Subject no. 1

1. $y = Y/Y_0 = Z_0/Z = 55\Omega / (46.4 + j\cdot34.3)\Omega = 0.766 - j\cdot0.567$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0310 + j\cdot0.0119)] / (0.02 + 0.0310 + j\cdot0.0119)$
$\Gamma = (-0.256) + j\cdot(-0.174) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.309\angle{-145.9°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

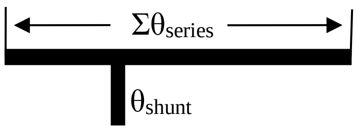
3. a) Lossless quadrature coupler, matched at the input; Isolation I = D + C =29.10dB
$P_{in} = 3.75mW = 5.740dBm$; $P_{is} = P_{in} - I = 5.740dBm - 29.10dB = -23.36dBm = 4.614\mu W$
b) L2, C5/2025, $\beta = 10^{-C/20} = 0.531$, $y_2 = 1.180$, $y_1 = 0.626$, $Z_1 = Z_0/y_1 = 79.8\ \Omega$, $Z_2 = Z_0/y_2 = 42.4\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot66)}\Omega = 57.45\Omega$
b) $Z_L = 66\Omega$ series with 0.73nH inductor at 10.0GHz $= 66.00\Omega + j\cdot(45.87)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 33.72\Omega + j\cdot(-23.43)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.80dB): $G = G_1 + G_4 = 5.9 + 11.6 = 17.5dB$; $G = G_2 + G_3 = 7.7 + 9.0 = 16.7dB$; $G = G_2 + G_4 = 7.7 + 11.6 = 19.3dB$; $G = G_3 + G_4 = 9.0 + 11.6 = 20.6dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.69dB=1.172$, $F_2 = 0.87dB=1.222$, $F_3 = 1.03dB=1.268$, $F_4 = 1.29dB=1.346$, $G_1 = 5.9dB=3.890$, $G_2 = 7.7dB=5.888$; $F(1,4) = 1.172 + (1.346-1)/3.890 = 1.261 = 1.01dB$; $F(2,3) = 1.222 + (1.268-1)/5.888 = 1.281 = 1.07dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.530 < 1$; $|S_{22}| = 0.263 < 1$; $K = 1.312 > 1$; $|\Delta| = |(-0.094)+ j\cdot(-0.070)| = 0.117 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 11.71 = 10.69dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.198$; $C_1 = (-0.547) + j\cdot(0.117)$; $\Gamma_S = (-0.672) + j\cdot(-0.144) = 0.687\angle{-167.9°}$
$B_2 = 0.775$; $C_2 = (-0.143) + j\cdot(-0.289)$; $\Gamma_L = (-0.237) + j\cdot(0.480) = 0.535\angle116.3°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 150.7°$; $\mathrm{Im}(y_S) = -1.892$; $\theta_{p1} = 117.9°$ <u>or</u> $\theta_{S2} = 17.3°$; $\mathrm{Im}(y_S) = 1.892$; $\theta_{p2} = 62.1°$
output: $\theta_{L1} = 3.0°$; $\mathrm{Im}(y_L) = -1.268$; $\theta_{p1} = 128.3°$ <u>or</u> $\theta_{L2} = 60.7°$; $\mathrm{Im}(y_L) = 1.268$; $\theta_{p2} = 51.7°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 3.0°$; $\mathrm{Im}(y_L) = -1.268 + (-1.892) = -3.159$; $\theta_{p1} = 107.6°$; $\theta_{S1} = 150.7°$;
d2) $\theta_{L2} = 60.7°$; $\mathrm{Im}(y_L) = 1.268 + (-1.892) = -0.624$; $\theta_{p2} = 148.0°$; $\theta_{S1} = 150.7°$;
d3) $\theta_{L1} = 3.0°$; $\mathrm{Im}(y_L) = -1.268 + (1.892) = 0.624$; $\theta_{p3} = 32.0°$; $\theta_{S2} = 17.3°$;
d4) $\theta_{L2} = 60.7°$; $\mathrm{Im}(y_L) = 1.268 + (1.892) = 3.159$; $\theta_{p4} = 72.4°$; $\theta_{S2} = 17.3°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 3.0 + 150.7 = 153.7$; $\theta_p = 107.6$; A ~ 16534.0
e2) $\Sigma\theta_s = 60.7 + 150.7 = 211.3$; $\theta_p = 148.0$; A ~ 31285.5
e3) $\Sigma\theta_s = 3.0 + 17.3 = 20.3$; $\theta_p = 32.0$; A ~ 649.2
e4) $\Sigma\theta_s = 60.7 + 17.3 = 77.9$; $\theta_p = 72.4$; A ~ 5645.7
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 2

1. $y = Y/Y_0 = Z_0/Z = 65\Omega / (44.8 - j\cdot 45.0)\Omega = 0.722 + j\cdot 0.725$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0345 + j\cdot 0.0370)] / (0.02 + 0.0345 + j\cdot 0.0370\ )$
$\Gamma = (-0.498) + j\cdot(-0.341) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.603\angle{-145.6°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

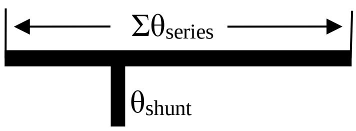
3. a) Lossless coupled line coupler, matched at the input; Isolation I =20.20dB
$P_{in} = 2.95\text{mW} = 4.698\text{dBm}$; $P_{is} = P_{in} - I = 4.698\text{dBm} - 20.20\text{dB} = -15.50\text{dBm} = 28.172\mu\text{W}$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.528$, $Z_{CE} = 89.94\Omega$, $Z_{CO} = 27.80\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 61)}\Omega = 55.23\Omega$
b) $Z_L = 61\Omega$ parallel with 0.97nH inductor at 7.3GHz $= 21.18\Omega + j\cdot(29.04)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-68.55)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 14.30dB): $G = G_1 + G_4 = 5.8 + 11.4 = 17.2\text{dB}$; $G = G_2 + G_3 = 7.4 + 8.4 = 15.8\text{dB}$; $G = G_2 + G_4 = 7.4 + 11.4 = 18.8\text{dB}$; $G = G_3 + G_4 = 8.4 + 11.4 = 19.8\text{dB}$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.60\text{dB}=1.148$, $F_2 = 0.75\text{dB}=1.189$, $F_3 = 0.97\text{dB}=1.250$, $F_4 = 1.20\text{dB}=1.318$, $G_1 = 5.8\text{dB}=3.802$, $G_2 = 7.4\text{dB}=5.495$; $F(1,4) = 1.148 + (1.318-1)/3.802 = 1.232 = 0.91\text{dB}$; $F(2,3) = 1.189 + (1.250-1)/5.495 = 1.246 = 0.96\text{dB}$;
$F(1,4) < F(2,3) \to$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.536 < 1$; $|\ S_{22}| = 0.251 < 1$; $K = 1.315 > 1$; $|\Delta| = |(-0.090)+ j\cdot(-0.076)| = 0.118 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2\text{-}1)}] = 10.97 = 10.40\text{dB}$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.210$; $C_1 = (-0.536) + j\cdot(0.180)$; $\Gamma_S = (-0.654) + j\cdot(-0.219) = 0.689\angle{-161.5°}$
$B_2 = 0.762$; $C_2 = (-0.156) + j\cdot(-0.273)$; $\Gamma_L = (-0.262) + j\cdot(0.457) = 0.527\angle 119.8°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 147.5°$; $\mathrm{Im}(y_S) = -1.902$; $\theta_{p1} = 117.7°$ <u>or</u> $\theta_{S2} = 14.0°$; $\mathrm{Im}(y_S) = 1.902$; $\theta_{p2} = 62.3°$
output: $\theta_{L1} = 1.0°$; $\mathrm{Im}(y_L) = -1.239$; $\theta_{p1} = 128.9°$ <u>or</u> $\theta_{L2} = 59.2°$; $\mathrm{Im}(y_L) = 1.239$; $\theta_{p2} = 51.1°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 1.0°$; $\mathrm{Im}(y_L) = -1.239 + (-1.902) = -3.142$; $\theta_{p1} = 107.7°$; $\theta_{S1} = 147.5°$;
d2) $\theta_{L2} = 59.2°$; $\mathrm{Im}(y_L) = 1.239 + (-1.902) = -0.663$; $\theta_{p2} = 146.5°$; $\theta_{S1} = 147.5°$;
d3) $\theta_{L1} = 1.0°$; $\mathrm{Im}(y_L) = -1.239 + (1.902) = 0.663$; $\theta_{p3} = 33.5°$; $\theta_{S2} = 14.0°$;
d4) $\theta_{L2} = 59.2°$; $\mathrm{Im}(y_L) = 1.239 + (1.902) = 3.142$; $\theta_{p4} = 72.3°$; $\theta_{S2} = 14.0°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 1.0 + 147.5 = 148.5$; $\theta_p = 107.7$; A ~ 15987.5
e2) $\Sigma\theta_s = 59.2 + 147.5 = 206.7$; $\theta_p = 146.5$; A ~ 30276.6
e3) $\Sigma\theta_s = 1.0 + 14.0 = 14.9$; $\theta_p = 33.5$; A ~ 501.0
e4) $\Sigma\theta_s = 59.2 + 14.0 = 73.2$; $\theta_p = 72.3$; A ~ 5292.1
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 3

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (69.0 - j\cdot 43.2)\Omega = 0.521 + j\cdot 0.326$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0198 - j\cdot 0.0238)] / (0.02 + 0.0198 - j\cdot 0.0238\ )$
$\Gamma = (-0.260) + j\cdot(0.443) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.513\angle 120.4° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

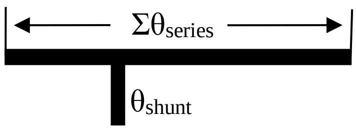
3. a) Lossless quadrature coupler, matched at the input; Isolation I =23.70dB
$P_{in} = 3.50mW = 5.441dBm$; $P_{is} = P_{in} - I = 5.441dBm - 23.70dB = -18.26dBm = 14.930\mu W$
b) L2, C5/2025, $\beta = 10^{-C/20} = 0.490$, $y_2 = 1.147$, $y_1 = 0.562$, $Z_1 = Z_0/y_1 = 89.0\ \Omega$, $Z_2 = Z_0/y_2 = 43.6\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 59)}\Omega = 54.31\Omega$
b) $Z_L = 59\Omega$ parallel with 1.18nH inductor at 8.9GHz $= 32.79\Omega + j\cdot(29.32)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-44.71)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.80dB): $G = G_1 + G_4 = 5.7 + 11.3 = 17.0dB$; $G = G_2 + G_3 = 8.9 + 9.3 = 18.2dB$; $G = G_2 + G_4 = 8.9 + 11.3 = 20.2dB$; $G = G_3 + G_4 = 9.3 + 11.3 = 20.6dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.62dB=1.153$, $F_2 = 0.74dB=1.186$, $F_3 = 0.92dB=1.236$, $F_4 = 1.25dB=1.334$, $G_1 = 5.7dB=3.715$, $G_2 = 8.9dB=7.762$; $F(1,4) = 1.153 + (1.334-1)/3.715 = 1.243 = 0.95dB$; $F(2,3) = 1.186 + (1.236-1)/7.762 = 1.229 = 0.89dB$;
$F(1,4) > F(2,3) \rightarrow$ For minimal noise factor we must use devices 2,3

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.553 < 1$; $|\ S_{22}| = 0.230 < 1$; $K = 1.308 > 1$; $|\Delta| = |(-0.098)+ j\cdot(-0.091)| = 0.134 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 9.67 = 9.86dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.235$; $C_1 = (-0.497) + j\cdot(0.299)$; $\Gamma_S = (-0.598) + j\cdot(-0.361) = 0.699\angle\text{-}148.9°$
$B_2 = 0.729$; $C_2 = (-0.179) + j\cdot(-0.236)$; $\Gamma_L = (-0.310) + j\cdot(0.409) = 0.513\angle 127.2°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 141.6°$; $\mathrm{Im}(y_S) = -1.953$; $\theta_{p1} = 117.1°$ <u>or</u> $\theta_{S2} = 7.3°$; $\mathrm{Im}(y_S) = 1.953$; $\theta_{p2} = 62.9°$
output: $\theta_{L1} = 176.9°$; $\mathrm{Im}(y_L) = -1.197$; $\theta_{p1} = 129.9°$ <u>or</u> $\theta_{L2} = 56.0°$; $\mathrm{Im}(y_L) = 1.197$; $\theta_{p2} = 50.1°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 176.9°$; $\mathrm{Im}(y_L) = -1.197 + (-1.953) = -3.149$; $\theta_{p1} = 107.6°$; $\theta_{S1} = 141.6°$;
d2) $\theta_{L2} = 56.0°$; $\mathrm{Im}(y_L) = 1.197 + (-1.953) = -0.756$; $\theta_{p2} = 142.9°$; $\theta_{S1} = 141.6°$;
d3) $\theta_{L1} = 176.9°$; $\mathrm{Im}(y_L) = -1.197 + (1.953) = 0.756$; $\theta_{p3} = 37.1°$; $\theta_{S2} = 7.3°$;
d4) $\theta_{L2} = 56.0°$; $\mathrm{Im}(y_L) = 1.197 + (1.953) = 3.149$; $\theta_{p4} = 72.4°$; $\theta_{S2} = 7.3°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 176.9 + 141.6 = 318.5$; $\theta_p = 107.6$; A ~ 34272.9
e2) $\Sigma\theta_s = 56.0 + 141.6 = 197.6$; $\theta_p = 142.9$; A ~ 28236.8
e3) $\Sigma\theta_s = 176.9 + 7.3 = 184.2$; $\theta_p = 37.1$; A ~ 6829.5
e4) $\Sigma\theta_s = 56.0 + 7.3 = 63.3$; $\theta_p = 72.4$; A ~ 4579.4
Smallest substrate area is occupied by solution e4 (d4)



Subject no. 4

1. $y = Y/Y_0 = Z_0/Z = 65\Omega\ /\ (62.1 + j\cdot 66.7)\Omega = 0.486 - j\cdot 0.522$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y)\ /\ (Y_0 + Y) = [0.02 - (0.0290 + j\cdot 0.0380)]\ /\ (0.02 + 0.0290 + j\cdot 0.0380\ )$
$\Gamma = (-0.490) + j\cdot(-0.395) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.630\angle\text{-}141.1° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

