

Microwave Devices - Homework n.2

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Considering my academic student number, the following parameters are used for this homework:

$$Z_0 = 50 \Omega, \quad Z_L = 705 \Omega, \quad f_0 = 2365 \text{ MHz}, \quad y_L = 0.0709$$

1 Design of the single stub filter

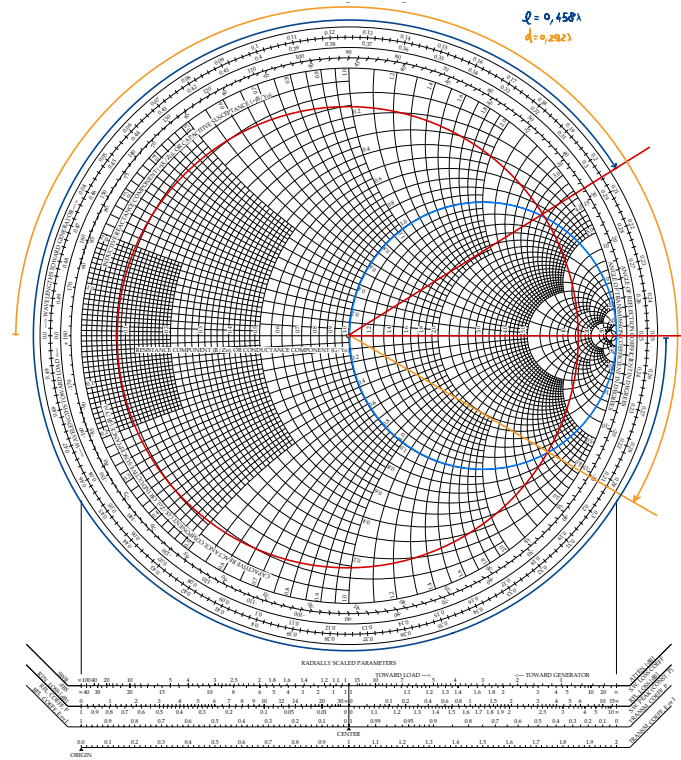


Figure 1: Smith chart graph.

As shown in Figure 1, we observe that $D_{\text{stub}} = 0.292 \lambda$.

Then we calculate λ :

$$\lambda = \frac{c}{f_0} = \frac{3 \times 10^8}{2365 \times 10^6} = 0.1268 \text{ m}$$

Therefore, the distance D_{stub} can also be computed as:

$$D_{\text{stub}} = 0.292 \lambda = 0.292 \times 0.1268 \text{ m} = 0.03702 \text{ m} = 37.02 \text{ mm}$$

The stub length must satisfy $\frac{\lambda}{4} < l_{\text{stub}} < \frac{\lambda}{2}$.

The stub must supply the opposite susceptance in order to cancel the imaginary part at this point:

$$b_{\text{stub}} = -3.45.$$

The long solution is selected and stub length is:

$$l_{\text{stub}} \approx 0.458 \lambda.$$

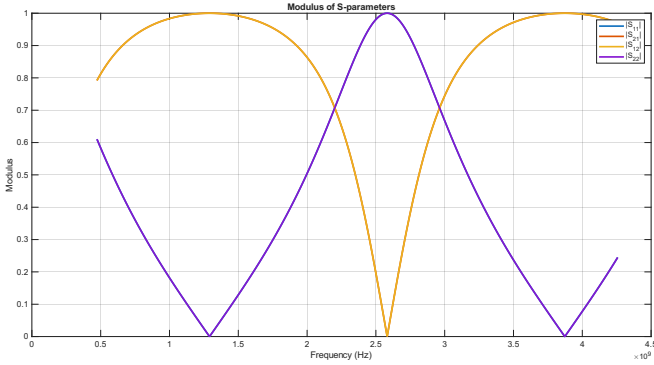
With $\lambda = 126.8$ mm, this corresponds to:

