The W5JCK Amateur 2008 Extra Exam Question Pool with Correct Answers and Guide to the Mathematical Problems

This document contains every question from the Extra Class (Element 4) 2008 Question Pool[1] with the correct answer only. All incorrect answers have been deleted. Additionally, all the necessary mathematical equations[2] have been illustrated and helpful hints and explanations have been included.

I designed this document as an aid for reviewing the exam questions and the mathematics necessary to solve the exam questions. It does not cover the mathematical or electrical theories behind the questions. 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.

Can you pass the exam without studying the theory? Yes. Should you? No! Please be a good ham and learn all you can about this wonderful hobby. Study hard, study often, and be courteous to your fellow hams.

 Good luck on your Amateur Extra exam.

73 de W5JCK

Last Updated: 25 August 2008

[1] Question Pool Element 4 - Extra Class, as released by the Question Pool Committee of the National Conference of Volunteer Examiner Coordinators February 20, 2008. This question pool is scheduled to be in service from July 1, 2008 until June 30, 2012

[2] As pertains to mathematics involving the Pi function (π), the Question Pool Committee apparently assumed that the test taker would round off π to 3.14. The answers to questions that include π as part of the solution reflect this fact. I believe most test takers, myself included, will use a calculator with a built-in π function. Since the built-in π function carries a much higher degree of accuracy in determining π, the answers in this document that include π as part of the solution are slightly more accurate than the answers provided by the Question Pool Committee. The differences are slight and unimportant, but should be noted to avoid any confusion.

Table of Contents

Subelement E1 — Commission's Rules

E1A Operating Standards: frequency privileges for Extra Class amateurs; emission standards; automatic message forwarding; frequency sharing; FCC license actions; stations aboard ships or aircraft

E1A01

When using a transceiver that displays the carrier frequency of phone signals, which of the following displayed frequencies will result in a normal USB emission being within the band?

3 kHz below the upper band edge

E1A02

When using a transceiver that displays the carrier frequency of phone signals, which of the following displayed frequencies will result in a normal LSB emission being within the band?

3 kHz above the lower band edge

E1A03

With your transceiver displaying the carrier frequency of phone signals, you hear a DX station's CQ on 14.349 MHz USB. Is it legal to return the call using upper sideband on the same frequency?

No, my sidebands will extend beyond the band edge

E1A04

With your transceiver displaying the carrier frequency of phone signals, you hear a DX station's CQ on 3.601 MHz LSB. Is it legal to return the call using lower sideband on the same frequency?

No, my sidebands will extend beyond the edge of the phone band segment

E1A05

Which is the only amateur band that does not permit the transmission of phone or image emissions?

30 meters

E1A06

What is the maximum power output permitted on the 60 meter band?

50 watts PEP effective radiated power relative to a dipole

E1A07

What is the only amateur band where transmission on specific channels rather than a range of frequencies is permitted?

60 meter band

E1A08

What is the only emission type permitted to be transmitted on the 60 meter band by an amateur station?

Single sideband, upper sideband only

E1A09

Which frequency bands contain at least one segment authorized only to control operators holding an Amateur Extra Class operator license?

80/75, 40, 20 and 15 meters

E1A10

If a station in a message forwarding system inadvertently forwards a message that is in violation of FCC rules, who is primarily accountable for the rules violation?

The control operator of the originating station

E1A11

What is the first action you should take if your digital message forwarding station inadvertently forwards a communication that violates FCC rules?

Discontinue forwarding the communication as soon as you become aware of it

E1A12

If an amateur station is installed on board a ship or aircraft, what condition must be met before the station is operated?

Its operation must be approved by the master of the ship or the pilot in command of the aircraft

E1A13

When a US-registered vessel is in international waters, what type of FCC-issued license or permit is required to transmit amateur communications from an on-board amateur transmitter?

Any amateur license or reciprocal permit for alien amateur licensee

E1B Station restrictions and special operations: restrictions on station location; general operating restrictions, spurious emissions, control operator reimbursement; antenna structure restrictions; RACES operations

E1B01

Which of the following constitutes a spurious emission?

An emission outside its necessary bandwidth that can be reduced or eliminated without affecting the information transmitted

E1B02

Which of the following factors might cause the physical location of an amateur station apparatus or antenna structure to be restricted?

The location is significant to our environment, American history, architecture, or culture.

E1B03

Within what distance must an amateur station protect an FCC monitoring facility from harmful interference?

1 mile

E1B04

What must be done before placing an amateur station within an officially designated wilderness area or wildlife preserve, or an area listed in the National Register of Historical Places?

An Environmental Assessment must be submitted to the FCC

E1B05

What height restrictions apply to an amateur station antenna structure not close to a public use airport unless the FAA is notified and it is registered with the FCC?

It must be no higher than 200 feet above ground level at its site

E1B06

Which of the following additional rules apply if you are installing an amateur station antenna at a site within 20,000 feet of a public use airport?

You may have to notify the Federal Aviation Administration and register it with the FCC

E1B07

Whose approval is required before erecting an amateur station antenna located at or near a public use airport if the antenna would exceed a certain height depending upon the antenna's distance from the nearest active runway?

The FAA must be notified and it must be registered with the FCC

E1B08

On what frequencies may the operation of an amateur station be restricted if its emissions cause interference to the reception of a domestic broadcast station on a receiver of good engineering design?

On the interfering amateur service transmitting frequencies

E1B09

What is the Radio Amateur Civil Emergency Service (RACES)?

A radio service of amateur stations for civil defense communications during periods of local, regional, or national civil emergencies

E1B10

Which amateur stations may be operated in RACES?

Any FCC-licensed amateur station certified by the responsible civil defense organization for the area served

E1B11

What frequencies are normally authorized to an amateur station participating in RACES?

All amateur service frequencies otherwise authorized to the control operator

E1B12

What are the frequencies authorized to an amateur station participating in RACES during a period when the President's War Emergency Powers are in force?

Specific amateur service frequency segments authorized in FCC Part 214

E1B13

What communications are permissible in RACES?

Authorized civil defense emergency communications affecting the immediate safety of life and property

E1C Station control: definitions and restrictions pertaining to local, automatic and remote control operation; control operator responsibilities for remote and automatically controlled stations

E1C01

What is a remotely controlled station?

A station controlled indirectly through a control link

E1C02

What is meant by automatic control of a station?

The use of devices and procedures for control so that the control operator does not have to be present at a control point

E1C03

How do the control operator responsibilities of a station under automatic control differ from one under local control?

Under automatic control the control operator is not required to be present at the control point

E1C04

When may an automatically controlled station retransmit third party communications?

Only when transmitting RTTY or data emissions

E1C05

When may an automatically controlled station originate third party communications?

Never

E1C06

Which of the following statements concerning remotely controlled amateur stations is true?

A control operator must be present at the control point

E1C07

What is meant by local control?

Direct manipulation of the transmitter by a control operator

E1C08

What is the maximum permissible duration of a remotely controlled station's transmissions if its control link malfunctions?

3 minutes

E1C09

Which of these frequencies are available for automatically controlled ground-station repeater operation?

29.500 - 29.700 MHz

E1C10

What types of amateur stations may automatically retransmit the radio signals of other amateur stations?

Only auxiliary, repeater or space stations

E1D Amateur Satellite service: definitions and purpose; license requirements for space stations; available frequencies and bands; telecommand and telemetry operations; restrictions, and special provisions; notification requirements

E1D01

What is the definition of the term telemetry?

One-way transmission of measurements at a distance from the measuring instrument

E1D02

What is the amateur-satellite service?

A radio communications service using amateur stations on satellites

E1D03

What is a telecommand station in the amateur satellite service?

An amateur station that transmits communications to initiate, modify or terminate certain functions of a space station

E1D04

What is an Earth station in the amateur satellite service?

An amateur station within 50 km of the Earth's surface for communications with amateur stations by means of objects in space

E1D05

What class of licensee is authorized to be the control operator of a space station?

A holder of any class of license

E1D06

Which of the following special provisions must a space station incorporate in order to comply with space station requirements?

The space station must be capable of effecting a cessation of transmissions by telecommand when so ordered by the FCC

E1D07

Which amateur service HF bands have frequencies authorized to space stations?

Only 40m, 20m, 17m, 15m, 12m and 10m

E1D08

Which VHF amateur service bands have frequencies available for space stations?

2 meters

E1D09

Which amateur service UHF bands have frequencies available for a space station?

70 cm, 23 cm, 13 cm

E1D10

Which amateur stations are eligible to be telecommand stations?

Any amateur station so designated by the space station licensee

E1D11

Which amateur stations are eligible to operate as Earth stations?

Any amateur station, subject to the privileges of the class of operator license held by the control operator

E1D12

Who must be notified before launching an amateur space station?

The FCC's International Bureau, Washington, DC

E1E Volunteer examiner program: definitions, qualifications, preparation and administration of exams; accreditation; question pools; documentation requirements

E1E01

What is the minimum number of qualified VEs required to administer an Element 4 amateur operator license examination?

3

E1E02

Where are the questions for all written US amateur license examinations listed?

In the VEC-maintained question pool

E1E03

Who is responsible for maintaining the question pools from which all amateur license examination questions must be taken?

All of the VECs

E1E04

What is a Volunteer Examiner Coordinator?

An organization that has entered into an agreement with the FCC to coordinate amateur operator license examinations

E1E05

What is a VE?

An amateur operator who is approved by a VEC to administer amateur operator license examinations

E1E06

What is a VE team?

A group of at least three VEs who administer examinations for an amateur operator license

E1E07

Which of the following persons seeking to become VEs cannot be accredited?

Persons who have ever had an amateur operator or amateur station license suspended or revoked

E1E08

Which of the following best describes the Volunteer Examiner accreditation process?

The procedure by which a VEC confirms that the VE applicant meets FCC requirements to serve as an examiner

E1E09

Where must the VE team be while administering an examination?

All of the administering VEs must be present where they can observe the examinees throughout the entire examination

E1E10

Who is responsible for the proper conduct and necessary supervision during an amateur operator license examination session?

Each administering VE

E1E11

What should a VE do if a candidate fails to comply with the examiner's instructions during an amateur operator license examination?

Immediately terminate the candidate's examination

E1E12

To which of the following examinees may a VE not administer an examination?

The VE's close relatives as listed in the FCC rules

E1E13

What may be the penalty for a VE who fraudulently administers or certifies an examination?

Revocation of the VE's amateur station license grant and the suspension of the VE's amateur operator license grant

E1E14

What must the VE team do with the examinee's test papers once they have finished the examination?

The VE team must collect and grade them immediately

E1E15

What must the VE team do if an examinee scores a passing grade on all examination elements needed for an upgrade or new license?

Three VEs must certify that the examinee is qualified for the license grant and that they have complied with the VE requirements

E1E16

What must the VE team do with the application form if the examinee does not pass the exam?

Return the application document to the examinee

E1E17

What are the consequences of failing to appear for re-administration of an examination when so directed by the FCC?

The licensee's license will be cancelled

E1E18

For which types of out-of-pocket expenses may VEs and VECs be reimbursed?

Preparing, processing, administering and coordinating an examination for an amateur radio license

E1E19

How much reimbursement may the VE team and VEC accept for preparing, processing, administering and coordinating an examination?

Actual out-of-pocket expenses

E1E20

What is the minimum age to be a volunteer examiner?

18 years old

E1F Miscellaneous rules: external RF power amplifiers; Line A; national quiet zone; business communications; compensated communications; spread spectrum; auxiliary stations; reciprocal operating privileges; IARP and CEPT licenses; third party communications with foreign countries; special temporary authority

E1F01

On what frequencies are spread spectrum transmissions permitted?

Only on amateur frequencies above 222 MHz

E1F02

Which of the following operating arrangements allows an FCC-licensed US citizen to operate in many European countries, and alien amateurs from many European countries to operate in the US?

CEPT agreement

E1F03

Which of the following operating arrangements allow an FCC-licensed US citizen and many Central and South American amateur operators to operate in each other's countries?

IARP agreement

E1F04

What does it mean if an external RF amplifier is listed on the FCC database as certificated for use in the amateur service?

That particular RF amplifier may be marketed for use in the amateur service

E1F05

Under what circumstances may a dealer sell an external RF power amplifier capable of operation below 144 MHz if it has not been granted FCC certification?

It was purchased in used condition from an amateur operator and is sold to another amateur operator for use at that operator's station

E1F06

Which of the following geographic descriptions approximately describes "Line A"?

A line roughly parallel to and south of the US-Canadian border

E1F07

Amateur stations may not transmit in which of the following frequency segments if they are located north of Line A?

420 - 430 MHz

E1F08

What is the National Radio Quiet Zone?

An area surrounding the National Radio Astronomy Observatory

E1F09

When may the control operator of a repeater accept payment for providing communication services to another party?

Under no circumstances

E1F10

When may an amateur station send a message to a business?

When neither the amateur nor his or her employer has a pecuniary interest in the communications

E1F11

Which of the following types of amateur-operator-to-amateur-operator communications are prohibited?

Communications transmitted for hire or material compensation, except as otherwise provided in the rules

E1F12

FCC-licensed amateur stations may use spread spectrum (SS) emissions to communicate under which of the following conditions?

A. When the other station is in an area regulated by the FCC

B. When the other station is in a country permitting SS communications

C. When the transmission is not used to obscure the meaning of any communication

D. All of these choices are correct

E1F13

What is the maximum transmitter power for an amateur station transmitting spread spectrum communications?

100 W

E1F14

Which of the following best describes one of the standards that must be met by an external RF power amplifier if it is to qualify for a grant of FCC certification?

It must satisfy the FCC's spurious emission standards when operated at its full output power

E1F15

Who may be the control operator of an auxiliary station?

Only Technician, General, Advanced or Amateur Extra Class operators

E1F16

What types of communications may be transmitted to amateur stations in foreign countries?

Communications incidental to the purpose of the amateur service and remarks of a personal nature

E1F17

Under what circumstances might the FCC issue a "Special Temporary Authority" (STA) to an amateur station?

To provide for experimental amateur communications

Subelement E2 — Operating Practices and Procedures

E2A Amateur radio in space: amateur satellites; orbital mechanics; frequencies and modes; satellite hardware; satellite operations

E2A01

What is the direction of an ascending pass for an amateur satellite?

From south to north

E2A02

What is the direction of a descending pass for an amateur satellite?

From north to south

E2A03

What is the orbital period of a satellite?

The time it takes for a satellite to complete one revolution around the Earth

E2A04

What is meant by the term “mode” as applied to an amateur radio satellite?

The satellite's uplink and downlink frequency bands

E2A05

What do the letters in a satellite's mode designator specify?

The uplink and downlink frequencies

E2A06

On what band would a satellite receive signals if it were operating in mode U/V?

432 MHz

E2A07

Which of the following types of signals can be relayed through a linear transponder?

All these answers are correct

E2A08

What is the primary reason for satellite users to limit their transmit ERP?

Because the satellite transmitter output power is limited

E2A09

What do the terms L band and S band specify with regard to satellite communications?

The 23 centimeter and 13 centimeter bands

E2A10

Why may the received signal from an amateur satellite exhibit a rapidly repeating fading effect?

Because the satellite is rotating

E2A11

What type of antenna can be used to minimize the effects of spin modulation and Faraday rotation?

A circularly polarized antenna

E2A12

What is one way to predict the location of a satellite at a given time?

By calculations using the Keplerian elements for the specified satellite

E2A13

What type of satellite appears to stay in one position in the sky?

Geosynchronous

E2A14

What happens to a satellite's transmitted signal due to the Doppler Effect?

The signal frequency shifts lower as the satellite passes overhead

E2B Television practices: fast scan television standards and techniques; slow scan television standards and techniques

E2B01

How many times per second is a new frame transmitted in a fast-scan (NTSC) television system?

30

E2B02

How many horizontal lines make up a fast-scan (NTSC) television frame?

525

E2B03

How is an interlace scanning pattern generated in a fast-scan (NTSC) television system?

By scanning odd numbered lines in one field and even numbered ones in the next

E2B04

What is blanking in a video signal?

Turning off the scanning beam while it is traveling from right to left or from bottom to top

E2B05

Which of the following is an advantage of using vestigial sideband for standard fast scan TV transmissions?

Vestigial sideband reduces bandwidth while allowing for simple video detector circuitry

E2B06 (A)

What is vestigial sideband modulation?

Amplitude modulation in which one complete sideband and a portion of the other sideband is transmitted

E2B07

What is the name of the video signal component that carries color information?

Chroma

E2B08

Which of the following is a common method of transmitting accompanying audio with amateur fast-scan television?

A. Frequency-modulated sub-carrier

B. A separate VHF or UHF audio link

C. Frequency modulation of the video carrier

D. All of these choices are correct

E2B09

What hardware, other than a transceiver with SSB capability and a suitable computer, is needed to decode SSTV based on Digital Radio Mondiale (DRM)?

No other hardware is needed

E2B10

Which of the following is an acceptable bandwidth for Digital Radio Mondiale (DRM) based voice or SSTV digital transmissions made on the HF amateur bands?

3 KHz

E2B11

What is the function of the Vertical Interval Signaling (VIS) code transmitted as part of an SSTV transmission?

To identify the SSTV mode being used

E2B12

How are analog slow-scan television images typically transmitted on the HF bands?

Varying tone frequencies representing the video are transmitted using single sideband

E2B13

How many lines are commonly used in each frame on an amateur slow-scan color television picture?