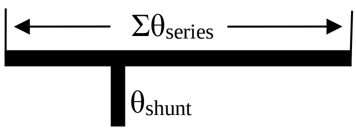
3. a) Lossless coupled line coupler, matched at the input; Isolation I =24.60dB
$P_{in} = 3.35mW = 5.250dBm$; $P_{is} = P_{in} - I = 5.250dBm - 24.60dB = -19.35dBm = 11.616\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.534$, $Z_{CE} = 90.71\Omega$, $Z_{CO} = 27.56\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 51)}\Omega = 50.50\Omega$
b) $Z_L = 51\Omega$ series with 0.73nH inductor at 9.8GHz $= 51.00\Omega + j\cdot(44.95)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 28.14\Omega + j\cdot(-24.80)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.15dB): $G = G_1 + G_4 = 6.1 + 11.0 = 17.1dB$; $G = G_2 + G_3 = 7.0 + 8.9 = 15.9dB$; $G = G_2 + G_4 = 7.0 + 11.0 = 18.0dB$; $G = G_3 + G_4 = 8.9 + 11.0 = 19.9dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.64dB=1.159$, $F_2 = 0.76dB=1.191$, $F_3 = 0.94dB=1.242$, $F_4 = 1.24dB=1.330$, $G_1 = 6.1dB=4.074$, $G_2 = 7.0dB=5.012$; $F(1,4) = 1.159 + (1.330-1)/4.074 = 1.240 = 0.93dB$; $F(2,3) = 1.191 + (1.242-1)/5.012 = 1.257 = 0.99dB$;
$F(1,4) < F(2,3) \to$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.540 < 1$; $|\ S_{22}| = 0.245 < 1$; $K = 1.310 > 1$; $|\Delta| = |(-0.091)+ j\cdot(-0.080)| = 0.121 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2\text{-}1)}] = 10.64 = 10.27dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.217$; $C_1 = (-0.529) + j\cdot(0.210)$; $\Gamma_S = (-0.643) + j\cdot(-0.256) = 0.692\angle\text{-}158.3°$
$B_2 = 0.754$; $C_2 = (-0.163) + j\cdot(-0.264)$; $\Gamma_L = (-0.276) + j\cdot(0.446) = 0.525\angle 121.7°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 146.1°$; $\mathrm{Im}(y_S) = -1.919$; $\theta_{p1} = 117.5°$ <u>or</u> $\theta_{S2} = 12.3°$; $\mathrm{Im}(y_S) = 1.919$; $\theta_{p2} = 62.5°$
output: $\theta_{L1} = 180.0°$; $\mathrm{Im}(y_L) = -1.233$; $\theta_{p1} = 129.1°$ <u>or</u> $\theta_{L2} = 58.3°$; $\mathrm{Im}(y_L) = 1.233$; $\theta_{p2} = 50.9°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 180.0°$; $\mathrm{Im}(y_L) = -1.233 + (-1.919) = -3.151$; $\theta_{p1} = 107.6°$; $\theta_{S1} = 146.1°$;
d2) $\theta_{L2} = 58.3°$; $\mathrm{Im}(y_L) = 1.233 + (-1.919) = -0.686$; $\theta_{p2} = 145.5°$; $\theta_{S1} = 146.1°$;
d3) $\theta_{L1} = 180.0°$; $\mathrm{Im}(y_L) = -1.233 + (1.919) = 0.686$; $\theta_{p3} = 34.5°$; $\theta_{S2} = 12.3°$;
d4) $\theta_{L2} = 58.3°$; $\mathrm{Im}(y_L) = 1.233 + (1.919) = 3.151$; $\theta_{p4} = 72.4°$; $\theta_{S2} = 12.3°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 180.0 + 146.1 = 326.1$; $\theta_p = 107.6$; A ~ 35085.1
e2) $\Sigma\theta_s = 58.3 + 146.1 = 204.4$; $\theta_p = 145.5$; A ~ 29750.0
e3) $\Sigma\theta_s = 180.0 + 12.3 = 192.2$; $\theta_p = 34.5$; A ~ 6624.1
e4) $\Sigma\theta_s = 58.3 + 12.3 = 70.6$; $\theta_p = 72.4$; A ~ 5110.7
Smallest substrate area is occupied by solution e4 (d4)



Subject no. 5

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (37.8 - j\cdot 31.0)\Omega = 0.791 + j\cdot 0.649$

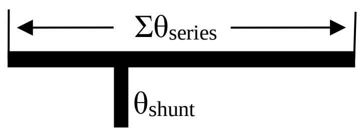
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0244 + j\cdot 0.0340)] / (0.02 + 0.0244 + j\cdot 0.0340\ )$
$\Gamma = (-0.432) + j\cdot(-0.435) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.613\angle{-134.8°} \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =21.70dB
$P_{in} = 1.25mW = 0.969dBm$; $P_{is} = P_{in} - I = 0.969dBm - 21.70dB = -20.73dBm = 8.451\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.613$, $Z_{CE} = 102.09\Omega$, $Z_{CO} = 24.49\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 72)}\Omega = 60.00\Omega$
b) $Z_L = 72\Omega$ parallel with 1.22nH inductor at 8.8GHz = $33.66\Omega + j\cdot(35.92)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-53.37)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.75dB): $G = G_1 + G_4 = 6.2 + 10.2 = 16.4dB$; $G = G_2 + G_3 = 8.4 + 9.3 = 17.7dB$; $G = G_2 + G_4 = 8.4 + 10.2 = 18.6dB$; $G = G_3 + G_4 = 9.3 + 10.2 = 19.5dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.66dB=1.164$, $F_2 = 0.81dB=1.205$, $F_3 = 1.08dB=1.282$, $F_4 = 1.11dB=1.291$, $G_1 = 6.2dB=4.169$, $G_2 = 8.4dB=6.918$; $F(1,4) = 1.164 + (1.291-1)/4.169 = 1.234 = 0.91dB$; $F(2,3) = 1.205 + (1.282-1)/6.918 = 1.247 = 0.96dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.530 < 1$; $|\ S_{22}| = 0.287 < 1$; $K = 1.222 > 1$; $|\Delta| = |(-0.120)+ j\cdot(-0.081)| = 0.144 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 13.98 = 11.45dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.178$; $C_1 = (-0.557) + j\cdot(-0.017)$; $\Gamma_S = (-0.717) + j\cdot(0.022) = 0.717\angle 178.2°$
$B_2 = 0.781$; $C_2 = (-0.124) + j\cdot(-0.318)$; $\Gamma_L = (-0.213) + j\cdot(0.550) = 0.589\angle 111.2°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 158.8°$; $\mathrm{Im}(y_S) = -2.057$; $\theta_{p1} = 115.9°$ <u>or</u> $\theta_{S2} = 23.0°$; $\mathrm{Im}(y_S) = 2.057$; $\theta_{p2} = 64.1°$
output: $\theta_{L1} = 7.5°$; $\mathrm{Im}(y_L) = -1.460$; $\theta_{p1} = 124.4°$ <u>or</u> $\theta_{L2} = 61.3°$; $\mathrm{Im}(y_L) = 1.460$; $\theta_{p2} = 55.6°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 7.5°$; $\mathrm{Im}(y_L) = -1.460 + (-2.057) = -3.517$; $\theta_{p1} = 105.9°$; $\theta_{S1} = 158.8°$;
d2) $\theta_{L2} = 61.3°$; $\mathrm{Im}(y_L) = 1.460 + (-2.057) = -0.597$; $\theta_{p2} = 149.1°$; $\theta_{S1} = 158.8°$;
d3) $\theta_{L1} = 7.5°$; $\mathrm{Im}(y_L) = -1.460 + (2.057) = 0.597$; $\theta_{p3} = 30.9°$; $\theta_{S2} = 23.0°$;
d4) $\theta_{L2} = 61.3°$; $\mathrm{Im}(y_L) = 1.460 + (2.057) = 3.517$; $\theta_{p4} = 74.1°$; $\theta_{S2} = 23.0°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 7.5 + 158.8 = 166.2$; $\theta_p = 105.9$; A ~ 17600.1
e2) $\Sigma\theta_s = 61.3 + 158.8 = 220.1$; $\theta_p = 149.1$; A ~ 32829.2
e3) $\Sigma\theta_s = 7.5 + 23.0 = 30.4$; $\theta_p = 30.9$; A ~ 938.9
e4) $\Sigma\theta_s = 61.3 + 23.0 = 84.3$; $\theta_p = 74.1$; A ~ 6249.5
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 6

1. $y = Y/Y_0 = Z_0/Z = 65\Omega$ / $(65.1 - j\cdot61.9)\Omega = 0.524 + j\cdot0.499$

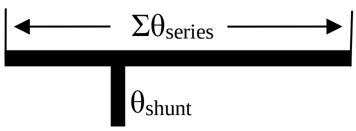
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0263 + j\cdot0.0351)] / (0.02 + 0.0263 + j\cdot0.0351)$
$\Gamma = (-0.451) + j\cdot(-0.416) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.614\angle\text{-}137.3° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I = D + C =25.55dB
$P_{in} = 1.20\text{mW} = 0.792\text{dBm}$; $P_{is} = P_{in} - I = 0.792\text{dBm} - 25.55\text{dB} = -24.76\text{dBm} = 3.343\mu\text{W}$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.528$, $Z_{CE} = 89.94\Omega$, $Z_{CO} = 27.80\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot62)}\Omega = 55.68\Omega$
b) $Z_L = 62\Omega$ parallel with 0.30pF capacitor at 8.2GHz = $32.32\Omega + j\cdot(-30.97)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(47.92)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.70dB): $G = G_1 + G_4 = 6.7 + 11.3 = 18.0$dB; $G = G_2 + G_3 = 7.6 + 9.4 = 17.0$dB; $G = G_2 + G_4 = 7.6 + 11.3 = 18.9$dB; $G = G_3 + G_4 = 9.4 + 11.3 = 20.7$dB;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.58\text{dB}=1.143$, $F_2 = 0.83\text{dB}=1.211$, $F_3 = 0.98\text{dB}=1.253$, $F_4 = 1.29\text{dB}=1.346$, $G_1 = 6.7\text{dB}=4.677$, $G_2 = 7.6\text{dB}=5.754$; $F(1,4) = 1.143 + (1.346-1)/4.677 = 1.217 = 0.85$dB; $F(2,3) = 1.211 + (1.253-1)/5.754 = 1.271 = 1.04$dB;
$F(1,4) < F(2,3) \to$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.532 < 1$; $|S_{22}| = 0.257 < 1$; $K = 1.321 > 1$; $|\Delta| = |(-0.091)+ j\cdot(-0.072)| = 0.116 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 11.29 = 10.53$dB
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.204$; $C_1 = (-0.541) + j\cdot(0.149)$; $\Gamma_S = (-0.661) + j\cdot(-0.182) = 0.685\angle\text{-}164.6°$
$B_2 = 0.770$; $C_2 = (-0.149) + j\cdot(-0.281)$; $\Gamma_L = (-0.247) + j\cdot(0.467) = 0.528\angle117.9°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 148.9°$; $\mathrm{Im}(y_S) = -1.883$; $\theta_{p1} = 118.0°$ <u>or</u> $\theta_{S2} = 15.7°$; $\mathrm{Im}(y_S) = 1.883$; $\theta_{p2} = 62.0°$
output: $\theta_{L1} = 2.0°$; $\mathrm{Im}(y_L) = -1.243$; $\theta_{p1} = 128.8°$ <u>or</u> $\theta_{L2} = 60.1°$; $\mathrm{Im}(y_L) = 1.243$; $\theta_{p2} = 51.2°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 2.0°$; $\mathrm{Im}(y_L) = -1.243 + (-1.883) = -3.127$; $\theta_{p1} = 107.7°$; $\theta_{S1} = 148.9°$;
d2) $\theta_{L2} = 60.1°$; $\mathrm{Im}(y_L) = 1.243 + (-1.883) = -0.640$; $\theta_{p2} = 147.4°$; $\theta_{S1} = 148.9°$;
d3) $\theta_{L1} = 2.0°$; $\mathrm{Im}(y_L) = -1.243 + (1.883) = 0.640$; $\theta_{p3} = 32.6°$; $\theta_{S2} = 15.7°$;
d4) $\theta_{L2} = 60.1°$; $\mathrm{Im}(y_L) = 1.243 + (1.883) = 3.127$; $\theta_{p4} = 72.3°$; $\theta_{S2} = 15.7°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 2.0 + 148.9 = 150.9$; $\theta_p = 107.7$; A ~ 16261.1
e2) $\Sigma\theta_s = 60.1 + 148.9 = 209.1$; $\theta_p = 147.4$; A ~ 30815.5
e3) $\Sigma\theta_s = 2.0 + 15.7 = 17.7$; $\theta_p = 32.6$; A ~ 575.7
e4) $\Sigma\theta_s = 60.1 + 15.7 = 75.8$; $\theta_p = 72.3$; A ~ 5476.7
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 7

1. $y = Y/Y_0 = Z_0/Z = 95\Omega\ /\ (62.7 - j\cdot 64.4)\Omega = 0.737 + j\cdot 0.757$