$$l_{\text{stub}} = 58.07 \text{ mm}.$$

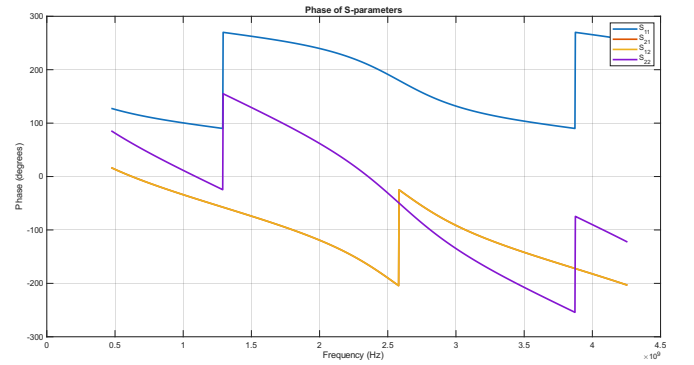
2 S-parameters of the matching network

The two-port composed of the short-circuited shunt stub and the line section of length $d = 0.292 \lambda$ was evaluated in the range $0.2f_0 \leq f \leq 1.8f_0$ via ABCD matrices. The periodic trend is expected for a lossless, reciprocal transmission-line network. Numerical checks confirm reciprocity and losslessness:

$$|S_{12} - S_{21}| \approx 0, \quad S S^H \approx I.$$



(a) Modulus of S-parameters.

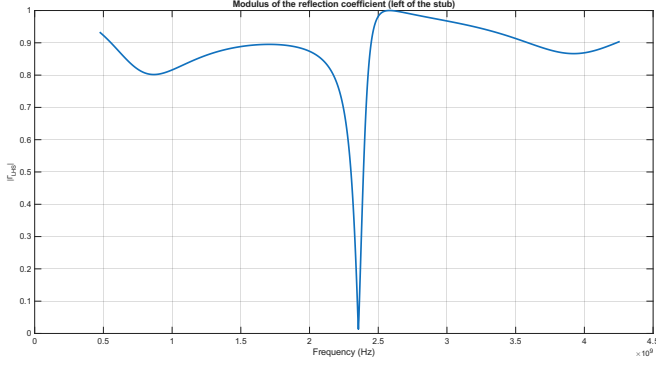


(b) Phase of S-parameters.

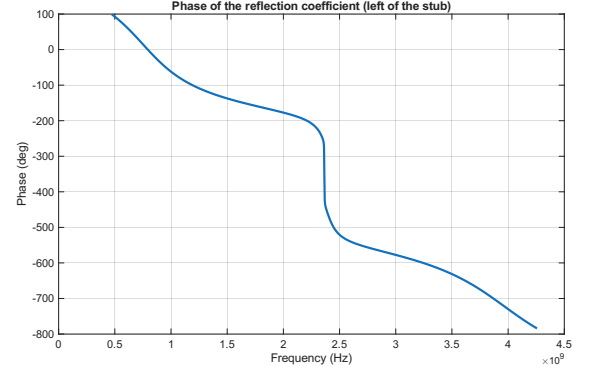
Figure 2: Scattering parameters of the matching network with the stub.

3 Reflection Coefficient Immediately Left of the Stub

Figure 3 shows the modulus and phase of the reflection coefficient evaluated immediately on the left side of the stub. At the design frequency f_0 , the reflection coefficient magnitude $|\Gamma|$ reaches a minimum, indicating that the combination of the stub and the line section provides a good impedance match when viewed from the input. As it can be seen, the local mismatch at the stub plane is not completely canceled.



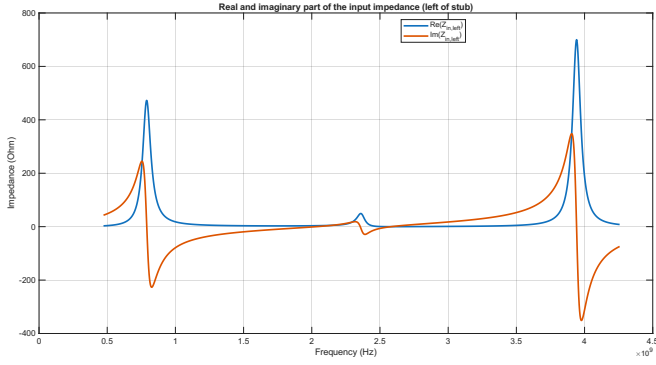
(a) Modulus of the reflection coefficient.



