The W5JCK Guide to the Mathematic Equations Required for the Amateur Extra Class Exam

This document contains every question from the Extra Class (Element 4) Question Pool* that requires one or more mathematical formulas to answer. Each question illustrates every formula necessary to answer the question in an easy to understand, step-by-step process.

> *Question Pool Element 4 - Extra Class, as released by the Question Pool Committee of the National Conference of Volunteer Examiner Coordinators November 30, 2001. Question Pool Element 4 was updated effective December 15, 2006 to reflect the FCC Report and Order (R&O) on docket 04-140. The current question pool is valid until June 30, 2008.

I designed this document as an aid for reviewing the mathematics necessary to solve the exam questions. It does not cover the mathematical or electrical theories behind the equations. To study the theory, I highly recommend *The ARRL Extra Class License Manual* and Gordon West's *Extra Class FCC License Preparation for Element 4*. Both of these publications were of great help to me in preparing for my Amateur Extra Class exam.

Good luck on your Amateur Extra exam.

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Section E4: Amateur Radio Practices

E4B04: If a frequency counter with a specified accuracy of +/- 1.0 ppm reads 146,520,000 Hz, what is the most the actual frequency being measured could differ from the reading?

$$\boldsymbol{Error} = \boldsymbol{f}\,(\boldsymbol{Hz}) \times \frac{\boldsymbol{counter\ error}}{\mathbf{1,000,000}} = 146{,}520{,}000 \times \frac{1}{1{,}000{,}000} = \mathbf{146.52}\ \boldsymbol{Hz}$$

E4B05: If a frequency counter with a specified accuracy of +/- 0.1 ppm reads 146,520,000 Hz, what is the most the actual frequency being measured could differ from the reading?

$$\boldsymbol{Error} = \boldsymbol{f}\,(\boldsymbol{Hz}) \times \frac{\boldsymbol{counter\ error}}{\mathbf{1,000,000}} = \mathbf{146,520,000} \times \frac{0.\mathbf{1}}{\mathbf{1,000,000}} = \mathbf{14.652}\ \boldsymbol{Hz}$$

E4B06: If a frequency counter with a specified accuracy of +/- 10 ppm reads 146,520,000 Hz, what is the most the actual frequency being measured could differ from the reading?

$$\boldsymbol{Error} = \boldsymbol{f}\,(\boldsymbol{Hz}) \times \frac{\boldsymbol{counter\ error}}{\mathbf{1,000,000}} = \mathbf{146,520,000} \times \frac{\mathbf{10}}{\mathbf{1,000,000}} = \mathbf{1465.2}\ \boldsymbol{Hz}$$

E4B07: If a frequency counter with a specified accuracy of +/- 1.0 ppm reads 432,100,000 Hz, what is the most the actual frequency being measured could differ from the reading?

$$\boldsymbol{Error} = \boldsymbol{f}\,(\boldsymbol{Hz}) \times \frac{\boldsymbol{counter\ error}}{\mathbf{1,000,000}} = 432{,}100{,}000 \times \frac{1}{1{,}000{,}000} = \mathbf{432.1}\ \boldsymbol{Hz}$$

E4B08: If a frequency counter with a specified accuracy of +/- 0.1 ppm reads 432,100,000 Hz, what is the most the actual frequency being measured could differ from the reading?

$$\boldsymbol{Error} = \boldsymbol{f}\,(\boldsymbol{Hz}) \times \frac{\boldsymbol{counter\ error}}{\mathbf{1,000,000}} = 432{,}100{,}000 \times \frac{0.1}{1{,}000{,}000} = \mathbf{43.21}\ \boldsymbol{Hz}$$

E4B09: If a frequency counter with a specified accuracy of +/- 10 ppm reads 432,100,000 Hz, what is the most the actual frequency being measured could differ from the reading?

$$\boldsymbol{Error} = \boldsymbol{f}\,(\boldsymbol{Hz}) \times \frac{\boldsymbol{counter\ error}}{\mathbf{1,000,000}} = 432{,}100{,}000 \times \frac{10}{1{,}000{,}000} = \mathbf{4321}\ \boldsymbol{Hz}$$

E4B10: If a 100 Hz signal is fed to the horizontal input of an oscilloscope and a 150 Hz signal is fed to the vertical input, what type of Lissajous figure will be displayed on the screen?

$$\frac{\boldsymbol{f_H}}{\boldsymbol{f_V}} = \frac{\boldsymbol{n_V}}{\boldsymbol{n_H}} = \frac{100\,Hz}{150\,Hz} = \frac{2}{3} = \boldsymbol{2\ vertical\ loops\ and\ 3\ horizontal\ loops}$$

E4C08: What is the blocking dynamic range for a receiver that has an 8-dB noise figure and an IF bandwidth of 500 Hz when the blocking level (1-dB compression point) is -20 dBm?

$$Bandwidth\ factor = 10 \times \log(bandwidth) = 10 \times \log(500) = 27\ dB$$

$$Noise\ floor = -174\ dBm + bandwidth\ factor + noise\ figure$$

$$Noise\ floor = -174\ dBm + 27\ dB + 8\ dB = -139\ dBm$$

$$\boldsymbol{BDR} = |\boldsymbol{Noise\ floor} - \boldsymbol{Blocking\ level}| = |-139\ dBm - -20\ dB| = |-119\ dB| = \boldsymbol{119\ dB}$$

Note that the use of vertical bars (for example, "$|-119\ dB|$") denotes absolute value.

E4C14: If a receiver tuned to 146.70 MHz receives an intermodulation-product signal whenever a nearby transmitter transmits on 146.52 MHz, what are the two most likely frequencies for the other interfering signal?

$$\boldsymbol{f_2} = (\boldsymbol{2} \times \boldsymbol{f_1}) - \boldsymbol{f_{IMD}} = (2 \times 146.52) - 146.70 = \boldsymbol{146.34\ MHz}$$

$$\boldsymbol{f_2} = \frac{\boldsymbol{f_{IMD}} + \boldsymbol{f_1}}{\boldsymbol{2}} = \frac{146.70 + 146.52}{2} = \boldsymbol{146.61\ MHz}$$

E4C26: In a receiver, if the third-order intermodulation products have a power of-70 dBm when using two test tones at -30 dBm, what is the third-order intercept point?

$$\boldsymbol{IP_3} = \frac{(\boldsymbol{3} \times \boldsymbol{Test\ Tone}) - \boldsymbol{P_{IMod}}}{\boldsymbol{3-1}} = \frac{(3 \times -30\ dBm) - -70\ dBm}{2} = \boldsymbol{-10\ dBm}$$

E4C27: In a receiver, if the second-order intermodulation products have a power of-70 dBm when using two test tones at -30 dBm, what is the second-order intercept point?

$$\boldsymbol{IP_2} = \frac{(\boldsymbol{2} \times \boldsymbol{Test\ Tone}) - \boldsymbol{P_{IMod}}}{\boldsymbol{2-1}} = \frac{(2 \times -30\ dBm) - -70\ dBm}{1} = \boldsymbol{+10\ dBm}$$

Section E5: Electrical Principles

E5A12: What is the half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 1.8 MHz and a Q of 95?

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}} = \frac{1.8 \times 10^6\ Hz}{95} = 18947\ Hz = \mathbf{18.9\ kHz}$$

E5A13: What is the half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 7.1 MHz and a Q of 150?

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}} = \frac{7.1 \times 10^6\ Hz}{150} = 47333\ Hz = \mathbf{47.3\ kHz}$$

E5A14: What is the half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 14.25 MHz and a Q of 150?

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}} = \frac{14.25 \times 10^6\ Hz}{150} = 95000\ Hz = \mathbf{95\ kHz}$$

E5A15: What is the half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 21.15 MHz and a Q of 95?

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}} = \frac{21.15 \times 10^6\ Hz}{95} = 222632\ Hz = \mathbf{222.6\ kHz}$$

E5A16: What is the half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 3.7 MHz and a Q of 118?

