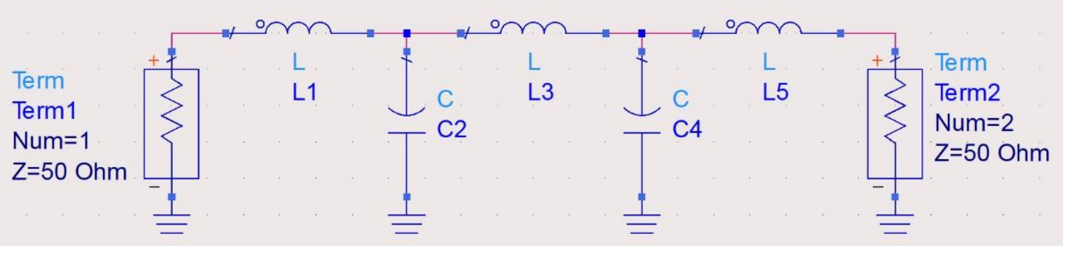
Subject no. 1

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (36.0 + j\cdot 42.6)\Omega = 0.579 + j\cdot 0.685$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.579 + j\cdot 0.685)] / (1 + 0.579 + j\cdot 0.685)$
$\Gamma = (0.066) + j\cdot(0.463) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.467\angle 81.8° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 7.9\text{dBm} - 5.30\text{dB} = 2.60\text{dBm}$;
b) $P_{in} = 7.9\text{dBm} = 6.166\text{mW}$; $P_c = 2.60\text{dBm} = 1.820\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 6.166\text{mW} - 1.820\text{mW} = 4.346\text{mW} = 6.381\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.543$, $y_2 = 1.191$, $y_1 = 0.647$, $Z_1 = Z_0/y_1 = 77.3\ \Omega$, $Z_2 = Z_0/y_2 = 42.0\Omega$

3. a) $Z = 66.00\Omega + j\cdot(27.22)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.183 + j\cdot(0.192) = 0.265\angle 46.3°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.265$; $\varphi = \arg(\Gamma) = 46.3°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 29.5°$; $\mathrm{Im}(y_S) = -0.550$; $\theta_{P1} = 151.2°$ **or** $\theta_{S2} = 104.1°$; $\mathrm{Im}(y_S) = 0.550$; $\theta_{P2} = 28.8°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 515\text{MHz} = 3.236\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 53.799\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 4.709\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 70.122\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 4.709\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 53.799\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 515 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 515$ MHz; In the stopband (f > 515 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1030.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 23.7\text{dB} + 24.8\text{dB} + 21.1\text{dB} = 69.6\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 9{,}120{,}108.4$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.90\text{dB} = 2.455$, $G_1 = 23.7\text{dB} = 234.423$, $F_2 = 4.23\text{dB} = 2.649$, $G_2 = 24.8\text{dB} = 301.995$, $F_3 = 5.65\text{dB} = 3.673$, $G_3 = 21.1\text{dB} = 128.825$;
$F = 2.649 + (2.455-1)/301.995 + (3.673-1)/301.995/234.423 = 2.653 = 4.238\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.649 + (3.673-1)/301.995 + (2.455-1)/301.995/128.825 = 2.657 = 4.245\text{dB}$

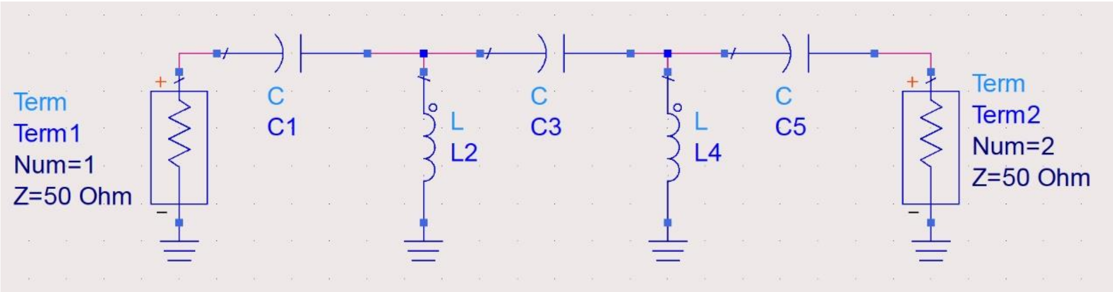
Subject no. 2

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (56.1 - j\cdot 61.4)\Omega = 0.406 - j\cdot 0.444$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.406 - j\cdot 0.444)] / (1 + 0.406 - j\cdot 0.444)$
$\Gamma = (0.294) + j\cdot(-0.409) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.503\angle -54.3° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 7.0\text{dBm} - 5.80\text{dB} = 1.20\text{dBm}$;
b) $P_{in} = 7.0\text{dBm} = 5.012\text{mW}$; $P_c = 1.20\text{dBm} = 1.318\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 5.012\text{mW} - 1.318\text{mW} = 3.694\text{mW} = 5.675\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.513$, $y_2 = 1.165$, $y_1 = 0.597$, $Z_1 = Z_0/y_1 = 83.7\ \Omega$, $Z_2 = Z_0/y_2 = 42.9\Omega$

3. a) $Z = 72.00\Omega + j\cdot(74.08)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.401 + j\cdot(0.364) = 0.541\angle 42.2°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.541$; $\varphi = \arg(\Gamma) = 42.2°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 40.3°$; $\mathrm{Im}(y_S) = -1.288$; $\theta_{P1} = 127.8°$ **or** $\theta_{S2} = 97.5°$; $\mathrm{Im}(y_S) = 1.288$; $\theta_{P2} = 52.2°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 315\text{MHz} = 1.979\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 5.924\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 20.545\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.977\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 20.545\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 5.924\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 315 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 315 MHz; In the stopband (f < 315 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 157.5 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 18.8\text{dB} + 22.7\text{dB} + 23.4\text{dB} = 64.9\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 3{,}090{,}295.4$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.17\text{dB} = 2.075$, $G_1 = 18.8\text{dB} = 75.858$, $F_2 = 4.12\text{dB} = 2.582$, $G_2 = 22.7\text{dB} = 186.209$, $F_3 = 5.18\text{dB} = 3.296$, $G_3 = 23.4\text{dB} = 218.776$;
$F = 2.582 + (3.296-1)/186.209 + (2.075-1)/186.209/218.776 = 2.595 = 4.141\text{dB}$
c) If the order is A1, A2, A3 the gain remains the same but $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$;
$F = 2.075 + (2.582-1)/75.858 + (3.296-1)/75.858/186.209 = 2.096 = 3.214\text{dB}$

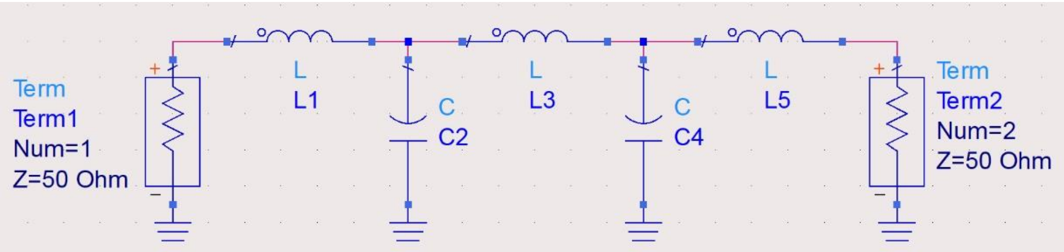
Subject no. 3

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (45.6 - j\cdot 36.0)\Omega = 0.675 - j\cdot 0.533$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.675 - j\cdot 0.533)] / (1 + 0.675 - j\cdot 0.533)$
$\Gamma = (0.084) + j\cdot(-0.345) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.355\angle{-76.3°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 4.8\text{dBm} - 4.10\text{dB} = 0.70\text{dBm}$;
b) $P_{in} = 4.8\text{dBm} = 3.020\text{mW}$; $P_c = 0.70\text{dBm} = 1.175\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 3.020\text{mW} - 1.175\text{mW} = 1.845\text{mW} = 2.660\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.624$, $y_2 = 1.279$, $y_1 = 0.798$, $Z_1 = Z_0/y_1 = 62.7\ \Omega$, $Z_2 = Z_0/y_2 = 39.1\Omega$

3. a) $Z = 60.00\Omega + j\cdot(67.46)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.339 + j\cdot(0.405) = 0.528\angle 50.0°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.528$; $\varphi = \arg(\Gamma) = 50.0°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 35.9°$; $\mathrm{Im}(y_S) = -1.245$; $\theta_{P1} = 128.8°$ **or** $\theta_{S2} = 94.0°$; $\mathrm{Im}(y_S) = 1.245$; $\theta_{P2} = 51.2°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 560\text{MHz} = 3.519\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 49.476\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 4.330\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 64.488\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 4.330\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 49.476\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 560 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 560$ MHz; In the stopband (f > 560 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1120.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 23.4\text{dB} + 24.8\text{dB} + 19.1\text{dB} = 67.3\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 5{,}370{,}318.0$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A1, A2 so: $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$; $F_1 = 3.81\text{dB} = 2.404$, $G_1 = 23.4\text{dB} = 218.776$, $F_2 = 4.83\text{dB} = 3.041$, $G_2 = 24.8\text{dB} = 301.995$, $F_3 = 5.30\text{dB} = 3.388$, $G_3 = 19.1\text{dB} = 81.283$;
$F = 3.388 + (2.404-1)/81.283 + (3.041-1)/81.283/218.776 = 3.406 = 5.322\text{dB}$
c) If the order is A1, A3, A2 the gain remains the same but $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$;
$F = 2.404 + (3.388-1)/218.776 + (3.041-1)/218.776/81.283 = 2.415 = 3.830\text{dB}$

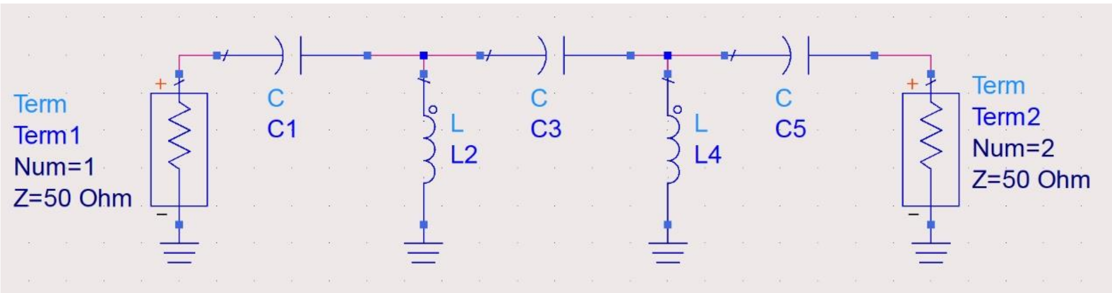
Subject no. 4

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (32.5 + j\cdot 33.1)\Omega = 0.755 + j\cdot 0.769$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.755 + j\cdot 0.769)] / (1 + 0.755 + j\cdot 0.769)$
$\Gamma = (-0.044) + j\cdot(0.419) \leftrightarrow \text{Re}\Gamma + j\cdot\text{Im}\Gamma$ or $\Gamma = 0.421\angle 96.0° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 5.9\text{dBm} - 7.60\text{dB} = -1.70\text{dBm}$;
b) $P_{in} = 5.9\text{dBm} = 3.890\text{mW}$; $P_c = -1.70\text{dBm} = 0.676\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 3.890\text{mW} - 0.676\text{mW} = 3.214\text{mW} = 5.071\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.417$, $y_2 = 1.100$, $y_1 = 0.459$, $Z_1 = Z_0/y_1 = 109.0\ \Omega$, $Z_2 = Z_0/y_2 = 45.4\Omega$

3. a) $Z = 18.02\Omega + j\cdot(-31.48)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.211 + j\cdot(-0.560) = 0.599\angle{-110.6°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.599$; $\varphi = \arg(\Gamma) = -110.6°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 118.7°$; $\text{Im}(y_S) = -1.495$; $\theta_{P1} = 123.8°$ **or** $\theta_{S2} = 171.9°$; $\text{Im}(y_S) = 1.495$; $\theta_{P2} = 56.2°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 575\text{MHz} = 3.613\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 8.958\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 8.553\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 2.768\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 8.553\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 8.958\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 575 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 575$ MHz; In the stopband (f < 575 MHz) the attenuation for 5^{th} order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 287.5$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 19.5\text{dB} + 19.7\text{dB} + 24.6\text{dB} = 63.8\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 2{,}398{,}832.9$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.88\text{dB} = 2.443$, $G_1 = 19.5\text{dB} = 89.125$, $F_2 = 4.25\text{dB} = 2.661$, $G_2 = 19.7\text{dB} = 93.325$, $F_3 = 5.46\text{dB} = 3.516$, $G_3 = 24.6\text{dB} = 288.403$;
$F = 2.661 + (2.443-1)/93.325 + (3.516-1)/93.325/89.125 = 2.676 = 4.276\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.661 + (3.516-1)/93.325 + (2.443-1)/93.325/288.403 = 2.688 = 4.294\text{dB}$

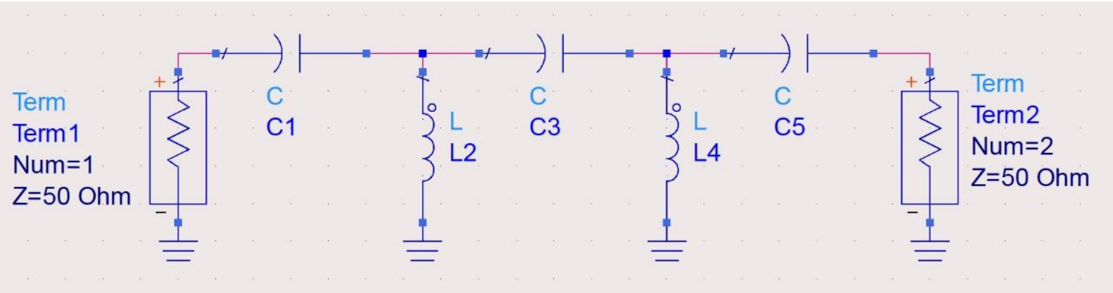
Subject no. 5

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (60.9 + j\cdot 54.2)\Omega = 0.458 + j\cdot 0.408$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.458 + j\cdot 0.408)] / (1 + 0.458 + j\cdot 0.408)$
$\Gamma = (0.272) + j\cdot(0.356) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.448\angle 52.6° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 8.7\text{dBm} - 4.70\text{dB} = 4.00\text{dBm}$;
b) $P_{in} = 8.7\text{dBm} = 7.413\text{mW}$; $P_c = 4.00\text{dBm} = 2.512\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 7.413\text{mW} - 2.512\text{mW} = 4.901\text{mW} = 6.903\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.582$, $y_2 = 1.230$, $y_1 = 0.716$, $Z_1 = Z_0/y_1 = 69.8\ \Omega$, $Z_2 = Z_0/y_2 = 40.7\Omega$

3. a) $Z = 25.00\Omega + j\cdot(29.48)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.155 + j\cdot(0.454) = 0.480\angle 108.8°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.480$; $\varphi = \arg(\Gamma) = 108.8°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 4.9°$; $\mathrm{Im}(y_S) = -1.093$; $\theta_{P1} = 132.4°$ **or** $\theta_{S2} = 66.3°$; $\mathrm{Im}(y_S) = 1.093$; $\theta_{P2} = 47.6°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 325\text{MHz} = 2.042\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 15.848\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 15.133\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 4.897\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 15.133\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 15.848\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 325 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 325$ MHz; In the stopband (f < 325 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 162.5$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.0\text{dB} + 15.9\text{dB} + 21.8\text{dB} = 61.7\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}479{,}108.4$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.01\text{dB} = 2.000$, $G_1 = 24.0\text{dB} = 251.189$, $F_2 = 4.20\text{dB} = 2.630$, $G_2 = 15.9\text{dB} = 38.905$, $F_3 = 5.64\text{dB} = 3.664$, $G_3 = 21.8\text{dB} = 151.356$;
$F = 2.630 + (3.664-1)/38.905 + (2.000-1)/38.905/151.356 = 2.699 = 4.312\text{dB}$
c) If the order is A1, A2, A3 the gain remains the same but $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$;
$F = 2.000 + (2.630-1)/251.189 + (3.664-1)/251.189/38.905 = 2.007 = 3.025\text{dB}$

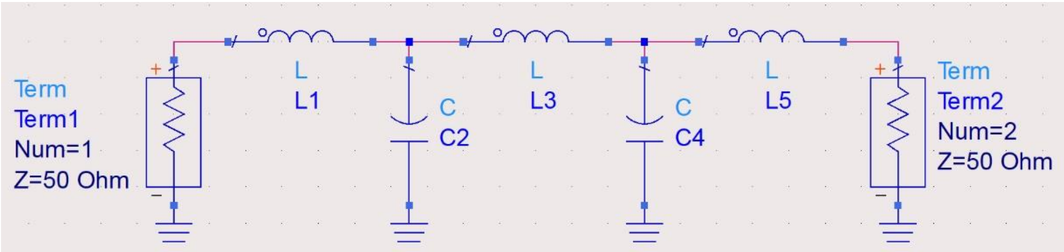
Subject no. 6

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (52.4 + j\cdot57.7)\Omega = 0.431 + j\cdot0.475$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.431 + j\cdot0.475)] / (1 + 0.431 + j\cdot0.475)$
$\Gamma = (0.259) + j\cdot(0.418) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.491\angle58.2° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 5.3\text{dBm} - 7.75\text{dB} = -2.45\text{dBm}$;
b) $P_{in} = 5.3\text{dBm} = 3.388\text{mW}$; $P_c = -2.45\text{dBm} = 0.569\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 3.388\text{mW} - 0.569\text{mW} = 2.820\text{mW} = 4.502\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.410$, $y_2 = 1.096$, $y_1 = 0.449$, $Z_1 = Z_0/y_1 = 111.3\ \Omega$, $Z_2 = Z_0/y_2 = 45.6\Omega$

3. a) $Z = 33.38\Omega + j\cdot(26.86)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.087 + j\cdot(0.350) = 0.361\angle103.9°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.361$; $\varphi = \arg(\Gamma) = 103.9°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 3.6°$; $\mathrm{Im}(y_S) = -0.773$; $\theta_{P1} = 142.3°$ **or** $\theta_{S2} = 72.5°$; $\mathrm{Im}(y_S) = 0.773$; $\theta_{P2} = 37.7°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot455\text{MHz} = 2.859\cdot10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 10.809\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 11.319\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 34.979\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 11.319\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 10.809\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 455 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 455$ MHz; In the stopband (f > 455 MHz) the attenuation for 5^{th} order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 910.0$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 17.0\text{dB} + 18.6\text{dB} + 23.6\text{dB} = 59.2\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 831{,}763.8$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.63\text{dB} = 2.307$, $G_1 = 17.0\text{dB} = 50.119$, $F_2 = 4.37\text{dB} = 2.735$, $G_2 = 18.6\text{dB} = 72.444$, $F_3 = 5.31\text{dB} = 3.396$, $G_3 = 23.6\text{dB} = 229.087$;
$F = 2.307 + (2.735-1)/50.119 + (3.396-1)/50.119/72.444 = 2.342 = 3.696\text{dB}$
c) If the order is A1, A3, A2 the gain remains the same but $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$;
$F = 2.307 + (3.396-1)/50.119 + (2.735-1)/50.119/229.087 = 2.355 = 3.719\text{dB}$

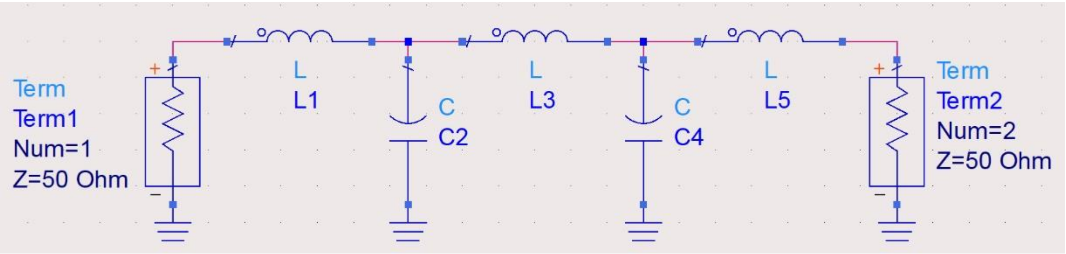
Subject no. 7

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (42.4 + j\cdot 55.7)\Omega = 0.433 + j\cdot 0.568$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.433 + j\cdot 0.568)] / (1 + 0.433 + j\cdot 0.568)$
$\Gamma = (0.206) + j\cdot(0.479) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.521\angle 66.7° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 2.4\text{dBm} - 8.05\text{dB} = -5.65\text{dBm}$;
b) $P_{in} = 2.4\text{dBm} = 1.738\text{mW}$; $P_c = -5.65\text{dBm} = 0.272\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 1.738\text{mW} - 0.272\text{mW} = 1.466\text{mW} = 1.660\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.396$, $y_2 = 1.089$, $y_1 = 0.431$, $Z_1 = Z_0/y_1 = 116.0\ \Omega$, $Z_2 = Z_0/y_2 = 45.9\Omega$

3. a) $Z = 63.00\Omega + j\cdot(-67.56)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.348 + j\cdot(-0.390) = 0.523\angle -48.2°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.523$; $\varphi = \arg(\Gamma) = -48.2°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 84.9°$; $\mathrm{Im}(y_S) = -1.226$; $\theta_{P1} = 129.2°$ **or** $\theta_{S2} = 143.4°$; $\mathrm{Im}(y_S) = 1.226$; $\theta_{P2} = 50.8°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 535\text{MHz} = 3.362\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no $\lambda/4$ transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 25.373\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 7.316\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 37.793\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 7.316\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 25.373\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 535 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation $L_{Ar} = 0.5$ dB, including at the cutoff frequency $f_1 = 535$ MHz; In the stopband (f > 535 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1070.0$ MHz the attenuation is $L_{As} = 42.039$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 23.4\text{dB} + 15.3\text{dB} + 16.4\text{dB} = 55.1\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 323{,}593.7$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A1, A2 so: $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$; $F_1 = 3.55\text{dB} = 2.265$, $G_1 = 23.4\text{dB} = 218.776$, $F_2 = 4.83\text{dB} = 3.041$, $G_2 = 15.3\text{dB} = 33.884$, $F_3 = 5.13\text{dB} = 3.258$, $G_3 = 16.4\text{dB} = 43.652$;
$F = 3.258 + (2.265-1)/43.652 + (3.041-1)/43.652/218.776 = 3.288 = 5.169\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 3.041 + (3.258-1)/33.884 + (2.265-1)/33.884/43.652 = 3.108 = 4.925\text{dB}$

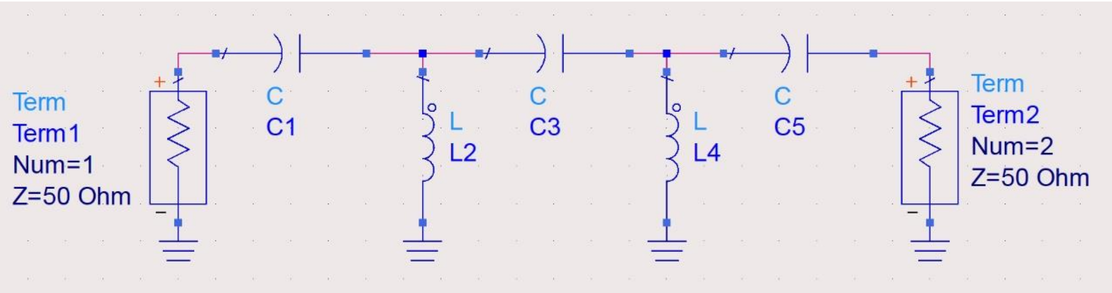
Subject no. 8

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (48.1 - j\cdot 45.6)\Omega = 0.547 - j\cdot 0.519$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.547 - j\cdot 0.519)] / (1 + 0.547 - j\cdot 0.519)$
$\Gamma = (0.162) + j\cdot(-0.390) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.422\angle -67.5° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 2.6\text{dBm} - 7.75\text{dB} = -5.15\text{dBm}$;
b) $P_{in} = 2.6\text{dBm} = 1.820\text{mW}$; $P_c = -5.15\text{dBm} = 0.305\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 1.820\text{mW} - 0.305\text{mW} = 1.514\text{mW} = 1.802\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.410$, $y_2 = 1.096$, $y_1 = 0.449$, $Z_1 = Z_0/y_1 = 111.3\ \Omega$, $Z_2 = Z_0/y_2 = 45.6\Omega$

