WELCOME

TO THE COURSE FOR THE FCC AMATEUR RADIO TECHNICIAN LICENSE

Your instructor is

Steve Collins
KI6TEQ

A Little Info About Myself

My Handle is: - Steve

My Call Is: KI6TEQ

First Licensed: - 16 Sep 2008

Current License Class: - Extra

Radio Locations: - Home, Portable

Favorite Parts Of Hobby: - Public Service Events

- Emergency Operations

Technician License	16 Sep 2008
General License	03 Dec 2008
Extra License	03 Dec 2008

Retired Communications Electronics Executive

Original class charts developed by Walt Ordway K1DFO, who taught classes for over 4 decades

The 4 B’s

BREAKS

BEVERAGES

BATHROOMS

BOOKS

Books and Other Material

- Copy of my Power Point charts — Free on-line
- Copy of the Gordon West book — $16, one per student
- A copy of the FCC Q&A pool is available on line
  - Go to https://ncvec.org/index.php/2026-2030-technician-question-pool
  - Click on link for 2026-2030 Technician Pool and syllabus Public Release
- Advantage of Gordon West book is that he explains the reason why a particular answer is the correct one, which helps in remembering for the test

Palos Verdes Amateur Radio Club – K6PV

- The meetings are the 1st Thursday of each month (except August and December) at 7:30 PM at Hesse Park, 29301 Hawthorne Blvd, Rancho Palos Verdes CA and the annual dues is $25

- Everyone who obtains their first ham radio license through a PVARC course and VE session, regardless of age, will receive a free membership to the Palos Verdes Amateur Radio Club for the remainder of the current calendar year

- We are very active in a variety of Peninsula services and events including various emergency communication services and communications for the, Ridgecrest School 5K, the Hills Are Alive 10K/5K, Conquer the Bridge, and more

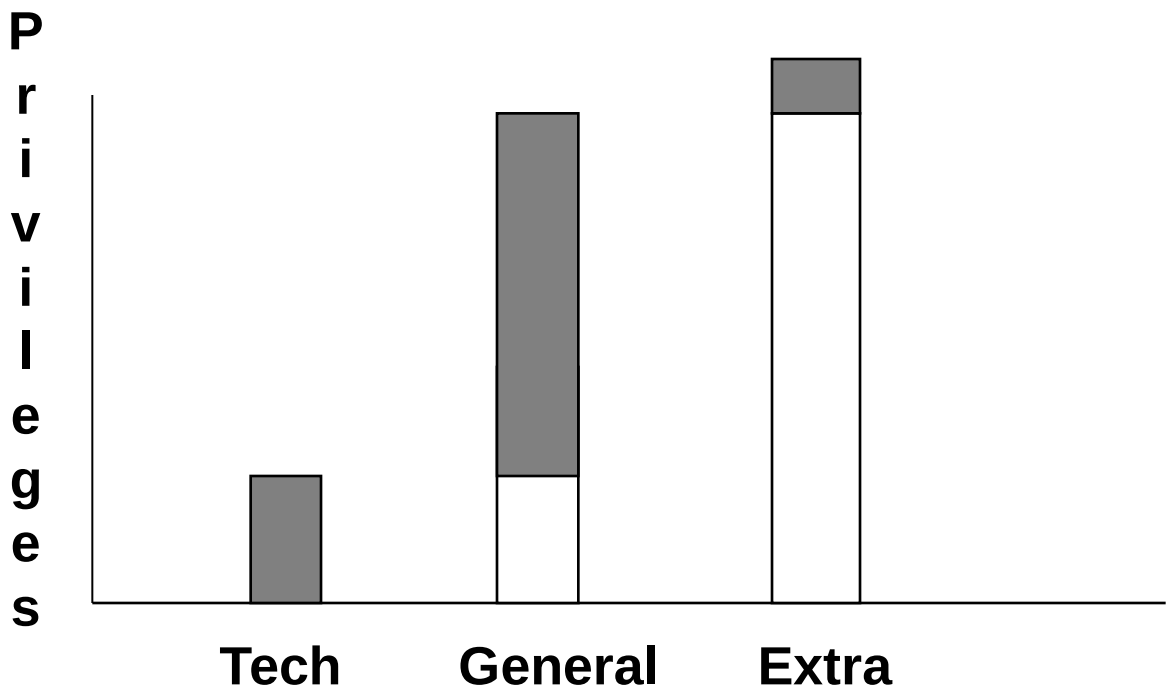
- For courses sponsored by the Palos Verdes Amateur Radio Club, students thru grade 12 who get their license will, upon application to the Club, be reimbursed up to a maximum of $85 to cover the cost of materials and the examination fee.

A Bit Of Amateur Radio History

- The license structure has been changed several times over the past couple decades
- There are 3 levels of amateur radio licenses
- Each level gives more privileges, which are primarily frequencies that can be used to talk over long distances and around the world
- On 23 February 2007, the FCC eliminated the Morse Code requirement
- The hobby has many parts including various types of contests
- Many amateur radio operators use the hobby to support various community events or functions (marathons, 5K/10K, disaster services, etc.) and also emergency communications.
- This hobby can be fun for folks of all ages

Amateur License Classes

CLASS	WRITTEN TEST
Technician	35 Questions
General	35 Questions
Extra	50 Questions



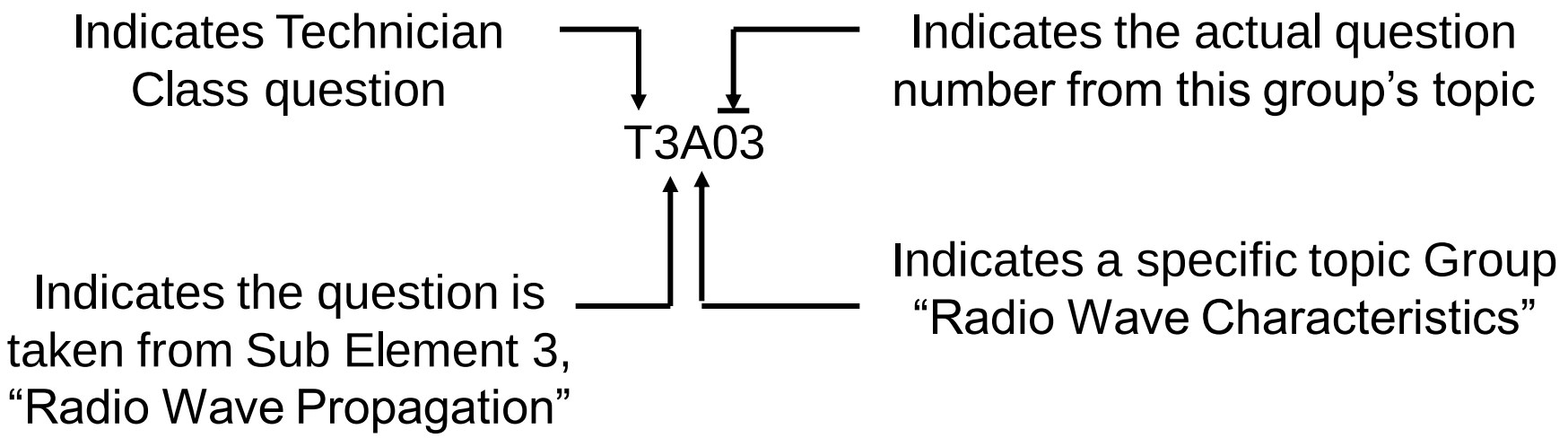
FCC Technician Topics vs. Pool and Test Questions

Sub Element	Topic	Pool	Test
T1	Commission's Rules	68	6
T2	Operating Procedures	37	3
T3	Radio Wave Propagation	35	3
T4	Amateur Radio Practices	23	2
T5	Electrical Principles	50	4
T6	Electronic and Electrical Components	46	4
T7	Practical Circuits	44	4
T8	Signals & Emissions	47	4
T9	Antennas and Feed Lines	23	2
T0	Safety	36	3
	Total	409	35
	NEED TO PASS >>		26

The technician pool has been updated as of July 1, 2026

ALL TEST QUESTIONS MUST COME FROM THE POOL

Question Pool Numbering



Question Numbering By Sub Topic	# of Pool Questions	# of Test Questions
T3A01 – T3A12	12	1
T3B01 – T3B12	12	1
T3C01 – T3C11	11	1
Total	35	3

Class Schedule and Other

- My course will cover all of the material in the 10 FCC Sub Elements
- The specific schedule for this Technician course is today 7 November and next Saturday 14 November from 9:30 AM to around 12:30 PM both Saturdays
- The specific schedule for the FCC test is Saturday 21 November from 10 AM to noon in this room
- Anyone needing special help can stick around after class or send me an e-mail at skibear90275@verizon.net
- The focus of the course is not to play with the radios but to help you pass the test

How I Teach The Class

What I'm Going To Do:

- Cover the 10 Pool Topics using the 20 categories that Gordon West uses in his Technician Class book
- Answer all of your questions
- Cover all of the material in the Question Pool

What I'm Not Going To Do:

- Read every question and all 4 answers (why?)

What You Need To Do:

- Ask me to explain something again if you don't understand it
- Ask me to slow down if I'm going too fast
- Let me know if you see an error, bad spelling, etc, on any chart
- If you're using my notes, let me know if you have a missing chart or a different chart than the one I am showing

Your FCC Registration Number

- In past years, once you passed the Technician test, the FCC created a "FCC Registration Number " FRN for you and it appeared on your Technician license
- On 20 May 2021, the FCC changed their process
- Now, you must go to the FCC web site and fill out the form that creates your FRN and then their database provides you your 10 digit FRN
- You can not take the Technician Test unless you show the test folks your FRN
- The FCC web site is https://www.fcc.gov/rofrn
- That web site has a short video about the process and it has a form that you fill in to get your 10 digit FRN
- Bring your FRN to the next Saturday Class and definitely to the test session

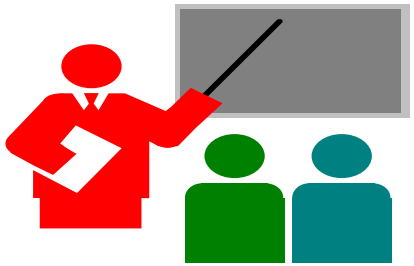
Course Sequence

I will be following the sequence from the Gordon West book

- Section 1 – About Ham Radio
- Section 2 – Call Signs
- Section 3 – Control
- Section 4 – Mind the Rules
- Section 5 – Tech Frequencies
- Section 6 – Your First Radio
- Section 7 – Going Solo
- Section 8 – Repeaters
- Section 9 – Emergency !
- Section 10 – Weak Signal Propagation
- Section 11 – Talk to Outer Space !
- Section 12 – Going Digital !
- Section 13 – Multi-mode Radio Excitement
- Section 14 – Run Some Interference Protection
- Section 15 – Electrons – Go with the Flow !
- Section 16 – It's the Law, per Mr. Ohm !
- Section 17 – Picture This !
- Section 18 – Antennas
- Section 19 – Feed Me with Some Good Coax !
- Section 20 – Safety First !

A Bit Of Amateur Radio History

- President William Howard Taft signed the “Radio Act of 1912” on 13 December 1912
- The Radio Act defined Amateur Radio and established privileges involving special frequencies, transmitter power and types of emission that could be used
- Prior to that date, there were no defined regulations
- They established several levels of licenses and you got them by passing written test or code tests or both
- It was incentive licensing. The entry level license got you some basic privileges, and you got the more desirable privileges as you passed higher level tests. There were 5 levels of licensing.
- To motivate you a bit, the entry level license couldn’t be renewed, and expired after 1 year. So you had to get the next level if you wanted to keep using the ham radio hobby.



Teaching and Learning Approaches

Types of Questions	Learning Approach	Instruction Time	
Answer can't be taught	Must be memorized	Very little	
Concepts can be taught	Intuitive	Some	
	1 concept, 1 question	More	
	1 concept, many questions	Most	**YES!**

Your study approach options:

- Opt 1 - Memorize every answer
- Opt 2 - Learn every "learnable" answer, memorize the rest
- Opt 3 - Learn as much as is reasonable, and memorize the rest

Other suggestions:

- Read "Study Suggestions" page 32 of Gordon West

Section 1

About Ham Radio

About Ham Radio

1A02 • The FCC (Federal Communications Commission) regulates and enforces the rules of Amateur Radio Service in the United States of America (and its possessions)

1A01 • The basis and purpose of the Amateur Radio Service is advancing skills in the technical and communications phases of the radio art

1C10 • After you pass your examination for your first amateur radio license you can operate a transmitter on the amateur radio bands as soon as your operator/station license grant appear in the FCC's license data base

• The FCC will e-mail you a copy of your license

1A05 • Proof that the FCC has issued an operator/primary license grant is when the license appears in the FCC ULS database

About Ham Radio

1C01

- The license classes currently available from the FCC are Technician (entry level), General and Extra
- The Technician gives some basic privileges on the higher frequencies and the radios are primarily hand held radios (HT)
- The General gives the majority of the frequencies, which let a ham talk across the country and around the world to other hams
- I would strongly suggest getting the General
- The Extra gives a few more frequencies privileges

1A04

- You receive official notification of your new license and call sign after passing the exam via an email from the FCC with link to download the license grant

About Ham Radio

1C08
- 10 years is the normal term of an FCC issued amateur radio license
- Do your renewal about 90 days prior to the expiration date

1C09
- There is a 2 year “grace” period to renew your license
- If you renew in the 2 year “grace” period, you will then keep the same call sign

1C11
- But, if your license has expired and you are within the “grace” period, you can’t knowingly transmit on amateur bands until your license has been renewed
- If you don’t renew by the end of the 2 year “grace” period, you would have to take the license tests again

About Ham Radio?

- There are no age limits to hold an amateur radio license
- A 9 year old boy who took Walt's class got his Technician license

A little Extra: Ten-year-old Samantha Sanford, AA3JS, of McDonald, Pennsylvania, received her Novice license at age 8 on May 3, 1994, then gave up TV for the summer and fall, and eight months later, on December 21, 1994, when she was 9½ years old, passed her Amateur Extra Class exam, and her license was issued this January 17.

UNITED STATES OF AMERICA
FEDERAL COMMUNICATIONS COMMISSION

AMATEUR RADIO LICENSE

KI6TEQ

ATTN: STEVEN D COLLINS
COLLINS, STEVEN D
29353 WHITLEY COLLINS DR
RANCHO PALOS VERDES, CA 90275

FCC Registration Number (FRN): 0017090788

Special Conditions / Endorsements

NONE

Grant Date	Effective Date	Print Date	Expiration Date
07-07-2018	07-07-2018	07-07-2018	09-16-2028

File Number	Operator Privileges	Station Privileges
0008275505	Amateur Extra	PRIMARY

THIS LICENSE IS NOT TRANSFERABLE

Steven D Collins

(Licensee's Signature)

FCC 660 - May 2007

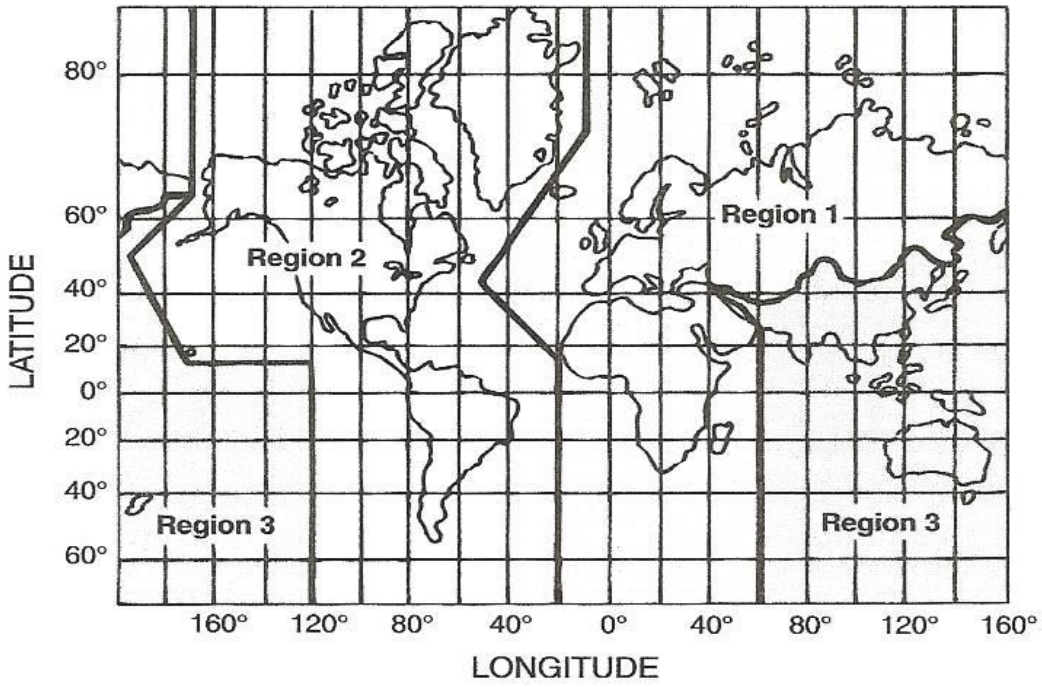
Official Copy

Section 2

Call Signs

The International Telecommunications Union

- The ITU (International Telecommunications Union) assists in managing frequency usage worldwide
- The ITU is a United Nations agency for information and communications technology issues
- The Earth is divided into three regions. The Americas and Greenland are ITU Region 2



ITU Regions

Call Signs

- The ITU establishes the prefix for amateur radio call signs in all countries

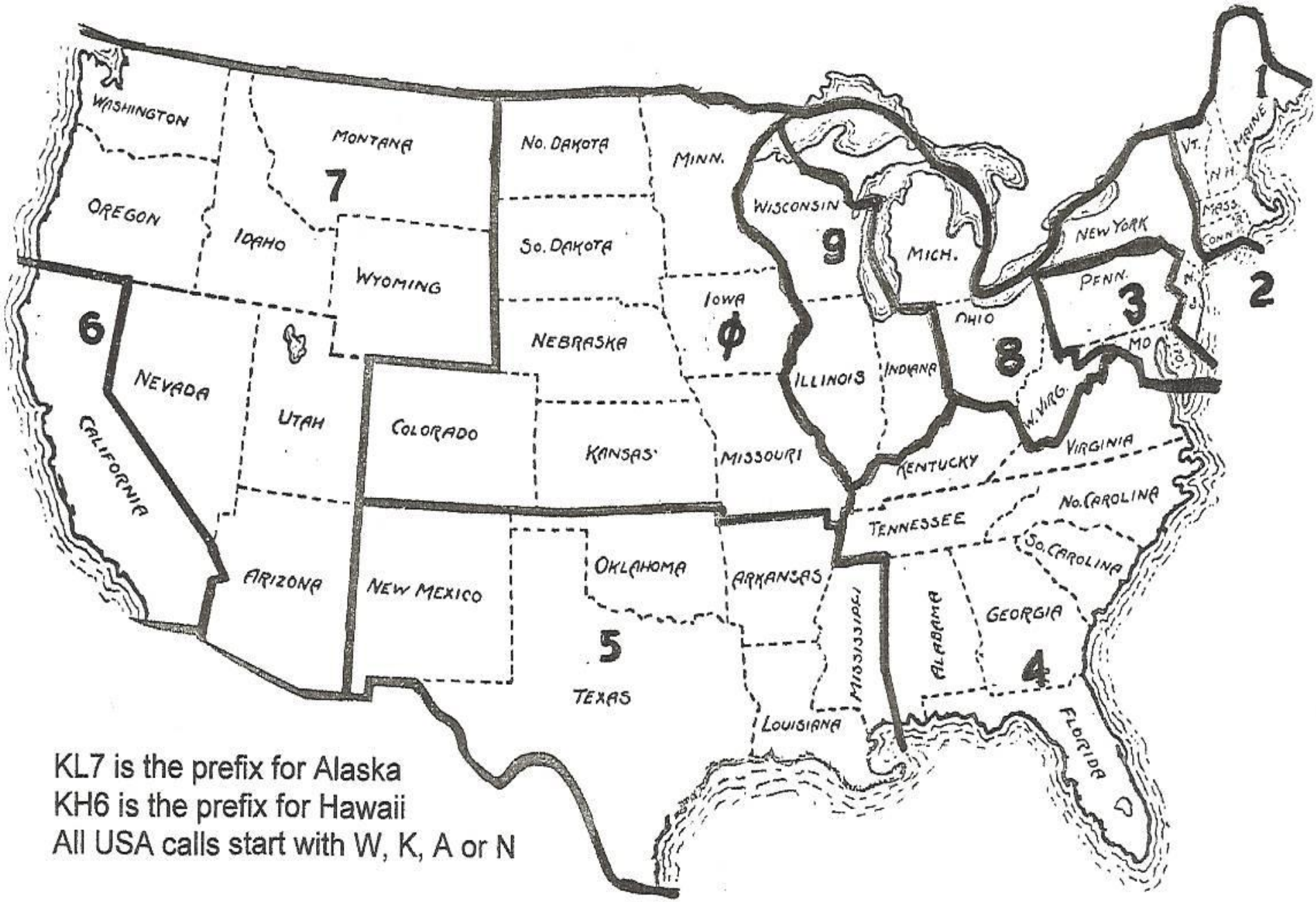
- All ham radio call signs in the USA have:
  - A prefix, 1 or 2 letters
  - Followed by a single number, 0 to 9
  - Followed by a suffix, 1, 2 or 3 letters

- The FCC issues amateur radio calls in the USA and its possessions

- The first letter of an FCC issued call must be either W, K, A, or N
  - W6BAK
  - K1DFO
  - AI6DF
  - NG9W

- The number in a call depends on the state where we get our license (see next chart)

USA Call Districts



KL7 is the prefix for Alaska
KH6 is the prefix for Hawaii
All USA calls start with W, K, A or N

Call Signs

- There are many “special events” where hams participate like the annual Boy Scout Jamboree

- The FCC will issue a “special event” call sign with a single letter in both the prefix and the suffix (example: W 6 B)

- These call signs are only valid for the length of the event (i.e., a couple days)

- The FCC will issue a call sign to a radio club, but the club must have at least 4 members

- A member of the club is the “call sign administrator”

Call Signs

1F03

- You are required to transmit your call sign every 10 minutes and at the end of your communication

- Most hams give their call signs at the beginning and end of every transmission, but this is not required

1F04

- When operating in a phone sub-band, you must give your station identification (call sign) in English

1A03

- The FCC encourages the use of a phonetic alphabet for station identification in the Amateur Radio Service

- The ITU has a phonetic alphabet (see next chart)

ITU Phonetic Alphabet

A	Alpha	N	November
B	Bravo	O	Oscar
C	Charlie	P	Papa
D	Delta	Q	Quebec
E	Echo	R	Romeo
F	Foxtrot	S	Sierra
G	Golf	T	Tango
H	Hotel	U	Uniform
I	India	V	Victor
J	Juliet	W	Whiskey
K	Kilo	X	X-ray
L	Lima	Y	Yankee
M	Mike	Z	Zulu

Call Signs

- You are not stuck with your call sign (example WZ6YXQ)
- You can ask the FCC for a new call sign, but it will be issued in sequence order
- If you move to another call district, you can request a call from that district
- Ex: Moved from California, district 6 to Nevada, district 7
- Your new call will now have a “7” in it

Group	Format	Example
C	1x3	K1DFO
D	2x3	KI6TEQ

- Format is 1 or 2 letters, 1 number, and 2 or 3 letters

Call Signs

1C02
- Any licensed amateur can request a Vanity Call

1C05
- A Technician can have a Vanity Call, but it must have 3 letters after the number. An example is K1XXX

- You can request specific letters (if they are not issued). This Vanity Call could be your initials or other
  - K1WFO W alter F rederick O rdway
  - K6MEL Mel Smith

- A Vanity Call for a radio club can only be selected by the person named as the trustee on the club station license grant

- The Palos Verdes Amateur Radio Club call is K6PV

1F11
- The club must have at least four members for the issuance of a club station license

Call Signs

- Operating events like a marathon, you can also use a “tactical call”

- A tactical call like “Water Station 1” might be used when working a race event at Water Station #1

1F02

- When using a tactical call, you must still give your ham radio call at the end of each communication and every 10 minutes during a communications

---

- If you are from Alaska and have the call sign KL7CC, you could be operating from the 3rd USA call sign district (like Maryland)

1F06

- When using <u>phone</u> transmission, you can say any of the following self-assigned indicators:
  - KL7CC stroke W3
  - KL7CC slant W3
  - KL7CC slash W3
- This happens when operating out of area to identify your home district so operators know you are now local

Radio Control of Model Aircraft

1D11

- An amateur station transmitting signals to control a model craft can transmit <u>without identifying</u>
- Put a “label” on the transmitter giving your name, call sign and address
- There are specific amateur frequencies to use
- Maximum power - **<u>1 watt</u>**

Where Can I Use My Call

- Once you are licensed, you can transmit (operate) from any place in the 50 states and the USA possessions

1C03

- The FCC defines international communications as communications incidental to the purposes of Amateur Radio Service and remarks of a personal character (i.e., no business, no payment, no obscenity)

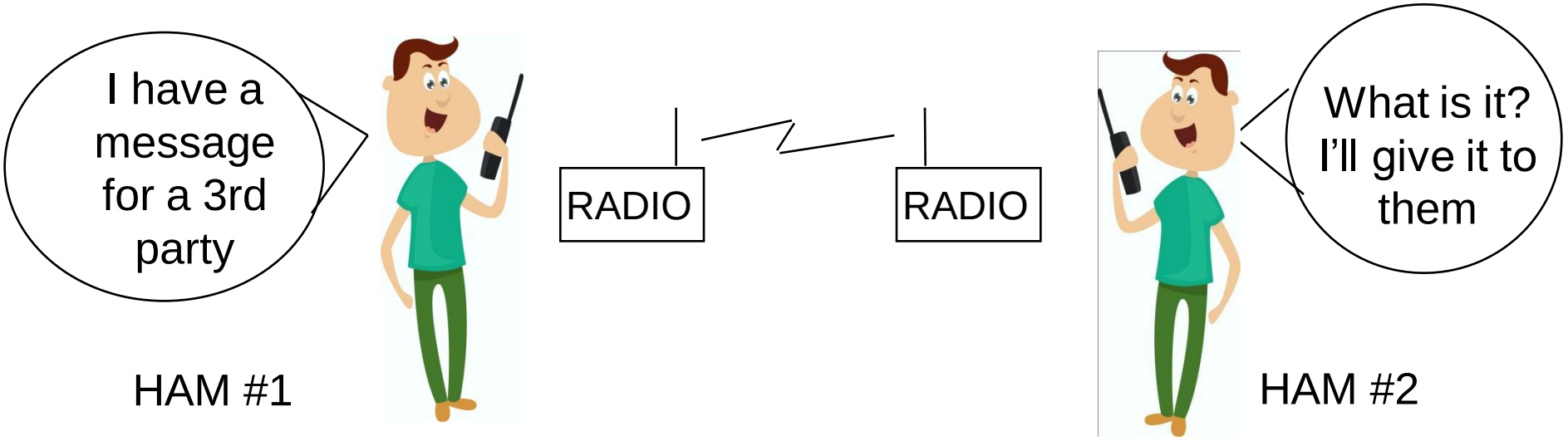
1D01

- A USA ham is not allowed to communicate with a ham in a foreign country if it is prohibited by either country, i.e., that country notified the ITU that it objects to these communications

- The Gordon West book has a list of countries holding USA reciprocal agreements (page 43)

- Two countries that prohibit amateur communications is North Korea and Eritrea (in Africa)

Call Signs and International Messages



Ham 1	Ham 2	3rd Party
USA	Foreign	Anywhere

1F08 • Third party communications is a message from one control operator to another amateur station on behalf of another person

1F07 • When a non-licensed person is allowed to speak to the foreign station, the foreign station must be in a country with which the U.S. has a third party agreement

• Gordy has a list of Third-Party traffic countries on page 43

Where Else Can I Use My License

1C06

- You can also operate on a vessel or craft located in international waters and is documented or registered in the USA

- If the vessel is a cruise ship, you will also need the permission of the ship's Captain at a minimum

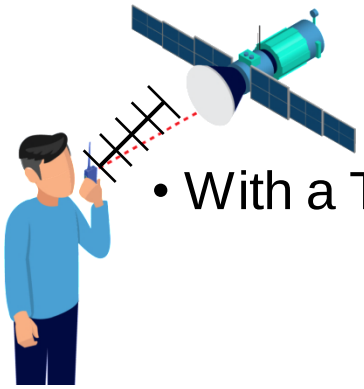
Section 3

Control

Control

1E01 • An amateur station can never operate without a control operator

1E02 • You can be the control operator of a station communicating through an amateur satellite or space station if your license privileges allow you to transmit on the satellite uplink frequency



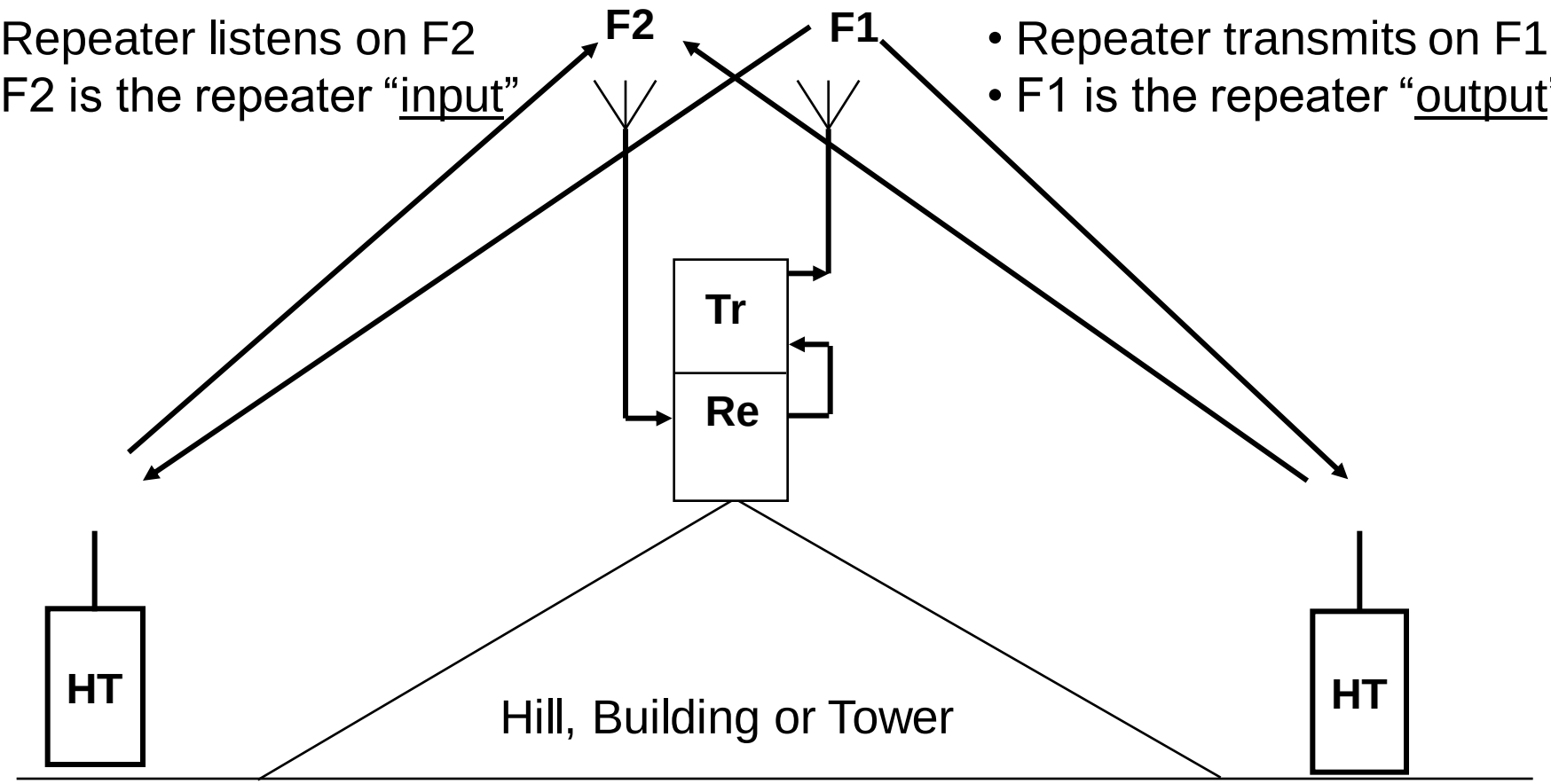
• With a Technician license, you can be the control operator of transmitters that are fixed, mobile, portable (HT), a repeater or even an amateur radio satellite

1E11 • The control operator, per Part 97, is an amateur operator designated by the licensee of a station to be responsible for transmissions and FCC rules compliance at the station

• If the FCC is monitoring, they assume that you were the control operator, unless you can provide documentation to the contrary in your station log book

What is a repeater?

- Repeater listens on F2
- F2 is the repeater "input"



- Repeater transmits on F1
- F1 is the repeater "output"`

- The repeater receives on its "input" frequency and transmits on its "output" frequency

- We'll cover this in more detail in Section 8

Control

1E05 • An amateur station's control point is the location at which the control operator function is performed

- Station control can be done three ways:
  - Local
  - Remote
  - Automatic

- Examples:
  - Local – You are physically present at the control point
    - Example – You can actually push the transmit button

1E10
  - Remote – Could be controlling a station via the internet

1E09
  - Any station may be remotely controlled
    - The control operator must be at the control point
    - A control operator is required at all times
    - The control operator indirectly manipulates the controls

1E08
  - A repeater is an example of automatic control (no operator present)

Control

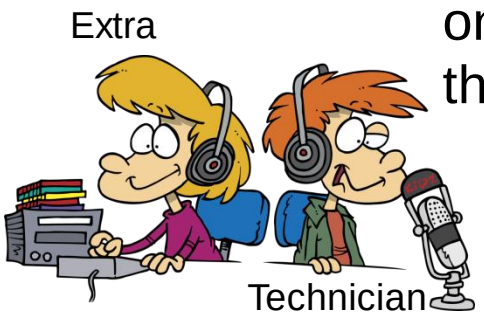
1E03 • As the station licensee, you can designate the control operator function to another licensed amateur radio operator

1E07 • When the control operator is not the station licensee the control operator and the station licensee are both responsible for the proper operation of the station

1E04 • The transmitting privileges of an amateur station is determined by the class of operator license held by the control operator

• If you have a Technician Class license and you visit a station of an Extra Class operator, <u>then as long as that person is present (i.e., the control operator)</u>, you can use that person's privileges, but you must use that person's call sign

• If that person leaves, then you are the control operator and you can only use your Technician privileges (and your call sign) and not the Extra Class privileges. See the next chart.