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}} = \frac{3.7 \times 10^6\ Hz}{118} = 31356\ Hz = \mathbf{31.4\ kHz}$$

E5A17: What is the half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 14.25 MHz and a Q of 187?

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}} = \frac{14.25 \times 10^6\ Hz}{187} = 76203\ Hz = \mathbf{76.2\ kHz}$$

E5A18: What is the resonant frequency of a series RLC circuit if R is 47 ohms, L is 50 microhenrys and C is 40 picofarads?

$$f_r = \frac{\mathbf{1}}{\mathbf{2}\,\boldsymbol{\pi}\,\sqrt{\boldsymbol{L}\,\boldsymbol{C}}} = \frac{1}{2\,\pi \times \sqrt{(50 \times 10^{-6}) \times (40 \times 10^{-12})}} = 3{,}558{,}812\ Hz = \mathbf{3.56}\ \boldsymbol{MHz}$$

E5A19: What is the resonant frequency of a series RLC circuit if R is 47 ohms, L is 40 microhenrys and C is 200 picofarads?

$$f_r = \frac{\mathbf{1}}{\mathbf{2}\,\boldsymbol{\pi}\,\sqrt{\boldsymbol{L}\,\boldsymbol{C}}} = \frac{1}{2\,\pi \times \sqrt{(40 \times 10^{-6}) \times (200 \times 10^{-12})}} = 1{,}780{,}309\ Hz = \mathbf{1.78}\ \boldsymbol{MHz}$$

E5A20: What is the resonant frequency of a series RLC circuit if R is 47 ohms, L is 50 microhenrys and C is 10 picofarads?

$$f_r = \frac{\mathbf{1}}{\mathbf{2}\,\boldsymbol{\pi}\,\sqrt{\boldsymbol{L}\,\boldsymbol{C}}} = \frac{1}{2\,\pi \times \sqrt{(50 \times 10^{-6}) \times (10 \times 10^{-12})}} = 7{,}121{,}236\ Hz = \mathbf{7.12}\ \boldsymbol{MHz}$$

E5A21: What is the resonant frequency of a series RLC circuit if R is 47 ohms, L is 25 microhenrys and C is 10 picofarads?

$$f_r = \frac{\mathbf{1}}{\mathbf{2}\,\boldsymbol{\pi}\,\sqrt{\boldsymbol{L}\,\boldsymbol{C}}} = \frac{1}{2\,\pi \times \sqrt{(25 \times 10^{-6}) \times (10 \times 10^{-12})}} = 10{,}070{,}948\ Hz = \mathbf{10.1}\ \boldsymbol{MHz}$$

E5A22: What is the resonant frequency of a series RLC circuit if R is 47 ohms, L is 3 microhenrys and C is 40 picofarads?

$$f_r = \frac{\mathbf{1}}{\mathbf{2}\,\boldsymbol{\pi}\,\sqrt{\boldsymbol{L}\,\boldsymbol{C}}} = \frac{1}{2\,\pi \times \sqrt{(3 \times 10^{-6}) \times (40 \times 10^{-12})}} = 14{,}536{,}161\ Hz = \mathbf{14.5}\ \boldsymbol{MHz}$$

E5A23: What is the resonant frequency of a series RLC circuit if R is 47 ohms, L is 4 microhenrys and C is 20 picofarads?

$$f_r = \frac{\mathbf{1}}{\mathbf{2}\,\boldsymbol{\pi}\,\sqrt{\boldsymbol{L}\,\boldsymbol{C}}} = \frac{1}{2\,\pi \times \sqrt{(4 \times 10^{-6}) \times (20 \times 10^{-12})}} = 17{,}803{,}089\ Hz = \mathbf{17.8}\ \boldsymbol{MHz}$$

E5A24: What is the resonant frequency of a series RLC circuit if R is 47 ohms, L is 8 microhenrys and C is 7 picofarads?

$$f_r = \frac{\mathbf{1}}{\mathbf{2}\,\boldsymbol{\pi}\,\sqrt{\boldsymbol{L}\,\boldsymbol{C}}} = \frac{1}{2\,\pi \times \sqrt{(8 \times 10^{-6}) \times (7 \times 10^{-12})}} = 21{,}278{,}761\ Hz = \mathbf{21.3}\ \boldsymbol{MHz}$$

E5A25: What is the resonant frequency of a series RLC circuit if R is 47 ohms, L is 3 microhenrys and C is 15 picofarads?

$$\boldsymbol{f_r} = \frac{\mathbf{1}}{\mathbf{2}\,\boldsymbol{\pi}\sqrt{\boldsymbol{L}\,\boldsymbol{C}}} = \frac{1}{2\,\pi \times \sqrt{(3 \times 10^{-6}) \times (15 \times 10^{-12})}} = 23{,}737{,}452\ Hz = \mathbf{23.7}\ \boldsymbol{MHz}$$

E5B06: What is the time constant of a circuit having two 100-microfarad capacitors and two 470-kilohm resistors all in series?

$$R_T\,(series) = R_1 + R_2 + \cdots + R_n = 470\ k\Omega + 470\ k\Omega = 940\ k\Omega$$

$$C_T\,(series) = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}} = \frac{1}{\frac{1}{100\ \mu F} + \frac{1}{100\ \mu F}} = 50\ \mu F$$

$$\boldsymbol{\tau} = \boldsymbol{R} \times \boldsymbol{C} = 940 \times 10^3\ \Omega \times 50 \times 10^{-6}\ F = \mathbf{47}\ \boldsymbol{seconds}$$

E5BO7: What is the time constant of a circuit having two 220-microfarad capacitors and two 1-megohm resistors all in parallel?

$$R_T\,(parallel) = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}} = \frac{1}{\frac{1}{1\ meg\Omega} + \frac{1}{1\ meg\Omega}} = 0.5\ meg\Omega$$

$$C_T\,(parallel) = C_1 + C_2 + \cdots + C_n = 220\ \mu F + 220\ \mu F = 440\ \mu F$$

$$\boldsymbol{\tau} = \boldsymbol{R} \times \boldsymbol{C} = 0.5 \times 10^6\ \Omega \times 440 \times 10^{-6}\ F = \mathbf{220}\ \boldsymbol{seconds}$$

E5B08: What is the time constant of a circuit having a 220-microfarad capacitor in series with a 470-kilohm resistor?

$$R_T\,(series) = R_1 + R_2 + \cdots + R_n = 470\ k\Omega = 470\ k\Omega$$

$$C_T\,(series) = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}} = \frac{1}{\frac{1}{220\ \mu F}} = 220\ \mu F$$

$$\boldsymbol{\tau} = \boldsymbol{R} \times \boldsymbol{C} = 470 \times 10^3\ \Omega \times 220 \times 10^{-6}\ F = \mathbf{103.4}\ \boldsymbol{seconds}$$

E5B09: How long does it take for an initial charge of 20 V DC to decrease to 7.36 V DC in a 0.01-microfarad capacitor when a 2-megohm resistor is connected across it?

$$time\ constant\ = \frac{discharged\ V}{charged\ V} = \frac{7.36\ V}{20\ V} = 0.368\ = 36.8\%\ = 1\tau$$

$$\boldsymbol{1\tau}\ = \boldsymbol{R}\ \times \boldsymbol{C}\ \times \boldsymbol{1}\ = 2\ \times\ 10^{6}\ \Omega\ \times 0.01\ \times\ 10^{-6}\ F\ = \mathbf{0.02}\ \boldsymbol{seconds}$$

E5B10: How long does it take for an initial charge of 20 V DC to decrease to 0.37 V DC in a 0.01-microfarad capacitor when a 2-megohm resistor is connected across it?