3. a) $Z = 20.78\Omega + j\cdot(-9.36)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.388 + j\cdot(-0.184) = 0.430\angle -154.7°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.430$; $\varphi = \arg(\Gamma) = -154.7°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 135.1°$; $\mathrm{Im}(y_S) = -0.952$; $\theta_{P1} = 136.4°$ **or** $\theta_{S2} = 19.6°$; $\mathrm{Im}(y_S) = 0.952$; $\theta_{P2} = 43.6°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 530\text{MHz} = 3.330\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 3.521\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 12.211\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 2.364\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 12.211\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 3.521\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 530 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 530 MHz; In the stopband (f < 530 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 265.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 18.4\text{dB} + 18.6\text{dB} + 20.7\text{dB} = 57.7\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 588{,}843.7$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.24\text{dB} = 2.109$, $G_1 = 18.4\text{dB} = 69.183$, $F_2 = 4.62\text{dB} = 2.897$, $G_2 = 18.6\text{dB} = 72.444$, $F_3 = 5.59\text{dB} = 3.622$, $G_3 = 20.7\text{dB} = 117.490$;
$F = 2.109 + (2.897-1)/69.183 + (3.622-1)/69.183/72.444 = 2.137 = 3.297\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.897 + (3.622-1)/72.444 + (2.109-1)/72.444/117.490 = 2.934 = 4.674\text{dB}$

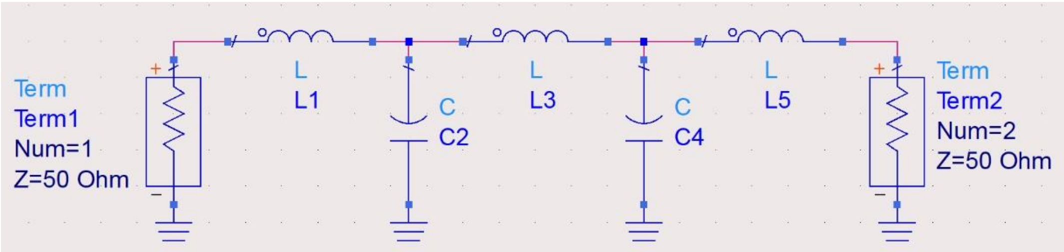
Subject no. 9

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (33.6 - j\cdot 58.3)\Omega = 0.371 - j\cdot 0.644$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.371 - j\cdot 0.644)] / (1 + 0.371 - j\cdot 0.644)$
$\Gamma = (0.195) + j\cdot(-0.561) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.594\angle -70.8° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 5.5\text{dBm} - 6.75\text{dB} = -1.25\text{dBm}$;
b) $P_{in} = 5.5\text{dBm} = 3.548\text{mW}$; $P_c = -1.25\text{dBm} = 0.750\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 3.548\text{mW} - 0.750\text{mW} = 2.798\text{mW} = 4.469\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.460$, $y_2 = 1.126$, $y_1 = 0.518$, $Z_1 = Z_0/y_1 = 96.6\ \Omega$, $Z_2 = Z_0/y_2 = 44.4\Omega$

3. a) $Z = 74.00\Omega + j\cdot(-28.69)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.235 + j\cdot(-0.177) = 0.294\angle -37.1°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.294$; $\varphi = \arg(\Gamma) = -37.1°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 72.1°$; $\mathrm{Im}(y_S) = -0.615$; $\theta_{P1} = 148.4°$ **<u>or</u>** $\theta_{S2} = 145.0°$; $\mathrm{Im}(y_S) = 0.615$; $\theta_{P2} = 31.6°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 400\text{MHz} = 2.513\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**<u>low-pass filter (LPF)</u>**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 33.936\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 9.785\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 50.548\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 9.785\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 33.936\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 400 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 400 MHz; In the stopband (f > 400 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at f_s = 800.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 20.7\text{dB} + 19.9\text{dB} + 21.0\text{dB} = 61.6\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}445{,}439.8$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.52\text{dB} = 2.249$, $G_1 = 20.7\text{dB} = 117.490$, $F_2 = 4.29\text{dB} = 2.685$, $G_2 = 19.9\text{dB} = 97.724$, $F_3 = 5.86\text{dB} = 3.855$, $G_3 = 21.0\text{dB} = 125.893$;
$F = 2.249 + (3.855-1)/117.490 + (2.685-1)/117.490/125.893 = 2.273 = 3.567\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.685 + (3.855-1)/97.724 + (2.249-1)/97.724/125.893 = 2.715 = 4.337\text{dB}$

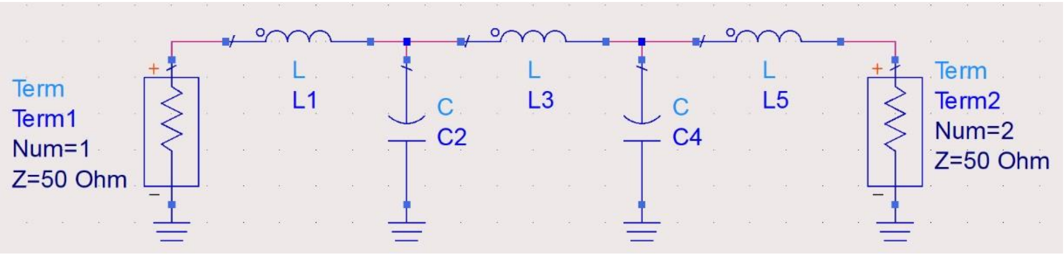
Subject no. 10

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (37.8 + j\cdot44.1)\Omega = 0.560 + j\cdot0.654$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.560 + j\cdot0.654)] / (1 + 0.560 + j\cdot0.654)$
$\Gamma = (0.090) + j\cdot(0.457) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.466\angle78.8° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 9.5\text{dBm} - 7.60\text{dB} = 1.90\text{dBm}$;
b) $P_{in} = 9.5\text{dBm} = 8.913\text{mW}$; $P_c = 1.90\text{dBm} = 1.549\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 8.913\text{mW} - 1.549\text{mW} = 7.364\text{mW} = 8.671\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.417$, $y_2 = 1.100$, $y_1 = 0.459$, $Z_1 = Z_0/y_1 = 109.0\ \Omega$, $Z_2 = Z_0/y_2 = 45.4\Omega$

3. a) $Z = 22.80\Omega + j\cdot(-27.92)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.197 + j\cdot(-0.459) = 0.500\angle{-113.3°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.500$; $\varphi = \arg(\Gamma) = -113.3°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 116.6°$; $\mathrm{Im}(y_S) = -1.155$; $\theta_{P1} = 130.9°$ **or** $\theta_{S2} = 176.6°$; $\mathrm{Im}(y_S) = 1.155$; $\theta_{P2} = 49.1°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot370\text{MHz} = 2.325\cdot10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 13.292\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 13.920\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 43.015\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 13.920\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 13.292\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 370 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 370$ MHz; In the stopband (f > 370 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 740.0$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 20.8\text{dB} + 19.2\text{dB} + 16.8\text{dB} = 56.8\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 478{,}630.1$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.35\text{dB} = 2.163$, $G_1 = 20.8\text{dB} = 120.226$, $F_2 = 4.34\text{dB} = 2.716$, $G_2 = 19.2\text{dB} = 83.176$, $F_3 = 5.20\text{dB} = 3.311$, $G_3 = 16.8\text{dB} = 47.863$;
$F = 2.163 + (2.716-1)/120.226 + (3.311-1)/120.226/83.176 = 2.177 = 3.379\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.716 + (3.311-1)/83.176 + (2.163-1)/83.176/47.863 = 2.745 = 4.385\text{dB}$

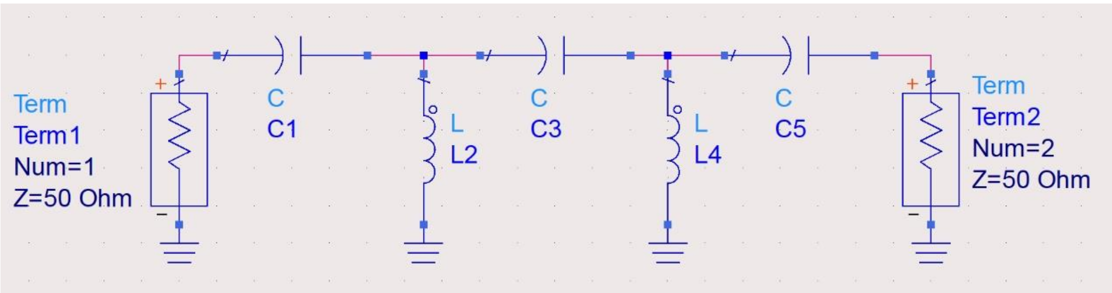
Subject no. 11

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (49.2 - j\cdot 35.9)\Omega = 0.663 - j\cdot 0.484$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.663 - j\cdot 0.484)] / (1 + 0.663 - j\cdot 0.484)$
$\Gamma = (0.109) + j\cdot(-0.323) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.340\angle{-71.4°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 8.3\text{dBm} - 5.20\text{dB} = 3.10\text{dBm}$;
b) $P_{in} = 8.3\text{dBm} = 6.761\text{mW}$; $P_c = 3.10\text{dBm} = 2.042\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 6.761\text{mW} - 2.042\text{mW} = 4.719\text{mW} = 6.739\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.550$, $y_2 = 1.197$, $y_1 = 0.658$, $Z_1 = Z_0/y_1 = 76.0\ \Omega$, $Z_2 = Z_0/y_2 = 41.8\Omega$

3. a) $Z = 50.00\Omega + j\cdot(29.09)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.078 + j\cdot(0.268) = 0.279\angle 73.8°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.279$; $\varphi = \arg(\Gamma) = 73.8°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 16.2°$; $\mathrm{Im}(y_S) = -0.582$; $\theta_{P1} = 149.8°$ **or** $\theta_{S2} = 90.0°$; $\mathrm{Im}(y_S) = 0.582$; $\theta_{P2} = 30.2°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 585\text{MHz} = 3.676\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 1.563\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 17.856\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 1.199\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 17.856\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 1.563\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 585 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 585$ MHz; In the stopband (f < 585 MHz) the attenuation for 5^{th} order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 292.5$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 18.8\text{dB} + 15.4\text{dB} + 17.9\text{dB} = 52.1\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 162{,}181.0$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.19\text{dB} = 2.084$, $G_1 = 18.8\text{dB} = 75.858$, $F_2 = 4.57\text{dB} = 2.864$, $G_2 = 15.4\text{dB} = 34.674$, $F_3 = 5.09\text{dB} = 3.228$, $G_3 = 17.9\text{dB} = 61.660$;
$F = 2.084 + (3.228-1)/75.858 + (2.864-1)/75.858/61.660 = 2.114 = 3.252\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.864 + (3.228-1)/34.674 + (2.084-1)/34.674/61.660 = 2.929 = 4.667\text{dB}$

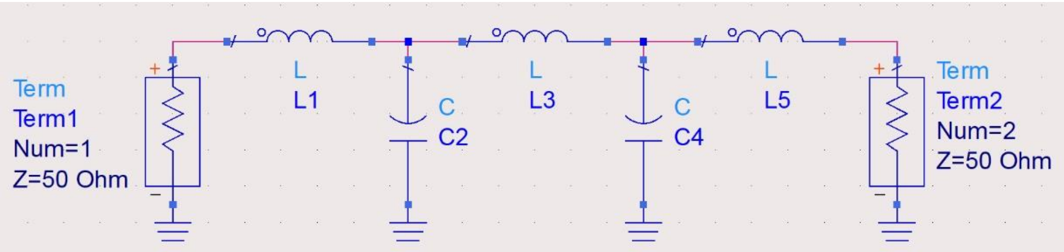
Subject no. 12

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (42.5 - j\cdot55.8)\Omega = 0.432 - j\cdot0.567$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.432 - j\cdot0.567)] / (1 + 0.432 - j\cdot0.567)$
$\Gamma = (0.207) + j\cdot(-0.478) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.521\angle{-66.6°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 8.1\text{dBm} - 6.45\text{dB} = 1.65\text{dBm}$;
b) $P_{in} = 8.1\text{dBm} = 6.457\text{mW}$; $P_c = 1.65\text{dBm} = 1.462\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 6.457\text{mW} - 1.462\text{mW} = 4.994\text{mW} = 6.985\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.476$, $y_2 = 1.137$, $y_1 = 0.541$, $Z_1 = Z_0/y_1 = 92.4\ \Omega$, $Z_2 = Z_0/y_2 = 44.0\Omega$

3. a) $Z = 58.00\Omega + j\cdot(-27.76)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.131 + j\cdot(-0.223) = 0.259\angle{-59.5°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.259$; $\varphi = \arg(\Gamma) = -59.5°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 82.3°$; $\mathrm{Im}(y_S) = -0.537$; $\theta_{P1} = 151.8°$ **or** $\theta_{S2} = 157.2°$; $\mathrm{Im}(y_S) = 0.537$; $\theta_{P2} = 28.2°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot300\text{MHz} = 1.885\cdot10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no $\lambda/4$ transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 16.393\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 17.168\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 53.052\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 17.168\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 16.393\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 300 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 300$ MHz; In the stopband (f > 300 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 600.0$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 16.2\text{dB} + 23.1\text{dB} + 22.0\text{dB} = 61.3\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1,348,962.9$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.16\text{dB} = 2.070$, $G_1 = 16.2\text{dB} = 41.687$, $F_2 = 4.46\text{dB} = 2.793$, $G_2 = 23.1\text{dB} = 204.174$, $F_3 = 5.80\text{dB} = 3.802$, $G_3 = 22.0\text{dB} = 158.489$;
$F = 2.793 + (2.070-1)/204.174 + (3.802-1)/204.174/41.687 = 2.798 = 4.469\text{dB}$
c) If the order is A1, A2, A3 the gain remains the same but $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$;
$F = 2.070 + (2.793-1)/41.687 + (3.802-1)/41.687/204.174 = 2.113 = 3.250\text{dB}$

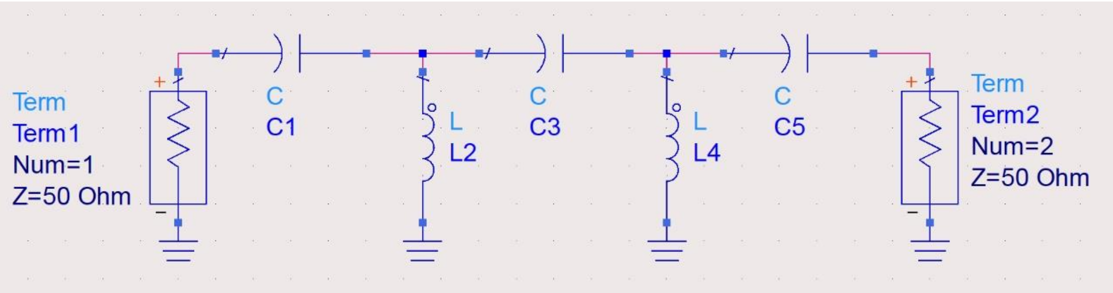
Subject no. 13

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (63.3 - j\cdot 52.3)\Omega = 0.469 - j\cdot 0.388$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.469 - j\cdot 0.388)] / (1 + 0.469 - j\cdot 0.388)$
$\Gamma = (0.272) + j\cdot(-0.336) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.432\angle{-51.0°} \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} – C = 7.3\text{dBm} – 6.55\text{dB} = 0.75\text{dBm}$;
b) $P_{in} = 7.3\text{dBm} = 5.370\text{mW}$; $P_c = 0.75\text{dBm} = 1.189\text{mW}$;
Lossless coupler $P_{th} = P_{in} – P_c = 5.370\text{mW} – 1.189\text{mW} = 4.182\text{mW} = 6.214\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.470$, $y_2 = 1.133$, $y_1 = 0.533$, $Z_1 = Z_0/y_1 = 93.8\ \Omega$, $Z_2 = Z_0/y_2 = 44.1\Omega$

3. a) $Z = 23.30\Omega + j\cdot(-15.03)\Omega$; $\Gamma = (Z – Z_0)/(Z + Z_0) = -0.309 + j\cdot(-0.269) = 0.410\angle{-139.0°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.410$; $\varphi = \arg(\Gamma) = -139.0°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 126.6°$; $\mathrm{Im}(y_S) = -0.898$; $\theta_{P1} = 138.1°$ **or** $\theta_{S2} = 12.4°$; $\mathrm{Im}(y_S) = 0.898$; $\theta_{P2} = 41.9°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 585\text{MHz} = 3.676\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 1.563\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 17.856\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 1.199\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 17.856\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 1.563\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 585 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 585$ MHz; In the stopband (f < 585 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 292.5$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 15.2\text{dB} + 23.3\text{dB} + 23.1\text{dB} = 61.6\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}445{,}439.8$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.52\text{dB} = 2.249$, $G_1 = 15.2\text{dB} = 33.113$, $F_2 = 4.37\text{dB} = 2.735$, $G_2 = 23.3\text{dB} = 213.796$, $F_3 = 5.49\text{dB} = 3.540$, $G_3 = 23.1\text{dB} = 204.174$;
$F = 2.249 + (3.540-1)/33.113 + (2.735-1)/33.113/204.174 = 2.326 = 3.666\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.735 + (3.540-1)/213.796 + (2.249-1)/213.796/204.174 = 2.747 = 4.389\text{dB}$

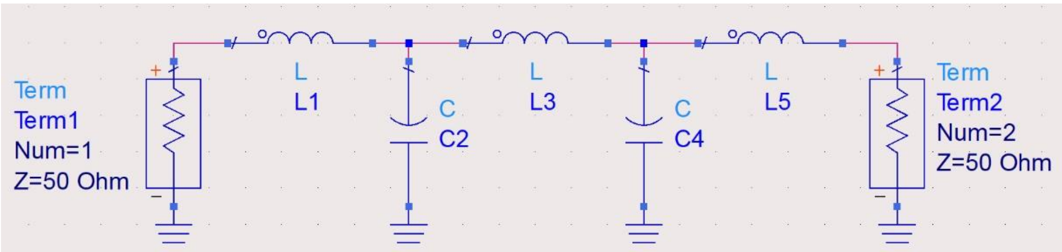
Subject no. 14

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (61.1 - j\cdot 60.9)\Omega = 0.411 - j\cdot 0.409$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.411 - j\cdot 0.409)] / (1 + 0.411 - j\cdot 0.409)$
$\Gamma = (0.308) + j\cdot(-0.379) \leftrightarrow \text{Re}\Gamma + j\cdot\text{Im}\Gamma$ or $\Gamma = 0.489\angle -50.9° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 7.0\text{dBm} - 5.60\text{dB} = 1.40\text{dBm}$;
b) $P_{in} = 7.0\text{dBm} = 5.012\text{mW}$; $P_c = 1.40\text{dBm} = 1.380\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 5.012\text{mW} - 1.380\text{mW} = 3.631\text{mW} = 5.601\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.525$, $y_2 = 1.175$, $y_1 = 0.617$, $Z_1 = Z_0/y_1 = 81.1\ \Omega$, $Z_2 = Z_0/y_2 = 42.6\Omega$

3. a) $Z = 15.07\Omega + j\cdot(25.14)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.337+ j\cdot(0.517) = 0.617\angle 123.1°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.617$; $\varphi = \arg(\Gamma) = 123.1°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 2.5°$; $\text{Im}(y_S) = -1.568$; $\theta_{P1} = 122.5°$ **or** $\theta_{S2} = 54.4°$; $\text{Im}(y_S) = 1.568$; $\theta_{P2} = 57.5°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 580\text{MHz} = 3.644\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 47.770\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 4.181\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 62.264\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 4.181\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 47.770\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 580 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 580$ MHz; In the stopband (f > 580 MHz) the attenuation for 5^{th} order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1160.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 15.4\text{dB} + 21.5\text{dB} + 21.3\text{dB} = 58.2\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 660{,}693.4$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A1, A2 so: $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$; $F_1 = 3.44\text{dB} = 2.208$, $G_1 = 15.4\text{dB} = 34.674$, $F_2 = 4.13\text{dB} = 2.588$, $G_2 = 21.5\text{dB} = 141.254$, $F_3 = 5.60\text{dB} = 3.631$, $G_3 = 21.3\text{dB} = 134.896$;
$F = 3.631 + (2.208-1)/134.896 + (2.588-1)/134.896/34.674 = 3.640 = 5.611\text{dB}$
c) If the order is A3, A2, A1 the gain remains the same but $F = F_3 + (F_2-1)/G_3 + (F_1-1)/G_3/G_2$;
$F = 3.631 + (2.588-1)/134.896 + (2.208-1)/134.896/141.254 = 3.643 = 5.614\text{dB}$

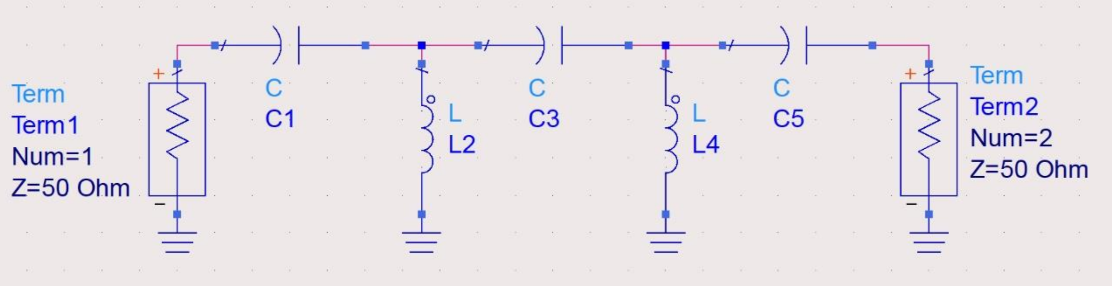
Subject no. 15

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (58.5 - j\cdot 51.8)\Omega = 0.479 - j\cdot 0.424$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.479 - j\cdot 0.424)] / (1 + 0.479 - j\cdot 0.424)$
$\Gamma = (0.249) + j\cdot(-0.358) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.437\angle{-55.2°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 7.6\text{dBm} - 5.25\text{dB} = 2.35\text{dBm}$;
b) $P_{in} = 7.6\text{dBm} = 5.754\text{mW}$; $P_c = 2.35\text{dBm} = 1.718\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 5.754\text{mW} - 1.718\text{mW} = 4.036\text{mW} = 6.060\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.546$, $y_2 = 1.194$, $y_1 = 0.652$, $Z_1 = Z_0/y_1 = 76.6\ \Omega$, $Z_2 = Z_0/y_2 = 41.9\Omega$

3. a) $Z = 27.00\Omega + j\cdot(-35.77)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.068 + j\cdot(-0.496) = 0.501\angle{-97.8°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.501$; $\varphi = \arg(\Gamma) = -97.8°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 108.9°$; $\mathrm{Im}(y_S) = -1.158$; $\theta_{P1} = 130.8°$ **or** $\theta_{S2} = 168.9°$; $\mathrm{Im}(y_S) = 1.158$; $\theta_{P2} = 49.2°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 305\text{MHz} = 1.916\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 2.997\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 34.249\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 2.300\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 34.249\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 2.997\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 305 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 305$ MHz; In the stopband (f < 305 MHz) the attenuation for 5^{th} order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 152.5$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.2\text{dB} + 19.7\text{dB} + 21.0\text{dB} = 64.9\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 3{,}090{,}295.4$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.58\text{dB} = 2.280$, $G_1 = 24.2\text{dB} = 263.027$, $F_2 = 4.54\text{dB} = 2.844$, $G_2 = 19.7\text{dB} = 93.325$, $F_3 = 5.82\text{dB} = 3.819$, $G_3 = 21.0\text{dB} = 125.893$;
$F = 2.844 + (3.819-1)/93.325 + (2.280-1)/93.325/125.893 = 2.875 = 4.586\text{dB}$
c) If the order is A1, A2, A3 the gain remains the same but $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$;
$F = 2.280 + (2.844-1)/263.027 + (3.819-1)/263.027/93.325 = 2.287 = 3.594\text{dB}$

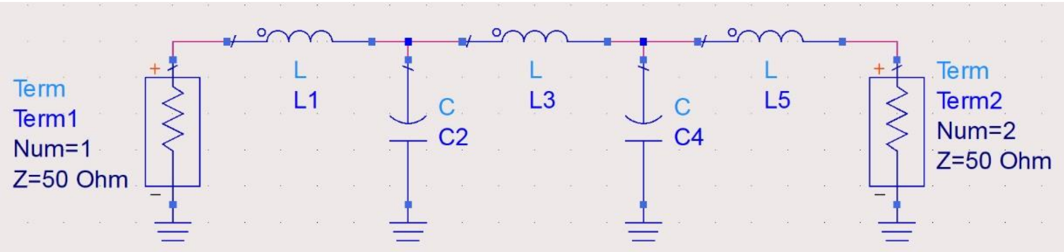
Subject no. 16

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (31.5 + j\cdot41.3)\Omega = 0.584 + j\cdot0.765$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.584 + j\cdot0.765)] / (1 + 0.584 + j\cdot0.765)$
$\Gamma = (0.024) + j\cdot(0.495) \leftrightarrow Re\Gamma + j\cdot Im\Gamma$ or $\Gamma = 0.495\angle 87.3° \leftrightarrow |\Gamma|\angle arg(\Gamma)$

