Subject no. 1

1. $y = Y/Y_0 = Z_0/Z = 75\Omega / (35.1 + j\cdot 59.1)\Omega = 0.557 - j\cdot 0.938$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0344 + j\cdot 0.0215)] / (0.02 + 0.0344 + j\cdot 0.0215)$
$\Gamma = (-0.364) + j\cdot(-0.251) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.442\angle -145.4° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =23.50dB
$P_{in} = 3.25mW = 5.119dBm$; $P_{is} = P_{in} - I = 5.119dBm - 23.50dB = -18.38dBm = 14.517\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.613$, $Z_{CE} = 102.09\Omega$, $Z_{CO} = 24.49\Omega$

4. a) $Z_1 = \sqrt{(Z_0 \cdot R_L)} = \sqrt{(50\cdot 57)}\Omega = 53.39\Omega$
b) $Z_L = 57\Omega$ series with 0.37pF capacitor at 7.0GHz $= 57.00\Omega + j\cdot(-61.45)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 23.12\Omega + j\cdot(24.93)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.30dB): $G = G_1 + G_4 = 6.7 + 10.9 = 17.6dB$; $G = G_2 + G_3 = 7.8 + 8.3 = 16.1dB$; $G = G_2 + G_4 = 7.8 + 10.9 = 18.7dB$; $G = G_3 + G_4 = 8.3 + 10.9 = 19.2dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.55dB=1.135$, $F_2 = 0.87dB=1.222$, $F_3 = 1.06dB=1.276$, $F_4 = 1.28dB=1.343$, $G_1 = 6.7dB=4.677$, $G_2 = 7.8dB=6.026$; $F(1,4) = 1.135 + (1.343-1)/4.677 = 1.208 = 0.82dB$; $F(2,3) = 1.222 + (1.276-1)/6.026 = 1.279 = 1.07dB$;
$F(1,4) < F(2,3) \to$ 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:
$|S_{11}| = 0.662 < 1$; $|S_{22}| = 0.516 < 1$; $K = 1.066 > 1$; $|\Delta| = |(-0.198)+ j\cdot(0.223)| = 0.298 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 25.61 = 14.08dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.083$; $C_1 = (-0.525) + j\cdot(-0.116)$; $\Gamma_S = (-0.862) + j\cdot(0.191) = 0.883\angle 167.5°$
$B_2 = 0.739$; $C_2 = (-0.171) + j\cdot(-0.321)$; $\Gamma_L = (-0.392) + j\cdot(0.735) = 0.833\angle 118.1°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 172.3°$; $\mathrm{Im}(y_S) = -3.769$; $\theta_{p1} = 104.9°$ <u>or</u> $\theta_{S2} = 20.2°$; $\mathrm{Im}(y_S) = 3.769$; $\theta_{p2} = 75.1°$
output: $\theta_{L1} = 14.2°$; $\mathrm{Im}(y_L) = -3.010$; $\theta_{p1} = 108.4°$ <u>or</u> $\theta_{L2} = 47.8°$; $\mathrm{Im}(y_L) = 3.010$; $\theta_{p2} = 71.6°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 14.2°$; $\mathrm{Im}(y_L) = -3.010 + (-3.769) = -6.779$; $\theta_{p1} = 98.4°$; $\theta_{S1} = 172.3°$;
d2) $\theta_{L2} = 47.8°$; $\mathrm{Im}(y_L) = 3.010 + (-3.769) = -0.759$; $\theta_{p2} = 142.8°$; $\theta_{S1} = 172.3°$;
d3) $\theta_{L1} = 14.2°$; $\mathrm{Im}(y_L) = -3.010 + (3.769) = 0.759$; $\theta_{p3} = 37.2°$; $\theta_{S2} = 20.2°$;
d4) $\theta_{L2} = 47.8°$; $\mathrm{Im}(y_L) = 3.010 + (3.769) = 6.779$; $\theta_{p4} = 81.6°$; $\theta_{S2} = 20.2°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 14.2 + 172.3 = 186.4$; $\theta_p = 98.4$; $A \sim 18344.4$
e2) $\theta_s = 47.8 + 172.3 = 220.0$; $\theta_p = 142.8$; $A \sim 31419.6$
e3) $\theta_s = 14.2 + 20.2 = 34.4$; $\theta_p = 37.2$; $A \sim 1279.9$
e4) $\theta_s = 47.8 + 20.2 = 68.0$; $\theta_p = 81.6$; $A \sim 5549.2$
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 2

1. $y = Y/Y_0 = Z_0/Z = 40\Omega / (54.8 + j\cdot 60.4)\Omega = 0.330 - j\cdot 0.363$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0360 - j\cdot 0.0255)] / (0.02 + 0.0360 - j\cdot 0.0255\ )$
$\Gamma = (-0.408) + j\cdot(0.269) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.489\angle 146.6° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I =22.80dB
$P_{in} = 2.70mW = 4.314dBm$; $P_{is} = P_{in} - I = 4.314dBm - 22.80dB = -18.49dBm = 14.170\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.531$, $y_1 = 0.531$, $y_2 = 0.847$, $Z_1 = Z_0/y_1 = 94.2\ \Omega$, $Z_2 = Z_0/y_2 = 59.0\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 40)}\Omega = 44.72\Omega$
b) $Z_L = 40\Omega$ parallel with 0.31pF capacitor at 7.4GHz = $30.02\Omega + j\cdot(-17.31)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(28.83)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.20dB): $G = G_1 + G_4 = 6.3 + 11.8 = 18.1dB$; $G = G_2 + G_3 = 7.0 + 9.5 = 16.5dB$; $G = G_2 + G_4 = 7.0 + 11.8 = 18.8dB$; $G = G_3 + G_4 = 9.5 + 11.8 = 21.3dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.54dB=1.132$, $F_2 = 0.88dB=1.225$, $F_3 = 0.99dB=1.256$, $F_4 = 1.12dB=1.294$, $G_1 = 6.3dB=4.266$, $G_2 = 7.0dB=5.012$; $F(1,4) = 1.132 + (1.294-1)/4.266 = 1.201 = 0.80dB$; $F(2,3) = 1.225 + (1.256-1)/5.012 = 1.283 = 1.08dB$;
$F(1,4) < F(2,3) \to$ 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:
$|S_{11}| = 0.640 < 1$; $|\ S_{22}| = 0.550 < 1$; $K = 1.181 > 1$; $|\Delta| = |(0.241)+ j\cdot(0.152)| = 0.285 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2\text{-}1)}] = 10.67 = 10.28dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.026$; $C_1 = (-0.406) + j\cdot(0.298)$; $\Gamma_S = (-0.664) + j\cdot(-0.488) = 0.824\angle\text{-}143.7°$
$B_2 = 0.812$; $C_2 = (-0.361) + j\cdot(-0.156)$; $\Gamma_L = (-0.717) + j\cdot(0.310) = 0.781\angle 156.6°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 144.6°$; $\mathrm{Im}(y_S) = -2.906$; $\theta_{p1} = 109.0°$ <u>or</u> $\theta_{S2} = 179.1°$; $\mathrm{Im}(y_S) = 2.906$; $\theta_{p2} = 71.0°$
output: $\theta_{L1} = 172.4°$; $\mathrm{Im}(y_L) = -2.503$; $\theta_{p1} = 111.8°$ <u>or</u> $\theta_{L2} = 31.0°$; $\mathrm{Im}(y_L) = 2.503$; $\theta_{p2} = 68.2°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 172.4°$; $\mathrm{Im}(y_L) = -2.503 + (-2.906) = -5.408$; $\theta_{p1} = 100.5°$; $\theta_{S1} = 144.6°$;
d2) $\theta_{L2} = 31.0°$; $\mathrm{Im}(y_L) = 2.503 + (-2.906) = -0.403$; $\theta_{p2} = 158.0°$; $\theta_{S1} = 144.6°$;
d3) $\theta_{L1} = 172.4°$; $\mathrm{Im}(y_L) = -2.503 + (2.906) = 0.403$; $\theta_{p3} = 22.0°$; $\theta_{S2} = 179.1°$;
d4) $\theta_{L2} = 31.0°$; $\mathrm{Im}(y_L) = 2.503 + (2.906) = 5.408$; $\theta_{p4} = 79.5°$; $\theta_{S2} = 179.1°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 172.4 + 144.6 = 317.0$; $\theta_p = 100.5$; A ~ 31846.3
e2) $\theta_s = 31.0 + 144.6 = 175.6$; $\theta_p = 158.0$; A ~ 27749.5
e3) $\theta_s = 172.4 + 179.1 = 351.5$; $\theta_p = 22.0$; A ~ 7719.3
e4) $\theta_s = 31.0 + 179.1 = 210.1$; $\theta_p = 79.5$; A ~ 16710.1
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 3

1. $y = Y/Y_0 = Z_0/Z = 80\Omega / (39.8 - j\cdot 57.3)\Omega = 0.654 + j\cdot 0.942$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0196 - j\cdot 0.0397)] / (0.02 + 0.0196 - j\cdot 0.0397)$
$\Gamma = (-0.496) + j\cdot(0.505) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.708\angle 134.5° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I =24.00dB
$P_{in} = 2.30mW = 3.617dBm$; $P_{is} = P_{in} - I = 3.617dBm - 24.00dB = -20.38dBm = 9.156\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.579$, $y_1 = 0.579$, $y_2 = 0.815$, $Z_1 = Z_0/y_1 = 86.4\ \Omega$, $Z_2 = Z_0/y_2 = 61.3\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 57)}\Omega = 53.39\Omega$
b) $Z_L = 57\Omega$ series with 0.34pF capacitor at 8.3GHz = $57.00\Omega + j\cdot(-56.40)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 25.27\Omega + j\cdot(25.00)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 14.05dB): $G = G_1 + G_4 = 5.1 + 11.8 = 16.9dB$; $G = G_2 + G_3 = 8.8 + 8.5 = 17.3dB$; $G = G_2 + G_4 = 8.8 + 11.8 = 20.6dB$; $G = G_3 + G_4 = 8.5 + 11.8 = 20.3dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.50dB=1.122$, $F_2 = 0.84dB=1.213$, $F_3 = 0.99dB=1.256$, $F_4 = 1.15dB=1.303$, $G_1 = 5.1dB=3.236$, $G_2 = 8.8dB=7.586$; $F(1,4) = 1.122 + (1.303-1)/3.236 = 1.216 = 0.85dB$; $F(2,3) = 1.213 + (1.256-1)/7.586 = 1.253 = 0.98dB$;
$F(1,4) < F(2,3) \to$ 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:
$|S_{11}| = 0.609 < 1$; $|S_{22}| = 0.557 < 1$; $K = 1.203 > 1$; $|\Delta| = |(0.236)+ j\cdot(-0.069)| = 0.246 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 8.95 = 9.52dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.000$; $C_1 = (-0.220) + j\cdot(0.437)$; $\Gamma_S = (-0.363) + j\cdot(-0.721) = 0.807\angle -116.7°$
$B_2 = 0.879$; $C_2 = (-0.424) + j\cdot(-0.045)$; $\Gamma_L = (-0.779) + j\cdot(0.082) = 0.783\angle 174.0°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 130.3°$; $\mathrm{Im}(y_S) = -2.736$; $\theta_{p1} = 110.1°$ <u>or</u> $\theta_{S2} = 166.4°$; $\mathrm{Im}(y_S) = 2.736$; $\theta_{p2} = 69.9°$
output: $\theta_{L1} = 163.8°$; $\mathrm{Im}(y_L) = -2.517$; $\theta_{p1} = 111.7°$ <u>or</u> $\theta_{L2} = 22.3°$; $\mathrm{Im}(y_L) = 2.517$; $\theta_{p2} = 68.3°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 163.8°$; $\mathrm{Im}(y_L) = -2.517 + (-2.736) = -5.252$; $\theta_{p1} = 100.8°$; $\theta_{S1} = 130.3°$;
d2) $\theta_{L2} = 22.3°$; $\mathrm{Im}(y_L) = 2.517 + (-2.736) = -0.219$; $\theta_{p2} = 167.7°$; $\theta_{S1} = 130.3°$;
d3) $\theta_{L1} = 163.8°$; $\mathrm{Im}(y_L) = -2.517 + (2.736) = 0.219$; $\theta_{p3} = 12.3°$; $\theta_{S2} = 166.4°$;
d4) $\theta_{L2} = 22.3°$; $\mathrm{Im}(y_L) = 2.517 + (2.736) = 5.252$; $\theta_{p4} = 79.2°$; $\theta_{S2} = 166.4°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 163.8 + 130.3 = 294.0$; $\theta_p = 100.8$; A ~ 29634.0
e2) $\theta_s = 22.3 + 130.3 = 152.5$; $\theta_p = 167.7$; A ~ 25570.5
e3) $\theta_s = 163.8 + 166.4 = 330.2$; $\theta_p = 12.3$; A ~ 4077.5
e4) $\theta_s = 22.3 + 166.4 = 188.7$; $\theta_p = 79.2$; A ~ 14948.2
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 4

1. $y = Y/Y_0 = Z_0/Z = 35\Omega\ /\ (37.3 + j\cdot59.1)\Omega = 0.267 - j\cdot0.424$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y)\ /\ (Y_0 + Y) = [0.02 - (0.0342 + j\cdot0.0247)]\ /\ (0.02 + 0.0342 + j\cdot0.0247\ )$
$\Gamma = (-0.389) + j\cdot(-0.278) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.478\angle{-144.4°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I =21.60dB
$P_{in} = 3.25\text{mW} = 5.119\text{dBm}$; $P_{is} = P_{in} - I = 5.119\text{dBm} - 21.60\text{dB} = -16.48\text{dBm} = 22.485\mu\text{W}$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.513$, $y_1 = 0.513$, $y_2 = 0.858$, $Z_1 = Z_0/y_1 = 97.5\ \Omega$, $Z_2 = Z_0/y_2 = 58.2\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot27)}\Omega = 36.74\Omega$
b) $Z_L = 27\Omega$ series with 1.24nH inductor at 8.0GHz $= 27.00\Omega + j\cdot(62.33)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 7.90\Omega + j\cdot(-18.24)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.30dB): $G = G_1 + G_4 = 6.4 + 11.6 = 18.0\text{dB}$; $G = G_2 + G_3 = 8.1 + 8.8 = 16.9\text{dB}$; $G = G_2 + G_4 = 8.1 + 11.6 = 19.7\text{dB}$; $G = G_3 + G_4 = 8.8 + 11.6 = 20.4\text{dB}$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.64\text{dB}=1.159$, $F_2 = 0.83\text{dB}=1.211$, $F_3 = 0.98\text{dB}=1.253$, $F_4 = 1.27\text{dB}=1.340$, $G_1 = 6.4\text{dB}=4.365$, $G_2 = 8.1\text{dB}=6.457$; $F(1,4) = 1.159 + (1.340-1)/4.365 = 1.237 = 0.92\text{dB}$; $F(2,3) = 1.211 + (1.253-1)/6.457 = 1.263 = 1.01\text{dB}$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.640 < 1$; $|\ S_{22}| = 0.550 < 1$; $K = 1.184 > 1$; $|\Delta| = |(0.251)+ j\cdot(0.130)| = 0.283 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 10.55 = 10.23\text{dB}$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.027$; $C_1 = (-0.393) + j\cdot(0.315)$; $\Gamma_S = (-0.642) + j\cdot(-0.515) = 0.824\angle{-141.3°}$
$B_2 = 0.813$; $C_2 = (-0.367) + j\cdot(-0.145)$; $\Gamma_L = (-0.726) + j\cdot(0.288) = 0.781\angle158.4°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 143.4°$; $\mathrm{Im}(y_S) = -2.903$; $\theta_{p1} = 109.0°$ <u>or</u> $\theta_{S2} = 177.9°$; $\mathrm{Im}(y_S) = 2.903$; $\theta_{p2} = 71.0°$
output: $\theta_{L1} = 171.5°$; $\mathrm{Im}(y_L) = -2.501$; $\theta_{p1} = 111.8°$ <u>or</u> $\theta_{L2} = 30.1°$; $\mathrm{Im}(y_L) = 2.501$; $\theta_{p2} = 68.2°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 171.5°$; $\mathrm{Im}(y_L) = -2.501 + (-2.903) = -5.404$; $\theta_{p1} = 100.5°$; $\theta_{S1} = 143.4°$;
d2) $\theta_{L2} = 30.1°$; $\mathrm{Im}(y_L) = 2.501 + (-2.903) = -0.402$; $\theta_{p2} = 158.1°$; $\theta_{S1} = 143.4°$;
d3) $\theta_{L1} = 171.5°$; $\mathrm{Im}(y_L) = -2.501 + (2.903) = 0.402$; $\theta_{p3} = 21.9°$; $\theta_{S2} = 177.9°$;
d4) $\theta_{L2} = 30.1°$; $\mathrm{Im}(y_L) = 2.501 + (2.903) = 5.404$; $\theta_{p4} = 79.5°$; $\theta_{S2} = 177.9°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 171.5 + 143.4 = 314.8$; $\theta_p = 100.5$; $A \sim 31636.5$
e2) $\theta_s = 30.1 + 143.4 = 173.5$; $\theta_p = 158.1$; $A \sim 27425.4$
e3) $\theta_s = 171.5 + 177.9 = 349.4$; $\theta_p = 21.9$; $A \sim 7659.8$
e4) $\theta_s = 30.1 + 177.9 = 208.1$; $\theta_p = 79.5$; $A \sim 16543.8$
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 5