128 or 256

E2B14

What aspect of an amateur slow-scan television signal encodes the brightness of the picture?

Tone frequency

E2B15

What signals SSTV receiving equipment to begin a new picture line?

Specific tone frequencies

E2B16

Which of the following is the video standard used by North American Fast Scan ATV stations?

NTSC

E2B17

Which of the following is NOT a characteristic of FMTV (Frequency-Modulated Amateur Television) as compared to vestigial sideband AM television?

Immunity from fading due to limiting

E2B18

What is the approximate bandwidth of a slow-scan TV signal?

3 kHz

E2B19

On which of the following frequencies is one likely to find FMTV transmissions?

1255 MHz

E2B20 (C)

What special operating frequency restrictions are imposed on slow scan TV transmissions?

They are restricted to phone band segments and their bandwidth can be no greater than that of a voice signal of the same modulation type

E2B21

If 100 IRE units correspond to the most-white level in the NTSC standard video format, what is the level of the most-black signal?

7.5 IRE units

E2C Operating methods, part 1: contest and DX operating; spread-spectrum transmissions; automatic HF forwarding; selecting an operating frequency

E2C01

Which of the following is true about contest operating?

Operators are permitted to make contacts even if they do not submit a log

E2C02

Which of the following best describes “self spotting” in regards to contest operating?

The generally prohibited practice of posting one’s own call sign and frequency on a call sign spotting network

E2C03

From which of the following bands is amateur radio contesting generally excluded?

30 meters

E2C04

On which of the following frequencies is an amateur radio contest contact generally discouraged?

146.52 MHz

E2C05

Which of the following frequencies would generally be acceptable for U.S. stations to work other U.S. stations in a phone contest?

14.310 MHz

E2C06

During a VHF/UHF contest, in which band segment would you expect to find the highest level of activity?

In the weak signal segment of the band, with most of the activity near the calling frequency

E2C07

What is the Cabrillo format?

A standard for organizing information in contest log files

E2C08

Why are received spread-spectrum signals resistant to interference?

Signals not using the spectrum-spreading algorithm are suppressed in the receiver

E2C09

How does the spread-spectrum technique of frequency hopping (FH) work?

The frequency of the transmitted signal is changed very rapidly according to a particular sequence also used by the receiving station

E2C10

Why might a phone DX station state that he is listening on another frequency?

A. Because the DX station may be transmitting on a frequency that is prohibited to some responding stations

B. To separate the calling stations from the DX station

C. To reduce interference, thereby improving operating efficiency

D. All of these choices are correct

E2C11

How should you generally sign your call when attempting to contact a DX station working a “pileup” or in a contest?

Send your full call sign once or twice

E2C12

In North America during low sunspot activity, when signals from Europe become weak and fluttery across an entire HF band two to three hours after sunset, what might help to contact other European DX stations?

Switch to a lower frequency HF band

E2D Operating methods, part 2: VHF and UHF digital modes; packet clusters; Automatic Position Reporting System (APRS)

E2D01

What does “command mode” mean in packet operations?

The TNC is ready to receive instructions via the keyboard

E2D02

What is the definition of “baud”?

The number of data symbols transmitted per second

E2D03

Which of the follow is true when comparing HF and 2-meter packet operations?

HF packet typically uses FSK with a data rate of 300 baud; 2-meter packet uses AFSK with a data rate of 1200 baud

E2D04

What is the purpose of digital store-and-forward functions on an Amateur satellite?

To store digital messages in the satellite for later download by other stations

E2D05

Which of the following techniques is normally used by low-earth orbiting digital satellites to relay messages around the world?

Store-and-forward

E2D06

Which of the following is a commonly used 2-meter APRS frequency?

144.39 MHz

E2D07

Which of the following digital protocols is used by APRS?

AX.25

E2D08

Which of the following types of packet frames is used to transmit APRS beacon data?

Unnumbered Information frames

E2D09

Under clear communications conditions, which of these digital communications modes has the fastest data throughput?

300-baud packet

E2D10

How can an APRS station be used to help support a public service communications activity?

An APRS station with a GPS unit can automatically transmit information to show a mobile station's position during the event

E2D11

Which of the following data sources are needed to accurately transmit your geographical location over the APRS network?

Any of these choices is correct

E2E Operating methods, part 3: operating HF digital modes; error correction

E2E01

What is a common method of transmitting data emissions below 30 MHz?

FSK/AFSK

E2E02

What do the letters FEC mean as they relate to digital operation?

Forward Error Correction

E2E03

How is Forward Error Correction implemented?

By transmitting extra data that may be used to detect and correct transmission errors

E2E04

What is indicated when one of the ellipses in an FSK crossed-ellipse display suddenly disappears?

Selective fading has occurred

E2E05

How does ARQ accomplish error correction?

If errors are detected, a retransmission is requested

E2E06

What is the most common data rate used for HF packet communications?

300 baud

E2E07

What is the typical bandwidth of a properly modulated MFSK16 signal?

316 Hz

E2E08

Which of the following HF digital modes can be used to transfer binary files?

PACTOR

E2E09

Which of the following HF digital modes uses variable-length coding for bandwidth efficiency?

PSK31

E2E10

This question has been removed by the QPC

E2E11

What is the Baudot code?

The International Telegraph Alphabet Number 2 (ITA2) which uses five data bits

E2E12

Which of these digital communications modes has the narrowest bandwidth?

PSK31

Subelement E3 — Radio Wave Propagation

E3A Propagation and technique, part 1: Earth-Moon-Earth communications (EME); meteor scatter

E3A01

What is the approximate maximum separation along the surface of the Earth between two stations communicating by moonbounce?

12,000 miles, as long as both can “see” the moon

E3A02

What characterizes libration fading of an earth-moon-earth signal?

A fluttery irregular fading

E3A03

When scheduling EME contacts, which of these conditions will generally result in the least path loss?

When the moon is at perigee

E3A04

What type of receiving system is desirable for EME communications?

Equipment with very low noise figures

E3A05

What transmit and receive time sequencing is normally used on 144 MHz when attempting an EME contact?

Two-minute sequences, where one station transmits for a full two minutes and then receives for the following two minutes

E3A06

What transmit and receive time sequencing is normally used on 432 MHz when attempting an EME contact?

Two-and-one-half minute sequences, where one station transmits for a full 2.5 minutes and then receives for the following 2.5 minutes

E3A07

What frequency range would you normally tune to find EME stations in the 2 meter band?

144.000 - 144.100 MHz

E3A08

What frequency range would you normally tune to find EME stations in the 70 cm band?

432.000 - 432.100 MHz

E3A09

When a meteor strikes the Earth's atmosphere, a cylindrical region of free electrons is formed at what layer of the ionosphere?

The E layer

E3A10

Which range of frequencies is well suited for meteor-scatter communications?

28 - 148 MHz

E3A11

What transmit and receive time sequencing is normally used on 144 MHz when attempting a meteor-scatter contact?

15-second sequences, where one station transmits for 15 seconds and then receives for the following 15 seconds

E3B Propagation and technique, part 2: transequatorial; long path; gray line; multi-path propagation

E3B01

What is transequatorial propagation?

Propagation between two points at approximately the same distance north and south of the magnetic equator

E3B02

What is the approximate maximum range for signals using transequatorial propagation?

5000 miles

E3B03

What is the best time of day for transequatorial propagation?

Afternoon or early evening

E3B04

What type of propagation is probably occurring if an HF beam antenna must be pointed in a direction 180 degrees away from a station to receive the strongest signals?

Long-path

E3B05

Which amateur bands typically support long-path propagation?

160 to 10 meters

E3B06

Which of the following amateur bands most frequently provides long-path propagation?

20 meters

E3B07

Which of the following could account for hearing an echo on the received signal of a distant station?

Receipt of a signal by more than one path

E3B08

What type of propagation is probably occurring if radio signals travel along the terminator between daylight and darkness?

Gray-line

E3B09

At what time of day is gray-line propagation most prevalent?

At sunrise and sunset

E3B10

What is the cause of gray-line propagation?

At twilight, solar absorption drops greatly, while atmospheric ionization is not weakened enough to reduce the MUF

E3B11

What communications are possible during gray-line propagation?

Contacts up to 8,000 to 10,000 miles on three or four HF bands

E3C Propagation and technique, part 3: Auroral propagation; selective fading; radio-path horizon; take-off angle over flat or sloping terrain; earth effects on propagation; less common propagation modes

E3C01

What effect does auroral activity have on radio communications?

CW signals have a fluttery tone

E3C02

What is the cause of auroral activity?

The emission of charged particles from the sun

E3C03

Where in the ionosphere does auroral activity occur?

At E-region height

E3C04

Which emission mode is best for auroral propagation?

CW

E3C05

What causes selective fading?

Phase differences in the received signal caused by different paths

E3C06

How much farther does the VHF/UHF radio-path horizon distance exceed the geometric horizon?

By approximately 15% of the distance

E3C07

How does the radiation pattern of a 3-element, horizontally polarized beam antenna vary with height above ground?

The main lobe takeoff angle decreases with increasing height

E3C08

What is the name of the high-angle wave in HF propagation that travels for some distance within the F2 region?

Pedersen ray

E3C09

What effect is usually responsible for propagating a VHF signal over 500 miles?

Tropospheric ducting

E3C10

How does the performance of a horizontally polarized antenna mounted on the side of a hill compare with the same antenna mounted on flat ground?

The main lobe takeoff angle decreases in the downhill direction

E3C11

From the contiguous 48 states, in which approximate direction should an antenna be pointed to take maximum advantage of auroral propagation?

North

E3C12

As the frequency of a signal is increased, how does its ground wave propagation change?

It decreases

E3C13

What type of polarization does most ground-wave propagation have?

Vertical

E3C14

Why does the radio-path horizon distance exceed the geometric horizon?

Radio waves may be bent

Subelement E4 — Amateur Radio Technology and Measurements

E4A Test equipment: analog and digital instruments; spectrum and network analyzers, antenna analyzers; oscilloscopes; testing transistors; RF measurements

E4A01

How does a spectrum analyzer differ from a conventional oscilloscope?

A spectrum analyzer displays signals in the frequency domain; an oscilloscope displays signals in the time domain

E4A02

Which of the following parameters would a typical spectrum analyzer display on the horizontal axis?

Frequency

E4A03

Which of the following parameters would a typical spectrum analyzer display on the vertical axis?

Amplitude

E4A04

Which of the following test instruments is used to display spurious signals from a radio transmitter?

A spectrum analyzer

E4A05

Which of the following test instruments is used to display intermodulation distortion products in an SSB transmission?

A spectrum analyzer

E4A06

Which of the following could be determined with a spectrum analyzer?

A. The degree of isolation between the input and output ports of a 2 meter duplexer

B. Whether a crystal is operating on its fundamental or overtone frequency

C. The spectral output of a transmitter

D. All of these choices are correct

E4A07

Which of the following is an advantage of using an antenna analyzer vs. a SWR bridge to measure antenna SWR?

Antenna analyzers typically do not need an external RF source

E4A08

Which of the following instruments would be best for measuring the SWR of a beam antenna?

An antenna analyzer

E4A09

Which of the following is most important when adjusting PSK31 transmitting levels?

ALC level

E4A10

Which of the following is a useful test for a functioning NPN transistor in an active circuit where the transistor should be biased "on" ?

Measure base-to-emitter voltage with a voltmeter; it should be approximately 0.6 to 0.7 volts

E4A11

Which of the following test instruments can be used to indicate pulse conditions in a digital logic circuit?

A logic probe

E4A12

Which of the following procedures is an important precaution to follow when connecting a spectrum analyzer to a transmitter output?

Attenuate the transmitter output going to the spectrum analyzer

E4B Measurement technique and limitations: instrument accuracy and performance limitations; probes; techniques to minimize errors; measurement of "Q"; instrument calibration

E4B01

Which of the following is a characteristic of a good harmonic frequency marker?

Frequency stability

E4B02

Which of the following factors most affects the accuracy of a frequency counter?

Time base accuracy

E4B03

What is an advantage of using a bridge circuit to measure impedance?

The measurement is based on obtaining a null in voltage, which can be done very precisely

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?

146.52 Hz (see equation below)

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

$$\boldsymbol{Error} = 146{,}520{,}000\ Hz \times \frac{1}{1{,}000{,}000} = \boldsymbol{146.52\ Hz}$$

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?

14.652 Hz (see equation below)

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

$$\boldsymbol{Error} = 146{,}520{,}000\ Hz \times \frac{0.1}{1{,}000{,}000} = \boldsymbol{14.652\ Hz}$$

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?

1465.20 Hz (see equation below)

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

$$\boldsymbol{Error} = 146{,}520{,}000\ Hz \times \frac{10}{1{,}000{,}000} = \boldsymbol{1465.20\ Hz}$$

E4B07

How much power is being absorbed by the load when a directional power meter connected between a transmitter and a terminating load reads 100 watts forward power and 25 watts reflected power?

75 watts (see equation below)

$$\boldsymbol{Load\ Absorbtion} = \boldsymbol{Forward\ Power - Reflected\ Power}$$

$$\boldsymbol{Load\ Absorbtion} = 100\ watts - 25\ watts = \boldsymbol{75\ watts}$$

E4B08

Which of the following is good practice when using an oscilloscope probe?

Keep the ground connection of the probe as short as possible

E4B09

Which of the following is a characteristic of a good DC voltmeter?

High impedance input

E4B10

What is indicated if the current reading on an RF ammeter placed in series with the antenna feedline of a transmitter increases as the transmitter is tuned to resonance?

There is more power going into the antenna

E4B11

Which of the following describes a method to measure intermodulation distortion in an SSB transmitter?

Modulate the transmitter with two non-harmonically related audio frequencies and observe the RF output with a spectrum analyzer

E4B12

How should a portable SWR analyzer be connected when measuring antenna resonance and feedpoint impedance?

Connect the antenna feed line directly to the analyzer's connector

E4B13

What is the significance of voltmeter sensitivity expressed in ohms per volt?

The full scale reading of the voltmeter multiplied by its ohms per volt rating will provide the input impedance of the voltmeter

E4B14

How is the compensation of an oscilloscope probe typically adjusted?

A square wave is observed and the probe is adjusted until the horizontal portions of the displayed wave is as nearly flat as possible

E4B15

What happens if a dip-meter is too tightly coupled to a tuned circuit being checked?

A less accurate reading results

E4B16

Which of these factors limits the accuracy of a D'Arsonval-type meter?

Coil impedance

E4B17

Which of the following can be used as a relative measurement of the Q for a series-tuned circuit?

The bandwidth of the circuit's frequency response

E4C Receiver performance characteristics, part 1: phase noise, capture effect, noise floor, image rejection, MDS, signal-to-noise-ratio; selectivity

E4C01

What is the effect of excessive phase noise in the local oscillator section of a receiver?

It can cause strong signals on nearby frequencies to interfere with reception of weak signals

E4C02

Which of the following is the result of the capture effect in an FM receiver?

The strongest signal received is the only demodulated signal

E4C03

What is the term for the blocking of one FM phone signal by another, stronger FM phone signal?

Capture effect

E4C04

What is meant by the noise floor of a receiver?

The equivalent input noise power when the antenna is replaced with a matched dummy load

E4C05

What does a value of -174 dBm/Hz represent with regard to the noise floor of a receiver?

The theoretical noise at the input of a perfect receiver at room temperature

E4C06

The thermal noise value of a receiver is -174 dBm/Hz. What is the theoretically best minimum detectable signal for a 400 Hz bandwidth receiver?

-148 dBm

Step 1: Calculate the noise figure

$$\boldsymbol{Noise\ Figure} = \mathbf{10} \times \mathbf{log}(\boldsymbol{bandwidth\ factor})$$

$$\boldsymbol{Noise\ Figure} = 10 \times \log(400\ Hz) = 26.02\ dB$$

Step 2: Calculate the noise floor

$$\boldsymbol{Noise\ Floor\ = MDS\ + Noise\ Figure}$$

$$\boldsymbol{Noise\ Floor\ = -}174\ dBm\ + 26\ = \mathbf{-148\ dBm}$$

Hint: MDS is the minimum discernible signal. In this case it is given as the thermal noise value of the receiver, –174 dBm/Hz. The noise floor is the theoretical best minimum signal the receiver can detect.

E4C07

What does the MDS of a receiver represent?

The minimum discernible signal

E4C08

How might lowering the noise figure affect receiver performance?

It would increase signal to noise ratio

E4C09

Which of the following is most likely to be the limiting condition for sensitivity in a modern communications receiver operating at 14 MHz?

Atmospheric noise

E4C10

Which of the following is a desirable amount of selectivity for an amateur RTTY HF receiver?

300 Hz

E4C11

Which of the following is a desirable amount of selectivity for an amateur single-sideband phone receiver?

2.4 kHz

E4C12

What is an undesirable effect of using too wide a filter bandwidth in the IF section of a receiver?

Undesired signals may be heard

E4C13

How does a narrow band roofing filter affect receiver performance?

It improves dynamic range by keeping strong signals near the receive frequency out of the IF stages

E4C14

Which of these choices is a desirable amount of selectivity for an amateur VHF FM receiver?

15 kHz

E4C15

What is the primary source of noise that can be heard from an HF-band receiver with an antenna connected?