2. a) $P_c = P_{in} - C = 9.5dBm - 7.55dB = 1.95dBm$;
b) $P_{in} = 9.5dBm = 8.913mW$; $P_c = 1.95dBm = 1.567mW$;
Lossless coupler $P_{th} = P_{in} - P_c = 8.913mW - 1.567mW = 7.346mW = 8.660dBm$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.419$, $y_2 = 1.101$, $y_1 = 0.462$, $Z_1 = Z_0/y_1 = 108.3\ \Omega$, $Z_2 = Z_0/y_2 = 45.4\Omega$

3. a) $Z = 12.12\Omega + j\cdot(22.53)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.423 + j\cdot(0.516) = 0.667\angle 129.3°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.667$; $\varphi = arg(\Gamma) = 129.3°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 1.3°$; $Im(y_S) = -1.790$; $\theta_{P1} = 119.2°$ **or** $\theta_{S2} = 49.4°$; $Im(y_S) = 1.790$; $\theta_{P2} = 60.8°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot500MHz = 3.142\cdot10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 27.149nH$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 7.828pF$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 40.438nH$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 7.828pF$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 27.149nH$;
b) Draw the schematic:



c) In the passband (f < 500 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 500 MHz; In the stopband (f > 500 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at f_s = 1000.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[dB] = G_1 + G_2 + G_3 = 18.3dB + 18.7dB + 24.2dB = 61.2dB$; $G[lin] = 10^{G[dB]/10} = 1{,}318{,}256.7$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.73dB = 2.360$, $G_1 = 18.3dB = 67.608$, $F_2 = 4.31dB = 2.698$, $G_2 = 18.7dB = 74.131$, $F_3 = 5.33dB = 3.412$, $G_3 = 24.2dB = 263.027$;
$F = 2.360 + (2.698-1)/67.608 + (3.412-1)/67.608/74.131 = 2.386 = 3.777dB$
c) If the order is A1, A3, A2 the gain remains the same but $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$;
$F = 2.360 + (3.412-1)/67.608 + (2.698-1)/67.608/263.027 = 2.396 = 3.795dB$

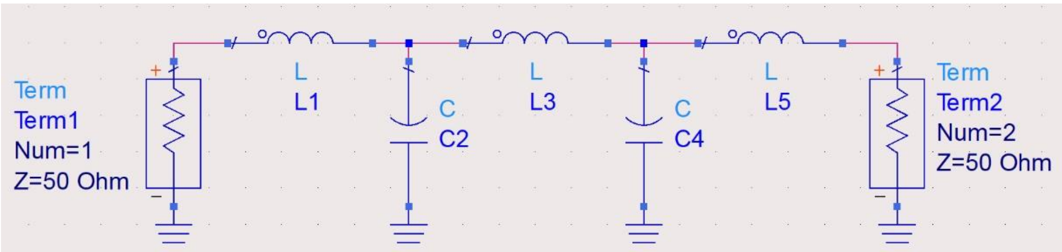
Subject no. 17

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (63.9 + j\cdot 40.8)\Omega = 0.556 + j\cdot 0.355$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.556 + j\cdot 0.355)] / (1 + 0.556 + j\cdot 0.355)$
$\Gamma = (0.222) + j\cdot(0.279) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.356\angle 51.5° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 4.4\text{dBm} - 5.45\text{dB} = -1.05\text{dBm}$;
b) $P_{in} = 4.4\text{dBm} = 2.754\text{mW}$; $P_c = -1.05\text{dBm} = 0.785\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 2.754\text{mW} - 0.785\text{mW} = 1.969\text{mW} = 2.942\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.534$, $y_2 = 1.183$, $y_1 = 0.632$, $Z_1 = Z_0/y_1 = 79.2\ \Omega$, $Z_2 = Z_0/y_2 = 42.3\Omega$

3. a) $Z = 28.89\Omega + j\cdot(-18.70)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.200 + j\cdot(-0.285) = 0.348\angle -125.1°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.348$; $\varphi = \arg(\Gamma) = -125.1°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 117.7°$; $\mathrm{Im}(y_S) = -0.742$; $\theta_{P1} = 143.4°$ **or** $\theta_{S2} = 7.4°$; $\mathrm{Im}(y_S) = 0.742$; $\theta_{P2} = 36.6°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 595\text{MHz} = 3.738\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 46.566\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 4.075\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 60.694\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 4.075\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 46.566\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 595 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 595$ MHz; In the stopband (f > 595 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1190.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.3\text{dB} + 20.5\text{dB} + 20.0\text{dB} = 64.8\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 3{,}019{,}951.7$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.33\text{dB} = 2.153$, $G_1 = 24.3\text{dB} = 269.153$, $F_2 = 4.39\text{dB} = 2.748$, $G_2 = 20.5\text{dB} = 112.202$, $F_3 = 5.90\text{dB} = 3.890$, $G_3 = 20.0\text{dB} = 100.000$;
$F = 2.748 + (3.890-1)/112.202 + (2.153-1)/112.202/100.000 = 2.774 = 4.431\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.890 + (2.153-1)/100.000 + (2.748-1)/100.000/269.153 = 3.902 = 5.913\text{dB}$

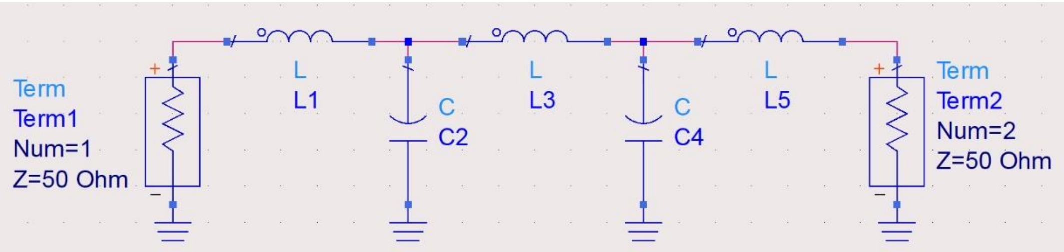
Subject no. 18

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (64.6 + j\cdot 35.5)\Omega = 0.594 + j\cdot 0.327$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.594 + j\cdot 0.327)] / (1 + 0.594 + j\cdot 0.327)$
$\Gamma = (0.204) + j\cdot(0.247) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.320\angle 50.4° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 4.1\text{dBm} - 5.00\text{dB} = -0.90\text{dBm}$;
b) $P_{in} = 4.1\text{dBm} = 2.570\text{mW}$; $P_c = -0.90\text{dBm} = 0.813\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 2.570\text{mW} - 0.813\text{mW} = 1.758\text{mW} = 2.449\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.562$, $y_2 = 1.209$, $y_1 = 0.680$, $Z_1 = Z_0/y_1 = 73.5\ \Omega$, $Z_2 = Z_0/y_2 = 41.3\Omega$

3. a) $Z = 26.58\Omega + j\cdot(15.82)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.252 + j\cdot(0.259) = 0.361\angle 134.3°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.361$; $\varphi = \arg(\Gamma) = 134.3°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 168.5°$; $\mathrm{Im}(y_S) = -0.775$; $\theta_{P1} = 142.2°$ **or** $\theta_{S2} = 57.3°$; $\mathrm{Im}(y_S) = 0.775$; $\theta_{P2} = 37.8°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 345\text{MHz} = 2.168\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 14.255\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 14.928\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 46.132\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 14.928\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 14.255\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 345 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 345$ MHz; In the stopband (f > 345 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 690.0$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 21.4\text{dB} + 19.1\text{dB} + 21.6\text{dB} = 62.1\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}621{,}810.1$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.46\text{dB} = 2.218$, $G_1 = 21.4\text{dB} = 138.038$, $F_2 = 4.07\text{dB} = 2.553$, $G_2 = 19.1\text{dB} = 81.283$, $F_3 = 5.39\text{dB} = 3.459$, $G_3 = 21.6\text{dB} = 144.544$;
$F = 2.218 + (3.459-1)/138.038 + (2.553-1)/138.038/144.544 = 2.236 = 3.495\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.459 + (2.218-1)/144.544 + (2.553-1)/144.544/138.038 = 3.468 = 5.401\text{dB}$

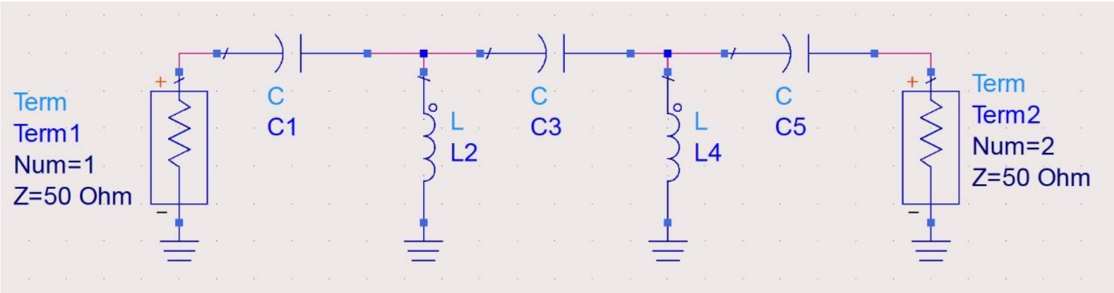
Subject no. 19

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (38.2 - j\cdot 33.8)\Omega = 0.734 - j\cdot 0.650$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.734 - j\cdot 0.650)] / (1 + 0.734 - j\cdot 0.650)$
$\Gamma = (0.011) + j\cdot(-0.379) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.379\angle -88.3° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 6.3\text{dBm} - 4.25\text{dB} = 2.05\text{dBm}$;
b) $P_{in} = 6.3\text{dBm} = 4.266\text{mW}$; $P_c = 2.05\text{dBm} = 1.603\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 4.266\text{mW} - 1.603\text{mW} = 2.663\text{mW} = 4.253\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.613$, $y_2 = 1.266$, $y_1 = 0.776$, $Z_1 = Z_0/y_1 = 64.4\ \Omega$, $Z_2 = Z_0/y_2 = 39.5\Omega$

3. a) $Z = 33.33\Omega + j\cdot(-36.82)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.004 + j\cdot(-0.444) = 0.444\angle -90.5°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.444$; $\varphi = \arg(\Gamma) = -90.5°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 103.4°$; $\mathrm{Im}(y_S) = -0.990$; $\theta_{P1} = 135.3°$ **or** $\theta_{S2} = 167.1°$; $\mathrm{Im}(y_S) = 0.990$; $\theta_{P2} = 44.7°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 565\text{MHz} = 3.550\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 3.303\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 11.455\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 2.217\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 11.455\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 3.303\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 565 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 565 MHz; In the stopband (f < 565 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 282.5 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 20.7\text{dB} + 24.1\text{dB} + 18.5\text{dB} = 63.3\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 2{,}137{,}962.1$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.59\text{dB} = 2.286$, $G_1 = 20.7\text{dB} = 117.490$, $F_2 = 4.41\text{dB} = 2.761$, $G_2 = 24.1\text{dB} = 257.040$, $F_3 = 5.57\text{dB} = 3.606$, $G_3 = 18.5\text{dB} = 70.795$;
$F = 2.286 + (2.761-1)/117.490 + (3.606-1)/117.490/257.040 = 2.301 = 3.619\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.606 + (2.286-1)/70.795 + (2.761-1)/70.795/117.490 = 3.624 = 5.592\text{dB}$

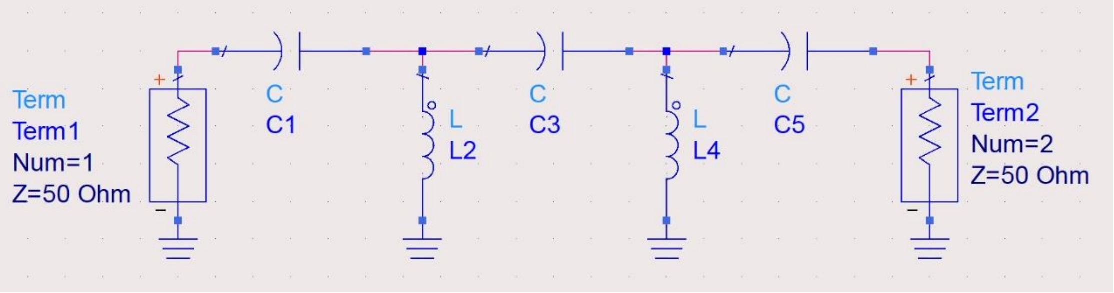
Subject no. 20

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (52.1 + j\cdot 56.6)\Omega = 0.440 + j\cdot 0.478$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.440 + j\cdot 0.478)] / (1 + 0.440 + j\cdot 0.478)$
$\Gamma = (0.251) + j\cdot(0.415) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.485\angle 58.9° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 4.2\text{dBm} - 4.05\text{dB} = 0.15\text{dBm}$;
b) $P_{in} = 4.2\text{dBm} = 2.630\text{mW}$; $P_c = 0.15\text{dBm} = 1.035\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 2.630\text{mW} - 1.035\text{mW} = 1.595\text{mW} = 2.028\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.627$, $y_2 = 1.284$, $y_1 = 0.806$, $Z_1 = Z_0/y_1 = 62.1\ \Omega$, $Z_2 = Z_0/y_2 = 38.9\Omega$

3. a) $Z = 37.46\Omega + j\cdot(34.91)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.014 + j\cdot(0.394) = 0.394\angle 88.0°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.394$; $\varphi = \arg(\Gamma) = 88.0°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 12.6°$; $\mathrm{Im}(y_S) = -0.857$; $\theta_{P1} = 139.4°$ **or** $\theta_{S2} = 79.4°$; $\mathrm{Im}(y_S) = 0.857$; $\theta_{P2} = 40.6°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 595\text{MHz} = 3.738\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 1.537\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 17.556\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 1.179\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 17.556\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 1.537\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 595 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 595$ MHz; In the stopband (f < 595 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 297.5$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 16.8\text{dB} + 22.2\text{dB} + 19.5\text{dB} = 58.5\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 707{,}945.8$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A1, A2 so: $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$; $F_1 = 3.79\text{dB} = 2.393$, $G_1 = 16.8\text{dB} = 47.863$, $F_2 = 4.56\text{dB} = 2.858$, $G_2 = 22.2\text{dB} = 165.959$, $F_3 = 5.44\text{dB} = 3.499$, $G_3 = 19.5\text{dB} = 89.125$;
$F = 3.499 + (2.393-1)/89.125 + (2.858-1)/89.125/47.863 = 3.516 = 5.460\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.858 + (3.499-1)/165.959 + (2.393-1)/165.959/89.125 = 2.873 = 4.583\text{dB}$

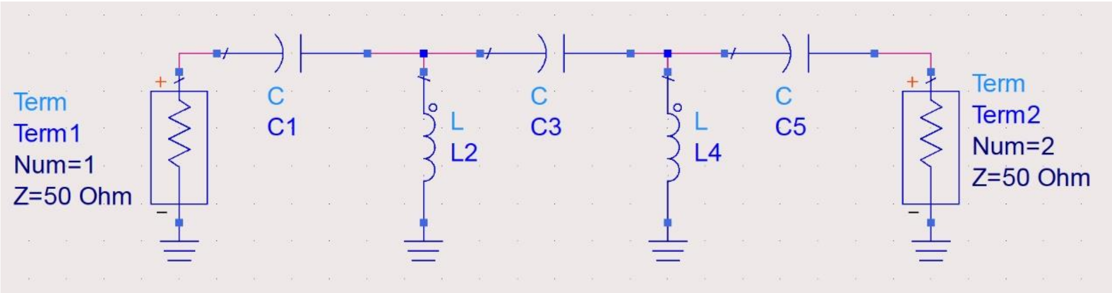
Subject no. 21

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (46.9 + j\cdot 49.8)\Omega = 0.501 + j\cdot 0.532$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.501 + j\cdot 0.532)] / (1 + 0.501 + j\cdot 0.532)$
$\Gamma = (0.184) + j\cdot(0.420) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.458\angle 66.4° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 7.7\text{dBm} - 4.00\text{dB} = 3.70\text{dBm}$;
b) $P_{in} = 7.7\text{dBm} = 5.888\text{mW}$; $P_c = 3.70\text{dBm} = 2.344\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 5.888\text{mW} - 2.344\text{mW} = 3.544\text{mW} = 5.495\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.631$, $y_2 = 1.289$, $y_1 = 0.813$, $Z_1 = Z_0/y_1 = 61.5\ \Omega$, $Z_2 = Z_0/y_2 = 38.8\Omega$

3. a) $Z = 14.73\Omega + j\cdot(-13.98)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.476 + j\cdot(-0.319) = 0.573\angle -146.2°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.573$; $\varphi = \arg(\Gamma) = -146.2°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 135.6°$; $\mathrm{Im}(y_S) = -1.398$; $\theta_{P1} = 125.6°$ **or** $\theta_{S2} = 10.6°$; $\mathrm{Im}(y_S) = 1.398$; $\theta_{P2} = 54.4°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 575\text{MHz} = 3.613\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 8.958\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 8.553\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 2.768\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 8.553\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 8.958\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 575 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 575$ MHz; In the stopband (f < 575 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 287.5$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 20.9\text{dB} + 18.7\text{dB} + 19.8\text{dB} = 59.4\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 870{,}963.6$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.68\text{dB} = 2.333$, $G_1 = 20.9\text{dB} = 123.027$, $F_2 = 4.24\text{dB} = 2.655$, $G_2 = 18.7\text{dB} = 74.131$, $F_3 = 5.98\text{dB} = 3.963$, $G_3 = 19.8\text{dB} = 95.499$;
$F = 2.655 + (3.963-1)/74.131 + (2.333-1)/74.131/95.499 = 2.695 = 4.305\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.963 + (2.333-1)/95.499 + (2.655-1)/95.499/123.027 = 3.977 = 5.995\text{dB}$

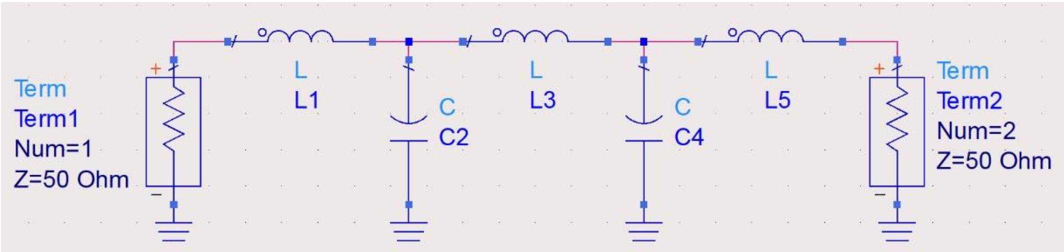
Subject no. 22

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (48.4 + j\cdot 35.1)\Omega = 0.677 + j\cdot 0.491$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.677 + j\cdot 0.491)] / (1 + 0.677 + j\cdot 0.491)$
$\Gamma = (0.098) + j\cdot(0.322) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.336\angle 73.0° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 1.7\text{dBm} - 5.95\text{dB} = -4.25\text{dBm}$;
b) $P_{in} = 1.7\text{dBm} = 1.479\text{mW}$; $P_c = -4.25\text{dBm} = 0.376\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 1.479\text{mW} - 0.376\text{mW} = 1.103\text{mW} = 0.427\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.504$, $y_2 = 1.158$, $y_1 = 0.584$, $Z_1 = Z_0/y_1 = 85.7\ \Omega$, $Z_2 = Z_0/y_2 = 43.2\Omega$

3. a) $Z = 31.00\Omega + j\cdot(-73.09)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.320 + j\cdot(-0.614) = 0.692\angle -62.5°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.692$; $\varphi = \arg(\Gamma) = -62.5°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 98.2°$; $\mathrm{Im}(y_S) = -1.918$; $\theta_{P1} = 117.5°$ **or** $\theta_{S2} = 144.4°$; $\mathrm{Im}(y_S) = 1.918$; $\theta_{P2} = 62.5°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 500\text{MHz} = 3.142\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 55.413\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 4.850\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 72.226\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 4.850\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 55.413\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 500 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 500$ MHz; In the stopband (f > 500 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1000.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.9\text{dB} + 15.7\text{dB} + 16.8\text{dB} = 57.4\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 549{,}540.9$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.97\text{dB} = 2.495$, $G_1 = 24.9\text{dB} = 309.030$, $F_2 = 4.95\text{dB} = 3.126$, $G_2 = 15.7\text{dB} = 37.154$, $F_3 = 5.84\text{dB} = 3.837$, $G_3 = 16.8\text{dB} = 47.863$;
$F = 3.126 + (2.495-1)/37.154 + (3.837-1)/37.154/309.030 = 3.167 = 5.006\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.837 + (2.495-1)/47.863 + (3.126-1)/47.863/309.030 = 3.868 = 5.875\text{dB}$

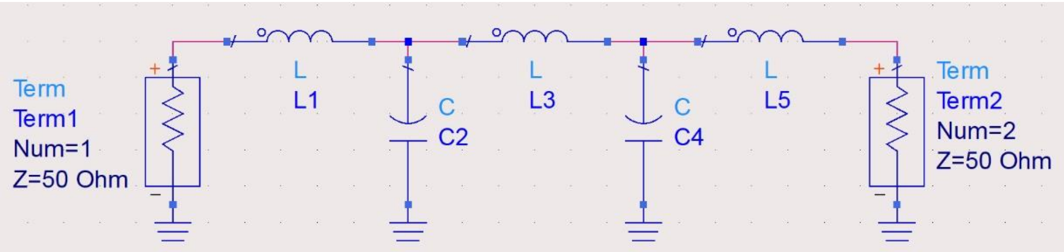
Subject no. 23

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (33.4 + j\cdot 31.0)\Omega = 0.804 + j\cdot 0.746$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.804 + j\cdot 0.746)] / (1 + 0.804 + j\cdot 0.746)$
$\Gamma = (-0.053) + j\cdot(0.392) \leftrightarrow \text{Re}\Gamma + j\cdot\text{Im}\Gamma$ or $\Gamma = 0.395\angle 97.8° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 9.8\text{dBm} - 5.35\text{dB} = 4.45\text{dBm}$;
b) $P_{in} = 9.8\text{dBm} = 9.550\text{mW}$; $P_c = 4.45\text{dBm} = 2.786\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 9.550\text{mW} - 2.786\text{mW} = 6.764\text{mW} = 8.302\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.540$, $y_2 = 1.188$, $y_1 = 0.642$, $Z_1 = Z_0/y_1 = 77.9\ \Omega$, $Z_2 = Z_0/y_2 = 42.1\Omega$

3. a) $Z = 69.00\Omega + j\cdot(31.10)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.213 + j\cdot(0.206) = 0.296\angle 43.9°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.296$; $\varphi = \arg(\Gamma) = 43.9°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 31.7°$; $\text{Im}(y_S) = -0.621$; $\theta_{P1} = 148.2°$ **or** $\theta_{S2} = 104.4°$; $\text{Im}(y_S) = 0.621$; $\theta_{P2} = 31.8°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 335\text{MHz} = 2.105\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no $\lambda/4$ transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 40.520\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 11.683\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 60.355\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 11.683\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 40.520\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 335 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation $L_{Ar} = 0.5$ dB, including at the cutoff frequency $f_1 = 335$ MHz; In the stopband (f > 335 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 670.0$ MHz the attenuation is $L_{As} = 42.039$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 19.2\text{dB} + 19.2\text{dB} + 21.3\text{dB} = 59.7\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 933{,}254.3$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.32\text{dB} = 2.148$, $G_1 = 19.2\text{dB} = 83.176$, $F_2 = 4.63\text{dB} = 2.904$, $G_2 = 19.2\text{dB} = 83.176$, $F_3 = 5.94\text{dB} = 3.926$, $G_3 = 21.3\text{dB} = 134.896$;
$F = 2.904 + (2.148-1)/83.176 + (3.926-1)/83.176/83.176 = 2.918 = 4.651\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.904 + (3.926-1)/83.176 + (2.148-1)/83.176/134.896 = 2.939 = 4.682\text{dB}$

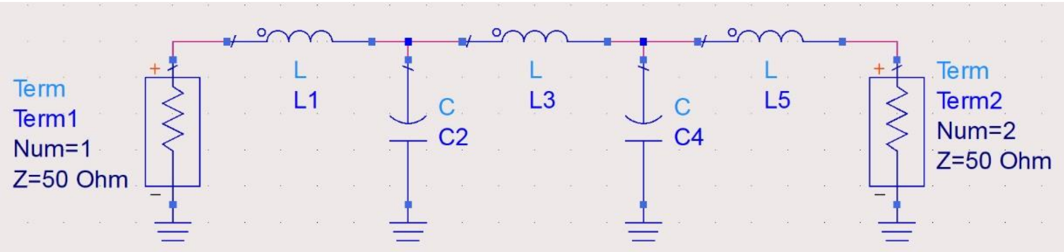
Subject no. 24

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (36.1 - j\cdot 64.3)\Omega = 0.332 - j\cdot 0.591$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.332 - j\cdot 0.591)] / (1 + 0.332 - j\cdot 0.591)$
$\Gamma = (0.254) + j\cdot(-0.557) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.612\angle -65.4° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 7.5\text{dBm} - 5.40\text{dB} = 2.10\text{dBm}$;
b) $P_{in} = 7.5\text{dBm} = 5.623\text{mW}$; $P_c = 2.10\text{dBm} = 1.622\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 5.623\text{mW} - 1.622\text{mW} = 4.002\text{mW} = 6.022\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.537$, $y_2 = 1.185$, $y_1 = 0.637$, $Z_1 = Z_0/y_1 = 78.5\ \Omega$, $Z_2 = Z_0/y_2 = 42.2\Omega$

