Clicker lecture 1 of Topic 3: Resonators and microwave circuits and network analysis

Feb 7, 2019

Tacoma bridge 1940

- Tacoma bridge 1940
- What went wrong?

near Seattle
(Washington, USA)

Today's agenda: we will talk about the resonance phenomenon and microwave filters based on resonant circuits.

Why? Various microwave components (such as *filters, oscillators, microwave cavities, antennas*) are based on the resonance phenomenon.

Registration

Go with your mobile phone to

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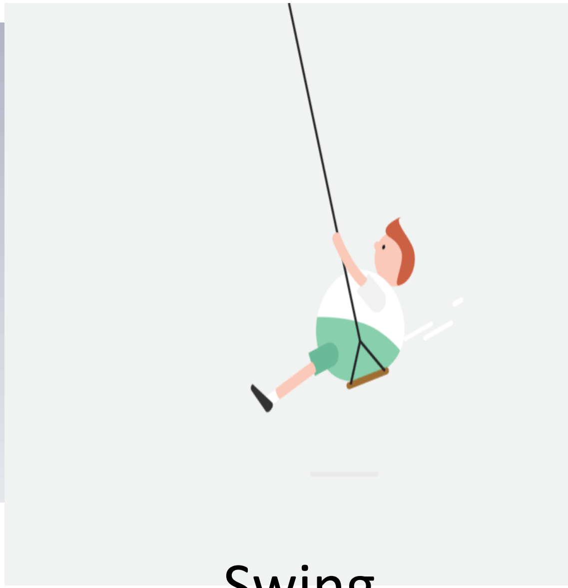
Fill your full name into the text field for registration.

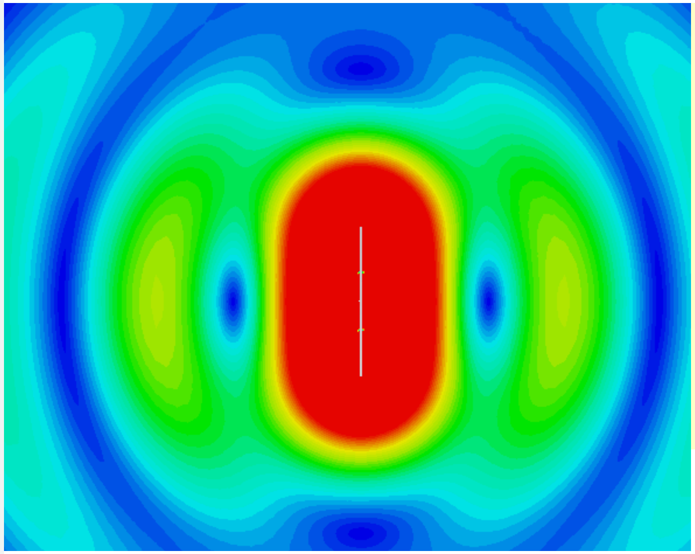
Q1: Which of the following is/are **not** related to the resonance phenomenon? Choose one or more.

1. Ability to store energy and transfer energy between two different storage modes. The modes are out-of-phase.
2. Oscillation at the maximum amplitude
3. Outside force
4. Frequency selective operation
5. Losses, e.g. due to friction or resistance, that cause damping
6. A ”pure” standing wave in a transmission line
7. Microwave filter
8. Series RLC (resistance inductor capacitor) circuit
9. Forward propagating wave in a transmission line
10. Operation of a half-wave dipole antenna

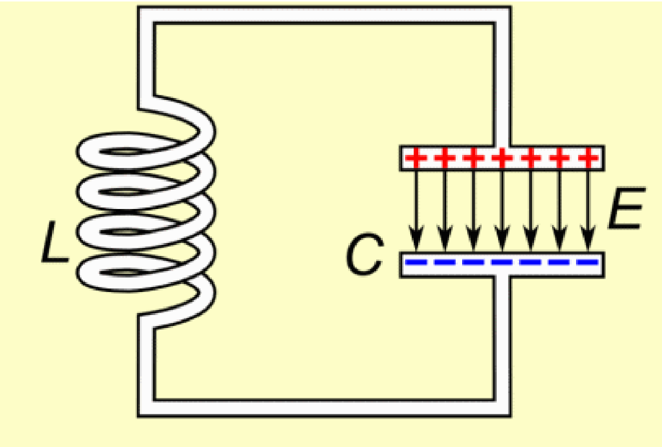
Examples: what are the two storage modes?



