Subject no. 1

1. Z_L = 37Ω paralel with 1.15nH inductor at 7.1GHz . It's easier to compute first: a) Y_L = 0.0270S + j·(-0.0195)S, y = Y_L·50Ω = 1.351 + j·(-0.975) then b) z = 1/y = 0.487 + j·(0.351
2. a) Γ = (z − 1) / (z + 1) = (0.880 + j·1.020 − 1) / (0.880 + j·1.020 + 1)
Γ = (0.178) + j·(0.446) ↔ ReΓ + j·ImΓ or Γ = 0.480∠68.2° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 26Ω load to a 50Ω source at f_1 = 7.3GHz so Z_1 = √(Z_0·Z_L) = 36.056 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.9GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1$ = 0.199·π = 0.624; tan(β·l) = 0.720

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 31.10\Omega + j\cdot(9.81)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 22.571Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/7) = 2π/7 ; C = tg(β·l) / (2·π·f) / Z_0 = 1.065pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.640∠-154.1° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.550∠143.0°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 141.9° ; Im(y_S) = -1.666 ; θ_{p1} = 121.0° <u>or</u> θ_{S2} = 12.2° ; Im(y_S) = 1.666 ; θ_{p2} = 59.0°
output: θ_{L1} = 170.2° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° <u>or</u> θ_{L2} = 46.8° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.694 = 2.289dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 3.059 = 4.856dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.289dB + 4.856dB + 1.565dB = 8.709dB
d) P_{in} = 135μW = -8.697dBm; $P_{out} = P_{in} + G_T$ = -8.697dBm + 8.709dB = 0.012dBm = 1.003mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.640 < 1 ; $|S_{22}|$ = 0.550 < 1 ; K = 1.177 > 1 ; |Δ| = |(0.229)+ j·(0.174)| = 0.288 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 2

1. Z_L = 50Ω series with 0.78nH inductor at 8.5GHz . It's easier to compute first: b) Z_L = 50.00Ω + j·(41.66)Ω, z = Z_L/50Ω = 1.000 + j·(0.833) then a) y = 1/z = 0.590 + j·(-0.492)
2. a) Γ = (z − 1) / (z + 1) = (0.730 − j·0.990 − 1) / (0.730 − j·0.990 + 1)
Γ = (0.129) + j·(-0.498) ↔ ReΓ + j·ImΓ or Γ = 0.515∠-75.5° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 50Ω load to a 50Ω source at f_1 = 9.0GHz so Z_1 = √(Z_0·Z_L) = 50.000 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 3.6GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1$ = 0.200·π = 0.628; tan(β·l) = 0.727

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 50.00\Omega + j\cdot(0.00)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 20.156Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/10) = 2π/10 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.463pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.692∠167.8° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠118.3°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 163.0° ; Im(y_S) = -1.917 ; θ_{p1} = 117.5° <u>or</u> θ_{S2} = 29.2° ; Im(y_S) = 1.917 ; θ_{p2} = 62.5°
output: θ_{L1} = 2.9° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 58.8° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°

b) The shunt stubs **must** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2) = 1.919 = 2.830dB$; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2) = 1.457 = 1.634dB$; $G_0 = |S_{21}|^2 = 3.865 = 5.872dB$;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax} = 2.830dB + 5.872dB + 1.634dB = 10.336dB$

d) $P_{in} = 135\mu W = -8.697dBm$; $P_{out} = P_{in} + G_T = -8.697dBm + 10.336dB = 1.640dBm = 1.459mW$

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}| = 0.692 < 1$; $|S_{22}| = 0.560 < 1$; $K = 1.062 > 1$; $|\Delta| = |(-0.049)+ j\cdot(0.352)| = 0.356 < 1$, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 3

1. $Z_L = 25\Omega$ series with 1.00nH inductor at 9.4GHz . It's easier to compute first: b) $Z_L = 25.00\Omega + j\cdot(59.06)\Omega$, $z = Z_L/50\Omega = 0.500 + j\cdot(1.181)$ then a) $y = 1/z = 0.304 + j\cdot(-0.718)$

2. a) $\Gamma = (z - 1) / (z + 1) = (0.895 - j\cdot0.750 - 1) / (0.895 - j\cdot0.750 + 1)$

$\Gamma = (0.088) + j\cdot(-0.361) \leftrightarrow Re\Gamma + j\cdot Im\Gamma$ or $\Gamma = 0.372\angle{-76.4°} \leftrightarrow |\Gamma|\angle arg(\Gamma)$

3. The quarter wave transformer is designed to match a 41Ω load to a 50Ω source at $f_1 = 6.7GHz$ so $Z_1 = \sqrt{(Z_0\cdot Z_L)} = 45.277\ \Omega$ and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At $f_2 = 3.9GHz$ the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.291\cdot\pi = 0.914$; $\tan(\beta\cdot l) = 1.298$

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 46.22\Omega + j\cdot(4.44)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C} = 35.806\Omega$.

For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/9) = 2\pi/9$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0 = 0.266pF$

5. a) $S_{12} = 0$, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; $\Gamma_S = 0.688\angle{-103.7°}$; Maximum gain match of the load $\Gamma_L = S_{22}^*$; $\Gamma_L = 0.298\angle{-153.2°}$

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have $Z_0 = 50\Omega$

input: $\theta_{S1} = 118.6°$; $Im(y_S) = -1.896$; $\theta_{p1} = 117.8°$ <u>or</u> $\theta_{S2} = 165.1°$; $Im(y_S) = 1.896$; $\theta_{p2} = 62.2°$

output: $\theta_{L1} = 130.3°$; $Im(y_L) = -0.624$; $\theta_{p1} = 148.0°$ <u>or</u> $\theta_{L2} = 22.9°$; $Im(y_L) = 0.624$; $\theta_{p2} = 32.0°$

b) The shunt stubs **must** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2) = 1.899 = 2.785dB$; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2) = 1.097 = 0.404dB$; $G_0 = |S_{21}|^2 = 2.843 = 4.537dB$;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax} = 2.785dB + 4.537dB + 0.404dB = 7.726dB$

d) $P_{in} = 105\mu W = -9.788dBm$; $P_{out} = P_{in} + G_T = -9.788dBm + 7.726dB = -2.062dBm = 0.622mW$

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}| = 0.688 < 1$; $|S_{22}| = 0.298 < 1$; $K = 1.118 > 1$; $|\Delta| = |(-0.259)+ j\cdot(-0.109)| = 0.281 < 1$, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 4

1. $Z_L = 63\Omega$ paralel with 1.13nH inductor at 9.5GHz . It's easier to compute first: a) $Y_L = 0.0159S + j\cdot(-0.0148)S$, $y = Y_L\cdot 50\Omega = 0.794 + j\cdot(-0.741)$ then b) $z = 1/y = 0.673 + j\cdot(0.629$

2. a) $\Gamma = (z - 1) / (z + 1) = (1.025 - j\cdot1.000 - 1) / (1.025 - j\cdot1.000 + 1)$

$\Gamma = (0.206) + j\cdot(-0.392) \leftrightarrow Re\Gamma + j\cdot Im\Gamma$ or $\Gamma = 0.443\angle{-62.3°} \leftrightarrow |\Gamma|\angle arg(\Gamma)$

3. The quarter wave transformer is designed to match a 37Ω load to a 50Ω source at $f_1 = 7.0GHz$ so $Z_1 = \sqrt{(Z_0\cdot Z_L)} = 43.012\ \Omega$ and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At $f_2 = 4.0GHz$ the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.286\cdot\pi = 0.898$; $\tan(\beta\cdot l) = 1.254$

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 43.99\Omega + j\cdot(6.48)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 26.049Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/7) = 2π/7 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.594pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.660∠-173.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.555∠135.0°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 152.1° ; Im(y_S) = -1.757 ; θ_{p1} = 119.6° <u>or</u> θ_{S2} = 20.9° ; Im(y_S) = 1.757 ; θ_{p2} = 60.4°
output: θ_{L1} = 174.4° ; Im(y_L) = -1.334 ; θ_{p1} = 126.8° <u>or</u> θ_{L2} = 50.6° ; Im(y_L) = 1.334 ; θ_{p2} = 53.2°
b) The shunt stubs **must** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.772 = 2.484dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.445 = 1.599dB; $G_0 = |S_{21}|^2$ = 3.276 = 5.154dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.484dB + 5.154dB + 1.599dB = 9.237dB
d) P_{in} = 130μW = -8.861dBm; $P_{out} = P_{in} + G_T$ = -8.861dBm + 9.237dB = 0.376dBm = 1.090mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.660 < 1 ; $|S_{22}|$ = 0.555 < 1 ; K = 1.125 > 1 ; |Δ| = |(0.144)+ j·(0.299)| = 0.332 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 5</u>
1. Z_L = 61Ω series with 1.32nH inductor at 6.5GHz . It's easier to compute first: b) Z_L = 61.00Ω + j·(53.91)Ω, z = Z_L/50Ω = 1.220 + j·(1.078) then a) y = 1/z = 0.460 + j·(-0.407)
2. a) Γ = (z − 1) / (z + 1) = (1.290 + j·0.970 − 1) / (1.290 + j·0.970 + 1)
Γ = (0.259) + j·(0.314) ↔ ReΓ + j·ImΓ or Γ = 0.407∠50.4° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 35Ω load to a 50Ω source at f_1 = 7.1GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 41.833 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.2GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.155\cdot\pi$ = 0.487; tan(β·l) = 0.529

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 37.46\Omega + j\cdot(5.55)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 24.027Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/13) = 2π/13 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.241pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.680∠172.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠128.2°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 160.4° ; Im(y_S) = -1.855 ; θ_{p1} = 118.3° <u>or</u> θ_{S2} = 27.6° ; Im(y_S) = 1.855 ; θ_{p2} = 61.7°
output: θ_{L1} = 177.9° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 53.9° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°
b) The shunt stubs **must** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.860 = 2.695dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.501 = 5.441dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.695dB + 5.441dB + 1.634dB = 9.771dB
d) P_{in} = 140μW = -8.539dBm; $P_{out} = P_{in} + G_T$ = -8.539dBm + 9.771dB = 1.232dBm = 1.328mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.680 < 1 ; $|S_{22}|$ = 0.560 < 1 ; K = 1.093 > 1 ; |Δ| = |(0.031)+ j·(0.367)| = 0.369 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 6

1. $Z_L = 25\Omega$ paralel with 0.56pF capacitor at 7.2GHz . It's easier to compute first: a) $Y_L = 0.0400S + j\cdot(0.0253)S$, $y = Y_L\cdot 50\Omega = 2.000 + j\cdot(1.267)$ then b) $z = 1/y = 0.357 + j\cdot(-0.226$

2. a) $\Gamma = (z - 1) / (z + 1) = (0.740 - j\cdot 1.055 - 1) / (0.740 - j\cdot 1.055 + 1)$

$\Gamma = (0.160) + j\cdot(-0.510) \leftrightarrow Re\Gamma + j\cdot Im\Gamma$ or $\Gamma = 0.534\angle{-72.6°} \leftrightarrow |\Gamma|\angle arg(\Gamma)$

3. The quarter wave transformer is designed to match a 50Ω load to a 50Ω source at $f_1 = 7.7GHz$ so $Z_1 = \sqrt{(Z_0\cdot Z_L)} = 50.000\ \Omega$ and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At $f_2 = 2.4GHz$ the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.156\cdot\pi = 0.490$; $\tan(\beta\cdot l) = 0.533$

$$Z_{in} = Z_1\cdot\frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 50.00\Omega + j\cdot(0.00)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C} = 25.908\Omega$.