3. a) $Z = 26.97\Omega + j\cdot(11.64)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.270 + j\cdot(0.192) = 0.331\angle 144.6°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.331$; $\varphi = \arg(\Gamma) = 144.6°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 162.4°$; $\mathrm{Im}(y_S) = -0.703$; $\theta_{P1} = 144.9°$ **or** $\theta_{S2} = 53.0°$; $\mathrm{Im}(y_S) = 0.703$; $\theta_{P2} = 35.1°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 315\text{MHz} = 1.979\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 15.612\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 16.350\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 50.525\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 16.350\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 15.612\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 315 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 315$ MHz; In the stopband (f > 315 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 630.0$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 21.3\text{dB} + 18.1\text{dB} + 22.2\text{dB} = 61.6\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}445{,}439.8$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A1, A2 so: $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$; $F_1 = 3.68\text{dB} = 2.333$, $G_1 = 21.3\text{dB} = 134.896$, $F_2 = 4.64\text{dB} = 2.911$, $G_2 = 18.1\text{dB} = 64.565$, $F_3 = 5.93\text{dB} = 3.917$, $G_3 = 22.2\text{dB} = 165.959$;
$F = 3.917 + (2.333-1)/165.959 + (2.911-1)/165.959/134.896 = 3.926 = 5.939\text{dB}$
c) If the order is A1, A3, A2 the gain remains the same but $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$;
$F = 2.333 + (3.917-1)/134.896 + (2.911-1)/134.896/165.959 = 2.355 = 3.720\text{dB}$

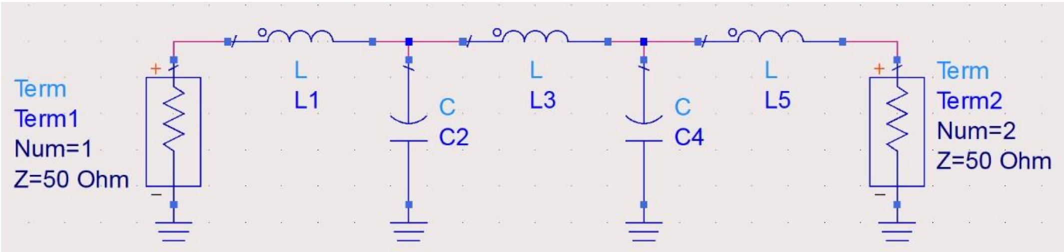
Subject no. 25

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (37.7 - j\cdot 39.9)\Omega = 0.626 - j\cdot 0.662$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.626 - j\cdot 0.662)] / (1 + 0.626 - j\cdot 0.662)$
$\Gamma = (0.055) + j\cdot(-0.430) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.433\angle -82.7° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 9.7\text{dBm} - 6.10\text{dB} = 3.60\text{dBm}$;
b) $P_{in} = 9.7\text{dBm} = 9.333\text{mW}$; $P_c = 3.60\text{dBm} = 2.291\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 9.333\text{mW} - 2.291\text{mW} = 7.042\text{mW} = 8.477\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.495$, $y_2 = 1.151$, $y_1 = 0.570$, $Z_1 = Z_0/y_1 = 87.7\ \Omega$, $Z_2 = Z_0/y_2 = 43.4\Omega$

3. a) $Z = 66.00\Omega + j\cdot(45.00)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.251 + j\cdot(0.291) = 0.384\angle 49.2°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.384$; $\varphi = \arg(\Gamma) = 49.2°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 31.7°$; $\mathrm{Im}(y_S) = -0.831$; $\theta_{P1} = 140.3°$ **or** $\theta_{S2} = 99.1°$; $\mathrm{Im}(y_S) = 0.831$; $\theta_{P2} = 39.7°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 380\text{MHz} = 2.388\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 35.722\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 10.300\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 53.208\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 10.300\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 35.722\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 380 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 380 MHz; In the stopband (f > 380 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at f_s = 760.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.7\text{dB} + 17.1\text{dB} + 20.2\text{dB} = 62.0\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}584{,}893.2$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.79\text{dB} = 2.393$, $G_1 = 24.7\text{dB} = 295.121$, $F_2 = 4.89\text{dB} = 3.083$, $G_2 = 17.1\text{dB} = 51.286$, $F_3 = 5.23\text{dB} = 3.334$, $G_3 = 20.2\text{dB} = 104.713$;
$F = 3.083 + (2.393-1)/51.286 + (3.334-1)/51.286/295.121 = 3.111 = 4.928\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.334 + (2.393-1)/104.713 + (3.083-1)/104.713/295.121 = 3.348 = 5.247\text{dB}$

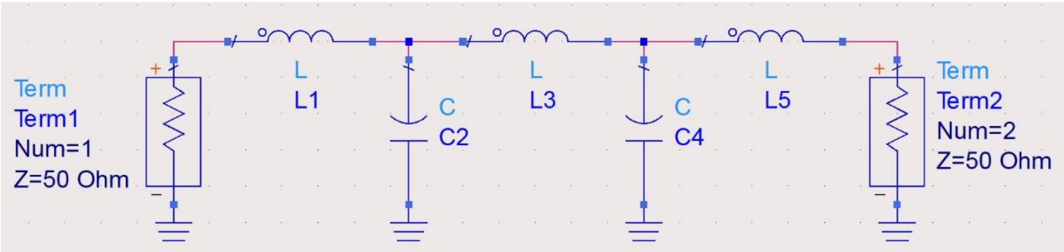
Subject no. 26

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (61.2 + j\cdot 49.5)\Omega = 0.494 + j\cdot 0.399$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.494 + j\cdot 0.399)] / (1 + 0.494 + j\cdot 0.399)$
$\Gamma = (0.249) + j\cdot(0.334) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.417\angle 53.3° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 3.3\text{dBm} - 5.55\text{dB} = -2.25\text{dBm}$;
b) $P_{in} = 3.3\text{dBm} = 2.138\text{mW}$; $P_c = -2.25\text{dBm} = 0.596\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 2.138\text{mW} - 0.596\text{mW} = 1.542\text{mW} = 1.882\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.528$, $y_2 = 1.177$, $y_1 = 0.621$, $Z_1 = Z_0/y_1 = 80.5\ \Omega$, $Z_2 = Z_0/y_2 = 42.5\Omega$

3. a) $Z = 58.00\Omega + j\cdot(-52.82)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.253 + j\cdot(-0.365) = 0.444\angle -55.3°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.444$; $\varphi = \arg(\Gamma) = -55.3°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 85.9°$; $\mathrm{Im}(y_S) = -0.992$; $\theta_{P1} = 135.2°$ **or** $\theta_{S2} = 149.5°$; $\mathrm{Im}(y_S) = 0.992$; $\theta_{P2} = 44.8°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 315\text{MHz} = 1.979\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 43.093\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 12.425\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 64.187\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 12.425\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 43.093\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 315 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation $L_{Ar} = 0.5$ dB, including at the cutoff frequency $f_1 = 315$ MHz; In the stopband (f > 315 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 630.0$ MHz the attenuation is $L_{As} = 42.039$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 20.0\text{dB} + 15.9\text{dB} + 15.4\text{dB} = 51.3\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 134{,}896.3$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.55\text{dB} = 2.265$, $G_1 = 20.0\text{dB} = 100.000$, $F_2 = 4.97\text{dB} = 3.141$, $G_2 = 15.9\text{dB} = 38.905$, $F_3 = 5.43\text{dB} = 3.491$, $G_3 = 15.4\text{dB} = 34.674$;
$F = 3.141 + (2.265-1)/38.905 + (3.491-1)/38.905/100.000 = 3.174 = 5.016\text{dB}$
c) If the order is A1, A2, A3 the gain remains the same but $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$;
$F = 2.265 + (3.141-1)/100.000 + (3.491-1)/100.000/38.905 = 2.287 = 3.592\text{dB}$

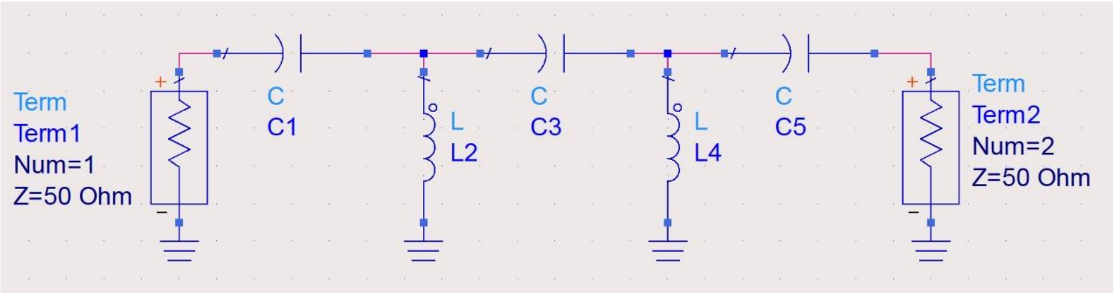
Subject no. 27

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (51.4 + j\cdot 31.3)\Omega = 0.710 + j\cdot 0.432$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.710 + j\cdot 0.432)] / (1 + 0.710 + j\cdot 0.432)$
$\Gamma = (0.100) + j\cdot(0.278) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.295\angle 70.3° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 8.0\text{dBm} - 7.70\text{dB} = 0.30\text{dBm}$;
b) $P_{in} = 8.0\text{dBm} = 6.310\text{mW}$; $P_c = 0.30\text{dBm} = 1.072\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 6.310\text{mW} - 1.072\text{mW} = 5.238\text{mW} = 7.192\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.412$, $y_2 = 1.098$, $y_1 = 0.452$, $Z_1 = Z_0/y_1 = 110.5\ \Omega$, $Z_2 = Z_0/y_2 = 45.6\Omega$

3. a) $Z = 14.39\Omega + j\cdot(26.99)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.321 + j\cdot(0.554) = 0.640\angle 120.1°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.640$; $\varphi = \arg(\Gamma) = 120.1°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 4.8°$; $\mathrm{Im}(y_S) = -1.666$; $\theta_{P1} = 121.0°$ **or** $\theta_{S2} = 55.1°$; $\mathrm{Im}(y_S) = 1.666$; $\theta_{P2} = 59.0°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 520\text{MHz} = 3.267\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 3.589\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 12.446\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 2.409\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 12.446\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 3.589\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 520 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 520 MHz; In the stopband (f < 520 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 260.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 17.8\text{dB} + 23.7\text{dB} + 20.7\text{dB} = 62.2\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}659{,}586.9$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.22\text{dB} = 2.099$, $G_1 = 17.8\text{dB} = 60.256$, $F_2 = 4.64\text{dB} = 2.911$, $G_2 = 23.7\text{dB} = 234.423$, $F_3 = 5.59\text{dB} = 3.622$, $G_3 = 20.7\text{dB} = 117.490$;
$F = 2.911 + (3.622-1)/234.423 + (2.099-1)/234.423/117.490 = 2.922 = 4.657\text{dB}$
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 2.911 + (2.099-1)/234.423 + (3.622-1)/234.423/60.256 = 2.916 = 4.647\text{dB}$

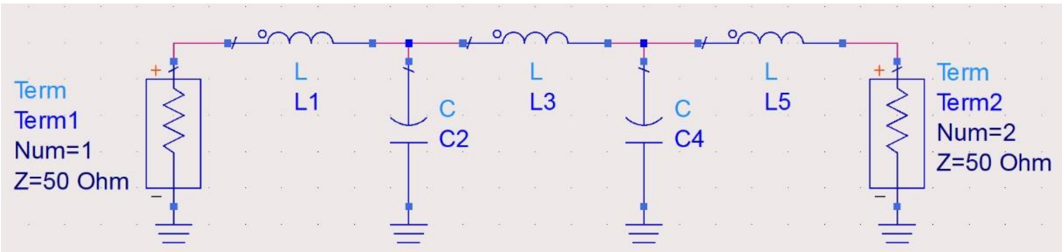
Subject no. 28

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (54.6 + j\cdot 50.8)\Omega = 0.491 + j\cdot 0.457$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.491 + j\cdot 0.457)] / (1 + 0.491 + j\cdot 0.457)$
$\Gamma = (0.226) + j\cdot(0.376) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.439\angle 58.9° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 4.8\text{dBm} - 4.85\text{dB} = -0.05\text{dBm}$;
b) $P_{in} = 4.8\text{dBm} = 3.020\text{mW}$; $P_c = -0.05\text{dBm} = 0.989\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 3.020\text{mW} - 0.989\text{mW} = 2.031\text{mW} = 3.078\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.572$, $y_2 = 1.219$, $y_1 = 0.698$, $Z_1 = Z_0/y_1 = 71.7\ \Omega$, $Z_2 = Z_0/y_2 = 41.0\Omega$

3. a) $Z = 30.00\Omega + j\cdot(64.94)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.247 + j\cdot(0.612) = 0.659\angle 68.0°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.659$; $\varphi = \arg(\Gamma) = 68.0°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 31.6°$; $\mathrm{Im}(y_S) = -1.755$; $\theta_{P1} = 119.7°$ **or** $\theta_{S2} = 80.3°$; $\mathrm{Im}(y_S) = 1.755$; $\theta_{P2} = 60.3°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 330\text{MHz} = 2.073\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 41.134\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 11.860\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 61.270\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 11.860\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 41.134\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 330 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 330 MHz; In the stopband (f > 330 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at f_s = 660.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 17.0\text{dB} + 21.9\text{dB} + 15.2\text{dB} = 54.1\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 257{,}039.6$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.95\text{dB} = 2.483$, $G_1 = 17.0\text{dB} = 50.119$, $F_2 = 4.10\text{dB} = 2.570$, $G_2 = 21.9\text{dB} = 154.882$, $F_3 = 5.64\text{dB} = 3.664$, $G_3 = 15.2\text{dB} = 33.113$;
$F = 2.483 + (2.570-1)/50.119 + (3.664-1)/50.119/154.882 = 2.515 = 4.005\text{dB}$
c) If the order is A1, A3, A2 the gain remains the same but $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$;
$F = 2.483 + (3.664-1)/50.119 + (2.570-1)/50.119/33.113 = 2.537 = 4.044\text{dB}$

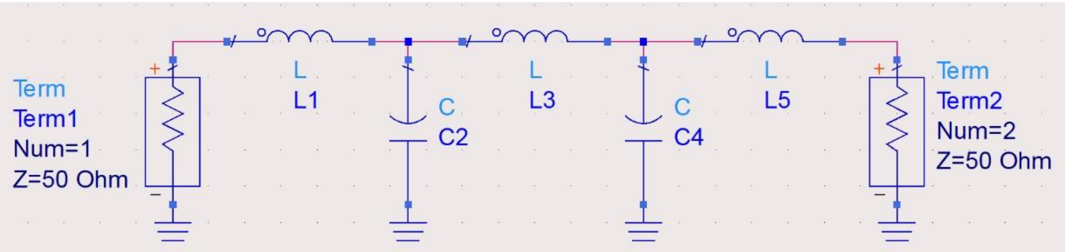
Subject no. 29

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (56.5 - j\cdot59.6)\Omega = 0.419 - j\cdot0.442$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.419 - j\cdot0.442)] / (1 + 0.419 - j\cdot0.442)$
$\Gamma = (0.285) + j\cdot(-0.400) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.491\angle{-54.5°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 5.6\text{dBm} - 6.65\text{dB} = -1.05\text{dBm}$;
b) $P_{in} = 5.6\text{dBm} = 3.631\text{mW}$; $P_c = -1.05\text{dBm} = 0.785\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 3.631\text{mW} - 0.785\text{mW} = 2.846\text{mW} = 4.542\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.465$, $y_2 = 1.130$, $y_1 = 0.525$, $Z_1 = Z_0/y_1 = 95.2\ \Omega$, $Z_2 = Z_0/y_2 = 44.3\Omega$

3. a) $Z = 24.52\Omega + j\cdot(12.60)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.305+ j\cdot(0.221) = 0.376\angle144.1°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.376$; $\varphi = \arg(\Gamma) = 144.1°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 164.0°$; $\mathrm{Im}(y_S) = -0.812$; $\theta_{P1} = 140.9°$ **or** $\theta_{S2} = 51.9°$; $\mathrm{Im}(y_S) = 0.812$; $\theta_{P2} = 39.1°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot560\text{MHz} = 3.519\cdot10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 =3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 49.476\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 4.330\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 64.488\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 4.330\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 49.476\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 560 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 560$ MHz; In the stopband (f > 560 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1120.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 17.0\text{dB} + 18.6\text{dB} + 15.7\text{dB} = 51.3\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 134{,}896.3$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.10\text{dB} = 2.042$, $G_1 = 17.0\text{dB} = 50.119$, $F_2 = 4.83\text{dB} = 3.041$, $G_2 = 18.6\text{dB} = 72.444$, $F_3 = 5.24\text{dB} = 3.342$, $G_3 = 15.7\text{dB} = 37.154$;
$F = 2.042 + (3.041-1)/50.119 + (3.342-1)/50.119/72.444 = 2.083 = 3.187\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.342 + (2.042-1)/37.154 + (3.041-1)/37.154/50.119 = 3.371 = 5.278\text{dB}$

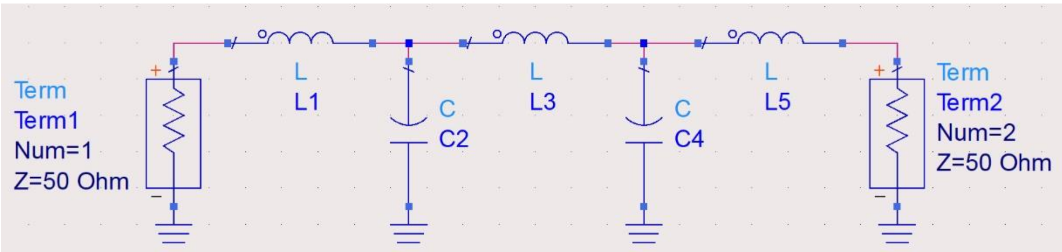
Subject no. 30

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (60.9 + j\cdot 63.7)\Omega = 0.392 + j\cdot 0.410$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.392 + j\cdot 0.410)] / (1 + 0.392 + j\cdot 0.410)$
$\Gamma = (0.322) + j\cdot(0.389) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.505\angle 50.4° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 6.4\text{dBm} - 4.70\text{dB} = 1.70\text{dBm}$;
b) $P_{in} = 6.4\text{dBm} = 4.365\text{mW}$; $P_c = 1.70\text{dBm} = 1.479\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 4.365\text{mW} - 1.479\text{mW} = 2.886\text{mW} = 4.603\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.582$, $y_2 = 1.230$, $y_1 = 0.716$, $Z_1 = Z_0/y_1 = 69.8\ \Omega$, $Z_2 = Z_0/y_2 = 40.7\Omega$

3. a) $Z = 11.14\Omega + j\cdot(23.57)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.424 + j\cdot(0.549) = 0.694\angle 127.7°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.694$; $\varphi = \arg(\Gamma) = 127.7°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 3.1°$; $\mathrm{Im}(y_S) = -1.926$; $\theta_{P1} = 117.4°$ **or** $\theta_{S2} = 49.2°$; $\mathrm{Im}(y_S) = 1.926$; $\theta_{P2} = 62.6°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 590\text{MHz} = 3.707\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no $\lambda/4$ transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 23.007\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 6.634\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 34.270\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 6.634\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 23.007\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 590 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation $L_{Ar} = 0.5$ dB, including at the cutoff frequency $f_1 = 590$ MHz; In the stopband (f > 590 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1180.0$ MHz the attenuation is $L_{As} = 42.039$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 20.9\text{dB} + 23.8\text{dB} + 19.7\text{dB} = 64.4\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 2{,}754{,}228.7$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.90\text{dB} = 2.455$, $G_1 = 20.9\text{dB} = 123.027$, $F_2 = 4.84\text{dB} = 3.048$, $G_2 = 23.8\text{dB} = 239.883$, $F_3 = 5.16\text{dB} = 3.281$, $G_3 = 19.7\text{dB} = 93.325$;
$F = 2.455 + (3.281-1)/123.027 + (3.048-1)/123.027/93.325 = 2.473 = 3.933\text{dB}$
c) If the order is A3, A2, A1 the gain remains the same but $F = F_3 + (F_2-1)/G_3 + (F_1-1)/G_3/G_2$;
$F = 3.281 + (3.048-1)/93.325 + (2.455-1)/93.325/239.883 = 3.303 = 5.189\text{dB}$

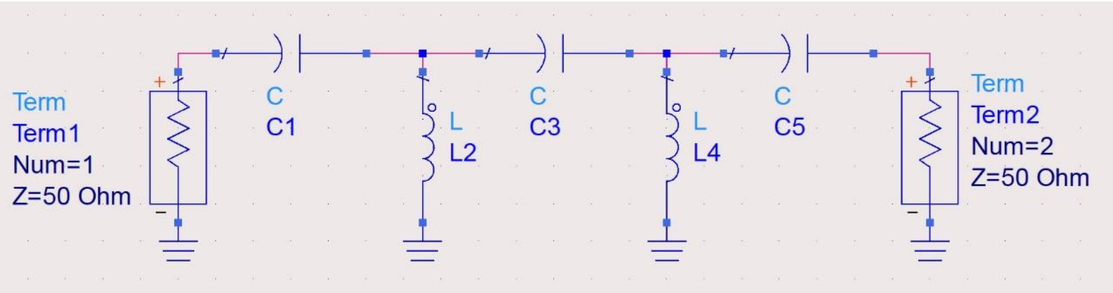
Subject no. 31

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (36.1 + j\cdot 63.8)\Omega = 0.336 + j\cdot 0.594$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.336 + j\cdot 0.594)] / (1 + 0.336 + j\cdot 0.594)$
$\Gamma = (0.250) + j\cdot(0.556) \leftrightarrow Re\Gamma + j\cdot Im\Gamma$ or $\Gamma = 0.609\angle 65.8° \leftrightarrow |\Gamma|\angle arg(\Gamma)$

2. a) $P_c = P_{in} - C = 7.9dBm - 7.25dB = 0.65dBm$;
b) $P_{in} = 7.9dBm = 6.166mW$; $P_c = 0.65dBm = 1.161mW$;
Lossless coupler $P_{th} = P_{in} - P_c = 6.166mW - 1.161mW = 5.005mW = 6.994dBm$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.434$, $y_2 = 1.110$, $y_1 = 0.482$, $Z_1 = Z_0/y_1 = 103.8\ \Omega$, $Z_2 = Z_0/y_2 = 45.0\Omega$

3. a) $Z = 62.00\Omega + j\cdot(67.54)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.345 + j\cdot(0.395) = 0.525\angle 48.8°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.525$; $\varphi = arg(\Gamma) = 48.8°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 36.4°$; $Im(y_S) = -1.232$; $\theta_{P1} = 129.1°$ **or** $\theta_{S2} = 94.8°$; $Im(y_S) = 1.232$; $\theta_{P2} = 50.9°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 380MHz = 2.388\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 4.911pF$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 17.031nH$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.297pF$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 17.031nH$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 4.911pF$;
b) Draw the schematic:



c) In the passband (f > 380 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 380 MHz; In the stopband (f < 380 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 190.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[dB] = G_1 + G_2 + G_3 = 18.4dB + 20.1dB + 16.6dB = 55.1dB$; $G[lin] = 10^{G[dB]/10} = 323,593.7$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A2, A1 so: $F = F_3 + (F_2-1)/G_3 + (F_1-1)/G_3/G_2$; $F_1 = 3.42dB = 2.198$, $G_1 = 18.4dB = 69.183$, $F_2 = 4.10dB = 2.570$, $G_2 = 20.1dB = 102.329$, $F_3 = 5.53dB = 3.573$, $G_3 = 16.6dB = 45.709$;
$F = 3.573 + (2.570-1)/45.709 + (2.198-1)/45.709/102.329 = 3.607 = 5.572dB$
c) If the order is A1, A2, A3 the gain remains the same but $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$;
$F = 2.198 + (2.570-1)/69.183 + (3.573-1)/69.183/102.329 = 2.221 = 3.465dB$

