

Enhanced Approximation for RBIR PHY Abstraction in TGm

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Purpose:

To modify the 802.16m EVM document related with Approximation part for RBIR PHY Abstractions

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Outline

- Numerical Integration RBIR
 - Current proposal
 - New proposal
 - Comparisons
 - Conclusions

Numerical Integration within RBIR PHY Abstraction

- Exact Expression:

$$SI = \int_{-\infty}^{+\infty} p(LLR) \log_2 \left(\frac{M}{1 + \exp(-LLR)} \right) dLLR = \log_2(M) - \frac{1}{\log_e(2)} J(AVE, VAR)$$

- Beceem Approximation (current EVM)

$$J_B = \frac{2}{3} f_1(AVE) + \frac{1}{6} f_1(AVE + \sqrt{3VAR}) + \frac{1}{6} f_1(AVE - \sqrt{3VAR})$$
$$f_1(x) = \log_e(1 + \exp(-x))$$

Numerical Integration within RBIR PHY Abstraction

- Asymptotic Approximation (new)

$$J_A = \sqrt{VAR} \cdot \left\{ \frac{-\eta}{2} \cdot \text{Erfc}\left(\frac{\eta}{\sqrt{2}}\right) + \frac{1}{\sqrt{2\pi}} \cdot \exp\left(-\frac{\eta^2}{2}\right) \right\} \quad \eta = \frac{AVE}{\sqrt{VAR}}$$

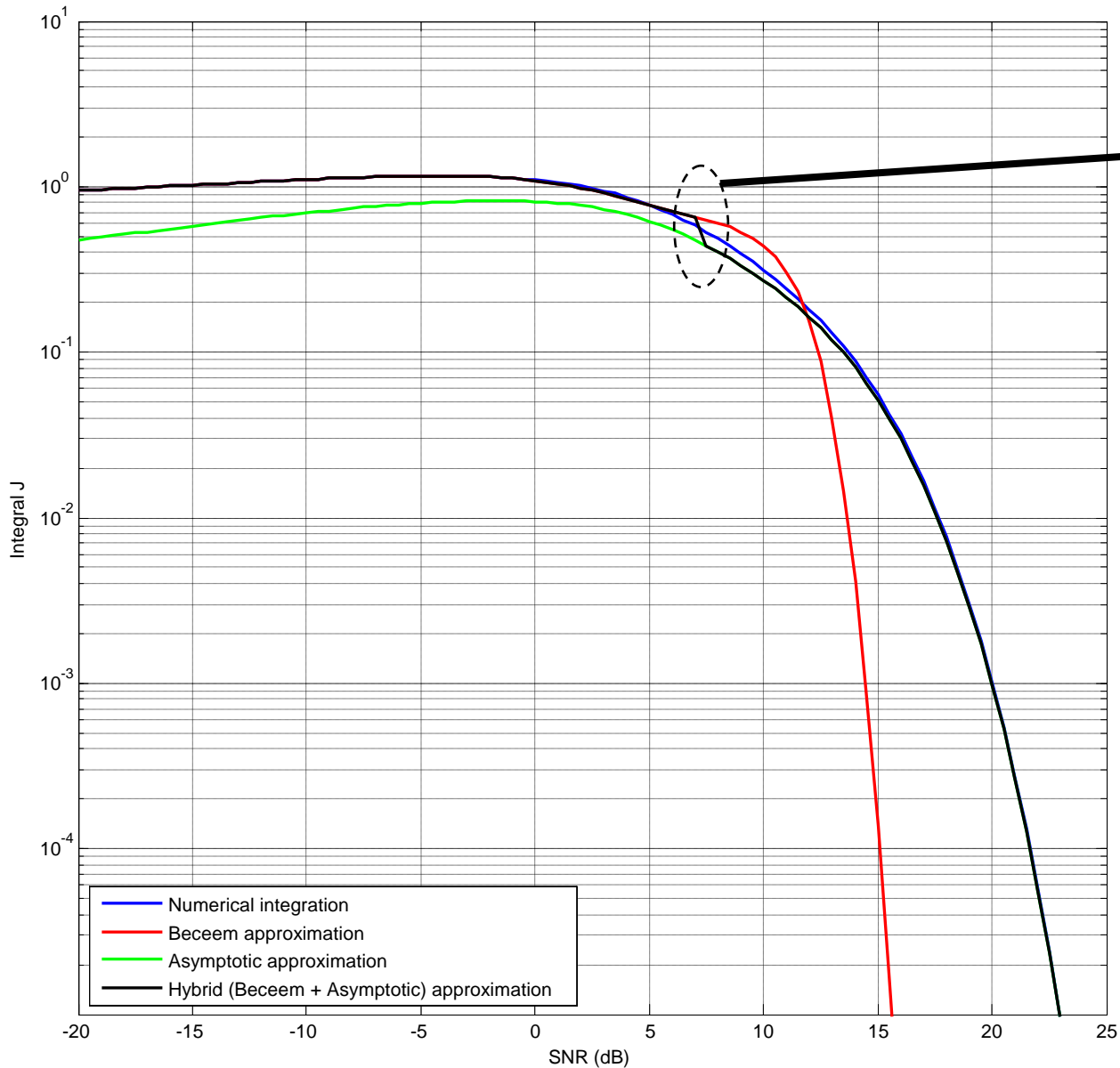
- NEW Proposal:

