Preparing for the Extra Class License Exam

Author: Jack Tiley AD7FO

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Required For this class:

- Copy of ARRL Ninth Edition of the Extra Class License Manual
  or recent copy of the ARRL Handbook (both are available from ARRL or ham radio retailers).
- Scientific Calculator <u>that you can operate.</u>
- A copy of this syllabus.
- Access to a computer with internet access to take practice exams.
- A desire to study, ask questions, and learn.

Amateur Radio Extra Class License Class Syllabus

Author: John (Jack) Tiley AD7FO

This material is based on the July 1, 2008 Extra Class Question Pool with additional information added to explain the correct answers. Questions were rewritten with the correct answer only, which in the authors view makes it easier when you see the other choices in your exam to identify the correct answer. Question numbers have been included so you can go to the ARRL Extra Class License Manual questions in the back of the manual to see the other incorrect answers and for the referenced page in the License Manual that will provide further explanation of the subject.

It is recommended you have your own copy of the ARRL Extra class license manual for the class which is available for purchase from ARRL publication sales on the ARRL web site and through amateur radio dealers. A copy of a recent ARRL Handbook could be used in lieu of purchasing the license manual as a reference to help understand the topics covered in this syllabus.

While every effort was made to insure the accuracy of the material herein, this material was prepared by ordinary folks, and there is always the possibility that a few typographical or other errors may remain.

Additional information and resources to help you study for the Extra Class License can be found on the ARRL web site at www.arrl.org/eclm . This site has articles and resources for reference materials on all aspects of the exam questions and links to math tutorials for those who have not used any algebra or trigonometry recently (the level of math required for the Extra Class License is not that difficult to master).

About the author

A retired Electrical Engineer with 44 years experience in the electronics and communications field, thirty four of those years with Hewlett Packard Test Instrument Group, now Agilent Technologies.

Hobbies

- Amateur Radio, Test Equipment, Electronics in general
- Attending every hamfests I can, including Hamvention in Dayton Ohio
- Teaching and mentoring others

Amateur Radio Activities:

Teaching and mentoring

- Teach General and Extra License Classes (with training materials I have written)
- Wrote and taught APRS, emergency power, EMCOMM I training classes,

Lead an amateur radio club at Agilent Technologies (where I used to work).

- The club operates and maintains a 2 meter repeater and a 440 repeater with Echo Link.
- The club web site is http://www.asarc.org/ where you will find information on activities, repeaters and upcoming hamfests

ARRL Appointments:

- ARRL VE (Volunteer Examiner)
- ARRL Technical Specialist for Spokane area
- ARRL Technical Coordinator for EWA
- ARES AEC (Assistant Emergency Coordinator) for Spokane County
- ARRL Registered Instructor

Author contact Information: ad7fo@arrl.net

Guide to using this syllabus.

Each question from the license manual is shown in bold type----- **E1A04**
The first two characters are the license class subelement number ---**E1**A04 ---for **E**xtra class subelement **1**.
The next letter identifies the group in the subelement ---E1**A**04--- and the groups are in alphabetical order.
The last two characters are the question number in the group --E1A**04--** in numerical order starting with **01**.

All question answers have been re-written as a true statement and the other choices are not shown. Studying this way will help you identify the correct answer and avoids the confusion of having studied both the correct and incorrect answers when you sit down to take the exam.

This Syllabus was written to teach the material not just teach the answers, although it can be used that way. When the Author teaches this class it includes equipment and theory demonstrations and "chalk Talk".

The author offers additional explanations of the answer when felt that it would aid in understanding. These comments and explanations are shown in blue italicized test as shown below:

> ***Telemetry*** *is a technology that allows the remote measurement …………………………..*

In problems involving math solutions are shown with precision that may be greater than the test answers (they may be rounded up or down) to allow you to verify your own solution to the problem. The following is an example:

> Z= SQR(X^2 + (X_L –Xc)^2) or Z= SQR(400^2 + $(0-300)^2$) or Z= SQR(250,000) or Z= 500 Ω
> Angle is arc tan (reactance/resistance) or arc tan (300/400) or arc tan (.75) or 36.86°

The author suggests you look at the number of questions in each sub element and if there is one element you find particularly difficult consider concentrating on those areas you find easier to learn. Keep in mind you need a 75% passing score on the 50 question exam (you can get 13 wrong and still pass).

If you can, find a local Ham to "Elmer" you on the difficult areas or locate a formal class in your area (check ARRL web site for listings). You can also check the ARRL Web Site or ARRL Section Web Sites for a volunteer Technical Specialist in your area who may be able provide some "Elmering" as well.

While studying take the online exams that are available from a number of sites to check your progress and for review.

ELEMENT 4 - EXTRA CLASS QUESTION POOL

Valid July 1, 2008 through June 30, 2012

SYLLABUS

There are 738 questions in the pool as released in 10 Sub elements, E1- thru E0. The Question topics for each element are given below and along with the number of questions total that will be included from each element on you exam. The author suggests you concentrate on those areas you can learn easily and those with the most questions in the exam. Elements with 8 questions are clearly more important than those with one question from the pool.

SUBELEMENT E1 — COMMISSION'S RULES [6 Exam Questions -- 6 Groups]

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

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

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

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

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

SUBELEMENT E2 -- OPERATING PRACTICES AND PROCEDURES [5 Exam Questions -- 5 Groups]

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

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

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

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

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

SUBELEMENT E3 -- RADIO WAVE PROPAGATION [3 Exam Questions -- 3 Groups]

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

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

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

SUBELEMENT E4 -- AMATEUR RADIO TECHNOLOGY AND MEASUREMENTS [5 Exam Questions -- 5 Groups]

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

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

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

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

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

SUBELEMENT E5 -- ELECTRICAL PRINCIPLES [4 Exam Questions -- 4 Groups]

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

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

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

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

SUBELEMENT E6 -- CIRCUIT COMPONENTS [6 Exam Questions -- 6 Groups]

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

E6B Semiconductor diodes

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

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

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

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

SUBELEMENT E7 -- PRACTICAL CIRCUITS [8 Exam Questions -- 8 Groups]

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

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

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

E7D Power supplies and voltage regulators

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

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

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

E7H Oscillators and signal sources: types of oscillators;
synthesizers and phase-locked loops; direct digital synthesizers

SUBELEMENT E8 -- SIGNALS AND EMISSIONS [4 Exam Questions -- 4 Groups]

E8A AC waveforms: sine, square, sawtooth and irregular waveforms; AC measurements; average and PEP of RF signals; pulse and digital signal waveforms

E8B Modulation and demodulation: modulation methods; modulation index and deviation ratio; pulse modulation; frequency and time division multiplexing

E8C Digital signals: digital communications modes; CW; information rate vs. bandwidth; spread-spectrum communications; modulation methods

E8D Waves, measurements, and RF grounding: peak-to-peak values, polarization; RF grounding

SUBELEMENT E9 — ANTENNAS AND TRANSMISSION LINES [8 Exam Questions -- 8 Groups]

E9A Isotropic and gain antennas: definition; used as a standard for comparison; radiation pattern; basic antenna parameters: radiation resistance and reactance, gain, beamwidth, efficiency

E9B Antenna patterns: E and H plane patterns; gain as a function of pattern; antenna design (computer modeling of antennas); Yagi antennas

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

E9D Directional antennas: gain; satellite antennas; antenna beamwidth; losses; SWR bandwidth; antenna efficiency; shortened and mobile antennas; grounding

E9E Matching: matching antennas to feed lines; power dividers

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

E9G The Smith chart

E9F Effective radiated power; system gain and losses; radio direction finding antennas

SUBELEMENT E0 – Safety - [1 exam question –– 1 group]

E0A Safety: amateur radio safety practices; RF radiation hazards; hazardous materials

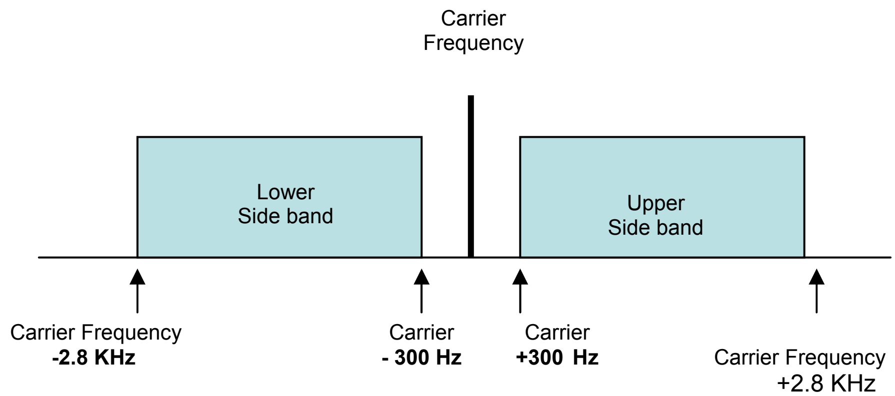
ELEMENT 4 - EXTRA CLASS QUESTION POOL

Valid July 1, 2008 through June 30, 2012

741 questions total

SUBELEMENT E1 — COMMISSION'S RULES [6 Exam Questions - 6 Groups]

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

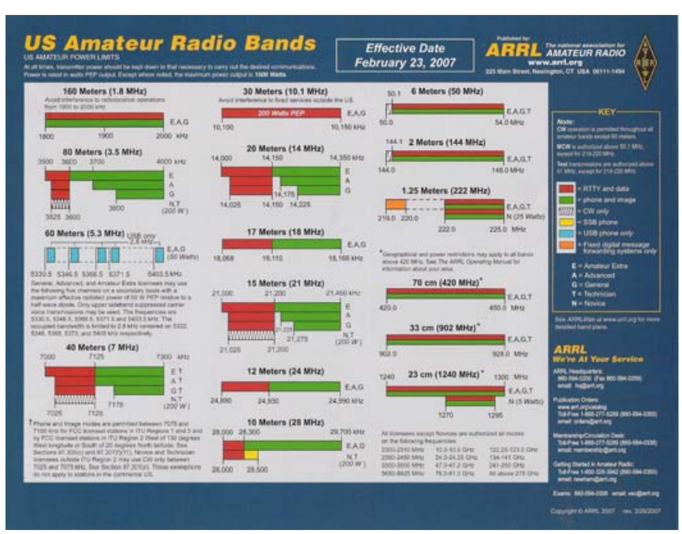


E1A01
When using a transceiver that displays the carrier frequency of phone signals, a displayed frequency of 3 kHz below the upper band edge will result in a normal USB emission being within the band.

E1A02
When using a transceiver that displays the carrier frequency of phone signals, a displayed frequency 3 kHz above the lower band edge carrier frequency display will result in a normal LSB emission being within the band.

E1A03
With your transceiver displaying the carrier frequency of phone signals, you hear a DX station's CQ on 14.349 MHz USB. It is not legal to return the call using upper sideband on the same frequency because your sidebands will extend beyond the band edge.

14.349 MHz + 3 KHz = 14.352 MHz.
The band edge for 20 meters is 14.350 MHz therefore your signal would be out of band by 2 KHz.



Band Plan (larger copy in appendix)

The above band plan shows the amateur band frequency limits by license class and agreed upon emission allowed in designated portions of the band. These are available from ARRL in packs of 50.

E1A04 *(Band Plan Chart)*
With your transceiver displaying the carrier frequency of phone signals, you hear a DX station's CQ on 3.601 MHz LSB. It is not legal to return the call using lower sideband on the same frequency because your sidebands will extend beyond the edge of the phone band segment.

3.601 MHz - 3 KHz = 3.598 MHz
The band edge for phone on 80 meters is 3.600 MHz; therefore your signal at 3.598 MHz would be out of the band by 2 KHz and in the RTTY and data segment of the 80 meter band

E1A05 (*Band Plan Chart)*
The only amateur band that does not permit the transmission of phone or image emissions is 30 meters

The 30 meter band is restricted to RTTY and data transmission only.

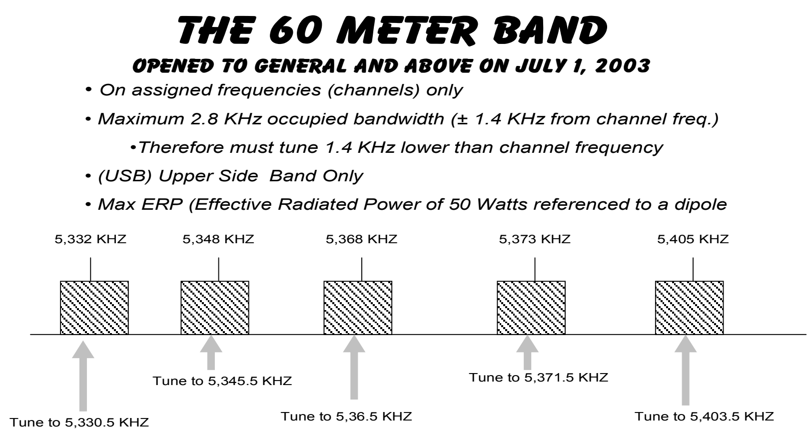
E1A06 (*Band Plan Chart)*
The maximum power output permitted on the 60 meter band is 50 watts PEP effective radiated power relative to a dipole.

You must do a calculation of transmitter power, antenna gain and line loss to determine your ERP.

*On the 60 meter band power is limited to **50 Watts ERP**, (Effective Radiated Power) referred to a dipole antenna which includes antenna gain and the path loss or gain from the transceiver to antenna itself. If you had an antenna with +6 dB of gain over a dipole and a coaxial line loss of -3dB the maximum output allowed from the transmitter would be 25 watts.*

Gain over dipole would be 6 dB -3dB Loss or 3db, therefore you would have to have a transmitter power of 3 db less than 50 watts, or 25 watts transmitter output power.

E1A07 *(Band Plan Chart)*
The 60 meter band is the only amateur band where transmissions on specific channels rather than a range of frequencies is permitted.



E1A08 *(Band Plan Chart)*
Upper sideband SSB is the only emission permitted to be transmitted on the 60 meter band by an amateur station.

E1A09 (*Band Plan Chart)*
The 80/75, 40, 20 and 15 meter frequency bands contain at least one segment authorized only to control operators holding an Amateur Extra Class operator license.

Exclusive HF Privileges for Amateur Extra Class Operators

Band	*Operating Privileges*	*Frequency Privileges*
80 m	CW, RTTY, Data	3500-3525 kHz
75 m	CW, Phone, Image	3600-3700 kHz
40 m	CW, RTTY, Data	7000-7025 kHz
20 m	CW, RTTY, Data	14.000-14.025 MHz
	CW, Phone, Image	14.150-14.175 MHz
15 m	CW, RTTY, Data	21.000-21.025 MHz
	CW, Phone, Image	21.200-21.225 MHz

E1A10 *(FCC Rules)*
If a station in a message forwarding system inadvertently forwards a message that is in violation of FCC rules, the control operator of the originating station is primarily accountable for the rules violation.

E1A11 (*FCC Rules)*
The first action you should take if your digital message forwarding station inadvertently forwards a communication that violates FCC rules is to discontinue forwarding the communication as soon as you become aware of it.

E1A12 ***(FCC Rules)***
If an amateur station is installed on board a ship or aircraft, its operation must be approved by the master of the ship or the pilot in command of the aircraft before the station is operated.


E1A13 *(FCC Rules)*
When a US-registered vessel is in international waters, any amateur license or reciprocal permit for an alien amateur licensee with an FCC-issued license or permit is allowed to transmit amateur communications from an on-board amateur transmitter.

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

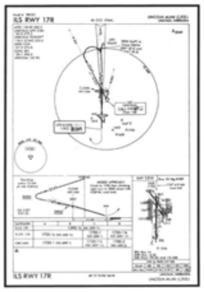
E1B01 *(FCC Rules)*
A spurious emission is an emission outside the necessary bandwidth that can be reduced or eliminated without affecting the information transmitted.

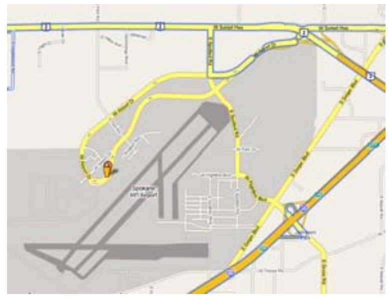
E1B02 *(FCC Rules)*
An amateur station apparatus or antenna structure may be restricted if the location is significant to our environment, American history, architecture, or culture.

E1B03 *(FCC Rules)*
If an amateur station is within a distance of 1 mile of an FCC monitoring facility the facility must be protected from harmful interference by the amateur station.

E1B04 *(FCC Rules)*
An Environmental Assessment must be submitted to the FCC 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.

E1B05 *(FCC Rules)*
An amateur station antenna structure not close to a public use airport, unless the FAA is notified and it is registered with the FCC, cannot be higher than 200 feet above ground level at its site.





E1B06 (*FCC Rules)*
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 (*FCC Rules)*
Before erecting an amateur station antenna located at or near a public use airport the FAA must be notified and it must be registered with the FCC if the antenna would exceed a certain height depending upon the antenna's distance from the nearest active runway.

E1B08 *(FCC Rules)*
An amateur station operation is restricted, if its emissions cause interference to the reception of a domestic broadcast station on a receiver of good engineering design, on those amateur service frequencies that cause interference to the broadcast receiver.

E1B09 *(FCC Rules)*
The Radio Amateur Civil Emergency Service (RACES) is a radio service of amateur stations for civil defense communications during periods of local, regional, or national civil emergencies.

E1B10 (*FCC Rules)*
Any FCC-licensed amateur station certified by the responsible civil defense organization for the area served may operate amateur stations under RACES.

E1B11 *(FCC Rules)*
All amateur service frequencies otherwise authorized to the control operator are normally authorized to any FCC licensed amateur station participating in RACES.

E1B12 *(FCC Rules)*
Specific amateur service frequency segments authorized in FCC Part 214 are authorized to an amateur station participating in RACES during a period when the President's War Emergency Powers are in force.

E1B13 ***(FCC Rules)***
Communications permissible in RACES include authorized civil defense emergency communications affecting the immediate safety of life and property.

E1C LOCAL, REMOTE AND AUTOMATIC CONTROL – 10 questions
Definitions and restrictions pertaining to local, automatic and remote control operation; amateur radio and the Internet; control operator responsibilities for remote and automatically controlled stations.

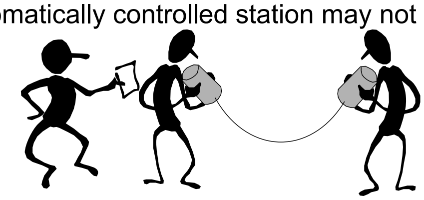
E1C01 *(FCC Rules)*
A remotely controlled station is a station controlled indirectly through a control link.

E1C02 *(FCC Rules)*
Automatic control of a station is the use of devices and procedures for control so that the control operator does not have to be present at a control point.

E1C03 *(FCC Rules)*
Control operator responsibilities of a station under automatic control differ from one under local control in that under automatic control the control operator is not required to be present at the control point.

E1C04 *(FCC Rules)*
Automatically controlled stations may retransmit third party communications only when transmitting RTTY or data emissions.

E1C05 *(FCC Rules)*
An automatically controlled station may not originate third party communications.



E1C06 *(FCC Rules)*
When operating remotely controlled amateur stations, a control operator must be present at the control point.

E1C07 *(FCC Rules)*
Local control means direct manipulation of the transmitter by a control operator.

E1C08 *(FCC Rules)*
The maximum permissible duration of a remotely controlled station's transmissions if its control link malfunctions is 3 minutes.

E1C09 *(FCC Rules)*
Frequencies from 29.500 - 29.700 MHz are available for automatically controlled ground-station repeater operation.

E1C10 *(FCC Rules)*
Only amateur auxiliary, repeater or space stations may automatically retransmit the radio signals of other amateur stations.

An example of an auxiliary relay station would be a mobile rig configured to be a cross band repeater.

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

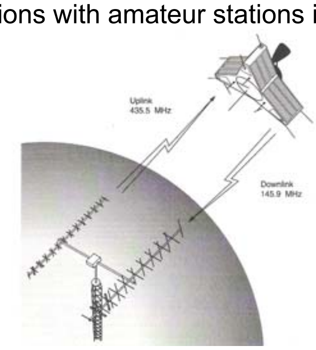
E1D01 (*FCC Rules)*
The definition of the term telemetry is one-way transmission of measurements at a distance from the measuring instrument.

***Telemetry** is a technology that allows the remote measurement and reporting of information of interest to the system designer or operator. Systems that need instructions and data sent to them in order to operate require the counterpart of telemetry, telecommand.*

E1D02 (*FCC Rules)*
The amateur-satellite service is a radio communications service using amateur stations on satellites.

E1D03 *(FCC Rules)*
A telecommand station in the amateur satellite service is an amateur station that transmits communications to initiate, modify or terminate certain functions of a space station.

E1D04 (*FCC Rules)* [97.3]
An earth station in the amateur satellite service is an amateur station within 50 km of the earth's surface for communications with amateur stations in space.



E1D05 *(FCC Rules)*
A holder of any class amateur licensee is authorized to be the control operator of a space station.

E1D06 (*FCC Rules)*
An amateur space station must incorporate the capability of effecting a cessation of transmissions by telecommand when so ordered by the FCC in order to comply with FCC amateur service space station requirements.ED107

E1D07 (*FCC Rules)*
The 40m, 20m, 17m, 15m, 12m and10m bands amateur service HF bands have frequencies authorized for space stations.

E1D08 (*FCC Rules)*
The 2 meter VHF amateur service band has frequencies available for space stations.
The 6 meter and 1.25 meter bands do not have frequencies available for space stations.

E1D09 (*FCC Rules)*
The 70 cm, 23 cm, 13 cm amateur service UHF bands have frequencies available for a space station.

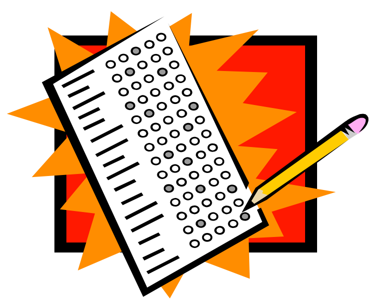
E1D10 *(FCC Rules)*
Any amateur stations so designated by the space station licensee are eligible to be telecommand stations.

E1D11 (*FCC Rules)*
Any amateur station, subject to the privileges of the class of operator license held by the control operator, is eligible to operate earth stations.

E1D12 (*FCC Rules)*
The FCC's International Bureau, Washington, DC must be notified before launching an amateur space station.

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

E1E01 *(FCC Rules)*
The minimum number of qualified VEs required to administer an Element 4 amateur operator license examination is three.



E1E02 (*FCC Rules)*
The questions for all written US amateur license examinations are listed In the VEC-maintained question pool *(and are covered in this syllabus).*

E1E03 *(FCC Rules)*
All of the VECs are responsible for maintaining the question pools from which all amateur license examination questions must be taken.

E1E04 *(FCC Rules)*
The Volunteer Examiner Coordinator (VEC) is an organization that has entered into an agreement with the FCC to coordinate amateur operator license exams.

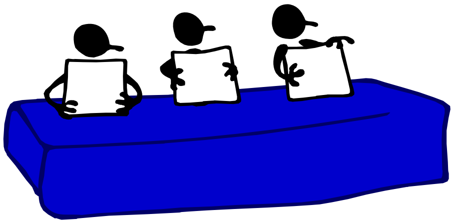
E1E05 *(FCC Rules)*
A VE (Volunteer Examiner) is an amateur operator who is approved by a VEC to administer amateur operator license examinations.

E1E06 *(FCC Rules)*
A VE team is a group of at least three VEs who administer examinations for an amateur operator license.

E1E07 *(FCC Rules)*
Persons seeking to become VEs who have ever had an amateur operator or amateur station license suspended or revoked cannot be accredited.

E1E08 *(FCC Rules)*
The Volunteer Examiner accreditation process is the procedure by which a VEC confirms that the VE applicant meets FCC requirements to serve as an examiner.

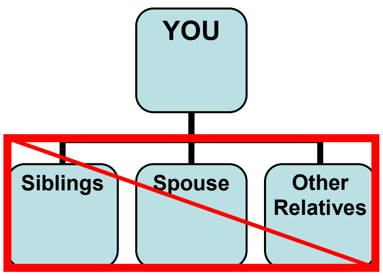
E1E09 *(FCC Rules)*
All of the administering VEs must be present be and located where they can observe the examinees throughout the entire examination session.



E1E10 *(FCC Rules)*
Each administering VE is responsible for the proper conduct and necessary supervision during an amateur operator license examination session.

E1E11 *(FCC Rules)*
If a candidate fails to comply with the examiner's instructions during an amateur operator license examination, the examiner should immediately terminate the candidate's examination.

E1E12 (*FCC Rules)*
A VE may not administer an examination to their close relatives as listed in the FCC rules.



E1E13 (*FCC Rules)*
The penalty for a VE who fraudulently administers or certifies an examination is the revocation of the VEs amateur station license grant and the suspension of the VEs amateur operator license grant.

E1E14 *(FCC Rules)*
The VE team must collect and immediately grade the examinee's test papers once they have finished the examination.

E1E15 (*FCC Rules)*
If an examinee scores a passing grade on all examination elements needed for an upgrade or new license a minimum of three attending VEs must certify that the examinee is qualified for the license grant and that they have complied with the VE requirements.

E1E16 [97.509] *(FCC Rules)*
If the examinee does not pass the exam the VE team will return the application form document to the examinee.

E1E17 *(FCC Rules)*
Failure to appear for re-administration of an examination when so directed by the FCC will cause the licensee's license to be cancelled.

E1E18 *(FCC Rules)*
Preparing, processing, administering and coordinating an examination for an amateur radio license are types of out-of-pocket expenses that VEs and VECs can be reimbursed for.

E1E19 *(FCC Rules)*
The VE team and VEC may accept reimbursement for preparing, processing, administering and coordinating an examination and actual out-of-pocket expenses.

E1E20 *(FCC Rules)*
You must be a minimum of 18 years of age to be a volunteer examiner.

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 *(FCC Rules)*
Spread spectrum transmissions are permitted only on amateur frequencies above 222 MHz.

E1F02 *(IARP Rules)*
The CEPT 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 is the European Conference of Post and Telecommunications Administration

E1F03 *(IARP Rules)*
The IARP agreement allows an FCC-licensed US citizen and many Central and South American amateur operators to operate in each other's countries.

IARP is an acronym for International Amateur Radio Permit.

The ARRL issues the International Amateur Radio Permit (IARP) that allows US amateurs to operate in Argentina, Brazil, Peru, Uruguay, and Venezuela without having to obtain a special license (the US and Canada also are CITEL signatories). The IARP is valid in any country that is a signatory to the CITEL Amateur Convention.

E1F04 *(FCC Rules)*
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 *(FCC Rules)*
A dealer may sell an external RF power amplifier capable of operation below 144 MHz if it has been granted FCC certification only if 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 *(FCC Rules)*
The "A line" is a line roughly parallel to and approx. 50 miles south of the US-Canadian border

E1F07 *(FCC Rules)*
Amateur stations may not transmit on the 420 - 430 MHz frequency segments if they are located north of Line A.

E1F08 (C) [97.3] *(FCC Rules)*
The National Radio Quiet Zone is an area surrounding the National Radio Astronomy observatory.

The National Radio Quiet Zone (NRQZ) was established by the Federal Communications Commission (FCC) in Docket No. 11745 (November 19, 1958) and by the Interdepartment Radio Advisory Committee (IRAC) in Document 3867/2 (March 26, 1958) to minimize possible harmful interference to the National Radio Astronomy Observatory (NRAO) in Green Bank, WV and the radio receiving facilities for the United States Navy in Sugar Grove, WV. The NRQZ is bounded by NAD-83 meridians of longitude at 78d 29m 59.0s W and 80d 29m 59.2s W and latitudes of 37d 30m 0.4s N and 39d 15m 0.4s N, and encloses a land area of approximately 13,000 square miles near the state border between Virginia and West Virginia.

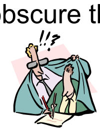
More information on the web at http://www.gb.nrao.edu/nrqz/nrqz.shtml

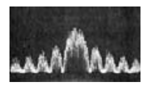
E1F09 (*FCC Rules)*
Under no circumstances may the control operator of a repeater accept payment for providing communication services to another party.

E1F10 *(FCC Rules)*
An amateur station may send a message to a business when neither the amateur nor his or her employer has a pecuniary interest in the communications.

E1F11 (*FCC Rules)*
Amateur-operator-to-amateur-operator communications transmitted for hire or material compensation are prohibited, except as otherwise provided in the FCC rules.

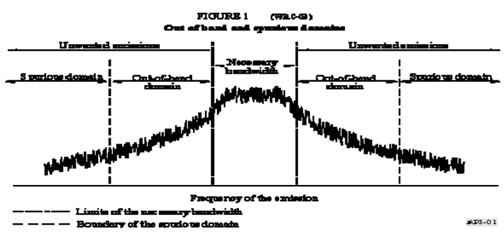
E1F12 (*FCC Rules)*
FCC-licensed amateur stations may use spread spectrum (SS) emissions to communicate when the other station is in an area regulated by the FCC, when the other station is in a country permitting SS communications and when the transmission is not used to obscure the meaning of any communication.





E1F13 *(FCC Rules)*
The maximum transmitter power for an amateur station transmitting spread spectrum communications is 100 watts.

E1F14 *(FCC Rules)*
An external RF power amplifier must satisfy the FCC's spurious emission standards when operated at its full output power in order to qualify for a grant of FCC certification.



E1F15 (*FCC Rules)*
Technician, General, Advanced or Extra Class Amateur operators may be the control operator of an auxiliary station.

Auxiliary stations transmit communications point to point within a system of cooperating stations. An example would be the Washington State Evergreen Inter-Tie System that links stations across the northwest.

E1F16 *(FCC Rules)*
Communications incidental to the purpose of the amateur service and remarks of a personal nature may be transmitted to amateur stations in foreign countries.

E1F17 *(FCC Rules)*
The FCC can issue a "Special Temporary Authority" (STA) to an amateur station to provide for experimental amateur communications.

SUBELEMENT E2 - OPERATING PRACTICES AND PROCEDURES [5 Exam Questions - 5 Groups]

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

E2A01
The direction of an ascending pass for an amateur satellite is from south to north.

Ascending and descending are defined for a satellite's motion referenced to the equator. Only the north or south motion is important and not the east-west motion. If the satellite is moving from south to north, then it makes an ascending pass.

E2A02
The direction of a descending pass for an amateur satellite is from north to south.

As we saw in the previous question, we only need be concerned with north and south orbital motions. Descending is a north-to-south motion.

E2A03
The time it takes for a satellite to complete one revolution around the earth is the orbital period of that satellite.

E2A04
The term "mode" as applied to an amateur radio satellite refers to the satellite's uplink and downlink frequency bands.

E2A05
The letters in a satellite's mode designator specify the uplink and downlink frequencies.

The following table summarizes the mode designators:

Mode	Satellite Receiving	Satellite Transmitting
V/H	VHF	HF
U/V	UHF	VHF
V/U	VHF	UHF
L/U	L-Band	UHF

E2A06
A satellite operating in the U/V mode would receive signals in the 432 MHz band.

E2A07
A linear transponder can relay FM, CW, SSB, SSTV, PSK and Packet signals.

E2A08
The primary reason for satellite users to limit their transmit ERP is because the satellite transmitter output power is limited *and using a lower power allows more users to use the transmitter* *(using the minimum power necessary for communication is the rule).*

E2A09
The terms L band and S band specify the 23 centimeter and 13 centimeter bands with regard to satellite communications.

Wave Guide Band Designator	Frequency Range
L	~ 1 GHz to 2 GHz
S	~2 GHz to 4 GHz
G	3.95 GHz to 5.85 GHz
C	4.9 GHz to 7.o5 GHz
H	7.05 GHz to 10 GHz
X	8.2 GHZ to 12.4 GHz
KU	12.4 GHz to 18 GHz
K	18 GHz to 26.5 GHz
KA	26.5 GHz to 40 GHz

E2A10
The received signal from an amateur satellite may exhibit a rapidly repeating fading effect because the satellite is rotating.

Satellite designers often spin the satellite to improve its pointing stability so a rapid fading effect can be due to satellite rotation.

E2A11
A circularly polarized antenna can be used to minimize the effects of spin modulation and Faraday rotation.