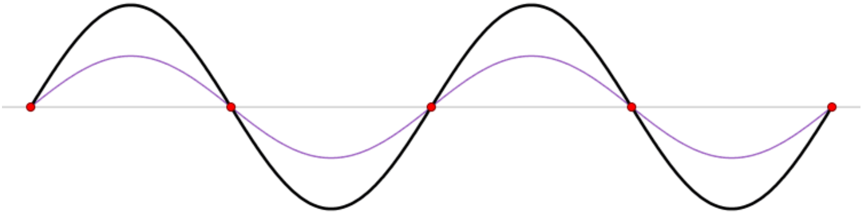
Swing



A half-wave dipole antenna
(here E field strength shown)



LC resonator circuit

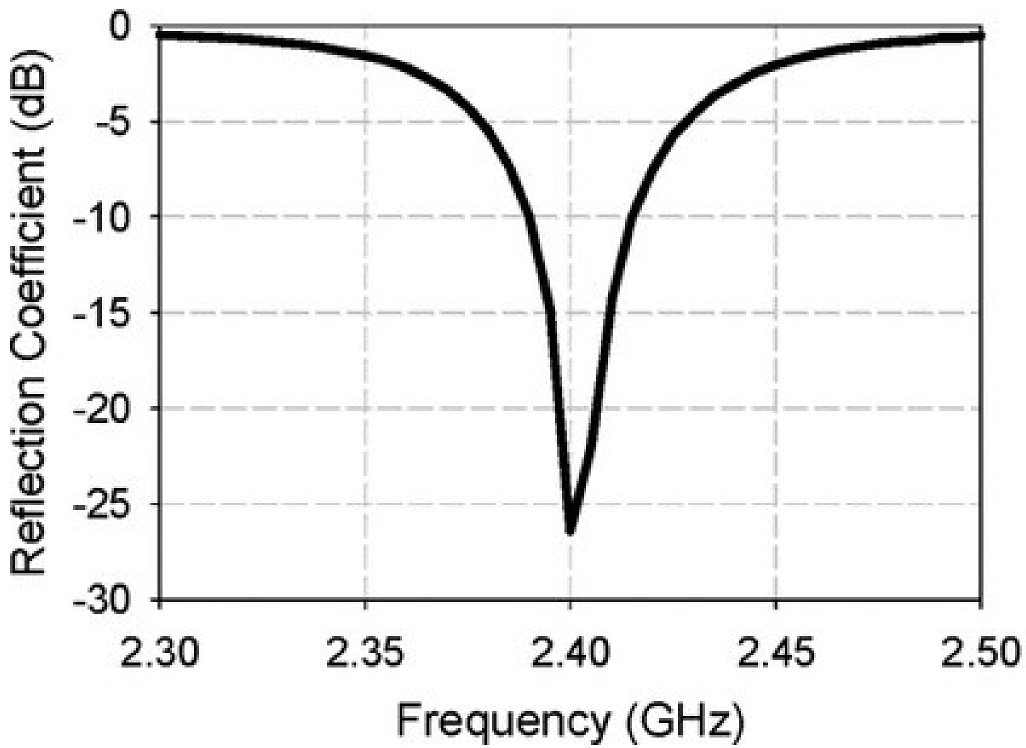


Pure standing wave

Tacoma bridge (1940)