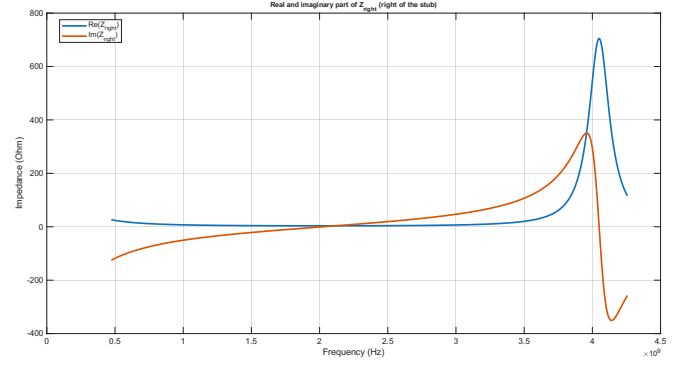
(b) Phase of the reflection coefficient.

Figure 3: Reflection coefficient immediately on the left of the stub.

4 Input impedance at the stub interface



(a) Impedance immediately left of the stub, $Z_{\text{left}}(f)$.



(b) Impedance immediately right of the stub, $Z_{\text{right}}(f)$.

Figure 4: Real and imaginary parts of the input impedance at the stub plane.

In figure 4 the left plot reports $Z_{\text{left}}(f)$, that is the impedance seen from the feeding line and including the shunt short-circuited stub ($Y_{\text{stub}} = -j Z_0^{-1} \cot(\beta l)$). The right plot reports $Z_{\text{right}}(f)$, that is the impedance of the transmission-line section of length D_{stub} terminated on Z_L ,

$$Z_{\text{right}}(f) = Z_0 \frac{Z_L + j Z_0 \tan(\beta D_{\text{stub}})}{Z_0 + j Z_L \tan(\beta D_{\text{stub}})}.$$

The two curves differ because Z_{left} includes the stub contribution, whereas Z_{right} depends only on the D_{stub} section and the load.

5 Voltage and current immediately left of the stub

Figure 5 shows the frequency behavior of voltage and current at the input of the single-stub matching network. At the design frequency f_0 , the voltage and current are nearly in phase (phase difference $\approx 0^\circ$), confirming a matched behavior.

For frequencies away from f_0 , the voltage and current display periodic variations resulting from the phase-dependent interference of forward and reflected waves in the lossless transmission line.