$$time\ constant\ = \frac{discharged\ V}{charged\ V} = \frac{0.37\ V}{20\ V} = 0.0185\ = 1.85\%\ = 4\tau$$

$$\boldsymbol{4\tau}\ = \boldsymbol{R}\ \times \boldsymbol{C}\ \times \boldsymbol{4}\ = 2\ \times\ 10^{6}\ \Omega\ \times 0.01\ \times\ 10^{-6}\ F\ \times 4\ = \mathbf{0.08}\ \boldsymbol{seconds}$$

E5B11: How long does it take for an initial charge of 800 V DC to decrease to 294 V DC in a 450-microfarad capacitor when a 1-megohm resistor is connected across it?

$$time\ constant\ = \frac{discharged\ V}{charged\ V} = \frac{294\ V}{800\ V} = 0.368\ = 36.8\%\ = 1\tau$$

$$\boldsymbol{1\tau}\ = \boldsymbol{R}\ \times \boldsymbol{C}\ \times \boldsymbol{1}\ = 1\ \times\ 10^{6}\ \Omega\ \times 450\ \times\ 10^{-6}\ F\ = \mathbf{450}\ \boldsymbol{seconds}$$

E5C10: In rectangular coordinates, what is the impedance of a network comprised of a 10-microhenry inductor in series with a 40-ohm resistor at 500 MHz?

$$X_L\ = 2\pi\ f\ L\ = 2\pi\ \times\ 500\ \times\ 10^{6}\ Hz\ \times 10\ \times\ 10^{-6}\ H\ = j31400\ \Omega$$

$$|\boldsymbol{Z}|\ = \sqrt{\boldsymbol{R}^{\mathbf{2}}\ +\ \boldsymbol{X}^{\mathbf{2}}}\ = \sqrt{40^{2}\ +\ 31400^{2}}\ = 31400$$

$\mathbf{40 + \boldsymbol{j}31,400}$ $(because\ L\ Reactance = +j\ and\ C\ Reactance = -j)$

E5C11: In polar coordinates, what is the impedance of a network comprised of a 100-picofarad capacitor in parallel with a 4,000-ohm resistor at 500 kHz?

$$X_C = \frac{1}{2\pi\, f\, C} = \frac{1}{2\pi \times 500 \times 10^3\, Hz \times 100 \times 10^{-12}\, F} = 3184.7\, \Omega$$

$$|I| = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X}\right)^2} = \sqrt{\left(\frac{1}{4000\, \Omega}\right)^2 + \left(\frac{1}{3184.7\, \Omega}\right)^2} = \sqrt{0.00025^2 + 0.000314^2} = 0.000401\, A$$

$$Phase\ angle = tan^{-1}\left(\frac{1/X}{1/R}\right) = tan^{-1}\left(\frac{0.000314}{0.00025}\right) = 51.5°$$

$$Z = \frac{E}{I} = \frac{1\, V,\ /0°}{0.000401\, A,\ \ /51.5°} = \mathbf{2494\, \Omega, /{-51.5}°}$$

E5D01: What is the phase angle between the voltage across and the current through a series R-L-C circuit if XC is 25 ohms, R is 100 ohms, and XL is 100 ohms?

$$X = X_L - X_C = 100 - 25 = 75\ (positive\ value\ means\ voltage\ is\ leading\ the\ current)$$

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right) = tan^{-1}\left(\frac{75\, \Omega}{100\, \Omega}\right) = \mathbf{36.87°}\ \boldsymbol{with\ voltage\ leading\ the\ current}$$

E5D02: What is the phase angle between the voltage across and the current through a series R-L-C circuit if XC is 500 ohms, R is 1 kilohm, and XL is 250 ohms?

$$X = X_L - X_C = 250 - 500 = -250\ (negative\ value\ means\ voltage\ is\ lagging\ the\ current)$$

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right) = tan^{-1}\left(\frac{250\, \Omega}{1000\, \Omega}\right) = \mathbf{14.04°}\ \boldsymbol{with\ voltage\ lagging\ the\ current}$$

E5D03: What is the phase angle between the voltage across and the current through a series R-L-C circuit if XC is 50 ohms, R is 100 ohms, and XL is 25 ohms?

$$X = X_L - X_C = 25 - 50 = -25\ (negative\ value\ means\ voltage\ is\ lagging\ the\ current)$$

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right) = tan^{-1}\left(\frac{25\, \Omega}{100\, \Omega}\right) = \mathbf{14.04°}\ \boldsymbol{with\ voltage\ lagging\ the\ current}$$

E5D04: What is the phase angle between the voltage across and the current through a series R-L-C circuit if XC is 100 ohms, R is 100 ohms, and XL is 75 ohms?

$X = X_L - X_C = 75 - 100 = -25$ $(negative\ value\ means\ voltage\ is\ lagging\ the\ current)$

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right) = tan^{-1}\left(\frac{25\ \Omega}{100\ \Omega}\right) = \boldsymbol{14.04° \ with\ voltage\ lagging\ the\ current}$$

E5D05: What is the phase angle between the voltage across and the current through a series R-L-C circuit if XC is 50 ohms, R is 100 ohms, and XL is 75 ohms?

$X = X_L - X_C = 75 - 50 = 25$ $(positive\ value\ means\ voltage\ is\ leading\ the\ current)$

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right) = tan^{-1}\left(\frac{25\ \Omega}{100\ \Omega}\right) = \boldsymbol{14.04° \ with\ voltage\ leading\ the\ current}$$

E5D08: What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 25 ohms, R is 100 ohms, and XL is 50 ohms?

$X = X_L - X_C = 50 - 25 = 25$ $(positive\ value\ means\ voltage\ is\ leading\ the\ current)$

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right) = tan^{-1}\left(\frac{25\ \Omega}{100\ \Omega}\right) = \boldsymbol{14.04° \ with\ voltage\ leading\ the\ current}$$

E5D09: What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 75 ohms, R is 100 ohms, and XL is 100 ohms?

$X = X_L - X_C = 100 - 75 = 25$ $(positive\ value\ means\ voltage\ is\ leading\ the\ current)$

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right) = tan^{-1}\left(\frac{25\ \Omega}{100\ \Omega}\right) = \boldsymbol{14.04° \ with\ voltage\ leading\ the\ current}$$

E5D10: What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 75 ohms, R is 100 ohms, and XL is 50 ohms?

$X = X_L - X_C = 50 - 75 = -25$ $(negative\ value\ means\ voltage\ is\ lagging\ the\ current)$

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right) = tan^{-1}\left(\frac{25\ \Omega}{100\ \Omega}\right) = \boldsymbol{14.04° \ with\ voltage\ lagging\ the\ current}$$

E5D11: What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 250 ohms, R is 1 kilohm, and XL is 500 ohms?

$X = X_L - X_C = 500 - 250 = 250$ (*positive value means voltage is leading the current*)

$$\boldsymbol{Phase\ angle = tan^{-1}\left(\frac{X}{R}\right)} = tan^{-1}\left(\frac{250\ \Omega}{1000\ \Omega}\right) = \mathbf{14.04°}\ \boldsymbol{with\ voltage\ leading\ the\ current}$$

E5E01: In polar coordinates, what is the impedance of a network comprised of a 100-ohm- reactance inductor in series with a 100-ohm resistor?

$X = X_L - X_C = 100 - 0 = 100$ (*positive value means phase angle is positive*)

$$Phase\ angle = tan^{-1}\left(\frac{X}{R}\right) = tan^{-1}\left(\frac{100\ \Omega}{100\ \Omega}\right) = 45°$$

$$|\boldsymbol{Z}| = \sqrt{\boldsymbol{R^2 + X^2}} = \sqrt{100^2 + 100^2} = \mathbf{141.42\ \Omega},\ \ /\mathbf{+45°}$$

E5E02: In polar coordinates, what is the impedance of a network comprised of a 100-ohm- reactance inductor, a 100-ohm-reactance capacitor, and a 100-ohm resistor all connected in series?