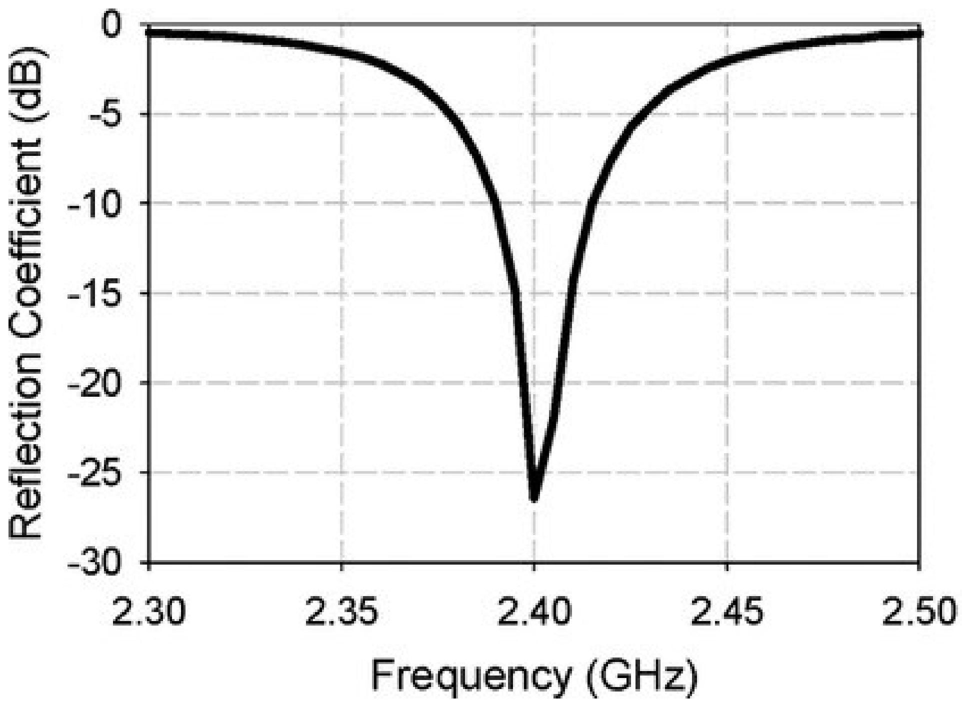
Frequency-selective, resonant behaviour

One can recognize a resonant behaviour from a strong frequency-selective response like this.



Band or bandwidth?

- Band is a *range of frequencies*, for instance, 2.3 … 2.5 GHz
- The corresponding bandwidth is the *width of the band*: 200 MHz (= 2.5 – 2.3 GHz)

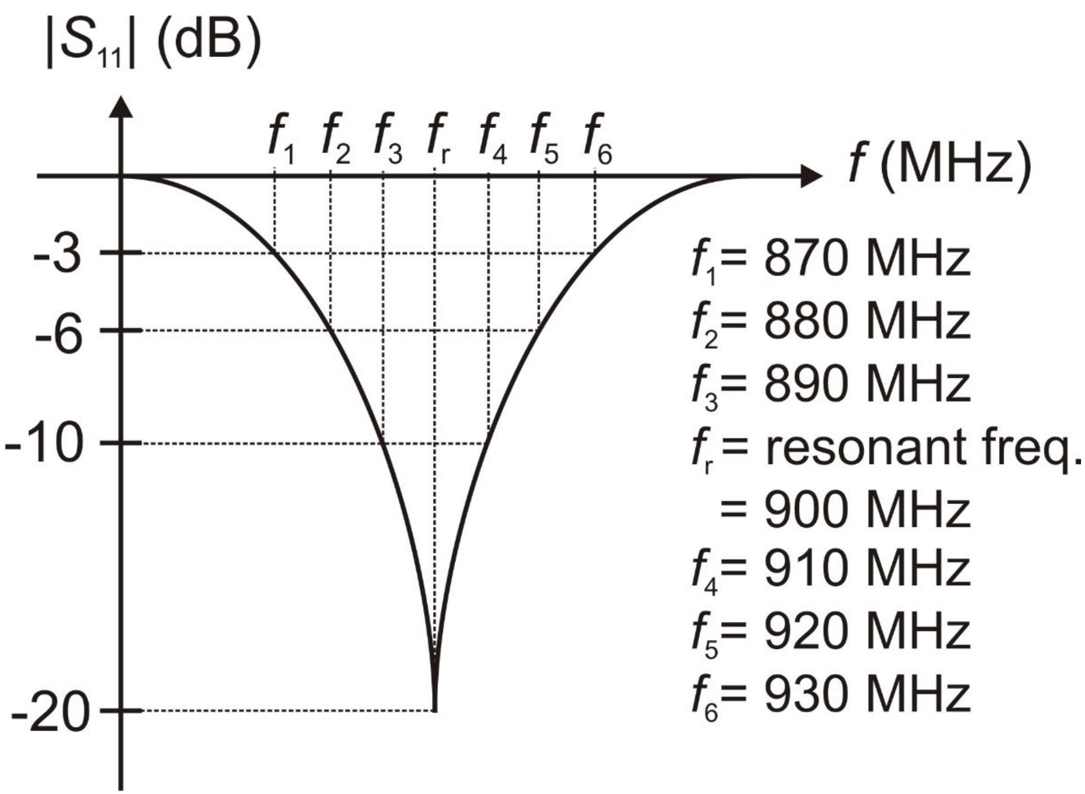


The impedance matching -10-dB (reflection coefficient) band & bandwidth.

Means the band where the impedance matching (reflection coefficient) is better (=lower) than -10 dB.

