Derivation of Outage Probability:

$$P_{out} = Pr[\log_2(1+\gamma) < R\}$$
$$= Pr\{\gamma < 2^R - 1\}$$

minimum required data Rate of system.

γ - SNR.

$\gamma_0 = 2^R - 1.$

$$P_{out} = Pr\{\gamma < \gamma_0\}$$

inst. value of channel gain in DRF.

$X = \rho_1\rho_2$
$Y = \rho_3\rho_4.$ $\{RSI \propto SNR\}$

$$P^f_{out} = Pr\{\gamma_f < \gamma_0\}$$

$$= Pr\left\{ \frac{(d_{SR}d_{RD})^{-\alpha} P_S P_R XY}{d_{RD}^{-\alpha} P_R Y(\gamma_{RSI} + \sigma^2) + \sigma^2/G_f^2} < \gamma_0 \right\}$$

$$= Pr\left\{ X < \frac{\sigma^2\gamma_0}{G_f^2 (d_{SR}d_{RD})^{-\alpha} P_S P_R Y} + \frac{(\gamma_{RSI}+\sigma^2)\gamma_0}{d_{SR}^{-\alpha} P_S} \right\}$$

Combining PDF & CDF

$$= 1 - \int_0^\infty \left[1 - F_X\left(\frac{\sigma^2\gamma_0}{G_f^2(d_{SR}d_{RD})^{-\alpha} P_S P_R \xi} + \frac{(\gamma_{RSI}+\sigma^2)\gamma_0}{d_{SR}^{-\alpha} P_S}\right)\right] f_Y(\xi)\, d\xi$$

$$P^f_{out} = 1 - \int_0^\infty \sqrt{\frac{4\sigma^2\gamma_0}{\Omega_1\Omega_2 G_f^2 (d_{SR}d_{RD})^{-\alpha} P_S P_R \xi} + \frac{4(\gamma_{RSI}+\sigma^2)\gamma_0}{\Omega_1\Omega_2 d_{SR}^{-\alpha} P_S}}$$
$$\times K_1\left(\sqrt{\frac{4\sigma^2\gamma_0}{\Omega_1\Omega_2 G_f^2 (d_{SR}d_{RD})^{-\alpha} P_S P_R \xi} + \frac{4(\gamma_{RSI}+\sigma^2)\gamma_0}{\Omega_1\Omega_2 d_{SR}^{-\alpha} P_S}}\right)$$
$$\times \frac{2}{\Omega_3\Omega_4} K_0\left(\sqrt{\frac{4\xi}{\Omega_3\Omega_4}}\right) d\xi.$$

$$= 1 - C_f \int_0^{\infty} \sqrt{\frac{A_f \gamma_0}{\xi} + B_f \gamma_0}\, K_1\left(\sqrt{\frac{A_f \gamma_0}{\xi} + B_f \gamma_0}\right)$$

$$\times K_0\left(\sqrt{2C_f \xi}\right) d\xi.$$

$$v = e^{-\xi}.$$

$$P^f_{out} = 1 - C_f \int_0^1 \sqrt{\frac{A_f \gamma_0}{-\ln v} + B_f \gamma_0}\, K_1 \cdot \left(\sqrt{\frac{A_f \gamma_0}{-\ln v} + B_f \gamma_0}\right)$$

$$\times K_0\left(\sqrt{-2C_f \ln v}\right) \frac{dv}{v}.$$

Applying Gaussian-Gebyshev Quadrature.

$$P^f_{out} = 1 - \frac{\pi C_f}{2M} \sum_{m=1}^{M} \sqrt{\frac{1-\phi_m^2}{z}} \sqrt{\frac{A_f \gamma_0}{-\ln z} + B_f \gamma_0}$$

$$\times K_0\left(\sqrt{-2C_f \ln z}\right) K_1 \sqrt{\frac{A_f \gamma_0}{-\ln z} + B_f \gamma_0}\Bigg).$$

$$A_f = \frac{4\sigma^2}{(d_{SR} d_{RD})^{-\alpha} \Omega_1 \Omega_2 P_S P_R G_f^2}$$: σ^2 : zero mean variance.

