Amateur Radio

Amateur Extra Class License

Study Guide

(For use July 1, 2024 to June 30, 2028)

Compliments of:

Earl Paazig

W8BR

Study Guide is based upon the FCC Exam Element 4 Question Pool for Amateur Extra Class, effective 7/01/2024-6/30/2028 with added and revised material.

Foreword

This document is based upon the publicly available question pool. Specific references to Part 97 are retained throughout. The format intent is to retain as much of the original words from the question pool as possible to leverage familiarization in the learning and memory process. It is designed to pair with an aligned set of PowerPoint Presentations for course instruction.

The 25 most frequently used phrases and terms used in the text are:

amateur	digital	line	phase	RF
antenna	figure	MHz	power	signal
band	filter	noise	propagation	station
circuit	frequency	output	radio	voltage
current	impedance	operating	receiver	wave

The author's hope is that this document might be useful as a resource in studying for the Element 4, Amateur Extra Class License Amateur Radio Exam.

In order to pass the exam, you must correctly answer 37 of 50 questions. While subject to change as the question pool is adjusted, the exam is constructed from the sections of the Question Pool in manner consistent with the following table:

Sub-element	Exam Questions
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Total	50

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SUBELEMENT E1 - COMMISSION RULES [6 Exam Questions - 6 Groups]

E1A Frequency privileges; Signal frequency range

- It is ***not legal*** to transmit a 3 kHz bandwidth USB signal with a carrier frequency of 14.348 MHz because the upper 1 kHz of the signal is outside the 20-meter band. *(Note: 14.348 + 0.003 = 14.351 MHz which is 1kHz above the bend edge.)* [97.305, 97.307(b)]
- When using a transceiver that displays the carrier frequency of phone signals, 3 kHz above the lower band edge represents the lowest frequency at which a properly adjusted LSB emission will be totally within the band. [97.301, 97.305]
- The highest legal carrier frequency on the 20-meter band for transmitting a 2.8 kHz wide USB data signal is 14.1472 MHz. [97.305, 97.307(b)]
- An Extra class operator ***<u>may not</u>*** answer the CQ of a station on 3.601 MHz LSB phone. The sideband components will extend beyond the edge of the phone band segment. [97.301, 97.305]

Stations aboard ships or aircraft

- Any person holding an FCC issued amateur license or who is authorized for alien reciprocal operation must be in physical control of the station apparatus of an amateur station aboard any vessel or craft that is documented or registered in the United States. [97.5]
- If an amateur station is installed aboard a ship or aircraft, its operation must be approved by the master of the ship or the pilot in command of the aircraft before operation. [97.11]
- Any applicable FCC-issued amateur license is required when operating an amateur station aboard a US-registered vessel in international waters. [97.5]

Power restriction on 630- and 2200-meter bands

- The required transmit frequency of a CW signal for channelized 60-meter operation is at the center frequency of the channel**.** [97.303(h)(1)]
- The maximum power permitted on the 2200-meter band is 1-watt EIRP (equivalent isotropic radiated power). [97.313(k)]
- Except in some parts of Alaska, 5 watts EIRP (equivalent isotropic radiated power) is the maximum power permitted on the 630-meter band. [97.313(l)]

Automatic message forwarding

- 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 who is primarily accountable for the rules violation. [97.219]

E1B Station restrictions and special operations

Spurious emissions

- A spurious emission is an emission outside the signal's necessary bandwidth that can be reduced or eliminated without affecting the information transmitted. [97.3]

General operating restrictions

- An acceptable bandwidth for digital voice or slow-scan TV transmissions made on the HF amateur bands is ***3 kHz***. [97.307(f)(2)]
- The amateur station must avoid transmitting during certain hours on frequencies that cause the interference if the FCC places limitations dues to signal causing interference to domestic broadcast reception, assuming that the receivers involved are of good engineering design. [97.121]

Restrictions on station location

- Within ***1 mile*** an amateur station must protect an FCC monitoring facility from harmful interference. [97.13]
- The control operator of a repeater operating in the 70-centimeter band must cease operation or make changes to the repeater that mitigate the interference***,*** if a radiolocation system experiences interference from that repeater. [97.303(b)]
- The National Radio Quiet Zone is an area surrounding the National Radio Astronomy Observatory. [97.3]

Antenna structure restrictions

- You may have to notify the Federal Aviation Administration and register it with the FCC, as required by Part 17 of the FCC rules, if you are erecting an amateur station antenna structure at a site at or near a public use airport. [97.15]
- PRB-1 applies to State and Local zoning regulations. [97.15]
- PRB-1 requires state and local regulations affecting amateur radio antenna size and structures to provide reasonable accommodations of amateur radio be made. [97.15]

RACES operations

- Any FCC-licensed amateur station certified by the responsible civil defense organization for the area served may be operated under RACES rules. [97.407]
- All amateur service frequencies authorized to the control operator are authorized to an amateur station operating under RACES rules. [97.407]

E1C Automatic and remote control

- A station may transmit third party communications while being automatically controlled only when transmitting RTTY or data emissions. [97.221(c)(1), 97.115(c)]
- The maximum permissible duration of a remotely controlled station’s transmissions is 3 minutes, if its control link malfunctions. [97.213]

Band-specific rules & regulations

- ☐ The maximum bandwidth for a data emission on 60 meters is 2.8 kHz. [97.303]
- ☐ After filing a notification with the Utilities Technology Council (UTC), Operators may operate on the 2200-meter or 630-meter band after 30 days, providing they have not been told that their station is within 1 kilometer of PLC systems using those frequencies. [97.303(g)]
- ☐ Operators must inform the Utilities Technology Council (UTC) of their call sign and coordinates of the station before transmitting on the 630- or 2200-meter bands. [97.303(g)]
- ☐ Phone emissions are permitted in the entire 630-meter band. [97.305(c)]

Operating in and communicating with foreign countries

- ☐ Communications must be limited to that incidental to the purpose of the amateur service and remarks of a personal nature when communication is transmitted to amateur stations in foreign countries. [97.117]
- ☐ An International Amateur Radio Permit (IARP) is a permit that allows US amateurs to operate in certain countries of the Americas.
- ☐ You must have a copy of FCC Public Notice DA 16-1048 in order to operate in accordance with CEPT rules in foreign countries, where permitted.
- ☐ The European Conference of Postal & Telecommunications Administrations (CEPT) operating arrangement allows an FCC-licensed US citizen to operate in many European countries, and amateurs from many European countries to operate in the US. [97.5] https://www.arrl.org/cept

HF modulation index limit

- ☐ Below 29.0 MHz, the highest modulation index permitted at the highest modulation frequency for angle modulation 1.0. [97.307]

Spurious emission standards

- ☐ The maximum mean power level for a spurious emission below 30 MHz with respect to the fundamental emission is - 43 dB. [97.307]

E1D Amateur Space and Earth stations

- ☐ The following HF amateur bands, 40 meters, 20 meters, 15 meters, and 10 meters, include allocations for space stations. [97.207]
- ☐ The two (2) meters band is a VHF amateur band having frequencies authorized for space stations. [97.207]
- ☐ The 70 centimeters and 13 centimeters, UHF amateur bands, have frequencies authorized for space stations. [97.207]
- ☐ Any amateur station so designated by the space station licensee are eligible to be telecommand stations of space stations, subject to the privileges of the class of operator license held by the control operator of the station. [97.211]
- ☐ Any amateur station, subject to the privileges of the class of operator license held by the control operator are eligible to operate as Earth stations. [97.209]

Telemetry and telecommand rules; One-way communications

- A space station, beacon station, or telecommand station may transmit one-way communications. [97.207(e), 97.203(g)]
- Telemetry is one-way transmission of measurements at a distance from the measuring instrument. [97.3]
- A space telecommand station may transmit encrypted messages. [97.211(b)]
- A space telecommand station is an amateur station that transmits communications to initiate, modify, or terminate functions of a space station. [97.3(a)(45)]
- The following must be posted at the location of a station being operated by telecommand on or within 50 kilometers of the Earth's surface:
  - A photocopy of the station license
  - A label with the name, address, and telephone number of the station licensee
  - A label with the name, address, and telephone number of the control operator
    (All these choices are correct) [97.213(d)]
- The maximum permitted transmitter output power when operating a model craft by telecommand is 1 watt. [97.215(c)]

Identification of balloon transmissions

- A Call sign is required in the identification transmissions from a balloon-borne telemetry station. [97.119(a)]

E1E Volunteer examiner program

Definitions

- A Volunteer Examiner Coordinator (VEC) is an organization that has entered into an agreement with the FCC to coordinate, prepare, and administer amateur operator license examinations. [97.521]

Qualifications & Accreditation

- To be accredited as a Volunteer Examiner, a VEC must confirm that the VE applicant meets FCC requirements to serve as an examiner. [97.509, 97.525]

Preparation and administration of exams

- Each administering VE is responsible for the proper conduct and necessary supervision during an amateur operator license examination session. [97.509]
- A VE must Immediately terminate the candidate's examination if a candidate fails to comply with the examiner's instructions during an amateur operator license examination. [97.509, 97.511]
- A VE may not administer an examination to relatives of the VE, as listed in the FCC rules. [97.509]
- The penalty for a VE who fraudulently administers or certifies an examination may be revocation of the VE's amateur station license grant and the suspension of the VE's amateur operator license grant. [97.509]

Documentation requirements

- After the administration of a successful examination for an amateur operator license, VEs must submit the application document to the coordinating VEC according to the coordinating VEC instructions. [97.509(m)]
- If an examinee scores a passing grade on all examination elements needed for an upgrade or new license, the VE Team (three VEs) must certify that the examinee is qualified for the license grant and that they have complied with the administering VE requirements. [97.509(i)]
- The VE team must return the application form document to the examinee if the examinee does not pass the exam. [97.509(j)]

Reimbursement

- The Part 97 rules state that VEs and VECs may be reimbursed the following types of out-of-pocket expenses: Preparing, processing, administering, and coordinating an examination for an amateur radio operator license. [97.527]

Question pools

- The VECs are tasked by Part 97 with maintaining the pools of questions for all US amateur license examinations. [97.523]

E1F Miscellaneous rules

Spread spectrum

- Spread spectrum transmissions are only permitted on amateur frequencies above 222 MHz. [97.305]

Canadian amateurs operating in the US

- In the US, persons holding an amateur service license granted by the government of Canada are authorized the operating terms and conditions of the Canadian amateur service license, not to exceed US Amateur Extra class license privileges. [97.107]

External RF power amplifiers

- A dealer may sell an external RF power amplifier capable of operation below 144 MHz if it has not been granted FCC certification if the amplifier is constructed or modified by an amateur radio operator for use at an amateur station. [97.315]
- An external RF power amplifier must satisfy the FCC’s spurious emission standards when operated at the lesser of 1500 watts, or its full output power, if it is to qualify for a grant of FCC certification. [97.317]

Prohibited communications

- Amateur stations may not transmit in the following frequency segments, 420 MHz - 430 MHz, if they are located in the contiguous 48 states and north of Line A. [97.303]
- “Line A” is a line roughly parallel to and south of the border between the US and Canada. [97.3]
- An amateur station may send a message to a business when neither the amateur nor their employer has a pecuniary interest in the communications. [97.113]
- Amateur station communications transmitted for hire or material compensation, except as otherwise provided in the rules, are prohibited. [97.113(c)]
- Messages encoded to obscure their meaning cannot be transmitted over an amateur radio mesh network. [FCC Part 97.113(a)(4)]

Special temporary authority

- The FCC might issue a Special Temporary Authority (STA) to an amateur station to provide for experimental amateur communications. [1.931]

Auxiliary stations

- Only Technician, General, Advanced, or Amateur Extra class operators may be the control operator of an auxiliary station. (Note: This excludes Novice due limited privileges.) [97.201]

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

E2A Amateur radio in space

Amateur satellites

- A Geostationary satellite appears to stay in one position in the sky.