A magneto-optic effect, also known as the Faraday effect, in which the plane of polarization of an electromagnetic wave is rotated under the influence of a magnetic field parallel to the direction of propagation. It is named after the English physicist Michael Faraday (1791-1867), who first observed the effect in 1845.

E2A12
You can predict the location of a satellite at a given time by using the Keplerian elements in the calculation for a particular satellite

AO-07
1 07530U 74089B 08178.55112313 -.00000027 00000-0 10000-3 0 2119
2 07530 101.4641 209.7337 0011631 243.9327 116.0550 12.53573805538156

AO-10
1 14129U 83058B 08177.48374017 -.00000046 00000-0 10000-3 0 05225
2 14129 025.9773 208.6393 5981167 134.9841 292.8543 02.05869584188276

For a definition of the Keplerian Elements go to:
http://marine.rutgers.edu/mrs/education/class/paul/orbits.html

E2A13
Geosynchronous satellites appear to stay in one (fixed) position in the sky.

E2A14
A satellite's transmitted signal frequency shifts lower as the satellite passes overhead due to the Doppler Effect.

When the satellite is approaching the receiving station its transmitted frequency is higher and when going away from the receiving station its frequency will be lower. Like a train whistle you hear as a train approaches you and passes away from you. This effect is more pronounced at the higher frequencies.

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

To understand how a TV receiver works and paints a picture by moving an electron beam from right to left and up and down go to: http://www.colorado.edu/physics/2000/tv/black_and_white.html

E2B01
A new frame is transmitted at a rate of 30 times per second in a fast-scan (NTSC) television system.

This and the following questions on television are ones whose answer must be memorized if you are not familiar with fast-scan TV (this type of transmission is currently used in analog commercial broadcast).

E2B02
525 horizontal lines make up a fast-scan (NTSC) television frame.
NTSC is the National Television Standards Committee.

E2B03
The interlace scanning pattern generated in a fast-scan (NTSC) television system is created by scanning odd numbered lines in one field and even numbered ones in the next.

E2B04
Blanking in a video signal is the turning off of the scanning beam while it is traveling from right to left or from bottom to top.

E2B05
The advantage of using vestigial sideband for standard fast scan TV transmissions is that vestigial sideband reduces bandwidth while allowing for simple video detector circuitry.

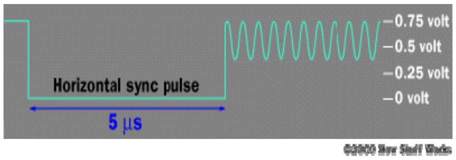
Vestigial sideband (VSB) is a type of amplitude modulation (AM) technique (sometimes called VSB-AM*) that encodes data by varying the amplitude of a single carrier frequency . Portions of one of the redundant sidebands are removed to form a vestigial sideband signal - so-called because a vestige of the sideband remains.*

VSB transmission is similar to single-sideband (SSB) transmission, in which one of the sidebands is completely removed. In VSB transmission, however, the second sideband is not completely removed, but is filtered to remove all but the desired range of frequencies . This technology achieves much of the bandwidth reduction goal of SSB but the technology required to demodulate the signal is much simpler than that needed for pure SSB.

E2B06
Vestigial sideband modulation is amplitude modulation in which one complete sideband and a portion of the other sideband is transmitted.

E2B07
The Chroma component of the video signal carries color information.

*A color TV signal starts off looking just like a black-and-white signal. An extra **chrominance** signal is added by superimposing a 3.579545 MHz sine wave onto the standard black-and-white signal following the horizontal sync pulse consisting of eight cycles of the 3.579545 MHz sine wave called the **color burst**.*



Following these eight cycles, a phase shift in the chrominance signal indicates the color to display. The amplitude of the signal determines the saturation. The following table shows you the relationship between color and phase:

Color	**Phase**
Burst	0 degrees
Yellow	15 degrees
Red	75 degrees
Magenta	135 degrees
Blue	195 degrees
Cyan	255 degrees
Green	315 degrees

A black-and-white TV filters out and ignores the chrominance signal. A color TV picks out the chrominance signal and decodes it, along with the normal intensity signal, to determine how to modulate the three color beams.

E2B08
Common methods of transmitting accompanying audio with amateur fast-scan television include a frequency-modulated sub-carrier, a separate VHF or UHF audio link or frequency modulation of the video carrier.

E2B09
No other hardware, other than a transceiver with SSB capability and a suitable computer, is needed to decode SSTV based on Digital Radio Mondiale (DRM).

DRM is a protocol for higher quality audio and images.

E2B10
An acceptable bandwidth for Digital Radio Mondiale (DRM) based voice or SSTV digital transmissions made on the HF amateur bands is 3 KHz.

E2B11
The function of the Vertical Interval Signaling (VIS) code transmitted as part of an SSTV transmission is to identify the SSTV mode being used.

E2B12
Analog slow-scan television images are typically transmitted on the HF bands by varying tone frequencies representing the video and are transmitted using single sideband modulation.

E2B13
128 or 256 lines are commonly used in each frame on an amateur slow-scan color television picture.

Fast scan TV uses 525 lines for each frame

E2B14
The tone frequency aspect of an amateur slow-scan television signal encodes the brightness of the picture.

E2B15
Specific tone frequencies signal SSTV receiving equipment to begin a new picture line.

E2B16
NTSC is the video standard used by North American Fast Scan ATV stations.

E2B17
Immunity from fading due to limiting is ***NOT*** a characteristic of FMTV (Frequency-Modulated Amateur Television) as compared to vestigial sideband AM television.

E2B18
The approximate bandwidth of a slow-scan TV signal is 3 kHz.

E2B19 (D)
You are likely to find FMTV (Frequency Modulated Television) transmissions on the 1255 MHz band.

E2B20
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, the level of the most-black signal would be 7.5 IRE units.

An "IRE unit" is a measure of video signal level based on an IEEE (Institute of Electrical and Electronic Engineers) standard.

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

E2C01
Operators are permitted to make contacts even if they do not submit a log when operating a contest.

E2C02
The generally **prohibited practice** of posting one's own call sign and frequency on a call sign spotting network is described as "self spotting" in regards to contest operation.

E2C03
Amateur radio contesting is generally excluded *(not allowed)* on 30 meters.

E2C04
An amateur radio contest contact is generally discouraged on 146.52 MHz (the national 2 meter calling frequency).

E2C05
14.310 MHz would generally be acceptable for U.S. stations to work other U.S. stations in a phone contest.

*5405 kHz, 50.050 MHz and 146.52 MHz would **generally not be acceptable** for U.S. stations to work other U.S. stations in a phone contest.*

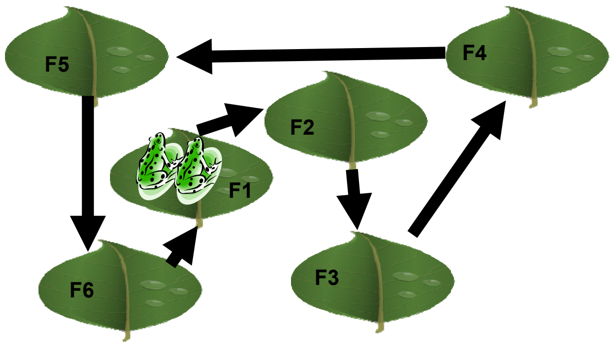
E2C06
During a VHF/UHF contest you would expect to find the highest level of activity in the weak signal segment of the band, with most of the activity near the calling frequency.

CW and weak signal:	*144.000 to 144.100*
	222.000 to 223.400
	432.000 to 432.125
	902.000 to 902.400
National calling frequencies:	*144.200 SSB and 146.52 FM*
	222.100 SSB and 223.500 FM
	432.100 SSB and 446.000 FM
	902.100 SSB

E2C07
The Cabrillo format is a standard for organizing information in contest log files.

Go to http://www.cqwpx.com/logs_cabrillo.htm for information on the Cabrillo Format.

E2C08
Spread-spectrum signals are resistant to interference because any signals not using the spectrum-spreading algorithm are suppressed in the receiver.



Frequency Hopping Spread Spectrum

E2C09
The frequency hopping (FH) spread-spectrum technique works by rapidly changing the transmit frequency of the transmitting station according to a particular pseudo random sequence. The same pseudo-random sequence is known and is time synchronized with the receiving station.

E2C10
A phone DX station might state that he or she is listening on another frequency for one or more reasons such as: 1. Because the DX station may be transmitting on a frequency that is prohibited to some responding stations. 2. To separate the calling stations from the DX station. 3. To reduce interference, thereby improving operating efficiency.

E2C11
You generally sign your full call sign once or twice when attempting to contact a DX station working a “pileup” or in a contest.

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, it might help to switch to a lower frequency HF band in order to contact other European DX stations.

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

E2D01
The “command mode” in packet operations means the TNC is ready to receive instructions via the keyboard.

Example TNC commands and responses

```
cmd:port
    PORT 2
cmd:myc
   MYCALL W5GB-7/W5GB-7
cmd:f
   FLOW OFF
   cmd:conm
  CONMODE TRANS
cmd:
```

E2D02
The definition of "baud" is the number of data symbols transmitted per second.

The baud rate can be higher than the bit rate if more than one parameter of the signal is changed during transmission, such as amplitude, width, or phase.

E2D03
When comparing HF and 2-meter packet operations, HF packet typically uses FSK *(Frequency Shift Keying)* with a data rate of 300 baud; 2-meter packet uses AFSK *(Audio Frequency Shift Keying)* with a data rate of 1200 baud.

FSK is a digital method of transmission using Marks and spaces which are transmitted as one of two different frequencies of the transmitter carrier. FSK is true Frequency Shift Keying of the transmitter's carrier. This shift can be applied to any of the transmitter oscillators. Audio Frequency Shift Keying is generated by shifting the frequency of an audio oscillator that is fed into the transmitter's normal transmit audio input. Unlike FSK, AFSK can be used for FM modulation.

E2D04
The purpose of digital store-and-forward functions on an amateur satellite is to store digital messages in the satellite for later download by other stations.

Like a post office box you can send a message and the recipient will go to that mailbox to retrieve your message.

E2D05
The Store-and-Forward technique is normally used by low-earth orbiting digital satellites to relay messages around the world *(beyond the footprint of the satellite when you send your message)*.

E2D06
144.39 MHz is a commonly used 2-meter APRS frequency.

E2D07
AX.25 digital protocol is used by APRS.

E2D08
Unnumbered Information frames are the packet frame type used to transmit APRS beacon data.

E2D09
Under clear communication conditions 300 baud packet digital communications mode has a faster data throughput than AMTOR; 170-Hz shift, 45 baud RTTY; and PSK31.

E2D10
An APRS station with a GPS unit can automatically transmit information showing a mobile station's position in support of a public service communications activity.

E2D11
Any one of the following data sources can be used to accurately transmit your geographical location over the APRS network:

- The NMEA-0183 formatted data from a Global Positioning System (GPS) satellite receiver
- The latitude and longitude of your location, preferably in degrees, minutes and seconds, manually entered into the APRS computer software
- The NMEA-0183 formatted data from a LORAN navigation system

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

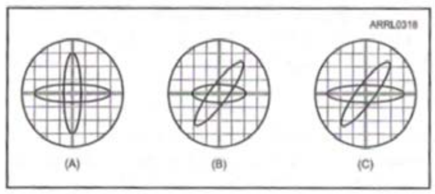
E2E01
A common method of transmitting data emissions below 30 MHz is FSK/AFSK.

E2E02
The letters FEC as they relate to digital operation stand for Forward Error Correction.

*In telecommunication, **forward error correction** (FEC) is a system of error control for data transmission, whereby the sender adds redundant data to its messages, also known as an **error correction code**. This allows the receiver to detect and correct errors (within some bounds) without the need to ask the sender for additional data. The advantage of forward error correction is that a back-channel is not required, or that retransmission of data can often be avoided, at the cost of higher bandwidth requirements on average. FEC is therefore applied in situations where retransmissions are relatively costly or impossible.*

E2E03
Forward Error Correction is implemented by transmitting extra data that may be used to detect and correct transmission errors.

E2E04
Selective fading has occurred when one of the ellipses in an FSK crossed-ellipse display suddenly disappears.



E2E05
If errors are detected in an AMTOR Mode A transmission, ARQ (Automatic Repeat Request) accomplishes error correction by requesting a retransmission.

E2E06
The most common data rate used for HF packet communications is 300 baud.

E2E07
The typical bandwidth of a properly modulated MFSK16 signal is 316 Hz

E2E08
The PACTOR HF digital mode can be used to transfer binary files.

E2E09
The PSK31 HF digital mode uses variable-length coding for bandwidth efficiency.

E2E10 ***This question has been removed by the QPC***

E2E11
Baudot code is the “International Telegraph Alphabet Number 2” (ITA2) which uses five data bits.

E2E12
The digital communication mode having the narrowest bandwidth is PSK31.

SUBELEMENT E3 -- RADIO WAVE PROPAGATION [3 Exam Questions -- 3 Groups]

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

E3A01
The approximate maximum separation along the surface of the Earth between two stations communicating by moonbounce is 12,000 miles, as long as both can "see" the moon.

E3A02
A fluttery irregular fading signal characterizes libration fading of an earth-moon-earth signal.

E3A03
Scheduling EME when the moon is at perigee will generally result in the least path loss.

E3A04
A receiving system with very low noise figure is desirable for EME communications.

Around 0.25 dB noise figure for VHF and UHF is desired.

E3A05
Two-minute transmit and receive sequences, where one station transmits for a full two minutes and then receives for the following two minutes is normally used on 144 MHz band when attempting an EME contact.

E3A06
Two-and-one-half minute time sequences, where one station transmits for a full 2.5 minutes and then receives for the following 2.5 minutes, are normally used on 432 MHz when attempting an EME contact.

E3A07
The 144.000 - 144.100 MHz frequency range is where you would you normally tune to find EME stations in the two meter band.

E3A08
The 432.000 - 432.100 MHz frequency range is where you would you normally tune to find EME stations in the 70 cm band.

E3A09
When a meteor strikes the Earth's atmosphere, a cylindrical region of free electrons is formed at the E layer of the ionosphere.

E3A10
The 28 - 148 MHz range of frequencies is well suited for meteor-scatter communications.

E3A11
Transmit and receive time sequencing of 15-second sequences, where one station transmits for 15 seconds and then receives for the following 15 seconds is normally used on 144 MHz when attempting a meteor-scatter contact.

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

E3B01
Transequatorial propagation is propagation between two points at approximately the same distance north and south of the magnetic equator.

The characteristics of TEP (Trans Equatorial Propagation) are:

- *Maximum useable frequency (MUF) up to about 60 MHz, which is usually about 15 to 25 MHz above the 2F mode frequency, for the same path.*
- *Occurs from around 1500 to 1900 local time. It is more prevalent near the equinoxes and at times of high sunspot numbers.*
- *Signals will normally be strong with limited fading and distortion (from multipathing or Doppler spread).*

E3B02
The approximate maximum range for signals using transequatorial propagation is 2500 miles.

E3B03
Afternoon or early evening is the best time of day for transequatorial propagation.

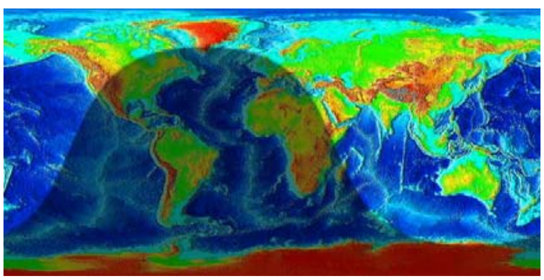
E3B04
Long-path propagation is probably occurring if an HF beam antenna must be pointed in a direction 180 degrees away from a station to in order to receive the strongest signals.

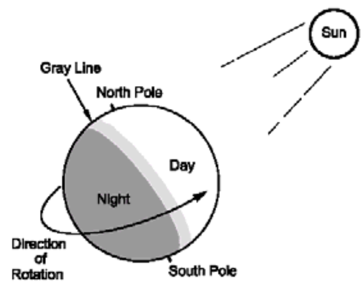
E3B05
The 160 to 10 meter amateur bands typically support long-path propagation.

E3B06
The 20 meter amateur band most frequently provides long-path propagation.

E3B07
Receipt of a signal by more than one path could account for hearing an echo on the received signal of a distant station.

E3B08
Gray-line propagation is probably occurring if radio signals travel along the terminator between daylight and darkness.





E3B09
Gray-line propagation is most prevalent at sunrise and sunset.

E3B10
At twilight, solar absorption drops greatly, while atmospheric ionization is not weakened enough to reduce the MUF allowing gray-line propagation to occur

E3B11
Contacts up to 8,000 to 10,000 miles on three or four HF bands are possible during gray-line propagation.

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
Auroral activity causes radio communication of CW signals have a fluttery tone.

E3C02
The cause of auroral activity is the emission of charged particles from the sun.

E3C03
Auroral activity in the ionosphere occurs at E-region height.

E3C04
The CW emission mode is best for auroral propagation.

E3C05
Selective fading is caused by phase differences in the received signal caused by different paths.

E3C06
VHF/UHF radio-path horizon distance exceeds the geometric horizon by approximately 15% of the distance.

E3C07
The radiation pattern of a 3-element, horizontally polarized beam antenna will vary with height above ground. The main lobe takeoff angle will decrease with increasing height.

E3C08
The name of the high-angle wave in HF propagation that travels for some distance within the F2 region is the Pedersen ray.

E3C09
Tropospheric ducting is usually responsible for propagating VHF signals over 500 miles.

E3C10
The performance of a horizontally polarized antenna mounted on the side of a hill when compared with the same antenna mounted on flat ground will have a main lobe takeoff angle that decreases in the downhill direction.

E3C11
From within the contiguous 48 states, an antenna should be pointed approximately north to take maximum advantage of auroral propagation.

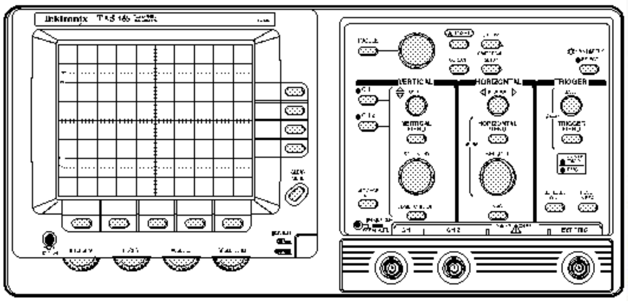
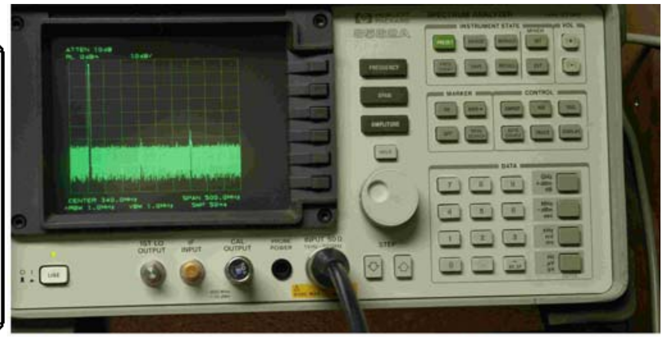
E3C12
As the frequency of a signal is increased, its ground wave propagation decreases.

E3C13
Most ground-wave propagation has a Vertical polarization.

E3C14
Because VHF and UHF radio waves may be bent, the radio-path horizon distance can exceed the geometric horizon (by about 15%).

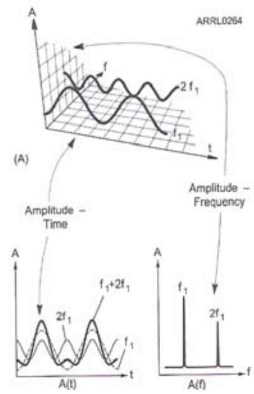
SUBELEMENT E4 -- AMATEUR RADIO TECHNOLOGY AND MEASUREMENTS [5 Exam Questions -- 5 Groups]

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

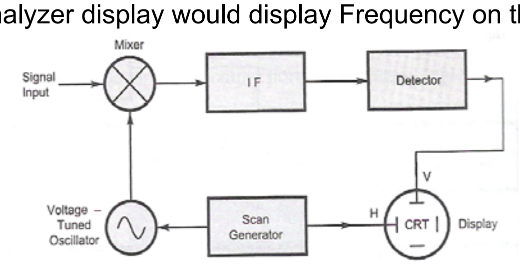



Oscilloscope | Spectrum Analyzer

E4A01
A spectrum analyzer differs from a conventional oscilloscope in that a spectrum analyzer displays signals in the frequency domain; an oscilloscope displays signals in the time domain.



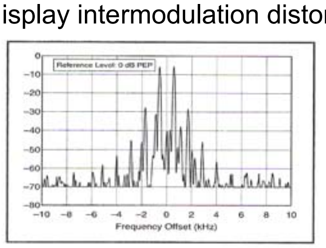
E4A02
A typical spectrum analyzer display would display Frequency on the horizontal axis.



E4A03
A typical spectrum analyzer displays signal Amplitude on the vertical axis.

E4A04
A spectrum analyzer can be used to display spurious signals from a radio transmitter.

E4A05
A spectrum analyzer can be used to display intermodulation distortion products in an SSB transmission.



E4A06
A spectrum analyzer could be used to determine the degree of isolation between the input and output ports of a 2 meter duplexer, whether a crystal is operating on its fundamental or overtone frequency, and the spectral output of a transmitter.

E4A07
The advantage of using an antenna analyzer vs. a SWR bridge to measure antenna SWR is that Antenna analyzers typically do not need an external RF source.

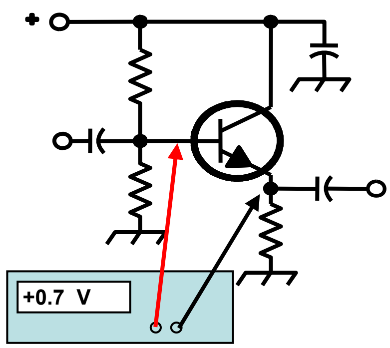

Noise Bridge


Antenna Analyzers

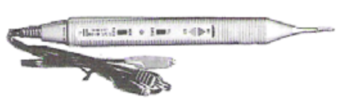
E4A08
An antenna analyzer would be best for measuring the SWR of a beam antenna.

E4A09
Adjusting the ALC Level is most important when adjusting PSK31 transmitting levels.

E4A10
A useful test for a functioning NPN transistor in an active circuit where the transistor should be biased "on" is to measure base-to-emitter voltage with a voltmeter; it should be approximately 0.6 to 0.7 volts.



E4A11
A logic probe can be used to indicate pulse conditions in a digital logic circuit.



E4A12
An important precaution to follow when connecting a spectrum analyzer to a transmitter output is to attenuate the transmitter output going to the spectrum analyzer [*So that the Spectrum analyzer input is around -20 DBM (.000,010 watts) or less*].

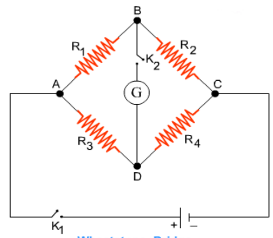
Excess power applied to the input of a spectrum analyzer, and for that matter many other test instruments, will cause expensive damage to the measuring instrument. Always think about this before connecting a transceiver (even an HT) to measurement equipment. It is good practice to place a 30 to 50 dB attenuator between the transmitter and the test equipment,

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

E4B01
Frequency stability is a characteristic of a good harmonic frequency marker.

E4B02
Time base accuracy has the most affect on the accuracy of a frequency counter.

E4B03
The advantage of using a bridge circuit to measure impedance is that the measurement is based on obtaining a null in voltage, which can be done very precisely.



Wheatstone Bridge

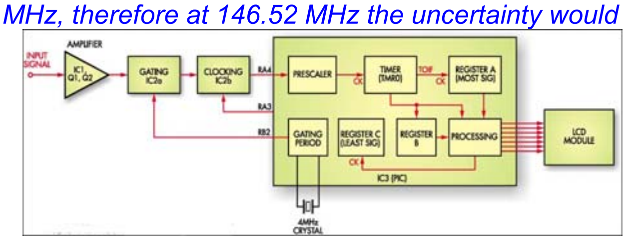
If the ratio between R3 and R4 is the same as the ratio between R1 and R2 the bridge is balanced and the potential (voltage across points B and D will be) 0 volts. Bridges can be built for AC and RF as well as for DC.

E4B04
If a frequency counter has a specified accuracy of +/- 1.0 ppm reads 146,520,000 Hz (146.52 MHz), the most the actual frequency being measured could differ from the reading is 146.52 Hz.

1 ppm is l Hz per MHz, therefore at 146.52 MHz the uncertainty would be 1 Hz x 146.52 or 146.52 Hz

E4B05
If a frequency counter with a specified accuracy of +/- 0.1 ppm reads 146,520,000 Hz, the most the actual frequency being measured could differ from the reading is 14.652 Hz.

0.1 ppm is 0.1 Hz per MHz, therefore at 146.52 MHz the uncertainty would be 0.1Hz x 146.52 or 14.652 Hz



E4B06
If a frequency counter with a specified accuracy of +/- 10 ppm reads 146,520,000 Hz, the most the actual frequency being measured could differ from the reading is 1.4652 KHz.

10 ppm is I0 Hz per MHz, therefore at 146.52 MHz the uncertainty would be 10 Hz x 146.52 or 1,465.2 Hz

E4B07
75 watts of 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.

Power output – power reflected = Delivered power or 100 Watts – 25 Watts + 75 Watts

E4B08
It is good practice when using an oscilloscope probe to keep the ground connection of the probe as short as possible.

The reason for this is that at RF frequencies the ground connection lead will look like and inductor and cause measurement inaccuracies.

E4B09
High impedance input is a characteristic of a good DC voltmeter.

The higher the input impedance of the voltmeter, the less of a load it will place on the circuit being measured. Most of today's digital voltmeters have fixed 10 megohm input impedance.

E4B10
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 will be more power going into the antenna.

E4B11
A method used to measure intermodulation distortion in an SSB transmitter is to modulate the transmitter with two non-harmonically related audio frequencies (in the audio pass band of the transmitter) while observing the RF output on a spectrum analyzer.

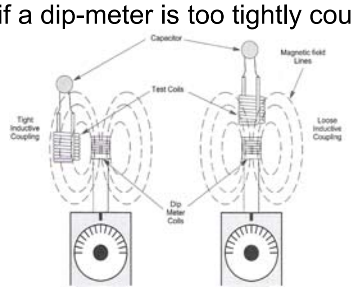
E4B12
When using a portable SWR analyzer to measure antenna resonance and feed-point impedance, connect the antenna feed line directly to the analyzer's test connector.

E4B13
Voltmeter sensitivity, expressed in ohms per volt, can be used to determine the input impedance of the voltmeter by taking the full scale reading of the voltmeter multiplied by its ohms per volt rating. This will provide the input impedance (circuit loading resistance) of the voltmeter

Example: A 100 volt full scale voltmeter with an input sensitivity of 20,000 ohms per volt would be:
100 x 20,000 or 2,000,000 ohms or 2 megohms

E4B14
The compensation of an oscilloscope probe is typically adjusted using a square wave that is observed and the probe is adjusted until the horizontal portions of the displayed wave is as nearly flat as possible

E4B15
A less accurate reading will result if a dip-meter is too tightly coupled to a tuned circuit being checked.



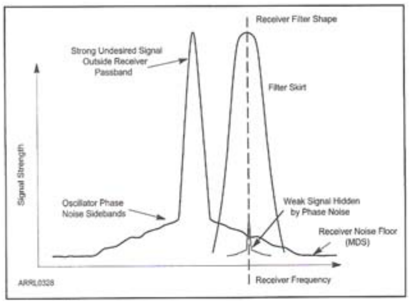
E4B16
The Coil impedance of a D'Arsonval-type meter limits its accuracy.

E4B17
The bandwidth of the circuit's frequency response can be used as a relative measurement of the Q for a series-tuned circuit.

The Narrower the bandwidth the higher the Q of the circuit

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

E4C01
The effect of excessive phase noise in the local oscillator section of a receiver can cause strong signals on nearby frequencies to interfere with reception of weak signals.



E4C02
As a result of the capture effect in an FM receiver the strongest signal received is the only signal demodulated.

E4C03
Capture effect is the term for the blocking of one FM phone signal by another, stronger FM phone signal.

E4C04
The noise floor of a receiver is the equivalent input noise power when the antenna is replaced with a matched dummy load.

Elements of a radio receiver that affect noise floor

In order to reduce the levels of noise and thereby improve the sensitivity of the radio receiver, the main element of the receiver that requires its performance to be optimised is the RF amplifier. The use of a low noise amplifier at the front end of the receiver will ensure that its performance will be maximised. Wither for use at microwaves or lower frequencies, this RF amplifier is the chief element in determining the performance of the whole receiver. The next most important element is the first mixer.

Radio receiver noise floor

While noise can emanate from many sources, when looking purely at the receiver, the noise is dependent upon a number of elements. The first is the minimum equivalent input noise for the receiver. This can be calculated from the following formula:

$$P = kTB$$

Where:
P is the power in watts
K is Boltzmann's constant (1.38 x 10^-23 J/K)
B is the bandwidth in Hertz

Using this formula it is possible to determine that the minimum equivalent input noise for a receiver at room temperature (290K) is -174 dBm / Hz.

It is then possible to calculate the noise floor for the receiver:

Noise floor = -174 + NF + 10 log Bandwidth

Where NF is the noise figure
dBm is the power level expressed in decibels relative to one milliwatt

Summary

The concept of noise floor is valuable in many radio communications systems and enables the radio receiver design and performance to be matched to the requirements of the overall system.

E4C05
The theoretical receiver noise floor at the input of a perfect receiver at room temperature is -174 dBm/Hz.

A typical receiver with a 3 KHz bandwidth would have a Theoretical noise floor of:

Noise Floor = -174 dBm + (10 x [log (bandwidth1 / bandwidth 2)]
or Noise Floor = -174 dBm +(10 x [log(3000/1)])
or Noise Floor = -174 dBm +(10 x 3.4771)
or noise floor = -174 dBm + 34.8 dB
or noise floor = -139.2 dBm

E4C06
If t he thermal noise value of a receiver is -174 dBm/Hz, then the theoretically best minimum detectable signal for a 400 Hz bandwidth receiver would be -148 dBm.

A typical receiver with a 400 Hz bandwidth would have a noise floor of:

Noise Floor = -174 dBm + (10 x [log (bw1/bw2)]
or Noise Floor = -174dBm +(10 x [log(400/1)])
or Noise Floor = -174 dBm +(10 x 2.602)
or noise floor = -174dBm + 26 dB
or noise floor = - 148 dBm

A typical 2 meter FM receiver with a 16 KHz bandwidth would have a noise floor of:

Noise Floor = -174 dBm + (10 x [log (bw1/bw2)]
or Noise Floor = -174dBm +(10 x [log(15,000/1)])
or Noise Floor = -174 dBm +(10 x 4.204)
or noise floor = -174dBm + 41.76 dB
or noise floor = - 132 dBm (~.05 μV)

E4C07
The MDS of a receiver represents the minimum discernible signal it could be expected to receive.

E4C08

Lowering the noise figure of a receiver would increase its signal to noise ratio performance *(making performance better)*

E4C09
In a modern communications receiver operating at 14 MHz the most likely limiting condition for sensitivity would be Atmospheric noise.

E4C10
A desirable amount of selectivity for an amateur RTTY HF receiver is 300 Hz.

E4C11
A desirable amount of selectivity for an amateur single-sideband phone receiver is 2.8 KHz.

E4C12
Using too wide a filter bandwidth in the IF section of a receiver may have the undesirable effect of allowing undesired signals to be heard.

E4C13
A narrow band roofing filter can improve performance and dynamic range by keeping strong signals near the receive frequency out of the IF stages.

Roofing filters are placed before the IF stages in a receiver.

E4C14
A desirable amount of selectivity for an amateur VHF FM receiver is 15 kHz.

The bandwidth for each sideband for a 5 KHz deviation voice signal would be the maximum 5 KHZ deviation + the max audio frequency of approx. 2.5 KHz or 7.5 KHz, multiplied by two for the upper and lower sideband would be 15 KHz.

E4C15
Atmospheric noise is the primary source of noise that can be heard from an HF-band receiver with an antenna connected.

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

E4D01
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 is the blocking dynamic range of a receiver.