$X = X_L - X_C = 100 - 100 = 0$ (*positive value means phase angle is positive*)

$$Phase\ angle = tan^{-1}\left(\frac{X}{R}\right) = tan^{-1}\left(\frac{0\ \Omega}{100\ \Omega}\right) = 0°$$

$$|\boldsymbol{Z}| = \sqrt{\boldsymbol{R^2 + X^2}} = \sqrt{100^2 + 0^2} = \mathbf{100\ \Omega},\ \ /\mathbf{+0°}$$

E5E03: In polar coordinates, what is the impedance of a network comprised of a 300-ohm- reactance capacitor, a 600-ohm-reactance inductor, and a 400-ohm resistor, all connected in series?

$X = X_L - X_C = 600 - 300 = 300$ (*positive value means phase angle is positive*)

$$Phase\ angle = tan^{-1}\left(\frac{X}{R}\right) = tan^{-1}\left(\frac{300\ \Omega}{400\ \Omega}\right) = 36.86°$$

$$|\boldsymbol{Z}| = \sqrt{\boldsymbol{R^2 + X^2}} = \sqrt{400^2 + 300^2} = \mathbf{500\ \Omega},\ \ /\mathbf{+37°}$$

E5E04: In polar coordinates, what is the impedance of a network comprised of a 400-ohm- reactance capacitor in series with a 300-ohm resistor?

$X \ = X_L - \ X_C \ = \ 0 - 400 = -400 \ (negative\ value\ means\ phase\ angle\ is\ negative)$

$$Phase\ angle \ = \ tan^{-1}\left(\frac{X}{R}\right) = \ tan^{-1}\left(\frac{-400\ \Omega}{300\ \Omega}\right) \ = -53.13°$$

$$|\boldsymbol{Z}| \ = \ \sqrt{\boldsymbol{R^2} \ + \ \boldsymbol{X^2}} \ = \ \sqrt{300^2 \ + \ 400^2} \ = \mathbf{500\ \Omega},\ \ /\mathbf{-53°}$$

E5E05: In polar coordinates, what is the impedance of a network comprised of a 400-ohm- reactance inductor in parallel with a 300-ohm resistor?

$X \ = X_L - \ X_C \ = \ 400 - 0 = 400 \ (positive\ value\ means\ phase\ angle\ is\ positive)$

$$Phase\ angle\ (parallel) \ = \ 90° \ - \ tan^{-1}\left(\frac{X}{R}\right) = 90° - \ tan^{-1}\left(\frac{400\ \Omega}{300\ \Omega}\right) \ = 36.97°$$

$$|\boldsymbol{Z}| \ = \ \frac{\boldsymbol{Z_R} \ \times \ \boldsymbol{Z_X}}{\sqrt{\boldsymbol{Z_R}^2 + \ \boldsymbol{Z_X}^2}} \ = \ \frac{300 \ \times \ 400}{\sqrt{300^2 + \ 400^2}} \ = \mathbf{240\ \Omega},\ \ /\mathbf{+37°}$$

E5E06: In polar coordinates, what is the impedance of a network comprised of a 100-ohm- reactance capacitor in series with a 100-ohm resistor?

$X \ = X_L - \ X_C \ = \ 0 - 100 = -100 \ (negative\ value\ means\ phase\ angle\ is\ negative)$

$$Phase\ angle \ = \ tan^{-1}\left(\frac{X}{R}\right) = \ tan^{-1}\left(\frac{-100\ \Omega}{100\ \Omega}\right) \ = -45°$$

$$|\boldsymbol{Z}| \ = \ \sqrt{\boldsymbol{R^2} \ + \ \boldsymbol{X^2}} \ = \ \sqrt{100^2 \ + \ 100^2} \ = \mathbf{141\ \Omega},\ \ /\mathbf{-45°}$$

E5E07: In polar coordinates, what is the impedance of a network comprised of a 100-ohm- reactance capacitor in parallel with a 100-ohm resistor?

$X \ = X_L - \ X_C \ = \ 0 - 100 = -100 \ (negative\ value\ means\ phase\ angle\ is\ negative)$

$$Phase\ angle\ (parallel) \ = \ -90° \ - \ tan^{-1}\left(\frac{X}{R}\right) = 90° - \ tan^{-1}\left(\frac{-100\ \Omega}{100\ \Omega}\right) \ = -45°$$

$$|\boldsymbol{Z}| \ = \ \frac{\boldsymbol{Z_R} \ \times \ \boldsymbol{Z_X}}{\sqrt{\boldsymbol{Z_R}^2 + \ \boldsymbol{Z_X}^2}} \ = \ \frac{100 \ \times \ 100}{\sqrt{100^2 + \ 100^2}} \ = \mathbf{71\ \Omega},\ \ /\mathbf{-45°}$$

E5E08: In polar coordinates, what is the impedance of a network comprised of a 300-ohm- reactance inductor in series with a 400-ohm resistor?

$X = X_L - X_C = 300 - 0 = 300\ (positive\ value\ means\ phase\ angle\ is\ positive)$

$$Phase\ angle = tan^{-1}\left(\frac{X}{R}\right) = tan^{-1}\left(\frac{300\ \Omega}{400\ \Omega}\right) = 36.86°$$

$$|\boldsymbol{Z}| = \sqrt{\boldsymbol{R^2} + \boldsymbol{X^2}} = \sqrt{400^2 + 300^2} = \mathbf{500\ \Omega},\ \ /\mathbf{+37°}$$

E5E16: In polar coordinates, what is the impedance of a circuit of 100 -j100 ohms impedance?

$$Phase\ angle = tan^{-1}\left(\frac{X}{R}\right) = tan^{-1}\left(\frac{-100\ \Omega}{100\ \Omega}\right) = -45°$$

$$|\boldsymbol{Z}| = \sqrt{\boldsymbol{R^2} + \boldsymbol{X^2}} = \sqrt{100^2 + 100^2} = \mathbf{141\ \Omega},\ \ /\mathbf{-45°}$$

E5E17: In polar coordinates, what is the impedance of a circuit that has an admittance of 7.09 millisiemens at 45 degrees?

$$\boldsymbol{Z} = \frac{\mathbf{1}}{\boldsymbol{admittance}} = \frac{1}{7.09 \times 10^{-3}\ /+45°} = \mathbf{141\ \Omega},\ \ /\mathbf{-45°}$$

Note that $\frac{1}{/+45°} = /-45°$.

E5E18: In rectangular coordinates, what is the impedance of a circuit that has an admittance of 5 millisiemens at -30 degrees?

$$Z_{polar} = \frac{1}{admittance} = \frac{1}{5 \times 10^{-3}\ /-30°} = 200\ \Omega,\ \ /+30°$$

Note that $\frac{1}{/-30°} = /+30°$.

$$R_{rectangular} = Z \times cos(phase\ angle) = 200 \times cos(30) = 173.2\ \Omega$$

$$jX_{rectangular} = Z \times sin(phase\ angle) = 200 \times sin(30) = j100\ \Omega$$

$$\boldsymbol{Z_{rectangular}} = \mathbf{173 + \boldsymbol{j}100}$$

E5E19: In rectangular coordinates, what is the admittance of a circuit that has an impedance of 240 ohms at 36.9 degrees?

