Timing Offset Synchronization using Gardner Timing Error Detector(TED) Algorithm.

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Contents

1. Gardner TED

A. Transmitter

$$P = \sin\left(2\pi\frac{[0 : T_{sym} - 1]}{2T_{sym}}\right) \tag{1.0.1}$$

Where T_{sym} is the samples per symbol. P is the half sine pulse shaping filter.

$$X = P \circledast C \tag{1.0.2}$$

Where C is upsampled by $T sym$ to the mapped data. And X is the convolution of pulse shaping filter and interpolated data. main equation

B. Receiver

$$Y = X + N \tag{1.0.3}$$

Where Y is the received vector.

$$U_t(r) = Y_I(r - 0.5)\left[Y_I(r) - Y_I(r - 1)\right] \tag{1.0.4}$$
$$+ Y_Q(r - 0.5)\left[Y_Q(r) - Y_Q(r - 1)\right] \tag{1.0.5}$$

Where r is the symbol index number. $Y_I(r - 0.5)$ is the mid sample between $Y_I(r)$ and $Y_I(r - 1)$.

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2. Derivation

$$U_t(r) = L(r - 1) - E(r) \tag{2.0.6}$$
$$= Y^2(\tau + (r - 1)T_{sym}) - Y^2(\tau + rT_{sym}) \tag{2.0.7}$$
$$+ 2Y(\tau + (r - 0.5)T_{sym})\left\{Y(\tau + rT_{sym}) - Y(\tau + (r - 1)T_{sy}\right. \tag{2.0.8}$$

Average over many samples,first two terms are equal.

$$U_t(r) = Y(\tau + (r - 0.5)T_{sym})\left\{Y(\tau + rT_{sym}) - Y(\tau + (r - 1)T_{sym}\right\} \tag{2.0.9}$$
$$= Y(r - 0.5)\left\{Y(r) - Y(r - 1)\right\} \tag{2.0.10}$$