1. $y = Y/Y_0 = Z_0/Z = 85\Omega / (47.4 - j\cdot 34.1)\Omega = 1.182 + j\cdot 0.850$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0142 + j\cdot 0.0265)] / (0.02 + 0.0142 + j\cdot 0.0265)$
$\Gamma = (-0.269) + j\cdot(-0.566) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.627\angle{-115.4°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =20.00dB
$P_{in} = 2.30mW = 3.617dBm$; $P_{is} = P_{in} - I = 3.617dBm - 20.00dB = -16.38dBm = 23.000\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.468$, $Z_{CE} = 83.03\Omega$, $Z_{CO} = 30.11\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 31)}\Omega = 39.37\Omega$
b) $Z_L = 31\Omega$ series with 0.41pF capacitor at 8.5GHz $= 31.00\Omega + j\cdot(-45.67)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 15.77\Omega + j\cdot(23.23)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations ($G > 16.75dB$): $G = G_1 + G_4 = 6.7 + 10.4 = 17.1dB$; $G = G_2 + G_3 = 7.4 + 9.5 = 16.9dB$; $G = G_2 + G_4 = 7.4 + 10.4 = 17.8dB$; $G = G_3 + G_4 = 9.5 + 10.4 = 19.9dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.59dB=1.146$, $F_2 = 0.70dB=1.175$, $F_3 = 1.03dB=1.268$, $F_4 = 1.19dB=1.315$, $G_1 = 6.7dB=4.677$, $G_2 = 7.4dB=5.495$; $F(1,4) = 1.146 + (1.315-1)/4.677 = 1.213 = 0.84dB$; $F(2,3) = 1.175 + (1.268-1)/5.495 = 1.232 = 0.91dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.634 < 1$; $|S_{22}| = 0.550 < 1$; $K = 1.213 > 1$; $|\Delta| = |(0.264)+ j\cdot(0.026)| = 0.265 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 9.79 = 9.91dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.029$; $C_1 = (-0.327) + j\cdot(0.383)$; $\Gamma_S = (-0.530) + j\cdot(-0.620) = 0.815\angle{-130.5°}$
$B_2 = 0.830$; $C_2 = (-0.389) + j\cdot(-0.103)$; $\Gamma_L = (-0.749) + j\cdot(0.199) = 0.775\angle 165.1°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 137.6°$; $\mathrm{Im}(y_S) = -2.818$; $\theta_{p1} = 109.5°$ <u>or</u> $\theta_{S2} = 172.9°$; $\mathrm{Im}(y_S) = 2.818$; $\theta_{p2} = 70.5°$
output: $\theta_{L1} = 167.8°$; $\mathrm{Im}(y_L) = -2.453$; $\theta_{p1} = 112.2°$ <u>or</u> $\theta_{L2} = 27.0°$; $\mathrm{Im}(y_L) = 2.453$; $\theta_{p2} = 67.8°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 167.8°$; $\mathrm{Im}(y_L) = -2.453 + (-2.818) = -5.271$; $\theta_{p1} = 100.7°$; $\theta_{S1} = 137.6°$;
d2) $\theta_{L2} = 27.0°$; $\mathrm{Im}(y_L) = 2.453 + (-2.818) = -0.364$; $\theta_{p2} = 160.0°$; $\theta_{S1} = 137.6°$;
d3) $\theta_{L1} = 167.8°$; $\mathrm{Im}(y_L) = -2.453 + (2.818) = 0.364$; $\theta_{p3} = 20.0°$; $\theta_{S2} = 172.9°$;
d4) $\theta_{L2} = 27.0°$; $\mathrm{Im}(y_L) = 2.453 + (2.818) = 5.271$; $\theta_{p4} = 79.3°$; $\theta_{S2} = 172.9°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 167.8 + 137.6 = 305.4$; $\theta_p = 100.7$; A ~ 30768.3
e2) $\theta_s = 27.0 + 137.6 = 164.6$; $\theta_p = 160.0$; A ~ 26332.7
e3) $\theta_s = 167.8 + 172.9 = 340.8$; $\theta_p = 20.0$; A ~ 6823.6
e4) $\theta_s = 27.0 + 172.9 = 200.0$; $\theta_p = 79.3$; A ~ 15849.2
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 6

1. $y = Y/Y_0 = Z_0/Z = 75\Omega / (42.8 + j\cdot 30.4)\Omega = 1.165 - j\cdot 0.827$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0200 + j\cdot 0.0115)] / (0.02 + 0.0200 + j\cdot 0.0115)$
$\Gamma = (-0.076) + j\cdot(-0.266) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.276\angle -106.0° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I = D + C =29.40dB
P_{in} = 2.60mW = 4.150dBm; $P_{is} = P_{in} - I$ = 4.150dBm − 29.40dB = -25.25dBm = 2.985µW
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.462$, $Z_{CE} = 82.46\Omega$, $Z_{CO} = 30.32\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 27)}\Omega = 36.74\Omega$
b) $Z_L = 27\Omega$ parallel with 0.48pF capacitor at 6.5GHz = $21.09\Omega + j\cdot(-11.16)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(26.46)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.35dB): $G = G_1 + G_4$ = 6.2 + 10.7 = 16.9dB; $G = G_2 + G_3$ = 8.6 + 8.5 = 17.1dB; $G = G_2 + G_4$ = 8.6 + 10.7 = 19.3dB; $G = G_3 + G_4$ = 8.5 + 10.7 = 19.2dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 = 0.84dB=1.213, F_3 = 1.09dB=1.285, F_4 = 1.21dB=1.321, G_1 = 6.2dB=4.169, G_2 = 8.6dB=7.244; F(1,4) = 1.169 + (1.321−1)/4.169 = 1.247 = 0.96dB; F(2,3) = 1.213 + (1.285−1)/7.244 = 1.258 = 1.00dB;
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:
$|S_{11}| = 0.627 < 1$; $|S_{22}| = 0.551 < 1$; $K = 1.227 > 1$; $|\Delta| = |(0.253)+ j\cdot(-0.026)| = 0.255 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}]$ = 9.34 = 9.70dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.025$; $C_1 = (-0.284) + j\cdot(0.413)$; $\Gamma_S = (-0.458) + j\cdot(-0.667) = 0.809\angle -124.5°$
$B_2 = 0.846$; $C_2 = (-0.401) + j\cdot(-0.080)$; $\Gamma_L = (-0.758) + j\cdot(0.151) = 0.773\angle 168.7°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 134.3°$; $\mathrm{Im}(y_S) = -2.757$; $\theta_{p1} = 109.9°$ <u>or</u> $\theta_{S2} = 170.2°$; $\mathrm{Im}(y_S) = 2.757$; $\theta_{p2} = 70.1°$
output: $\theta_{L1} = 165.9°$; $\mathrm{Im}(y_L) = -2.434$; $\theta_{p1} = 112.3°$ <u>or</u> $\theta_{L2} = 25.3°$; $\mathrm{Im}(y_L) = 2.434$; $\theta_{p2} = 67.7°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 165.9°$; $\mathrm{Im}(y_L) = -2.434 + (-2.757) = -5.192$; $\theta_{p1} = 100.9°$; $\theta_{S1} = 134.3°$;
d2) $\theta_{L2} = 25.3°$; $\mathrm{Im}(y_L) = 2.434 + (-2.757) = -0.323$; $\theta_{p2} = 162.1°$; $\theta_{S1} = 134.3°$;
d3) $\theta_{L1} = 165.9°$; $\mathrm{Im}(y_L) = -2.434 + (2.757) = 0.323$; $\theta_{p3} = 17.9°$; $\theta_{S2} = 170.2°$;
d4) $\theta_{L2} = 25.3°$; $\mathrm{Im}(y_L) = 2.434 + (2.757) = 5.192$; $\theta_{p4} = 79.1°$; $\theta_{S2} = 170.2°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 165.9 + 134.3 = 300.2$; $\theta_p = 100.9$; A ~ 30288.8
e2) $\theta_s = 25.3 + 134.3 = 159.6$; $\theta_p = 162.1$; A ~ 25866.9
e3) $\theta_s = 165.9 + 170.2 = 336.1$; $\theta_p = 17.9$; A ~ 6021.0
e4) $\theta_s = 25.3 + 170.2 = 195.5$; $\theta_p = 79.1$; A ~ 15466.7
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 7

1. $y = Y/Y_0 = Z_0/Z = 30\Omega / (51.9 - j\cdot 49.5)\Omega = 0.303 + j\cdot 0.289$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0327 + j\cdot 0.0259)] / (0.02 + 0.0327 + j\cdot 0.0259)$
$\Gamma = (-0.389) + j\cdot(-0.300) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.491\angle -142.3° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I =24.00dB
$P_{in} = 1.30mW = 1.139dBm$; $P_{is} = P_{in} - I = 1.139dBm - 24.00dB = -22.86dBm = 5.175\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.562$, $y_1 = 0.562$, $y_2 = 0.827$, $Z_1 = Z_0/y_1 = 88.9\ \Omega$, $Z_2 = Z_0/y_2 = 60.5\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 31)}\Omega = 39.37\Omega$
b) $Z_L = 31\Omega$ parallel with 0.26pF capacitor at 9.3GHz $= 25.37\Omega + j\cdot(-11.95)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(23.55)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.65dB): $G = G_1 + G_4 = 5.7 + 10.6 = 16.3dB$; $G = G_2 + G_3 = 7.3 + 9.8 = 17.1dB$; $G = G_2 + G_4 = 7.3 + 10.6 = 17.9dB$; $G = G_3 + G_4 = 9.8 + 10.6 = 20.4dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.53dB=1.130$, $F_2 = 0.71dB=1.178$, $F_3 = 0.97dB=1.250$, $F_4 = 1.29dB=1.346$, $G_1 = 5.7dB=3.715$, $G_2 = 7.3dB=5.370$; $F(1,4) = 1.130 + (1.346-1)/3.715 = 1.223 = 0.87dB$; $F(2,3) = 1.178 + (1.250-1)/5.370 = 1.242 = 0.94dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.653 < 1$; $|S_{22}| = 0.519 < 1$; $K = 1.090 > 1$; $|\Delta| = |(-0.149)+ j\cdot(0.243)| = 0.285 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 23.66 = 13.74dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.076$; $C_1 = (-0.526) + j\cdot(-0.083)$; $\Gamma_S = (-0.856) + j\cdot(0.135) = 0.866\angle 171.0°$
$B_2 = 0.762$; $C_2 = (-0.199) + j\cdot(-0.316)$; $\Gamma_L = (-0.434) + j\cdot(0.690) = 0.815\angle 122.2°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 169.5°$; $\mathrm{Im}(y_S) = -3.465$; $\theta_{p1} = 106.1°$ <u>or</u> $\theta_{S2} = 19.5°$; $\mathrm{Im}(y_S) = 3.465$; $\theta_{p2} = 73.9°$
output: $\theta_{L1} = 11.2°$; $\mathrm{Im}(y_L) = -2.814$; $\theta_{p1} = 109.6°$ <u>or</u> $\theta_{L2} = 46.6°$; $\mathrm{Im}(y_L) = 2.814$; $\theta_{p2} = 70.4°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 11.2°$; $\mathrm{Im}(y_L) = -2.814 + (-3.465) = -6.279$; $\theta_{p1} = 99.0°$; $\theta_{S1} = 169.5°$;
d2) $\theta_{L2} = 46.6°$; $\mathrm{Im}(y_L) = 2.814 + (-3.465) = -0.651$; $\theta_{p2} = 146.9°$; $\theta_{S1} = 169.5°$;
d3) $\theta_{L1} = 11.2°$; $\mathrm{Im}(y_L) = -2.814 + (3.465) = 0.651$; $\theta_{p3} = 33.1°$; $\theta_{S2} = 19.5°$;
d4) $\theta_{L2} = 46.6°$; $\mathrm{Im}(y_L) = 2.814 + (3.465) = 6.279$; $\theta_{p4} = 81.0°$; $\theta_{S2} = 19.5°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 11.2 + 169.5 = 180.7$; $\theta_p = 99.0$; $A \sim 17898.3$
e2) $\theta_s = 46.6 + 169.5 = 216.1$; $\theta_p = 146.9$; $A \sim 31751.0$
e3) $\theta_s = 11.2 + 19.5 = 30.7$; $\theta_p = 33.1$; $A \sim 1015.2$
e4) $\theta_s = 46.6 + 19.5 = 66.1$; $\theta_p = 81.0$; $A \sim 5350.6$
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 8

1. $y = Y/Y_0 = Z_0/Z = 80\Omega / (62.2 - j\cdot 51.2)\Omega = 0.767 + j\cdot 0.631$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0325 - j\cdot 0.0195)] / (0.02 + 0.0325 - j\cdot 0.0195\ )$
$\Gamma = (-0.330) + j\cdot(0.249) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.414\angle 143.0° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I = D + C =28.25dB
P_{in} = 2.15mW = 3.324dBm; $P_{is} = P_{in} - I$ = 3.324dBm − 28.25dB = -24.93dBm = 3.217μW
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.449$, $Z_{CE} = 81.11\Omega$, $Z_{CO} = 30.82\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 41)}\Omega = 45.28\Omega$
b) $Z_L = 41\Omega$ series with 0.88nH inductor at 8.1GHz = $41.00\Omega + j\cdot(44.79)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 22.80\Omega + j\cdot(-24.90)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.10dB): $G = G_1 + G_4$ = 6.5 + 10.2 = 16.7dB; $G = G_2 + G_3$ = 7.5 + 9.1 = 16.6dB; $G = G_2 + G_4$ = 7.5 + 10.2 = 17.7dB; $G = G_3 + G_4$ = 9.1 + 10.2 = 19.3dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 = 0.51dB=1.125, F_2 = 0.83dB=1.211, F_3 = 1.03dB=1.268, F_4 = 1.17dB=1.309, G_1 = 6.5dB=4.467, G_2 = 7.5dB=5.623; F(1,4) = 1.125 + (1.309−1)/4.467 = 1.194 = 0.77dB; F(2,3) = 1.211 + (1.268−1)/5.623 = 1.266 = 1.02dB;
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:
$|S_{11}| = 0.605 < 1$; $|\ S_{22}| = 0.520 < 1$; $K = 1.169 > 1$; $|\Delta| = |(-0.037)+ j\cdot(0.262)| = 0.264 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}]$ = 16.34 = 12.13dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.026$; $C_1 = (-0.486) + j\cdot(0.119)$; $\Gamma_S = (-0.778) + j\cdot(-0.191) = 0.801\angle -166.2°$
$B_2 = 0.835$; $C_2 = (-0.242) + j\cdot(-0.321)$; $\Gamma_L = (-0.457) + j\cdot(0.606) = 0.759\angle 127.0°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 154.7°$; $\mathrm{Im}(y_S) = -2.674$; $\theta_{p1} = 110.5°$ <u>or</u> $\theta_{S2} = 11.5°$; $\mathrm{Im}(y_S) = 2.674$; $\theta_{p2} = 69.5°$
output: $\theta_{L1} = 6.2°$; $\mathrm{Im}(y_L) = -2.333$; $\theta_{p1} = 113.2°$ <u>or</u> $\theta_{L2} = 46.8°$; $\mathrm{Im}(y_L) = 2.333$; $\theta_{p2} = 66.8°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 6.2°$; $\mathrm{Im}(y_L) = -2.333 + (-2.674) = -5.007$; $\theta_{p1} = 101.3°$; $\theta_{S1} = 154.7°$;
d2) $\theta_{L2} = 46.8°$; $\mathrm{Im}(y_L) = 2.333 + (-2.674) = -0.341$; $\theta_{p2} = 161.2°$; $\theta_{S1} = 154.7°$;
d3) $\theta_{L1} = 6.2°$; $\mathrm{Im}(y_L) = -2.333 + (2.674) = 0.341$; $\theta_{p3} = 18.8°$; $\theta_{S2} = 11.5°$;
d4) $\theta_{L2} = 46.8°$; $\mathrm{Im}(y_L) = 2.333 + (2.674) = 5.007$; $\theta_{p4} = 78.7°$; $\theta_{S2} = 11.5°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 6.2 + 154.7 = 160.9$; $\theta_p = 101.3$; A ~ 16296.5
e2) $\theta_s = 46.8 + 154.7 = 201.5$; $\theta_p = 161.2$; A ~ 32476.7
e3) $\theta_s = 6.2 + 11.5 = 17.7$; $\theta_p = 18.8$; A ~ 332.6
e4) $\theta_s = 46.8 + 11.5 = 58.3$; $\theta_p = 78.7$; A ~ 4587.0
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 9

1. $y = Y/Y_0 = Z_0/Z = 70\Omega / (40.8 + j\cdot 68.5)\Omega = 0.449 - j\cdot 0.754$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0236 + j\cdot 0.0112)] / (0.02 + 0.0236 + j\cdot 0.0112\ )$
$\Gamma = (-0.139) + j\cdot(-0.221) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.261\angle{-122.2°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =22.00dB
$P_{in} = 3.25\text{mW} = 5.119\text{dBm}$; $P_{is} = P_{in} - I = 5.119\text{dBm} - 22.00\text{dB} = -16.88\text{dBm} = 20.506\mu\text{W}$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.572$, $Z_{CE} = 95.84\Omega$, $Z_{CO} = 26.08\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 56)}\Omega = 52.92\Omega$
b) $Z_L = 56\Omega$ series with 1.05nH inductor at 9.8GHz = $56.00\Omega + j\cdot(64.65)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 21.43\Omega + j\cdot(-24.74)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.35dB): $G = G_1 + G_4 = 5.4 + 10.3 = 15.7$dB; $G = G_2 + G_3 = 8.1 + 9.9 = 18.0$dB; $G = G_2 + G_4 = 8.1 + 10.3 = 18.4$dB; $G = G_3 + G_4 = 9.9 + 10.3 = 20.2$dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.64\text{dB}=1.159$, $F_2 = 0.87\text{dB}=1.222$, $F_3 = 1.01\text{dB}=1.262$, $F_4 = 1.18\text{dB}=1.312$, $G_1 = 5.4\text{dB}=3.467$, $G_2 = 8.1\text{dB}=6.457$; $F(1,4) = 1.159 + (1.312-1)/3.467 = 1.249 = 0.96$dB; $F(2,3) = 1.222 + (1.262-1)/6.457 = 1.270 = 1.04$dB;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.656 < 1$; $|\ S_{22}| = 0.518 < 1$; $K = 1.082 > 1$; $|\Delta| = |(-0.166)+ j\cdot(0.237)| = 0.289 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2\text{-}1)}] = 24.28 = 13.85$dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.078$; $C_1 = (-0.526) + j\cdot(-0.094)$; $\Gamma_S = (-0.858) + j\cdot(0.154) = 0.872\angle 169.9°$
$B_2 = 0.754$; $C_2 = (-0.189) + j\cdot(-0.318)$; $\Gamma_L = (-0.420) + j\cdot(0.705) = 0.821\angle 120.8°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 170.4°$; $\mathrm{Im}(y_S) = -3.557$; $\theta_{p1} = 105.7°$ <u>or</u> $\theta_{S2} = 19.7°$; $\mathrm{Im}(y_S) = 3.557$; $\theta_{p2} = 74.3°$
output: $\theta_{L1} = 12.2°$; $\mathrm{Im}(y_L) = -2.872$; $\theta_{p1} = 109.2°$ <u>or</u> $\theta_{L2} = 47.0°$; $\mathrm{Im}(y_L) = 2.872$; $\theta_{p2} = 70.8°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 12.2°$; $\mathrm{Im}(y_L) = -2.872 + (-3.557) = -6.430$; $\theta_{p1} = 98.8°$; $\theta_{S1} = 170.4°$;
d2) $\theta_{L2} = 47.0°$; $\mathrm{Im}(y_L) = 2.872 + (-3.557) = -0.685$; $\theta_{p2} = 145.6°$; $\theta_{S1} = 170.4°$;
d3) $\theta_{L1} = 12.2°$; $\mathrm{Im}(y_L) = -2.872 + (3.557) = 0.685$; $\theta_{p3} = 34.4°$; $\theta_{S2} = 19.7°$;
d4) $\theta_{L2} = 47.0°$; $\mathrm{Im}(y_L) = 2.872 + (3.557) = 6.430$; $\theta_{p4} = 81.2°$; $\theta_{S2} = 19.7°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 12.2 + 170.4 = 182.6$; $\theta_p = 98.8$; $A \sim 18046.2$
e2) $\theta_s = 47.0 + 170.4 = 217.4$; $\theta_p = 145.6$; $A \sim 31656.0$
e3) $\theta_s = 12.2 + 19.7 = 31.9$; $\theta_p = 34.4$; $A \sim 1098.5$
e4) $\theta_s = 47.0 + 19.7 = 66.8$; $\theta_p = 81.2$; $A \sim 5419.4$
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 10