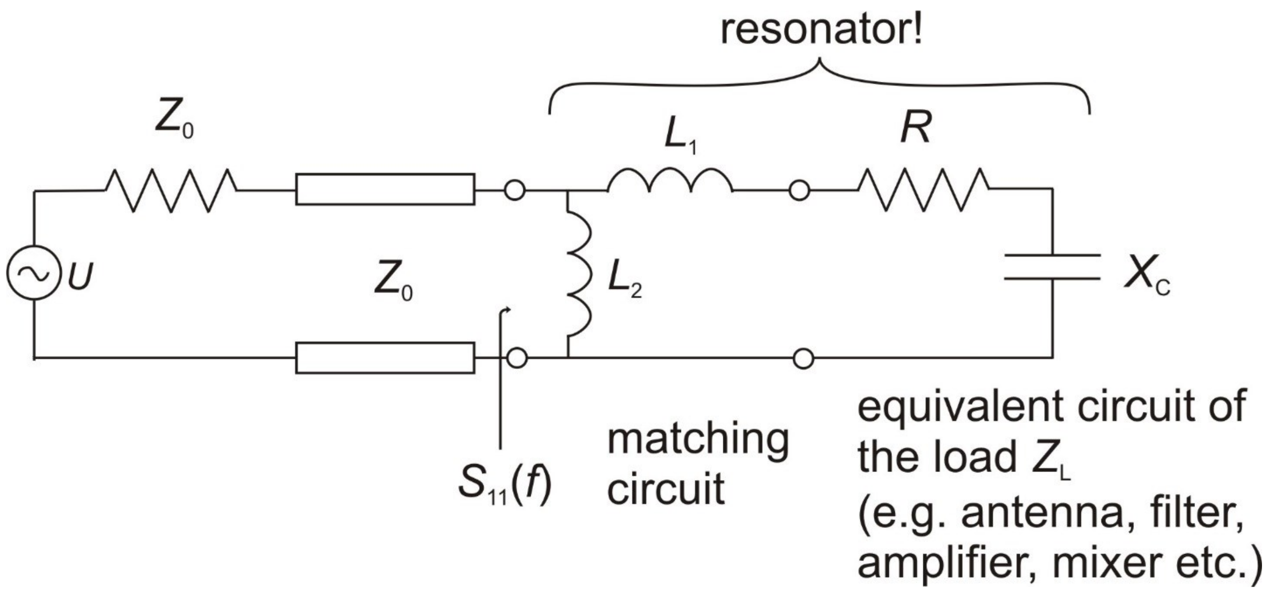
- The -10-dB band 2.39 … 2.42 GHz
- The -10-dB bandwidth 0.030 GHz = 30 MHz

Q2: The figure shows the frequency response of a resonant component. What is the **bandwidth (MHz)** where **less than 25%** of the power is reflected?

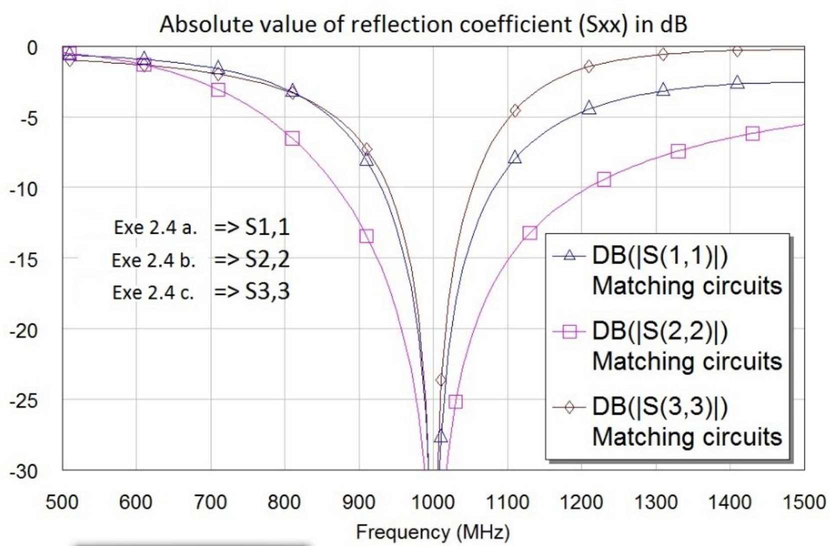


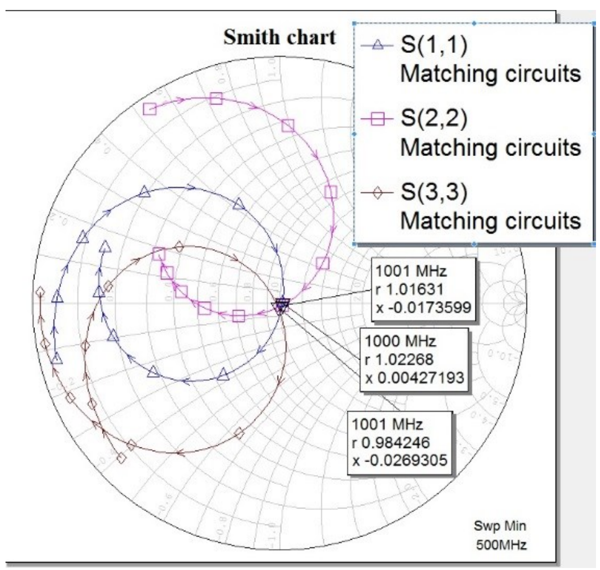
1. 0 MHz
2. 10 MHz
3. 20 MHz
4. 40 MHz
5. 60 MHz
6. None of above

Load + matching circuit = resonator



How does the resonance behavior take place?

