UWB Transmitted Reference Signaling Schemes Part I: Performance Analysis

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Transmitted Reference System Model

- Transmitted signal

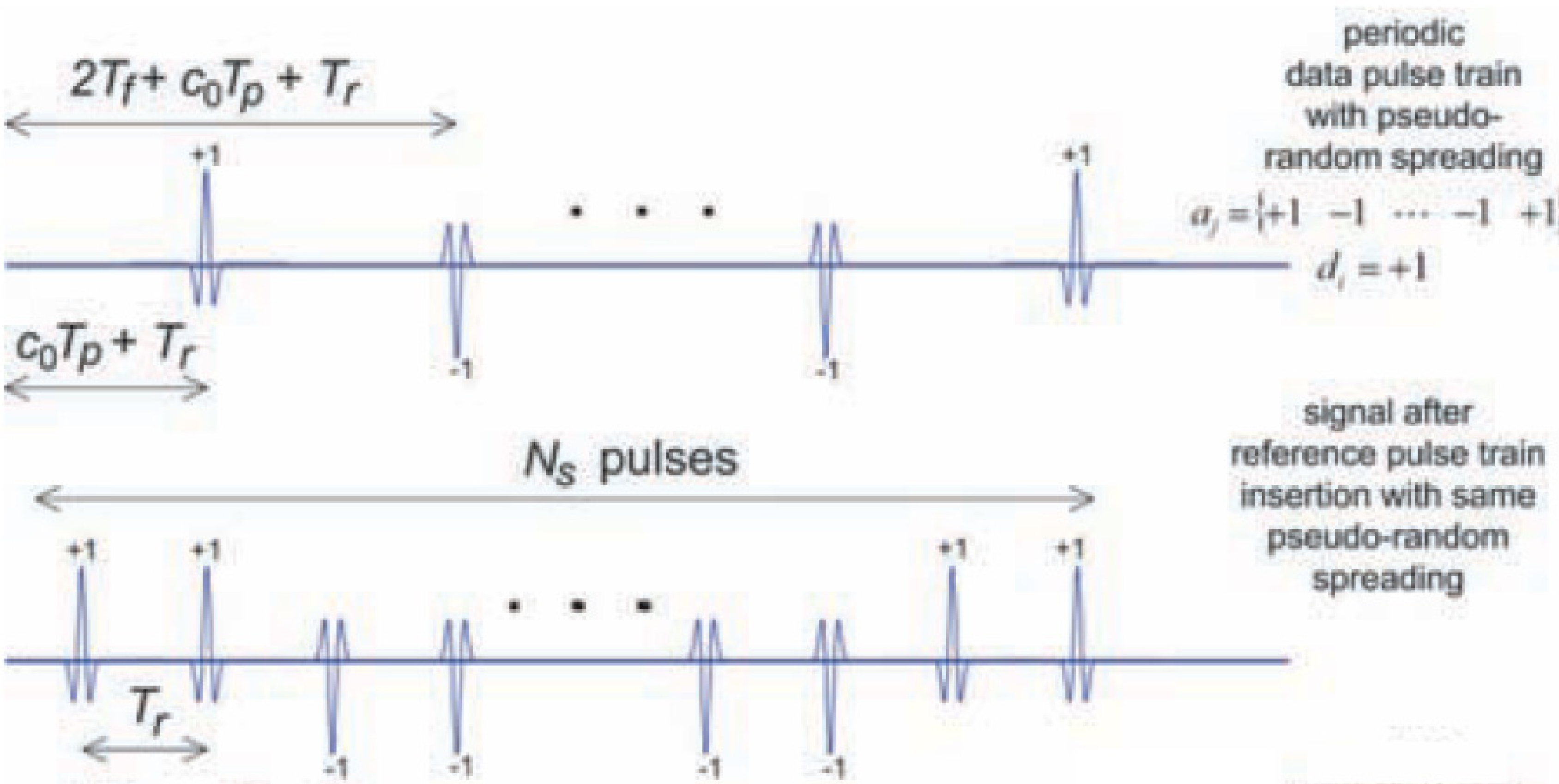
$$s_{\mathrm{TR}}(t) = \sum_{i} b_{\mathrm{r}}(t - iN_{\mathrm{s}}T_{\mathrm{f}}) + d_i b_{\mathrm{d}}(t - iN_{\mathrm{s}}T_{\mathrm{f}}),$$