For a section of an open-circuited transmission line $Z_{in} = - j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/ (j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/6) = 2\pi/6$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0 = 1.400pF$

5. a) $S_{12} = 0$, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; $\Gamma_S = 0.680\angle 172.0°$; Maximum gain match of the load $\Gamma_L = S_{22}^*$; $\Gamma_L = 0.560\angle 130.0°$

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have $Z_0 = 50\Omega$

input: $\theta_{S1} = 160.4°$; $Im(y_S) = -1.855$; $\theta_{p1} = 118.3°$ or $\theta_{S2} = 27.6°$; $Im(y_S) = 1.855$; $\theta_{p2} = 61.7°$

output: $\theta_{L1} = 177.0°$; $Im(y_L) = -1.352$; $\theta_{p1} = 126.5°$ or $\theta_{L2} = 53.0°$; $Im(y_L) = 1.352$; $\theta_{p2} = 53.5°$

b) The shunt stubs **must** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2) = 1.860 = 2.695dB$; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2) = 1.457 = 1.634dB$; $G_0 = |S_{21}|^2 = 3.437 = 5.362dB$;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax} = 2.695dB + 5.362dB + 1.634dB = 9.692dB$

d) $P_{in} = 75\mu W = -11.249dBm$; $P_{out} = P_{in} + G_T = -11.249dBm + 9.692dB = -1.558dBm = 0.699mW$

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}| = 0.680 < 1$; $|S_{22}| = 0.560 < 1$; $K = 1.091 > 1$; $|\Delta| = |(0.042)+ j\cdot(0.372)| = 0.374 < 1$, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 7

1. $Z_L = 58\Omega$ paralel with 0.26pF capacitor at 9.6GHz . It's easier to compute first: a) $Y_L = 0.0172S + j\cdot(0.0157)S$, $y = Y_L\cdot 50\Omega = 0.862 + j\cdot(0.784)$ then b) $z = 1/y = 0.635 + j\cdot(-0.577$

2. a) $\Gamma = (z - 1) / (z + 1) = (0.725 - j\cdot 0.800 - 1) / (0.725 - j\cdot 0.800 + 1)$

$\Gamma = (0.046) + j\cdot(-0.443) \leftrightarrow Re\Gamma + j\cdot Im\Gamma$ or $\Gamma = 0.445\angle{-84.1°} \leftrightarrow |\Gamma|\angle arg(\Gamma)$

3. The quarter wave transformer is designed to match a 43Ω load to a 50Ω source at $f_1 = 9.5GHz$ so $Z_1 = \sqrt{(Z_0\cdot Z_L)} = 46.368\ \Omega$ and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At $f_2 = 2.0GHz$ the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.105\cdot\pi = 0.331$; $\tan(\beta\cdot l) = 0.343$

$$Z_{in} = Z_1\cdot\frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 43.64\Omega + j\cdot(2.02)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C} = 29.345\Omega$.

For a section of an open-circuited transmission line $Z_{in} = - j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/ (j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/14) = 2\pi/14$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0 = 0.179pF$

5. a) $S_{12} = 0$, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; $\Gamma_S = 0.640\angle{-158.0°}$; Maximum gain match of the load $\Gamma_L = S_{22}^*$; $\Gamma_L = 0.550\angle 140.0°$

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have $Z_0 = 50\Omega$

input: $\theta_{S1} = 143.9°$; $Im(y_S) = -1.666$; $\theta_{p1} = 121.0°$ or $\theta_{S2} = 14.1°$; $Im(y_S) = 1.666$; $\theta_{p2} = 59.0°$

output: θ_{L1} = 171.7° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° or θ_{L2} = 48.3° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°
b) The shunt stubs **must** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.694 = 2.289dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 3.119 = 4.940dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.289dB + 4.940dB + 1.565dB = 8.793dB
d) P_{in} = 110μW = -9.586dBm; $P_{out} = P_{in} + G_T$ = -9.586dBm + 8.793dB = -0.793dBm = 0.833mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}| = 0.640 < 1$; $|S_{22}| = 0.550 < 1$; K = 1.173 > 1 ; |Δ| = |(0.208)+ j·(0.204)| = 0.292 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 8

1. Z_L = 57Ω paralel with 0.55nH inductor at 8.6GHz . It's easier to compute first: a) Y_L = 0.0175S + j·(-0.0336)S, y = Y_L·50Ω = 0.877 + j·(-1.682) then b) z = 1/y = 0.244 + j·(0.467
2. a) Γ = (z − 1) / (z + 1) = (1.190 + j·1.025 − 1) / (1.190 + j·1.025 + 1)
Γ = (0.251) + j·(0.351) ↔ ReΓ + j·ImΓ or Γ = 0.431∠54.4° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 72Ω load to a 50Ω source at f_1 = 8.8GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 60.000 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 3.8GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.216\cdot\pi$ = 0.678; tan(β·l) = 0.806
$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)} = 61.37\Omega + j\cdot(-10.99)\Omega$$
4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 32.787Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/14) = 2π/14 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.231pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.680∠172.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠127.3°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 160.4° ; Im(y_S) = -1.855 ; θ_{p1} = 118.3° or θ_{S2} = 27.6° ; Im(y_S) = 1.855 ; θ_{p2} = 61.7°
output: θ_{L1} = 178.4° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° or θ_{L2} = 54.3° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°
b) The shunt stubs **must** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.860 = 2.695dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.534 = 5.483dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.695dB + 5.483dB + 1.634dB = 9.813dB
d) P_{in} = 120μW = -9.208dBm; $P_{out} = P_{in} + G_T$ = -9.208dBm + 9.813dB = 0.605dBm = 1.149mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}| = 0.680 < 1$; $|S_{22}| = 0.560 < 1$; K = 1.094 > 1 ; |Δ| = |(0.026)+ j·(0.365)| = 0.366 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 9

1. Z_L = 68Ω series with 0.49nH inductor at 8.3GHz . It's easier to compute first: b) Z_L = 68.00Ω + j·(25.55)Ω, z = Z_L/50Ω = 1.360 + j·(0.511) then a) y = 1/z = 0.644 + j·(-0.242)
2. a) Γ = (z − 1) / (z + 1) = (0.815 − j·1.280 − 1) / (0.815 − j·1.280 + 1)
Γ = (0.264) + j·(-0.519) ↔ ReΓ + j·ImΓ or Γ = 0.582∠-63.0° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 63Ω load to a 50Ω source at f_1 = 7.1GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 56.125 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.7GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.190\cdot\pi$ = 0.597; tan(β·l) = 0.680

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 58.21Ω + j·(-6.27)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 24.450Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/9) = 2π/9 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.587pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.640∠-148.9° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.550∠147.0°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 139.3° ; Im(y_S) = -1.666 ; θ_{p1} = 121.0° <u>or</u> θ_{S2} = 9.6° ; Im(y_S) = 1.666 ; θ_{p2} = 59.0°

output: θ_{L1} = 168.2° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° <u>or</u> θ_{L2} = 44.8° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°

b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.694 = 2.289dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 2.979 = 4.741dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.289dB + 4.741dB + 1.565dB = 8.594dB

d) P_{in} = 125μW = -9.031dBm; $P_{out} = P_{in} + G_T$ = -9.031dBm + 8.594dB = -0.437dBm = 0.904mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.640 < 1 ; $|S_{22}|$ = 0.550 < 1 ; K = 1.184 > 1 ; |Δ| = |(0.251)+ j·(0.130)| = 0.283 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 10</u>

1. Z_L = 55Ω paralel with 0.71nH inductor at 8.5GHz . It's easier to compute first: a) Y_L = 0.0182S + j·(-0.0264)S, y = Y_L·50Ω = 0.909 + j·(-1.319) then b) z = 1/y = 0.354 + j·(0.514

2. a) Γ = (z − 1) / (z + 1) = (0.935 − j·0.740 − 1) / (0.935 − j·0.740 + 1)

Γ = (0.098) + j·(-0.345) ↔ ReΓ + j·ImΓ or Γ = 0.359∠-74.1° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 48Ω load to a 50Ω source at f_1 = 9.5GHz so $Z_1 = \sqrt{(Z_0 \cdot Z_L)}$ = 48.990 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 3.5GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2 \cdot \pi/\lambda_2 \cdot l_1 = 2 \cdot \pi/(c/f_2) \cdot (c/4/f_1) = \pi/2 \cdot f_2/f_1 = 0.184 \cdot \pi$ = 0.579; tan(β·l) = 0.653

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 48.58Ω + j·(0.91)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 38.534Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/9) = 2π/9 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.271pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.680∠172.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠124.6°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 160.4° ; Im(y_S) = -1.855 ; θ_{p1} = 118.3° <u>or</u> θ_{S2} = 27.6° ; Im(y_S) = 1.855 ; θ_{p2} = 61.7°

output: θ_{L1} = 179.7° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 55.7° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°

b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.860 = 2.695dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.633 = 5.602dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.695dB + 5.602dB + 1.634dB = 9.932dB

d) P_{in} = 120μW = -9.208dBm; $P_{out} = P_{in} + G_T$ = -9.208dBm + 9.932dB = 0.724dBm = 1.181mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.680 < 1 ; $|S_{22}|$ = 0.560 < 1 ; K = 1.100 > 1 ; |Δ| = |(0.011)+ j·(0.358)| = 0.358 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 11