1. $y = Y/Y_0 = Z_0/Z = 80\Omega \,/\, (56.3 + j\cdot 57.9)\Omega = 0.691 - j\cdot 0.710$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0216 + j\cdot 0.0204)] / (0.02 + 0.0216 + j\cdot 0.0204\ )$
$\Gamma = (-0.225) + j\cdot(-0.380) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.442\angle{-120.6°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I = D + C =24.75dB
$P_{in} = 2.10mW = 3.222dBm$; $P_{is} = P_{in} - I = 3.222dBm - 24.75dB = -21.53dBm = 7.034\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.627$, $Z_{CE} = 104.48\Omega$, $Z_{CO} = 23.93\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 74)}\Omega = 60.83\Omega$
b) $Z_L = 74\Omega$ parallel with 0.30pF capacitor at 8.8GHz = $29.52\Omega + j\cdot(-36.24)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(61.37)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.35dB): $G = G_1 + G_4 = 6.0 + 10.8 = 16.8dB$; $G = G_2 + G_3 = 8.7 + 9.3 = 18.0dB$; $G = G_2 + G_4 = 8.7 + 10.8 = 19.5dB$; $G = G_3 + G_4 = 9.3 + 10.8 = 20.1dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.57dB=1.140$, $F_2 = 0.77dB=1.194$, $F_3 = 0.98dB=1.253$, $F_4 = 1.24dB=1.330$, $G_1 = 6.0dB=3.981$, $G_2 = 8.7dB=7.413$; $F(1,4) = 1.140 + (1.330-1)/3.981 = 1.223 = 0.88dB$; $F(2,3) = 1.194 + (1.253-1)/7.413 = 1.239 = 0.93dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.621 < 1$; $|S_{22}| = 0.553 < 1$; $K = 1.218 > 1$; $|\Delta| = |(0.248)+ j\cdot(-0.041)| = 0.252 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 9.22 = 9.65dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.017$; $C_1 = (-0.262) + j\cdot(0.422)$; $\Gamma_S = (-0.427) + j\cdot(-0.687) = 0.809\angle{-121.9°}$
$B_2 = 0.857$; $C_2 = (-0.409) + j\cdot(-0.069)$; $\Gamma_L = (-0.766) + j\cdot(0.128) = 0.776\angle 170.5°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 132.9°$; $\mathrm{Im}(y_S) = -2.751$; $\theta_{p1} = 110.0°$ <u>or</u> $\theta_{S2} = 168.9°$; $\mathrm{Im}(y_S) = 2.751$; $\theta_{p2} = 70.0°$
output: $\theta_{L1} = 165.2°$; $\mathrm{Im}(y_L) = -2.463$; $\theta_{p1} = 112.1°$ <u>or</u> $\theta_{L2} = 24.3°$; $\mathrm{Im}(y_L) = 2.463$; $\theta_{p2} = 67.9°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 165.2°$; $\mathrm{Im}(y_L) = -2.463 + (-2.751) = -5.214$; $\theta_{p1} = 100.9°$; $\theta_{S1} = 132.9°$;
d2) $\theta_{L2} = 24.3°$; $\mathrm{Im}(y_L) = 2.463 + (-2.751) = -0.288$; $\theta_{p2} = 163.9°$; $\theta_{S1} = 132.9°$;
d3) $\theta_{L1} = 165.2°$; $\mathrm{Im}(y_L) = -2.463 + (2.751) = 0.288$; $\theta_{p3} = 16.1°$; $\theta_{S2} = 168.9°$;
d4) $\theta_{L2} = 24.3°$; $\mathrm{Im}(y_L) = 2.463 + (2.751) = 5.214$; $\theta_{p4} = 79.1°$; $\theta_{S2} = 168.9°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 165.2 + 132.9 = 298.1$; $\theta_p = 100.9$; $A \sim 30070.1$
e2) $\theta_s = 24.3 + 132.9 = 157.2$; $\theta_p = 163.9$; $A \sim 25772.2$
e3) $\theta_s = 165.2 + 168.9 = 334.2$; $\theta_p = 16.1$; $A \sim 5373.6$
e4) $\theta_s = 24.3 + 168.9 = 193.2$; $\theta_p = 79.1$; $A \sim 15293.7$
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 11

1. $y = Y/Y_0 = Z_0/Z = 45\Omega / (43.8 + j\cdot 55.5)\Omega = 0.394 - j\cdot 0.500$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0297 + j\cdot 0.0108)] / (0.02 + 0.0297 + j\cdot 0.0108)$
$\Gamma = (-0.231) + j\cdot(-0.167) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.285\angle -144.2° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I =22.80dB
$P_{in} = 3.60mW = 5.563dBm$; $P_{is} = P_{in} - I = 5.563dBm - 22.80dB = -17.24dBm = 18.893\mu W$
b) L2, C12/2017, $\beta = 10^{-C/20} = 0.460$, $y_2 = 1.126$, $y_1 = 0.518$, $Z_1 = Z_0/y_1 = 96.6\ \Omega$, $Z_2 = Z_0/y_2 = 44.4\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 54)}\Omega = 51.96\Omega$
b) $Z_L = 54\Omega$ series with 0.49pF capacitor at 7.7GHz $= 54.00\Omega + j\cdot(-42.18)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 31.05\Omega + j\cdot(24.26)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations ($G > 15.05dB$): $G = G_1 + G_4 = 6.6 + 11.7 = 18.3dB$; $G = G_2 + G_3 = 7.5 + 8.1 = 15.6dB$; $G = G_2 + G_4 = 7.5 + 11.7 = 19.2dB$; $G = G_3 + G_4 = 8.1 + 11.7 = 19.8dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.50dB=1.122$, $F_2 = 0.88dB=1.225$, $F_3 = 1.01dB=1.262$, $F_4 = 1.15dB=1.303$, $G_1 = 6.6dB=4.571$, $G_2 = 7.5dB=5.623$; $F(1,4) = 1.122 + (1.303-1)/4.571 = 1.188 = 0.75dB$; $F(2,3) = 1.225 + (1.262-1)/5.623 = 1.279 = 1.07dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.631 < 1$; $|S_{22}| = 0.550 < 1$; $K = 1.227 > 1$; $|\Delta| = |(0.258)+ j\cdot(-0.008)| = 0.258 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 9.51 = 9.78dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.029$; $C_1 = (-0.303) + j\cdot(0.402)$; $\Gamma_S = (-0.488) + j\cdot(-0.649) = 0.811\angle -126.9°$
$B_2 = 0.838$; $C_2 = (-0.395) + j\cdot(-0.090)$; $\Gamma_L = (-0.753) + j\cdot(0.171) = 0.772\angle 167.2°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 135.6°$; $\mathrm{Im}(y_S) = -2.776$; $\theta_{p1} = 109.8°$ <u>or</u> $\theta_{S2} = 171.4°$; $\mathrm{Im}(y_S) = 2.776$; $\theta_{p2} = 70.2°$
output: $\theta_{L1} = 166.7°$; $\mathrm{Im}(y_L) = -2.430$; $\theta_{p1} = 112.4°$ <u>or</u> $\theta_{L2} = 26.1°$; $\mathrm{Im}(y_L) = 2.430$; $\theta_{p2} = 67.6°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 166.7°$; $\mathrm{Im}(y_L) = -2.430 + (-2.776) = -5.206$; $\theta_{p1} = 100.9°$; $\theta_{S1} = 135.6°$;
d2) $\theta_{L2} = 26.1°$; $\mathrm{Im}(y_L) = 2.430 + (-2.776) = -0.347$; $\theta_{p2} = 160.9°$; $\theta_{S1} = 135.6°$;
d3) $\theta_{L1} = 166.7°$; $\mathrm{Im}(y_L) = -2.430 + (2.776) = 0.347$; $\theta_{p3} = 19.1°$; $\theta_{S2} = 171.4°$;
d4) $\theta_{L2} = 26.1°$; $\mathrm{Im}(y_L) = 2.430 + (2.776) = 5.206$; $\theta_{p4} = 79.1°$; $\theta_{S2} = 171.4°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 166.7 + 135.6 = 302.3$; $\theta_p = 100.9$; A ~ 30490.4
e2) $\theta_s = 26.1 + 135.6 = 161.7$; $\theta_p = 160.9$; A ~ 26017.6
e3) $\theta_s = 166.7 + 171.4 = 338.0$; $\theta_p = 19.1$; A ~ 6464.5
e4) $\theta_s = 26.1 + 171.4 = 197.5$; $\theta_p = 79.1$; A ~ 15626.9
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 12

1. $y = Y/Y_0 = Z_0/Z = 70\Omega / (41.7 + j\cdot 61.5)\Omega = 0.529 - j\cdot 0.780$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0379 - j\cdot 0.0114)] / (0.02 + 0.0379 - j\cdot 0.0114)$
$\Gamma = (-0.335) + j\cdot(0.131) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.360\angle 158.6° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I = D + C =29.95dB
$P_{in} = 1.50mW = 1.761dBm$; $P_{is} = P_{in} - I = 1.761dBm - 29.95dB = -28.19dBm = 1.517\mu W$
b) L2, C12/2017, $\beta = 10^{-C/20} = 0.487$, $y_2 = 1.145$, $y_1 = 0.558$, $Z_1 = Z_0/y_1 = 89.7\ \Omega$, $Z_2 = Z_0/y_2 = 43.7\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 51)}\Omega = 50.50\Omega$
b) $Z_L = 51\Omega$ parallel with 0.80nH inductor at 9.2GHz $= 23.01\Omega + j\cdot(25.38)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-55.14)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.25dB): $G = G_1 + G_4 = 6.9 + 10.8 = 17.7dB$; $G = G_2 + G_3 = 7.7 + 8.3 = 16.0dB$; $G = G_2 + G_4 = 7.7 + 10.8 = 18.5dB$; $G = G_3 + G_4 = 8.3 + 10.8 = 19.1dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.62dB=1.153$, $F_2 = 0.88dB=1.225$, $F_3 = 1.02dB=1.265$, $F_4 = 1.12dB=1.294$, $G_1 = 6.9dB=4.898$, $G_2 = 7.7dB=5.888$; $F(1,4) = 1.153 + (1.294-1)/4.898 = 1.214 = 0.84dB$; $F(2,3) = 1.225 + (1.265-1)/5.888 = 1.275 = 1.05dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.606 < 1$; $|S_{22}| = 0.558 < 1$; $K = 1.199 > 1$; $|\Delta| = |(0.232)+ j\cdot(-0.076)| = 0.244 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 8.90 = 9.49dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 0.996$; $C_1 = (-0.209) + j\cdot(0.440)$; $\Gamma_S = (-0.346) + j\cdot(-0.729) = 0.807\angle -115.4°$
$B_2 = 0.884$; $C_2 = (-0.428) + j\cdot(-0.039)$; $\Gamma_L = (-0.782) + j\cdot(0.071) = 0.785\angle 174.8°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 129.6°$; $\mathrm{Im}(y_S) = -2.735$; $\theta_{p1} = 110.1°$ <u>or</u> $\theta_{S2} = 165.8°$; $\mathrm{Im}(y_S) = 2.735$; $\theta_{p2} = 69.9°$
output: $\theta_{L1} = 163.4°$; $\mathrm{Im}(y_L) = -2.533$; $\theta_{p1} = 111.5°$ <u>or</u> $\theta_{L2} = 21.7°$; $\mathrm{Im}(y_L) = 2.533$; $\theta_{p2} = 68.5°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 163.4°$; $\mathrm{Im}(y_L) = -2.533 + (-2.735) = -5.267$; $\theta_{p1} = 100.7°$; $\theta_{S1} = 129.6°$;
d2) $\theta_{L2} = 21.7°$; $\mathrm{Im}(y_L) = 2.533 + (-2.735) = -0.202$; $\theta_{p2} = 168.6°$; $\theta_{S1} = 129.6°$;
d3) $\theta_{L1} = 163.4°$; $\mathrm{Im}(y_L) = -2.533 + (2.735) = 0.202$; $\theta_{p3} = 11.4°$; $\theta_{S2} = 165.8°$;
d4) $\theta_{L2} = 21.7°$; $\mathrm{Im}(y_L) = 2.533 + (2.735) = 5.267$; $\theta_{p4} = 79.3°$; $\theta_{S2} = 165.8°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 163.4 + 129.6 = 293.0$; $\theta_p = 100.7$; A ~ 29524.2
e2) $\theta_s = 21.7 + 129.6 = 151.3$; $\theta_p = 168.6$; A ~ 25514.5
e3) $\theta_s = 163.4 + 165.8 = 329.2$; $\theta_p = 11.4$; A ~ 3757.0
e4) $\theta_s = 21.7 + 165.8 = 187.5$; $\theta_p = 79.3$; A ~ 14861.2
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 13

1. $y = Y/Y_0 = Z_0/Z = 60\Omega / (60.6 - j\cdot 60.9)\Omega = 0.493 + j\cdot 0.495$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0283 + j\cdot 0.0144)] / (0.02 + 0.0283 + j\cdot 0.0144)$
$\Gamma = (-0.239) + j\cdot(-0.227) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.330\angle{-136.6°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =23.50dB
$P_{in} = 3.15\text{mW} = 4.983\text{dBm}$; $P_{is} = P_{in} - I = 4.983\text{dBm} - 23.50\text{dB} = -18.52\text{dBm} = 14.071\mu\text{W}$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.613$, $Z_{CE} = 102.09\Omega$, $Z_{CO} = 24.49\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 29)}\Omega = 38.08\Omega$
b) $Z_L = 29\Omega$ series with 0.60nH inductor at 8.4GHz = $29.00\Omega + j\cdot(31.67)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 22.81\Omega + j\cdot(-24.90)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 17.50dB): $G = G_1 + G_4 = 6.1 + 11.6 = 17.7\text{dB}$; $G = G_2 + G_3 = 8.8 + 9.8 = 18.6\text{dB}$; $G = G_2 + G_4 = 8.8 + 11.6 = 20.4\text{dB}$; $G = G_3 + G_4 = 9.8 + 11.6 = 21.4\text{dB}$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.52\text{dB}=1.127$, $F_2 = 0.85\text{dB}=1.216$, $F_3 = 1.06\text{dB}=1.276$, $F_4 = 1.10\text{dB}=1.288$, $G_1 = 6.1\text{dB}=4.074$, $G_2 = 8.8\text{dB}=7.586$; $F(1,4) = 1.127 + (1.288-1)/4.074 = 1.198 = 0.78\text{dB}$; $F(2,3) = 1.216 + (1.276-1)/7.586 = 1.254 = 0.98\text{dB}$;
$F(1,4) < F(2,3)$ → 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:
$|S_{11}| = 0.640 < 1$; $|S_{22}| = 0.550 < 1$; $K = 1.187 > 1$; $|\Delta| = |(0.259)+ j\cdot(0.107)| = 0.280 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 10.43 = 10.18\text{dB}$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.028$; $C_1 = (-0.380) + j\cdot(0.332)$; $\Gamma_S = (-0.620) + j\cdot(-0.542) = 0.823\angle{-138.8°}$
$B_2 = 0.814$; $C_2 = (-0.371) + j\cdot(-0.134)$; $\Gamma_L = (-0.734) + j\cdot(0.265) = 0.781\angle 160.1°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 142.1°$; $\mathrm{Im}(y_S) = -2.900$; $\theta_{p1} = 109.0°$ <u>or</u> $\theta_{S2} = 176.7°$; $\mathrm{Im}(y_S) = 2.900$; $\theta_{p2} = 71.0°$
output: $\theta_{L1} = 170.6°$; $\mathrm{Im}(y_L) = -2.499$; $\theta_{p1} = 111.8°$ <u>or</u> $\theta_{L2} = 29.3°$; $\mathrm{Im}(y_L) = 2.499$; $\theta_{p2} = 68.2°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 170.6°$; $\mathrm{Im}(y_L) = -2.499 + (-2.900) = -5.399$; $\theta_{p1} = 100.5°$; $\theta_{S1} = 142.1°$;
d2) $\theta_{L2} = 29.3°$; $\mathrm{Im}(y_L) = 2.499 + (-2.900) = -0.402$; $\theta_{p2} = 158.1°$; $\theta_{S1} = 142.1°$;
d3) $\theta_{L1} = 170.6°$; $\mathrm{Im}(y_L) = -2.499 + (2.900) = 0.402$; $\theta_{p3} = 21.9°$; $\theta_{S2} = 176.7°$;
d4) $\theta_{L2} = 29.3°$; $\mathrm{Im}(y_L) = 2.499 + (2.900) = 5.399$; $\theta_{p4} = 79.5°$; $\theta_{S2} = 176.7°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 170.6 + 142.1 = 312.7$; $\theta_p = 100.5$; $A \sim 31426.9$
e2) $\theta_s = 29.3 + 142.1 = 171.4$; $\theta_p = 158.1$; $A \sim 27101.5$
e3) $\theta_s = 170.6 + 176.7 = 347.3$; $\theta_p = 21.9$; $A \sim 7599.9$
e4) $\theta_s = 29.3 + 176.7 = 206.0$; $\theta_p = 79.5$; $A \sim 16377.5$
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 14