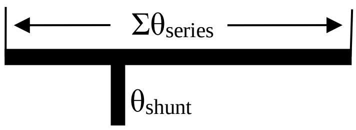
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y)\ /\ (Y_0 + Y) = [0.02 - (0.0295 + j\cdot 0.0280)]\ /\ (0.02 + 0.0295 + j\cdot 0.0280\ )$
$\Gamma = (-0.388) + j\cdot(-0.346) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.520\angle{-138.2°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I =23.90dB
$P_{in} = 2.00mW = 3.010dBm$; $P_{is} = P_{in} - I = 3.010dBm - 23.90dB = -20.89dBm = 8.148\mu W$
b) L2, C5/2025, $\beta = 10^{-C/20} = 0.546$, $y_2 = 1.194$, $y_1 = 0.652$, $Z_1 = Z_0/y_1 = 76.6\ \Omega$, $Z_2 = Z_0/y_2 = 41.9\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 44)}\Omega = 46.90\Omega$
b) $Z_L = 44\Omega$ parallel with 0.35pF capacitor at 7.2GHz $= 29.62\Omega + j\cdot(-20.64)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(34.83)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.60dB): $G = G_1 + G_4 = 5.5 + 10.6 = 16.1dB$; $G = G_2 + G_3 = 8.9 + 9.6 = 18.5dB$; $G = G_2 + G_4 = 8.9 + 10.6 = 19.5dB$; $G = G_3 + G_4 = 9.6 + 10.6 = 20.2dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.65dB=1.161$, $F_2 = 0.86dB=1.219$, $F_3 = 0.91dB=1.233$, $F_4 = 1.20dB=1.318$, $G_1 = 5.5dB=3.548$, $G_2 = 8.9dB=7.762$; $F(1,4) = 1.161 + (1.318-1)/3.548 = 1.251 = 0.97dB$; $F(2,3) = 1.219 + (1.233-1)/7.762 = 1.260 = 1.00dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.615 < 1$; $|\ S_{22}| = 0.237 < 1$; $K = 1.287 > 1$; $|\Delta| = |(-0.133)+ j\cdot(-0.127)| = 0.184 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 8.12 = 9.09dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.288$; $C_1 = (-0.379) + j\cdot(0.486)$; $\Gamma_S = (-0.455) + j\cdot(-0.583) = 0.740\angle{-128.0°}$
$B_2 = 0.644$; $C_2 = (-0.215) + j\cdot(-0.148)$; $\Gamma_L = (-0.421) + j\cdot(0.290) = 0.511\angle 145.4°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 132.8°$; $\mathrm{Im}(y_S) = -2.198$; $\theta_{p1} = 114.5°$ <u>or</u> $\theta_{S2} = 175.1°$; $\mathrm{Im}(y_S) = 2.198$; $\theta_{p2} = 65.5°$
output: $\theta_{L1} = 167.7°$; $\mathrm{Im}(y_L) = -1.190$; $\theta_{p1} = 130.0°$ <u>or</u> $\theta_{L2} = 46.9°$; $\mathrm{Im}(y_L) = 1.190$; $\theta_{p2} = 50.0°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 167.7°$; $\mathrm{Im}(y_L) = -1.190 + (-2.198) = -3.388$; $\theta_{p1} = 106.4°$; $\theta_{S1} = 132.8°$;
d2) $\theta_{L2} = 46.9°$; $\mathrm{Im}(y_L) = 1.190 + (-2.198) = -1.008$; $\theta_{p2} = 134.8°$; $\theta_{S1} = 132.8°$;
d3) $\theta_{L1} = 167.7°$; $\mathrm{Im}(y_L) = -1.190 + (2.198) = 1.008$; $\theta_{p3} = 45.2°$; $\theta_{S2} = 175.1°$;
d4) $\theta_{L2} = 46.9°$; $\mathrm{Im}(y_L) = 1.190 + (2.198) = 3.388$; $\theta_{p4} = 73.6°$; $\theta_{S2} = 175.1°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 167.7 + 132.8 = 300.5$; $\theta_p = 106.4$; A ~ 31984.5
e2) $\Sigma\theta_s = 46.9 + 132.8 = 179.7$; $\theta_p = 134.8$; A ~ 24221.7
e3) $\Sigma\theta_s = 167.7 + 175.1 = 342.8$; $\theta_p = 45.2$; A ~ 15505.1
e4) $\Sigma\theta_s = 46.9 + 175.1 = 222.0$; $\theta_p = 73.6$; A ~ 16331.6
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 8

1. $y = Y/Y_0 = Z_0/Z = 30\Omega / (51.3 + j\cdot 64.0)\Omega = 0.229 - j\cdot 0.285$

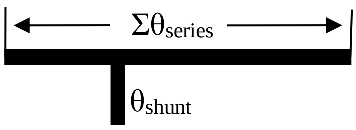
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0216 + j\cdot 0.0125)] / (0.02 + 0.0216 + j\cdot 0.0125)$
$\Gamma = (-0.118) + j\cdot(-0.265) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.290\angle{-114.0°} \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =27.95dB
P_{in} = 1.15mW = 0.607dBm; $P_{is} = P_{in} - I$ = 0.607dBm − 27.95dB = -27.34dBm = 1.844μW
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.449$, $y_1 = 0.449$, $y_2 = 0.893$, $Z_1 = Z_0/y_1 = 111.3\ \Omega$, $Z_2 = Z_0/y_2 = 56.0\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 48)}\Omega = 48.99\Omega$
b) $Z_L = 48\Omega$ series with 0.31pF capacitor at 8.4GHz = $48.00\Omega + j\cdot(-61.12)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 19.07\Omega + j\cdot(24.29)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.30dB): $G = G_1 + G_4$ = 5.1 + 11.0 = 16.1dB; $G = G_2 + G_3$ = 7.4 + 9.8 = 17.2dB; $G = G_2 + G_4$ = 7.4 + 11.0 = 18.4dB; $G = G_3 + G_4$ = 9.8 + 11.0 = 20.8dB;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
F_1 = 0.57dB=1.140, F_2 = 0.74dB=1.186, F_3 = 1.00dB=1.259, F_4 = 1.12dB=1.294, G_1 = 5.1dB=3.236, G_2 = 7.4dB=5.495; F(1,4) = 1.140 + (1.294−1)/3.236 = 1.231 = 0.90dB; F(2,3) = 1.186 + (1.259−1)/5.495 = 1.239 = 0.93dB;
F(1,4) < F(2,3) → For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.559 < 1$; $|S_{22}| = 0.230 < 1$; $K = 1.318 > 1$; $|\Delta| = |(-0.096)+ j\cdot(-0.094)| = 0.134 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}]$ = 9.39 = 9.73dB
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.242$; $C_1 = (-0.484) + j\cdot(0.325)$; $\Gamma_S = (-0.581) + j\cdot(-0.390) = 0.700\angle{-146.1°}$
$B_2 = 0.722$; $C_2 = (-0.186) + j\cdot(-0.225)$; $\Gamma_L = (-0.325) + j\cdot(0.392) = 0.509\angle 129.6°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 140.3°$; $\mathrm{Im}(y_S) = -1.960$; $\theta_{p1} = 117.0°$ or $\theta_{S2} = 5.8°$; $\mathrm{Im}(y_S) = 1.960$; $\theta_{p2} = 63.0°$
output: $\theta_{L1} = 175.5°$; $\mathrm{Im}(y_L) = -1.182$; $\theta_{p1} = 130.2°$ or $\theta_{L2} = 54.9°$; $\mathrm{Im}(y_L) = 1.182$; $\theta_{p2} = 49.8°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 175.5°$; $\mathrm{Im}(y_L) = -1.182 + (-1.960) = -3.142$; $\theta_{p1} = 107.7°$; $\theta_{S1} = 140.3°$;
d2) $\theta_{L2} = 54.9°$; $\mathrm{Im}(y_L) = 1.182 + (-1.960) = -0.777$; $\theta_{p2} = 142.1°$; $\theta_{S1} = 140.3°$;
d3) $\theta_{L1} = 175.5°$; $\mathrm{Im}(y_L) = -1.182 + (1.960) = 0.777$; $\theta_{p3} = 37.9°$; $\theta_{S2} = 5.8°$;
d4) $\theta_{L2} = 54.9°$; $\mathrm{Im}(y_L) = 1.182 + (1.960) = 3.142$; $\theta_{p4} = 72.3°$; $\theta_{S2} = 5.8°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute all solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s$ = 175.5 + 140.3 = 315.7 ; θ_p = 107.7 ; A ~ 33991.4
e2) $\Sigma\theta_s$ = 54.9 + 140.3 = 195.2 ; θ_p = 142.1 ; A ~ 27740.4
e3) $\Sigma\theta_s$ = 175.5 + 5.8 = 181.3 ; θ_p = 37.9 ; A ~ 6863.9
e4) $\Sigma\theta_s$ = 54.9 + 5.8 = 60.7 ; θ_p = 72.3 ; A ~ 4394.1
Smallest substrate area is occupied by solution e4 (d4)



Subject no. 9

1. $y = Y/Y_0 = Z_0/Z = 85\Omega / (67.7 - j\cdot 54.8)\Omega = 0.759 + j\cdot 0.614$

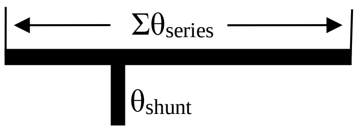
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0369 - j\cdot 0.0295)] / (0.02 + 0.0369 - j\cdot 0.0295\ )$
$\Gamma = (-0.446) + j\cdot(0.287) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.530\angle 147.2° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =26.05dB
$P_{in} = 1.95mW = 2.900dBm$; $P_{is} = P_{in} - I = 2.900dBm - 26.05dB = -23.15dBm = 4.842\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.627$, $y_1 = 0.627$, $y_2 = 0.779$, $Z_1 = Z_0/y_1 = 79.7\ \Omega$, $Z_2 = Z_0/y_2 = 64.2\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 64)}\Omega = 56.57\Omega$
b) $Z_L = 64\Omega$ parallel with 1.17nH inductor at 8.9GHz $= 32.71\Omega + j\cdot(31.99)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-48.91)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.15dB): $G = G_1 + G_4 = 5.4 + 10.3 = 15.7dB$; $G = G_2 + G_3 = 8.2 + 9.4 = 17.6dB$; $G = G_2 + G_4 = 8.2 + 10.3 = 18.5dB$; $G = G_3 + G_4 = 9.4 + 10.3 = 19.7dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.54dB=1.132$, $F_2 = 0.84dB=1.213$, $F_3 = 0.91dB=1.233$, $F_4 = 1.25dB=1.334$, $G_1 = 5.4dB=3.467$, $G_2 = 8.2dB=6.607$; $F(1,4) = 1.132 + (1.334-1)/3.467 = 1.229 = 0.89dB$; $F(2,3) = 1.213 + (1.233-1)/6.607 = 1.264 = 1.02dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.530 < 1$; $|\ S_{22}| = 0.290 < 1$; $K = 1.213 > 1$; $|\Delta| = |(-0.123)+ j\cdot(-0.084)| = 0.149 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2\text{-}1)}] = 14.28 = 11.55dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.175$; $C_1 = (-0.556) + j\cdot(-0.034)$; $\Gamma_S = (-0.719) + j\cdot(0.043) = 0.721\angle 176.5°$
$B_2 = 0.781$; $C_2 = (-0.121) + j\cdot(-0.322)$; $\Gamma_L = (-0.209) + j\cdot(0.558) = 0.596\angle 110.6°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 159.8°$; $\mathrm{Im}(y_S) = -2.079$; $\theta_{p1} = 115.7°$ <u>or</u> $\theta_{S2} = 23.7°$; $\mathrm{Im}(y_S) = 2.079$; $\theta_{p2} = 64.3°$
output: $\theta_{L1} = 8.0°$; $\mathrm{Im}(y_L) = -1.484$; $\theta_{p1} = 124.0°$ <u>or</u> $\theta_{L2} = 61.4°$; $\mathrm{Im}(y_L) = 1.484$; $\theta_{p2} = 56.0°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 8.0°$; $\mathrm{Im}(y_L) = -1.484 + (-2.079) = -3.563$; $\theta_{p1} = 105.7°$; $\theta_{S1} = 159.8°$;
d2) $\theta_{L2} = 61.4°$; $\mathrm{Im}(y_L) = 1.484 + (-2.079) = -0.594$; $\theta_{p2} = 149.3°$; $\theta_{S1} = 159.8°$;
d3) $\theta_{L1} = 8.0°$; $\mathrm{Im}(y_L) = -1.484 + (2.079) = 0.594$; $\theta_{p3} = 30.7°$; $\theta_{S2} = 23.7°$;
d4) $\theta_{L2} = 61.4°$; $\mathrm{Im}(y_L) = 1.484 + (2.079) = 3.563$; $\theta_{p4} = 74.3°$; $\theta_{S2} = 23.7°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 8.0 + 159.8 = 167.8$; $\theta_p = 105.7$; A ~ 17731.5
e2) $\Sigma\theta_s = 61.4 + 159.8 = 221.2$; $\theta_p = 149.3$; A ~ 33019.7
e3) $\Sigma\theta_s = 8.0 + 23.7 = 31.7$; $\theta_p = 30.7$; A ~ 973.6
e4) $\Sigma\theta_s = 61.4 + 23.7 = 85.1$; $\theta_p = 74.3$; A ~ 6325.1
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 10

1. $y = Y/Y_0 = Z_0/Z = 95\Omega / (52.5 - j\cdot 67.4)\Omega = 0.683 + j\cdot 0.877$