1. Z_L = 50Ω series with 0.99nH inductor at 7.0GHz . It's easier to compute first: b) Z_L = 50.00Ω + j·(43.54)Ω, z = Z_L/50Ω = 1.000 + j·(0.871) then a) y = 1/z = 0.569 + j·(-0.495)
2. a) Γ = (z − 1) / (z + 1) = (0.925 + j·1.175 − 1) / (0.925 + j·1.175 + 1)
Γ = (0.243) + j·(0.462) ↔ ReΓ + j·ImΓ or Γ = 0.522∠62.3° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 27Ω load to a 50Ω source at f_1 = 10.0GHz so Z_1 = √(Z_0·Z_L) = 36.742 Ω and the line physical length is l_1 = λ_1/4 = c/4/f_1.
At f_2 = 4.1GHz the characteristic impedance and physical length do not change but β·l = β_2·l_1 = 2·π/λ_2·l_1 = 2·π/(c/f_2)·(c/4/f_1) = π/2·f_2/f_1 = 0.205·π = 0.644; tan(β·l) = 0.751
$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 32.37Ω + j·(9.73)Ω
4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 33.622Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/7) = 2π/7 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.530pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.676∠-106.4° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.286∠-157.4°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 119.5° ; Im(y_S) = -1.835 ; θ_{p1} = 118.6° <u>or</u> θ_{S2} = 166.9° ; Im(y_S) = 1.835 ; θ_{p2} = 61.4°
output: θ_{L1} = 132.0° ; Im(y_L) = -0.597 ; θ_{p1} = 149.2° <u>or</u> θ_{L2} = 25.4° ; Im(y_L) = 0.597 ; θ_{p2} = 30.8°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.842 = 2.652dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.089 = 0.371dB; $G_0 = |S_{21}|^2$ = 2.965 = 4.721dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.652dB + 4.721dB + 0.371dB = 7.743dB
d) P_{in} = 55μW = -12.596dBm; $P_{out} = P_{in} + G_T$ = -12.596dBm + 7.743dB = -4.853dBm = 0.327mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.676 < 1 ; $|S_{22}|$ = 0.286 < 1 ; K = 1.155 > 1 ; |Δ| = |(-0.240)+ j·(-0.119)| = 0.268 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 12

1. Z_L = 32Ω series with 0.38pF capacitor at 8.9GHz . It's easier to compute first: b) Z_L = 32.00Ω + j·(-47.06)Ω, z = Z_L/50Ω = 0.640 + j·(-0.941) then a) y = 1/z = 0.494 + j·(0.727)
2. a) Γ = (z − 1) / (z + 1) = (1.025 − j·0.925 − 1) / (1.025 − j·0.925 + 1)
Γ = (0.183) + j·(-0.373) ↔ ReΓ + j·ImΓ or Γ = 0.416∠-63.9° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 57Ω load to a 50Ω source at f_1 = 8.8GHz so Z_1 = √(Z_0·Z_L) = 53.385 Ω and the line physical length is l_1 = λ_1/4 = c/4/f_1.
At f_2 = 3.4GHz the characteristic impedance and physical length do not change but β·l = β_2·l_1 = 2·π/λ_2·l_1 = 2·π/(c/f_2)·(c/4/f_1) = π/2·f_2/f_1 = 0.193·π = 0.607; tan(β·l) = 0.694
$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 54.52Ω + j·(-3.35)Ω
4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 18.550Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/13) = 2π/13 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.617pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.680∠172.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠126.4°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 160.4° ; Im(y_S) = -1.855 ; θ_{p1} = 118.3° <u>or</u> θ_{S2} = 27.6° ; Im(y_S) = 1.855 ; θ_{p2} = 61.7°

output: θ_{L1} = 178.8° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 54.8° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.860 = 2.695dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.565 = 5.520dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.695dB + 5.520dB + 1.634dB = 9.850dB
d) P_{in} = 50μW = -13.010dBm; $P_{out} = P_{in} + G_T$ = -13.010dBm + 9.850dB = -3.161dBm = 0.483mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.680 < 1 ; $|S_{22}|$ = 0.560 < 1 ; K = 1.096 > 1 ; |Δ| = |(0.021)+ j·(0.363)| = 0.363 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 13</u>

1. Z_L = 67Ω series with 0.25pF capacitor at 8.9GHz . It's easier to compute first: b) Z_L = 67.00Ω + j·(-71.53)Ω, z = Z_L/50Ω = 1.340 + j·(-1.431) then a) y = 1/z = 0.349 + j·(0.372)
2. a) Γ = (z − 1) / (z + 1) = (0.720 + j·1.185 − 1) / (0.720 + j·1.185 + 1)
Γ = (0.211) + j·(0.543) ↔ ReΓ + j·ImΓ or Γ = 0.583∠68.7° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 47Ω load to a 50Ω source at f_1 = 9.0GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 48.477 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.9GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.161\cdot\pi$ = 0.506; tan(β·l) = 0.554

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)} = 47.67\Omega + j\cdot(1.25)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 36.018Ω.
For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0 \cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/8) = 2\pi/8$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0$ = 0.388pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.684∠170.6° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠120.1°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 161.3° ; Im(y_S) = -1.875 ; θ_{p1} = 118.1° <u>or</u> θ_{S2} = 28.1° ; Im(y_S) = 1.875 ; θ_{p2} = 61.9°
output: θ_{L1} = 2.0° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 57.9° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.879 = 2.740dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.795 = 5.792dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.740dB + 5.792dB + 1.634dB = 10.166dB
d) P_{in} = 70μW = -11.549dBm; $P_{out} = P_{in} + G_T$ = -11.549dBm + 10.166dB = -1.383dBm = 0.727mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.684 < 1 ; $|S_{22}|$ = 0.560 < 1 ; K = 1.095 > 1 ; |Δ| = |(-0.020)+ j·(0.350)| = 0.350 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 14</u>

1. Z_L = 57Ω series with 0.54nH inductor at 9.7GHz . It's easier to compute first: b) Z_L = 57.00Ω + j·(32.91)Ω, z = Z_L/50Ω = 1.140 + j·(0.658) then a) y = 1/z = 0.658 + j·(-0.380)
2. a) Γ = (z − 1) / (z + 1) = (1.050 + j·1.100 − 1) / (1.050 + j·1.100 + 1)
Γ = (0.242) + j·(0.406) ↔ ReΓ + j·ImΓ or Γ = 0.473∠59.2° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 62Ω load to a 50Ω source at f_1 = 7.0GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 55.678 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 3.7GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.264\cdot\pi$ = 0.830; tan(β·l) = 1.094

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 54.83Ω + j·(-5.88)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 18.363Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/14) = 2π/14 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.373pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.640∠-145.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.550∠150.0°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 137.4° ; Im(y_S) = -1.666 ; θ_{p1} = 121.0° <u>or</u> θ_{S2} = 7.6° ; Im(y_S) = 1.666 ; θ_{p2} = 59.0°
output: θ_{L1} = 166.7° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° <u>or</u> θ_{L2} = 43.3° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.694 = 2.289dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 2.921 = 4.655dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.289dB + 4.655dB + 1.565dB = 8.508dB
d) P_{in} = 125μW = -9.031dBm; $P_{out} = P_{in} + G_T$ = -9.031dBm + 8.508dB = -0.523dBm = 0.887mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.640 < 1 ; $|S_{22}|$ = 0.550 < 1 ; K = 1.189 > 1 ; |Δ| = |(0.262)+ j·(0.095)| = 0.279 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 15</u>

1. Z_L = 56Ω series with 0.37pF capacitor at 7.0GHz . It's easier to compute first: b) Z_L = 56.00Ω + j·(-61.45)Ω, z = Z_L/50Ω = 1.120 + j·(-1.229) then a) y = 1/z = 0.405 + j·(0.445)

2. a) Γ = (z − 1) / (z + 1) = (0.755 + j·1.020 − 1) / (0.755 + j·1.020 + 1)
Γ = (0.148) + j·(0.495) ↔ ReΓ + j·ImΓ or Γ = 0.517∠73.3° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 53Ω load to a 50Ω source at f_1 = 9.9GHz so $Z_1 = \sqrt{(Z_0 \cdot Z_L)}$ = 51.478 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 4.0GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2 \cdot \pi/\lambda_2 \cdot l_1 = 2 \cdot \pi/(c/f_2) \cdot (c/4/f_1) = \pi/2 \cdot f_2/f_1$ = 0.202·π = 0.635; tan(β·l) = 0.736

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 51.91Ω + j·(-1.44)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 27.832Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/10) = 2π/10 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.301pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.688∠169.2° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠119.2°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 162.1° ; Im(y_S) = -1.896 ; θ_{p1} = 117.8° <u>or</u> θ_{S2} = 28.7° ; Im(y_S) = 1.896 ; θ_{p2} = 62.2°
output: θ_{L1} = 2.4° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 58.4° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.899 = 2.785dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.830 = 5.832dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.785dB + 5.832dB + 1.634dB = 10.251dB
d) P_{in} = 55μW = -12.596dBm; $P_{out} = P_{in} + G_T$ = -12.596dBm + 10.251dB = -2.346dBm = 0.583mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.688 < 1 ; $|S_{22}|$ = 0.560 < 1 ; K = 1.079 > 1 ; |Δ| = |(-0.034)+ j·(0.351)| = 0.353 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 16

1. Z_L = 48Ω paralel with 0.30pF capacitor at 7.5GHz . It's easier to compute first: a) Y_L = 0.0208S + j·(0.0141)S, y = Y_L·50Ω = 1.042 + j·(0.707) then b) z = 1/y = 0.657 + j·(-0.446

2. a) Γ = (z − 1) / (z + 1) = (1.265 − j·1.250 − 1) / (1.265 − j·1.250 + 1)

Γ = (0.323) + j·(-0.374) ↔ ReΓ + j·ImΓ or Γ = 0.494∠-49.1° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 33Ω load to a 50Ω source at f_1 = 8.1GHz so Z_1 = √(Z_0·Z_L) = 40.620 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 4.3GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.265\cdot\pi = 0.834$; tan(β·l) = 1.102

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 40.56\Omega + j\cdot(8.45)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 19.540Ω.