– **Hybrid {Beceem + Asymptotic}**

$$J = \left(\frac{J_A + J_B}{2}\right) + \left(\frac{J_A - J_B}{2}\right) \text{sign}(T - J_B) \quad ; \quad T \approx 0.65$$

$$\text{sign}(x) = \begin{cases} +1 & ; \quad x \geq 0 \\ -1 & ; \quad x < 0 \end{cases}$$

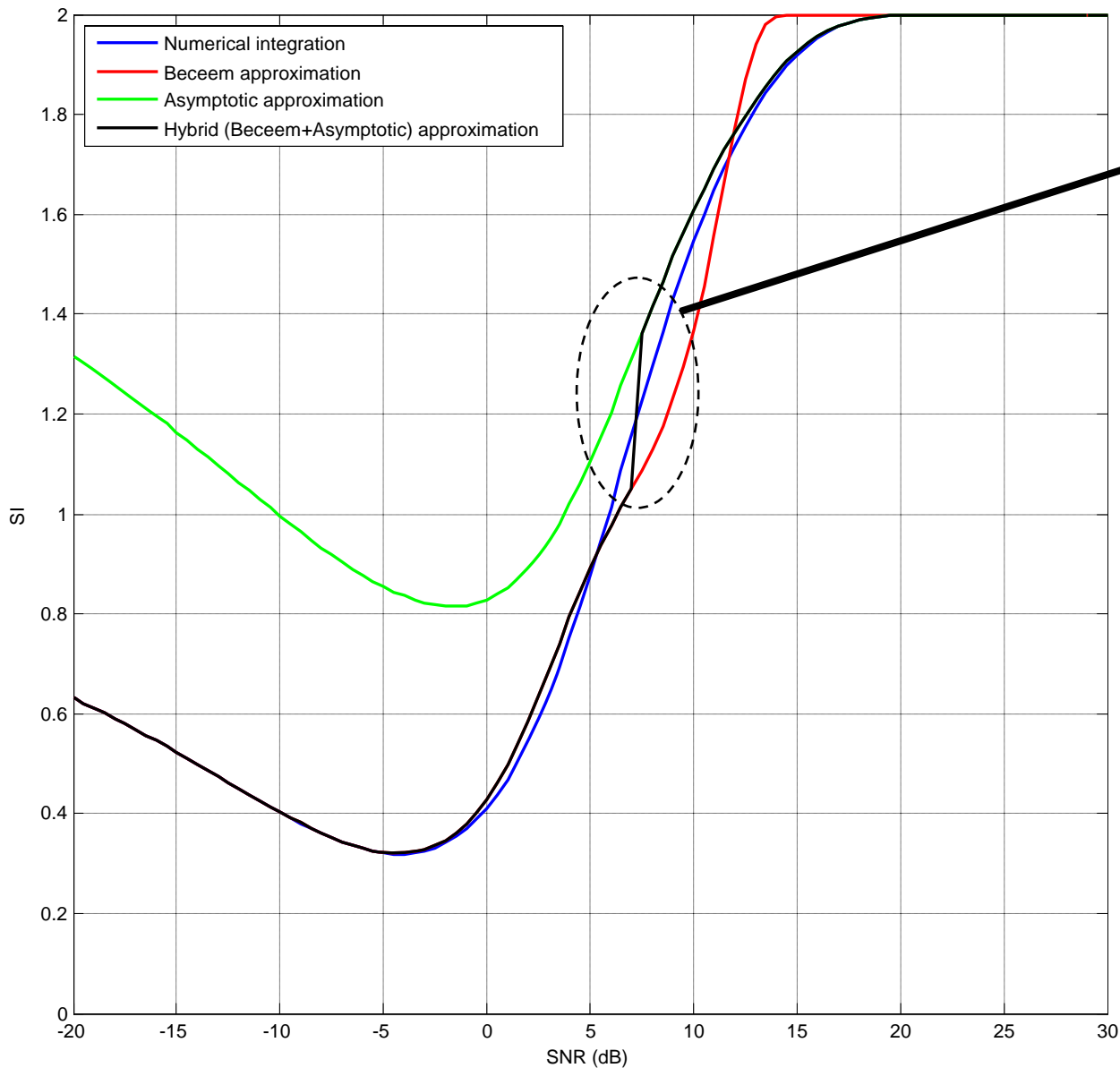
Accuracy of J approximation



**Switching point
($J \approx 0.65$)**

**Perfect matching
of hybrid scheme**

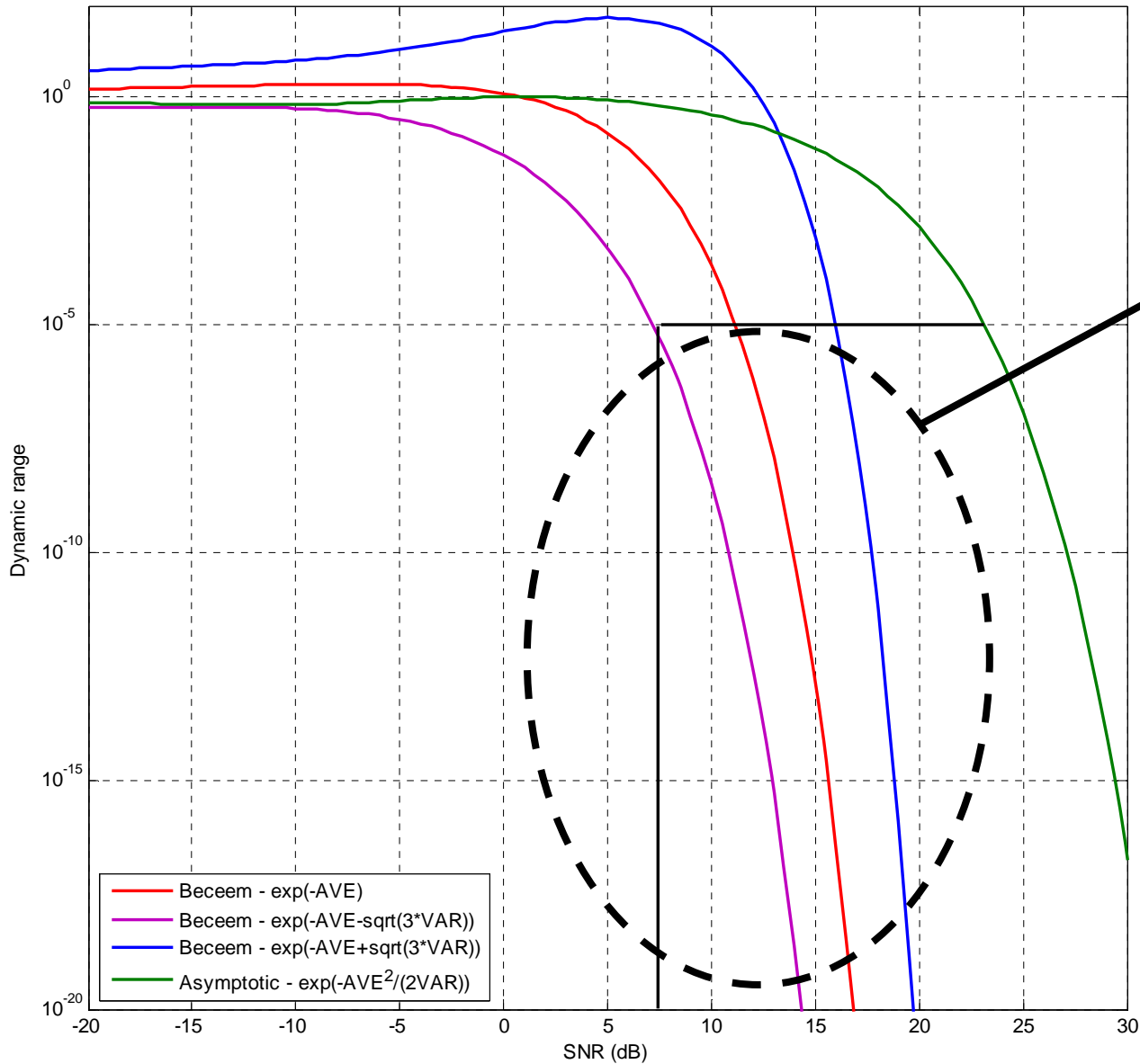
Accuracy of SI approximation