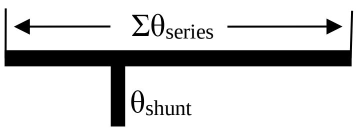
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0355 + j\cdot 0.0217)] / (0.02 + 0.0355 + j\cdot 0.0217\ )$
$\Gamma = (-0.375) + j\cdot(-0.244) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.448\angle{-146.9°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =24.90dB
$P_{in} = 3.80mW = 5.798dBm$; $P_{is} = P_{in} - I = 5.798dBm - 24.90dB = -19.10dBm = 12.297\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.572$, $Z_{CE} = 95.84\Omega$, $Z_{CO} = 26.08\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 29)}\Omega = 38.08\Omega$
b) $Z_L = 29\Omega$ parallel with 1.16nH inductor at 6.9GHz = $21.76\Omega + j\cdot(12.55)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-28.83)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.35dB): $G = G_1 + G_4 = 5.3 + 10.8 = 16.1dB$; $G = G_2 + G_3 = 8.0 + 9.4 = 17.4dB$; $G = G_2 + G_4 = 8.0 + 10.8 = 18.8dB$; $G = G_3 + G_4 = 9.4 + 10.8 = 20.2dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.65dB=1.161$, $F_2 = 0.86dB=1.219$, $F_3 = 1.00dB=1.259$, $F_4 = 1.16dB=1.306$, $G_1 = 5.3dB=3.388$, $G_2 = 8.0dB=6.310$; $F(1,4) = 1.161 + (1.306-1)/3.388 = 1.252 = 0.98dB$; $F(2,3) = 1.219 + (1.259-1)/6.310 = 1.268 = 1.03dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.550 < 1$; $|\ S_{22}| = 0.320 < 1$; $K = 1.191 > 1$; $|\Delta| = |(-0.137)+ j\cdot(-0.101)| = 0.170 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 17.58 = 12.45dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.171$; $C_1 = (-0.525) + j\cdot(-0.196)$; $\Gamma_S = (-0.695) + j\cdot(0.260) = 0.742\angle 159.5°$
$B_2 = 0.771$; $C_2 = (-0.081) + j\cdot(-0.337)$; $\Gamma_L = (-0.146) + j\cdot(0.606) = 0.624\angle 103.5°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 169.2°$; $\mathrm{Im}(y_S) = -2.215$; $\theta_{p1} = 114.3°$ <u>or</u> $\theta_{S2} = 31.3°$; $\mathrm{Im}(y_S) = 2.215$; $\theta_{p2} = 65.7°$
output: $\theta_{L1} = 12.5°$; $\mathrm{Im}(y_L) = -1.595$; $\theta_{p1} = 122.1°$ <u>or</u> $\theta_{L2} = 64.0°$; $\mathrm{Im}(y_L) = 1.595$; $\theta_{p2} = 57.9°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 12.5°$; $\mathrm{Im}(y_L) = -1.595 + (-2.215) = -3.810$; $\theta_{p1} = 104.7°$; $\theta_{S1} = 169.2°$;
d2) $\theta_{L2} = 64.0°$; $\mathrm{Im}(y_L) = 1.595 + (-2.215) = -0.619$; $\theta_{p2} = 148.2°$; $\theta_{S1} = 169.2°$;
d3) $\theta_{L1} = 12.5°$; $\mathrm{Im}(y_L) = -1.595 + (2.215) = 0.619$; $\theta_{p3} = 31.8°$; $\theta_{S2} = 31.3°$;
d4) $\theta_{L2} = 64.0°$; $\mathrm{Im}(y_L) = 1.595 + (2.215) = 3.810$; $\theta_{p4} = 75.3°$; $\theta_{S2} = 31.3°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 12.5 + 169.2 = 181.7$; $\theta_p = 104.7$; A ~ 19028.6
e2) $\Sigma\theta_s = 64.0 + 169.2 = 233.2$; $\theta_p = 148.2$; A ~ 34560.6
e3) $\Sigma\theta_s = 12.5 + 31.3 = 43.8$; $\theta_p = 31.8$; A ~ 1392.0
e4) $\Sigma\theta_s = 64.0 + 31.3 = 95.2$; $\theta_p = 75.3$; A ~ 7170.8
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 11

1. $y = Y/Y_0 = Z_0/Z = 60\Omega / (41.2 - j\cdot 46.1)\Omega = 0.647 + j\cdot 0.724$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0399 + j\cdot 0.0125)] / (0.02 + 0.0399 + j\cdot 0.0125)$
$\Gamma = (-0.360) + j\cdot(-0.134) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.384\angle{-159.7°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

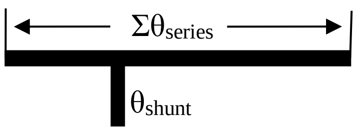
3. a) Lossless coupled line coupler, matched at the input; Isolation I =21.10dB
$P_{in} = 4.05mW = 6.075dBm$; $P_{is} = P_{in} - I = 6.075dBm - 21.10dB = -15.03dBm = 31.438\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.550$, $Z_{CE} = 92.74\Omega$, $Z_{CO} = 26.96\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 62)}\Omega = 55.68\Omega$
b) $Z_L = 62\Omega$ parallel with 0.26pF capacitor at 9.9GHz $= 30.92\Omega + j\cdot(-31.00)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(50.14)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.70dB): $G = G_1 + G_4 = 5.5 + 11.6 = 17.1dB$; $G = G_2 + G_3 = 8.5 + 9.8 = 18.3dB$; $G = G_2 + G_4 = 8.5 + 11.6 = 20.1dB$; $G = G_3 + G_4 = 9.8 + 11.6 = 21.4dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.68dB=1.169$, $F_2 = 0.70dB=1.175$, $F_3 = 1.01dB=1.262$, $F_4 = 1.20dB=1.318$, $G_1 = 5.5dB=3.548$, $G_2 = 8.5dB=7.079$; $F(1,4) = 1.169 + (1.318-1)/3.548 = 1.259 = 1.00dB$; $F(2,3) = 1.175 + (1.262-1)/7.079 = 1.220 = 0.86dB$;
$F(1,4) > F(2,3) \rightarrow$ For minimal noise factor we must use devices 2,3

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.542 < 1$; $|S_{22}| = 0.308 < 1$; $K = 1.197 > 1$; $|\Delta| = |(-0.131)+ j\cdot(-0.091)| = 0.159 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 16.24 = 12.11dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.174$; $C_1 = (-0.544) + j\cdot(-0.132)$; $\Gamma_S = (-0.715) + j\cdot(0.174) = 0.735\angle 166.3°$
$B_2 = 0.776$; $C_2 = (-0.098) + j\cdot(-0.332)$; $\Gamma_L = (-0.174) + j\cdot(0.590) = 0.615\angle 106.4°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 165.5°$; $\mathrm{Im}(y_S) = -2.170$; $\theta_{p1} = 114.7°$ <u>or</u> $\theta_{S2} = 28.2°$; $\mathrm{Im}(y_S) = 2.170$; $\theta_{p2} = 65.3°$
output: $\theta_{L1} = 10.8°$; $\mathrm{Im}(y_L) = -1.561$; $\theta_{p1} = 122.7°$ <u>or</u> $\theta_{L2} = 62.8°$; $\mathrm{Im}(y_L) = 1.561$; $\theta_{p2} = 57.3°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 10.8°$; $\mathrm{Im}(y_L) = -1.561 + (-2.170) = -3.731$; $\theta_{p1} = 105.0°$; $\theta_{S1} = 165.5°$;
d2) $\theta_{L2} = 62.8°$; $\mathrm{Im}(y_L) = 1.561 + (-2.170) = -0.610$; $\theta_{p2} = 148.6°$; $\theta_{S1} = 165.5°$;
d3) $\theta_{L1} = 10.8°$; $\mathrm{Im}(y_L) = -1.561 + (2.170) = 0.610$; $\theta_{p3} = 31.4°$; $\theta_{S2} = 28.2°$;
d4) $\theta_{L2} = 62.8°$; $\mathrm{Im}(y_L) = 1.561 + (2.170) = 3.731$; $\theta_{p4} = 75.0°$; $\theta_{S2} = 28.2°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 10.8 + 165.5 = 176.3$; $\theta_p = 105.0$; A ~ 18509.9
e2) $\Sigma\theta_s = 62.8 + 165.5 = 228.3$; $\theta_p = 148.6$; A ~ 33934.3
e3) $\Sigma\theta_s = 10.8 + 28.2 = 38.9$; $\theta_p = 31.4$; A ~ 1221.5
e4) $\Sigma\theta_s = 62.8 + 28.2 = 91.0$; $\theta_p = 75.0$; A ~ 6822.6
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 12

1. $y = Y/Y_0 = Z_0/Z = 35\Omega\ /\ (34.3 + j\cdot 39.1)\Omega = 0.444 - j\cdot 0.506$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y)\ /\ (Y_0 + Y) = [0.02 - (0.0131 - j\cdot 0.0240)]\ /\ (0.02 + 0.0131 - j\cdot 0.0240\ )$
$\Gamma = (-0.208) + j\cdot(0.574) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.611\angle 109.9° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

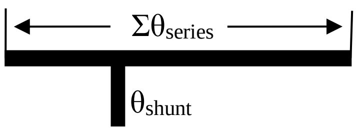
3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =25.15dB
$P_{in} = 2.65mW = 4.232dBm$; $P_{is} = P_{in} - I = 4.232dBm - 25.15dB = -20.92dBm = 8.096\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.599$, $y_1 = 0.599$, $y_2 = 0.801$, $Z_1 = Z_0/y_1 = 83.5\ \Omega$, $Z_2 = Z_0/y_2 = 62.4\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 73)}\Omega = 60.42\Omega$
b) $Z_L = 73\Omega$ series with 0.90nH inductor at 7.6GHz $= 73.00\Omega + j\cdot(42.98)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 37.13\Omega + j\cdot(-21.86)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.95dB): $G = G_1 + G_4 = 6.6 + 11.7 = 18.3dB$; $G = G_2 + G_3 = 8.8 + 8.9 = 17.7dB$; $G = G_2 + G_4 = 8.8 + 11.7 = 20.5dB$; $G = G_3 + G_4 = 8.9 + 11.7 = 20.6dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.50dB=1.122$, $F_2 = 0.73dB=1.183$, $F_3 = 0.99dB=1.256$, $F_4 = 1.26dB=1.337$, $G_1 = 6.6dB=4.571$, $G_2 = 8.8dB=7.586$; $F(1,4) = 1.122 + (1.337-1)/4.571 = 1.196 = 0.78dB$; $F(2,3) = 1.183 + (1.256-1)/7.586 = 1.227 = 0.89dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.590 < 1$; $|\ S_{22}| = 0.232 < 1$; $K = 1.339 > 1$; $|\Delta| = |(-0.108)+ j\cdot(-0.113)| = 0.156 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 8.32 = 9.20dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.270$; $C_1 = (-0.415) + j\cdot(0.434)$; $\Gamma_S = (-0.493) + j\cdot(-0.515) = 0.713\angle -133.8°$
$B_2 = 0.681$; $C_2 = (-0.208) + j\cdot(-0.173)$; $\Gamma_L = (-0.380) + j\cdot(0.315) = 0.494\angle 140.3°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 134.6°$; $\mathrm{Im}(y_S) = -2.034$; $\theta_{p1} = 116.2°$ <u>or</u> $\theta_{S2} = 179.1°$; $\mathrm{Im}(y_S) = 2.034$; $\theta_{p2} = 63.8°$
output: $\theta_{L1} = 169.6°$; $\mathrm{Im}(y_L) = -1.137$; $\theta_{p1} = 131.3°$ <u>or</u> $\theta_{L2} = 50.0°$; $\mathrm{Im}(y_L) = 1.137$; $\theta_{p2} = 48.7°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 169.6°$; $\mathrm{Im}(y_L) = -1.137 + (-2.034) = -3.170$; $\theta_{p1} = 107.5°$; $\theta_{S1} = 134.6°$;
d2) $\theta_{L2} = 50.0°$; $\mathrm{Im}(y_L) = 1.137 + (-2.034) = -0.897$; $\theta_{p2} = 138.1°$; $\theta_{S1} = 134.6°$;
d3) $\theta_{L1} = 169.6°$; $\mathrm{Im}(y_L) = -1.137 + (2.034) = 0.897$; $\theta_{p3} = 41.9°$; $\theta_{S2} = 179.1°$;
d4) $\theta_{L2} = 50.0°$; $\mathrm{Im}(y_L) = 1.137 + (2.034) = 3.170$; $\theta_{p4} = 72.5°$; $\theta_{S2} = 179.1°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 169.6 + 134.6 = 304.3$; $\theta_p = 107.5$; A ~ 32709.4
e2) $\Sigma\theta_s = 50.0 + 134.6 = 184.6$; $\theta_p = 138.1$; A ~ 25500.5
e3) $\Sigma\theta_s = 169.6 + 179.1 = 348.8$; $\theta_p = 41.9$; A ~ 14611.6
e4) $\Sigma\theta_s = 50.0 + 179.1 = 229.2$; $\theta_p = 72.5$; A ~ 16613.0
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 13

1. $y = Y/Y_0 = Z_0/Z = 55\Omega \,/\, (36.5 + j\cdot 58.2)\Omega = 0.425 - j\cdot 0.678$

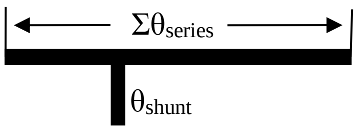
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0387 + j\cdot 0.0282)] / (0.02 + 0.0387 + j\cdot 0.0282\ )$
$\Gamma = (-0.446) + j\cdot(-0.266) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.520\angle{-149.2°} \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation $I = D + C = 28.55dB$
$P_{in} = 3.20mW = 5.051dBm$; $P_{is} = P_{in} - I = 5.051dBm - 28.55dB = -23.50dBm = 4.468\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.540$, $Z_{CE} = 91.50\Omega$, $Z_{CO} = 27.32\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 72)}\Omega = 60.00\Omega$
b) $Z_L = 72\Omega$ parallel with 1.11nH inductor at 7.1GHz $= 23.12\Omega + j\cdot(33.62)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l) \to \infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-72.70)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations ($G > 15.05dB$): $G = G_1 + G_4 = 5.2 + 11.2 = 16.4dB$; $G = G_2 + G_3 = 7.3 + 8.4 = 15.7dB$; $G = G_2 + G_4 = 7.3 + 11.2 = 18.5dB$; $G = G_3 + G_4 = 8.4 + 11.2 = 19.6dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b - 1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3 - 1)/G_2 < F_2 + (F_4 - 1)/G_2$ and $F_2 + (F_3 - 1)/G_2 < F_3 + (F_4 - 1)/G_3$
$F_1 = 0.67dB = 1.167$, $F_2 = 0.79dB = 1.199$, $F_3 = 1.01dB = 1.262$, $F_4 = 1.12dB = 1.294$, $G_1 = 5.2dB = 3.311$, $G_2 = 7.3dB = 5.370$; $F(1,4) = 1.167 + (1.294 - 1)/3.311 = 1.256 = 0.99dB$; $F(2,3) = 1.199 + (1.262 - 1)/5.370 = 1.254 = 0.98dB$;
$F(1,4) > F(2,3) \to$ For minimal noise factor we must use devices 2,3