For a section of an open-circuited transmission line $Z_{in} = - j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/ (j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/11) = 2\pi/11$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0$ = 0.400pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.684∠-104.6° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.294∠-154.6°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 118.9° ; Im(y_S) = -1.875 ; θ_{p1} = 118.1° or θ_{S2} = 165.7° ; Im(y_S) = 1.875 ; θ_{p2} = 61.9°

output: θ_{L1} = 130.8° ; Im(y_L) = -0.615 ; θ_{p1} = 148.4° or θ_{L2} = 23.8° ; Im(y_L) = 0.615 ; θ_{p2} = 31.6°

b) The shunt stubs **must** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.879 = 2.740dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.095 = 0.393dB; $G_0 = |S_{21}|^2$ = 2.883 = 4.599dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.740dB + 4.599dB + 0.393dB = 7.731dB

d) P_{in} = 145µW = -8.386dBm; $P_{out} = P_{in} + G_T$ = -8.386dBm + 7.731dB = -0.655dBm = 0.860mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.684 < 1 ; $|S_{22}|$ = 0.294 < 1 ; K = 1.130 > 1 ; |Δ| = |(-0.252)+ j·(-0.113)| = 0.276 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 17

1. Z_L = 59Ω series with 1.16nH inductor at 9.5GHz . It's easier to compute first: b) Z_L = 59.00Ω + j·(69.24)Ω, z = Z_L/50Ω = 1.180 + j·(1.385) then a) y = 1/z = 0.356 + j·(-0.418)

2. a) Γ = (z − 1) / (z + 1) = (1.070 − j·0.865 − 1) / (1.070 − j·0.865 + 1)

Γ = (0.177) + j·(-0.344) ↔ ReΓ + j·ImΓ or Γ = 0.387∠-62.7° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 71Ω load to a 50Ω source at f_1 = 7.3GHz so Z_1 = √(Z_0·Z_L) = 59.582 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 2.8GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.192\cdot\pi = 0.602$; tan(β·l) = 0.688

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 62.56\Omega + j\cdot(-10.30)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 33.806Ω.

For a section of an open-circuited transmission line $Z_{in} = - j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/ (j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/14) = 2\pi/14$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0$ = 0.160pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.680∠172.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠125.5°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 160.4° ; Im(y_S) = -1.855 ; θ_{p1} = 118.3° or θ_{S2} = 27.6° ; Im(y_S) = 1.855 ; θ_{p2} = 61.7°

output: θ_{L1} = 179.3° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 55.2° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°
b) The shunt stubs **must** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.860 = 2.695dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.599 = 5.561dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.695dB + 5.561dB + 1.634dB = 9.891dB
d) P_{in} = 80μW = -10.969dBm; $P_{out} = P_{in} + G_T$ = -10.969dBm + 9.891dB = -1.078dBm = 0.780mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.680 < 1 ; $|S_{22}|$ = 0.560 < 1 ; K = 1.098 > 1 ; |Δ| = |(0.016)+ j·(0.360)| = 0.361 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 18

1. Z_L = 28Ω series with 1.14nH inductor at 7.5GHz . It's easier to compute first: b) Z_L = 28.00Ω + j·(53.72)Ω, z = Z_L/50Ω = 0.560 + j·(1.074) then a) y = 1/z = 0.381 + j·(-0.732)
2. a) Γ = (z − 1) / (z + 1) = (0.865 + j·1.135 − 1) / (0.865 + j·1.135 + 1)
Γ = (0.217) + j·(0.476) ↔ ReΓ + j·ImΓ or Γ = 0.524∠65.5° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 27Ω load to a 50Ω source at f_1 = 7.4GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 36.742 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.8GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.189\cdot\pi$ = 0.594; tan(β·l) = 0.676
$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 31.55Ω + j·(9.16)Ω
4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 22.704Ω.
For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0 \cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/8) = 2\pi/8$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0$ = 0.701pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.692∠-102.8° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.302∠-151.8°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 118.3° ; Im(y_S) = -1.917 ; θ_{p1} = 117.5° <u>or</u> θ_{S2} = 164.5° ; Im(y_S) = 1.917 ; θ_{p2} = 62.5°
output: θ_{L1} = 129.7° ; Im(y_L) = -0.634 ; θ_{p1} = 147.6° <u>or</u> θ_{L2} = 22.1° ; Im(y_L) = 0.634 ; θ_{p2} = 32.4°
b) The shunt stubs **must** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.919 = 2.830dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.100 = 0.415dB; $G_0 = |S_{21}|^2$ = 2.802 = 4.475dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.830dB + 4.475dB + 0.415dB = 7.721dB
d) P_{in} = 120μW = -9.208dBm; $P_{out} = P_{in} + G_T$ = -9.208dBm + 7.721dB = -1.487dBm = 0.710mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.692 < 1 ; $|S_{22}|$ = 0.302 < 1 ; K = 1.106 > 1 ; |Δ| = |(-0.265)+ j·(-0.105)| = 0.285 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 19

1. Z_L = 35Ω paralel with 0.60nH inductor at 8.2GHz . It's easier to compute first: a) Y_L = 0.0286S + j·(-0.0323)S, y = Y_L·50Ω = 1.429 + j·(-1.617) then b) z = 1/y = 0.307 + j·(0.347
2. a) Γ = (z − 1) / (z + 1) = (1.235 − j·0.760 − 1) / (1.235 − j·0.760 + 1)
Γ = (0.198) + j·(-0.273) ↔ ReΓ + j·ImΓ or Γ = 0.337∠-54.0° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 26Ω load to a 50Ω source at f_1 = 8.1GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 36.056 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.9GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.179\cdot\pi$ = 0.562; tan(β·l) = 0.630

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 30.11Ω + j·(9.04)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 31.623Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/9) = 2π/9 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.285pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.640∠-146.3° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.550∠149.0°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 138.0° ; Im(y_S) = -1.666 ; θ_{p1} = 121.0° <u>or</u> θ_{S2} = 8.3° ; Im(y_S) = 1.666 ; θ_{p2} = 59.0°
output: θ_{L1} = 167.2° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° <u>or</u> θ_{L2} = 43.8° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.694 = 2.289dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 2.941 = 4.685dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.289dB + 4.685dB + 1.565dB = 8.538dB
d) P_{in} = 70μW = -11.549dBm; $P_{out} = P_{in} + G_T$ = -11.549dBm + 8.538dB = -3.011dBm = 0.500mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.640 < 1 ; $|S_{22}|$ = 0.550 < 1 ; K = 1.187 > 1 ; |Δ| = |(0.259)+ j·(0.107)| = 0.280 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 20</u>

1. Z_L = 68Ω paralel with 0.51nH inductor at 8.7GHz . It's easier to compute first: a) Y_L = 0.0147S + j·(-0.0359)S, y = Y_L·50Ω = 0.735 + j·(-1.793) then b) z = 1/y = 0.196 + j·(0.477

2. a) Γ = (z − 1) / (z + 1) = (1.025 + j·1.075 − 1) / (1.025 + j·1.075 + 1)
Γ = (0.229) + j·(0.409) ↔ ReΓ + j·ImΓ or Γ = 0.469∠60.7° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 46Ω load to a 50Ω source at f_1 = 9.7GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 47.958 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 3.7GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2 \cdot \pi/\lambda_2 \cdot l_1 = 2 \cdot \pi/(c/f_2) \cdot (c/4/f_1) = \pi/2 \cdot f_2/f_1$ = 0.191·π = 0.599; tan(β·l) = 0.683

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 47.20Ω + j·(1.83)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 21.880Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/12) = 2π/12 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.286pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.680∠-105.5° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.290∠-156.0°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 119.2° ; Im(y_S) = -1.855 ; θ_{p1} = 118.3° <u>or</u> θ_{S2} = 166.3° ; Im(y_S) = 1.855 ; θ_{p2} = 61.7°
output: θ_{L1} = 131.4° ; Im(y_L) = -0.606 ; θ_{p1} = 148.8° <u>or</u> θ_{L2} = 24.6° ; Im(y_L) = 0.606 ; θ_{p2} = 31.2°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.860 = 2.695dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.092 = 0.382dB; $G_0 = |S_{21}|^2$ = 2.924 = 4.660dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.695dB + 4.660dB + 0.382dB = 7.737dB
d) P_{in} = 75μW = -11.249dBm; $P_{out} = P_{in} + G_T$ = -11.249dBm + 7.737dB = -3.513dBm = 0.445mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.680 < 1 ; $|S_{22}|$ = 0.290 < 1 ; K = 1.143 > 1 ; |Δ| = |(-0.246)+ j·(-0.116)| = 0.272 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 21

1. Z_L = 31Ω series with 1.09nH inductor at 8.4GHz . It's easier to compute first: b) Z_L = 31.00Ω + j·(57.53)Ω, z = Z_L/50Ω = 0.620 + j·(1.151) then a) y = 1/z = 0.363 + j·(-0.674)
2. a) Γ = (z − 1) / (z + 1) = (1.005 − j·0.820 − 1) / (1.005 − j·0.820 + 1)
Γ = (0.145) + j·(-0.349) ↔ ReΓ + j·ImΓ or Γ = 0.379∠-67.4° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 57Ω load to a 50Ω source at f_1 = 8.8GHz so Z_1 = √(Z_0·Z_L) = 53.385 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.5GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1$ = $2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1$ = 0.142·π = 0.446; tan(β·l) = 0.478

$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)}$ = 55.55Ω + j·(-2.84)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 24.537Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/7) = 2π/7 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.594pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.672∠178.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.558∠132.0°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 157.1° ; Im(y_S) = -1.815 ; θ_{p1} = 118.9° <u>or</u> θ_{S2} = 24.9° ; Im(y_S) = 1.815 ; θ_{p2} = 61.1°
output: θ_{L1} = 176.0° ; Im(y_L) = -1.345 ; θ_{p1} = 126.6° <u>or</u> θ_{L2} = 52.0° ; Im(y_L) = 1.345 ; θ_{p2} = 53.4°
b) The shunt stubs <u>**must**</u> be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.823 = 2.609dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.452 = 1.620dB; $G_0 = |S_{21}|^2$ = 3.371 = 5.277dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.609dB + 5.277dB + 1.620dB = 9.506dB
d) P_{in} = 100μW = -10.000dBm; $P_{out} = P_{in} + G_T$ = -10.000dBm + 9.506dB = -0.494dBm = 0.893mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.672 < 1 ; $|S_{22}|$ = 0.558 < 1 ; K = 1.103 > 1 ; |Δ| = |(0.087)+ j·(0.346)| = 0.357 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 22