Control

- If you let a ham with a higher class license operate your station, they can use their privileges, but with proper ID (their call)

- Look at the illustration below:
  - We can all use Steve's privileges and his call as long as he is present, i.e., he is the control operator
  - If Steve leaves, then Sue is the control operator and Sue and Tom can use Sue's privileges and her call
  - But if Sue leaves, then Tom is the control operator and can only use his privileges and his call

Control

- If you are transmitting to a repeater and there was music in the background, then the music is being retransmitted through the repeater, which is against FCC rules (i.e., transmitting music)

1F10
- The control operator of the originating station is responsible should a repeater inadvertently retransmit communications that violate the FCC rules (not the ham who owns the repeater)

1D08
- The control operator of an amateur station could get financial compensation if the communication is incidental to classroom instruction at an educational institute
- Otherwise, amateur radio operators can not get financially compensated for using their radios

1E06
- Under no normal circumstances may a Technician class licensee be the control operator of a station operating in an Amateur Extra Class band

Section 4

Mind the Rules

Mind the Rules

- The FCC defines the rules and regulations for amateur radio in what they refer to as Part 97 of their documentation

1D06

- The transmission of indecent and obscene language is prohibited in amateur radio service (there is no list of prohibited obscene and indecent words)

- Regretfully, you will occasionally hear foul language on the amateur bands. You can either report it to the FCC or tape the transmission and provide it to the FCC

1D10

- The FCC defines broadcasting as transmissions intended for reception by the general public

- Transmitting information to the general public (i.e., broadcasting) is not permitted in amateur radio service

1D02

- One way transmissions by an amateur station are prohibited is when it is broadcasting

Mind the Rules

1D09
- When directly related to the immediate safety of human life or protection of property, amateur stations may transmit information in support of broadcasting, program production, or news gathering, assuming no other means are available

- Brief transmissions to make station adjustments are permitted

1D03
- Transmitting messages encoded to hide their meaning is only permitted when transmitting command codes to space stations (ham satellites) or radio controlled craft (explain)

1D04
- Amateur stations are authorized to retransmit manned spacecraft, communications, which may have music in the background (otherwise no music)

1C07
- The FCC can revoke or suspend your station license if the FCC is unable to reach you by email, so keep it up to date

1C04
- An amateur radio license can be renewed up to 90 days before the expiration date

Mind the Rules

- As noted previously, amateur radio can't be used for business

1D05

- But it is permitted to tell other hams on the radio that you have ham radio equipment for sale or trade but not on a regular basis

- It is extremely rare, but the FCC can ask to inspect your station

1F01

- But the station licensee must make the station and its records available for an FCC inspection at any time requested by an FCC representative

- The FCC defines harmful interference as that which seriously degrades, obstructs, or repeatedly interrupts a radio communications service operating in accordance with the Radio Regulations

1A11

- Willful interference to another amateur radio station is never permitted

Section 5

Tech Frequencies

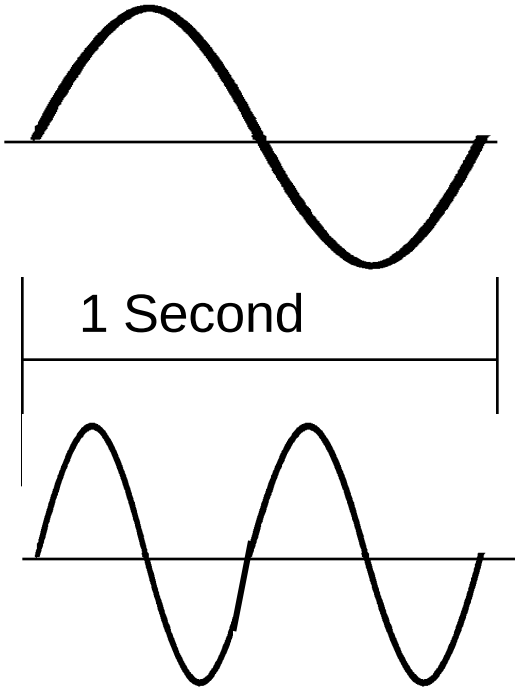
Common Conversion Factors

A thousand = a kilo
A million = a mega
A billion = a giga

Examples:

1,000 grams = 1 kilogram
1,000,000 dollars = 1 megabuck
1,000,000,000 bytes = 1 gigabyte

Frequencies



1 Cycle Frequency = 1 cycle/second
= 1 hertz = 1 Hz

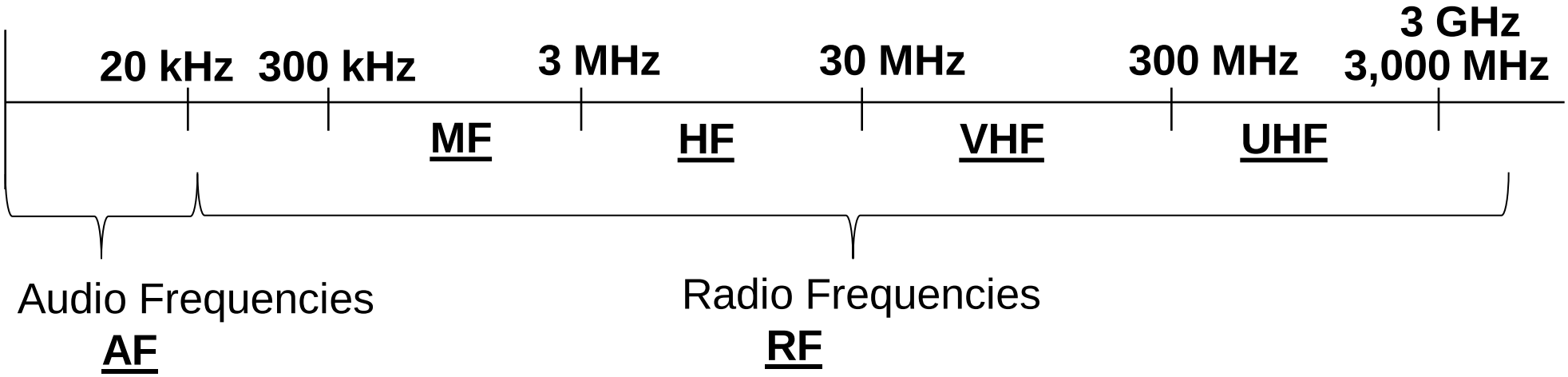
2 Cycles Frequency = 2 cycles/second
= 2 hertz = 2 Hz

- Frequency is the number of times per second that a wave goes through a complete cycle

5A04

- Frequency is the term used to describe the number of times per second that an alternating current makes a complete cycle (example 60 Hz)

Frequencies



5C06

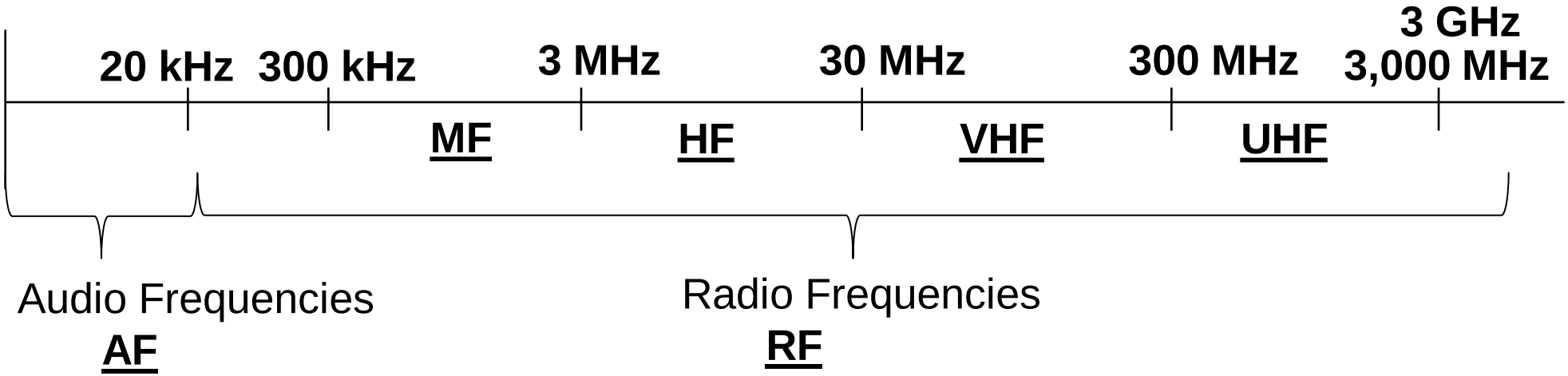
- kHz is the abbreviation for kilohertz (note which letters are capitalized)

- Audio waves are in the range of 300 Hz to 20 kHz and electromagnetic waves are typically greater than 20 kHz

3B03

- The two components of radio waves are electric and magnetic fields

Frequencies



- These are very commonly used abbreviations in Amateur Radio and throughout the question pool
- **Memorize these and the frequency ranges NOW** →

HF	High Frequency
VHF	Very High Frequency
UHF	Ultra High Frequency

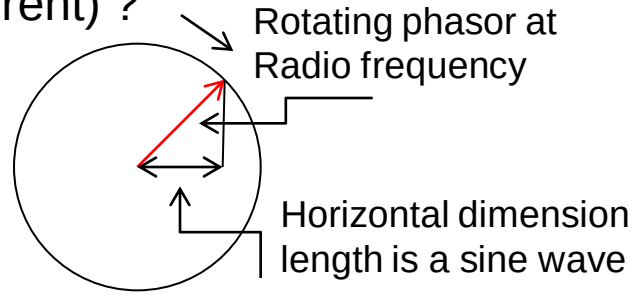
3B10 • The frequency range of 3 MHz to 30 MHz is referred to as HF

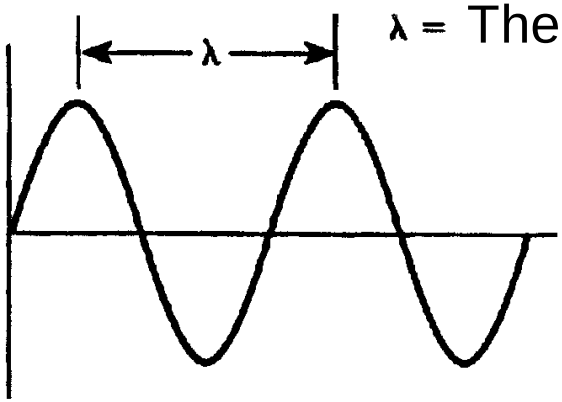
3B08 • The frequency range of 30 MHz to 300 MHz is referred to as VHF

3B09 • The frequency range of 300 MHz to 3,000 MHz is referred to as UHF

Frequencies

What is a sine wave (alternating current) ?





λ = The wavelength

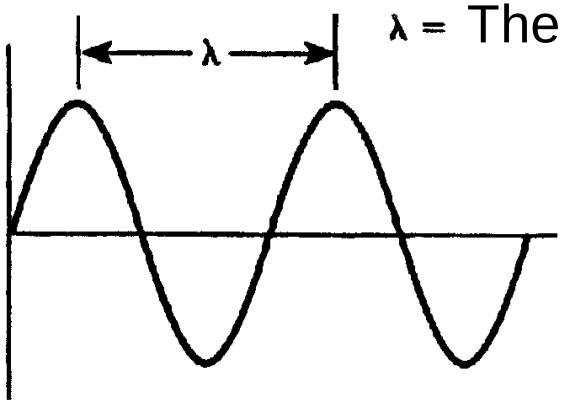
- Wavelength (meters) = $\frac{300}{\text{frequency (in MHz)}}$
- f (MHz) = $\frac{300}{\text{wavelength (in meters)}}$

3B04 • Radio waves travel at the speed of light

3B11 • The radio wave velocity is 300,000,000 meters per second

3B12 • All radio frequencies travel at the highest velocity in free space

Frequencies



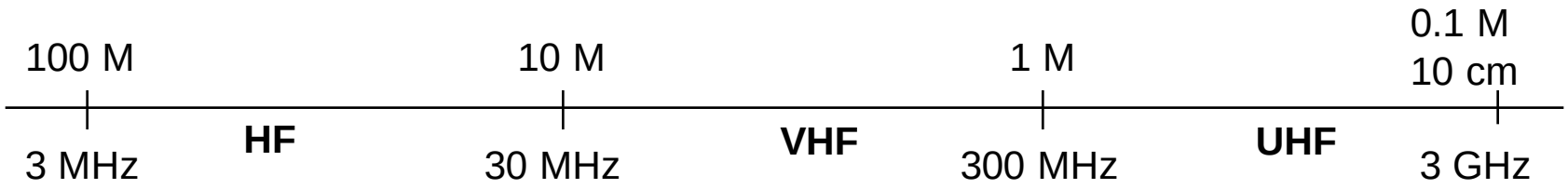
λ = The wavelength

- Wavelength (meters) = $\frac{300}{\text{frequency (in MHz)}}$
- f (MHz) = $\frac{300}{\text{wavelength (in meters)}}$

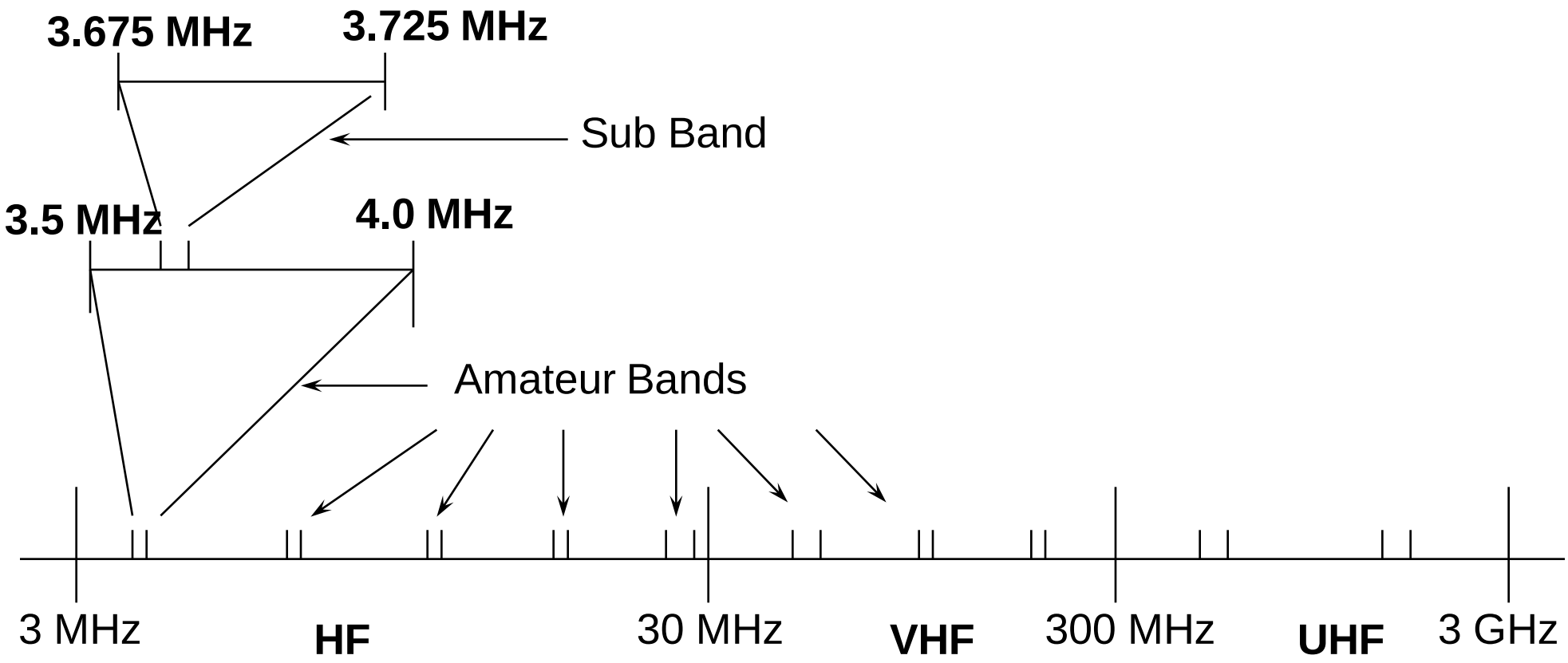
3B01 • The relationship between electric and magnetic fields of an electromagnetic wave is that they are at right angles

3B05 • The wavelength gets shorter as the frequency increases

3B06 • The formula for converting frequency to wavelength in meters is 300 divided by frequency in megahertz

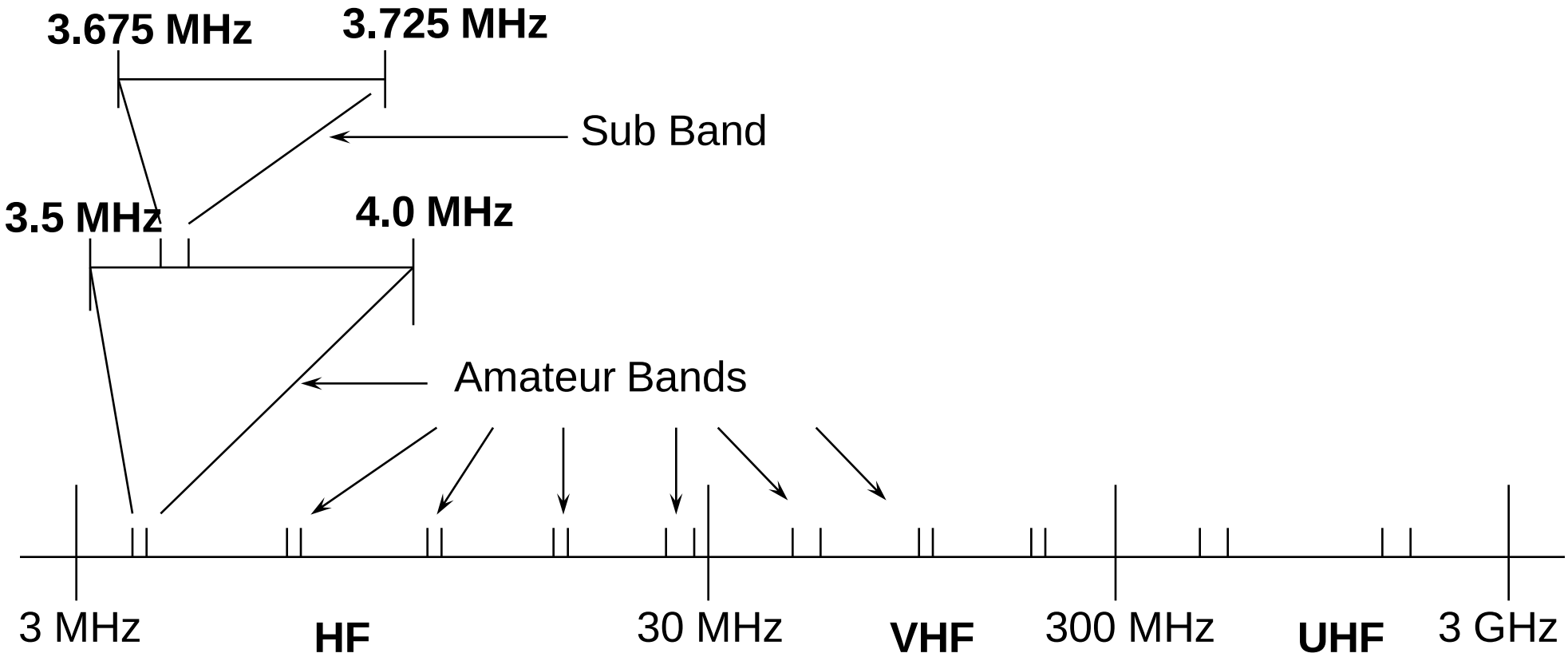


Frequencies



- Amateur Radio has been allocated many frequency ranges we call "bands"
- Most Amateur Radio bands are in the HF, VHF, UHF portion of the RF spectrum
- Some bands have sub-bands, used only with certain class of licenses

Frequencies



3B07

- Different frequency bands are often referred to by their wavelength (in meters 80 M, 40 M, 20 M, 15 M, 10 M, 6 M, 2 M)

- In summary, an amateur radio operator will identify a specific band or frequency by its wavelength (give example)

Frequencies & Bands

- These are the most popular amateur bands
- Technician, General and Extra privileges are noted below
- Nothing to memorize here

	Freq. Band			Wavelength	Privileges		
	From	To		(Meters)	Tech	General	Extra
HF	3.5	4	MHz	80 M 75 M	Few	Most	All
HF	7	7.3	MHz	40 M	Few	Most	All
HF	14	14.35	MHz	20 M		Most	All
HF	21	21.45	MHz	15 M	Few	Most	All
HF	28	29.7	MHz	10 M	Some	All	All
VHF	50	54	MHz	6 M			
VHF	144	148	MHz	2 M	All classes have all privileges		
VHF	222	225	MHz	1.25 M	on these bands		
UHF	420	450	MHz	70 CM			
UHF	1,240	1,300	MHz	23 CM			

Tech Frequencies

Frequency From	Band To	Wavelength (Meters)
50	54 MHz	6 M
144	148 MHz	2 M
219	220 MHz	1.25 M
222	225 MHz	1.25 M
420	450 MHz	70 cm
902	928 MHz	33 cm
1,240	1,300 MHz	23 cm

1B03 • 52.525 MHz is in the 6 meter amateur band

1B04 • 146.52 MHz is in the 2 meter amateur band

2A02 • 146.52 MHZ is the national calling frequency on FM simplex on the 2 meter band (what is simplex??)

• There are many more bands at higher frequencies

Tech Frequencies

Frequency From	Band To	Wavelength (Meters)	Emission Privileges
50	54 MHz	6 M	ALL
144	148 MHz	2 M	ALL
219	220 MHz	1.25 M	Data
222	225 MHz	1.25 M	ALL
420	450 MHz	70 cm	ALL
902	928 MHz	33 cm	ALL
1,240	1,300 MHz	23 cm	ALL

- The fact that a Technician Class license holder has **ALL** emission privileges on almost all bands above 50 MHz is **NEVER** acknowledged or revealed in the question pool

- Later, I'll give you a brief summary of what many of them are

Tech Frequencies

	Frequency Band From	To	Wavelength (Meters)	Emission Privileges	* Power (Watts PEP)
	50	54 MHz	6 M	ALL	0 - 1,500
	144	148 MHz	2 M	ALL	0 - 1,500
1B05	219	220 MHz	1.25 M	Data	??
	222	225 MHz	1.25 M	ALL	0 - 1,500
	420	450 MHz	70 cm	ALL	??
	902	928 MHz	33 cm	ALL	0 - 1,500
	1,240	1,300 MHz	23 cm	ALL	0 - 1,500

1B12 • Except for some specific restrictions, the maximum peak envelope power output for Technician class operators using frequencies above 30 MHz is 1,500 watts

• However, when most of us use these bands, we are using a hand held and they typically only put out 5 watts

1B05 • 10, 6 and 2 meters all have bands available for Technicians to use digital modes such as FT8

Frequencies

- The FCC question pool now uses the term “band plan”

2A10

- The term “band plan” goes beyond the FCC established privileges and is a voluntary guideline for using different modes or activities within an amateur band

- The voluntary “band plans” make efficient use of the amateur radio spectrum on these bands

- These “band plans” were developed by the amateur community

- Some “band plans” define repeater frequencies, simplex frequencies, and other issues, but don’t conflict with the FCC rules

- The repeater “band plan” is done by a local coordination group

Frequencies

- Primary privilege means I have the first priority to use the frequency
- Secondary privilege means a Primary privilege station has priority

1B08

- Your Amateur Radio license will say Primary privilege, but is secondary in all or portions of some amateur bands (such as portions of the 70 cm band) because there are non amateur stations in portions, and we must avoid interfering with them

Primary	Secondary	Comments
Non Amateur	Amateurs	- Amateurs can use the frequency if they don't cause interference to the Primary station (example)

Primary	Secondary	Comments
Non Amateur	Amateurs	- Amateurs move to another frequency if it causes interference to the Primary station (example)

Tech Frequencies

Frequency From	Band To	Wavelength In Meters	Emission Privileges	Power (Watts PEP)
3,525	3,600 kHz	80 M 75 M	CW	0 - 200
7,025	7,125 kHz	40 M	CW	0 - 200
21.025	21.200 MHz	15 M	CW	0 - 200
28.000	28.300 MHz	10 M	CW, RTTY, Data	0 - 200
28.300	28.500 MHz	10 M	CW, SSB	0 - 200

- Prior to 23 February 2007, a Technician passing a 5 wpm Morse Code test got the privileges shown above (license called Tech + Morse)
- On 23 February 2007, the FCC eliminated all Morse Code requirements
- Starting then, all Technicians also get all of these HF privileges

1B11 • The maximum peak envelope power output for Technician class operators using their HF band segments is 200 watts

Frequencies

1B09

- Never set your transmitter on the exact edge frequency of a band or sub-band:
  - To allow for calibration error in the transmitter frequency display
  - So that modulation sidebands do not exceed beyond the band edge
  - To allow for transmitter frequency drift

Frequencies

5A06 • Hertz (cycles per second) is the unit of frequency

5C06 • kHz is the abbreviation for kilohertz (note which letters are capitalized

5C07 • MHz is the abbreviation for megahertz (note which letters are capitalized

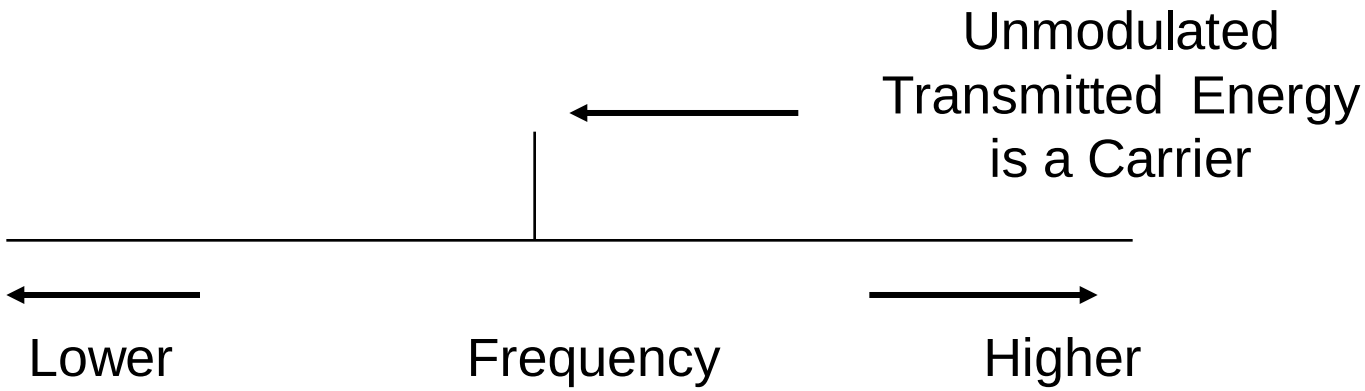
5B07 • 3.525 MHz is the same as 3525 kHz (move the decimal 3 places)

Section 6

Your First Radio

Question T7A08 is in this section not section 13

RF Carrier



- Radio Frequency (RF) energy transmitted at a single frequency is typically called a “Carrier”

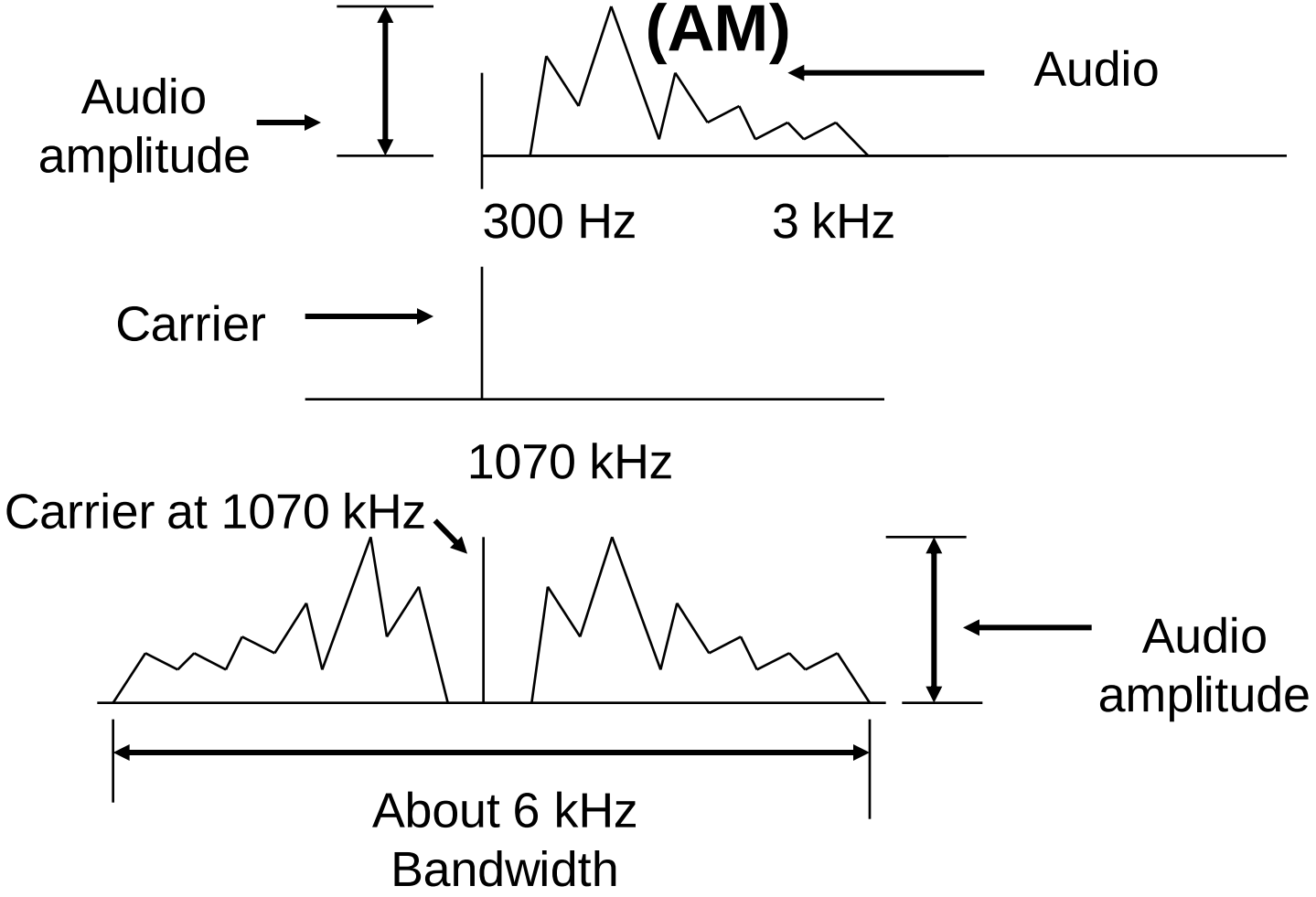
- The Carrier will carry the information we wish to transmit, like our voice

7A08

- Modulation is the process of combining speech with an RF carrier signal

- Lets look at three popular types of modulation, AM, SSB (single sideband) and FM

Emissions Types, Amplitude Modulation (AM)



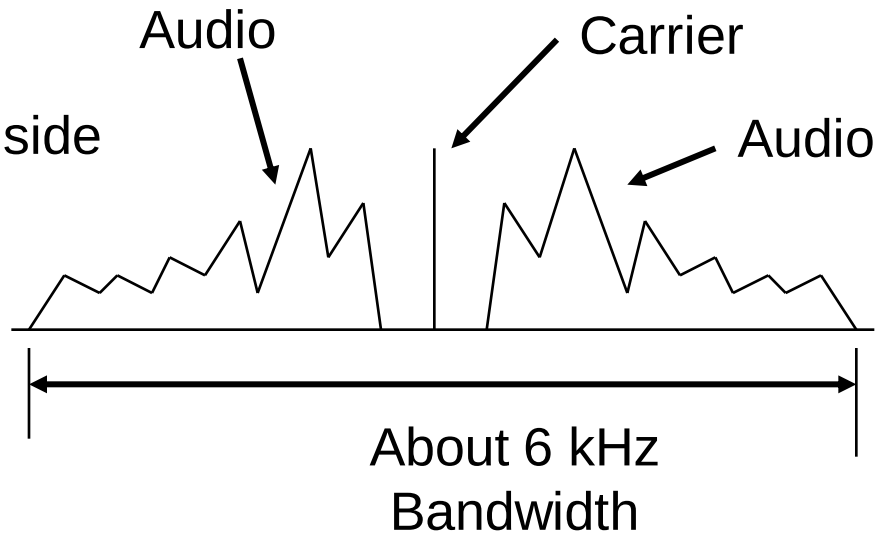
- Audio modulation can be on each side of the Carrier

- Amplitude increases and decreases as my voice loudness changes, hence, Amplitude Modulation (AM)

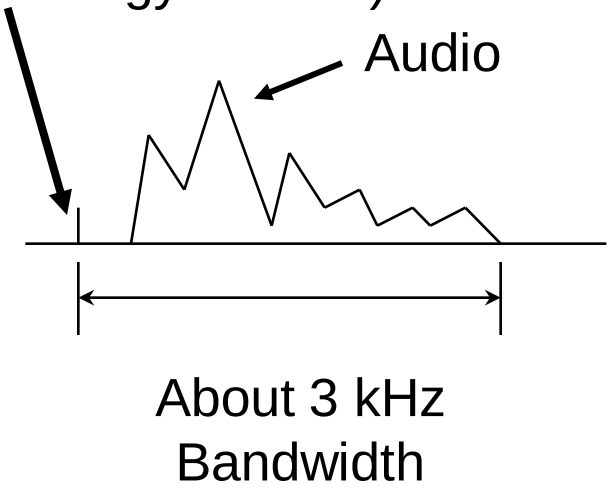
Emissions Types, Single Sideband (SSB)

Start with AM

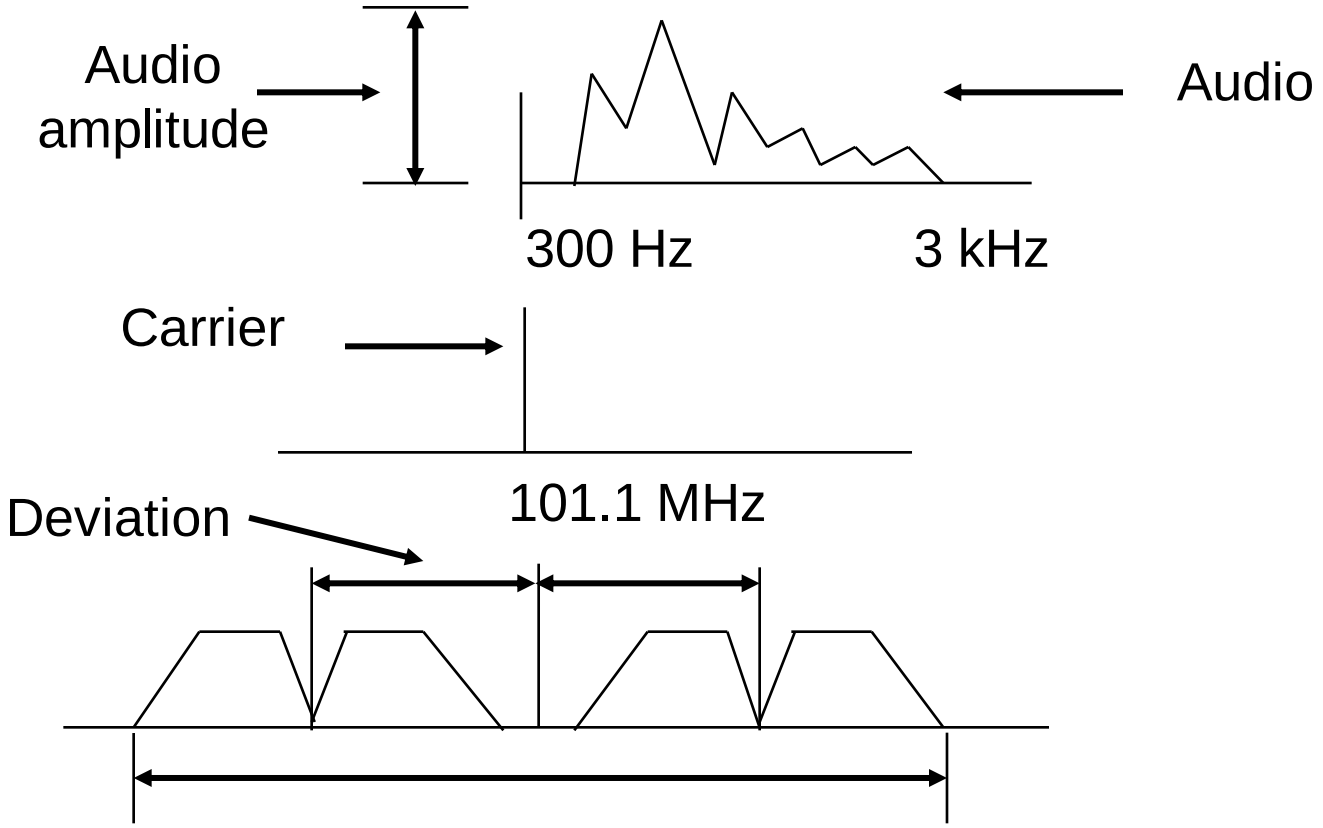
- Audio sidebands on each side of the carrier



- Suppress the carrier (take most of the energy out of it)
- Eliminate one sideband
- This is single sideband, SSB
- Single sideband is a form of AM



Emissions Types, Frequency Modulation (FM)

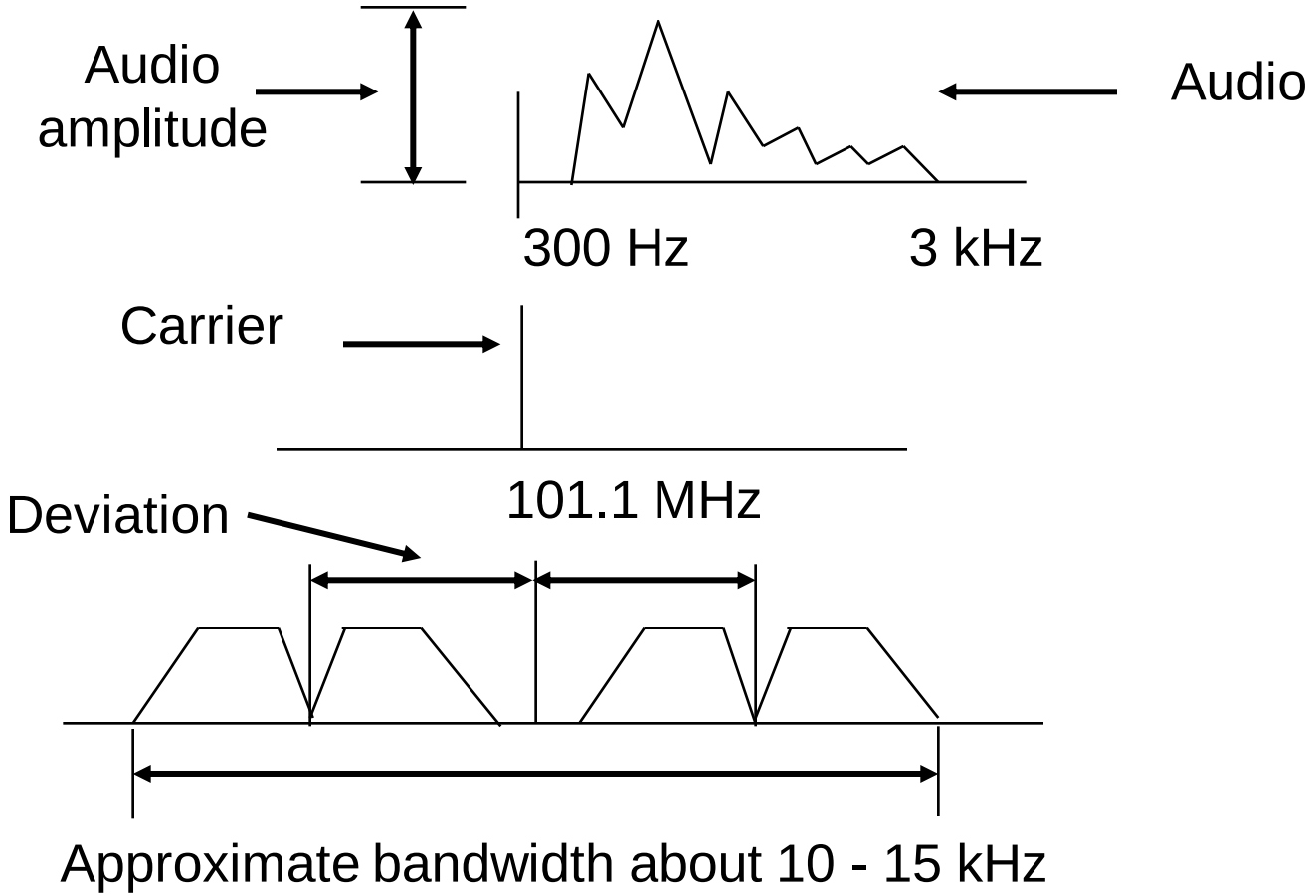


- The Carrier shifts frequency, i.e., **deviation**

- The amount of frequency deviation of an FM signal is set by the amplitude of the modulating signal (my voice loudness)