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.532 < 1$; $|S_{22}| = 0.293 < 1$; $K = 1.209 > 1$; $|\Delta| = |(-0.124) + j\cdot(-0.084)| = 0.150 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K - \sqrt{(K^2-1)}] = 14.60 = 11.64dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.175$; $C_1 = (-0.556) + j\cdot(-0.050)$; $\Gamma_S = (-0.720) + j\cdot(0.065) = 0.723\angle 174.8°$
$B_2 = 0.780$; $C_2 = (-0.117) + j\cdot(-0.324)$; $\Gamma_L = (-0.204) + j\cdot(0.564) = 0.600\angle 109.9°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 160.7°$; $\mathrm{Im}(y_S) = -2.096$; $\theta_{p1} = 115.5°$ <u>or</u> $\theta_{S2} = 24.4°$; $\mathrm{Im}(y_S) = 2.096$; $\theta_{p2} = 64.5°$
output: $\theta_{L1} = 8.5°$; $\mathrm{Im}(y_L) = -1.499$; $\theta_{p1} = 123.7°$ <u>or</u> $\theta_{L2} = 61.6°$; $\mathrm{Im}(y_L) = 1.499$; $\theta_{p2} = 56.3°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 8.5°$; $\mathrm{Im}(y_L) = -1.499 + (-2.096) = -3.594$; $\theta_{p1} = 105.5°$; $\theta_{S1} = 160.7°$;
d2) $\theta_{L2} = 61.6°$; $\mathrm{Im}(y_L) = 1.499 + (-2.096) = -0.597$; $\theta_{p2} = 149.2°$; $\theta_{S1} = 160.7°$;
d3) $\theta_{L1} = 8.5°$; $\mathrm{Im}(y_L) = -1.499 + (2.096) = 0.597$; $\theta_{p3} = 30.8°$; $\theta_{S2} = 24.4°$;
d4) $\theta_{L2} = 61.6°$; $\mathrm{Im}(y_L) = 1.499 + (2.096) = 3.594$; $\theta_{p4} = 74.5°$; $\theta_{S2} = 24.4°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 8.5 + 160.7 = 169.2$; $\theta_p = 105.5$; $A \sim 17861.4$
e2) $\Sigma\theta_s = 61.6 + 160.7 = 222.4$; $\theta_p = 149.2$; $A \sim 33170.8$
e3) $\Sigma\theta_s = 8.5 + 24.4 = 32.9$; $\theta_p = 30.8$; $A \sim 1014.2$
e4) $\Sigma\theta_s = 61.6 + 24.4 = 86.0$; $\theta_p = 74.5$; $A \sim 6406.1$
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 14

1. $y = Y/Y_0 = Z_0/Z = 65\Omega\ /\ (50.9 + j\cdot 56.6)\Omega = 0.571 - j\cdot 0.635$

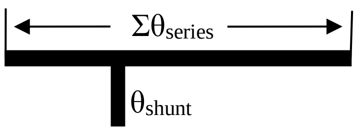
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y)\ /\ (Y_0 + Y) = [0.02 - (0.0364 - j\cdot 0.0144)]\ /\ (0.02 + 0.0364 - j\cdot 0.0144\ )$
$\Gamma = (-0.334) + j\cdot(0.170) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.375\angle 153.0° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I = D + C =29.25dB
$P_{in} = 2.45mW = 3.892dBm$; $P_{is} = P_{in} - I = 3.892dBm - 29.25dB = -25.36dBm = 2.912\mu W$
b) L2, C5/2025, $\beta = 10^{-C/20} = 0.528$, $y_2 = 1.177$, $y_1 = 0.621$, $Z_1 = Z_0/y_1 = 80.5\ \Omega$, $Z_2 = Z_0/y_2 = 42.5\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 54)}\Omega = 51.96\Omega$
b) $Z_L = 54\Omega$ parallel with 0.87nH inductor at 9.6GHz $= 26.23\Omega + j\cdot(26.99)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-51.45)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 14.15dB): $G = G_1 + G_4 = 5.1 + 11.1 = 16.2dB$; $G = G_2 + G_3 = 7.4 + 9.0 = 16.4dB$; $G = G_2 + G_4 = 7.4 + 11.1 = 18.5dB$; $G = G_3 + G_4 = 9.0 + 11.1 = 20.1dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.55dB=1.135$, $F_2 = 0.83dB=1.211$, $F_3 = 0.91dB=1.233$, $F_4 = 1.18dB=1.312$, $G_1 = 5.1dB=3.236$, $G_2 = 7.4dB=5.495$; $F(1,4) = 1.135 + (1.312-1)/3.236 = 1.231 = 0.90dB$; $F(2,3) = 1.211 + (1.233-1)/5.495 = 1.267 = 1.03dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.544 < 1$; $|\ S_{22}| = 0.239 < 1$; $K = 1.307 > 1$; $|\Delta| = |(-0.093)+ j\cdot(-0.084)| = 0.126 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 10.31 = 10.13dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.223$; $C_1 = (-0.520) + j\cdot(0.241)$; $\Gamma_S = (-0.630) + j\cdot(-0.292) = 0.695\angle -155.1°$
$B_2 = 0.745$; $C_2 = (-0.168) + j\cdot(-0.255)$; $\Gamma_L = (-0.287) + j\cdot(0.435) = 0.522\angle 123.4°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 144.6°$; $\mathrm{Im}(y_S) = -1.933$; $\theta_{p1} = 117.4°$ <u>or</u> $\theta_{S2} = 10.6°$; $\mathrm{Im}(y_S) = 1.933$; $\theta_{p2} = 62.6°$
output: $\theta_{L1} = 179.0°$; $\mathrm{Im}(y_L) = -1.223$; $\theta_{p1} = 129.3°$ <u>or</u> $\theta_{L2} = 57.6°$; $\mathrm{Im}(y_L) = 1.223$; $\theta_{p2} = 50.7°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 179.0°$; $\mathrm{Im}(y_L) = -1.223 + (-1.933) = -3.155$; $\theta_{p1} = 107.6°$; $\theta_{S1} = 144.6°$;
d2) $\theta_{L2} = 57.6°$; $\mathrm{Im}(y_L) = 1.223 + (-1.933) = -0.710$; $\theta_{p2} = 144.6°$; $\theta_{S1} = 144.6°$;
d3) $\theta_{L1} = 179.0°$; $\mathrm{Im}(y_L) = -1.223 + (1.933) = 0.710$; $\theta_{p3} = 35.4°$; $\theta_{S2} = 10.6°$;
d4) $\theta_{L2} = 57.6°$; $\mathrm{Im}(y_L) = 1.223 + (1.933) = 3.155$; $\theta_{p4} = 72.4°$; $\theta_{S2} = 10.6°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 179.0 + 144.6 = 323.6$; $\theta_p = 107.6$; A ~ 34811.8
e2) $\Sigma\theta_s = 57.6 + 144.6 = 202.1$; $\theta_p = 144.6$; A ~ 29235.5
e3) $\Sigma\theta_s = 179.0 + 10.6 = 189.6$; $\theta_p = 35.4$; A ~ 6703.9
e4) $\Sigma\theta_s = 57.6 + 10.6 = 68.1$; $\theta_p = 72.4$; A ~ 4932.7
Smallest substrate area is occupied by solution e4 (d4)



Subject no. 15

1. $y = Y/Y_0 = Z_0/Z = 65\Omega\ /\ (67.0 + j\cdot55.1)\Omega = 0.579 - j\cdot0.476$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y)\ /\ (Y_0 + Y) = [0.02 - (0.0289 - j\cdot0.0185)]\ /\ (0.02 + 0.0289 - j\cdot0.0185\ )$
$\Gamma = (-0.284) + j\cdot(0.271) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.393\angle136.4° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

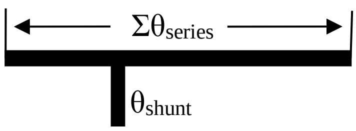
3. a) Lossless coupled line coupler, matched at the input; Isolation I =24.20dB
$P_{in} = 2.65mW = 4.232dBm$; $P_{is} = P_{in} - I = 4.232dBm - 24.20dB = -19.97dBm = 10.075\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.449$, $Z_{CE} = 81.11\Omega$, $Z_{CO} = 30.82\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot43)}\Omega = 46.37\Omega$
b) $Z_L = 43\Omega$ series with 1.12nH inductor at 8.4GHz $= 43.00\Omega + j\cdot(59.11)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 17.30\Omega + j\cdot(-23.79)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations ($G > 15.15dB$): $G = G_1 + G_4 = 6.2 + 11.1 = 17.3dB$; $G = G_2 + G_3 = 8.8 + 8.3 = 17.1dB$; $G = G_2 + G_4 = 8.8 + 11.1 = 19.9dB$; $G = G_3 + G_4 = 8.3 + 11.1 = 19.4dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.69dB=1.172$, $F_2 = 0.82dB=1.208$, $F_3 = 0.96dB=1.247$, $F_4 = 1.26dB=1.337$, $G_1 = 6.2dB=4.169$, $G_2 = 8.8dB=7.586$; $F(1,4) = 1.172 + (1.337-1)/4.169 = 1.253 = 0.98dB$; $F(2,3) = 1.208 + (1.247-1)/7.586 = 1.252 = 0.98dB$;
$F(1,4) > F(2,3) \rightarrow$ For minimal noise factor we must use devices 2,3

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.548 < 1$; $|\ S_{22}| = 0.317 < 1$; $K = 1.192 > 1$; $|\Delta| = |(-0.135)+ j\cdot(-0.098)| = 0.167 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 17.24 = 12.37dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.172$; $C_1 = (-0.531) + j\cdot(-0.180)$; $\Gamma_S = (-0.701) + j\cdot(0.238) = 0.741\angle161.2°$
$B_2 = 0.772$; $C_2 = (-0.085) + j\cdot(-0.336)$; $\Gamma_L = (-0.153) + j\cdot(0.603) = 0.622\angle104.2°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 168.3°$; $\mathrm{Im}(y_S) = -2.205$; $\theta_{p1} = 114.4°$ <u>or</u> $\theta_{S2} = 30.5°$; $\mathrm{Im}(y_S) = 2.205$; $\theta_{p2} = 65.6°$
output: $\theta_{L1} = 12.1°$; $\mathrm{Im}(y_L) = -1.588$; $\theta_{p1} = 122.2°$ <u>or</u> $\theta_{L2} = 63.6°$; $\mathrm{Im}(y_L) = 1.588$; $\theta_{p2} = 57.8°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 12.1°$; $\mathrm{Im}(y_L) = -1.588 + (-2.205) = -3.793$; $\theta_{p1} = 104.8°$; $\theta_{S1} = 168.3°$;
d2) $\theta_{L2} = 63.6°$; $\mathrm{Im}(y_L) = 1.588 + (-2.205) = -0.617$; $\theta_{p2} = 148.3°$; $\theta_{S1} = 168.3°$;
d3) $\theta_{L1} = 12.1°$; $\mathrm{Im}(y_L) = -1.588 + (2.205) = 0.617$; $\theta_{p3} = 31.7°$; $\theta_{S2} = 30.5°$;
d4) $\theta_{L2} = 63.6°$; $\mathrm{Im}(y_L) = 1.588 + (2.205) = 3.793$; $\theta_{p4} = 75.2°$; $\theta_{S2} = 30.5°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 12.1 + 168.3 = 180.4$; $\theta_p = 104.8$; A ~ 18898.8
e2) $\Sigma\theta_s = 63.6 + 168.3 = 231.9$; $\theta_p = 148.3$; A ~ 34402.3
e3) $\Sigma\theta_s = 12.1 + 30.5 = 42.6$; $\theta_p = 31.7$; A ~ 1349.0
e4) $\Sigma\theta_s = 63.6 + 30.5 = 94.1$; $\theta_p = 75.2$; A ~ 7082.4
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 16

1. $y = Y/Y_0 = Z_0/Z = 35\Omega / (38.2 - j\cdot 42.7)\Omega = 0.407 + j\cdot 0.455$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0129 + j\cdot 0.0127)] / (0.02 + 0.0129 + j\cdot 0.0127\ )$
$\Gamma = (0.058) + j\cdot(-0.408) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.413\angle\text{-}81.9° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

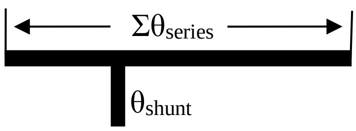
3. a) Lossless coupled line coupler, matched at the input; Isolation I =24.20dB
$P_{in} = 1.70mW = 2.304dBm$; $P_{is} = P_{in} - I = 2.304dBm - 24.20dB = -21.90dBm = 6.463\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.566$, $Z_{CE} = 94.92\Omega$, $Z_{CO} = 26.34\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 72)}\Omega = 60.00\Omega$
b) $Z_L = 72\Omega$ series with 0.41pF capacitor at 7.6GHz $= 72.00\Omega + j\cdot(-51.08)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 33.26\Omega + j\cdot(23.60)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations ($G > 17.15dB$): $G = G_1 + G_4 = 6.7 + 11.0 = 17.7dB$; $G = G_2 + G_3 = 8.8 + 9.0 = 17.8dB$; $G = G_2 + G_4 = 8.8 + 11.0 = 19.8dB$; $G = G_3 + G_4 = 9.0 + 11.0 = 20.0dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b - 1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3 - 1)/G_2 < F_2 + (F_4 - 1)/G_2$ and $F_2 + (F_3 - 1)/G_2 < F_3 + (F_4 - 1)/G_3$
$F_1 = 0.58dB=1.143$, $F_2 = 0.89dB=1.227$, $F_3 = 1.06dB=1.276$, $F_4 = 1.21dB=1.321$, $G_1 = 6.7dB=4.677$, $G_2 = 8.8dB=7.586$; $F(1,4) = 1.143 + (1.321-1)/4.677 = 1.212 = 0.83dB$; $F(2,3) = 1.227 + (1.276-1)/7.586 = 1.270 = 1.04dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.585 < 1$; $|S_{22}| = 0.231 < 1$; $K = 1.350 > 1$; $|\Delta| = |(-0.105)+ j\cdot(-0.109)| = 0.152 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2\text{-}1)}] = 8.35 = 9.22dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.266$; $C_1 = (-0.421) + j\cdot(0.423)$; $\Gamma_S = (-0.499) + j\cdot(-0.501) = 0.707\angle\text{-}134.9°$
$B_2 = 0.688$; $C_2 = (-0.206) + j\cdot(-0.178)$; $\Gamma_L = (-0.371) + j\cdot(0.320) = 0.490\angle 139.3°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 135.0°$; $\mathrm{Im}(y_S) = -2.001$; $\theta_{p1} = 116.5°$ <u>or</u> $\theta_{S2} = 179.9°$; $\mathrm{Im}(y_S) = 2.001$; $\theta_{p2} = 63.5°$
output: $\theta_{L1} = 170.0°$; $\mathrm{Im}(y_L) = -1.125$; $\theta_{p1} = 131.6°$ <u>or</u> $\theta_{L2} = 50.7°$; $\mathrm{Im}(y_L) = 1.125$; $\theta_{p2} = 48.4°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 170.0°$; $\mathrm{Im}(y_L) = -1.125 + (-2.001) = -3.126$; $\theta_{p1} = 107.7°$; $\theta_{S1} = 135.0°$;
d2) $\theta_{L2} = 50.7°$; $\mathrm{Im}(y_L) = 1.125 + (-2.001) = -0.877$; $\theta_{p2} = 138.8°$; $\theta_{S1} = 135.0°$;
d3) $\theta_{L1} = 170.0°$; $\mathrm{Im}(y_L) = -1.125 + (2.001) = 0.877$; $\theta_{p3} = 41.2°$; $\theta_{S2} = 179.9°$;
d4) $\theta_{L2} = 50.7°$; $\mathrm{Im}(y_L) = 1.125 + (2.001) = 3.126$; $\theta_{p4} = 72.3°$; $\theta_{S2} = 179.9°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 170.0 + 135.0 = 305.0$; $\theta_p = 107.7$; A ~ 32860.7
e2) $\Sigma\theta_s = 50.7 + 135.0 = 185.7$; $\theta_p = 138.8$; A ~ 25760.6
e3) $\Sigma\theta_s = 170.0 + 179.9 = 350.0$; $\theta_p = 41.2$; A ~ 14434.5
e4) $\Sigma\theta_s = 50.7 + 179.9 = 230.6$; $\theta_p = 72.3$; A ~ 16665.9
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 17