1. $y = Y/Y_0 = Z_0/Z = 100\Omega / (53.9 - j\cdot 68.9)\Omega = 0.704 + j\cdot 0.900$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0337 - j\cdot 0.0358)] / (0.02 + 0.0337 - j\cdot 0.0358)$
$\Gamma = (-0.484) + j\cdot(0.344) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.594\angle 144.6° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I =22.80dB
$P_{in} = 2.90mW = 4.624dBm$; $P_{is} = P_{in} - I = 4.624dBm - 22.80dB = -18.18dBm = 15.219\mu W$
b) L2, C12/2017, $\beta = 10^{-C/20} = 0.510$, $y_2 = 1.162$, $y_1 = 0.593$, $Z_1 = Z_0/y_1 = 84.3\ \Omega$, $Z_2 = Z_0/y_2 = 43.0\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 29)}\Omega = 38.08\Omega$
b) $Z_L = 29\Omega$ series with 0.46pF capacitor at 7.1GHz $= 29.00\Omega + j\cdot(-48.73)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 13.08\Omega + j\cdot(21.97)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 17.00dB): $G = G_1 + G_4 = 6.5 + 10.6 = 17.1dB$; $G = G_2 + G_3 = 8.8 + 9.7 = 18.5dB$; $G = G_2 + G_4 = 8.8 + 10.6 = 19.4dB$; $G = G_3 + G_4 = 9.7 + 10.6 = 20.3dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.65dB=1.161$, $F_2 = 0.73dB=1.183$, $F_3 = 1.05dB=1.274$, $F_4 = 1.14dB=1.300$, $G_1 = 6.5dB=4.467$, $G_2 = 8.8dB=7.586$; $F(1,4) = 1.161 + (1.300-1)/4.467 = 1.229 = 0.89dB$; $F(2,3) = 1.183 + (1.274-1)/7.586 = 1.223 = 0.87dB$;
$F(1,4) > F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.637 < 1$; $|S_{22}| = 0.550 < 1$; $K = 1.201 > 1$; $|\Delta| = |(0.265)+ j\cdot(0.060)| = 0.272 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 10.08 = 10.03dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.029$; $C_1 = (-0.351) + j\cdot(0.363)$; $\Gamma_S = (-0.570) + j\cdot(-0.589) = 0.819\angle -134.1°$
$B_2 = 0.823$; $C_2 = (-0.381) + j\cdot(-0.116)$; $\Gamma_L = (-0.744) + j\cdot(0.227) = 0.778\angle 163.0°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 139.5°$; $\mathrm{Im}(y_S) = -2.858$; $\theta_{p1} = 109.3°$ <u>or</u> $\theta_{S2} = 174.5°$; $\mathrm{Im}(y_S) = 2.858$; $\theta_{p2} = 70.7°$
output: $\theta_{L1} = 169.0°$; $\mathrm{Im}(y_L) = -2.475$; $\theta_{p1} = 112.0°$ <u>or</u> $\theta_{L2} = 27.9°$; $\mathrm{Im}(y_L) = 2.475$; $\theta_{p2} = 68.0°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 169.0°$; $\mathrm{Im}(y_L) = -2.475 + (-2.858) = -5.333$; $\theta_{p1} = 100.6°$; $\theta_{S1} = 139.5°$;
d2) $\theta_{L2} = 27.9°$; $\mathrm{Im}(y_L) = 2.475 + (-2.858) = -0.383$; $\theta_{p2} = 159.1°$; $\theta_{S1} = 139.5°$;
d3) $\theta_{L1} = 169.0°$; $\mathrm{Im}(y_L) = -2.475 + (2.858) = 0.383$; $\theta_{p3} = 20.9°$; $\theta_{S2} = 174.5°$;
d4) $\theta_{L2} = 27.9°$; $\mathrm{Im}(y_L) = 2.475 + (2.858) = 5.333$; $\theta_{p4} = 79.4°$; $\theta_{S2} = 174.5°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 169.0 + 139.5 = 308.5$; $\theta_p = 100.6$; A ~ 31045.6
e2) $\theta_s = 27.9 + 139.5 = 167.5$; $\theta_p = 159.1$; A ~ 26640.4
e3) $\theta_s = 169.0 + 174.5 = 343.5$; $\theta_p = 20.9$; A ~ 7191.6
e4) $\theta_s = 27.9 + 174.5 = 202.5$; $\theta_p = 79.4$; A ~ 16071.8
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 15

1. $y = Y/Y_0 = Z_0/Z = 100\Omega / (54.6 + j\cdot 52.3)\Omega = 0.955 - j\cdot 0.915$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0240 + j\cdot 0.0187)] / (0.02 + 0.0240 + j\cdot 0.0187)$
$\Gamma = (-0.230) + j\cdot(-0.327) \leftrightarrow Re\Gamma + j\cdot Im\Gamma$ or $\Gamma = 0.400\angle -125.1° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =21.10dB
P_{in} = 2.05mW = 3.118dBm; $P_{is} = P_{in} - I$ = 3.118dBm − 21.10dB = -17.98dBm = 15.913µW
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.465$, $Z_{CE} = 82.74\Omega$, $Z_{CO} = 30.21\Omega$

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 0.91nH inductor at 9.0GHz $= 25.49\Omega + j\cdot(29.23)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-57.33)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.25dB): $G = G_1 + G_4$ = 6.7 + 10.0 = 16.7dB; $G = G_2 + G_3$ = 8.9 + 9.5 = 18.4dB; $G = G_2 + G_4$ = 8.9 + 10.0 = 18.9dB; $G = G_3 + G_4$ = 9.5 + 10.0 = 19.5dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 = 0.75dB=1.189, F_3 = 0.99dB=1.256, F_4 = 1.13dB=1.297, G_1 = 6.7dB=4.677, G_2 = 8.9dB=7.762; F(1,4) = 1.164 + (1.297−1)/4.677 = 1.228 = 0.89dB; F(2,3) = 1.189 + (1.256−1)/7.762 = 1.227 = 0.89dB;
F(1,4) > F(2,3) → 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:
$|S_{11}| = 0.630 < 1$; $|S_{22}| = 0.550 < 1$; $K = 1.231 > 1$; $|\Delta| = |(0.255)+ j\cdot(-0.019)| = 0.256 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}]$ = 9.41 = 9.74dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.029$; $C_1 = (-0.294) + j\cdot(0.408)$; $\Gamma_S = (-0.473) + j\cdot(-0.657) = 0.810\angle -125.8°$
$B_2 = 0.840$; $C_2 = (-0.397) + j\cdot(-0.085)$; $\Gamma_L = (-0.754) + j\cdot(0.162) = 0.771\angle 167.9°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 134.9°$; $Im(y_S) = -2.762$; $\theta_{p1} = 109.9°$ <u>or</u> $\theta_{S2} = 170.8°$; $Im(y_S) = 2.762$; $\theta_{p2} = 70.1°$
output: $\theta_{L1} = 166.3°$; $Im(y_L) = -2.421$; $\theta_{p1} = 112.4°$ <u>or</u> $\theta_{L2} = 25.8°$; $Im(y_L) = 2.421$; $\theta_{p2} = 67.6°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 166.3°$; $Im(y_L) = -2.421 + (-2.762) = -5.183$; $\theta_{p1} = 100.9°$; $\theta_{S1} = 134.9°$;
d2) $\theta_{L2} = 25.8°$; $Im(y_L) = 2.421 + (-2.762) = -0.341$; $\theta_{p2} = 161.2°$; $\theta_{S1} = 134.9°$;
d3) $\theta_{L1} = 166.3°$; $Im(y_L) = -2.421 + (2.762) = 0.341$; $\theta_{p3} = 18.8°$; $\theta_{S2} = 170.8°$;
d4) $\theta_{L2} = 25.8°$; $Im(y_L) = 2.421 + (2.762) = 5.183$; $\theta_{p4} = 79.1°$; $\theta_{S2} = 170.8°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) θ_s = 166.3 + 134.9 = 301.2 ; θ_p = 100.9 ; A ~ 30397.8
e2) θ_s = 25.8 + 134.9 = 160.8 ; θ_p = 161.2 ; A ~ 25911.5
e3) θ_s = 166.3 + 170.8 = 337.1 ; θ_p = 18.8 ; A ~ 6345.9
e4) θ_s = 25.8 + 170.8 = 196.7 ; θ_p = 79.1 ; A ~ 15553.0
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 16

1. $y = Y/Y_0 = Z_0/Z = 70\Omega / (68.4 - j\cdot 60.3)\Omega = 0.576 + j\cdot 0.508$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0210 + j\cdot 0.0388)] / (0.02 + 0.0210 + j\cdot 0.0388\ )$
$\Gamma = (-0.485) + j\cdot(-0.487) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.688\angle -134.9° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I = D + C =25.45dB
P_{in} = 2.05mW = 3.118dBm; $P_{is} = P_{in} - I$ = 3.118dBm − 25.45dB = -22.33dBm = 5.845µW
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.599$, $Z_{CE} = 99.86\Omega$, $Z_{CO} = 25.04\Omega$

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 0.67nH inductor at 9.0GHz = $72.00\Omega + j\cdot(37.89)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 39.16\Omega + j\cdot(-20.61)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.80dB): $G = G_1 + G_4$ = 5.2 + 11.0 = 16.2dB; $G = G_2 + G_3$ = 7.7 + 8.9 = 16.6dB; $G = G_2 + G_4$ = 7.7 + 11.0 = 18.7dB; $G = G_3 + G_4$ = 8.9 + 11.0 = 19.9dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 = 0.77dB=1.194, F_3 = 1.01dB=1.262, F_4 = 1.12dB=1.294, G_1 = 5.2dB=3.311, G_2 = 7.7dB=5.888; F(1,4) = 1.148 + (1.294−1)/3.311 = 1.237 = 0.92dB; F(2,3) = 1.194 + (1.262−1)/5.888 = 1.244 = 0.95dB;
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:
$|S_{11}| = 0.599 < 1$; $|\ S_{22}| = 0.520 < 1$; $K = 1.191 > 1$; $|\Delta| = |(-0.015)+ j\cdot(0.257)| = 0.258 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}]$ = 15.60 = 11.93dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.022$; $C_1 = (-0.476) + j\cdot(0.142)$; $\Gamma_S = (-0.756) + j\cdot(-0.226) = 0.789\angle -163.4°$
$B_2 = 0.845$; $C_2 = (-0.251) + j\cdot(-0.318)$; $\Gamma_L = (-0.464) + j\cdot(0.588) = 0.749\angle 128.3°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 152.7°$; $\mathrm{Im}(y_S) = -2.569$; $\theta_{p1} = 111.3°$ <u>or</u> $\theta_{S2} = 10.6°$; $\mathrm{Im}(y_S) = 2.569$; $\theta_{p2} = 68.7°$
output: $\theta_{L1} = 5.1°$; $\mathrm{Im}(y_L) = -2.261$; $\theta_{p1} = 113.9°$ <u>or</u> $\theta_{L2} = 46.6°$; $\mathrm{Im}(y_L) = 2.261$; $\theta_{p2} = 66.1°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 5.1°$; $\mathrm{Im}(y_L) = -2.261 + (-2.569) = -4.831$; $\theta_{p1} = 101.7°$; $\theta_{S1} = 152.7°$;
d2) $\theta_{L2} = 46.6°$; $\mathrm{Im}(y_L) = 2.261 + (-2.569) = -0.308$; $\theta_{p2} = 162.9°$; $\theta_{S1} = 152.7°$;
d3) $\theta_{L1} = 5.1°$; $\mathrm{Im}(y_L) = -2.261 + (2.569) = 0.308$; $\theta_{p3} = 17.1°$; $\theta_{S2} = 10.6°$;
d4) $\theta_{L2} = 46.6°$; $\mathrm{Im}(y_L) = 2.261 + (2.569) = 4.831$; $\theta_{p4} = 78.3°$; $\theta_{S2} = 10.6°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 5.1 + 152.7 = 157.9$; $\theta_p = 101.7$; A ~ 16053.6
e2) $\theta_s = 46.6 + 152.7 = 199.3$; $\theta_p = 162.9$; A ~ 32469.7
e3) $\theta_s = 5.1 + 10.6 = 15.8$; $\theta_p = 17.1$; A ~ 269.8
e4) $\theta_s = 46.6 + 10.6 = 57.2$; $\theta_p = 78.3$; A ~ 4482.7
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 17

1. $y = Y/Y_0 = Z_0/Z = 90\Omega / (41.2 + j\cdot 37.4)\Omega = 1.198 - j\cdot 1.087$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0195 + j\cdot 0.0299)] / (0.02 + 0.0195 + j\cdot 0.0299)$
$\Gamma = (-0.356) + j\cdot(-0.487) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.604\angle -126.2° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I = D + C =28.95dB
$P_{in} = 3.10mW = 4.914dBm$; $P_{is} = P_{in} - I = 4.914dBm - 28.95dB = -24.04dBm = 3.948\mu W$
b) L2, C12/2017, $\beta = 10^{-C/20} = 0.465$, $y_2 = 1.130$, $y_1 = 0.525$, $Z_1 = Z_0/y_1 = 95.2\ \Omega$, $Z_2 = Z_0/y_2 = 44.3\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 50)}\Omega = 50.00\Omega$
b) $Z_L = 50\Omega$ series with 0.78nH inductor at 9.6GHz = $50.00\Omega + j\cdot(47.05)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 26.52\Omega + j\cdot(-24.95)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 14.95dB): $G = G_1 + G_4 = 5.2 + 11.0 = 16.2dB$; $G = G_2 + G_3 = 8.7 + 8.0 = 16.7dB$; $G = G_2 + G_4 = 8.7 + 11.0 = 19.7dB$; $G = G_3 + G_4 = 8.0 + 11.0 = 19.0dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.53dB=1.130$, $F_2 = 0.75dB=1.189$, $F_3 = 1.05dB=1.274$, $F_4 = 1.22dB=1.324$, $G_1 = 5.2dB=3.311$, $G_2 = 8.7dB=7.413$; $F(1,4) = 1.130 + (1.324-1)/3.311 = 1.228 = 0.89dB$; $F(2,3) = 1.189 + (1.274-1)/7.413 = 1.232 = 0.91dB$;
$F(1,4) < F(2,3) \to$ 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:
$|S_{11}| = 0.603 < 1$; $|S_{22}| = 0.559 < 1$; $K = 1.195 > 1$; $|\Delta| = |(0.229)+ j\cdot(-0.082)| = 0.243 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 8.83 = 9.46dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 0.992$; $C_1 = (-0.198) + j\cdot(0.443)$; $\Gamma_S = (-0.329) + j\cdot(-0.736) = 0.807\angle -114.1°$
$B_2 = 0.890$; $C_2 = (-0.431) + j\cdot(-0.032)$; $\Gamma_L = (-0.784) + j\cdot(0.059) = 0.786\angle 175.7°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 128.9°$; $\mathrm{Im}(y_S) = -2.731$; $\theta_{p1} = 110.1°$ <u>or</u> $\theta_{S2} = 165.2°$; $\mathrm{Im}(y_S) = 2.731$; $\theta_{p2} = 69.9°$
output: $\theta_{L1} = 163.1°$; $\mathrm{Im}(y_L) = -2.546$; $\theta_{p1} = 111.4°$ <u>or</u> $\theta_{L2} = 21.2°$; $\mathrm{Im}(y_L) = 2.546$; $\theta_{p2} = 68.6°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 163.1°$; $\mathrm{Im}(y_L) = -2.546 + (-2.731) = -5.277$; $\theta_{p1} = 100.7°$; $\theta_{S1} = 128.9°$;
d2) $\theta_{L2} = 21.2°$; $\mathrm{Im}(y_L) = 2.546 + (-2.731) = -0.185$; $\theta_{p2} = 169.5°$; $\theta_{S1} = 128.9°$;
d3) $\theta_{L1} = 163.1°$; $\mathrm{Im}(y_L) = -2.546 + (2.731) = 0.185$; $\theta_{p3} = 10.5°$; $\theta_{S2} = 165.2°$;
d4) $\theta_{L2} = 21.2°$; $\mathrm{Im}(y_L) = 2.546 + (2.731) = 5.277$; $\theta_{p4} = 79.3°$; $\theta_{S2} = 165.2°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 163.1 + 128.9 = 292.0$; $\theta_p = 100.7$; A ~ 29415.1
e2) $\theta_s = 21.2 + 128.9 = 150.2$; $\theta_p = 169.5$; A ~ 25458.6
e3) $\theta_s = 163.1 + 165.2 = 328.2$; $\theta_p = 10.5$; A ~ 3435.4
e4) $\theta_s = 21.2 + 165.2 = 186.4$; $\theta_p = 79.3$; A ~ 14774.7
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 18

1. $y = Y/Y_0 = Z_0/Z = 30\Omega / (69.2 - j\cdot 53.4)\Omega = 0.272 + j\cdot 0.210$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0133 - j\cdot 0.0316)] / (0.02 + 0.0133 - j\cdot 0.0316)$
$\Gamma = (-0.368) + j\cdot(0.600) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.704\angle 121.5° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =31.10dB
$P_{in} = 3.45mW = 5.378dBm$; $P_{is} = P_{in} - I = 5.378dBm - 31.10dB = -25.72dBm = 2.678\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.473$, $y_1 = 0.473$, $y_2 = 0.881$, $Z_1 = Z_0/y_1 = 105.7\ \Omega$, $Z_2 = Z_0/y_2 = 56.8\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 71)}\Omega = 59.58\Omega$
b) $Z_L = 71\Omega$ parallel with 0.42pF capacitor at 9.9GHz $= 15.99\Omega + j\cdot(-29.66)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(92.75)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 14.75dB): $G = G_1 + G_4 = 5.9 + 11.1 = 17.0dB$; $G = G_2 + G_3 = 8.6 + 8.8 = 17.4dB$; $G = G_2 + G_4 = 8.6 + 11.1 = 19.7dB$; $G = G_3 + G_4 = 8.8 + 11.1 = 19.9dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.55dB=1.135$, $F_2 = 0.86dB=1.219$, $F_3 = 0.90dB=1.230$, $F_4 = 1.13dB=1.297$, $G_1 = 5.9dB=3.890$, $G_2 = 8.6dB=7.244$; $F(1,4) = 1.135 + (1.297-1)/3.890 = 1.211 = 0.83dB$; $F(2,3) = 1.219 + (1.230-1)/7.244 = 1.260 = 1.00dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.608 < 1$; $|S_{22}| = 0.520 < 1$; $K = 1.157 > 1$; $|\Delta| = |(-0.048)+ j\cdot(0.263)| = 0.267 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 16.74 = 12.24dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.028$; $C_1 = (-0.491) + j\cdot(0.108)$; $\Gamma_S = (-0.788) + j\cdot(-0.173) = 0.807\angle -167.6°$
$B_2 = 0.829$; $C_2 = (-0.238) + j\cdot(-0.322)$; $\Gamma_L = (-0.454) + j\cdot(0.615) = 0.765\angle 126.4°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 155.7°$; $\mathrm{Im}(y_S) = -2.732$; $\theta_{p1} = 110.1°$ <u>or</u> $\theta_{S2} = 11.9°$; $\mathrm{Im}(y_S) = 2.732$; $\theta_{p2} = 69.9°$
output: $\theta_{L1} = 6.7°$; $\mathrm{Im}(y_L) = -2.373$; $\theta_{p1} = 112.8°$ <u>or</u> $\theta_{L2} = 46.8°$; $\mathrm{Im}(y_L) = 2.373$; $\theta_{p2} = 67.2°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 6.7°$; $\mathrm{Im}(y_L) = -2.373 + (-2.732) = -5.105$; $\theta_{p1} = 101.1°$; $\theta_{S1} = 155.7°$;
d2) $\theta_{L2} = 46.8°$; $\mathrm{Im}(y_L) = 2.373 + (-2.732) = -0.358$; $\theta_{p2} = 160.3°$; $\theta_{S1} = 155.7°$;
d3) $\theta_{L1} = 6.7°$; $\mathrm{Im}(y_L) = -2.373 + (2.732) = 0.358$; $\theta_{p3} = 19.7°$; $\theta_{S2} = 11.9°$;
d4) $\theta_{L2} = 46.8°$; $\mathrm{Im}(y_L) = 2.373 + (2.732) = 5.105$; $\theta_{p4} = 78.9°$; $\theta_{S2} = 11.9°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 6.7 + 155.7 = 162.4$; $\theta_p = 101.1$; A ~ 16418.7
e2) $\theta_s = 46.8 + 155.7 = 202.5$; $\theta_p = 160.3$; A ~ 32468.6
e3) $\theta_s = 6.7 + 11.9 = 18.6$; $\theta_p = 19.7$; A ~ 367.1
e4) $\theta_s = 46.8 + 11.9 = 58.8$; $\theta_p = 78.9$; A ~ 4637.0
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 19