Orbital mechanics

- The direction of an ascending pass for an amateur satellite is from South to North.
- The Keplerian elements are parameters that define the orbit of a satellite.

Satellite operations and hardware

- The characteristics of an inverting linear transponder are:
  - Doppler shift is reduced because the uplink and downlink shifts are in opposite directions
  - Signal position in the band is reversed
  - Upper sideband on the uplink becomes lower sideband on the downlink, and vice versa

    (All these choices are correct)
- An inverting linear transponder processes an upload signal by mixing with a local oscillator signal and the difference product is transmitted.
- A circularly polarized antenna can be used to minimize the effects of spin modulation and Faraday rotation.
- The effective radiated power (ERP) should be limited to a satellite that uses a linear transponder to avoid reducing the downlink power to all other users.
- The purpose of digital store-and-forward functions on an amateur radio satellite is to hold digital messages in the satellite for later download.
- Store-and-forward techniques are used by digital satellites to relay messages.
- The following types of signals can be relayed through a linear transponder:
  - FM and CW
  - SSB and SSTV
  - PSK and packet

    (All these choices are correct.)

Frequencies and modes

- The “mode” of an amateur radio satellite is the satellite’s uplink and downlink frequency bands.
- The letters in a satellite’s mode designator specify the uplink and downlink frequency ranges.
- The terms “L band” and “S band” specify the 23- and 13-centimeter bands.

E2B Television practices

Fast-scan television standards and techniques

- In digital television, a coding rate of 3/4 mean, means 25% of the data sent is forward error correction data.
- A fast-scan, National Television System Committee (NTSC), television frame has 525 horizontal lines.
- An interlaced scanning pattern is generated in a fast-scan (NTSC) television system by scanning odd-numbered lines in one field and even-numbered lines in the next.
- Vestigial sideband reduces the bandwidth while increasing the fidelity of low frequency video components in analog fast-scan TV transmissions.
- Vestigial sideband modulation is amplitude modulation in which one complete sideband and a portion of the other are transmitted.
- Quadrature Amplitude Modulation (QAM) and Quadrature Phase Shift Keying (QPSK) types of modulation are used for amateur television Digital Video Broadcasting – Terrestrial (DVB-T) signals.
- Transmitting on channels shared with cable TV allows commercial analog TV receivers to be used for fast-scan TV operations on the 70-centimeter band.

Slow scan television standards and techniques

- Color information lines are sent sequentially in analog Slow Scan Television (SSTV).
- A SSB receiver can be used to receive and decode SSTV using the Digital Radio Mondiale (DRM) protocol.
- Tone frequency aspect of an analog slow-scan television signal encodes the brightness of the picture.
- The function of the vertical interval signaling (VIS) code sent as part of an SSTV transmission is to identify the SSTV mode being used.
- Specific tone frequencies signal SSTV receiving software to begin a new picture line.

E2C Contest and DX operating

- Amateur radio contesting is generally <u>*excluded*</u> on the 30 meters band.
- During a VHF/UHF contest, you would expect to find the highest level of SSB or CW activity in the weak signal segment of the band, with most of the activity near the calling frequency.
- DX stations often transmit and receive on different frequencies:
  - Because the DX station may be transmitting on a frequency that is prohibited to some responding stations
  - To separate the calling stations from the DX station
  - To improve operating efficiency by reducing interference

    (All these choices are correct)
- You generally identify your station by sending your call sign once or twice when attempting to contact a DX station during a contest or in a pileup.
- Latency indicates the delay between a control operator action and the corresponding change in the transmitted signal.

Remote operation techniques

- No additional indicator is required to be used by US-licensed operators when operating a station via remote control and the remote transmitter located in the US.

Log data format

- The Amateur Data Interchange Format (ADIF) file format is used for exchanging amateur radio log data.
- The Cabrillo format is a standard for submission of electronic contest logs.

Contact confirmation

- The function of a DX QSL Manager is to handle the receiving and sending of confirmations for a DX station.
- The following contacts may be confirmed through the Logbook of The World (LoTW):
  - Special event contacts between stations in the US
  - Contacts between a US station and a non-US station
  - Contacts for Worked All States credit
    (All these choices are correct)

RF network systems

- Frequencies shared with various unlicensed wireless data services can be used for amateur radio mesh networks.
- A wireless router running custom firmware is commonly used to implement an amateur radio mesh network.

E2D Operating methods

Digital modes and procedures for VHF and UHF

- Grid square information replaces signal-to-noise ratio when using the FT8 or FT4 modes in a VHF contest.
- The characteristic of the JT65 mode is it decodes signals with a very low signal-to-noise ratio.
- A multitone AFSK type of modulation is used by JT65.
- The packet path WIDE3-1 designates three digipeater hops are requested with one remaining.

APRS

- APRS technology is used for real-time tracking of balloons carrying amateur radio transmitters.
- The AX.25 digital protocol is used by APRS.
- An unnumbered Information type of packet frame is used to transmit APRS beacon data.
- APRS stations relay data by packet digipeaters.

Earth-Moon-Earth (EME) procedures

- Q65 digital mode is designed for EME communications.
- Time-synchronous transmissions alternating between stations is a method for establishing EME contacts.

Meteor scatter procedures

- MSK144 digital modes is designed for meteor scatter communications.

E2E Operating methods: Digital modes and procedures for HF

- FSK types of modulation are used for data emissions below 30 MHz.
- The difference between direct FSK and audio FSK is direct FSK modulates the transmitter VFO.
- Synchronization of computer clocks synchronizes WSJT-X digital mode transmit/receive timing.
- The "4" in FT4 refers to four-tone continuous-phase frequency shift keying.
- WSPR digital mode does not support keyboard-to-keyboard operation.
- The length of an FT8 transmission cycle is 15 seconds.
- FT8 digital mode has the narrowest bandwidth.
- The Q65 differs from JT65 in that multiple receive cycles are averaged.
- PACTOR HF digital mode can be used to transfer binary files.
- PSK31 HF digital mode uses variable-length character coding.
- ALE stations establish contact by ALE constantly scans a list of frequencies, activating the radio when the designated call sign is received.
- PACTOR IV digital mode has the highest data throughput under clear communication conditions.
- The characteristics of the FST4 mode are:
    - Four-tone Gaussian frequency shift keying
    - Variable transmit/receive periods
    - Seven different tone spacings
      (All these choices are correct)

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

E3A Electromagnetic Waves and Specialized Propagation

- An electromagnetic wave travels at a right angle to the electric and magnetic fields.
- The component fields of an electromagnetic wave are oriented at right angles.
- The index of refraction determines the speed of electromagnetic waves through a medium.

Earth-Moon-Earth (EME) communications

- If the moon is “visible” by both stations, the approximate maximum separation measured along the surface of the Earth between two stations communicating by EME is 12,000 miles.
- A fluttery, irregular fading characterizes libration fading of an EME signal.
- When scheduling EME contacts, the least path loss will occur when the Moon is at perigee.

Meteor scatter

- When a meteor strikes the Earth’s atmosphere, a linear ionized region is formed at the E region of the ionosphere.
- The frequency range of 28 MHz to 148 MHz are most suited for meteor-scatter communications.

Microwave tropospheric and scatter propagation

- A typical range for tropospheric duct propagation of microwave signals is 100 miles to 300 miles.

Auroral propagation

- Severe geomagnetic storms are most likely to result in auroral propagation.
- CW emission mode is best for auroral propagation.

Daily variation of ionospheric propagation

- To continue a long-distance contact when the MUF for that path decreases due to darkness, switch to a lower frequency HF band.
- Atmospheric ducts capable of propagating microwave signals often form over large bodies of water.

Circular polarization

- Circularly polarized electromagnetic waves are waves with rotating electric and magnetic fields.

E3B Transequatorial propagation

- Transequatorial propagation (TEP) is most likely to occur between points separated by 2,000 miles to 3,000 miles over a path perpendicular to the geomagnetic equator.
- The approximate maximum range for signals using transequatorial propagation is 5,000 miles.
- Transequatorial propagation is most likely to occur in the afternoon or early evening.

Long-path propagation

- A path entirely in darkness is most likely to support long-distance propagation on 160 meters.
- Long-path propagation is most frequent on the 40 meters and 20 meters bands.
- For ionospheric HF skip propagation, the effect of lowering a signal's transmitted elevation angle increases the distance covered by each hop.

Ordinary and extraordinary waves

- "Extraordinary" and "ordinary" waves are, independently propagating, elliptically polarized waves created in the ionosphere.

Chordal hop

- The effect of chordal-hop propagation is the signal experiences less loss compared to multi-hop propagation, which uses Earth as a reflector.
- Chordal-hop propagation is successive ionospheric refractions without an intermediate reflection from the ground.

Sporadic-E mechanisms

- Sporadic-E propagation is most likely to occur around the solstices, especially the summer solstice, and between sunrise and sunset.

Ground-wave propagation

- The maximum range of ground-wave propagation decreases when the signal frequency is increased.
- Vertical polarization is supported by ground-wave propagation.

E3C Propagation prediction and reporting

Radio horizon

- The VHF/UHF radio horizon is approximately 15 percent farther than the geographic horizon.

Effects of space-weather phenomena

- Solar flares are a cause of short-term radio blackouts.
- Increasing disturbance of the geomagnetic field is indicated by a rising A-index or K-index.
- The signal paths through the auroral oval are most likely to experience high levels of absorption when the A-index or K-index is elevated.
- The value of Bz (B sub z) represents North-south strength of the interplanetary magnetic field.
- A Southward orientation of Bz (B sub z) increases the likelihood that charged particles from the Sun will cause disturbed conditions.
- Class X indicates the greatest solar flare intensity.
- G5 is the space-weather term for an extreme geomagnetic storm.
- Digital-mode and CW data signals are reported by amateur radio propagation reporting networks.

- The 304A solar parameter measures UV emissions at 304 angstroms, correlated to the solar flux index.
- VOACAP software models HF propagation.
- A coronal mass ejection impact or a solar flare has occurred as indicated by a sudden rise in radio background noise across a large portion of the HF spectrum.

SUBELEMENT E4 - AMATEUR PRACTICES [5 Exam Questions - 5 Groups]

E4A Test equipment: Analog and digital instruments

Spectrum analyzers

- A spectrum analyzer displays on the vertical and horizontal axes, signal amplitude and frequency, respectively.
- A Spectrum analyzer is used to display spurious signals and/or intermodulation distortion products generated by an SSB transmitter.

Antenna analyzers

- An advantage of using an antenna analyzer compared to an SWR bridge is that Antenna analyzers compute SWR and impedance automatically.
- All of the following can be measured with an antenna analyzer:
    - Velocity factor
    - Cable length
    - Resonant frequency of a tuned circuit
      (All these choices are correct)

Oscilloscopes

- Sampling rate of the analog-to-digital converter limits the highest frequency signal that can be accurately displayed on a digital oscilloscope.
- Compensation of an oscilloscope probe is performed by displaying a square wave and the probe is adjusted until the horizontal portions of the displayed wave are as nearly flat as possible.
- The effect of aliasing on a digital oscilloscope when displaying a waveform is a false, jittery low-frequency version of the waveform is displayed.
- A good practice when using an oscilloscope probe is minimize the length of the probe's ground connection.
- The Line trigger mode is most effective when using an oscilloscope to measure a linear power supply’s output ripple.

RF measurements

- The purpose of using a prescaler with a frequency counter is to reduce the signal frequency to within the counter's operating range.
- The following are used to measure SWR:
    - Directional wattmeter
    - Vector network analyzer
    - Antenna analyzer
      (All these choices are correct)

E4B Measurement technique and limitations

Instrument accuracy and performance limitations

- Time base accuracy most affects the accuracy of a frequency counter.
- The significance of voltmeter sensitivity expressed in ohms per volt is the full-scale reading of the voltmeter multiplied by its ohms per volt rating equals the input impedance of the voltmeter.

Measurement of Q

- The bandwidth of the circuit's frequency response can be used to determine the Q of a series-tuned circuit.