1. Z_L = 56Ω series with 0.54nH inductor at 9.4GHz . It's easier to compute first: b) Z_L = 56.00Ω + j·(31.89)Ω, z = Z_L/50Ω = 1.120 + j·(0.638) then a) y = 1/z = 0.674 + j·(-0.384)
2. a) Γ = (z − 1) / (z + 1) = (1.180 + j·0.920 − 1) / (1.180 + j·0.920 + 1)
Γ = (0.221) + j·(0.329) ↔ ReΓ + j·ImΓ or Γ = 0.396∠56.0° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 34Ω load to a 50Ω source at f_1 = 7.7GHz so Z_1 = √(Z_0·Z_L) = 41.231 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 3.2GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1$ = $2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1$ = 0.208·π = 0.653; tan(β·l) = 0.765

$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)}$ = 38.55Ω + j·(7.22)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 41.079Ω.
For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/7) = 2π/7 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.540pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.676∠175.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.559∠131.0°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 158.8° ; Im(y_S) = -1.835 ; θ_{p1} = 118.6° <u>or</u> θ_{S2} = 26.2° ; Im(y_S) = 1.835 ; θ_{p2} = 61.4°

output: θ_{L1} = 176.5° ; Im(y_L) = -1.348 ; θ_{p1} = 126.6° <u>or</u> θ_{L2} = 52.5° ; Im(y_L) = 1.348 ; θ_{p2} = 53.4°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.842 = 2.652dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.455 = 1.627dB; $G_0 = |S_{21}|^2$ = 3.404 = 5.320dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.652dB + 5.320dB + 1.627dB = 9.599dB
d) P_{in} = 50μW = -13.010dBm; $P_{out} = P_{in} + G_T$ = -13.010dBm + 9.599dB = -3.411dBm = 0.456mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.676 < 1 ; $|S_{22}|$ = 0.559 < 1 ; K = 1.097 > 1 ; |Δ| = |(0.065)+ j·(0.360)| = 0.366 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 23</u>

1. Z_L = 39Ω paralel with 0.66nH inductor at 8.9GHz . It's easier to compute first: a) Y_L = 0.0256S + j·(-0.0271)S, y = Y_L·50Ω = 1.282 + j·(-1.355) then b) z = 1/y = 0.369 + j·(0.389
2. a) Γ = (z − 1) / (z + 1) = (0.825 + j·1.075 − 1) / (0.825 + j·1.075 + 1)
Γ = (0.186) + j·(0.479) ↔ ReΓ + j·ImΓ or Γ = 0.514∠68.7° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 68Ω load to a 50Ω source at f_1 = 9.7GHz so $Z_1 = \sqrt{(Z_0 \cdot Z_L)}$ = 58.310 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 3.1GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2 \cdot f_2/f_1 = 0.160\cdot\pi$ = 0.502; tan(β·l) = 0.549

$$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)} = 62.77\Omega + j\cdot(-8.17)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 28.452Ω.
For a section of an open-circuited transmission line $Z_{in} = - j \cdot Z_0 \cdot ctg(\beta \cdot l) = 1/ (j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; β·l = 2π/λ·(λ/14) = 2π/14 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.228pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.680∠172.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠129.1°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 160.4° ; Im(y_S) = -1.855 ; θ_{p1} = 118.3° <u>or</u> θ_{S2} = 27.6° ; Im(y_S) = 1.855 ; θ_{p2} = 61.7°
output: θ_{L1} = 177.5° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 53.4° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.860 = 2.695dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.471 = 5.404dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.695dB + 5.404dB + 1.634dB = 9.734dB
d) P_{in} = 140μW = -8.539dBm; $P_{out} = P_{in} + G_T$ = -8.539dBm + 9.734dB = 1.195dBm = 1.317mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.680 < 1 ; $|S_{22}|$ = 0.560 < 1 ; K = 1.091 > 1 ; |Δ| = |(0.037)+ j·(0.370)| = 0.371 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 24</u>

1. Z_L = 40Ω paralel with 1.19nH inductor at 6.9GHz . It's easier to compute first: a) Y_L = 0.0250S + j·(-0.0194)S, y = Y_L·50Ω = 1.250 + j·(-0.969) then b) z = 1/y = 0.500 + j·(0.387
2. a) Γ = (z − 1) / (z + 1) = (0.765 + j·0.710 − 1) / (0.765 + j·0.710 + 1)
Γ = (0.025) + j·(0.392) ↔ ReΓ + j·ImΓ or Γ = 0.393∠86.4° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 46Ω load to a 50Ω source at f_1 = 9.4GHz so $Z_1 = \sqrt{(Z_0 \cdot Z_L)}$ = 47.958 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.1GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2 \cdot f_2/f_1 = 0.112\cdot\pi$ = 0.351; tan(β·l) = 0.366

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 46.44Ω + j·(1.25)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 27.961Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/9) = 2π/9 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.549pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.668∠-179.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.557∠133.0°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 155.5° ; Im(y_S) = -1.795 ; θ_{p1} = 119.1° <u>or</u> θ_{S2} = 23.5° ; Im(y_S) = 1.795 ; θ_{p2} = 60.9°

output: θ_{L1} = 175.4° ; Im(y_L) = -1.341 ; θ_{p1} = 126.7° <u>or</u> θ_{L2} = 51.6° ; Im(y_L) = 1.341 ; θ_{p2} = 53.3°

b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.806 = 2.567dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.450 = 1.613dB; $G_0 = |S_{21}|^2$ = 3.342 = 5.240dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.567dB + 5.240dB + 1.613dB = 9.419dB

d) P_{in} = 85μW = -10.706dBm; $P_{out} = P_{in} + G_T$ = -10.706dBm + 9.419dB = -1.287dBm = 0.744mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.668 < 1 ; $|S_{22}|$ = 0.557 < 1 ; K = 1.110 > 1 ; |Δ| = |(0.107)+ j·(0.332)| = 0.349 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 25</u>

1. Z_L = 61Ω series with 0.25pF capacitor at 9.2GHz . It's easier to compute first: b) Z_L = 61.00Ω + j·(-69.20)Ω, z = Z_L/50Ω = 1.220 + j·(-1.384) then a) y = 1/z = 0.358 + j·(0.407)

2. a) Γ = (z − 1) / (z + 1) = (1.075 − j·0.760 − 1) / (1.075 − j·0.760 + 1)

Γ = (0.150) + j·(-0.311) ↔ ReΓ + j·ImΓ or Γ = 0.346∠-64.2° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 49Ω load to a 50Ω source at f_1 = 9.0GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 49.497 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 4.3GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2 \cdot \pi/\lambda_2 \cdot l_1 = 2 \cdot \pi/(c/f_2) \cdot (c/4/f_1) = \pi/2 \cdot f_2/f_1$ = 0.239·π = 0.750; tan(β·l) = 0.933

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 49.46Ω + j·(0.50)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 25.000Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/8) = 2π/8 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.663pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.696∠166.4° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠117.4°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 163.9° ; Im(y_S) = -1.939 ; θ_{p1} = 117.3° <u>or</u> θ_{S2} = 29.7° ; Im(y_S) = 1.939 ; θ_{p2} = 62.7°

output: θ_{L1} = 3.3° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 59.3° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°

b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.940 = 2.877dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.897 = 5.907dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.877dB + 5.907dB + 1.634dB = 10.418dB

d) P_{in} = 80μW = -10.969dBm; $P_{out} = P_{in} + G_T$ = -10.969dBm + 10.418dB = -0.551dBm = 0.881mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.696 < 1 ; $|S_{22}|$ = 0.560 < 1 ; K = 1.046 > 1 ; |Δ| = |(-0.063)+ j·(0.353)| = 0.358 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 26

1. Z_L = 44Ω series with 1.24nH inductor at 8.4GHz . It's easier to compute first: b) Z_L = 44.00Ω + j·(65.45)Ω, z = Z_L/50Ω = 0.880 + j·(1.309) then a) y = 1/z = 0.354 + j·(-0.526)

2. a) Γ = (z − 1) / (z + 1) = (1.175 − j·0.875 − 1) / (1.175 − j·0.875 + 1)

Γ = (0.209) + j·(-0.318) ↔ ReΓ + j·ImΓ or Γ = 0.381∠-56.8° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 48Ω load to a 50Ω source at f_1 = 7.8GHz so Z_1 = √(Z_0·Z_L) = 48.990 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 3.1GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.199\cdot\pi = 0.624$; tan(β·l) = 0.720

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 48.67\Omega + j\cdot(0.94)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 24.900Ω.

For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/9) = 2\pi/9$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0$ = 0.397pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.640∠-150.2° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.550∠146.0°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 140.0° ; Im(y_S) = -1.666 ; θ_{p1} = 121.0° <u>or</u> θ_{S2} = 10.2° ; Im(y_S) = 1.666 ; θ_{p2} = 59.0°

output: θ_{L1} = 168.7° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° <u>or</u> θ_{L2} = 45.3° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°

b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 − |S_{11}|^2)$ = 1.694 = 2.289dB; the gain from load match: $G_{Lmax} = 1 / (1 − |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 3.000 = 4.771dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.289dB + 4.771dB + 1.565dB = 8.624dB

d) P_{in} = 120μW = -9.208dBm; $P_{out} = P_{in} + G_T$ = -9.208dBm + 8.624dB = -0.584dBm = 0.874mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.640 < 1 ; $|S_{22}|$ = 0.550 < 1 ; K = 1.182 > 1 ; |Δ| = |(0.246)+ j·(0.141)| = 0.284 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 27

1. Z_L = 72Ω paralel with 0.83nH inductor at 8.4GHz . It's easier to compute first: a) Y_L = 0.0139S + j·(-0.0228)S, y = Y_L·50Ω = 0.694 + j·(-1.141) then b) z = 1/y = 0.389 + j·(0.639

2. a) Γ = (z − 1) / (z + 1) = (0.745 + j·0.985 − 1) / (0.745 + j·0.985 + 1)

Γ = (0.131) + j·(0.491) ↔ ReΓ + j·ImΓ or Γ = 0.508∠75.1° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 74Ω load to a 50Ω source at f_1 = 9.8GHz so Z_1 = √(Z_0·Z_L) = 60.828 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 3.8GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.194\cdot\pi = 0.609$; tan(β·l) = 0.698

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 63.95\Omega + j\cdot(-11.84)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 18.132Ω.