$$B_f = \frac{4(\gamma_{RS1} + \sigma^2)}{d_{SR}^{-\alpha} \Omega_1 \Omega_2 P_S}$$: K_0, K_1 - zero order & First order Bessel function.

$$C_f = \frac{2}{\Omega_3 \Omega_4}$$: $$A_v = \frac{4\sigma^2(\gamma_{RS1} + \sigma^2)}{(d_{SR} d_{RD})^{-\alpha} \Omega_1 \Omega_2 P_S P_R}$$

$B_v = B_f$, $C_v = C_f$: $$D_v = \frac{4\sigma^2}{d_{RD}^{-\alpha} \Omega_3 \Omega_4 P_R}.$$

$z = \frac{1}{2} + \frac{1}{2}\phi_m$: $\phi_m = \cos\left(\frac{(2m-1)\pi}{m}\right)$.

Ω - Avg channel gain of the link $i = 1, 2, 3 \ldots$ 4.

M = complexity-accuracy trade-off parameter.

$$G_f = \sqrt{\frac{1}{d_{sR}^{-\alpha} f_1 f_2 P_S + \gamma_{RS1} + \sigma^2}}$$

$$G_V = \sqrt{\frac{1}{d_{SR}^{-\alpha} \rho_1 \rho_2 P_S + \gamma_{RS1} + \sigma^2}}$$

channel gain $|h|^2 = g_1 g_2 = \rho_1 \rho_2$

$\therefore \cancel{P^f_{out} = 1 - \frac{PTC_f}{2\pi}}$

$$P^V_{out} = P_r \left\{ \frac{(d_{SR} d_{RD})^{-\alpha} P_S P_R X Y}{d_{RD}^{-\alpha} P_R Y (\gamma_{RS1} + \sigma^2) + \sigma^2 (d_{SR}^{-\alpha} P_S X + \gamma_{RS1} + \sigma^2)} < \gamma_0 \right\}$$

$$= P_r \left\{ d_{SR}^{-\alpha} X P_S \; (d_{RD}^{-\alpha} P_R Y - \sigma^2 \gamma_0) < d_{RD}^{-\alpha} P_R Y (\gamma_{RS1} + \sigma^2) \gamma_0 + (\gamma_{RS1} + \sigma^2) \gamma_0 \right\}$$

Setting $Y = Z + \frac{\sigma^2 \gamma_0}{d_{RD}^{-\alpha} P_R}$

$$P^V_{out} = P_r \left\{ (d_{SR} d_{RD})^{-\alpha} P_S P_R X Z < d_{RD}^{-\alpha} P_R \left(Z + \frac{\sigma^2 \gamma_0}{d_{RD}^{-\alpha} P_R} \right) \times (\gamma_{RS1} + \sigma^2) \gamma_0 + (\gamma_{RS1} + \sigma^2) \sigma^2 \gamma_0 \right\}$$

$$P^V_{out} = 1 - \int_0^\infty \left[1 - F_X \left(\frac{(\gamma_{RS1} + \sigma^2) \sigma^2 (\gamma_0 + \gamma_0^2)}{(d_{SR} d_{RD})^{-\alpha} P_S P_R \xi} + \frac{(\gamma_{RS1} + \sigma^2) \gamma_0}{d_{SR}^{-\alpha} P_S} \right) \right] \times f_Z \left(\xi + \frac{\sigma^2 \gamma_0}{d_{RD}^{-\alpha} P_R} \right) d\xi$$

$$1-\int_0^\infty \sqrt{\frac{(4\gamma_{RS1}+\sigma^2)\sigma^2(\gamma_0+\gamma_0^2)}{\Omega_1\Omega_2(d_{SR}d_{RD})^{-\alpha}P_SP_R\xi_1}+\frac{4(\gamma_{RS1}+\sigma^2)\gamma_0}{\Omega_1\Omega_2 d_{SR}^{-\alpha}P_S}}$$