S parameters

- The subscripts of S parameters represent the port or ports at which measurements are made.
- The S11 parameter represents input port return loss or reflection coefficient (equivalent to VSWR).
- The S21 parameter is equivalent to forward gain.

Vector network analyzers/Instrument calibration

- A short circuit, open circuit, and 50 ohms test loads are used to calibrate an RF vector network analyzer.
- Filter frequency response can be measured by a two-port vector network analyzer.
- The following can be measured with a vector network analyzer:
    - Input impedance
    - Output impedance
    - Reflection coefficient
      (All these choices are correct)

RF signals

- A power of 75 watts 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 (absorbed by load) = Forward Power - Reflected Power
  Power (absorbed by load) = 100 watts – 25 watts
  Power (absorbed by load) = 75 watts

- To measure intermodulation distortion in an SSB transmitter, modulate the transmitter using two AF signals having non-harmonically related frequencies and observe the RF output with a spectrum analyzer.

E4C Receiver performance

Phase noise

- An effect of excessive phase noise in an SDR receiver's master clock oscillator is it can combine with strong signals on nearby frequencies to generate interference.

Noise floor

- A receiver noise floor of -174 dBm represents the theoretical noise in a 1 Hz bandwidth at the input of a perfect receiver at room temperature.

$Noisefloor_{dBm/Hz}$ $=10 * \log_{10}(k * T * B) + 30dB$

$=10 * \log_{10}((1.38*10^{-23}) * 290^{\circ} * 1\ Hz) + 30$

$= -204.0\ dBW/Hz + 30\ dB$

$= -174.0\ dBm/Hz$

- Increasing a receiver's bandwidth from 50 Hz to 1,000 Hz increases the receiver's noise floor by 13 dB.

Note the difference below. -157 dBm/Hz – (-144 dBm/Hz) = 13 d**B**

Given: 50 Hz	Given: 1000 Hz
$Noisefloor_{dBm/Hz} =10 * \log_{10}(k * T * B) + 30dB$	$Noisefloor_{dBm/Hz} =10 * \log_{10}(k * T * B) + 30dB$
$= 10 * \log_{10}((1.38*10^{-23}) * 290^{\circ} * 50\ Hz) + 30$	$= 10 * \log_{10}((1.38*10^{-23}) * 290^{\circ} * 1000\ Hz) + 30$
= -187.0 dBW/Hz + 30 dB	= -174.0 dBW/Hz + 30 dB
= -157.0 dBm/Hz	= -144.0 dBm/Hz

Noise figure

- The noise figure of a receiver is the ratio in dB of the noise generated by the receiver to the theoretical minimum noise.

$$\frac{\text{Noise Figure}}{1} = \frac{\text{Receiver Noise}}{\text{Theoretical Minimum Noise}}$$

Image rejection

- A good reason for selecting a high IF for a superheterodyne HF or VHF communications receiver is its easier for front-end circuitry to eliminate image responses.

Minimum detectable signal (MDS)

- The MDS of a receiver represents the minimum discernible signal (MDS).

Increasing signal-to-noise ratio and dynamic range

- An advantage of having a variety of receiver bandwidths from which to select is receive bandwidth can be set to match the modulation bandwidth, maximizing signal-to-noise ratio and minimizing interference.

Reciprocal mixing

- Reciprocal mixing is local oscillator phase noise mixing with adjacent strong signals to create interference to desired signals.

Selectivity

- A front-end filter or preselector receiver circuit can be effective in eliminating interference from strong out-of-band signals.
- Capture effect is the term for the suppression in an FM receiver of one signal by another stronger signal on the same frequency.

SDR non-linearity

- An SDR receiver is overloaded when input signals exceed the reference voltage of the analog-to-digital converter.

Use of attenuators at low frequencies

- Input attenuation reduces receiver overload on the lower frequency HF bands with little or no impact on signal-to-noise ratio because atmospheric noise is generally greater than internally generated noise even after attenuation.
- A narrow-band roofing filter affects receiver performance by improving blocking dynamic range by attenuating strong signals near the receive frequency.
- The purpose of the receiver IF Shift control is to reduce interference from stations transmitting on adjacent frequencies.

E4D Receiver performance characteristics

Dynamic range

- Blocking dynamic range of a receiver is the difference in dB between the noise floor and the level of an incoming signal that will cause 1 dB of gain compression.
- Problems caused by poor dynamic range in a receiver causes spurious signals caused by cross modulation and desensitization from strong adjacent signals.

Third-order intercept

- A third-order intercept level of 40 dBm means, with respect to receiver performance, a pair of 40 dBm input signals will theoretically generate a third-order intermodulation product that has the same output amplitude as either of the input signals.
- Odd-order intermodulation products, created within a receiver, of particular interest compared to other products, because odd-order products of two signals in the band being received are also likely to be within the band.

Desensitization

- Desensitization is the reduction in receiver sensitivity caused by a strong signal near the received frequency.
- Insert attenuation before the first RF stage to reduce the likelihood of receiver desensitization.

Preselector

- The purpose of the preselector in a communications receiver it to increase the rejection of signals outside the band being received.

Intermodulation and cross-modulation interference

- The output signals mixing in the final amplifier of one or both transmitters creates intermodulation interference between two repeaters in close proximity.
- A properly terminated circulator at the output of the repeater’s transmitter is used to reduce or eliminate intermodulation interference in a repeater caused by a nearby transmitter.
- Nonlinear circuits or devices cause intermodulation in an electronic circuit.

- Transmitter frequencies 146.34 MHz and 146.61 MHz would create an intermodulation-product signal in a receiver tuned to 146.70 MHz when a nearby station transmits on 146.52 MHz.

  Note: The unwanted signals occur at frequencies corresponding with the sum and difference of two times one signal frequency and a second signal frequency. Only the difference products are close enough to cause significant interference.

  $f_{IMD1} = (2*f_1) - f_2$

  $f_{IMD1} = (2*146.52) – 146.70$

  $f_{IMD1} = 293.04 – 146.70$

  $\mathbf{f_{IMD1} = 146.34\ MHz}$

  $f_{IMD2} = (2*f_2) - f_1$

  $F_{IMD2} + f_1 = 2* f_2$

  $F_{IMD2} = (F_2 + F_1) / 2$

  $F_{IMD2} = (146.70 + 146.52) /2$

  $F_{IMD2} = 293.22 / 2$

  $\mathbf{F_{IMD2} = 146.61\ MHz}$

Sensitivity

- The received signal level with a transmit power of 10 W (+40 dBm), a transmit antenna gain of 6 dBi, a receive antenna gain of 3 dBi, and a path loss of 100 dB is -51 dBm.

  +40dBm + 6dBi + 3dBi – 100db = -51dBm

- A receiver minimum discernible signal of -100 dBm represents a power level of 0.1 picowatts.

  $\mathbf{P_{watts} = 10^{(P(dBm) - 30)/10}}$
  $P_{watts} = 10^{(-100dBm - 30)/10}$
  $P_{watts} = 10^{-130/10}$
  $P_{watts} = 1 * 10^{-13}$
  $P_{watts} = 0.1 * 10^{-12}$
  P = 0.1 picowatts

  Note on prefixes: Nano is 10^{-9} and Pico is 10^{-12}

Link margin

- The link margin is +8dB in a system with a transmit power level of 10 W (+40 dBm), a system antenna gain of 10 dBi, a cable loss of 3 dB, a path loss of 136 dB, a receiver minimum discernable signal of -103 dBm, and a required signal-to-noise ratio of 6 dB.

40dBm + 10dBi - 3dB - 136dB - (-103dBm) - 6dB = +8

E4E Noise and interference

External RF interference

- When using an automatic notch filter (ANF) to remove interfering carriers while receiving CW signals, a problem can occur by removal of the CW signal as well as the interfering carrier.
- A potential cause of local AM broadcast band signals combining to generate spurious signals on the MF or HF bands is nearby corroded metal connections are mixing and reradiating the broadcast signals.
- Switch-mode power supplies can cause interference received as a series of carriers at regular intervals across a wide frequency range.

Electrical and computer noise

- Conducted noise from an automobile battery charging system can be suppressed by installing ferrite chokes on the charging system leads.
- Impulse noise is removed by a noise blanker.
- An undesirable effect can occur when using a noise blanker demonstrated by strong signals may be distorted and appear to cause spurious emissions.
- A type of electrical interference in the form of the appearance of unstable modulated or unmodulated signals at specific frequencies can be caused by computer network equipment

Line noise

- A brute-force AC-line filter, in series with the motor’s power leads, can be used to suppress radio frequency interference from a line-driven AC motor.
- All of the following can create intermittent loud roaring or buzzing AC line interference:
    - Arcing contacts in a thermostatically controlled device
    - A defective doorbell or doorbell transformer inside a nearby residence
    - A malfunctioning illuminated advertising display
    (All these choices are correct)

DSP filtering and noise reduction

- The following types of noise can often be reduced by a digital noise reduction: broadband white noise, Ignition noise, and Power line noise. (All these choices are correct)

Common-mode current

- Common-mode current flows equally on all conductors of an unshielded multiconductor cable.
- Common-mode currents on the shield and conductors can cause shielded cables to radiate or receive interference.

Surge protectors

- A station AC surge protector should be installed on the single point ground panel.

Single point ground panel

- The purpose of a single point ground panel is to ensure all lightning protectors activate at the same time.

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

E5A Resonance and Q

Characteristics of resonant circuits / Series and parallel resonance

- Resonance can cause the voltage across reactance in a series RLC circuit to be higher than the voltage applied to the entire circuit.
- The magnitude of the impedance of a series RLC circuit at resonance is approximately equal to circuit resistance.
- The magnitude of the impedance of a parallel RLC circuit at resonance is approximately equal to circuit resistance.
- The magnitude of the circulating current within the components of a parallel LC circuit at resonance is at a maximum.
- The magnitude of the current at the input of a parallel RLC circuit at resonance is at a minimum.
- The voltage and current are in phase across a series resonant circuit at resonance.
- The resonant frequency of an RLC circuit if R is 22 ohms, L is 50 microhenries, and C is 40 picofarads is 3.56 MHz.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Given: R = 22 ohms, L = 50 microhenries, and C = 40 picofarads

Fr = 1 / (2 * pi * Sqrt(L*C))

Fr = 1 / (2 * 3.14159 * Sqrt (50 microhenries * 40 picofarads))

Fr = 1 / (6.283185 * Sqrt (50 * 10^{-6} * 40 * 10^{-12}))

Fr = 1 / (6.283195 * Sqrt (2000 * 10^{-18}))

Fr = 1 / (6.283195 * 4.47213595^{-8})

Fr = 1 / 2.80993^{-7}

Fr = 3,558,807 Hz

Fr = 3.56 MHz

- The resonant frequency of an RLC circuit if R is 33 ohms, L is 50 microhenries, and C is 10 picofarads is 7.12 MHz.

