**OTFS System**

In this section, we disuses the mathematical format and input-output relations of the Orthogonal Time Frequency Space (OTFS) modulated signal. The modulation process is shown in Figure 1, which is a 2D modulation. The transmitter uses a $k \times l$ of delay-Doppler for multiplexing the information symbols $(N, M)$, which are greater than zero and denoted by x. These symbols belong to the QAM modulation alphabet and are mapped to the delay-Doppler grid in 2D $(k = 0, 1, \ldots N - 1)$ and $(l = 0, 1, \ldots, M - 1)$. The time duration of the OTFS transmitted signal is given by N × T and the transmitted signal Bandwidth (BW) is MΔf, where N and M denote the number of input symbols and the length of the subcarriers respectively, T is the symbol time and Δf is the frequency spacing. In order to convert the delay-Doppler domain input signal $X(k, l)$ to the time-frequency domain signal $X(n, m)$, the Inverse Symplectic Finite Fourier Transform (ISFFT) is used:

$$X(n, m) = \frac{1}{\sqrt{NM}} \sum_{k=0}^{N-1} \sum_{l=0}^{M-1} x(k, l) e^{j2\pi(\frac{nk}{N} - \frac{ml}{M})}$$

The time-frequency domain signal $X(n, m)$ is then converted to the time domain signal s(t) using Heisenberg transform:

$$S(t) = \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} X(n, m) g_{tx}(t - nT) e^{j2\pi\Delta f(t-nT)}$$

This is the OTFS modulated or transmitted signal, where $g_{tx}$ is the basic pulse of the transmission (for example, a rectangular pulse). During the OTFS demodulation, the Wigner transform is used to convert the time domain r(t) to the time-frequency $Y(n, m)$:

$$Y(n, m = A_{g_{rx}, r}(n, m) \triangleq \int g^{*}_{rx}(n' - n) r(n') e^{-j\pi \ (n'-n)} dt'$$

The time-frequency domain $Y\ (n, m)$ is then converted to the delay-Doppler domain $y(k, l)$ using Symplectic Finite Fourier Transform (SFFT):

$$y(k, l) = \frac{1}{\sqrt{NM}} \sum_{k=0}^{N-1} \sum_{l=0}^{M-1} Y(n, m) e^{-j2\pi(\frac{nk}{N} - \frac{ml}{M})}$$

By using the symbol demapper, the delay-Doppler domain is then converted into the time domain, expressed as

$$y(t) = \sqrt{T} \int_{0}^{\Delta f} y(k, l) dl, T > 0$$

$y(t)$ is the demodulated signal.