

# Enhanced Approximation for RBIR PHY Abstraction in TGm

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Base Contribution:

None

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)

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

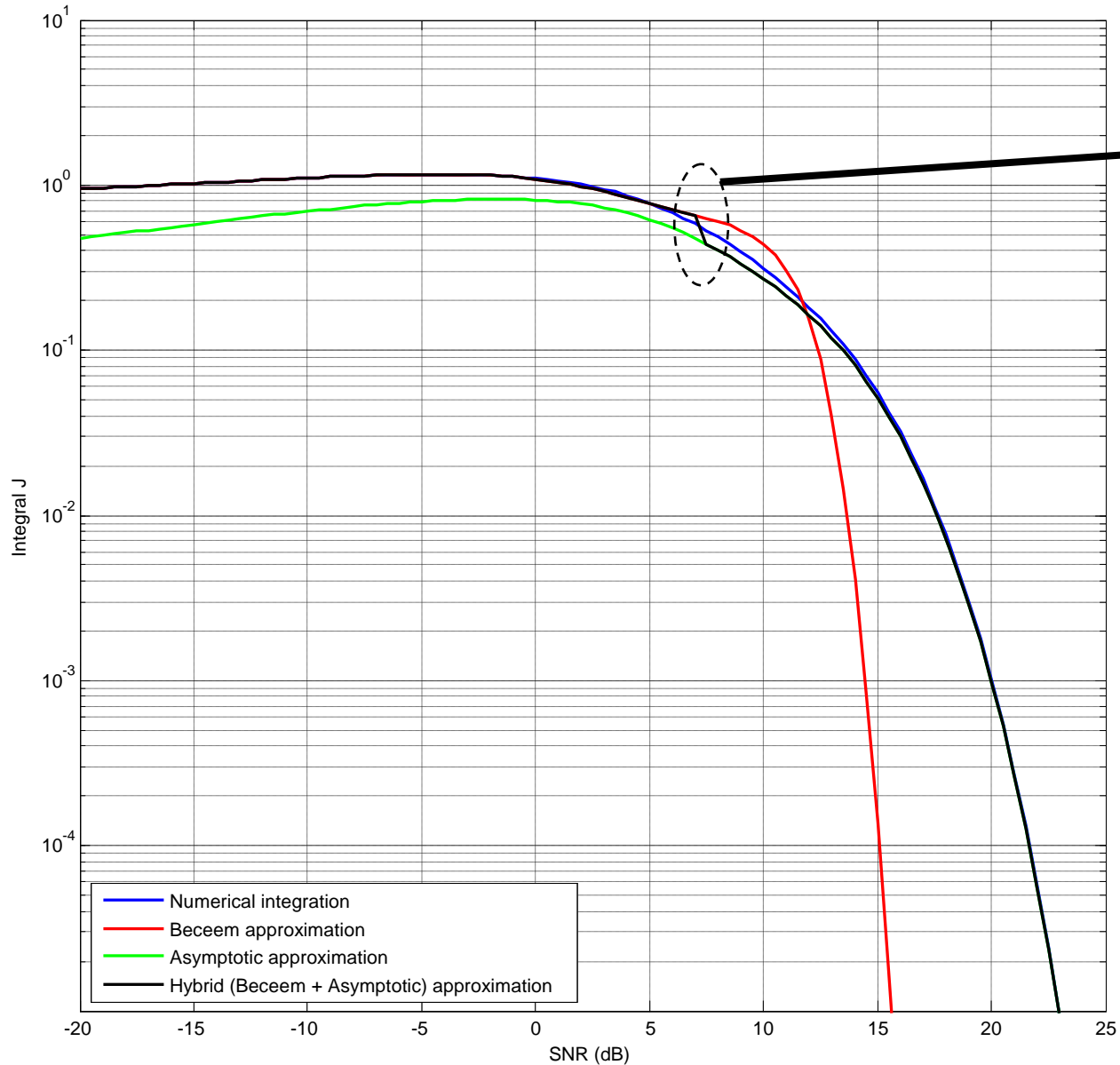
$$\eta = \frac{AVE}{\sqrt{VAR}}$$

- NEW Proposal:

– **Hybrid {Beceem + Asymptotic}**

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

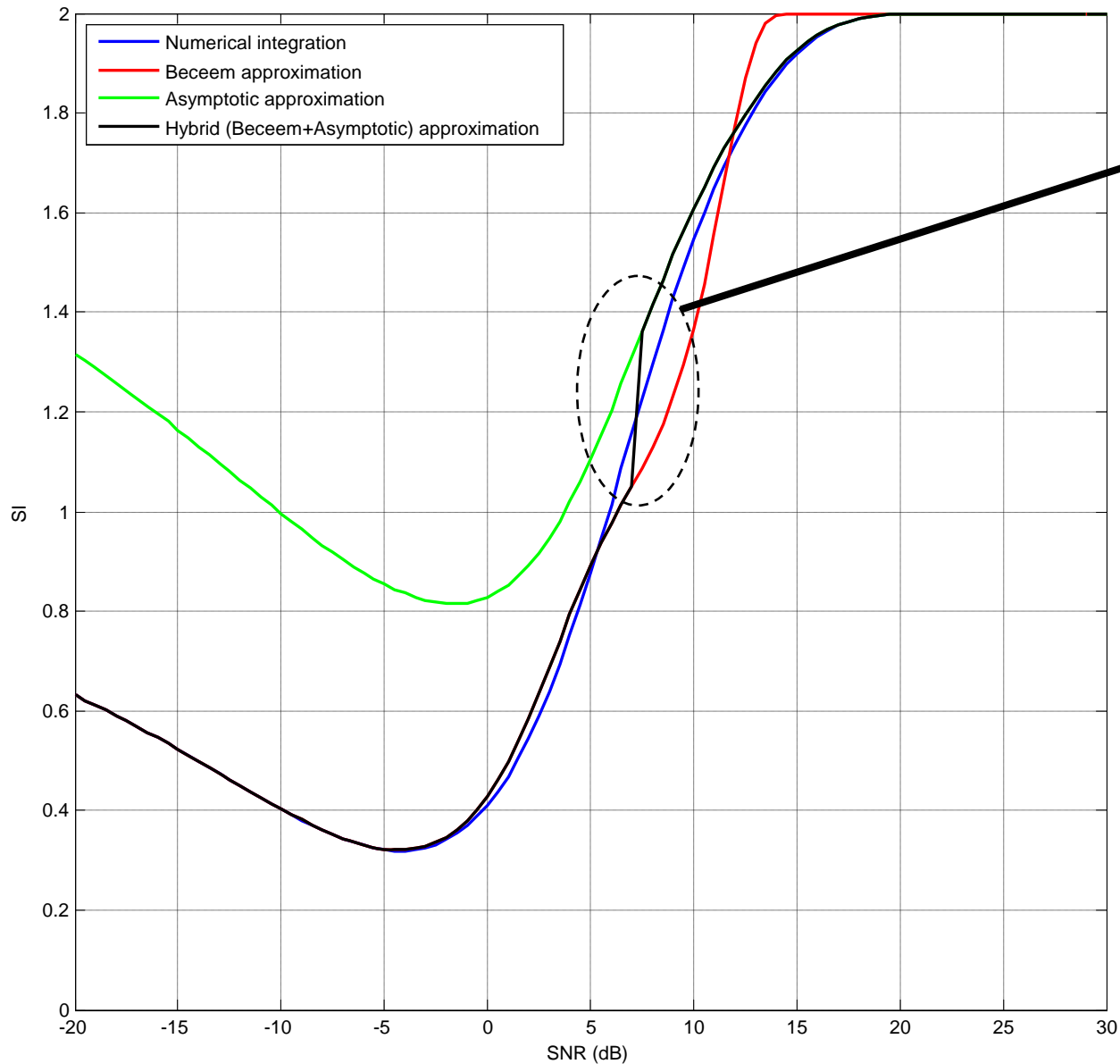
# Accuracy of J approximation



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

**Perfect matching  
of hybrid scheme**

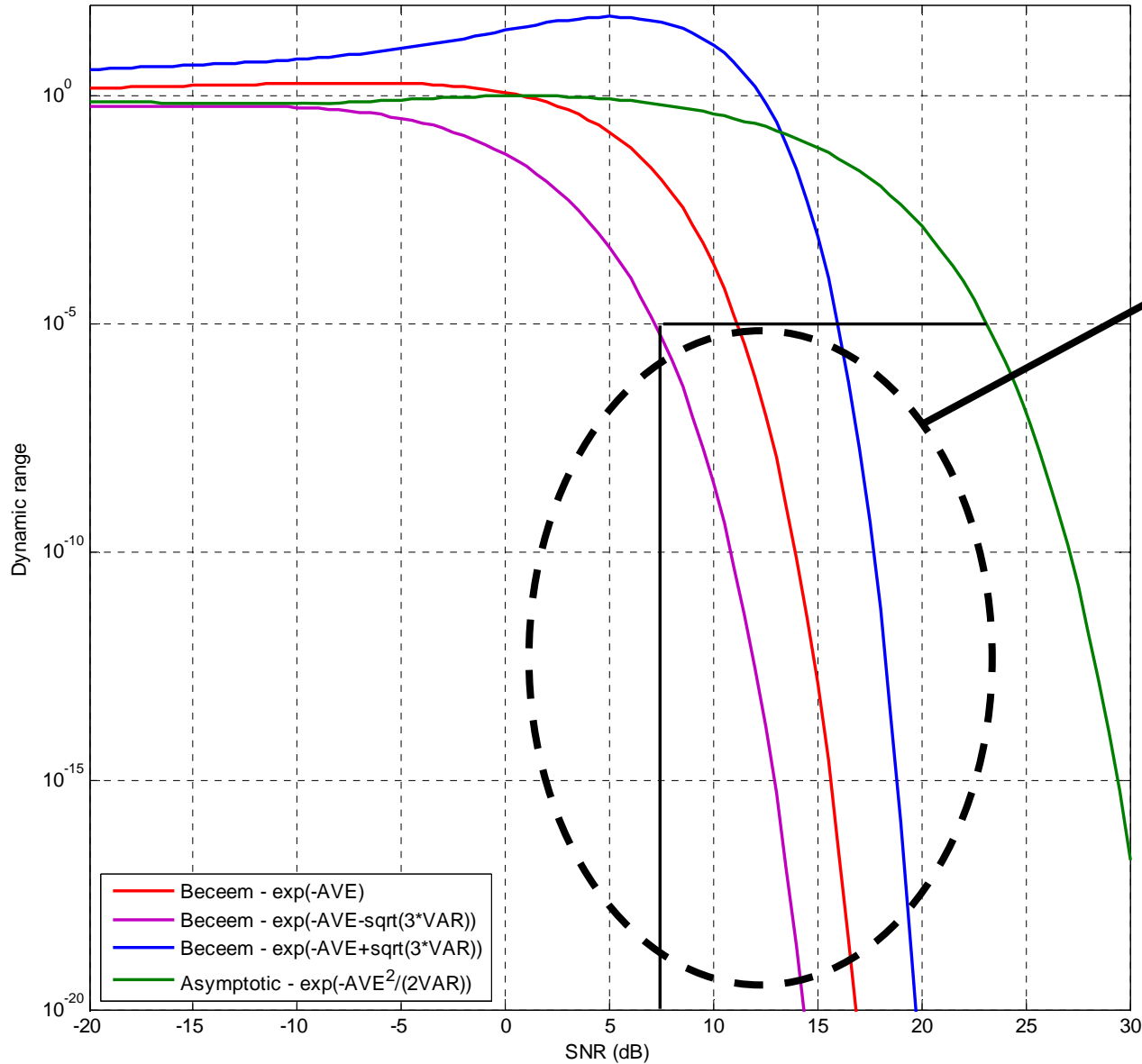
# Accuracy of SI approximation



**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)
<a href="#">Hybrid</a>	100001	4.866 s	2.339 s	
<a href="#">erfc</a>	100001	2.527 s	1.872 s	
<a href="#">beceem</a>	100001	1.201 s	1.201 s	
<a href="#">erfc</a> (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