- Reference and data blocks

$$b_{\mathrm{r}}(t) = \sum_{j=0}^{\frac{N_{\mathrm{s}}}{2}-1} \sqrt{E_{\mathrm{p}}} a_j p(t - j2T_{\mathrm{f}} - c_j T_{\mathrm{p}}),$$

$$b_{\mathrm{d}}(t) = \sum_{j=0}^{\frac{N_{\mathrm{s}}}{2}-1} \sqrt{E_{\mathrm{p}}} a_j p(t - j2T_{\mathrm{f}} - c_j T_{\mathrm{p}} - T_{\mathrm{r}}),$$

Transmitted Signal



Differencially Transmitted Reference

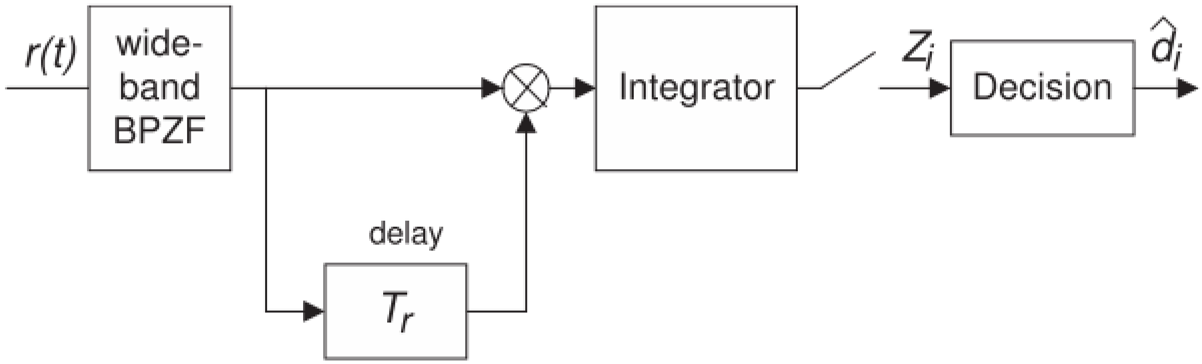
- Transmitted Signal

$$s_{\mathrm{DTR}}(t) = \sum_i e_i b(t - iN_\mathrm{s}T_\mathrm{f}),$$

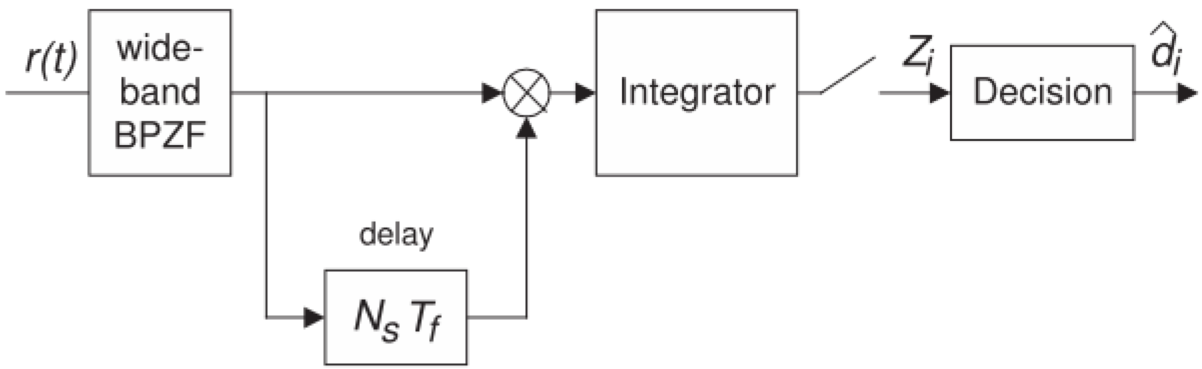
$$b(t) = \sum_{j=0}^{N_\mathrm{s}-1} \sqrt{E_\mathrm{p}} a_j p(t - jT_\mathrm{f} - c_j T_\mathrm{p}),$$

- Channel Model

$$h(t) = \sum_{l=1}^{L} \alpha_l \delta(t - \tau_l)$$



TR signaling with AcR



DTR signaling with AcR

Autocorrelation Receiver

- TR Receiver

$$Z_{\mathrm{TR}} = \sum_{j=0}^{\frac{N_{\mathrm{s}}}{2}-1} \int_{j2T_{\mathrm{f}}+T_{\mathrm{r}}+c_jT_{\mathrm{p}}}^{j2T_{\mathrm{f}}+T_{\mathrm{r}}+c_jT_{\mathrm{p}}+T} \widetilde{r}_{\mathrm{TR}}(t)\,\widetilde{r}_{\mathrm{TR}}(t-T_{\mathrm{r}})dt,$$