1. $y = Y/Y_0 = Z_0/Z = 70\Omega / (31.2 - j\cdot 59.0)\Omega = 0.490 + j\cdot 0.927$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0249 + j\cdot 0.0350)] / (0.02 + 0.0249 + j\cdot 0.0350)$
$\Gamma = (-0.446) + j\cdot(-0.432) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.621\angle\text{-}135.9° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =26.35dB
$P_{in} = 3.30mW = 5.185dBm$; $P_{is} = P_{in} - I = 5.185dBm - 26.35dB = -21.16dBm = 7.647\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.585$, $y_1 = 0.585$, $y_2 = 0.811$, $Z_1 = Z_0/y_1 = 85.4\ \Omega$, $Z_2 = Z_0/y_2 = 61.7\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 74)}\Omega = 60.83\Omega$
b) $Z_L = 74\Omega$ series with 0.73nH inductor at 8.7GHz = $74.00\Omega + j\cdot(39.90)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 38.74\Omega + j\cdot(-20.89)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.30dB): $G = G_1 + G_4 = 5.0 + 11.9 = 16.9dB$; $G = G_2 + G_3 = 8.2 + 9.4 = 17.6dB$; $G = G_2 + G_4 = 8.2 + 11.9 = 20.1dB$; $G = G_3 + G_4 = 9.4 + 11.9 = 21.3dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.66dB=1.164$, $F_2 = 0.78dB=1.197$, $F_3 = 1.02dB=1.265$, $F_4 = 1.19dB=1.315$, $G_1 = 5.0dB=3.162$, $G_2 = 8.2dB=6.607$; $F(1,4) = 1.164 + (1.315-1)/3.162 = 1.264 = 1.02dB$; $F(2,3) = 1.197 + (1.265-1)/6.607 = 1.244 = 0.95dB$;
$F(1,4) > F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.620 < 1$; $|S_{22}| = 0.520 < 1$; $K = 1.114 > 1$; $|\Delta| = |(-0.096)+ j\cdot(0.264)| = 0.281 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2\text{-}1)}] = 18.51 = 12.67dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.035$; $C_1 = (-0.506) + j\cdot(0.059)$; $\Gamma_S = (-0.827) + j\cdot(-0.097) = 0.833\angle\text{-}173.3°$
$B_2 = 0.807$; $C_2 = (-0.220) + j\cdot(-0.325)$; $\Gamma_L = (-0.443) + j\cdot(0.654) = 0.790\angle 124.1°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 159.9°$; $\mathrm{Im}(y_S) = -3.011$; $\theta_{p1} = 108.4°$ <u>or</u> $\theta_{S2} = 13.5°$; $\mathrm{Im}(y_S) = 3.011$; $\theta_{p2} = 71.6°$
output: $\theta_{L1} = 9.0°$; $\mathrm{Im}(y_L) = -2.574$; $\theta_{p1} = 111.2°$ <u>or</u> $\theta_{L2} = 46.9°$; $\mathrm{Im}(y_L) = 2.574$; $\theta_{p2} = 68.8°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 9.0°$; $\mathrm{Im}(y_L) = -2.574 + (-3.011) = -5.585$; $\theta_{p1} = 100.2°$; $\theta_{S1} = 159.9°$;
d2) $\theta_{L2} = 46.9°$; $\mathrm{Im}(y_L) = 2.574 + (-3.011) = -0.436$; $\theta_{p2} = 156.4°$; $\theta_{S1} = 159.9°$;
d3) $\theta_{L1} = 9.0°$; $\mathrm{Im}(y_L) = -2.574 + (3.011) = 0.436$; $\theta_{p3} = 23.6°$; $\theta_{S2} = 13.5°$;
d4) $\theta_{L2} = 46.9°$; $\mathrm{Im}(y_L) = 2.574 + (3.011) = 5.585$; $\theta_{p4} = 79.8°$; $\theta_{S2} = 13.5°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 9.0 + 159.9 = 168.9$; $\theta_p = 100.2$; A ~ 16915.2
e2) $\theta_s = 46.9 + 159.9 = 206.7$; $\theta_p = 156.4$; A ~ 32339.5
e3) $\theta_s = 9.0 + 13.5 = 22.5$; $\theta_p = 23.6$; A ~ 530.2
e4) $\theta_s = 46.9 + 13.5 = 60.3$; $\theta_p = 79.8$; A ~ 4817.6
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 20

1. $y = Y/Y_0 = Z_0/Z = 50\Omega \,/\, (56.6 + j\cdot 36.8)\Omega = 0.621 - j\cdot 0.404$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0105 - j\cdot 0.0151)] / (0.02 + 0.0105 - j\cdot 0.0151\ )$
$\Gamma = (0.053) + j\cdot(0.521) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.524\angle 84.2° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I = D + C =31.20dB
$P_{in} = 3.90mW = 5.911dBm$; $P_{is} = P_{in} - I = 5.911dBm - 31.20dB = -25.29dBm = 2.958\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.468$, $Z_{CE} = 83.03\Omega$, $Z_{CO} = 30.11\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 65)}\Omega = 57.01\Omega$
b) $Z_L = 65\Omega$ series with 0.30pF capacitor at 9.0GHz = $65.00\Omega + j\cdot(-58.95)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 27.44\Omega + j\cdot(24.88)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.85dB): $G = G_1 + G_4 = 6.1 + 11.4 = 17.5dB$; $G = G_2 + G_3 = 7.2 + 9.9 = 17.1dB$; $G = G_2 + G_4 = 7.2 + 11.4 = 18.6dB$; $G = G_3 + G_4 = 9.9 + 11.4 = 21.3dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.57dB=1.140$, $F_2 = 0.70dB=1.175$, $F_3 = 0.94dB=1.242$, $F_4 = 1.19dB=1.315$, $G_1 = 6.1dB=4.074$, $G_2 = 7.2dB=5.248$; $F(1,4) = 1.140 + (1.315-1)/4.074 = 1.218 = 0.86dB$; $F(2,3) = 1.175 + (1.242-1)/5.248 = 1.235 = 0.92dB$;
$F(1,4) < F(2,3) \to$ 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:
$|S_{11}| = 0.639 < 1$; $|\ S_{22}| = 0.550 < 1$; $K = 1.193 > 1$; $|\Delta| = |(0.264)+ j\cdot(0.084)| = 0.277 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 10.26 = 10.11dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.029$; $C_1 = (-0.366) + j\cdot(0.348)$; $\Gamma_S = (-0.595) + j\cdot(-0.566) = 0.822\angle -136.4°$
$B_2 = 0.818$; $C_2 = (-0.376) + j\cdot(-0.125)$; $\Gamma_L = (-0.740) + j\cdot(0.245) = 0.779\angle 161.7°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 140.8°$; $\mathrm{Im}(y_S) = -2.883$; $\theta_{p1} = 109.1°$ <u>or</u> $\theta_{S2} = 175.6°$; $\mathrm{Im}(y_S) = 2.883$; $\theta_{p2} = 70.9°$
output: $\theta_{L1} = 169.8°$; $\mathrm{Im}(y_L) = -2.488$; $\theta_{p1} = 111.9°$ <u>or</u> $\theta_{L2} = 28.6°$; $\mathrm{Im}(y_L) = 2.488$; $\theta_{p2} = 68.1°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 169.8°$; $\mathrm{Im}(y_L) = -2.488 + (-2.883) = -5.372$; $\theta_{p1} = 100.5°$; $\theta_{S1} = 140.8°$;
d2) $\theta_{L2} = 28.6°$; $\mathrm{Im}(y_L) = 2.488 + (-2.883) = -0.395$; $\theta_{p2} = 158.5°$; $\theta_{S1} = 140.8°$;
d3) $\theta_{L1} = 169.8°$; $\mathrm{Im}(y_L) = -2.488 + (2.883) = 0.395$; $\theta_{p3} = 21.5°$; $\theta_{S2} = 175.6°$;
d4) $\theta_{L2} = 28.6°$; $\mathrm{Im}(y_L) = 2.488 + (2.883) = 5.372$; $\theta_{p4} = 79.5°$; $\theta_{S2} = 175.6°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 169.8 + 140.8 = 310.6$; $\theta_p = 100.5$; A ~ 31230.5
e2) $\theta_s = 28.6 + 140.8 = 169.4$; $\theta_p = 158.5$; A ~ 26842.5
e3) $\theta_s = 169.8 + 175.6 = 345.4$; $\theta_p = 21.5$; A ~ 7440.4
e4) $\theta_s = 28.6 + 175.6 = 204.1$; $\theta_p = 79.5$; A ~ 16220.5
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 21

1. $y = Y/Y_0 = Z_0/Z = 80\Omega / (43.6 + j\cdot 37.4)\Omega = 1.057 - j\cdot 0.907$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0336 + j\cdot 0.0168)] / (0.02 + 0.0336 + j\cdot 0.0168\ )$
$\Gamma = (-0.320) + j\cdot(-0.213) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.385\angle -146.4° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =24.95dB
$P_{in} = 1.85mW = 2.672dBm$; $P_{is} = P_{in} - I = 2.672dBm - 24.95dB = -22.28dBm = 5.918\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.613$, $y_1 = 0.613$, $y_2 = 0.790$, $Z_1 = Z_0/y_1 = 81.6\ \Omega$, $Z_2 = Z_0/y_2 = 63.3\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 54)}\Omega = 51.96\Omega$
b) $Z_L = 54\Omega$ series with 0.37pF capacitor at 6.6GHz = $54.00\Omega + j\cdot(-65.17)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 20.35\Omega + j\cdot(24.56)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.05dB): $G = G_1 + G_4 = 6.1 + 11.7 = 17.8dB$; $G = G_2 + G_3 = 8.5 + 9.4 = 17.9dB$; $G = G_2 + G_4 = 8.5 + 11.7 = 20.2dB$; $G = G_3 + G_4 = 9.4 + 11.7 = 21.1dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.67dB=1.167$, $F_2 = 0.76dB=1.191$, $F_3 = 0.97dB=1.250$, $F_4 = 1.20dB=1.318$, $G_1 = 6.1dB=4.074$, $G_2 = 8.5dB=7.079$; $F(1,4) = 1.167 + (1.318-1)/4.074 = 1.245 = 0.95dB$; $F(2,3) = 1.191 + (1.250-1)/7.079 = 1.236 = 0.92dB$;
$F(1,4) > F(2,3) \to$ 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:
$|S_{11}| = 0.644 < 1$; $|S_{22}| = 0.520 < 1$; $K = 1.101 > 1$; $|\Delta| = |(-0.126)+ j\cdot(0.250)| = 0.280 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 22.09 = 13.44dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.066$; $C_1 = (-0.525) + j\cdot(-0.045)$; $\Gamma_S = (-0.853) + j\cdot(0.073) = 0.856\angle 175.1°$
$B_2 = 0.777$; $C_2 = (-0.211) + j\cdot(-0.316)$; $\Gamma_L = (-0.447) + j\cdot(0.671) = 0.807\angle 123.7°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 166.9°$; $\mathrm{Im}(y_S) = -3.311$; $\theta_{p1} = 106.8°$ <u>or</u> $\theta_{S2} = 18.0°$; $\mathrm{Im}(y_S) = 3.311$; $\theta_{p2} = 73.2°$
output: $\theta_{L1} = 10.0°$; $\mathrm{Im}(y_L) = -2.730$; $\theta_{p1} = 110.1°$ <u>or</u> $\theta_{L2} = 46.3°$; $\mathrm{Im}(y_L) = 2.730$; $\theta_{p2} = 69.9°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 10.0°$; $\mathrm{Im}(y_L) = -2.730 + (-3.311) = -6.042$; $\theta_{p1} = 99.4°$; $\theta_{S1} = 166.9°$;
d2) $\theta_{L2} = 46.3°$; $\mathrm{Im}(y_L) = 2.730 + (-3.311) = -0.581$; $\theta_{p2} = 149.8°$; $\theta_{S1} = 166.9°$;
d3) $\theta_{L1} = 10.0°$; $\mathrm{Im}(y_L) = -2.730 + (3.311) = 0.581$; $\theta_{p3} = 30.2°$; $\theta_{S2} = 18.0°$;
d4) $\theta_{L2} = 46.3°$; $\mathrm{Im}(y_L) = 2.730 + (3.311) = 6.042$; $\theta_{p4} = 80.6°$; $\theta_{S2} = 18.0°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 10.0 + 166.9 = 176.9$; $\theta_p = 99.4$; A ~ 17586.7
e2) $\theta_s = 46.3 + 166.9 = 213.2$; $\theta_p = 149.8$; A ~ 31937.7
e3) $\theta_s = 10.0 + 18.0 = 28.1$; $\theta_p = 30.2$; A ~ 846.6
e4) $\theta_s = 46.3 + 18.0 = 64.3$; $\theta_p = 80.6$; A ~ 5181.6
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 22

1. $y = Y/Y_0 = Z_0/Z = 85\Omega\ /\ (44.4 - j\cdot 56.6)\Omega = 0.729 + j\cdot 0.930$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y)\ /\ (Y_0 + Y) = [0.02 - (0.0184 - j\cdot 0.0361)]\ /\ (0.02 + 0.0184 - j\cdot 0.0361\ )$
$\Gamma = (-0.447) + j\cdot(0.520) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.686\angle 130.7° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I =21.50dB
$P_{in} = 4.05mW = 6.075dBm$; $P_{is} = P_{in} - I = 6.075dBm - 21.50dB = -15.43dBm = 28.672\mu W$
b) L2, C12/2017, $\beta = 10^{-C/20} = 0.572$, $y_2 = 1.219$, $y_1 = 0.698$, $Z_1 = Z_0/y_1 = 71.7\ \Omega$, $Z_2 = Z_0/y_2 = 41.0\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 67)}\Omega = 57.88\Omega$
b) $Z_L = 67\Omega$ series with 1.05nH inductor at 7.5GHz $= 67.00\Omega + j\cdot(49.48)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 32.35\Omega + j\cdot(-23.89)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 14.55dB): $G = G_1 + G_4 = 5.1 + 11.6 = 16.7dB$; $G = G_2 + G_3 = 8.7 + 9.4 = 18.1dB$; $G = G_2 + G_4 = 8.7 + 11.6 = 20.3dB$; $G = G_3 + G_4 = 9.4 + 11.6 = 21.0dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.51dB=1.125$, $F_2 = 0.80dB=1.202$, $F_3 = 0.94dB=1.242$, $F_4 = 1.21dB=1.321$, $G_1 = 5.1dB=3.236$, $G_2 = 8.7dB=7.413$; $F(1,4) = 1.125 + (1.321-1)/3.236 = 1.224 = 0.88dB$; $F(2,3) = 1.202 + (1.242-1)/7.413 = 1.246 = 0.95dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.635 < 1$; $|\ S_{22}| = 0.520 < 1$; $K = 1.105 > 1$; $|\Delta| = |(-0.115)+ j\cdot(0.256)| = 0.280 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 20.69 = 13.16dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.054$; $C_1 = (-0.520) + j\cdot(-0.005)$; $\Gamma_S = (-0.848) + j\cdot(0.008) = 0.848\angle 179.4°$
$B_2 = 0.789$; $C_2 = (-0.214) + j\cdot(-0.320)$; $\Gamma_L = (-0.446) + j\cdot(0.665) = 0.801\angle 123.9°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 164.3°$; $\mathrm{Im}(y_S) = -3.202$; $\theta_{p1} = 107.3°$ <u>or</u> $\theta_{S2} = 16.3°$; $\mathrm{Im}(y_S) = 3.202$; $\theta_{p2} = 72.7°$
output: $\theta_{L1} = 9.7°$; $\mathrm{Im}(y_L) = -2.677$; $\theta_{p1} = 110.5°$ <u>or</u> $\theta_{L2} = 46.5°$; $\mathrm{Im}(y_L) = 2.677$; $\theta_{p2} = 69.5°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 9.7°$; $\mathrm{Im}(y_L) = -2.677 + (-3.202) = -5.878$; $\theta_{p1} = 99.7°$; $\theta_{S1} = 164.3°$;
d2) $\theta_{L2} = 46.5°$; $\mathrm{Im}(y_L) = 2.677 + (-3.202) = -0.525$; $\theta_{p2} = 152.3°$; $\theta_{S1} = 164.3°$;
d3) $\theta_{L1} = 9.7°$; $\mathrm{Im}(y_L) = -2.677 + (3.202) = 0.525$; $\theta_{p3} = 27.7°$; $\theta_{S2} = 16.3°$;
d4) $\theta_{L2} = 46.5°$; $\mathrm{Im}(y_L) = 2.677 + (3.202) = 5.878$; $\theta_{p4} = 80.3°$; $\theta_{S2} = 16.3°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 9.7 + 164.3 = 174.0$; $\theta_p = 99.7$; A ~ 17337.3
e2) $\theta_s = 46.5 + 164.3 = 210.7$; $\theta_p = 152.3$; A ~ 32095.0
e3) $\theta_s = 9.7 + 16.3 = 26.0$; $\theta_p = 27.7$; A ~ 719.4
e4) $\theta_s = 46.5 + 16.3 = 62.7$; $\theta_p = 80.3$; A ~ 5040.3
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 23