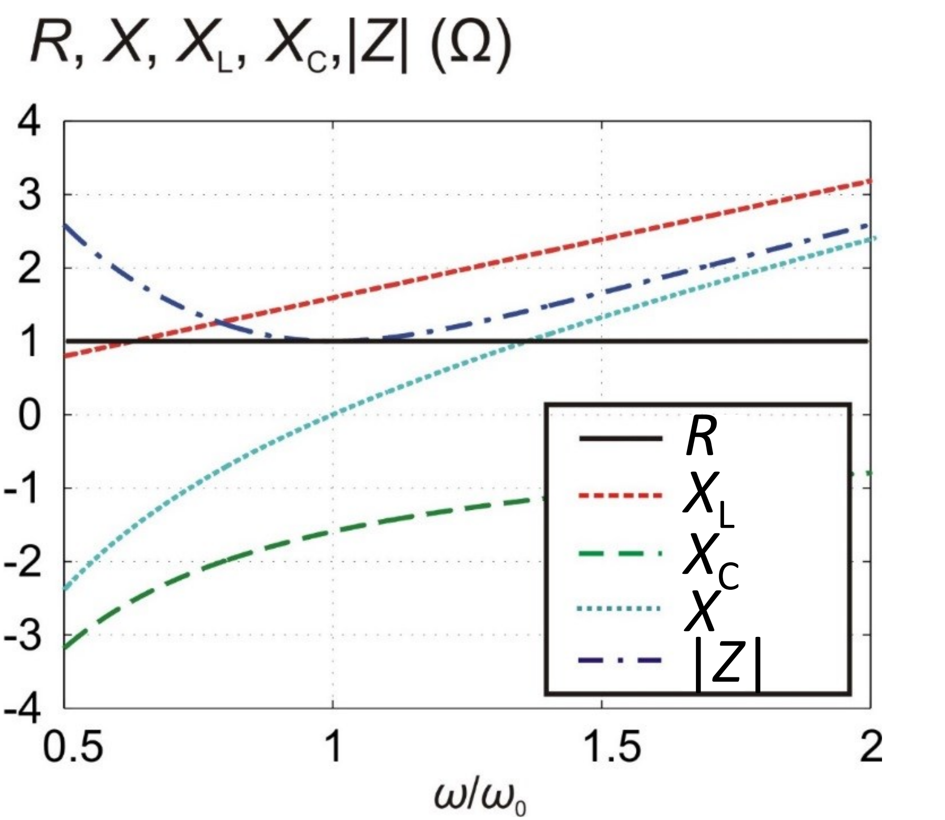




Q3: The curves below show the impedance of a resonator as a function of angular frequency. What is the **type** of the resonator?

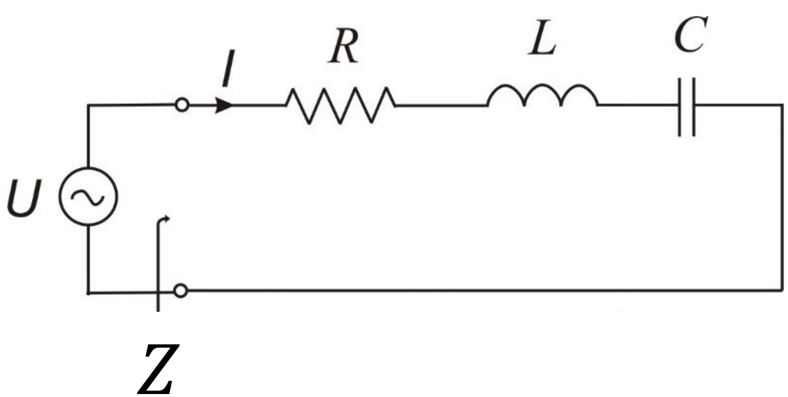
R = resistance, *X* = total reactance, X_L = inductive reactance, X_C = capacitive reaktance, *Z* = impedance