E4D02
Cross modulation of the desired signal and desensitization from strong adjacent signals are two types of problems caused by poor dynamic range in a communications receiver.

E4D03
Intermodulation interference between two repeaters can occur when the repeaters are in close proximity and the signals mix in one or both transmitter final amplifiers.

E4D04
An effective way to reduce or eliminate intermodulation interference between two repeater transmitters operating in close proximity to one another is to install 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, the two most likely frequencies for the other interfering signal is 146.34 MHz and 146.61 MHz.

Intermodulation products are the result of two frequencies being mixed together to give the sum and difference of those frequencies. To make maters more complex harmonics of one or both of the initial frequencies or the mixed frequencies can mix and create additional sum and difference frequencies, sometimes very close to the tuned frequency of your receiver. See page 8-22 and 23 in the Extra Class License Manual for more information.

In this example: $F_{imd} = 2f_1 - f_2$ or $f_2 = 2f1 - F_{imd}$

F_{imd}=146.70, F1 = 146.52, F_2 = Unknown interfering signal

$f_2 = 2f_1 - 146.70$ or $2(146.52) - 146.70$ or 146.34 MHz

$2f_1 = f_1 + 146.70$ or $146.52 + 146.70$ or 146.61 MHz

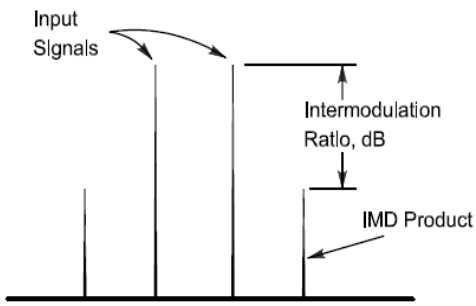
E4D06
If the signals of two transmitters mix together in one or both of their final amplifiers and unwanted signals at the sum and difference frequencies of the original signals are generated, the signals are called intermodulation interference.

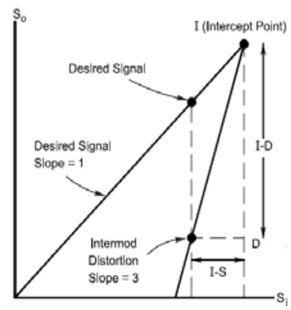
E4D07
The most significant effect of an off-frequency signal when it is causing cross-modulation interference to a desired signal is that the off-frequency, unwanted signal is heard in addition to the desired signal.

E4D08
Nonlinear circuits or devices cause intermodulation in an electronic circuit.

E4D09
The purpose of the preselector in a communications receiver is to improve the rejection of unwanted signals.

E4D10
A third-order intercept level of 40 dBm with respect to receiver performance means a pair of 40 dBm signals will theoretically generate the same output on the third order intermodulation frequency as on the input frequency.





E4D11
Third-order intermodulation products within a receiver are of particular interest compared to other products. This is because the third-order product of two signals which are in the band is likely to be within the band.

E4D12
Desensitization is the term for the reduction in receiver sensitivity caused by a strong signal near the received frequency.

E4D13
Strong adjacent-channel signals can cause receiver desensitization.

E4D14
Decreasing the RF bandwidth of the receiver is a way to reduce the likelihood of receiver desensitization.

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

E4E01
Ignition Noise can often be reduced by use of a receiver noise blanker.

E4E02
Broadband “white” noise, ignition noise and power line noise are types of receiver noise that can often be reduced with a DSP noise filter.

E4E03
Signals which appear correlated *(mathematically similar)* across a wide bandwidth might be able to be removed from desired signals with a receiver noise blanker.

E4E04
Conducted and radiated noise caused by an automobile alternator can be suppressed by connecting the radio's power leads directly to the battery and by installing Feed Through capacitors in line with the alternator leads.

E4E05
Noise from an electric motor can be suppressed by installing a brute-force AC-line filter in series with the motor leads.

E4E06
Thunderstorms are a major cause of atmospheric static.

E4E07
You can determine if line-noise interference is being generated within your home by turning off the AC power line main circuit breaker while listening on a battery-operated radio.

E4E08
A common-mode signal at the frequency of the radio transmitter can be picked up by electrical wiring near the radio transmitter.

E4E09
When using an IF type noise blanker nearby signals may appear to be excessively wide even if they meet emission standards.

E4E10
Common characteristics of interference caused by "touch controlled" electrical devices include:

- The interfering signal sounds like AC hum on an AM receiver or a carrier modulated by 60 Hz FM on a SSB or a CW receiver.
- The interfering signal may drift slowly across the HF spectrum.
- the interfering signal can be several kHz in width and usually repeats at regular intervals across a HF band.

E4E11
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 is nearby corroded metal joints that are mixing and re-radiating the BC signals *(Broadcast band)* as an intermodulation product.

E4E12
One disadvantage of using some automatic DSP notch-filters when attempting to copy CW signals is that the DSP filter can remove the desired signal at the same time as it removes interfering signals.

E4E13
Arcing contacts in a thermostatically controlled device, a defective doorbell or doorbell transformer inside a nearby residence or a malfunctioning illuminated advertising display might be the cause of a loud "roaring" or "buzzing" AC line type of interference that comes and goes at intervals.

E4E14
One type of electrical interference that might be caused by the operation of a nearby personal computer is the appearance of unstable modulated or unmodulated signals at specific frequencies.

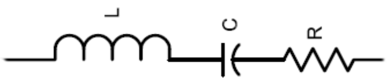
SUBELEMENT E5 -- ELECTRICAL PRINCIPLES [4 Exam Questions -- 4 Groups]

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

E5A01
Resonance can cause the voltage across reactances in series to be larger than the voltage applied to them.

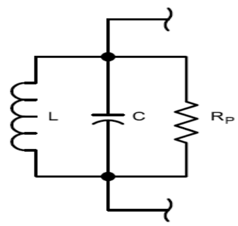
E5A02
Resonance in an electrical circuit is the frequency at which the capacitive reactance equals the inductive reactance.

E5A03
The magnitude of the impedance of a series R-L-C circuit at resonance is approximately equal to circuit resistance.



At resonance a series resonant circuit L and C presents a low impedance so the circuit resistance is set by the resistor.

E5A04
The magnitude of the impedance of a circuit with a resistor, an inductor and a capacitor all in parallel, at resonance is approximately equal to circuit resistance.



At resonance a parallel resonant circuit presents a very high impedance across the resistor.

E5A05
The magnitude of the current at the input of a series R-L-C circuit as the frequency goes through resonance is Maximum.

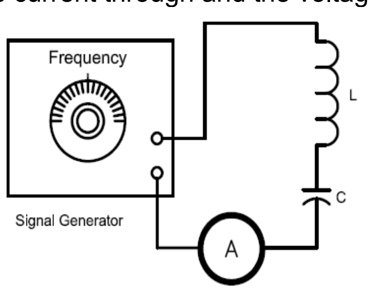
At resonance a series circuit presents a low impedance and current would be limited by the resistor Tuning to either side of resonance would causeadditional reactive resistance and therefore lower current flow in the circuit.

E5A06
The magnitude of the circulating current within the components of a parallel L-C circuit at resonance is at a maximum.

E5A07
The magnitude of the current at the input of a parallel R-L-C circuit at resonance is at a Minimum.

E5A08
The voltage and the current through and the voltage across a series resonant circuit are in phase

E5A09
The voltage and the current through and the voltage across a parallel resonant circuit are in phase.



E5A10
The half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 1.8 MHz and a Q of 95 is 18.9 kHz.

BW= Frequency / Q or 1,800 KHz/95 or 18.94 KHz

E5A11
The half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 7.1 MHz and a Q of 150 is 47.3 kHz.

BW= Frequency / Q or 7,100 KHz/150 or 47.3 KHz

E5A12
The half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 3.7 MHz and a Q of 118 is 31.4 kHz.

BW= Frequency / Q or 3,700 KHz/118 or 31.36 KHz

E5A13
The half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 14.25 MHz and a Q of 187 is 76.2 kHz.

BW= Frequency / Q or 14,250 KHz/187 or 76.20 KHz

E5A14
The resonant frequency of a series RLC circuit with R of 22 ohms, L of 50 microhenrys and C of 40 picofarads is 3.56 MHz.

$$F_R = \frac{1}{2\pi\sqrt{L \times C}} = \frac{1}{6.28 \times \sqrt{50x10\text{^}{-6} \times 40 x10\text{^}{-12}}} = 3.56 \text{ MHz}$$

E5A15
The resonant frequency of a series RLC circuit with R of 56 ohms, L of 40 microhenrys and C of 200 picofarads is 1.78 MHz.

$$F_R = \frac{1}{2\pi\sqrt{L \times C}} = \frac{1}{6.28 \times \sqrt{40x10\text{^}{-6} \times 200x10\text{^}{-12}}} = 1.78 \text{ MHz}$$

E5A16
The resonant frequency of a parallel RLC circuit with R of 33 ohms, L of 50 microhenrys and C of 10 picofarads is 7.12 MHz.

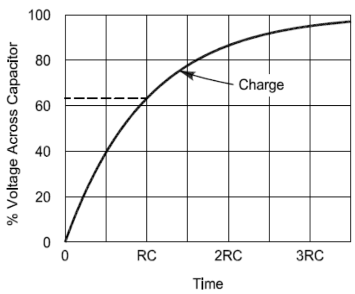
$$F_R = \frac{1}{2\pi\sqrt{L \times C}} = \frac{1}{6.28 \times \sqrt{50x10\text{^}{-6} \times 10x10\text{^}{-12}}} = 7.121 \text{ MHz}$$

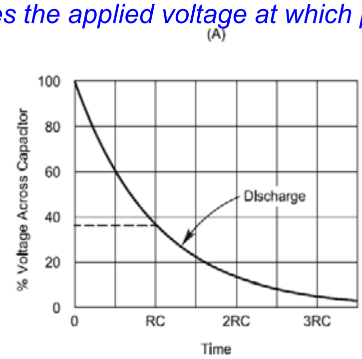
E5A17
The resonant frequency of a parallel RLC circuit with R of 47 ohms, L of 25 microhenrys and C of 10 picofarads is 10.1 MHz.

$$F_R = \frac{1}{2\pi\sqrt{L \times C}} = \frac{1}{6.28 \times \sqrt{25x10\text{^}{-6} \times 10x10\text{^}{-12}}} = 10.1 \text{ MHz}$$

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

When a voltage is applied to a capacitor through a resistance (all circuits have resistance) it takes time for the voltage across the capacitor to reach the applied voltage. At the instant the voltage is applied the current in the circuit is at a maximum limited only by the circuit resistance. As time passes the voltage across the capacitor rises and the current decreases until the capacitor reaches the applied voltage at which point the current goes to zero.





The voltage across the capacitor will rise to 63.2 % of the applied voltage in one time constant. The time constant in seconds is calculated by multiplying the resistance in megohms by the capacitance in microfarads.

TC= R(ohms) x C(farads) or in terms of more common values --TC= R (megohms) x C(microfarads)

For example, 100 volts applied to 1µF capacitor with a series one megohm resistor will charge to 63.2 volts in one second. Remember that TC= R (megohms) x C(microfarads) or TC= 1x1 or 1 second and the charge after 1 time constant will be 63.2% of the applied 100 volts, or 63.2 volts

E5B01
One time constant is the term for the time required for the capacitor in an RC circuit to be charged to 63.2% of the supply voltage.

Time Constants	Charge % of applied voltage	Discharge % of starting voltage
1	63.2%	36.8%
2	86.5%	13.5 %
3	95.0%	5%
4	98.2%	1.8%
5	99.3%	.7%

E5B02
One time constant is the time it takes for a charged capacitor in an RC circuit to discharge to 36.8% of its initial value of stored charge.

Conversely a time constant is the time it takes a discharged capacitor to reach 63.2% of the applied voltage.

E5B03
The capacitor in an RC circuit is discharged to 13.5% percentage of the starting voltage after two time constants.

%= (100-((100 x .632)) – (100 – (100 x.632) x .632)) or 100+(- 63.2 – 23.25) or 13.54%

E5B04
The time constant of a circuit having two 220-microfarad capacitors and two 1-megohm resistors all in parallel is 220 seconds.

TC (seconds) = R (megohms) x C (microfarads or TC =(1/2) x (220 x 2) or 0.5 x 440 or 220 seconds

Remember that capacitors in parallel add and resistors of equal value in parallel are equal to one resistor divided by the number of resistors.

E5B05

It will take .020 seconds (or 20 milliseconds) 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.

To discharge to 7.36 VDC would take one time constant it is 20V –(.632 x 20V) or 7.36 Volts
TC = 2 x .01 or .02 seconds or 20 milliseconds

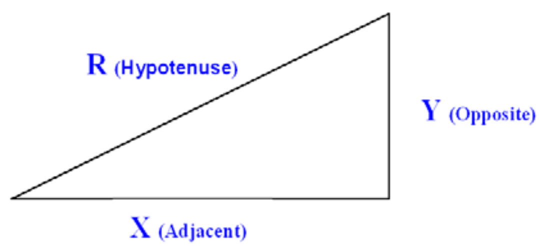
E5B06

It takes 450 seconds 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.

To discharge to 294 VDC would take one time constant
800V – (.632 x 800V) = 294.4V
TC = 1 x 450 or 450 seconds

Basic Trigonometric Functions

For a number of problems associated with electronics involving series circuits of resistance and reactance and the Extra class Exam you will need a basic understanding of trigonometry. The problems center on a right triangle (that is a triangle that has one angle that is 90° and the sum of the remaining two angles is equal to 90°). Using trigonometric functions if we know two sides, or an angle (other than the 90°angle) and one side of the triangle we can calculate the remaining angles and dimensions.



Examples:
If X=3 and Y=4 then R=5 and θ = 53.1°

If X=50 and Y=100 then R=111.8 and θ = 63.4°

If X=5 and Y=10 then R=8.66 and θ = 63.1°

If X=153 and Y=52 then R=161.6 and θ = 18.7°

*The sides of the triangle are given names from the rectangular coordinate system with the horizontal side called **X** (also called the Adjacent side) and the vertical side is called **Y** (also called the opposite side) and the side connecting the X and Y sides is called the Hypotenuse called **R in this example** If two of the three sides are known the third side can be found using the following equation:*

Hypotenuse² = X² + Y² or as commonly expressed $R = \sqrt{X^2 + Y^2}$

There are 6 trigonometric functions that can be used to calculate the angle between X and R and between Y and R. We will focus on three of these functions; Sine, Cosine and Tangent to solve for the angle between the X side and the R side (θ).

Sine of θ = Y / R *Secant = R/Y*
Cosine of θ = X / R *Cosecant = R/X*
Tangent of θ = Y / X *Cotangent = X/Y*

Example 1:
To find the angle, θ for a triangle with side X value of 3 and a side Y value of 6:

Tangent of θ = 6 / 3 or 2.00. To find the angle enter 2 into your calculator and press the Arc Tan key which will show you the angle represented by the tangent value, in this case 2.00. The Arc Tan of 2 is 63.43°.

Example 2:
To find the angle, θ for a triangle with a side X value of 3 and a side Y value of 4:

Tangent of θ = 4 / 3 or 1.333 To find the angle enter 1.333 into your calculator and press the Arc Tan(or Tan^-1 on some calculators) key which will show you 53.03°

Example 3:
To find the angle, θ for a triangle with a side X value of 12 and a side Y value of 12

Tangent of θ = 12/12 or 1 To find the angle enter 1 into your calculator and press the Arc Tan key which will show you 45.0°

Reactance (AC resistance of capacitors and inductors)
Capacitors and inductors exhibit a resistance to current flow much like a resistor but with values that change with the frequency of the applied circuit.

The AC resistance of a capacitor is called capacitive reactance (X_C) and is calculated using the formula:

$X_C = 1/(2\pi \times F \times C)$ *with C in μF and F in MHz*

Examples:
Find the capacitive reactance of a 1 μf capacitor at 200 Hz

$X_C = 1/(2\pi \times F \times C)$ or $X_C = 1/(6.28 \times .0002 \times 1)$ or $X_C = 796\ \Omega$

Find the Capacitive reactance of a 10 PF capacitor at 7 MHz

$X_C = 1/(2\pi \times F \times C)$ or $X_C = 1/(6.28 \times 7.0 \times 10$ ^-6 $)$ or $X_C = 2{,}275\ \Omega$

The AC resistance of an Inductor is called Inductive reactance (X_L) and is calculated using the formula:

$X_L = 2\pi \times F \times L$ *with L in μH and F in MHz*

Examples:
Find the inductive reactance of a 1 μH inductor at 100 MHz

$X_L = 2\pi \times F \times L$ or $X_L = 6.28 \times 100 \times 1$ or $X_L = 628\ \Omega$

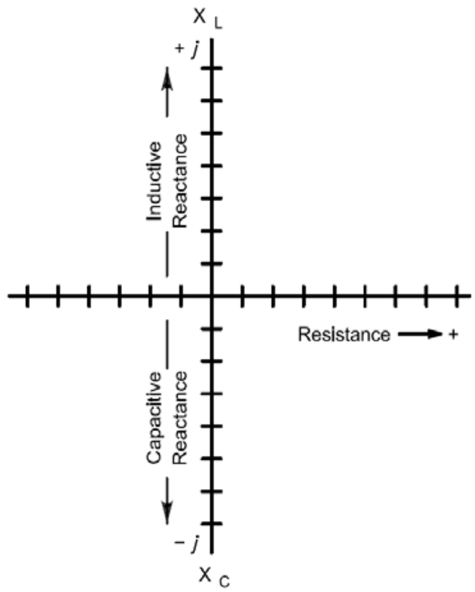
Find the inductive reactance of a 100 μH inductor at 7 MHz

$X_L = 2\pi \times F \times L$ or $X_L = 6.28 \times 7 \times 100$ or $X_L = 4{,}396\ \Omega$

Circuit Impedance
The term Impedance refers to the equivalent circuit resistance in ohms for a circuit consisting of resistance and capacitive reactance and / or inductive reactance. To solve these problems for series circuits we use a rectangular coordinate graph and basic algebra and trigonometry. When working with complex circuits containing resistance and reactance, the reactive components are shown with a lower case j prefix. Inductive reactance is shown with a +j prefix and capacitive reactance with a –j prefix.

Rectangular Coordinate System

When solving problems involving impedance and phase angle of AC series circuits we show the circuit element values in a rectangular format. The rectangular format consists of a horizontal line intersected at 90° by a vertical line. Values on the horizontal or X axis are positive to the right of the vertical line and negative to the left. Values on the vertical or Y axis are positive above the X axis and Negative below the X axis.



E5B07
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 kiliohm, and XL is 250 ohms is 14.0 degrees with the voltage lagging the current.

Tangent of θ = Y / X or Tangent of θ = 250 / 1000 or Tangent of θ = .25 or θ = -14.04°

E5B08
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 is 14 degrees with the voltage lagging the current.

Tangent of θ = Y / X or Tangent of θ = (75-100)/100 or Tangent of θ = -.25 or θ = -14.04°

Rules for calculating impedances and phase angles

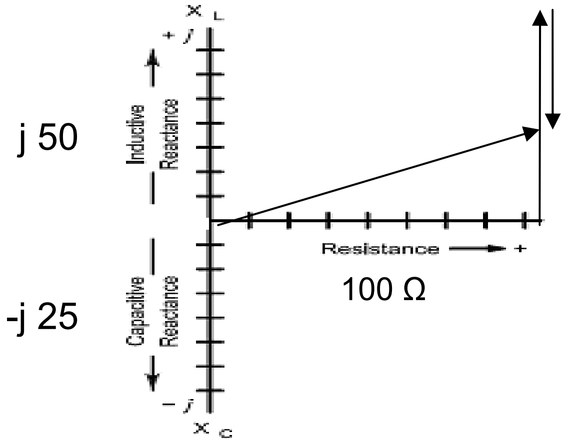
1) Impedances in series add together
2) Admittance is the reciprocal of impedance
3) Admittances in parallel add together
4) Inductive and capacitive reactance in series cancel
5) $1/j = -j$

E5B09
The relationship between the current through and the voltage across a capacitor is that the current leads the voltage by 90 degrees.

E5B10
The relationship between the current through an inductor and the voltage across an inductor is that the voltage leads current by 90 degrees.

E5B11
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 is 14 degrees with the voltage leading the current.

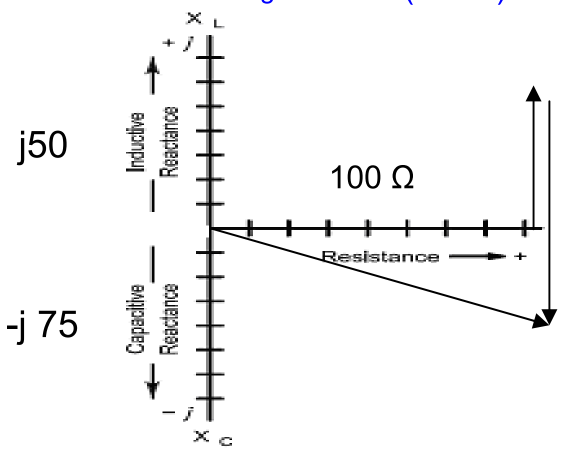
Tangent of θ = Y / X or Tangent of θ = (50-25)/100 or Tangent of θ = -.25 or θ = 14.04°



E5B12

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 is 14 degrees with the voltage lagging the current,

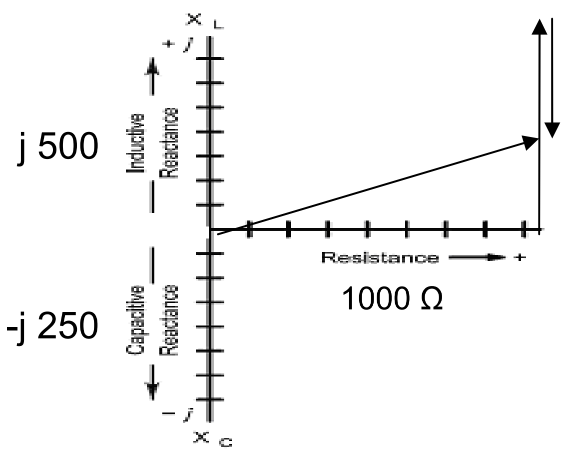
Tangent of $\theta = Y / X$ or Tangent of $\theta = (50-75)/100$ or Tangent of $\theta = -.25$ or $\theta = -14.04°$



E5B13

The phase angle between the voltage across and the current through a series RLC circuit if X_C is 250 ohms, R is 1 kiliohm, and X_L is 500 ohms is 14.04 degrees with the voltage leading the current.

Tangent of $\theta = Y/X$ or Tangent of $\theta = (X_L - X_C)/I$ or $\theta = (500-250)/1000$ or Tangent of $\theta = 0.25$ or $\theta = 14.036°$



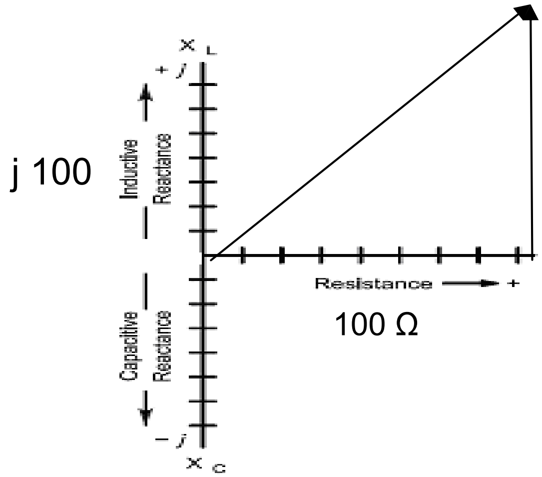
E5C Impedance plots and coordinate systems: plotting impedances in polar coordinates; rectangular coordinates

E5C01

In polar coordinates, the impedance of a network consisting of a 100-ohm-reactance inductor in series with a 100-ohm resistor is 141 ohms at an angle of 45°.

$Z = \sqrt{(X^2 + Y^2)}$ or $Z = \sqrt{(100^2 + 100^2)}$ or $Z = \sqrt{(20{,}000)}$ or $Z = 141.42\ \Omega$

θ = arc tan (reactance/resistance) or arc tan 100/100 or arc tan 1 or 45°



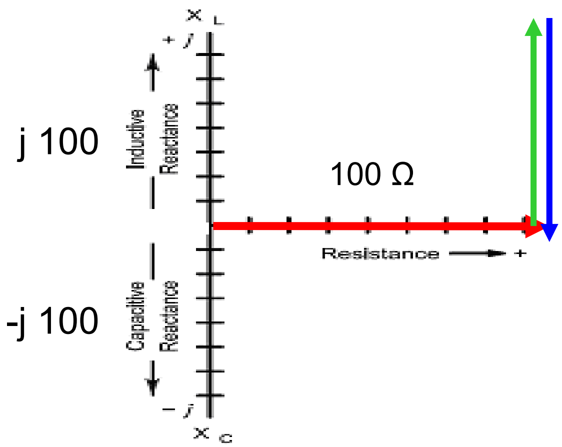
E5C02

In polar coordinates, 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 is 100 ohms at an angle of 0 degrees .

$Z = \sqrt{(R^2 + (X_L - X_C)^2)}$ or $Z = \sqrt{(100^2 + (100-100)^2)}$ or $Z = \sqrt{(10{,}000)}$ or $Z = 100\ \Omega$

θ = arc tan (reactance/resistance) or arc tan 0/100 or arc tan 0 or 0°

Note- the Y side is the vector sum of the inductive reactance and capacitive reactance or ($X_L - X_C$)

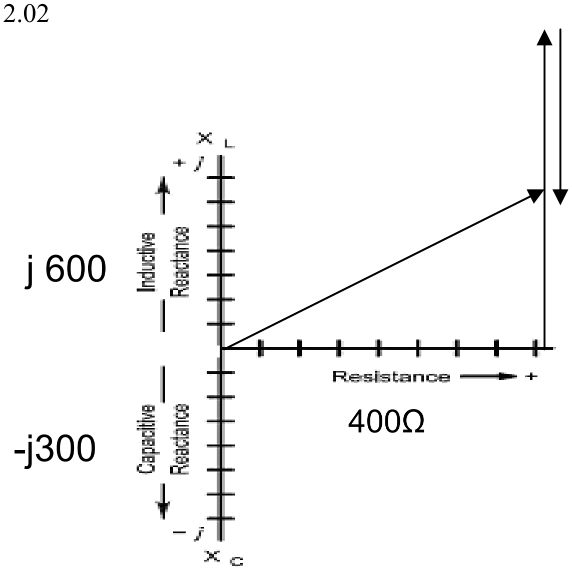


E5C03

In polar coordinates, 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 is 500 ohms at an angle of 37 degrees.

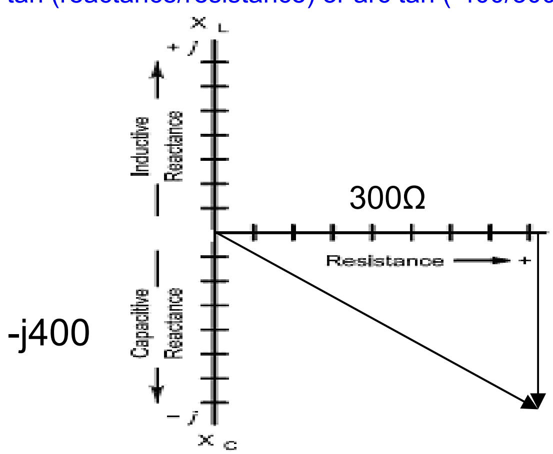
$Z = \sqrt{(R^2 + (X_L - X_C)^2)}$ or $Z = \sqrt{(400^2 + (600-300)^2)}$ or $Z = \sqrt{(250{,}000)}$ or $Z = 500\ \Omega$

θ = arc tan (reactance/resistance) or 300/400 or arc tan .75 or 36.9°



E5C04
In polar coordinates, the impedance of a network consisting of a 400-ohm-reactance capacitor in series with a 300-ohm resistor is 500 ohms at an angle of -53.1 degrees.

$Z = \sqrt{X^2 + (X_L - X_C)^2}$ or $Z = \sqrt{300^2 + (0-400)^2}$ or $Z = \sqrt{250{,}000}$ or $Z = 500\ \Omega$
θ = arc tan (reactance/resistance) or arc tan (-400/300) or arc tan (0/100 or arc tan (- 1.33) or -53.13°



E5C05 (A)
In polar coordinates, the impedance of a network consisting of a 400-ohm-reactance inductor in parallel with a 300-ohm resistor is 240 ohms at an angle of 36.9 degrees.

$$\text{Impedance} = \frac{R \times X_L}{\sqrt{R^2 + X_L^2}} = \frac{300 \times 400}{\sqrt{300^2 + 400^2}} = 120{,}000 / 500 = 240\ \Omega$$

θ = arctan 1/ (Reactance/Resistance) or θ= arctan 1/ (400 / 300) or θ= arctan 1/ 1.333 or arctan =.750 or θ =36.87°

E5C06
In polar coordinates, the impedance of a network consisting of a 100-ohm-reactance capacitor in series with a 100-ohm resistor is 141 ohms at an angle of -45 degrees.

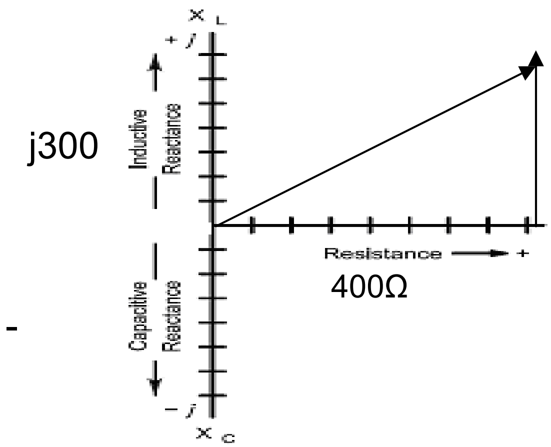
$Z = \sqrt{X^2 + (X_L - X_C)^2}$ or $Z = \sqrt{100^2 + (-100)^2}$ or $Z = \sqrt{20{,}000}$ or $Z = 141.4\ \Omega$
Angle is arctan 1/ (reactance/resistance) or arctan 1/ (100/100) or arc tan (- 1) or -45°

E5C07 (C)
In polar coordinates, the impedance of a network comprised of a 100-ohm-reactance capacitor in parallel with a 100-ohm resistor is 71 ohms at an angle of -45 degrees.

Admittance = 1/100 +(-j/100) or 0.01 +j 0.01 Angle =arc tan .01/.01 or 45° (-45° in polar coordinates)
Impedance = 1/ ($\sqrt{}$ ($(.01)^2$ x $(.01)^2$)) or 1/(.0141) or 70.71 Ω

E5C08
In polar coordinates, the impedance of a network comprised of a 300-ohm-reactance inductor in series with a 400-ohm resistor is 500 ohms at an angle of 37 degrees.

$Z= \sqrt{(X^2 + (X_L - X_C)^2)}$ or $Z= \sqrt{(400^2 + (0-300)^2)}$ or $Z= \sqrt{(250{,}000)}$ or Z= 500 Ω
Angle is arc tan (reactance/resistance) or arc tan (300/400) or arc tan (.75) or 36.86°



E5C09
When using rectangular coordinates to graph the impedance of a circuit, the horizontal axis represents the voltage or current associated with the resistive component.

E5C10
When using rectangular coordinates to graph the impedance of a circuit, the vertical axis represents the voltage or current associated with the reactive component.

E5C11
The two numbers used to define a point on a graph using rectangular coordinates represent 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, you know the circuit is equivalent to a pure resistance.

E5C13
The Rectangular coordinate system is often used to display the resistive, inductive, and/or capacitive reactance components of impedance.

E5C14
The Polar coordinate system is often used to display the phase angle of a circuit containing resistance, inductive and/or capacitive reactance.

E5C15 (A)
In polar coordinates, the impedance of a circuit of 100 -j100 ohms impedance is 141 ohms at an angle of -45 degrees.