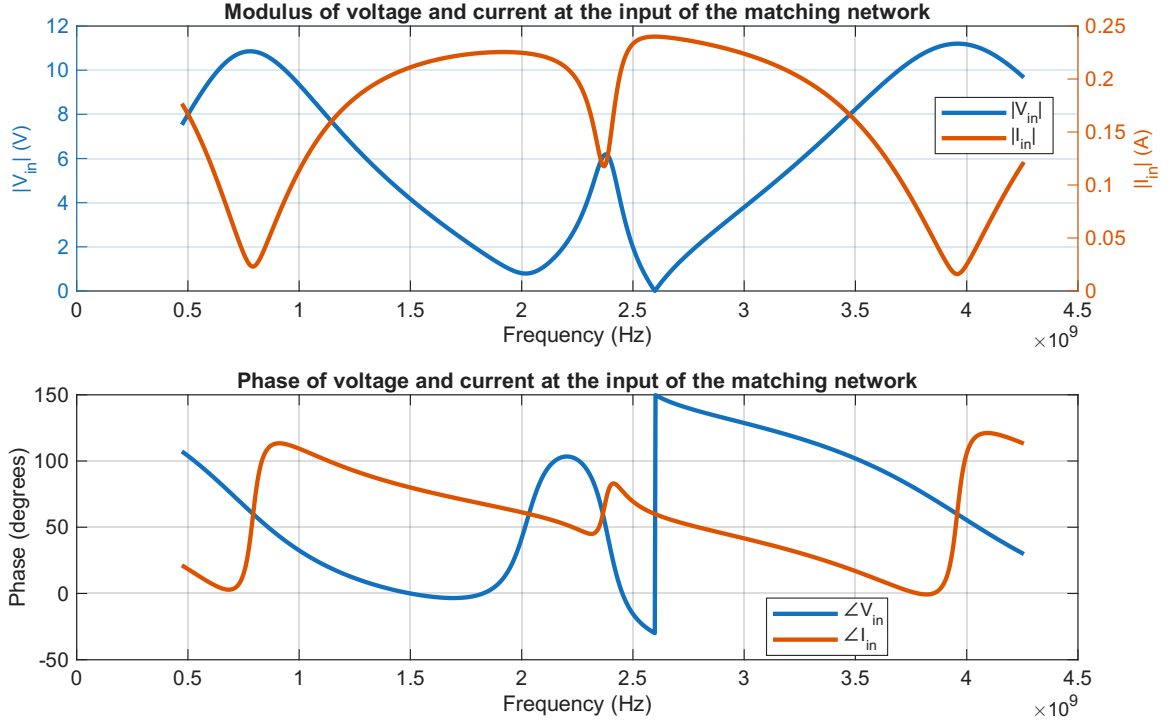


Figure 5: Modulus and phase of the voltage and current at the input of the matching network.

6 Voltage and current immediately right of the Stub

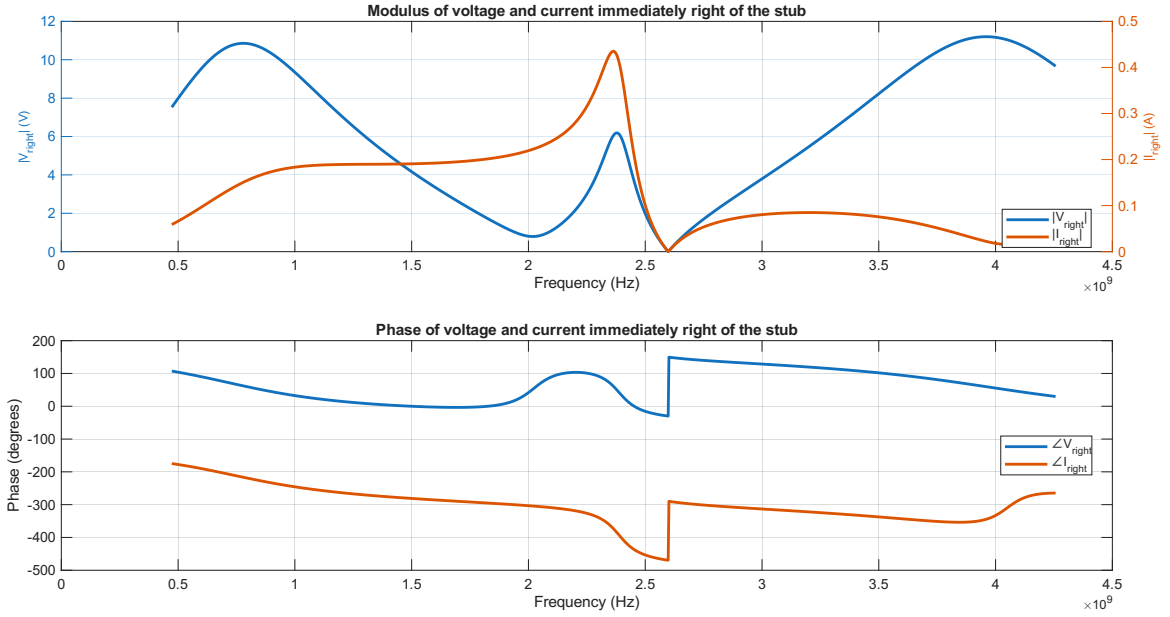


Figure 6: Modulus and phase of the voltage and current immediately after the stub.