Atmospheric noise

E4D Receiver performance characteristics, part 2: blocking dynamic range, intermodulation and cross-modulation interference; 3rd order intercept; desensitization; preselection

E4D01

What is meant by the blocking dynamic range of a receiver?

The difference in dB between the level of an incoming signal which will cause 1 dB of gain compression, and the level of the noise floor

E4D02

Which of the following describes two types of problems caused by poor dynamic range in a communications receiver?

Cross modulation of the desired signal and desensitization from strong adjacent signals

E4D03

How can intermodulation interference between two repeaters occur?

When the repeaters are in close proximity and the signals mix in one or both transmitter final amplifiers

E4D04

What is an effective way to reduce or eliminate intermodulation interference between two repeater transmitters operating in close proximity to one another?

By installing a properly terminated circulator at the output of the transmitter

E4D05

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?

146.34 MHz and 146.61 MHz (see equations below)

$$f_2 = (2 \times f_1) - f_{IMD}$$

$$f_2 = (2 \times 146.52) - 146.70 = \mathbf{146.34\ MHz}$$

$$f_2 = \frac{f_{IMD} + f_1}{2}$$

$$f_2 = \frac{146.70 + 146.52}{2} = \mathbf{146.61\ MHz}$$

E4D06

If the signals of two transmitters mix together in one or both of their final amplifiers, and unwanted signals at the sum and difference frequencies of the original signals are generated, what is this called?

Intermodulation interference

E4D07

Which of the following describes the most significant effect of an off-frequency signal when it is causing cross-modulation interference to a desired signal?

The off-frequency unwanted signal is heard in addition to the desired signal

E4D08

What causes intermodulation in an electronic circuit?

Nonlinear circuits or devices

E4D09

What is the purpose of the preselector in a communications receiver?

To improve rejection of unwanted signals

E4D10

What does a third-order intercept level of 40 dBm mean with respect to receiver performance?

A pair of 40 dBm signals will theoretically generate the same output on the third order intermodulation frequency as on the input frequency

E4D11

Why are third-order intermodulation products within a receiver of particular interest compared to other products?

The third-order product of two signals which are in the band is itself likely to be within the band

E4D12

What is the term for the reduction in receiver sensitivity caused by a strong signal near the received frequency?

Desensitization

E4D13

Which of the following can cause receiver desensitization?

Strong adjacent-channel signals

E4D14

Which of the following is a way to reduce the likelihood of receiver desensitization?

Decrease the RF bandwidth of the receiver

E4E Noise suppression: system noise; electrical appliance noise; line noise; locating noise sources; DSP noise reduction; noise blankers

E4E01

Which of the following types of receiver noise can often be reduced by use of a receiver noise blanker?

Ignition Noise

E4E02

Which of the following types of receiver noise can often be reduced with a DSP noise filter?

A. Broadband “white” noise

B. Ignition noise

C. Power line noise

D. All of these choices are correct

E4E03

Which of the following signals might a receiver noise blanker be able to remove from desired signals?

Signals which appear correlated across a wide bandwidth

E4E04

How can conducted and radiated noise caused by an automobile alternator be suppressed?

By connecting the radio's power leads directly to the battery and by installing coaxial capacitors in line with the alternator leads

E4E05

How can noise from an electric motor be suppressed?

By installing a brute-force AC-line filter in series with the motor leads

E4E06

What is a major cause of atmospheric static?

Thunderstorms

E4E07

How can you determine if line-noise interference is being generated within your home?

By turning off the AC power line main circuit breaker and listening on a battery-operated radio

E4E08

What type of signal is picked up by electrical wiring near a radio transmitter?

A common-mode signal at the frequency of the radio transmitter

E4E09

What undesirable effect can occur when using an IF type noise blanker?

Nearby signals may appear to be excessively wide even if they meet emission standards

E4E10

What is a common characteristic of interference caused by a "touch controlled" electrical device?

A. The interfering signal sounds like AC hum on an AM receiver or a carrier modulated by 60 Hz FM on a SSB or CW receiver

B. The interfering signal may drift slowly across the HF spectrum

C. The interfering signal can be several kHz in width and usually repeats at regular intervals across a HF band

D. All of these answers are correct

E4E11

What is the most likely cause if you are hearing combinations of local AM broadcast signals inside one or more of the MF or HF ham bands?

Nearby corroded metal joints are mixing and re-radiating the BC signals

E4E12

What is one disadvantage of using some automatic DSP notch-filters when attempting to copy CW signals?

The DSP filter can remove the desired signal at the same time as it removes interfering signals

E4E13

What might be the cause of a loud "roaring" or "buzzing" AC line type of interference that comes and goes at intervals?

A. Arcing contacts in a thermostatically controlled device

B. A defective doorbell or doorbell transformer inside a nearby residence

C. A malfunctioning illuminated advertising display

D. All of these answers are correct

E4E14

What is one type of electrical interference that might be caused by the operation of a nearby personal computer?

The appearance of unstable modulated or unmodulated signals at specific frequencies

Subelement E5 — Electrical Principles

E5A Resonance and Q: characteristics of resonant circuits: series and parallel resonance; Q; half-power bandwidth; phase relationships in reactive circuits

E5A01

What can cause the voltage across reactances in series to be larger than the voltage applied to them?

Resonance

E5A02

What is resonance in an electrical circuit?

The frequency at which the capacitive reactance equals the inductive reactance

E5A03

What is the magnitude of the impedance of a series R-L-C circuit at resonance?

Approximately equal to circuit resistance

E5A04

What is the magnitude of the impedance of a circuit with a resistor, an inductor and a capacitor all in parallel, at resonance?

Approximately equal to circuit resistance

E5A05

What is the magnitude of the current at the input of a series R-L-C circuit as the frequency goes through resonance?

Maximum

E5A06

What is the magnitude of the circulating current within the components of a parallel L-C circuit at resonance?

It is at a maximum

E5A07

What is the magnitude of the current at the input of a parallel R-L-C circuit at resonance?

Minimum

E5A08

What is the phase relationship between the current through and the voltage across a series resonant circuit?

The voltage and current are in phase

E5A09

What is the phase relationship between the current through and the voltage across a parallel resonant circuit?

The voltage and current are in phase

E5A10

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?

18.9 kHz (see equation below)

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}}$$

$$\boldsymbol{Half\ power\ bandwidth} = \frac{1{,}800{,}000\ Hz}{95} = 18947\ Hz = \boldsymbol{18.9\ kHz}$$

E5A11

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?

47.3 kHz (see equation below)

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}}$$

$$\boldsymbol{Half\ power\ bandwidth} = \frac{7{,}100{,}000\ Hz}{150} = 47333\ Hz = \boldsymbol{47.3\ kHz}$$

E5A12

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?

31.4 kHz (see equation below)

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}}$$

$$\boldsymbol{Half\ power\ bandwidth} = \frac{3{,}700{,}000\ Hz}{118} = 31356\ Hz = \boldsymbol{31.4\ kHz}$$

E5A13

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?

76.2 kHz (see equation below)

$$\boldsymbol{Half\ power\ bandwidth} = \frac{\boldsymbol{f_r}}{\boldsymbol{Q}}$$

$$\boldsymbol{Half\ power\ bandwidth} = \frac{14.250{,}000\ Hz}{187} = 76203\ Hz = \boldsymbol{76.2\ kHz}$$

E5A14

What is the resonant frequency of a series RLC circuit if R is 22 ohms, L is 50 microhenrys and C is 40 picofarads?

3.56 MHz (see equation below)

$$\boldsymbol{f_r} = \frac{\boldsymbol{1}}{\boldsymbol{2\,\pi\sqrt{L\,C}}}$$

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

Hint: Ignore the resistance. A microhenry is 10^{-6} henrys. A picofarad is 10^{-12} farads. You can add the exponents of similar exponential numbers to simplify this equation as follows:

$$\boldsymbol{f_r} = \frac{1}{2\,\pi \times \sqrt{(50 \times 40 \times 10^{-18})}}$$

E5A15

What is the resonant frequency of a series RLC circuit if R is 56 ohms, L is 40 microhenrys and C is 200 picofarads?

1.78 MHz (see equation below)

$$f_r = \frac{1}{2\,\pi\,\sqrt{L\,C}}$$

$$f_r = \frac{1}{2\,\pi\,\times\,\sqrt{(40\,\times\,10^{-6})\,\times\,(200\,\times\,10^{-12})}} = 1{,}779{,}406\;Hz\;=\mathbf{1.78\;MHz}$$

Hint: Ignore the resistance. A microhenry is 10^{-6} henrys. A picofarad is 10^{-12} farads. You can add the exponents of similar exponential numbers to simplify this equation as follows:

$$f_r = \frac{1}{2\,\pi\,\times\,\sqrt{(40\,\times 200\,\times\,10^{-18})}}$$

E5A16

What is the resonant frequency of a parallel RLC circuit if R is 33 ohms, L is 50 microhenrys and C is 10 picofarads?

7.12 MHz (see equation below)

$$f_r = \frac{1}{2\,\pi\,\sqrt{L\,C}}$$

$$f_r = \frac{1}{2\,\pi\,\times\,\sqrt{(50\,\times\,10^{-6})\,\times\,(10\,\times\,10^{-12})}} = 7{,}117{,}626\;Hz\;=\mathbf{7.12\;MHz}$$

Hint: Ignore the resistance. A microhenry is 10^{-6} henrys. A picofarad is 10^{-12} farads. You can add the exponents of similar exponential numbers to simplify this equation as follows:

$$f_r = \frac{1}{2\,\pi\,\times\,\sqrt{(50\,\times 10\,\times\,10^{-18})}}$$

E5A17

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

10.1 MHz (see equation below)

$$f_r = \frac{1}{2\,\pi\,\sqrt{L\,C}}$$

$$f_r = \frac{1}{2\,\pi\,\times\,\sqrt{(25\,\times\,10^{-6})\,\times\,(10\,\times\,10^{-12})}} = 10{,}065{,}842\ Hz\ = \mathbf{10.1\ MHz}$$

Hint: Ignore the resistance. A microhenry is 10^{-6} henrys. A picofarad is 10^{-12} farads. You can add the exponents of similar exponential numbers to simplify this equation as follows:

$$f_r = \frac{1}{2\,\pi\,\times\,\sqrt{(25\,\times 10\,\times\,10^{-18})}}$$

E5B Time constants and phase relationships: R/L/C time constants: definition; time constants in RL and RC circuits; phase angle between voltage and current; phase angles of series and parallel circuits

E5B01

What is the term for the time required for the capacitor in an RC circuit to be charged to 63.2% of the supply voltage?

One time constant

E5B02

What is the term for the time it takes for a charged capacitor in an RC circuit to discharge to 36.8% of its initial value of stored charge?

One time constant

E5B03

The capacitor in an RC circuit is discharged to what percentage of the starting voltage after two time constants?

13.5%

E5B04

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

220 seconds (see equations below)

Step 1: Calculate the resistance in the parallel circuit

$$\boldsymbol{R_T\,(parallel)} = \frac{\mathbf{1}}{\frac{\mathbf{1}}{\boldsymbol{R_1}} + \frac{\mathbf{1}}{\boldsymbol{R_2}} + \cdots + \frac{\mathbf{1}}{\boldsymbol{R_n}}}$$

$$\boldsymbol{R_T\,(parallel)} = \frac{1}{\frac{1}{1\ meg\Omega} + \frac{1}{1\ meg\Omega}} = 0.5\ meg\Omega$$

Step 2: Calculate the capacitance in the parallel circuit

$$\boldsymbol{C_T\,(parallel)} = \boldsymbol{C_1} + \boldsymbol{C_2} + \cdots + \boldsymbol{C_n}$$

$$\boldsymbol{C_T\,(parallel)} = 220\ \mu F + 220\ \mu F = 440\ \mu F$$

Step 3: Calculate the time constant

$$\tau = R \times C$$

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

Hint: A microfarad is 10^{-6} farads. A megohm is 10^{6} ohms. You can add the exponents of similar exponential numbers. In this case, $10^{(-6+6)} = 10^{0} = 1$, therefore it cancels out the exponential numbers. Thus you can simplify this equation as follows:

$$\tau = 0.5 \times 440$$

E5B05

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?

0.02 seconds (see equations below)

Step 1: Calculate the discharged ratio

$$discharged\ ratio = \frac{discharged\ V}{charged\ V}$$

$$discharged\ ratio = \frac{7.36\ V}{20\ V} = 0.368 = 36.8\%$$

Step 2: Calculate the number of time constants

$$number\ of\ \tau = |\ln discharged\ ratio|$$

$$number\ of\ \tau = |\ln 0.368| = 1$$

Hint: On your scientific calculator enter 0.368 then press the 

button. The absolute value of the result is the number of time constants. In this case, it is 1τ.

Step 3: Calculate the time

$$\tau = R \times C \times number\ of\ \tau$$

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

Hint: A microfarad is 10^{-6} farads. A megohm is 10^{6} ohms. You can add the exponents of similar exponential numbers. In this case, $10^{(-6+6)} = 10^{0} = 1$, therefore it cancels out the exponential numbers. Thus you can simplify this equation as follows:

$$\tau = 2 \times 0.01$$

E5B06

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?

450 seconds (see equations below)

Step 1: Calculate the number of time constants

$$\boldsymbol{number\ of\ time\ constants} = \frac{\boldsymbol{discharged\ V}}{\boldsymbol{charged\ V}}$$

$$\boldsymbol{number\ of\ time\ constants} = \frac{294\ V}{800\ V} = 0.368 = 36.8\%$$

Step 2: Calculate the number of time constants

$$\boldsymbol{number\ of\ \tau} = |\ \mathbf{ln}\ \boldsymbol{discharged\ ratio}\ |$$

$$\boldsymbol{number\ of\ \tau} = |\ \ln 0.368\ | = 1$$

Hint: On your scientific calculator enter 0.368 then press the 

button. The absolute value of the result is the number of time constants. In this case, it is 1τ.

Step 3: Calculate the time

$$\boldsymbol{\tau} = \boldsymbol{R} \times \boldsymbol{C} \times \boldsymbol{number\ of\ \tau}$$

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

Hint: A microfarad is 10^{-6} farads. A megohm is 10^{6} ohms. You can add the exponents of similar exponential numbers. In this case, $10^{(-6+6)} = 10^{0} = 1$, therefore it cancels out the exponential numbers. Thus you can simplify this equation as follows:

$$\boldsymbol{\tau} = 1 \times 450$$

E5B07

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?

14.0 degrees with the voltage lagging the current (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X} = \boldsymbol{X_L} - \boldsymbol{X_C}$$

$$\boldsymbol{X} = 250 - 500 = -250$$

Hint: Since X is negative, voltage is lagging the current.

Step 2: Calculate the Phase Angle for a series circuit

$$\boldsymbol{Phase\ angle = tan^{-1}\left(\frac{X}{R}\right)}$$

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

Hint: Use the absolute value of X to determine the phase angle.

E5B08

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?

14 degrees with the voltage lagging the current (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X = X_L - X_C}$$

$$\boldsymbol{X} = 75 - 100 = -25$$

Hint: Since X is negative, voltage is lagging the current.

Step 2: Calculate the Phase Angle for a series circuit

$$\boldsymbol{Phase\ angle = tan^{-1}\left(\frac{X}{R}\right)}$$

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

Hint: Use the absolute value of X to determine the phase angle.

E5B09

What is the relationship between the current through and the voltage across a capacitor?

Current leads voltage by 90 degrees

E5B10

What is the relationship between the current through an inductor and the voltage across an inductor?

Voltage leads current by 90 degrees

E5B11

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?

14 degrees with the voltage leading the current (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X} = \boldsymbol{X_L} - \boldsymbol{X_C}$$

$$\boldsymbol{X} = 50 - 25 = 25$$

Hint: Since X is positive, voltage is leading the current.

Step 2: Calculate the Phase Angle for a series circuit

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right)$$

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

Hint: Use the absolute value of X to determine the phase angle.

E5B12

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?

14 degrees with the voltage lagging the current (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X} = \boldsymbol{X_L} - \boldsymbol{X_C}$$

$$\boldsymbol{X} = 50 - 75 = -25$$

Hint: Since X is negative, voltage is lagging the current.

Step 2: Calculate the Phase Angle for a series circuit

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right)$$

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

Hint: Use the absolute value of X to determine the phase angle.

E5B13

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?

14.04 degrees with the voltage leading the current (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X = X_L - X_C}$$

$$\boldsymbol{X} = 500 - 250 = 250$$

Hint: Since X is positive, voltage is leading the current.

Step 2: Calculate the Phase Angle for a series circuit

$$\boldsymbol{Phase\ angle = tan^{-1}\left(\frac{X}{R}\right)}$$

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

Hint: Use the absolute value of X to determine the phase angle.

E5C Impedance plots and coordinate systems: plotting impedances in polar coordinates; rectangular coordinates

E5C01

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

141 ohms at an angle of 45 degrees (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X} = \boldsymbol{X_L} - \boldsymbol{X_C}$$

$$\boldsymbol{X} = 100 - 0 = 100$$

Step 2: Calculate the phase angle for a series circuit

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right)$$

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

Hint: Since X is positive, the phase angle is positive.

Step 3: Calculate the impedance

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

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

E5C02

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

100 ohms at an angle of 0 degrees (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X} = \boldsymbol{X_L} - \boldsymbol{X_C}$$

$$\boldsymbol{X} = 100 - 100 = 0$$

Step 2: Calculate the phase angle for a series circuit

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right)$$

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

Hint: Since X is positive, the phase angle is positive.