- DTR Receiver

$$Z_{\mathrm{DTR}} = \sum_{j=0}^{N_{\mathrm{s}}-1} \int_{jT_{\mathrm{f}}+c_jT_{\mathrm{p}}}^{jT_{\mathrm{f}}+c_jT_{\mathrm{p}}+T} \widetilde{r}_{\mathrm{DTR}}(t)\,\widetilde{r}_{\mathrm{DTR}}(t-N_{\mathrm{s}}T_{\mathrm{f}})dt,$$

Modified AcR Receiver

$$Z_{\mathrm{ATR}} = \sum_{j=0}^{\frac{N_\mathrm{s}}{2}-1} a_j \int_{j2T_\mathrm{f}+T_\mathrm{r}+c_jT_\mathrm{p}}^{j2T_\mathrm{f}+T_\mathrm{r}+c_jT_\mathrm{p}+T} \widetilde{r}_{\mathrm{TR}}(t) \left(\frac{2}{N_\mathrm{s}} \sum_{k=-j}^{\frac{N_\mathrm{s}}{2}-1-j} a_{j+k}\widetilde{r}_{\mathrm{TR}}(t-(N_\mathrm{s}-2k)T_\mathrm{f} - (c_j - c_{j+k})T_\mathrm{p} - T_\mathrm{r})\right)dt,$$

Performance Analysis

- Transmitted-Reference

$$Z_{\mathrm{TR}} = \sum_{j=0}^{\frac{N_s}{2}-1} \int_0^T (w_j(t) + \eta_{1,j}(t))(d_0 w_j(t) + \eta_{2,j}(t))dt \quad = \sum_{j=0}^{\frac{N_s}{2}-1} U_j,$$

$$U_j = \frac{1}{W} \sum_{m=1}^{2WT} \left(d_0 w_{j,m}^2 + w_{j,m}\eta_{2,j,m} + d_0 w_{j,m}\eta_{1,j,m} + \eta_{1,j,m}\eta_{2,j,m}\right),$$

TR Performance Analysis

$$Y_1 \triangleq \frac{1}{2\sigma_{\mathrm{TR}}^2} \sum_{j=0}^{\frac{N_s}{2}-1} \sum_{m=1}^{2WT} \left(\frac{1}{\sqrt{W}} w_{j,m} + \beta_{1,j,m}\right)^2,$$

$$Y_2 \triangleq \frac{1}{2\sigma_{\mathrm{TR}}^2} \sum_{j=0}^{\frac{N_s}{2}-1} \sum_{m=1}^{2WT} \beta_{2,j,m}^2,$$

$$Y_3 \triangleq \frac{1}{2\sigma_{\mathrm{TR}}^2} \sum_{j=0}^{\frac{N_s}{2}-1} \sum_{m=1}^{2WT} \left(\frac{1}{\sqrt{W}} w_{j,m} - \beta_{2,j,m}\right)^2,$$

$$Y_4 \triangleq \frac{1}{2\sigma_{\mathrm{TR}}^2} \sum_{j=0}^{\frac{N_s}{2}-1} \sum_{m=1}^{2WT} \beta_{1,j,m}^2.$$

TR Performance Analysis

- Non-central and central Chi-squared variables

$$f_{\mathrm{NC}}(y,\mu,n) \triangleq e^{-(y+\mu)} \left(\frac{y}{\mu}\right)^{\frac{(n-1)}{2}} I_{n-1}\left(2\sqrt{y\mu}\right), \quad y \geq 0$$