At the design frequency f_0 , both quantities assume moderate values and are nearly in phase, indicating a locally resistive impedance. As the frequency increases, however, the voltage magnitude grows significantly, while the current exhibits a milder variation, revealing a strong frequency-dependent transformation of the wave impedance inside the d_{stub} section. The phase plots show rapid variations for both quantities, reflecting the dispersive nature of the transmission-line network and the increasing influence of standing-wave effects away from the matching frequency.

7 Normalized Reflected and Transmitted Active Power

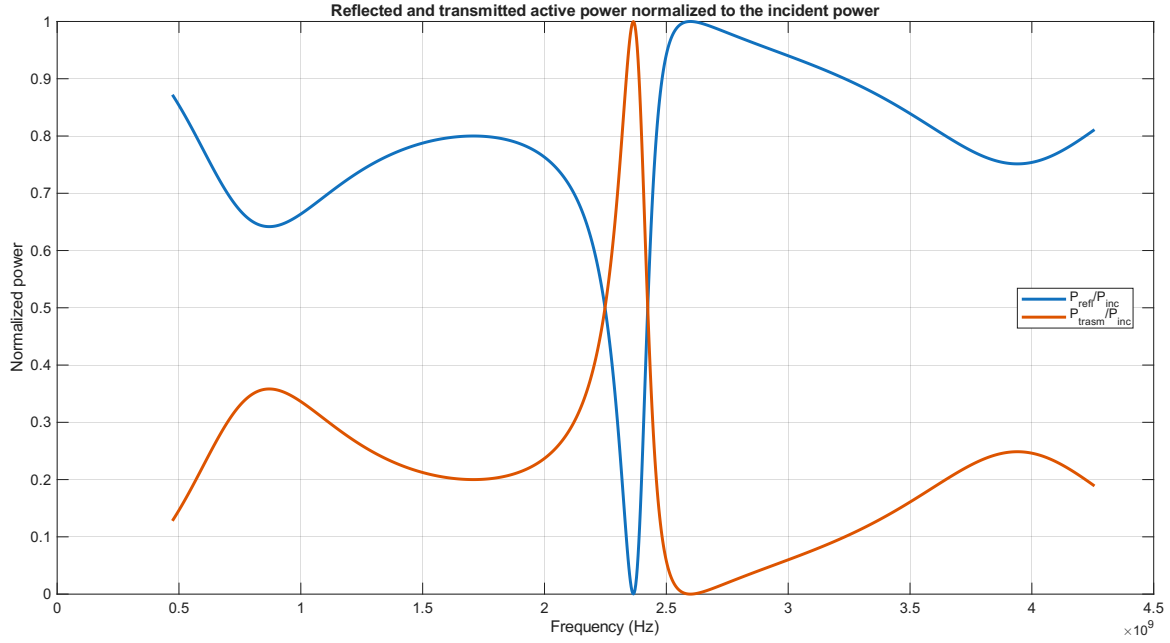


Figure 7: Normalized reflected and transmitted active power at the input of the matching network.

At the design frequency f_0 , the reflected component $P_{\text{refl}}/P_{\text{inc}}$ reaches a minimum while the transmitted power $P_{\text{trasm}}/P_{\text{inc}}$ approaches unity, this confirms the matched condition. Away from f_0 , both curves show complementary oscillations and their sum remains constant at one, as expected for a lossless and reciprocal single-stub matching network.