Step 3: Calculate the impedance

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

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

E5C03

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

500 ohms at an angle of 37 degrees (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X = X_L - X_C}$$

$$\boldsymbol{X} = 600 - 300 = 300$$

Step 2: Calculate the phase angle for a series circuit

$$\boldsymbol{Phase\ angle = tan^{-1}\left(\frac{X}{R}\right)}$$

$$\boldsymbol{Phase\ angle} = tan^{-1}\left(\frac{300\ \Omega}{400\ \Omega}\right) = 36.87°$$

Hint: Since X is positive, the phase angle is positive.

Step 3: Calculate the impedance

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

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

E5C04

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

500 ohms at an angle of -53.1 degrees (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X = X_L - X_C}$$

$$\boldsymbol{X} = 0 - 400 = -400$$

Step 2: Calculate the phase angle for a series circuit

$$\boldsymbol{Phase\ angle = tan^{-1}\left(\frac{X}{R}\right)}$$

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

Hint: Since X is negative, the phase angle is negative.

Step 3: Calculate the impedance

$$|Z| = \sqrt{R^2 + X^2}$$

$$|Z| = \sqrt{300^2 + -400^2} = \mathbf{500\ \Omega,\ /-53.1^\circ}$$

E5C05

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

240 ohms at an angle of 36.9 degrees (see equations below)

Step 1: Calculate the reactance

$$X = X_L - X_C$$

$$X = 400 - 0 = 400$$

Step 2: Calculate the phase angle for a parallel circuit

$$\mathbf{Phase\ angle} = \mathbf{90^\circ} - \mathbf{tan^{-1}}\left(\frac{X}{R}\right)$$

$$\mathbf{Phase\ angle} = 90^\circ - tan^{-1}\left(\frac{400\ \Omega}{300\ \Omega}\right) = 36.87^\circ$$

Step 3: Calculate the impedance

$$|Z| = \frac{Z_R \times Z_X}{\sqrt{{Z_R}^2 + {Z_X}^2}} = \frac{300 \times 400}{\sqrt{300^2 + 400^2}} = \mathbf{240\ \Omega,\ /+36.9^\circ}$$

E5C06

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

141 ohms at an angle of -45 degrees (see equations below)

Step 1: Calculate the reactance

$$X = X_L - X_C$$

$$X = 0 - 100 = -100$$

Step 2: Calculate the phase angle for a series circuit

$$\mathbf{Phase\ angle} = \mathbf{tan^{-1}}\left(\frac{X}{R}\right)$$

$$\mathbf{Phase\ angle} = tan^{-1}\left(\frac{-100\ \Omega}{100\ \Omega}\right) = -45^\circ$$

Hint: Since X is negative, the phase angle is negative.

Step 3: Calculate the impedance

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

$$|\boldsymbol{Z}| = \sqrt{100^2 + -100^2} = \mathbf{141.42\ \Omega,\ /-53.1^\circ}$$

E5C07

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

71 ohms at an angle of -45 degrees (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X = X_L - X_C}$$

$$\boldsymbol{X} = 0 - 100 = -100$$

Step 2: Calculate the phase angle for a parallel circuit

$$\boldsymbol{Phase\ angle = -90^\circ - tan^{-1}\left(\frac{X}{R}\right)}$$

$$\boldsymbol{Phase\ angle} = -90^\circ - tan^{-1}\left(\frac{-100\ \Omega}{100\ \Omega}\right) = -45^\circ$$

Step 3: Calculate the impedance

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

E5C08

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

500 ohms at an angle of 37 degrees (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X = X_L - X_C}$$

$$\boldsymbol{X} = 300 - 0 = 300$$

Step 2: Calculate the phase angle for a series circuit

$$\boldsymbol{Phase\ angle = tan^{-1}\left(\frac{X}{R}\right)}$$

$$\boldsymbol{Phase\ angle} = tan^{-1}\left(\frac{300\ \Omega}{400\ \Omega}\right) = 36.87^\circ$$

Hint: Since X is negative, the phase angle is negative.

Step 3: Calculate the impedance

$$|Z| = \sqrt{R^2 + X^2}$$

$$|Z| = \sqrt{400^2 + 300^2} = \mathbf{500\ \Omega,\ \angle{+37°}}$$

E5C09

When using rectangular coordinates to graph the impedance of a circuit, what does the horizontal axis represent?

The voltage or current associated with the resistive component

E5C10

When using rectangular coordinates to graph the impedance of a circuit, what does the vertical axis represent?

The voltage or current associated with the reactive component

E5C11

What do the two numbers represent that are used to define a point on a graph using rectangular coordinates?

The coordinate values along the horizontal and vertical axes

E5C12

If you plot the impedance of a circuit using the rectangular coordinate system and find the impedance point falls on the right side of the graph on the horizontal line, what do you know about the circuit?

It is equivalent to a pure resistance

E5C13

What coordinate system is often used to display the resistive, inductive, and/or capacitive reactance components of an impedance?

Rectangular coordinates

E5C14

What coordinate system is often used to display the phase angle of a circuit containing resistance, inductive and/or capacitive reactance?

Polar coordinates

E5C15

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

141 ohms at an angle of -45 degrees (see equations below)

Step 1: Calculate the phase angle

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right)$$

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

Step 2: Calculate the impedance

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

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

E5C16

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

141 ohms at an angle of -45 degrees (see equations below)

$$\boldsymbol{Z} = \frac{\mathbf{1}}{\boldsymbol{admittance}}$$

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

Hint: A millisiemen is 10^{-3} siemens. Note that $\frac{1}{/+45°} = /-45°$. Therefore the equation can be written:

$$\boldsymbol{Z} = \frac{1}{7.09 \times 10^{-3}}, \qquad /-45°$$

E5C17

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

173 + j100 ohms (see equations below)

Step 1: Calculate the polar impedance

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

Hint: A millisiemen is 10^{-3} siemens. Note that $\frac{1}{\angle -30°} = \angle +30°$. Therefore the equation can be written:

$$\boldsymbol{Z_{polar}} = \frac{1}{5 \times 10^{-3}}, \qquad \angle +45°$$

Step 2: Calculate the rectangular resistance

$$\boldsymbol{R_{rectangular}} = \boldsymbol{Z_{polar}} \times \boldsymbol{cos}(\boldsymbol{phase\ angle})$$

$$\boldsymbol{R_{rectangular}} = 200\ \Omega \times cos(30) = 173.2\ \Omega$$

Step 3: Calculate the rectangular reactance

$$\boldsymbol{jX_{rectangular}} = \boldsymbol{Z_{polar}} \times \boldsymbol{sin}(\boldsymbol{phase\ angle})$$

$$\boldsymbol{jX_{rectangular}} = 200\ \Omega \times sin(30) = j100\ \Omega$$

Step 4: Illustrate the rectangular impedance

$$\boldsymbol{Z_{rectangular}} = \boldsymbol{R_{rectangular}} + \boldsymbol{jX_{rectangular}}$$

$$\boldsymbol{Z_{rectangular}} = \mathbf{173 + j100}$$

E5C18

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?

5 ohms at an angle of 37 degrees (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X} = \boldsymbol{X_L} - \boldsymbol{X_C}$$

$$\boldsymbol{X} = 4 - 1 = 3$$

Step 2: Calculate the phase angle for a series circuit

$$\boldsymbol{Phase\ angle} = \boldsymbol{tan^{-1}}\left(\frac{\boldsymbol{X}}{\boldsymbol{R}}\right)$$

$$\boldsymbol{Phase\ angle} = tan^{-1}\left(\frac{3\ \Omega}{4\ \Omega}\right) = 36.87°$$

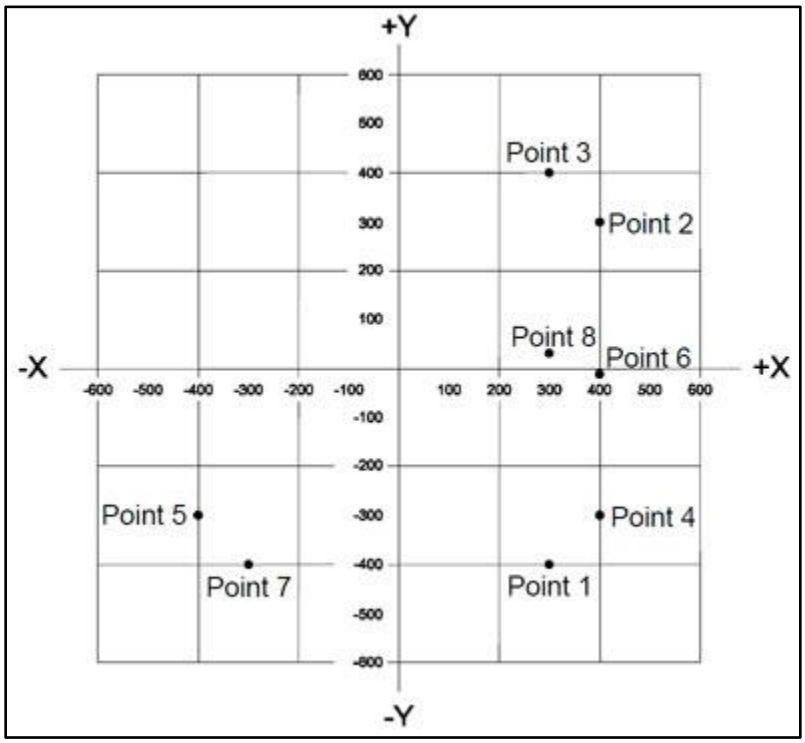
Hint: Since X is positive, the phase angle is positive.

Step 3: Calculate the impedance

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

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

Figure E5–2



E5C19

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

Point 4 (see equation below)

$$\boldsymbol{X_C = \frac{1}{2\pi f C}}$$

$$X_C = \frac{1}{2\pi \times 14 \times 10^6\ Hz \times 38 \times 10^{-12}\ F} = 299.16\ \Omega$$

Hint: A picofarad is 10^{-12} farads. A megahertz is 10^6 Hz. You can add the exponents of similar exponential numbers. Thus you can simplify this equation as follows:

$$X_C = \frac{1}{2\pi \times 14 \times 38 \times 10^{-6}}$$

***Point 4** because **$R = 400$** and **$X = -300$** (capacitive reactance is negative)*

E5C20

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?

Point 3 (see equation below)

$$\boldsymbol{X_L = 2\pi f L}$$

$$X_L = 2\pi \times 3.505 \times 10^6\ Hz \times 18 \times 10^{-6}\ H = 396.4\ \Omega$$

Hint: A microhenry is 10^{-6} henrys. A megahertz is 10^6 Hz. You can add the exponents of similar exponential numbers. In this case, $10^{(-6+6)} = 10^0 = 1$, therefore it cancels out the exponential numbers. Thus you can simplify this equation as follows:

$$X_L = 2\pi \times 3.505 \times 18$$

***Point 3** because **$R = 300$** and **$X = 400$** (inductive reactance is positive)*

E5C21

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?

Point 1 (see equation below)

$$\boldsymbol{X_C = \frac{1}{2\pi f C}}$$

$$X_C = \frac{1}{2\pi \times 21.2 \times 10^6\ Hz \times 19 \times 10^{-12}\ F} = 395.12\ \Omega$$

Hint: A picofarad is 10^{-12} farads. A megahertz is 10^6 Hz. You can add the exponents of similar exponential numbers. Thus you can simplify this equation as follows:

$$X_C = \frac{1}{2\pi \times 21.2 \times 19 \times 10^{-6}}$$

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

E5C22

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?

40 + j31,400 (see equations below)

Step 1: Calculate the reactance

$$\boldsymbol{X_L = 2\pi f L}$$

$$X_L = 2\pi \times 500 \times 10^6\ Hz \times 10 \times 10^{-6}\ H = j31416\ \Omega$$

Hint: A microhenry is 10^{-6} henrys. A megahertz is 10^6 Hz. You can add the exponents of similar exponential numbers. In this case, $10^{(-6+6)} = 10^0 = 1$, therefore it cancels out the exponential numbers. Thus you can simplify this equation as follows:

$$X_L = 2\pi \times 500 \times 10 = j31416\ \Omega$$

Step 2: Calculate impedance

$$|Z| = \sqrt{R^2 + X^2}$$

$$|Z| = \sqrt{40^2 + 31416^2} = 31416$$

Step 3: Illustrate the impedance

$\boldsymbol{40 + j31,400}$ $(because\ L\ Reactance = +j\ and\ C\ Reactance = -j)$

Note: Even though the actual impedance is 40 +j31,416, 40 +j31,400 is essentially correct though less accurate. The question pool committee made the assumption that people will substitute a rounded 3.14 for π. If you use the rounded 3.14 then the answer will be 40 +j31,400. However, if you use a calculator with a built-in π function then you will get the more accurate solution of 40 +j31,416. I disagree with the question pool committee's assumption because I was taught to always carry π to at least five places beyond the decimal, that is π = 3.14159.

E5C23

Which point on Figure E5-2 best represents the impedance of a series circuit consisting of a 300-ohm resistor, a 0.64-microhenry inductor and an 85-picofarad capacitor at 24.900 MHz?

Point 8 (see equations below)

Step 1: Calculate the capacitive reactance

$$\boldsymbol{X_C = \frac{1}{2\pi f C}}$$

$$X_C = \frac{1}{2\pi \times 24.9 \times 10^6\ Hz \times 85 \times 10^{-12}\ F} = 75.2\ \Omega$$

Hint: A picofarad is 10^{-12} farads. A megahertz is 10^6 Hz. You can add the exponents of similar exponential numbers. Thus you can simplify this equation as follows:

$$X_C = \frac{1}{2\pi \times 24.9 \times 85 \times 10^{-6}}$$

Step 2: Calculate the inductive reactance

$$\boldsymbol{X_L = 2\pi f L}$$

$$X_L = 2\pi \times 24.9 \times 10^6\ Hz \times 0.64 \times 10^{-6}\ H = j100.1\ \Omega$$

Hint: A microhenry is 10^{-6} henrys. A megahertz is 10^6 Hz. You can add the exponents of similar exponential numbers. In this case, $10^{(-6+6)} = 10^0 = 1$, therefore it cancels out the exponential numbers. Thus you can simplify this equation as follows:

$$X_L = 2\pi \times 24.9 \times 0.64 = j100.1\ \Omega$$

Step 3: Calculate the reactance

$$\boldsymbol{X = X_L - X_C}$$

$$X = 100.1\ \Omega - 75.2\ \Omega = 24.9\ \Omega$$

Step 4: Locate the point

$$\boldsymbol{Point\ 8}\ because\ \boldsymbol{R = 300}\ and\ \boldsymbol{X = 25}\ (inductive\ reactance\ is\ positive)$$

E5D AC and RF energy in real circuits: skin effect; electrostatic and electromagnetic fields; reactive power; power factor; coordinate systems

E5D01

What is the result of skin effect?

As frequency increases, RF current flows in a thinner layer of the conductor, closer to the surface

E5D02

Why is the resistance of a conductor different for RF currents than for direct currents?

Because of skin effect

E5D03

What device is used to store electrical energy in an electrostatic field?

A capacitor

E5D04

What unit measures electrical energy stored in an electrostatic field?

Joule

E5D05

What is a magnetic field?

The region surrounding a magnet through which a magnetic force acts

E5D06

In what direction is the magnetic field oriented about a conductor in relation to the direction of electron flow?

In a direction determined by the left-hand rule

E5D07

What determines the strength of a magnetic field around a conductor?

The amount of current

E5D08

What is the term for energy that is stored in an electromagnetic or electrostatic field?

Potential energy

E5D09

What is the term for an out-of-phase, nonproductive power associated with inductors and capacitors?

Reactive power

E5D10

In a circuit that has both inductors and capacitors, what happens to reactive power?

It is repeatedly exchanged between the associated magnetic and electric fields, but is not dissipated

E5D11

How can the true power be determined in an AC circuit where the voltage and current are out of phase?

By multiplying the apparent power times the power factor

E5D12

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

0.5 (see equation below)

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

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

E5D13

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?

80 watts (see equation below)

$$\boldsymbol{True\ power} = \boldsymbol{E} \times \boldsymbol{I} \times \boldsymbol{power\ factor}$$

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

E5D14

How much power is consumed in a circuit consisting of a 100 ohm resistor in series with a 100 ohm inductive reactance drawing 1 ampere?

100 Watts (see equation below)

Step 1: Calculate the voltage across the resistor

$$E_R = I \times R$$

$$E_R = 1\ A \times 100\ \Omega = 100\ \text{V}$$

Step 2: Calculate the power

$$Power = E \times I$$

$$Power = 100\ V \times 1\ A = \mathbf{100\ watts}$$

Hint: Reactance is wattless.

E5D15

What is reactive power?

Wattless, nonproductive power

E5D16

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

0.707 (see equation below)

$$power\ factor = cos(phase\ angle)$$

$$power\ factor = cos(45) = \mathbf{0.707}$$

E5D17

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

0.866 (see equation below)

$$power\ factor = cos(phase\ angle)$$

$$power\ factor = cos(30) = \mathbf{0.866}$$

E5D18

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

600 watts (see equation below)

$$\boldsymbol{True\ power} = \boldsymbol{E} \times \boldsymbol{I} \times \boldsymbol{power\ factor}$$

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

E5D19

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

355 W (see equation below)

$$\boldsymbol{True\ power} = \boldsymbol{apparent\ power} \times \boldsymbol{power\ factor}$$

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

Subelement E6 — Circuit Components

E6A Semiconductor materials and devices: semiconductor materials (germanium, silicon, P-type, N-type); transistor types: NPN, PNP, junction, power; field-effect transistors: enhancement mode; depletion mode; MOS; CMOS; N-channel; P-channel

E6A01

In what application is gallium arsenide used as a semiconductor material in preference to germanium or silicon?