- When the deviation increases the FM signal occupies more bandwidth

Emissions Types, Frequency Modulation (FM)

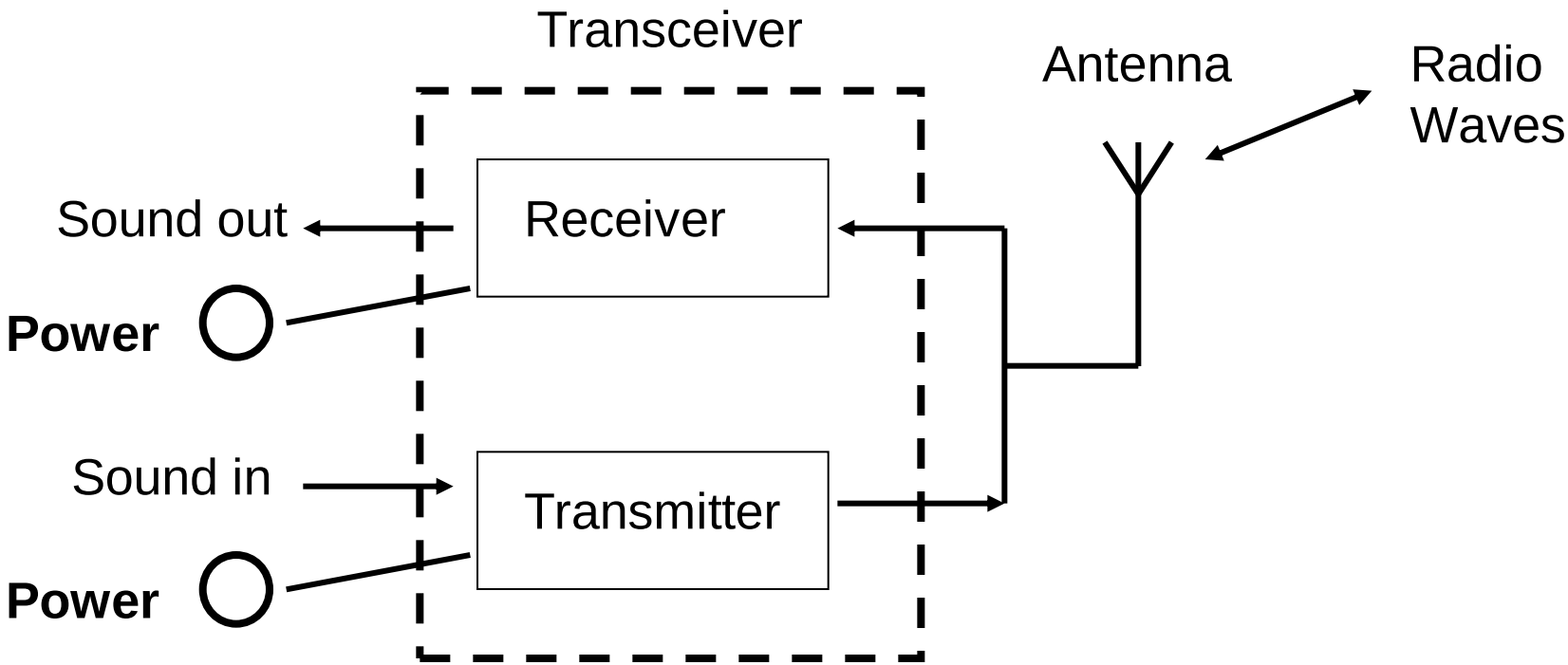


- The FM repeaters need to have enough bandwidth to allow these FM signals to get through

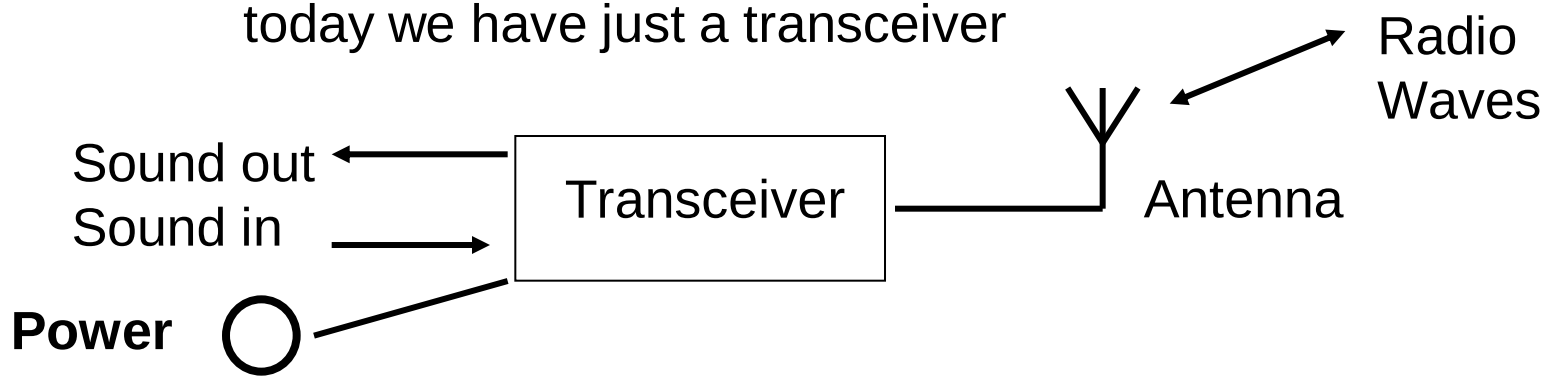
8A09

- The bandwidth of a VHF FM repeater FM voice signal is between 10 and 15 kHz

Radio Transceivers



- Years ago we had separate receivers and transmitters but today we have just a transceiver



FM & Digital

- FM is the emission transmitted by all HT's (HT = handie-talkie, i.e., a hand held radio)

- PM is phase modulation

8A04

- FM (frequency modulation) or PM (phase modulation) is most commonly used modulation for VHF and UHF voice repeaters

- One of many digital communication modes is called packet

8A02

- FM or PM is the most commonly uses modulation for VHF packet (data) radio transmissions

Your First Radio

- Once you get your Technician license, your first radio will probably be a hand held, also called an HT

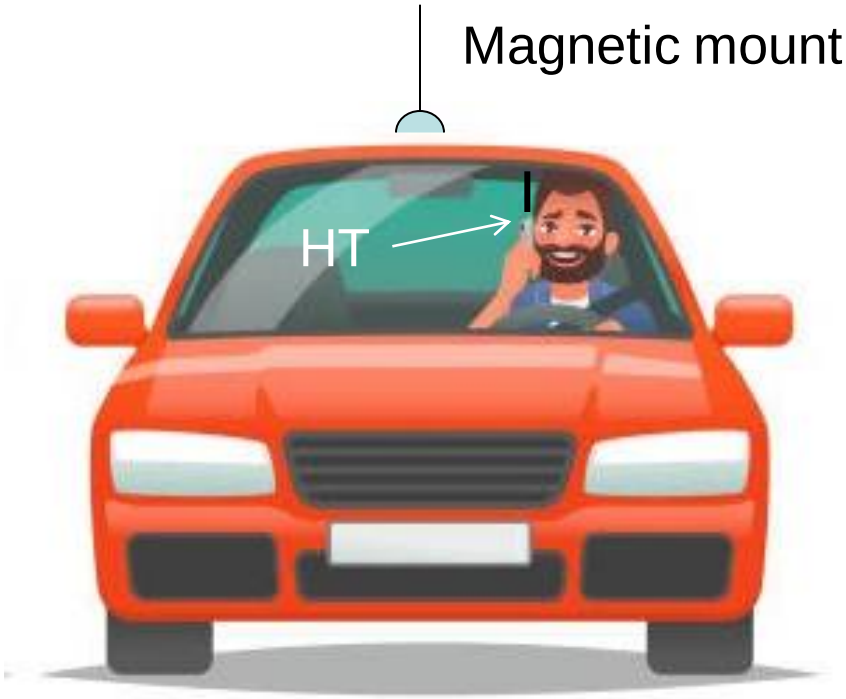
- They have hundreds of memory channels

4B04 • An FM signal sounds distorted when received slightly off frequency

9A04 • The disadvantage of the short, flexible antenna supplied with most handheld radio transceivers is that it is shorter than a full-size quarter-wave antenna and has low efficiency (in both transmit and receive – more in Section 18, Antennas)

7A07 • The function of a transceiver's PTT input is it switches the transceiver from receive to transmit when grounded

Mobile Operation



9A07

- A disadvantage of operating an HT transceiver with it's flexible antenna inside the car is that the signal strength is reduced due to the shielding effect of the vehicle

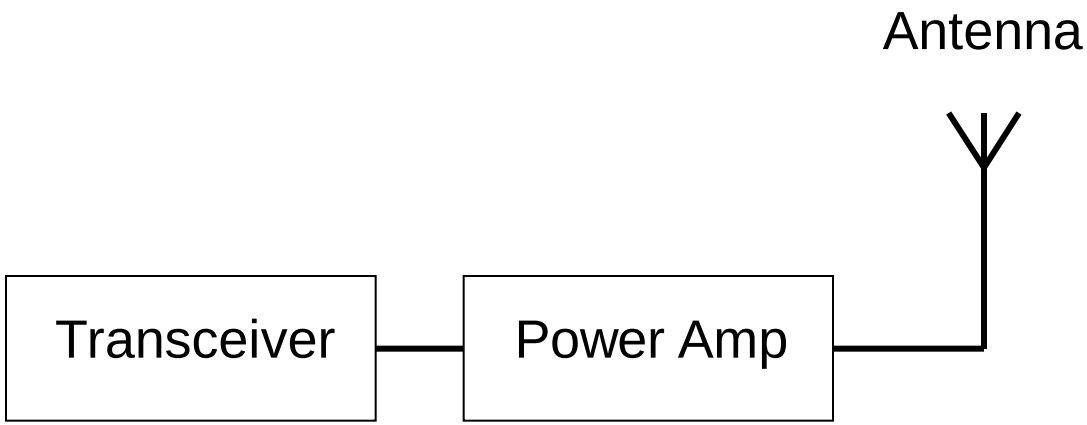
- To improve the radiation and reception efficiency, use a magnet mount vertical antenna connected to the HT

- The "mag-mount" can be left on the car or removed and stored in the car

More Power

- HT's typically put out 5 watts
- But if you use your HT in a car, some folks want more power

7A10
- An RF power amplifier can increase the low-power output of a handheld transceiver
- Power amplifiers are typically not used with HT's



Section 7

Going Solo

Going on the Air

- Let's talk about many of the issues that you need to understand when you start to go on the air

4B02
- The two ways to enter a transceiver's operating frequency are the VFO knob or the keypad
  - The first is to turn the VFO knob (variable frequency oscillator)
  - The second to use the keypad, typically on the microphone or on the HT

- When using FM on your radio, you would normally hear a lot of receiver output noise when there is no incoming signal

2B13
- The squelch control on a transceiver can mute receiver audio when a signal is not present (do a demo)

4B03
- To make sure that a weak FM signal can be heard, set the squelch threshold so that the receiver output audio is on all the time

Amateur Radio Abbreviations

- Amateurs use many abbreviations, mostly for Morse code but some carried over to voice modes. Here's a few examples

- Common abbreviations

2A08

CQ	means	"Calling any station"
DX	means	"Distant station"
73	means	"Best regards"
88	means	"Love and kisses"
OM	means	"Old Man" (a male)
YL	means	"Young Lady" (a female)

- Some, but not all, are called "Q" signals. Common "Q" Signals

QTH	means	"My location"
QSO	means	"Conversation (in process)"
2B10 QRM	means	"Interference from another station"
QSL	means	"Yes, or to confirm"
2B11 QSY	means	"Change frequency"

- **ONLY MEMORIZE THE ONES THAT ARE IN THE POOL**
- Gordon West has many of the popular Q signals on page 76

Going on the Air

2A11

- When we transmit and then receive on the same frequency, it is called simplex communication

2A05

- If you hear a station calling CQ, then say the other stations call sign followed by your call sign
- If I was to call CQ, I would say "CQ, CQ, CQ, this is KI6TEQ"
- Then I would listen to hear if anyone called me back

2B14

- A "talkgroup" is an identifier used by DMR to organize radio traffic so that those who want to hear the group aren't bothered by other radio traffic

Going on the Air

- To transmit on one frequency and listen on a different frequency, it is called duplex communication (repeaters)

2A04
- When calling a station you know on a repeater, say the other station's call sign and (then say "this is") then say your call sign

2B03
- A network of repeaters in which signals received by one repeater are transmitted by all the repeaters in the network is called a linked repeater network

2B09
- Simplex frequencies are designated in VHF/UHF band plans so that stations within range of each other can communicate without tying up a repeater

3A01
- VHF signal strength sometimes varies greatly when the antenna is moving only a few feet because the multipathing propagation cancels or reinforces signals (explain)

Going on the Air

3A06 • Picket fencing" means that there is rapid flutter on a mobile signal due to multipath propagation (explain)

2B08 • When two stations are transmitting on the same frequency and interfering with each other, the stations should negotiate continued used of the frequency (i.e., which one should move to another frequency)

8C03 • Contests are ham radio activities which involve contacting as many stations as possible in a specific period of time

• There are dozens of these contests and there are many awards given out to the hams who have the best score

8C04 • When you make a contact in a contest, you send only the minimum information needed for proper identification and the contest exchange (explain)

Going on the Air

1D12 • When making on-the-air test transmissions the transmitting station must identify itself

2A06 • When not using a repeater (simplex), an effective way to seek a call from any phone station is to repeat “CQ” a few times, followed by “this is” and your call sign, then pause to listen; repeat as necessary

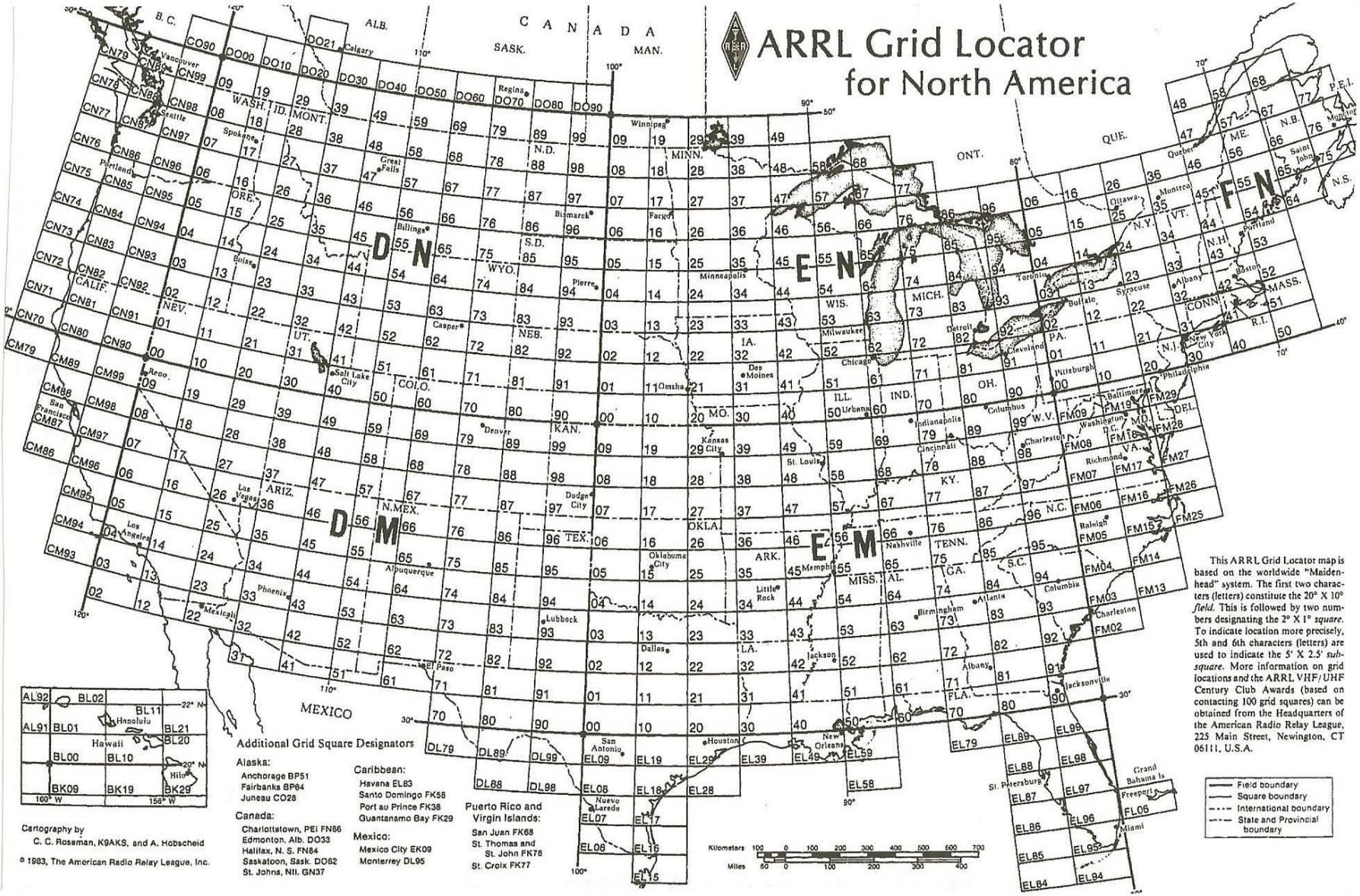
Grid Squares

- Amateur radio has broken up the earth into grid squares
- Each grid square is 1 degree of latitude and 2 degrees of longitude
- Each square has a 2 letter and 2 number name called a grid locator

8C05

- A grid locator is a letter-number designator assigned to a geographic location
- I think the Palos Verdes Peninsula is in grid locator DM03
- They use grid squares in many contests
- See next chart

Grid Squares



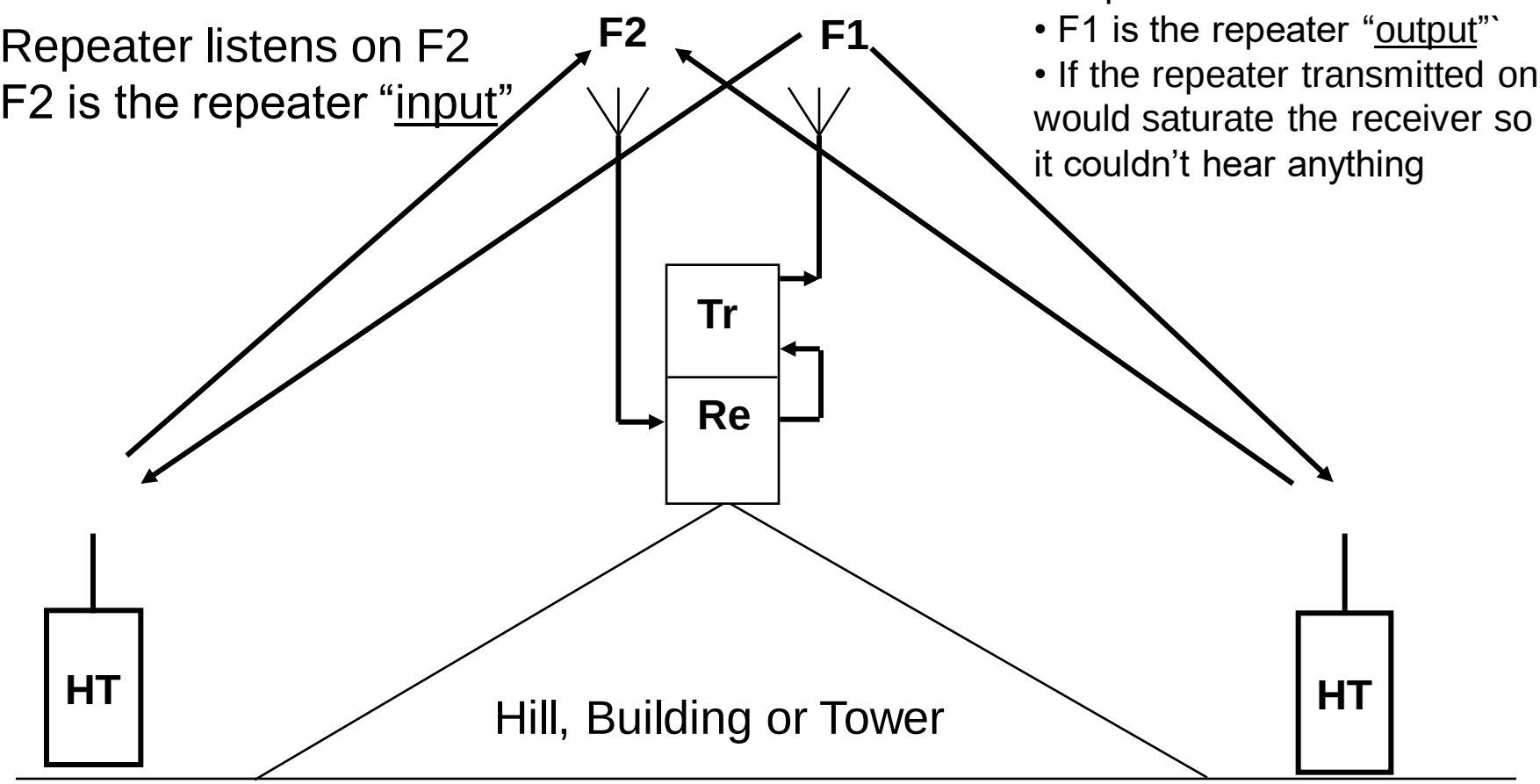
Section 8

Repeaters

What is a repeater?

- Repeater listens on F2
- F2 is the repeater "input"

- Repeater transmits on F1
- F1 is the repeater "output"`
- If the repeater transmitted on F2, it would saturate the receiver so that it couldn't hear anything



1F09 • A repeater station simultaneously retransmits the signal of another amateur station on a different channel or channels

• T1F09 uses "channel" vs. frequency

Repeaters and their “Offset”

2A07 • The frequency difference between the repeater transmit and receive frequencies is called the “repeater offset” (also called the “split”)

• If:
  • The repeater’s output is 145.38 MHz (the frequency we listen to)
  • The repeater’s input is 144.78 MHz (the frequency we transmit on)
  • Then the offset is - 0.60 MHz (or – 600 kHz)

		Band	Offset	Repeater Duplex
2A01	2 M	144 - 148	600 kHz	Plus or Minus
2A03	70 cm	420 - 450	5.0 MHz	Plus or Minus

• The 2 M and 70 cm bands are the most common “dual band” HT’s

2B01 • A common use of “reverse split” is to listen on a repeater’s input frequency

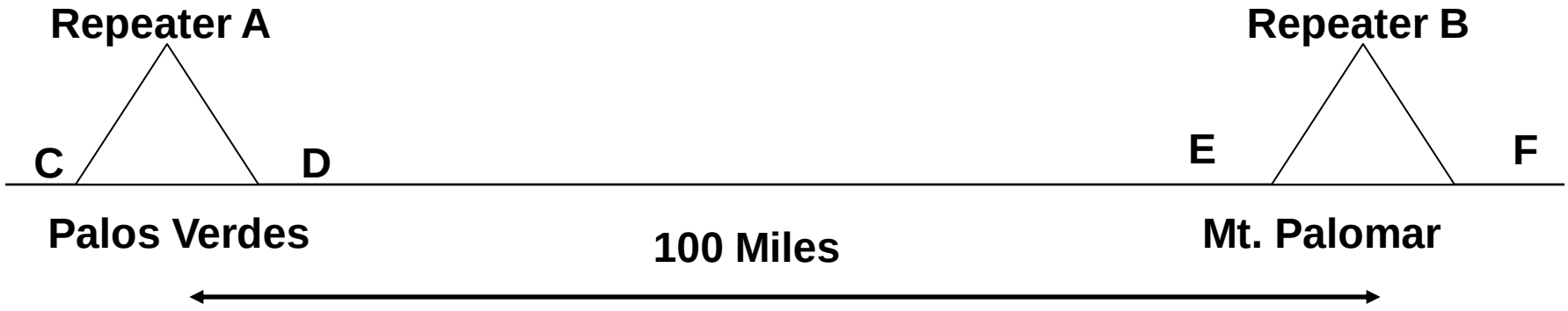
2B03 • A linked repeater network lets signals received by one repeater get transmitted by all the repeaters in the network

Repeaters and CTCSS (PL)

- Problem - Repeaters A and B use the same input & output frequencies,
  - Radios C & D typically communicate through Repeater A
  - Radios E & F typically communicate through Repeater B
  - But when E transmits to Repeater B, it can also unintentionally activate Repeater A. Similarly for D activating Repeater B

- Solution – Most repeaters have a sub-audible tone feature (see next page)
  - CTCSS = Continuous Tone Coded Squelch System
  - Most hams simply call it a PL tone = Private Line tone (a Motorola trademark)

- A repeater using a CTCSS tone activates ONLY when it detects the sub-audible tone on the incoming signal (see next sheet)

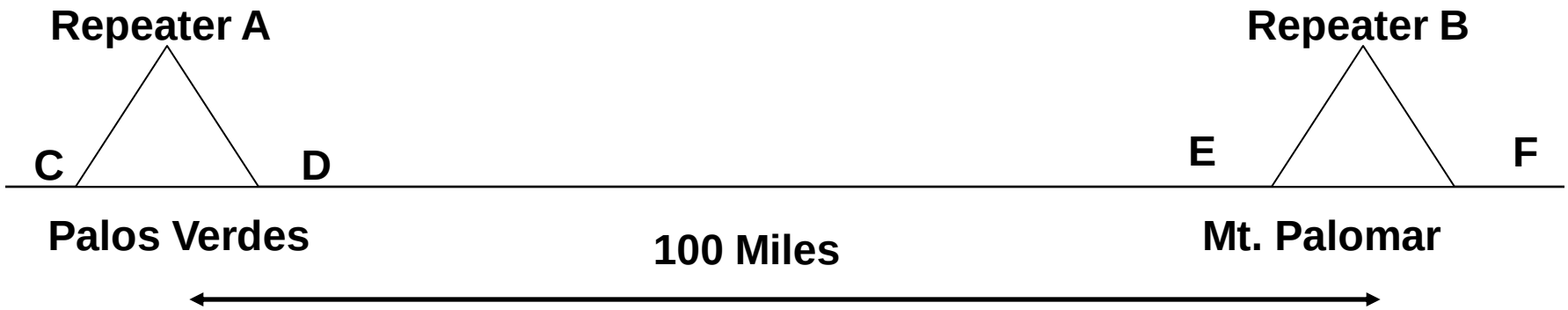


Repeaters and CTCSS (tone)

- There are around 36 sub-audible tones (Gordon book page 82)

2B02
- Transmit the sub-audible tone (CTCSS) along with normal voice audio to open the squelch of the (repeater) receiver

2B04
- If you can hear a repeater but can't access it, it could be the following:
  - Improper transceiver offset
  - The repeater may require a proper CTCSS tone from your transceiver
  - The repeater my require a DCS (digital coded squelch) tone from your transceiver



Repeaters

- A repeater uses a courtesy tone to indicate when a transmission is complete (demo)

- When using a repeater, pause briefly between transmissions to see if anyone wants to break in

2A09

- If a station is listening on a repeater and looking for a contact, say the stations call sign followed by the word “monitoring”

- When you use a repeater, you still only need to give your call every 10 minutes and at the end of the communication

- The repeater must also give the call of the repeater owner every 10 minutes

1F05

- Repeaters are programmed to identify by sending identification in CW (Morse Code) or using a phone (voice) emission

- There are books that list all the repeaters in the USA

Repeaters

1D07

- Amateur stations which can retransmit the signals from other amateur stations are repeaters, auxiliaries and space stations (the wording in T1D07 is a bit awkward)

- An auxiliary station is simply a link from one repeater to another repeater

- A linked repeater network is a network of repeaters where signals received by one repeater are repeated by all the repeaters

- Some HAMs have a repeater at their house which is linked up the coast of California to several repeaters, and so when they talk into the local repeater, you can hear them coming out of all the repeaters and they can chat with you if you are at one of them

Repeater Coordinator

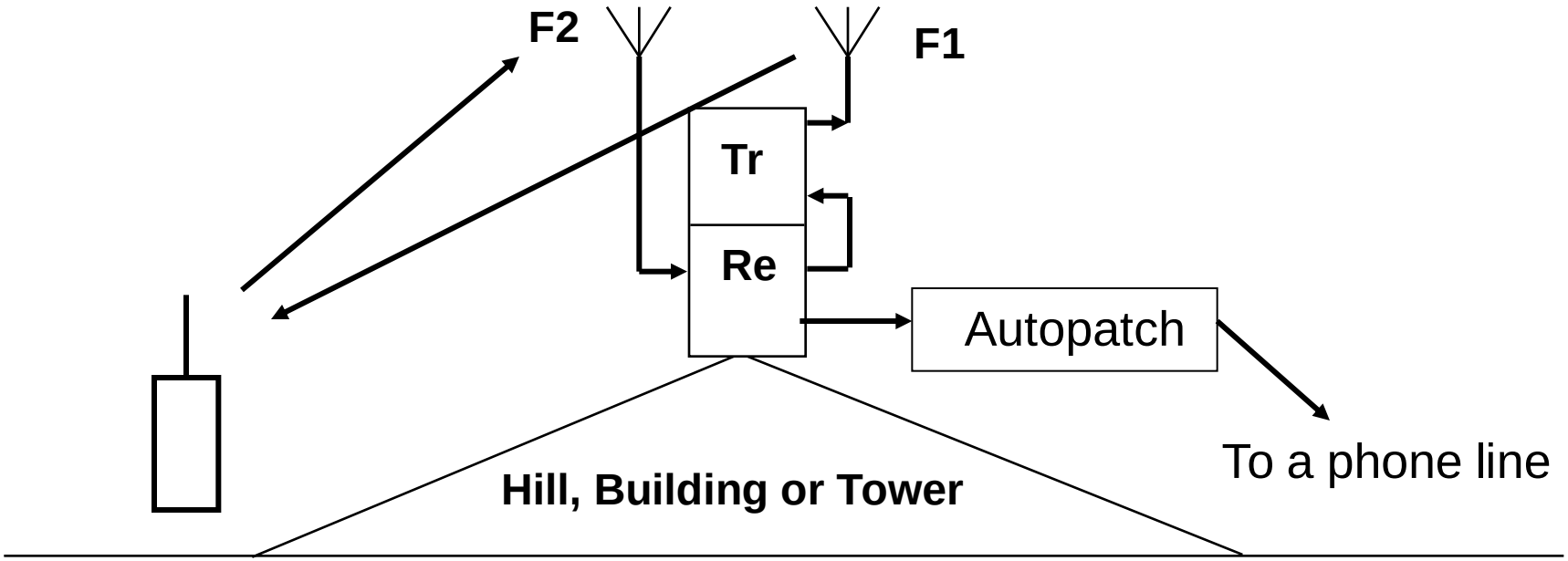
- A repeater coordinator is a local amateur who coordinates the use of repeater frequency pairs in a specific region (like LA County)

- The repeater coordinator:
  - Assigns repeater frequency pairs to amateurs that request them
  - Establishes a waiting list when all frequency pairs are assigned
  - Attempts to resolve problems between repeater operators and coordinates with other regional repeater coordinators (like San Diego County)

1A08
- A Volunteer Frequency Coordinator is recommended by local amateurs and is entitled to recommend transmit/receive channels and other parameters for auxiliary and repeater stations

1A09
- The Frequency Coordinators are selected by amateur operators in local areas whose stations are eligible to be a repeater or auxiliary stations

Repeater Autopatch



- An Autopatch is an electronic box that can connect a radio or repeater to a phone line, allowing calls to be made using your radio
- No conversations are private (why)
- Amateur radio and an autopatch can't be used for business
- The cost of the repeater, the site rental, the autopatch, the phone bill, etc., is paid for by the owner, the members, other

Section 9

Emergency!

Emergency!

2C09

- In situations involving the immediate safety of human life or protection of property an operator is permitted to operate outside the frequency privileges of their license class, but must still identify with your call sign

- If you are communicating with another amateur station and you hear a station in a distress break-in, acknowledge the station in distress and determine what assistance may be needed

- When sending a distress call, use whichever frequency has the best chance of communicating the distress message

- During an actual emergency, an amateur radio station may use any means at its disposal to assist another station in distress

- If you are in a disaster situation, give the answering station your location and the nature of the disaster

Emergency!

2C04
- ARES, the Amateur Radio Emergency Service, is a group of licensed amateurs who have voluntarily registered their qualifications and equipment for communications duty in the public service

2C06
- RACES, the Radio Amateur Civil Emergency Services, is an FCC Part 97 amateur radio service for civil defense communications during national emergencies
- It is the highest level of ham radio emergency activities
- Below RACES are regional groups such as DCS the Disaster Communications Services
- The hams in many towns & cities have set up their own emergency group
- I am a member of PVAN, the Palos Verdes Alert Network

2C12
- RACES is the organization where operators require certification by a civil defense agency

1A10
- For the control operator of a Radio Amateur Civil Emergency Service (RACES) station, in addition to an FCC issued amateur operator license, certification of current enrollment by a civil defense organization is required

Emergency!

2C07 • When you participate in a net, standard practice is to transmit only when directed by the net control station, unless you are reporting an emergency

2C01 • There is never a time when FCC Part 97 Amateur Radio Services rules do not apply to the operation of an amateur station.