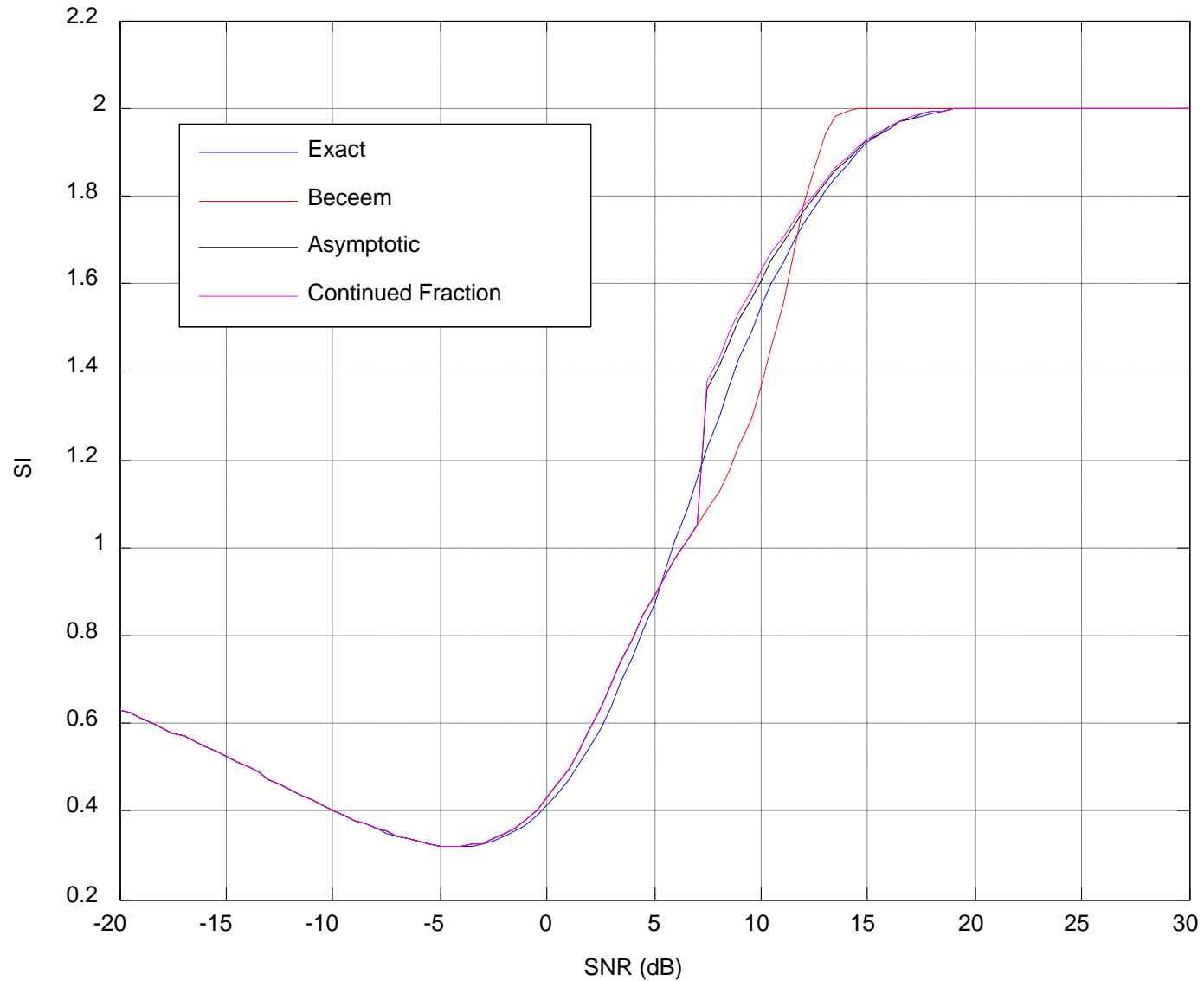
$$\Gamma(0.5, x) \approx e^{-x} \cdot \sqrt{x} \cdot \frac{2x+3}{(2x+1) \cdot (x+1.5) - 1}$$

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

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

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

# Continued Fraction comparison

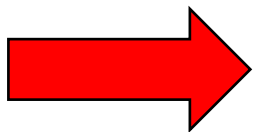


# Final Expression

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

## 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

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

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

$$\text{where } \left\{ \begin{array}{l} J_A = \sqrt{VAR} \cdot \left\{ \frac{-\eta}{2} \cdot \text{Erfc}\left(\frac{\eta}{\sqrt{2}}\right) + \frac{1}{\sqrt{2\pi}} \cdot \exp\left(-\frac{\eta^2}{2}\right) \right\} \\ J_B = \frac{2}{3} f_1(AVE) + \frac{1}{6} f_1(AVE + \sqrt{3VAR}) + \frac{1}{6} f_1(AVE - \sqrt{3VAR}) \\ \eta = \frac{AVE}{\sqrt{VAR}} \\ f_1(x) = \log_e(1 + \exp(-x)) \end{array} \right.$$