At microwave frequencies

E6A02

What type of semiconductor material contains more free electrons than pure germanium or silicon crystals?

N-type

E6A03

What are the majority charge carriers in P-type semiconductor material?

Holes

E6A04

What is the name given to an impurity atom that adds holes to a semiconductor crystal structure?

Acceptor impurity

E6A05

What is the alpha of a bipolar junction transistor?

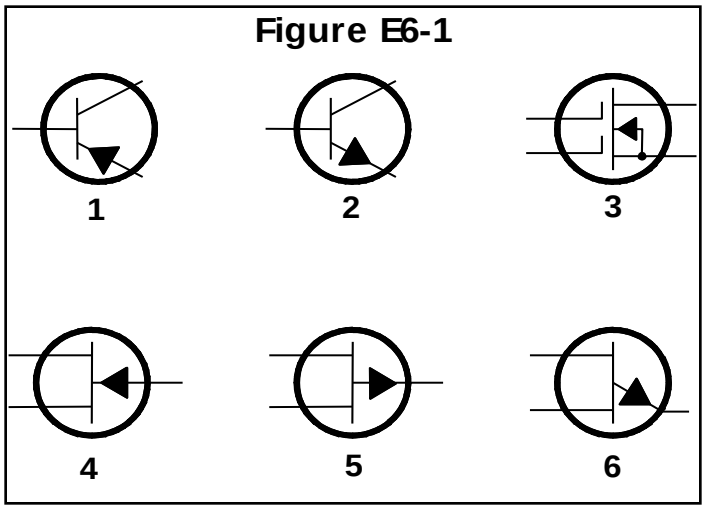
The change of collector current with respect to emitter current

E6A06

What is meant by the beta of a bipolar junction transistor?

The change in collector current with respect to base current

Figure E6–1



E6A07

In Figure E6-1, what is the schematic symbol for a PNP transistor?

1

E6A08

What term indicates the frequency at which a transistor grounded base current gain has decreased to 0.7 of the gain obtainable at 1 kHz?

Alpha cutoff frequency

E6A09

What is a depletion-mode FET?

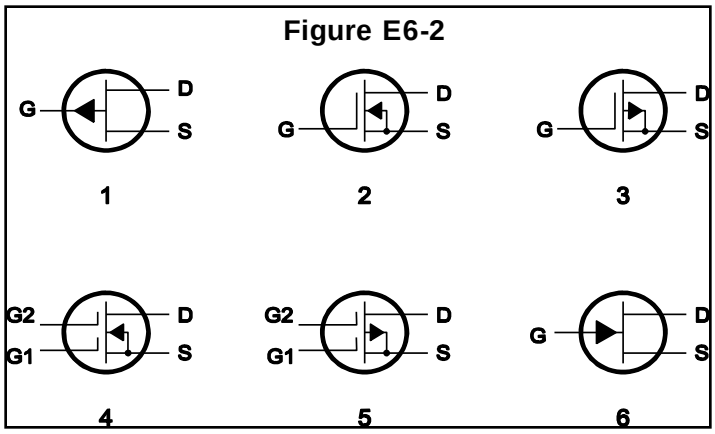
An FET that exhibits a current flow between source and drain when no gate voltage is applied

E6A10

In Figure E6-2, what is the schematic symbol for an N-channel dual-gate MOSFET?

4

Figure E6–2



E6A11

In Figure E6-2, what is the schematic symbol for a P-channel junction FET?

1

E6A12

Why do many MOSFET devices have built-in gate-protective Zener diodes?

To reduce the chance of the gate insulation being punctured by static discharges or excessive voltages

E6A13

What do the initials CMOS stand for?

Complementary metal-oxide semiconductor

E6A14

How does DC input impedance at the gate of a field-effect transistor compare with the DC input impedance of a bipolar transistor?

An FET has high input impedance; a bipolar transistor has low input impedance

E6A15

What two elements widely used in semiconductor devices exhibit both metallic and nonmetallic characteristics?

Silicon and germanium

E6A16

What type of semiconductor material contains fewer free electrons than pure germanium or silicon crystals?

P-type

E6A17

What are the majority charge carriers in N-type semiconductor material?

Free electrons

E6A18

What are the names of the three terminals of a field-effect transistor?

Gate, drain, source

E6B Semiconductor diodes

E6B01

What is the principal characteristic of a Zener diode?

A constant voltage under conditions of varying current

E6B02

What is the principal characteristic of a tunnel diode?

A negative resistance region

E6B03

What is an important characteristic of a Schottky Barrier diode as compared to an ordinary silicon diode when used as a power supply rectifier?

Less forward voltage drop

E6B04

What special type of diode is capable of both amplification and oscillation?

Tunnel

E6B05

What type of semiconductor device varies its internal capacitance as the voltage applied to its terminals varies?

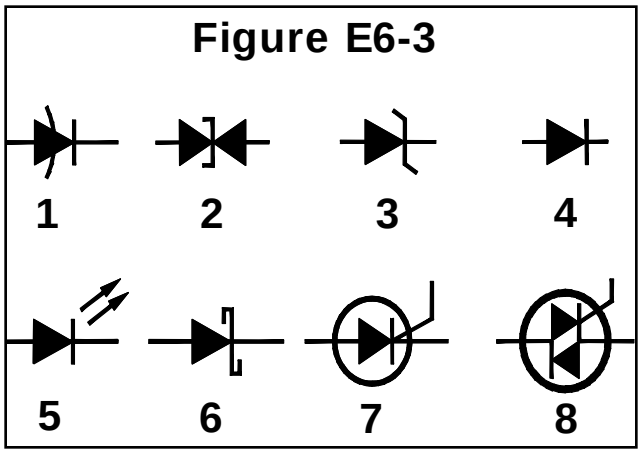
Varactor diode

E6B06

In Figure E6-3, what is the schematic symbol for a varactor diode?

1

Figure E6–3



E6B07

What is a common use of a hot-carrier diode?

As a VHF / UHF mixer or detector

E6B08

What limits the maximum forward current rating in a junction diode?

Junction temperature

E6B09

Which of the following describes a type of semiconductor diode?

Metal-semiconductor junction

E6B10

What is a common use for point contact diodes?

As an RF detector

E6B11

In Figure E6-3, what is the schematic symbol for a light-emitting diode?

5

E6B12

How are junction diodes rated?

Maximum forward current and PIV

E6B13

What is one common use for PIN diodes?

As an RF switch

E6B14

What type of bias is required for an LED to produce luminescence?

Forward bias

E6C Integrated circuits: TTL digital integrated circuits; CMOS digital integrated circuits; gates

E6C01

What is the recommended power supply voltage for TTL series integrated circuits?

5 volts

E6C02

What logic state do the inputs of a TTL device assume if they are left open?

A logic-high state

E6C03

What level of input voltage is a logic "high" in a TTL device operating with a positive 5-volt power supply?

2.0 to 5.5 volts

E6C04

What level of input voltage is a logic "low" in a TTL device operating with a positive 5-volt power-supply?

0.0 to 0.8 volts

E6C05

Which of the following is an advantage of CMOS logic devices over TTL devices?

Lower power consumption

E6C06

Why do CMOS digital integrated circuits have high immunity to noise on the input signal or power supply?

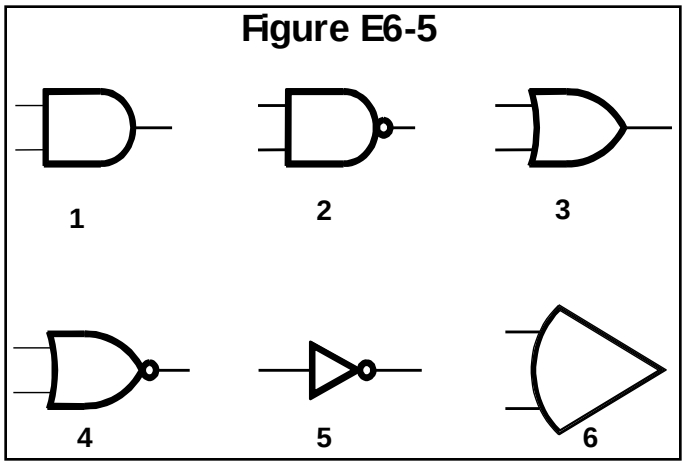
The input switching threshold is about one-half the power supply voltage

E6C07

In Figure E6-5, what is the schematic symbol for an AND gate?

1

Figure E6–5



E6C08

In Figure E6-5, what is the schematic symbol for a NAND gate?

2

E6C09

In Figure E6-5, what is the schematic symbol for an OR gate?

3

E6C10

In Figure E6-5, what is the schematic symbol for a NOR gate?

4

E6C11

In Figure E6-5, what is the schematic symbol for the NOT operation (inverter)?

5

E6D Optical devices and toroids: vidicon and cathode-ray tube devices; charge-coupled devices (CCDs); liquid crystal displays (LCDs); toroids: permeability, core material, selecting, winding

E6D01

How is the electron beam deflected in a vidicon?

By varying electromagnetic fields

E6D02

What is cathode ray tube (CRT) persistence?

The length of time the image remains on the screen after the beam is turned off

E6D03

If a cathode ray tube (CRT) is designed to operate with an anode voltage of 25,000 volts, what will happen if the anode voltage is increased to 35,000 volts?

The image size will decrease

E6D04

Exceeding what design rating can cause a cathode ray tube (CRT) to generate X-rays?

The anode voltage

E6D05

Which of the following is true of a charge-coupled device (CCD)?

It samples an analog signal and passes it in stages from the input to the output

E6D06

What function does a charge-coupled device (CCD) serve in a modern video camera?

It stores photogenerated charges as signals corresponding to pixels

E6D07

What is a liquid-crystal display (LCD)?

A display that uses a crystalline liquid to change the way light is refracted

E6D08

What material property determines the inductance of a toroidal inductor with a 10-turn winding?

Core permeability

E6D09

What is the usable frequency range of inductors that use toroidal cores, assuming a correct selection of core material for the frequency being used?

From less than 20 Hz to approximately 300 MHz

E6D10

What is one important reason for using powdered-iron toroids rather than ferrite toroids in an inductor?

Powdered-iron toroids generally have better temperature stability

E6D11

What devices are commonly used as VHF and UHF parasitic suppressors at the input and output terminals of transistorized HF amplifiers?

Ferrite beads

E6D12

What is a primary advantage of using a toroidal core instead of a solenoidal core in an inductor?

Toroidal cores have lower Q characteristics

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?

43 turns (see equation below)

$$\boldsymbol{N = 1000 \times \sqrt{\frac{L}{A_L}}}$$

$$\boldsymbol{N} = 1000 \times \sqrt{\frac{1\ mH}{523\ mH}} = \boldsymbol{43.7\ turns}$$

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?

35 turns (see equation below)

$$N = 100 \times \sqrt{\frac{L}{A_L}}$$

$$N = 100 \times \sqrt{\frac{5\ mH}{40\ mH}} = 35.4\ turns$$

E6D15

What type of CRT deflection is better when high-frequency waves are to be displayed on the screen?

Electrostatic

E6D16

Which is NOT true of a charge-coupled device (CCD)?

It is commonly used as an analog-to-digital converter

E6D17

What is the principle advantage of liquid-crystal display (LCD) devices over other types of display devices?

They consume less power

E6D18

What is one reason for using ferrite toroids rather than powdered-iron toroids in an inductor?

Ferrite toroids generally require fewer turns to produce a given inductance value

E6E Piezoelectric crystals and MMICS: quartz crystals (as used in oscillators and filters); monolithic amplifiers (MMICs)

E6E01

Which of these filter bandwidths would be a good choice for use in a SSB radiotelephone transmitter?

2.4 kHz at -6 dB

E6E02

Which of these filter bandwidths would be a good choice for use with standard double-sideband AM transmissions?

6 kHz at -6 dB

E6E03

What is a crystal lattice filter?

A filter with narrow bandwidth and steep skirts made using quartz crystals

E6E04

What technique is used to construct low-cost, high-performance crystal ladder filters?

Measure crystal frequencies and carefully select units with a frequency variation of less than 10% of the desired filter bandwidth

E6E05

Which of the following factors has the greatest effect in helping determine the bandwidth and response shape of a crystal ladder filter?

The relative frequencies of the individual crystals

E6E06

What is one aspect of the piezoelectric effect?

Physical deformation of a crystal by the application of a voltage

E6E07

What is the characteristic impedance of circuits in which almost all MMICs are designed to work?

50 ohms

E6E08

What is the typical noise figure of a monolithic microwave integrated circuit (MMIC) amplifier?

Approximately 3.5 to 6 dB

E6E09

What type of amplifier device consists of a small pill-type package with an input lead, an output lead and 2 ground leads?

A monolithic microwave integrated circuit (MMIC)

E6E10

What typical construction technique is used when building an amplifier for the microwave bands containing a monolithic microwave integrated circuit (MMIC)?

Microstrip construction

E6E11

How is the operating bias voltage normally supplied to the most common type of monolithic microwave integrated circuit (MMIC)?

Through a resistor and/or RF choke connected to the amplifier output lead

E6E12

What supply voltage do monolithic microwave integrated circuits (MMIC) amplifiers typically require?

12 volts DC

E6E13

What is the most common package for inexpensive monolithic microwave integrated circuit (MMIC) amplifiers?

Plastic packages

E6F Optical components and power systems: photoconductive principles and effects, photovoltaic systems, optical couplers, optical sensors, and optoisolators

E6F01

What is photoconductivity?

The increased conductivity of an illuminated semiconductor

E6F02

What happens to the conductivity of a photoconductive material when light shines on it?

It increases

E6F03

What is the most common configuration for an optocoupler?

An LED and a phototransistor

E6F04

Which of the following is an optoisolator?

An LED and a phototransistor

E6F05

What is an optical shaft encoder?

An array of optocouplers whose light transmission path is controlled by a rotating wheel

E6F06

What characteristic of a crystalline solid will photoconductivity change?

The resistance

E6F07

Which material will exhibit the greatest photoconductive effect when illuminated by visible light?

Cadmium sulfide

E6F08

Which material will exhibit the greatest photoconductive effect when illuminated by infrared light?

Lead sulfide

E6F09

Which of the following materials is affected the most by photoconductivity?

A crystalline semiconductor

E6F10

What characteristic of optoisolators is often used in power supplies?

They have very high impedance between the light source and the phototransistor

E6F11

What characteristic of optoisolators makes them suitable for use with a triac to form the solid-state equivalent of a mechanical relay for a 120 V AC household circuit?

Optoisolators provide a very high degree of electrical isolation between a control circuit and a power circuit

E6F12

Which of the following types of photovoltaic cell has the highest efficiency?

Gallium arsenide

E6F13

What is the most common type of photovoltaic cell used for electrical power generation?

Silicon

E6F14

Which of the following is the approximate open-circuit voltage produced by a fully-illuminated silicon photovoltaic cell?

0.5 V

E6F15

What absorbs the energy from light falling on a photovoltaic cell?

Electrons

Subelement E7 — Practical Circuits

E7 Digital circuits: digital circuit principles and logic circuits: classes of logic elements; positive and negative logic; frequency dividers; truth tables

E7A01

What is a bistable circuit?

A flip-flop

E7A02

How many output level changes are obtained for every two trigger pulses applied to the input of a "T" flip-flop circuit?

Two

E7A03

Which of the following can divide the frequency of pulse train by 2?

A flip-flop

E7A04

How many flip-flops are required to divide a signal frequency by 4?

2

E7A05

Which of the following is a circuit that continuously alternates between two unstable states without an external clock?

Astable Multivibrator

E7A06

What is a characteristic of a monostable multivibrator?

It switches momentarily to the opposite binary state and then returns, after a set time, to its original state

E7A07

What logical operation does an AND gate perform?

It produces a logic "1" at its output only if all inputs are logic "1"

E7A08

What logical operation does a NAND gate perform?

It produces a logic "0" at its output only when all inputs are logic "1"

E7A09

What logical operation does an OR gate perform?

It produces a logic "1" at its output if any or all inputs are logic "1"

E7A10

What logical operation does a NOR gate perform?

It produces a logic "0" at its output if any or all inputs are logic "1"

E7A11

What is a truth table?

A list of inputs and corresponding outputs for a digital device

E7A12

What is the name for logic which represents a logic "1" as a high voltage?

Positive Logic

E7A13

What is the name for logic which represents a logic "0" as a high voltage?

Negative logic

E7B Amplifiers: Class of operation; vacuum tube and solid-state circuits; distortion and intermodulation; spurious and parasitic suppression; microwave amplifiers

E7B01

For what portion of a signal cycle does a Class AB amplifier operate?

More than 180 degrees but less than 360 degrees

E7B02

Which class of amplifier, of the types shown, provides the highest efficiency?

Class C

E7B03

Where on the load line of a Class A common emitter amplifier would bias normally be set?

Approximately half-way between saturation and cutoff

E7B04

What can be done to prevent unwanted oscillations in a power amplifier?