2C02 • Typical duties of a Net Control Station is to call the net to order and direct communications between station checking in

2C05 • The formal messages exchanged by net stations is called “traffic”

2C10 • The preamble of a formal traffic message is the information needed to track the message

2C08 • Winlink relays messages using email addresses based on amateur callsigns

2C03 • To ensure that voice messages containing unusual words are received correctly, spell the words using a standard phonetic alphabet

2C11 • “Check” in a radiogram header is the number of words or word equivalents in the text portion of the message

Section 10

Weak Signal Propagation

Radio Wave Propagation

- When electromagnetic waves leave your antenna and travel through space, we have radio waves
- When a radio wave (transmitted energy) leaves an antenna, it can go in many directions, depending on the type of antenna, or in the direction that the antenna is pointed
- What happens to the energy is then a function of the frequency of the transmitted energy
- This is called radio wave propagation
- There are three basic types of radio wave propagation:
  - Line-of-sight
  - Ground wave
  - Sky wave
- Let's take a look at each

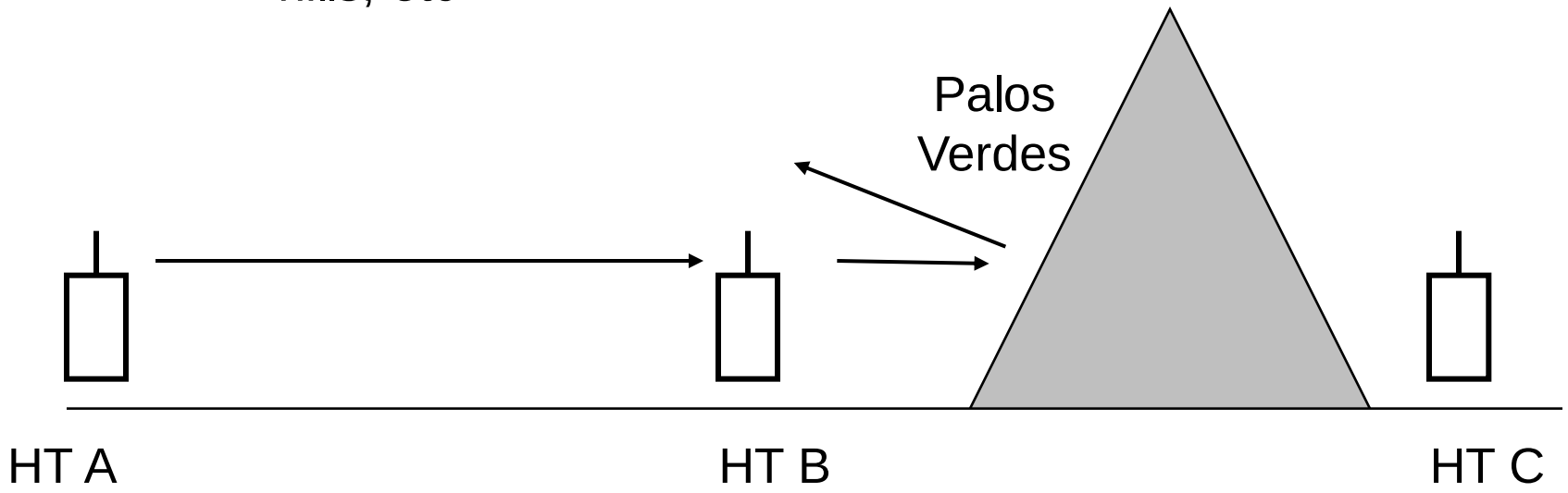
Radio Wave Propagation, Line-of-Sight

- "Line-of-sight" is when radio waves move from point-to-point in a straight line

- VHF & UHF frequencies primarily propagate well in a straight line and are known as "line-of-sight" frequencies

- When HT A transmits, HT B can receive the transmission but not HT C. This is why we have repeaters

- VHF & UHF signals also reflect (bounce) off of metal buildings and hills, etc



VHF-UHF Line of Sight Propagation

- The radio horizon is the distance over which two stations can communicate by direct path (i.e., line-of-sight propagation)

- But line-of-sight radio waves will travel about 1/3 further along the curvature of the earth than the visual line-of-sight

3C11 • The radio horizon for VHF and UHF signals are more distant than visual horizon because the atmosphere refracts radio waves slightly

3A12 • Fog or rain has little effect on 10-meter and 6-meter band signals

3A07 • However microwave frequencies has significant attenuation from fog and rain

3A02 • UHF and microwave signals are affected by vegetation by absorbing signals, leading to poor reception of weak signals

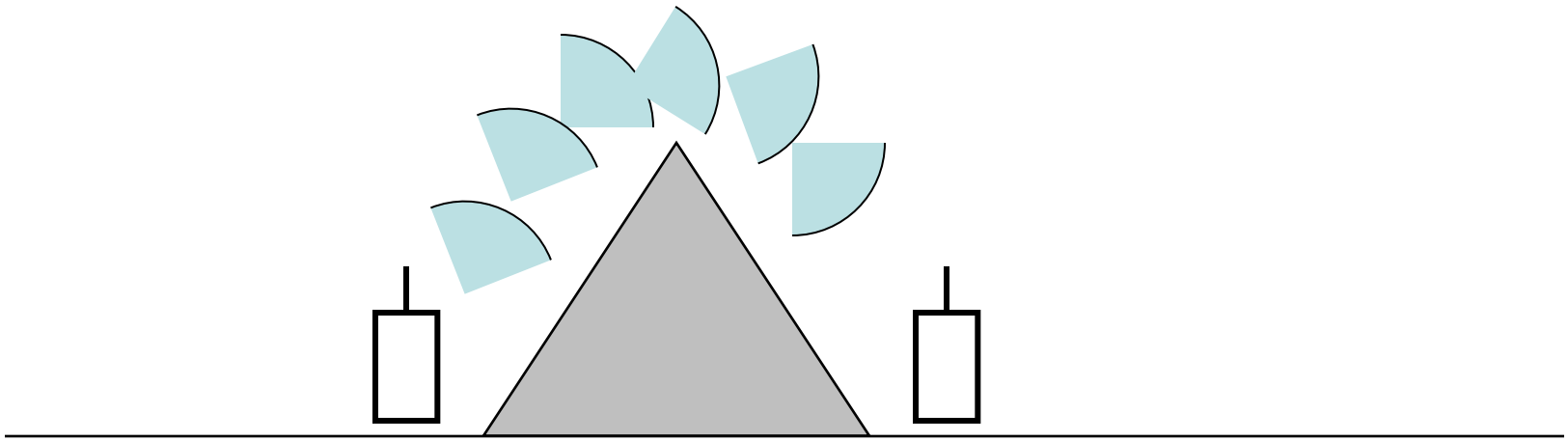
VHF-UHF Knife Edge Propagation

- As noted earlier, line-of-sight propagation is basically straight and limited by the curvature of the earth

3C05

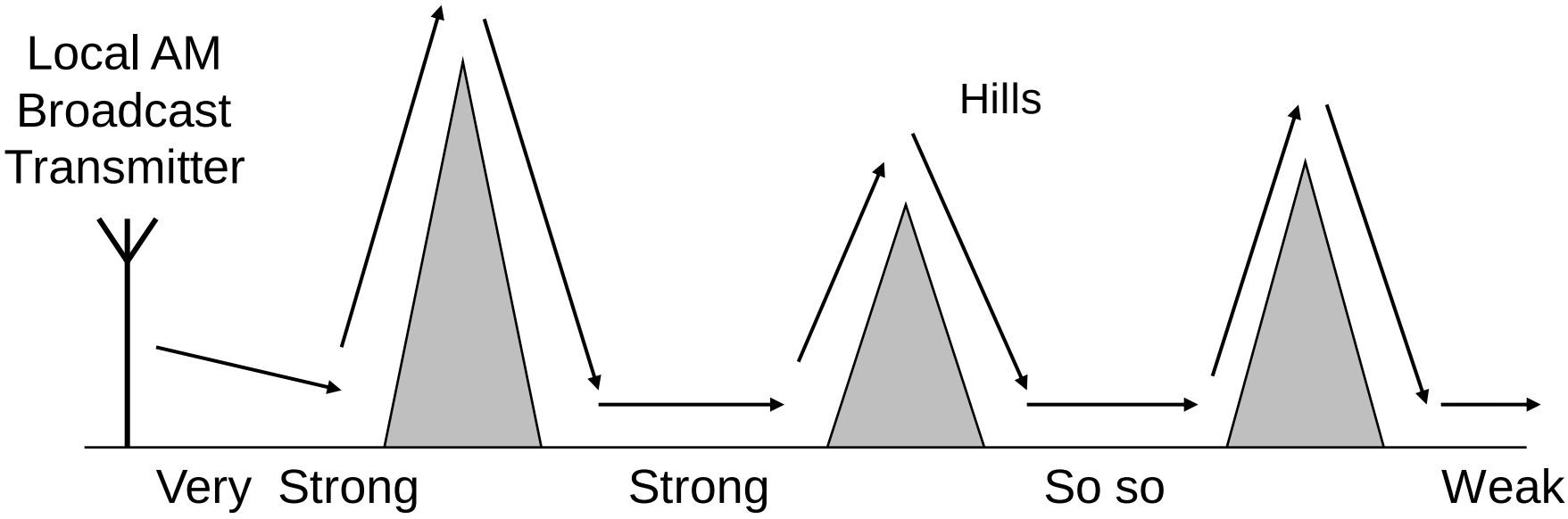
- However, knife-edge diffraction may allow radio signals to travel beyond obstructions between the transmitting and receiving stations

- This typically occurs on line-of-sight propagation signals



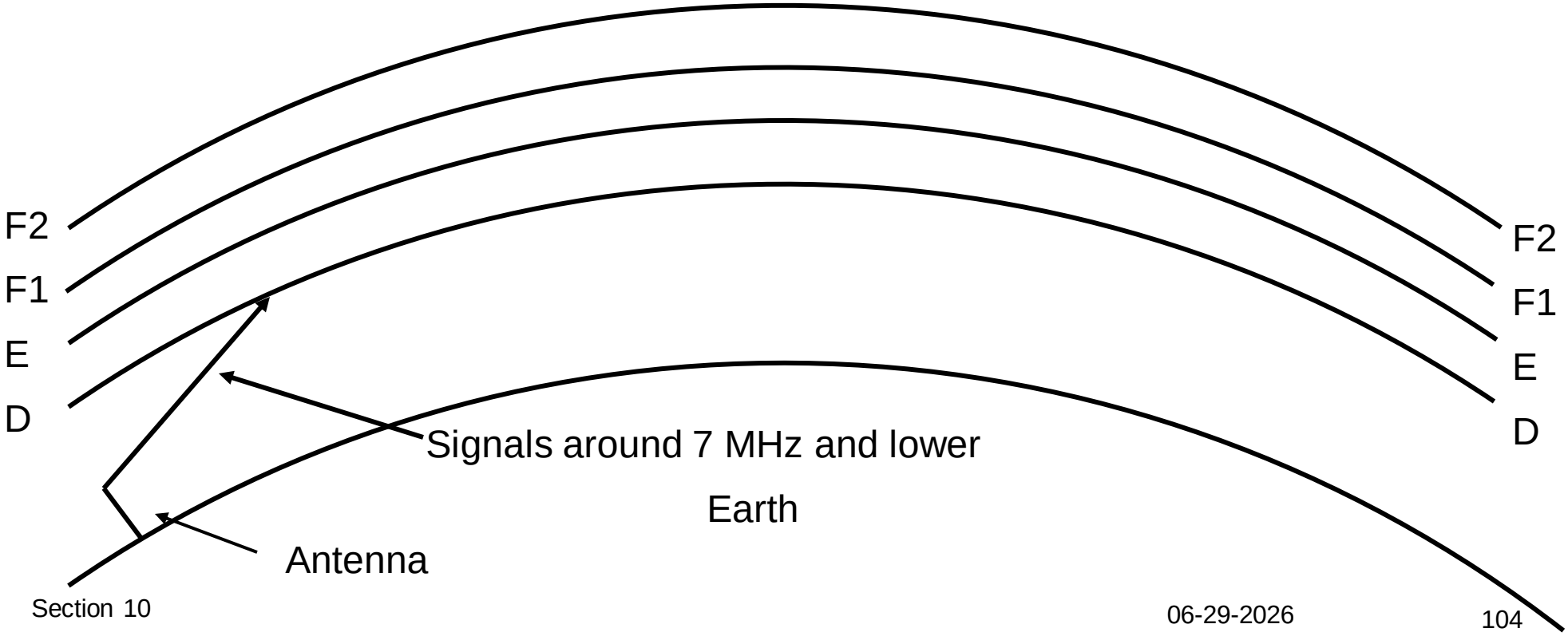
Radio Wave Propagation, Ground Wave

- “Ground Wave” is when radio waves move along the surface of the earth
- There are no breaks in reception (example: AM broadcast station)
- The signal gets weaker as it travels along the ground until it can’t be heard any more



Radio Wave Propagation and the Ionosphere

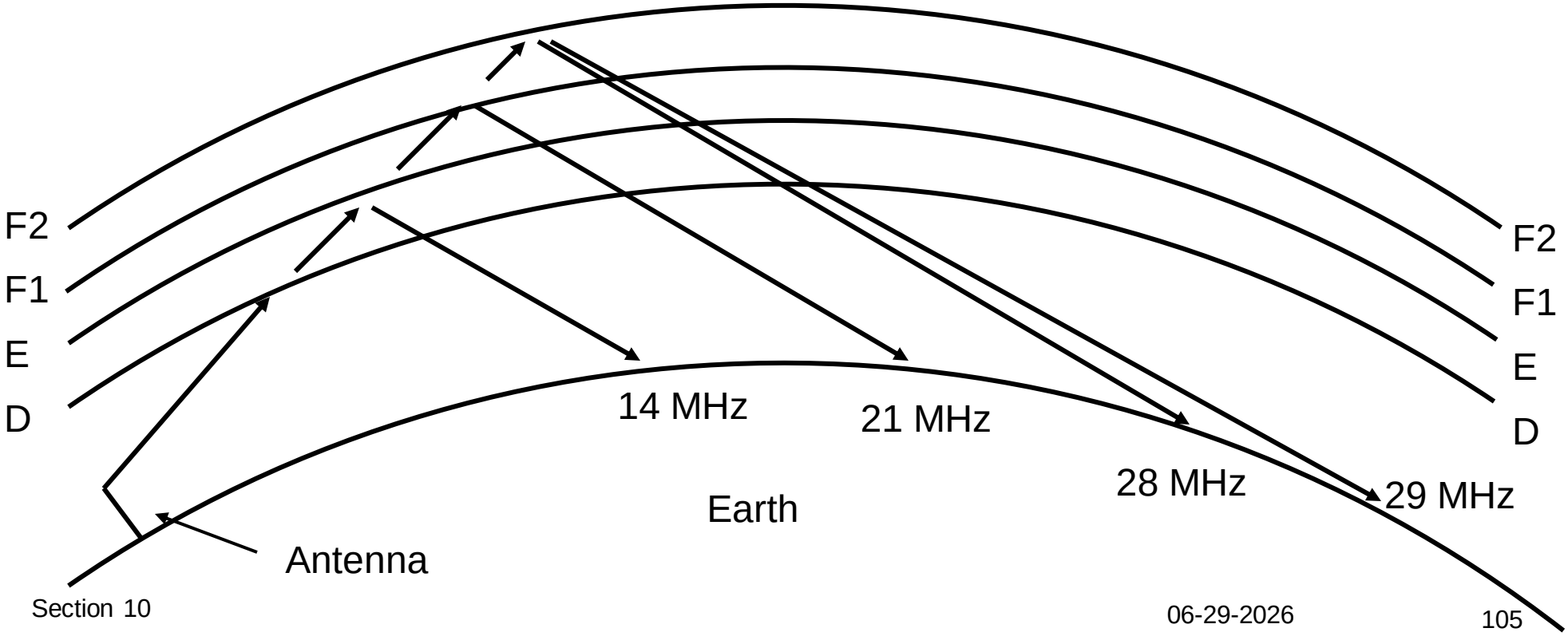
- The ionosphere is regions of ionized gas and has 3 layers called the D, E and F layers at night
- When the sun hits the F layer, it splits into the F1 and F2 layers
- Frequencies approximately 7 MHz and lower get absorbed into the D layer



Radio Wave Propagation, Sky Wave

3A11

- The ionosphere in the atmosphere can refract or bend HF and VHF radio waves
- The radio waves can bounce back to the ionosphere and back again
- They can bounce several times (multi-hop) and around the world
- This is called Sky Wave

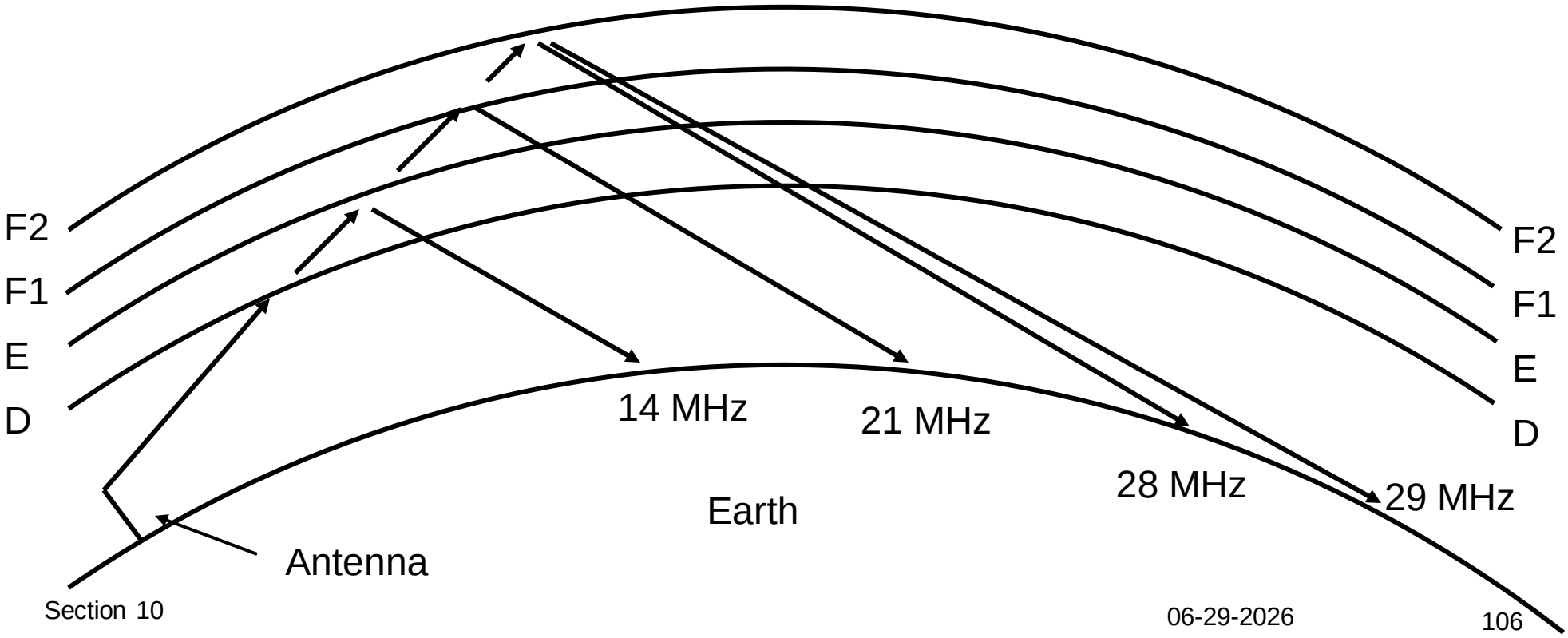


Radio Wave Propagation, Sky Wave

- The 10M band tends to bounce off of the F2 layer, which is only present during daylight hours and is the highest layer

3C09

- So, the best time for long-distance 10 meter band propagation via the F layer is from dawn to shortly after sunset during periods of high sunspot activity (see the next couple charts)
-



Radio Wave Propagation, Sky Wave

3A08 • Irregular fading of signals received by ionospheric reflection (sky wave propagation) can happen due to random combining of signals arriving via different paths (explain multi-pathing)

Sunspot Cycle and Sunspot Numbers

- Sunspots appear on the sun where shafts of intense magnetic force leave cooler areas that appear darker against the brilliant surface

- These cooler areas are around 8,000 degrees Fahrenheit and the larger sunspots are about the size of the earth

- The sunspot number is a count of active sunspots and sunspot groups

- The number of sunspots occurring on the sun are recorded each year

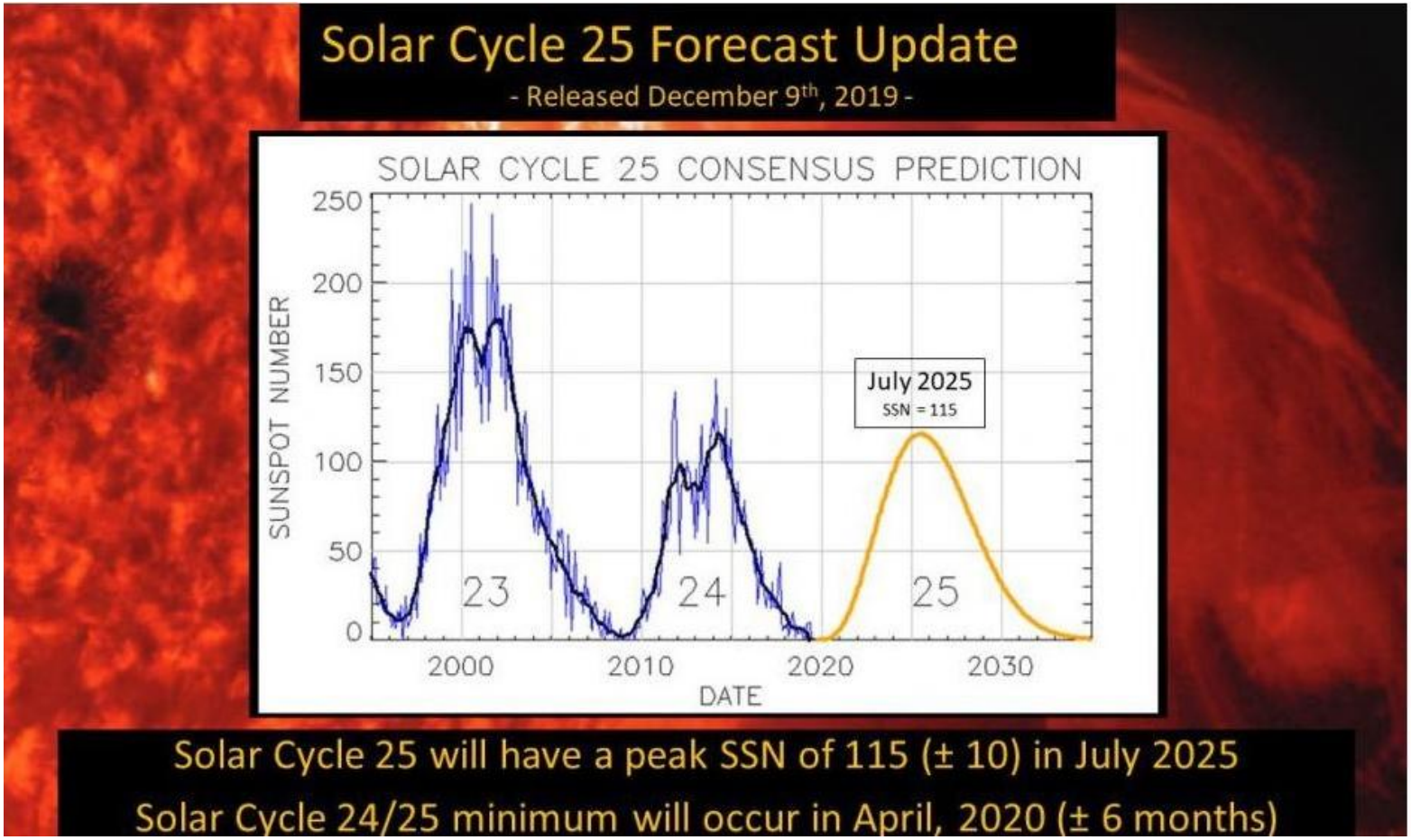
- The number of sunspots annually varies over an 11 year cycle

3C10 • The 6M and 10M bands may provide the long distance communications via the ionosphere's F region during the peak of the sunspot cycle

Sunspot Cycle and Sunspot Numbers

- The last peak was in 2015 (Cycle 24) and we are now in Cycle 25

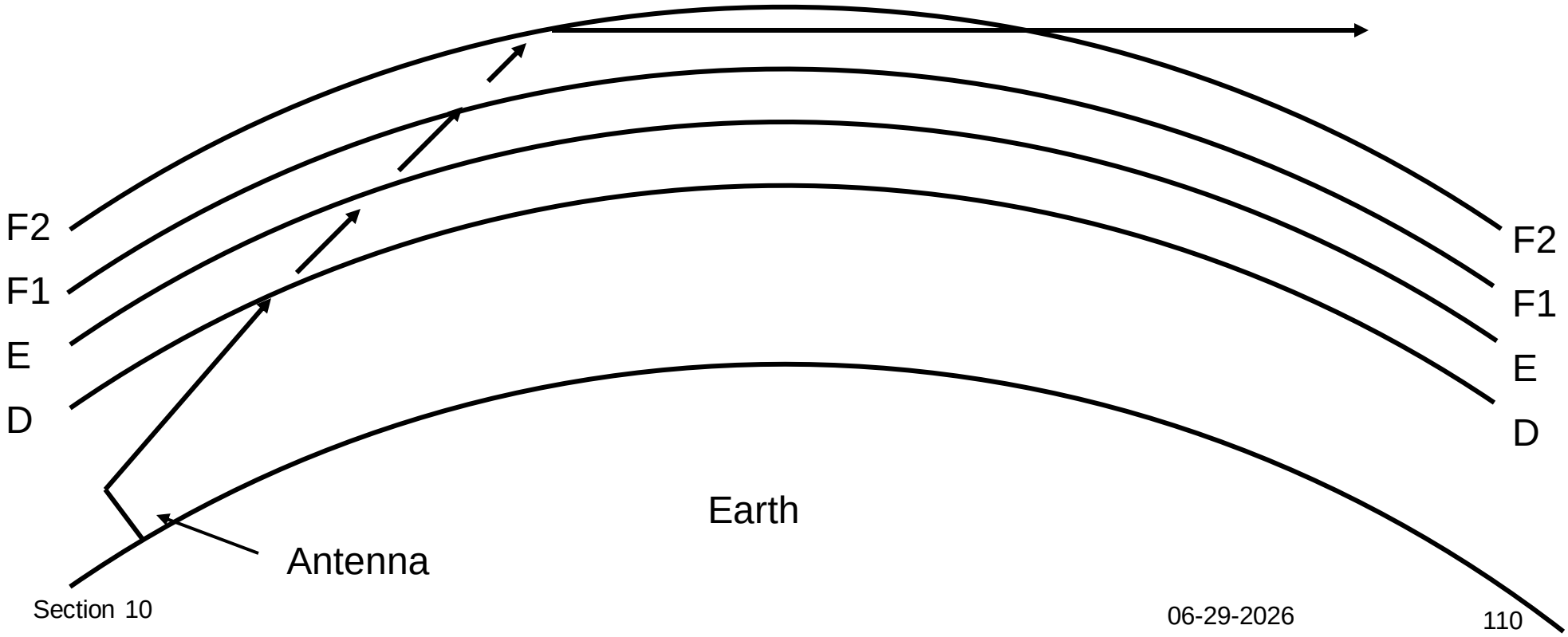
- The more sunspots (i.e., solar activity), the greater the ionization level in our ionosphere and better the sky wave propagation



Radio Wave Propagation

- VHF frequencies between around 40 MHz to and 140 MHz may bounce off the F2 layer at an angle

- But, they don't bounce back to earth and they don't go straight through the ionosphere



Other VHF-UHF Propagation

3C02
- The advantage of HF versus VHF or higher frequencies is that long distance ionospheric propagation is far more common on HF

3C04
- Sporadic E propagation is most commonly associated with occasional strong signals on the 10, 6 and 2 meter bands from beyond the radio horizon

- Lets explain 3C04

- What this means is that the 10M signal is heard at a much closer distance than its normal sky wave propagation

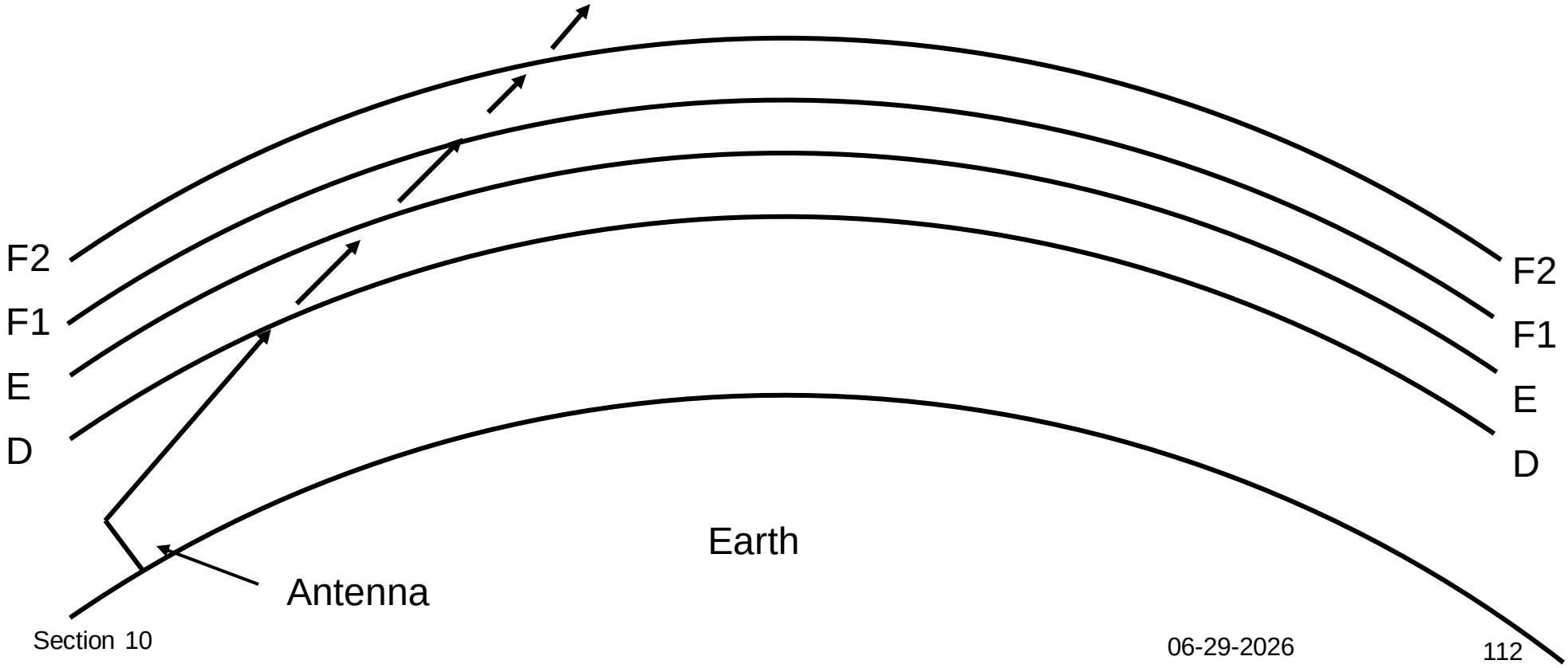
- The 6M and 2M signals are line of sight propagation but under the Sporadic E propagation, these signals will be heard as a sky wave type signal

Other VHF-UHF Propagation

- Frequencies greater than approximately 140 MHz go straight through

3C01

- So, simplex UHF station (greater than 300 MHz) are rarely heard beyond their radio horizon because UHF signals are not propagated (reflected) by the ionosphere



SUMMARY: Propagation vs. Amateur Bands

The **predominate** propagation is indicated for each band

	Popular Band	Ground Wave	Sky Wave	Line of Sight	Sun Spot Cycle Comments
Ground Wave Bands	2 MHz	X			
	4 MHz	X			
	7 MHz	X			
Sky Wave Bands	10 MHz		X		Reduced range
	14 MHz		X		Reduced range
	18 MHz		X		Dead at low cycle
	21 MHz		X		Dead at low cycle
	24 MHz		X		Dead at low cycle
	28 MHz		X		Dead at low cycle
Line of Sight Bands	50 MHz		X??	X	So so on high cycle
	144 MHz			X	
	222 MHz			X	
	440 MHz			X	
	902 MHz			X	
	1,300 MHz			X	

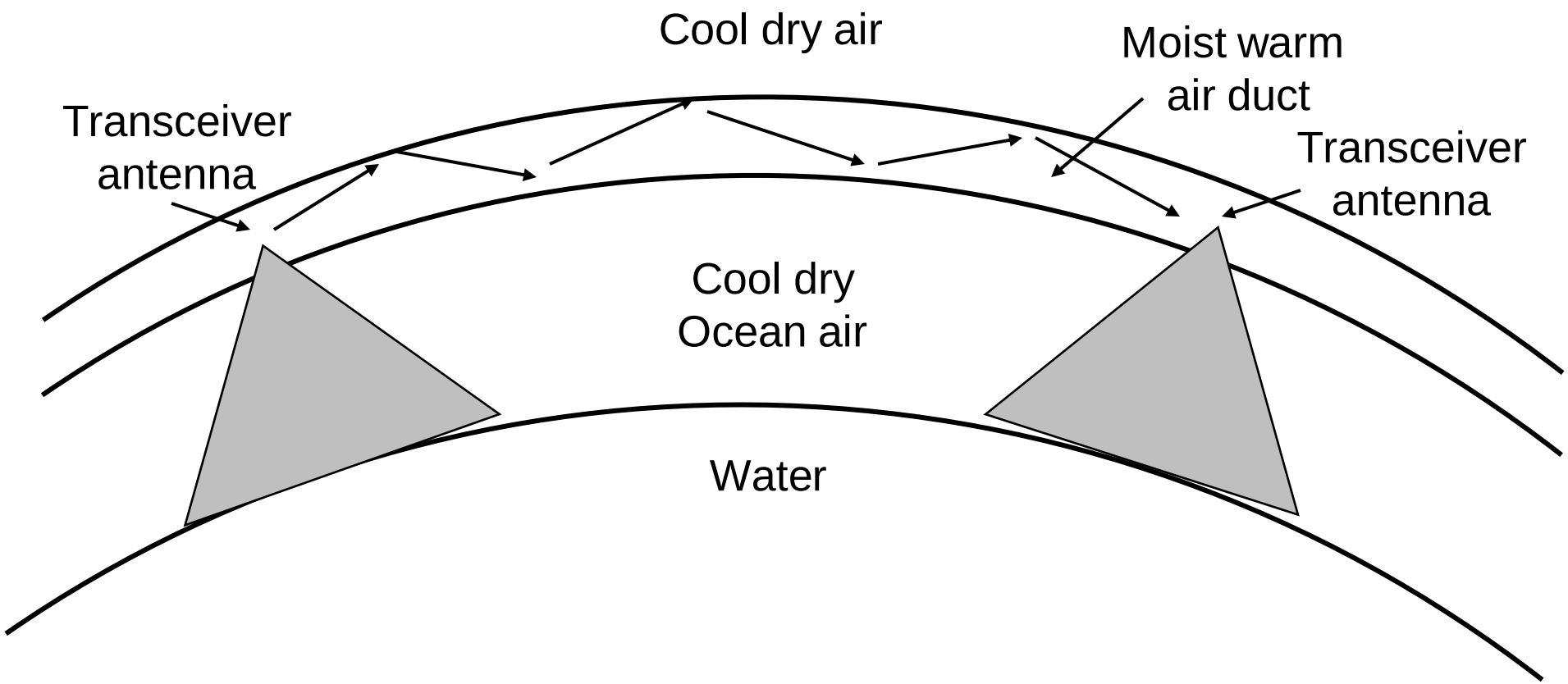
Note: The Line-of-Sight bands are where Technicians primarily operate

DON'T MEMORIZE ANY OF THIS

VHF-UHF Tropospheric Ducting

3C06 • Sometimes VHF & UHF communications will occur around 300 miles over-the-horizon due to tropospheric ducting

3C08 • Tropospheric ducting is caused by temperature inversions in the atmosphere



Meteor Scatter, Auroral Reflections, Polarization

3C07 • The best band for communications during meteor scatter is the 6 meter band (50 – 54 MHz)

3C03 • The characteristic of VHF signals received via auroral reflections is that these signals are distorted and signal strength varies considerably

- -

• When a radio wave leaves an antenna, it typically has a certain polarization, regardless of the frequency

3B02 • The polarization is determined by the orientation of the electric field
• The antenna element orientation determines the polarization
• But, if that radio wave reflects off the ionosphere, the polarization can change or be circular polarized

Misc

3A09 • Signals propagating from the ionosphere are elliptically polarized and either horizontally of vertically polarized antennas can be used for transmission or reception

1B06 • A Technician class operator only has phone privileges on one HF band, the 10 meter band

1B01 • 28.300 MHz to 28.500 MHz is available for phone by a Technician

1B10 • SSB phone may be used in amateur bands above 50 MHz in at least some segments of all these bands

1A06 • Automatically controlled amateur propagation beacons can be found on ten meters, between 28.200 MHz and 28.300 MHz

Section 11

Talk To Outer Space !