1. $y = Y/Y_0 = Z_0/Z = 45\Omega / (66.4 + j\cdot 60.6)\Omega = 0.370 - j\cdot 0.337$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0346 + j\cdot 0.0275)] / (0.02 + 0.0346 + j\cdot 0.0275)$
$\Gamma = (-0.416) + j\cdot(-0.294) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.509\angle{-144.7°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

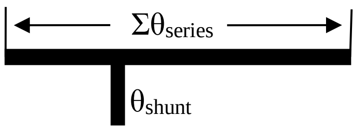
3. a) Lossless coupled line coupler, matched at the input; Isolation I =20.10dB
$P_{in} = 1.85mW = 2.672dBm$; $P_{is} = P_{in} - I = 2.672dBm - 20.10dB = -17.43dBm = 18.079\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.507$, $Z_{CE} = 87.42\Omega$, $Z_{CO} = 28.60\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 42)}\Omega = 45.83\Omega$
b) $Z_L = 42\Omega$ parallel with 0.44pF capacitor at 10.0GHz = $17.89\Omega + j\cdot(-20.77)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(58.06)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.80dB): $G = G_1 + G_4 = 6.4 + 11.5 = 17.9dB$; $G = G_2 + G_3 = 8.1 + 9.3 = 17.4dB$; $G = G_2 + G_4 = 8.1 + 11.5 = 19.6dB$; $G = G_3 + G_4 = 9.3 + 11.5 = 20.8dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.59dB=1.146$, $F_2 = 0.89dB=1.227$, $F_3 = 0.90dB=1.230$, $F_4 = 1.29dB=1.346$, $G_1 = 6.4dB=4.365$, $G_2 = 8.1dB=6.457$; $F(1,4) = 1.146 + (1.346-1)/4.365 = 1.225 = 0.88dB$; $F(2,3) = 1.227 + (1.230-1)/6.457 = 1.281 = 1.08dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.534 < 1$; $|S_{22}| = 0.254 < 1$; $K = 1.318 > 1$; $|\Delta| = |(-0.090)+ j\cdot(-0.074)| = 0.117 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 11.13 = 10.46dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.207$; $C_1 = (-0.539) + j\cdot(0.164)$; $\Gamma_S = (-0.658) + j\cdot(-0.200) = 0.687\angle{-163.1°}$
$B_2 = 0.766$; $C_2 = (-0.153) + j\cdot(-0.277)$; $\Gamma_L = (-0.255) + j\cdot(0.462) = 0.528\angle 118.9°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 148.2°$; $\mathrm{Im}(y_S) = -1.893$; $\theta_{p1} = 117.8°$ <u>or</u> $\theta_{S2} = 14.8°$; $\mathrm{Im}(y_S) = 1.893$; $\theta_{p2} = 62.2°$
output: $\theta_{L1} = 1.5°$; $\mathrm{Im}(y_L) = -1.242$; $\theta_{p1} = 128.8°$ <u>or</u> $\theta_{L2} = 59.6°$; $\mathrm{Im}(y_L) = 1.242$; $\theta_{p2} = 51.2°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 1.5°$; $\mathrm{Im}(y_L) = -1.242 + (-1.893) = -3.135$; $\theta_{p1} = 107.7°$; $\theta_{S1} = 148.2°$;
d2) $\theta_{L2} = 59.6°$; $\mathrm{Im}(y_L) = 1.242 + (-1.893) = -0.651$; $\theta_{p2} = 146.9°$; $\theta_{S1} = 148.2°$;
d3) $\theta_{L1} = 1.5°$; $\mathrm{Im}(y_L) = -1.242 + (1.893) = 0.651$; $\theta_{p3} = 33.1°$; $\theta_{S2} = 14.8°$;
d4) $\theta_{L2} = 59.6°$; $\mathrm{Im}(y_L) = 1.242 + (1.893) = 3.135$; $\theta_{p4} = 72.3°$; $\theta_{S2} = 14.8°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 1.5 + 148.2 = 149.7$; $\theta_p = 107.7$; A ~ 16124.0
e2) $\Sigma\theta_s = 59.6 + 148.2 = 207.9$; $\theta_p = 146.9$; A ~ 30544.5
e3) $\Sigma\theta_s = 1.5 + 14.8 = 16.3$; $\theta_p = 33.1$; A ~ 539.0
e4) $\Sigma\theta_s = 59.6 + 14.8 = 74.5$; $\theta_p = 72.3$; A ~ 5384.0
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 18

1. $y = Y/Y_0 = Z_0/Z = 40\Omega / (45.8 - j\cdot 64.4)\Omega = 0.293 + j\cdot 0.412$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0182 + j\cdot 0.0306)] / (0.02 + 0.0182 + j\cdot 0.0306)$
$\Gamma = (-0.362) + j\cdot(-0.511) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.626\angle -125.3° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

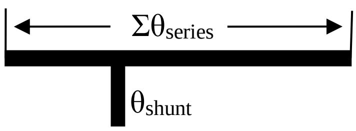
3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =27.10dB
$P_{in} = 1.15mW = 0.607dBm$; $P_{is} = P_{in} - I = 0.607dBm - 27.10dB = -26.49dBm = 2.242\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.519$, $y_1 = 0.519$, $y_2 = 0.855$, $Z_1 = Z_0/y_1 = 96.4\ \Omega$, $Z_2 = Z_0/y_2 = 58.5\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 45)}\Omega = 47.43\Omega$
b) $Z_L = 45\Omega$ parallel with 1.16nH inductor at 9.5GHz $= 31.64\Omega + j\cdot(20.56)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-32.50)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.50dB): $G = G_1 + G_4 = 6.5 + 10.4 = 16.9dB$; $G = G_2 + G_3 = 7.0 + 9.8 = 16.8dB$; $G = G_2 + G_4 = 7.0 + 10.4 = 17.4dB$; $G = G_3 + G_4 = 9.8 + 10.4 = 20.2dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.67dB=1.167$, $F_2 = 0.89dB=1.227$, $F_3 = 0.94dB=1.242$, $F_4 = 1.11dB=1.291$, $G_1 = 6.5dB=4.467$, $G_2 = 7.0dB=5.012$; $F(1,4) = 1.167 + (1.291-1)/4.467 = 1.232 = 0.91dB$; $F(2,3) = 1.227 + (1.242-1)/5.012 = 1.286 = 1.09dB$;
$F(1,4) < F(2,3) \to$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.574 < 1$; $|S_{22}| = 0.230 < 1$; $K = 1.348 > 1$; $|\Delta| = |(-0.098)+ j\cdot(-0.102)| = 0.142 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 8.68 = 9.38dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.257$; $C_1 = (-0.446) + j\cdot(0.388)$; $\Gamma_S = (-0.529) + j\cdot(-0.461) = 0.702\angle -138.9°$
$B_2 = 0.703$; $C_2 = (-0.200) + j\cdot(-0.195)$; $\Gamma_L = (-0.353) + j\cdot(0.345) = 0.494\angle 135.7°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 136.7°$; $\mathrm{Im}(y_S) = -1.969$; $\theta_{p1} = 116.9°$ <u>or</u> $\theta_{S2} = 2.2°$; $\mathrm{Im}(y_S) = 1.969$; $\theta_{p2} = 63.1°$
output: $\theta_{L1} = 171.9°$; $\mathrm{Im}(y_L) = -1.135$; $\theta_{p1} = 131.4°$ <u>or</u> $\theta_{L2} = 52.3°$; $\mathrm{Im}(y_L) = 1.135$; $\theta_{p2} = 48.6°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 171.9°$; $\mathrm{Im}(y_L) = -1.135 + (-1.969) = -3.104$; $\theta_{p1} = 107.9°$; $\theta_{S1} = 136.7°$;
d2) $\theta_{L2} = 52.3°$; $\mathrm{Im}(y_L) = 1.135 + (-1.969) = -0.833$; $\theta_{p2} = 140.2°$; $\theta_{S1} = 136.7°$;
d3) $\theta_{L1} = 171.9°$; $\mathrm{Im}(y_L) = -1.135 + (1.969) = 0.833$; $\theta_{p3} = 39.8°$; $\theta_{S2} = 2.2°$;
d4) $\theta_{L2} = 52.3°$; $\mathrm{Im}(y_L) = 1.135 + (1.969) = 3.104$; $\theta_{p4} = 72.1°$; $\theta_{S2} = 2.2°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 171.9 + 136.7 = 308.7$; $\theta_p = 107.9$; $A \sim 33292.9$
e2) $\Sigma\theta_s = 52.3 + 136.7 = 189.1$; $\theta_p = 140.2$; $A \sim 26510.1$
e3) $\Sigma\theta_s = 171.9 + 2.2 = 174.1$; $\theta_p = 39.8$; $A \sim 6931.2$
e4) $\Sigma\theta_s = 52.3 + 2.2 = 54.5$; $\theta_p = 72.1$; $A \sim 3935.1$
Smallest substrate area is occupied by solution e4 (d4)



Subject no. 19

1. $y = Y/Y_0 = Z_0/Z = 55\Omega / (58.5 + j\cdot 50.5)\Omega = 0.539 - j\cdot 0.465$

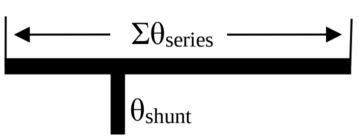
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0136 - j\cdot 0.0295)] / (0.02 + 0.0136 - j\cdot 0.0295\ )$
$\Gamma = (-0.328) + j\cdot(0.590) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.675\angle 119.0° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I = D + C =27.10dB
$P_{in} = 3.15mW = 4.983dBm$; $P_{is} = P_{in} - I = 4.983dBm - 27.10dB = -22.12dBm = 6.142\mu W$
b) L2, C5/2025, $\beta = 10^{-C/20} = 0.569$, $y_2 = 1.216$, $y_1 = 0.692$, $Z_1 = Z_0/y_1 = 72.3\ \Omega$, $Z_2 = Z_0/y_2 = 41.1\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 38)}\Omega = 43.59\Omega$
b) $Z_L = 38\Omega$ parallel with 0.71nH inductor at 9.2GHz $= 20.46\Omega + j\cdot(18.94)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-46.29)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.15dB): $G = G_1 + G_4 = 5.3 + 10.1 = 15.4dB$; $G = G_2 + G_3 = 7.2 + 9.6 = 16.8dB$; $G = G_2 + G_4 = 7.2 + 10.1 = 17.3dB$; $G = G_3 + G_4 = 9.6 + 10.1 = 19.7dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.53dB=1.130$, $F_2 = 0.71dB=1.178$, $F_3 = 1.00dB=1.259$, $F_4 = 1.11dB=1.291$, $G_1 = 5.3dB=3.388$, $G_2 = 7.2dB=5.248$; $F(1,4) = 1.130 + (1.291-1)/3.388 = 1.216 = 0.85dB$; $F(2,3) = 1.178 + (1.259-1)/5.248 = 1.233 = 0.91dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.562 < 1$; $|\ S_{22}| = 0.230 < 1$; $K = 1.324 > 1$; $|\Delta| = |(-0.096)+ j\cdot(-0.095)| = 0.135 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2\text{-}1)}] = 9.25 = 9.66dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.245$; $C_1 = (-0.477) + j\cdot(0.338)$; $\Gamma_S = (-0.572) + j\cdot(-0.405) = 0.700\angle\text{-}144.7°$
$B_2 = 0.719$; $C_2 = (-0.189) + j\cdot(-0.219)$; $\Gamma_L = (-0.331) + j\cdot(0.383) = 0.506\angle 130.8°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 139.6°$; $\mathrm{Im}(y_S) = -1.962$; $\theta_{p1} = 117.0°$ <u>or</u> $\theta_{S2} = 5.1°$; $\mathrm{Im}(y_S) = 1.962$; $\theta_{p2} = 63.0°$
output: $\theta_{L1} = 174.8°$; $\mathrm{Im}(y_L) = -1.174$; $\theta_{p1} = 130.4°$ <u>or</u> $\theta_{L2} = 54.4°$; $\mathrm{Im}(y_L) = 1.174$; $\theta_{p2} = 49.6°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 174.8°$; $\mathrm{Im}(y_L) = -1.174 + (-1.962) = -3.137$; $\theta_{p1} = 107.7°$; $\theta_{S1} = 139.6°$;
d2) $\theta_{L2} = 54.4°$; $\mathrm{Im}(y_L) = 1.174 + (-1.962) = -0.788$; $\theta_{p2} = 141.8°$; $\theta_{S1} = 139.6°$;
d3) $\theta_{L1} = 174.8°$; $\mathrm{Im}(y_L) = -1.174 + (1.962) = 0.788$; $\theta_{p3} = 38.2°$; $\theta_{S2} = 5.1°$;
d4) $\theta_{L2} = 54.4°$; $\mathrm{Im}(y_L) = 1.174 + (1.962) = 3.137$; $\theta_{p4} = 72.3°$; $\theta_{S2} = 5.1°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 174.8 + 139.6 = 314.4$; $\theta_p = 107.7$; A ~ 33851.3
e2) $\Sigma\theta_s = 54.4 + 139.6 = 193.9$; $\theta_p = 141.8$; A ~ 27493.2
e3) $\Sigma\theta_s = 174.8 + 5.1 = 179.9$; $\theta_p = 38.2$; A ~ 6879.5
e4) $\Sigma\theta_s = 54.4 + 5.1 = 59.5$; $\theta_p = 72.3$; A ~ 4301.8
Smallest substrate area is occupied by solution e4 (d4)