**Switching point
($J \approx 0.65$)**

**Perfect matching
of hybrid scheme**





Accuracy of Implementation



Region of high dynamic range for Beceem elementary functions

Avoided by Hybrid scheme

Computation Time

Function Name	Calls	Total Time	Self Time*	Total Time Plot (dark band = self time)
Hybrid	100001	4.866 s	2.339 s	
erfc	100001	2.527 s	1.872 s	
beceem	100001	1.201 s	1.201 s	
erfc (MEX-function)	100001	0.655 s	0.655 s	

Self time is the time spent in a function excluding the time spent in its child functions.
Self time also includes overhead resulting from the process of profiling.

Continued Fraction

- Property of Erfc

$$\text{Erfc}(x) = Q(1/2, x^2) = \frac{\Gamma(0.5, x^2)}{\Gamma(0.5)}$$

$$\Gamma(0.5) = \sqrt{\pi}$$

- Legendre continued Fraction

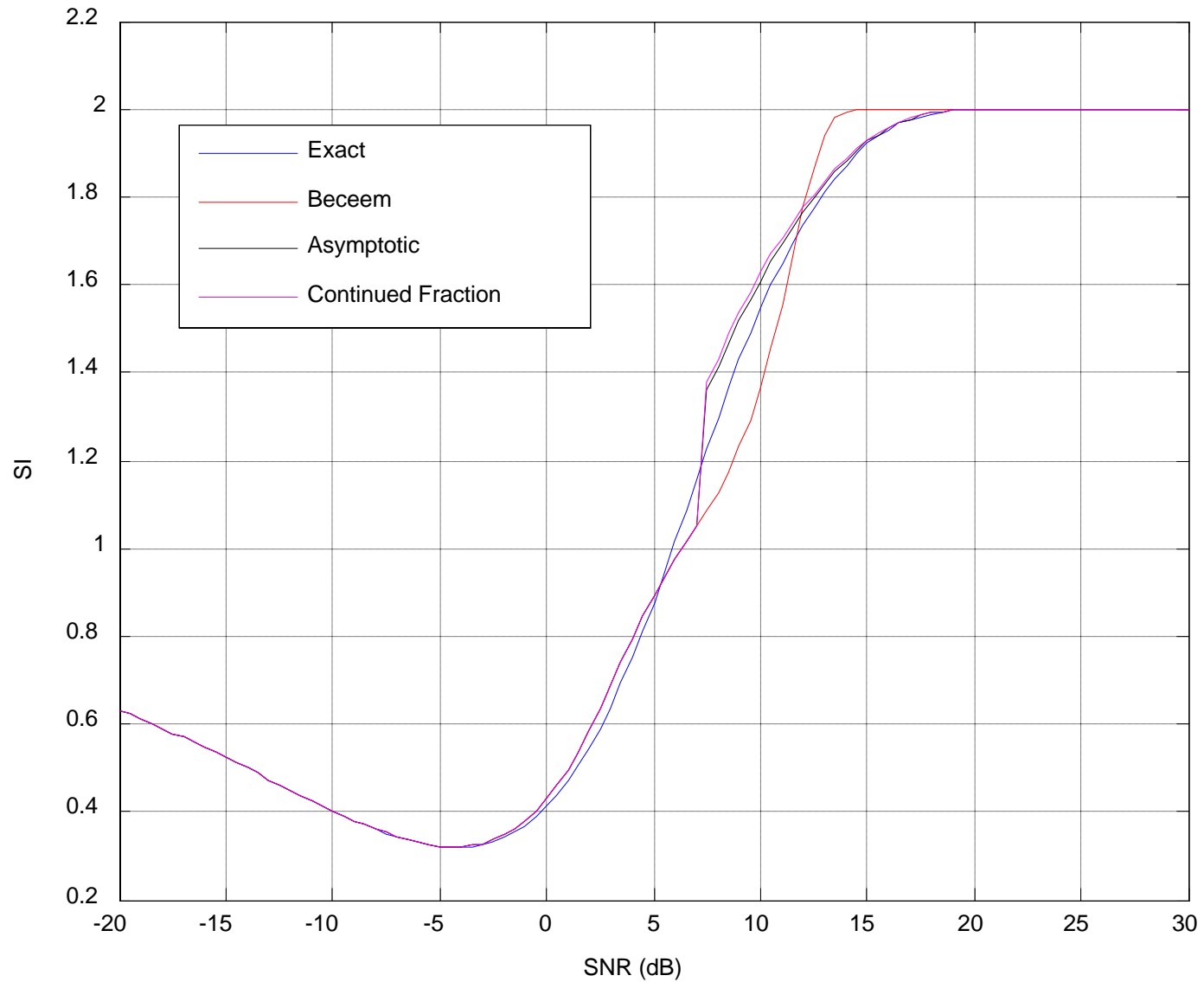
$$\Gamma(0.5, x) \approx e^{-x} \cdot \sqrt{x} \cdot \frac{2x+3}{(2x+1) \cdot (x+1.5) - 1}$$