$$\times K_1\left(\sqrt{\frac{(4\gamma_{RS1}+\sigma^2)\sigma^2(\gamma_0+\gamma_0^2)}{\Omega_1\Omega_2(d_{SR}d_{RD})^{-\alpha}P_SP_R\xi_1}+\frac{4(\gamma_{RS1}+\sigma^2)\gamma_0}{\Omega_1\Omega_2 d_{SR}^{-\alpha}P_S}}\right)$$

$$\times \frac{2}{\Omega_3\Omega_4}K_0\sqrt{\frac{4\left(\xi_1+\frac{\sigma^2\gamma_0}{d_{RD}P_R}\right)}{\Omega_3\Omega_4}}\, d\xi_1$$

$$= 1-C_V\int_0^\infty \sqrt{\frac{A_V(\gamma_0+\gamma_0^2)}{\xi_1}+B_V\gamma_0}\,\cdot$$

$$\times K_1\sqrt{\frac{A_V(\cancel{}\gamma_0+\gamma_0^2)}{\xi_1}+B_V\gamma_0}$$

$$\times K_0\left(\sqrt{2C_V\xi_1+D_V\gamma_0}\, d\xi_1\right)$$

Now, $V=e^{-\xi_1}$

$$P^V_{out}=1-C_V\int_0^1\sqrt{\frac{A_V(\gamma_0+\gamma_0^2)}{-\ln v}+B_V\gamma_0}$$

$$\times K_1\sqrt{\frac{A_V(\gamma_0+\gamma_0^2)}{-\ln v}+B_V\gamma_0}$$

$$\times K_0\left(\sqrt{2C_V(-\ln v)+D_V\gamma_0}\right)\frac{dv}{v}$$

SER : Analytical

$$SER = \frac{a\sqrt{b}}{2\sqrt{2\pi}} \int_0^\infty \frac{e^{-bx/2}}{\sqrt{x}} F(x)\, dx \quad --- \ (1)$$

substitute f_f out $= \frac{1-\pi C_f}{2M} \sum_{m=1}^{M} \frac{\sqrt{1-\phi^2 m}}{2} \sqrt{\frac{A_f \gamma_0}{-\ln 2} + B_f \gamma_0}$

$$\times K_0 (\sqrt{-2C_f \ln 2})\, K_1 \left(\sqrt{\frac{A_b \gamma_0}{-\ln 2} + B_v \gamma_0}\right)$$

in (1) to get SER_f

$$\therefore SER_f = \frac{a\sqrt{b}}{2\sqrt{2\pi}} \left[\int_0^\infty \frac{e^{-bx/2}}{\sqrt{x}} dx - \int_0^\infty \frac{e^{-bx/2}}{\sqrt{x}} \frac{\pi C_f}{2M} \sum_{m=1}^{M} \frac{\sqrt{1-\phi m^2}}{2} \right.$$

$$\left. \times \sqrt{\frac{A_b x}{-\ln 2} + B_b x}\ K_0 (\sqrt{-2C_f \ln 2})\, K_1 \left(\sqrt{\frac{A_b x}{-\ln 2} + B_b x}\right) dx \right]$$

$$= \frac{a\sqrt{b}}{2\sqrt{2\pi}} \left[\int_0^\infty \frac{e^{-bx/2}}{\sqrt{x}} dx - \frac{\pi C_f}{2M} \sum_{m=1}^{M} \frac{\sqrt{1-\phi m^2}}{2} \sqrt{\frac{A_f}{-\ln 2} + B_f} \right.$$

$$\left. \times K_0 (\sqrt{-2C_b \ln 2}) \times \int_0^\infty e^{-bx/2} K_1 \left(\sqrt{\frac{A_b x}{-\ln 2} + B_b x}\right) dx \right] \quad --- \ (2)$$

Now $\int_0^\infty \frac{e^{-bx/2}}{\sqrt{x}} dx = \sqrt{\frac{2\pi}{b}}$ in (2) $\quad --- \ (3)$