Subject no. 20

1. $y = Y/Y_0 = Z_0/Z = 90\Omega / (36.8 - j\cdot 34.7)\Omega = 1.295 + j\cdot 1.221$

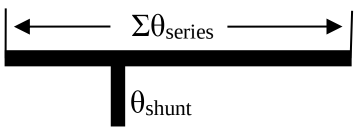
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0180 - j\cdot 0.0333)] / (0.02 + 0.0180 - j\cdot 0.0333\ )$
$\Gamma = (-0.405) + j\cdot(0.522) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.660\angle 127.8° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation $I = D + C = 27.30dB$
$P_{in} = 1.55mW = 1.903dBm$; $P_{is} = P_{in} - I = 1.903dBm - 27.30dB = -25.40dBm = 2.886\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.631$, $Z_{CE} = 105.11\Omega$, $Z_{CO} = 23.78\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 51)}\Omega = 50.50\Omega$
b) $Z_L = 51\Omega$ series with 1.12nH inductor at 6.7GHz $= 51.00\Omega + j\cdot(47.15)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 26.96\Omega + j\cdot(-24.92)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations ($G > 16.00dB$): $G = G_1 + G_4 = 6.4 + 10.9 = 17.3dB$; $G = G_2 + G_3 = 8.5 + 8.1 = 16.6dB$; $G = G_2 + G_4 = 8.5 + 10.9 = 19.4dB$; $G = G_3 + G_4 = 8.1 + 10.9 = 19.0dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.56dB=1.138$, $F_2 = 0.79dB=1.199$, $F_3 = 1.07dB=1.279$, $F_4 = 1.20dB=1.318$, $G_1 = 6.4dB=4.365$, $G_2 = 8.5dB=7.079$; $F(1,4) = 1.138 + (1.318-1)/4.365 = 1.211 = 0.83dB$; $F(2,3) = 1.199 + (1.279-1)/7.079 = 1.244 = 0.95dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.530 < 1$; $|S_{22}| = 0.266 < 1$; $K = 1.299 > 1$; $|\Delta| = |(-0.096)+ j\cdot(-0.071)| = 0.119 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 11.98 = 10.78dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.196$; $C_1 = (-0.550) + j\cdot(0.100)$; $\Gamma_S = (-0.680) + j\cdot(-0.124) = 0.691\angle -169.7°$
$B_2 = 0.776$; $C_2 = (-0.141) + j\cdot(-0.293)$; $\Gamma_L = (-0.235) + j\cdot(0.489) = 0.542\angle 115.7°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 151.7°$; $\mathrm{Im}(y_S) = -1.911$; $\theta_{p1} = 117.6°$ <u>or</u> $\theta_{S2} = 18.0°$; $\mathrm{Im}(y_S) = 1.911$; $\theta_{p2} = 62.4°$
output: $\theta_{L1} = 3.6°$; $\mathrm{Im}(y_L) = -1.291$; $\theta_{p1} = 127.8°$ <u>or</u> $\theta_{L2} = 60.7°$; $\mathrm{Im}(y_L) = 1.291$; $\theta_{p2} = 52.2°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 3.6°$; $\mathrm{Im}(y_L) = -1.291 + (-1.911) = -3.202$; $\theta_{p1} = 107.3°$; $\theta_{S1} = 151.7°$;
d2) $\theta_{L2} = 60.7°$; $\mathrm{Im}(y_L) = 1.291 + (-1.911) = -0.620$; $\theta_{p2} = 148.2°$; $\theta_{S1} = 151.7°$;
d3) $\theta_{L1} = 3.6°$; $\mathrm{Im}(y_L) = -1.291 + (1.911) = 0.620$; $\theta_{p3} = 31.8°$; $\theta_{S2} = 18.0°$;
d4) $\theta_{L2} = 60.7°$; $\mathrm{Im}(y_L) = 1.291 + (1.911) = 3.202$; $\theta_{p4} = 72.7°$; $\theta_{S2} = 18.0°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 3.6 + 151.7 = 155.3$; $\theta_p = 107.3$; A ~ 16668.8
e2) $\Sigma\theta_s = 60.7 + 151.7 = 212.4$; $\theta_p = 148.2$; A ~ 31480.6
e3) $\Sigma\theta_s = 3.6 + 18.0 = 21.6$; $\theta_p = 31.8$; A ~ 686.8
e4) $\Sigma\theta_s = 60.7 + 18.0 = 78.7$; $\theta_p = 72.7$; A ~ 5721.3
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 21

1. $y = Y/Y_0 = Z_0/Z = 50\Omega\ /\ (30.3 - j\cdot 52.1)\Omega = 0.417 + j\cdot 0.717$

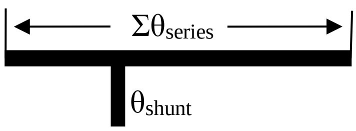
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y)\ /\ (Y_0 + Y) = [0.02 - (0.0348 + j\cdot 0.0132)]\ /\ (0.02 + 0.0348 + j\cdot 0.0132\ )$
$\Gamma = (-0.310) + j\cdot(-0.166) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.352\angle{-151.8°} \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =24.00dB
$P_{in} = 1.25mW = 0.969dBm$; $P_{is} = P_{in} - I = 0.969dBm - 24.00dB = -23.03dBm = 4.976\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.562$, $Z_{CE} = 94.47\Omega$, $Z_{CO} = 26.46\Omega$

4. a) $Z_1 = \sqrt{}(Z_0\cdot R_L) = \sqrt{}(50\cdot 48)\Omega = 48.99\Omega$
b) $Z_L = 48\Omega$ series with 0.30pF capacitor at 8.9GHz $= 48.00\Omega + j\cdot(-59.61)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 19.67\Omega + j\cdot(24.42)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.80dB): $G = G_1 + G_4 = 6.9 + 11.1 = 18.0dB$; $G = G_2 + G_3 = 7.3 + 8.7 = 16.0dB$; $G = G_2 + G_4 = 7.3 + 11.1 = 18.4dB$; $G = G_3 + G_4 = 8.7 + 11.1 = 19.8dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.59dB=1.146$, $F_2 = 0.84dB=1.213$, $F_3 = 0.96dB=1.247$, $F_4 = 1.12dB=1.294$, $G_1 = 6.9dB=4.898$, $G_2 = 7.3dB=5.370$; $F(1,4) = 1.146 + (1.294-1)/4.898 = 1.206 = 0.81dB$; $F(2,3) = 1.213 + (1.247-1)/5.370 = 1.268 = 1.03dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.620 < 1$; $|\ S_{22}| = 0.238 < 1$; $K = 1.277 > 1$; $|\Delta| = |(-0.139)+ j\cdot(-0.129)| = 0.190 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{}(K^2-1)] = 8.08 = 9.07dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.292$; $C_1 = (-0.370) + j\cdot(0.496)$; $\Gamma_S = (-0.446) + j\cdot(-0.596) = 0.745\angle{-126.8°}$
$B_2 = 0.636$; $C_2 = (-0.216) + j\cdot(-0.143)$; $\Gamma_L = (-0.428) + j\cdot(0.285) = 0.514\angle 146.4°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 132.5°$; $\mathrm{Im}(y_S) = -2.232$; $\theta_{p1} = 114.1°$ <u>or</u> $\theta_{S2} = 174.3°$; $\mathrm{Im}(y_S) = 2.232$; $\theta_{p2} = 65.9°$
output: $\theta_{L1} = 167.3°$; $\mathrm{Im}(y_L) = -1.199$; $\theta_{p1} = 129.8°$ <u>or</u> $\theta_{L2} = 46.3°$; $\mathrm{Im}(y_L) = 1.199$; $\theta_{p2} = 50.2°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 167.3°$; $\mathrm{Im}(y_L) = -1.199 + (-2.232) = -3.431$; $\theta_{p1} = 106.2°$; $\theta_{S1} = 132.5°$;
d2) $\theta_{L2} = 46.3°$; $\mathrm{Im}(y_L) = 1.199 + (-2.232) = -1.032$; $\theta_{p2} = 134.1°$; $\theta_{S1} = 132.5°$;
d3) $\theta_{L1} = 167.3°$; $\mathrm{Im}(y_L) = -1.199 + (2.232) = 1.032$; $\theta_{p3} = 45.9°$; $\theta_{S2} = 174.3°$;
d4) $\theta_{L2} = 46.3°$; $\mathrm{Im}(y_L) = 1.199 + (2.232) = 3.431$; $\theta_{p4} = 73.8°$; $\theta_{S2} = 174.3°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 167.3 + 132.5 = 299.7$; $\theta_p = 106.2$; $A \sim 31845.4$
e2) $\Sigma\theta_s = 46.3 + 132.5 = 178.8$; $\theta_p = 134.1$; $A \sim 23971.0$
e3) $\Sigma\theta_s = 167.3 + 174.3 = 341.6$; $\theta_p = 45.9$; $A \sim 15684.3$
e4) $\Sigma\theta_s = 46.3 + 174.3 = 220.6$; $\theta_p = 73.8$; $A \sim 16272.5$
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 22

1. $y = Y/Y_0 = Z_0/Z = 85\Omega / (55.5 + j\cdot 68.6)\Omega = 0.606 - j\cdot 0.749$

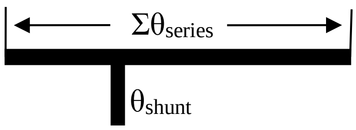
2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0311 + j\cdot 0.0283)] / (0.02 + 0.0311 + j\cdot 0.0283)$
$\Gamma = (-0.401) + j\cdot(-0.332) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.520\angle{-140.4°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I =21.80dB
$P_{in} = 3.65mW = 5.623dBm$; $P_{is} = P_{in} - I = 5.623dBm - 21.80dB = -16.18dBm = 24.115\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.507$, $y_1 = 0.507$, $y_2 = 0.862$, $Z_1 = Z_0/y_1 = 98.6\ \Omega$, $Z_2 = Z_0/y_2 = 58.0\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 39)}\Omega = 44.16\Omega$
b) $Z_L = 39\Omega$ series with 0.28pF capacitor at 8.1GHz $= 39.00\Omega + j\cdot(-70.17)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 11.80\Omega + j\cdot(21.23)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 14.50dB): $G = G_1 + G_4 = 5.6 + 10.7 = 16.3dB$; $G = G_2 + G_3 = 7.5 + 8.2 = 15.7dB$; $G = G_2 + G_4 = 7.5 + 10.7 = 18.2dB$; $G = G_3 + G_4 = 8.2 + 10.7 = 18.9dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.60dB=1.148$, $F_2 = 0.75dB=1.189$, $F_3 = 0.91dB=1.233$, $F_4 = 1.18dB=1.312$, $G_1 = 5.6dB=3.631$, $G_2 = 7.5dB=5.623$; $F(1,4) = 1.148 + (1.312-1)/3.631 = 1.234 = 0.91dB$; $F(2,3) = 1.189 + (1.233-1)/5.623 = 1.244 = 0.95dB$;
$F(1,4) < F(2,3) \to$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.530 < 1$; $|S_{22}| = 0.275 < 1$; $K = 1.264 > 1$; $|\Delta| = |(-0.105)+ j\cdot(-0.073)| = 0.128 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 12.81 = 11.08dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.189$; $C_1 = (-0.557) + j\cdot(0.050)$; $\Gamma_S = (-0.699) + j\cdot(-0.062) = 0.702\angle{-174.9°}$
$B_2 = 0.778$; $C_2 = (-0.134) + j\cdot(-0.304)$; $\Gamma_L = (-0.227) + j\cdot(0.515) = 0.563\angle 113.8°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 154.8°$; $\mathrm{Im}(y_S) = -1.972$; $\theta_{p1} = 116.9°$ or $\theta_{S2} = 20.2°$; $\mathrm{Im}(y_S) = 1.972$; $\theta_{p2} = 63.1°$
output: $\theta_{L1} = 5.2°$; $\mathrm{Im}(y_L) = -1.362$; $\theta_{p1} = 126.3°$ or $\theta_{L2} = 61.0°$; $\mathrm{Im}(y_L) = 1.362$; $\theta_{p2} = 53.7°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 5.2°$; $\mathrm{Im}(y_L) = -1.362 + (-1.972) = -3.335$; $\theta_{p1} = 106.7°$; $\theta_{S1} = 154.8°$;
d2) $\theta_{L2} = 61.0°$; $\mathrm{Im}(y_L) = 1.362 + (-1.972) = -0.610$; $\theta_{p2} = 148.6°$; $\theta_{S1} = 154.8°$;
d3) $\theta_{L1} = 5.2°$; $\mathrm{Im}(y_L) = -1.362 + (1.972) = 0.610$; $\theta_{p3} = 31.4°$; $\theta_{S2} = 20.2°$;
d4) $\theta_{L2} = 61.0°$; $\mathrm{Im}(y_L) = 1.362 + (1.972) = 3.335$; $\theta_{p4} = 73.3°$; $\theta_{S2} = 20.2°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute all solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 5.2 + 154.8 = 160.0$; $\theta_p = 106.7$; A ~ 17070.4
e2) $\Sigma\theta_s = 61.0 + 154.8 = 215.7$; $\theta_p = 148.6$; A ~ 32062.1
e3) $\Sigma\theta_s = 5.2 + 20.2 = 25.4$; $\theta_p = 31.4$; A ~ 796.9
e4) $\Sigma\theta_s = 61.0 + 20.2 = 81.1$; $\theta_p = 73.3$; A ~ 5947.7
Smallest substrate area is occupied by solution e3 (d3)



Subject no. 23

1. $y = Y/Y_0 = Z_0/Z = 60\Omega / (38.4 + j\cdot 31.5)\Omega = 0.934 - j\cdot 0.766$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0127 - j\cdot 0.0374)] / (0.02 + 0.0127 - j\cdot 0.0374\ )$
$\Gamma = (-0.470) + j\cdot(0.606) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.767\angle 127.8° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