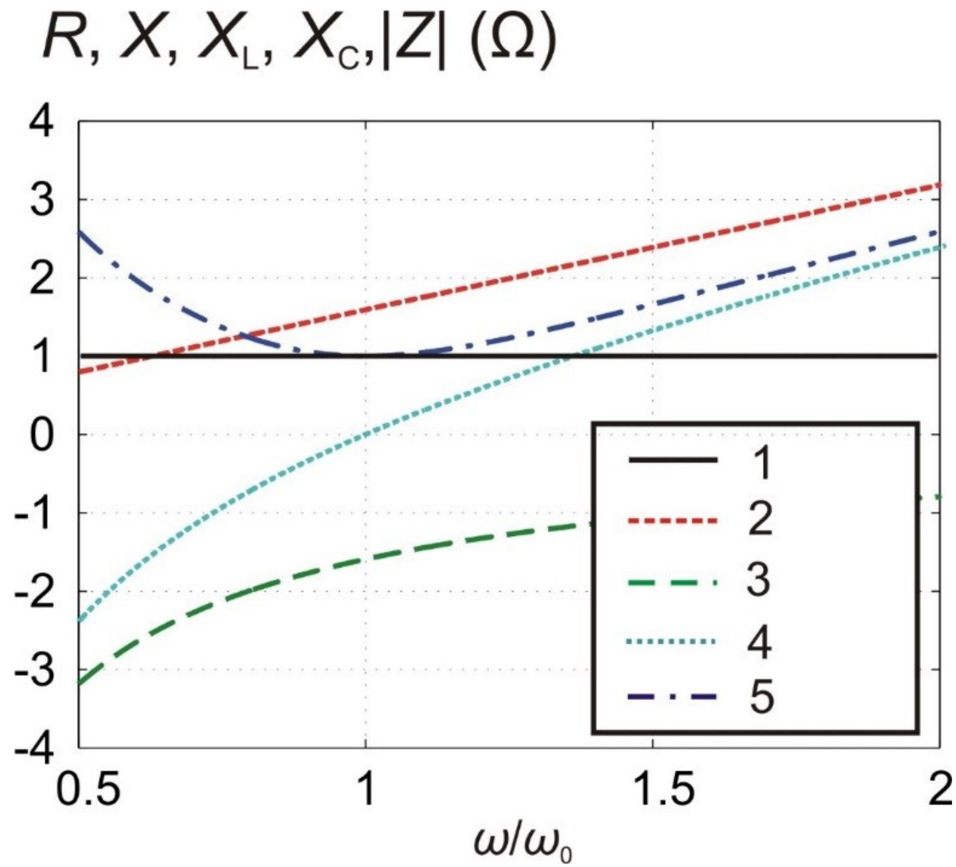
1. Series resonant circuit
2. Parallel resonant circuit
3. L-section lumped element matching circuit
4. Dual-resonant matching circuit
5. None of above
6. I don't know



Series RLC circuit

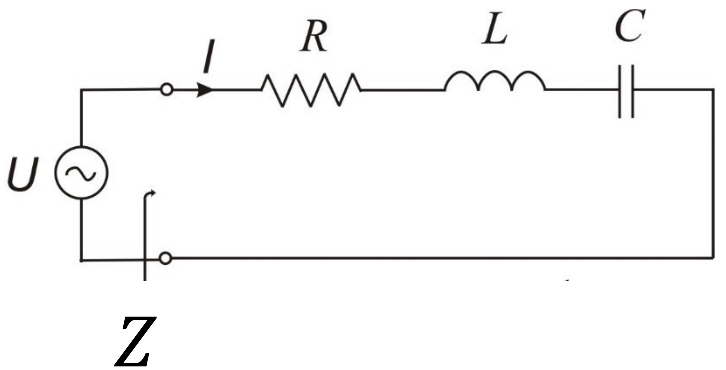
The simplest form of resonator is good for understanding the phenomenon!





$$Z = R + \mathrm{j}\,X = R + \mathrm{j}\,(X_L - X_c) = R + \mathrm{j}\,\left(\omega L - \frac{1}{\omega C}\right)$$

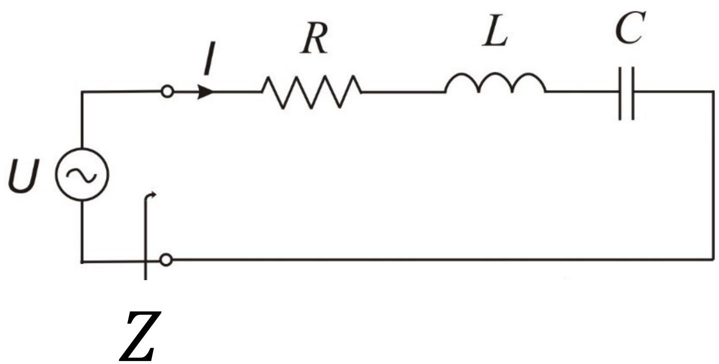
Q4: Which of alternatives is the definition of the resonant frequency



$$Z = R + \mathrm{j}\,X = R + \mathrm{j}\,(X_L - X_c)$$
$$= R + \mathrm{j}\left(\omega L - \frac{1}{\omega C}\right)$$