$Z= \sqrt{(X^2 + (X_L - X_C)^2)}$ or $Z= \sqrt{(100^2 + (-100)^2)}$ or $Z= \sqrt{(20{,}000)}$ or Z= 141.42 Ω
Angle is arc tan (reactance/resistance) or arc tan (-100/100) or arc tan (1) or -45°

PARALLEL CIRCUIT SOLUTIONS

Solving for parallel circuits for ac circuits is similar to the way we solved resistance parallel circuits. Remember the Equation:

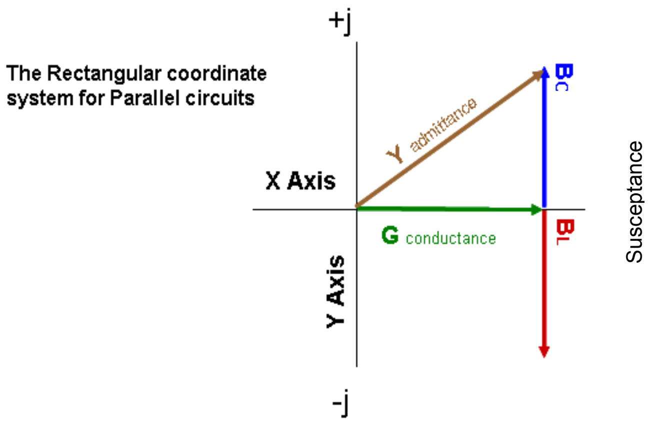
$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

The solution involved finding the conductance (G) of each leg by dividing the resistances into 1 and summing them. This gave the total circuit conductance in Siemens. The Mho was the term previously used for Seimen.

$$\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

To find the resistance we divided the conductance into 1 and ended up with the parallel circuit resistance.

We do the same thing to find the impedance of parallel ac circuits. The names of the circuit references change- Impedance becomes **admittance, "Y",** (1/impedance). Resistance becomes **conductance, "G",** (1/resistance) and **susceptance , "B"** (1/reactance) We start by finding the "conductance of the resistive and reactive components and just add them as we did in the resistance solution (remember we will be summing resistive (real) and reactive (imaginary) conductance. The rectangular coordinates for parallel circuit solutions are shown below. Note that the reactive axis direction is opposite that of the series circuit solutions in that that reactive conductance is + for capacity and – for inductance.



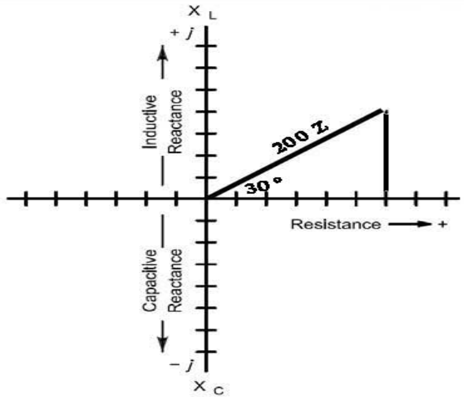
E5C16
In polar coordinates, the impedance of a circuit that has an admittance of 7.09 milli-siemens at 45 degrees is 141 ohms at an angle of -45 degrees.

Polar Impedance (Z) =1/admittance or Z= 1/.00709 or Z= 141.04Ω
Polar angle = 1 / j (admittance angle) = 1/j(45°) or -j45°

E5C17 (C)
In rectangular coordinates, the impedance of a circuit that has an admittance of 5 millisiemens at -30 degrees is C. 173 + j100 ohms.

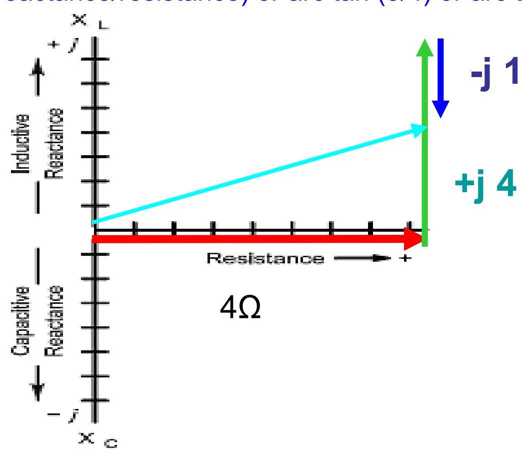
Polar Impedance (Z) =1/admittance or Z= 1/.005 or Z= 200Ω
Polar angle = 1/amdittance angle = 1/- 30° or +30°

Cos θ= resistance(R) / Impedance(Z) or R = 200Ω x Cosine 30° or R = 200Ω x .866 or 173.2 Ω
Sin θ= reactance(j) / Impedance(Z) or j = 200 x Sine 30° or j = 200Ω x .50 or j100Ω



E5C18
In polar coordinates, 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 is 5 ohms at an angle of 37 degrees.

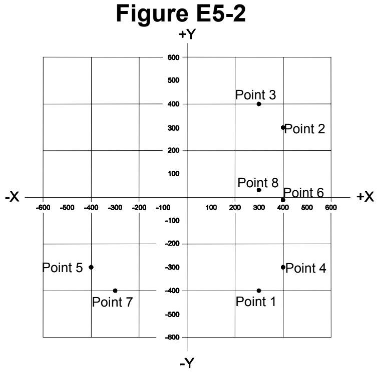
$Z = \sqrt{(X^2 + (X_L - X_c)^2)}$ or $Z = \sqrt{(4^2 + (4-1)^2)}$ or $Z = \sqrt{(25)}$ or $Z = 5\ \Omega$
Angle is arc tan (reactance/resistance) or arc tan (3/4) or arc tan (.75) or 36.86°



E5C19
In Figure E5-2, point 4 best represents that impedance of a series circuit consisting of a 400 ohm resistor and a 38 picofarad capacitor at 14 MHz.

R=400 Ω
$X_c = 1/(2\pi FC)$ or $X_c = 1/(6.28 \times 14 \times .000038)$ or $X_c = -300\ \Omega$ (remember capacitive reactance is negative).

Figure E5-2



E5C20
In Figure E5-2, Point 3 best represents the impedance of a series circuit consisting of a 300 ohm resistor and an 18 microhenry inductor at 3.505 MHz.

R=300 Ω

X_L= (2 π FL) or X_L = (6.28 x 3.505 x 18) or X_L = 396.4 Ω (remember inductive reactance is positive)

Answer is 300 Ω + j 395 Ω

E5C21

In Figure E5-2, Point 1 best represents the impedance of a series circuit consisting of a 300 ohm resistor and a 19 picofarad capacitor at 21.200 MHz?

R=300 Ω

Xc= 1/ (2 π FC) or Xc= 1/(6.28 x 21.2 x .000019) or Xc= -395.1 Ω (remember capacitive reactance is negative)

Answer is 300 –j 395

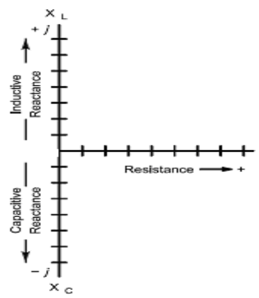
E5C22

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?

R=40 Ω

X_L= (2 π FL) or X_L = (6.28 x 500 x 10) or X_L = 31,416 Ω (remember inductive reactance is positive)

Answer is 40 + j 31,400



E5C23

On Figure E5-2, Point 8 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.

R=300 Ω

Xc= 1/ (2 π FC) or Xc= 1/(6.28 x 24.9 x .000085) or Xc= -75.19 Ω (remember capacitive reactance is negative)

X_L= (2 π FL) or X_L = (6.28 x 24.9 x .64) or X_L = 100.12 Ω (remember inductive reactance is positive)

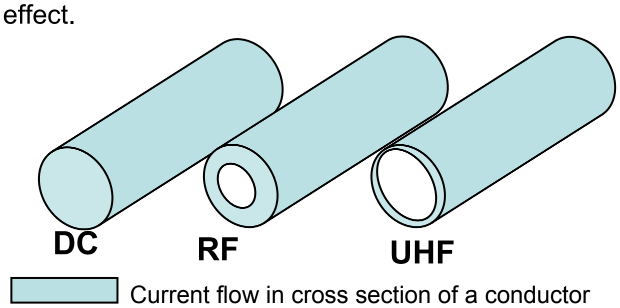
Net reactance is the sum of Xc and X_L **or** -75.19 + 100.12 **or** +24.9

Answer is 300 + j 24.9

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

E5D01

As frequency increases, RF current flows in a thinner layer of the conductor, closer to the surface this is called skin effect.



E5D02

The resistance of a conductor is different for RF currents than for direct currents because of skin effect.

E5D03
A capacitor is a device that is used to store electrical energy in an electrostatic field.

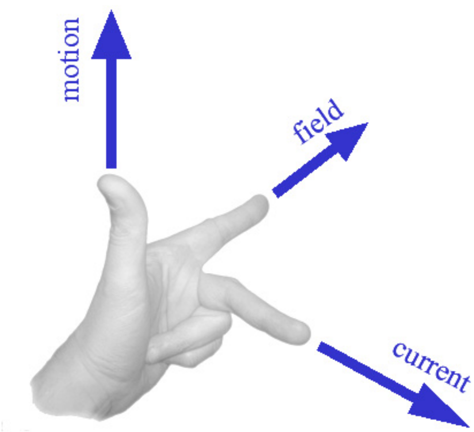
E5D04
The Joule is the unit of electrical energy stored in an electrostatic field.

A Joule is defined as a quantity of energy equal to one Newton of force acting over 1 meter

E5D05
The region surrounding a magnet through which a magnetic force acts is a magnetic field.

E5D06
The direction of the magnetic field oriented about a conductor in relation to the direction of electron flow is in a direction determined by the left-hand rule.

Fleming's Left Hand Rule (remember that current flows from negative to positive)



Also known as the Motor Rule this is a way of determining the direction of a force on a current carrying conductor in a magnetic field.

The thumb, the first and the second fingers on the left hand are held so that they are at right angles to each other.

If the first finger points in the direction of the magnetic field and the second finger the direction of the current in the wire, then the thumb will point in the direction of the force on the conductor.

E5D07
The amount of current determines the strength of a magnetic field around a conductor.

E5D08
Potential energy is the term for energy that is stored in an electromagnetic or electrostatic field.

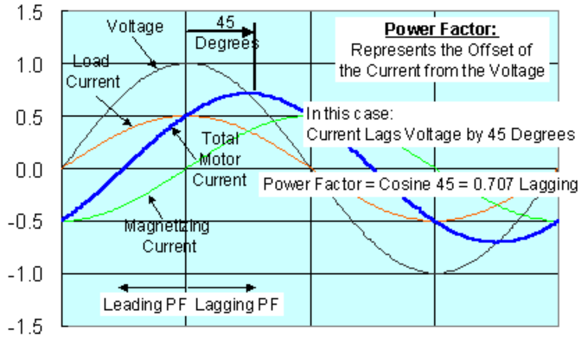
E5D09
Reactive power is the term for an out-of-phase, nonproductive power associated with inductors and capacitors.

E5D10
In a circuit that has both inductors and capacitors the reactive power is repeatedly exchanged between the associated magnetic and electric fields, but is not dissipated (assuming perfect lossless components).

Understanding the Power Factor explanation will be easy, now that you understand the fundamentals.

The components of motor (or other inductive load) current are load current and magnetizing current (adding those instantaneous values yields the total circuit current). Also, because load current is in phase with voltage and magnetizing current lags voltage by 90 degrees, their sum will be a sine wave that peaks somewhere between 0 and 90 degrees lagging which is the inductive current's offset (in time) from voltage. There are negative effects associated with increased offset and that's part of the power factor explanation.

Power Factor represents the offset in time between voltage and the total current and is defined as the cosine of that offset. So when you look at the example in the graphic below, Total Current lags the voltage by 45 degrees. That is the offset. The cosine of 45 degrees is 0.707, and we call it "lagging" because the current lags behind the voltage



If the offset was 0 degrees (voltage and current in phase), the power factor would be 1.0 (cosine 0 = 1) and if the offset were a full 90 degrees (this would be all magnetizing current), the power factor would be 0.0 (cosine 90 = 0). So big deal....why is this offset so important?

In a motor (or Inductive load), the component of load current is the current associated with doing work (i.e. pumping fluid, compressing gas, running your Kilowatt rig, etc.) and the magnetizing current is not doing work. I know without the magnetic field the things like motors wouldn't work. This is true, however, as stated earlier; the magnetic field takes some energy to get built up in one half cycle and then returns that energy to the system in the next half cycle, so its net effect is that it uses no energy.

But if we consider the cable that delivers power to the circuit; when we add the magnetizing current to the load current, the cable's total current flow becomes larger. We, however, really just want to drive the load. If we could find a way to supply the magnetizing current without sending it down the cable, then the cable would only need to deliver the load current. This can be done by adding a capacitor across the inductive load which stores and releases energy for use by the inductive load locally at the motor-end of the cable delivering power.

E5D11

The true power can be determined in an AC circuit where the voltage and current are out of phase by multiplying the apparent power times the power factor.

Apparent power is the voltage times the current into the circuit
True Power is the apparent power times the power factor
The only time true power and apparent power are the same is if the power factor is 1.00 (the phase angle is zero)

E5D12
The power factor (PF) of an R-L circuit having a 60 degree phase angle between the voltage and the current is 0.5.

PF is the cosine function of the voltage to current angle ►*PF =cosine of 60° or PF= 0.5*

E5D13
80 watts are consumed in a circuit having a power factor of 0.2 if the input is 100-V AC at 4 amperes.

Power Consumed = V x I x PF or 100 x 4 x .2 or 80 watts

E5D14

The power is consumed in a circuit consisting of a 100 ohm resistor in series with a 100 ohm inductive reactance drawing 1 ampere is 100 Watts.

$Power_{(real)} = I^2 \times R$ or $Power_{(real)} = (1)^2 \times 100$ or 100 watts. (Only the circuit resistance consumes power)

E5D15

Wattless, nonproductive power is reactive power.

E5D16

The power factor of an RL circuit having a 45 degree phase angle between the voltage and the current is 0.707.

PF = Cosine of 45° or PF = 0.707

E5D17

The power factor of an RL circuit having a 30 degree phase angle between the voltage and the current is 0.866.

PF Cosine of 30° or PF = 0.866

E5D18

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

Power Consumed = V x I x PF or 200 x 5 x .6 or 600 watts

E5D19

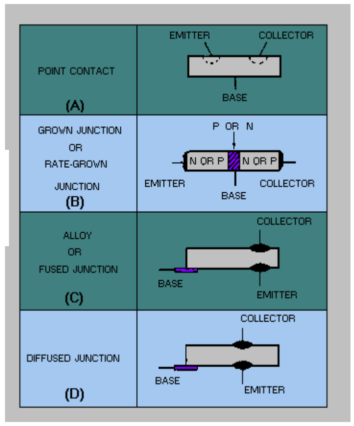
The power consumed in a circuit having a power factor of 0.71 if the apparent power is 500 watts is 355 W.

Power Consumed = Apparent power x PF or 500 x .71 or 355 watts

SUBELEMENT E6 -- CIRCUIT COMPONENTS [6 Exam Questions -- 6 Groups]

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

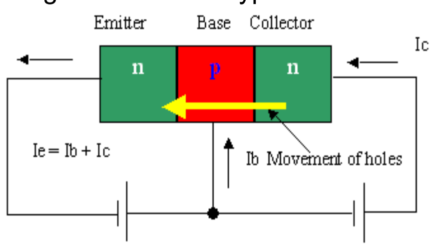
Transistor Construction



E6A01
Free electrons are the majority charge carriers in N-type semiconductor material.

E6A02
N-type type of semiconductor material contains more free electrons than pure germanium or silicon crystals.

E6A03
Holes are the majority charge carriers in P-type semiconductor material.

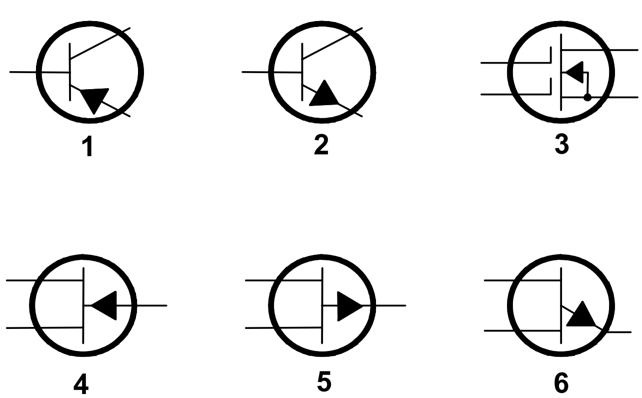


E6A04
The name given to an impurity atom that adds holes to a semiconductor crystal structure is acceptor impurity.

E6A05
The **alpha** of a bipolar junction transistor refers to the **change of collector current with respect to emitter current.**

E6A06
The **beta** of a bipolar junction transistor refers to the **change in collector current with respect to base current.**

Figure E6-1

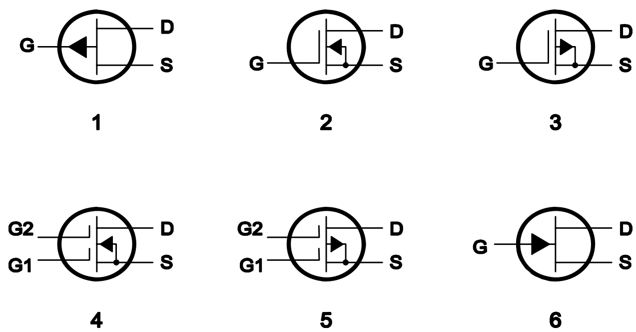


E6A07
In Figure E6-1, the schematic symbol for a PNP transistor is number 1.

E6A08
Alpha cutoff frequency indicates the frequency at which a transistor grounded base current gain has decreased to 0.7 of the gain obtainable at 1 kHz.

E6A09
A depletion-mode FET is a FET that exhibits a current flow between source and drain when no gate voltage is applied.

Figure E6-2



E6A10
In Figure E6-2, the schematic symbol for an N-channel dual-gate MOSFET is number 4.

E6A11
In Figure E6-2, the schematic symbol for a P-channel junction FET is number 1.

E6A12
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
The initials CMOS stand for Complementary metal-oxide semiconductor.

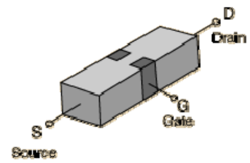
E6A14
How does
The DC input impedance at the gate of a field-effect transistor is high. The DC input impedance of the bipolar transistor is low.

E6A15
Silicon and germanium are widely used in semiconductor devices and exhibit both metallic and nonmetallic characteristics.

E6A16
P-type semiconductor material contains fewer free electrons than pure germanium or silicon crystals.

E6A17
Gallium arsenide is used as a semiconductor material in preference to germanium or silicon at microwave frequencies.

E6A18
The names of the three terminals of a field-effect transistor are gate, drain, and source.



Field-effect transistors exist in two major classifications. These are known as the *junction FET (JFET)* and the *metal-oxide- semiconductor FET (MOSFET)*.

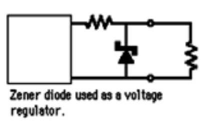
The FET has some advantages relative to the bipolar transistor. Field-effect transistors are preferred for weak-signal work, for example in wireless communications and broadcast receivers. They are also preferred in circuits and systems requiring high input impedance.

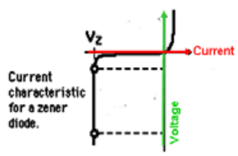
E6B Semiconductor diodes

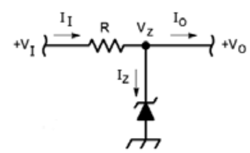
E6B01

The principal characteristic of a Zener diode is a constant voltage under conditions of varying current.

The Zener diode symbol is number 3 in figure E6-3. Once the Zener voltage is reached increasing V_1 will not cause V_o to increase only the current will increase creating a larger voltage drop across R, up to the maximum current rating for the zener diode.

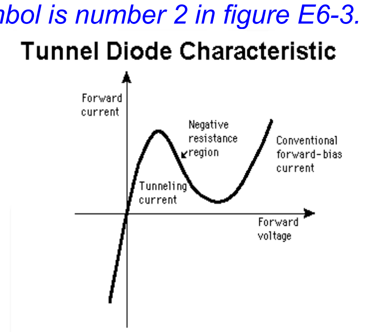






E6B02

The principal characteristic of a tunnel diode is a negative resistance region.
The tunnel diode symbol is number 2 in figure E6-3.



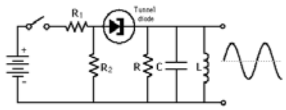
E6B03

An important characteristic of a Schottky Barrier diode as compared to an ordinary silicon diode when used as a power supply rectifier is less forward voltage drop.

The Schottky diode or Schottky Barrier diode is an electronics component that is widely used for radio frequency (RF) applications as a mixer or detector diode. The Schottky diode is also used in power applications as a rectifier, again because of its low forward voltage drop leading to lower levels of power loss compared to ordinary PN junction diodes. Although normally called the Schottky diode these days, named after Schottky, it is also sometimes referred to as the surface barrier diode, hot carrier or even hot electron diode.

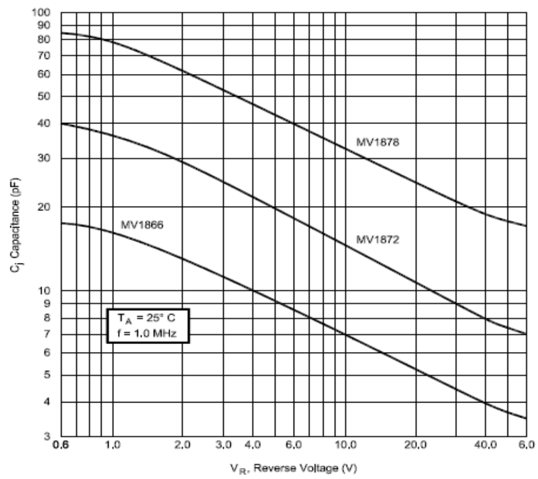
Despite the fact that Schottky barrier diodes have many applications in today's high tech electronics scene, it is actually one of the oldest semiconductor devices in existence. As a metal-semiconductor devices, its applications can be traced back to before 1900 where crystal detectors, cat's whisker detectors and the like were all effectively Schottky barrier diodes.

E6B04
A Tunnel diode is capable of both amplification and oscillation.



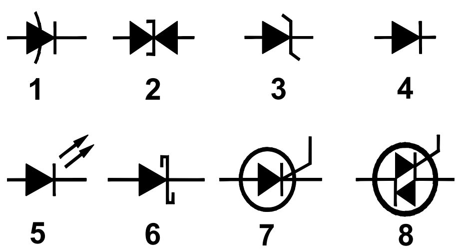
E6B05
A Varactor diode is a type of semiconductor device varies its internal capacitance as the voltage applied to its terminals varies.

The Varactor diode symbol is number 1 in figure E6-3 and as shown to the right of the graphic below.



E6B06
In Figure E6-3, the schematic symbol for a varactor diode is number 1.

Figure E6-3



E6B07
A common use of a hot-carrier diode is as a VHF / UHF mixer or detector.

E6B08
Junction temperature limits the maximum forward current rating in a junction diode.

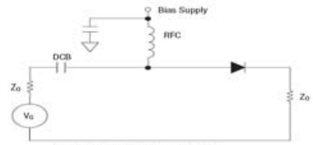
E6B09
Metal-semiconductor junction describes a type of semiconductor diode.

E6B10
A common use for point contact diodes is as an RF detector.

E6B11
In Figure E6-3, the schematic symbol for a light-emitting diode is number 5.

E6B12
Junction diodes are rated for maximum forward current and PIV (peak Inverse Voltage).

E6B13
A common use for PIN diodes is as an RF switch.



A. Single Pole Single Throw (SPST)

E6B14
Forward bias is required for an LED to produce luminescence.

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

E6C01
5 volts is the recommended power supply voltage for TTL series integrated circuits.

E6C02
The inputs of a TTL device assume a logic-high state if they are left open.

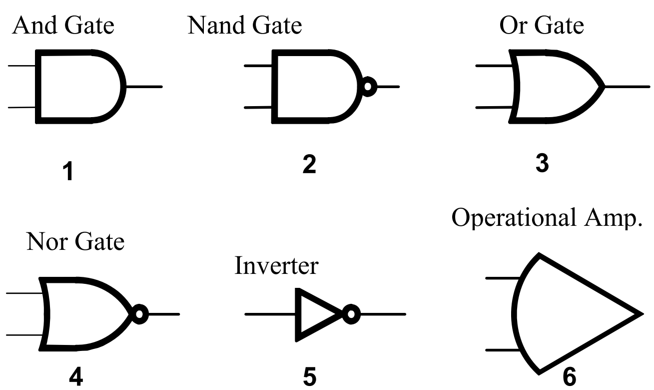
E6C03
The input voltage for a logic "high" in a TTL device operating with a positive 5-volt power supply is 2.0 to 5.5 volts.

E6C04
The input voltage for a logic "low" in a TTL device operating with a positive 5-volt power-supply is 0.0 to 0.8 volts.

E6C05
The advantage of CMOS logic devices over TTL devices is lower power consumption.

E6C06
Because the input switching threshold is about one-half the power supply voltage, CMOS digital integrated circuits have high immunity to noise on the input signal or power supply.

Figure E6-5



E6C07
In Figure E6-5, the schematic symbol for an AND gate is number 1

If inputs ***A and B*** *are 1 then the output is 1.*

Input A	*Input B*	*output*
0	*0*	*0*
0	*1*	*0*
1	*0*	*0*
1	*1*	*1*

Nor Gate Inverter

Operational
Amplif...

E6C08
In Figure E6-5, the schematic symbol for a NAND gate is number 2

*If **not A and B** are 1 then the output is 1.*

Input A	*Input B*	*output*
0	*0*	*0*
0	*1*	*1*
1	*0*	*1*
1	*1*	*1*

E6C09
In Figure E6-5, the schematic symbol for an OR gate is number 3.

*If either **A or B** input are 1 then the output is 1.*

Input A	*Input B*	*output*
0	*0*	*0*
0	*1*	*1*
1	*0*	*1*
1	*1*	*1*

E6C10
In Figure E6-5, the schematic symbol for a NOR gate is number 4.

*If **neither A or B** are 1 then the output will be 1.*

Input A	*Input B*	*output*
0	*0*	*1*
0	*1*	*0*
1	*0*	*0*
1	*1*	*0*

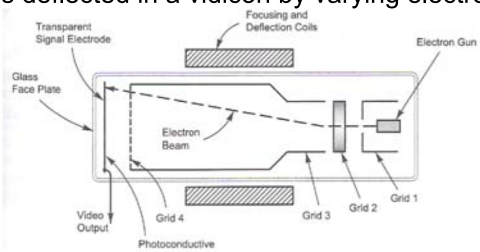
E6C11
In Figure E6-5, the schematic symbol for the NOT operation (inverter) is number 5.

If the input is high the output is low, if the input is low the output will be high.

Input	*Output*
0	*1*
1	*0*

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
The electron beam is deflected in a vidicon by varying electromagnetic fields.



E6D02
Cathode ray tube (CRT) persistence refers to the length of time the image remains on the phosphor 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, and the anode voltage is increased to 35,000 volts the image size will decrease.

E6D04
Exceeding the anode voltage design rating can cause a cathode ray tube (CRT) to generate X-rays.

E6D05
A charge-coupled device (CCD) samples an analog signal and passes it in stages from the input to the output.

E6D06
A charge-coupled device (CCD) in a modern video camera stores photo-generated charges as signals corresponding to pixels.

E6D07
A liquid-crystal display (LCD) is a display that uses a crystalline liquid to change the way light is refracted.

E6D08
Core permeability *(for a given size core)* is the property that determines the inductance of a toroidal inductor with a 10-turn winding.

E6D09
The usable frequency range of inductors that use toroidal cores, assuming a correct selection of core material for the frequency being used is from less than 20 Hz to approximately 300 MHz.

E6D10
One important reason for using powdered-iron toroids rather than ferrite toroids in an inductor is that powdered-iron toroids generally have better temperature stability.

Applications for powdered Iron toroids would be oscillator and filter circuits where inductance stability with temperature is important.

.

E6D11
Ferrite beads are commonly used as VHF and UHF parasitic suppressors at the input and output terminals of transistorized HF amplifiers.

E6D12
A primary advantage of using a toroidal core instead of a solenoidal core in an inductor is that toroidal cores contain most of the magnetic field within the core material.

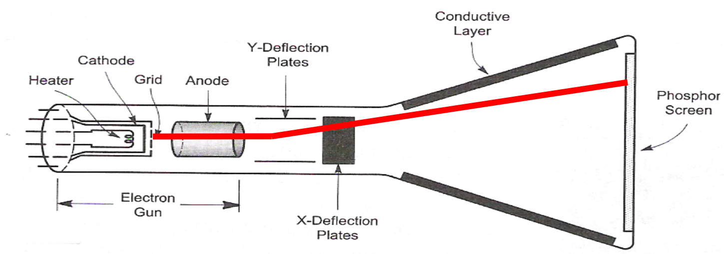
E6D13
Forty three turns of wire will be required to produce a 1-mH inductor using a ferrite toroidal core that has an inductance index (A_L) value of 523 millihenrys/1000 turns.

$N_{turns} = 1000 \times (\sqrt{(L / A_L)})$ or $N_{turns} = 1000 \times (\sqrt{(1 / 523)})$ or 43.7 turns

E6D14
Thirty five turns of wire 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.

$N_{turns} = 100 \times (\sqrt{(L / A_L)})$ or $N_{turns} = 100 \times (\sqrt{(5 / 40)})$ or 35.35 turns

E6D15
Electrostatic CRT deflection is better when high-frequency waves are to be displayed on the screen..



E6D16
A charge-coupled device (CCD) is not commonly used as an analog to digital converter.

A charge-coupled device (CCD) uses a combination of analog and digital circuitry, can be used to make an audio delay line, and it can sample and store analog signals.

E6D17
The principle advantage of liquid-crystal display (LCD) devices over other types of display devices is that they consume less power.

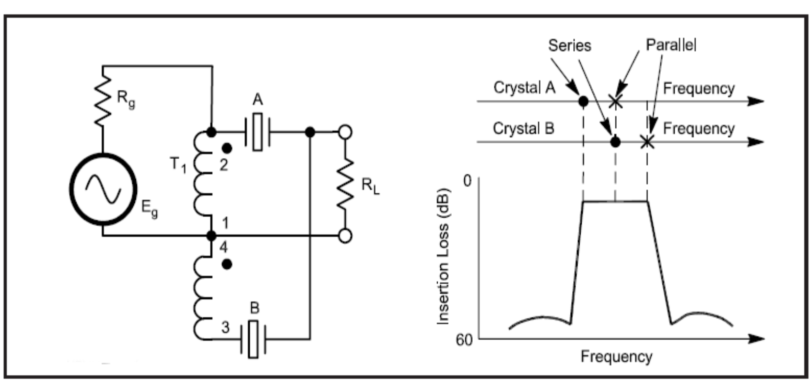
E6D18
One reason for using ferrite toroids rather than powdered-iron toroids in an inductor is that Ferrite toroids generally require fewer turns to produce a given inductance value.

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

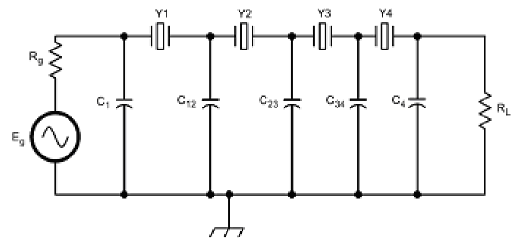
E6E01
A filter bandwidth of 2.4 kHz at -6 dB would be a good choice for use in a SSB radiotelephone transmitter.

E6E02
A filter bandwidth of 6 kHz at -6 dB would be a good choice for use with standard double-sideband AM transmissions.

E6E03
A crystal lattice filter is a filter with narrow bandwidth and steep skirts made using quartz crystals.

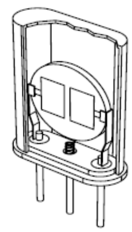


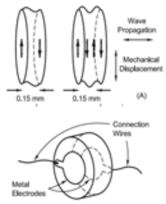
E6E04
The technique used to construct low-cost, high-performance crystal ladder filters is to measure crystal frequencies and carefully select units with a frequency variation of less than 10% of the desired filter bandwidth.



E6E05
The relative frequency of the individual crystals has the greatest effect in helping determine the bandwidth and response shape of a crystal ladder filter.

E6E06
One aspect of the piezoelectric effect is the physical deformation of a crystal by the application of a voltage.

