Modern Digital Synchronization Techniques for Reliable Communication

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***Abstract*—A brief description about the design and implementation of Modern Digital Synchronization Techniques for reliable communication.**

1. Time Offset: Gardner TED

Let the mth sample in the rth received symbol time slot be

$$Y_k(m) = X_k + V_k(m), \quad k = 1, \dots, N, m = 1, \dots, M. \tag{1.1}$$

where X_k is the transmitted symbol in the kth time slot and $V_k(m) \sim \mathcal{N}\left(0, \sigma^2\right)$. The decision variable for the kth symbol is [2]

$$U_k = Y_{k-1}\left(\frac{M}{2}\right)\left[Y_k(M) - Y_{k-1}(M)\right] \tag{1.2}$$

A. Plots

The codes for generating the plots are available at

Fig. 1 shows the variation of the bit error rate respect to the snr with different timing offsets. Δf when the SNR = 10 dB.

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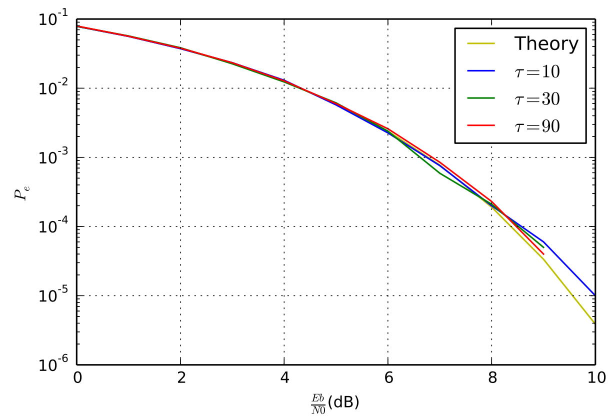

Fig. 1: SNR vs BER for varying τ.

2. Frequency Offset: LR Technique

Let the frequency offset be Δf [3]. Then

$$Y_k = X_k e^{j2\pi\Delta f kM} + V_k, \quad k = 1, \dots, N \tag{2.1}$$

From (2.1),

$$Y_k X_k^* = |X_k|^2 e^{j2\pi\Delta f kM} + X_k^* V_k \tag{2.2}$$

$$\implies r_k = e^{j2\pi\Delta f kM} + \bar{V}_k \tag{2.3}$$

where

$$r_k = Y_k X_k^*, \bar{V}_k = X_k^* V_k, |X_k|^2 = 1 \tag{2.4}$$

The autocorrelation can be calculated as

$$R(k) \triangleq \frac{1}{N-k}\sum_{i=k+1}^{N} r_i r_{i-k}^*, 1 \le k \le N-1 \tag{2.5}$$

Where N is the length of the received signal. For large centre frequency, the following yields a good approximation for frequency offset upto 40 MHz.

$$\Delta\hat{f} \approx \frac{1}{2\pi M}\frac{\sum_{k=1}^{P}\mathrm{Im}(R(k))}{\sum_{k=1}^{P} k\mathrm{Re}(R(k))}, \quad P\Delta f M << 1 \tag{2.6}$$

where P is the number of pilot symbols.

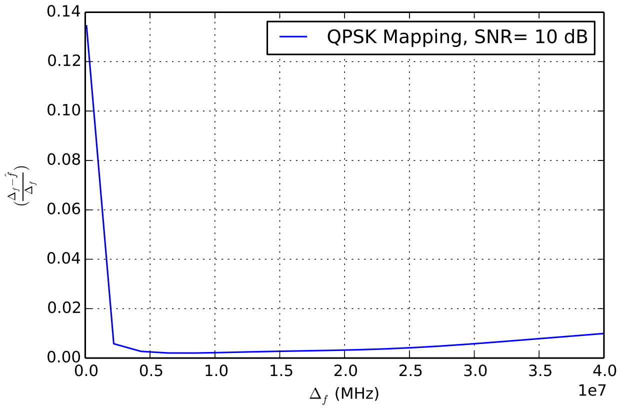

Fig. 2: Error variation with respect to frequency offset.

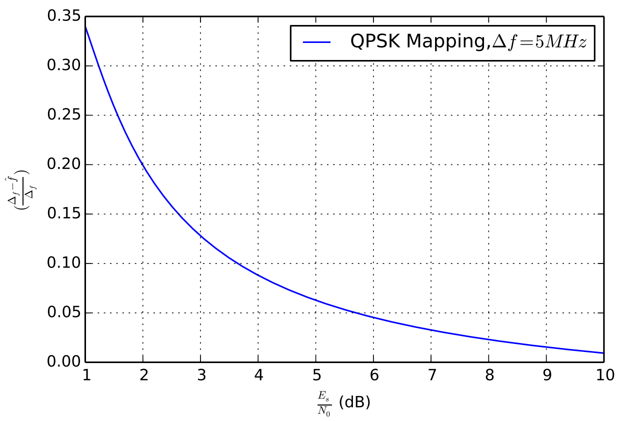

Fig. 3: Δf = 5 MHz, Center frequency f_c = 25 GHz

A. Plots

The number of pilot symbols is $P = 18$. The codes for generating the plots are available at

Fig. 2 shows the variation of the error in the offset estimate with respect to the offset Δf when the SNR = 10 dB. Similarly Fig. 3 shows the variation of the error with respect to the SNR for $\Delta f = 5MHz$.