1. $y = Y/Y_0 = Z_0/Z = 40\Omega / (30.7 + j\cdot 53.0)\Omega = 0.327 - j\cdot 0.565$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0315 - j\cdot 0.0161)] / (0.02 + 0.0315 - j\cdot 0.0161)$
$\Gamma = (-0.292) + j\cdot(0.221) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.367\angle 142.9° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =24.50dB
$P_{in} = 2.80mW = 4.472dBm$; $P_{is} = P_{in} - I = 4.472dBm - 24.50dB = -20.03dBm = 9.935\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.631$, $Z_{CE} = 105.11\Omega$, $Z_{CO} = 23.78\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 46)}\Omega = 47.96\Omega$
b) $Z_L = 46\Omega$ series with 0.30pF capacitor at 9.3GHz $= 46.00\Omega + j\cdot(-57.04)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 19.70\Omega + j\cdot(24.43)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.10dB): $G = G_1 + G_4 = 5.6 + 10.3 = 15.9dB$; $G = G_2 + G_3 = 8.5 + 9.1 = 17.6dB$; $G = G_2 + G_4 = 8.5 + 10.3 = 18.8dB$; $G = G_3 + G_4 = 9.1 + 10.3 = 19.4dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.64dB=1.159$, $F_2 = 0.82dB=1.208$, $F_3 = 0.98dB=1.253$, $F_4 = 1.19dB=1.315$, $G_1 = 5.6dB=3.631$, $G_2 = 8.5dB=7.079$; $F(1,4) = 1.159 + (1.315-1)/3.631 = 1.246 = 0.95dB$; $F(2,3) = 1.208 + (1.253-1)/7.079 = 1.252 = 0.98dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.633 < 1$; $| S_{22}| = 0.550 < 1$; $K = 1.218 > 1$; $|\Delta| = |(0.262)+ j\cdot(0.015)| = 0.263 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 9.69 = 9.87dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.029$; $C_1 = (-0.319) + j\cdot(0.390)$; $\Gamma_S = (-0.516) + j\cdot(-0.630) = 0.814\angle -129.3°$
$B_2 = 0.833$; $C_2 = (-0.391) + j\cdot(-0.099)$; $\Gamma_L = (-0.750) + j\cdot(0.190) = 0.774\angle 165.8°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 136.9°$; $\mathrm{Im}(y_S) = -2.803$; $\theta_{p1} = 109.6°$ <u>or</u> $\theta_{S2} = 172.4°$; $\mathrm{Im}(y_S) = 2.803$; $\theta_{p2} = 70.4°$
output: $\theta_{L1} = 167.5°$; $\mathrm{Im}(y_L) = -2.445$; $\theta_{p1} = 112.2°$ <u>or</u> $\theta_{L2} = 26.7°$; $\mathrm{Im}(y_L) = 2.445$; $\theta_{p2} = 67.8°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 167.5°$; $\mathrm{Im}(y_L) = -2.445 + (-2.803) = -5.248$; $\theta_{p1} = 100.8°$; $\theta_{S1} = 136.9°$;
d2) $\theta_{L2} = 26.7°$; $\mathrm{Im}(y_L) = 2.445 + (-2.803) = -0.358$; $\theta_{p2} = 160.3°$; $\theta_{S1} = 136.9°$;
d3) $\theta_{L1} = 167.5°$; $\mathrm{Im}(y_L) = -2.445 + (2.803) = 0.358$; $\theta_{p3} = 19.7°$; $\theta_{S2} = 172.4°$;
d4) $\theta_{L2} = 26.7°$; $\mathrm{Im}(y_L) = 2.445 + (2.803) = 5.248$; $\theta_{p4} = 79.2°$; $\theta_{S2} = 172.4°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 167.5 + 136.9 = 304.4$; $\theta_p = 100.8$; A ~ 30676.0
e2) $\theta_s = 26.7 + 136.9 = 163.6$; $\theta_p = 160.3$; A ~ 26229.3
e3) $\theta_s = 167.5 + 172.4 = 339.9$; $\theta_p = 19.7$; A ~ 6701.9
e4) $\theta_s = 26.7 + 172.4 = 199.2$; $\theta_p = 79.2$; A ~ 15775.2
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 24

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (49.9 + j\cdot 60.2)\Omega = 0.408 - j\cdot 0.492$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0327 - j\cdot 0.0257)] / (0.02 + 0.0327 - j\cdot 0.0257)$
$\Gamma = (-0.387) + j\cdot(0.299) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.489\angle 142.3° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =21.00dB
P_{in} = 2.70mW = 4.314dBm; $P_{is} = P_{in} - I$ = 4.314dBm − 21.00dB = -16.69dBm = 21.447μW
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.631$, $Z_{CE} = 105.11\Omega$, $Z_{CO} = 23.78\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 70)}\Omega = 59.16\Omega$
b) $Z_L = 70\Omega$ parallel with 1.39nH inductor at 7.7GHz = $33.60\Omega + j\cdot(34.97)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-52.05)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.60dB): $G = G_1 + G_4$ = 6.0 + 11.3 = 17.3dB; $G = G_2 + G_3$ = 8.6 + 8.5 = 17.1dB; $G = G_2 + G_4$ = 8.6 + 11.3 = 19.9dB; $G = G_3 + G_4$ = 8.5 + 11.3 = 19.8dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 = 0.72dB=1.180, F_3 = 0.94dB=1.242, F_4 = 1.15dB=1.303, G_1 = 6.0dB=3.981, G_2 = 8.6dB=7.244; F(1,4) = 1.132 + (1.303−1)/3.981 = 1.209 = 0.82dB; F(2,3) = 1.180 + (1.242−1)/7.244 = 1.222 = 0.87dB;
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:
$|S_{11}| = 0.600 < 1$; $|S_{22}| = 0.560 < 1$; $K = 1.192 > 1$; $|\Delta| = |(0.225)+ j\cdot(-0.088)| = 0.242 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}]$ = 8.77 = 9.43dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 0.988$; $C_1 = (-0.187) + j\cdot(0.445)$; $\Gamma_S = (-0.313) + j\cdot(-0.743) = 0.806\angle -112.8°$
$B_2 = 0.895$; $C_2 = (-0.434) + j\cdot(-0.026)$; $\Gamma_L = (-0.787) + j\cdot(0.047) = 0.788\angle 176.6°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 128.3°$; $\mathrm{Im}(y_S) = -2.727$; $\theta_{p1} = 110.1°$ <u>or</u> $\theta_{S2} = 164.5°$; $\mathrm{Im}(y_S) = 2.727$; $\theta_{p2} = 69.9°$
output: $\theta_{L1} = 162.7°$; $\mathrm{Im}(y_L) = -2.560$; $\theta_{p1} = 111.3°$ <u>or</u> $\theta_{L2} = 20.7°$; $\mathrm{Im}(y_L) = 2.560$; $\theta_{p2} = 68.7°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 162.7°$; $\mathrm{Im}(y_L) = -2.560 + (-2.727) = -5.287$; $\theta_{p1} = 100.7°$; $\theta_{S1} = 128.3°$;
d2) $\theta_{L2} = 20.7°$; $\mathrm{Im}(y_L) = 2.560 + (-2.727) = -0.168$; $\theta_{p2} = 170.5°$; $\theta_{S1} = 128.3°$;
d3) $\theta_{L1} = 162.7°$; $\mathrm{Im}(y_L) = -2.560 + (2.727) = 0.168$; $\theta_{p3} = 9.5°$; $\theta_{S2} = 164.5°$;
d4) $\theta_{L2} = 20.7°$; $\mathrm{Im}(y_L) = 2.560 + (2.727) = 5.287$; $\theta_{p4} = 79.3°$; $\theta_{S2} = 164.5°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) θ_s = 162.7 + 128.3 = 291.0 ; θ_p = 100.7 ; A ~ 29306.1
e2) θ_s = 20.7 + 128.3 = 149.0 ; θ_p = 170.5 ; A ~ 25400.9
e3) θ_s = 162.7 + 164.5 = 327.2 ; θ_p = 9.5 ; A ~ 3114.9
e4) θ_s = 20.7 + 164.5 = 185.2 ; θ_p = 79.3 ; A ~ 14688.2
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 25

1. $y = Y/Y_0 = Z_0/Z = 30\Omega / (35.4 + j\cdot 58.9)\Omega = 0.225 - j\cdot 0.374$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0342 + j\cdot 0.0358)] / (0.02 + 0.0342 + j\cdot 0.0358\ )$
$\Gamma = (-0.486) + j\cdot(-0.339) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.593\angle -145.1° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I =22.90dB
$P_{in} = 1.75mW = 2.430dBm$; $P_{is} = P_{in} - I = 2.430dBm - 22.90dB = -20.47dBm = 8.975\mu W$
b) L2, C12/2017, $\beta = 10^{-C/20} = 0.490$, $y_2 = 1.147$, $y_1 = 0.562$, $Z_1 = Z_0/y_1 = 89.0\ \Omega$, $Z_2 = Z_0/y_2 = 43.6\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 28)}\Omega = 37.42\Omega$
b) $Z_L = 28\Omega$ series with 1.44nH inductor at 7.5GHz $= 28.00\Omega + j\cdot(67.86)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 7.27\Omega + j\cdot(-17.63)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations ($G > 14.65dB$): $G = G_1 + G_4 = 5.1 + 11.9 = 17.0dB$; $G = G_2 + G_3 = 8.2 + 8.6 = 16.8dB$; $G = G_2 + G_4 = 8.2 + 11.9 = 20.1dB$; $G = G_3 + G_4 = 8.6 + 11.9 = 20.5dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.64dB=1.159$, $F_2 = 0.81dB=1.205$, $F_3 = 0.98dB=1.253$, $F_4 = 1.25dB=1.334$, $G_1 = 5.1dB=3.236$, $G_2 = 8.2dB=6.607$; $F(1,4) = 1.159 + (1.334-1)/3.236 = 1.262 = 1.01dB$; $F(2,3) = 1.205 + (1.253-1)/6.607 = 1.256 = 0.99dB$;
$F(1,4) > F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.623 < 1$; $|\ S_{22}| = 0.520 < 1$; $K = 1.112 > 1$; $|\Delta| = |(-0.100)+ j\cdot(0.262)| = 0.281 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 18.93 = 12.77dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.039$; $C_1 = (-0.509) + j\cdot(0.047)$; $\Gamma_S = (-0.833) + j\cdot(-0.076) = 0.836\angle -174.8°$
$B_2 = 0.804$; $C_2 = (-0.219) + j\cdot(-0.324)$; $\Gamma_L = (-0.443) + j\cdot(0.656) = 0.792\angle 124.0°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 160.8°$; $\mathrm{Im}(y_S) = -3.049$; $\theta_{p1} = 108.2°$ <u>or</u> $\theta_{S2} = 14.0°$; $\mathrm{Im}(y_S) = 3.049$; $\theta_{p2} = 71.8°$
output: $\theta_{L1} = 9.2°$; $\mathrm{Im}(y_L) = -2.596$; $\theta_{p1} = 111.1°$ <u>or</u> $\theta_{L2} = 46.8°$; $\mathrm{Im}(y_L) = 2.596$; $\theta_{p2} = 68.9°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 9.2°$; $\mathrm{Im}(y_L) = -2.596 + (-3.049) = -5.645$; $\theta_{p1} = 100.0°$; $\theta_{S1} = 160.8°$;
d2) $\theta_{L2} = 46.8°$; $\mathrm{Im}(y_L) = 2.596 + (-3.049) = -0.454$; $\theta_{p2} = 155.6°$; $\theta_{S1} = 160.8°$;
d3) $\theta_{L1} = 9.2°$; $\mathrm{Im}(y_L) = -2.596 + (3.049) = 0.454$; $\theta_{p3} = 24.4°$; $\theta_{S2} = 14.0°$;
d4) $\theta_{L2} = 46.8°$; $\mathrm{Im}(y_L) = 2.596 + (3.049) = 5.645$; $\theta_{p4} = 80.0°$; $\theta_{S2} = 14.0°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 9.2 + 160.8 = 169.9$; $\theta_p = 100.0$; $A \sim 17000.2$
e2) $\theta_s = 46.8 + 160.8 = 207.5$; $\theta_p = 155.6$; $A \sim 32293.4$
e3) $\theta_s = 9.2 + 14.0 = 23.2$; $\theta_p = 24.4$; $A \sim 565.6$
e4) $\theta_s = 46.8 + 14.0 = 60.8$; $\theta_p = 80.0$; $A \sim 4861.0$
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 26

1. $y = Y/Y_0 = Z_0/Z = 85\Omega / (33.8 - j\cdot 69.6)\Omega = 0.480 + j\cdot 0.988$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0352 - j\cdot 0.0178)] / (0.02 + 0.0352 - j\cdot 0.0178\ )$
$\Gamma = (-0.344) + j\cdot(0.212) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.404\angle 148.4° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I =20.70dB
$P_{in} = 3.80mW = 5.798dBm$; $P_{is} = P_{in} - I = 5.798dBm - 20.70dB = -14.90dBm = 32.343\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.465$, $y_1 = 0.465$, $y_2 = 0.885$, $Z_1 = Z_0/y_1 = 107.5\ \Omega$, $Z_2 = Z_0/y_2 = 56.5\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 27)}\Omega = 36.74\Omega$
b) $Z_L = 27\Omega$ parallel with 0.43pF capacitor at 9.3GHz $= 18.49\Omega + j\cdot(-12.54)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l) \to \infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(33.92)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.95dB): $G = G_1 + G_4 = 6.7 + 11.6 = 18.3dB$; $G = G_2 + G_3 = 8.1 + 8.9 = 17.0dB$; $G = G_2 + G_4 = 8.1 + 11.6 = 19.7dB$; $G = G_3 + G_4 = 8.9 + 11.6 = 20.5dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.62dB=1.153$, $F_2 = 0.83dB=1.211$, $F_3 = 1.03dB=1.268$, $F_4 = 1.23dB=1.327$, $G_1 = 6.7dB=4.677$, $G_2 = 8.1dB=6.457$; $F(1,4) = 1.153 + (1.327-1)/4.677 = 1.223 = 0.88dB$; $F(2,3) = 1.211 + (1.268-1)/6.457 = 1.261 = 1.01dB$;
$F(1,4) < F(2,3) \to$ 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:
$|S_{11}| = 0.614 < 1$; $|\ S_{22}| = 0.520 < 1$; $K = 1.136 > 1$; $|\Delta| = |(-0.072)+ j\cdot(0.264)| = 0.274 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 17.58 = 12.45dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.031$; $C_1 = (-0.499) + j\cdot(0.084)$; $\Gamma_S = (-0.808) + j\cdot(-0.136) = 0.819\angle -170.5°$
$B_2 = 0.818$; $C_2 = (-0.229) + j\cdot(-0.324)$; $\Gamma_L = (-0.448) + j\cdot(0.634) = 0.777\angle 125.2°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 157.7°$; $\mathrm{Im}(y_S) = -2.860$; $\theta_{p1} = 109.3°$ <u>or</u> $\theta_{S2} = 12.7°$; $\mathrm{Im}(y_S) = 2.860$; $\theta_{p2} = 70.7°$
output: $\theta_{L1} = 7.8°$; $\mathrm{Im}(y_L) = -2.465$; $\theta_{p1} = 112.1°$ <u>or</u> $\theta_{L2} = 46.9°$; $\mathrm{Im}(y_L) = 2.465$; $\theta_{p2} = 67.9°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 7.8°$; $\mathrm{Im}(y_L) = -2.465 + (-2.860) = -5.324$; $\theta_{p1} = 100.6°$; $\theta_{S1} = 157.7°$;
d2) $\theta_{L2} = 46.9°$; $\mathrm{Im}(y_L) = 2.465 + (-2.860) = -0.395$; $\theta_{p2} = 158.4°$; $\theta_{S1} = 157.7°$;
d3) $\theta_{L1} = 7.8°$; $\mathrm{Im}(y_L) = -2.465 + (2.860) = 0.395$; $\theta_{p3} = 21.6°$; $\theta_{S2} = 12.7°$;
d4) $\theta_{L2} = 46.9°$; $\mathrm{Im}(y_L) = 2.465 + (2.860) = 5.324$; $\theta_{p4} = 79.4°$; $\theta_{S2} = 12.7°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 7.8 + 157.7 = 165.6$; $\theta_p = 100.6$; $A \sim 16665.1$
e2) $\theta_s = 46.9 + 157.7 = 204.7$; $\theta_p = 158.4$; $A \sim 32425.6$
e3) $\theta_s = 7.8 + 12.7 = 20.6$; $\theta_p = 21.6$; $A \sim 443.3$
e4) $\theta_s = 46.9 + 12.7 = 59.6$; $\theta_p = 79.4$; $A \sim 4731.7$
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 27

1. $y = Y/Y_0 = Z_0/Z = 70\Omega / (31.4 + j\cdot 55.9)\Omega = 0.535 - j\cdot 0.952$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0289 + j\cdot 0.0158)] / (0.02 + 0.0289 + j\cdot 0.0158)$
$\Gamma = (-0.259) + j\cdot(-0.239) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.353\angle{-137.3}° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =25.85dB
$P_{in} = 4.00mW = 6.021dBm$; $P_{is} = P_{in} - I = 6.021dBm - 25.85dB = -19.83dBm = 10.401\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.516$, $y_1 = 0.516$, $y_2 = 0.857$, $Z_1 = Z_0/y_1 = 96.9\ \Omega$, $Z_2 = Z_0/y_2 = 58.4\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 57)}\Omega = 53.39\Omega$
b) $Z_L = 57\Omega$ parallel with 0.79pF capacitor at 6.6GHz $= 12.70\Omega + j\cdot(-23.72)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(93.37)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.15dB): $G = G_1 + G_4 = 5.2 + 11.6 = 16.8dB$; $G = G_2 + G_3 = 7.1 + 8.8 = 15.9dB$; $G = G_2 + G_4 = 7.1 + 11.6 = 18.7dB$; $G = G_3 + G_4 = 8.8 + 11.6 = 20.4dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.53dB=1.130$, $F_2 = 0.88dB=1.225$, $F_3 = 1.00dB=1.259$, $F_4 = 1.27dB=1.340$, $G_1 = 5.2dB=3.311$, $G_2 = 7.1dB=5.129$; $F(1,4) = 1.130 + (1.340-1)/3.311 = 1.232 = 0.91dB$; $F(2,3) = 1.225 + (1.259-1)/5.129 = 1.291 = 1.11dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.632 < 1$; $|S_{22}| = 0.520 < 1$; $K = 1.106 > 1$; $|\Delta| = |(-0.111)+ j\cdot(0.257)| = 0.280 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 20.24 = 13.06dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.051$; $C_1 = (-0.518) + j\cdot(0.008)$; $\Gamma_S = (-0.845) + j\cdot(-0.013) = 0.845\angle{-179.1}°$
$B_2 = 0.792$; $C_2 = (-0.216) + j\cdot(-0.321)$; $\Gamma_L = (-0.446) + j\cdot(0.663) = 0.799\angle 123.9°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 163.4°$; $\mathrm{Im}(y_S) = -3.164$; $\theta_{p1} = 107.5°$ <u>or</u> $\theta_{S2} = 15.7°$; $\mathrm{Im}(y_S) = 3.164$; $\theta_{p2} = 72.5°$
output: $\theta_{L1} = 9.6°$; $\mathrm{Im}(y_L) = -2.657$; $\theta_{p1} = 110.6°$ <u>or</u> $\theta_{L2} = 46.5°$; $\mathrm{Im}(y_L) = 2.657$; $\theta_{p2} = 69.4°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 9.6°$; $\mathrm{Im}(y_L) = -2.657 + (-3.164) = -5.821$; $\theta_{p1} = 99.7°$; $\theta_{S1} = 163.4°$;
d2) $\theta_{L2} = 46.5°$; $\mathrm{Im}(y_L) = 2.657 + (-3.164) = -0.507$; $\theta_{p2} = 153.1°$; $\theta_{S1} = 163.4°$;
d3) $\theta_{L1} = 9.6°$; $\mathrm{Im}(y_L) = -2.657 + (3.164) = 0.507$; $\theta_{p3} = 26.9°$; $\theta_{S2} = 15.7°$;
d4) $\theta_{L2} = 46.5°$; $\mathrm{Im}(y_L) = 2.657 + (3.164) = 5.821$; $\theta_{p4} = 80.3°$; $\theta_{S2} = 15.7°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 9.6 + 163.4 = 173.0$; $\theta_p = 99.7$; A ~ 17253.5
e2) $\theta_s = 46.5 + 163.4 = 209.9$; $\theta_p = 153.1$; A ~ 32146.3
e3) $\theta_s = 9.6 + 15.7 = 25.3$; $\theta_p = 26.9$; A ~ 679.2
e4) $\theta_s = 46.5 + 15.7 = 62.2$; $\theta_p = 80.3$; A ~ 4994.5
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 28