Talk To Outer Space

- Amateur radio operators can have a radio in a space station

1B02

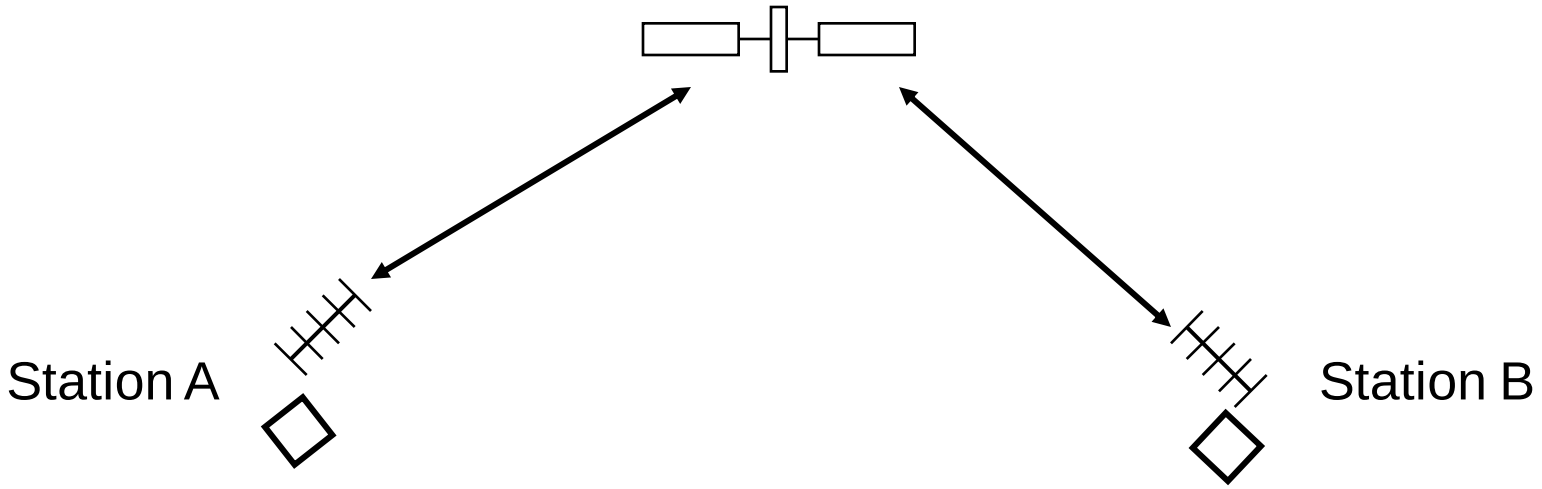
- Any amateur radio station holding a Technician or higher class license may make a contact with the International Space Station on VHF bands

- As you will see in the following charts, there are also repeaters in satellites

- Space stations and satellites rotate around the earth

- One of the major issues is having the ability of pointing your antenna at the moving space station or satellite

Amateur Satellite Operation



- There are repeaters in some satellites

- AMSAT (Amateur Satellite Corporation) coordinates the building and/or launching of most amateur satellites with repeaters

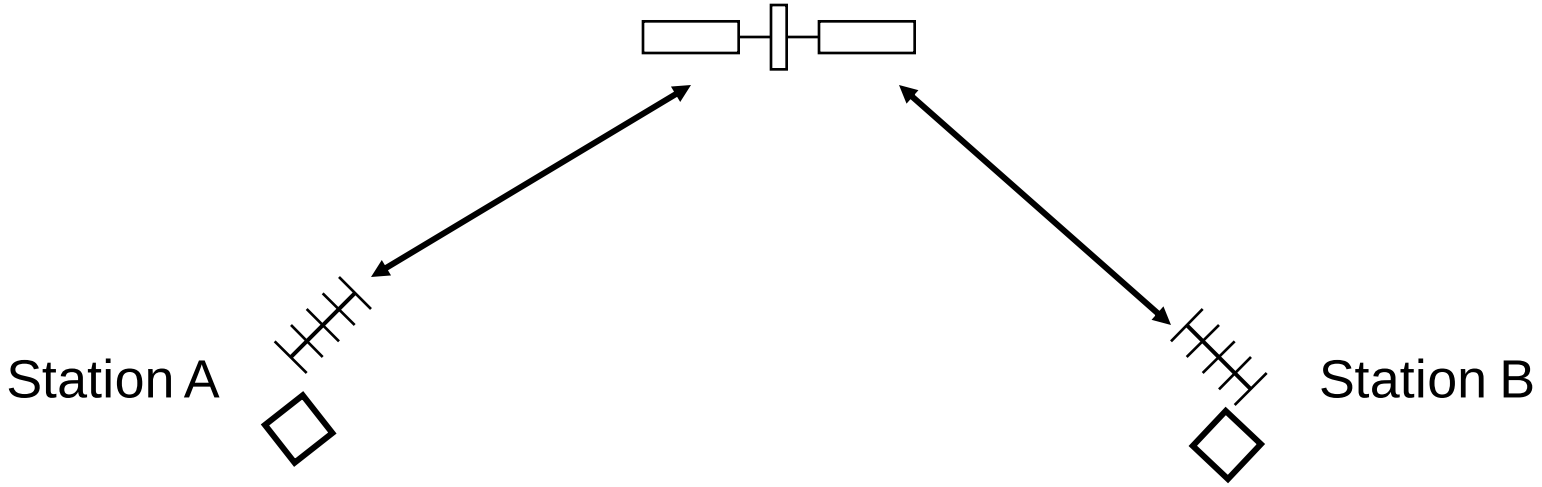
- There are around 15 of those satellites

8B08

- When the satellite is in “mode U/V” the uplink is in the 70 centimeter band (UHF) and the downlink is in the 2 meter band (VHF)

- We can use amateur satellites to talk to hams in other countries

Amateur Satellite Operation

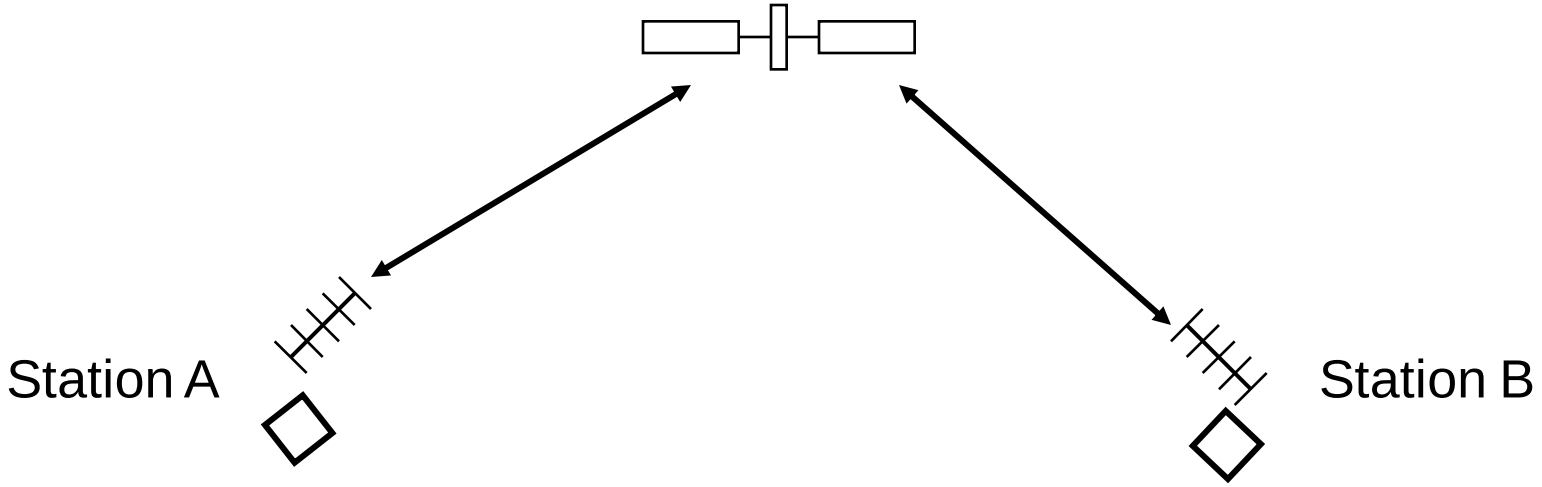


- In order to point your antenna at the moving satellite, you will need a tracking program

8B03

- Satellite tracking programs provide the items below:
  - Maps showing the real-time position of the satellite track over the earth
  - The time, azimuth and elevation of the start, maximum altitude and the end of the pass
  - The apparent frequency of the satellite transmission, including the effects of Doppler shift

Amateur Satellite Operation



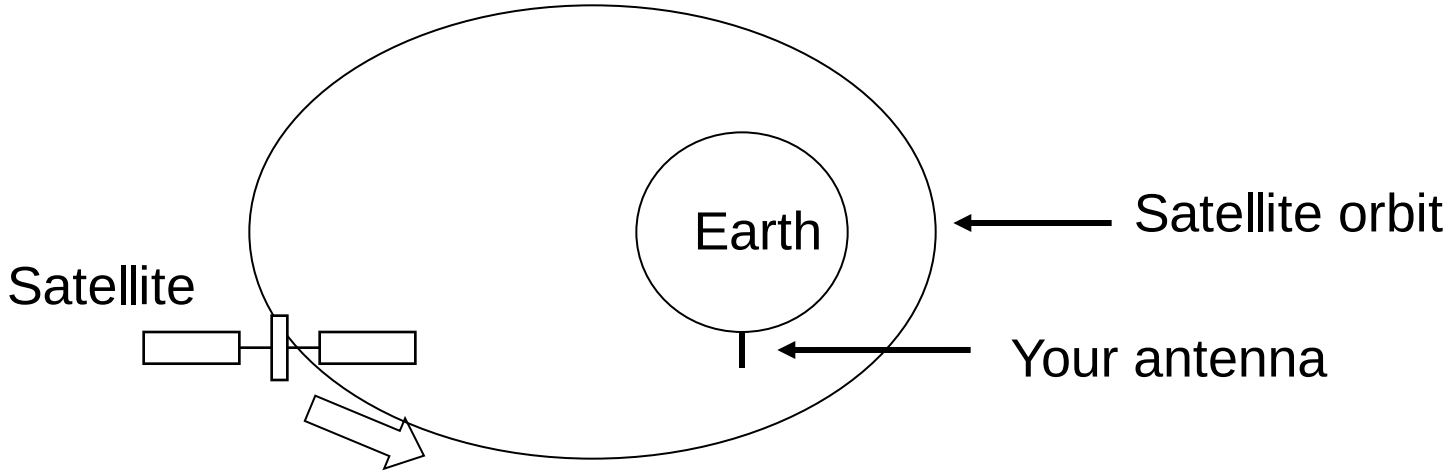
8B06 • The Keplerian elements are inputs to your satellite tracking program

• The satellite tracking programs are used to point your antenna at a satellite or at a space station to communicate with an amateur in the space station

8B02 • When transmitting on the uplink frequency of the amateur satellite, using too much power may block access to other users

8B12 • A good way to tell if your uplink power is neither too low or too high is that your signal strength on the downlink should be about the same as the beacon

Talk To Outer Space



8B10
- A LEO satellite travels around the earth in Low Earth Orbit
- As the satellite comes closer to you or goes away, there is a Doppler effect (example: the train going by)
- Typical altitude is 200 to 800 miles

8B07
- The Doppler shift creates an observed change in the signal frequency caused by the relative motion between the satellite and the Earth station

8B09
- “Spin fading” refers to the satellite signals when the satellite and the antennas are rotating (the signals rise and fall in strength)

More Space Stuff

8B05 • A satellite beacon is a transmission from the satellite that contains status information

1A07 • The FCC Part 97 definition of a “space station” is an amateur station located more than 50 km above the earth’s surface

8B11 • Telemetry from a space station can be received by anyone (who can receive the telemetry signal)

8B01 • Telemetry information is typically the health and status of the satellite

• A telecommand to a satellite could turn on or turn off the amateur radio station, or do something else

8B04 • Transmission modes commonly used by amateur radio satellites are SSB, FM, CW and data

• Note that telemetry is data **from** the satellite and telecommand is data sent **to** the satellite

Section 12

Going Digital !

Ham Digital

8D09
- Another name for Morse code transmission is CW (continuous wave)

1B07
- Segments of the VHF and UHF bands are limited to CW only:
  - 50.0 MHz to 50.1 MHz
  - 144.0 MHz to 144.1 MHz

- CW (Morse code) can be sent using any of the following:
  - A straight key
  - An electronic keyer
  - A computer keyboard

4A12
- An electronic keyer is a device that assists in manual sending of Morse Code

- A computer can be used as 3 parts of an Amateur Radio station
  - For logging contacts and contact information
  - For sending and/or receiving CW
  - For generating and decoding digital signals

Ham Digital

8D06

- PSK means Phase Shift Keying
- PSK-31 is a low rate data transmission mode that works well in noisy conditions

8D01

- Several types of digital emissions are listed below:
  - Packet radio
  - IEEE 802.11
  - JT65
- See the next chart for comments about JT modes

8D02

- FT8 is a digital mode capable of low signal-to-noise operation

Ham Digital

8D10

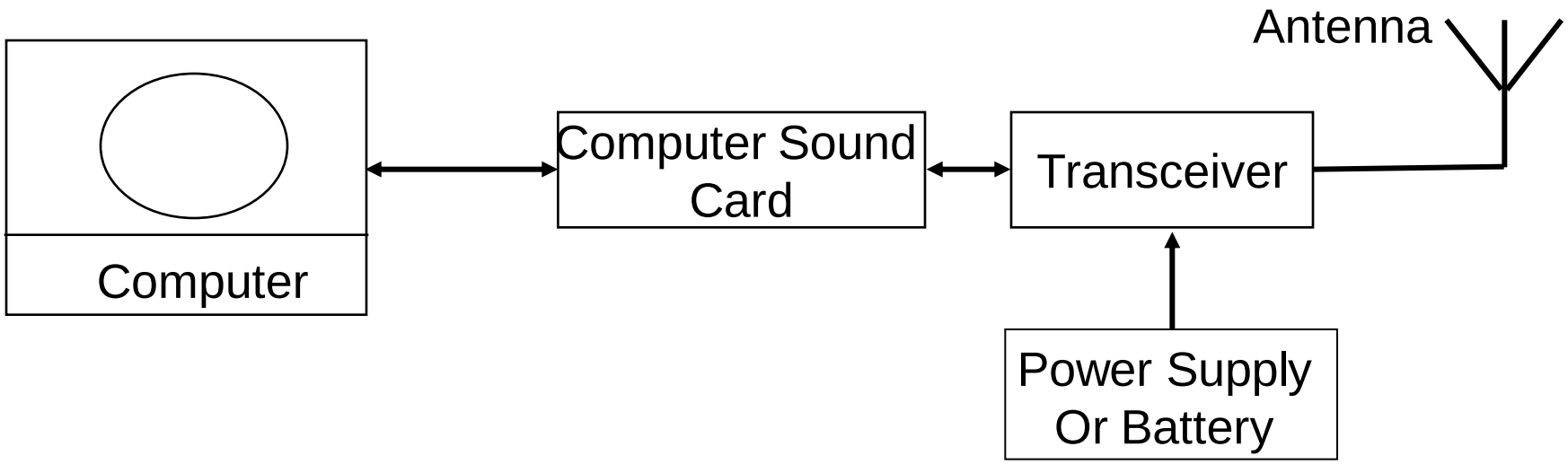
- The following operating activities is supported digital mode software in the WSJT-X software suite
  - Earth-Moon-Earth
  - Weak-signal propagation beacons
  - Meteor scatter

- WSJT is a computer program used for weak signal communications between amateur radio stations

- All of the various JT modes were developed with weak signal work in mind

- The various JT modes were invented by Nobel Prize winner Joseph Hooton Taylor Jr., W1JT

Packet Mode Connections

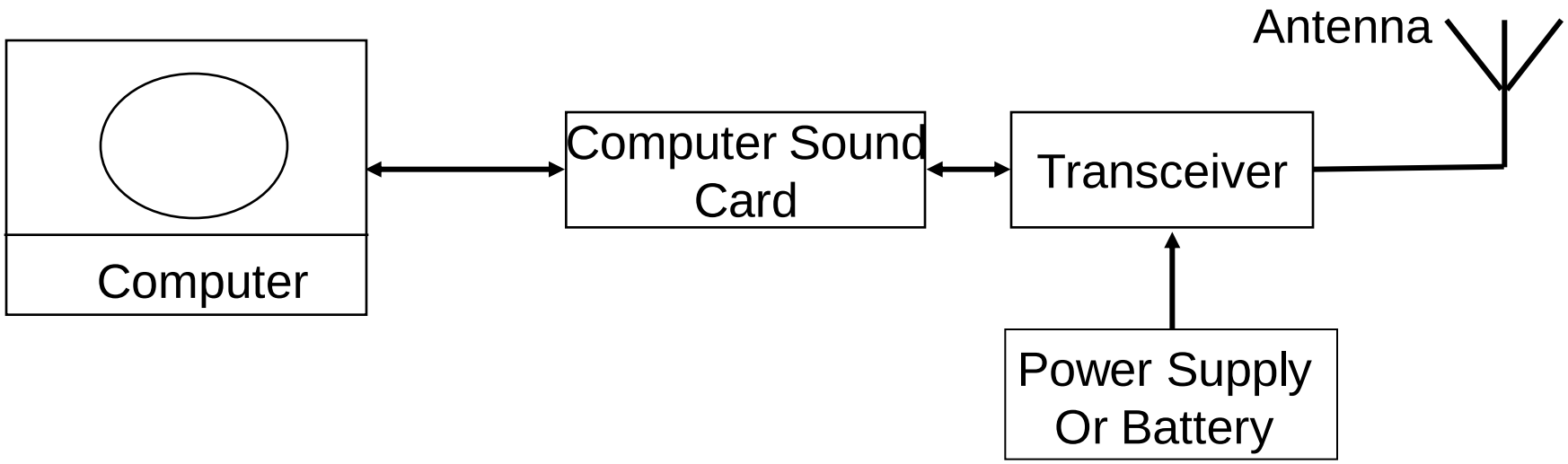


4A04 • Configured to operate using FT8, the transceiver audio input and output are connected to the audio input and output of a computer running WSJT-X software

4A07 • The computer “line in” to transceiver speaker connector is the connection used when operating digital modes

4A06 • The following signals are used in a computer-radio interface for digital mode operation: receive audio, transmit audio and transmitter keying

Packet Mode Connections



- Packet is a digital emission mode and is like e-mail, but uses a radio and a computer instead of a telephone line and a computer

8D08
- Packet transmissions can include the following:
  - A checksum which permits error detection
  - A header which contains the call sign of the station to which the information is being sent
  - An automatic repeat request in case of an error (see below)

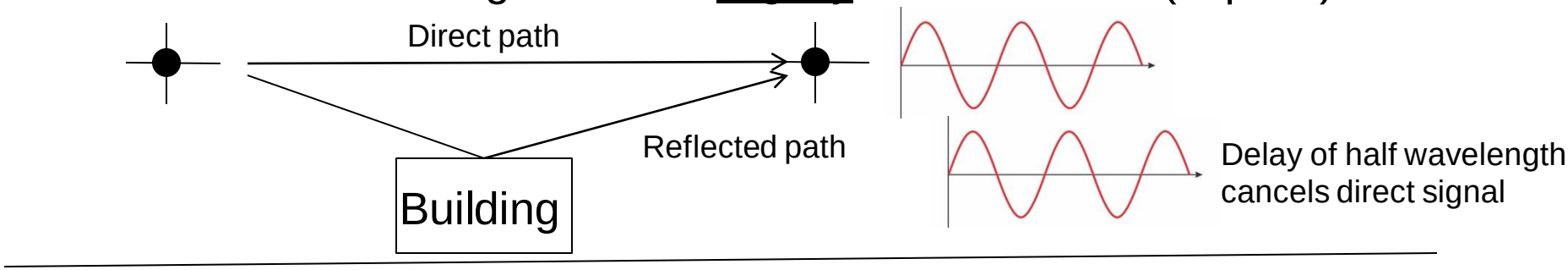
8D11
- An ARQ (Automatic Repeat Request) transmission system is an error correction method in which the receiving station detects errors and sends a request for retransmission

Ham Digital

3A10

- When data transmissions arrive over multiple paths, error rates are likely to increase

- That is because the multiple path radio signals can arrive at the receiving station at <u>slightly</u> different times (explain)



- The term APRS means Automatic Packet Reporting System

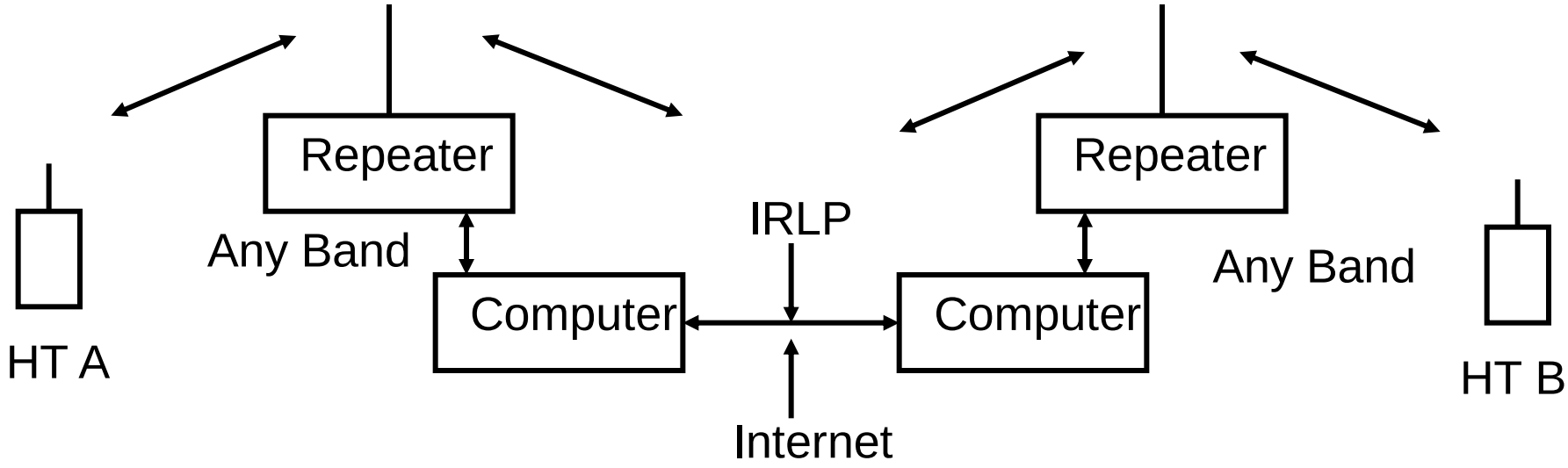
8D05

- . An application of an APRS is to provide real time tactical digital communications in conjunction with a map showing the location of stations

8D03

- APRS can transmit:
  - GPS position data
  - Text messages
  - Weather data

Radio Communications Using the Internet

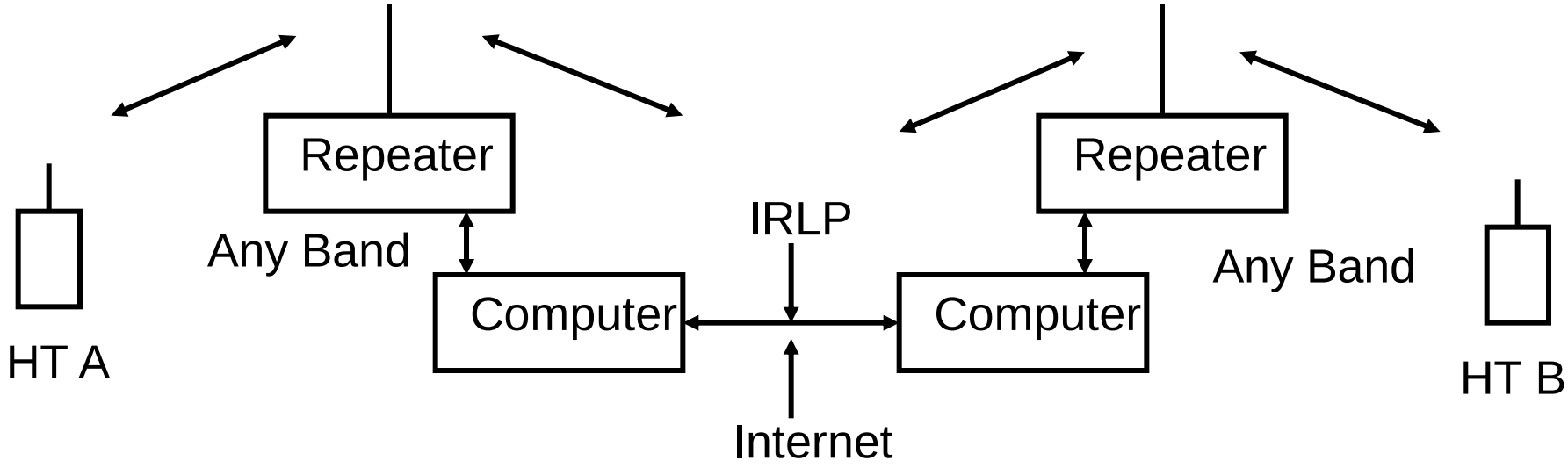


8C11 • An amateur radio station (or repeaters) that connects to other amateur stations via the internet is called a gateway

8C08 • Internet Radio Linking Project (IRLP) is a technique to connect amateur radio systems, such as repeaters, via the Internet using Voice over Internet Protocol (VoIP)

4A10 • For nearby transceivers, a digital mode hotspot provides communication with a digital voice or data network

Radio Communications Using the Internet

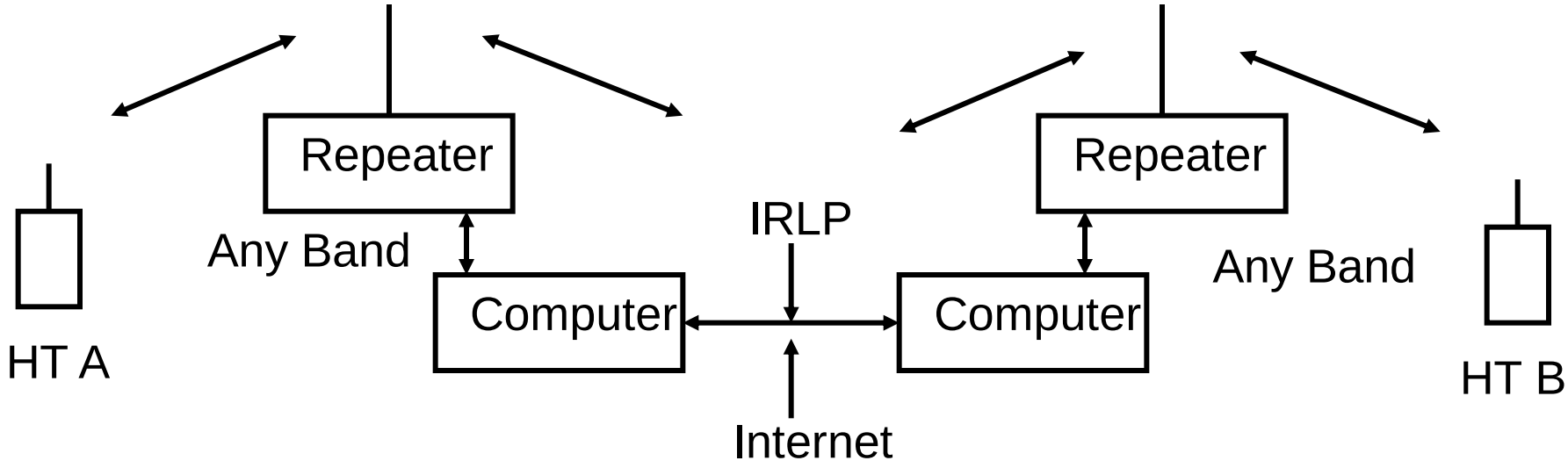


8C07 • Voice Over Internet Protocol (VoIP) is a method of delivering voice communications over the internet using digital techniques

2B06 • DTMF (Dual Tone Multi-Frequency) is a type of signaling to a repeater that uses pairs of audio tones

8C06 • Over the air access to Internet Radio Linking Project (IRLP) nodes is accomplished by using DTMF signals

Radio Communications Using the Internet

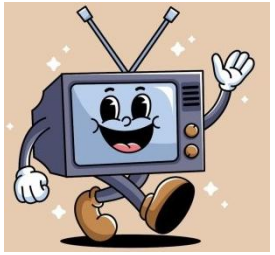


8C10 • Before you can use the EchoLink system, you must register your call sign and provide proof of a license

8C09 • The Echolink protocol enables an amateur station to transmit through a repeater without using a radio to initiate the transmission

• If you hear a ham in Italy on a local repeater, then you are listening to an Internet linked repeater

Fast Scan Television



- The FCC Part 97 lets hams transmit fast scan television on certain ham bands

- Fast scan television is basically the analog television that we had for decades

8D04

- The transmission format for analog fast scan color TV signals is called NTSC (National Television System Committee)

8A10

- The bandwidth of AM fast scan TV is about 6 MHz

- Amateur radio operators can use TV format on the 70 cm band and above (70 cm band is the 440 MHz band)

- Many hams today that use the TV mode are using the digital format DVB-T on 70 cm and 23 cm, which has a better picture and uses much less bandwidth

Section 13

Multi-Mode Radio Excitement

Question T7A08 is in section 6, not this section

Multi-Mode Radio Excitement

- Different emissions require a different amount of bandwidth

8A05 • CW (Morse code) has the narrowest bandwidth (comment)

8A11 • The approximate bandwidth of a CW signal is 150 Hz (explain)

- Emissions like AM, SSB, FM, all have different bandwidths (as noted in Section 6)

- Some of the narrow bandwidth emissions will be more useful in weak signal communications

- Most folks getting a Technician license will simply buy an HT, but HT's are FM (wide bandwidth)

7A02 • A transceiver is a device that combines the functions of a receiver and transmitter (as noted in Section 6)

Multi-Mode Radio Excitement

8A01 • Single Sideband (SSB) is a form of Amplitude Modulation (as noted in Section 6)

8A03 • SSB is the voice mode most often used for long-distance (weak signal) contacts on the VHF and UHF bands

8A07 • The characteristic of single sideband (SSB) compared to FM is that SSB signals have narrower bandwidth

• The narrower bandwidth makes more efficient use of the power out of your transceiver

8A12 • The disadvantage of FM compared to single sideband is that only one signal can be received at a time

7A09 • The function of the SSB/CW-FM switch on a VHF power amplifier is to set the amplifier for proper operation in the selected mode

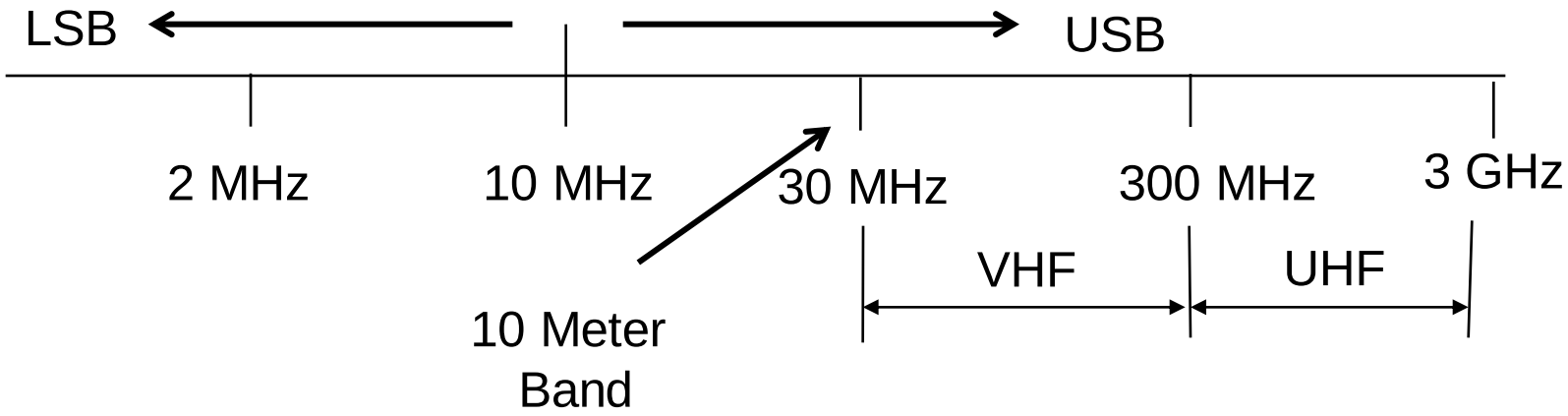
Multi-Mode Radio Excitement

7A08

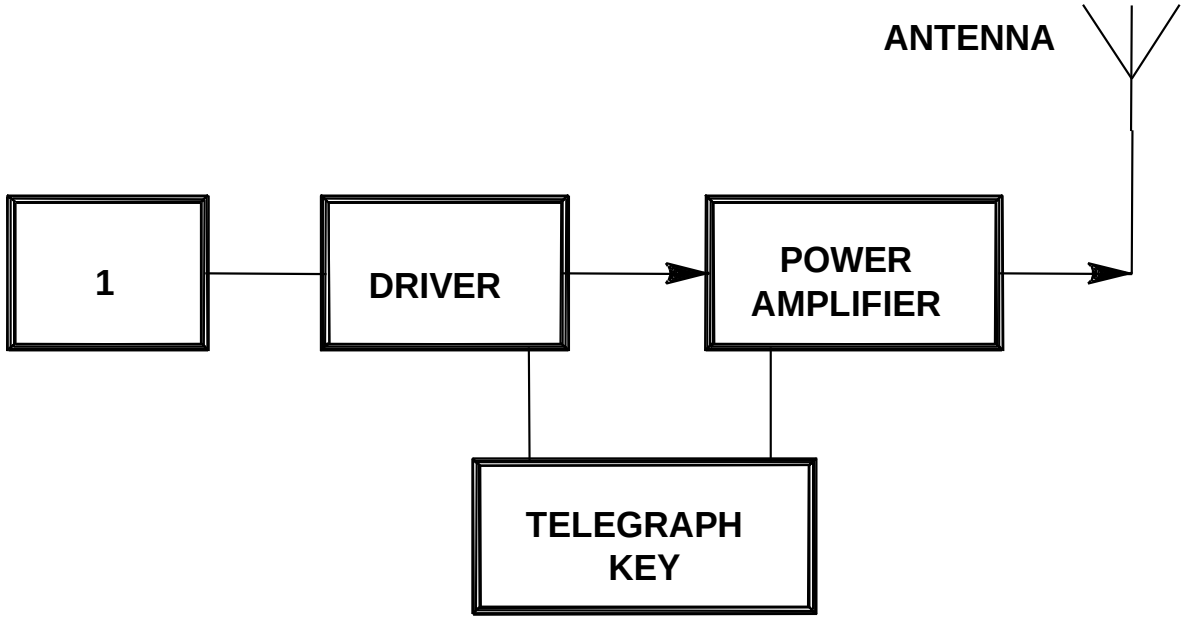
- Modulation combines speech with an RF carrier signal
- As described in Section 6, there are two versions of the Single Sideband (SSB) mode

8A06

- There is Upper Sideband (USB) and Lower Sideband (LSB)
- Upper Sideband is normally used for the 10 meter HF, VHF and UHF single-sideband communications (see below)
- SSB is permitted in some portions of all the amateur bands above 50 MHz



An Oscillator Circuit

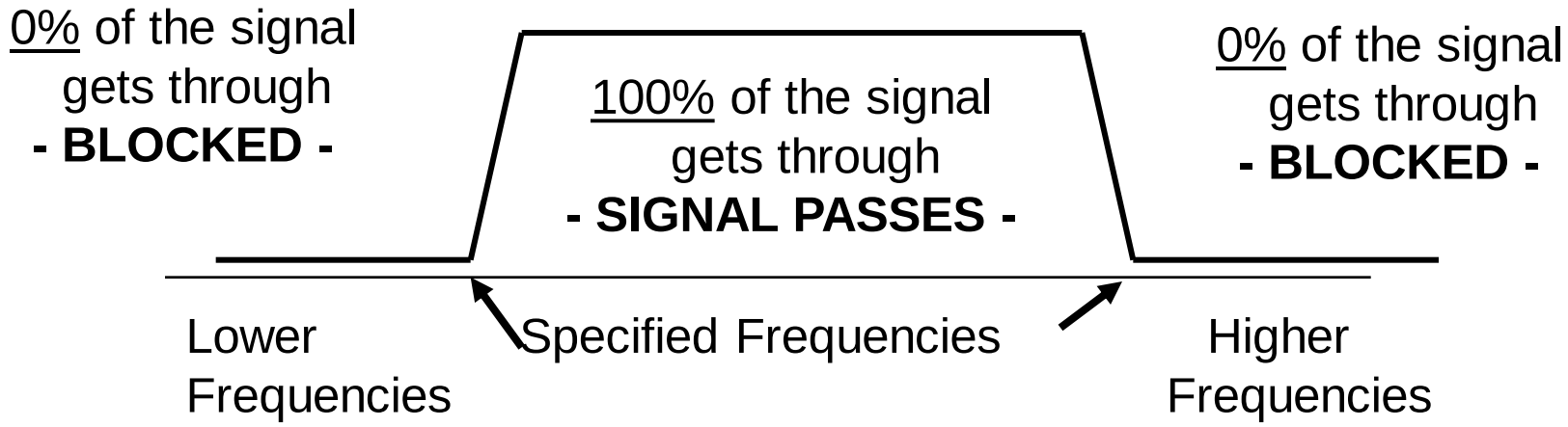


- The block diagram above is a basic transmitter and Block 1 is an oscillator

7A05

- The oscillator is the circuit that generates a signal of a specific frequency

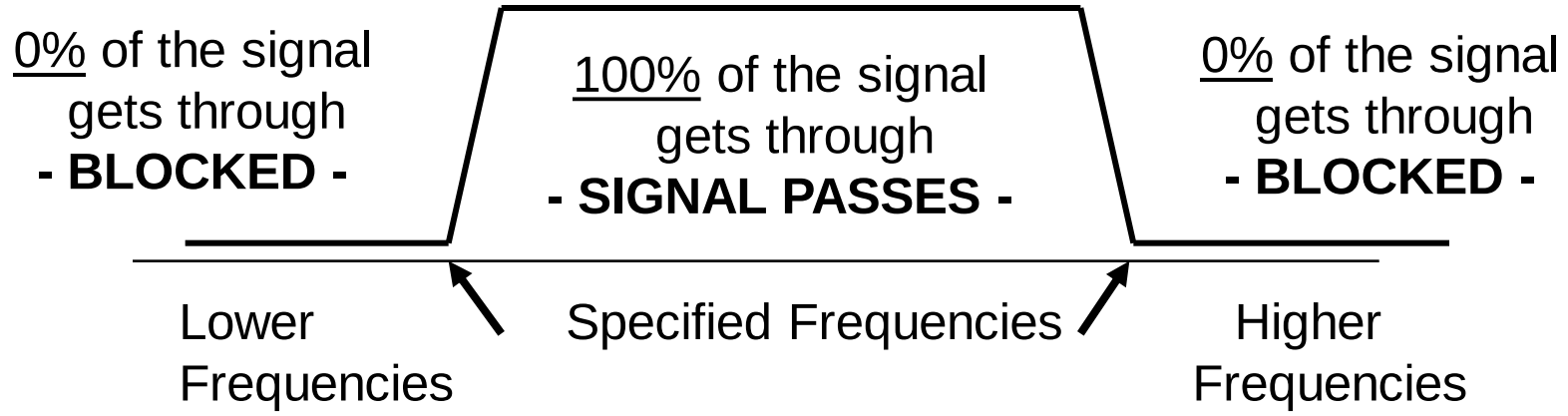
Receiver Band-Pass Filters



- Band-pass filters:
  - Block all RF signals above and below specified frequencies and pass all RF signals between the specified frequencies
  - Are used in the Intermediate Frequency (IF) section of **all receivers** to block signals outside of frequency range we want to listen to
  - Their bandwidth depends on the emission selected (discuss)

4B08
- So, multimode transceivers use multiple bandwidth filters to permit noise or interference reduction by selecting a bandwidth matching the mode (explain, also band-pass vs. bandwidth)