$$Admittance = \frac{1}{Z_{polar}} = \frac{1}{240\ \Omega,\ \ /{+36.9°}}$$

$$R_{rectangular} = \frac{1}{Z} \times cos(phase\ angle) = 0.00416 \times cos(36.9) = 3.33 \times 10^{-3}\ S$$

$$jX_{rectangular} = \frac{1}{Z} \times sin(phase\ angle) = 0.00416 \times sin(36.9) = -j2.5 \times 10^{-3}\ S$$

$$\boldsymbol{Z_{rectangular} = 3.33 \times 10^{-3} - j2.5 \times 10^{-3}}$$

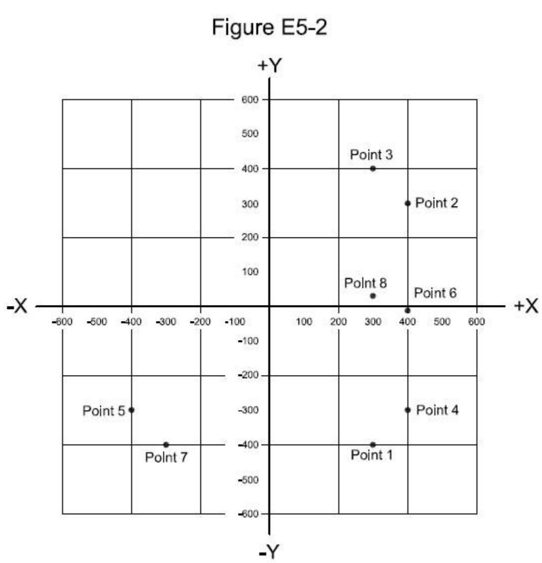
E5E20: In polar coordinates, what is the impedance of a series circuit consisting of a resistance of 4 ohms, an inductive reactance of 4 ohms, and a capacitive reactance of 1 ohm?

$$X = X_L - X_C = 4 - 1 = 3\ (positive\ value\ means\ phase\ angle\ is\ positive)$$

$$Phase\ angle = tan^{-1}\left(\frac{X}{R}\right) = tan^{-1}\left(\frac{3\ \Omega}{4\ \Omega}\right) = 36.86°$$

$$|\boldsymbol{Z}| = \sqrt{\boldsymbol{R^2} + \boldsymbol{X^2}} = \sqrt{4^2 + 3^2} = \mathbf{5\ \Omega,\ \ /{+37°}}$$

Figure E5-2 for E5E21, E5E22, and E5E23



E5E21: Which point on Figure E5-2 best represents the impedance of a series circuit consisting of a 400 ohm resistor and a 38 picofarad capacitor at 14 MHz?

$$X_C = \frac{1}{2\pi\, f\, C} = \frac{1}{2\pi \times 14 \times 10^6\, Hz \times 38 \times 10^{-12}\, F} = 299.3\, \Omega$$

$$\boldsymbol{Point\ 4}\ because\ \boldsymbol{R = 400}\ and\ \boldsymbol{X = -300}\ (capacitive\ reactance\ is\ negative)$$

E5E22: Which point in Figure E5-2 best represents the impedance of a series circuit consisting of a 300 ohm resistor and an 18 microhenry inductor at 3.505 MHz?

$$X_L = 2\pi\, f\, L = 2\pi \times 3.505 \times 10^3\, Hz \times 18 \times 10^{-3}\, H = 396.2\, \Omega$$

$$\boldsymbol{Point\ 3}\ because\ \boldsymbol{R = 300}\ and\ \boldsymbol{X = 400}\ (inductive\ reactance\ is\ positive)$$

E5E23: Which point on Figure E5-2 best represents the impedance of a series circuit consisting of a 300 ohm resistor and a 19 picofarad capacitor at 21.200 MHz?

$$X_C = \frac{1}{2\pi\, f\, C} = \frac{1}{2\pi \times 21.2 \times 10^6\, Hz \times 19 \times 10^{-12}\, F} = 395.3\, \Omega$$

$$\boldsymbol{Point\ 1}\ because\ \boldsymbol{R = 300}\ and\ \boldsymbol{X = -400}\ (capacitive\ reactance\ is\ negative)$$

E5G01: What is the Q of a parallel R-L-C circuit if the resonant frequency is 14.128 MHz, L is 2.7 microhenrys and R is 18 kilohms?

$$X_L = 2\pi\, f_r\, L = 6.28 \times (14.128 \times 10^6\, Hz) \times (2.7 \times 10^{-6}\, H) = 239.6\, \Omega$$

$$\boldsymbol{Q} = \frac{\boldsymbol{R}}{\boldsymbol{X}} = \frac{18 \times 10^3\, \Omega}{239.6\, \Omega} = \boldsymbol{75.1}$$

E5G02: What is the Q of a parallel R-L-C circuit if the resonant frequency is 4.468 MHz, L is 47 microhenrys and R is 180 ohms?

$$X_L = 2\pi\, f_r\, L = 6.28 \times (4.468 \times 10^6\, Hz) \times (47 \times 10^{-6}\, H) = 1318.8\, \Omega$$

$$\boldsymbol{Q} = \frac{\boldsymbol{R}}{\boldsymbol{X}} = \frac{180\, \Omega}{1318.8\, \Omega} = \boldsymbol{0.136}$$

E5G03: What is the Q of a parallel R-L-C circuit if the resonant frequency is 7.125 MHz, L is 8.2 microhenrys and R is 1 kilohm?

$X_L = 2\pi f_r L = 6.28 \times (7.125 \times 10^6\ Hz) \times (8.2 \times 10^{-6}\ H) = 366.9\ \Omega$

$$\boldsymbol{Q} = \frac{\boldsymbol{R}}{\boldsymbol{X}} = \frac{1 \times 10^3\ \Omega}{366.9\ \Omega} = \mathbf{2.72}$$

E5G04: What is the Q of a parallel R-L-C circuit if the resonant frequency is 7.125 MHz, L is 12.6 microhenrys and R is 22 kilohms?

$X_L = 2\pi f_r L = 6.28 \times (7.125 \times 10^6\ Hz) \times (12.6 \times 10^{-6}\ H) = 563.8\ \Omega$

$$\boldsymbol{Q} = \frac{\boldsymbol{R}}{\boldsymbol{X}} = \frac{22 \times 10^3\ \Omega}{563.8\ \Omega} = \mathbf{39}$$

E5G05: What is the Q of a parallel R-L-C circuit if the resonant frequency is 3.625 MHz, L is 42 microhenrys and R is 220 ohms?

$X_L = 2\pi f_r L = 6.28 \times (3.625 \times 10^6\ Hz) \times (42 \times 10^{-6}\ H) = 956.1\ \Omega$

$$\boldsymbol{Q} = \frac{\boldsymbol{R}}{\boldsymbol{X}} = \frac{220\ \Omega}{956.1\ \Omega} = \mathbf{0.23}$$

E5G10: What is the power factor of an R-L circuit having a 60 degree phase angle between the voltage and the current?

$\boldsymbol{power\ factor} = \boldsymbol{cos}(\boldsymbol{phase\ angle}) = cos(60) = \mathbf{0.5}$

E5G11: How many watts are consumed in a circuit having a power factor of 0.2 if the input is 100-V AC at 4 amperes?

$\boldsymbol{True\ power} = \boldsymbol{E} \times \boldsymbol{I} \times \boldsymbol{power\ factor} = 100\ V \times 4\ A \times 0.2 = \mathbf{80}\ \boldsymbol{watts}$

E5G13: What is the Q of a parallel RLC circuit if the resonant frequency is 14.128 MHz, L is 4.7 microhenrys and R is 18 kilohms?