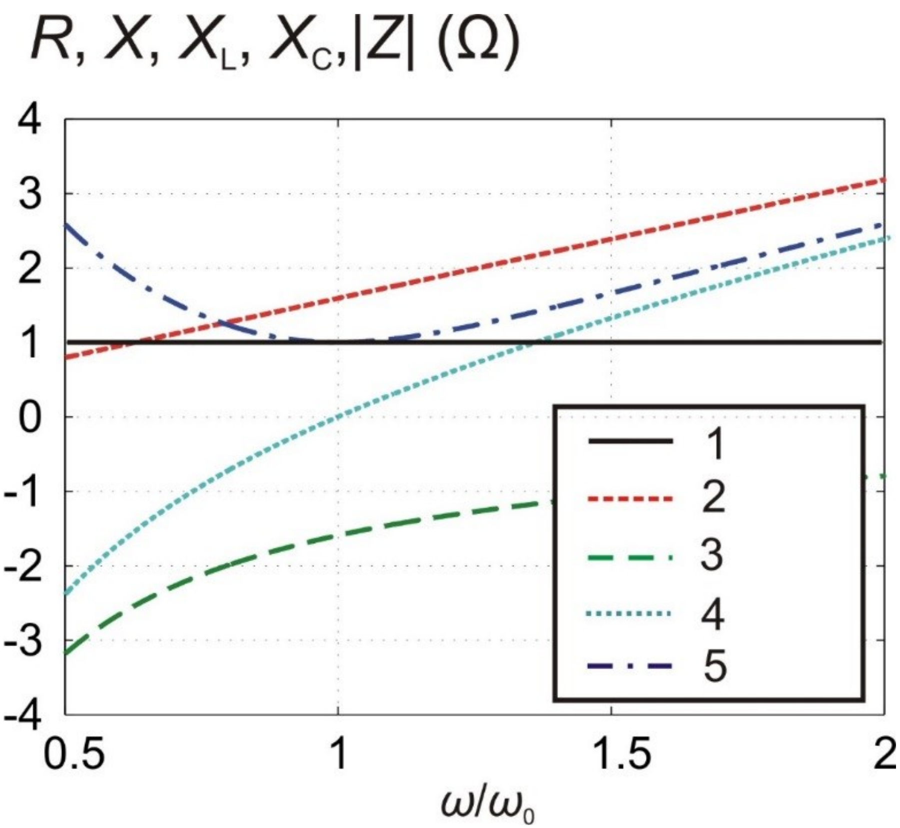
1. A time-average energy in the **electric** mode takes place
2. Energy in the **magnetic** mode is at its maximum
3. Amplitude of the current (oscillation) is at its maximum
4. The inductance *L* equals the capacitance *C*
5. None of above
6. I don’t know

Q5: At which normalized angular frequency the resonanator is in the resonance?



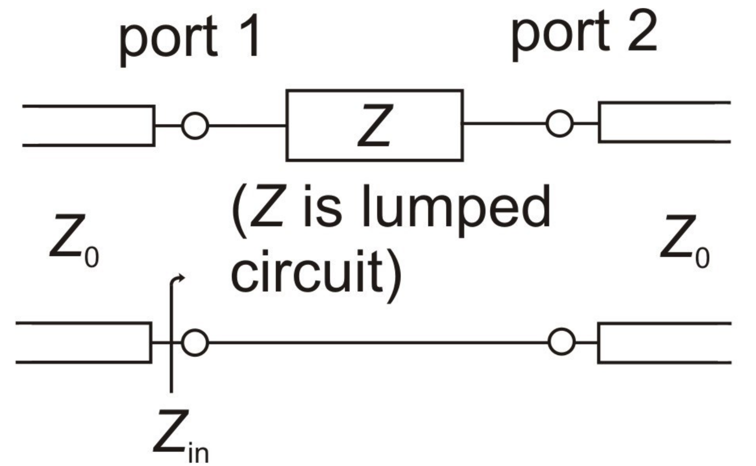
$$Z = R + \mathrm{j}\,X = R + \mathrm{j}\,(X_L - X_c)$$
$$= R + \mathrm{j}\,\left(\omega L - \frac{1}{\omega C}\right)$$

1. ω = 0.5 rad/s
2. ω = 1.0 rad/s
3. ω = 1.5 rad/s
4. ω = 2.0 rad/s
5. None of above
6. I don't know