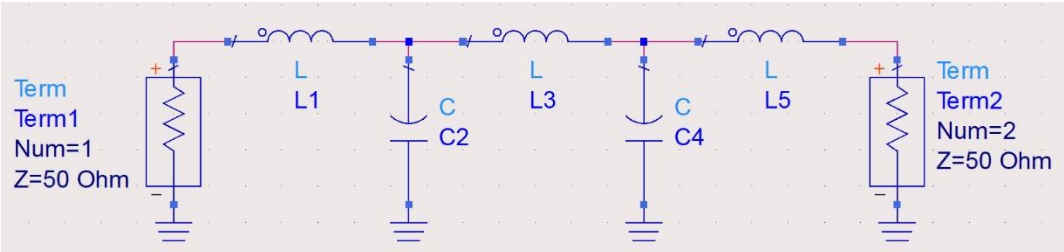
Subject no. 32

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (45.1 - j\cdot 60.5)\Omega = 0.396 - j\cdot 0.531$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.396 - j\cdot 0.531)] / (1 + 0.396 - j\cdot 0.531)$
$\Gamma = (0.251) + j\cdot(-0.476) \leftrightarrow \text{Re}\Gamma + j\cdot\text{Im}\Gamma$ or $\Gamma = 0.539\angle -62.2° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 8.6\text{dBm} - 7.15\text{dB} = 1.45\text{dBm}$;
b) $P_{in} = 8.6\text{dBm} = 7.244\text{mW}$; $P_c = 1.45\text{dBm} = 1.396\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 7.244\text{mW} - 1.396\text{mW} = 5.848\text{mW} = 7.670\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.439$, $y_2 = 1.113$, $y_1 = 0.489$, $Z_1 = Z_0/y_1 = 102.3\ \Omega$, $Z_2 = Z_0/y_2 = 44.9\Omega$

3. a) $Z = 23.88\Omega + j\cdot(-23.50)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.229 + j\cdot(-0.391) = 0.453\angle -120.4°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.453$; $\varphi = \arg(\Gamma) = -120.4°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 118.7°$; $\text{Im}(y_S) = -1.017$; $\theta_{P1} = 134.5°$ **or** $\theta_{S2} = 1.7°$; $\text{Im}(y_S) = 1.017$; $\theta_{P2} = 45.5°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 320\text{MHz} = 2.011\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 42.420\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 12.231\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 63.185\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 12.231\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 42.420\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 320 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation $L_{Ar} = 0.5$ dB, including at the cutoff frequency $f_1 = 320$ MHz; In the stopband (f > 320 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 640.0$ MHz the attenuation is $L_{As} = 42.039$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 18.9\text{dB} + 19.7\text{dB} + 15.2\text{dB} = 53.8\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 239{,}883.3$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.81\text{dB} = 2.404$, $G_1 = 18.9\text{dB} = 77.625$, $F_2 = 4.09\text{dB} = 2.564$, $G_2 = 19.7\text{dB} = 93.325$, $F_3 = 5.40\text{dB} = 3.467$, $G_3 = 15.2\text{dB} = 33.113$;
$F = 2.404 + (2.564-1)/77.625 + (3.467-1)/77.625/93.325 = 2.425 = 3.847\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.564 + (3.467-1)/93.325 + (2.404-1)/93.325/33.113 = 2.591 = 4.135\text{dB}$

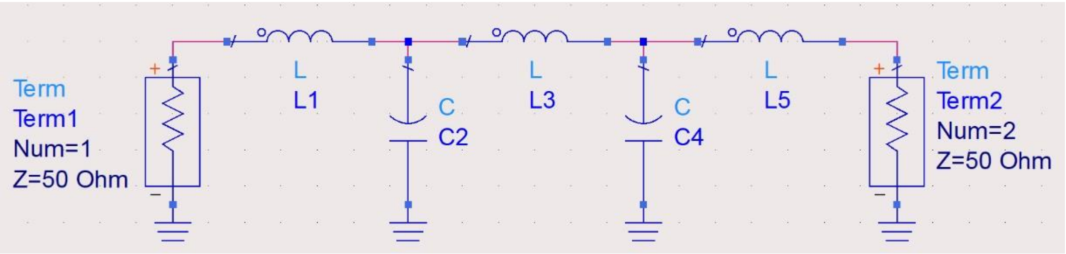
Subject no. 33

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (52.8 - j\cdot 49.4)\Omega = 0.505 - j\cdot 0.472$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.505 - j\cdot 0.472)] / (1 + 0.505 - j\cdot 0.472)$
$\Gamma = (0.210) + j\cdot(-0.380) \leftrightarrow \text{Re}\Gamma + j\cdot \text{Im}\Gamma$ or $\Gamma = 0.434\angle{-61.1°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 3.0\text{dBm} - 5.90\text{dB} = -2.90\text{dBm}$;
b) $P_{in} = 3.0\text{dBm} = 1.995\text{mW}$; $P_c = -2.90\text{dBm} = 0.513\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 1.995\text{mW} - 0.513\text{mW} = 1.482\text{mW} = 1.710\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.507$, $y_2 = 1.160$, $y_1 = 0.588$, $Z_1 = Z_0/y_1 = 85.0\ \Omega$, $Z_2 = Z_0/y_2 = 43.1\Omega$

3. a) $Z = 13.72\Omega + j\cdot(18.62)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.446 + j\cdot(0.423) = 0.614\angle 136.5°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.614$; $\varphi = \arg(\Gamma) = 136.5°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 175.7°$; $\text{Im}(y_S) = -1.557$; $\theta_{P1} = 122.7°$ **or** $\theta_{S2} = 47.8°$; $\text{Im}(y_S) = 1.557$; $\theta_{P2} = 57.3°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 330\text{MHz} = 2.073\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no $\lambda/4$ transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 41.134\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 11.860\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 61.270\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 11.860\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 41.134\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 330 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation $L_{Ar} = 0.5$ dB, including at the cutoff frequency $f_1 = 330$ MHz; In the stopband (f > 330 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 660.0$ MHz the attenuation is $L_{As} = 42.039$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 21.6\text{dB} + 22.1\text{dB} + 21.2\text{dB} = 64.9\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 3{,}090{,}295.4$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.80\text{dB} = 2.399$, $G_1 = 21.6\text{dB} = 144.544$, $F_2 = 4.99\text{dB} = 3.155$, $G_2 = 22.1\text{dB} = 162.181$, $F_3 = 5.59\text{dB} = 3.622$, $G_3 = 21.2\text{dB} = 131.826$;
$F = 2.399 + (3.155-1)/144.544 + (3.622-1)/144.544/162.181 = 2.414 = 3.827\text{dB}$
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 3.155 + (2.399-1)/162.181 + (3.622-1)/162.181/144.544 = 3.164 = 5.002\text{dB}$

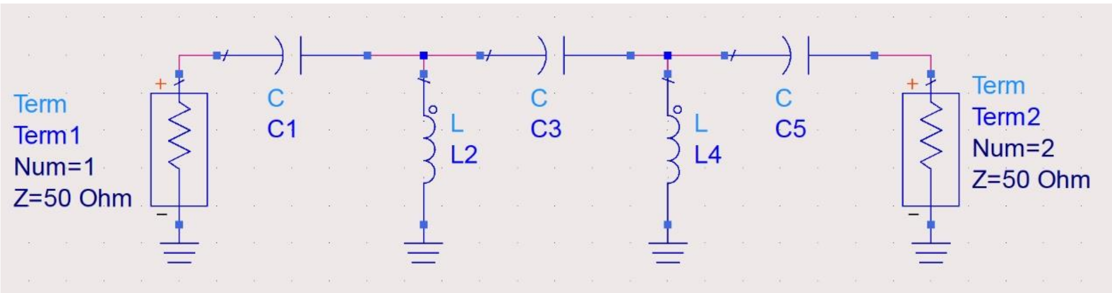
Subject no. 34

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (43.2 + j\cdot 62.3)\Omega = 0.376 + j\cdot 0.542$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.376 + j\cdot 0.542)] / (1 + 0.376 + j\cdot 0.542\ )$
$\Gamma = (0.258) + j\cdot(0.496) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.559\angle 62.5° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 5.8\text{dBm} - 8.45\text{dB} = -2.65\text{dBm}$;
b) $P_{in} = 5.8\text{dBm} = 3.802\text{mW}$; $P_c = -2.65\text{dBm} = 0.543\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 3.802\text{mW} - 0.543\text{mW} = 3.259\text{mW} = 5.130\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.378$, $y_2 = 1.080$, $y_1 = 0.408$, $Z_1 = Z_0/y_1 = 122.5\ \Omega$, $Z_2 = Z_0/y_2 = 46.3\Omega$

3. a) $Z = 31.00\Omega + j\cdot(-70.12)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.294 + j\cdot(-0.611) = 0.678\angle{-64.3°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.678$; $\varphi = \arg(\Gamma) = -64.3°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 98.5°$; $\mathrm{Im}(y_S) = -1.845$; $\theta_{P1} = 118.5°$ **or** $\theta_{S2} = 145.8°$; $\mathrm{Im}(y_S) = 1.845$; $\theta_{P2} = 61.5°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 505\text{MHz} = 3.173\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 1.810\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 20.685\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 1.389\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 20.685\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 1.810\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 505 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 505$ MHz; In the stopband (f < 505 MHz) the attenuation for 5^{th} order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 252.5$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.5\text{dB} + 24.4\text{dB} + 20.2\text{dB} = 69.1\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 8{,}128{,}305.2$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A1, A2 so: $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$; $F_1 = 3.09\text{dB} = 2.037$, $G_1 = 24.5\text{dB} = 281.838$, $F_2 = 4.11\text{dB} = 2.576$, $G_2 = 24.4\text{dB} = 275.423$, $F_3 = 5.47\text{dB} = 3.524$, $G_3 = 20.2\text{dB} = 104.713$;
$F = 3.524 + (2.037-1)/104.713 + (2.576-1)/104.713/281.838 = 3.534 = 5.482\text{dB}$
c) If the order is A1, A3, A2 the gain remains the same but $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$;
$F = 2.037 + (3.524-1)/281.838 + (2.576-1)/281.838/104.713 = 2.046 = 3.109\text{dB}$

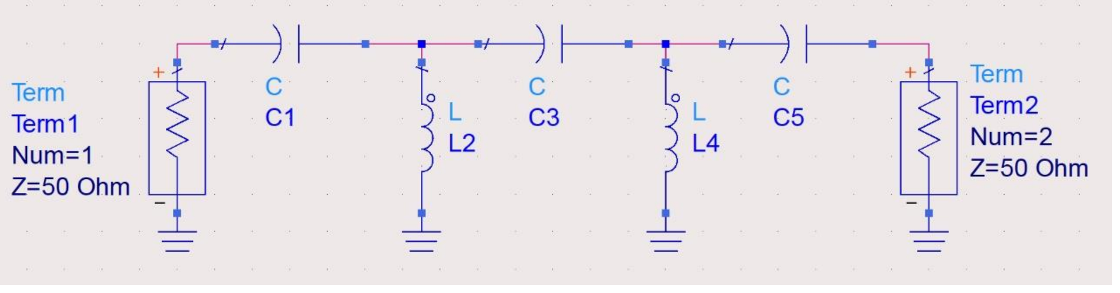
Subject no. 35

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (36.0 - j\cdot 36.8)\Omega = 0.679 - j\cdot 0.694$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.679 - j\cdot 0.694)] / (1 + 0.679 - j\cdot 0.694)$
$\Gamma = (0.017) + j\cdot(-0.421) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.421\angle -87.7° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 4.7\text{dBm} - 7.05\text{dB} = -2.35\text{dBm}$;
b) $P_{in} = 4.7\text{dBm} = 2.951\text{mW}$; $P_c = -2.35\text{dBm} = 0.582\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 2.951\text{mW} - 0.582\text{mW} = 2.369\text{mW} = 3.746\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.444$, $y_2 = 1.116$, $y_1 = 0.496$, $Z_1 = Z_0/y_1 = 100.9\ \Omega$, $Z_2 = Z_0/y_2 = 44.8\Omega$

3. a) $Z = 34.03\Omega + j\cdot(29.73)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.058 + j\cdot(0.374) = 0.379\angle 98.8°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.379$; $\varphi = \arg(\Gamma) = 98.8°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 6.7°$; $\mathrm{Im}(y_S) = -0.818$; $\theta_{P1} = 140.7°$ **or** $\theta_{S2} = 74.5°$; $\mathrm{Im}(y_S) = 0.818$; $\theta_{P2} = 39.3°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 475\text{MHz} = 2.985\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 10.843\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 10.354\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.351\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 10.354\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 10.843\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 475 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 475$ MHz; In the stopband (f < 475 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 237.5$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.4\text{dB} + 22.1\text{dB} + 21.3\text{dB} = 67.8\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 6{,}025{,}595.9$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A2, A1 so: $F = F_3 + (F_2-1)/G_3 + (F_1-1)/G_3/G_2$; $F_1 = 3.44\text{dB} = 2.208$, $G_1 = 24.4\text{dB} = 275.423$, $F_2 = 4.12\text{dB} = 2.582$, $G_2 = 22.1\text{dB} = 162.181$, $F_3 = 5.50\text{dB} = 3.548$, $G_3 = 21.3\text{dB} = 134.896$;
$F = 3.548 + (2.582-1)/134.896 + (2.208-1)/134.896/162.181 = 3.560 = 5.514\text{dB}$
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 2.582 + (2.208-1)/162.181 + (3.548-1)/162.181/275.423 = 2.590 = 4.133\text{dB}$

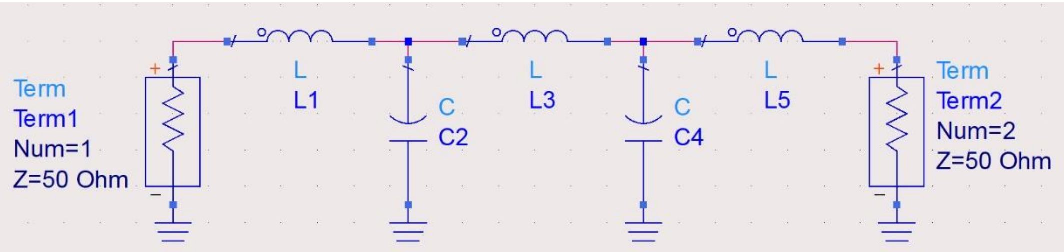
Subject no. 36

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (61.2 - j\cdot 51.4)\Omega = 0.479 - j\cdot 0.402$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.479 - j\cdot 0.402)] / (1 + 0.479 - j\cdot 0.402)$
$\Gamma = (0.259) + j\cdot(-0.342) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.429\angle -52.9° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 6.5\text{dBm} - 7.75\text{dB} = -1.25\text{dBm}$;
b) $P_{in} = 6.5\text{dBm} = 4.467\text{mW}$; $P_c = -1.25\text{dBm} = 0.750\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 4.467\text{mW} - 0.750\text{mW} = 3.717\text{mW} = 5.702\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.410$, $y_2 = 1.096$, $y_1 = 0.449$, $Z_1 = Z_0/y_1 = 111.3\ \Omega$, $Z_2 = Z_0/y_2 = 45.6\Omega$

3. a) $Z = 44.00\Omega + j\cdot(64.14)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.274 + j\cdot(0.495) = 0.566\angle 61.0°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.566$; $\varphi = \arg(\Gamma) = 61.0°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 31.7°$; $\mathrm{Im}(y_S) = -1.373$; $\theta_{P1} = 126.1°$ **or** $\theta_{S2} = 87.2°$; $\mathrm{Im}(y_S) = 1.373$; $\theta_{P2} = 53.9°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 370\text{MHz} = 2.325\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 74.882\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 6.554\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 97.603\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 6.554\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 74.882\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 370 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 370$ MHz; In the stopband (f > 370 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 740.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 16.6\text{dB} + 20.3\text{dB} + 16.4\text{dB} = 53.3\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 213{,}796.2$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.38\text{dB} = 2.178$, $G_1 = 16.6\text{dB} = 45.709$, $F_2 = 4.60\text{dB} = 2.884$, $G_2 = 20.3\text{dB} = 107.152$, $F_3 = 5.10\text{dB} = 3.236$, $G_3 = 16.4\text{dB} = 43.652$;
$F = 2.178 + (3.236-1)/45.709 + (2.884-1)/45.709/43.652 = 2.228 = 3.478\text{dB}$
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 2.884 + (2.178-1)/107.152 + (3.236-1)/107.152/45.709 = 2.895 = 4.617\text{dB}$

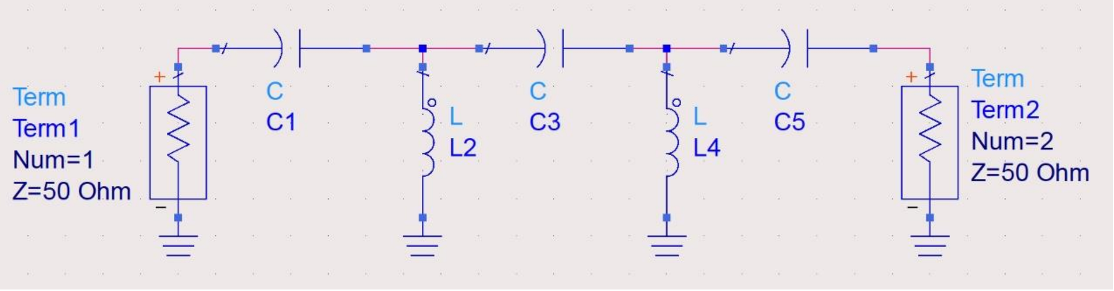
Subject no. 37

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (34.8 - j\cdot 50.8)\Omega = 0.459 - j\cdot 0.670$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.459 - j\cdot 0.670)] / (1 + 0.459 - j\cdot 0.670)$
$\Gamma = (0.132) + j\cdot(-0.520) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.536\angle -75.7° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 9.4\text{dBm} - 7.55\text{dB} = 1.85\text{dBm}$;
b) $P_{in} = 9.4\text{dBm} = 8.710\text{mW}$; $P_c = 1.85\text{dBm} = 1.531\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 8.710\text{mW} - 1.531\text{mW} = 7.179\text{mW} = 8.560\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.419$, $y_2 = 1.101$, $y_1 = 0.462$, $Z_1 = Z_0/y_1 = 108.3\ \Omega$, $Z_2 = Z_0/y_2 = 45.4\Omega$

3. a) $Z = 61.00\Omega + j\cdot(-49.24)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.247 + j\cdot(-0.334) = 0.415\angle -53.5°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.415$; $\varphi = \arg(\Gamma) = -53.5°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 84.0°$; $\mathrm{Im}(y_S) = -0.913$; $\theta_{P1} = 137.6°$ **or** $\theta_{S2} = 149.5°$; $\mathrm{Im}(y_S) = 0.913$; $\theta_{P2} = 42.4°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 460\text{MHz} = 2.890\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 1.987\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 22.709\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 1.525\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 22.709\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 1.987\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 460 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 460$ MHz; In the stopband (f < 460 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 230.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.0\text{dB} + 20.4\text{dB} + 18.4\text{dB} = 62.8\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}905{,}460.7$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A2, A1 so: $F = F_3 + (F_2-1)/G_3 + (F_1-1)/G_3/G_2$; $F_1 = 3.08\text{dB} = 2.032$, $G_1 = 24.0\text{dB} = 251.189$, $F_2 = 4.28\text{dB} = 2.679$, $G_2 = 20.4\text{dB} = 109.648$, $F_3 = 5.26\text{dB} = 3.357$, $G_3 = 18.4\text{dB} = 69.183$;
$F = 3.357 + (2.679-1)/69.183 + (2.032-1)/69.183/109.648 = 3.382 = 5.291\text{dB}$
c) If the order is A1, A3, A2 the gain remains the same but $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$;
$F = 2.032 + (3.357-1)/251.189 + (2.679-1)/251.189/69.183 = 2.042 = 3.100\text{dB}$

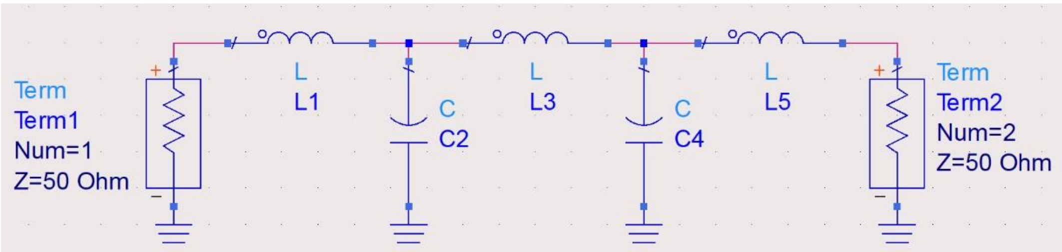
Subject no. 38

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (68.8 - j\cdot 48.6)\Omega = 0.485 - j\cdot 0.342$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.485 - j\cdot 0.342)] / (1 + 0.485 - j\cdot 0.342)$
$\Gamma = (0.279) + j\cdot(-0.295) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.406\angle -46.6° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 9.0\text{dBm} - 7.60\text{dB} = 1.40\text{dBm}$;
b) $P_{in} = 9.0\text{dBm} = 7.943\text{mW}$; $P_c = 1.40\text{dBm} = 1.380\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 7.943\text{mW} - 1.380\text{mW} = 6.563\text{mW} = 8.171\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.417$, $y_2 = 1.100$, $y_1 = 0.459$, $Z_1 = Z_0/y_1 = 109.0\ \Omega$, $Z_2 = Z_0/y_2 = 45.4\Omega$

3. a) $Z = 22.59\Omega + j\cdot(-8.77)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.358 + j\cdot(-0.164) = 0.394\angle -155.4°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.394$; $\varphi = \arg(\Gamma) = -155.4°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 134.3°$; $\mathrm{Im}(y_S) = -0.856$; $\theta_{P1} = 139.4°$ **or** $\theta_{S2} = 21.1°$; $\mathrm{Im}(y_S) = 0.856$; $\theta_{P2} = 40.6°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 515\text{MHz} = 3.236\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 53.799\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 4.709\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 70.122\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 4.709\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 53.799\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 515 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 515$ MHz; In the stopband (f > 515 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1030.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 17.3\text{dB} + 19.4\text{dB} + 19.0\text{dB} = 55.7\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 371{,}535.2$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A1, A2 so: $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$; $F_1 = 3.77\text{dB} = 2.382$, $G_1 = 17.3\text{dB} = 53.703$, $F_2 = 4.78\text{dB} = 3.006$, $G_2 = 19.4\text{dB} = 87.096$, $F_3 = 5.56\text{dB} = 3.597$, $G_3 = 19.0\text{dB} = 79.433$;
$F = 3.597 + (2.382-1)/79.433 + (3.006-1)/79.433/53.703 = 3.615 = 5.582\text{dB}$
c) If the order is A1, A2, A3 the gain remains the same but $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$;
$F = 2.382 + (3.006-1)/53.703 + (3.597-1)/53.703/87.096 = 2.420 = 3.839\text{dB}$

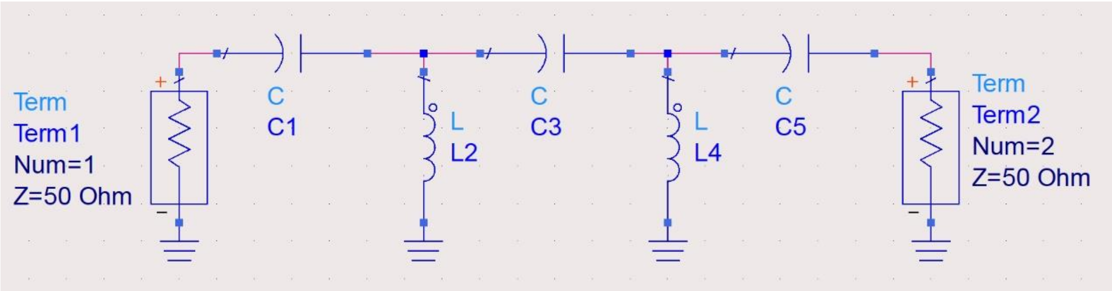
Subject no. 39

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (46.1 - j\cdot 32.3)\Omega = 0.727 - j\cdot 0.510$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.727 - j\cdot 0.510)] / (1 + 0.727 - j\cdot 0.510\ )$
$\Gamma = (0.065) + j\cdot(-0.314) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.321\angle\text{-}78.3° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 8.0\text{dBm} - 6.55\text{dB} = 1.45\text{dBm}$;
b) $P_{in} = 8.0\text{dBm} = 6.310\text{mW}$; $P_c = 1.45\text{dBm} = 1.396\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 6.310\text{mW} - 1.396\text{mW} = 4.913\text{mW} = 6.914\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.470$, $y_2 = 1.133$, $y_1 = 0.533$, $Z_1 = Z_0/y_1 = 93.8\ \Omega$, $Z_2 = Z_0/y_2 = 44.1\Omega$