Install parasitic suppressors and/or neutralize the stage

E7B05

Which of the following amplifier types reduces or eliminates even-order harmonics?

Push-pull

E7B06

Which of the following is a likely result when a Class C rather than a class AB amplifier is used to amplify a single-sideband phone signal?

The signal may become distorted and occupy excessive bandwidth

E7B07

How can a vacuum-tube power amplifier be neutralized?

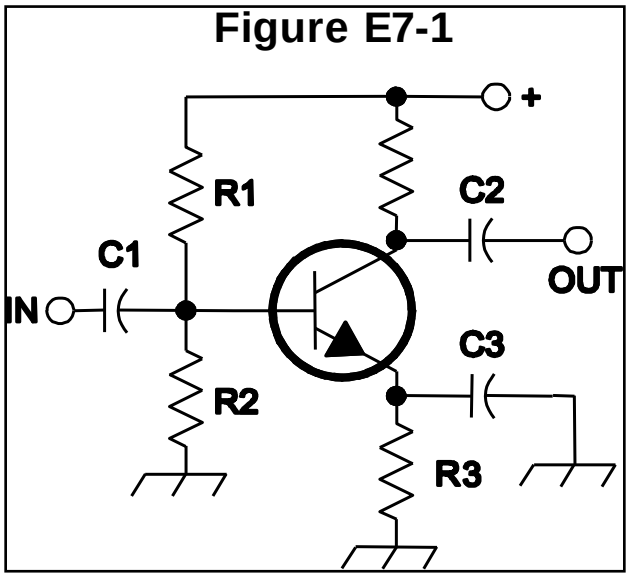
By feeding back an out-of-phase component of the output to the input

E7B08

Which of the following describes how the loading and tuning capacitors are to be adjusted when tuning a vacuum tube RF power amplifier that employs a pi-network output circuit?

The tuning capacitor is adjusted for minimum plate current, while the loading capacitor is adjusted for maximum permissible plate current

Figure E7–1



E7B09

In Figure E7-1, what is the purpose of R1 and R2?

Fixed bias

E7B10

In Figure E7-1, what is the purpose of R3?

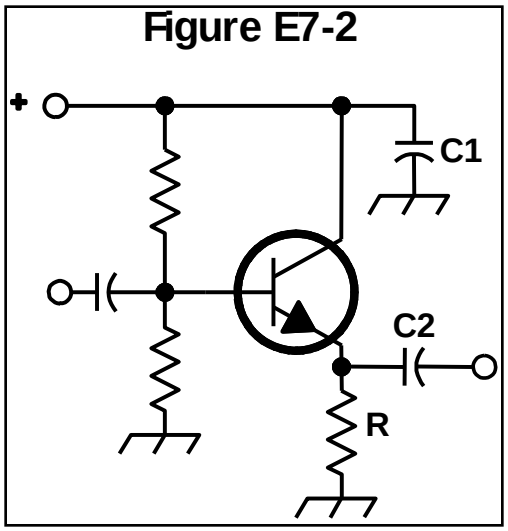
Self bias

E7B11

What type of circuit is shown in Figure E7-1?

Common emitter amplifier

Figure E7–2



E7B12

In Figure E7-2, what is the purpose of R?

Emitter load

E7B13

In Figure E7-2, what is the purpose of C2?

Output coupling

E7B14

What is one way to prevent thermal runaway in a transistor amplifier?

Use degenerative emitter feedback

E7B15

What is the effect of intermodulation products in a linear power amplifier?

Transmission of spurious signals

E7B16

Why are third-order intermodulation distortion products of particular concern in linear power amplifiers?

Because they are relatively close in frequency to the desired signal

E7B17

Which of the following is a characteristic of a grounded-grid amplifier?

Low input impedance

E7B18

What is a klystron?

A VHF, UHF, or microwave vacuum tube that uses velocity modulation

E7B19

What is a parametric amplifier?

A low-noise VHF or UHF amplifier relying on varying reactance for amplification

E7B20

Which of the following devices is generally best suited for UHF or microwave power amplifier applications?

FET

E7C Filters and matching networks: filters and impedance matching networks: types of networks; types of filters; filter applications; filter characteristics; impedance matching; DSP filtering

E7C01

How are the capacitors and inductors of a low-pass filter Pi-network arranged between the network's input and output?

A capacitor is in parallel with the input, another capacitor is in parallel with the output, and an inductor is in series between the two

E7C02

A T-network with series capacitors and a parallel (shunt) inductor has which of the following properties?

It transforms impedance and is a high-pass filter

E7C03

What advantage does a Pi-L-network have over a Pi-network for impedance matching between the final amplifier of a vacuum-tube type transmitter and an antenna?

Greater harmonic suppression

E7C04

How does a network transform a complex impedance to a resistive impedance?

It cancels the reactive part of an impedance and transforms the resistive part to the desired value

E7C05

Which filter type is described as having ripple in the passband and a sharp cutoff?

A Chebyshev filter

E7C06

What are the distinguishing features of an elliptical filter?

Extremely sharp cutoff, with one or more infinitely deep notches in the stop band

E7C07

What kind of audio filter would you use to attenuate an interfering carrier signal while receiving an SSB transmission?

A notch filter

E7C08

What kind of digital signal processing audio filter might be used to remove unwanted noise from a received SSB signal?

An adaptive filter

E7C09

What type of digital signal processing filter might be used in generating an SSB signal?

A Hilbert-transform filter

E7C10

Which of the following filters would be the best choice for use in a 2-meter repeater duplexer?

A cavity filter

E7C11

Which of the following is the common name for a filter network which is equivalent to two L networks back-to-back?

Pi

E7C12

What is a Pi-L network, as used when matching a vacuum-tube final amplifier to a 50-ohm unbalanced output?

A network consisting of two series inductors and two shunt capacitors

E7C13

What is one advantage of a Pi matching network over an L matching network?

Q of Pi networks can be varied depending on the component values chosen

E7C14

Which of these modes is most affected by non-linear phase response in a receiver IF filter?

Digital

E7D Power supplies and voltage regulators

E7D01

What is one characteristic of a linear electronic voltage regulator?

The conduction of a control element is varied to maintain a constant output voltage

E7D02

What is one characteristic of a switching electronic voltage regulator?

The control device's duty cycle is controlled to produce a constant average output voltage

E7D03

What device is typically used as a stable reference voltage in a linear voltage regulator?

A Zener diode

E7D04

Which of the following types of linear regulator makes the most efficient use of the primary power source?

A series regulator

E7D05

Which of the following types of linear voltage regulator places a constant load on the unregulated voltage source?

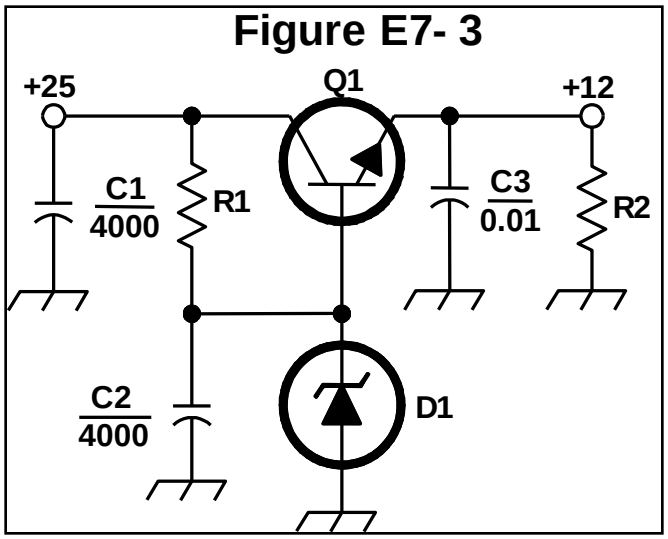
A shunt regulator

E7D06

What is the purpose of Q1 in the circuit shown in Figure E7-3?

It increases the current-handling capability of the regulator

Figure E7–3



E7D07

What is the purpose of C2 in the circuit shown in Figure E7-3?

It bypasses hum around D1

E7D08

What type of circuit is shown in Figure E7-3?

Linear voltage regulator

E7D09

What is the purpose of C1 in the circuit shown in Figure E7-3?

It filters the supply voltage

E7D10

What is the purpose of C3 in the circuit shown in Figure E7-3?

It prevents self-oscillation

E7D11

What is the purpose of R1 in the circuit shown in Figure E7-3?

It supplies current to D1

E7D12

What is the purpose of R2 in the circuit shown in Figure E7-3?

It provides a constant minimum load for Q1

E7D13

What is the purpose of D1 in the circuit shown in Figure E7-3?

To provide a voltage reference

E7D14

What is one purpose of a "bleeder" resistor in a conventional (unregulated) power supply?

To improve output voltage regulation

E7D15

What is the purpose of a "step-start" circuit in a high-voltage power supply?

To allow the filter capacitors to charge gradually

E7D16

When several electrolytic filter capacitors are connected in series to increase the operating voltage of a power supply filter circuit, why should resistors be connected across each capacitor?

A. To equalize, as much as possible, the voltage drop across each capacitor

B. To provide a safety bleeder to discharge the capacitors when the supply is off

C. To provide a minimum load current to reduce voltage excursions at light loads

D. All of these answers are correct

E7D17

What is the primary reason that a high-frequency inverter type high-voltage power supply can be both less expensive and lighter in weight than a conventional power supply?

The high frequency inverter design uses much smaller transformers and filter components for an equivalent power output

E7E Modulation and demodulation: reactance, phase and balanced modulators; detectors; mixer stages; DSP modulation and demodulation; software defined radio systems

E7E01

Which of the following can be used to generate FM-phone emissions?

A reactance modulator on the oscillator

E7E02

What is the function of a reactance modulator?

To produce PM signals by using an electrically variable inductance or capacitance

E7E03

What is the fundamental principle of a phase modulator?

It varies the tuning of an amplifier tank circuit to produce PM signals

E7E04

What is one way a single-sideband phone signal can be generated?

By using a balanced modulator followed by a filter

E7E05

What circuit is added to an FM transmitter to proportionally attenuate the lower audio frequencies?

A pre-emphasis network

E7E06

What circuit is added to an FM receiver to restore attenuated lower audio frequencies?

A de-emphasis network

E7E07

What is one result of the process of mixing two signals?

The creation of new signals at the sum and difference frequencies

E7E08

What are the principal frequencies that appear at the output of a mixer circuit?

The original frequencies, and the sum and difference frequencies

E7E09

What occurs when an excessive amount of signal energy reaches a mixer circuit?

Spurious mixer products are generated

E7E10

What is the process of detection?

The recovery of information from a modulated RF signal

E7E11

How does a diode detector function?

By rectification and filtering of RF signals

E7E12

Which of the following types of detector is well suited for demodulating SSB signals?

Product detector

E7E13

What is a frequency discriminator?

A circuit for detecting FM signals

E7E14

Which of the following describes a common means of generating a SSB signal when using digital signal processing?

The phasing or quadrature method

E7E15

What is meant by “direct conversion” when referring to a software defined receiver?

Incoming RF is mixed to “baseband” for analog-to-digital conversion and subsequent processing

E7F Frequency markers and counters: frequency divider circuits; frequency marker generators; frequency counters

E7F01

What is the purpose of a prescaler circuit?

It divides a higher frequency signal so a low-frequency counter can display the operating frequency

E7F02

Which of the following would be used to reduce a signal's frequency by a factor of ten?

A prescaler

E7F03

What is the function of a decade counter digital IC?

It produces one output pulse for every ten input pulses

E7F04

What additional circuitry must be added to a 100-kHz crystal-controlled marker generator so as to provide markers at 50 and 25 kHz?

Two flip-flops

E7F05

Which of the following circuits can be combined to produce a 100 kHz fundamental signal with harmonics at 100 kHz intervals?

A 1 MHz oscillator and a decade counter

E7F06

Which of these choices best describes a crystal marker generator?

A crystal-controlled oscillator that generates a series of reference signals at known frequency intervals

E7F07

Which type of circuit would be a good choice for generating a series of harmonically related receiver calibration signals?

A crystal oscillator followed by a frequency divider

E7F08

What is one purpose of a marker generator?

To provide a means of calibrating a receiver's frequency settings

E7F09

What determines the accuracy of a frequency counter?

The accuracy of the time base

E7F10

How does a conventional frequency counter determine the frequency of a signal?

It counts the number of input pulses occurring within a specific period of time

E7F11

What is the purpose of a frequency counter?

To provide a digital representation of the frequency of a signal

E7F12

What alternate method of determining frequency, other than by directly counting input pulses, is used by some frequency counters?

Period measurement

E7F13

What is an advantage of a period-measuring frequency counter over a direct-count type?

It provides improved resolution of signals within a comparable time period

E7G Active filters and op-amps: active audio filters; characteristics; basic circuit design; operational amplifiers

E7G01

What determines the gain and frequency characteristics of an op-amp RC active filter?

The values of capacitors and resistors external to the op-amp

E7G02

What causes ringing in a filter?

The frequency and phase response of the filter

E7G03

What are the advantages of using an op-amp instead of LC elements in an audio filter?

Op-amps exhibit gain rather than insertion loss

E7G04

Which of the following capacitor types is best suited for use in high-stability op-amp RC active filter circuits?

Polystyrene

E7G05

How can unwanted ringing and audio instability be prevented in a multi-section op-amp RC audio filter circuit?

Restrict both gain and Q

E7G06

What steps are typically followed when selecting the external components for an op-amp RC active filter?

Standard capacitor values are chosen first, the resistances are calculated, and resistors of the nearest standard value are used

E7G07

Which of the following is the most appropriate use of an op-amp RC active filter?

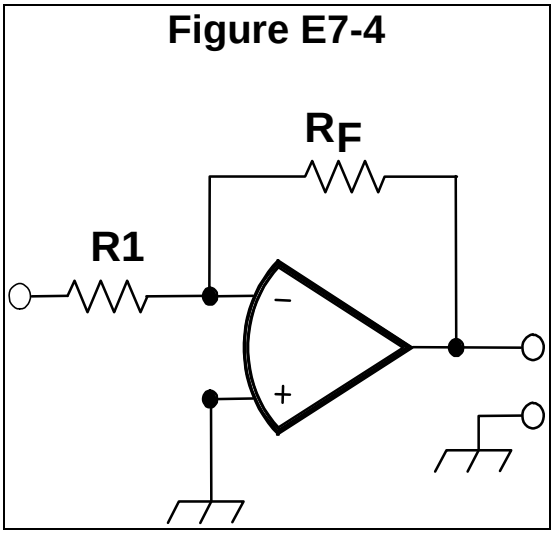
As an audio receiving filter

E7G08

Which of the following is a type of active op-amp filter circuit?

Sallen-Key

Figure E7–4



E7G09

What voltage gain can be expected from the circuit in Figure E7-4 when R1 is 10 ohms and RF is 470 ohms?

47 (see equation below)

$$Gain = \frac{R_f}{R_1}$$

$$Gain = \frac{470\ \Omega}{10\ \Omega} = 47$$

E7G10

How does the gain of a theoretically ideal operational amplifier vary with frequency?

It does not vary with frequency

E7G11

What will be the output voltage of the circuit shown in Figure E7-4 if R1 is 1000 ohms, RF is 10,000 ohms, and 0.23 volts is applied to the input?

–2.3 volts (see equation below)

$$V_{out} = -\left(\frac{R_f}{R_1}\right) \times V_{in}$$

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

E7G12

What voltage gain can be expected from the circuit in Figure E7-4 when R1 is 1800 ohms and RF is 68 kilohms?

38 (see equation below)

$$Gain = \frac{R_f}{R_1}$$

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

E7G13

What voltage gain can be expected from the circuit in Figure E7-4 when R1 is 3300 ohms and RF is 47 kilohms?

14 (see equation below)

$$Gain = \frac{R_f}{R_1}$$

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

E7G14

What is an operational amplifier?

A high-gain, direct-coupled differential amplifier whose characteristics are determined by components external to the amplifier

E7G15

What is meant by the term "op-amp input-offset voltage"?

The potential between the amplifier input terminals of the op-amp in a closed-loop condition

E7G16

What is the typical input impedance of an integrated circuit op-amp?

Very high

E7G17

What is the typical output impedance of an integrated circuit op-amp?

Very low

E7H Oscillators and signal sources: types of oscillators; synthesizers and phase-locked loops; direct digital synthesizers

E7H01

What are three major oscillator circuits often used in Amateur Radio equipment?

Colpitts, Hartley and Pierce

E7H02

What condition must exist for a circuit to oscillate?

It must have a positive feedback loop with a gain greater than 1

E7H03

How is positive feedback supplied in a Hartley oscillator?

Through a tapped coil

E7H04

How is positive feedback supplied in a Colpitts oscillator?

Through a capacitive divider

E7H05

How is positive feedback supplied in a Pierce oscillator?

Through a quartz crystal

E7H06

Which type of oscillator circuits are commonly used in VFOs?

Colpitts and Hartley

E7H07

What is a magnetron oscillator?

A UHF or microwave oscillator consisting of a diode vacuum tube with a specially shaped anode, surrounded by an external magnet

E7H08

What is a Gunn diode oscillator?

An oscillator based on the negative resistance properties of properly-doped semiconductors

E7H09

What type of frequency synthesizer circuit uses a stable voltage-controlled oscillator, programmable divider, phase detector, loop filter and a reference frequency source?