8 Effect of a Stub Length Increased

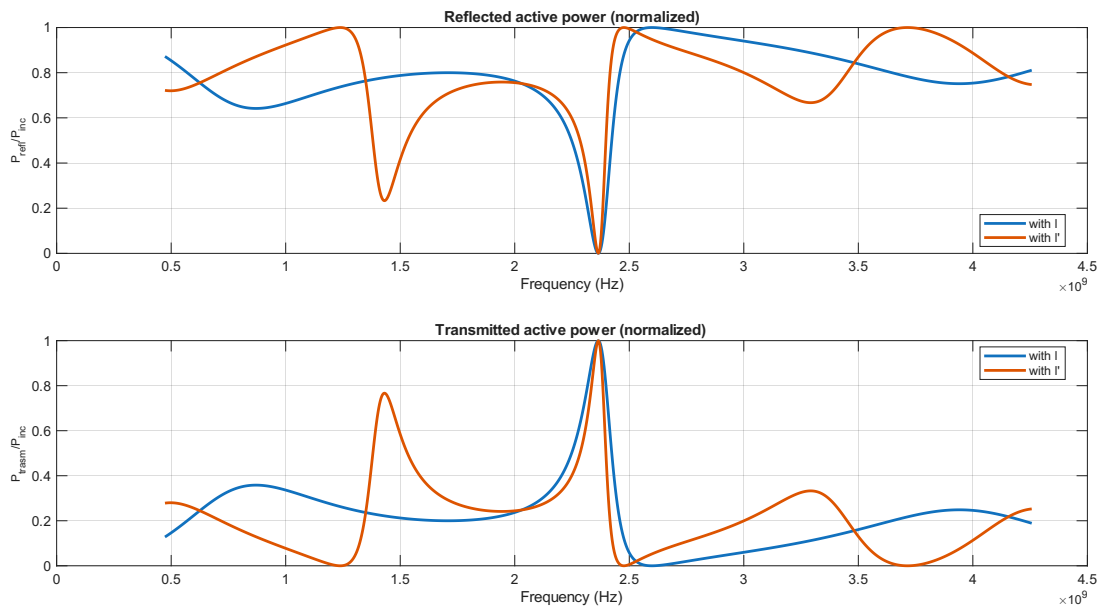


Figure 8: Normalized reflected and transmitted active powers for the original stub length l and for the longer stub $l' = l + \left(\frac{c}{2f_0}\right)$.

As it can be seen in figure 8, at the design frequency f_0 , the two configurations provide identical matching results, since $\cot(\beta l') = \cot(\beta l)$ for $\beta l' = \beta l + \pi$. This means that adding half a wavelength to a short-circuited stub does not change its input admittance. In both cases, the relation

$$\frac{P_{\text{refl}}}{P_{\text{inc}}} + \frac{P_{\text{trasm}}}{P_{\text{inc}}} = 1$$

is verified, confirming that the network remains lossless.