$X_L = 2\pi f_r L = 6.28 \times (14.128 \times 10^6\ Hz) \times (4.7 \times 10^{-6}\ H) = 417\ \Omega$

$$\boldsymbol{Q} = \frac{\boldsymbol{R}}{\boldsymbol{X}} = \frac{18 \times 10^3\ \Omega}{417\ \Omega} = \mathbf{43.1}$$

E5G14: What is the Q of a parallel RLC circuit if the resonant frequency is 14.225 MHz, L is 3.5 microhenrys and R is 10 kilohms?

$$X_L = 2\pi f_r L = 6.28 \times (14.225 \times 10^6\ Hz) \times (3.5 \times 10^{-6}\ H) = 312.7\ \Omega$$

$$\boldsymbol{Q} = \frac{\boldsymbol{R}}{\boldsymbol{X}} = \frac{10 \times 10^3\ \Omega}{312.7\ \Omega} = \mathbf{31.9}$$

E5G15: What is the Q of a parallel RLC circuit if the resonant frequency is 7.125 MHz, L is 10.1 microhenrys and R is 100 ohms?

$$X_L = 2\pi f_r L = 6.28 \times (7.125 \times 10^6\ Hz) \times (10.1 \times 10^{-6}\ H) = 451.9\ \Omega$$

$$\boldsymbol{Q} = \frac{\boldsymbol{R}}{\boldsymbol{X}} = \frac{100\ \Omega}{451.9\ \Omega} = \mathbf{0.221}$$

E5G16: What is the Q of a parallel RLC circuit if the resonant frequency is 3.625 MHz, L is 3 microhenrys and R is 2.2 kilohms?

$$X_L = 2\pi f_r L = 6.28 \times (3.625 \times 10^6\ Hz) \times (3 \times 10^{-6}\ H) = 68.3\ \Omega$$

$$\boldsymbol{Q} = \frac{\boldsymbol{R}}{\boldsymbol{X}} = \frac{2.2 \times 10^3\ \Omega}{68.3\ \Omega} = \mathbf{32.2}$$

E5H01: What is the effective radiated power of a repeater station with 50 watts transmitter power output, 4-dB feed line loss, 2-dB duplexer loss, 1-dB circulator loss and 6-dBd antenna gain?

$$system\ gain = -4\ dB + -2\ dB + -1\ dB + 6\ dBd = -1\ dB$$

$$\boldsymbol{ERP} = \boldsymbol{log^{-1}}\left(\frac{\boldsymbol{P_2}}{\mathbf{10}}\right) \times \boldsymbol{P_1} = log^{-1}\left(\frac{-1\ dB}{10}\right) \times 50\ W = \mathbf{39.7}\ \boldsymbol{W}$$

E5H02: What is the effective radiated power of a repeater station with 50 watts transmitter power output, 5-dB feed line loss, 3-dB duplexer loss, 1-dB circulator loss and 7-dBd antenna gain?

$$system\ gain = -5\ dB + -3\ dB + -1\ dB + 7\ dBd = -2\ dB$$

$$\boldsymbol{ERP} = \boldsymbol{log^{-1}}\left(\frac{\boldsymbol{P_2}}{\mathbf{10}}\right) \times \boldsymbol{P_1} = log^{-1}\left(\frac{-2\ dB}{10}\right) \times 50\ W = \mathbf{31.5}\ \boldsymbol{W}$$

E5H03: What is the effective radiated power of a station with 75 watts transmitter power output, 4-dB feed line loss and 10-dBd antenna gain?

$$system\ gain\ =\ -4\ dB\ +\ 10\ dBd\ =\ 6\ dB$$

$$\boldsymbol{ERP\ =\ log^{-1}\left(\frac{P_2}{10}\right)\times P_1}\ =\ log^{-1}\left(\frac{6\ dB}{10}\right)\times 75\ W\ =\boldsymbol{298.6\ W}$$

E5H04: What is the effective radiated power of a repeater station with 75 watts transmitter power output, 5-dB feed line loss, 3-dB duplexer loss, 1-dB circulator loss and 6-dBd antenna gain?

$$system\ gain\ =\ -5\ dB\ +\ -3\ dB\ +\ -1\ dB\ +6\ dBd\ =\ -3\ dB$$

$$\boldsymbol{ERP\ =\ log^{-1}\left(\frac{P_2}{10}\right)\times P_1}\ =\ log^{-1}\left(\frac{-3\ dB}{10}\right)\times 75\ W\ =\boldsymbol{37.6\ W}$$

E5H05: What is the effective radiated power of a station with 100 watts transmitter power output, 1-dB feed line loss and 6-dBd antenna gain?

$$system\ gain\ =\ -1\ dB\ +6\ dBd\ =\ 5\ dB$$

$$\boldsymbol{ERP\ =\ log^{-1}\left(\frac{P_2}{10}\right)\times P_1}\ =\ log^{-1}\left(\frac{5\ dB}{10}\right)\times 100\ W\ =\boldsymbol{316\ W}$$

E5H06: What is the effective radiated power of a repeater station with 100 watts transmitter power output, 5-dB feed line loss, 3-dB duplexer loss, 1-dB circulator loss and 10-dBd antenna gain?

$$system\ gain\ =\ -5\ dB\ +\ -3\ dB\ +\ -1\ dB\ +10\ dBd\ =\ 1\ dB$$

$$\boldsymbol{ERP\ =\ log^{-1}\left(\frac{P_2}{10}\right)\times P_1}\ =\ log^{-1}\left(\frac{1\ dB}{10}\right)\times 100\ W\ =\boldsymbol{125.9\ W}$$

E5H07: What is the effective radiated power of a repeater station with 120 watts transmitter power output, 5-dB feed line loss, 3-dB duplexer loss, 1-dB circulator loss and 6-dBd antenna gain?

$$system\ gain\ =\ -5\ dB\ +\ -3\ dB\ +\ -1\ dB\ +6\ dBd\ =\ -3\ dB$$

$$\boldsymbol{ERP\ =\ log^{-1}\left(\frac{P_2}{10}\right)\times P_1}\ =\ log^{-1}\left(\frac{-3\ dB}{10}\right)\times 120\ W\ =\boldsymbol{60.1\ W}$$

E5H08: What is the effective radiated power of a repeater station with 150 watts transmitter power output, 2-dB feed line loss, 2.2-dB duplexer loss and 7-dBd antenna gain?

$system\ gain\ =\ -2\ dB\ +\ -2.2\ dB\ +7\ dBd\ =\ 2.8\ dB$

$$\boldsymbol{ERP}\ =\ \boldsymbol{log^{-1}}\left(\frac{\boldsymbol{P_2}}{\boldsymbol{10}}\right)\times\boldsymbol{P_1}\ =\ log^{-1}\left(\frac{2.8\ dB}{10}\right)\times 150\ W\ =\ \boldsymbol{285.8\ W}$$

E5H09: What is the effective radiated power of a repeater station with 200 watts transmitter power output, 4-dB feed line loss, 3.2-dB duplexer loss, 0.8-dB circulator loss and 10-dBd antenna gain?

$system\ gain\ =\ -4\ dB\ +\ -3.2\ dB\ +\ -0.8\ dB\ +10\ dBd\ =\ 2\ dB$

$$\boldsymbol{ERP}\ =\ \boldsymbol{log^{-1}}\left(\frac{\boldsymbol{P_2}}{\boldsymbol{10}}\right)\times\boldsymbol{P_1}\ =\ log^{-1}\left(\frac{2\ dB}{10}\right)\times 200\ W\ =\ \boldsymbol{317\ W}$$

E5H10: What is the effective radiated power of a repeater station with 200 watts transmitter power output, 2-dB feed line loss, 2.8-dB duplexer loss, 1.2-dB circulator loss and 7-dBd antenna gain?

$system\ gain\ =\ -2\ dB\ +\ -2.8\ dB\ +\ -1.2\ dB\ +7\ dBd\ =\ 1\ dB$

$$\boldsymbol{ERP}\ =\ \boldsymbol{log^{-1}}\left(\frac{\boldsymbol{P_2}}{\boldsymbol{10}}\right)\times\boldsymbol{P_1}\ =\ log^{-1}\left(\frac{1\ dB}{10}\right)\times 200\ W\ =\ \boldsymbol{252\ W}$$

E5H13: What is the power factor of an RL circuit having a 45 degree phase angle between the voltage and the current?

$\boldsymbol{power\ factor}\ =\boldsymbol{cos}(\boldsymbol{phase\ angle})\ =cos(45)\ =\boldsymbol{0.707}$

E5H14: What is the power factor of an RL circuit having a 30 degree phase angle between the voltage and the current?