A phase locked loop synthesizer

E7H10

What type of frequency synthesizer circuit uses a phase accumulator, lookup table, digital to analog converter and a low-pass anti-alias filter?

A direct digital synthesizer

E7H11

What information is contained in the lookup table of a direct digital frequency synthesizer?

The amplitude values that represent a sine-wave output

E7H12

What are the major spectral impurity components of direct digital synthesizers?

Spurs at discrete frequencies

E7H13

Which of these circuits would be classified as a principal component of a direct digital synthesizer (DDS)?

Phase accumulator

E7H14

What circuit is often used in conjunction with a direct digital synthesizer (DDS) to expand the available tuning range?

Phase locked loop

E7H15

What is the capture range of a phase-locked loop circuit?

The frequency range over which the circuit can lock

E7H16

What is a phase-locked loop circuit?

An electronic servo loop consisting of a phase detector, a low-pass filter and voltage-controlled oscillator

E7H17

Which of these functions can be performed by a phase-locked loop?

Frequency synthesis, FM demodulation

E7H18

Why is a stable reference oscillator normally used as part of a phase locked loop (PLL) frequency synthesizer?

Any phase variations in the reference oscillator signal will produce phase noise in the synthesizer output

E7H19

Why is a phase-locked loop often used as part of a variable frequency synthesizer for receivers and transmitters?

It makes it possible for a VFO to have the same degree of stability as a crystal oscillator

E7H20

What are the major spectral impurity components of phase-locked loop synthesizers?

Broadband noise

Subelement E8 — Signals and Emissions

E8A AC waveforms: sine, square, sawtooth and irregular waveforms; AC measurements; average and PEP of RF signals; pulse and digital signal waveforms

E8A01

What type of wave is made up of a sine wave plus all of its odd harmonics?

A square wave

E8A02

What type of wave has a rise time significantly faster than its fall time (or vice versa)?

A sawtooth wave

E8A03

What type of wave is made up of sine waves of a given fundamental frequency plus all its harmonics?

A sawtooth wave

E8A04

What is the equivalent to the root-mean-square value of an AC voltage?

The DC voltage causing the same amount of heating in a resistor as the corresponding RMS AC voltage

E8A05

What would be the most accurate way of measuring the RMS voltage of a complex waveform?

By measuring the heating effect in a known resistor

E8A06

What is the approximate ratio of PEP-to-average power in a typical voice-modulated single-sideband phone signal?

2.5 to 1

E8A07

What determines the PEP-to-average power ratio of a single-sideband phone signal?

The characteristics of the modulating signal

E8A08

What is the period of a wave?

The time required to complete one cycle

E8A09

What type of waveform is produced by human speech?

Irregular

E8A10

Which of the following is a distinguishing characteristic of a pulse waveform?

Narrow bursts of energy separated by periods of no signal

E8A11

What is one use for a pulse modulated signal?

Digital data transmission

E8A12

What type of information can be conveyed using digital waveforms?

A. Human speech

B. Video signals

C. Data

D. All of these answers are correct

E8A13

What is an advantage of using digital signals instead of analog signals to convey the same information?

Digital signals can be regenerated multiple times without error

E8A14

Which of these methods is commonly used to convert analog signals to digital signals?

Sequential sampling

E8A15

What would the waveform of a digital data stream signal look like on a conventional oscilloscope?

A series of pulses with varying patterns

E8B Modulation and demodulation: modulation methods; modulation index and deviation ratio; pulse modulation; frequency and time division multiplexing

E8B01

What is the term for the ratio between the frequency deviation of an RF carrier wave, and the modulating frequency of its corresponding FM-phone signal?

Modulation index

E8B02

How does the modulation index of a phase-modulated emission vary with RF carrier frequency (the modulated frequency)?

It does not depend on the RF carrier frequency

E8B03

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

3 (see equation below)

$$\boldsymbol{Modulation\ index} = \frac{\boldsymbol{D_{PEAK}}}{\boldsymbol{m}}$$

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

E8B04

What is the modulation index of an FM-phone signal having a maximum carrier deviation of plus or minus 6 kHz when modulated with a 2-kHz modulating frequency?

3 (see equation below)

$$\boldsymbol{Modulation\ index} = \frac{\boldsymbol{D_{PEAK}}}{\boldsymbol{m}}$$

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

E8B05

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?

1.67 (see equation below)

$$\boldsymbol{Deviation\ ratio} = \frac{\boldsymbol{D_{MAX}}}{\boldsymbol{m}}$$

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

E8B06

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 frequency of 3.5 kHz?

2.14 (see equation below)

$$\boldsymbol{Deviation\ ratio} = \frac{\boldsymbol{D_{MAX}}}{\boldsymbol{m}}$$

$$\boldsymbol{Deviation\ ratio} = \frac{7.5\ kHz}{3.5\ kHz} = \mathbf{2.14}$$

E8B07

When using a pulse-width modulation system, why is the transmitter's peak power greater than its average power?

The signal duty cycle is less than 100%

E8B08

What parameter does the modulating signal vary in a pulse-position modulation system?

The time at which each pulse occurs

E8B09

How are the pulses of a pulse-modulated signal usually transmitted?

A pulse of relatively short duration is sent; a relatively long period of time separates each pulse

E8B10

What is meant by deviation ratio?

The ratio of the maximum carrier frequency deviation to the highest audio modulating frequency

E8B11

Which of these methods can be used to combine several separate analog information streams into a single analog radio frequency signal?

Frequency division multiplexing

E8B12

Which of the following describes frequency division multiplexing?

Two or more information streams are merged into a "baseband", which then modulates the transmitter

E8B13

What is time division multiplexing?

Two or more signals are arranged to share discrete time slots of a digital data transmission

E8C Digital signals: digital communications modes; CW; information rate vs. bandwidth; spread-spectrum communications; modulation methods

E8C01

Which one of the following digital codes consists of elements having unequal length?

Morse code

E8C02

What are some of the differences between the Baudot digital code and ASCII?

Baudot uses five data bits per character, ASCII uses seven; Baudot uses two characters as shift codes, ASCII has no shift code

E8C03

What is one advantage of using the ASCII code for data communications?

It is possible to transmit both upper and lower case text

E8C04

This question has been removed by the QPC

E8C05

What technique is used to minimize the bandwidth requirements of a PSK-31 signal?

Use of sinusoidal data pulses

E8C06

What is the necessary bandwidth of a 13-WPM international Morse code transmission?

Approximately 52 Hz

E8C07

What is the necessary bandwidth of a 170-hertz shift, 300-baud ASCII transmission?

0.5 kHz

E8C08

What is the necessary bandwidth of a 4800-Hz frequency shift, 9600-baud ASCII FM transmission?

15.36 kHz

E8C09

What term describes a wide-bandwidth communications system in which the transmitted carrier frequency varies according to some predetermined sequence?

Spread-spectrum communication

E8C10

Which of these techniques causes a digital signal to appear as wide-band noise to a conventional receiver?

Spread-spectrum

E8C11

What spread-spectrum communications technique alters the center frequency of a conventional carrier many times per second in accordance with a pseudo-random list of channels?

Frequency hopping

E8C12

What spread-spectrum communications technique uses a high speed binary bit stream to shift the phase of an RF carrier?

Direct sequence

E8C13

What makes spread-spectrum communications resistant to interference?

Only signals using the correct spreading sequence are received

E8C14

What is the advantage of including a parity bit with an ASCII character stream?

Some types of errors can be detected

E8C15

What is one advantage of using JT-65 coding?

Virtually perfect decoding of signals well below the noise

E8D Waves, measurements, and RF grounding: peak-to-peak values, polarization; RF grounding

E8D01

What is the easiest voltage amplitude parameter to measure when viewing a pure sine wave signal on an oscilloscope?

Peak-to-peak voltage

E8D02

What is the relationship between the peak-to-peak voltage and the peak voltage amplitude of a symmetrical waveform?

2:1

E8D03

What input-amplitude parameter is valuable in evaluating the signal-handling capability of a Class A amplifier?

Peak voltage

E8D04

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?

9 watts (see equations below)

Step 1: Calculate the RMS voltage

$$\boldsymbol{V_{RMS}} = \mathbf{0.707} \times \boldsymbol{V_{peak}}$$

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

Step 2: Calculate the peak–envelope power

$$\boldsymbol{PEP} = \frac{(\boldsymbol{V_{RMS}})^2}{\boldsymbol{Z}}$$

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

E8D05

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

184 volts (see equation below)

$$V_{P2P} = V_{RMS} \times 1.414 \times 2$$

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

E8D06

What is the advantage of using a peak-reading wattmeter to monitor the output of a SSB phone transmitter?

It gives a more accurate display of the PEP output when modulation is present

E8D07

What is an electromagnetic wave?

A wave consisting of an electric field and a magnetic field oscillating at right angles to each other

E8D08

Which of the following best describes electromagnetic waves traveling in free space?

Changing electric and magnetic fields propagate the energy

E8D09

What is meant by circularly polarized electromagnetic waves?

Waves with a rotating electric field

E8D10

What is the polarization of an electromagnetic wave if its magnetic field is parallel to the surface of the Earth?

Vertical

E8D11

What is the polarization of an electromagnetic wave if its magnetic field is perpendicular to the surface of the Earth?

Horizontal

E8D12

At approximately what speed do electromagnetic waves travel in free space?

300 million meters per second

E8D13

What type of meter should be used to monitor the output signal of a voice-modulated single-sideband transmitter to ensure you do not exceed the maximum allowable power?

A peak-reading wattmeter

E8D14

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

12.2 watts (see equations below)

Step 1: Calculate the RMS voltage

$$\boldsymbol{V_{RMS}} = \mathbf{0.707} \times \boldsymbol{V_{peak}}$$

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

Step 2: Calculate the average power dissipated

$$\boldsymbol{P_{average}} = \frac{(\boldsymbol{V_{RMS}})^{\mathbf{2}}}{\boldsymbol{R}}$$

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

E8D15

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

48 volts (see equation below)

$$\boldsymbol{V_{peak}} = \mathbf{1.414} \times \boldsymbol{V_{RMS}}$$

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

E8D16

Which of the following is a typical value for the peak voltage at a common household electrical outlet?

170 volts (see equation below)

$$V_{peak} = V_{RMS} \times 1.414$$

$$V_{peak} = 120\,V \times 1.414 = 169.7\,V$$

E8D17

Which of the following is a typical value for the peak-to-peak voltage at a common household electrical outlet?

340 volts (see equation below)

$$V_{P2P} = V_{RMS} \times 1.414 \times 2$$

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

E8D18

Which of the following is a typical value for the RMS voltage at a common household electrical power outlet?

120-V AC

E8D19

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

120-V AC

Subelement E9 — Antennas and Transmission Lines

E9A Isotropic and gain antennas: definition; used as a standard for comparison; radiation pattern; basic antenna parameters: radiation resistance and reactance, gain, beamwidth, efficiency

E9A01

Which of the following describes an isotropic Antenna?

A theoretical antenna used as a reference for antenna gain

E9A02

How much gain does a 1/2-wavelength dipole have compared to an isotropic antenna?

2.15 dB

E9A03

Which of the following antennas has no gain in any direction?

Isotropic antenna

E9A04

Why would one need to know the feed point impedance of an antenna?

To match impedances for maximum power transfer from a feed line

E9A05

Which of the following factors determine the radiation resistance of an antenna?

Antenna height and conductor length/diameter ratio, and location of nearby conductive objects

E9A06

What is the term for the ratio of the radiation resistance of an antenna to the total resistance of the system?

Antenna efficiency

E9A07

What is included in the total resistance of an antenna system?

Radiation resistance plus ohmic resistance

E9A08

What is a folded dipole antenna?

A dipole constructed from one wavelength of wire forming a very thin loop

E9A09

What is meant by antenna gain?

The numerical ratio relating the radiated signal strength of an antenna in the direction of maximum radiation to that of a reference antenna

E9A10

What is meant by antenna bandwidth?

The frequency range over which an antenna satisfies a performance requirement

E9A11

How is antenna efficiency calculated?

(radiation resistance / total resistance) x 100%

E9A12

How can the efficiency of an HF quarter-wave grounded vertical antenna be improved?

By installing a good radial system

E9A13

Which is the most important factor that determines ground losses for a ground-mounted vertical antenna operating in the 3-30 MHz range?

Soil conductivity

E9A14

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

3.85 dB (see equation below)

$$\boldsymbol{dB\ Gain = dBi\ Gain - 2.15}$$

$$\boldsymbol{dB\ Gain} = 6dB - 2.15 = \boldsymbol{3.85\ dB}$$

Hint: A 1/2-wavelength dipole has no gain over an isotropic antenna. An isotropic antenna has 2.15 dBi gain.

E9A15

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

9.85 dB (see equation below)

$$\boldsymbol{dB\ Gain = dBi\ Gain - 2.15}$$

$$\boldsymbol{dB\ Gain} = 12dB - 2.15 = \boldsymbol{9.85\ dB}$$

Hint: A 1/2-wavelength dipole has no gain over an isotropic antenna. An isotropic antenna has 2.15 dBi gain.

E9A16

What is meant by the radiation resistance of an antenna?

The value of a resistance that would dissipate the same amount of power as that radiated from an antenna

E9B Antenna patterns: E and H plane patterns; gain as a function of pattern; antenna design (computer modeling of antennas); Yagi antennas

E9B01

What determines the free-space polarization of an antenna?

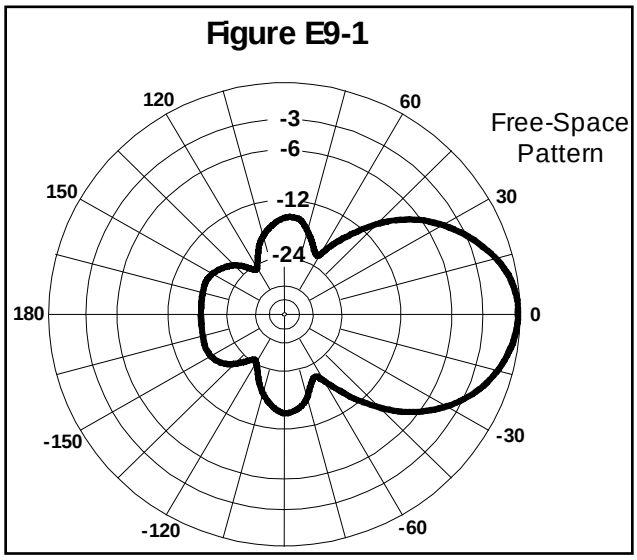
The orientation of its electric field (E Field)

E9B02

In the antenna radiation pattern shown in Figure E9-1, what is the 3-dB beamwidth?

50 degrees

Figure E9–1



E9B03

In the antenna radiation pattern shown in Figure E9-1, what is the front-to-back ratio?

18 dB

E9B04

In the antenna radiation pattern shown in Figure E9-1, what is the front-to-side ratio?

14 dB

E9B05

What may occur when a directional antenna is operated at different frequencies within the band for which it was designed?

The gain may exhibit significant variations

E9B06

What usually occurs if a Yagi antenna is designed solely for maximum forward gain?

The front-to-back ratio decreases

E9B07

If the boom of a Yagi antenna is lengthened and the elements are properly retuned, what usually occurs?

The gain increases

E9B08

How does the total amount of radiation emitted by a directional (gain) antenna compare with the total amount of radiation emitted from an isotropic antenna, assuming each is driven by the same amount of power?

There is no difference between the two antennas

E9B09

How can the approximate beamwidth of a directional antenna be determined?

Note the two points where the signal strength of the antenna is 3 dB less than maximum and compute the angular difference

E9B10

What type of computer program technique is commonly used for modeling antennas?

Method of Moments

E9B11

What is the principle of a Method of Moments analysis?

A wire is modeled as a series of segments, each having a distinct value of current

E9B12

What is a disadvantage of decreasing the number of wire segments in an antenna model below the guideline of 10 segments per half-wavelength?

The computed feed-point impedance may be incorrect

E9B13

Which of the following is a disadvantage of NEC-based antenna modeling programs?

Computing time increases as the number of wire segments is increased

E9B14

What does the abbreviation NEC stand for when applied to antenna modeling programs?

Numerical Electromagnetics Code

E9B15

What type of information can be obtained by submitting the details of a proposed new antenna to a modeling program?

A. SWR vs. frequency charts

B. Polar plots of the far-field elevation and azimuth patterns

C. Antenna gain

D. All of these answers are correct

E9C Wire and phased vertical antennas: beverage antennas; terminated and resonant rhombic antennas; elevation above real ground; ground effects as related to polarization; take-off angles

E9C01

What is the radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed 180 degrees out of phase?

A figure-8 oriented along the axis of the array

E9C02

What is the radiation pattern of two 1/4-wavelength vertical antennas spaced 1/4-wavelength apart and fed 90 degrees out of phase?

A cardioid

E9C03

What is the radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed in phase?

A Figure-8 broadside to the axis of the array

E9C04

Which of the following describes a basic rhombic antenna?

Bidirectional; four-sided, each side one or more wavelengths long; open at the end opposite the transmission line connection

E9C05

What are the main advantages of a terminated rhombic antenna?

Wide frequency range, high gain and high front-to-back ratio

E9C06

What are the disadvantages of a terminated rhombic antenna for the HF bands?

The antenna requires a large physical area and 4 separate supports

E9C07

What is the effect of a terminating resistor on a rhombic antenna?