9 Voltage, Current and Active Power at 15 mm from the Load

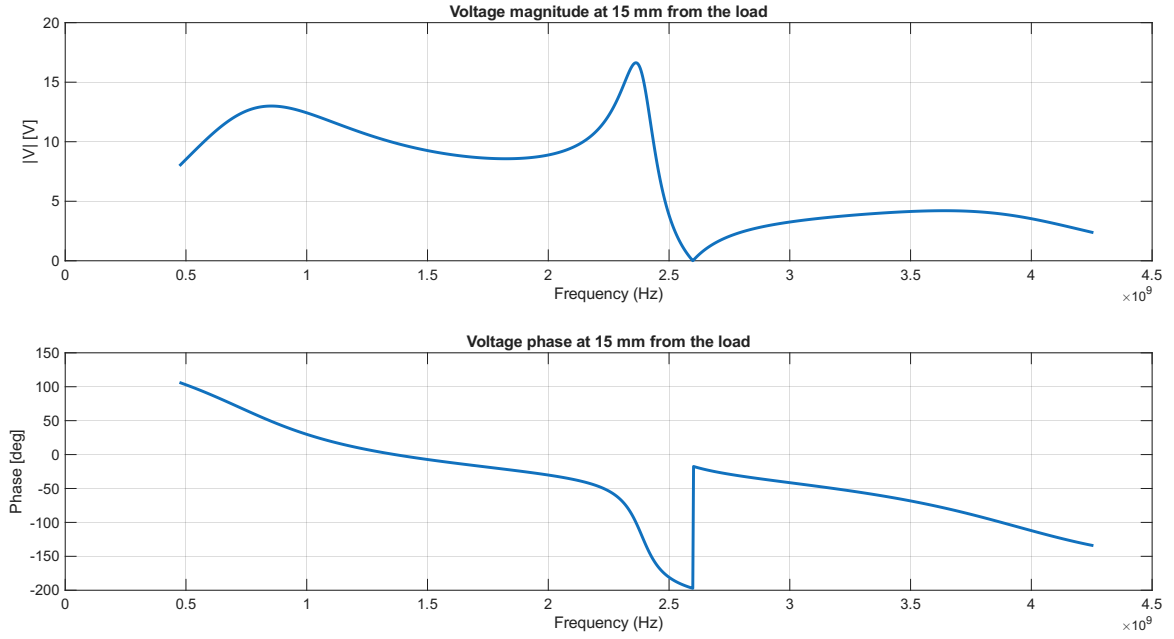


Figure 9: Voltage at 15 mm from the load inside the d -section.

Figure 9 shows the behavior of the voltage at a distance of 15 mm from the load within the transmission line section of length d_{stub} . At the design frequency f_0 , the phase remains almost constant, indicating a locally resistive impedance corresponding to matched conditions.

Figure 10 reports the current magnitude and phase at 15 mm from the load. At f_0 , voltage and current are almost in phase, demonstrating that the circuit is matched and lossless.

Figure 11 illustrates the mean active power evaluated at the same location, computed as

$$P = \frac{1}{2} \Re\{VI^*\}.$$

At the design frequency f_0 , the power reaches its maximum value, consistent with the matched condition where voltage and current are in phase. Away from f_0 , the power shows oscillations due to the progressive phase shift between the two quantities, a characteristic effect of a single-stub matching network.