For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/12) = 2\pi/12$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0$ = 0.618pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.668∠-108.2° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.278∠-160.2°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 120.1° ; Im(y_S) = -1.795 ; θ_{p1} = 119.1° <u>or</u> θ_{S2} = 168.1° ; Im(y_S) = 1.795 ; θ_{p2} = 60.9°

output: θ_{L1} = 133.2° ; Im(y_L) = -0.579 ; θ_{p1} = 149.9° <u>or</u> θ_{L2} = 27.0° ; Im(y_L) = 0.579 ; θ_{p2} = 30.1°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.806 = 2.567dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.084 = 0.349dB; $G_0 = |S_{21}|^2$ = 3.049 = 4.841dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.567dB + 4.841dB + 0.349dB = 7.757dB
d) P_{in} = 100µW = -10.000dBm; $P_{out} = P_{in} + G_T$ = -10.000dBm + 7.757dB = -2.243dBm = 0.597mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.668 < 1 ; $|S_{22}|$ = 0.278 < 1 ; K = 1.180 > 1 ; |Δ| = |(-0.228)+ j·(-0.125)| = 0.260 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 28</u>

1. Z_L = 55Ω paralel with 1.62nH inductor at 7.0GHz . It's easier to compute first: a) Y_L = 0.0182S + j·(-0.0140)S, y = Y_L·50Ω = 0.909 + j·(-0.702) then b) z = 1/y = 0.689 + j·(0.532
2. a) Γ = (z − 1) / (z + 1) = (0.860 + j·1.220 − 1) / (0.860 + j·1.220 + 1)
Γ = (0.248) + j·(0.493) ↔ ReΓ + j·ImΓ or Γ = 0.552∠63.3° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 47Ω load to a 50Ω source at f_1 = 8.2GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 48.477 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 3.1GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.189\cdot\pi$ = 0.594; tan(β·l) = 0.675

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j\cdot Z_L \cdot tan(\beta l)} = 47.90\Omega + j\cdot(1.37)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 19.211Ω.
For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/8) = 2\pi/8$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0$ = 1.076pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.700∠-101.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.310∠-149.0°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 117.7° ; Im(y_S) = -1.960 ; θ_{p1} = 117.0° <u>or</u> θ_{S2} = 163.3° ; Im(y_S) = 1.960 ; θ_{p2} = 63.0°
output: θ_{L1} = 128.5° ; Im(y_L) = -0.652 ; θ_{p1} = 146.9° <u>or</u> θ_{L2} = 20.5° ; Im(y_L) = 0.652 ; θ_{p2} = 33.1°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.961 = 2.924dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.106 = 0.439dB; $G_0 = |S_{21}|^2$ = 2.723 = 4.350dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.924dB + 4.350dB + 0.439dB = 7.713dB
d) P_{in} = 85µW = -10.706dBm; $P_{out} = P_{in} + G_T$ = -10.706dBm + 7.713dB = -2.993dBm = 0.502mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.700 < 1 ; $|S_{22}|$ = 0.310 < 1 ; K = 1.083 > 1 ; |Δ| = |(-0.278)+ j·(-0.095)| = 0.294 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 29</u>

1. Z_L = 32Ω paralel with 1.31nH inductor at 6.5GHz . It's easier to compute first: a) Y_L = 0.0313S + j·(-0.0187)S, y = Y_L·50Ω = 1.563 + j·(-0.935) then b) z = 1/y = 0.471 + j·(0.282
2. a) Γ = (z − 1) / (z + 1) = (1.020 − j·0.765 − 1) / (1.020 − j·0.765 + 1)
Γ = (0.134) + j·(-0.328) ↔ ReΓ + j·ImΓ or Γ = 0.354∠-67.8° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 59Ω load to a 50Ω source at f_1 = 6.6GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 54.314 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 4.0GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.303\cdot\pi$ = 0.952; tan(β·l) = 1.404

$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j\cdot Z_L \cdot tan(\beta l)}$ = 52.71Ω + j·(-4.13)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 21.635Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/7) = 2π/7 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.913pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.644∠-161.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.551∠139.0°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 145.5° ; Im(y_S) = -1.684 ; θ_{p1} = 120.7° or θ_{S2} = 15.5° ; Im(y_S) = 1.684 ; θ_{p2} = 59.3°

output: θ_{L1} = 172.2° ; Im(y_L) = -1.321 ; θ_{p1} = 127.1° or θ_{L2} = 48.8° ; Im(y_L) = 1.321 ; θ_{p2} = 52.9°

b) The shunt stubs **must** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.709 = 2.326dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.436 = 1.571dB; $G_0 = |S_{21}|^2$ = 3.151 = 4.984dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.326dB + 4.984dB + 1.571dB = 8.882dB

d) P_{in} = 100µW = -10.000dBm; $P_{out} = P_{in} + G_T$ = -10.000dBm + 8.882dB = -1.118dBm = 0.773mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.644 < 1 ; $|S_{22}|$ = 0.551 < 1 ; K = 1.162 > 1 ; |Δ| = |(0.198)+ j·(0.225)| = 0.299 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 30

1. Z_L = 52Ω series with 0.48pF capacitor at 7.4GHz . It's easier to compute first: b) Z_L = 52.00Ω + j·(-44.81)Ω, z = Z_L/50Ω = 1.040 + j·(-0.896) then a) y = 1/z = 0.552 + j·(0.475)

2. a) Γ = (z − 1) / (z + 1) = (0.900 − j·0.900 − 1) / (0.900 − j·0.900 + 1)

Γ = (0.140) + j·(-0.407) ↔ ReΓ + j·ImΓ or Γ = 0.431∠-71.0° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 36Ω load to a 50Ω source at f_1 = 9.3GHz so Z_1 = √(Z_0·Z_L) = 42.426 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 2.8GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1$ = 0.151·π = 0.473; tan(β·l) = 0.512

$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j\cdot Z_L \cdot tan(\beta l)}$ = 38.22Ω + j·(5.11)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 18.744Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/13) = 2π/13 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.365pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.660∠-110.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.270∠-163.0°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 120.6° ; Im(y_S) = -1.757 ; θ_{p1} = 119.6° or θ_{S2} = 169.4° ; Im(y_S) = 1.757 ; θ_{p2} = 60.4°

output: θ_{L1} = 134.3° ; Im(y_L) = -0.561 ; θ_{p1} = 150.7° or θ_{L2} = 28.7° ; Im(y_L) = 0.561 ; θ_{p2} = 29.3°

b) The shunt stubs **must** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.772 = 2.484dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.079 = 0.329dB; $G_0 = |S_{21}|^2$ = 3.133 = 4.959dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.484dB + 4.959dB + 0.329dB = 7.772dB

d) P_{in} = 85µW = -10.706dBm; $P_{out} = P_{in} + G_T$ = -10.706dBm + 7.772dB = -2.933dBm = 0.509mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.660 < 1 ; $|S_{22}|$ = 0.270 < 1 ; K = 1.206 > 1 ; |Δ| = |(-0.216)+ j·(-0.130)| = 0.252 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 31

1. $Z_L = 36\Omega$ paralel with 1.16nH inductor at 9.9GHz . It's easier to compute first: a) $Y_L = 0.0278S + j\cdot(-0.0139)S$, $y = Y_L\cdot 50\Omega = 1.389 + j\cdot(-0.693)$ then b) $z = 1/y = 0.576 + j\cdot(0.288$

2. a) $\Gamma = (z - 1) / (z + 1) = (1.105 + j\cdot 0.765 - 1) / (1.105 + j\cdot 0.765 + 1)$

$\Gamma = (0.161) + j\cdot(0.305) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.345\angle 62.2° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. The quarter wave transformer is designed to match a 72Ω load to a 50Ω source at f_1 = 9.7GHz so $Z_1 = \sqrt{(Z_0\cdot Z_L)} = 60.000\ \Omega$ and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 2.2GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.113\cdot\pi = 0.356$; $\tan(\beta\cdot l) = 0.372$

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 68.34\Omega + j\cdot(-8.19)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C} = 28.868\Omega$.

For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/9) = 2\pi/9$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0 = 0.406$pF

5. a) $S_{12} = 0$, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; $\Gamma_S = 0.680\angle 172.0°$; Maximum gain match of the load $\Gamma_L = S_{22}^*$; $\Gamma_L = 0.560\angle 123.7°$

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have $Z_0 = 50\Omega$

input: $\theta_{S1} = 160.4°$; $\mathrm{Im}(y_S) = -1.855$; $\theta_{p1} = 118.3°$ <u>or</u> $\theta_{S2} = 27.6°$; $\mathrm{Im}(y_S) = 1.855$; $\theta_{p2} = 61.7°$

output: $\theta_{L1} = 0.2°$; $\mathrm{Im}(y_L) = -1.352$; $\theta_{p1} = 126.5°$ <u>or</u> $\theta_{L2} = 56.1°$; $\mathrm{Im}(y_L) = 1.352$; $\theta_{p2} = 53.5°$

b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2) = 1.860 = 2.695$dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2) = 1.457 = 1.634$dB; $G_0 = |S_{21}|^2 = 3.663 = 5.639$dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.695dB + 5.639dB + 1.634dB = 9.968dB

d) P_{in} = 145µW = -8.386dBm; $P_{out} = P_{in} + G_T$ = -8.386dBm + 9.968dB = 1.582dBm = 1.440mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}| = 0.680 < 1$; $|S_{22}| = 0.560 < 1$; $K = 1.103 > 1$; $|\Delta| = |(0.007) + j\cdot(0.355)| = 0.355 < 1$, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 32

1. $Z_L = 46\Omega$ paralel with 0.60pF capacitor at 6.7GHz . It's easier to compute first: a) $Y_L = 0.0217S + j\cdot(0.0253)S$, $y = Y_L\cdot 50\Omega = 1.087 + j\cdot(1.263)$ then b) $z = 1/y = 0.391 + j\cdot(-0.455$

2. a) $\Gamma = (z - 1) / (z + 1) = (0.835 + j\cdot 0.830 - 1) / (0.835 + j\cdot 0.830 + 1)$

$\Gamma = (0.095) + j\cdot(0.409) \leftrightarrow \mathrm{Re}\Gamma + j\cdot\mathrm{Im}\Gamma$ or $\Gamma = 0.420\angle 76.9° \leftrightarrow |\Gamma|\angle\arg(\Gamma)$

3. The quarter wave transformer is designed to match a 72Ω load to a 50Ω source at f_1 = 10.0GHz so $Z_1 = \sqrt{(Z_0\cdot Z_L)} = 60.000\ \Omega$ and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 2.1GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.105\cdot\pi = 0.330$; $\tan(\beta\cdot l) = 0.342$

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 68.82\Omega + j\cdot(-7.73)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C} = 32.596\Omega$.