1. $y = Y/Y_0 = Z_0/Z = 70\Omega / (31.9 - j\cdot49.7)\Omega = 0.640 + j\cdot0.998$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0260 + j\cdot0.0291)] / (0.02 + 0.0260 + j\cdot0.0291)$
$\Gamma = (-0.379) + j\cdot(-0.393) \leftrightarrow Re\Gamma + j\cdot Im\Gamma$ or $\Gamma = 0.546\angle{-134.0°} \leftrightarrow |\Gamma|\angle arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =27.95dB
P_{in} = 3.25mW = 5.119dBm; $P_{is} = P_{in} - I$ = 5.119dBm − 27.95dB = -22.83dBm = 5.211μW
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.606$, $y_1 = 0.606$, $y_2 = 0.795$, $Z_1 = Z_0/y_1 = 82.5\ \Omega$, $Z_2 = Z_0/y_2 = 62.9\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot51)}\Omega = 50.50\Omega$
b) $Z_L = 51\Omega$ parallel with 1.11nH inductor at 7.4GHz = $25.80\Omega + j\cdot(25.50)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-49.41)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 14.50dB): $G = G_1 + G_4$ = 5.8 + 10.3 = 16.1dB; $G = G_2 + G_3$ = 7.7 + 8.6 = 16.3dB; $G = G_2 + G_4$ = 7.7 + 10.3 = 18.0dB; $G = G_3 + G_4$ = 8.6 + 10.3 = 18.9dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 = 0.87dB=1.222, F_3 = 1.05dB=1.274, F_4 = 1.23dB=1.327, G_1 = 5.8dB=3.802, G_2 = 7.7dB=5.888; F(1,4) = 1.164 + (1.327−1)/3.802 = 1.250 = 0.97dB; F(2,3) = 1.222 + (1.274−1)/5.888 = 1.277 = 1.06dB;
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:
$|S_{11}| = 0.632 < 1$; $|S_{22}| = 0.550 < 1$; $K = 1.223 > 1$; $|\Delta| = |(0.261)+ j\cdot(0.003)| = 0.261 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 9.59$ = 9.82dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.029$; $C_1 = (-0.311) + j\cdot(0.396)$; $\Gamma_S = (-0.502) + j\cdot(-0.639) = 0.813\angle{-128.1°}$
$B_2 = 0.835$; $C_2 = (-0.393) + j\cdot(-0.094)$; $\Gamma_L = (-0.752) + j\cdot(0.181) = 0.773\angle{166.5°}$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 136.2°$; $Im(y_S) = -2.789$; $\theta_{p1} = 109.7°$ <u>or</u> $\theta_{S2} = 171.9°$; $Im(y_S) = 2.789$; $\theta_{p2} = 70.3°$
output: $\theta_{L1} = 167.1°$; $Im(y_L) = -2.436$; $\theta_{p1} = 112.3°$ <u>or</u> $\theta_{L2} = 26.4°$; $Im(y_L) = 2.436$; $\theta_{p2} = 67.7°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 167.1°$; $Im(y_L) = -2.436 + (-2.789) = -5.225$; $\theta_{p1} = 100.8°$; $\theta_{S1} = 136.2°$;
d2) $\theta_{L2} = 26.4°$; $Im(y_L) = 2.436 + (-2.789) = -0.352$; $\theta_{p2} = 160.6°$; $\theta_{S1} = 136.2°$;
d3) $\theta_{L1} = 167.1°$; $Im(y_L) = -2.436 + (2.789) = 0.352$; $\theta_{p3} = 19.4°$; $\theta_{S2} = 171.9°$;
d4) $\theta_{L2} = 26.4°$; $Im(y_L) = 2.436 + (2.789) = 5.225$; $\theta_{p4} = 79.2°$; $\theta_{S2} = 171.9°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) θ_s = 167.1 + 136.2 = 303.3 ; θ_p = 100.8 ; A ~ 30583.6
e2) θ_s = 26.4 + 136.2 = 162.7 ; θ_p = 160.6 ; A ~ 26124.9
e3) θ_s = 167.1 + 171.9 = 339.0 ; θ_p = 19.4 ; A ~ 6581.3
e4) θ_s = 26.4 + 171.9 = 198.3 ; θ_p = 79.2 ; A ~ 15701.2
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 29

1. $y = Y/Y_0 = Z_0/Z = 60\Omega / (49.2 - j\cdot 38.3)\Omega = 0.759 + j\cdot 0.591$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0305 + j\cdot 0.0172)] / (0.02 + 0.0305 + j\cdot 0.0172\ )$
$\Gamma = (-0.290) + j\cdot(-0.242) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.378\angle{-140.2°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless ring coupler, matched at the input; Isolation I = D + C =27.85dB
P_{in} = 1.15mW = 0.607dBm; $P_{is} = P_{in} - I$ = 0.607dBm − 27.85dB = -27.24dBm = 1.887μW
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.516$, $y_1 = 0.516$, $y_2 = 0.857$, $Z_1 = Z_0/y_1 = 96.9\ \Omega$, $Z_2 = Z_0/y_2 = 58.4\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 53)}\Omega = 51.48\Omega$
b) $Z_L = 53\Omega$ parallel with 0.40pF capacitor at 8.0GHz = $24.82\Omega + j\cdot(-26.45)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(53.28)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 14.45dB): $G = G_1 + G_4$ = 5.2 + 11.2 = 16.4dB; $G = G_2 + G_3$ = 8.2 + 8.3 = 16.5dB; $G = G_2 + G_4$ = 8.2 + 11.2 = 19.4dB; $G = G_3 + G_4$ = 8.3 + 11.2 = 19.5dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 = 0.73dB=1.183, F_3 = 1.08dB=1.282, F_4 = 1.15dB=1.303, G_1 = 5.2dB=3.311, G_2 = 8.2dB=6.607; F(1,4) = 1.140 + (1.303−1)/3.311 = 1.232 = 0.91dB; F(2,3) = 1.183 + (1.282−1)/6.607 = 1.229 = 0.90dB;
F(1,4) > F(2,3) → 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:
$|S_{11}| = 0.640 < 1$; $|S_{22}| = 0.550 < 1$; $K = 1.189 > 1$; $|\Delta| = |(0.262)+ j\cdot(0.095)| = 0.279 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}]$ = 10.36 = 10.15dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.029$; $C_1 = (-0.373) + j\cdot(0.340)$; $\Gamma_S = (-0.608) + j\cdot(-0.555) = 0.823\angle{-137.6°}$
$B_2 = 0.815$; $C_2 = (-0.374) + j\cdot(-0.129)$; $\Gamma_L = (-0.738) + j\cdot(0.254) = 0.780\angle 161.0°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 141.5°$; $\mathrm{Im}(y_S) = -2.897$; $\theta_{p1} = 109.0°$ or $\theta_{S2} = 176.1°$; $\mathrm{Im}(y_S) = 2.897$; $\theta_{p2} = 71.0°$
output: $\theta_{L1} = 170.1°$; $\mathrm{Im}(y_L) = -2.496$; $\theta_{p1} = 111.8°$ or $\theta_{L2} = 28.9°$; $\mathrm{Im}(y_L) = 2.496$; $\theta_{p2} = 68.2°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 170.1°$; $\mathrm{Im}(y_L) = -2.496 + (-2.897) = -5.393$; $\theta_{p1} = 100.5°$; $\theta_{S1} = 141.5°$;
d2) $\theta_{L2} = 28.9°$; $\mathrm{Im}(y_L) = 2.496 + (-2.897) = -0.401$; $\theta_{p2} = 158.1°$; $\theta_{S1} = 141.5°$;
d3) $\theta_{L1} = 170.1°$; $\mathrm{Im}(y_L) = -2.496 + (2.897) = 0.401$; $\theta_{p3} = 21.9°$; $\theta_{S2} = 176.1°$;
d4) $\theta_{L2} = 28.9°$; $\mathrm{Im}(y_L) = 2.496 + (2.897) = 5.393$; $\theta_{p4} = 79.5°$; $\theta_{S2} = 176.1°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute all solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) θ_s = 170.1 + 141.5 = 311.7 ; θ_p = 100.5 ; A ~ 31322.5
e2) θ_s = 28.9 + 141.5 = 170.4 ; θ_p = 158.1 ; A ~ 26941.0
e3) θ_s = 170.1 + 176.1 = 346.3 ; θ_p = 21.9 ; A ~ 7568.0
e4) θ_s = 28.9 + 176.1 = 205.0 ; θ_p = 79.5 ; A ~ 16294.6
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 30

1. $y = Y/Y_0 = Z_0/Z = 85\Omega / (35.7 + j\cdot66.3)\Omega = 0.535 - j\cdot0.994$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0133 - j\cdot0.0223)] / (0.02 + 0.0133 - j\cdot0.0223\ )$
$\Gamma = (-0.171) + j\cdot(0.555) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.581\angle107.1° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =21.50dB
$P_{in} = 1.80mW = 2.553dBm$; $P_{is} = P_{in} - I = 2.553dBm - 21.50dB = -18.95dBm = 12.743\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.617$, $Z_{CE} = 102.67\Omega$, $Z_{CO} = 24.35\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot46)}\Omega = 47.96\Omega$
b) $Z_L = 46\Omega$ series with 0.32pF capacitor at 7.3GHz $= 46.00\Omega + j\cdot(-68.13)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 15.66\Omega + j\cdot(23.19)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.80dB): $G = G_1 + G_4 = 5.5 + 11.9 = 17.4dB$; $G = G_2 + G_3 = 7.5 + 9.8 = 17.3dB$; $G = G_2 + G_4 = 7.5 + 11.9 = 19.4dB$; $G = G_3 + G_4 = 9.8 + 11.9 = 21.7dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.64dB=1.159$, $F_2 = 0.84dB=1.213$, $F_3 = 0.95dB=1.245$, $F_4 = 1.25dB=1.334$, $G_1 = 5.5dB=3.548$, $G_2 = 7.5dB=5.623$; $F(1,4) = 1.159 + (1.334-1)/3.548 = 1.253 = 0.98dB$; $F(2,3) = 1.213 + (1.245-1)/5.623 = 1.273 = 1.05dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.626 < 1$; $|\ S_{22}| = 0.520 < 1$; $K = 1.110 > 1$; $|\Delta| = |(-0.103)+ j\cdot(0.261)| = 0.280 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 19.36 = 12.87dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.043$; $C_1 = (-0.512) + j\cdot(0.034)$; $\Gamma_S = (-0.837) + j\cdot(-0.055) = 0.839\angle-176.2°$
$B_2 = 0.800$; $C_2 = (-0.218) + j\cdot(-0.323)$; $\Gamma_L = (-0.444) + j\cdot(0.659) = 0.795\angle124.0°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 161.6°$; $\mathrm{Im}(y_S) = -3.088$; $\theta_{p1} = 107.9°$ <u>or</u> $\theta_{S2} = 14.6°$; $\mathrm{Im}(y_S) = 3.088$; $\theta_{p2} = 72.1°$
output: $\theta_{L1} = 9.3°$; $\mathrm{Im}(y_L) = -2.617$; $\theta_{p1} = 110.9°$ <u>or</u> $\theta_{L2} = 46.7°$; $\mathrm{Im}(y_L) = 2.617$; $\theta_{p2} = 69.1°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 9.3°$; $\mathrm{Im}(y_L) = -2.617 + (-3.088) = -5.705$; $\theta_{p1} = 99.9°$; $\theta_{S1} = 161.6°$;
d2) $\theta_{L2} = 46.7°$; $\mathrm{Im}(y_L) = 2.617 + (-3.088) = -0.471$; $\theta_{p2} = 154.8°$; $\theta_{S1} = 161.6°$;
d3) $\theta_{L1} = 9.3°$; $\mathrm{Im}(y_L) = -2.617 + (3.088) = 0.471$; $\theta_{p3} = 25.2°$; $\theta_{S2} = 14.6°$;
d4) $\theta_{L2} = 46.7°$; $\mathrm{Im}(y_L) = 2.617 + (3.088) = 5.705$; $\theta_{p4} = 80.1°$; $\theta_{S2} = 14.6°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel} \sim$ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 9.3 + 161.6 = 170.9$; $\theta_p = 99.9$; $A \sim 17084.9$
e2) $\theta_s = 46.7 + 161.6 = 208.3$; $\theta_p = 154.8$; $A \sim 32245.7$
e3) $\theta_s = 9.3 + 14.6 = 23.9$; $\theta_p = 25.2$; $A \sim 602.3$
e4) $\theta_s = 46.7 + 14.6 = 61.3$; $\theta_p = 80.1$; $A \sim 4905.0$
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 31

1. $y = Y/Y_0 = Z_0/Z = 100\Omega \,/\, (51.9 + j\cdot 67.1)\Omega = 0.721 - j\cdot 0.932$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0114 - j\cdot 0.0232)] / (0.02 + 0.0114 - j\cdot 0.0232\ )$
$\Gamma = (-0.176) + j\cdot(0.609) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.634\angle 106.1° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I = D + C =30.70dB
P_{in} = 3.40mW = 5.315dBm; $P_{is} = P_{in} - I$ = 5.315dBm − 30.70dB = -25.39dBm = 2.894μW
b) L2, C12/2017, $\beta = 10^{-C/20} = 0.484$, $y_2 = 1.143$, $y_1 = 0.553$, $Z_1 = Z_0/y_1 = 90.4\ \Omega$, $Z_2 = Z_0/y_2 = 43.7\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 41)}\Omega = 45.28\Omega$
b) $Z_L = 41\Omega$ series with 0.74nH inductor at 9.5GHz = $41.00\Omega + j\cdot(44.17)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 23.14\Omega + j\cdot(-24.93)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.70dB): $G = G_1 + G_4 = 6.8 + 11.8 = 18.6$dB; $G = G_2 + G_3 = 7.4 + 9.8 = 17.2$dB; $G = G_2 + G_4 = 7.4 + 11.8 = 19.2$dB; $G = G_3 + G_4 = 9.8 + 11.8 = 21.6$dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 = 0.63dB=1.156, F_2 = 0.88dB=1.225, F_3 = 0.99dB=1.256, F_4 = 1.26dB=1.337, G_1 = 6.8dB=4.786, G_2 = 7.4dB=5.495; F(1,4) = 1.156 + (1.337−1)/4.786 = 1.226 = 0.89dB; F(2,3) = 1.225 + (1.256−1)/5.495 = 1.286 = 1.09dB;
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:
$|S_{11}| = 0.640 < 1$; $|\ S_{22}| = 0.550 < 1$; $K = 1.182 > 1$; $|\Delta| = |(0.246)+ j\cdot(0.141)| = 0.284 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 10.62 = 10.26$dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.026$; $C_1 = (-0.400) + j\cdot(0.307)$; $\Gamma_S = (-0.653) + j\cdot(-0.502) = 0.824\angle -142.5°$
$B_2 = 0.812$; $C_2 = (-0.364) + j\cdot(-0.151)$; $\Gamma_L = (-0.722) + j\cdot(0.299) = 0.781\angle 157.5°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 144.0°$; $\mathrm{Im}(y_S) = -2.906$; $\theta_{p1} = 109.0°$ <u>or</u> $\theta_{S2} = 178.5°$; $\mathrm{Im}(y_S) = 2.906$; $\theta_{p2} = 71.0°$
output: $\theta_{L1} = 171.9°$; $\mathrm{Im}(y_L) = -2.503$; $\theta_{p1} = 111.8°$ <u>or</u> $\theta_{L2} = 30.6°$; $\mathrm{Im}(y_L) = 2.503$; $\theta_{p2} = 68.2°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 171.9°$; $\mathrm{Im}(y_L) = -2.503 + (-2.906) = -5.409$; $\theta_{p1} = 100.5°$; $\theta_{S1} = 144.0°$;
d2) $\theta_{L2} = 30.6°$; $\mathrm{Im}(y_L) = 2.503 + (-2.906) = -0.403$; $\theta_{p2} = 158.1°$; $\theta_{S1} = 144.0°$;
d3) $\theta_{L1} = 171.9°$; $\mathrm{Im}(y_L) = -2.503 + (2.906) = 0.403$; $\theta_{p3} = 21.9°$; $\theta_{S2} = 178.5°$;
d4) $\theta_{L2} = 30.6°$; $\mathrm{Im}(y_L) = 2.503 + (2.906) = 5.409$; $\theta_{p4} = 79.5°$; $\theta_{S2} = 178.5°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 171.9 + 144.0 = 315.9$; $\theta_p = 100.5$; A ~ 31740.9
e2) $\theta_s = 30.6 + 144.0 = 174.5$; $\theta_p = 158.1$; A ~ 27585.9
e3) $\theta_s = 171.9 + 178.5 = 350.4$; $\theta_p = 21.9$; A ~ 7691.5
e4) $\theta_s = 30.6 + 178.5 = 209.1$; $\theta_p = 79.5$; A ~ 16626.7
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 32