Receiver Band-Pass Filters

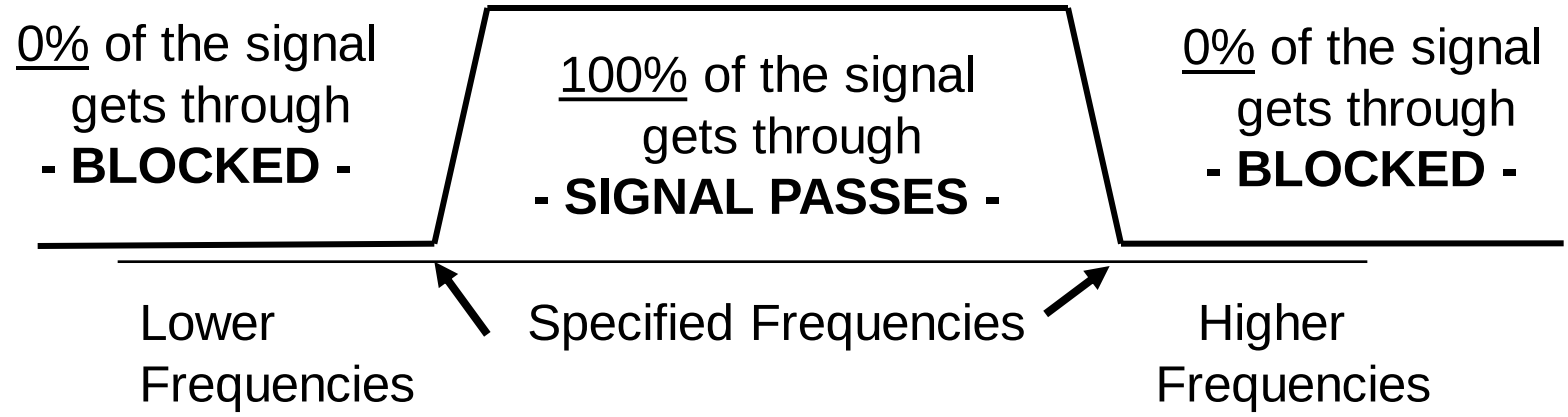


8A08 • The approximate bandwidth of a typical single sideband (SSB) voice signal is 3 kHz

4B10 • A 2,400 Hz (2.4 kHz) receiver filter bandwidth provides the best signal-to-noise ratio for SSB reception

• A 2.4 kHz bandpass filter is “OK” for a 3 kHz SSB voice bandwidth because it is close enough to the nominal bandwidth to preserve intelligibility while still providing good selectivity and interference rejection. In practice, many operators use it as a balance between audio quality and noise performance, especially in crowded HF conditions

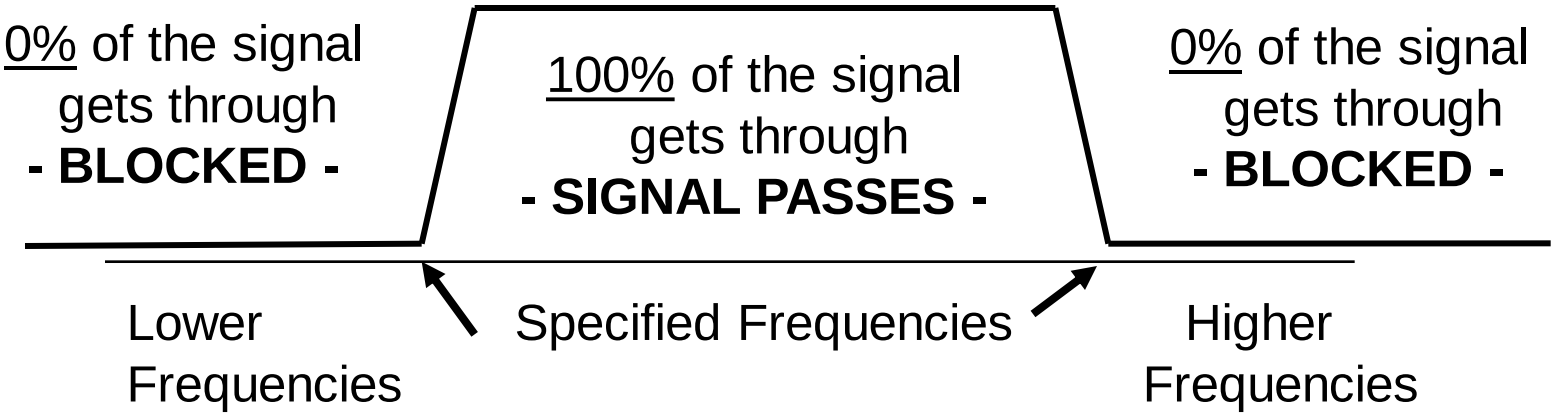
Receiver Band-Pass Filters



- When you change your mode to CW, a narrower filter is switched in

- Since the bandwidth of CW is around 150 Hz. you would assume that the filter bandwidth would also be around 150 Hz. But this question pool doesn't address it

Receiver Band-Pass Filters



- Many receivers have multiple bandwidth filters, based on the various types of emissions it can receive

7A04
- The term that describes the ability of a receiver to discriminate between multiple signals is called selectivity

- This is done using the various bandwidth filters

7A01
- Sensitivity is the term that describes the receivers ability to detect the presence of a signal

- Be careful not to confuse the term selectivity with the term sensitivity

Miscellaneous

- When you tune in a SSB signal, the pitch of the voice changes

- Tune to the frequency where the voice sound almost normal

4B06 • But if the SSB signal voice pitch sounds too high or low, you make the adjustment using the receiver RIT (Receiver Incremental Tuning) control or a clarifier

7A11 • The function of the Variable Frequency Oscillator (VFO) circuit in a transceiver is to set the receive and transmit frequency

7A06 • A transverter can convert the RF input and output of a transceiver to another band

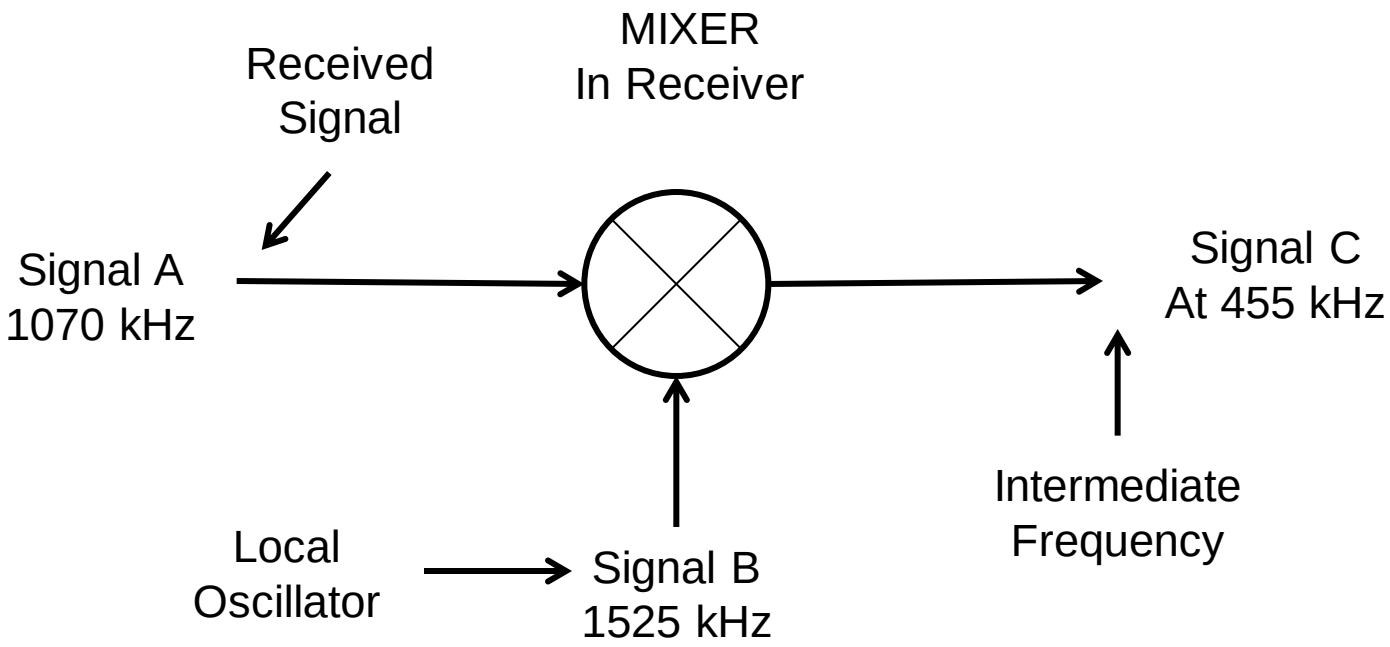
4B11 • Your call sign must be programmed into a D-Star digital transceiver before transmitting

Miscellaneous

- Once an RF signal is received, the receiver must then convert it to a much lower frequency, before the signal can be processed

7A03

- The Mixer stage in a receiver is used to convert a radio signal from one frequency to another (explain diagram below)



- The mixer generates the sum and difference of the input frequencies so a filter is used at the output to reject the unwanted signal

Miscellaneous

8D07 • A DMR (Digital Mobile Radio) uses a technique for time-multiplexing two digital voice signals on a single 12.5 kHz repeater channel

4B07 • The DMR “code plug” is configuration data loaded onto your radio for access into for repeaters and talk groups

2B12 • A digital color code used on a DMR repeater system is an access code which must be programmed into a DMR transmitter to access a specific repeater

2B07 • You can join a digital repeater “talk group” by programming your radio with the group’s ID or code

4B09 • A specific group of stations are selected on a digital voice transceiver by entering the group’s identification code

8D12 • An amateur radio mesh network is an amateur radio based data network using commercial Wi-Fi equipment with modified firmware

Section 14

Run Some Interference Protection

Run Some Interference Protection

7B10

- If you receive a report that your audio signal through a repeater is distorted or unintelligible, then the problem could be any of the following:
  - Your transmitter is slightly off frequency
  - You are speaking too loudly or too close to the microphone
  - You are in a bad location

4B01

- If you have excessive microphone gain on SSB, you will have distorted audio

- Note that there is no microphone gain control on an HT

Fundamental Overload Interference

7B02
- Sometimes an AM or FM radio receives an amateur transmission unintentionally because the AM or FM receiver is unable to reject strong signals outside the AM and FM band

- This can happen to my AM/FM radio or to my TV

- When it happens to my AM/FM radio, it is called RFI, radio frequency interference (example: KNX 1070 at Hawthorne & 190th)

- When it happens to a TV set, it's called TVI, television interference

7B07
- You can reduce overload to a VHF transceiver from a nearby commercial FM station by using a band-rejection filter:

- I will describe most of these in the following charts

Harmonic Radiation Interference

- Harmonic radiation is when your signal also appears on exact multiples of the frequency on which you are transmitting (fundamental frequency)

Example:

Fundamental Frequency	51 MHz
2nd Harmonic	102 MHz
3rd Harmonic	153 MHz
4th Harmonic	204 MHz

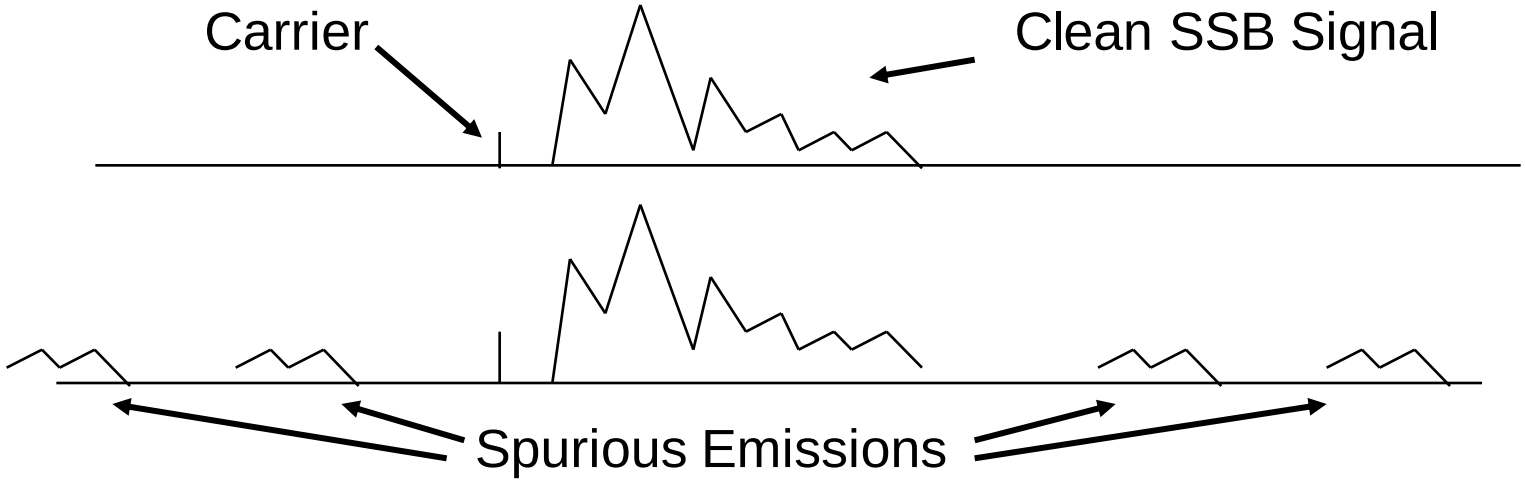
- A properly operating transmitter won't transmit unwanted harmonic frequencies, but there are ways to stop some types of harmonic radiation if they occur

7B03

- Radio frequency interference can be caused by the following:
  - Fundamental overload
  - Harmonics
  - Spurious emissions

Spurious Emissions

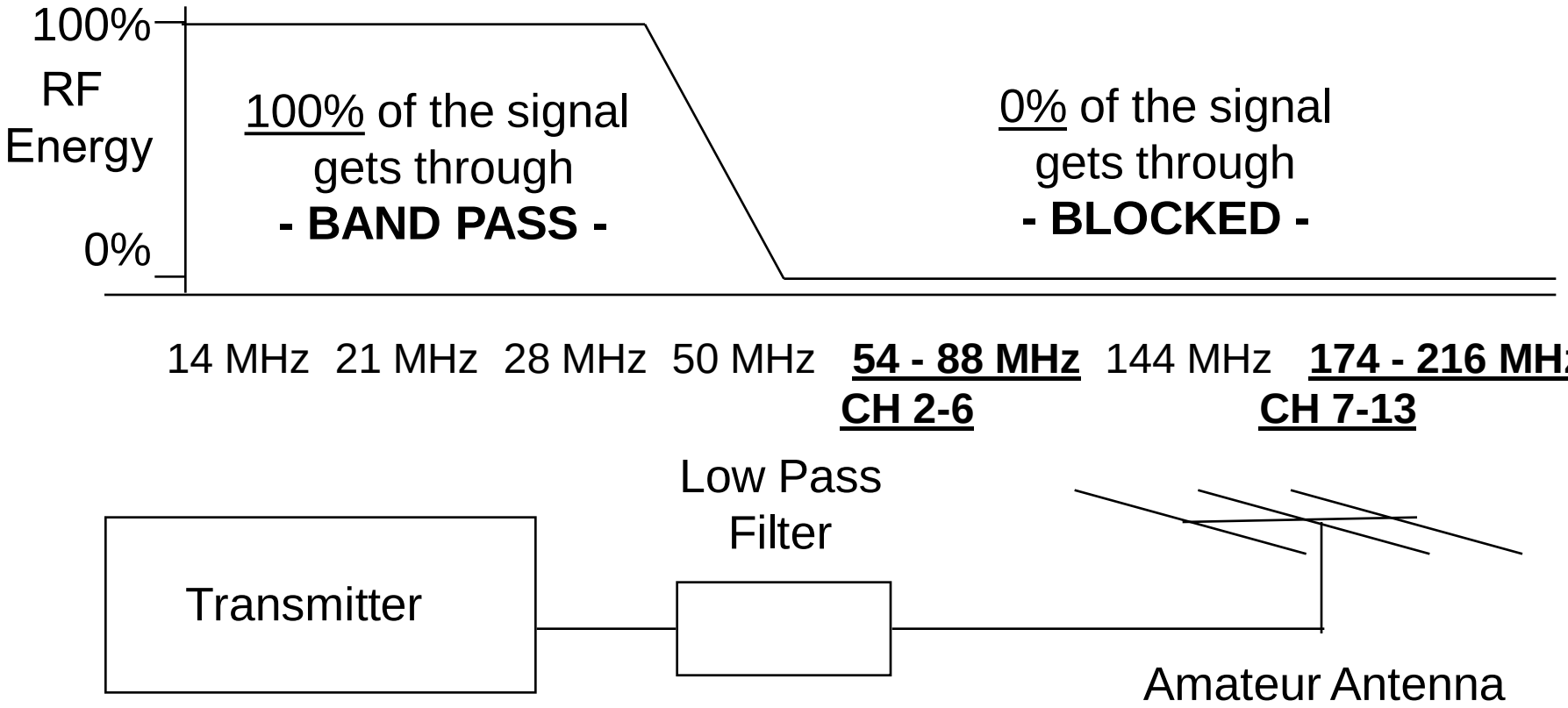
SSB Example



- If someone tells you that your transmissions are causing interference on nearby frequencies, then you may have spurious emissions

- Spurious emissions can be caused by any of the following:
  - A transmitter problem
  - The microphone gain is set too high
  - You are talking too loud
  - You are talking too close to the microphone

Low-Pass Filters

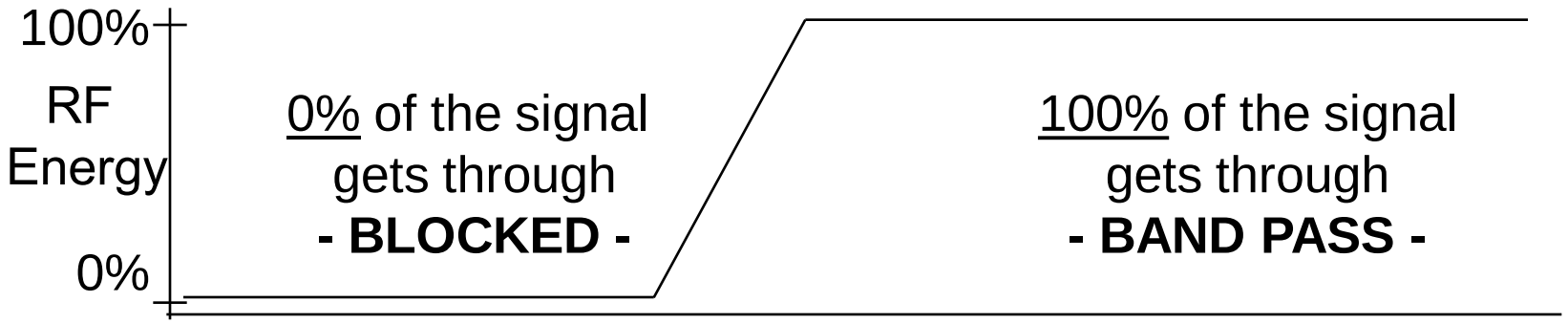


- A (low-pass) filter is placed between the transmitter and the antenna to reduce harmonic emissions

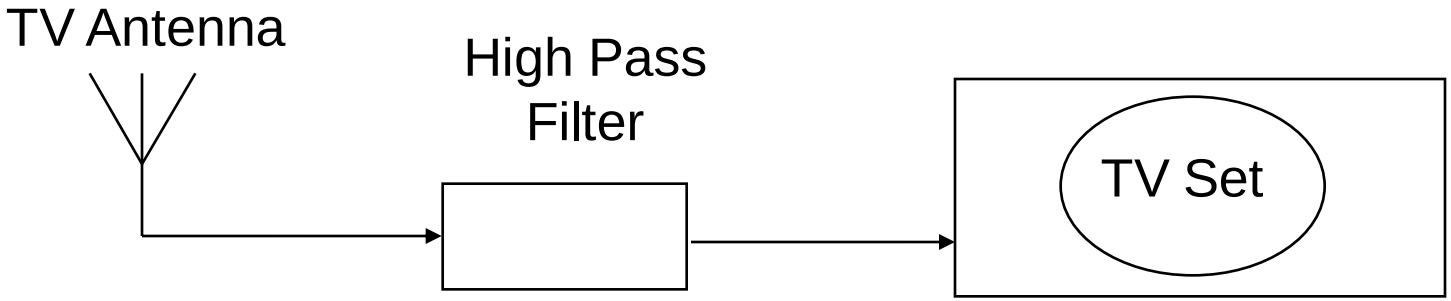
- It passes all RF energy (signals) below a specified frequency and blocks all RF energy (signals) above a specified frequency

- Low-pass filters are now built into many HF transceivers

High-Pass Filters



14 MHz 21 MHz 28 MHz 50 MHz **54 - 88 MHz CH 2-6** 144 MHz **174 - 216 MHz CH 7-13**



- It blocks all RF energy (signals) below a specified frequency
- It passes all RF energy (signals) above a specified frequency

7B05

- So by blocking the amateur signal with a filter at the antenna input of the effected receiver, we can reduce or eliminate the overload to a TV receiver or non/Amateur Radio

TV Interference (TVI) and Who's Responsible

7B06 If a neighbor tells you that your stations transmissions are interfering with their radio or TV reception, make sure that your station is functioning properly and that it does not cause interference to your own radio or television when it is tuned to the same channel

Other Interference

- Telephone Interference of non-cordless telephones:
  - Most of those telephones didn't have adequate interference protection (filters) built in from the factory
  - A transmitters signal causes the phone to act like a receiver

7B08
- If your neighbor has something in their home which is causing harmful interference to your amateur station:
  - Work with your neighbor to identify the offending device
  - Politely inform your neighbor that FCC rules prohibit the use of devices that cause interference (good luck)
  - Make sure your station meets the standards of good practice (too vague)

7B09
- The first step to resolve non fiber-optic cable TV interference caused by your amateur radio transmission is to be sure that all TV feed line coaxial connectors are installed properly

Miscellaneous

- If you transmit and are very close to another amateur radio station, the audio from the other stations speaker may get back into your microphone as you are transmitting and it will create RF feedback

7B11
- Adding a clip on ferrite “choke” to the microphone cable to prevent the transmitted signal from feeding back into the transmitter can eliminate distorted voice transmissions

7B04
- High SWR (standing wave ratio) can be the cause of low RF power output from a solid state transceiver

6D03
- A common reason to use shielded wire is to prevent coupling of unwanted signals to or from the wire

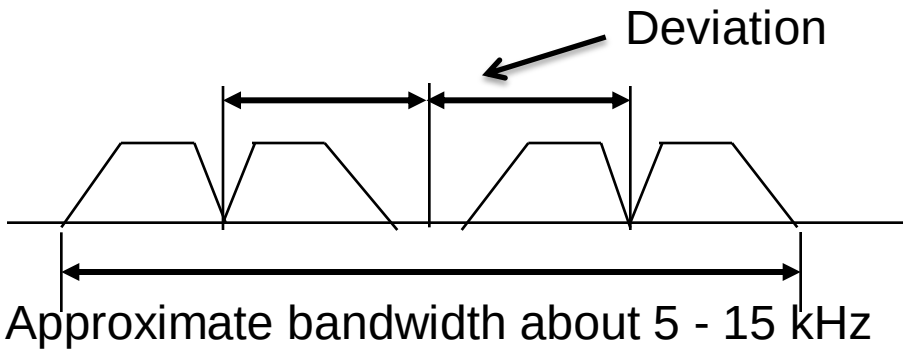
Miscellaneous

- In the FM mode, when you talk into the microphone, the carrier frequency of your signal shifts up and down frequency, and is referred to as the deviation, which is how Frequency Modulation (FM) works (see Section 6)

7B01 • If you are told that your FM handheld or mobile transceiver is over-deviating, then talk further from the microphone

2B05 • If your FM transmission audio is distorted on voice peaks, you are talking too loudly

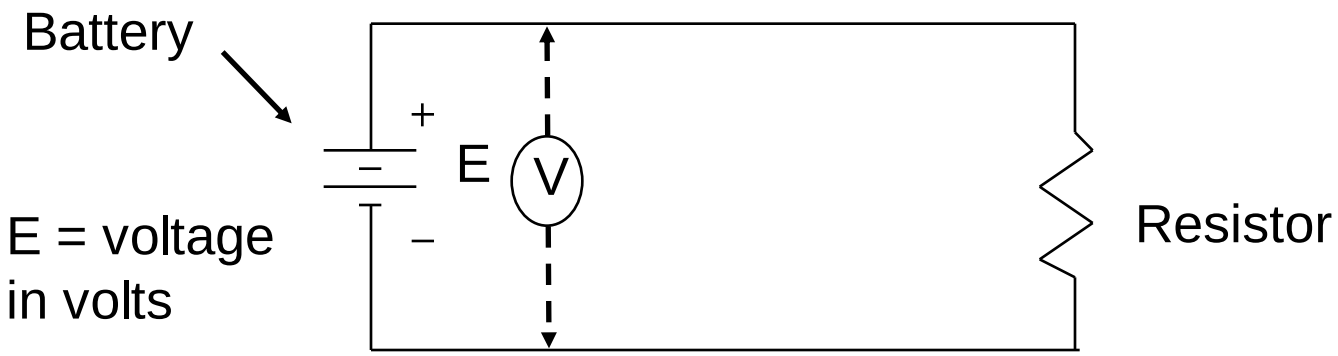
4B05 • The scanning function of an FM transceiver tunes through a range of frequencies to check for activity



Section 15

Electrons – Go With The Flow !

Voltage



5A05 • The electronic term voltage is what causes electrons to flow

5A11 • Resistance opposes the flow of direct current, alternating current and RF current

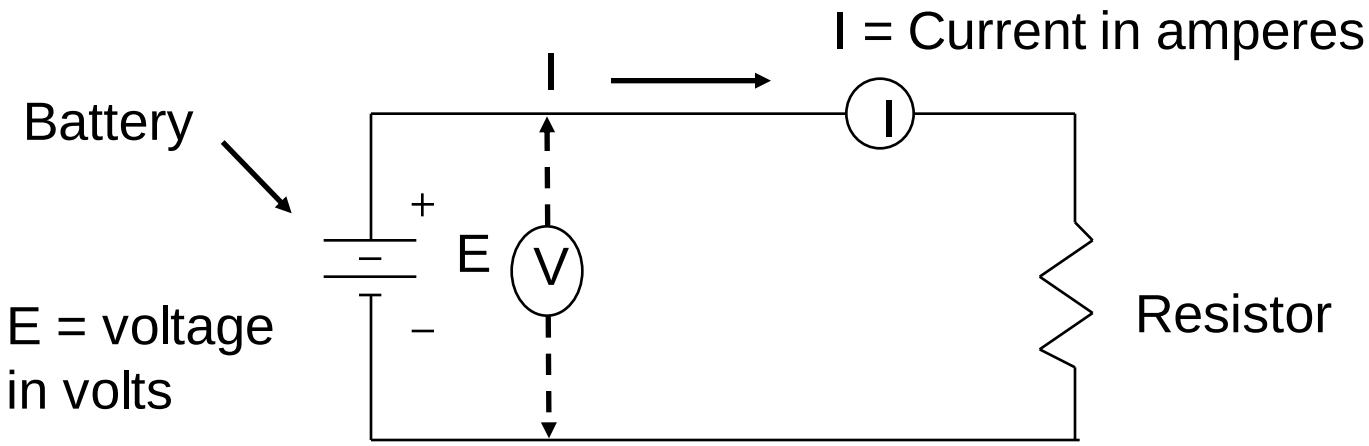
7D01 • To measure electric potential use a voltmeter

7D02 • A voltmeter is connected in parallel with a component

• A typical mobile transceiver will require 12 volts

4A11 • Connect the negative power return of a mobile transceiver to the 12V-battery chassis ground

Current



5A03
- When electrons flow in a circuit, it is called current

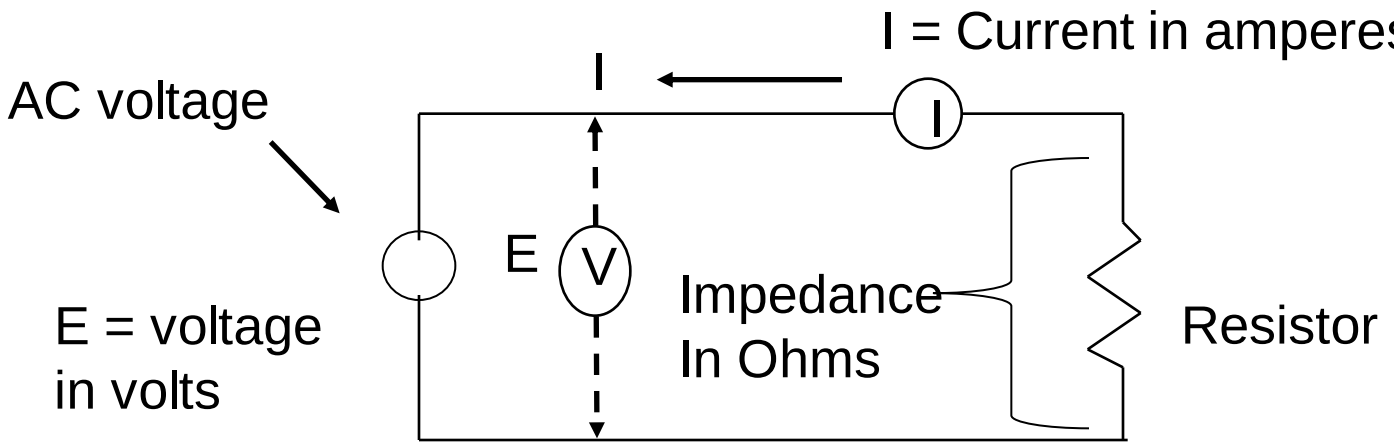
- Current flows from positive to negative (convention)
- Electrons flow from negative to positive due to negative charge

5A01
- Electrical current is measured in amperes

7D04
- Electrical current is measured with an ammeter

7D03
- To measure current, a multimeter is connected in series with the component

Impedance



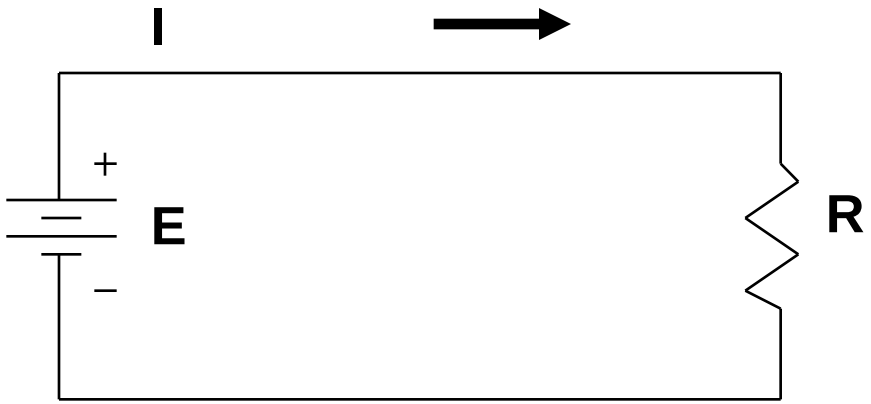
5C12 • Impedance is the opposition to AC current flow

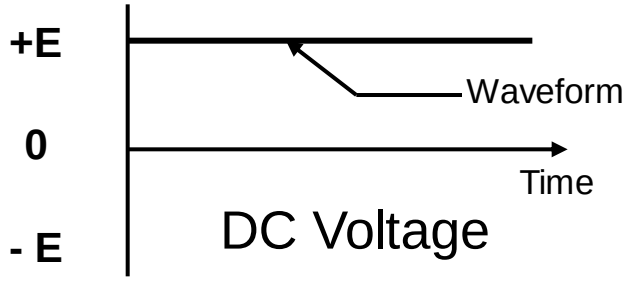
5C05 • The unit of impedance is ohms

• This is confusing because if it was a DC voltage, they would call it “resistance”, but when the voltage is AC, then they call it “impedance”

Alternating Current (AC) and Direct Current (DC)

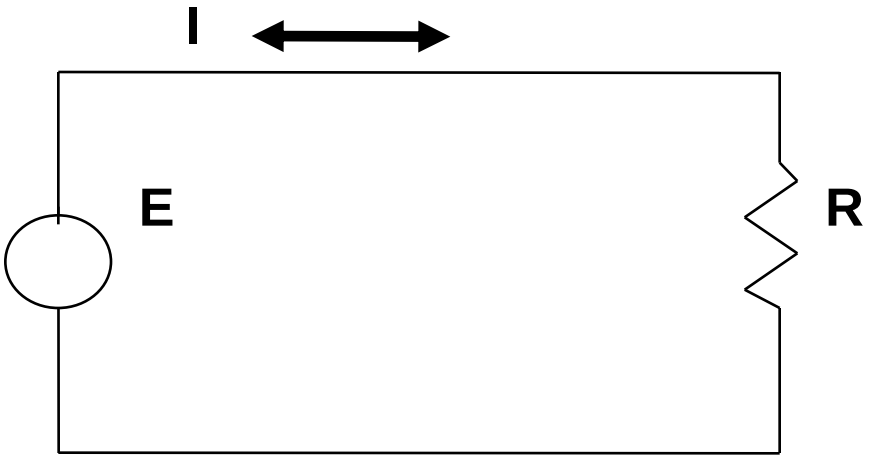
- Current that flows only in one direction is called Direct Current, DC

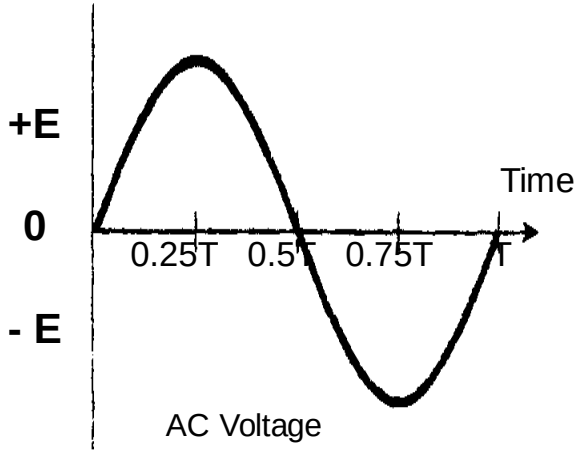




5A09

- Current that alternates between positive and negative directions is called Alternating Current, AC





Insulators and Conductors

- CONDUCTORS:

5A07

- Good electrical conductors tend to be metal because they have many free electrons
- Copper is a very good electrical conductor
- The better the conductor, the <u>less the resistance</u>
- Too much resistance in a conductor can be bad

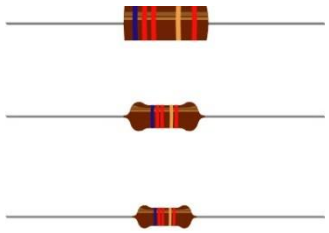
- INSULATORS:
  - Good insulators tend to be non metal

5A08

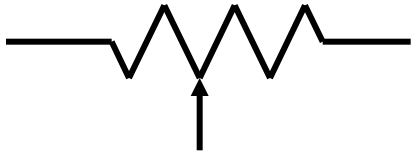
- Glass is a good insulator
- The better the insulator the <u>more the resistance</u>
- Very high resistance stops the flow of current

Resistance

Symbol for Fixed resistor



Symbol for Variable resistor

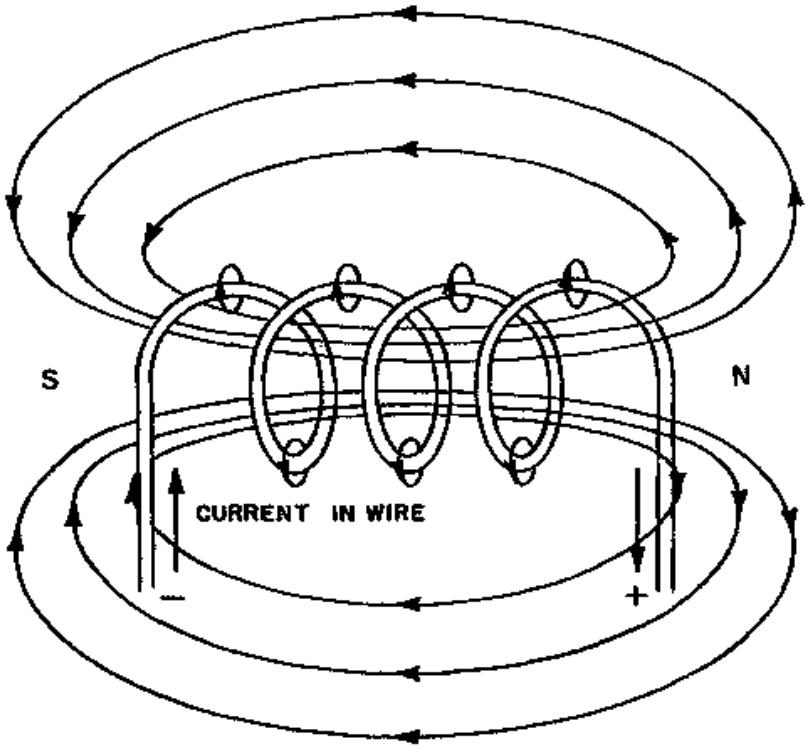


6A01 • A resistor opposes the flow of current (electrons) in a DC circuit

6A02 • A potentiometer is used as an adjustable volume control

6A03 • A potentiometer controls the electrical parameter resistance

Inductor



Inductor Symbol

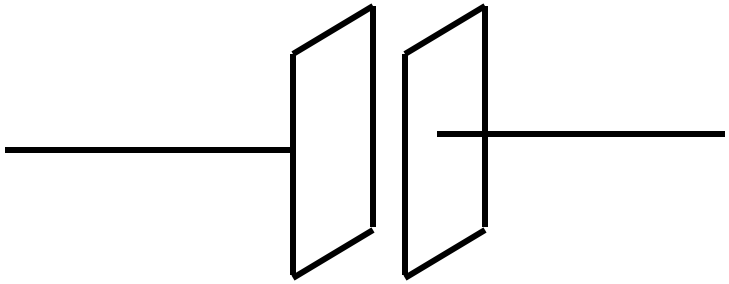
6A07 • An inductor is constructed as a coil of wire