  Given: R = 33 ohms, L = 50 microhenries, and C = 10 picofarads

  $$f_r = \frac{1}{2\pi\sqrt{LC}}$$

  Fr = 1 / (2 * pi * Sqrt(L*C))

  Fr = 1 / (2 * 3.14159 * Sqrt (50 microhenries * 10 picofarads))

  Fr = 1 / (6.283185 * Sqrt (50 * 10^{-6} * 10 * 10^{-12}))

  Fr = 1 / (6.283195 * Sqrt (500 * 10^{-18}))

  Fr = 1 / (6.283195 * 2.236067977^{-8})

  Fr = 1 / 1.404965^{-7}

  Fr = 7,117,614 Hz

  Fr = 7.12 MHz

Definitions and effects of Q

- The result of increasing the Q of an impedance-matching circuit is matching bandwidth is decreased.
- An effect of increasing Q in a series resonant circuit is internal voltages increase.
- The Q of an RLC parallel resonant circuit calculated as Resistance divided by the reactance of either the inductance or capacitance.

$$Q = \frac{R}{X_T}$$

Half-power bandwidth

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

Given: F_r = 7.1 MHz and Q = 150

Half-Power Bandwidth (B_{hp}) = Resonant Frequency (F_r) / Circuit Q

Half-Power Bandwidth (B_{hp}) = 7.1 MHz / 150

Half-Power Bandwidth (B_{hp}) = 0.047333 MHz

Half-Power Bandwidth (B_{hp}) = 47.3 kHz

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

Given: F_r = 3.7 MHz and Q = 118

Half-Power Bandwidth (B_{hp}) = Resonant Frequency (F_r) / Circuit Q

Half-Power Bandwidth (B_{hp}) = 3.7 MHz / 118

Half-Power Bandwidth (B_{hp}) = 0.0313559 MHz

Half-Power Bandwidth (B_{hp}) = 31.4 kHz

E5B Time constants and phase relationships

RL and RC time constants

- **One time constant** is the time required for the capacitor in an RC circuit to be charged to 63.2% of the applied voltage or to discharge to 36.8% of its initial voltage.
- The time constant of a circuit having two 220-microfarad capacitors and two 1-megohm resistors, all in parallel is 220 seconds.

C_T = C1 + C2 = 220 uF + 220 uF = <u>$440 * 10^{-6}$ Farads or 440 microfarads</u>

$R_T = (R1*R2)/(R1+R2)$

$R_T = (1 * 10^{6} * 1 * 10^{6}) / (1 * 10^{6} + 1 * 10^{6})$

$R_T = (1 * 10^{12}) / (2 * 10^{6})$

$R_T = (1 * 10^{6}) / 2$

R_T = <u>$0.5 * 10^{6}$ or 500,000 ohms</u>

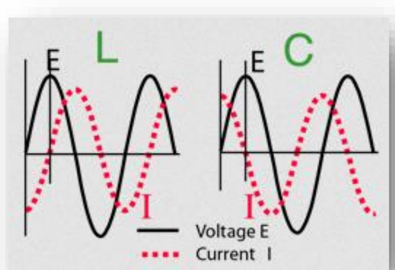
$TC = 0.5 * 10^{6} * 440 * 10^{-6}$

TC = 0.5 * 440 = <u>220 seconds</u>

$$TC = R * C$$

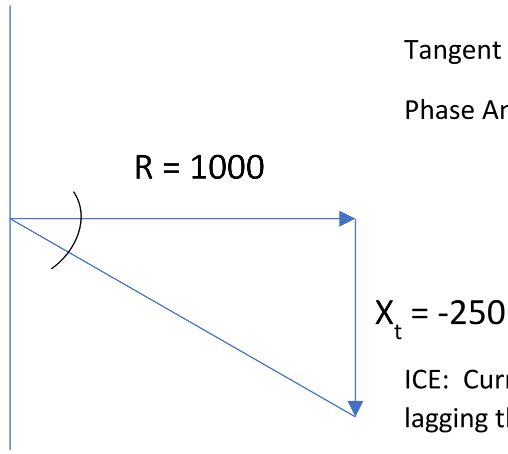
Phase angle in reactive circuits and components

- Impedance in polar form is converted to an equivalent admittance by taking the reciprocal of the magnitude and change the sign of the angle.
- The relationship between the AC current through a capacitor and the voltage across a capacitor is current leads voltage by 90 degrees. ICE
- The relationship between the AC current through an inductor and the voltage across an inductor is voltage leads current by 90 degrees. ELI



☐ The phase angle between the voltage across and the current through a series RLC circuit if XC is 500 ohms, R is 1 kilohm, and XL is 250 ohms is 14.0 degrees with the voltage lagging the current.

Given: $X_c = 500$, $X_L = 250$, and $R = 1000$ **Remember: ELI the ICE man**
$X_t = X_L – X_c = 250 – 500 = -250$



Tangent of Angle = (Opposite side / Adjacent Side)

Phase Angle = inverse tangent (Opposite side / Adjacent side)

$= \tan^{-1}(-250/1000)$

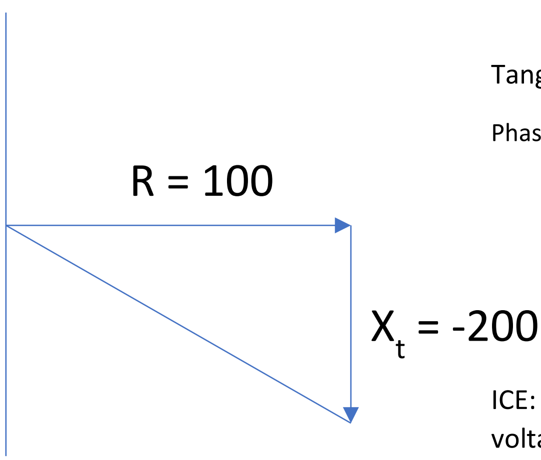
$= \tan^{-1}(-0.25)$

= -14.0 degrees

ICE: Current is leading voltage, or as otherwise stated, voltage is lagging the current.

☐ The phase angle between the voltage across and the current through a series RLC circuit if XC is 300 ohms, R is 100 ohms, and XL is 100 ohms is 63 degrees with the voltage lagging the current.

Given: $X_c = 300$, $X_L = 100$, and $R = 100$
Remember: ELI the ICE man
$X_t = X_L – X_c = 100-300 = -200$



Tangent of Angle = (Opposite side / Adjacent Side)

Phase Angle = inverse tangent (Opposite side / Adjacent side)

$= \tan^{-1}(-200/100)$

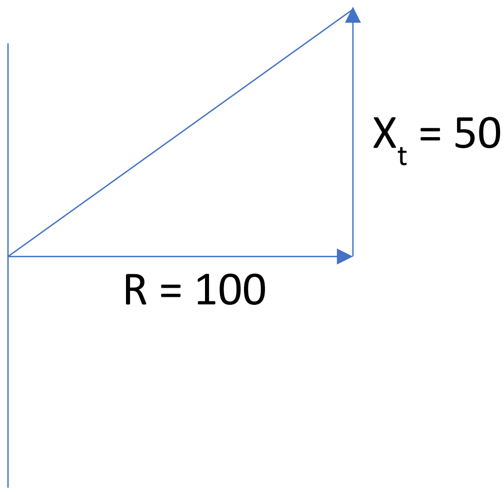
$= \tan^{-1}(-2.0)$

= -63.4 degrees

ICE: Current is leading voltage or as otherwise stated, voltage is lagging the current.

- 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 75 ohms is 27 degrees with the voltage leading the current.

  Given: X_c = 25, X_L = 75, and R = 100
  Remember: E<u>L</u>I the I<u>C</u>E man
  $X_t = X_L – X_c$ = 75-25 = 50



Tangent of Angle = (Opposite side / Adjacent Side)

Phase Angle = inverse tangent (Opposite side / Adjacent side)

= $\tan^{-1}$ (50/100)

= $\tan^{-1}$ (0.5)

= 26.6 degrees

ELI: Voltage is leading the current.

Admittance and susceptance

- The letter ‘B’ is commonly used to represent susceptance.
- The effect on the magnitude of pure reactance when it is converted to susceptance is that it is replaced by its reciprocal.
- Susceptance is the imaginary part of admittance.
- Admittance is the inverse of impedance.

E5C Coordinate systems and phasors in electronics

Polar coordinates

- Impedances are described in polar coordinates by magnitude and phase angle.
- A positive 90-degree phase angle represents a pure inductive reactance in polar coordinates.
- A Polar coordinate system is often used to display the phase angle of a circuit containing resistance, inductive, and/or capacitive reactance.

Phasors

- A Phasor diagram is used to show the phase relationship between impedances at a given frequency.

Logarithmic axes

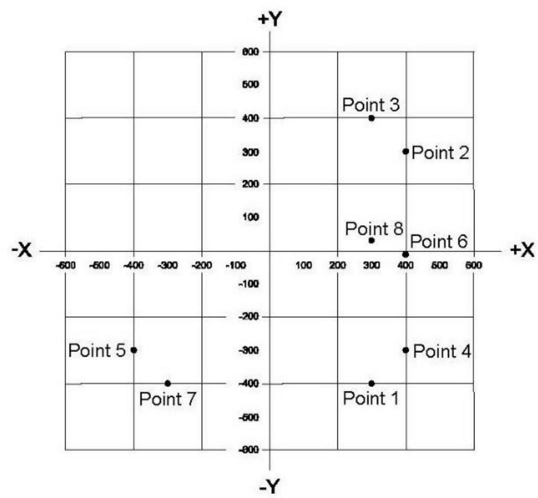
- A Logarithmic type of Y-axis scale is most often used for graphs of circuit frequency response.

Rectangular coordinates

- In rectangular notation, 0 - j100 represents pure capacitive reactance of 100 ohms.
- The impedance 50 - j25 ohms represents 50 ohms resistance in series with 25 ohms capacitive reactance.
- The impedance of a pure resistance is plotted on the horizontal axis of rectangular coordinates.
- When using rectangular coordinates to graph the impedance of a circuit, the X axis represents the resistive component, and the Y axis represents the reactive component.

- Point 1 on Figure E5-1 best represents the impedance of a series circuit consisting of a 300-ohm resistor and a 19-picofarad capacitor at 21.200 MHz.
- Point 3 in Figure E5-1 best represents the impedance of a series circuit consisting of a 300-ohm resistor and an 18-microhenry inductor at 3.505 MHz.
- Point 4 on Figure E5-1 best represents the impedance of a series circuit consisting of a 400-ohm resistor and a 38-picofarad capacitor at 14 MHz.

Figure E5-1



$$X_L = 2\Pi FL$$

$$X_C = \frac{1}{2\Pi FC}$$

Math Example for Point 4

Given: C = 38 pF, R = 400 and F = 14 MHz

Xc = 1/ (2 *Pi * F * C)

Xc = 1 / (2 * 3.14159 * 14 * 10^{6} * 38 * 10^{-12}

Xc = 1 / (3,342.65176 * 10^{-6})

Xc = 1 / 0.00334265176

Xc = 299.16

The calculation verification for Point 1 and Point 3 are left to you.

E5D RF effects in components and circuits

Skin effect

- The result of conductor skin effect is resistance increases as frequency increases because RF current flows closer to the surface.
- Skin effect is the primary cause of loss in film capacitors at RF.

Real and reactive power

- Reactive power is Wattless, nonproductive power.
- The phase relationship between current and voltage for reactive power is 90 degrees out of phase.
- In ideal inductors and capacitors, energy is stored in magnetic or electric fields, but reactive power is not dissipated.
- The real power consumed in a circuit consisting of a 100-ohm resistor in series with a 100-ohm inductive reactance drawing 1 ampere is 100 watts.

Given: R = 100 ohms, X_L = 100 ohms, I = 1 ampere

$P = I^2 * R$

P = 1 * 1 * 100

P = 100 watts

Electrical length of conductors

- It is important to keep lead lengths short for components used in circuits for VHF and above to minimize inductive reactance.
- Short connections are used at microwave frequencies to reduce phase shift along the connection.
- A parasitic characteristic, Inductance, causes electrolytic capacitors to be unsuitable for use at RF.
- A parasitic characteristic, Inter-turn capacitance, creates an inductor’s self-resonance.
- The component’s nominal and parasitic reactance combines to create the self-resonance of a component.
- As a conductor’s diameter increases, its electrical length increases.

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

E6A Semiconductor materials and devices

Semiconductor materials

- Gallium arsenide is used as a semiconductor material in microwave circuits.
- N-type semiconductor materials contains excess free electrons.
- Acceptor impurity is the name given to an impurity atom that adds holes to a semiconductor crystal structure.
- A PN-junction diode does not conduct current when reverse biased due to Holes in P-type material and electrons in the N-type material are separated by the applied voltage, widening the depletion region.