3. a) $Z = 27.00\Omega + j\cdot(-72.42)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.311 + j\cdot(-0.648) = 0.719\angle\text{-}64.4°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.719$; $\varphi = \arg(\Gamma) = -64.4°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 100.2°$; $\mathrm{Im}(y_S) = -2.068$; $\theta_{P1} = 115.8°$ **or** $\theta_{S2} = 144.2°$; $\mathrm{Im}(y_S) = 2.068$; $\theta_{P2} = 64.2°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 370\text{MHz} = 2.325\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no $\lambda/4$ transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 5.043\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 17.491\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.386\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 17.491\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 5.043\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 370 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 370 MHz; In the stopband (f < 370 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 185.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 21.0\text{dB} + 19.1\text{dB} + 19.0\text{dB} = 59.1\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 812{,}830.5$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.70\text{dB} = 2.344$, $G_1 = 21.0\text{dB} = 125.893$, $F_2 = 4.55\text{dB} = 2.851$, $G_2 = 19.1\text{dB} = 81.283$, $F_3 = 5.51\text{dB} = 3.556$, $G_3 = 19.0\text{dB} = 79.433$;
$F = 2.851 + (3.556-1)/81.283 + (2.344-1)/81.283/79.433 = 2.883 = 4.598\text{dB}$
c) If the order is A3, A2, A1 the gain remains the same but $F = F_3 + (F_2-1)/G_3 + (F_1-1)/G_3/G_2$;
$F = 3.556 + (2.851-1)/79.433 + (2.344-1)/79.433/81.283 = 3.580 = 5.539\text{dB}$

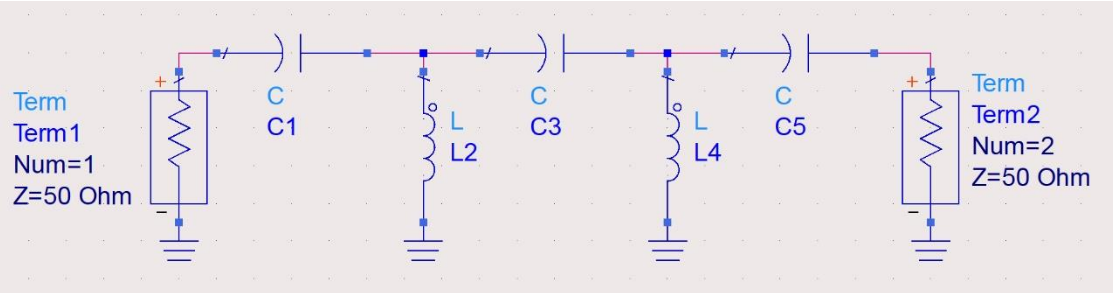
Subject no. 40

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (64.9 + j\cdot 54.7)\Omega = 0.450 + j\cdot 0.380$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.450 + j\cdot 0.380)] / (1 + 0.450 + j\cdot 0.380\ )$
$\Gamma = (0.290) + j\cdot(0.338) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.446\angle 49.3° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 3.9\text{dBm} - 5.35\text{dB} = -1.45\text{dBm}$;
b) $P_{in} = 3.9\text{dBm} = 2.455\text{mW}$; $P_c = -1.45\text{dBm} = 0.716\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 2.455\text{mW} - 0.716\text{mW} = 1.739\text{mW} = 2.402\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.540$, $y_2 = 1.188$, $y_1 = 0.642$, $Z_1 = Z_0/y_1 = 77.9\ \Omega$, $Z_2 = Z_0/y_2 = 42.1\Omega$

3. a) $Z = 19.11\Omega + j\cdot(-18.49)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.350 + j\cdot(-0.361) = 0.503\angle -134.1°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.503$; $\varphi = \arg(\Gamma) = -134.1°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 127.2°$; $\mathrm{Im}(y_S) = -1.165$; $\theta_{P1} = 130.6°$ **or** $\theta_{S2} = 7.0°$; $\mathrm{Im}(y_S) = 1.165$; $\theta_{P2} = 49.4°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 540\text{MHz} = 3.393\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 3.456\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 11.985\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 2.320\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 11.985\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 3.456\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 540 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 540 MHz; In the stopband (f < 540 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 270.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 22.4\text{dB} + 16.4\text{dB} + 19.9\text{dB} = 58.7\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 741{,}310.2$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.18\text{dB} = 2.080$, $G_1 = 22.4\text{dB} = 173.780$, $F_2 = 4.47\text{dB} = 2.799$, $G_2 = 16.4\text{dB} = 43.652$, $F_3 = 5.09\text{dB} = 3.228$, $G_3 = 19.9\text{dB} = 97.724$;
$F = 2.080 + (3.228-1)/173.780 + (2.799-1)/173.780/97.724 = 2.093 = 3.207\text{dB}$
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 2.799 + (2.080-1)/43.652 + (3.228-1)/43.652/173.780 = 2.824 = 4.509\text{dB}$

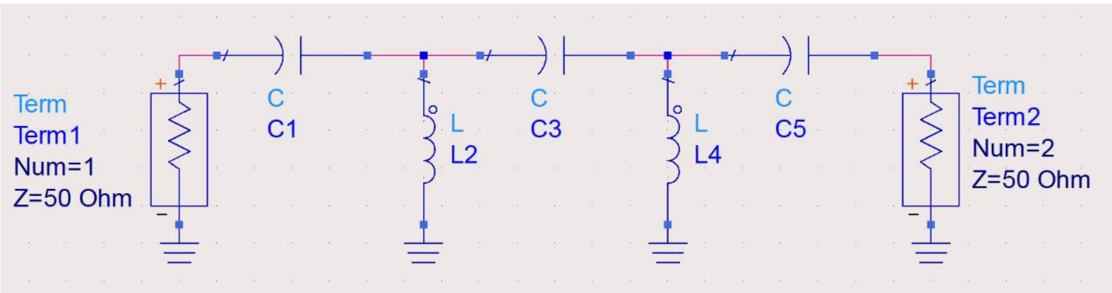
Subject no. 41

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (50.1 + j\cdot 64.9)\Omega = 0.373 + j\cdot 0.483$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.373 + j\cdot 0.483)] / (1 + 0.373 + j\cdot 0.483)$
$\Gamma = (0.297) + j\cdot(0.456) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.544\angle 57.0° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 7.1\text{dBm} - 7.55\text{dB} = -0.45\text{dBm}$;
b) $P_{in} = 7.1\text{dBm} = 5.129\text{mW}$; $P_c = -0.45\text{dBm} = 0.902\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 5.129\text{mW} - 0.902\text{mW} = 4.227\text{mW} = 6.260\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.419$, $y_2 = 1.101$, $y_1 = 0.462$, $Z_1 = Z_0/y_1 = 108.3\ \Omega$, $Z_2 = Z_0/y_2 = 45.4\Omega$

3. a) $Z = 56.00\Omega + j\cdot(-71.41)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.351 + j\cdot(-0.437) = 0.561\angle -51.2°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.561$; $\varphi = \arg(\Gamma) = -51.2°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 87.7°$; $\mathrm{Im}(y_S) = -1.354$; $\theta_{P1} = 126.4°$ **or** $\theta_{S2} = 143.6°$; $\mathrm{Im}(y_S) = 1.354$; $\theta_{P2} = 53.6°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 495\text{MHz} = 3.110\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 10.405\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 9.936\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.215\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 9.936\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 10.405\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 495 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 495$ MHz; In the stopband (f < 495 MHz) the attenuation for 5^{th} order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 247.5$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 15.9\text{dB} + 18.3\text{dB} + 15.1\text{dB} = 49.3\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 85{,}113.8$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.86\text{dB} = 2.432$, $G_1 = 15.9\text{dB} = 38.905$, $F_2 = 4.59\text{dB} = 2.877$, $G_2 = 18.3\text{dB} = 67.608$, $F_3 = 5.52\text{dB} = 3.565$, $G_3 = 15.1\text{dB} = 32.359$;
$F = 2.877 + (3.565-1)/67.608 + (2.432-1)/67.608/32.359 = 2.916 = 4.648\text{dB}$
c) If the order is A3, A2, A1 the gain remains the same but $F = F_3 + (F_2-1)/G_3 + (F_1-1)/G_3/G_2$;
$F = 3.565 + (2.877-1)/32.359 + (2.432-1)/32.359/67.608 = 3.623 = 5.591\text{dB}$

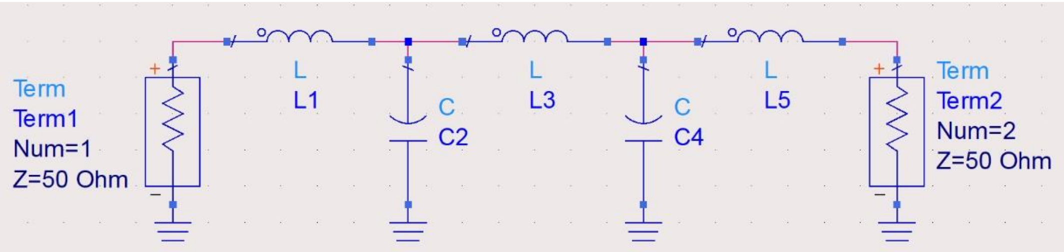
Subject no. 42

1. $y = Y/Y_0 = Z_0/Z = 50\Omega\ /\ (32.3 + j\cdot 68.4)\Omega = 0.282 + j\cdot 0.598$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.282 + j\cdot 0.598)] / (1 + 0.282 + j\cdot 0.598)$
$\Gamma = (0.281) + j\cdot(0.597) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.660\angle 64.8° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 1.1\text{dBm} - 7.85\text{dB} = -6.75\text{dBm}$;
b) $P_{in} = 1.1\text{dBm} = 1.288\text{mW}$; $P_c = -6.75\text{dBm} = 0.211\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 1.288\text{mW} - 0.211\text{mW} = 1.077\text{mW} = 0.322\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.405$, $y_2 = 1.094$, $y_1 = 0.443$, $Z_1 = Z_0/y_1 = 112.9\ \Omega$, $Z_2 = Z_0/y_2 = 45.7\Omega$

3. a) $Z = 61.00\Omega + j\cdot(49.17)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.247 + j\cdot(0.334) = 0.415\angle 53.5°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.415$; $\varphi = \arg(\Gamma) = 53.5°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 30.5°$; $\mathrm{Im}(y_S) = -0.912$; $\theta_{P1} = 137.6°$ **or** $\theta_{S2} = 96.0°$; $\mathrm{Im}(y_S) = 0.912$; $\theta_{P2} = 42.4°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 330\text{MHz} = 2.073\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 41.134\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 11.860\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 61.270\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 11.860\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 41.134\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 330 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation $L_{Ar} = 0.5$ dB, including at the cutoff frequency $f_1 = 330$ MHz; In the stopband (f > 330 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 660.0$ MHz the attenuation is $L_{As} = 42.039$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 17.7\text{dB} + 17.9\text{dB} + 19.1\text{dB} = 54.7\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 295{,}120.9$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.93\text{dB} = 2.472$, $G_1 = 17.7\text{dB} = 58.884$, $F_2 = 4.72\text{dB} = 2.965$, $G_2 = 17.9\text{dB} = 61.660$, $F_3 = 5.74\text{dB} = 3.750$, $G_3 = 19.1\text{dB} = 81.283$;
$F = 2.965 + (3.750-1)/61.660 + (2.472-1)/61.660/81.283 = 3.010 = 4.785\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.750 + (2.472-1)/81.283 + (2.965-1)/81.283/58.884 = 3.768 = 5.761\text{dB}$

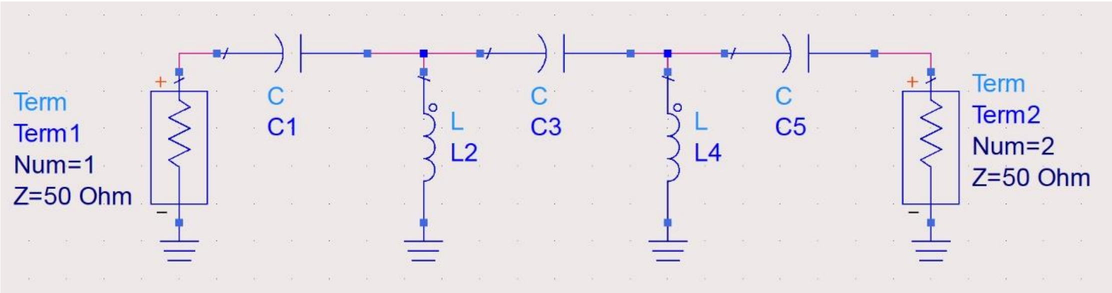
Subject no. 43

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (50.9 + j\cdot 41.4)\Omega = 0.591 + j\cdot 0.481$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.591 + j\cdot 0.481)] / (1 + 0.591 + j\cdot 0.481)$
$\Gamma = (0.152) + j\cdot(0.348) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.380\angle 66.4° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 3.4\text{dBm} - 4.20\text{dB} = -0.80\text{dBm}$;
b) $P_{in} = 3.4\text{dBm} = 2.188\text{mW}$; $P_c = -0.80\text{dBm} = 0.832\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 2.188\text{mW} - 0.832\text{mW} = 1.356\text{mW} = 1.323\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.617$, $y_2 = 1.270$, $y_1 = 0.783$, $Z_1 = Z_0/y_1 = 63.8\ \Omega$, $Z_2 = Z_0/y_2 = 39.4\Omega$

3. a) $Z = 22.13\Omega + j\cdot(14.78)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.331 + j\cdot(0.273) = 0.429\angle 140.5°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.429$; $\varphi = \arg(\Gamma) = 140.5°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 167.4°$; $\mathrm{Im}(y_S) = -0.949$; $\theta_{P1} = 136.5°$ **<u>or</u>** $\theta_{S2} = 52.1°$; $\mathrm{Im}(y_S) = 0.949$; $\theta_{P2} = 43.5°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 530\text{MHz} = 3.330\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**<u>high-pass filter (HPF)</u>**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 1.725\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 19.709\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 1.323\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 19.709\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 1.725\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 530 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 530$ MHz; In the stopband (f < 530 MHz) the attenuation for 5^{th} order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 265.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 20.8\text{dB} + 23.3\text{dB} + 24.8\text{dB} = 68.9\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 7{,}762{,}471.2$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.06\text{dB} = 2.023$, $G_1 = 20.8\text{dB} = 120.226$, $F_2 = 4.76\text{dB} = 2.992$, $G_2 = 23.3\text{dB} = 213.796$, $F_3 = 5.96\text{dB} = 3.945$, $G_3 = 24.8\text{dB} = 301.995$;
$F = 2.992 + (3.945-1)/213.796 + (2.023-1)/213.796/301.995 = 3.006 = 4.780\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.945 + (2.023-1)/301.995 + (2.992-1)/301.995/120.226 = 3.948 = 5.964\text{dB}$

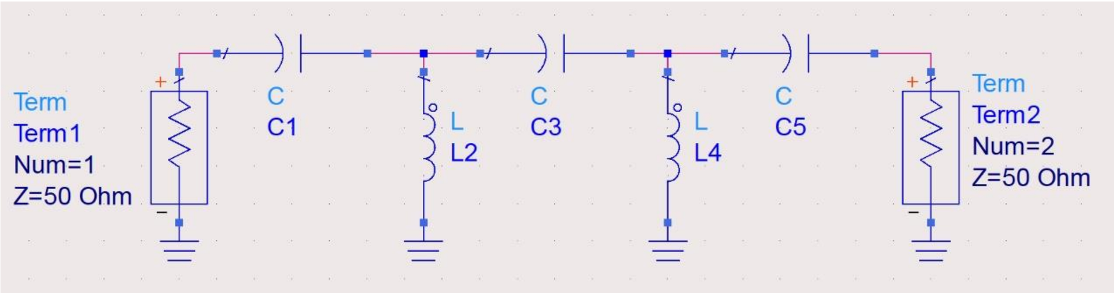
Subject no. 44

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (53.2 + j\cdot 68.3)\Omega = 0.355 + j\cdot 0.456$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.355 + j\cdot 0.456)] / (1 + 0.355 + j\cdot 0.456)$
$\Gamma = (0.326) + j\cdot(0.446) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.553\angle 53.8° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 7.3\text{dBm} - 4.90\text{dB} = 2.40\text{dBm}$;
b) $P_{in} = 7.3\text{dBm} = 5.370\text{mW}$; $P_c = 2.40\text{dBm} = 1.738\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 5.370\text{mW} - 1.738\text{mW} = 3.633\text{mW} = 5.602\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.569$, $y_2 = 1.216$, $y_1 = 0.692$, $Z_1 = Z_0/y_1 = 72.3\ \Omega$, $Z_2 = Z_0/y_2 = 41.1\Omega$

3. a) $Z = 35.00\Omega + j\cdot(-32.02)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.030 + j\cdot(-0.388) = 0.389\angle -94.5°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.389$; $\varphi = \arg(\Gamma) = -94.5°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 103.7°$; $\mathrm{Im}(y_S) = -0.845$; $\theta_{P1} = 139.8°$ **or** $\theta_{S2} = 170.8°$; $\mathrm{Im}(y_S) = 0.845$; $\theta_{P2} = 40.2°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 410\text{MHz} = 2.576\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 12.563\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 11.996\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.882\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 11.996\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 12.563\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 410 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 410$ MHz; In the stopband (f < 410 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 205.0$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 19.3\text{dB} + 18.3\text{dB} + 20.0\text{dB} = 57.6\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 575{,}439.9$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.53\text{dB} = 2.254$, $G_1 = 19.3\text{dB} = 85.114$, $F_2 = 4.47\text{dB} = 2.799$, $G_2 = 18.3\text{dB} = 67.608$, $F_3 = 5.91\text{dB} = 3.899$, $G_3 = 20.0\text{dB} = 100.000$;
$F = 2.254 + (2.799-1)/85.114 + (3.899-1)/85.114/67.608 = 2.276 = 3.571\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.799 + (3.899-1)/67.608 + (2.254-1)/67.608/100.000 = 2.842 = 4.536\text{dB}$

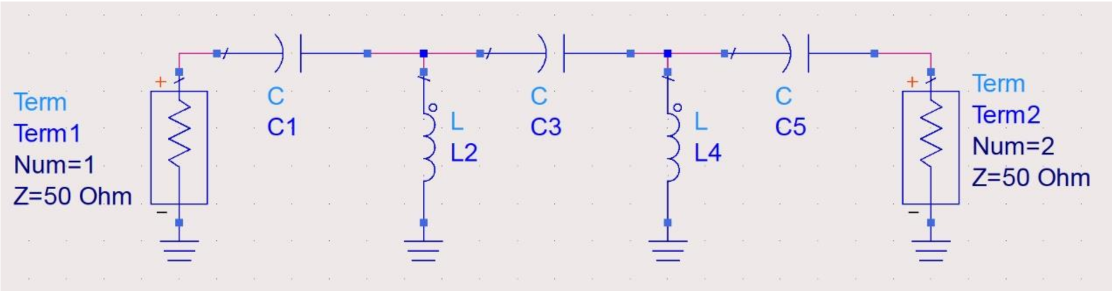
Subject no. 45

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (61.0 + j\cdot 64.9)\Omega = 0.384 + j\cdot 0.409$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.384 + j\cdot 0.409)] / (1 + 0.384 + j\cdot 0.409)$
$\Gamma = (0.329) + j\cdot(0.393) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.512\angle 50.1° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 8.1\text{dBm} - 6.25\text{dB} = 1.85\text{dBm}$;
b) $P_{in} = 8.1\text{dBm} = 6.457\text{mW}$; $P_c = 1.85\text{dBm} = 1.531\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 6.457\text{mW} - 1.531\text{mW} = 4.925\text{mW} = 6.924\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.487$, $y_2 = 1.145$, $y_1 = 0.558$, $Z_1 = Z_0/y_1 = 89.7\ \Omega$, $Z_2 = Z_0/y_2 = 43.7\Omega$

3. a) $Z = 47.00\Omega + j\cdot(-54.96)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.220 + j\cdot(-0.442) = 0.494\angle -63.6°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.494$; $\varphi = \arg(\Gamma) = -63.6°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 91.6°$; $\mathrm{Im}(y_S) = -1.135$; $\theta_{P1} = 131.4°$ **or** $\theta_{S2} = 152.0°$; $\mathrm{Im}(y_S) = 1.135$; $\theta_{P2} = 48.6°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 395\text{MHz} = 2.482\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 2.315\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 26.446\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 1.776\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 26.446\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 2.315\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 395 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 395$ MHz; In the stopband (f < 395 MHz) the attenuation for 5^{th} order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 197.5$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 21.5\text{dB} + 18.2\text{dB} + 22.8\text{dB} = 62.5\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}778{,}279.4$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.63\text{dB} = 2.307$, $G_1 = 21.5\text{dB} = 141.254$, $F_2 = 4.41\text{dB} = 2.761$, $G_2 = 18.2\text{dB} = 66.069$, $F_3 = 5.97\text{dB} = 3.954$, $G_3 = 22.8\text{dB} = 190.546$;
$F = 2.307 + (2.761-1)/141.254 + (3.954-1)/141.254/66.069 = 2.320 = 3.654\text{dB}$
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 2.761 + (2.307-1)/66.069 + (3.954-1)/66.069/141.254 = 2.781 = 4.441\text{dB}$

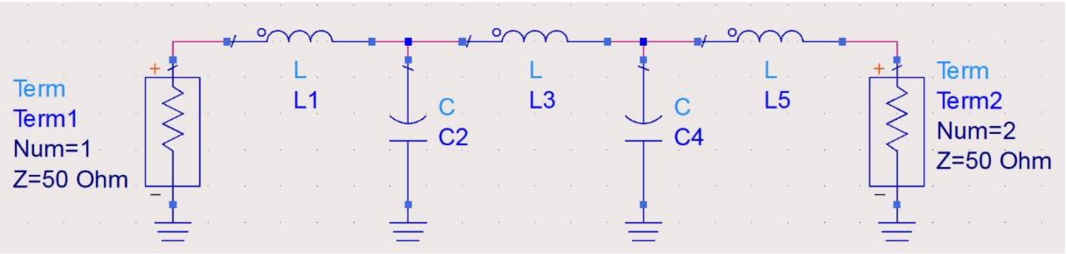
Subject no. 46

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (53.7 - j\cdot 35.3)\Omega = 0.650 - j\cdot 0.427$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.650 - j\cdot 0.427)] / (1 + 0.650 - j\cdot 0.427)$
$\Gamma = (0.136) + j\cdot(-0.294) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.324\angle{-65.2°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 6.6\text{dBm} - 5.40\text{dB} = 1.20\text{dBm}$;
b) $P_{in} = 6.6\text{dBm} = 4.571\text{mW}$; $P_c = 1.20\text{dBm} = 1.318\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 4.571\text{mW} - 1.318\text{mW} = 3.253\text{mW} = 5.122\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.537$, $y_2 = 1.185$, $y_1 = 0.637$, $Z_1 = Z_0/y_1 = 78.5\ \Omega$, $Z_2 = Z_0/y_2 = 42.2\Omega$

3. a) $Z = 67.00\Omega + j\cdot(75.22)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.395 + j\cdot(0.389) = 0.554\angle 44.5°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.554$; $\varphi = \arg(\Gamma) = 44.5°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 39.6°$; $\mathrm{Im}(y_S) = -1.332$; $\theta_{P1} = 126.9°$ **or** $\theta_{S2} = 95.9°$; $\mathrm{Im}(y_S) = 1.332$; $\theta_{P2} = 53.1°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 405\text{MHz} = 2.545\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 68.411\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 5.987\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 89.168\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 5.987\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 68.411\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 405 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 405$ MHz; In the stopband (f > 405 MHz) the attenuation for 5^{th} order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 810.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.5\text{dB} + 24.6\text{dB} + 23.1\text{dB} = 72.2\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 16{,}595{,}869.1$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.28\text{dB} = 2.128$, $G_1 = 24.5\text{dB} = 281.838$, $F_2 = 4.64\text{dB} = 2.911$, $G_2 = 24.6\text{dB} = 288.403$, $F_3 = 5.25\text{dB} = 3.350$, $G_3 = 23.1\text{dB} = 204.174$;
$F = 2.128 + (2.911-1)/281.838 + (3.350-1)/281.838/288.403 = 2.135 = 3.294\text{dB}$
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 2.911 + (2.128-1)/288.403 + (3.350-1)/288.403/281.838 = 2.915 = 4.646\text{dB}$

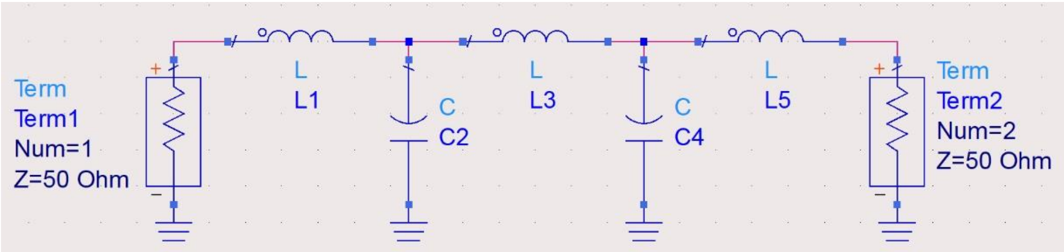
Subject no. 47

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (52.8 + j\cdot 56.0)\Omega = 0.446 + j\cdot 0.473$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.446 + j\cdot 0.473)] / (1 + 0.446 + j\cdot 0.473)$
$\Gamma = (0.250) + j\cdot(0.409) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.479\angle 58.6° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} – C = 2.2\text{dBm} – 6.25\text{dB} = -4.05\text{dBm}$;
b) $P_{in} = 2.2\text{dBm} = 1.660\text{mW}$; $P_c = -4.05\text{dBm} = 0.394\text{mW}$;
Lossless coupler $P_{th} = P_{in} – P_c = 1.660\text{mW} – 0.394\text{mW} = 1.266\text{mW} = 1.024\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.487$, $y_2 = 1.145$, $y_1 = 0.558$, $Z_1 = Z_0/y_1 = 89.7\ \Omega$, $Z_2 = Z_0/y_2 = 43.7\Omega$