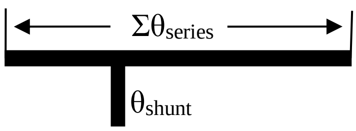
3. a) Lossless coupled line coupler, matched at the input; Isolation I =22.60dB
$P_{in} = 3.40mW = 5.315dBm$; $P_{is} = P_{in} - I = 5.315dBm - 22.60dB = -17.29dBm = 18.684\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.473$, $Z_{CE} = 83.61\Omega$, $Z_{CO} = 29.90\Omega$

4. a) $Z_1 = \sqrt{}(Z_0\cdot R_L) = \sqrt{}(50\cdot 60)\Omega = 54.77\Omega$
b) $Z_L = 60\Omega$ parallel with 0.37pF capacitor at 7.9GHz $= 27.10\Omega + j\cdot(-29.86)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(55.10)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations ($G > 15.25dB$): $G = G_1 + G_4 = 6.7 + 11.5 = 18.2dB$; $G = G_2 + G_3 = 8.4 + 8.0 = 16.4dB$; $G = G_2 + G_4 = 8.4 + 11.5 = 19.9dB$; $G = G_3 + G_4 = 8.0 + 11.5 = 19.5dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.68dB=1.169$, $F_2 = 0.75dB=1.189$, $F_3 = 1.02dB=1.265$, $F_4 = 1.20dB=1.318$, $G_1 = 6.7dB=4.677$, $G_2 = 8.4dB=6.918$; $F(1,4) = 1.169 + (1.318-1)/4.677 = 1.238 = 0.93dB$; $F(2,3) = 1.189 + (1.265-1)/6.918 = 1.235 = 0.91dB$;
$F(1,4) > F(2,3) \rightarrow$ For minimal noise factor we must use devices 2,3

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.580 < 1$; $|\ S_{22}| = 0.230 < 1$; $K = 1.362 > 1$; $|\Delta| = |(-0.102)+ j\cdot(-0.106)| = 0.147 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{}(K^2-1)] = 8.39 = 9.24dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.262$; $C_1 = (-0.427) + j\cdot(0.412)$; $\Gamma_S = (-0.505) + j\cdot(-0.487) = 0.702\angle -136.0°$
$B_2 = 0.695$; $C_2 = (-0.204) + j\cdot(-0.182)$; $\Gamma_L = (-0.362) + j\cdot(0.324) = 0.486\angle 138.2°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 135.3°$; $\mathrm{Im}(y_S) = -1.970$; $\theta_{p1} = 116.9°$ <u>or</u> $\theta_{S2} = 0.7°$; $\mathrm{Im}(y_S) = 1.970$; $\theta_{p2} = 63.1°$
output: $\theta_{L1} = 170.5°$; $\mathrm{Im}(y_L) = -1.113$; $\theta_{p1} = 132.0°$ <u>or</u> $\theta_{L2} = 51.4°$; $\mathrm{Im}(y_L) = 1.113$; $\theta_{p2} = 48.0°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 170.5°$; $\mathrm{Im}(y_L) = -1.113 + (-1.970) = -3.082$; $\theta_{p1} = 108.0°$; $\theta_{S1} = 135.3°$;
d2) $\theta_{L2} = 51.4°$; $\mathrm{Im}(y_L) = 1.113 + (-1.970) = -0.857$; $\theta_{p2} = 139.4°$; $\theta_{S1} = 135.3°$;
d3) $\theta_{L1} = 170.5°$; $\mathrm{Im}(y_L) = -1.113 + (1.970) = 0.857$; $\theta_{p3} = 40.6°$; $\theta_{S2} = 0.7°$;
d4) $\theta_{L2} = 51.4°$; $\mathrm{Im}(y_L) = 1.113 + (1.970) = 3.082$; $\theta_{p4} = 72.0°$; $\theta_{S2} = 0.7°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 170.5 + 135.3 = 305.8$; $\theta_p = 108.0$; A ~ 33014.2
e2) $\Sigma\theta_s = 51.4 + 135.3 = 186.7$; $\theta_p = 139.4$; A ~ 26021.9
e3) $\Sigma\theta_s = 170.5 + 0.7 = 171.2$; $\theta_p = 40.6$; A ~ 6950.4
e4) $\Sigma\theta_s = 51.4 + 0.7 = 52.1$; $\theta_p = 72.0$; A ~ 3753.1
Smallest substrate area is occupied by solution e4 (d4)



Subject no. 24

1. $y = Y/Y_0 = Z_0/Z = 45\Omega / (34.5 + j\cdot 50.1)\Omega = 0.420 - j\cdot 0.609$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0134 + j\cdot 0.0273)] / (0.02 + 0.0134 + j\cdot 0.0273)$
$\Gamma = (-0.282) + j\cdot(-0.587) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.651\angle -115.7° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

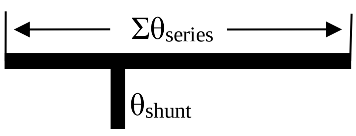
3. a) Lossless coupled line coupler, matched at the input; Isolation I = D + C =30.20dB
$P_{in} = 1.85mW = 2.672dBm$; $P_{is} = P_{in} - I = 2.672dBm - 30.20dB = -27.53dBm = 1.767\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.490$, $Z_{CE} = 85.44\Omega$, $Z_{CO} = 29.26\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 36)}\Omega = 42.43\Omega$
b) $Z_L = 36\Omega$ parallel with 1.50nH inductor at 7.4GHz = $28.43\Omega + j\cdot(14.67)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-25.81)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.70dB): $G = G_1 + G_4 = 5.7 + 11.2 = 16.9dB$; $G = G_2 + G_3 = 7.2 + 9.8 = 17.0dB$; $G = G_2 + G_4 = 7.2 + 11.2 = 18.4dB$; $G = G_3 + G_4 = 9.8 + 11.2 = 21.0dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.57dB=1.140$, $F_2 = 0.80dB=1.202$, $F_3 = 0.95dB=1.245$, $F_4 = 1.26dB=1.337$, $G_1 = 5.7dB=3.715$, $G_2 = 7.2dB=5.248$; $F(1,4) = 1.140 + (1.337-1)/3.715 = 1.231 = 0.90dB$; $F(2,3) = 1.202 + (1.245-1)/5.248 = 1.266 = 1.03dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.546 < 1$; $|S_{22}| = 0.314 < 1$; $K = 1.194 > 1$; $|\Delta| = |(-0.134)+ j\cdot(-0.095)| = 0.164 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 16.91 = 12.28dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.173$; $C_1 = (-0.536) + j\cdot(-0.165)$; $\Gamma_S = (-0.707) + j\cdot(0.217) = 0.739\angle 162.9°$
$B_2 = 0.773$; $C_2 = (-0.090) + j\cdot(-0.335)$; $\Gamma_L = (-0.160) + j\cdot(0.599) = 0.620\angle 105.0°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 167.4°$; $\mathrm{Im}(y_S) = -2.194$; $\theta_{p1} = 114.5°$ <u>or</u> $\theta_{S2} = 29.7°$; $\mathrm{Im}(y_S) = 2.194$; $\theta_{p2} = 65.5°$
output: $\theta_{L1} = 11.7°$; $\mathrm{Im}(y_L) = -1.580$; $\theta_{p1} = 122.3°$ <u>or</u> $\theta_{L2} = 63.4°$; $\mathrm{Im}(y_L) = 1.580$; $\theta_{p2} = 57.7°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 11.7°$; $\mathrm{Im}(y_L) = -1.580 + (-2.194) = -3.774$; $\theta_{p1} = 104.8°$; $\theta_{S1} = 167.4°$;
d2) $\theta_{L2} = 63.4°$; $\mathrm{Im}(y_L) = 1.580 + (-2.194) = -0.615$; $\theta_{p2} = 148.4°$; $\theta_{S1} = 167.4°$;
d3) $\theta_{L1} = 11.7°$; $\mathrm{Im}(y_L) = -1.580 + (2.194) = 0.615$; $\theta_{p3} = 31.6°$; $\theta_{S2} = 29.7°$;
d4) $\theta_{L2} = 63.4°$; $\mathrm{Im}(y_L) = 1.580 + (2.194) = 3.774$; $\theta_{p4} = 75.2°$; $\theta_{S2} = 29.7°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.

e1) $\Sigma\theta_s = 11.7 + 167.4 = 179.0$; $\theta_p = 104.8$; A ~ 18769.1
e2) $\Sigma\theta_s = 63.4 + 167.4 = 230.7$; $\theta_p = 148.4$; A ~ 34245.2
e3) $\Sigma\theta_s = 11.7 + 29.7 = 41.4$; $\theta_p = 31.6$; A ~ 1306.3
e4) $\Sigma\theta_s = 63.4 + 29.7 = 93.1$; $\theta_p = 75.2$; A ~ 6994.9



Smallest substrate area is occupied by solution e3 (d3)

Subject no. 25

1. $y = Y/Y_0 = Z_0/Z = 60\Omega / (46.5 - j\cdot 58.2)\Omega = 0.503 + j\cdot 0.629$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0176 + j\cdot 0.0391)] / (0.02 + 0.0176 + j\cdot 0.0391)$
$\Gamma = (-0.489) + j\cdot(-0.532) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.722\angle -132.6° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =27.20dB
$P_{in} = 1.20mW = 0.792dBm$; $P_{is} = P_{in} - I = 0.792dBm - 27.20dB = -26.41dBm = 2.287\mu W$
b) L2,C5/2025, $\beta = 10^{-C/20} = 0.562$, $y_1 = 0.562$, $y_2 = 0.827$, $Z_1 = Z_0/y_1 = 88.9\ \Omega$, $Z_2 = Z_0/y_2 = 60.5\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 43)}\Omega = 46.37\Omega$
b) $Z_L = 43\Omega$ parallel with 0.38pF capacitor at 8.0GHz $= 25.68\Omega + j\cdot(-21.09)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(41.07)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 17.35dB): $G = G_1 + G_4 = 6.9 + 11.6 = 18.5dB$; $G = G_2 + G_3 = 8.9 + 9.1 = 18.0dB$; $G = G_2 + G_4 = 8.9 + 11.6 = 20.5dB$; $G = G_3 + G_4 = 9.1 + 11.6 = 20.7dB$;
b) Friis Formula (C10/2025, S50), $F = F_a + (F_b-1)/G_a$; We note that $F_1 < F_2 < F_3 < F_4$;
From the 4 combinations that meet the gain requirement, we must compare only (1,4) and (2,3) because $F_2 + (F_3-1)/G_2 < F_2 + (F_4-1)/G_2$ and $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.62dB=1.153$, $F_2 = 0.76dB=1.191$, $F_3 = 1.00dB=1.259$, $F_4 = 1.12dB=1.294$, $G_1 = 6.9dB=4.898$, $G_2 = 8.9dB=7.762$; $F(1,4) = 1.153 + (1.294-1)/4.898 = 1.214 = 0.84dB$; $F(2,3) = 1.191 + (1.259-1)/7.762 = 1.229 = 0.90dB$;
$F(1,4) < F(2,3) \rightarrow$ For minimal noise factor we must use devices 1,4

6. a) The transistor can be conjugately matched for maximum gain only if it is unconditionally stable:
$|S_{11}| = 0.536 < 1$; $|S_{22}| = 0.299 < 1$; $K = 1.204 > 1$; $|\Delta| = |(-0.126)+ j\cdot(-0.086)| = 0.153 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 15.24 = 11.83dB$
b_2) Complex calculus from C9/2025, S70:
$B_1 = 1.174$; $C_1 = (-0.553) + j\cdot(-0.083)$; $\Gamma_S = (-0.721) + j\cdot(0.108) = 0.729\angle 171.4°$
$B_2 = 0.779$; $C_2 = (-0.110) + j\cdot(-0.327)$; $\Gamma_L = (-0.193) + j\cdot(0.575) = 0.606\angle 108.5°$
c) Complex calculus from C7/2025, S112, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 162.7°$; $\mathrm{Im}(y_S) = -2.128$; $\theta_{p1} = 115.2°$ <u>or</u> $\theta_{S2} = 25.9°$; $\mathrm{Im}(y_S) = 2.128$; $\theta_{p2} = 64.8°$
output: $\theta_{L1} = 9.4°$; $\mathrm{Im}(y_L) = -1.526$; $\theta_{p1} = 123.2°$ <u>or</u> $\theta_{L2} = 62.1°$; $\mathrm{Im}(y_L) = 1.526$; $\theta_{p2} = 56.8°$
d) Second stage is identical to the first one, we can reuse c) results. There are 4 solutions (any offers the points) from the first stage output towards the second stage input (Pr.2025, C12/2025,S140÷156):
d1) $\theta_{L1} = 9.4°$; $\mathrm{Im}(y_L) = -1.526 + (-2.128) = -3.653$; $\theta_{p1} = 105.3°$; $\theta_{S1} = 162.7°$;
d2) $\theta_{L2} = 62.1°$; $\mathrm{Im}(y_L) = 1.526 + (-2.128) = -0.602$; $\theta_{p2} = 148.9°$; $\theta_{S1} = 162.7°$;
d3) $\theta_{L1} = 9.4°$; $\mathrm{Im}(y_L) = -1.526 + (2.128) = 0.602$; $\theta_{p3} = 31.1°$; $\theta_{S2} = 25.9°$;
d4) $\theta_{L2} = 62.1°$; $\mathrm{Im}(y_L) = 1.526 + (2.128) = 3.653$; $\theta_{p4} = 74.7°$; $\theta_{S2} = 25.9°$;
e) We note that the electrical length $\theta = \beta\cdot l$ is proportional to the physical length and the layout is T shaped (series lines are perpendicular to the shunt stub), $\Sigma\theta_{series} \times \theta_{shunt}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{series} \times \theta_{shunt}$.
e1) $\Sigma\theta_s = 9.4 + 162.7 = 172.1$; $\theta_p = 105.3$; A ~ 18120.9
e2) $\Sigma\theta_s = 62.1 + 162.7 = 224.7$; $\theta_p = 148.9$; A ~ 33474.4
e3) $\Sigma\theta_s = 9.4 + 25.9 = 35.3$; $\theta_p = 31.1$; A ~ 1096.2
e4) $\Sigma\theta_s = 62.1 + 25.9 = 88.0$; $\theta_p = 74.7$; A ~ 6570.4
Smallest substrate area is occupied by solution e3 (d3)