3. Phase Offset: Feed Forward Maximum Likelihood (FF-ML)technique

Let the phase offset be $\Delta\phi$ [4]. Then

$$Y_k = X_k e^{j\Delta\phi} + V_k, \quad k = 1, \ldots, N \tag{3.1}$$

From (3.1),

$$Y_k X_k^* = |X_k|^2 e^{j\Delta\phi} + X_k^* V_k \tag{3.2}$$

$$\implies r_k = e^{j\Delta\phi} + \bar{V}_k \tag{3.3}$$

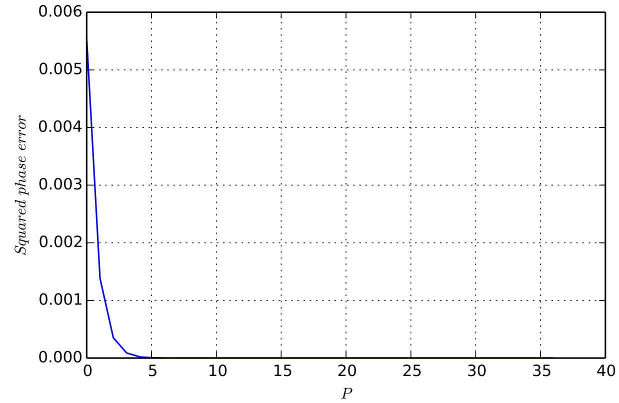

Fig. 4: Phase error variation with respect to pilot symbols

where

$$r_k = Y_k X_k^*, \bar{V}_k = X_k^* V_k, |X_k|^2 = 1 \tag{3.4}$$

$\hat{\phi}$ can be written as:

$$\hat{\Delta\phi}_k = arg(r_k) \tag{3.5}$$

This equation gives the final estimation of phase

$$\hat{\Delta\phi}_f^{(p)}(l) = \hat{\Delta\phi}_f^{(p)}(l-1) + \alpha SAW[\hat{\Delta\phi}^{(p)}(l) - \hat{\Delta\phi}_f^{(p)}(l-1)] \tag{3.6}$$

$$SAW[\phi] = [\phi]_{-\pi}^{\pi} \tag{3.7}$$

Where SAW is sawtooth non-linearity and $\alpha \leq 1$. l counts the number of pilot-based estimates. $\hat{\Delta\phi}_f^{(p)}(l)$ is the final unwrapped pilot estimate.

A. Plots

The codes for generating the plots are available at

Fig. 4 shows the variation of the phase error in the offset estimate with respect to the pilot symbols. Δf when the SNR = 10 dB. Similarly Fig. 5 shows the variation of the error with respect to the SNR for pilot symbols $P = 18$.

References

[1] U. Mengali and A. N. D'Andrea:'synchronization Techniques for Digital Receivers,' New York: Plenum, 1997.

[2] F. M. Gardner:'A BPSK/QPSK timing-error detector for sampled receivers,' IEEE TRANSACTIONS ON COMMUNICATIONS, VOL.COM-34,NO.5,MAY 1986

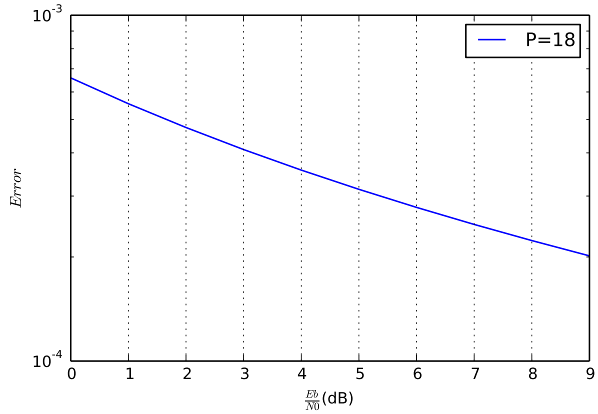

Fig. 5: $\Delta f = 5$ MHz

[3] M. Luise and R. Reggiannini:'Carrier frequency recovery in all-digital modems for burst mode transmissions,' IEEE Trans. Commun., vol. 43, no. 2/3/4, pp. 1169-1178, Feb/Mar/Apr 1995.

[4] E. Casini, R. De Gaudenzi, and A. Ginesi:'DVB-S2 modem algorithms design and performance over typical satellite channels,' International Journal of Satellite Communications and Networking 2004, vol. 22(3), pp. 281-318, 2004.