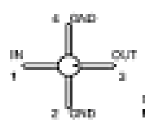




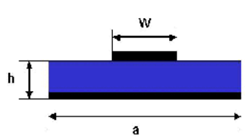
E6E07
The characteristic impedance of circuits in which almost all MMICs are designed to work is 50 ohms.

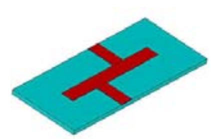
E6E08
The typical noise figure of a monolithic microwave integrated circuit (MMIC) amplifier is approximately 3.5 to 6 dB.

E6E09
An amplifier device that consists of a small pill-type package with an input lead, an output lead and 2 ground leads is a monolithic microwave integrated circuit (MMIC).

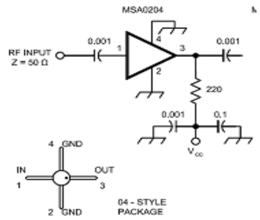


E6E10
Typically a microstrip construction technique is used when building an amplifier for the microwave bands containing a monolithic microwave integrated circuit (MMIC).





E6E11
The operating bias voltage normally supplied to the most common type of monolithic microwave integrated circuit (MMIC) is through a resistor and/or RF choke connected to the amplifier output lead.



E6E12
Monolithic microwave integrated circuits (MMIC) amplifiers typically require a supply voltage of 12 volts DC.

E6E13
Plastic packages are the most common package for inexpensive monolithic microwave integrated circuit (MMIC) amplifiers.

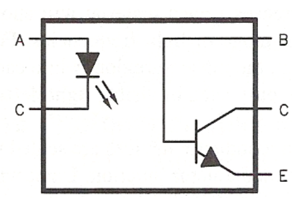
E6F Optical components and power systems: photoconductive principles and effects, photovoltaic systems, optical couplers, optical sensors, and optoisolators

E6F01
Photoconductivity is the increased conductivity of an illuminated semiconductor.

E6F02
The conductivity of a photoconductive material increases when light shines on it.

In other words the resistance decreases

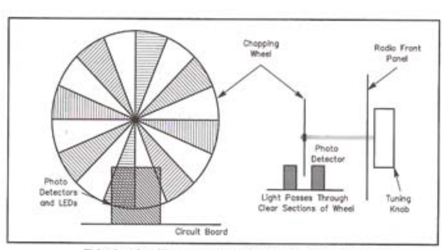
E6F03
The most common configuration for an optocoupler is an LED and a phototransistor.



E6F04
An LED and a phototransistor in the same package is an optoisolator.

Optocoupler and Optoisolator are terms that are used interchangeably for the same device.

E6F05
What is an optical shaft encoder is an array of optocouplers whose light transmission path is controlled *(interrupted)* by a rotating wheel.



This drawing illustrates the operation of an optical shaft encoder, often used as a tuning mechanism on modern transceivers.

E6F06
Photoconductivity will change the resistance of a crystalline solid.

E6F07
Cadmium sulfide will exhibit the greatest photoconductive effect when illuminated by visible light.

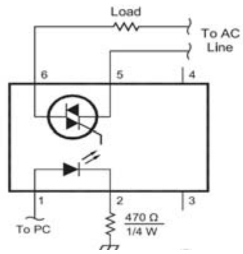
E6F08
Lead sulfide will exhibit the greatest photoconductive effect when illuminated by infrared light.

E6F09
A crystalline semiconductor is affected the most by photoconductivity when compared to heavy metal, ordinary metal, or a liquid semiconductor.

E6F10
A characteristic of optoisolators that are often used in power supplies is that they have very high impedance between the light source and the phototransistor.

This makes them an excellent choice for controlling high voltages with a low isolated voltage.

E6F11
Because optoisolators provide a very high degree of electrical isolation between a control circuit and a power circuit it makes them suitable for use with a triac to form the solid-state equivalent of a mechanical relay for 120 V AC household circuit.



E6F12
A Gallium arsenide photovoltaic cell has the highest efficiency.

E6F13
Silicon is the most common type of photovoltaic cell used for electrical power generation.

E6F14
B) The approximate open-circuit voltage produced by a fully-illuminated silicon photovoltaic cell 0.5 Volts.

Twenty seven cells would be required to produce 13.5 volts for charging a 12 volt battery.

E6F15
Electrons absorb the energy from light falling on a photovoltaic cell.

SUBELEMENT E7 -- PRACTICAL CIRCUITS [8 Exam Questions -- 8 Groups]

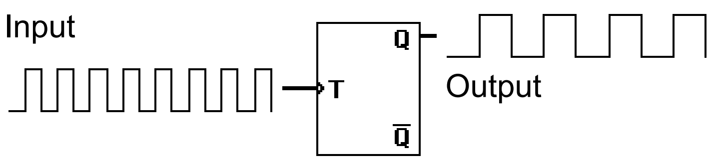
E7 Digital circuits: digital circuit principles and logic circuits: classes of logic elements; positive and negative logic; frequency dividers; truth tables

E7A01
A flip-flop is a bistable circuit.

Bistable means that it can remain in a 1 or 0 state after being driven by a single input pulse or bit. Each input pulse will cause it to change state from a 1 to a 0 or a 0 to1.

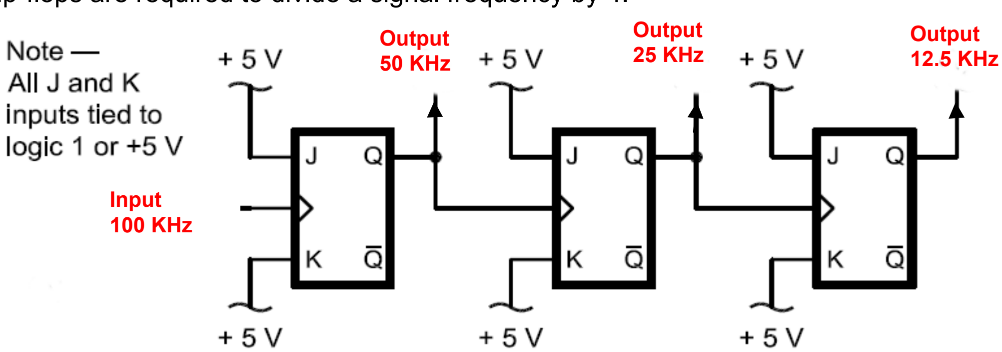
E7A02
One output level change is obtained for every two trigger pulses applied to the input of a "T" (triggered) flip-flop circuit.

Every rising edge toggles the output (makes it change state). The rise on the first pulse sets the output high the rise from the second pulse sets the output low.

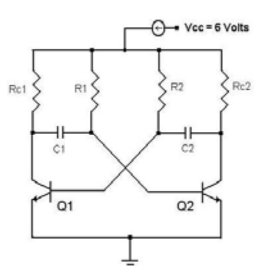


E7A03
A flip-flop can divide the frequency of the pulse train by 2.

E7A04
Two flip-flops are required to divide a signal frequency by 4.



E7A05
An astable multivibrator is a circuit that continuously alternates between two unstable states without an external clock.



E7A06
The characteristic of a mono-stable multivibrator is that it switches momentarily to the opposite binary state and then returns, after a set time, to its original state.

E7A07

An AND gate produces a logic "1" at its output only if all inputs are logic "1".

Input A	*Input B*	*output*
0	*0*	*0*
0	*1*	*0*
1	*0*	*0*
1	*1*	*1*

E7A08

An NAND gate perform produces a logic "0" at its output only when all inputs are logic "1".

Input A	*Input B*	*output*
0	*0*	*1*
0	*1*	*1*
1	*0*	*1*
1	*1*	*0*

E7A09

An OR gate produces a logic "1" at its output if any or all inputs are logic "1".

Input A	*Input B*	*output*
0	*0*	*0*
0	*1*	*1*
1	*0*	*1*
1	*1*	*1*

E7A10

A NOR gate perform produces a logic "0" at its output if any or all inputs are logic "1".

Input A	*Input B*	*output*
0	*0*	*1*
0	*1*	*0*
1	*0*	*0*
1	*1*	*0*

E7A11

A list of input combinations and corresponding outputs for a digital device is a called a truth table.

E7A12

The name for logic which represents logic "1" as a high voltage is Positive Logic.

E7A13

The name for logic which represents logic "0" as a high voltage is Negative logic

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

Amplifier classes: *Power amplifiers are classified primarily by the design of the output stage. Classification is based on the amount of time the output device(s) operate during each cycle of the input signal. .*

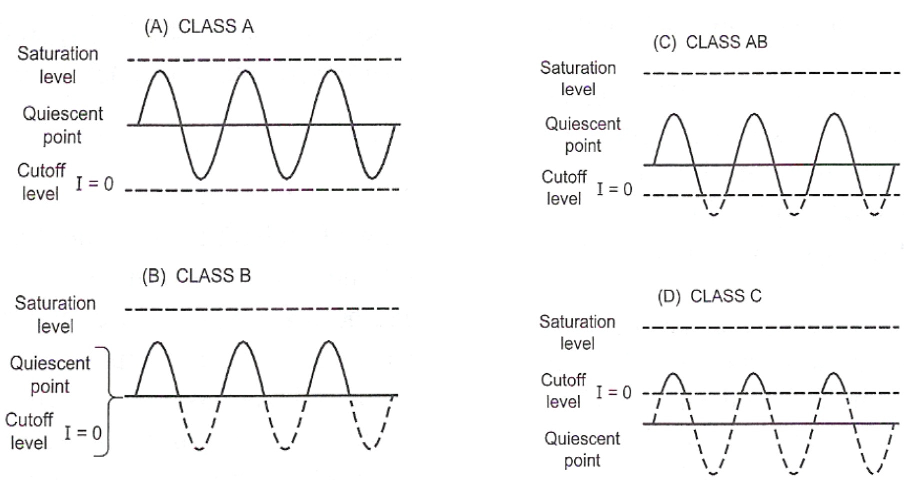
Class A *operation is where the tube conducts continuously for the entire cycle of the input signal, or a bias current flows in the output devices at all times. The key ingredient of class A operation is that the output is always on. Conversely the output device is never turned off. Because of this, class A amplifiers are single-ended designs. Class A is the most inefficient of all power amplifier designs, averaging only around 20%. Because of this, class A amplifiers are large, heavy and run very hot. On the positive side, class A designs are inherently the most linear, and have the least amount of distortion.*

When driving an A class amplifier care should be taken to insure the peak to peak input voltage stays within the linear range of the amplifier.

Class B *has conduction occurring for only for ½ of the input cycle. Class B amplifiers typically have dual output devices operating 180º out of phase with each other in a push / pull configuration to allow the full cycle of the input to be amplified. Both output devices are never allowed to be on at the same time, bias is set so that current flow in a specific output device is zero without an input signal. Current only flows in each of the push / pull amplifier output amplifiers for one half cycle. Thus each output amplifier is only on for ½ of a complete sinusoidal signal cycle. Class B push pull designs show high efficiency but poor linearity around the 0 voltage crossover region. This is due to the time it takes to turn one device off and the other device on, which translates into extreme crossover distortion. Thus restricting class B designs to power consumption critical applications, e.g., battery operated equipment. Class B push / pull transmitter power amplifiers reduce or prevent even order harmonics in the output signal.*

Class AB *operation allows both devices to be on at the same time (like in class A), but just barely. The output bias is set so that current flows in a specific output device appreciably more than a half cycle but less than the entire cycle. That is, only a small amount of current is allowed to flow through both devices, unlike the complete load current of class A designs, but enough to keep each device operating so they respond instantly to input voltage demands. Thus the inherent non-linearity of class B designs is eliminated, without the gross inefficiencies of the class A design. It is this combination of good efficiency (around 50%) with excellent linearity that makes class AB the most popular audio amplifier design.*

Class C *operation allows current flows for less than one half cycle of the input signal. The class C operation is achieved by reverse biasing the amplifier to point below cutoff and allows only the portion of the input signal that overcomes the reverse bias to cause current flow. The class C operated amplifier is used as a radio-frequency amplifier in frequency modulated or CW transmitters.*



E7B01
a Class AB amplifier operates over more than 180 degrees but less than 360 degree portion of a signal cycle.

E7B02
A Class C amplifier provides the highest efficiency.

E7B03
The bias point of a Class A common emitter amplifier would normally be set Approximately half-way between saturation and cutoff.

E7B04
To prevent unwanted oscillations in a power amplifier you will need to install parasitic suppressors and/or neutralize the stage.

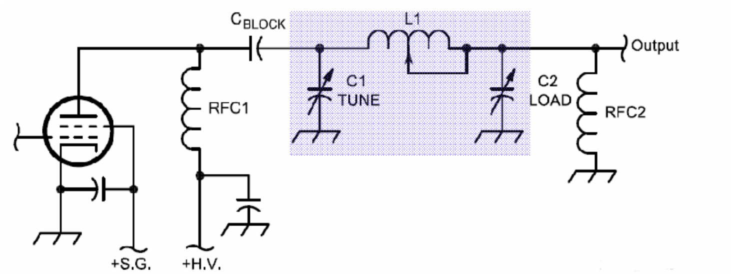
E7B05
A push-pull type amplifier reduces or eliminates even-order harmonics.

E7B06

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.

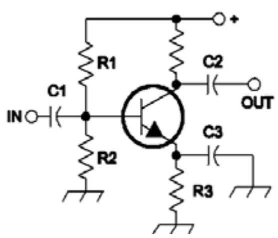
E7B07
A vacuum-tube power amplifier can be neutralized by feeding back an out-of-phase component of the output to the input.

E7B08
When tuning a vacuum tube RF power amplifier that employs a pi-network output circuit transmitter output stage the tuning capacitor should be adjusted for minimum plate current, while the loading capacitor is adjusted for maximum permissible plate current.



E7B09
In Figure E7-1, the purpose of R1 and R2 are to set a fixed bias level.

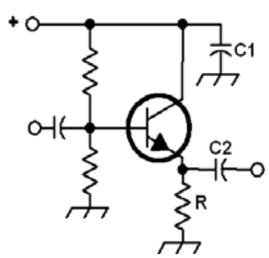
Figure E7-1



E7B10
In Figure E7-1, the purpose of R3 is to provide self biasing.

E7B11
The type of circuit is shown in Figure E7-1 is a common emitter amplifier.

Figure E7-2



E7B12
In Figure E7-2, the purpose of R is to serves as an Emitter load.

E7B13
In Figure E7-2, the purpose of C2 is Output coupling.

E7B14
Using degenerative emitter feedback is one way to prevent thermal runaway in a transistor amplifier.

Also called negative feedback, a portion of the output of an amplifier is inverted and connected back to the input. This controls the gain of the amplifier and reduces distortion and noise.

E7B15
The effect of intermodulation products in a linear power amplifier is the transmission of spurious signals.

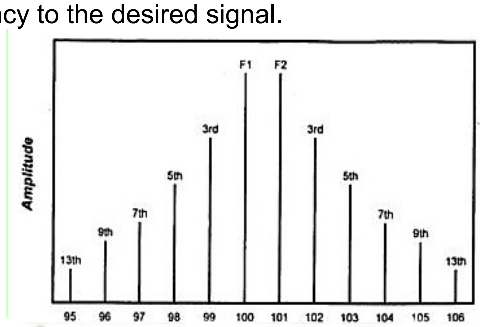
Table 1 – Intermodulation Products

1st Order	f1,	f2	100 kHz	101 kHz
2nd Order	f1+f2,	f2-f1	201 kHz	1 kHz
3rd Order	2f1-f2,	2f2-f1	99 kHz	102 kHz
	2f1+f2,	2f2+f1	301 kHz	302 kHz
4th Order	2f2+2f1,	2f2-2f1	402 kHz	2 kHz
5th Order	3f1-2f2,	3f2-2f1	98 kHz	103 kHz
	3f1+2f2,	3f2+2f1	502 kHz	503 kHz
Etc.				

Table 2 – Odd Order Products

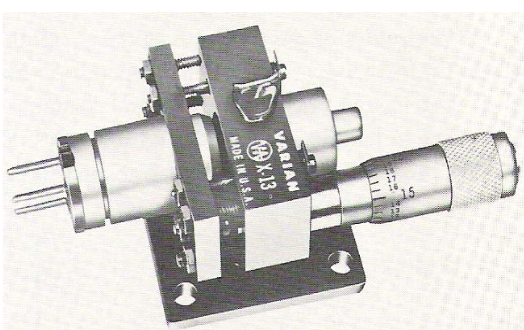
3rd Order	2f1-f2,	2f2-f1	99 kHz	102 kHz
5th Order	3f1-2f2,	3f2-2f1	98 kHz	103 kHz
7th Order	4f1-3f2,	4f2-3f1	97 kHz	104 kHz
9th Order	5f1-4f2,	5f2-4f1	96 kHz	105 kHz
Etc.				

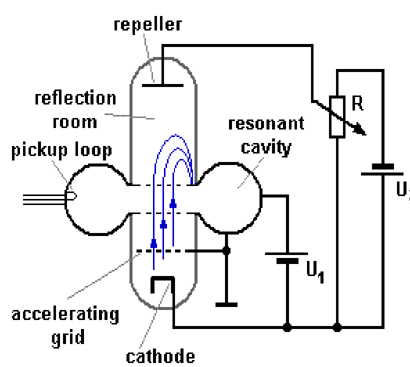
E7B16
Third-order intermodulation distortion products are of particular concern in linear power amplifiers because they are relatively close in frequency to the desired signal.



E7B17
A grounded-grid amplifier has low input impedance.

E7B18
A klystron is a VHF, UHF, or microwave vacuum tube that uses velocity modulation.



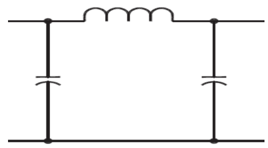


E7B19
A parametric amplifier is a low-noise VHF or UHF amplifier relying on varying reactance for amplification.

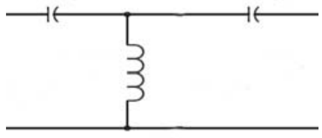
E7B20
Generally a FET is best suited for UHF or microwave power amplifier applications.

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

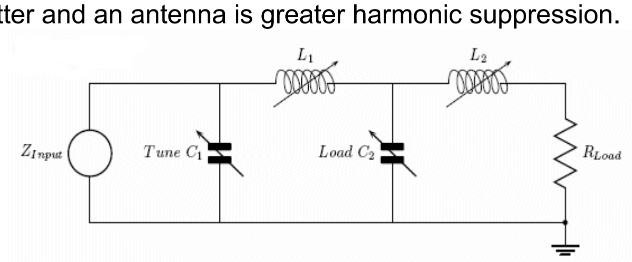
E7C01
In a low-pass filter Pi-network the circuit consists of a capacitor in parallel with the input, another capacitor is in parallel with the output, and an inductor is in series between the two and between the network's input and output.



E7C02
A T-network with series capacitors and a parallel (shunt) inductor transforms impedance and is a high-pass filter.

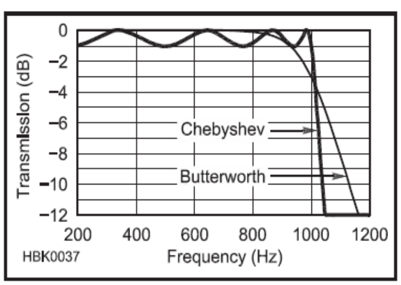


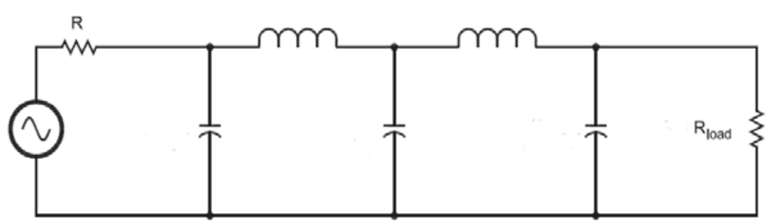
E7C03
The advantage of a Pi-L-network over a Pi-network for impedance matching between the final amplifier of a vacuum-tube type transmitter and an antenna is greater harmonic suppression.



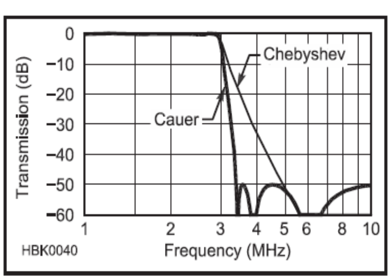
E7C04
A network can transform complex impedance to resistive impedance by canceling the reactive part of an impedance and transforms the resistive part to the desired value.

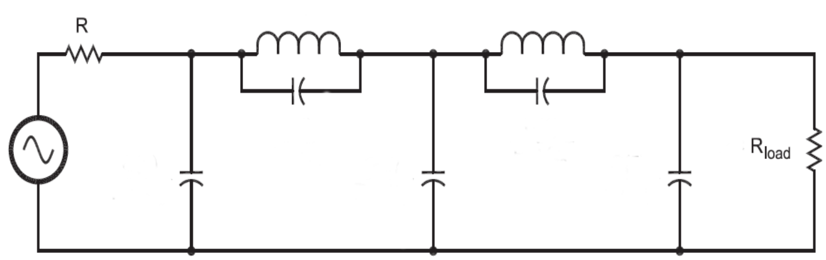
E7C05
A Chebyshev filter type is described as having ripple in the passband and a sharp cutoff.



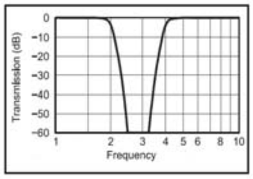


E7C06
The distinguishing features of an elliptical filter is extremely sharp cutoff, with one or more infinitely deep notches in the stop band





E7C07
An audio notch filter would be used to attenuate an interfering carrier signal while receiving an SSB transmission.

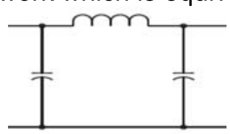


E7C08
An adaptive filter type of digital signal processing audio filter might be used to remove unwanted noise from a received SSB signal.

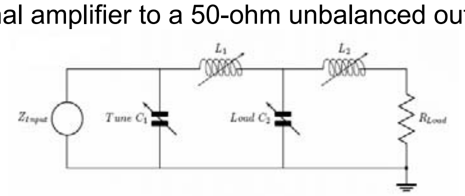
E7C09
A Hilbert-transform filter type of digital signal processing filter might be used in generating an SSB signal.

E7C10
A cavity filter would be the best choice for use in a 2-meter repeater duplexer.


E7C11
Pi Filter is the common name for a filter network which is equivalent to two L networks back-to-back.



E7C12
A Pi-L network, which is a network consisting of two series inductors and two shunt capacitors is used when matching a vacuum-tube final amplifier to a 50-ohm unbalanced output.

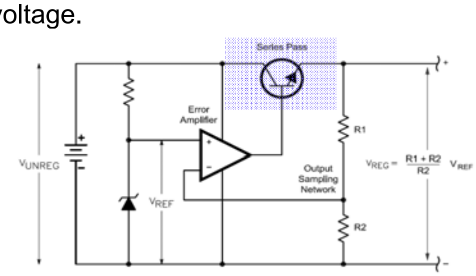


E7C13
One advantage of a Pi matching network over an L matching network is that the Q of Pi networks can be varied depending on the component values chosen.

E7C14
Digital modes are most affected by non-linear phase response in a receiver IF filter.

E7D Power supplies and voltage regulators

E7D01
One characteristic of a linear electronic voltage regulator is the conduction of a control element is varied to maintain a constant output voltage.



E7D02
One characteristic of a switching electronic voltage regulator is the control device's duty cycle is controlled to produce a constant average output voltage.

E7D03
A Zener diode is typically used as a stable reference voltage in a linear voltage regulator.

E7D04
A series regulator type of linear regulator makes the most efficient use of the primary power source.

E7D05
A shunt regulator type of linear voltage regulator places a constant load on the unregulated voltage source.

Figure E7- 3

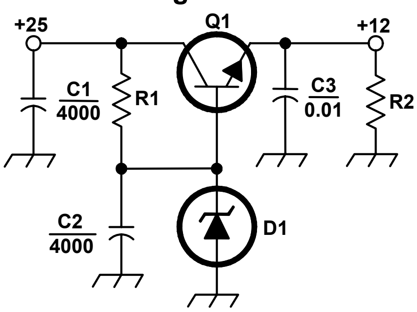
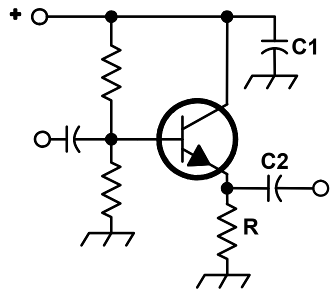


Figure E7-2



E7D06
The purpose of Q1 in the circuit shown in Figure E7-3 is to increases the current-handling capability of the regulator.

E7D07
The purpose of C2 in the circuit shown in Figure E7-3 is to bypass hum around D1.

E7D08
The circuit shown in Figure E7-3 is a linear voltage regulator.

E7D09
The purpose of C1 in the circuit shown in Figure E7-3 is to filter the supply Power voltage.

E7D10
The purpose of C3 in the circuit shown in Figure E7-3 is to prevent self-oscillation.

E7D11
The purpose of R1 in the circuit shown in Figure E7-3 is to It supply current to D1.

E7D12
The purpose of R2 in the circuit shown in Figure E7-3 is to provide a constant minimum load for Q1.

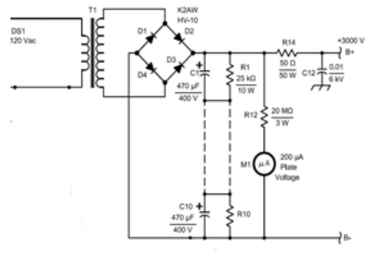
E7D13
The purpose of D1 in the circuit shown in Figure E7-3 is to provide a voltage reference.

E7D14
One purpose of a "bleeder" resistor in a conventional (unregulated) power supply is to improve output voltage regulation.

E7D15
The purpose of a "step-start" circuit in a high-voltage power supply is to allow the filter capacitors to charge gradually.

This consists of inserting a resistor in the primary side of the transformer to limit the charge current on the capacitors at initial turn on. The series resistor is switched out after a few seconds of operation.

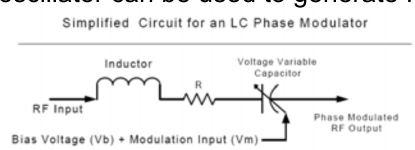
E7D16
When several electrolytic filter capacitors are connected in series to increase the operating voltage of a power supply filter circuit, resistors should be connected across each capacitor to equalize, as much as possible, the voltage drop across each capacitor; to provide a safety bleeder to discharge the capacitors when the supply is off; and to provide a minimum load current to reduce voltage excursions at light loads.



E7D17
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 is because 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

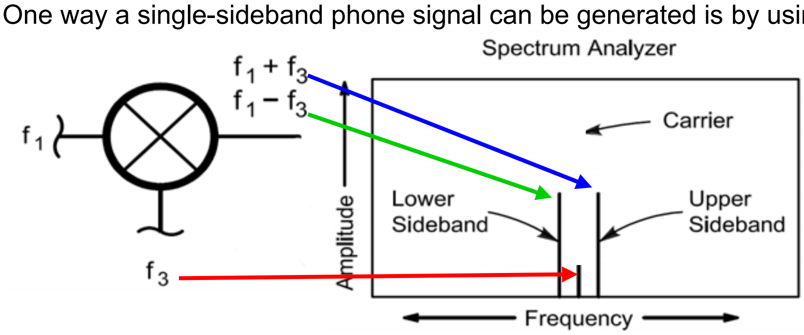
E7E01
A reactance modulator on the oscillator can be used to generate FM-phone emissions.



E7E02
The function of a reactance modulator is to produce PM (Phase Modulated) signals by using an electrically variable inductance or capacitance.

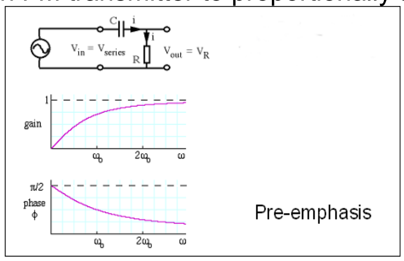
E7E03
The fundamental principle of a phase modulator is it varies the tuning of an amplifier tank circuit to produce PM (phase Modulated) signals.

E7E04
One way a single-sideband phone signal can be generated is by using a balanced modulator followed by a filter.

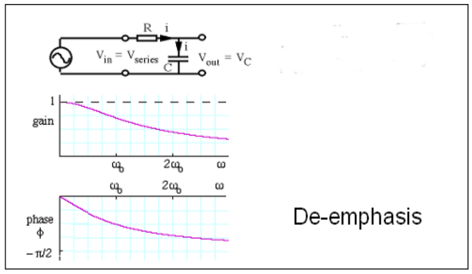


A balanced mixer will output the sum and difference of the two signals applied (Carrier and SSB audio) and the carrier, suppressed by passing the modulator output through a filter so that the upper or lower sideband can be filtered leaving only one of the sideband signals.

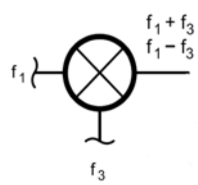
E7E05
A pre-emphasis network is added to an FM transmitter to proportionally attenuate the lower audio frequencies.



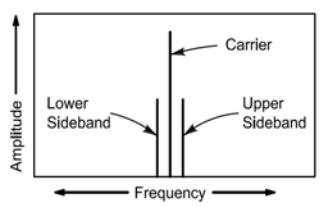
E7E06
A de-emphasis network ***(circuit)*** is added to an FM receiver to restore attenuated lower audio frequencies.



E7E07
One result of the process of mixing two signals is the creation of new signals at the sum and difference frequencies.



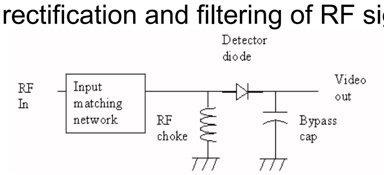
E7E08
The principal frequencies that appear at the output of a mixer circuit are the original frequencies, and the sum and difference frequencies.



E7E09
Spurious mixer products are generated when an excessive amount of signal energy reaches a mixer circuit.

E7E10
The process of detection refers to the recovery of information from a modulated RF signal.

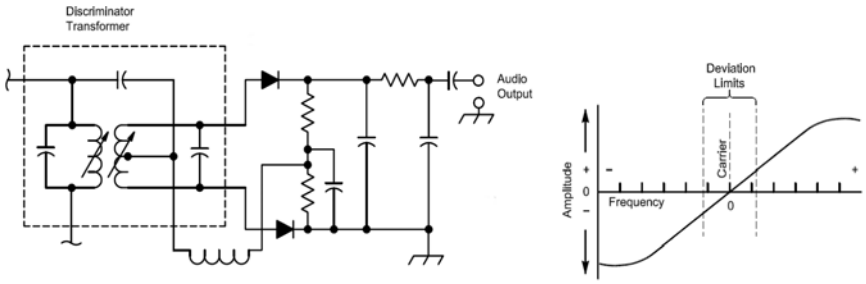
E7E11
The diode detector function is the rectification and filtering of RF signals.



Basic detector circuit

E7E12
A product detector is well suited for demodulating SSB signals.

E7E13
A frequency discriminator is a circuit for detecting FM signals



E7E14
The phasing or quadrature method describes a common means of generating a SSB signal when using digital signal processing.

E7E15
In a "direct conversion" 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

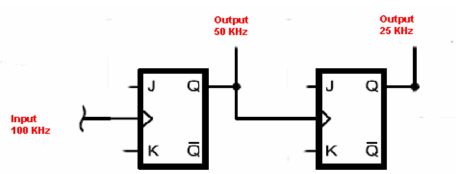
E7F01
The purpose of a prescaler circuit is to divide a higher frequency signal so a low-frequency counter can display the operating frequency.

E7F02
A prescaler would be used to reduce a signal's frequency by a factor of ten.

E7F03
The function of a decade counter digital IC is to produce one output pulse for every ten input pulses.

A decade counter (divider) can be used as a prescaler for a counter (assuming it works high enough in frequency) to increase the counters frequency range by a factor of 10 (allowing a 10 MHz counter to have an extended frequency range to100 MHz). A circuit with 2 decade dividers in series would divide the input by 100, extending the range of our 10 MHz to 1,000 MHz

E7F04
Two flip-flops must be added to a 100-kHz crystal-controlled marker generator so as to provide markers at 50 and 25 kHz.