$\boldsymbol{power\ factor}\ =\boldsymbol{cos}(\boldsymbol{phase\ angle})\ =cos(30)\ =\boldsymbol{0.866}$

E5H15: How many watts are consumed in a circuit having a power factor of 0.6 if the input is 200V AC at 5 amperes?

$\boldsymbol{True\ power}=\boldsymbol{E}\ \times\boldsymbol{I}\ \times\boldsymbol{power\ factor}=200\ V\ \times 5\ A\ \times 0.6=\boldsymbol{600\ watts}$

E5H16: How many watts are consumed in a circuit having a power factor of 0.71 if the apparent power is 500 watts?

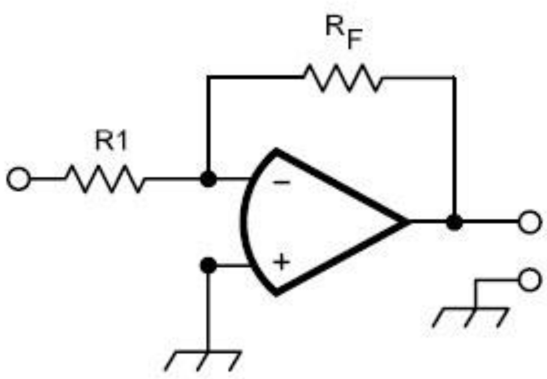
$\boldsymbol{True\ power} = \boldsymbol{apparent\ power} \times \boldsymbol{power\ factor} = 500\ watts \times 0.71 = \boldsymbol{355\ watts}$

Section E6: Circuit Components

E6B11: What voltage gain can be expected from the circuit in Figure E6-4 when R1 is 10 ohms and RF is 470 ohms?

$$\boldsymbol{Gain} = \frac{\boldsymbol{R_f}}{\boldsymbol{R_1}} = \frac{470\ \Omega}{10\ \Omega} = \mathbf{47}$$

Figure E6-4



E6B14: What will be the voltage of the circuit shown in Figure E6-4 if R1 is 1000 ohms and RF is 10,000 ohms and 0.23 volts is applied to the input?

$$\boldsymbol{V_{out}} = -\left(\frac{\boldsymbol{R_f}}{\boldsymbol{R_1}}\right) \times \boldsymbol{V_{in}} = -\left(\frac{10{,}000\ \Omega}{1{,}000\ \Omega}\right) \times\ 0.23\ V = \mathbf{-2.3\ V}$$

E6B15: What voltage gain can be expected from the circuit in Figure E6-4 when R1 is 1800 ohms and RF is 68 kilohms?

$$\boldsymbol{Gain} = \frac{\boldsymbol{R_f}}{\boldsymbol{R_1}} = \frac{68{,}000\ \Omega}{1{,}800\ \Omega} = \mathbf{37.8}$$

E6B16: What voltage gain can be expected from the circuit in Figure E6-4 when R1 is 3300 ohms and RF is 47 kilohms?

$$\boldsymbol{Gain} = \frac{\boldsymbol{R_f}}{\boldsymbol{R_1}} = \frac{47{,}000\ \Omega}{3{,}300\ \Omega} = \mathbf{14.2}$$

E6D13: How many turns will be required to produce a 1-mH inductor using a ferrite toroidal core that has an inductance index (A L) value of 523 millihenrys/1000 turns?

$$\boldsymbol{N\ (for\ Powdered - Iron\ Cores) = 1000 \times \sqrt{\frac{L}{A_L}} = 1000 \times \sqrt{\frac{1\ mH}{523\ mH}} = 43.7\ turns}$$

E6D14: How many turns will be required to produce a 5-microhenry inductor using a powdered-iron toroidal core that has an inductance index (A L) value of 40 microhenrys/100 turns?

$$\boldsymbol{N\ (for\ Powdered - Iron\ Cores) = 100 \times \sqrt{\frac{L}{A_L}} = 100 \times \sqrt{\frac{5\ microH}{40\ microH}} = 35.4\ turns}$$

Section E8: Signals and Emissions

E8A08: What is the peak voltage at a common household electrical outlet?

$$\boldsymbol{V_{PEAK}} = \boldsymbol{V_{RMS}} \times \mathbf{1.414} = 120\,V \times 1.414 = \mathbf{169.7\,V}$$

E8A09: What is the peak-to-peak voltage at a common household electrical outlet?

$$\boldsymbol{V_{P2P}} = \boldsymbol{V_{RMS}} \times \mathbf{1.414} \times \mathbf{2} = 120\,V \times 1.414 \times 2 = \mathbf{339.4\,V}$$

E8A11: What is the RMS value of a 340-volt peak-to-peak pure sine wave?

$$\boldsymbol{V_{RMS}} = \mathbf{0.707} \times \frac{\boldsymbol{V_{P2P}}}{\mathbf{2}} = 0.707 \times \frac{340\,V}{2} = \mathbf{120.2\,V}$$

E8A16: What is the approximate DC input power to a Class B RF power amplifier stage in an FM-phone transmitter when the PEP output power is 1500 watts?

$$Class\ B\ efficiency = 60\% = 0.6$$

$$\boldsymbol{P_{DC}} = \frac{\boldsymbol{PEP}}{\boldsymbol{Effeciency}} = \frac{1500\ watts}{0.6} = \mathbf{2500\ watts}$$

E8A17: What is the approximate DC input power to a Class AB RF power amplifier stage in an unmodulated carrier transmitter when the PEP output power is 500 watts?

$$Class\ AB\ efficiency = 50\% = 0.5$$

$$\boldsymbol{P_{DC}} = \frac{\boldsymbol{PEP}}{\boldsymbol{Effeciency}} = \frac{500\ watts}{0.5} = \mathbf{1000\ watts}$$

E8B11: In an FM-phone signal having a maximum frequency deviation of 3000 Hz either side of the carrier frequency, what is the modulation index when the modulating frequency is 1000 Hz?

$$\boldsymbol{Modulation\ index} = \frac{\boldsymbol{D_{PEAK}}}{\boldsymbol{m}} = \frac{3000\ kHz}{1000\ kHz} = \mathbf{3}$$

E8B12: What is the modulation index of an FM-phone transmitter producing a maximum carrier deviation of 6 kHz when modulated with a 2-kHz modulating frequency?

$$\boldsymbol{Modulation\ index} = \frac{\boldsymbol{D_{PEAK}}}{\boldsymbol{m}} = \frac{6\ kHz}{2\ kHz} = \mathbf{3}$$

E8B13: What is the deviation ratio of an FM-phone signal having a maximum frequency swing of plus or minus 5 kHz and accepting a maximum modulation rate of 3 kHz?

$$\boldsymbol{Deviation\ ratio} = \frac{\boldsymbol{D_{MAX}}}{\boldsymbol{m}} = \frac{5\ kHz}{3\ kHz} = \mathbf{1.67}$$

E8B24: What is the deviation ratio of an FM-phone signal having a maximum frequency swing of plus or minus 7.5 kHz and accepting a maximum modulation rate of 3.5 kHz?

$$\boldsymbol{Deviation\ ratio} = \frac{\boldsymbol{D_{MAX}}}{\boldsymbol{m}} = \frac{7500\ kHz}{3500\ kHz} = \mathbf{2.14}$$

E8C07: What is the necessary bandwidth of a 13-WPM international Morse code emission A1A transmission?

$$\boldsymbol{Bw} = \left(\frac{\boldsymbol{wpm}}{\mathbf{1.2}}\right) \times \boldsymbol{K} = \left(\frac{13\ wpm}{1.2}\right) \times 4.8 = \mathbf{52}\ \boldsymbol{Hz}$$

E8C08: What is the necessary bandwidth for a 170-hertz shift, 300-baud ASCII emission J2D transmission?

$$\boldsymbol{Bw} = (\boldsymbol{K} \times \boldsymbol{Shift}) + \boldsymbol{B} = (1.2 \times 170\ Hz) + 300\ baud = 504\ Hz = \mathbf{0.5}\ \boldsymbol{kHz}$$