For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/7) = 2\pi/7$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0 = 0.658$pF

5. a) $S_{12} = 0$, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; $\Gamma_S = 0.640\angle -147.6°$; Maximum gain match of the load $\Gamma_L = S_{22}^*$; $\Gamma_L = 0.550\angle 148.0°$

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have $Z_0 = 50\Omega$

input: $\theta_{S1} = 138.7°$; $\mathrm{Im}(y_S) = -1.666$; $\theta_{p1} = 121.0°$ <u>or</u> $\theta_{S2} = 8.9°$; $\mathrm{Im}(y_S) = 1.666$; $\theta_{p2} = 59.0°$

output: θ_{L1} = 167.7° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° <u>or</u> θ_{L2} = 44.3° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°
b) The shunt stubs **must** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.694 = 2.289dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 2.958 = 4.711dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.289dB + 4.711dB + 1.565dB = 8.564dB
d) P_{in} = 50μW = -13.010dBm; $P_{out} = P_{in} + G_T$ = -13.010dBm + 8.564dB = -4.447dBm = 0.359mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.640 < 1 ; $|S_{22}|$ = 0.550 < 1 ; K = 1.186 > 1 ; |Δ| = |(0.255)+ j·(0.119)| = 0.282 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 33</u>

1. Z_L = 25Ω series with 0.30pF capacitor at 7.8GHz . It's easier to compute first: b) Z_L = 25.00Ω + j·(-68.01)Ω, z = Z_L/50Ω = 0.500 + j·(-1.360) then a) y = 1/z = 0.238 + j·(0.648)
2. a) Γ = (z − 1) / (z + 1) = (1.290 − j·0.755 − 1) / (1.290 − j·0.755 + 1)
Γ = (0.212) + j·(-0.260) ↔ ReΓ + j·ImΓ or Γ = 0.335∠-50.7° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 60Ω load to a 50Ω source at f_1 = 7.0GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 54.772 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.0GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.143\cdot\pi$ = 0.449; tan(β·l) = 0.482
$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)} = 57.82\Omega + j\cdot(-4.13)\Omega$$
4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 25.081Ω.
For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0\cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/7) = 2\pi/7$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0$ = 0.534pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.672∠-107.3° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.282∠-158.8°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 119.8° ; Im(y_S) = -1.815 ; θ_{p1} = 118.9° <u>or</u> θ_{S2} = 167.5° ; Im(y_S) = 1.815 ; θ_{p2} = 61.1°
output: θ_{L1} = 132.6° ; Im(y_L) = -0.588 ; θ_{p1} = 149.6° <u>or</u> θ_{L2} = 26.2° ; Im(y_L) = 0.588 ; θ_{p2} = 30.4°
b) The shunt stubs **must** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.823 = 2.609dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.086 = 0.360dB; $G_0 = |S_{21}|^2$ = 3.007 = 4.781dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.609dB + 4.781dB + 0.360dB = 7.750dB
d) P_{in} = 55μW = -12.596dBm; $P_{out} = P_{in} + G_T$ = -12.596dBm + 7.750dB = -4.847dBm = 0.328mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.672 < 1 ; $|S_{22}|$ = 0.282 < 1 ; K = 1.167 > 1 ; |Δ| = |(-0.234)+ j·(-0.122)| = 0.264 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 34</u>

1. Z_L = 58Ω series with 1.75nH inductor at 6.5GHz . It's easier to compute first: b) Z_L = 58.00Ω + j·(71.47)Ω, z = Z_L/50Ω = 1.160 + j·(1.429) then a) y = 1/z = 0.342 + j·(-0.422)
2. a) Γ = (z − 1) / (z + 1) = (0.870 + j·0.705 − 1) / (0.870 + j·0.705 + 1)
Γ = (0.064) + j·(0.353) ↔ ReΓ + j·ImΓ or Γ = 0.359∠79.8° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 64Ω load to a 50Ω source at f_1 = 8.2GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 56.569 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.9GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.177\cdot\pi$ = 0.556; tan(β·l) = 0.621

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 59.38Ω + j·(-6.58)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 40.311Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/6) = 2π/6 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.844pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.664∠-176.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.556∠134.0°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 153.8° ; Im(y_S) = -1.776 ; θ_{p1} = 119.4° or θ_{S2} = 22.2° ; Im(y_S) = 1.776 ; θ_{p2} = 60.6°

output: θ_{L1} = 174.9° ; Im(y_L) = -1.338 ; θ_{p1} = 126.8° or θ_{L2} = 51.1° ; Im(y_L) = 1.338 ; θ_{p2} = 53.2°

b) The shunt stubs **must** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.789 = 2.525dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.447 = 1.606dB; $G_0 = |S_{21}|^2$ = 3.309 = 5.197dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.525dB + 5.197dB + 1.606dB = 9.328dB

d) P_{in} = 60μW = -12.218dBm; $P_{out} = P_{in} + G_T$ = -12.218dBm + 9.328dB = -2.891dBm = 0.514mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.664 < 1 ; $|S_{22}|$ = 0.556 < 1 ; K = 1.117 > 1 ; |Δ| = |(0.126)+ j·(0.316)| = 0.340 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 35

1. Z_L = 66Ω paralel with 0.54nH inductor at 7.8GHz . It's easier to compute first: a) Y_L = 0.0152S + j·(-0.0378)S, y = Y_L·50Ω = 0.758 + j·(-1.889) then b) z = 1/y = 0.183 + j·(0.456

2. a) Γ = (z − 1) / (z + 1) = (1.290 − j·0.765 − 1) / (1.290 − j·0.765 + 1)

Γ = (0.214) + j·(-0.262) ↔ ReΓ + j·ImΓ or Γ = 0.339∠-50.8° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 55Ω load to a 50Ω source at f_1 = 8.5GHz so $Z_1 = \sqrt{(Z_0 \cdot Z_L)}$ = 52.440 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 4.1GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2 \cdot \pi/\lambda_2 \cdot l_1$ = $2 \cdot \pi/(c/f_2) \cdot (c/4/f_1) = \pi/2 \cdot f_2/f_1$ = 0.241·π = 0.758; tan(β·l) = 0.946

$Z_{in} = Z_1 \cdot \frac{Z_L + j \cdot Z_1 \cdot tan(\beta l)}{Z_1 + j \cdot Z_L \cdot tan(\beta l)}$ = 52.52Ω + j·(-2.50)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 16.903Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/14) = 2π/14 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.515pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.640∠-151.5° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.550∠145.0°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 140.6° ; Im(y_S) = -1.666 ; θ_{p1} = 121.0° or θ_{S2} = 10.9° ; Im(y_S) = 1.666 ; θ_{p2} = 59.0°

output: θ_{L1} = 169.2° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° or θ_{L2} = 45.8° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°

b) The shunt stubs **must** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.694 = 2.289dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 3.017 = 4.796dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.289dB + 4.796dB + 1.565dB = 8.649dB

d) P_{in} = 55μW = -12.596dBm; $P_{out} = P_{in} + G_T$ = -12.596dBm + 8.649dB = -3.947dBm = 0.403mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.640 < 1 ; $|S_{22}|$ = 0.550 < 1 ; K = 1.181 > 1 ; |Δ| = |(0.241)+ j·(0.152)| = 0.285 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 36

1. Z_L = 42Ω paralel with 0.94nH inductor at 7.1GHz . It's easier to compute first: a) Y_L = 0.0238S + j·(-0.0238)S, y = Y_L·50Ω = 1.190 + j·(-1.192) then b) z = 1/y = 0.419 + j·(0.420

2. a) Γ = (z − 1) / (z + 1) = (1.045 − j·1.195 − 1) / (1.045 − j·1.195 + 1)

Γ = (0.271) + j·(-0.426) ↔ ReΓ + j·ImΓ or Γ = 0.505∠-57.5° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 48Ω load to a 50Ω source at f_1 = 9.3GHz so Z_1 = √(Z_0·Z_L) = 48.990 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 2.4GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.129\cdot\pi = 0.405$; tan(β·l) = 0.429

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 48.30\Omega + j\cdot(0.71)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 30.000Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/10) = 2π/10 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.507pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.637∠-141.1° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.550∠152.7°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 135.3° ; Im(y_S) = -1.653 ; θ_{p1} = 121.2° or θ_{S2} = 5.8° ; Im(y_S) = 1.653 ; θ_{p2} = 58.8°

output: θ_{L1} = 165.3° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° or θ_{L2} = 42.0° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°

b) The shunt stubs **must** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.683 = 2.260dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 2.863 = 4.568dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.260dB + 4.568dB + 1.565dB = 8.393dB

d) P_{in} = 65μW = -11.871dBm; $P_{out} = P_{in} + G_T$ = -11.871dBm + 8.393dB = -3.478dBm = 0.449mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.637 < 1 ; $|S_{22}|$ = 0.550 < 1 ; K = 1.201 > 1 ; |Δ| = |(0.265)+ j·(0.060)| = 0.272 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

Subject no. 37

1. Z_L = 38Ω paralel with 0.26pF capacitor at 9.7GHz . It's easier to compute first: a) Y_L = 0.0263S + j·(0.0158)S, y = Y_L·50Ω = 1.316 + j·(0.792) then b) z = 1/y = 0.558 + j·(-0.336

2. a) Γ = (z − 1) / (z + 1) = (0.935 + j·1.065 − 1) / (0.935 + j·1.065 + 1)