E7F05
A 1 MHz oscillator and a decade counter circuit can be combined to produce a 100 kHz fundamental signal with harmonics at 100 kHz intervals.

E7F06
A crystal marker generator consists of a crystal-controlled oscillator that generates a series of reference signals at known frequency intervals

E7F07
A crystal oscillator followed by a frequency divider circuit would be a good choice for generating a series of harmonically related receiver calibration signals.

E7F08
One purpose of a marker generator is to provide a means of calibrating a receiver's frequency settings.

E7F09
The accuracy of the time base determines the accuracy of a frequency counter.

E7F10
A conventional frequency counter determines the frequency of a signal by counting the number of input pulses occurring within a specific period of time.

E7F11
The purpose of a frequency counter is to provide a digital representation of the frequency of a signal.

E7F12
Period measurement is an alternate method of determining frequency, other than by directly counting input pulses, and is used by some frequency counters.

E7F13
The advantage of a period-measuring frequency counter over a direct-count type is that 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
The values of capacitors and resistors external to the op-amp determine the gain and frequency characteristics of an op-amp RC active filter.

E7G02
Ringing in a filter is caused by frequency and phase response of the filter *(non linear group delay)*.

E7G03
The advantages of using an op-amp instead of LC elements in an audio filter is that Op-amps exhibit gain rather than insertion loss.

E7G04
A polystyrene capacitor is best suited for use in high-stability op-amp RC active filter circuits.

E7G05
Unwanted ringing and audio instability can be prevented in a multi-section op-amp RC audio filter circuit by restricting both gain and Q.

E7G06
Standard capacitor values are chosen first, then the resistances are calculated, and resistors of the nearest standard value selected for the external components in an op-amp RC active filter.

E7G07
The most appropriate use of an op-amp RC active filter is as an audio receiving filter.

Operational amplifiers:
*An operational amplifier, or op amp, is one of the most useful linear devices that have been developed with integrated circuitry. While it is possible to build an op amp with discrete components, the symmetry of this circuit requires a close match of many components and is more effective, and much easier, to implement in integrated circuitry. **Fig 5.43** shows a basic op-amp circuit. The op amp approaches a perfect analog circuit building block.*

Ideally, an op amp has infinite input impedance (Zi), zero output impedance (Zo) and an open loop voltage gain (Av) of infinity. Obviously, practical op amps do not meet these specifications, but they do come closer than most other types of amplifiers.

The gain of an op amp is the function of the input resistor and the feed back resistor. Gain in calculated by dividing the input resistor R1 value into the feedback resistor Rf. In figure E7-4 if the input resistor,R1, is 10,000 ohms and the feedback resistor ,Rf, 1s 1,000,000 ohms the gain would be 1,000,0000 / 10,000 or a gain of 100. The output is inverted in this configuration when the signal is feed into the – pin of the op amp. This is the most commonly used configuration. The op amp can be configured in a non inverting mode so the out put signal is the same polarity as the input signal

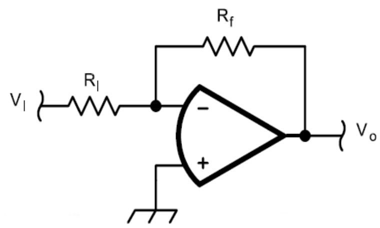


Figure E7-4

E7G08
A Sallen-Key *(named after the equation designers)* is a type of active op-amp filter circuit.

E7G09
The voltage gain that can be expected from the circuit in Figure E7-4 when R_1 is 10 ohms and R_f is 470 ohms is 47. *(The gain is actually -47 since the output is inverted that is the output polarity is opposite the input polarity)*

Gain = R_F / R_1 or 470 / 10 or 47

E7G10
The gain of a *theoretically ideal* operational amplifier does not vary with frequency.

E7G11
The output voltage of the circuit shown in Figure E7-4 if R_1 is 1000 ohms, R_f is 10,000 ohms, and 0.23 volts is applied to the input is – 2.3 volts.

Gain = R_f / R_1 or 10,000 / 1000 or 10
Output Voltage = input voltage x Gain or .23 volts x 10 or - 2.3 volts

Remember this operational amplifier configuration is an inverting operational amplifier

E7G12
The voltage gain that can be expected from the circuit in Figure E7-4 when R1 is 1800 ohms and RF is 68 kiliohms is 38.

Gain = R_f / R_1 or 68,000 / 1800 or 37.77

E7G13
The voltage gain that can be expected from the circuit in Figure E7-4 when R1 is 3300 ohms and RF is 47 kiliohms is 14.

Gain = R_f / R_1 or 47,000 / 3300 or 14.24

E7G14
An operational amplifier is a high-gain, direct-coupled differential amplifier whose characteristics are (response is) determined by components external to the amplifier.

E7G15
The term "op-amp input-offset voltage" refers to the potential between the amplifier input terminals of the op-amp in a closed-loop condition.

Closed loop condition means a feedback loop is present around the amplifier.

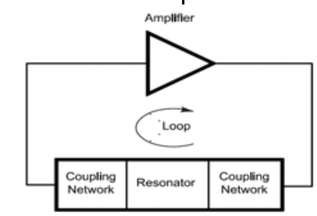
E7G16
The typical input impedance of an integrated circuit op-amp is Very high.

E7G17
The typical output impedance of an integrated circuit op-amp is Very low.

E7H Oscillators and signal sources: types of oscillators; synthesizers and phase-locked loops; direct digital synthesizers

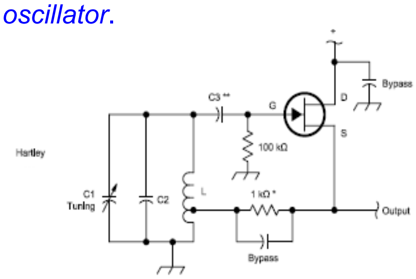
E7H01
The Colpitts, Hartley and Pierce are the three major oscillator circuits often used in Amateur Radio equipment.

E7H02
For a circuit to oscillate it must have a positive feedback loop with a gain greater than 1.



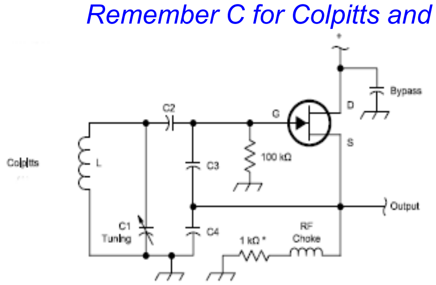
E7H03
Positive feedback is supplied in a Hartley oscillator through a tapped coil.

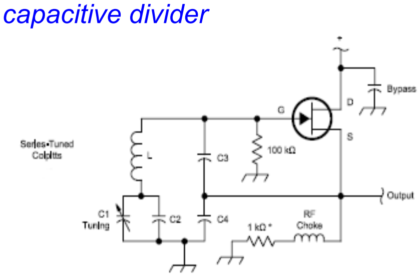
Remember Hartley uses a taped coil for feedback. Henry is the measure of inductance of the coil in a Hartley oscillator.



E7H04
Positive feedback is supplied in a Colpitts oscillator through a capacitive divider.

Remember C for Colpitts and capacitive divider





E7H05
Positive feedback is supplied in a Pierce oscillator through a quartz crystal.

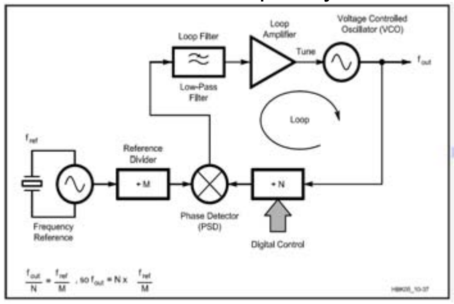
E7H06
Colpitts and Hartley oscillator circuits are commonly used in VFO circuits.

E7H07
A magnetron oscillator is a UHF or microwave oscillator consisting of a diode vacuum *(Magnetron)* tube with a specially shaped anode (resonator), surrounded by an external magnet.

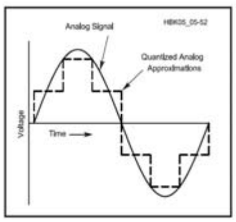
E7H08
A Gunn diode oscillator is an oscillator based on the negative resistance properties of properly-doped semiconductors.

Gun Diodes in a resonant circuit or cavity work as oscillators well into the microwave region

E7H09
A phase locked loop frequency synthesizer circuit uses a stable, voltage-controlled oscillator, programmable divider, phase detector, loop filter and a reference frequency source.



E7H10
A direct digital synthesizer circuit uses a phase accumulator, lookup table, digital to analog converter and a low-pass anti-alias filter.



E7H11
Information contained in the lookup table of a direct digital frequency synthesizer contains the amplitude values that represent a sine-wave output.

Can also contain complex non sinusoidal waveforms, for complex waveform simulation and generation.

E7H12
Spurs at discrete frequencies are the major spectral impurity components of direct digital synthesizers.

A direct digital synthesizer has spurious outputs because the DAC's (Digital to Analog Converters) are not perfect and periodic errors result.

E7H13
Phase accumulator circuit would be classified as a principal component of a direct digital synthesizer (DDS).

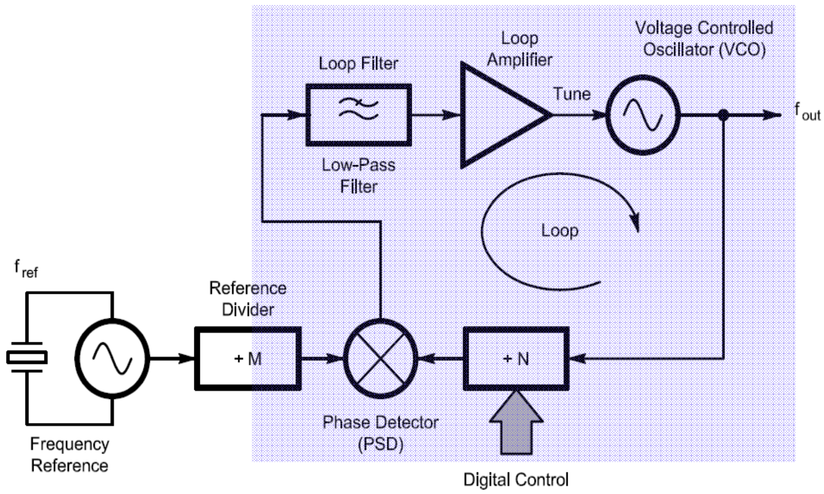
E7H14
A phase locked loop circuit is often used in conjunction with a direct digital synthesizer (DDS) to expand the available tuning range.

E7H15
The frequency range over which a phase-locked loop circuit can lock is its capture range.

E7H16
A phase-locked loop circuit is an electronic servo loop consisting of a phase detector, a low-pass filter and voltage-controlled oscillator.

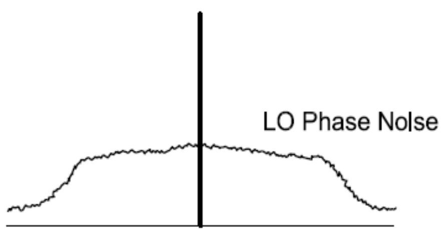
E7H17
Both frequency synthesis and FM demodulation can be performed by a phase-locked loop.

E7H18
A stable reference oscillator is normally used as part of a phase locked loop (PLL) frequency synthesizer because any phase variations in the reference oscillator signal will produce phase noise in the synthesizer output.



E7H19
A phase-locked loop is often used as part of a variable frequency synthesizer for receivers and transmitters because it makes it possible for a VFO to have the same degree of stability as a crystal oscillator.

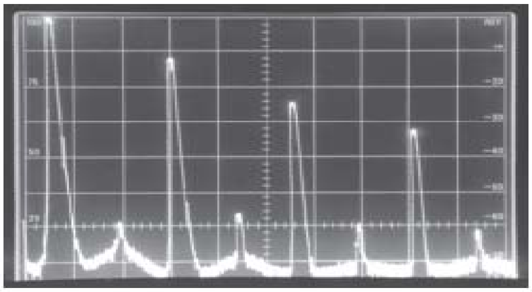
E7H20
The major spectral impurity component of phase-locked loop synthesizers is phase noise.



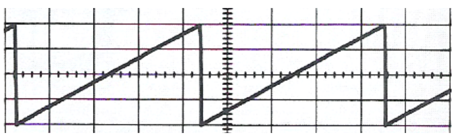
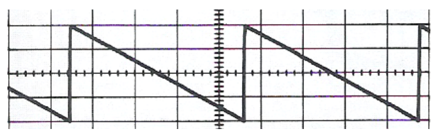
SUBELEMENT E8 -- SIGNALS AND EMISSIONS [4 Exam Questions -- 4 Groups]

E8A AC waveforms: sine, square, sawtooth and irregular waveforms; AC measurements; average and PEP of RF signals; pulse and digital signal waveforms

E8A01
A square wave is made up of a sine wave plus all of its odd harmonics.

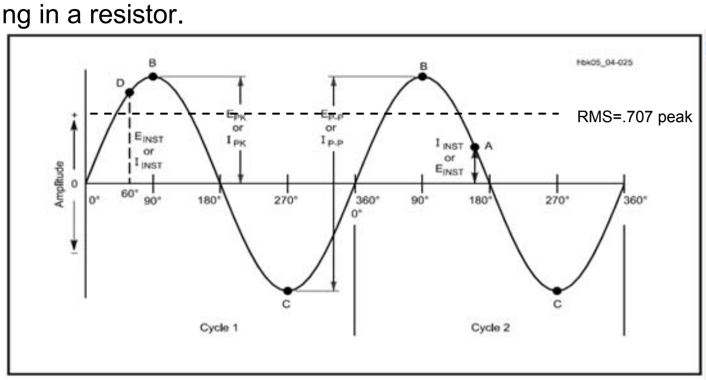


E8A02
A sawtooth wave has a rise time significantly faster than its fall time (or vice versa).

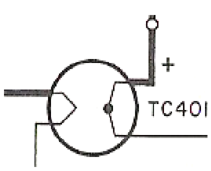

or


E8A03
A sawtooth wave is made up of sine waves of a given fundamental frequency plus all of its harmonics.

E8A04
The equivalent to the root-mean-square value of an AC voltage is the equivalent DC voltage that causes the same amount of heating in a resistor.



E8A05
The most accurate way of measuring the RMS voltage of a complex waveform is by measuring the heating effect in a known resistor.

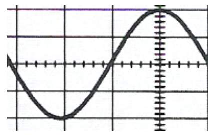


In precision measuring instruments a filament is heated with a current from an AC circuit and its temperature is measured by the voltage generated in a thermocouple attached to it. Then a DC current is applied to generate the same thermocouple voltage output. This dc current is then equal to the AC RMS current.

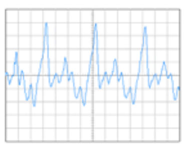
E8A06
The approximate ratio of PEP-to-average power for a typical voice-modulated single-sideband phone signal is 2.5 to 1.

E8A07
The characteristics of a modulating signal determine the PEP-to-average power ratio of a single-sideband phone signal.

E8A08
The period of a wave is the time required for it to complete one cycle.

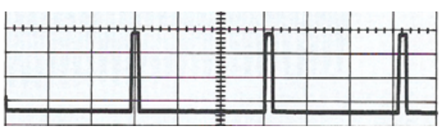


E8A09
An Irregular waveform is produced by human speech.



This is because human speech is complex and contains many frequencies.

E8A10
The distinguishing characteristic of a pulse waveform is narrow bursts of energy separated by periods of no signal.

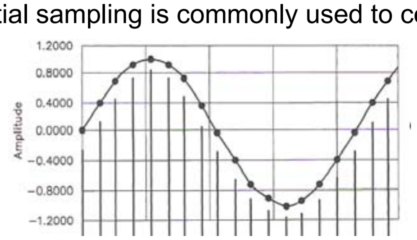


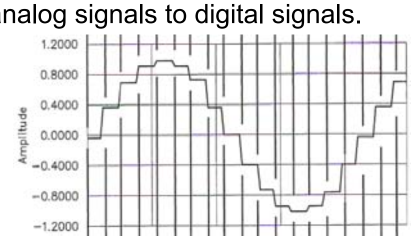
E8A11
Digital data transmission is one use for a pulse modulated signal.

E8A12
Human speech, Video signals and Data information can all be conveyed using digital waveforms.

E8A13
One advantage of using digital signals instead of analog signals to convey the same information is that digital signals can be regenerated multiple times without error.

E8A14
Sequential sampling is commonly used to convert analog signals to digital signals.





E8A15
The waveform of a digital data stream signal would look like a series of pulses with varying patterns on a conventional oscilloscope.

E8B Modulation and demodulation: modulation methods; modulation index and deviation ratio; pulse modulation; frequency and time division multiplexing

E8B01
Modulation index 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.

E8B02
The modulation index of a phase-modulated emission does not depend on the RF carrier frequency.

Modulation index = Deviation / Modulation frequency

E8B03
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 is 3.0.

Modulation index = Deviation / Modulation frequency or 3000/1000 or 3.0

E8B04
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 is 3.0.

Modulation index = Deviation / Modulation frequency or 6000/2000 or 3.0

E8B05
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 is 1.66.

Deviation Ratio = Max Deviation / Max Modulation frequency or 5000/3000 or 1.666

E8B06
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 is 2.14.

Deviation Ratio = Max Deviation / Max Modulation frequency or 7500/3500 or 2.142

E8B07
When using a pulse-width modulation system, the transmitter's peak power is greater than its average power because the signal duty cycle is less than 100%.

E8B08
The modulating signal in a pulse-position modulation system will vary the time at which each pulse occurs.

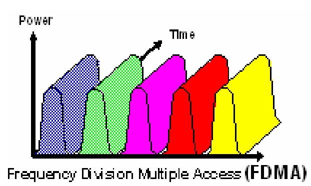
E8B09
The pulses of a pulse-modulated signal are usually transmitted as a pulse of relatively short duration and sent with a relatively long period of time separating each pulse.

This keeps the average power much lower than the peak power.

E8B10
Deviation ratio is the ratio of the maximum carrier frequency deviation to the highest audio modulating frequency.

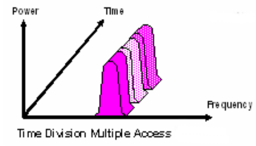
Deviation Ratio = maximum carrier deviation / highest modulating frequency

E8B11
Frequency division multiplexing can be used to combine several separate analog information streams into a single analog radio frequency signal.



E8B12
In frequency division multiplexing, two or more information streams are merged into a "baseband", which then modulates the transmitter.

E8B13
In 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
Morse code is a digital code consisting of elements having unequal length.

E8C02
Some of the differences between the Baudot digital code and ASCII are; Baudot uses five data bits per character and ASCII uses seven; Baudot uses two characters as shift codes, ASCII has no shift code.

E8C03
One advantage of using the ASCII code for data communications is that it is possible to transmit both upper and lower case text.

E8C04 This question has been removed by the QPC

E8C05
The Technique of using sinusoidal data pulses minimizs the bandwidth requirements of a PSK-31 signal.

In PSK31 (1's) are represented by a tone with no phase shift compared to the previous bit and (0's) are tone with a 180 degree phase shift relative to the phase of the previous bit. The phase shift occurs during the zero level modulation to minimize bandwidth. When the modulation level returns, the positions of the sinewave top and bottom are reversed from the previous bit. Thus the phase changes by 180 degrees while the frequency remains constant.

E8C06
The necessary bandwidth of a 13-WPM international Morse code transmission is approximately 52 Hz.

E8C07
The necessary bandwidth of a 170-hertz shift, 300-baud ASCII transmission is 0.5 kHz *(or 500Hz)*.

E8C08
The necessary bandwidth of a 4800-Hz frequency shift, 9600-baud ASCII FM transmission is 15.36 kHz.

E8C09
The term Spread-spectrum communication describes a wide-bandwidth communications system in which the transmitted carrier frequency varies according to some predetermined sequence.

E8C10
A spread-spectrum technique causes a digital signal to appear as wide-band noise to a conventional receiver.

E8C11
Frequency hopping is a spread-spectrum communications technique that alters the center frequency of a conventional carrier many times per second in accordance with a pseudo-random list of channels.

E8C12
A direct sequence spread-spectrum communications technique uses a high speed binary bit stream to shift the phase of an RF carrier.

E8C13

Spread-spectrum communications are resistant to interference because only signals using the correct spreading sequence are received.

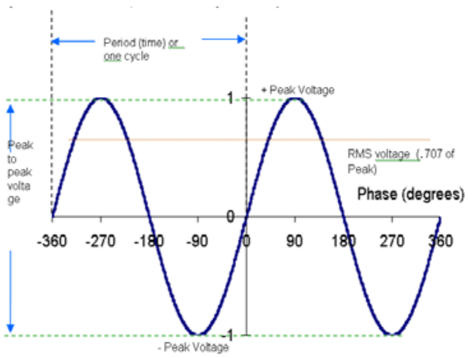
E8C14
The advantage of including a parity bit with an ASCII character stream is that some types of errors can be detected.

E8C15
One advantage of using JT-65 coding is virtually perfect decoding of signals well below the noise.

JT65 is a digital protocol intended for Amateur Radio communication with extremely weak signals. It was designed to optimize Earth-Moon-Earth (EME) contacts on the VHF bands, and conforms efficiently to the established standards and procedures for such QSOs.

E8D Waves, measurements, and RF grounding: peak-to-peak values, polarization; RF grounding

E8D01
Peak-to-peak voltage is the easiest voltage amplitude parameter to measure when viewing a pure sine wave signal on an oscilloscope



E8D02
The relationship between the peak-to-peak voltage and the peak voltage amplitude of a symmetrical waveform is 2:1.

The peak to peak includes both the positive and negative excursions of the sine wave, therefore it is twice the value of only the peak voltage.

E8D03
The Peak voltage input-amplitude parameter is valuable in evaluating the signal-handling capability of a Class A amplifier.

E8D04
The PEP output of a transmitter that has a maximum peak of 30 volts to a 50-ohm load as observed on an oscilloscope is 9 watts.

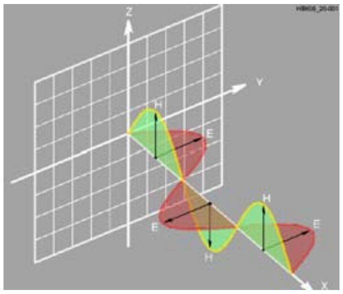
Step 1 - RMS= .707 x Peak or RMS = .707 x 30 or RMS = 21.21 Volts
Step 2 – Power = (RMS)^2 / Resistance or P = (21.21)^2 / 50 or P = 449.86 / 50 or P = 8.997 Watts

E8D05
If an RMS-reading AC voltmeter reads 65 volts on a sinusoidal waveform, the peak-to-peak voltage would be 184 volts.

Peak to Peak = 2(RMS x 1.414) or PP = 2(65 x 1.414) or PP = 2 x 91.91 or PP 183.82 Volts

E8D06
The advantage of using a peak-reading wattmeter to monitor the output of a SSB phone transmitter is that it gives a more accurate display of the PEP output when modulation is present.

E8D07
An electromagnetic wave is a wave consisting of an electric field and a magnetic field oscillating at right angles to each other.



E8D08
Electromagnetic waves traveling in free space change electric and magnetic fields to propagate the energy.

E8D09
Circularly polarized electromagnetic waves are waves with a rotating electric field.

E8D10
The polarization of an electromagnetic wave when its magnetic field is parallel to the surface of the earth is vertical.

E8D11
The polarization of an electromagnetic wave if its magnetic field is perpendicular to the surface of the Earth is Horizontal.

E8D12
Electromagnetic waves travel in free space at approximately 300 million meters per second.

E8D13
A peak-reading wattmeter 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.

E8D14
The average power dissipated by a 50-ohm resistive load during one complete RF cycle having a peak voltage of 35 volts is 12.2 watts.

Step 1 - RMS= .707 x Peak or RMS = .707 x 35 or RMS = 24.74 Volts
Step 2 – Power = (RMS)^2 / Resistance or P = (24.74)^2 / 50 or P = 612.31 / 50 or P = 12.24 Watts

E8D15
If an RMS reading voltmeter reads 34 volts on a sinusoidal waveform, it's the peak voltage would be 48 volts.

Peak = 1.414 x RMS or Peak = 1.414 x 34 or peak = 48.07 volts

E8D16
170 volts is a typical value for the peak voltage at a common household electrical outlet.

Peak = 1.414 x RMS or Peak = 1.414 x 120 or peak = 169.68 volts

E8D17
340 volts is a typical value for the peak-to-peak voltage at a common household electrical outlet.

Peak to Peak= 2 (1.414 x RMS) or PP = 2 (1.414 x 120) or PP = 2 x 169.68 or PP = 339.36 volts

E8D18
A typical value for the RMS voltage at a common household electrical power outlet is 120-V AC.

E8D19
The RMS value of a 340-volt peak-to-peak pure sine wave is 120-V AC.

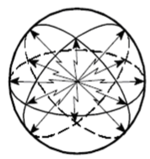
RMS= (peak to Peak/2) / 1.414 or RMS= (340/2) / 1.414 or RMS= 170 / 1.414 or RMS = 120.22 volts

SUBELEMENT E9 — ANTENNAS AND TRANSMISSION LINES [8 Exam Questions -- 8 Groups]

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
An isotropic Antenna is a theoretical antenna used as a reference for antenna gain.

An isotropic source radiates equally in all directions



E9A02
A 1/2-wavelength dipole has 2.15 dB gain compared to an isotropic antenna.

Actually 2.14 dB gain, the test question answer is rounded to 2.15 dB

E9A03
An Isotropic antenna has no *(zero)* gain in any direction.

E9A04
One needs to know the feed point impedance of an antenna to match impedances for maximum power transfer from a feed line.

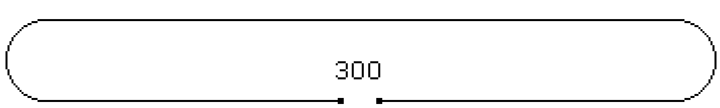
E9A05
Antenna height and conductor length/diameter ratio, and location of nearby conductive objects determine the radiation resistance of an antenna.

E9A06
The term for the ratio of the radiation resistance of an antenna to the total resistance of the system is antenna efficiency.

Efficiency = $(R_R / R_t) \times 100\%$ *With* R_R *= radiation resistance and* R_t *=Total Resistance*

E9A07
Radiation resistance plus ohmic resistance are included in the total resistance of an antenna system.

E9A08
A dipole constructed from one wavelength of wire forming a very thin loop is a folded dipole antenna.



half wave folded dipole

E9A09
Antenna gain is the numerical ratio relating the radiated signal strength of an antenna in the direction of maximum radiation to that of a reference antenna.

Gain is generally expressed in dB relative to either an Isotropic source or a dipole.

E9A10
Antenna bandwidth is the frequency range over which an antenna satisfies a performance requirement.

Performance examples would be – Gain - SWR or impedance - Beam width - etc

E9A11
Antenna efficiency is calculated by (radiation resistance / total resistance) x 100%.

Can also be calculated by the equation: Efficiency = Radiated Power / Input power

E9A12
The efficiency of an HF quarter-wave grounded vertical antenna can be improved by installing a good radial system.

E9A13
Soil conductivity is the most important factor in determining ground losses for a ground-mounted vertical antenna operating in the 3-30 MHz range.

E9A14
If an antenna has 3.85 dB gain over a 1/2-wavelength dipole then it has 6 dB gain over an isotropic antenna.

*The gain over isotropic source for an antenna with a 3.85 dB gain over a dipole antenna would be an additional 2.14 dB of gain. Remember dipole gain over an isotropic source is 2.14 dB or **3.85 dB +1.14dB** or **5.99dB***

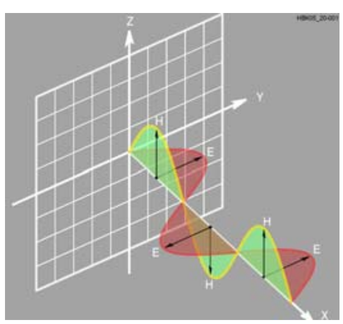
E9A15
An antenna has 9.85 dB of gain over a 1/2-wavelength dipole when it has 12 dB of gain over an isotropic antenna.

Remember that a dipole has 2.14 dB of gain as referenced to an isotropic antenna.
12 dB -2.14 dB or gain =9.86dB

E9A16
The radiation resistance of an antenna is the value of a resistance that would dissipate the same amount of power as that radiated from an antenna.

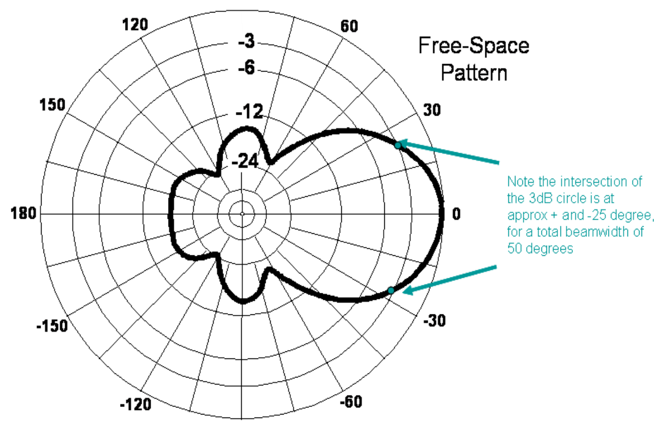
E9B - Antenna patterns: E and H plane patterns; gain as a function of pattern; antenna design (computer modeling of antennas); Yagi antennas

E9B01
The orientation of its electric field (E Field) determines the free-space polarization of an antenna.



E9B02
In the antenna radiation pattern shown in Figure E9-1, what the 3-dB beamwidth is 50 degrees.

Figure E9-1



E9B03
In the antenna radiation pattern shown in Figure E9-1, the front-to-back ratio is 18 dB.

E9B04
In the antenna radiation pattern shown in Figure E9-1, the front-to-side ratio is 14 dB.

E9B05
When a directional antenna is operated at different frequencies within the band for which it was designed the gain may exhibit significant variations.

E9B06
If a Yagi antenna is designed solely for maximum forward gain the front-to-back ratio decreases.

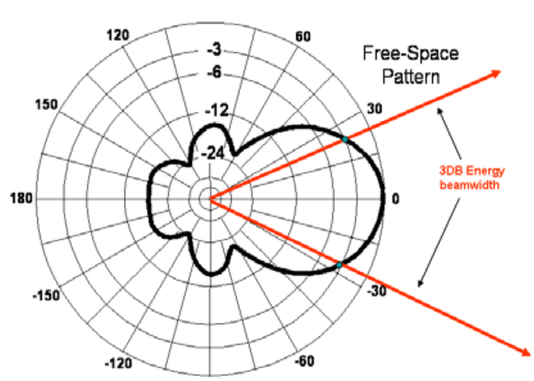
E9B07
If the boom of a Yagi antenna is lengthened and the elements are properly retuned, usually the gain increases.

E9B08
The total amount of radiation emitted by a directional (gain) antenna compared with the total amount of radiation emitted from an isotropic antenna will be the same when each is driven by the same amount of power. There will be no difference in total radiated power between the two antennas.

> *Remember the key word is total power. In an isotropic antenna power is equally radiated in all directions. In a gain antenna the power is focused in one direction so in that direction it is stronger but in other directions it is weaker. Total power is the sum of all power in all directions assuming both antennas are 100% efficient.*

E9B09
You can approximate beamwidth of a directional antenna by noting the two points where the signal strength of the antenna is 3 dB less than maximum and compute the angular difference.

Figure E9-1



E9B10
The “Method of Moments” computer program technique is commonly used for modeling antennas.

E9B11
The principle that the “Method of Moments” analysis is based on is a wire that is modeled as a series of segments, each having a distinct value of current.

E9B12
The disadvantage of decreasing the number of wire segments in an antenna model below the guideline of 10 segments per half-wavelength is that the computed feed-point impedance may be incorrect.

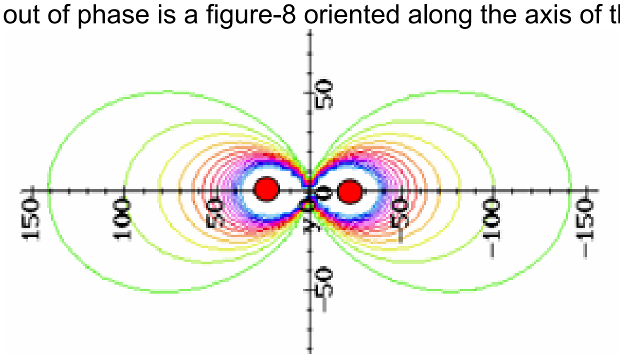
E9B13
The disadvantage of NEC-based antenna modeling programs is that computing time increases as the number of wire segments is increased.