3. a) $Z = 28.00\Omega + j\cdot(67.33)\Omega$; $\Gamma = (Z – Z_0)/(Z + Z_0) = 0.265+ j\cdot(0.634) = 0.687\angle 67.3°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.687$; $\varphi = \arg(\Gamma) = 67.3°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 33.1°$; $\mathrm{Im}(y_S) = -1.893$; $\theta_{P1} = 117.8°$ **<u>or</u>** $\theta_{S2} = 79.6°$; $\mathrm{Im}(y_S) = 1.893$; $\theta_{P2} = 62.2°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 450\text{MHz} = 2.827\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**<u>low-pass filter (LPF)</u>**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 61.570\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 5.389\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 80.251\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 5.389\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 61.570\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 450 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 450$ MHz; In the stopband (f > 450 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 900.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 21.8\text{dB} + 15.3\text{dB} + 18.1\text{dB} = 55.2\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 331{,}131.1$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.27\text{dB} = 2.123$, $G_1 = 21.8\text{dB} = 151.356$, $F_2 = 4.49\text{dB} = 2.812$, $G_2 = 15.3\text{dB} = 33.884$, $F_3 = 5.87\text{dB} = 3.864$, $G_3 = 18.1\text{dB} = 64.565$;
$F = 2.123 + (2.812-1)/151.356 + (3.864-1)/151.356/33.884 = 2.136 = 3.296\text{dB}$
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 2.812 + (2.123-1)/33.884 + (3.864-1)/33.884/151.356 = 2.846 = 4.542\text{dB}$

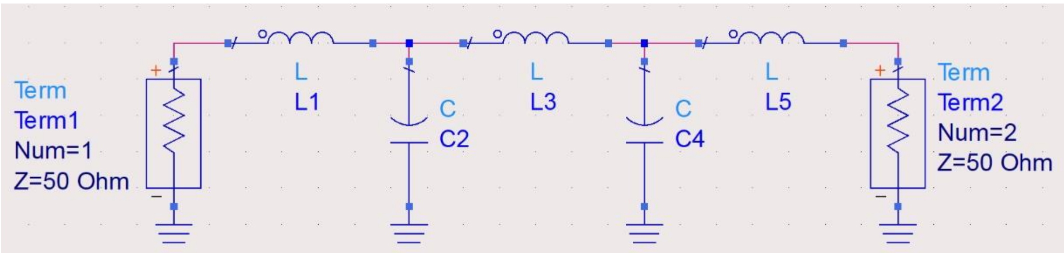
Subject no. 48

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (49.6 + j\cdot 68.3)\Omega = 0.348 + j\cdot 0.479$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.348 + j\cdot 0.479)] / (1 + 0.348 + j\cdot 0.479)$
$\Gamma = (0.317) + j\cdot(0.468) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.566\angle 55.9° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 8.1\text{dBm} - 5.70\text{dB} = 2.40\text{dBm}$;
b) $P_{in} = 8.1\text{dBm} = 6.457\text{mW}$; $P_c = 2.40\text{dBm} = 1.738\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 6.457\text{mW} - 1.738\text{mW} = 4.719\text{mW} = 6.738\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.519$, $y_2 = 1.170$, $y_1 = 0.607$, $Z_1 = Z_0/y_1 = 82.4\ \Omega$, $Z_2 = Z_0/y_2 = 42.7\Omega$

3. a) $Z = 24.54\Omega + j\cdot(-33.76)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.113 + j\cdot(-0.504) = 0.517\angle -102.7°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.517$; $\varphi = \arg(\Gamma) = -102.7°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 111.9°$; $\mathrm{Im}(y_S) = -1.207$; $\theta_{P1} = 129.6°$ **or** $\theta_{S2} = 170.8°$; $\mathrm{Im}(y_S) = 1.207$; $\theta_{P2} = 50.4°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 335\text{MHz} = 2.105\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 82.706\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 7.238\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 107.800\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 7.238\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 82.706\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 335 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 335$ MHz; In the stopband (f > 335 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 670.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 17.8\text{dB} + 16.8\text{dB} + 20.4\text{dB} = 55.0\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 316{,}227.8$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A3, A1 so: $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$; $F_1 = 3.03\text{dB} = 2.009$, $G_1 = 17.8\text{dB} = 60.256$, $F_2 = 4.22\text{dB} = 2.642$, $G_2 = 16.8\text{dB} = 47.863$, $F_3 = 5.76\text{dB} = 3.767$, $G_3 = 20.4\text{dB} = 109.648$;
$F = 2.642 + (3.767-1)/47.863 + (2.009-1)/47.863/109.648 = 2.700 = 4.314\text{dB}$
c) If the order is A1, A2, A3 the gain remains the same but $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$;
$F = 2.009 + (2.642-1)/60.256 + (3.767-1)/60.256/47.863 = 2.037 = 3.091\text{dB}$

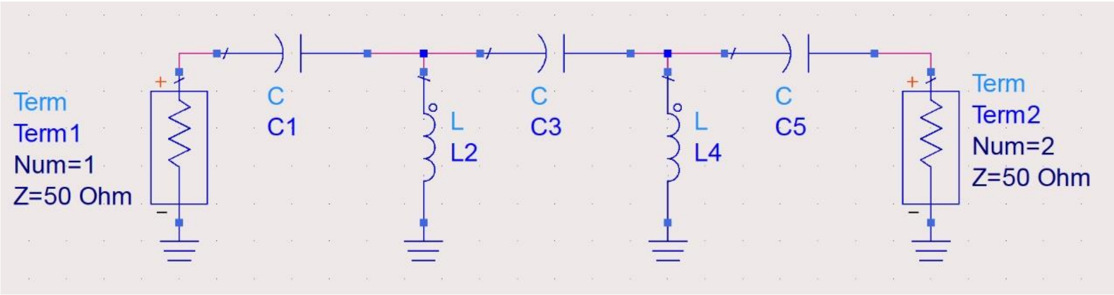
Subject no. 49

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (57.2 - j\cdot 62.1)\Omega = 0.401 - j\cdot 0.436$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.401 - j\cdot 0.436)] / (1 + 0.401 - j\cdot 0.436)$
$\Gamma = (0.302) + j\cdot(-0.405) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.505\angle{-53.3°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 1.0\text{dBm} - 7.40\text{dB} = -6.40\text{dBm}$;
b) $P_{in} = 1.0\text{dBm} = 1.259\text{mW}$; $P_c = -6.40\text{dBm} = 0.229\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 1.259\text{mW} - 0.229\text{mW} = 1.030\text{mW} = 0.128\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.427$, $y_2 = 1.106$, $y_1 = 0.472$, $Z_1 = Z_0/y_1 = 106.0\ \Omega$, $Z_2 = Z_0/y_2 = 45.2\Omega$

3. a) $Z = 28.97\Omega + j\cdot(-35.71)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.051 + j\cdot(-0.475) = 0.478\angle{-96.2°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.478$; $\varphi = \arg(\Gamma) = -96.2°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 107.4°$; $\mathrm{Im}(y_S) = -1.089$; $\theta_{P1} = 132.6°$ **or** $\theta_{S2} = 168.8°$; $\mathrm{Im}(y_S) = 1.089$; $\theta_{P2} = 47.4°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 365\text{MHz} = 2.293\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 5.112\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 17.731\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.432\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 17.731\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 5.112\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 365 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 365 MHz; In the stopband (f < 365 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 182.5 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 21.8\text{dB} + 15.3\text{dB} + 15.3\text{dB} = 52.4\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 173{,}780.1$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.20\text{dB} = 2.089$, $G_1 = 21.8\text{dB} = 151.356$, $F_2 = 4.02\text{dB} = 2.523$, $G_2 = 15.3\text{dB} = 33.884$, $F_3 = 5.96\text{dB} = 3.945$, $G_3 = 15.3\text{dB} = 33.884$;
$F = 2.089 + (3.945-1)/151.356 + (2.523-1)/151.356/33.884 = 2.109 = 3.241\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.523 + (3.945-1)/33.884 + (2.089-1)/33.884/33.884 = 2.611 = 4.169\text{dB}$

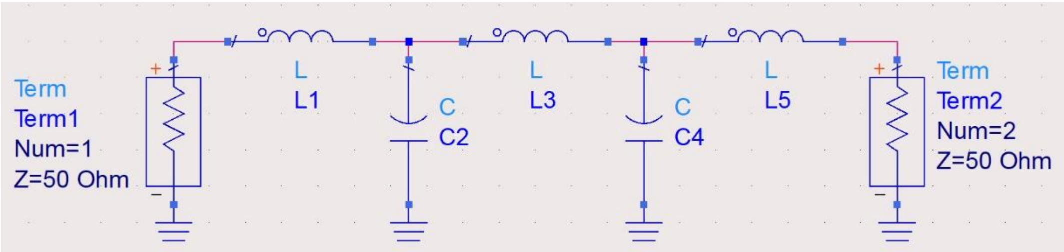
Subject no. 50

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (30.8 + j\cdot 63.5)\Omega = 0.309 + j\cdot 0.637$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.309 + j\cdot 0.637)] / (1 + 0.309 + j\cdot 0.637)$
$\Gamma = (0.235) + j\cdot(0.601) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.646\angle 68.7° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 4.4\text{dBm} - 5.10\text{dB} = -0.70\text{dBm}$;
b) $P_{in} = 4.4\text{dBm} = 2.754\text{mW}$; $P_c = -0.70\text{dBm} = 0.851\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 2.754\text{mW} - 0.851\text{mW} = 1.903\text{mW} = 2.795\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.556$, $y_2 = 1.203$, $y_1 = 0.669$, $Z_1 = Z_0/y_1 = 74.8\ \Omega$, $Z_2 = Z_0/y_2 = 41.6\Omega$

3. a) $Z = 69.00\Omega + j\cdot(-50.85)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.289 + j\cdot(-0.304) = 0.420\angle -46.4°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.420$; $\varphi = \arg(\Gamma) = -46.4°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 80.6°$; $\mathrm{Im}(y_S) = -0.924$; $\theta_{P1} = 137.3°$ **or** $\theta_{S2} = 145.8°$; $\mathrm{Im}(y_S) = 0.924$; $\theta_{P2} = 42.7°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 515\text{MHz} = 3.236\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 53.799\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 4.709\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 70.122\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 4.709\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 53.799\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 515 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 515$ MHz; In the stopband (f > 515 MHz) the attenuation for 5^{th} order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 1030.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 19.4\text{dB} + 24.9\text{dB} + 20.6\text{dB} = 64.9\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 3{,}090{,}295.4$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A1, A2 so: $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$; $F_1 = 3.88\text{dB} = 2.443$, $G_1 = 19.4\text{dB} = 87.096$, $F_2 = 4.68\text{dB} = 2.938$, $G_2 = 24.9\text{dB} = 309.030$, $F_3 = 5.59\text{dB} = 3.622$, $G_3 = 20.6\text{dB} = 114.815$;
$F = 3.622 + (2.443-1)/114.815 + (2.938-1)/114.815/87.096 = 3.635 = 5.605\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.938 + (3.622-1)/309.030 + (2.443-1)/309.030/114.815 = 2.946 = 4.693\text{dB}$

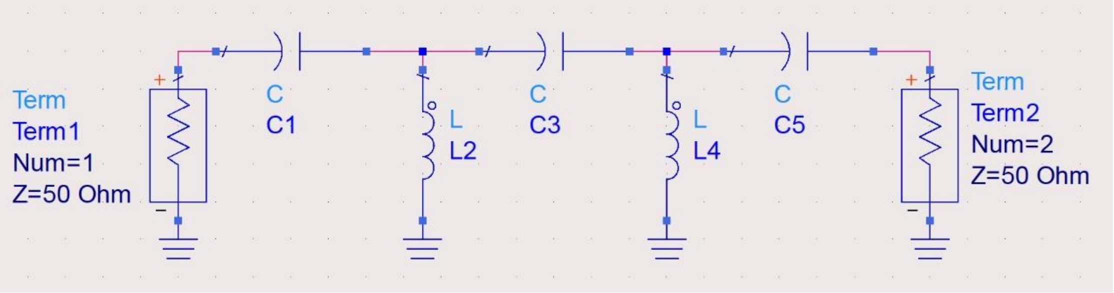
Subject no. 51

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (68.3 + j\cdot 52.0)\Omega = 0.463 + j\cdot 0.353$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.463 + j\cdot 0.353)] / (1 + 0.463 + j\cdot 0.353)$
$\Gamma = (0.292) + j\cdot(0.311) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.427\angle 46.9° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 3.0\text{dBm} - 6.20\text{dB} = -3.20\text{dBm}$;
b) $P_{in} = 3.0\text{dBm} = 1.995\text{mW}$; $P_c = -3.20\text{dBm} = 0.479\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 1.995\text{mW} - 0.479\text{mW} = 1.517\text{mW} = 1.809\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.490$, $y_2 = 1.147$, $y_1 = 0.562$, $Z_1 = Z_0/y_1 = 89.0\ \Omega$, $Z_2 = Z_0/y_2 = 43.6\Omega$

3. a) $Z = 73.00\Omega + j\cdot(54.43)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.320 + j\cdot(0.301) = 0.439\angle 43.2°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.439$; $\varphi = \arg(\Gamma) = 43.2°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 36.4°$; $\mathrm{Im}(y_S) = -0.978$; $\theta_{P1} = 135.6°$ **or** $\theta_{S2} = 100.4°$; $\mathrm{Im}(y_S) = 0.978$; $\theta_{P2} = 44.4°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 440\text{MHz} = 2.765\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 11.706\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 11.178\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.617\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 11.178\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 11.706\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 440 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 440$ MHz; In the stopband (f < 440 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 220.0$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 23.8\text{dB} + 21.4\text{dB} + 24.5\text{dB} = 69.7\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 9{,}332{,}543.0$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.50\text{dB} = 2.239$, $G_1 = 23.8\text{dB} = 239.883$, $F_2 = 4.00\text{dB} = 2.512$, $G_2 = 21.4\text{dB} = 138.038$, $F_3 = 5.07\text{dB} = 3.214$, $G_3 = 24.5\text{dB} = 281.838$;
$F = 2.239 + (2.512-1)/239.883 + (3.214-1)/239.883/138.038 = 2.245 = 3.512\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.512 + (3.214-1)/138.038 + (2.239-1)/138.038/281.838 = 2.528 = 4.028\text{dB}$

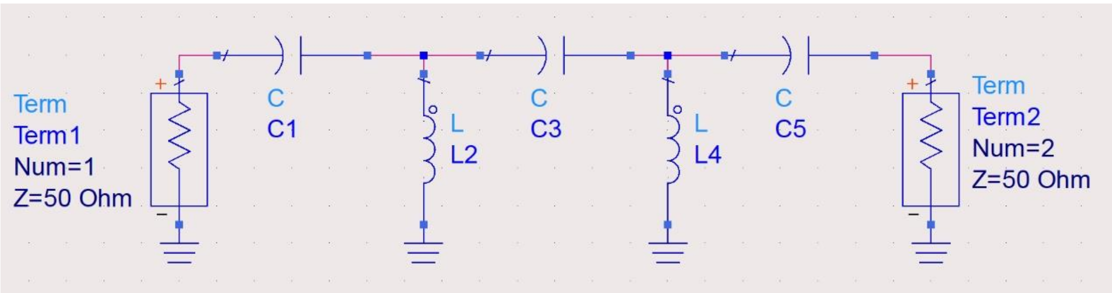
Subject no. 52

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (69.4 - j\cdot 64.6)\Omega = 0.386 - j\cdot 0.359$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.386 - j\cdot 0.359)] / (1 + 0.386 - j\cdot 0.359)$
$\Gamma = (0.352) + j\cdot(-0.351) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.497\angle -44.9° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 2.7\text{dBm} - 4.40\text{dB} = -1.70\text{dBm}$;
b) $P_{in} = 2.7\text{dBm} = 1.862\text{mW}$; $P_c = -1.70\text{dBm} = 0.676\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 1.862\text{mW} - 0.676\text{mW} = 1.186\text{mW} = 0.741\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.603$, $y_2 = 1.253$, $y_1 = 0.755$, $Z_1 = Z_0/y_1 = 66.2\ \Omega$, $Z_2 = Z_0/y_2 = 39.9\Omega$

3. a) $Z = 26.57\Omega + j\cdot(-20.89)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.216 + j\cdot(-0.332) = 0.396\angle -123.0°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.396$; $\varphi = \arg(\Gamma) = -123.0°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 118.2°$; $\mathrm{Im}(y_S) = -0.861$; $\theta_{P1} = 139.3°$ **or** $\theta_{S2} = 4.9°$; $\mathrm{Im}(y_S) = 0.861$; $\theta_{P2} = 40.7°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 500\text{MHz} = 3.142\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 3.732\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 12.944\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 2.506\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 12.944\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 3.732\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 500 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 500 MHz; In the stopband (f < 500 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 250.0 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 22.8\text{dB} + 21.3\text{dB} + 23.5\text{dB} = 67.6\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 5{,}754{,}399.4$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.49\text{dB} = 2.234$, $G_1 = 22.8\text{dB} = 190.546$, $F_2 = 4.36\text{dB} = 2.729$, $G_2 = 21.3\text{dB} = 134.896$, $F_3 = 5.42\text{dB} = 3.483$, $G_3 = 23.5\text{dB} = 223.872$;
$F = 2.729 + (2.234-1)/134.896 + (3.483-1)/134.896/190.546 = 2.738 = 4.375\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.729 + (3.483-1)/134.896 + (2.234-1)/134.896/223.872 = 2.747 = 4.389\text{dB}$

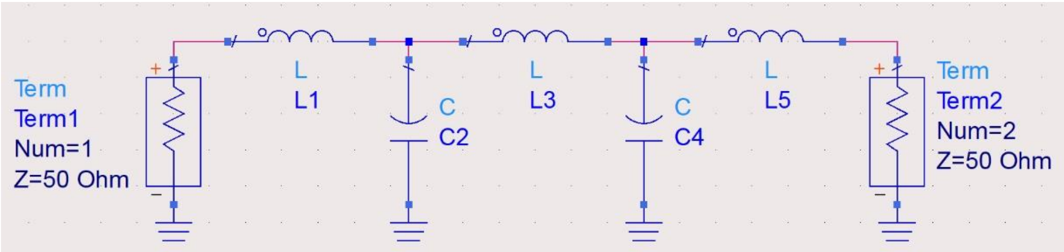
Subject no. 53

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (53.4 - j\cdot 67.9)\Omega = 0.358 - j\cdot 0.455$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.358 - j\cdot 0.455)] / (1 + 0.358 - j\cdot 0.455)$
$\Gamma = (0.324) + j\cdot(-0.444) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.550\angle -53.8° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} – C = 8.2\text{dBm} – 6.90\text{dB} = 1.30\text{dBm}$;
b) $P_{in} = 8.2\text{dBm} = 6.607\text{mW}$; $P_c = 1.30\text{dBm} = 1.349\text{mW}$;
Lossless coupler $P_{th} = P_{in} – P_c = 6.607\text{mW} – 1.349\text{mW} = 5.258\text{mW} = 7.208\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.452$, $y_2 = 1.121$, $y_1 = 0.507$, $Z_1 = Z_0/y_1 = 98.7\ \Omega$, $Z_2 = Z_0/y_2 = 44.6\Omega$

3. a) $Z = 34.99\Omega + j\cdot(35.00)\Omega$; $\Gamma = (Z – Z_0)/(Z + Z_0) = -0.006+ j\cdot(0.414) = 0.414\angle 90.8°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.414$; $\varphi = \arg(\Gamma) = 90.8°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 11.8°$; $\mathrm{Im}(y_S) = -0.910$; $\theta_{P1} = 137.7°$ **or** $\theta_{S2} = 77.3°$; $\mathrm{Im}(y_S) = 0.910$; $\theta_{P2} = 42.3°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 315\text{MHz} = 1.979\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 =1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 43.093\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 12.425\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 64.187\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 12.425\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 43.093\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 315 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation $L_{Ar} = 0.5$ dB, including at the cutoff frequency $f_1 = 315$ MHz; In the stopband (f > 315 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 630.0$ MHz the attenuation is $L_{As} = 42.039$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 23.5\text{dB} + 16.2\text{dB} + 16.9\text{dB} = 56.6\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 457{,}088.2$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.81\text{dB} = 2.404$, $G_1 = 23.5\text{dB} = 223.872$, $F_2 = 4.65\text{dB} = 2.917$, $G_2 = 16.2\text{dB} = 41.687$, $F_3 = 5.29\text{dB} = 3.381$, $G_3 = 16.9\text{dB} = 48.978$;
$F = 2.917 + (2.404-1)/41.687 + (3.381-1)/41.687/223.872 = 2.951 = 4.700\text{dB}$
c) If the order is A1, A2, A3 the gain remains the same but $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$;
$F = 2.404 + (2.917-1)/223.872 + (3.381-1)/223.872/41.687 = 2.413 = 3.826\text{dB}$

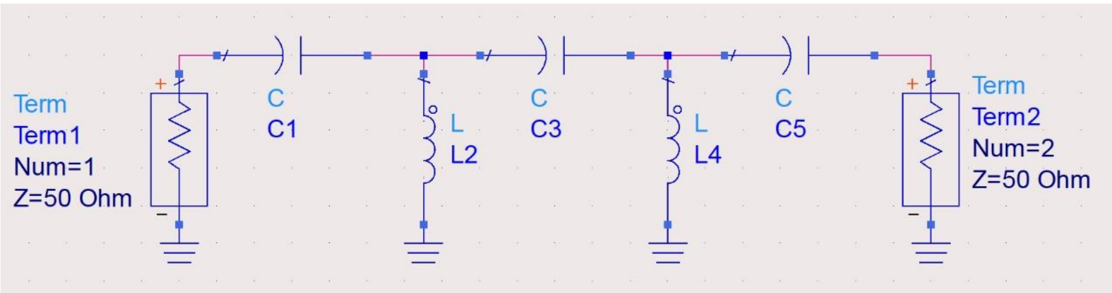
Subject no. 54

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (62.8 + j\cdot 47.4)\Omega = 0.507 + j\cdot 0.383$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.507 + j\cdot 0.383)] / (1 + 0.507 + j\cdot 0.383\ )$
$\Gamma = (0.247) + j\cdot(0.317) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.401\angle 52.1° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C$ = 3.0dBm – 7.05dB = -4.05dBm;
b) P_{in} = 3.0dBm = 1.995mW; P_c = -4.05dBm = 0.394mW;
Lossless coupler $P_{th} = P_{in} - P_c$ = 1.995mW – 0.394mW = 1.602mW = 2.046dBm
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.444$, $y_2 = 1.116$, $y_1 = 0.496$, $Z_1 = Z_0/y_1 = 100.9\ \Omega$, $Z_2 = Z_0/y_2 = 44.8\Omega$

3. a) $Z = 59.00\Omega + j\cdot(-74.51)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.375+ j\cdot(-0.427) = 0.568\angle{-48.8°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.568$; $\varphi = \arg(\Gamma) = -48.8°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 86.7°$; $\mathrm{Im}(y_S) = -1.382$; $\theta_{P1} = 125.9°$ **or** $\theta_{S2} = 142.1°$; $\mathrm{Im}(y_S) = 1.382$; $\theta_{P2} = 54.1°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 595\text{MHz} = 3.738\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c$ = 8.657pF; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c$ = 8.266nH;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c$ = 2.675pF; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c$ = 8.266nH;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c$ = 8.657pF;
b) Draw the schematic:



c) In the passband (f > 595 MHz) we have maximally flat behavior, maximum attenuation L_{Ar} = 3.0 dB, including at the cutoff frequency f_1 = 595 MHz; In the stopband (f < 595 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 297.5 MHz the attenuation is L_{As} = 30.107 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[dB] = G_1 + G_2 + G_3$ = 15.0dB + 18.2dB + 16.9dB = 50.1dB; $G[lin] = 10^{G[dB]/10}$ = 102,329.3
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A3, A1, A2 so: $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$; F_1 = 3.06dB = 2.023, G_1 = 15.0dB = 31.623, F_2 = 4.84dB = 3.048, G_2 = 18.2dB = 66.069, F_3 = 5.83dB = 3.828, G_3 = 16.9dB = 48.978;
$F = 3.828 + (2.023-1)/48.978 + (3.048-1)/48.978/31.623 = 3.850$ = 5.855dB
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 3.048 + (2.023-1)/66.069 + (3.828-1)/66.069/31.623 = 3.065$ = 4.864dB