Γ = (0.207) + j·(0.437) ↔ ReΓ + j·ImΓ or Γ = 0.483∠64.7° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 73Ω load to a 50Ω source at f_1 = 9.1GHz so Z_1 = √(Z_0·Z_L) = 60.415 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 4.4GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2\cdot l_1 = 2\cdot\pi/\lambda_2\cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.242\cdot\pi = 0.760$; tan(β·l) = 0.950

$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1\cdot tan(\beta l)}{Z_1 + j\cdot Z_L\cdot tan(\beta l)} = 59.93\Omega + j\cdot(-11.39)\Omega$$

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 41.138Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/9) = 2π/9 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.321pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.680∠172.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.560∠121.0°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 160.4° ; Im(y_S) = -1.855 ; θ_{p1} = 118.3° or θ_{S2} = 27.6° ; Im(y_S) = 1.855 ; θ_{p2} = 61.7°

output: θ_{L1} = 1.5° ; Im(y_L) = -1.352 ; θ_{p1} = 126.5° <u>or</u> θ_{L2} = 57.5° ; Im(y_L) = 1.352 ; θ_{p2} = 53.5°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.860 = 2.695dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.457 = 1.634dB; $G_0 = |S_{21}|^2$ = 3.764 = 5.756dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.695dB + 5.756dB + 1.634dB = 10.086dB
d) P_{in} = 70μW = -11.549dBm; $P_{out} = P_{in} + G_T$ = -11.549dBm + 10.086dB = -1.463dBm = 0.714mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.680 < 1 ; $|S_{22}|$ = 0.560 < 1 ; K = 1.112 > 1 ; |Δ| = |(-0.006)+ j·(0.348)| = 0.348 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 38</u>

1. Z_L = 44Ω series with 0.48nH inductor at 8.8GHz . It's easier to compute first: b) Z_L = 44.00Ω + j·(26.54)Ω, z = Z_L/50Ω = 0.880 + j·(0.531) then a) y = 1/z = 0.833 + j·(-0.503)
2. a) Γ = (z − 1) / (z + 1) = (0.885 − j·0.875 − 1) / (0.885 − j·0.875 + 1)
Γ = (0.127) + j·(-0.405) ↔ ReΓ + j·ImΓ or Γ = 0.425∠-72.6° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 57Ω load to a 50Ω source at f_1 = 7.5GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 53.385 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 2.2GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.147\cdot\pi$ = 0.461; tan(β·l) = 0.496
$$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j\cdot Z_L \cdot tan(\beta l)} = 55.46\Omega + j\cdot(-2.90)\Omega$$
4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 28.636Ω.
For a section of an open-circuited transmission line $Z_{in} = -j\cdot Z_0 \cdot ctg(\beta\cdot l) = 1/(j\cdot\omega\cdot C) = -j\cdot 1/\omega/C$; $\beta\cdot l = 2\pi/\lambda\cdot(\lambda/8) = 2\pi/8$; $C = tg(\beta\cdot l) / (2\cdot\pi\cdot f) / Z_0$ = 0.695pF
5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.664∠-109.1° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.274∠-161.6°
Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω
input: θ_{S1} = 120.4° ; Im(y_S) = -1.776 ; θ_{p1} = 119.4° <u>or</u> θ_{S2} = 168.7° ; Im(y_S) = 1.776 ; θ_{p2} = 60.6°
output: θ_{L1} = 133.8° ; Im(y_L) = -0.570 ; θ_{p1} = 150.3° <u>or</u> θ_{L2} = 27.8° ; Im(y_L) = 0.570 ; θ_{p2} = 29.7°
b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load
c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.789 = 2.525dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.081 = 0.339dB; $G_0 = |S_{21}|^2$ = 3.091 = 4.900dB;
The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.525dB + 4.900dB + 0.339dB = 7.764dB
d) P_{in} = 110μW = -9.586dBm; $P_{out} = P_{in} + G_T$ = -9.586dBm + 7.764dB = -1.822dBm = 0.657mW
e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.664 < 1 ; $|S_{22}|$ = 0.274 < 1 ; K = 1.193 > 1 ; |Δ| = |(-0.222)+ j·(-0.128)| = 0.256 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 39</u>

1. Z_L = 72Ω series with 0.62pF capacitor at 9.0GHz . It's easier to compute first: b) Z_L = 72.00Ω + j·(-28.52)Ω, z = Z_L/50Ω = 1.440 + j·(-0.570) then a) y = 1/z = 0.600 + j·(0.238)
2. a) Γ = (z − 1) / (z + 1) = (1.060 + j·0.940 − 1) / (1.060 + j·0.940 + 1)
Γ = (0.196) + j·(0.367) ↔ ReΓ + j·ImΓ or Γ = 0.416∠61.8° ↔ |Γ|∠arg(Γ)
3. The quarter wave transformer is designed to match a 56Ω load to a 50Ω source at f_1 = 7.4GHz so $Z_1 = \sqrt{Z_0 \cdot Z_L}$ = 52.915 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.
At f_2 = 3.0GHz the characteristic impedance and physical length do not change but $\beta \cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1 = 2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1 = 0.203\cdot\pi$ = 0.637; tan(β·l) = 0.740

$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j\cdot Z_L \cdot tan(\beta l)}$ = 53.72Ω + j·(-2.91)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 28.868Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/11) = 2π/11 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.417pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.652∠-167.0° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.553∠137.0°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 148.8° ; Im(y_S) = -1.720 ; θ_{p1} = 120.2° <u>or</u> θ_{S2} = 18.2° ; Im(y_S) = 1.720 ; θ_{p2} = 59.8°

output: θ_{L1} = 173.3° ; Im(y_L) = -1.327 ; θ_{p1} = 127.0° <u>or</u> θ_{L2} = 49.7° ; Im(y_L) = 1.327 ; θ_{p2} = 53.0°

b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.739 = 2.404dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.441 = 1.585dB; $G_0 = |S_{21}|^2$ = 3.211 = 5.067dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.404dB + 5.067dB + 1.585dB = 9.056dB

d) P_{in} = 105µW = -9.788dBm; $P_{out} = P_{in} + G_T$ = -9.788dBm + 9.056dB = -0.732dBm = 0.845mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.652 < 1 ; $|S_{22}|$ = 0.553 < 1 ; K = 1.143 > 1 ; |Δ| = |(0.174)+ j·(0.263)| = 0.316 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)

<u>Subject no. 40</u>

1. Z_L = 26Ω series with 0.67nH inductor at 9.8GHz . It's easier to compute first: b) Z_L = 26.00Ω + j·(41.26)Ω, z = Z_L/50Ω = 0.520 + j·(0.825) then a) y = 1/z = 0.547 + j·(-0.867)

2. a) Γ = (z − 1) / (z + 1) = (0.900 − j·0.990 − 1) / (0.900 − j·0.990 + 1)

Γ = (0.172) + j·(-0.431) ↔ ReΓ + j·ImΓ or Γ = 0.464∠-68.2° ↔ |Γ|∠arg(Γ)

3. The quarter wave transformer is designed to match a 65Ω load to a 50Ω source at f_1 = 8.2GHz so $Z_1 = \sqrt{(Z_0 \cdot Z_L)}$ = 57.009 Ω and the line physical length is $l_1 = \lambda_1/4 = c/4/f_1$.

At f_2 = 3.0GHz the characteristic impedance and physical length do not change but $\beta\cdot l = \beta_2 \cdot l_1 = 2\cdot\pi/\lambda_2 \cdot l_1$ = $2\cdot\pi/(c/f_2)\cdot(c/4/f_1) = \pi/2\cdot f_2/f_1$ = 0.183·π = 0.575; tan(β·l) = 0.648

$Z_{in} = Z_1 \cdot \frac{Z_L + j\cdot Z_1 \cdot tan(\beta l)}{Z_1 + j\cdot Z_L \cdot tan(\beta l)}$ = 59.71Ω + j·(-7.17)Ω

4. R = G = 0, thus the line is lossless, $Z_0 = \sqrt{L/C}$ = 16.720Ω.

For a section of an open-circuited transmission line Z_{in} = - j·Z_0·ctg(β·l) = 1/ (j·ω·C) = -j·1/ω/C ; β·l = 2π/λ·(λ/12) = 2π/12 ; C = tg(β·l) / (2·π·f) / Z_0 = 0.470pF

5. a) S_{12} = 0, we have an unilateral transistor, maximum gain match of the source is when $\Gamma_S = S_{11}^*$; Γ_S = 0.638∠-142.4° ; Maximum gain match of the load $\Gamma_L = S_{22}^*$; Γ_L = 0.550∠151.8°

Formulae from L6/2019, S97-101, two solutions for the input match, two solutions for the output match, all lines have Z_0 = 50Ω

input: θ_{S1} = 136.0° ; Im(y_S) = -1.657 ; θ_{p1} = 121.1° <u>or</u> θ_{S2} = 6.4° ; Im(y_S) = 1.657 ; θ_{p2} = 58.9°

output: θ_{L1} = 165.8° ; Im(y_L) = -1.317 ; θ_{p1} = 127.2° <u>or</u> θ_{L2} = 42.4° ; Im(y_L) = 1.317 ; θ_{p2} = 52.8°

b) The shunt stubs **<u>must</u>** be placed in parallel with the 50Ω source/load

c) The gain from source match: $G_{Smax} = 1 / (1 - |S_{11}|^2)$ = 1.686 = 2.270dB; the gain from load match: $G_{Lmax} = 1 / (1 - |S_{22}|^2)$ = 1.434 = 1.565dB; $G_0 = |S_{21}|^2$ = 2.883 = 4.599dB;

The transducer power gain: $G_T = G_{Smax} + G_0 + G_{Lmax}$ = 2.270dB + 4.599dB + 1.565dB = 8.433dB

d) P_{in} = 105µW = -9.788dBm; $P_{out} = P_{in} + G_T$ = -9.788dBm + 8.433dB = -1.355dBm = 0.732mW

e) Stability can be analyzed in different ways, in this case the most simple one: $|S_{11}|$ = 0.638 < 1 ; $|S_{22}|$ = 0.550 < 1 ; K = 1.197 > 1 ; |Δ| = |(0.265)+ j·(0.072)| = 0.274 < 1, thus the transistor is unconditionally stable, in particular is stable including the match designed at a)