E9B14
The abbreviation NEC stands for Numerical Electromagnetics Code when applied to antenna modeling programs.

E9B15
SWR vs. frequency charts, polar plots of the far-field elevation and azimuth patterns, and antenna gain can be obtained by submitting *(entering)* the details of a proposed new antenna to a modeling program.

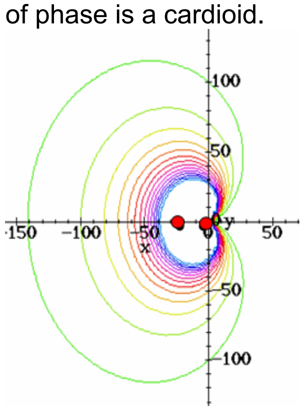
E9C - Wire and phased vertical antennas: beverage antennas; terminated and resonant rhombic antennas; elevation above real ground; ground effects as related to polarization; take-off angles

E9C01
The radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed 180 degrees out of phase is a figure-8 oriented along the axis of the array.



Two vertical ¼ wave antennas
Feed points180° out of phase
½ wavelength apart

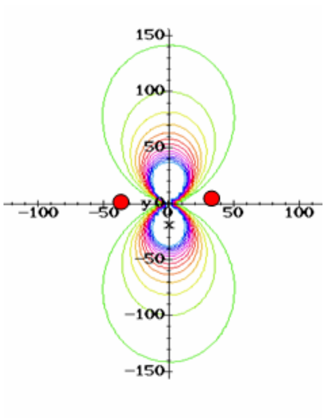
E9C02
The radiation pattern of two 1/4-wavelength vertical antennas spaced 1/4-wavelength apart and fed 90 degrees out of phase is a cardioid.



Two ¼ wavelength verticals
¼ wavelength apart with
Feed points 90° out of phase

E9C03

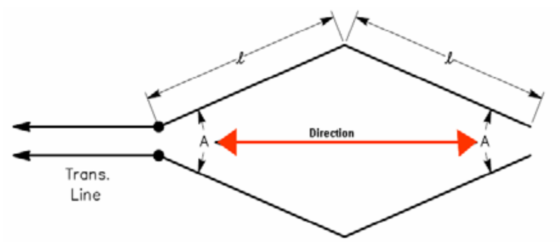
The radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed in phase is a figure-8 broadside to the axis of the array.



Two 1/4 wavelength verticals
1/2 wavelength apart, feed in phase

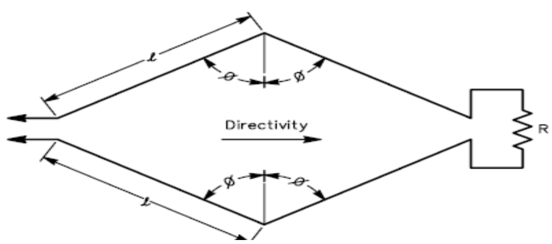
E9C04

A basic rhombic antenna is a bidirectional. It is four-sided. Each side is one or more wavelengths long and is open at the end opposite the transmission line connection



E9C05

The main advantages of a terminated rhombic antenna are wide frequency range, high gain and high front-to-back ratio *(gain)*.



E9C06

The disadvantages of a terminated rhombic antenna for the HF bands are that the antenna requires a large physical area and 4 separate supports.

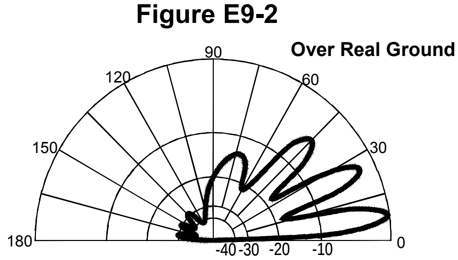
E9C07

A terminating resistor on a rhombic antenna changes the radiation pattern from bidirectional to unidirectional.

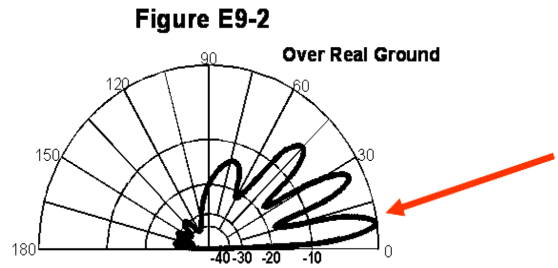
E9C08

An antenna elevation pattern over real ground is shown in Figure E9-2.

Figure E9-2



E9C09
The elevation angle of peak response in the antenna radiation pattern shown in Figure E9-2 is 7.5 degrees.



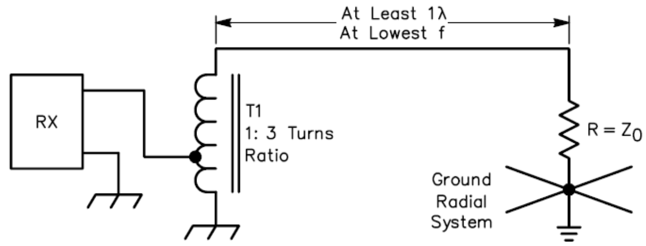
E9C10
The front-to-back ratio of the radiation pattern shown in Figure E9-2 is 28 dB.

E9C11
Four elevation lobes appear in the forward direction of the antenna radiation pattern shown in Figure E9-2.

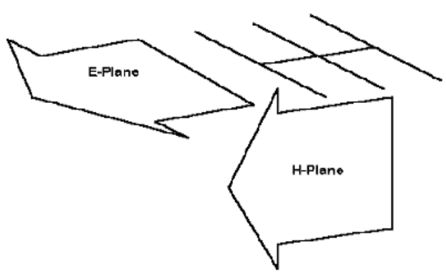
E9C12
When a vertically polarized antenna is mounted over seawater versus rocky ground the far-field elevation pattern low-angle radiation increases.

A lower angle of radiation means longer skip.

E9C13
When constructing a Beverage antenna, to achieve good performance at the desired frequency it should be one or more wavelengths long.



E9C14
The electric field will be horizontally oriented for a Yagi with three elements mounted parallel to the ground.



E9C15
The conductivity and dielectric constant of the soil in the area of the antenna strongly affects the shape of the far-field, low-angle elevation pattern of a vertically polarized antenna.

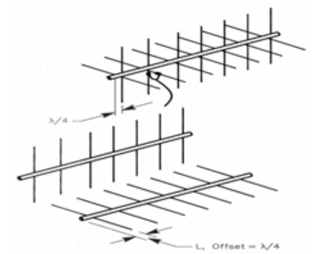
****** E9C16 This question has been removed by the QPC*

E9C17
The main effect of placing a vertical antenna over an imperfect ground is that it reduces low-angle radiation

E9D - Directional antennas: gain; satellite antennas; antenna beamwidth; losses; SWR bandwidth; antenna efficiency; shortened and mobile antennas; grounding

E9D01
The gain of a parabolic dish antenna increases 6 dB when the operating frequency is doubled.

E9D02
One way to produce circular polarization, when using linearly polarized antennas, is to arrange two Yagi antennas perpendicular to each other with the driven elements at the same point on the boom and fed 90 degrees out of phase.



E9D03
The beamwidth of an antenna decreases as the gain is increased.

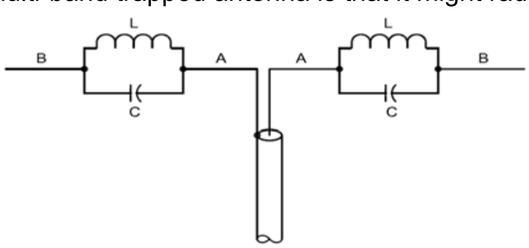
The antenna becomes more directional

E9D04
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.

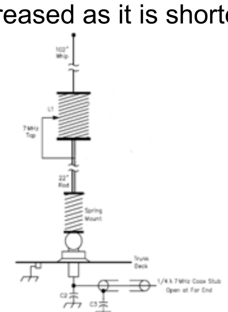
E9D05
For a shortened vertical antenna, a loading coil is placed near the center of the vertical radiator to minimize losses and produce the most effective performance.

E9D06
An HF mobile antenna loading coil should have a high ratio of reactance to resistance to minimize losses.

E9D07
A disadvantage of using a multi-band trapped antenna is that it might radiate harmonics.

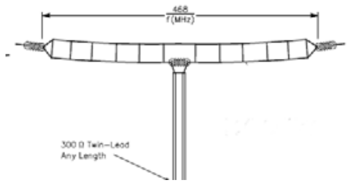


E9D08
The bandwidth of an antenna is decreased as it is shortened through the use of loading coils.



E9D09
An advantage of using top loading in a shortened HF vertical antenna is improved radiation efficiency.

E9D10
The approximate feed-point impedance at the center of a folded dipole antenna is 300 ohms.



E9D11
A loading coil is often used with an HF mobile antenna to cancel capacitive reactance.

E9D12
An advantage of using a trapped antenna is that It may be used for multi-band operation.

E9D13
The resistance decreases and the capacitive reactance increases at the base feed-point of a fixed-length HF mobile antenna as the frequency of operation is lowered.

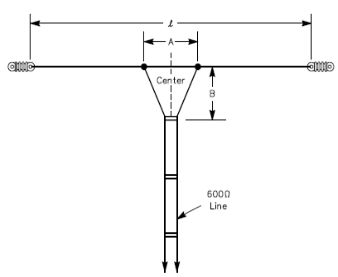
E9D14
A thin, flat copper strap several inches wide would be best for minimizing losses in a station's RF ground system.

The thin copper strap will have lower inductive reactance making it a lower loss to the earth ground point.

E9D15
A connection to 3 or 4 interconnected ground rods driven into the earth would provide the best RF ground for your station.

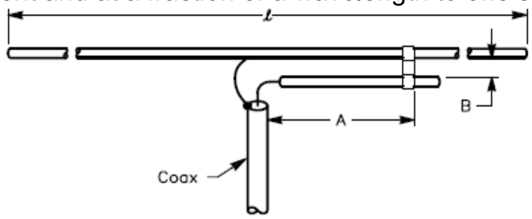
E9E Matching: matching antennas to feed lines; power dividers

E9E01
The delta matching 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.



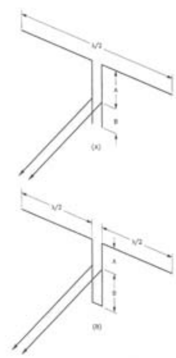
E9E02

The gamma match is a 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.



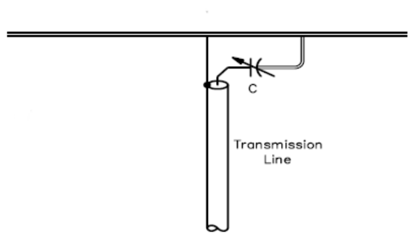
E9E03

The stub match uses a short perpendicular section of transmission line connected to the feed line near the antenna.



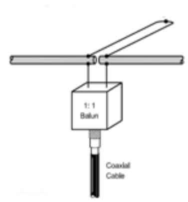
E9E04

The purpose of the series capacitor in a gamma-type antenna matching network is to compensate for the inductive reactance of the matching network.



E9E05

The driven element reactance must be capacitive in a 3-element Yagi to be tuned using a hairpin matching system.



E9E06

The equivalent lumped-constant network for a hairpin matching system on a 3-element Yagi is an L network.

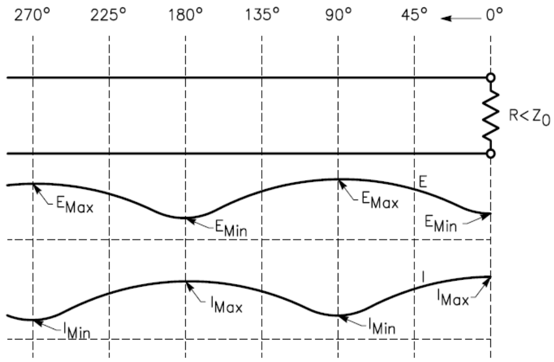
E9E07

Reflection coefficient best describes the interactions at the load end of a mismatched transmission line.

The terms - VSWR, Return Loss, Reflected Power are all ways to describe match or mismatch between a transmitter and antenna system. The table end of sub element E9 shows the relationship between them and the amount of power that would be reflected back from a given mismatch. Note that with a VSWR of 1.4 to 1 only 2.8 % of the transmitter power is reflected back.

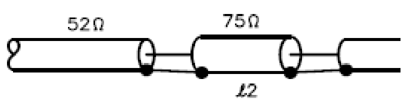
E9E08
An SWR greater than 1:1 measurement describes a mismatched transmission line.

SWR is the ratio of the maximum voltage (resulting from the interaction of Incident and reflected voltages along a transmission line) to the minimum voltage.



E9E09
Using a Gamma match 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.

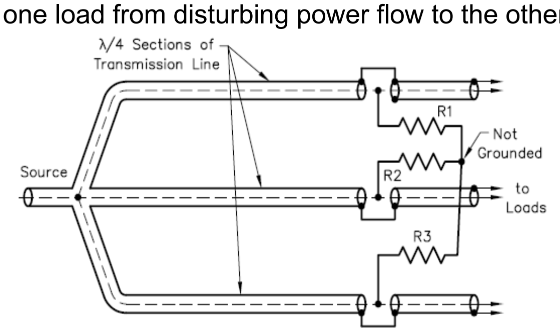
E9E10
Inserting a 1/4-wavelength piece of 75-ohm coaxial cable transmission line in series between the antenna terminals and the 50-ohm feed cable is an effective way to match an antenna with 100-ohm terminal impedance to a 50-ohm coaxial cable feed-line.



E9E11
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 is to use the "universal stub" matching technique.

E9E12
The primary purpose of a "phasing line" when used with an antenna having multiple driven elements is to ensure that each driven element operates in concert with the others to create the desired antenna pattern.

E9E13
The purpose of a "Wilkinson divider is to divide 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
The velocity factor of a transmission line is the velocity of the wave in the transmission line divided by the velocity of light in a vacuum.

Velocity Factor = Velocity of wave in Transmission line / Velocity of light

E9F02
The transmission line dielectric materials used determine the velocity factor in a transmission line.

E9F03
Because Electrical signals move more slowly in a coaxial cable than in air, the physical length of a coaxial cable transmission line is shorter than its electrical length.

E9F04
The typical velocity factor for a coaxial cable with solid polyethylene dielectric is 0.66.

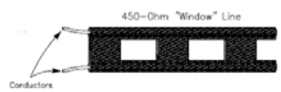
E9F05
The physical length of a coaxial transmission line that is electrically one-quarter wavelength long at 14.1 MHz is *(Assuming a velocity factor of 0.66.)* 3.5 Meters.

¼ Wavelength (in Transmission line) = (300/F(MHz)) / 4 x Velocity Factor
¼ Wavelength (in Transmission line) =(300/14.1 x .66) / 4 or 14.04/4 or 3.51 meters

E9F06
The physical length of a parallel conductor feed line that is electrically one-half wavelength long at 14.10 MHz (Assuming a velocity factor of 0.95.) is 10 meters.

½ Wavelength (in Transmission line) = (300/F(MHz))/2 x Velocity Factor
½ Wavelength (in Transmission line) = (300/14.1 x .95)/2 or 20.21/2 or 10.10 meters

E9F07
450-ohm ladder line, at 50 MHz, will have a lower loss when compared to 0.195-inch-diameter coaxial cable (such as RG-58).



E9F08
Velocity factor 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.

E9F09
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) would be 6.9 meters.

¼ Wavelength(in Transmission line) = (300/F(MHz))/4 x Velocity Factor
¼ Wavelength(in Transmission line) =(300/7.2 x..66)/4 or 27.50/4 or 6.87 meters

E9F10
A 1/8-wavelength transmission line presents an inductive reactance to a generator when the line is shorted at the far end.

Impedance of coaxial stubs		
Wavelength	**Open Stub**	**Shorted Stub**
1/8	Capacitive	Inductive
1/4	Low imp.	High imp.
1/2	High imp	Low imp

E9F11
A 1/8-wavelength transmission line presents a capacitive reactance to a generator when the line is open at the far end.

E9F12
A 1/4-wavelength transmission line presents a very low impedance to a generator when the line is open at the far end.

E9F13
A 1/4-wavelength transmission line presents a very high impedance to a generator when the line is shorted at the far end.

E9F14
A 1/2-wavelength transmission line presents a very low impedance to a generator when the line is shorted at the far end.

E9F15
A 1/2-wavelength transmission line presents very high impedance to a generator when the line is open at the far end.

E9F16
The primary differences between foam-dielectric coaxial cable as opposed to solid-dielectric cable, assuming all other parameters are the same are reduced safe operating voltage limits, reduced losses per unit of length and higher velocity factor.

E9G - The Smith chart

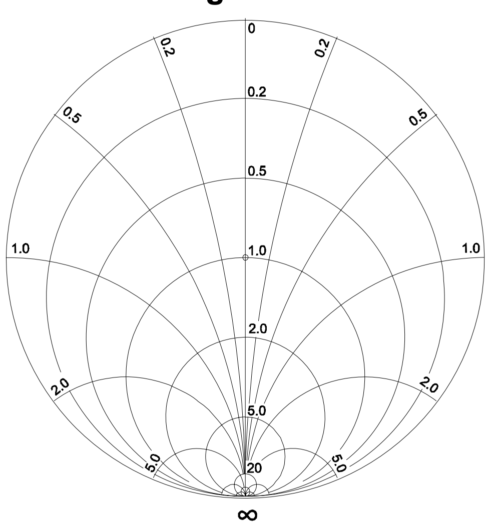
E9G01
Impedance along transmission lines can be calculated using a Smith chart.

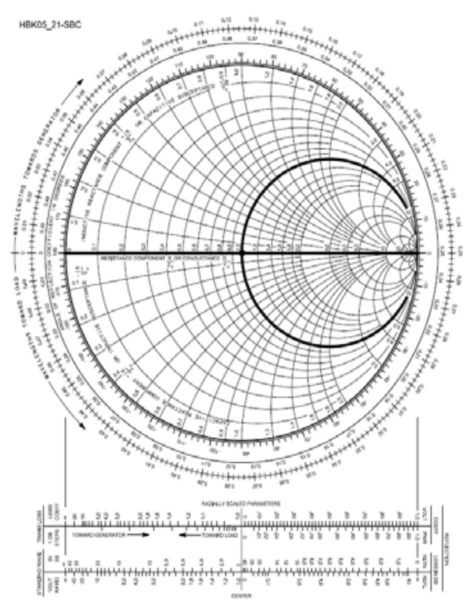
E9G02
The coordinate system is used in a Smith chart is resistance circles and reactance arcs.

E9G03
Impedance and SWR values in transmission lines are often determined using a Smith chart.

E9G04
Resistance and reactance are the two families of circles and arcs that make up a Smith chart.

Figure E9-3





E9G05
The type of chart shown in Figure E9-3 is a Smith chart.

E9G06
On the Smith chart shown in Figure E9-3, the name of the large outer circle on which the reactance arcs terminate is the reactance axis.

E9G07
On the Smith chart shown in Figure E9-3, the only straight line shown is the resistance axis.

E9G08
The process of normalization with regard to a Smith chart is reassigning impedance values with regard to the prime center.

E9G09
Standing-wave ratio circles are a third family of circles that are often added to a Smith chart during the process of solving problems.

E9G10
The arcs on a Smith chart represent points with constant reactance.

E9G11
The wavelength scales on a Smith chart are calibrated in fractions of transmission line electrical wavelength.

E9H - Effective radiated power; system gains and losses; radio direction finding antennas

E9H01
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 is 286 watts.

ERP = Power + gain(s) – Loss(es)
ERP= 150 watts + (7 dB) – (2 dB + 2.2 dB) or 150 watts + 2.8 dB
Gain/loss ratio = 10^(dB/10)or 10^(2.8/10) or 10^.28 or 1.905
ERP = 150 watts x 1.905(the overall db gain/loss ratio) or 285.8 watts

E9H02
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 is 317 watts.

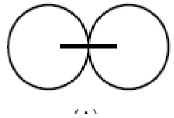
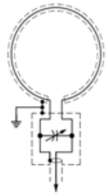
ERP = Power + gain(s) – Loss(es)
ERP= 150 watts + (10 dB) – (4 dB + 3.2 dB +0.8 dB) or 150 watts + 2 dB
Gain/loss ratio = 10^(dB/10)or 10^(2.0/10) or 10^.20 or 1.584
ERP = 200 watts x 1.584(the overall db gain/loss ratio) or 316.9 watts

E9H03
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 is 252 watts.

ERP = Power + gain(s) – Loss(es)
ERP= 200 watts + (7 dB) – (2 dB + 2.8 dB +1.2 dB) or ERP = 200 watts + 1 dB
Gain/loss ratio = 10^(dB/10) or 10^(1/10) or 10^.1 or 1.258
ERP = 200 watts x 1.258 (the overall db gain/loss ratio) or 251.7 watts

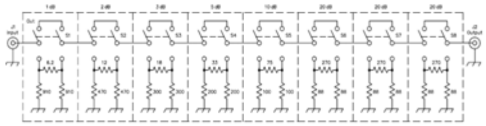
E9H04
Effective radiated power is the term that describes station output (including the transmitter, antenna and everything in between), when considering transmitter power and system gains and losses.

E9H05
The main drawback of a wire-loop antenna for direction finding is that it has a bidirectional pattern.

E9H06
The triangulation method of direction finding is when antenna headings from several different receiving stations are used to locate the signal source.

E9H07
An RF attenuator is desirable in a receiver used for direction finding because it prevents receiver overload from extremely strong signals.

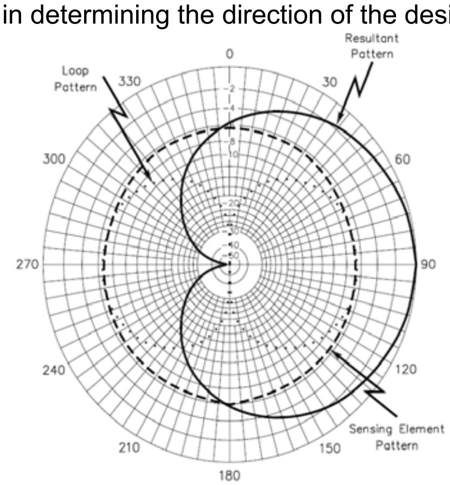


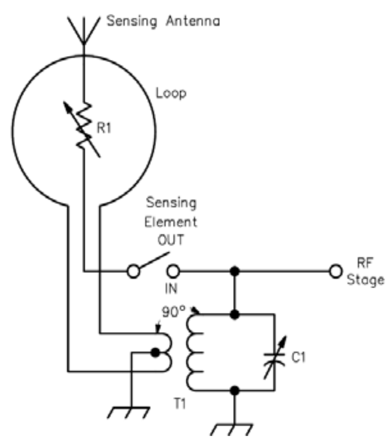

E9H08
The function of a sense antenna is that it modifies the pattern of a DF antenna array to provide a null in one direction

E9H09
A receiving loop antenna is an antenna made of one or more turns of wire wound in the shape of a large open coil

E9H10
The output voltage of a receiving loop antenna can be increased by increasing either the number of wire turns in the loop or the area of the loop structure

E9H11
A cardioid pattern is desirable for a direction-finding system because response characteristics of the cardioid pattern can assist in determining the direction of the desired station.





E9H12
An advantage of using a shielded loop antenna for direction finding is that it is electro-statically balanced against ground, giving better nulls.

VSWR vs return loss – Reflected power and Transmission loss Table

VSWR	Return Loss (dB)	Reflected Power (%)	Transmiss. Loss (dB)	VSWR	Return Loss (dB)	Reflected Power (%)	Transmiss. Loss (dB)
1.00	oo	0.000	0.000	1.38	15.9	2.55	0.112
1.01	46.1	0.005	0.0002	1.39	15.7	2.67	0.118
1.02	40.1	0.010	0.0005	1.40	15.55	2.78	0.122
1.03	36.6	0.022	0.0011	1.41	15.38	2.90	0.126
1.04	34.1	0.040	0.0018	1.42	15.2	3.03	0.132
1.05	32.3	0.060	0.0028	1.43	15.03	3.14	0.137
1.06	30.7	0.082	0.0039	1.44	14.88	3.28	0.142
1.07	29.4	0.116	0.0051	1.45	14.7	3.38	0.147
1.08	28.3	0.144	0.0066	1.46	14.6	3.50	0.152
1.09	27.3	0.184	0.0083	1.47	14.45	3.62	0.157
1.10	26.4	0.228	0.0100	1.48	14.3	3.74	0.164
1.11	25.6	0.276	0.0118	1.49	14.16	3.87	0.172
1.12	24.9	0.324	0.0139	1.50	14.0	4.00	0.18
1.13	24.3	0.375	0.0160	1.55	13.3	4.8	0.21
1.14	23.7	0.426	0.0185	1.60	12.6	5.5	0.24
1.15	23.1	0.488	0.0205	1.65	12.2	6.2	0.27
1.16	22.6	0.550	0.0235	1.70	11.7	6.8	0.31
1.17	22.1	0.615	0.0260	1.75	11.3	7.4	0.34
1.18	21.6	0.682	0.0285	1.80	10.9	8.2	0.37
1.19	21.2	0.750	0.0318	1.85	10.5	8.9	0.40
1.20	20.8	0.816	0.0353	1.90	10.2	9.6	0.44
1.21	20.4	0.90	0.0391	1.95	09.8	10.2	0.47
1.22	20.1	0.98	0.0426	2.00	09.5	11.0	0.50
1.23	19.7	1.08	0.0455	2.10	09.0	12.4	0.57
1.24	19.4	1.15	0.049	2.20	08.6	13.8	0.65
1.25	19.1	1.23	0.053	2.30	08.2	15.3	0.73
1.26	18.8	1.34	0.056	2.40	07.7	16.6	0.80
1.27	18.5	1.43	0.060	2.50	07.3	18.0	0.88
1.28	18.2	1.52	0.064	2.60	07.0	19.5	0.95
1.29	17.9	1.62	0.068	2.70	06.7	20.8	1.03
1.30	17.68	1.71	0.073	2.80	06.5	22.3	1.10
1.31	17.4	1.81	0.078	2.90	06.2	23.7	1.17
1.32	17.2	1.91	0.083	3.00	06.0	24.9	1.25
1.33	17.0	2.02	0.087	3.50	05.1	31.0	1.61
1.34	16.8	2.13	0.092	4.00	04.4	36.0	1.93
1.35	16.53	2.23	0.096	4.50	03.9	40.6	2.27
1.36	16.3	2.33	0.101	5.00	03.5	44.4	2.56
1.37	16.1	2.44	0.106	6.00	02.9	50.8	3.08

SUBELEMENT E0 -- SAFETY [1 exam question -– 1 group]

E0A Safety: amateur radio safety practices; RF radiation hazards; hazardous materials

E0A01
The difference between the radiation produced by radioactive materials and the electromagnetic energy radiated by an antenna is that 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, you must make sure signals from your station are less than the uncontrolled MPE limits.

E0A03
A practical way to estimate whether the RF fields produced by an amateur radio station are within permissible MPE limits would be to 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 each transmitter that produces 5% or more of its maximum permissible exposure limit at accessible locations are responsible for mitigating over-exposure situations

E0A05
One of the potential hazards of using microwaves in the amateur radio bands is the high gain antennas commonly used can result in high exposure levels.

For example a transmitter at 2.5 GHz with a power output of 100 watts and an antenna gain of 12 dB would be the equivalent of 800 watts in the direction the antenna is pointing. Your home microwave oven operates at about this frequency with a power output of around 600 watts. Would you stand in front of your microwave oven with the door open and operating?

E0A06
There are separate electric (E) and magnetic (H) field MPE limits because:
1. The body reacts to electromagnetic radiation from both the E and H fields.,
2. Ground reflections and scattering make the field impedance vary with location.
3. E field and H field radiation intensity peaks can occur at different locations.

E0A07
The "far-field" zone of an antenna is the area where the shape of the antenna pattern is independent of distance.

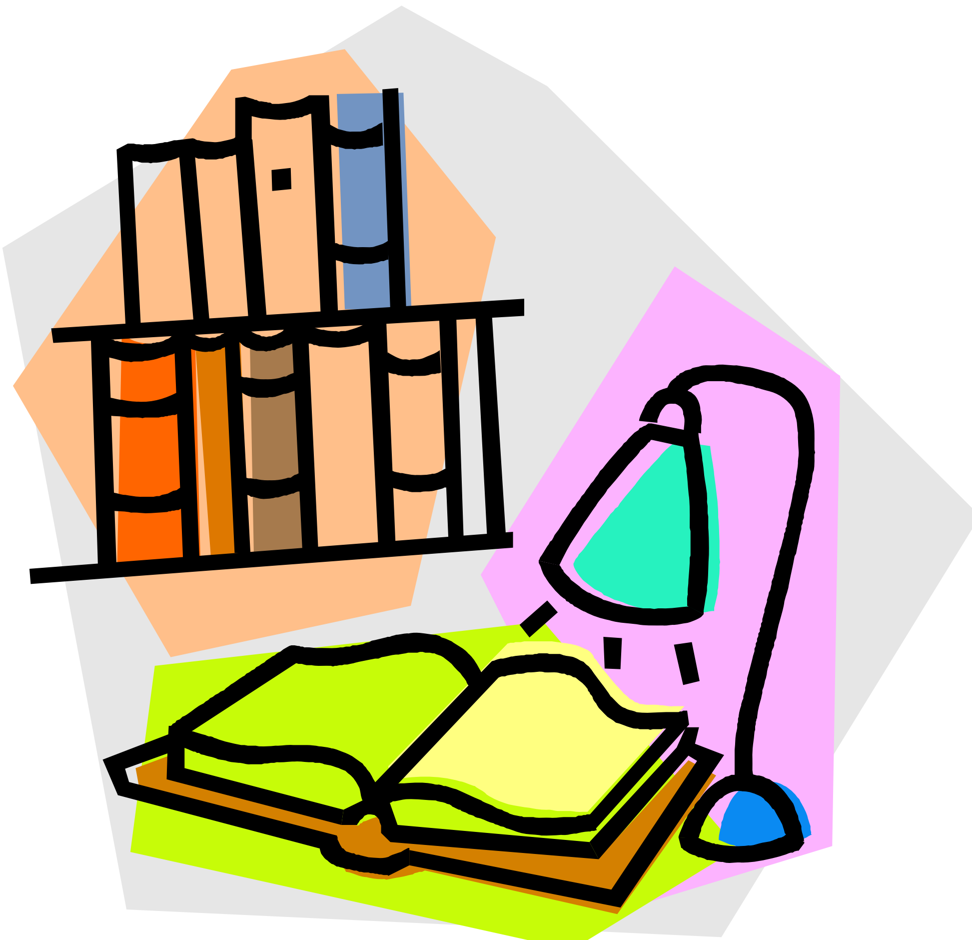
E0A08
SAR (*Specific Absorption Rate)* is a measure of the rate at which RF energy is absorbed by the body.

