1. **(20pts)** A series purely reactive element, is measured to have $S_{11} = \sqrt{2} e^{j \frac{\pi}{4}}$. You can assume that the generator’s impedance is $Z_0 = 50\Omega$ in this measurement. Explain which element is this, and calculate other S-parameters. If you are using properties of microwave networks such as reciprocity etc, to find other S-parameters, state so.
2. **(50pts)** Design a transmission-line microwave low-pass Butterworth filter with the corner frequency of 2GHz. The impedance of the generator is 50Ω. Filter needs to have the minimum number of elements, so that at 4GHz, the attenuation is greater than 20dB. Relative permittivity of dielectric is 2.6, and thickness of the dielectric is 0.4mm. You cannot make the characteristic impedance lower than 20Ω or higher than 120Ω. Clearly write and explain all steps you are doing to solve this problem. Use CAD to verify your design. Email Dr. Markovic your circuit, and the simulation in a word file. To get credit, you have to send this email during the final.
3. (30pts) Match the load $Z_L = 100 + j600$ to a 300$\Omega$ line using transmission lines. The constraints are: only series stubs can be manufactured, only shorted stubs can be manufactured.

(a) [5pts] Using a marker, highlighter or colored pencil, sketch the path you will use to match impedance given to the load. Label clearly on the Smith Chart three important points that will be used to explain the circuit.

(b) [10pts] Write in the space provided below all impedances and admittances for the two important points in the previous step. For example, first you will read impedance and admittance of the load, and write them in $Z_L$, $Y_L$ boxes below. Then you will find the next important point on the Smith Chart and you will write impedance and admittance of that point in $Z_2$, $Y_2$. Explain how you picked the transmission line lengths. Explain how do you know whether the stub is added in parallel or in series.

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\begin{align*}
Z_L &= \ldots \\
Y_L &= \ldots \\
Z_2 &= \ldots \\
Y_2 &= \ldots
\end{align*}
\]

(c) [15pts] Draw the impedance matching circuit below in the space provided, and clearly write what are the transmission line lengths.
4. [10pts] Explain what is a radar and how would you find the range of a radar? Write what are the variables in the range formula. Give brief definitions of each, with numerical example of what the value could be.