6A06 • An inductor stores energy in a magnetic field

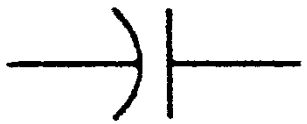
5C03 • Storing energy in a magnetic field is called inductance

5C04 • The basic unit of inductance is the henry

Capacitor



Two conductive surfaces separated by an insulator



Capacitor Symbol

6A05 • A capacitor consists of conductive surfaces separated by an insulator

6A04 • A capacitor stores energy in an electric field

5C01 • Storing energy in an electric field is called capacitance

5C02 • The basic unit of capacitance is the farad

Full-wave Rectifier Power Supplies

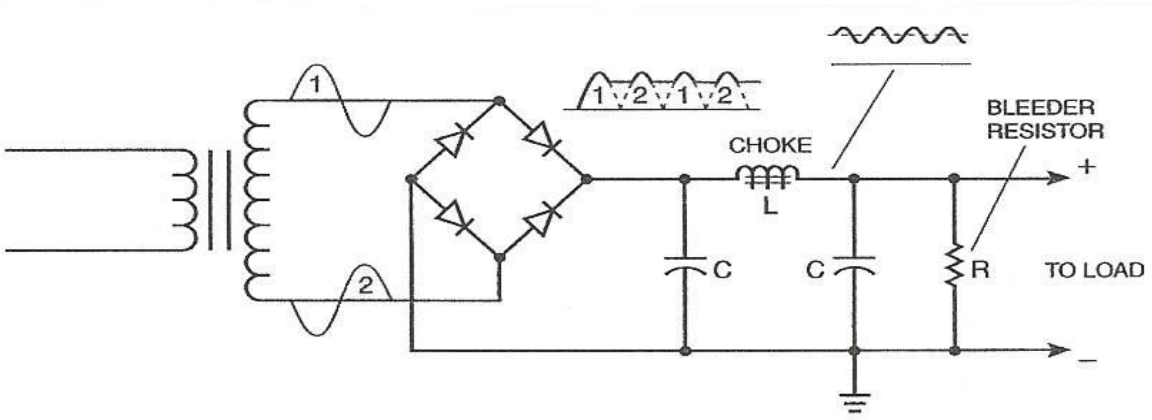
6D01 • The rectifier (in a power supply) changes alternating current (AC) into a varying direct current (DC) signal

6B02 • The diodes allow current to only flow in one direction

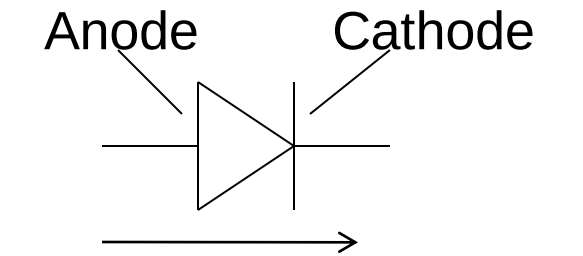
6B09 • The two electrodes in a diode are the anode and the cathode

6B06 • The cathode lead of a semiconductor diode is often marked with a stripe

6B01 • The forward voltage drop across a diode is lower in some diodes



Full-Wave Power Supply with Bleeder Resistor



Current flows ? (explain)

Electrons flow ←

Full-wave Rectifier Power Supplies

4A03

- Short heavy gauge wires are used for a transceiver's DC power connection to minimize voltage drop when transmitting

4A01

- The appropriate power supply rating for a typical 50 watt output mobile FM transceiver would be 13.8 volts at 12 amperes

- A typical transceiver is about 30% efficient

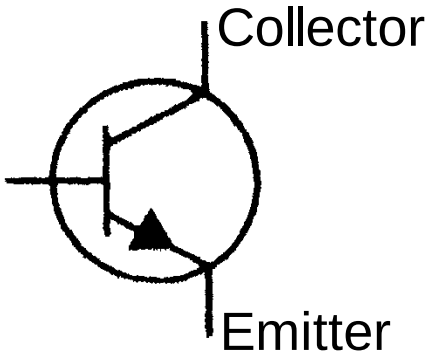
- So, to put out 50 watts, you would need about 170 watts of input power from the power supply

- Current is watts/voltage

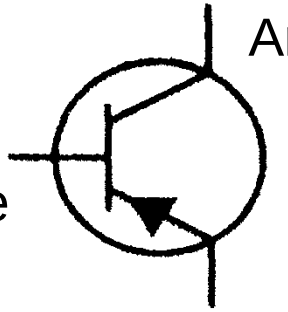
- We have 170 watts/13.8 volts from a car battery = 12.4 amps

- The best answer in the pool is 13.8 volts at 12 amperes

Transistors



NPN Transistor



PNP Transistor

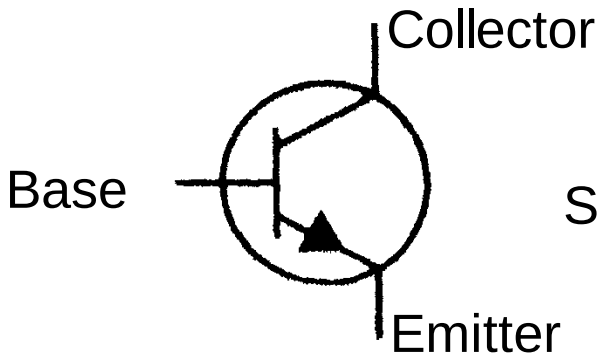
- A transistor is a solid state version of a vacuum tube

6B03
- A transistor can be used as an electronic switch
- A transistor can amplify signals

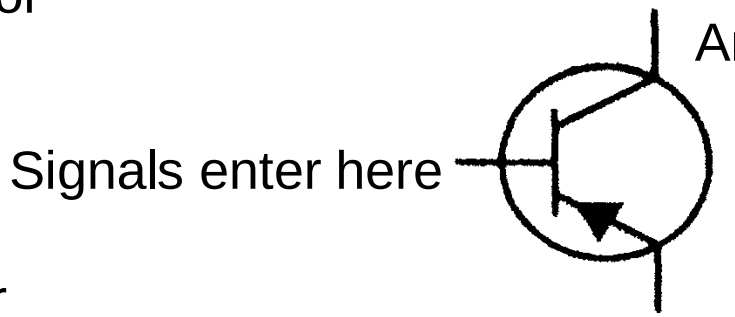
6B11
- The ability of a device to amplify a signal is called its gain
- The output signal voltage, current, or power relative to the input signal power

6B12
- The names of the electrodes in a bipolar junction transistor are emitter, base, collector

Transistors



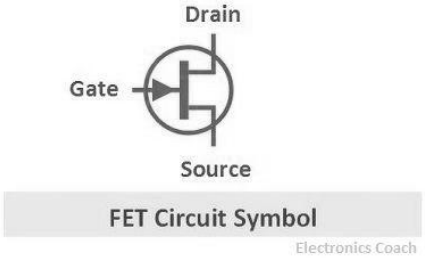
NPN Transistor



PNP Transistor

6B10 • The transistor can provide power gain

6B04 • The transistor can consist of three regions of semiconductor material



6B08 • FET means Field Effect Transistor

6B05 • The FET has 3 electrodes, gate, drain, and source

• Lots of modern ham gear use powerful transistors called FETs

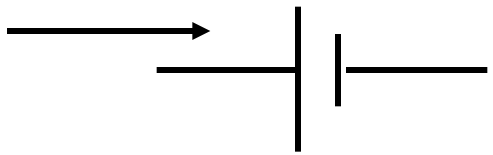
Batteries

- Listed below are several types of batteries:
  - Alkaline — not rechargeable
  - Carbon-zinc — not rechargeable
  - Lead-acid gel-cell — rechargeable
  - Mercury — not rechargeable
  - Nickel-cadmium — rechargeable
  - Lithium-ion — rechargeable
  - Nickel-metal-hydride — rechargeable
  - Silver oxide — not rechargeable

6A10 • The following battery chemistries are rechargeable: Nickel-metal-hydride, Lithium-ion, Lead-acid

6A11 • Carbon-zinc battery chemistry is not rechargeable

4A09 • To determine the length of time that equipment can be powered from a battery, divide the battery ampere-hour rating by the average current draw of the equipment

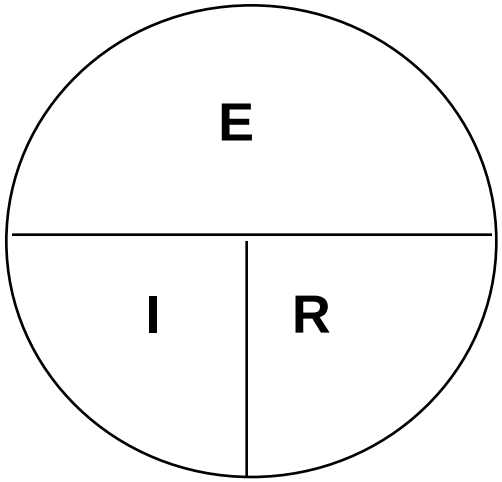
The positive terminal 

Section 16

It’s the Law, Per Mr. Ohm !

Ohm's Law

- Ohm's Law is a formula defining the relationship between voltage, current and resistance



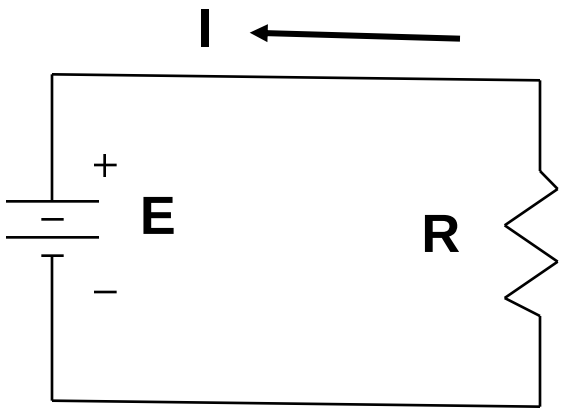
5D02 **E = I X R**

E = Voltage in Volts
I = Current in Amperes
R = Resistance in Ohms

5D10 If I = 0.5 amps R = 2 ohms
Then E = 1 volt

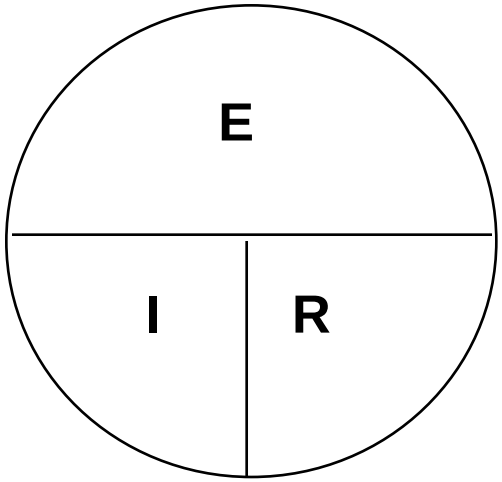
5D11 If I = 1 amps R = 10 ohms
Then E = 10 volts

5D12 If I = 2 amps R = 10 ohms
Then E = 20 volts



Ohm's Law

- Ohm's Law is a formula defining the relationship between voltage, current and resistance



5D02 **E = I X R**

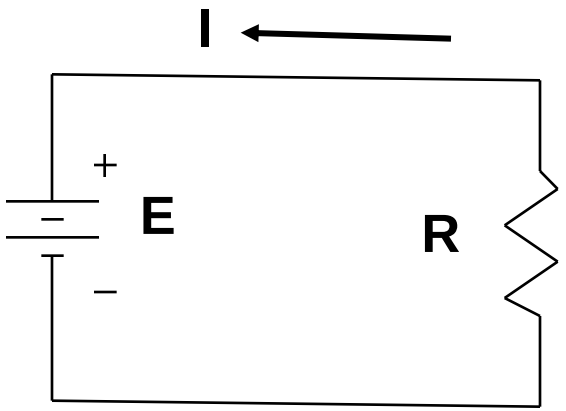
E = Voltage in Volts
I = Current in Amperes
R = Resistance in Ohms

5D01 $I = \frac{E}{R}$

5D07 If E = 120 volts R = 80 ohms
Then I = 1.5 amps

5D08 If E = 200 volts R = 100 ohms
Then I = 2 amps

5D09 If E = 240 volts R = 24 ohms
Then I = 10 amps



Ohm's Law

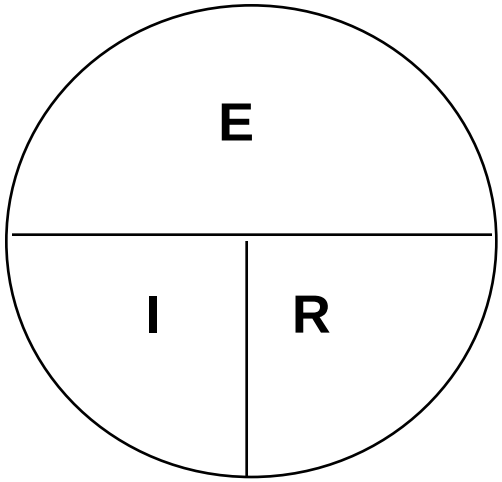
- Ohm's Law is a formula defining the relationship between voltage, current and resistance

5D02 **E = I X R**

5D01 $I = \frac{E}{R}$

5D03 $R = \frac{E}{I}$

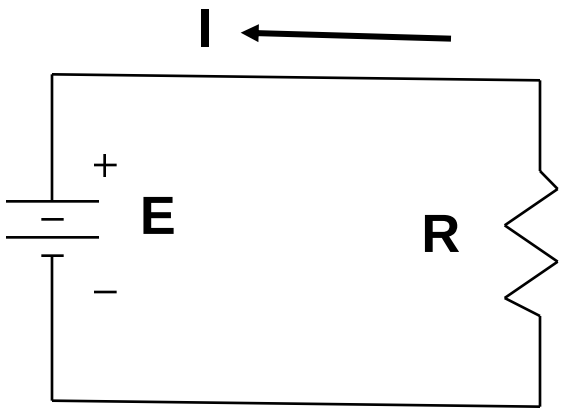
E = Voltage in Volts
I = Current in Amperes
R = Resistance in Ohms



5D04 If E = 90 volts I = 3 amps
Then R = 30 ohms

5D05 If E = 12 volts I = 1.5 amps
Then R = 8 ohms

5D06 If E = 12 volts I = 4 amps
Then R = 3 ohms



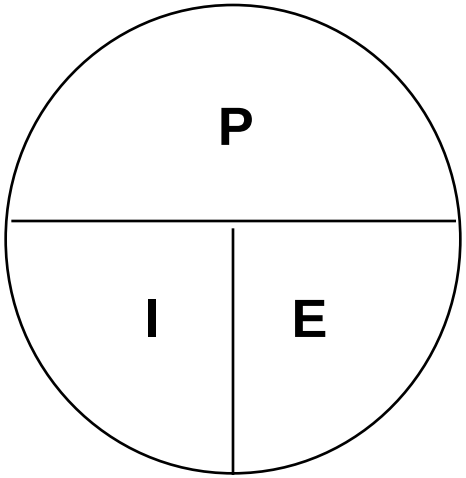
Voltage

5A10 • Power is the rate electrical energy is used

5A02 • Electric power is measured in watts

5C08 **P = I X E**
DC circuit explain

P = Power in Watts
E = Voltage in Volts
I = Current in Amperes

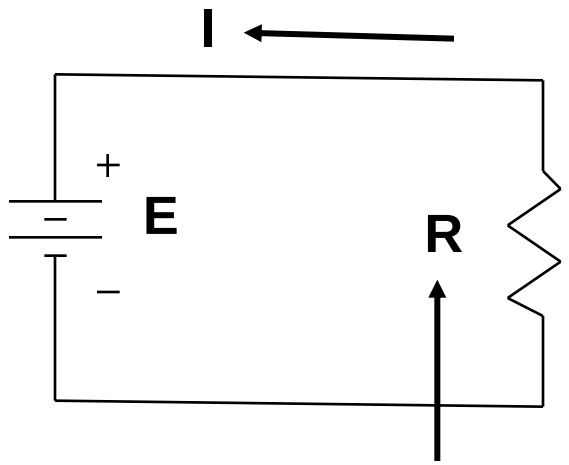


5C09 If E = 13.8 volts DC I = 10 amps
Then P = 138 watts

5C10 If E = 12 volts DC I = 2.5 amps
Then P = 30 watts

$$I = \frac{P}{E}$$

5C11 If E = 12 volts DC P = 120 watts
Then I = 10 amps



Power is consumed in the load

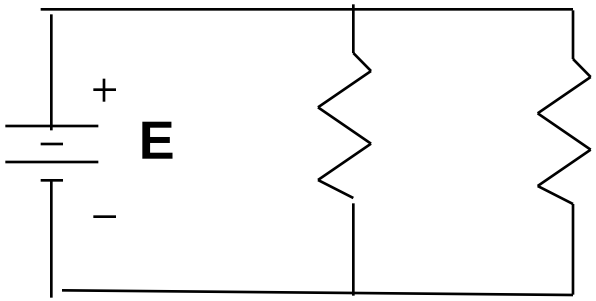
Voltage

5D14 • In a parallel circuit, the voltage is the same across all components

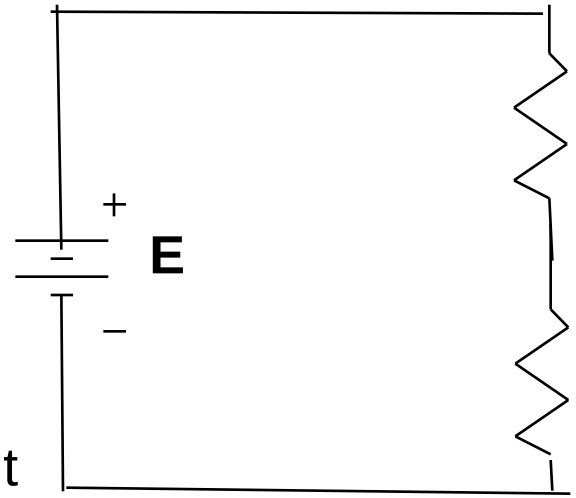
• The voltage across two components in series is determined by the type and value of the components

5D13 • The current is the same through all components in a series circuit

Parallel circuit



Series circuit



Section 17

Picture This !

Schematics

6C01 • A schematic is an electrical wiring diagram that uses standard component symbols

6C12 • The electrical schematics represent the way components are connected

6C10 • Component 3 in Figure T3 is a variable inductor

6C11 • Component 4 in Figure T3 is an antenna

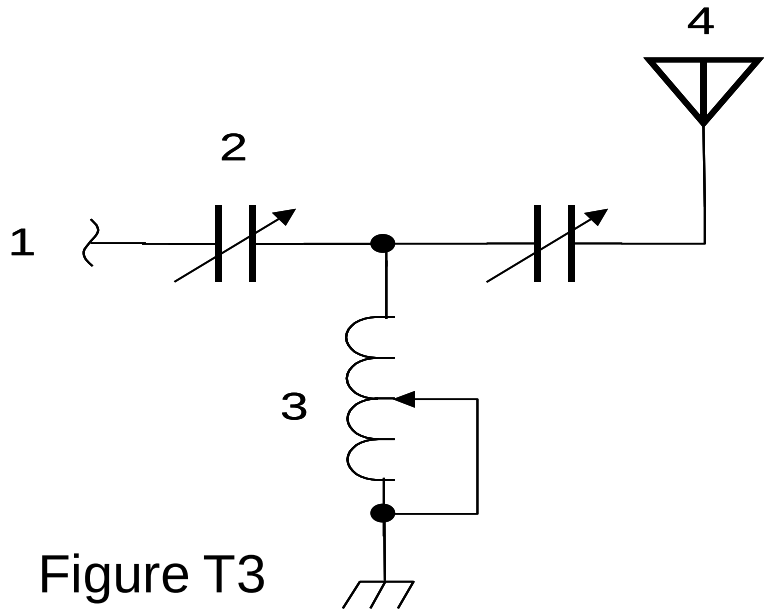


Figure T3

Schematics

6C02 • Component 1 in Figure T1 is a resistor

6C03 • Component 2 in Figure T1 is a transistor

6D10 • Component 2 is a transistor and will control the flow of current

6C04 • Component 3 in Figure T1 is a lamp

6C05 • Component 4 is Figure T1 is a battery

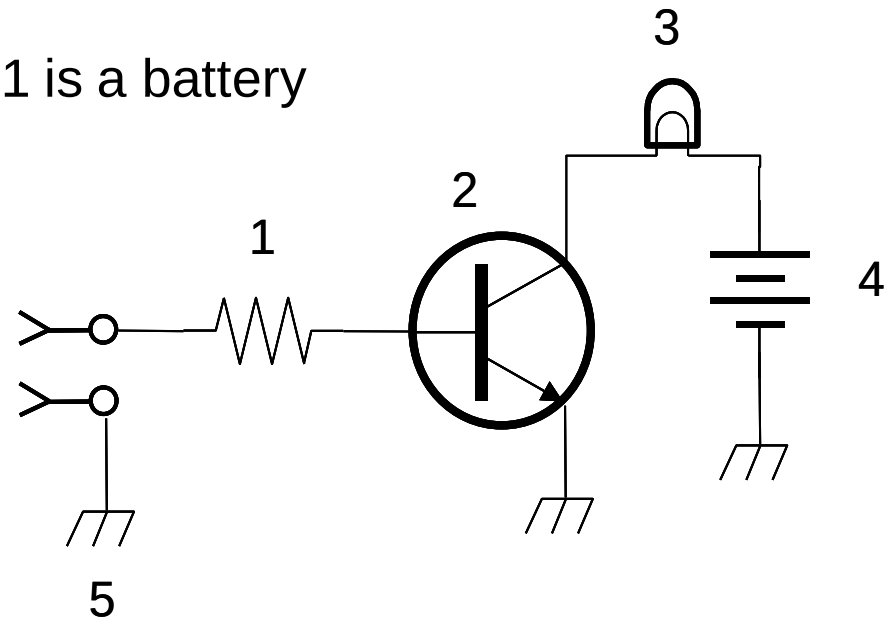


Figure T1

Schematics

6A09 • Component 3 in Figure T2 is a single-pole single-throw switch

6A08 • The function of a SPDT (single pole double throw) switch is to switch a single circuit between one of two other circuits

6C09 • Component 4 in Figure T2 is a transformer

6C06 • Component 6 in Figure T2 is a capacitor

6C07 • Component 8 in Figure T2 is an LED (light emitting diode)

6C08 • Component 9 in Figure T2 is a variable resistor

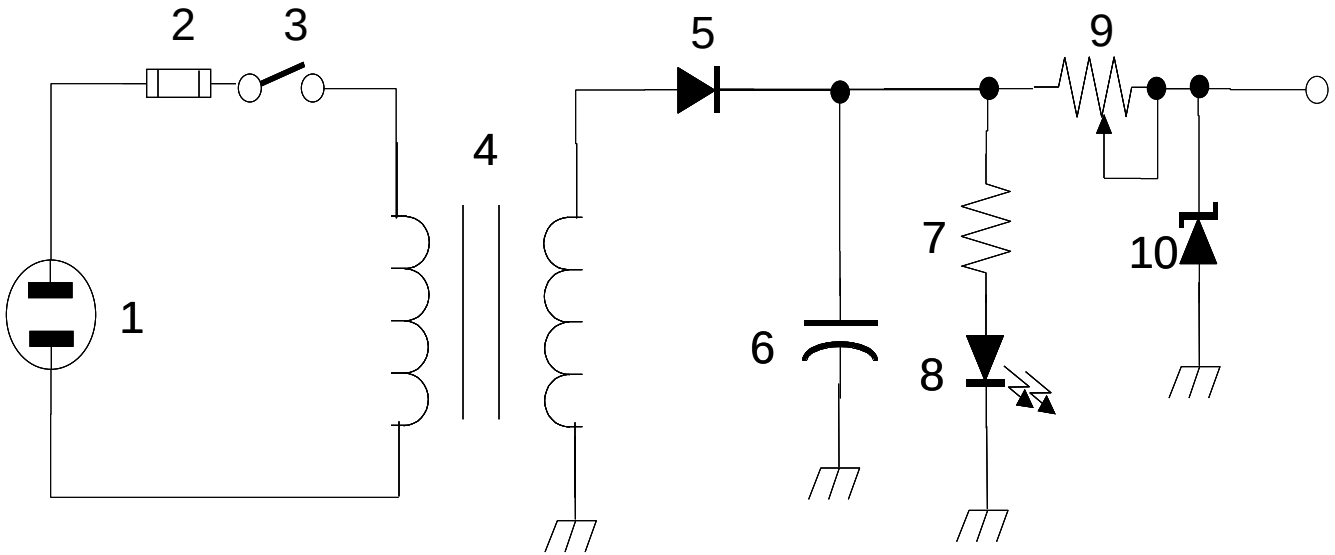


Figure T2

Multi-Meters

Multimeter

AC and DC Voltage
AC and DC Current
Resistance

- Years ago, you needed a separate meter to measure
  - AC voltage
  - DC voltage
  - AC current
  - DC current
  - Resistance

- Today, a multimeter can be used to measure all of the above

7D07

- Voltage and resistance measurements are made using multimeters

- Let me explain the issue in Question 7D07

Multi-Meters

Multimeter

AC and DC Voltage
AC and DC Current
Resistance

7D11 • When measuring in-circuit resistance with an ohmmeter, ensure that the circuit is not powered (it could damage the meter)

7D06 • Another way to damage the meter would be trying to measure voltage when the meter is on the resistance setting

7D10 • When measuring resistance with an ohmmeter in an unpowered circuit and the initial resistance is low, but then slowly increases, there is probably a large capacitor in the circuit (explain)

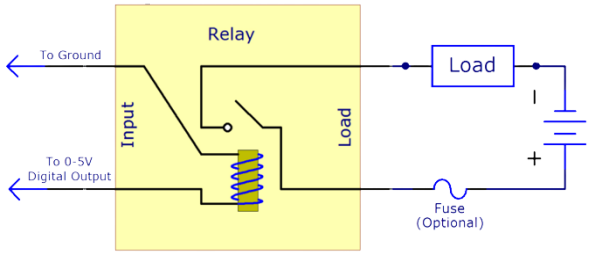
7D05 • An ohmmeter measures the resistance of a circuit or component by applying a small current and measuring the resulting voltage

Miscellaneous

6D08 • When an inductor and a capacitor are combined in a circuit, it becomes a resonant or tuned circuit (which means that a frequency can be created)

6D11 • A resonant or tuned circuit is an inductor and capacitor in series or parallel

6D02 • A relay is an electrically-controlled switch



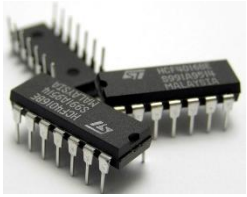
• When power is applied to the electromagnet, it turns the switch on (explain why to use these)

6D04 • A meter indicates an electrical quantity as a numerical value

Miscellaneous

6D09

- When several semiconductors and other components are combined into one package, that device is called an integrated circuit



- Our HTs and mobile radios typically run off of a DC voltage

- To run the HT in our house, we can use the battery that comes with the HT or use the wall charger for the HT

- If we want to run our mobile radio in our house, we can buy a 120V AC to 12V DC power supply

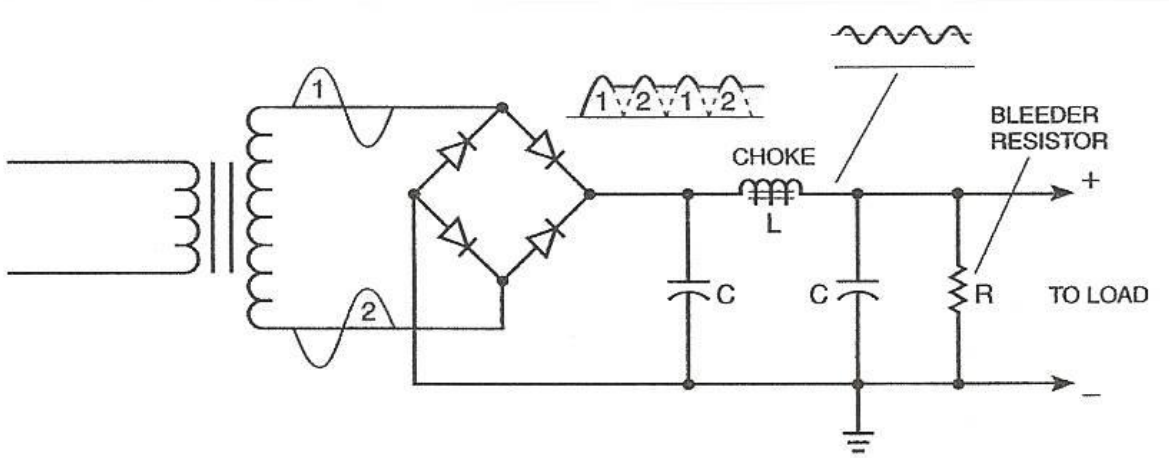
- Lets take a look at a typical AC to DC power supply on the next chart

Miscellaneous

6D06 • The transformer is the component that changes the 120V AC to the lower AC voltage (before we convert to DC)

6D05 • A regulator circuit is what controls the voltage from the power supply

• The power supply below does not have a regulator circuit



Full-Wave Power Supply with Bleeder Resistor

Miscellaneous

- Decibels vs. Power change
  - 0 dB = 0 change
  - 3 dB = 2 times change or 1/2 change
  - 6 dB = 4 times change or 1/4 change
  - 9 dB = 8 times change or 1/8 change
  - 10 dB= 10 times change or 1/10 change

10 log N = X dB

10 ^ (X dB/10) = N

5B09

- If there would be a power increase from 5 watts to 10 watts, that would be a +3 dB change

5B10

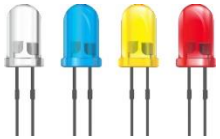
- If there would be a power decrease from 12 watts to 3 watts, that would be a – 6 dB change

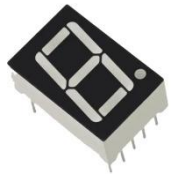
- The decrease from 12 watts to 6 watts would be -3 dB and then the decrease from 6 watts to 3 watts would be – 3 dB more for a total of -6 dB

5B11

- If there would be a power increase from 20 watts to 200 watts, that would be a +10 dB change

Miscellaneous





- LED stands for Light Emitting Diode

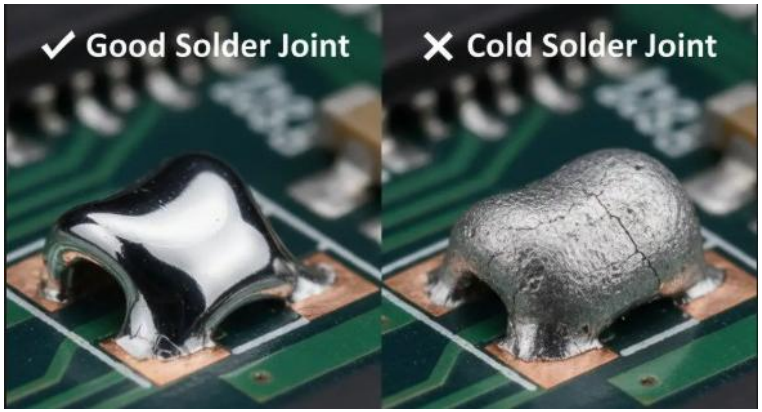
6B07 • Forward current causes a light-emitting diode (LED) to emit light

6D07 • A LED is commonly used as a visual indicator

- The displays on an HT are typically LED displays, and they take very little power, which is one reason they are used

7D08 • The type of solder that should not be used for radio and electronic applications is acid-core solder

7D09 • But if you have a “cold” solder joint (not good), your cold tin-lead solder joint will have a rough or lumpy surface



Miscellaneous Prefixes & Conversions

5B01 • 1.5 amps = 1,500 milliamps

5B02 • 1,500,000 Hz = 1,500 kHz (1.5 MHz)

5B03 • 1 kilovolt = 1,000 volts

5B04 • 1 microvolt = 1/1,000,000 of a volt

5B05 • 500 milliwatts = 0.5 watts

5B06 • 3 amperes = 3,000 milliamperes

5B08 • 1 microfarad = 1,000,000 picofarads (pico=1 trillionth)

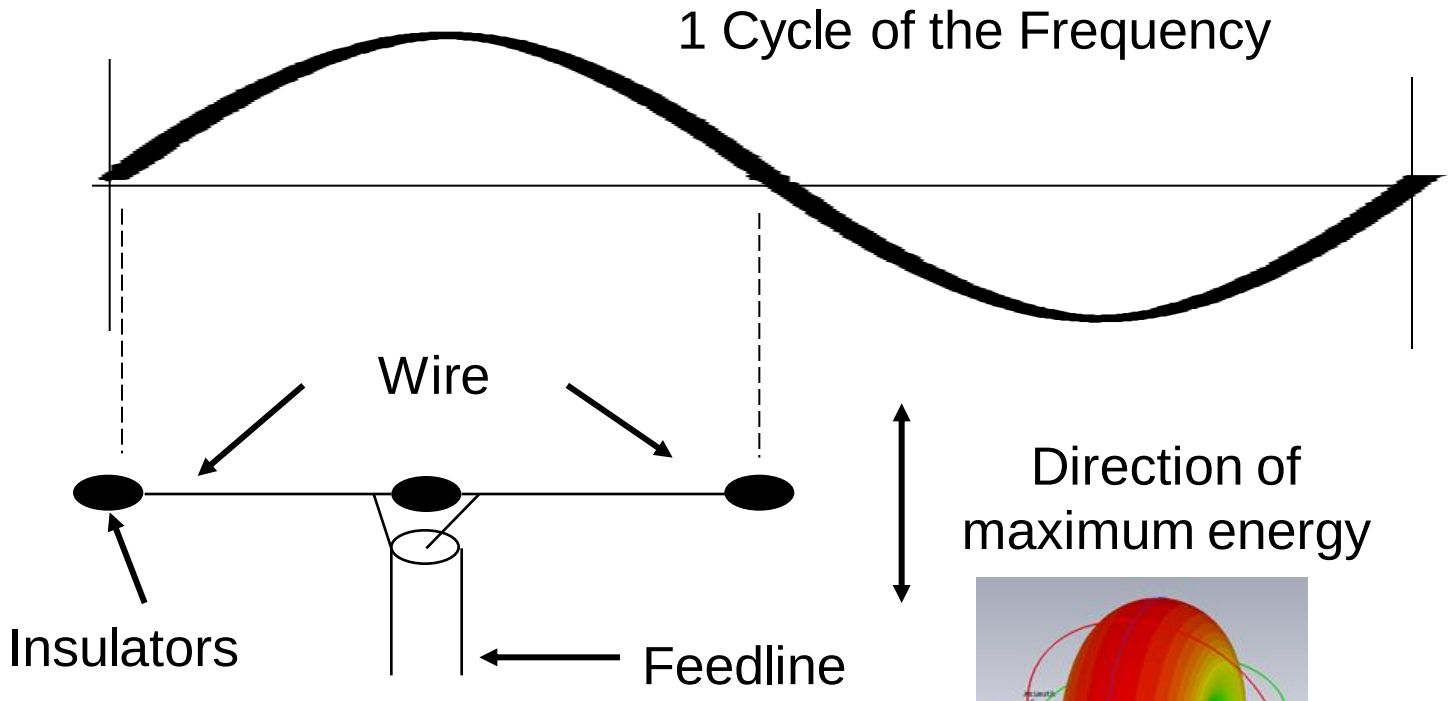
5B12 • 28,400 KHz = 28.4 MHz

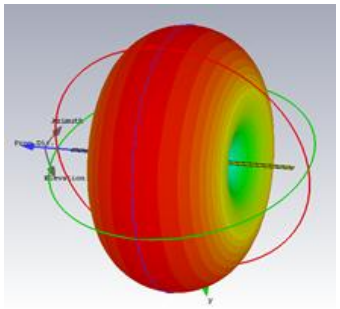
5B13 • 2,425 MHz = 2.425 GHz

Section 18

Antennas

The Half Wave Dipole



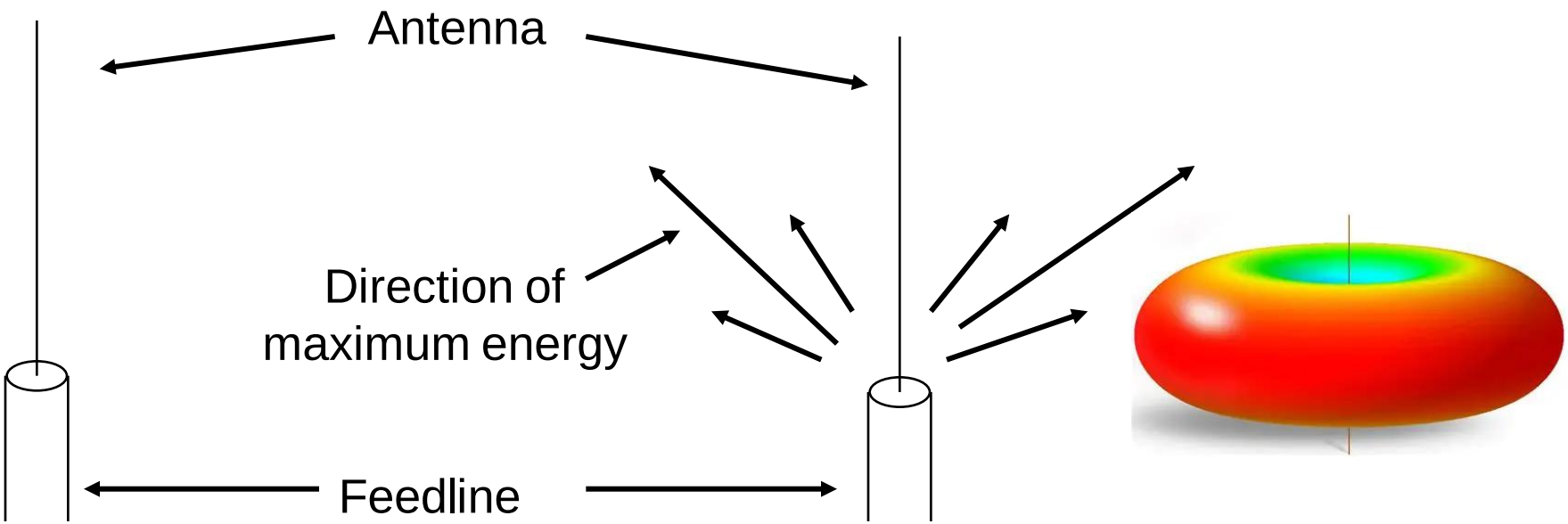


- Length (ft) = $\frac{468}{\text{Freq. (MHz)}}$

9A05 • To increase the resonant frequency, shorten the antenna

9A10 • A half-wave dipole radiates the strongest broadside to the antenna (2.15 dBi gain)