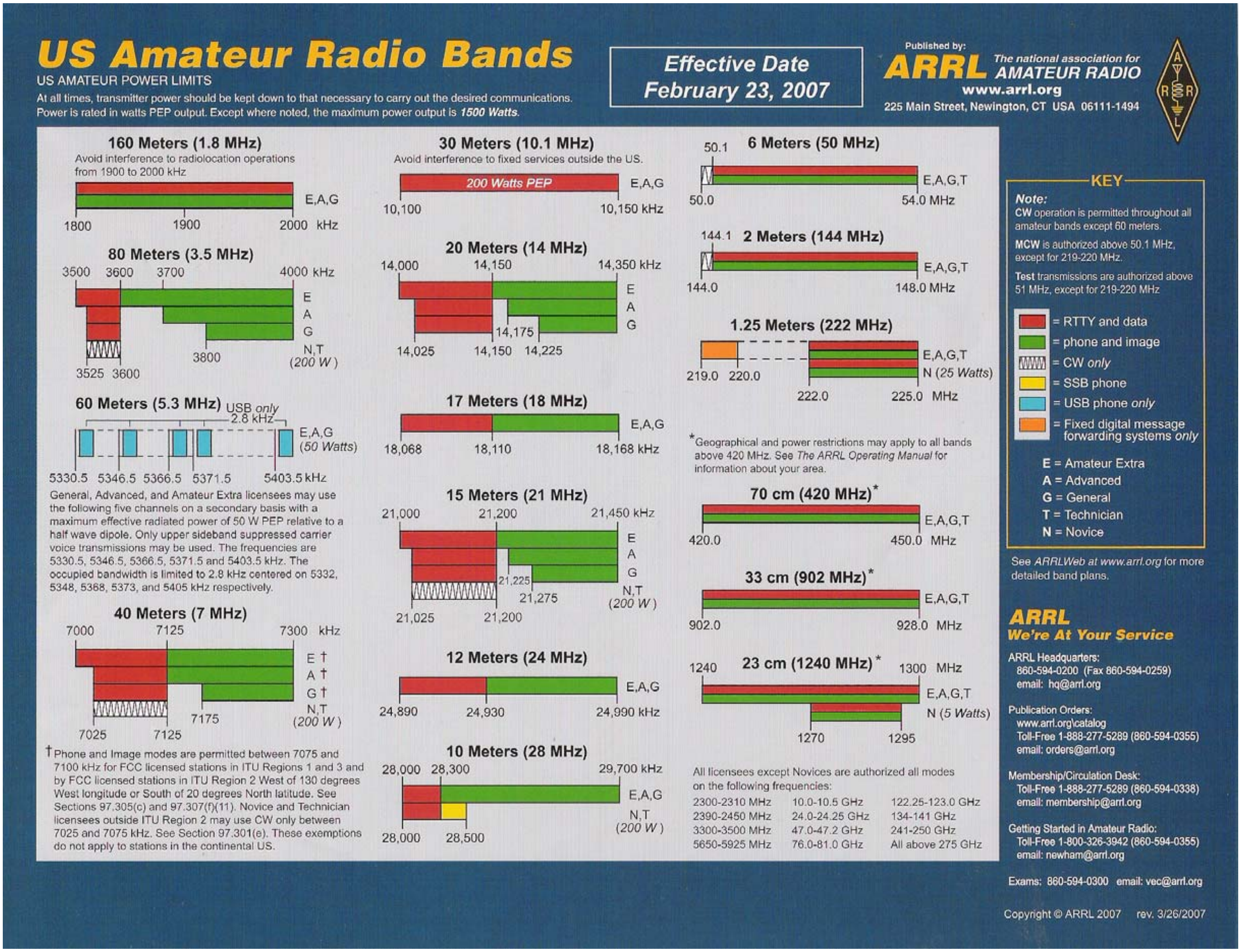
E0A09
Beryllium Oxide, an insulating material commonly used as a thermal conductor for some types of electronic devices, is extremely toxic if broken or crushed and the particles are accidentally inhaled.

E0A10
Polychlorinated biphenyls found in some electronic components, such as high-voltage capacitors and transformers, are considered toxic.

E0A11
Injuries from radiation leaks that exceed the MPE limits are considered a significant hazard when operating a klystron or cavity magnetron transmitter.

REFERENCE MATERIALS




US Amateur Radio Bands
US AMATEUR POWER LIMITS
At all times, transmitter power should be kept down to that necessary to carry out the desired communications. Power is rated in watts PEP output. Except where noted, the maximum power output is 1500 Watts.
Effective Date February 23, 2007
Published by: ARRL The national association for AMATEUR RADIO www.arrl.org
225 Main Street, Newington, CT USA 06111-1494
160 Meters (1.8 MHz)
Avoid interference to radiolocation operations from 1900 to 2000 kHz
E,A,G
1800 1900 2000 kHz
80 Meters (3.5 MHz)
3500 3600 3700 4000 kHz
E A G N,T (200 W)
3525 3600 3800
60 Meters (5.3 MHz) USB only 2.8 kHz
E,A,G (50 Watts)
5330.5 5346.5 5366.5 5371.5 5403.5 kHz
General, Advanced, and Amateur Extra licensees may use the following five channels on a secondary basis with a maximum effective radiated power of 50 W PEP relative to a half wave dipole. Only upper sideband suppressed carrier voice transmissions may be used. The frequencies are 5330.5, 5346.5, 5366.5, 5371.5 and 5403.5 kHz. The occupied bandwidth is limited to 2.8 kHz centered on 5332, 5348, 5368, 5373, and 5405 kHz respectively.
40 Meters (7 MHz)
7000 7125 7300 kHz
E † A † G † N,T (200 W)
7025 7125 7175
† Phone and Image modes are permitted between 7075 and 7100 kHz for FCC licensed stations in ITU Regions 1 and 3 and by FCC licensed stations in ITU Region 2 West of 130 degrees West longitude or South of 20 degrees North latitude. See Sections 97.305(c) and 97.307(f)(11). Novice and Technician licensees outside ITU Region 2 may use CW only between 7025 and 7075 kHz. See Section 97.301(e). These exemptions do not apply to stations in the continental US.
30 Meters (10.1 MHz)
Avoid interference to fixed services outside the US.
200 Watts PEP
E,A,G
10,100 10,150 kHz
20 Meters (14 MHz)
14,000 14,150 14,350 kHz
E A G
14,175
14,025 14,150 14,225
17 Meters (18 MHz)
E,A,G
18,068 18,110 18,168 kHz
15 Meters (21 MHz)
21,000 21,200 21,450 kHz
E A G N,T (200 W)
21,225 21,275
21,025 21,200
12 Meters (24 MHz)
E,A,G
24,890 24,930 24,990 kHz
10 Meters (28 MHz)
28,000 28,300 29,700 kHz
E,A,G N,T (200 W)
28,000 28,500
6 Meters (50 MHz)
50.1
E,A,G,T
50.0 54.0 MHz
2 Meters (144 MHz)
144.1
E,A,G,T
144.0 148.0 MHz
1.25 Meters (222 MHz)
E,A,G,T N (25 Watts)
219.0 220.0 222.0 225.0 MHz
*Geographical and power restrictions may apply to all bands above 420 MHz. See The ARRL Operating Manual for information about your area.
70 cm (420 MHz)*
E,A,G,T
420.0 450.0 MHz
33 cm (902 MHz)*
E,A,G,T
902.0 928.0 MHz
23 cm (1240 MHz)*
1240 1300 MHz
E,A,G,T N (5 Watts)
1270 1295
All licensees except Novices are authorized all modes on the following frequencies:
2300-2310 MHz 10.0-10.5 GHz 122.25-123.0 GHz
2390-2450 MHz 24.0-24.25 GHz 134-141 GHz
3300-3500 MHz 47.0-47.2 GHz 241-250 GHz
5650-5925 MHz 76.0-81.0 GHz All above 275 GHz
KEY
Note:
CW operation is permitted throughout all amateur bands except 60 meters.
MCW is authorized above 50.1 MHz, except for 219-220 MHz.
Test transmissions are authorized above 51 MHz, except for 219-220 MHz
= RTTY and data
= phone and image
= CW only
= SSB phone
= USB phone only
= Fixed digital message forwarding systems only
E = Amateur Extra
A = Advanced
G = General
T = Technician
N = Novice
See ARRLWeb at www.arrl.org for more detailed band plans.
ARRL We're At Your Service
ARRL Headquarters: 860-594-0200 (Fax 860-594-0259) email: hq@arrl.org
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Getting Started in Amateur Radio: Toll-Free 1-800-326-3942 (860-594-0355) email: newham@arrl.org
Exams: 860-594-0300 email: vec@arrl.org
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Extra Exam Help and Review

International System of Units (SI)—Metric Units

Prefix	Symbol	Multiplication Factor	
exe	E	10+18	1,000,000 000,000,000,000
peta	P	10+15	1,000 000,000,000,000
tera	T	10+12	1,000,000,000,000
giga	G	10+9	1,000,000,000
mega	M	10+6	1,000,000
kilo	k	10+3	1,000
hecto	h	10+2	100
deca	da	10+1	10
(unit)		10+0	1
deci	d	10-1	0.1
centi	c	10-2	0.01
milli	m	10-3	0.001
micro	µ	10-6	0.000001
nano	n	10-9	0.000000001
pico	p	10-12	0.000000000001
femto	f	10-15	0.000000000000001
atto	a	10-18	0.000000000000000001

Scientific Notation to component values

Milli	m= .001 or	1x 10^-3
Micro	µ = .000,001 or	1x 10^-6
Nano	n= .000,000,001 or	1 x 10^-9
Pico	p= .000,000,000,001 or	1 x 10^-12
Fempto	f= .000,000,000,000,001 or	1 x 10^-15

Ohms Law

I=E/R	R=E/I	E=I * R	(Amperes – Volts-Ohms)
P=E * I	P= E^2 /R	I= P/E	(amperes-volts-ohms-watts)

Series connected Resistors

R = R1 + R2 + R3 + Rx

Parallel connected Resistors

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \frac{1}{R_x}}$$

Series inductors

Total Inductance = $L_1 + L_2 + L_3 + L_x$

Parallel inductors

$$L = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots \frac{1}{L_x}}$$

Capicators in parallel

$C = C_1 + C_2 + C_3 + C_x$

Capacitors in series

$$C = \cfrac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots \frac{1}{C_x}}$$

Reactance

Reactance is the equivalent AC resistance of a capacitor or inductor at a given frequency

For an inductor, $X_L = 2\pi FL$

$X_L = 2\pi FL$ frequency is in Hertz and Inductance is in Henries. or Mili-Henries and Kilo-Hertz or Micro-Henries and Megahertz

Example 20 mH inductor at 3.5 KHz
XL =2πFL = 6.28 x .02 x 3,500 = 6.28x 70 = 439.8 Ω
OR
XL =2πFL = 6.28 x 20 x 3.5 = 6.28x 70 = 439.8 Ω
OR
XL =2πFL = 6.28 x 20,000 x .0035 = 6.28x 70 = 439.8 Ω

For a capacitor
Reactance (Xc) is equal to 1/ (2π FC) frequency is in Hertz and Capacitance is in Farads. or Microfarads and Megahertz

Example 20 µF Capacitor at 3.5 KHz
Xc =1/(2πFC) = 1/(6.28 x .000,020 x 3,500) = 1/(6.28x .07) = 2.27 Ω
OR
Xc =1/(2πFC) = 1/(6.28 x 20 x .0035) = 1/(6.28 x .7) = 1/.44 = 2.27 Ω

RC Time Constant

TC = C * R farads - ohms or microfarads – megohms

Charge vs number of time constants

Time Constant	% Charge / Discharge
1	63.2
2	86.5
3	95
4	98.2
5	99.3

dB Calculations

Power dB = 10 * LOG (P1/P2) P1 andP2 must be the same i.e.: µWatts. Miliwatts or Watts
Voltage - dB = 20 * LOG (V1/V2) V1 and V2 must be the same i.e.: µvolts. Milivolts or Volts

The following table will allow you to quickly estimate dB gain or loss. The one and two dB values are close enough to get you to the correct answer in the test.

Gain (+)	dB	Loss (-)
x 1.2	1	**80%**
x 1.6	2	**63%**
x 2	3	**50%**
x 4	6	**25%**
x 10	10	**10%**

Noise Figure vs Sensitivity

Noise figure is what the front end amplifier adds to the theoretical noise floor

Theoretical noise floor is -174dBm in a 1HZ bandwidth. For a 500 HZ receiver bandwidth this would be:

Noise Floor

Noise Floor = -174 + 10*Log (500/1) dB or -174dBm +27dB or -147 dBm

If in the Previous example our receiver has a noise figure of 8dB then the smallest signal you could possibly receive would need to be 8 dB larger. :

Noise floor would be -147 dBm + 8 dB or -139 dBm or about .03µV

Blocking dynamic range

The blocking dynamic range of a receiver that has an 8 db noise figure and an IF bandwidth of 500 Hz and a -1 dB compression point of -20dBm is 119 db

Theoretical noise floor for 500 Hz bandwidth is -147dBm

Noise Floor = -174 dBm + (10 log (1/500)))dB
Noise floor = - 174 dBm +(10 log (.002))dB
Noise floor = - 174 dBm +27dB
Noise floor = - 147 dBm

Add the +8 db Noise figure to the noise floor and get the actual noise floor of -139 dBm.

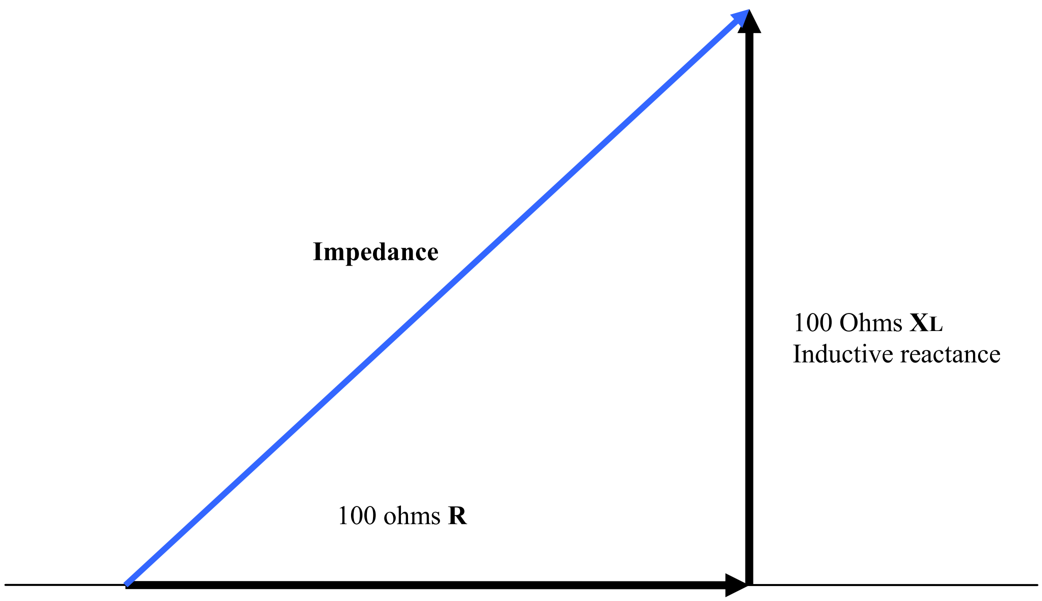
Receiver Noise floor = theoretical noise floor plus noise figure
Receiver Noise floor = -147dBm + 8dB = -139 dBm

Subtracting the – 20 dBm compression point gives us a difference of 119dB which is the Blocking dynamic range.

Blocking Dynamic range = Receiver Noise floor – 1 dBCompression point
Blocking Dynamic range = -139 –(– 20 dB) = -119 dB
Blocking Dynamic range is expressed as a positive number so the answer is 119 dB

For a 2.8 KHz wide receiver the theoretical noise floor with a 5 dB noise figure would be
-174dBm + 10 * LOG (2800/1) + 5 Or -174 + 34.5 + 5 or – 134.5 dB

Impedance of complex series circuits



Series circuit Impedance = ***√(resistance²+ reactance²) = √(10,000+10,000) =√20,000=141.4 Ohms***

Angle = arc tangent =Opposite/Adjacent or arc tangent =100/100 or Arc tangent (1.00) = 45 º

The equation for calculating Impedance given resistance and inductive and/or capacitive reactance is:

Impedance (Z) = $\sqrt{(R^2 + Reactance^2)}$

For a circuit with 53 Ohms of resistance and 25 ohms of reactance (either Inductive or capacitive) it would be:

$Z = \sqrt{[(53)^2 + (15)^2)]} = \sqrt{3034} = 55\Omega$

For a circuit with 35 Ohms resistance, 38 Ohms Inductive reactance 50 Ohms Capacitive Reactance. The resistor value in this problem is 35 ohms and the reactance is 38 (inductance is +) + (- 50ohms) (capacitive reactance is -) or a total reactive value of -12 ohms (capacitive)

$Z = \sqrt{[(35)^2 + (38-50)^2]} = \sqrt{[(35)^2 + (12)^2]} = \sqrt{1369} = 37\ \Omega$

Remember that Impedance is never less than the resistance in the circuit.

Component Q

The Q of a capacitor or inductor can be calculated from the following equations:

Capacitor Q= Capacitive Reactance/ resistance
Inductor Q= Inductive Reactance/ resistance

The Q of a parallel RLC network with a 8.2 µH inductor, R of 1000 Ω with a resonant frequency of 7.125 MHz is 0.23:

$Q = R/Reactance = R/(2\pi FL) = 220/(6.28*3.625*42) = 220/956.6 = 0.230$

The Q of a parallel RLC network with a 42 µH inductor, R of 220 Ω with a resonant frequency of 7.125 MHz is 2.72:

$Q = R/Reactance = R/(2\pi FL) = 1000/(6.28*7.125*8.2) = 1000/367.09 = 2.724$

Effective Radiated Power

Lets take an example with the following characteristics:

- Power output from radio = **50 watts**
- Feed line loss = **- 4dB**
- Duplexer loss = **-2 dB**
- Circulator loss = **- 1dB**
- Antenna Gain =**+ 4 dB**

First we calculate the overall ERP as follows:

ERP=Transmitter Power Out = +((-4)+(-2)+(-=1)+(+4)) = 50 - 3 dB or 25 watts

Resonant circuits

- In any resonant circuit the X L is equal to the XC at resonance
- In a series resonant circuit the impedance at the resonant frequency is zero
- In a parallel resonant circuit the impedance at resonance is ∞
- In a parallel resonant circuit with perfect components once the circuit is energized it will continue to oscillate forever with the capacitor charging the inductor then the inductor charging the capacitor. Since our components are not perfect this will not happen.

Series resonant circuits

Series Resonant Circuits look like a short to the signal source (assuming ideal components) with the only limit on current being the resistance of the components and any external resistance added in series

Series Resonant Frequency is determined by the following equation with Frequency in Hertz, Inductance in Henries and Capacity in farads. (or frequency in kHz, inductance in mH and capacity in µ Henries and µH)

$$FR = \frac{1}{2\pi\sqrt{(LC)}}$$

For a circuit with an inductance of 50 µH and 40 pF

FR = 1/ (2π√(LC)) = 1/(6.28 √(.000050 x .000,000,000,040) = 3,558,812 Hz

or

FR = 1/ (2π√(LC)) = 1/(6.28 √(50 x . 000,040) = 3.559 kHz

Parallel Resonant circuits

Has high output voltage and looks like a high resistance (or in a perfect circuit an open circuit) to the signal source.

Calculating resonant frequency for a parallel inductor and capacitor circuit:

Resonant frequency = 1/ (2π √ (LC))

Let's calculate the resonant frequency for a circuit a circuit with a 10 µH inductor and 300 pf capacitor. Remember that this equation requires the inductance to be in Henries and capacitance in Farads, the resonant frequency answer will be in Hz.

F = 1/ (2π √ (LC)) = 1/ (2 π √ ((10 ↑-6) * (300 ↑-12)) = 1/ (2 π √(30↑-16))

F= 2,900,000 Hz or 2.9 MHz

If you need to determine which L or C component is needed to resonate at a specific frequency, the following equations can be used:

$$L = 1/((2\pi F)^2 C) \quad \textbf{or} \quad C = 1/((2\pi F)^2 L)$$

Calculating Component values for resonance at a specific frequency Capacity in Farads, Inductance in Henries, and Frequency in Hertz (or *frequency in MHz, Inductance in μH and capacity in μF*):

$$C = \frac{1}{(2\pi FR)^2 L} \qquad L = \frac{1}{(2\pi FR)^2 C}$$

Find the capacitor value for:
A resonant frequency of F=3,600,000 Hz (3.6 MHz)
A 20μH (.000,020 H) inductor:

C= 1/(6.28 x 3,600,000)² x 000020 = 1/(.000516) x 20 = 1/ 10,23 = 97.7 ^-12F or 98 pF
Or
C = 1/(6.28 x 3.6)² x 20 = 1/(511.6 x 20) = 1/ 10.23 = 97.7 ^-6 μ F or 98 pF

For 7.3 MHz and 19μH
C = 1/(6.28 x 7.3)² x 19 = 25pF

For 21 MHz and 3 μH
C = 1/(6.28 x 21)² x 3 = 19.1 pF

Finding an Inductor value
For a resonant frequency of 10 MHz with a capacitor of 10 pF

L = 1/(6.28 x 10)² x .000,010 = 1/(39.44 x .000,010 = 1/ .39.44 = 25μH

A resonant frequency of 21 MHz with a capacitor of 7 pF

L = 1/(6.28 x 21)² x .000,007 = 8.21μH

A resonant frequency of 7.3 MHz with a capacitor of 25 pF

L = 1/(6.28 x 7.3)² x .000,025 = 19μH

Resonant Circuit Q
Q for a resonant circuit is a function of the circuit resistance vs the reactance at a given frequency.

For a series circuit Q = XL /R
Example- a circuit with 1000 ohms of inductive reactance and 100 ohms of resistance would be Q = 1000 / 100 or 10

For a parallel circuit Q = Resistance /Reactance
Example a circuit with 500 ohms of Inductive reactance and 100 Ohms
And 10,000 ohms of parallel resistance would be Q = 10,000 / 500 or 20

The bandwidth of the resonant circuit
The 3 dB bandwidth of a resonant circuit is equal to:
Bandwidth = Resonant Frequency / Q
A circuit resonant at 3.5 MHz with a Q of 50 would have a bandwidth of **3,500,000 / 50 or 70 kHz**

A circuit resonant at 25 MHz with a Q of 85 would have a bandwidth of **25,000,000 / 85 or 294 kHz**

A circuit resonant at 7.25 MHz with a Q of 180 would have a bandwidth of **7,250,000 / 180 or 40.3 kHz**

Power Factor

Power Factor is the Cosine of the impedance angle this a number between 1 and 0 and represents a ratio between the real and the apparent power in the circuit

If you know the magnitude of the resistance and Reactance you can determine power factor and real power from their angle as a tangent function (Opposite over Adjacent sides of a right triangle), then determine the cosine function of that angle, this will be the circuit ‘ ***power factor’***

Example 1 - For a circuit with resistance of 50 ohms and a reactance of 19 ohms, you would calculate the power factor as follows:

- Find the tangent function -tangent = opposite/ adjacent = 10 / 50 = .2
- Using a calculator find the angle whose tangent is .2 = 11°
- Using a calculator find the cosine of 11° = .982

Example 2 - For a circuit with resistance of 30 ohms and a reactance of 17 ohms, you would calculate the power factor as follows:

- Find the tangent function -tangent = opposite/ adjacent = 17 / 30 = .567
- Using a calculator find the angle whose tangent is .567 = 29.5°
- Using a calculator find the cosine of 29.5° = .87

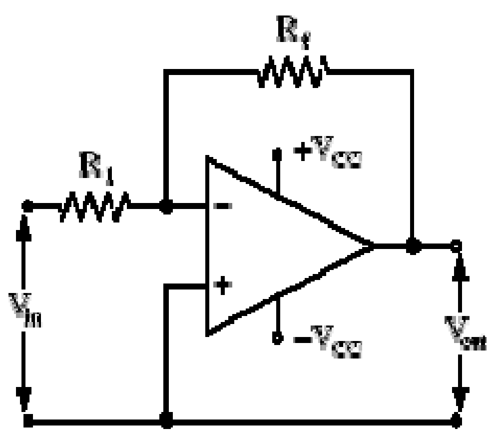
If you know the real and the apparent power you can calculate the power factor directly using the equation:

Power Factor = P real / P apparent

For a circuit with an apparent power of 120VA and a real power of 100 watts the power factor would be 100/120 or .833.

For a circuit with an apparent power of 400VA and a power factor of .2 the real power would be 400 x .2 or 80 Watts

Operational Amplifiers



Gain = Rfedback /Rinput

If the feedback resistor was 100,000 Ω and the input resistor was 1,000 Ω the **gain would be 100,000/1,000 or 100.** Since the input impedance is very high there is no current flowing through Rinput, and the voltage applied is accurately amplified.

AC Voltage Calculations

The RMS (Root Mean Square) value for a sine wave is the value of an equivalent DC voltage required to generate the same amount of power or heat in a resistive load

For a pure sine wave the equivalent **RMS value is .707 times the peak value**. Conversely the **peak voltage can be calculated as 1.414 times the RMS Value.**

The peak voltage for standard 120V RMS AC line voltage is
Peak Voltage = 1.414 x 120V or ~170 volts peak.

The peak to peak would be two times the peak voltage
Voltage Peak to peak = 2 x 170 or 340 Volts pp

An AC voltage that reads 65 volts on an RMS meter will have a peak to peak voltage of **Peak to Peak = 65 x 1.414 x 2 or *~184 Volts.***

The average power dissipated by a 50 ohm resistor during one cycle of voltage with a peak voltage of 35 volts is 12.2 Watts.

P(avge)= E^2 (avge) / R = $(.707 \times 35)^2$ / 50 = 12.2 Watts

FM Modulation

Modulation Index

M index = Deviation /Modulating Frequency

The Modulation Index for a FM phone signal with 3 KHz deviation and a 1 KHz tone would be:

M Index = 3,000/1,000 = 3

From the above equation you can see that Modulation index is independent of the carrier frequency

Deviation Ratio
Deviation Ratio = Maximum Deviation / Maximum modulating frequency

For a FM phone transmission with a ± 5 KHz deviation and a 3 KHz maximum modulating tone the deviation ration would be:

Deviation ratio= 5,000/3,000 = 1.67
Deviation ratio describes a maximum event (max deviations and max audio frequency, while **modulation index describes an instantaneous set of conditions**

Transmitter Power Measurements

The PEP power output for a transmitter with an observed 30 volt peak envelope voltage (as seen on an oscilloscope) would be 9 watts. To determent the PEP power we take the peak voltage and multiply it by >707 to get the Peak RMS voltage then using the Peak RMS voltage we calculate power using the equation P(watts) = $V(RMS)^2$ / R (load)

PEP (watts) = $[V(peak) \times .707]^2$ / Load Resistance

PEP (watts) = $[V(peak) \times .707]^2$ / 50 = $(21.2)^2$/ 50 = 449 / 50 = 9

Amplifier efficiency
Amplifier efficiency is the ratio of power divided by power input times 100%.

Efficiency = P(out) / P(input) x 100

A typical 1500 Watt PEP class B amplifier will require 2500 watts of DC input power (assume 60% efficiency). A typical class A amplifier will be typically 25 to 35% efficient.

P(input) = P(output) / Efficiently = 1500 Watts/.60 = 2500Watts

Transmission lines

The Velocity Factor of a cable is calculated as the Velocity of the wave in the transmission line (coaxial cable) divided by the velocity of light (which is the velocity of the electrical wave in a vacuum).

VF = V (transmission line) / V (light)

Since energy moves slower in a coaxial cable its electrical length will be shorter than the electrical length. A typical velocity for common coaxial cable with a polyethylene dielectric is about .66

The physical length of a typical transmission line (VF= .66) one quarter wavelength long at 14. 1 MHz would be 3.5 Meters.

Physical length (PL)= [Wavelength/4] x Velocity Factor

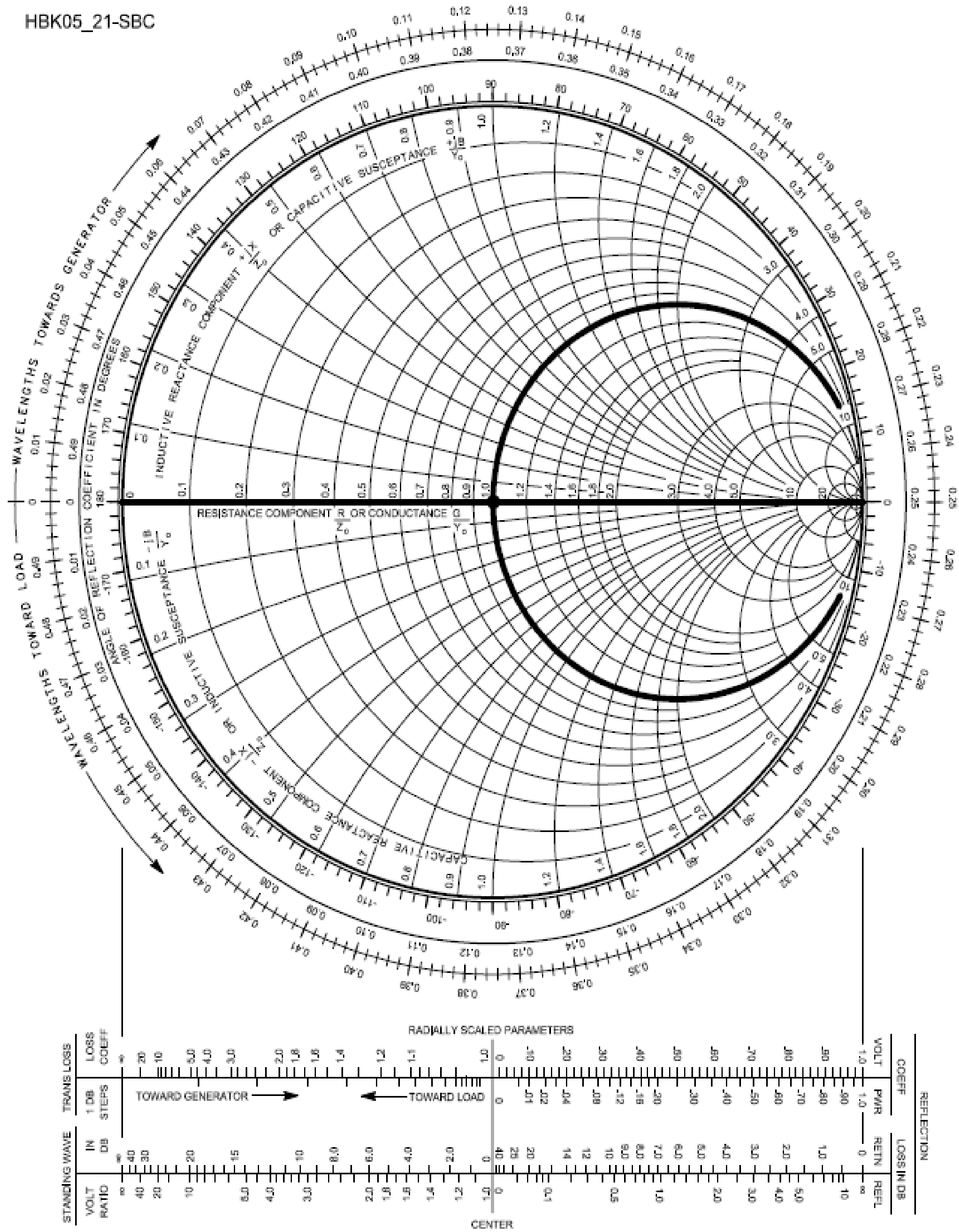
PL= [((300/14.1))/4] x .66 = [5.32] x .66 = 3.5 meters

Coaxial Stubs

Stub Length	¼ wave length	½ wave length
Shorted at far end	High Impedance	Low impedance
Open at far end	Low Impedance	High impedance

Think about it as moving around the Smith Chart which is 1/2 a wavelength all the way around (180 degrees). If we move 90° on the smith chart our transmission line does the opposite of our input, so a short at 90° will appear as an open to the generator (transmitter input) end and an open will look like a short. Moving to ½ wavelength or 180° brings us back to the starting point so there is no opposite transformation, therefore a short at the output will look like a short at the input and an open will look like an open. For partial wavelengths the impedance between 0 and ¼ wavelength the line will look like an inductive reactance and for a ¼ to ½ wavelength the line will look like a capacitive reactance depending on the actual fractional wavelength.

HBK05_21-SBC


WAVELENGTHS TOWARDS GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
INDUCTIVE REACTANCE COMPONENT
OR CAPACITIVE SUSCEPTANCE
CAPACITIVE REACTANCE COMPONENT
OR INDUCTIVE SUSCEPTANCE
RESISTANCE COMPONENT R/Z0 OR CONDUCTANCE G/Y0
RADIALLY SCALED PARAMETERS
TOWARD GENERATOR
TOWARD LOAD
CENTER
TRANS LOGS
LOGS COEFF
1 DB STEPS
STANDING WAVE
IN DB
VOLT RATIO
REFLECTION
VOLT
PWR
COEFF
RETN
REFL
LOGS IN DB