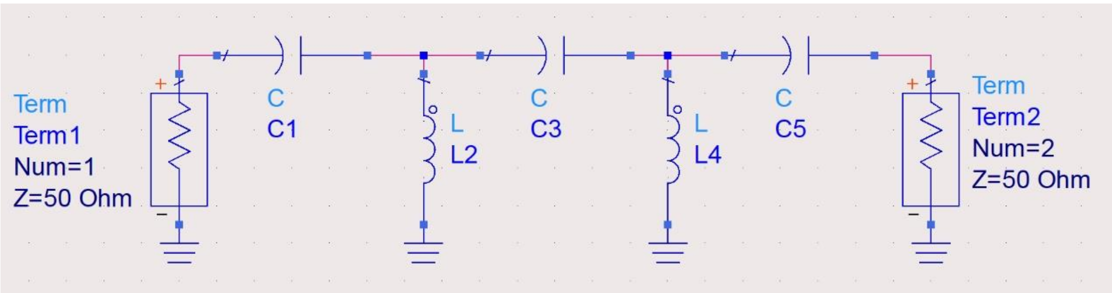
Subject no. 55

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (43.7 + j\cdot 30.0)\Omega = 0.778 + j\cdot 0.534$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.778 + j\cdot 0.534)] / (1 + 0.778 + j\cdot 0.534)$
$\Gamma = (0.032) + j\cdot(0.310) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.312\angle 84.1° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 6.2\text{dBm} - 5.80\text{dB} = 0.40\text{dBm}$;
b) $P_{in} = 6.2\text{dBm} = 4.169\text{mW}$; $P_c = 0.40\text{dBm} = 1.096\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 4.169\text{mW} - 1.096\text{mW} = 3.072\text{mW} = 4.875\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.513$, $y_2 = 1.165$, $y_1 = 0.597$, $Z_1 = Z_0/y_1 = 83.7\ \Omega$, $Z_2 = Z_0/y_2 = 42.9\Omega$

3. a) $Z = 60.00\Omega + j\cdot(68.89)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = 0.347 + j\cdot(0.409) = 0.536\angle 49.7°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.536$; $\varphi = \arg(\Gamma) = 49.7°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 36.4°$; $\mathrm{Im}(y_S) = -1.271$; $\theta_{P1} = 128.2°$ **or** $\theta_{S2} = 93.9°$; $\mathrm{Im}(y_S) = 1.271$; $\theta_{P2} = 51.8°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), series circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 540\text{MHz} = 3.393\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 1.693\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 19.344\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 1.299\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 19.344\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 1.693\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 540 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 540$ MHz; In the stopband (f < 540 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 270.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 23.8\text{dB} + 24.9\text{dB} + 20.4\text{dB} = 69.1\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 8{,}128{,}305.2$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.47\text{dB} = 2.223$, $G_1 = 23.8\text{dB} = 239.883$, $F_2 = 4.11\text{dB} = 2.576$, $G_2 = 24.9\text{dB} = 309.030$, $F_3 = 5.23\text{dB} = 3.334$, $G_3 = 20.4\text{dB} = 109.648$;
$F = 2.223 + (3.334-1)/239.883 + (2.576-1)/239.883/109.648 = 2.233 = 3.489\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.576 + (3.334-1)/309.030 + (2.223-1)/309.030/109.648 = 2.584 = 4.123\text{dB}$

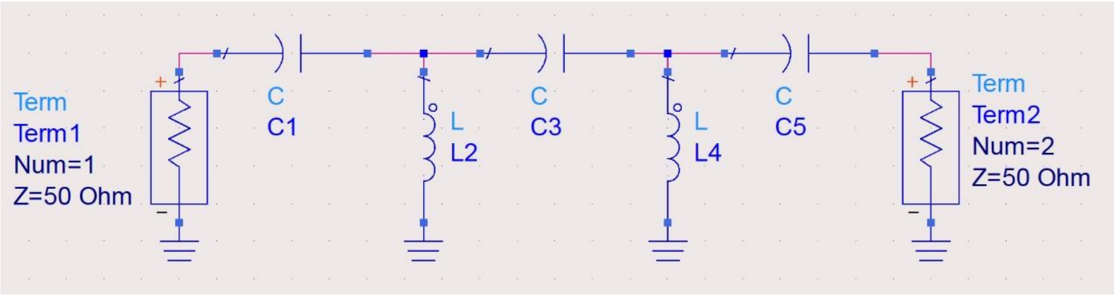
Subject no. 56

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (58.1 + j\cdot38.9)\Omega = 0.594 + j\cdot0.398$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.594 + j\cdot0.398)] / (1 + 0.594 + j\cdot0.398)$
$\Gamma = (0.181) + j\cdot(0.295) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.346\angle58.4° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 6.2\text{dBm} - 8.00\text{dB} = -1.80\text{dBm}$;
b) $P_{in} = 6.2\text{dBm} = 4.169\text{mW}$; $P_c = -1.80\text{dBm} = 0.661\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 4.169\text{mW} - 0.661\text{mW} = 3.508\text{mW} = 5.451\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.398$, $y_2 = 1.090$, $y_1 = 0.434$, $Z_1 = Z_0/y_1 = 115.2\ \Omega$, $Z_2 = Z_0/y_2 = 45.9\Omega$

3. a) $Z = 8.67\Omega + j\cdot(-21.70)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.499 + j\cdot(-0.555) = 0.746\angle-132.0°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.746$; $\varphi = \arg(\Gamma) = -132.0°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 135.1°$; $\mathrm{Im}(y_S) = -2.242$; $\theta_{P1} = 114.0°$ **or** $\theta_{S2} = 176.9°$; $\mathrm{Im}(y_S) = 2.242$; $\theta_{P2} = 66.0°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot405\text{MHz} = 2.545\cdot10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 4.608\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 15.980\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.093\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 15.980\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 4.608\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 405 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 405 MHz; In the stopband (f < 405 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 202.5 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.1\text{dB} + 20.2\text{dB} + 15.2\text{dB} = 59.5\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 891{,}250.9$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.81\text{dB} = 2.404$, $G_1 = 24.1\text{dB} = 257.040$, $F_2 = 4.84\text{dB} = 3.048$, $G_2 = 20.2\text{dB} = 104.713$, $F_3 = 5.92\text{dB} = 3.908$, $G_3 = 15.2\text{dB} = 33.113$;
$F = 2.404 + (3.908-1)/257.040 + (3.048-1)/257.040/33.113 = 2.416 = 3.831\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 3.048 + (3.908-1)/104.713 + (2.404-1)/104.713/33.113 = 3.076 = 4.880\text{dB}$

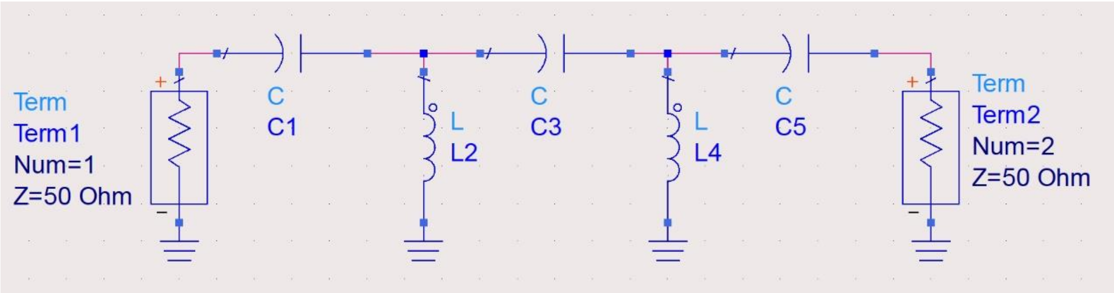
Subject no. 57

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (45.7 + j\cdot 60.6)\Omega = 0.397 + j\cdot 0.526$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.397 + j\cdot 0.526)] / (1 + 0.397 + j\cdot 0.526\ )$
$\Gamma = (0.254) + j\cdot(0.472) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.536\angle 61.7° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 5.3\text{dBm} - 7.80\text{dB} = -2.50\text{dBm}$;
b) $P_{in} = 5.3\text{dBm} = 3.388\text{mW}$; $P_c = -2.50\text{dBm} = 0.562\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 3.388\text{mW} - 0.562\text{mW} = 2.826\text{mW} = 4.512\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.407$, $y_2 = 1.095$, $y_1 = 0.446$, $Z_1 = Z_0/y_1 = 112.1\ \Omega$, $Z_2 = Z_0/y_2 = 45.7\Omega$

3. a) $Z = 13.52\Omega + j\cdot(15.81)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.482 + j\cdot(0.369) = 0.607\angle 142.6°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.607$; $\varphi = \arg(\Gamma) = 142.6°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 172.4°$; $\mathrm{Im}(y_S) = -1.529$; $\theta_{P1} = 123.2°$ **or** $\theta_{S2} = 45.0°$; $\mathrm{Im}(y_S) = 1.529$; $\theta_{P2} = 56.8°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + inductor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 395\text{MHz} = 2.482\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (0.5dB) filter: $g_1 = 1.7058$, $g_2 = 1.2296$, $g_3 = 2.5408$, $g_4 = 1.2296$, $g_5 = 1.7058$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 4.724\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 16.384\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 3.172\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 16.384\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 4.724\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 395 MHz) we have equal ripple (0.5dB) behavior, maximum attenuation L_{Ar} = 0.5 dB, including at the cutoff frequency f_1 = 395 MHz; In the stopband (f < 395 MHz) the attenuation for 5th order, equal ripple (0.5dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at f_s = 197.5 MHz the attenuation is L_{As} = 42.039 dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 18.1\text{dB} + 15.2\text{dB} + 21.9\text{dB} = 55.2\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 331{,}131.1$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.80\text{dB} = 2.399$, $G_1 = 18.1\text{dB} = 64.565$, $F_2 = 4.42\text{dB} = 2.767$, $G_2 = 15.2\text{dB} = 33.113$, $F_3 = 5.52\text{dB} = 3.565$, $G_3 = 21.9\text{dB} = 154.882$;
$F = 2.767 + (2.399-1)/33.113 + (3.565-1)/33.113/64.565 = 2.810 = 4.488\text{dB}$
c) If the order is A2, A3, A1 the gain remains the same but $F = F_2 + (F_3-1)/G_2 + (F_1-1)/G_2/G_3$;
$F = 2.767 + (3.565-1)/33.113 + (2.399-1)/33.113/154.882 = 2.845 = 4.540\text{dB}$

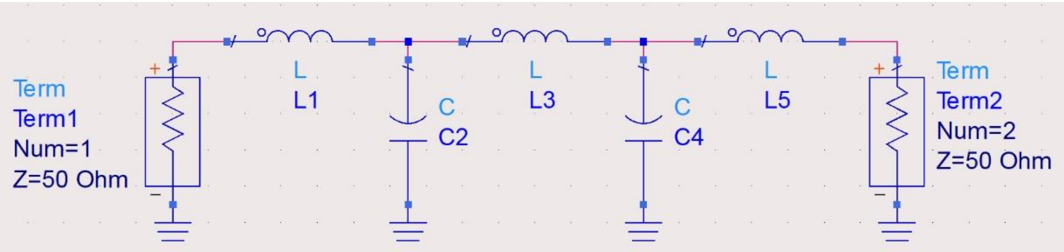
Subject no. 58

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (48.2 - j\cdot 43.0)\Omega = 0.578 - j\cdot 0.515$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.578 - j\cdot 0.515)] / (1 + 0.578 - j\cdot 0.515)$
$\Gamma = (0.146) + j\cdot(-0.374) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.401\angle -68.7° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 5.3\text{dBm} - 4.45\text{dB} = 0.85\text{dBm}$;
b) $P_{in} = 5.3\text{dBm} = 3.388\text{mW}$; $P_c = 0.85\text{dBm} = 1.216\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 3.388\text{mW} - 1.216\text{mW} = 2.172\text{mW} = 3.369\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.599$, $y_2 = 1.249$, $y_1 = 0.748$, $Z_1 = Z_0/y_1 = 66.8\ \Omega$, $Z_2 = Z_0/y_2 = 40.0\Omega$

3. a) $Z = 29.74\Omega + j\cdot(-35.03)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.051 + j\cdot(-0.462) = 0.465\angle -96.3°$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.465$; $\varphi = \arg(\Gamma) = -96.3°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 107.0°$; $\mathrm{Im}(y_S) = -1.049$; $\theta_{P1} = 133.6°$ **or** $\theta_{S2} = 169.3°$; $\mathrm{Im}(y_S) = 1.049$; $\theta_{P2} = 46.4°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 445\text{MHz} = 2.796\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an equal ripple (3dB) filter: $g_1 = 3.4817$, $g_2 = 0.7618$, $g_3 = 4.5381$, $g_4 = 0.7618$, $g_5 = 3.4817$, $g_6 = 1$ (works directly on 50Ω load, no $\lambda/4$ transformer needed).
Element equations depend on filter type (**low-pass filter (LPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series inductor $L_1 = g_1 \cdot R_0 / \omega_c = 62.262\text{nH}$; g_2 : shunt capacitor $C_2 = g_2 / R_0 / \omega_c = 5.449\text{pF}$;
g_3 : series inductor $L_3 = g_3 \cdot R_0 / \omega_c = 81.153\text{nH}$; g_4 : shunt capacitor $C_4 = g_4 / R_0 / \omega_c = 5.449\text{pF}$;
g_5 : series inductor $L_5 = g_5 \cdot R_0 / \omega_c = 62.262\text{nH}$;
b) Draw the schematic:



c) In the passband (f < 445 MHz) we have equal ripple (3dB) behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 445$ MHz; In the stopband (f > 445 MHz) the attenuation for 5th order, equal ripple (3dB) filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c \cdot 2$) so at $f_s = 890.0$ MHz the attenuation is $L_{As} = 51.174$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 24.8\text{dB} + 18.9\text{dB} + 16.9\text{dB} = 60.6\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 1{,}148{,}153.6$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A2, A3 so: $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$; $F_1 = 3.12\text{dB} = 2.051$, $G_1 = 24.8\text{dB} = 301.995$, $F_2 = 4.36\text{dB} = 2.729$, $G_2 = 18.9\text{dB} = 77.625$, $F_3 = 5.17\text{dB} = 3.289$, $G_3 = 16.9\text{dB} = 48.978$;
$F = 2.051 + (2.729-1)/301.995 + (3.289-1)/301.995/77.625 = 2.057 = 3.132\text{dB}$
c) If the order is A1, A3, A2 the gain remains the same but $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$;
$F = 2.051 + (3.289-1)/301.995 + (2.729-1)/301.995/48.978 = 2.059 = 3.136\text{dB}$

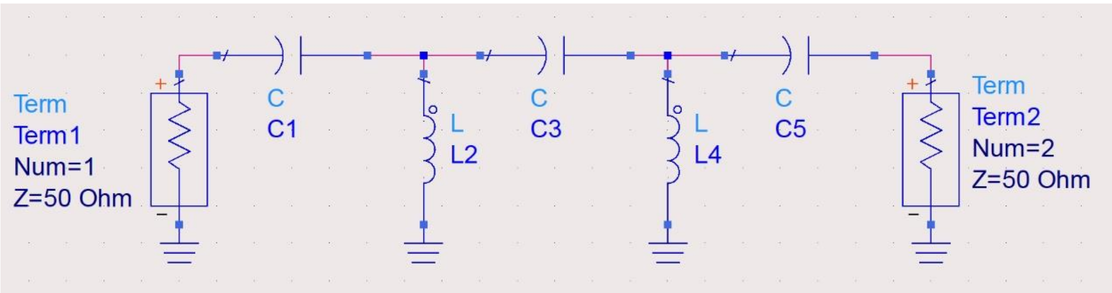
Subject no. 59

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (37.9 + j\cdot 33.6)\Omega = 0.739 + j\cdot 0.655$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.739 + j\cdot 0.655)] / (1 + 0.739 + j\cdot 0.655)$
$\Gamma = (0.007) + j\cdot(0.379) \leftrightarrow \mathrm{Re}\Gamma + j\cdot \mathrm{Im}\Gamma$ or $\Gamma = 0.380\angle 88.9° \leftrightarrow |\Gamma|\angle \arg(\Gamma)$

2. a) $P_c = P_{in} - C = 4.4\text{dBm} - 5.50\text{dB} = -1.10\text{dBm}$;
b) $P_{in} = 4.4\text{dBm} = 2.754\text{mW}$; $P_c = -1.10\text{dBm} = 0.776\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 2.754\text{mW} - 0.776\text{mW} = 1.978\text{mW} = 2.962\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.531$, $y_2 = 1.180$, $y_1 = 0.626$, $Z_1 = Z_0/y_1 = 79.8\ \Omega$, $Z_2 = Z_0/y_2 = 42.4\Omega$

3. a) $Z = 19.51\Omega + j\cdot(-28.10)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.237 + j\cdot(-0.500) = 0.553\angle{-115.3°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.553$; $\varphi = \arg(\Gamma) = -115.3°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 119.5°$; $\mathrm{Im}(y_S) = -1.328$; $\theta_{P1} = 127.0°$ **or** $\theta_{S2} = 175.9°$; $\mathrm{Im}(y_S) = 1.328$; $\theta_{P2} = 53.0°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 315\text{MHz} = 1.979\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no $\lambda/4$ transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 16.351\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 15.614\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 5.053\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 15.614\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 16.351\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 315 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 315$ MHz; In the stopband (f < 315 MHz) the attenuation for 5th order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 157.5$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 19.3\text{dB} + 19.2\text{dB} + 16.5\text{dB} = 55.0\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 316{,}227.8$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A2, A1, A3 so: $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$; $F_1 = 3.19\text{dB} = 2.084$, $G_1 = 19.3\text{dB} = 85.114$, $F_2 = 4.02\text{dB} = 2.523$, $G_2 = 19.2\text{dB} = 83.176$, $F_3 = 5.91\text{dB} = 3.899$, $G_3 = 16.5\text{dB} = 44.668$;
$F = 2.523 + (2.084-1)/83.176 + (3.899-1)/83.176/85.114 = 2.537 = 4.043\text{dB}$
c) If the order is A3, A1, A2 the gain remains the same but $F = F_3 + (F_1-1)/G_3 + (F_2-1)/G_3/G_1$;
$F = 3.899 + (2.084-1)/44.668 + (2.523-1)/44.668/85.114 = 3.924 = 5.937\text{dB}$

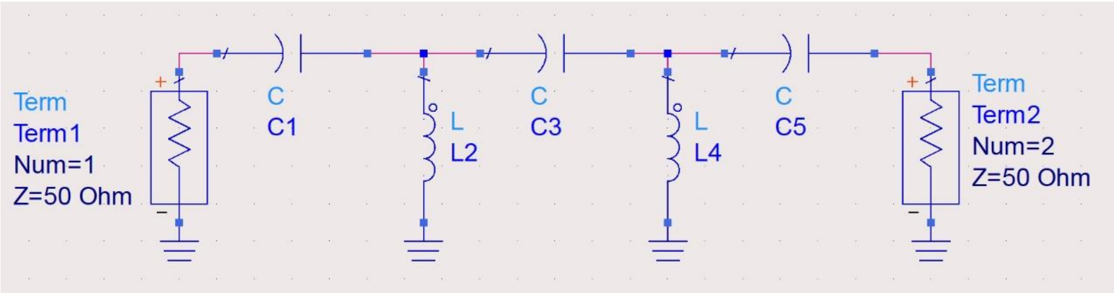
Subject no. 60

1. $y = Y/Y_0 = Z_0/Z = 50\Omega / (63.0 - j\cdot 59.6)\Omega = 0.419 - j\cdot 0.396$;
$\Gamma = (1 - y) / (1 + y) = [1 - (0.419 - j\cdot 0.396)] / (1 + 0.419 - j\cdot 0.396)$
$\Gamma = (0.308) + j\cdot(-0.365) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.477\angle{-49.9°} \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

2. a) $P_c = P_{in} - C = 2.4\text{dBm} - 4.75\text{dB} = -2.35\text{dBm}$;
b) $P_{in} = 2.4\text{dBm} = 1.738\text{mW}$; $P_c = -2.35\text{dBm} = 0.582\text{mW}$;
Lossless coupler $P_{th} = P_{in} - P_c = 1.738\text{mW} - 0.582\text{mW} = 1.156\text{mW} = 0.628\text{dBm}$
c) L2, C12/2017, $\beta = 10^{-C/20} = 0.579$, $y_2 = 1.226$, $y_1 = 0.710$, $Z_1 = Z_0/y_1 = 70.5\ \Omega$, $Z_2 = Z_0/y_2 = 40.8\Omega$

3. a) $Z = 24.51\Omega + j\cdot(-33.02)\Omega$; $\Gamma = (Z - Z_0)/(Z + Z_0) = -0.122 + j\cdot(-0.497) = 0.512\angle{-103.8°}$;
b) plot point (Γ) in complex plane either with rectangular coordinates or polar coordinates.
c) $|\Gamma| = 0.512$; $\varphi = \arg(\Gamma) = -103.8°$; Complex calculus from L8/2024, S114÷115, all lines have $Z_0 = 50\Omega$
$\theta_{S1} = 112.3°$; $\mathrm{Im}(y_S) = -1.192$; $\theta_{P1} = 130.0°$ **or** $\theta_{S2} = 171.5°$; $\mathrm{Im}(y_S) = 1.192$; $\theta_{P2} = 50.0°$
c) source (50Ω), shunt stub (50Ω, $\theta_{P1/2}$), series line (50Ω, $\theta_{S1/2}$), paralel circuit: resistor + capacitor

4. a) Cutoff frequency $\omega_c = 2\cdot\pi\cdot f_c = 2\cdot\pi\cdot 575\text{MHz} = 3.613\cdot 10^9$ rad/s ; $R_0 = 50\Omega$. Filter coefficients from tables in Lect.11/2024, Sd. 120,122, for an maximally flat filter: $g_1 = 0.6180$, $g_2 = 1.6180$, $g_3 = 2.0000$, $g_4 = 1.6180$, $g_5 = 0.6180$, $g_6 = 1$ (works directly on 50Ω load, no λ/4 transformer needed).
Element equations depend on filter type (**high-pass filter (HPF)**) and on choice between starting the prototype filter with series inductor or shunt capacitor. If we choose to start with series inductor:
g_1 : series capacitor $C_1 = 1 / R_0 / g_1 / \omega_c = 8.958\text{pF}$; g_2 : shunt inductor $L_2 = R_0 / g_2 / \omega_c = 8.553\text{nH}$;
g_3 : series capacitor $C_3 = 1 / R_0 / g_3 / \omega_c = 2.768\text{pF}$; g_4 : shunt inductor $L_4 = R_0 / g_4 / \omega_c = 8.553\text{nH}$;
g_5 : series capacitor $C_5 = 1 / R_0 / g_5 / \omega_c = 8.958\text{pF}$;
b) Draw the schematic:



c) In the passband (f > 575 MHz) we have maximally flat behavior, maximum attenuation $L_{Ar} = 3.0$ dB, including at the cutoff frequency $f_1 = 575$ MHz; In the stopband (f < 575 MHz) the attenuation for 5^{th} order, maximally flat filter can be estimated from Lect.11/2024, equations in Sd. 109-110 or plots in Sd. 113-115, for $|\omega / \omega_c| - 1 = 1$ (equivalent to: $\omega = \omega_c / 2$) so at $f_s = 287.5$ MHz the attenuation is $L_{As} = 30.107$ dB; Draw a plot similar to Lect. 11 Sd. 104.

5. a) Whatever the order in which the amplifiers are connected:
$G[\text{dB}] = G_1 + G_2 + G_3 = 16.5\text{dB} + 24.4\text{dB} + 23.7\text{dB} = 64.6\text{dB}$; $G[\text{lin}] = 10^{G[\text{dB}]/10} = 2{,}884{,}031.5$
b) 3 amplifiers Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$ but the connection order is A1, A3, A2 so: $F = F_1 + (F_3-1)/G_1 + (F_2-1)/G_1/G_3$; $F_1 = 3.42\text{dB} = 2.198$, $G_1 = 16.5\text{dB} = 44.668$, $F_2 = 4.13\text{dB} = 2.588$, $G_2 = 24.4\text{dB} = 275.423$, $F_3 = 5.94\text{dB} = 3.926$, $G_3 = 23.7\text{dB} = 234.423$;
$F = 2.198 + (3.926-1)/44.668 + (2.588-1)/44.668/234.423 = 2.264 = 3.548\text{dB}$
c) If the order is A2, A1, A3 the gain remains the same but $F = F_2 + (F_1-1)/G_2 + (F_3-1)/G_2/G_1$;
$F = 2.588 + (2.198-1)/275.423 + (3.926-1)/275.423/44.668 = 2.593 = 4.138\text{dB}$