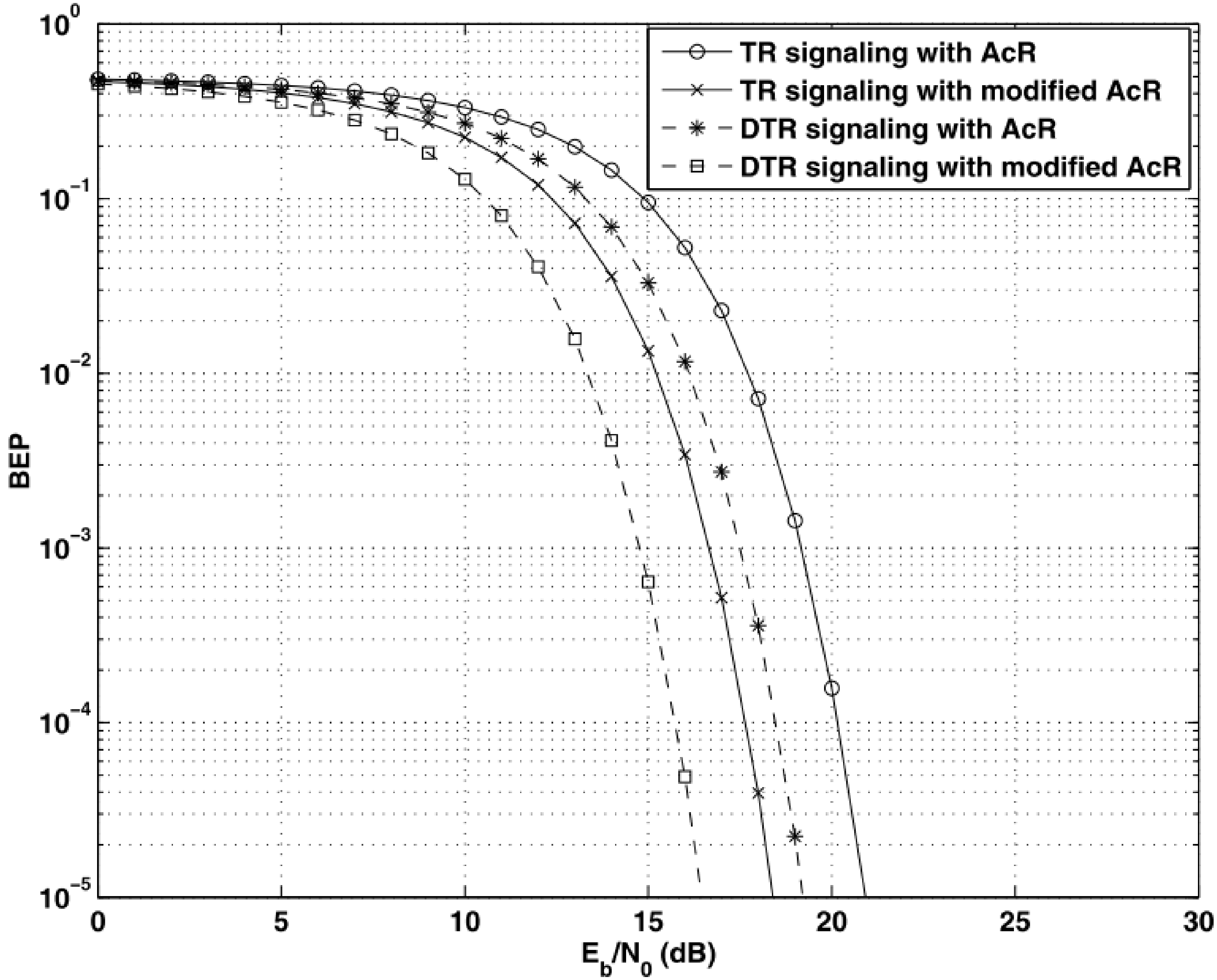
$$f_{\mathrm{C}}(y,n) \triangleq \frac{y^{(n-1)}}{(n-1)!} \exp\left(-y\right), \quad y \geq 0$$

DTR Performance Analysis

$$U_j = \frac{1}{W} \sum_{m=1}^{2WT} \left(d_0 w_{j,m}^2 + e_{-1} w_{j,m} \eta_{2,j,m} + e_0 w_{j,m} \eta_{1,j,m} + \eta_{1,j,m} \eta_{2,j,m} \right),$$

$$U_{j|d_0=+1} = \sum_{m=1}^{2WT} \left[\left(\frac{1}{\sqrt{W}} w_{j,m} + \beta_{1,j,m} \right)^2 - \beta_{2,j,m}^2 \right],$$

$$U_{j|d_0=-1} = \sum_{m=1}^{2WT} \left[- \left(\frac{1}{\sqrt{W}} w_{j,m} - \beta_{2,j,m} \right)^2 + \beta_{1,j,m}^2 \right],$$



TR signaling with AcR
TR signaling with modified AcR
DTR signaling with AcR
DTR signaling with modified AcR
BEP
E_b/N_0 (dB)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
5
10
15
20
25
30

Thank you for your time ☺