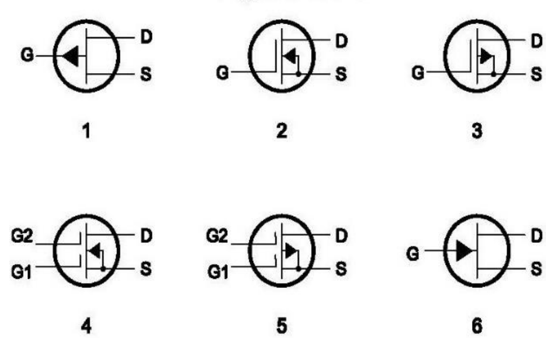
Bipolar junction transistors

- The beta of a bipolar junction transistor is the change in collector current with respect to the change in base current.
- A silicon NPN junction transistor is biased on with a Base-to-emitter voltage of approximately 0.6 volts to 0.7 volts.
- Alpha cutoff frequency is the term for the frequency at which the grounded-base current gain of a bipolar junction transistor has decreased to 0.7 of the gain obtainable at 1 kHz.

Operation and types of field-effect transistors

- A field-effect transistor (FET) has higher DC input impedance at the gate of a FET compared with that of a bipolar transistor.
- A depletion-mode field-effect transistor (FET) is an FET that exhibits a current flow between source and drain when no gate voltage is applied.
- The purpose of connecting Zener diodes between a MOSFET gate and its source or drain is to protect the gate from static damage.
- In Figure E6-1, schematic symbol 1 is for a P-channel junction FET.
- In Figure E6-1, schematic symbol 4 is for an N-channel dual-gate MOSFET.

Figure E6-1

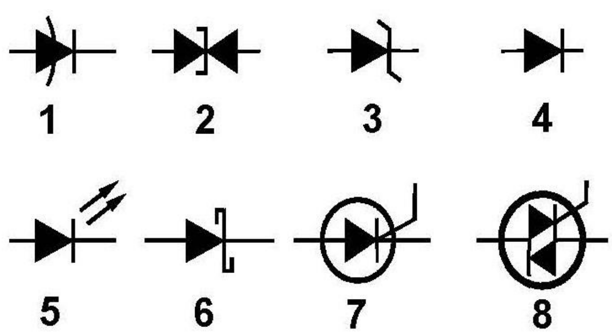


E6B Diodes

- The most useful characteristic of a Zener diode is a constant voltage drop under conditions of varying current.
- The Band Gap property of an LED's semiconductor material determines its forward voltage drop.
- A Varactor diode type of semiconductor device is designed for use as a voltage-controlled capacitor.
- Low junction capacitance of a PIN diode makes it useful as an RF switch.
- Forward DC bias current is used to control the attenuation of RF signals by a PIN diode.
- Excessive junction temperature causes a junction diode to fail from excessive current.
- A common use for point-contact diodes is as an RF detector.

- A common use of a Schottky diode is as a VHF/UHF mixer or detector.
- The lower forward voltage drop characteristic of a Schottky diode makes it a better choice than a silicon junction diode for use as a power supply rectifier.
- Metal-semiconductor junction is a Schottky barrier diode.
- In Figure E6-2, schematic symbol 6 is for a Schottky diode.

Figure E6-2



E6C Digital ICs

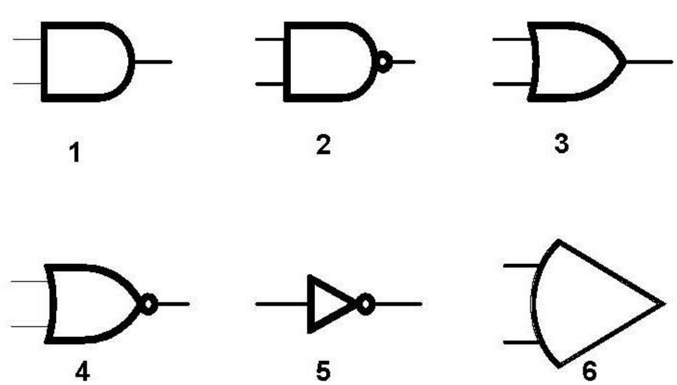
Families of digital ICs

- The function of hysteresis in a comparator is to prevent input noise from causing unstable output signals.
- When the level of a comparator's input signal crosses the threshold voltage the comparator changes its output state.
- Tri-state logic are logic devices with 0, 1, and high-impedance output states.
- An advantage of BiCMOS logic is it has the high input impedance of CMOS and the low output impedance of bipolar transistors.
- CMOS digital logic has the lowest power consumption.
- CMOS digital integrated circuits have high immunity to noise on the input signal or power supply due to the input switching threshold is about half the power supply voltage.
- A pull-up or pull-down resistor is best described as a resistor connected to the positive or negative supply used to establish a voltage when an input or output is an open circuit.

Gates

- In Figure E6-3, the schematic symbol 2 is for a NAND gate.
- In Figure E6-3, the schematic symbol 4 is for a NOR gate.
- In Figure E6-3, the schematic symbol 5 is for the NOT operation (inversion).

Figure E6-3



Programmable logic devices

- Hardware description language (HDL) is used to design the configuration of a field-programmable gate array (FPGA).

E6D Inductors and piezoelectricity

Permeability

- Permeability is the core material property that determines the inductance of an inductor.

Core material and configuration

- Cores of inductors and transformers sometimes constructed of thin layers to reduce power loss from eddy currents in the core.
- Ferrite and powdered iron compare for use in an inductor core in that ferrite cores generally require fewer turns to produce a given inductance value.
- Powdered iron materials have the highest temperature stability of its magnetic characteristics.
- Ferrite beads are commonly used as VHF and UHF parasitic suppressors at the input and output terminals of a transistor HF amplifier.
- A primary advantage of using a toroidal core instead of a solenoidal core in an inductor is toroidal cores confine most of the magnetic field within the core material.
- Brass core material decreases inductance when inserted into a coil.
- Operation at excessive magnetic flux causes inductor saturation.

Transformers

- Magnetizing current is the current that flows in the primary winding of a transformer when there is no load on the secondary winding.

Piezoelectric devices

- Piezoelectricity is a characteristic of materials that generate a voltage when stressed and that flex when a voltage is applied.
- An aspect of the piezoelectric effect is a mechanical deformation of material due to the application of a voltage.
- The equivalent circuit of a quartz crystal is a series RLC in parallel with a shunt C representing electrode and stray capacitance.

E6E Semiconductor materials and packages for RF use

- Gallium arsenide (GaAs) is useful for semiconductor devices operating at UHF and higher frequencies due to higher electron mobility.
- Gallium nitride material supports the highest frequency of operation when used in MMICs.
- The most common input and output impedance of MMICs is 50 ohms.
- Noise figure values of 0.5db is typical of a low-noise UHF preamplifier.
- Controlled gain, low noise figure, and constant input and output impedance over the specified frequency range are characteristics of MMICs making them a popular choice for VHF through microwave circuits.
- Microstrip transmission lines are often used for connections to MMICs.
- Power is supplied to the most common type of MMIC through a resistor and/or RF choke connected to the amplifier output lead.
- Surface Mount component package types have the least parasitic effects at frequencies above the HF range.
- Surface-mount technology offers advantages at RF compared to using through-hole components such as:
    - Smaller circuit area
    - Shorter circuit board traces
    - Components have less parasitic inductance and capacitance
      (All these choices are correct)
- DIP device packages are a through-hole type.
- A characteristic of DIP packaging used for integrated circuits is two rows of connecting pins on opposite sides of package (dual in-line package).
- DIP through-hole package ICs are not typically used at UHF and higher frequencies due to excessive lead length.

E6F Electro-optical technology

Photoconductivity

- Resistance decreases when light shines on a photoconductive material.
- Crystalline semiconductor materials are most commonly used to create photoconductive devices.

Photovoltaic devices

- Electrons absorb the energy from light falling on a photovoltaic cell.
- The photovoltaic effect is the conversion of light to electrical energy.
- The efficiency of a photovoltaic cell is the relative fraction of light that is converted to current.
- The approximate open-circuit voltage produced by a fully illuminated silicon photovoltaic cell is 0.5 volts.

Optical sensors and encoders

- An optical shaft encoder is a device that detects rotation by interrupting a light source with a patterned wheel.
- Silicon is the most common material used in power-generating photovoltaic cells.

Optically isolated switching

- The most common configuration of an optoisolator or optocoupler is an LED and a phototransistor.
- A solid-state relay is a device that uses semiconductors to implement the functions of an electromechanical relay.
- Optoisolators are often used in conjunction with solid-state circuits that control 120 VAC circuits because optoisolators provide an electrical isolation between a control circuit and the circuit being switched.

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

E7A Digital circuits

Digital circuits principles and logic circuits

- A flip-flop circuit is bistable.
- A flip-flop can divide the frequency of a pulse train by 2.
- A decade counter produces one output pulse for every 10 input pulses.
- An astable multivibrator circuit continuously alternates between two states without an external clock signal.
- A characteristic of a monostable multivibrator is it switches temporarily to an alternate state for a set time.

Classes of logic elements

- A NAND gate performs a logical operation by producing a 0 at its output only if all inputs are 1.
- An OR gate performs a logical operation by producing a 1 at its output if any input is 1.
- A two-input exclusive NOR gate performs a logical operation by producing a 0 at its output if one and only one of its inputs is 1.

Positive and negative logic

- A “positive logic” means, in reference to logic devices, a high voltage represents a 1, low voltage a 0.

Frequency dividers

- Four (4) flip-flops are required to divide a signal frequency by 16.

Truth tables

- A truth table is a list of inputs and corresponding outputs for a digital device.

E7B Amplifiers

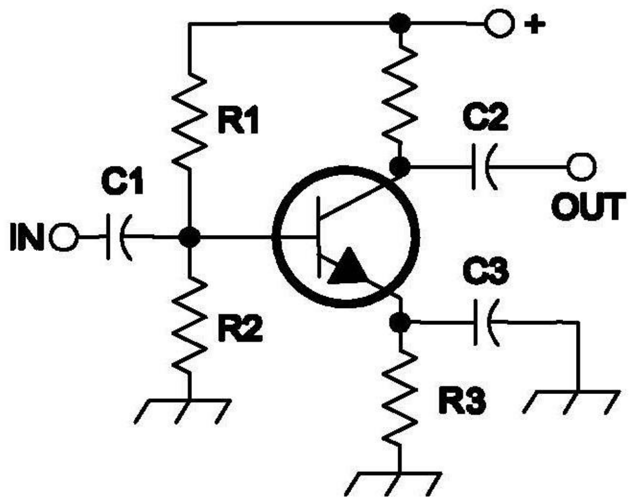
Class of operation

- Each active element in a push-pull, Class AB amplifier conducts more than 180 degrees but less than 360 degrees of the signal cycle.
- A Class D amplifier is an amplifier that uses switching technology to achieve high efficiency.
- The operating point of a Class A common emitter amplifier is approximately halfway between saturation and cutoff.

Vacuum tube and solid-state circuits

- A characteristic of a grounded-grid amplifier is low input impedance.
- A characteristic of an emitter follower (or common collector) amplifier is the input and output signals in-phase.
- A common emitter type of amplifier circuit is shown in Figure E7-1.
- In Figure E7-1, the purpose of R1 and R2 is Voltage divider bias.
- In Figure E7-1, the purpose of R3 is Self bias.

Figure E7-1



Distortion and intermodulation

- Signal distortion and excessive bandwidth is the likely result of using a Class C amplifier to amplify a single-sideband phone signal.

Spurious and parasitic suppression

- Install parasitic suppressors and/or neutralize the stage to prevent unwanted oscillations in an RF power amplifier.

Switching-type amplifiers

- A filter to remove harmonic content is required at the output of an RF switching amplifier.
- Switching amplifiers are more efficient than linear amplifiers due to the switching device is at saturation or cutoff most of the time.

E7C Filters and matching networks

Types of networks

- The capacitors and inductors of a low-pass filter Pi-network arranged between the network's input and output so that a capacitor is connected between the input and ground, another capacitor is connected between the output and ground, and an inductor is connected between the input and output.
- The frequency response of a T-network with series capacitors and a shunt inductor is High-pass.
- The purpose of adding an inductor to a Pi-network to create a Pi-L-network is greater harmonic suppression.
- A Pi-L network is a Pi-network with an additional output series inductor.