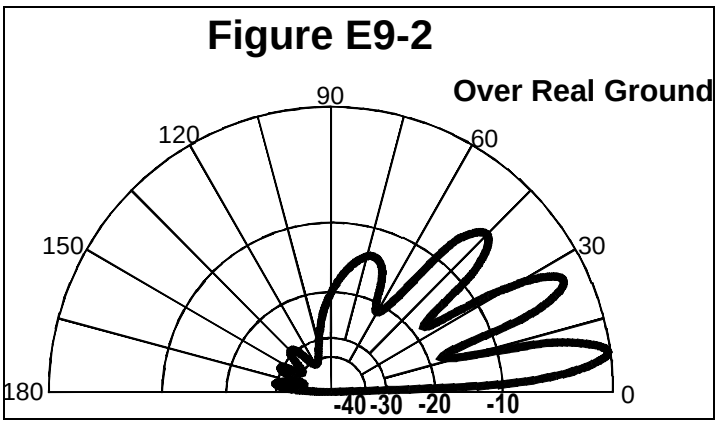
It changes the radiation pattern from bidirectional to unidirectional

E9C08

What type of antenna pattern over real ground is shown in Figure E9-2?

Elevation

Figure E9–2



E9C09

What is the elevation angle of peak response in the antenna radiation pattern shown in Figure E9-2?

7.5 degrees

E9C10

What is the front-to-back ratio of the radiation pattern shown in Figure E9-2?

28 dB

E9C11

How many elevation lobes appear in the forward direction of the antenna radiation pattern shown in Figure E9-2?

4

E9C12

How is the far-field elevation pattern of a vertically polarized antenna affected by being mounted over seawater versus rocky ground?

The low-angle radiation increases

E9C13

When constructing a Beverage antenna, which of the following factors should be included in the design to achieve good performance at the desired frequency?

It should be one or more wavelengths long

E9C14

How would the electric field be oriented for a Yagi with three elements mounted parallel to the ground?

Horizontally

E9C15

What strongly affects the shape of the far-field, low-angle elevation pattern of a vertically polarized antenna?

The conductivity and dielectric constant of the soil in the area of the antenna

E9C16

This question has been removed by the QPC

E9C17

What is the main effect of placing a vertical antenna over an imperfect ground?

It reduces low-angle radiation

E9D Directional antennas: gain; satellite antennas; antenna beamwidth; losses; SWR bandwidth; antenna efficiency; shortened and mobile antennas; grounding

E9D01

How does the gain of a parabolic dish antenna change when the operating frequency is doubled?

Gain increases 6 dB

E9D02

What is one way to produce circular polarization when using linearly polarized antennas?

Arrange two Yagis perpendicular to each other with the driven elements at the same point on the boom and fed 90 degrees out of phase

E9D03

How does the beamwidth of an antenna vary as the gain is increased?

It decreases

E9D04

Why is it desirable for a ground-mounted satellite communications antenna system to be able to move in both azimuth and elevation?

In order to track the satellite as it orbits the earth

E9D05

For a shortened vertical antenna, where should a loading coil be placed to minimize losses and produce the most effective performance?

Near the center of the vertical radiator

E9D06

Why should an HF mobile antenna loading coil have a high ratio of reactance to resistance?

To minimize losses

E9D07

What is a disadvantage of using a multiband trapped antenna?

It might radiate harmonics

E9D08

What happens to the bandwidth of an antenna as it is shortened through the use of loading coils?

It is decreased

E9D09

What is an advantage of using top loading in a shortened HF vertical antenna?

Improved radiation efficiency

E9D10

What is the approximate feed-point impedance at the center of a folded dipole antenna?

300 ohms

E9D11

Why is a loading coil often used with an HF mobile antenna?

To cancel capacitive reactance

E9D12

What is an advantage of using a trapped antenna?

It may be used for multi-band operation

E9D13

What happens at the base feed-point of a fixed-length HF mobile antenna as the frequency of operation is lowered?

The resistance decreases and the capacitive reactance increases

E9D14

Which of the following types of conductor would be best for minimizing losses in a station's RF ground system?

A thin, flat copper strap several inches wide

E9D15

Which of these choices would provide the best RF ground for your station?

A connection to 3 or 4 interconnected ground rods driven into the Earth

E9E Matching: matching antennas to feed lines; power dividers

E9E01

What system matches a high-impedance transmission line to a lower impedance antenna by connecting the line to the driven element in two places spaced a fraction of a wavelength each side of element center?

The delta matching system

E9E02

What is the name of an antenna matching system that matches an unbalanced feed line to an antenna by feeding the driven element both at the center of the element and at a fraction of a wavelength to one side of center?

The gamma match

E9E03

What is the name of the matching system that uses a short perpendicular section of transmission line connected to the feed line near the antenna?

The stub match

E9E04

What is the purpose of the series capacitor in a gamma-type antenna matching network?

To compensate for the inductive reactance of the matching network

E9E05

How must the driven element in a 3-element Yagi be tuned to use a hairpin matching system?

The driven element reactance must be capacitive

E9E06

What is the equivalent lumped-constant network for a hairpin matching system on a 3-element Yagi?

L network

E9E07

What parameter best describes the interactions at the load end of a mismatched transmission line?

Reflection coefficient

E9E08

Which of the following measurements describes a mismatched transmission line?

An SWR greater than 1:1

E9E09

Which of these matching systems is an effective method of connecting a 50-ohm coaxial cable feed-line to a grounded tower so it can be used as a vertical antenna?

Gamma match

E9E10

Which of these choices is an effective way to match an antenna with a 100-ohm terminal impedance to a 50-ohm coaxial cable feed-line?

Insert a 1/4-wavelength piece of 75-ohm coaxial cable transmission line in series between the antenna terminals and the 50-ohm feed cable

E9E11

What is an effective way of matching a feed-line to a VHF or UHF antenna when the impedances of both the antenna and feed-line are unknown?

Use the "universal stub" matching technique

E9E12

What is the primary purpose of a "phasing line" when used with an antenna having multiple driven elements?

It ensures that each driven element operates in concert with the others to create the desired antenna pattern

E9E13

What is the purpose of a "Wilkinson divider"?

It divides power equally among multiple loads while preventing changes in one load from disturbing power flow to the others

E9F Transmission lines: characteristics of open and shorted feed lines: 1/8 wavelength; 1/4 wavelength; 1/2 wavelength; feed lines: coax versus open-wire; velocity factor; electrical length; transformation characteristics of line terminated in impedance not equal to characteristic impedance

E9F01

What is the velocity factor of a transmission line?

The velocity of the wave in the transmission line divided by the velocity of light in a vacuum

E9F02

What determines the velocity factor in a transmission line?

Dielectric materials used in the line

E9F03

Why is the physical length of a coaxial cable transmission line shorter than its electrical length?

Electrical signals move more slowly in a coaxial cable than in air

E9F04

What is the typical velocity factor for a coaxial cable with solid polyethylene dielectric?

0.66

E9F05

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

3.5 meters (see equation below)

$$\frac{1}{4}\lambda\ (\boldsymbol{in\ meters}) = \frac{\boldsymbol{300/4}}{\boldsymbol{f\ (MHz)}} \times \boldsymbol{VF}$$

$$\frac{1}{4}\lambda\ (\boldsymbol{in\ meters}) = \frac{75}{14.1} \times 0.66 = \boldsymbol{3.51\ meters}$$

Hint: The speed of light is roughly 300 million meters per second in the vacuum of space. Radio waves travel at the speed of light. To determine one wavelength we divide the speed of light by the frequency in MHz. To calculate a quarter-wavelength we use the speed of light divided by 4, which is 75 million meters. Since our coaxial line is not in the vacuum of space, we must adjust the length for earth by using a velocity factor to make it electrically equivalent to being in the vacuum of space.

E9F06

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.)

10 meters (see equation below)

$$\frac{1}{4}\lambda\,(in\ meters) = \frac{300/2}{f\,(MHz)} \times VF$$

$$\frac{1}{4}\lambda\,(in\ meters) = \frac{150}{14.1} \times 0.95 = 10.1\ meters$$

Hint: The speed of light is roughly 300 million meters per second in the vacuum of space. Radio waves travel at the speed of light. To determine one wavelength we divide the speed of light by the frequency in MHz. To calculate a half-wavelength we use the speed of light divided by 2, which is 150 million meters. Since our feed line is not in the vacuum of space, we must adjust the length for earth by using a velocity factor to make it electrically equivalent to being in the vacuum of space.

E9F07

What characteristic will 450-ohm ladder line have at 50 MHz, as compared to 0.195-inch-diameter coaxial cable (such as RG-58)?

Lower loss

E9F08

What is the term for the ratio of the actual speed at which a signal travels through a transmission line to the speed of light in a vacuum?

Velocity factor

E9F09

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)

6.9 meters (see equation below)

$$\frac{1}{4}\lambda\,(in\ meters) = \frac{300/4}{f\,(MHz)} \times VF$$

$$\frac{1}{4}\lambda\,(in\ meters) = \frac{75}{7.2} \times 0.66 = 6.9\ meters$$

Hint: The speed of light is roughly 300 million meters per second in the vacuum of space. Radio waves travel at the speed of light. To determine one wavelength we divide the speed of light by the frequency in MHz. To calculate a quarter-wavelength we use the speed of light divided by 4, which is 75 million meters. Since our feed line is not in the vacuum of space, we must adjust the length for earth by using a velocity factor to make it electrically equivalent to being in the vacuum of space.

E9F10

What kind of impedance does a 1/8-wavelength transmission line present to a generator when the line is shorted at the far end?

An inductive reactance

E9F11

What kind of impedance does a 1/8-wavelength transmission line present to a generator when the line is open at the far end?

A capacitive reactance

E9F12

What kind of impedance does a 1/4-wavelength transmission line present to a generator when the line is open at the far end?

A very low impedance

E9F13

What kind of impedance does a 1/4-wavelength transmission line present to a generator when the line is shorted at the far end?

A very high impedance

E9F14

What kind of impedance does a 1/2-wavelength transmission line present to a generator when the line is shorted at the far end?

A very low impedance

E9F15

What kind of impedance does a 1/2-wavelength transmission line present to a generator when the line is open at the far end?

A very high impedance

E9F16

What is the primary difference between foam-dielectric coaxial cable as opposed to solid-dielectric cable, assuming all other parameters are the same?

A. Reduced safe operating voltage limits

B. Reduced losses per unit of length

C. Higher velocity factor

D. All of these answers are correct

E9G The Smith chart

E9G01

Which of the following can be calculated using a Smith chart?

Impedance along transmission lines

E9G02

What type of coordinate system is used in a Smith chart?

Resistance circles and reactance arcs

E9G03

Which of the following is often determined using a Smith chart?

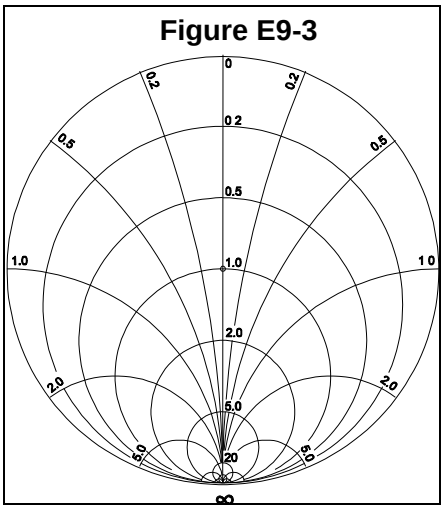
Impedance and SWR values in transmission lines

E9G04

What are the two families of circles and arcs that make up a Smith chart?

Resistance and reactance

Figure E9–3



E9G05

What type of chart is shown in Figure E9-3?

Smith chart

E9G06

On the Smith chart shown in Figure E9-3, what is the name for the large outer circle on which the reactance arcs terminate?

Reactance axis

E9G07

On the Smith chart shown in Figure E9-3, what is the only straight line shown?

The resistance axis

E9G08

What is the process of normalization with regard to a Smith chart?

Reassigning impedance values with regard to the prime center

E9G09

What third family of circles is often added to a Smith chart during the process of solving problems?

Standing-wave ratio circles

E9G10

What do the arcs on a Smith chart represent?

Points with constant reactance

E9G11

How are the wavelength scales on a Smith chart calibrated?

In fractions of transmission line electrical wavelength

E9H Effective radiated power; system gains and losses; radio direction finding antennas

E9H01

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?

286 watts

Step 1: Calculate the system gain

$$\boldsymbol{system\ gain} = \mathbf{gain}_1 + \mathbf{gain}_2 + \mathbf{gain}_3 \cdots + \cdots \mathbf{gain}_X$$

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

Hint: Losses or negative and gains or positive.

Step 2: Calculate the effective radiated power

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

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

Hint: The expression $\mathbf{log^{-1}\ (\ x\ )}$ is equivalent to $\mathbf{10^x}$, that is, **10** to the power of **X**. On your scientific calculator calculate **X**, press the 

button, then press the 

button.

E9H02

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?

317 watts

Step 1: Calculate the system gain

$$\boldsymbol{system\ gain} = \mathbf{gain}_1 + \mathbf{gain}_2 + \mathbf{gain}_3 \cdots + \cdots \mathbf{gain}_X$$

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

Hint: Losses or negative and gains or positive.

Step 2: Calculate the effective radiated power

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

$$\boldsymbol{ERP} = log^{-1}\left(\frac{2\ dB}{10}\right) \times 200\ W = \mathbf{316.9\ W}$$

Hint: The expression **$\log^{-1}$ (x)** is equivalent to **10^x**, that is, **10** to the power of **X**. On your scientific calculator calculate **X**, press the 2nd button, then press the 10^x LOG button.

E9H03

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?

252 watts

Step 1: Calculate the system gain

$$\boldsymbol{system\ gain} = \mathbf{gain}_1 + \mathbf{gain}_2 + \mathbf{gain}_3 \cdots + \cdots \mathbf{gain}_X$$

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

Hint: Losses or negative and gains or positive.

Step 2: Calculate the effective radiated power

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

$$\boldsymbol{ERP} = log^{-1}\left(\frac{1\ dB}{10}\right) \times 200\ W = \mathbf{251.8\ W}$$

Hint: The expression **$\log^{-1}$ (x)** is equivalent to **10^x**, that is, **10** to the power of **X**. On your scientific calculator calculate **X**, press the 2nd button, then press the 10^x LOG button.

E9H04

What term describes station output (including the transmitter, antenna and everything in between), when considering transmitter power and system gains and losses?

Effective radiated power

E9H05

What is the main drawback of a wire-loop antenna for direction finding?

It has a bidirectional pattern

E9H06

What is the triangulation method of direction finding?

Antenna headings from several different receiving stations are used to locate the signal source

E9H07

Why is an RF attenuator desirable in a receiver used for direction finding?

It prevents receiver overload from extremely strong signals

E9H08

What is the function of a sense antenna?

It modifies the pattern of a DF antenna array to provide a null in one direction

E9H09

What is a receiving loop antenna?

One or more turns of wire wound in the shape of a large open coil

E9H10

How can the output voltage of a receiving loop antenna be increased?

By increasing either the number of wire turns in the loop or the area of the loop structure

E9H11

Why is an antenna with a cardioid pattern desirable for a direction-finding system?

The response characteristics of the cardioid pattern can assist in determining the direction of the desired station

E9H12

What is an advantage of using a shielded loop antenna for direction finding?

It is electro-statically balanced against ground, giving better nulls

Subelement E0 — Safety

E0A Safety: amateur radio safety practices; RF radiation hazards; hazardous materials

E0A01

What, if any, are the differences between the radiation produced by radioactive materials and the electromagnetic energy radiated by an antenna?

RF radiation does not have sufficient energy to break apart atoms and molecules; radiation from radioactive sources does

E0A02

When evaluating exposure levels from your station at a neighbor's home, what must you do?

Make sure signals from your station are less than the uncontrolled MPE limits

E0A03

Which of the following would be a practical way to estimate whether the RF fields produced by an amateur radio station are within permissible MPE limits?

Use a computer-based antenna modeling program to calculate field strength at accessible locations

E0A04

When evaluating a site with multiple transmitters operating at the same time, the operators and licensees of which transmitters are responsible for mitigating over-exposure situations?

Each transmitter that produces 5% or more of its maximum permissible exposure limit at accessible locations

E0A05

What is one of the potential hazards of using microwaves in the amateur radio bands?

The high gain antennas commonly used can result in high exposure levels

E0A06

Why are there separate electric (E) and magnetic (H) field MPE limits?

A. The body reacts to electromagnetic radiation from both the E and H fields

B. Ground reflections and scattering make the field impedance vary with location

C. E field and H field radiation intensity peaks can occur at different locations

D. All of these answers are correct

E0A07

What is the "far-field" zone of an antenna?

The area where the shape of the antenna pattern is independent of distance

E0A08

What does SAR measure?

The rate at which RF energy is absorbed by the body

E0A09

Which insulating material commonly used as a thermal conductor for some types of electronic devices is extremely toxic if broken or crushed and the particles are accidentally inhaled?

Beryllium Oxide

E0A10

What material found in some electronic components such as high-voltage capacitors and transformers is considered toxic?

Polychlorinated biphenyls

E0A11

Which of these items might be a significant hazard when operating a klystron or cavity magnetron transmitter?

Injury from radiation leaks that exceed the MPE limits