For Second Integral, we apply

$$\int_0^\infty e^{-bx/2} K_1 \left(\sqrt{\frac{A_b x}{-\ln 2} + B_b x}\right) dx$$

$$= \exp\left(\frac{1}{4b}\left(\frac{A_b}{-\ln 2} + B_b\right)\right) \frac{\Gamma(3/2)\,\Gamma(1/2)}{\sqrt{b/2 \left(\frac{A_b}{-\ln 2} + B_b\right)}}$$

$$\times W_{-\frac{1}{2}, \frac{1}{2}} \left(\frac{1}{2b}\left(\frac{A_b}{-\ln 2} + B_b\right)\right) \quad --- \ (4)$$

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→ Substitute (3) and (4) in (2), we get

$$SER_f = \frac{a\sqrt{b}}{2\sqrt{2\pi}}\left[\sqrt{\frac{2\pi}{b}} - \frac{\pi C_f}{2M}\sum_{m=1}^{M}\frac{\sqrt{1-\Phi^2 m}}{z}\sqrt{\frac{Ab}{-\ln z}+B_f}\right.$$

$$\times\, k_0\left(\sqrt{-2C_f\ln z}\right)\exp\left(\frac{1}{4b}\left(\frac{Ab}{-\ln z}+B_f\right)\right)$$

$$\left.\times\,\frac{\Gamma(3/2)\,\Gamma(1/2)}{\sqrt{\frac{b}{2}\left(\frac{Ab}{-\ln z}+B_f\right)}}\,W_{-\frac{1}{2},\frac{1}{2}}\left(\frac{1}{2b}\left(\frac{Ab}{-\ln z}+B_f\right)\right)\right] \quad \text{---- (5)}$$

2]

$$SER_v = \frac{a\sqrt{b}}{2\sqrt{2\pi}}\left[\int_0^\infty \frac{e^{-bx/2}}{\sqrt{x}}\,dx - \int_0^\infty \frac{e^{-bx/2}}{\sqrt{x}}\,\frac{\pi C_v}{2M}\sum_{m=1}^{M}\frac{\sqrt{1-\phi_m^2}}{z}\right.$$

$$\times\sqrt{\frac{A_v(x^2+x)}{-\ln z}+B_v x}\; K_0\left(\sqrt{-2C_v\ln z + D_v x}\right)$$

$$\left.\times\, k_1\left(\sqrt{\frac{A_v(x^2+x)}{-\ln z}+B_v x}\right)dx\right]$$

$$= \frac{a\sqrt{b}}{2\sqrt{2\pi}}\left[\int_0^\infty \frac{e^{-bx/2}}{\sqrt{x}}\,dx - \frac{\pi C_v}{2M}\sum_{m=1}^{M}\frac{\sqrt{1-\phi_m^2}}{z}\int_0^\infty\right.$$

$$\times\, e^{-bx/2}\sqrt{\frac{A_v(x+1)}{-\ln z}+B_v}\; K_0\left(\sqrt{-2C_v\ln z + D_v x}\right)$$

$$\left.\times\, k_1\left(\sqrt{\frac{A_v(x^2+x)}{-\ln z}+B_v x}\right)dx\right] \quad \text{---- (6)}$$

For the second integral, we set $X = e^{-bx/2}$.
Thus, $x = \frac{-2}{b}\ln X$, substituting in (6);

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$$\therefore \int_0^\infty e^{-bx/2}\sqrt{\frac{A_v(x+1)}{-\ln z} + B_v K_0\left(\sqrt{-2C_v \ln z + D_v x}\right)}$$

$$\times K_1\left(\sqrt{\frac{A_v(x^2+x)}{-\ln z} + B_v x}\right) dx$$

$$= \frac{2}{b}\int_0^1 \sqrt{\frac{A_v(b-2\ln x)}{-b\ln z} + B_v K_0\left(\sqrt{-2C_v \ln z - \frac{2D_v \ln x}{b}}\right)}$$

$$\times K_1\left(\sqrt{-\frac{2}{b}\left[\frac{A_v(b-2\ln x)}{-b\ln z} + B_v\right]\ln x}\right) dx \quad \ldots\ldots (7)$$