Types of filters / Filter Applications & Characteristics

- A helical filter is most frequently used as a band-pass or notch filter in VHF and UHF transceivers.
- A crystal lattice is a filter for low-level signals made using quartz crystals.
- A cavity filter is used in a 2-meter band repeater duplexer.
- A Chebyshev filter type has ripple in the passband and a sharp cutoff.
- The characteristics of an elliptical filter is extremely sharp cutoff with one or more notches in the stop band.
- Shape factor measures a filter's ability to reject signals in adjacent channels.

Impedance matching

- An impedance-matching circuit transforms a complex impedance to a resistive impedance by cancelling the reactive part of the impedance and changes the resistive part to the desired value.

E7D Power supplies

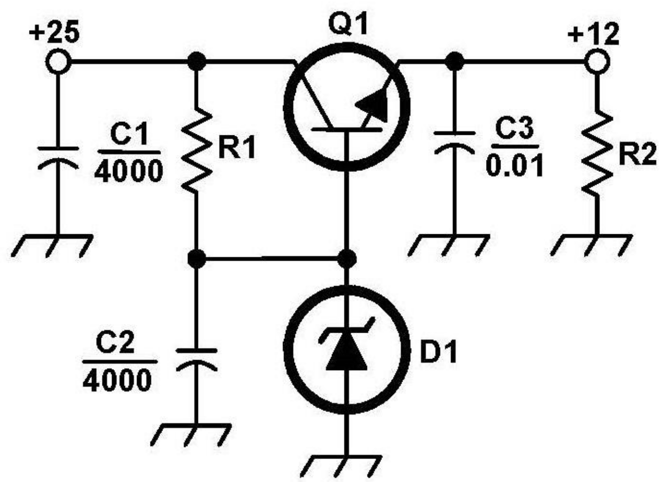
- A switching type power supply is less expensive and lighter than an equivalent linear power supply due to the high frequency inverter design uses much smaller transformers and filter components for an equivalent power output.
- The purpose of a step-start circuit in a high-voltage power supply is to allow the filter capacitors to charge gradually.

Voltage regulators

- A switch-mode voltage regulator works by varying the duty cycle of pulses input to a filter.
- A Zener diode is used as a stable voltage reference.
- A series regulator describes a three-terminal voltage regulator.
- A shunt regulator type of linear voltage regulator operates by loading the unregulated voltage source.
- A linear electronic voltage regulator works in that the conduction of a control element is varied to maintain a constant output voltage.
- The dropout voltage of a linear voltage regulator is the minimum input-to-output voltage required to maintain regulation.

- The power dissipated by a series linear voltage regulator is calculated by the voltage difference from input to output multiplied by output current.
- The purpose of connecting equal-value resistors across power supply filter capacitors connected in series is to:
  - Equalize the voltage across each capacitor
  - Discharge the capacitors when voltage is removed
  - Provide a minimum load on the supply
    (All these choices are correct)
- The purpose of Q1 in the circuit shown in Figure E7-2 is to control the current to keep the output voltage constant.
- The purpose of C2 in the circuit shown in Figure E7-2 is it bypasses rectifier output ripple around D1.
- A linear voltage regulator circuit is shown in Figure E7-2.

Figure E7-2



Solar array charge controllers

- Battery operating time is calculated as capacity in amp-hours divided by average current.
- The purpose of an inverter connected to a solar panel output is to convert the panel's output from DC to AC.

E7E Modulation and demodulation

- The term "baseband" in radio communications is the frequency range occupied by a message signal prior to modulation.
- A pre-emphasis network is added to an FM speech channel to boost the higher audio frequencies.

Reactance

- Reactance modulation of a local oscillator can be used to generate FM phone signals.
- The function of a reactance modulator is to produce PM or FM signals by varying a capacitance.

Phase

- De-emphasis is used in FM communications receivers for compatibility with transmitters using phase modulation.

Balanced modulators

- One way to produce a single-sideband phone signal is to use a balanced modulator followed by a filter.

Detectors

- A frequency discriminator is a circuit for detecting FM signals.
- A diode envelope detector functions by rectification and filtering of RF signals.
- A Product Detector is used for demodulating SSB signals.

Mixers

- The principal frequencies that appear at the output of a mixer are the two input frequencies along with their sum and difference frequencies.
- When the input signal levels to a mixer are too high, spurious mixer products are generated.

E7F Software defined radio fundamentals

- "Direct sampling" in software defined radios means incoming RF is digitized by an analog-to-digital converter without being mixed with a local oscillator signal.
- An analog signal must be sampled at least twice the rate of the highest frequency component of the signal to be accurately reproduced.
- The minimum number of bits required to sample a signal with a range of 1 volt at a resolution of 1 millivolt is 10 bits.
- A Fast Fourier Transform function converts signals from the time domain to the frequency domain.
- Reference voltage level and sample width in bits sets the minimum detectable signal level for a direct-sampling software defined receiver in the absence of atmospheric or thermal noise.

Digital signal processing (DSP) filtering

- An adaptive, digital signal processing audio, filter is used to remove unwanted noise from a received SSB signal.
- A Hilbert-transform, digital signal processing, filter is used to generate an SSB signal.
- A method where signals are combined in quadrature phase relationship generates an SSB signal using digital signal processing.
- The function of taps in a digital signal processing filter are providing incremental signal delays for filter algorithms.
- More taps would allow a digital signal processing filter to create a sharper filter response.

Modulation and Demodulation

Analog-digital conversion

- The sample rate aspect of receiver analog-to-digital conversion determines the maximum receive bandwidth of a direct-sampling software defined radio (SDR).
- The function of decimation is reducing the effective sample rate by removing samples.

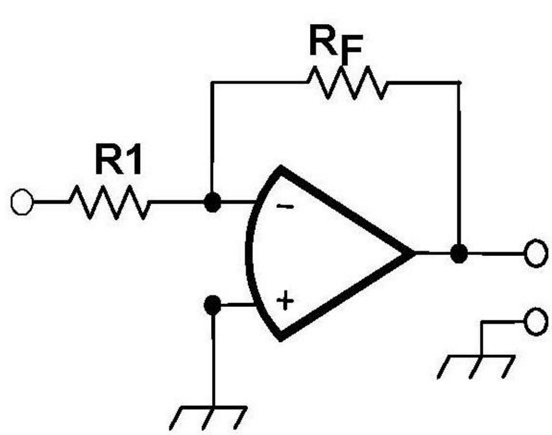
Digital filters

- Finite Impulse Response (FIR) filters can delay all frequency components of the signal by the same amount.
- An anti-aliasing filter is required in a decimator as it removes high-frequency signal components that would otherwise be reproduced as lower frequency components.

E7G Operational amplifiers: characteristics and applications

- The typical input impedance of an op-amp is very high.
- The typical output impedance of an op-amp is very low.
- An operational amplifier is a high-gain, direct-coupled differential amplifier with very high input impedance and very low output impedance.
- The gain of an ***ideal*** operational amplifier does not vary with frequency.
- The term “op-amp input offset voltage” is the differential input voltage needed to bring the open loop output voltage to zero.
- Unwanted ringing and audio instability can be prevented in an op-amp audio filter by restricting both gain and Q.
- The gain-bandwidth of an operational amplifier is the frequency at which the open-loop gain of the amplifier equals one.
- If a capacitor is added across the feedback resistor in circuit E7-3, the frequency response will be a low pass filter.

Figure E7-3



- The voltage gain that can be expected from the circuit in Figure E7-3 when R1 is 10 ohms and RF is 470 ohms is 47.

Given: R_1 = 10 ohms and R_F = 470 ohms

$V_{gain} = R_F / R_1$

$V_{gain} = 470 / 10$

$V_{gain} = 47$

- The output voltage of the circuit shown in Figure E7-3 if R1 is 1,000 ohms, RF is 10,000 ohms, and 0.23 volts DC is applied to the input is -2.3 volts.

Given: R_1 = 1000 ohms, R_F = 10000 ohms, and Vin = 0.23 volts DC

V_{out} = -(Rf/R1) * Vin

V_{out} = -(10000 / 1000) * 0.23

V_{out} = -(10 * 0.23)

V_{out} = -2.3 volts

Note: The amplifier depicted in Figure E7-3 is an Inverting Amplifier. The output is inverted relative to the input.

- The absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 1,800 ohms and RF is 68 kilohms is 38.

Given: R_1 = 1800 ohms and R_F = 68000 ohms

$V_{gain} = R_F / R_1$

$V_{gain} = 68000 / 1800$

$V_{gain} = 37.8$

- The absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 3,300 ohms and RF is 47 kilohms is 14.

Given: R_1 = 3300 ohms and R_F = 47000 ohms

$V_{gain} = R_F / R_1$

$V_{gain} = 47000 / 3300$

$V_{gain} = 14.2$

E7H Oscillators and signal sources

Types of oscillators

- Three common oscillator circuits are Colpitts, Hartley, and Pierce.
- Positive feedback supplied in a Colpitts oscillator is through a capacitive divider.
- Positive feedback supplied in a Pierce oscillator is through a quartz crystal.
- To ensure that a crystal oscillator operates on the frequency specified by the crystal manufacturer, provide the crystal with a specified parallel capacitance.

Synthesizers and phase-locked loops

- A phase-locked loop is an electronic servo loop consisting of a phase detector, a low-pass filter, a voltage-controlled oscillator, and a stable reference oscillator.
- Frequency synthesis and FM demodulation functions can be performed by a phase-locked loop.

Direct digital synthesizers

- A direct digital synthesizer, frequency synthesizer, circuit uses a phase accumulator, lookup table, digital-to-analog converter, and a low-pass anti-alias filter.
- Amplitude values that represent the desired waveform are contained in the lookup table of a direct digital synthesizer (DDS).
- Spurious signals at discrete frequencies are the major spectral impurity components of direct digital synthesizers.

Stabilizing thermal drift

- NP0 capacitors can be used to reduce thermal drift in crystal oscillators.

Microphonics

- Microphonic changes in oscillator frequency are caused by mechanical vibration.
- An oscillator’s microphonic responses can be reduced by mechanically isolating the oscillator circuitry from its enclosure.

High-accuracy oscillators

- Techniques for providing highly accurate and stable oscillators needed for microwave transmission and reception:
  - Use a GPS signal reference
  - Use a rubidium stabilized reference oscillator
  - Use a temperature-controlled high Q dielectric resonator
    (All these choices are correct)

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

E8A Fourier analysis

- Fourier analysis shows that a square wave is made up of a sine wave and its odd harmonics.
- Amplitude at different times describes a signal in the time domain.

RMS measurements

- The benefit of making voltage measurements with a true-RMS calculating meter is RMS is measured for both sinusoidal and non-sinusoidal signals.

Average RF power and peak envelope power (PEP)

- The approximate ratio of PEP-to-average power in an unprocessed single-sideband phone signal is 2.5 to 1.
- Speech characteristics determine the PEP-to-average power ratio of an unprocessed single-sideband phone signal.

Analog/digital conversion

- Successive approximation is a type of analog-to-digital conversion.
- With respect to analog-to-digital converters, 'dither' is a small amount of noise added to the input signal to reduce quantization noise.
- Direct or flash conversion analog-to-digital converters are used for a software defined radio due to very high speed allows digitizing high frequencies.
- A total of 256 different input levels can be encoded by an analog-to-digital converter with 8-bit resolution. *(00000000 to 11111111 or 0 to 255)*
- The purpose of a low-pass filter used at the output of a digital-to-analog converter is to remove spurious sampling artifacts from the output signal.
- Total harmonic distortion is a measure of the quality of an analog-to-digital converter.