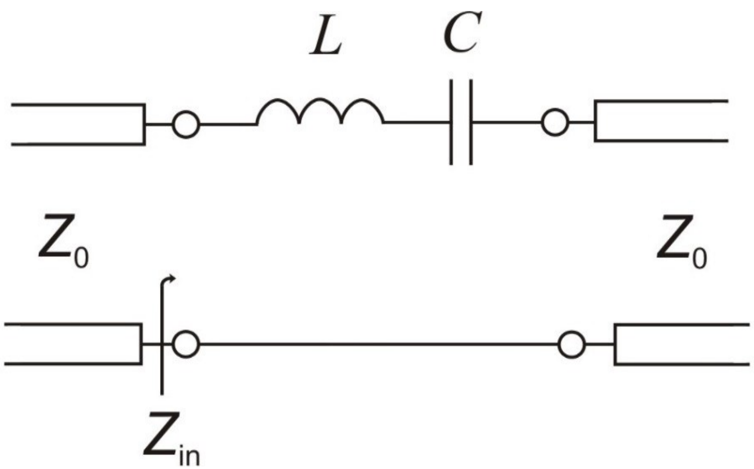
Q6: A 2-port with lumped impedance Z is connected between two transmission lines (with Z_0). What is the input impedance Z_{in} seen in Port 1 to the **right** (towards Port 2)?

Assume lines very long.



1. $Z_{in} = Z$
2. $Z_{in} = Z_0$
3. $Z_{in} = Z + Z_0$
4. $Z_{in} = Z \cdot Z_0/(Z + Z_0)$
5. None of above
6. I don't know

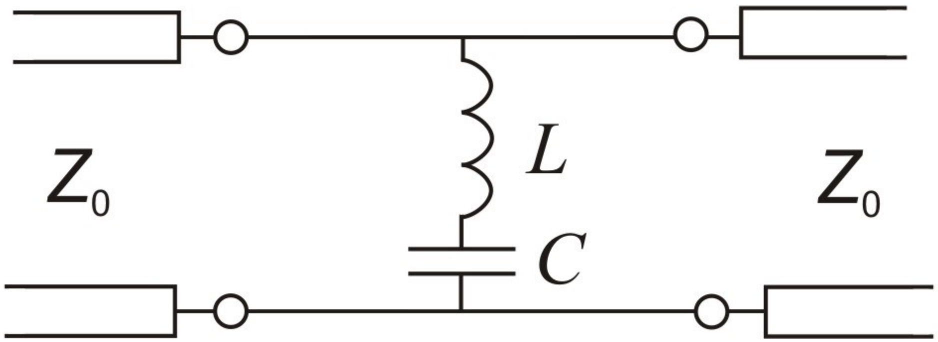
Q7: This LC series circuit topology might work as ...



$$\omega_0 = \frac{1}{\sqrt{LC}}$$

1. Low-pass filter below ω_0
2. High-pass filter above ω_0
3. Band-pass filter around ω_0
4. Band-stop filter around ω_0
5. None of above
6. I don’t know

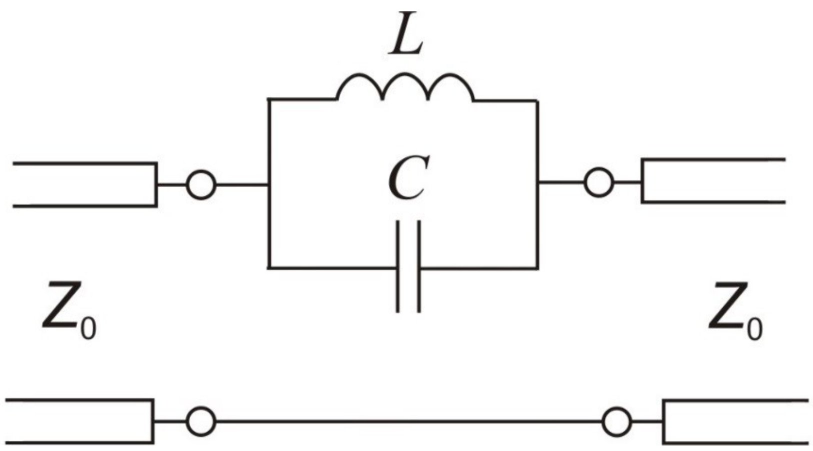
Q8: This LC series circuit topology might work as …



$$\omega_0 = \frac{1}{\sqrt{LC}}$$

1. Low-pass filter below ω_0
2. High-pass filter above ω_0
3. Band-pass filter around ω_0
4. Band-stop filter around ω_0
5. None of above
6. I don’t know

Q9: This LC parallel circuit topology might work as …



$$\omega_0 = \frac{1}{\sqrt{LC}}$$

1. Low-pass filter below ω_0
2. High-pass filter above ω_0
3. Band-pass filter around ω_0
4. Band-stop filter around ω_0
5. None of above
6. I don’t know