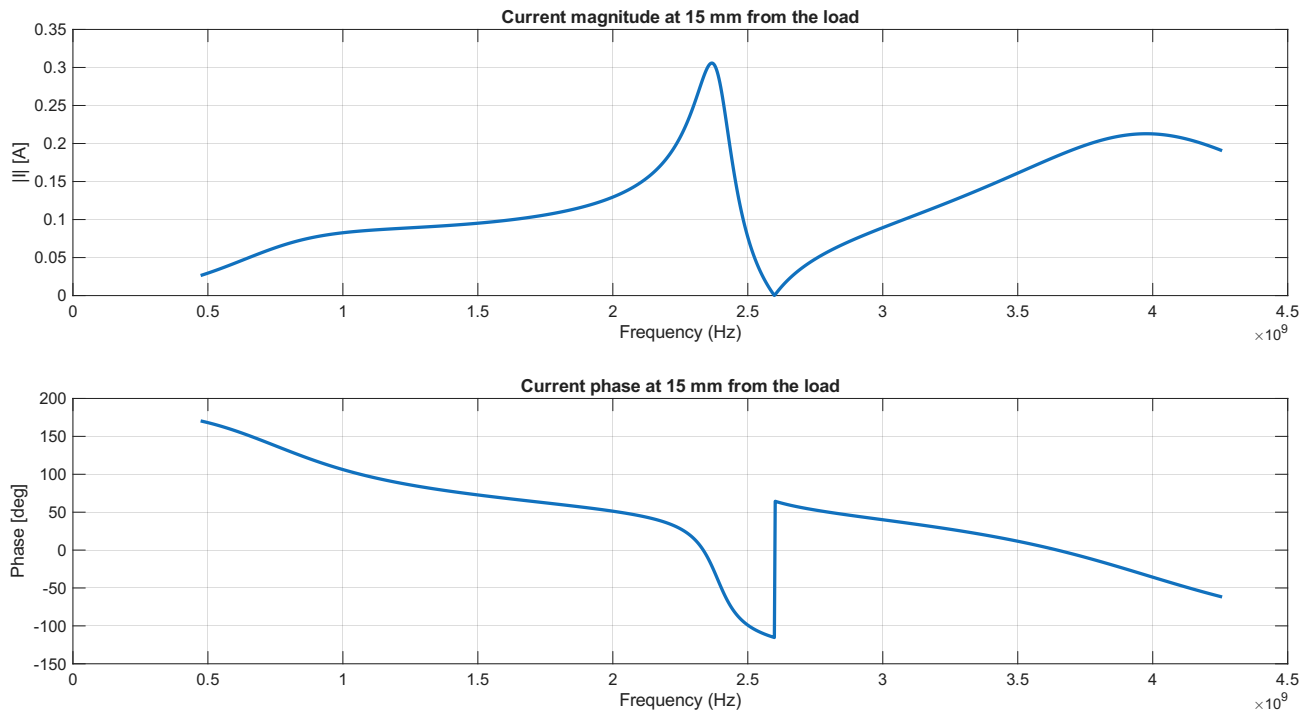


Figure 10: Current at 15 mm from the load.

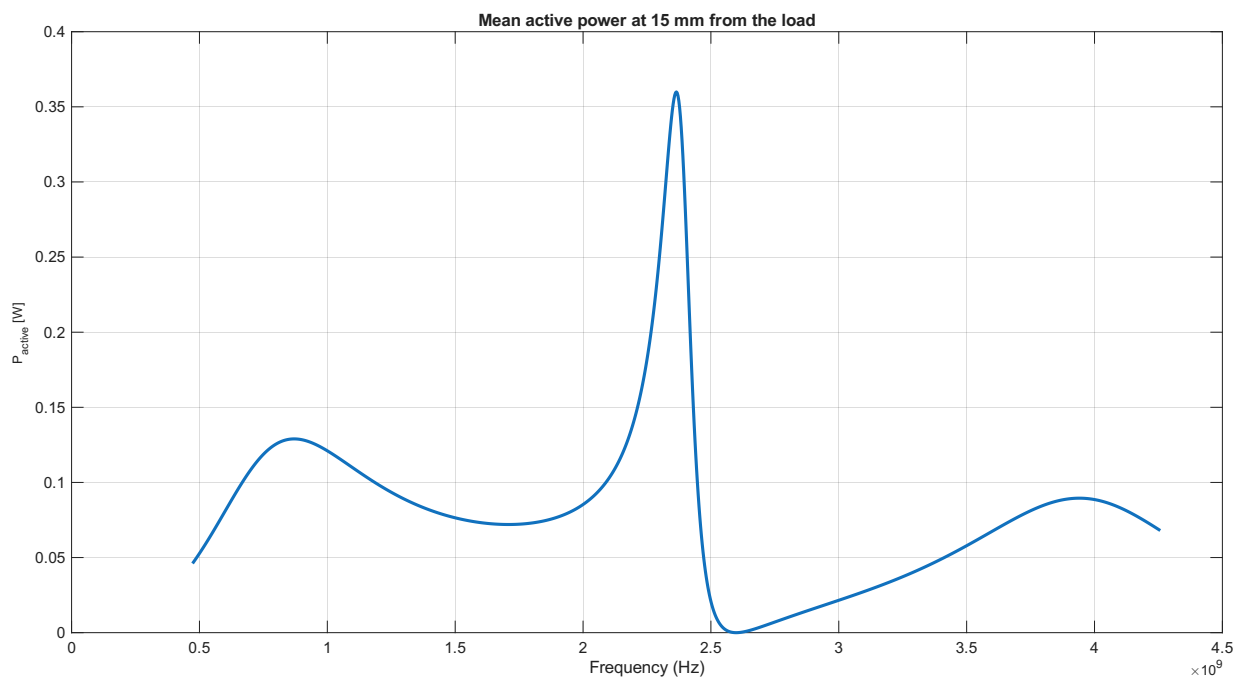


Figure 11: Mean active power at 15 mm from the load.