1. $y = Y/Y_0 = Z_0/Z = 60\Omega / (62.2 - j\cdot 58.7)\Omega = 0.510 + j\cdot 0.482$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0299 + j\cdot 0.0282)] / (0.02 + 0.0299 + j\cdot 0.0282\ )$
$\Gamma = (-0.392) + j\cdot(-0.343) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.521\angle -138.8° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I = D + C =29.00dB
P_{in} = 1.95mW = 2.900dBm; $P_{is} = P_{in} - I$ = 2.900dBm − 29.00dB = -26.10dBm = 2.455μW
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.473$, $Z_{CE} = 83.61\Omega$, $Z_{CO} = 29.90\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 53)}\Omega = 51.48\Omega$
b) $Z_L = 53\Omega$ parallel with 0.35pF capacitor at 7.1GHz = $31.46\Omega + j\cdot(-26.03)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(41.38)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.10dB): $G = G_1 + G_4$ = 6.2 + 11.5 = 17.7dB; $G = G_2 + G_3$ = 7.6 + 8.2 = 15.8dB; $G = G_2 + G_4$ = 7.6 + 11.5 = 19.1dB; $G = G_3 + G_4$ = 8.2 + 11.5 = 19.7dB;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 = 0.52dB=1.127, F_2 = 0.89dB=1.227, F_3 = 0.98dB=1.253, F_4 = 1.21dB=1.321, G_1 = 6.2dB=4.169, G_2 = 7.6dB=5.754; F(1,4) = 1.127 + (1.321−1)/4.169 = 1.204 = 0.81dB; F(2,3) = 1.227 + (1.253−1)/5.754 = 1.283 = 1.08dB;
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:
$|S_{11}| = 0.638 < 1$; $|S_{22}| = 0.550 < 1$; $K = 1.197 > 1$; $|\Delta| = |(0.265)+ j\cdot(0.072)| = 0.274 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}]$ = 10.18 = 10.08dB
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.029$; $C_1 = (-0.358) + j\cdot(0.355)$; $\Gamma_S = (-0.583) + j\cdot(-0.578) = 0.821\angle -135.2°$
$B_2 = 0.820$; $C_2 = (-0.379) + j\cdot(-0.120)$; $\Gamma_L = (-0.742) + j\cdot(0.236) = 0.779\angle 162.4°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 140.2°$; $\mathrm{Im}(y_S) = -2.872$; $\theta_{p1} = 109.2°$ <u>or</u> $\theta_{S2} = 175.0°$; $\mathrm{Im}(y_S) = 2.872$; $\theta_{p2} = 70.8°$
output: $\theta_{L1} = 169.4°$; $\mathrm{Im}(y_L) = -2.483$; $\theta_{p1} = 111.9°$ <u>or</u> $\theta_{L2} = 28.2°$; $\mathrm{Im}(y_L) = 2.483$; $\theta_{p2} = 68.1°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 169.4°$; $\mathrm{Im}(y_L) = -2.483 + (-2.872) = -5.355$; $\theta_{p1} = 100.6°$; $\theta_{S1} = 140.2°$;
d2) $\theta_{L2} = 28.2°$; $\mathrm{Im}(y_L) = 2.483 + (-2.872) = -0.389$; $\theta_{p2} = 158.8°$; $\theta_{S1} = 140.2°$;
d3) $\theta_{L1} = 169.4°$; $\mathrm{Im}(y_L) = -2.483 + (2.872) = 0.389$; $\theta_{p3} = 21.2°$; $\theta_{S2} = 175.0°$;
d4) $\theta_{L2} = 28.2°$; $\mathrm{Im}(y_L) = 2.483 + (2.872) = 5.355$; $\theta_{p4} = 79.4°$; $\theta_{S2} = 175.0°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) θ_s = 169.4 + 140.2 = 309.6 ; θ_p = 100.6 ; A ~ 31137.7
e2) θ_s = 28.2 + 140.2 = 168.4 ; θ_p = 158.8 ; A ~ 26740.5
e3) θ_s = 169.4 + 175.0 = 344.4 ; θ_p = 21.2 ; A ~ 7317.3
e4) θ_s = 28.2 + 175.0 = 203.3 ; θ_p = 79.4 ; A ~ 16145.9
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 33

1. $y = Y/Y_0 = Z_0/Z = 70\Omega / (34.3 - j\cdot 38.7)\Omega = 0.898 + j\cdot 1.013$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0388 + j\cdot 0.0238)] / (0.02 + 0.0388 + j\cdot 0.0238)$
$\Gamma = (-0.415) + j\cdot(-0.237) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.478\angle -150.3° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless coupled line coupler, matched at the input; Isolation I =24.60dB
$P_{in} = 3.05mW = 4.843dBm$; $P_{is} = P_{in} - I = 4.843dBm - 24.60dB = -19.76dBm = 10.575\mu W$
b) L2,C12/2017, $\beta = 10^{-C/20} = 0.606$, $Z_{CE} = 100.95\Omega$, $Z_{CO} = 24.76\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 31)}\Omega = 39.37\Omega$
b) $Z_L = 31\Omega$ parallel with 0.62nH inductor at 9.0GHz $= 17.40\Omega + j\cdot(15.38)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-44.21)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.70dB): $G = G_1 + G_4 = 6.0 + 11.1 = 17.1dB$; $G = G_2 + G_3 = 8.1 + 9.9 = 18.0dB$; $G = G_2 + G_4 = 8.1 + 11.1 = 19.2dB$; $G = G_3 + G_4 = 9.9 + 11.1 = 21.0dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.53dB=1.130$, $F_2 = 0.77dB=1.194$, $F_3 = 0.92dB=1.236$, $F_4 = 1.27dB=1.340$, $G_1 = 6.0dB=3.981$, $G_2 = 8.1dB=6.457$; $F(1,4) = 1.130 + (1.340-1)/3.981 = 1.215 = 0.85dB$; $F(2,3) = 1.194 + (1.236-1)/6.457 = 1.247 = 0.96dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.638 < 1$; $|S_{22}| = 0.520 < 1$; $K = 1.103 > 1$; $|\Delta| = |(-0.118)+ j\cdot(0.254)| = 0.280 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 21.15 = 13.25dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.058$; $C_1 = (-0.522) + j\cdot(-0.018)$; $\Gamma_S = (-0.850) + j\cdot(0.030) = 0.851\angle 178.0°$
$B_2 = 0.785$; $C_2 = (-0.213) + j\cdot(-0.318)$; $\Gamma_L = (-0.447) + j\cdot(0.667) = 0.803\angle 123.8°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 165.2°$; $\mathrm{Im}(y_S) = -3.239$; $\theta_{p1} = 107.2°$ <u>or</u> $\theta_{S2} = 16.9°$; $\mathrm{Im}(y_S) = 3.239$; $\theta_{p2} = 72.8°$
output: $\theta_{L1} = 9.8°$; $\mathrm{Im}(y_L) = -2.695$; $\theta_{p1} = 110.4°$ <u>or</u> $\theta_{L2} = 46.4°$; $\mathrm{Im}(y_L) = 2.695$; $\theta_{p2} = 69.6°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 9.8°$; $\mathrm{Im}(y_L) = -2.695 + (-3.239) = -5.934$; $\theta_{p1} = 99.6°$; $\theta_{S1} = 165.2°$;
d2) $\theta_{L2} = 46.4°$; $\mathrm{Im}(y_L) = 2.695 + (-3.239) = -0.544$; $\theta_{p2} = 151.5°$; $\theta_{S1} = 165.2°$;
d3) $\theta_{L1} = 9.8°$; $\mathrm{Im}(y_L) = -2.695 + (3.239) = 0.544$; $\theta_{p3} = 28.5°$; $\theta_{S2} = 16.9°$;
d4) $\theta_{L2} = 46.4°$; $\mathrm{Im}(y_L) = 2.695 + (3.239) = 5.934$; $\theta_{p4} = 80.4°$; $\theta_{S2} = 16.9°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 9.8 + 165.2 = 175.0$; $\theta_p = 99.6$; A ~ 17420.8
e2) $\theta_s = 46.4 + 165.2 = 211.5$; $\theta_p = 151.5$; A ~ 32042.9
e3) $\theta_s = 9.8 + 16.9 = 26.7$; $\theta_p = 28.5$; A ~ 760.7
e4) $\theta_s = 46.4 + 16.9 = 63.2$; $\theta_p = 80.4$; A ~ 5086.7
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 34

1. $y = Y/Y_0 = Z_0/Z = 80\Omega / (33.0 - j\cdot 54.7)\Omega = 0.647 + j\cdot 1.072$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0206 - j\cdot 0.0147)] / (0.02 + 0.0206 - j\cdot 0.0147)$
$\Gamma = (-0.129) + j\cdot(0.315) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.341\angle 112.2° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I = D + C =30.30dB
$P_{in} = 1.55mW = 1.903dBm$; $P_{is} = P_{in} - I = 1.903dBm - 30.30dB = -28.40dBm = 1.447\mu W$
b) L2, C12/2017, $\beta = 10^{-C/20} = 0.457$, $y_2 = 1.124$, $y_1 = 0.514$, $Z_1 = Z_0/y_1 = 97.3\ \Omega$, $Z_2 = Z_0/y_2 = 44.5\Omega$

4. a) $Z_1 = \sqrt{(Z_0\cdot R_L)} = \sqrt{(50\cdot 58)}\Omega = 53.85\Omega$
b) $Z_L = 58\Omega$ series with 0.33pF capacitor at 7.6GHz $= 58.00\Omega + j\cdot(-63.46)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\to\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 22.76\Omega + j\cdot(24.90)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 16.65dB): $G = G_1 + G_4 = 6.7 + 10.2 = 16.9dB$; $G = G_2 + G_3 = 8.4 + 9.8 = 18.2dB$; $G = G_2 + G_4 = 8.4 + 10.2 = 18.6dB$; $G = G_3 + G_4 = 9.8 + 10.2 = 20.0dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.69dB=1.172$, $F_2 = 0.77dB=1.194$, $F_3 = 1.07dB=1.279$, $F_4 = 1.29dB=1.346$, $G_1 = 6.7dB=4.677$, $G_2 = 8.4dB=6.918$; $F(1,4) = 1.172 + (1.346-1)/4.677 = 1.246 = 0.96dB$; $F(2,3) = 1.194 + (1.279-1)/6.918 = 1.244 = 0.95dB$;
$F(1,4) > F(2,3) \to$ 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:
$|S_{11}| = 0.650 < 1$; $|S_{22}| = 0.520 < 1$; $K = 1.099 > 1$; $|\Delta| = |(-0.133)+ j\cdot(0.247)| = 0.281 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 23.05 = 13.63dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.073$; $C_1 = (-0.526) + j\cdot(-0.072)$; $\Gamma_S = (-0.853) + j\cdot(0.117) = 0.861\angle 172.2°$
$B_2 = 0.769$; $C_2 = (-0.208) + j\cdot(-0.313)$; $\Gamma_L = (-0.448) + j\cdot(0.675) = 0.810\angle 123.6°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 168.6°$; $\mathrm{Im}(y_S) = -3.381$; $\theta_{p1} = 106.5°$ <u>or</u> $\theta_{S2} = 19.2°$; $\mathrm{Im}(y_S) = 3.381$; $\theta_{p2} = 73.5°$
output: $\theta_{L1} = 10.3°$; $\mathrm{Im}(y_L) = -2.761$; $\theta_{p1} = 109.9°$ <u>or</u> $\theta_{L2} = 46.2°$; $\mathrm{Im}(y_L) = 2.761$; $\theta_{p2} = 70.1°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 10.3°$; $\mathrm{Im}(y_L) = -2.761 + (-3.381) = -6.142$; $\theta_{p1} = 99.2°$; $\theta_{S1} = 168.6°$;
d2) $\theta_{L2} = 46.2°$; $\mathrm{Im}(y_L) = 2.761 + (-3.381) = -0.620$; $\theta_{p2} = 148.2°$; $\theta_{S1} = 168.6°$;
d3) $\theta_{L1} = 10.3°$; $\mathrm{Im}(y_L) = -2.761 + (3.381) = 0.620$; $\theta_{p3} = 31.8°$; $\theta_{S2} = 19.2°$;
d4) $\theta_{L2} = 46.2°$; $\mathrm{Im}(y_L) = 2.761 + (3.381) = 6.142$; $\theta_{p4} = 80.8°$; $\theta_{S2} = 19.2°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute <u>all</u> solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 10.3 + 168.6 = 178.9$; $\theta_p = 99.2$; A ~ 17750.9
e2) $\theta_s = 46.2 + 168.6 = 214.8$; $\theta_p = 148.2$; A ~ 31832.7
e3) $\theta_s = 10.3 + 19.2 = 29.5$; $\theta_p = 31.8$; A ~ 936.5
e4) $\theta_s = 46.2 + 19.2 = 65.4$; $\theta_p = 80.8$; A ~ 5279.7
Smallest substrate area is occupied by solution e3 (d3)

Subject no. 35

1. $y = Y/Y_0 = Z_0/Z = 100\Omega / (55.9 + j\cdot 61.3)\Omega = 0.812 - j\cdot 0.891$

2. $Y_0 = 0.02S$; $\Gamma = (Y_0 - Y) / (Y_0 + Y) = [0.02 - (0.0275 - j\cdot 0.0313)] / (0.02 + 0.0275 - j\cdot 0.0313)$
$\Gamma = (-0.413) + j\cdot(0.387) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.566\angle 136.9° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

3. a) Lossless quadrature coupler, matched at the input; Isolation I =20.20dB
$P_{in} = 2.50mW = 3.979dBm$; $P_{is} = P_{in} - I = 3.979dBm - 20.20dB = -16.22dBm = 23.875\mu W$
b) L2, C12/2017, $\beta = 10^{-C/20} = 0.585$, $y_2 = 1.234$, $y_1 = 0.722$, $Z_1 = Z_0/y_1 = 69.2\ \Omega$, $Z_2 = Z_0/y_2 = 40.5\Omega$

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 0.73nH inductor at 7.6GHz $= 16.88\Omega + j\cdot(21.79)\Omega$
$\theta = \pi/4$, $\tan(\beta\cdot l)\rightarrow\infty$, $Z_{in} = Z_1^2/Z_L = Z_0\cdot R_L/Z_L = 50.00\Omega + j\cdot(-64.55)\Omega$

5. a) From the 6 possible combinations, 2 don't meet the required gain (1,2 ; 1,3).
Valid combinations (G > 15.40dB): $G = G_1 + G_4 = 6.8 + 10.5 = 17.3dB$; $G = G_2 + G_3 = 7.6 + 8.2 = 15.8dB$; $G = G_2 + G_4 = 7.6 + 10.5 = 18.1dB$; $G = G_3 + G_4 = 8.2 + 10.5 = 18.7dB$;
b) Friis Formula (C9/2017, S92), $F = F_a + (F_b-1)/G_a$; 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 $F_2 + (F_3-1)/G_2 < F_3 + (F_4-1)/G_3$
$F_1 = 0.56dB=1.138$, $F_2 = 0.81dB=1.205$, $F_3 = 0.93dB=1.239$, $F_4 = 1.22dB=1.324$, $G_1 = 6.8dB=4.786$, $G_2 = 7.6dB=5.754$; $F(1,4) = 1.138 + (1.324-1)/4.786 = 1.205 = 0.81dB$; $F(2,3) = 1.205 + (1.239-1)/5.754 = 1.261 = 1.01dB$;
$F(1,4) < F(2,3) \rightarrow$ 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:
$|S_{11}| = 0.641 < 1$; $|S_{22}| = 0.520 < 1$; $K = 1.102 > 1$; $|\Delta| = |(-0.122)+ j\cdot(0.252)| = 0.280 < 1$
b_1) $G_{Tmax} = |S_{21}|/|S_{12}|\cdot[K-\sqrt{(K^2-1)}] = 21.61 = 13.35dB$
b_2) Complex calculus from C8/2017, S106:
$B_1 = 1.062$; $C_1 = (-0.523) + j\cdot(-0.032)$; $\Gamma_S = (-0.852) + j\cdot(0.052) = 0.853\angle 176.5°$
$B_2 = 0.781$; $C_2 = (-0.212) + j\cdot(-0.317)$; $\Gamma_L = (-0.447) + j\cdot(0.669) = 0.805\angle 123.7°$
c) Complex calculus from C7/2017, S28÷34, 2 solutions for the input/output match, $Z_0 = 50\Omega$ lines
input: $\theta_{S1} = 166.0°$; $\mathrm{Im}(y_S) = -3.276$; $\theta_{p1} = 107.0°$ or $\theta_{S2} = 17.4°$; $\mathrm{Im}(y_S) = 3.276$; $\theta_{p2} = 73.0°$
output: $\theta_{L1} = 9.9°$; $\mathrm{Im}(y_L) = -2.713$; $\theta_{p1} = 110.2°$ or $\theta_{L2} = 46.3°$; $\mathrm{Im}(y_L) = 2.713$; $\theta_{p2} = 69.8°$
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.2017, C10/2017,S76÷84):
d1) $\theta_{L1} = 9.9°$; $\mathrm{Im}(y_L) = -2.713 + (-3.276) = -5.989$; $\theta_{p1} = 99.5°$; $\theta_{S1} = 166.0°$;
d2) $\theta_{L2} = 46.3°$; $\mathrm{Im}(y_L) = 2.713 + (-3.276) = -0.562$; $\theta_{p2} = 150.6°$; $\theta_{S1} = 166.0°$;
d3) $\theta_{L1} = 9.9°$; $\mathrm{Im}(y_L) = -2.713 + (3.276) = 0.562$; $\theta_{p3} = 29.4°$; $\theta_{S2} = 17.4°$;
d4) $\theta_{L2} = 46.3°$; $\mathrm{Im}(y_L) = 2.713 + (3.276) = 5.989$; $\theta_{p4} = 80.5°$; $\theta_{S2} = 17.4°$;
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), $\Sigma\theta_{serie} \times \theta_{paralel}$ ~ Substrate Area. We must compute all solutions for d) and compare individual products $\Sigma\theta_{serie} \times \theta_{paralel}$.
e1) $\theta_s = 9.9 + 166.0 = 176.0$; $\theta_p = 99.5$; A ~ 17503.9
e2) $\theta_s = 46.3 + 166.0 = 212.3$; $\theta_p = 150.6$; A ~ 31990.4
e3) $\theta_s = 9.9 + 17.4 = 27.4$; $\theta_p = 29.4$; A ~ 803.1
e4) $\theta_s = 46.3 + 17.4 = 63.8$; $\theta_p = 80.5$; A ~ 5133.8
Smallest substrate area is occupied by solution e3 (d3)