E8B Modulation and demodulation

Modulation index

- The modulation index of an FM signal is the ratio of frequency deviation to modulating signal frequency.

$$\frac{\text{Modulation Index}}{1} = \frac{\text{Frequency Deviation}}{\text{Modulating Signal Frequency}}$$

- The modulation index of a phase-modulated emission does not depend on the RF carrier frequency so it doesn't vary with RF carrier frequency.

- The modulation index is 3 of an FM phone signal having a maximum frequency deviation of 3000 Hz, either side of the carrier frequency, if the highest modulating frequency is 1000 Hz.

Given: Maximum Frequency Deviation = 3000 Hz and Modulating Frequency = 1000 Hz

Modulation Index = Deviation / Modulating Frequency

Modulation Index = 3000 / 1000

Modulation Index = 3

- The modulation index is 3, of an FM phone signal having a maximum carrier deviation of plus or minus 6 kHz, if the highest modulating frequency is 2 kHz.

Given: Maximum Frequency Deviation = 6000 Hz and Modulating Frequency = 2000 Hz

Modulation Index = Deviation / Modulating Frequency

Modulation Index = 6000 / 2000

Modulation Index = 3

Deviation Ratio

- Deviation ratio is the ratio of the maximum carrier frequency deviation to the highest audio modulating frequency.

$$\frac{\text{Deviation Ratio}}{1} = \frac{\text{Max Carrier Freq Dev}}{\text{Highest Audio Mod Freq}}$$

- The deviation ratio is 1.67 of an FM phone signal having a maximum frequency swing of plus or minus 5 kHz if the highest modulation frequency is 3 kHz.

Given: Maximum Deviation = 5000 Hz and Maximum Modulation Frequency = 3000 Hz

Deviation Ratio = Maximum Deviation / Maximum Modulation Frequency

Deviation Ratio = 5000 / 3000

Deviation Ratio = 1.666

- The deviation ratio 2.14 of an FM phone signal having a maximum frequency swing of plus or minus 7.5 kHz if the highest modulation frequency is 3.5 kHz.

  Given: Maximum Deviation = 7500 Hz and Maximum Modulation Frequency = 3500 Hz

  Deviation Ratio = Maximum Deviation / Maximum Modulation Frequency

  Deviation Ratio = 7500 / 3500

  Deviation Ratio = 2.14

Frequency- and time-division multiplexing

- Frequency division multiplexing (FDM) is dividing the transmitted signal into separate frequency bands that each carry a different data stream.
- Digital time division multiplexing is two or more signals are arranged to share discrete time slots of a data transmission.

Orthogonal frequency-division multiplexing (OFDM)

- Orthogonal frequency-division multiplexing (OFDM) is a technique used for amateur communication digital modes.
- Orthogonal frequency-division multiplexing (OFDM) is a digital modulation technique using subcarriers at frequencies chosen to avoid inter-symbol interference.

E8C Digital signals

Digital communication modes

- Quadrature Amplitude Modulation (QAM) is transmission of data by modulating the amplitude of two carriers of the same frequency but 90 degrees out of phase.
- The phase of a PSK signal should be changed at the zero crossing of the RF signal to minimize bandwidth.
- A technique using sinusoidal data pulses minimizes the bandwidth of a PSK31 signal.
- Nodes have Internet Protocol (IP) addresses in a mesh network.
- Individual nodes use Discovery and Link Establishment protocols to form a mesh network.

Information rate vs. bandwidth

- Symbol rate in a digital transmission is the rate at which the waveform changes to convey information
- The bandwidth of an FT8 signal is 50 Hz.
- Data rate can be increased without increasing bandwidth by using a more efficient digital code.
- The relationship between symbol rate and baud – They are the same.
- Keying speed and shape factor (rise and fall time) affect the bandwidth of a transmitted CW signal.
- The approximate bandwidth of a 13-WPM International Morse Code transmission is 52 Hz.

  Baud = WPM / 1.2

  Baud = 13 / 1.2

  Baud = 10.83

  Bandwidth = Speed of Transmission in Baud * Keying Envelope Factor

  Keying Factor varies in range of 3 to 5. Keying factor is commonly approximated at 4.80.

  B_w = 10.83 * 4.80

  B_w = 52

- The bandwidth of a 4,800-Hz frequency shift, 9,600-baud ASCII FM transmission is 15.36 kHz.

  Given: Baud Rate = 9600 and Frequency Shift = 4800 Hz

  Note: For most Amateur Radio communications K ~ 1.2 approximated based upon allowable signal distortion and transmission path.

  Bw = (K * shift) + B

  Bw = (1.2 * 4800) + 9600

  Bw = 5760 +9600

  Bw = 15,360 Hz

Error correction

- ARQ accomplishes error correction, if errors are detected, a retransmission is requested.
- Gray code, digital code, allows only one bit to change between sequential code values.

Constellation diagrams

- The constellation diagram of a QAM or QPSK signal describes the possible phase and amplitude states for each symbol.

E8D Keying defects and overmodulation of digital signals

- The primary effect of extremely short rise or fall time on a CW signal is the generation of key clicks.
- The most common method of reducing key clicks is to increase keying waveform rise and fall times.
- A common cause of overmodulation of AFSK signals is excessive transmit audio levels.
- Intermodulation Distortion (IMD) parameter evaluates distortion of an AFSK signal caused by excessive input audio levels.
- An acceptable maximum IMD level for an idling PSK signal is -30 dB.

Digital codes

- The advantage of including parity bits in ASCII characters is some types of errors can be detected.
- Some of the differences between the Baudot digital code and ASCII include Baudot uses 5 data bits per character, ASCII uses 7 or 8; Baudot uses 2 characters as letters/figures shift codes, ASCII has no letters/figures shift code.
- One advantage of using ASCII code for data communication is that it is possible to transmit both uppercase and lowercase text.

Spread spectrum

- Received spread spectrum signals are resistant to interference due to signals not using the spread spectrum algorithm are suppressed in the receiver.
- Direct sequence, spread spectrum communications technique, uses a high-speed binary bit stream to shift the phase of an RF carrier.
- Spread spectrum frequency hopping is rapidly varying the frequency of a transmitted signal according to a pseudorandom sequence.

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

E9A Basic antenna parameters

- An isotropic radiator is a hypothetical, lossless antenna having equal radiation intensity in all directions used as a reference for antenna gain.

Radiation resistance

- Antenna height affects the feed point impedance of an antenna.
- Antenna efficiency is radiation resistance divided by total resistance.

$$\text{Antenna Efficiency} = \frac{\text{Radiation Resistance}}{\text{Total Resistance}}$$

Gain

- The term “ground gain” means an increase in signal strength from ground reflections in the environment of the antenna.
- If an antenna has 6 dB gain over an isotropic radiator it has a gain compared to a half-wavelength dipole of 3.85 dB.

Given: Gain = 6 dB relative to an isotropic radiator

Reminder: A dipole has 2.14 dB of gain relative to an ideal isotropic radiator.

dBd = dBi – 2.14 dB

dBd = 6 – 2.14

dBd = 3.86

Beamwidth

- The 5.8 GHz frequency band has the smallest first Fresnel zone.

Efficiency

- Installing a ground radial system improves the efficiency of a ground-mounted quarter-wave vertical antenna.
- Soil conductivity determines ground losses for a ground-mounted vertical antenna operating on HF.

Effective radiated power (ERP)

- The effective radiated power (ERP) 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.

  Given: P_{in} = 150 watts and System Gains & Losses

  System Gain = (-2 dB – 2.2 dB + 7dBd) = +2.8 dB gain

  $dB = 10 \log (P_{out} / P_{in})$

  $2.8 = 10 \log (P_{out} / 150)$

  $\log (P_{out} / 150) = 0.28$

  $\log^{-1} (\log (P_{out}/150) = \log^{-1}(0.28)$

  $P_{out}/150 = \log^{-1}(0.28)$

  $P_{out} = \log^{-1}(0.28) * 150$

  $P_{out} = 1.90546 * 150$

  P_{out} = 285.8 watts ERP

- **Effective radiated power describes total radiated power takes into account all gains and losses.**

- The effective radiated power (ERP) 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.

  Given: P_{in} = 200 watts and System Gains & Losses
  System Gain = (-4 dB – 3.2 dB – 0.8 + 10 dBd)

  System Gain = +2.0 dB gain

  dB = 10 log (Pout / Pin)

  2.0 = 10 log (Pout / 200)

  Log (Pout / 200) = 0.20

  Log^{-1} (log (Pout/200) = Log^{-1}(0.20)

  Pout/200 = $\log^{-1}$(0.20)

  Pout = $\log^{-1}$(0.20) * 200

  Pout = 1.584893 * 200

  Pout = 317 watts ERP

Effective isotropic radiated power (EIRP)

- The effective isotropic radiated power (EIRP) 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 dBi antenna gain is 252 watts.

Given: Pin = 200 watts and System Gains & Losses

System Gain = (-2 dB – 2.8 dB – 1.2 + 7 dBi)
System Gain = +1.0 dB gain

dB = 10 log (Pout / Pin)

1.0 = 10 log (Pout / 200)

Log (Pout / 200) = 0.10

Log^{-1} (log (Pout/200) = Log^{-1} (0.10)

Pout/200 = log^{-1} (0.10)

Pout = log^{-1} (0.10) * 200

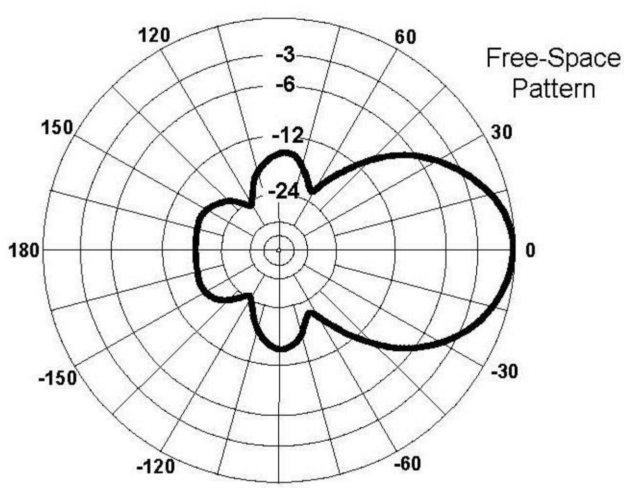
Pout = 1.258925 * 200

Pout = 251.8 watts ERP

E9B Antenna patterns and designs

- The ***3 dB beamwidth*** of the antenna radiation pattern shown in Figure E9-1 is 50 degrees.
- The front-to-back ratio of the antenna radiation pattern shown in Figure E9-1 is 18 dB.
- The front-to-side ratio of the antenna radiation pattern shown in Figure E9-1 is 14 dB.

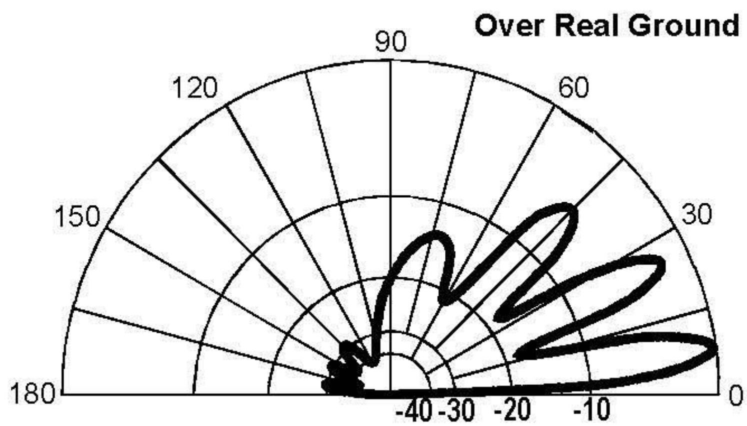
Figure E9-1



Azimuth and elevation patterns

- Elevation type of antenna pattern is shown in Figure E9-2.
- The elevation angle of peak response in the antenna radiation pattern shown in Figure E9-2 is 7.5 degrees.
- The front-to-back ratio of the radiation pattern shown in Figure E9-2 is 28 dB.