E8C09: What is the necessary bandwidth of a 1000-Hz shift, 1200-baud ASCII emission F1D transmission?

$$\boldsymbol{Bw} = (\boldsymbol{K} \times \boldsymbol{Shift}) + \boldsymbol{B} = (1.2 \times 1000\ Hz) + 1200\ baud = \mathbf{2400}\ \boldsymbol{Hz}$$

E8C10: What is the necessary bandwidth of a 4800-Hz frequency shift, 9600-baud ASCII emission F1D transmission?

$$\boldsymbol{Bw} = (\boldsymbol{K} \times \boldsymbol{Shift}) + \boldsymbol{B} = (1.2 \times 4800\ Hz) + 9600\ baud = 15360\ Hz = \mathbf{15.36}\ \boldsymbol{kHz}$$

E8D05: What is the PEP output of a transmitter that has a maximum peak of 30 volts to a 50-ohm load as observed on an oscilloscope?

$$V_{RMS} = 0.707 \times V_{peak} = 0.707 \times 30\ V = 21.2\ V$$

$$\boldsymbol{PEP} = \frac{(\boldsymbol{V_{RMS}})^2}{\boldsymbol{Z}} = \frac{(21.2\ V)^2}{50\ \Omega} = 8.98\ W = \mathbf{9}\ \boldsymbol{W}$$

E8D06: If an RMS reading AC voltmeter reads 65 volts on a sinusoidal waveform, what is the peak-to-peak voltage?

$\boldsymbol{V_{P2P}} = \boldsymbol{V_{RMS}} \times \mathbf{1.414} \times \mathbf{2} = 65\,V \times 1.414 \times 2 = \mathbf{183.8}\,\boldsymbol{V}$

E8D16: What is the average power dissipated by a 50-ohm resistive load during one complete RF cycle having a peak voltage of 35 volts?

$V_{RMS} = 0.707 \times V_{peak} = 0.707 \times 35V = 24.745\,V$

$$\boldsymbol{P_{average}} = \frac{(\boldsymbol{V_{RMS}})^2}{\boldsymbol{R}} = \frac{(24.745\,V)^2}{50\,\Omega} = \mathbf{12.2}\,\boldsymbol{W}$$

E8D17: If an RMS reading voltmeter reads 34 volts on a sinusoidal waveform, what is the peak voltage?

$\boldsymbol{V_{peak}} = \mathbf{1.414} \times \boldsymbol{V_{RMS}} = 1.414 \times 34\,V = \mathbf{48}\,\boldsymbol{V}$

Section E9: Antennas

E9A17: How much gain does an antenna have over a 1/2-wavelength dipole when it has 6 dB gain over an isotropic radiator?

$$\boldsymbol{dBd = dBi - 2.14\,dB} = 6\,dBi - 2.14 = \mathbf{3.86\,dBd}$$

E9A18: How much gain does an antenna have over a 1/2-wavelength dipole when it has 12 dB gain over an isotropic radiator?

$$\boldsymbol{dBd = dBi - 2.14\,dB} = 12\,dBi - 2.14 = \mathbf{9.86\,dBd}$$

E9D03: What is the approximate beamwidth of a symmetrical pattern antenna with a gain of 20 dB as compared to an isotropic radiator?

$$\boldsymbol{Gain\ Ratio = 10^{\left(\frac{dB}{10}\right)}} = 10^{\left(\frac{20\,dB}{10}\right)} = 100$$

$$\boldsymbol{Beamwidth\ \theta = \frac{203}{\sqrt{Gain\ Ratio}}} = \frac{203}{\sqrt{100}} = \mathbf{20.3°}$$

E9D19: What is the beamwidth of a symmetrical pattern antenna with a gain of 30 dB as compared to an isotropic radiator?

$$\boldsymbol{Gain\ Ratio = 10^{\left(\frac{dB}{10}\right)}} = 10^{\left(\frac{30\,dB}{10}\right)} = 1000$$

$$\boldsymbol{Beamwidth\ \theta = \frac{203}{\sqrt{Gain\ Ratio}}} = \frac{203}{\sqrt{1000}} = \mathbf{6.4°}$$

E9D20: What is the beamwidth of a symmetrical pattern antenna with a gain of 15 dB as compared to an isotropic radiator?

$$\boldsymbol{Gain\ Ratio = 10^{\left(\frac{dB}{10}\right)}} = 10^{\left(\frac{15\,dB}{10}\right)} = 31.62$$

$$\boldsymbol{Beamwidth\ \theta = \frac{203}{\sqrt{Gain\ Ratio}}} = \frac{203}{\sqrt{31.62}} = \mathbf{36.09°}$$

E9D21: What is the beamwidth of a symmetrical pattern antenna with a gain of 12 dB as compared to an isotropic radiator?

$$\boldsymbol{Gain\ Ratio} = \mathbf{10}^{\left(\frac{\boldsymbol{dB}}{\mathbf{10}}\right)} = 10^{\left(\frac{12\ dB}{10}\right)} = 15.85$$

$$\boldsymbol{Beamwidth\ \theta} = \frac{\mathbf{203}}{\sqrt{\boldsymbol{Gain\ Ratio}}} = \frac{203}{\sqrt{15.85}} = \mathbf{50.98°}$$

E9E04: What should be the approximate capacitance of the resonating capacitor in a gamma matching circuit on a Yagi beam antenna for the 20-meter band?

$$\boldsymbol{Appx.Capacitance} = \mathbf{7}\ \boldsymbol{pF} \times \boldsymbol{\lambda\ in\ meters} = 7\ pF \times 20 = \mathbf{140}\ \boldsymbol{pF}$$

E9E05: What should be the approximate capacitance of the resonating capacitor in a gamma matching circuit on a Yagi beam antenna for the 10-meter band?

$$\boldsymbol{Appx.Capacitance} = \mathbf{7}\ \boldsymbol{pF} \times \boldsymbol{\lambda\ in\ meters} = 7\ pF \times 10 = \mathbf{70}\ \boldsymbol{pF}$$

E9E10: What would be the physical length of a typical coaxial transmission line that is electrically one-quarter wavelength long at 14.1 MHz? (Assume a velocity factor of 0.66.)

$$\mathbf{1}\boldsymbol{\lambda}\ (\boldsymbol{meters}) = \frac{\mathbf{300}}{\boldsymbol{f}\ (\boldsymbol{MHz})} \times \boldsymbol{V} = \frac{300}{14.1} \times 0.66 = 14.04,\ \ so\ \frac{1}{4}\lambda = \frac{14.04}{4} = \mathbf{3.51}\ \boldsymbol{meters}$$

E9E11: What is the physical length of a parallel conductor feed line that is electrically one-half wavelength long at 14.10 MHz? (Assume a velocity factor of 0.95.)

$$\mathbf{1}\boldsymbol{\lambda}\ (\boldsymbol{meters}) = \frac{\mathbf{300}}{\boldsymbol{f}\ (\boldsymbol{MHz})} \times \boldsymbol{V} = \frac{300}{14.1} \times 0.95 = 20.21,\ \ so\ \frac{1}{2}\lambda = \frac{20.21}{2} = \mathbf{10.1}\ \boldsymbol{meters}$$

E9E16: What would be the physical length of a typical coaxial transmission line that is electrically one-quarter wavelength long at 7.2 MHz? (Assume a velocity factor of 0.66.)

$$\mathbf{1}\boldsymbol{\lambda}\ (\boldsymbol{meters}) = \frac{\mathbf{300}}{\boldsymbol{f}\ (\boldsymbol{MHz})} \times \boldsymbol{V} = \frac{300}{7.2} \times 0.66 = 27.5,\ \ so\ \frac{1}{4}\lambda = \frac{27.5}{4} = \mathbf{6.88}\ \boldsymbol{meters}$$