration leads to a received signal $\{R_\tau\}_{0 \le \tau < T}$ in the form of

$$\begin{aligned} R_\tau &= (h(\cdot, t+\tau) * S_\cdot)(\tau) \\ &= \frac{1}{\sqrt{\sum_{\iota=0}^{255} (a_t^{(\iota)})^2}} \sum_{\iota=0}^{255} a_t^{(\iota)} \exp(i\theta_t^{(\iota)} + i2\pi f_{D_t}^{(\iota)} \tau)(\delta_{\sigma_t^{(\iota)}}(\cdot) * S_\cdot)(\tau). \end{aligned} \tag{1}$$

This parametrisation is used in and delivers a realistic approximation of real-world scenarios for numbers of summands greater than 100 . In order to allow continuous time delays to be applied to discrete time signals, the impulse function $\delta_{\sigma_t^{(\iota)}}(\cdot)$ in () is convolved with a windowed $\text{sinc}(\cdot)$ function scaled with a given bandwidth. Overall, the channel transmission including pulse shaping with bandwidth restricted to half the sample rate and additive noise is approximated by replacing the $\delta_{\sigma_t^{(\iota)}}(\cdot)$ in () by $\sin(\pi(\cdot/2))/(\pi(\cdot/2))\mathbf{1}_{[-8,8]}$ and adding independent and identically distributed Gaussian white noise $\sim \mathcal{N}(0, \sigma^2)$ to the transmitted signal with power σ^2 resulting in a signal-to-noise ratio of 12dB.

1 Channel Estimation

The time-variant channel transfer functions $\mathcal{F}h(\cdot, t+\tau)$ for $t = 0, \ldots, 4095T$ and $0 \le \tau < T$ simulated in Section are approximated by a time series of block wise time-invariant transfer functions $\{\mathcal{F}h^t\}_{t=0,\ldots,4095}$ based on which the estimation and prediction of the channel transmission are conducted. For each transmission block beginning at time step t, in order to estimate the corresponding channel transfer function $\mathcal{F}h^t$, a complex-valued (white noise) test signal $\{\tilde{S}_\tau^t\}_{\tau=0,\ldots,N-1}$ whose Fourier transform has constant amplitude and random phases $\sim \mathcal{U}(-\pi, \pi)$ is generated and then transmitted through the channel simulated in Section resulting in a received signal $\{R_\tau^t\}_{\tau=0,\ldots,N-1}$.