Figure E9-2



Gain as a function of pattern

- The difference in radiated power between a lossless antenna with gain and an isotropic radiator driven by the same power is they are the same.
- The far field of an antenna is the region where the shape of the radiation pattern no longer varies with distance.

Antenna modeling

- Method of Moments analysis is commonly used for modeling antennas.
- The principle of a Method of Moments analysis is a wire is modeled as a series of segments, each having a uniform value of current.
- A disadvantage of decreasing the number of wire segments in an antenna model below 10 segments per half-wavelength is the computed feed point impedance may be incorrect.

E9C Practical wire antennas

- A figure-eight oriented, along the axis of the array, radiation pattern is created by two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed 180 degrees out of phase.
- A figure-eight, broadside to the axis of the array, radiation pattern is created by two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed in phase.
- The radiation pattern of an unterminated long wire antenna, as the wire length is increased, forms additional lobes with major lobes increasingly aligned with the axis of the antenna.
- The purpose of feeding an off-center-fed dipole (OCFD) between the center and one end instead of at the midpoint is to create a similar feed point impedance on multiple bands.
- The effect of adding a terminating resistor to a rhombic or long-wire antenna is it changes the radiation pattern from bidirectional to unidirectional.
- A G5RV antenna is a wire antenna center-fed through a specific length of open-wire line connected to a balun and coaxial feed line.
- A Zepp antenna is an end-fed half-wavelength dipole.
- An extended double Zepp antenna is a center-fed 1.25-wavelength dipole antenna.

Folded dipoles

- The approximate feed point impedance at the center of a two-wire half-wave folded dipole antenna is 300 ohms.
- A folded dipole antenna is a half-wave dipole with an additional parallel wire connecting its two ends.

Phased arrays

- A Cardioid radiation pattern is created by two 1/4-wavelength vertical antennas spaced 1/4-wavelength apart and fed 90 degrees out of phase.

Effects of ground near antennas

- When the far-field elevation pattern of a vertically polarized antenna is being mounted over seawater versus soil, the radiation at low angles increases.
- The radiation pattern of a horizontally polarized antenna varies with increasing height above ground -- the takeoff angle of the lowest elevation lobe decreases.
- The radiation pattern of a horizontally-polarized antenna mounted above a long slope varies with the same antenna mounted above flat ground -- the main lobe takeoff angle decreases in the downhill direction.

E9D Yagi antennas

- Two linearly polarized Yagi antennas can be used to produce circular polarization by arranging two Yagis on the same axis and perpendicular to each other with the driven elements at the same point on the boom and fed 90 degrees out of phase.
- A Yagi's driven element is approximately ½ wavelength long.
- Most two-element Yagis with normal spacing have a reflector instead of a director for higher gain.
- The purpose of making a Yagi's parasitic elements either longer or shorter than resonance is to control of phase shift.

Parabolic reflectors

- The gain of an ideal parabolic reflector antenna increases when the operating frequency is doubled by 6 dB.

Feed point impedance and loading of electrically short antennas

- The most efficient location for a loading coil on an electrically short whip is near the center of the vertical radiator.
- Antenna loading coils should have a high ratio of reactance to resistance to maximize efficiency
- The SWR bandwidth is decreased when one or more loading coils are used to resonate an electrically short antenna.
- An advantage of top loading an electrically short HF vertical antenna is improved radiation efficiency.
- The function of a loading coil in an electrically short antenna is to resonate the antenna by cancelling the capacitive reactance.
- A Base-fed whip antenna's radiation resistance decreases below its resonant frequency.

Antenna Q

- SWR bandwidth decreases as the Q of an antenna increases.

E9E Impedance matching

- A 75 ohms transmission line impedance would be suitable for constructing a quarter-wave Q-section for matching a 100-ohm feed point impedance to a 50-ohm transmission line.

Matching antennas to feed lines

- Reflection coefficient describes the interaction of a load and transmission line.
- The Beta or hairpin matching system for Yagi antennas requires the driven element to be insulated from the boom.
- A Capacitive (driven element electrically shorter than 1/2 wavelength), Yagi driven element feed point impedance, is required to use a beta or hairpin matching system.
- Gamma match is used to shunt feed a grounded tower at its base.
- The Gamma match, antenna matching system, matches coaxial cable to an antenna by connecting the shield to the center of the antenna and the conductor a fraction of a wavelength to one side.
- The purpose of the series capacitor in a gamma match is to cancel unwanted inductive reactance.
- The Stub match, matching system, uses a short length of transmission line connected in parallel with the feed line at or near the feed point.

Phasing lines

- The purpose of using multiple driven elements connected through phasing lines is to control the antenna's radiation pattern.

Power dividers

- Use a Wilkinson divider to divide power equally between two 50-ohm loads while maintaining 50-ohm input impedance.

E9F Transmission lines

Characteristics of open and shorted feed lines

- A 1/2-wavelength transmission line presents a very low impedance to an RF generator when the line is shorted at the far end.
- A 1/4-wavelength transmission line presents a very high impedance to an RF generator when the line is shorted at the far end.
- A 1/4-wavelength transmission line presents very low impedance to an RF generator when the line is open at the far end.
- A 1/8-wavelength transmission line presents an inductive reactance to an RF generator when the line is shorted at the far end.
- A 1/8-wavelength transmission line presents a capacitive reactance to an RF generator when the line is open at the far end.

Coax versus open wire

- A parallel conductor transmission line has **lower loss** compared to coaxial cable with a plastic dielectric.

Velocity factor

- The velocity factor of a transmission line is the velocity of a wave in the transmission line divided by the velocity of light in a vacuum.

$$\frac{\text{Velocity Factor}}{1} = \frac{\text{Wave Velocity in Transmission Line}}{\text{Velocity of Light in a Vacuum}}$$

Electrical length

- The electrical length of a coaxial cable is longer than its physical length because electromagnetic waves move more slowly in a coaxial cable than in air.
- The approximate physical length of an air-insulated, parallel conductor transmission line that is electrically 1/2 wavelength long at 14.10 MHz, is 10.6 meters.

Given: ½ wavelength long, F = 14.10 MHz, air insulated parallel conductor

Assume: Velocity Factor = 1.0

$Length_{meters} = ((300 / F_{MHz}) * \text{Velocity Factor}) / 2$

$L = ((300/14.1) * 1.0) / 2$

$L = (21.276595 * 1.0) /2$

$L = 21.276595 / 2$

L = 10.6 meters

Coaxial cable dielectrics

- The insulating dielectric material has the biggest effect on the velocity factor of a transmission line.
- Here are significant differences between foam dielectric coaxial cable and solid dielectric coaxial cable, assuming all other parameters are the same:
  - Foam dielectric coaxial cable has lower safe maximum operating voltage
  - Foam dielectric coaxial cable has lower loss per unit of length
  - Foam dielectric coaxial cable has higher velocity factor
    (All these choices are correct)

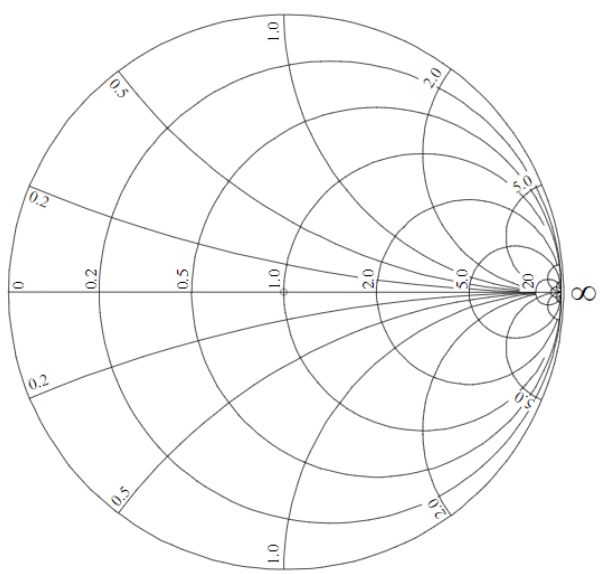
Microstrip

- A microstrip is a precision printed circuit conductors above a ground plane that provide constant impedance interconnects at microwave frequencies.

E9G The Smith chart

- Impedance along transmission lines can be calculated using a Smith chart.
- Resistance circles and reactance arcs, coordinate system, are used in a Smith chart.
- Impedance and SWR values in transmission lines are often determined using a Smith chart.
- Resistance and reactance circles and arcs make up a Smith chart.
- A common use for a Smith chart is to determine the length and position of an impedance matching stub.
- A Smith chart is normalized by reassigning the prime center's impedance value.
- Constant-SWR circles are the third family of circles often added to a Smith chart during the process of designing impedance matching networks.
- The arcs on a Smith chart represent points with constant reactance.
- The units of the wavelength scales on a Smith chart are calibrated in fractions of transmission line electrical wavelength.
- On the Smith chart shown in Figure E9-3, the name for the large outer circle on which the reactance arcs terminate is the Reactance axis.
- On the Smith chart shown in Figure E9-3, the only straight line shown is the resistance axis.

Figure E9-3



E9H Receiving antennas

- For 160- and 80-meter receiving antennas, atmospheric noise is so high that directivity is much more important than losses.
- The function of a sense antenna is to modify the pattern of a DF antenna to provide a null in only one direction.
- A Cardioid type of radiation pattern is created by a single-turn, terminated loop such as a pennant antenna.
- A single null feature of a cardioid pattern antenna makes it useful for direction-finding antennas.

Radio direction finding (RDF) techniques

- Receiving directivity factor (RDF) is the peak antenna gain compared to average gain over the hemisphere around and above the antenna.

Beverage antennas

- When constructing a Beverage antenna, it should be at least one wavelength long to achieve good performance at the desired frequency.
- Maximum DC current in the terminating resistor indicates the correct value of terminating resistance for a Beverage antenna.
- The function of a Beverage antenna's termination resistor is to absorb signals from the reverse direction.

Single- and multiple-turn loops

- The purpose of placing an electrostatic shield around a small-loop direction-finding antenna is that it eliminates unbalanced capacitive coupling to the antenna's surroundings, improving the depth of its nulls.
- A small wire-loop antenna for direction finding presents a challenge in that it has a bidirectional null pattern.
- The output voltage of a multiple-turn receiving loop antenna can be increased by increasing the number of turns and/or the area enclosed by the loop.

SUBELEMENT E0 - SAFETY - [1 exam question - 1 group]

E0A Safety

RF radiation hazards

- When evaluating RF exposure levels from your station at a neighbor's home, you must ensure signals from your station are less than the uncontrolled maximum permissible exposure (MPE) limits.
- The range of frequencies 30 to 300 MHz are most restrictive for the FCC human body RF exposure limits.
- When evaluating a site with multiple transmitters operating at the same time, the operators and licensees of which transmitters are responsible for mitigating over-exposure situations for each transmitter that produces 5 percent or more of its MPE limit in areas where the total MPE limit is exceeded.
- The hazard created by operating at microwave frequencies is high gain antennas commonly used can result in high exposure levels.
- There are separate electric (E) and magnetic (H) MPE limits at frequencies below 300 MHz because:
  - The body reacts to electromagnetic radiation from both the E and H fields
  - Ground reflections and scattering cause the field strength to vary with location
  - E field and H field radiation intensity peaks can occur at different locations
    (All these choices are correct)
- SAR measures the rate at which RF energy is absorbed by the body.
- Hand-held transceivers sold before May 3, 2021 are exempt from RF exposure evaluations.
- An RF exposure evaluation must always be performed on an amateur station operating on 80 meters.

Grounding

- Lightning charge dissipation is the primary function of an external earth connection or ground rod.

Tower/Climbing Safety

- The principle, "100% tie-off", regarding tower safety, means at least one lanyard attached to the tower at all times.
- Lanyards should be attached to tower legs while climbing.
- A shock-absorbing lanyard should be attached above the climber's head level to a tower when working above ground.

End of Study Guide