$$Q(a, x) = \frac{\Gamma(a, x)}{\Gamma(a)}$$

$$\Gamma(a, x) = \int_x^{+\infty} t^{a-1} \cdot e^{-t} \cdot dt$$

$$\Gamma(a) = \int_0^{+\infty} t^{a-1} \cdot e^{-t} \cdot dt$$

Continued Fraction comparison

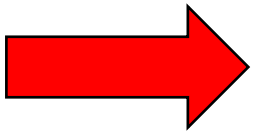


Final Expression

$$J_A = \sqrt{VAR} \cdot \frac{\exp\left(-\frac{\eta^2}{2}\right)}{\sqrt{2\pi}} \cdot \left\{ 1 - \eta^2 \cdot \frac{\eta^2 + 3}{[(\eta^2 + 1) \cdot (\eta^2 + 3) - 2]} \right\}$$

Impact on adjustment parameters (a, p_1, p_2)

- The proposal **does not impact the concept** behind introducing parameters (a, p_1, p_2)
 - a introduced to enhance the accuracy of derivation of AVE and VAR
 - p_1 and p_2 introduced for the mixture of two LLR Gaussians in MIMO Matrix B + vertical encoding
- But as far as **SINR-RBIR mapping** is used for calibration, the **values of (a, p_1, p_2) might be affected**



It might be interesting to agree also about the numerical integration itself.

Conclusions RBIR

- Proposal to replace current EVM RBIR Numerical Approximation of SI given by Equation (43), p.70:

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$$SI \approx \log_2 M - \frac{1}{\log_e 2} \left[\begin{array}{l} \frac{2}{3} f_1(AVE) \\ + \frac{f_1(AVE + \sqrt{3VAR})}{6} \\ + \frac{f_1(AVE - \sqrt{3VAR})}{6} \end{array} \right] \quad (43)$$

- With

$$SI \approx \log_2(M) - \frac{1}{\log_e(2)} \cdot J$$

$$J = \left(\frac{J_A + J_B}{2} \right) + \left(\frac{J_A - J_B}{2} \right) \text{sign}(T - J_B) \quad ; \quad T \approx 0.65$$

where

$$J_A = \sqrt{VAR} \cdot \left\{ \frac{-\eta}{2} \cdot \text{Erfc}\left(\frac{\eta}{\sqrt{2}}\right) + \frac{1}{\sqrt{2\pi}} \cdot \exp\left(-\frac{\eta^2}{2}\right) \right\} \quad \eta = \frac{AVE}{\sqrt{VAR}}$$

$$J_B = \frac{2}{3} f_1(AVE) + \frac{1}{6} f_1(AVE + \sqrt{3VAR}) + \frac{1}{6} f_1(AVE - \sqrt{3VAR})$$

$$f_1(x) = \log_e(1 + \exp(-x))$$

$$\text{sign}(x) = +1; x \geq 0 \quad \text{and} \quad -1; x < 0$$