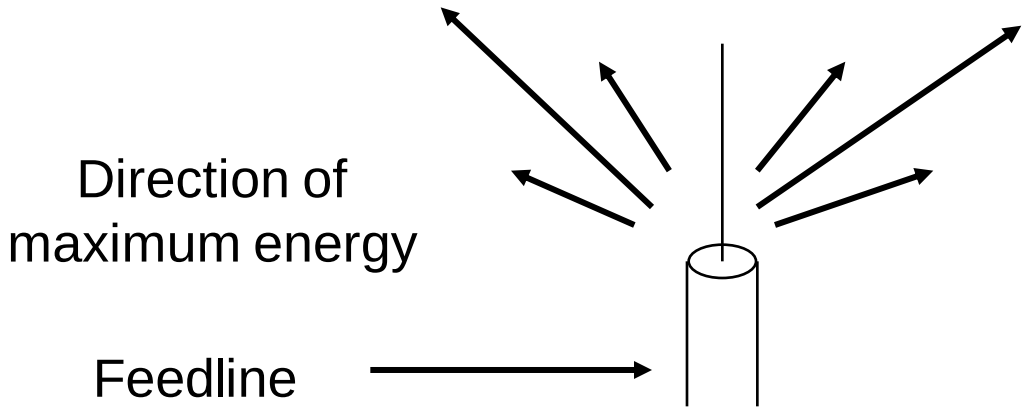
The Vertical



- Vertical antennas have an element perpendicular to the earth
- They are described by their wavelength, typically ¼ wave or longer
- A “rubber duck” (HT) antenna would be much shorter (1/8th wavelength or less), and less efficient than the ¼ wave
- The antenna radiation is omni directional, 360^0

The Vertical

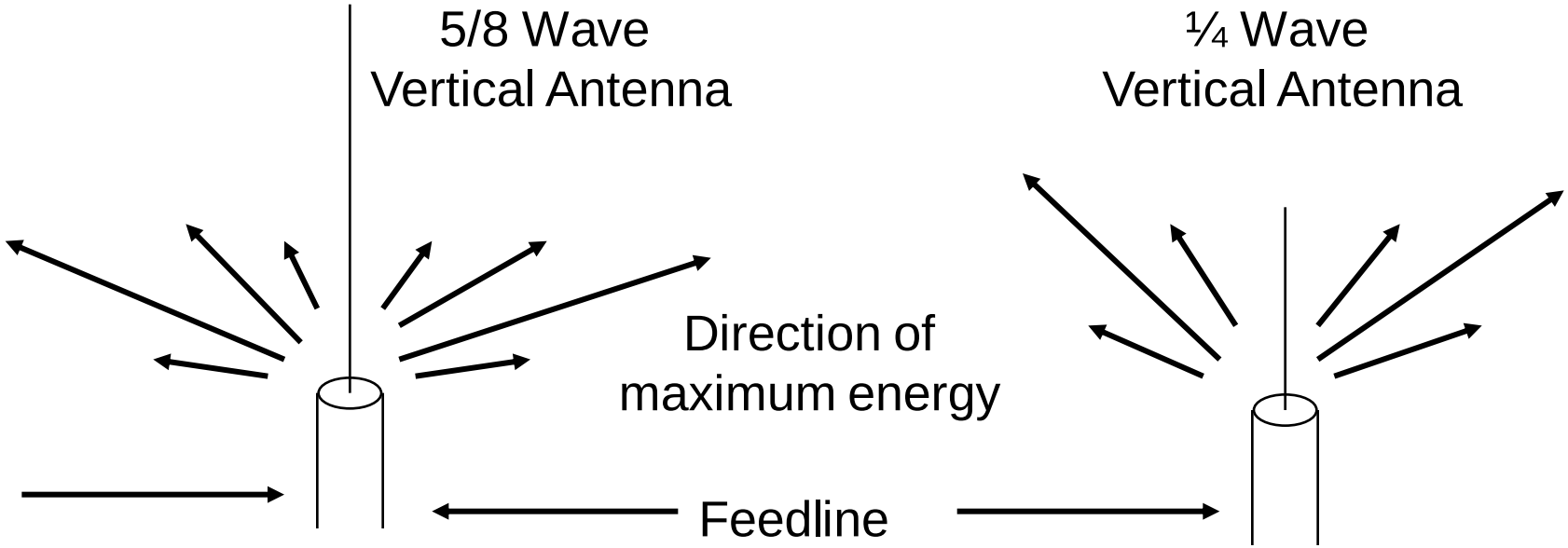
¼ Wave
Vertical Antenna



- Length (ft) = $\frac{234}{\text{Freq. (MHz)}}$

9A08 • The approximate length of a quarter-wavelength vertical for 146 MHz (2 meters) would be approximately 19”

The Vertical



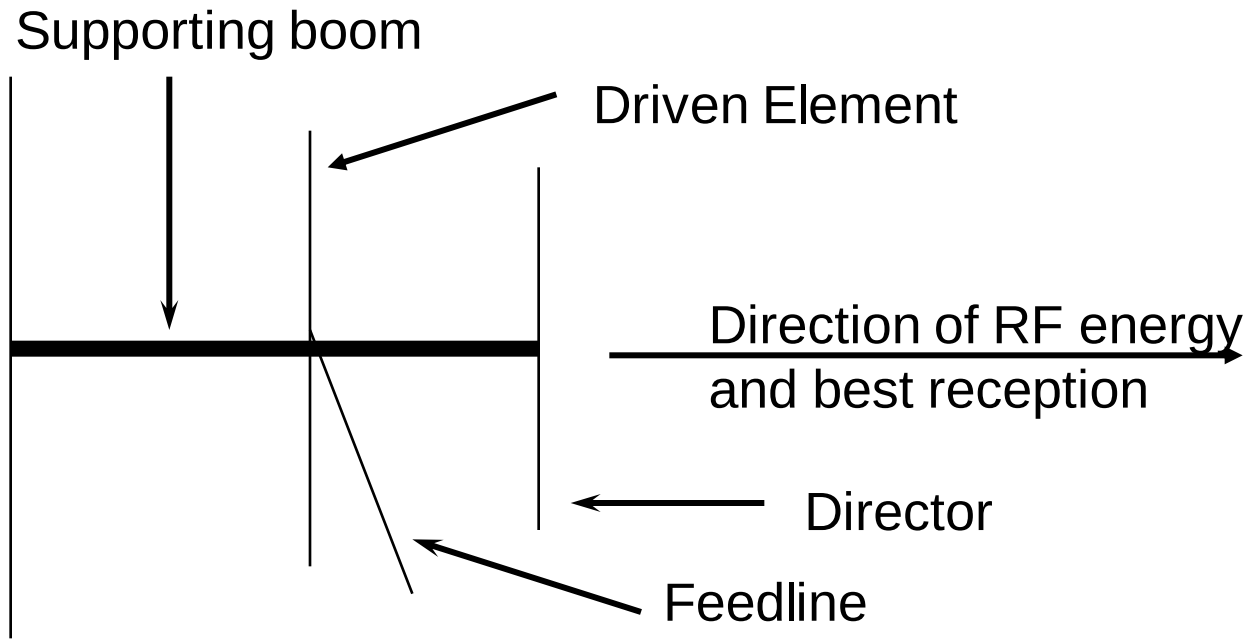
- Available antennas include a 1/4 wavelength vertical and a 5/8 wavelength vertical, both for 2 meters

9A09

- The advantage of a 5/8-wavelength whip antenna for VHF or UHF mobile service compared to a ¼-wave antenna is that it has more gain

- It also has a lower radiation angle and usually provides better coverage

The Yagi (Beam)



- A Yagi (beam) is one type of <u>directional antenna</u>

9A01 • A beam antenna is an antenna that concentrates signals in one direction (9-18 dBi)

9A11 • The gain of an antenna is the increase in signal strength in a specific direction, when compared to a reference antenna

- The reference antenna is sometimes a dipole (explain)
- dBi gain is typically 2 more than dB relative to a dipole

Very Directional Antennas

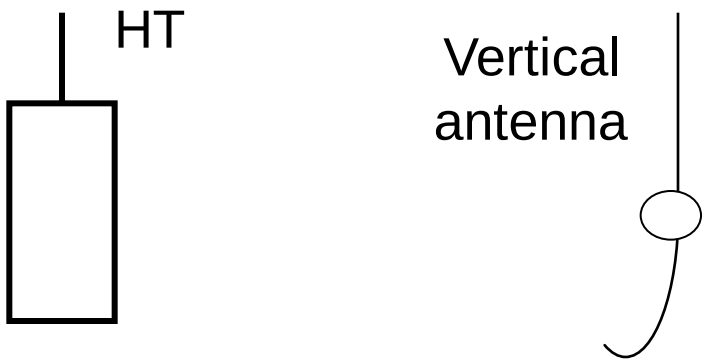
3A05 • When buildings or obstructions are blocking the direct line of sight path to a repeater, then try to find a path that reflects signals to the repeater

9A06 • The Yagi (beam) antenna has more gain than a 5/8 wavelength vertical antenna, an isotropic antenna and a J pole antenna

• The three antennas referred to in question 9A06 were all in the possible answers

J-pole antenna

Antenna Polarization

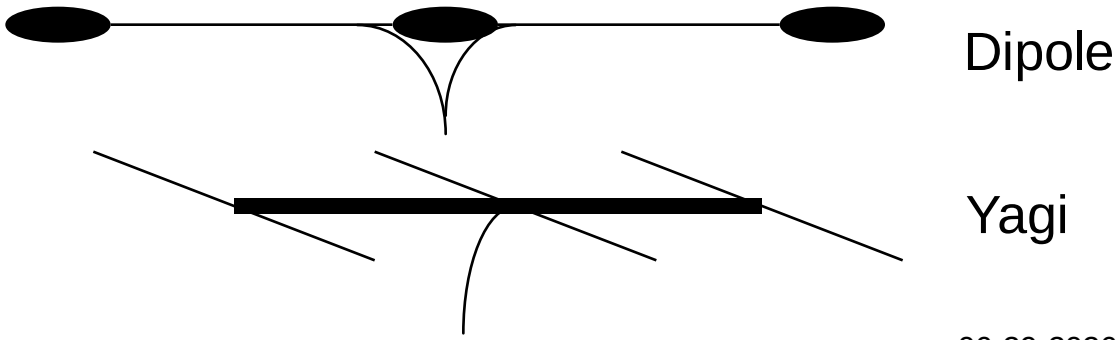


9A03

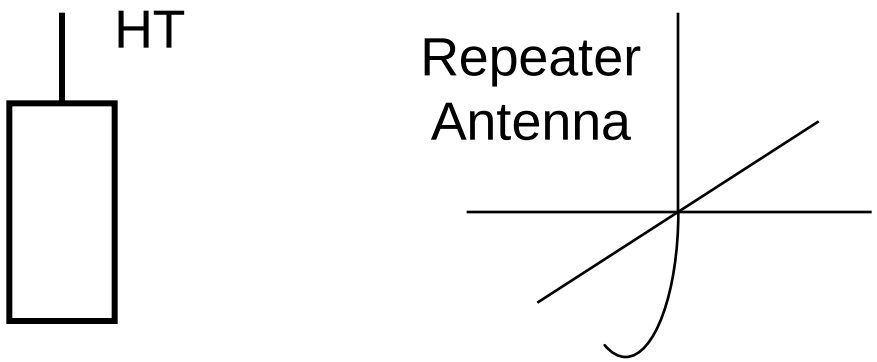
- The polarization of an antenna is described by the orientation of the electric field

- When an antenna is perpendicular to the earth's surface it is a vertically polarized antenna

- A simple dipole oriented parallel to the Earth's surface is a horizontally polarized antenna



Antenna Polarization



- You have <u>best communications</u> when the polarizations are the same for both antennas (more on this later)

- Repeaters use vertical antennas so they can receive and transmit a full 360^0 (therefore, vertical polarization)

- We use a vertically polarized antenna (an HT, a mag-mount) for best communication with a repeater

3A04

- If radios are using the VHF or UHF line-of-sight spectrum and are not the same polarization, the received signal strength is reduced

- So, when using an HT, keep the antenna physically vertical to maintain the same polarization as the repeater antenna

More Antenna Stuff

3A03 • Horizontal polarization is normally used for long distance CW and SSB contacts using the VHF and UHF bands (explain)

8C01 • Radio direction finding is used to locate sources of noise interference or jamming

• To do this, you would use directional antennas

• Some hams engage in hidden transmitter hunts to practice for finding “jammers” (Fox Hunt)

8C02 • A directional antenna is also what you’d use for a hidden transmitter hunt

Miscellaneous

- Many amateur radio operators have mobile HF transceivers in their car

- The antennas that are used are vertical antennas

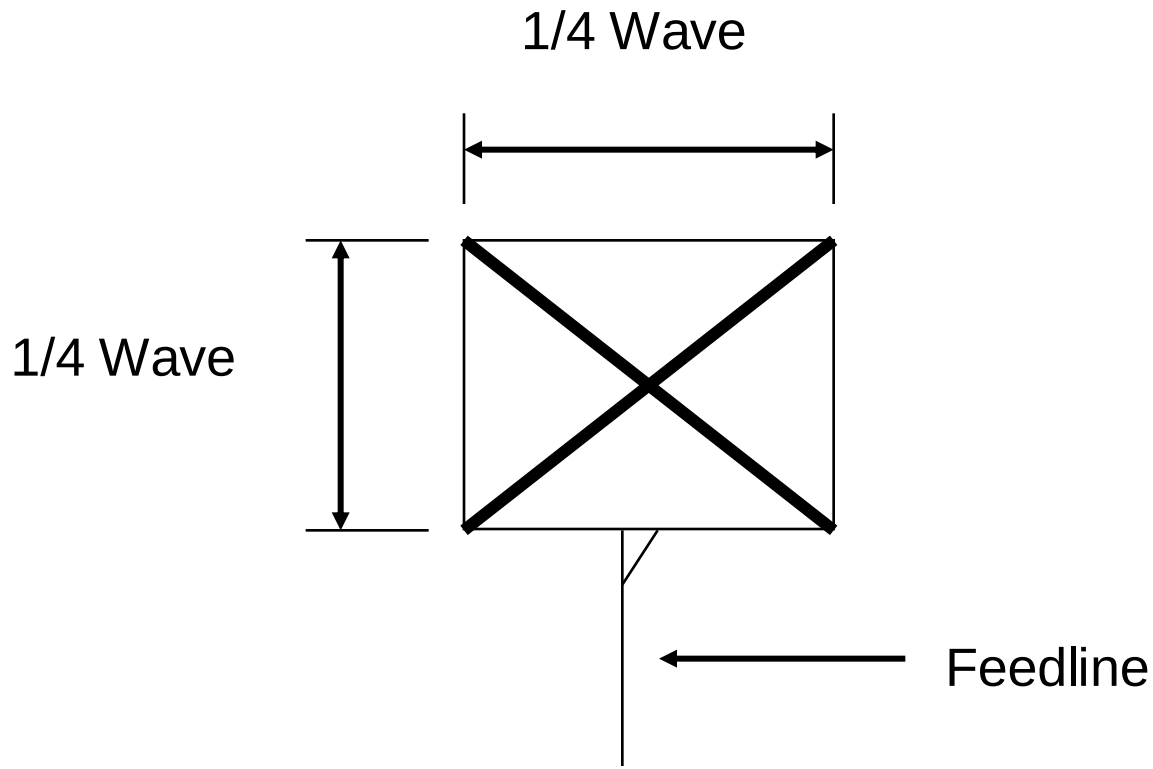
- The problem is that when you do the calculations, the length of a 1/4 wave antenna could be as short as 8 feet for the 10 meter band and as long as 66 feet for the 80 meter band

- So, to get those vertical antennas down to around 6 feet, a loading coil is inserted in the vertical antenna, which has inductance

9A02

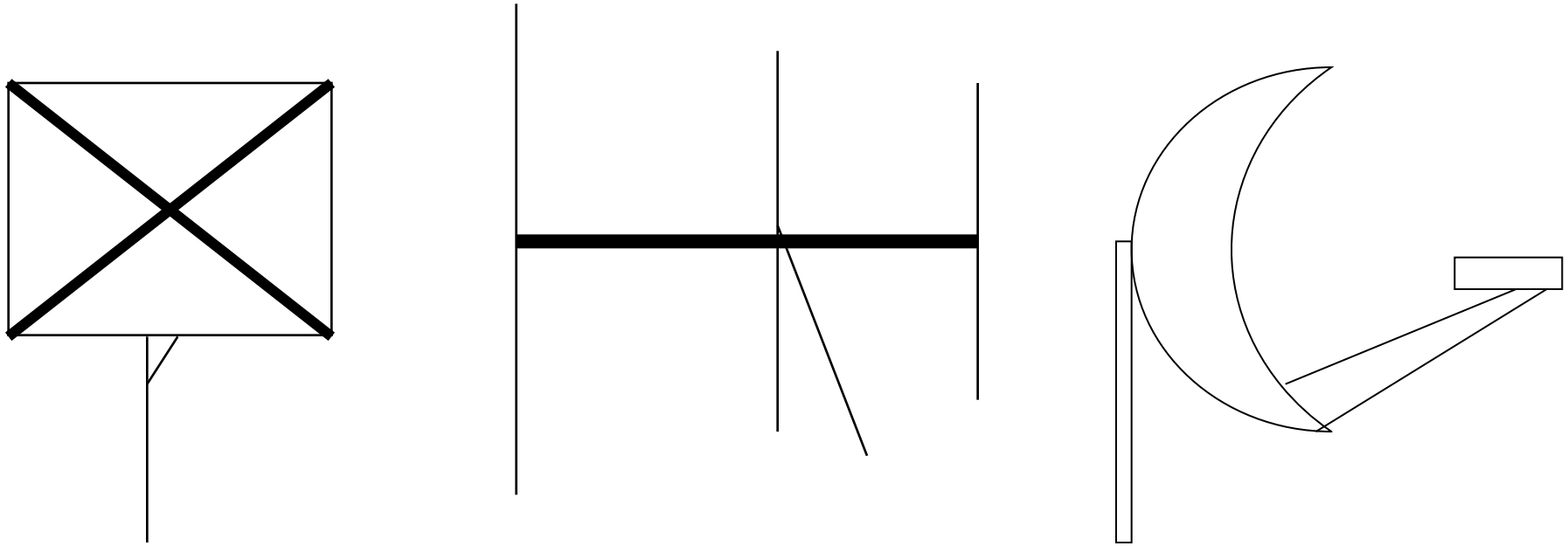
- Putting an inductor (loading coil) into the radiating portion of the antenna makes it <u>electrically</u> longer (and physically shorter)

The Quad Antenna



- A quad is 4-sided wire loop
- Each side is ¼ wavelength long
- It radiates and receives best front and back (not off the sides)

Very Directional Antennas

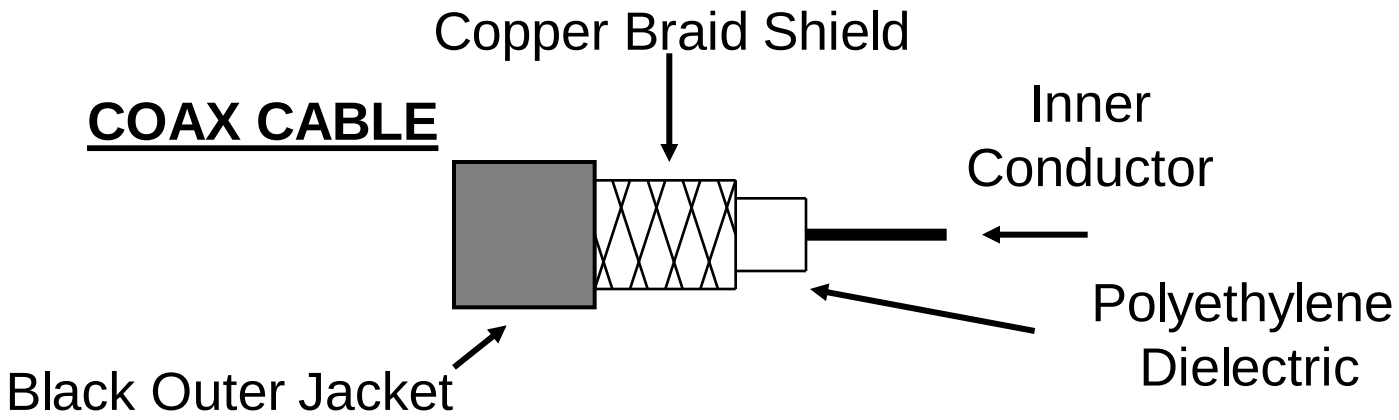


- Antennas like a Quad, a Yagi (beam) and a dish are directional antennas
- They have to be pointed to the direction of interest
- A directional antenna makes your signal sound much stronger
- A directional antenna also makes received signals sound louder

Section 19

Feed Me With Some Good Coax !

Unbalanced Feed Lines



- Coax is a center wire covered by insulation and a metal shield, typically copper braid and an outer jacket

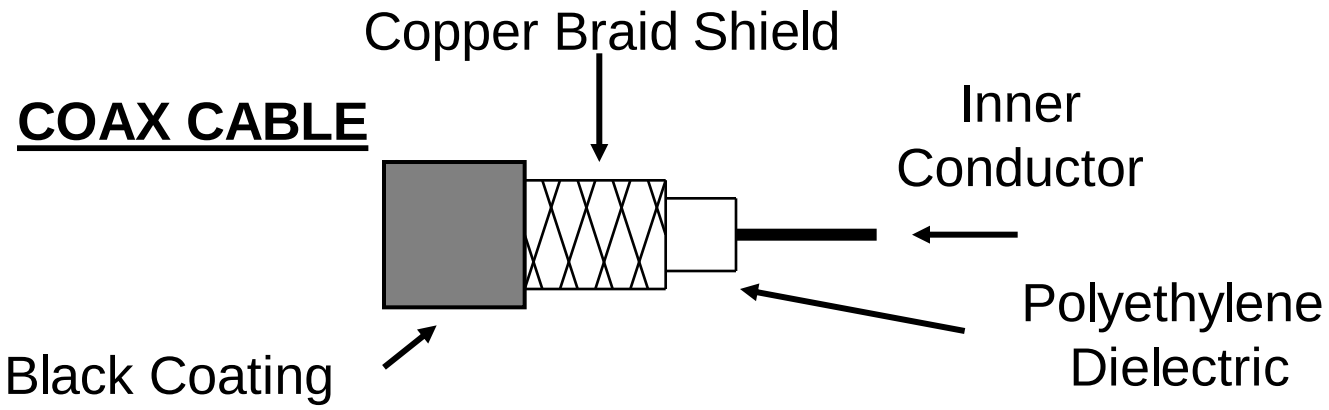
7C10

- The outer jacket should be resistant to ultraviolet light, otherwise ultraviolet light can damage the jacket and allow water to enter the cable

7C09

- Moisture contamination is the most common cause for failure of coaxial cables

Unbalanced Feed Lines



9B03 • Coax is the most common feed line for amateur radio antenna systems because it is easy to use and requires few special installation considerations

• Coax is mostly used to carry RF signals between a radio and an antenna

9B02 • The most common impedance of coax used in amateur radio is 50 ohms

Coax Connectors

- The coax attaches to our radio or other devices using special connectors

9B07

- The PL-259 coax connector is the common type of coax connector used at HF and VHF frequencies

9B06

- The Type N RF connector is the most suitable for frequencies above 400 MHz

- However, you will not see a Type N connector on your VHF/UHF HT (explain) (SO-239/PL-259 used instead)

9B08

- A source of loss in a coaxial feed line is:
  - Water intrusion into the coax connectors
  - High SWR
  - Multiple connectors in a line

Coax Cable Loss

- Coax cable is frequency sensitive and inherently has some loss

- The amount of the RF signal that actually gets through the coax cable depends on the frequency of the RF signal

9B05 - As the frequency of the signal in the coax increases, the loss increases (power lost)

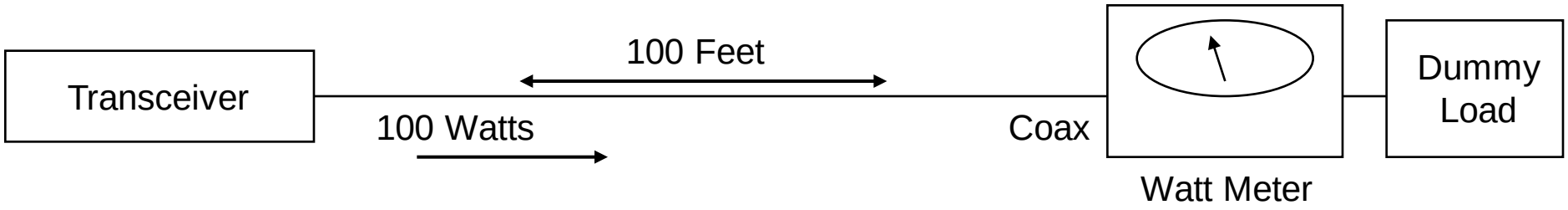
7C07 - Power loss in the feedline is converted to heat in the feedline

- That means that the signal passing through the cable gets smaller in strength

- There are different types of coax that are designed to work better at higher frequencies

- Lets take a look (next chart)

Coax Loss vs. Frequency



Type	Coax Size	Loss at HF 100 MHz	Loss at UHF 400 MHz	Watts at HF 100 MHz	Watts at UHF 400 MHz
RG-58	Small	4.3 dB	9.4 dB	38	10
RG-213	Large	1.9 dB	4.1 dB	94	35
Hard line	Large, Rigid	0.5 dB	1.5 dB	99	75

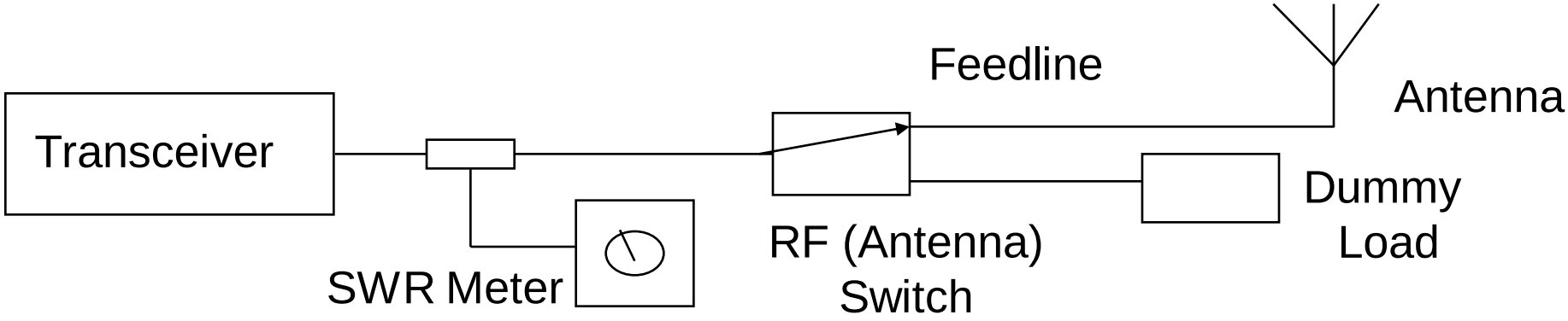
- The larger cables tend to have lower losses

9B10 • RG-213 coax cable has less loss at a given frequency than RG-58

9B11 • Air insulated hard line has the lowest loss at VHF and UHF

7C11 • Foam-dielectric has less loss per foot than solid-dielectric coaxial cable but must be kept dry

Standing Wave Ratio (SWR)



- The Standing Wave Ratio (SWR) is the ratio of the load impedance (the antenna) to the feed line impedance

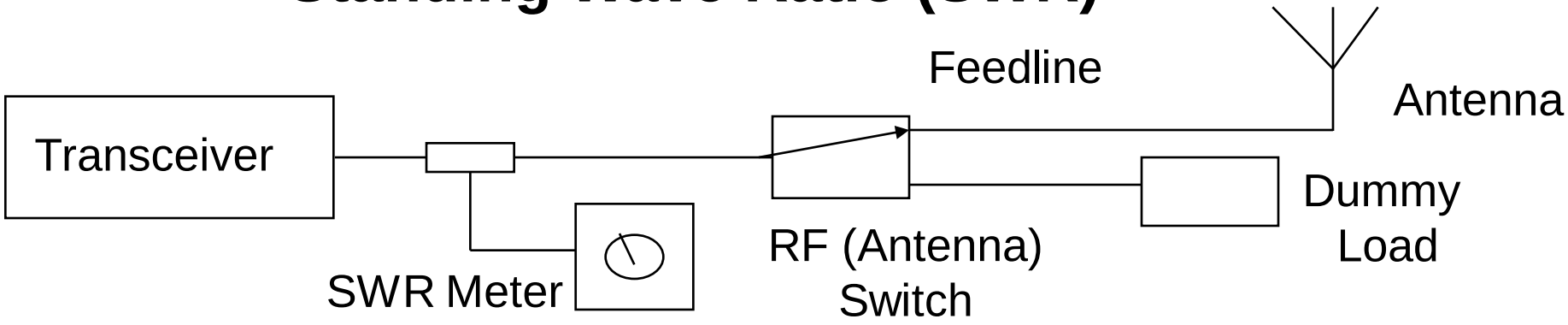
9B12 • SWR is a measure of how well a load is matched to the transmission line

4A02 • When selecting an SWR meter, consider the frequency and power level at which the measurements will be made

- An SWR meter is connected in series with the feed line and between the transmitter and antenna

- Many new HF transceivers have an SWR meter built in

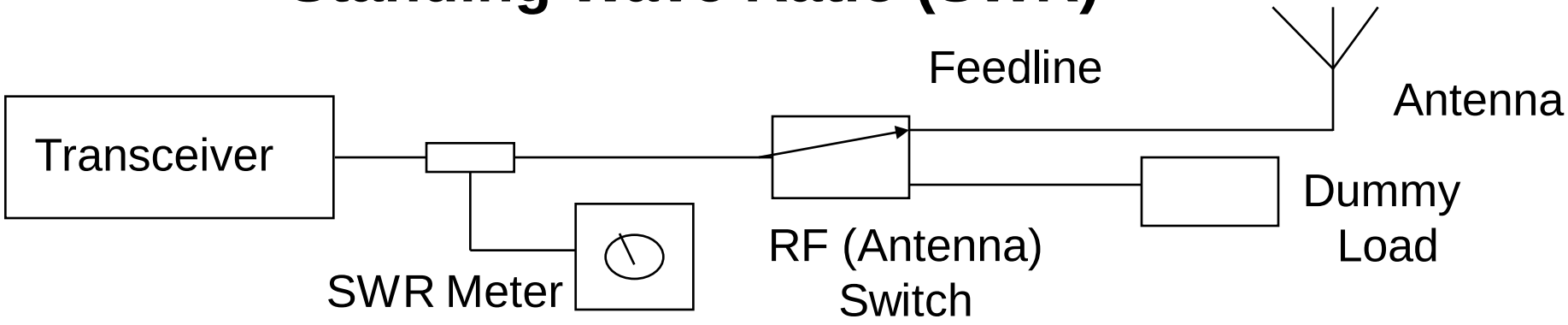
Standing Wave Ratio (SWR)



	SWR	COMMENT
7C04	1:1	An SWR of 1:1 indicates a perfect match between the antenna and the feed line
	1.5:1	Some energy gets reflected back to the transceiver
7C06	4:1	An SWR of 4:1 means an impedance mismatch. (Most of the RF energy is reflected back)

9B01 • The following connectors should be carefully taped for weather protection when used outdoors: PL259, BNC, and Type N

Standing Wave Ratio (SWR)



7C05 • Most solid-state transmitters reduce the output power as the SWR increases to protect the output amplifier transistors

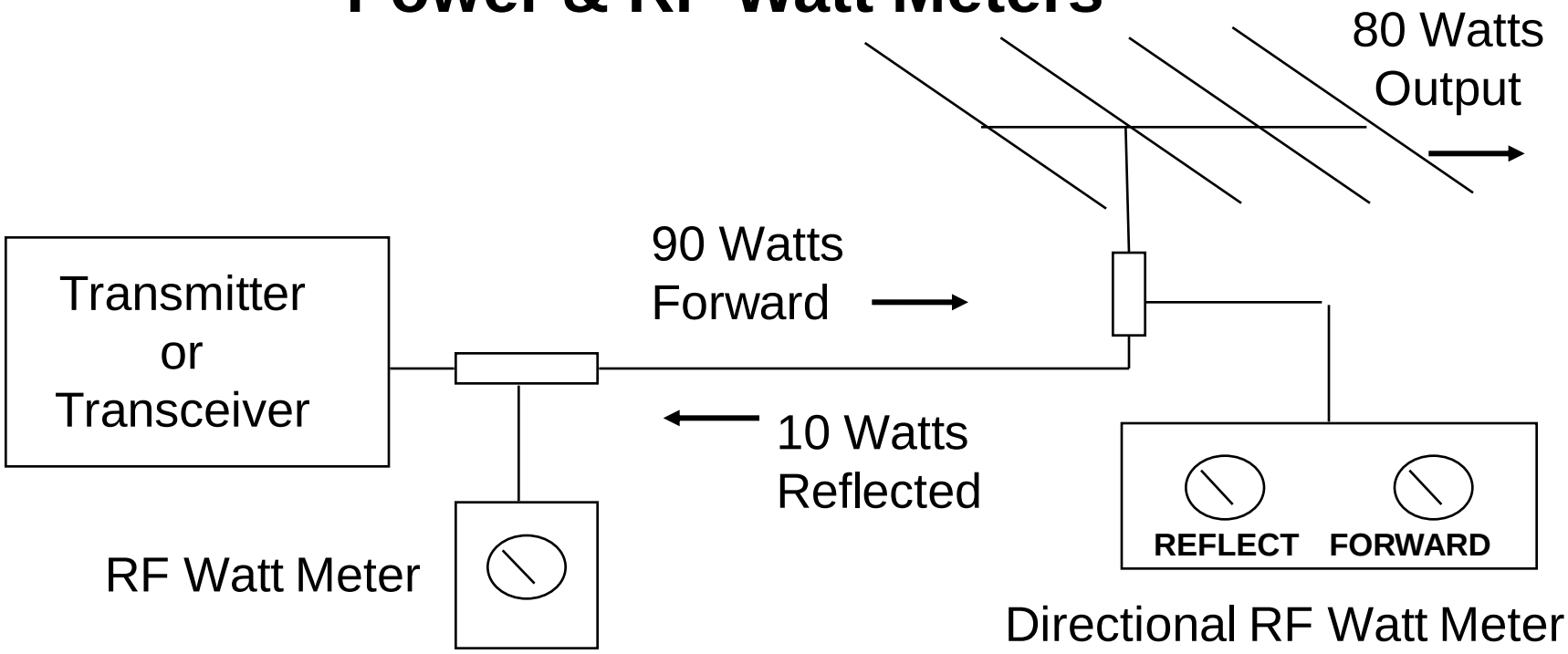
9B09 • Erratic changes in the SWR may be caused by a loose connector in the antenna or feedline (tighten it)

7C03 • A dummy load is a non-inductive resistor mounted on a heat sink (typically in a metal container)

7C01 • The primary purpose of a dummy load is to prevent transmitting signals over the air when making tests

• By not radiating over the air waves, other people can use the frequency and you do not have to give your call (explain)

Power & RF Watt Meters



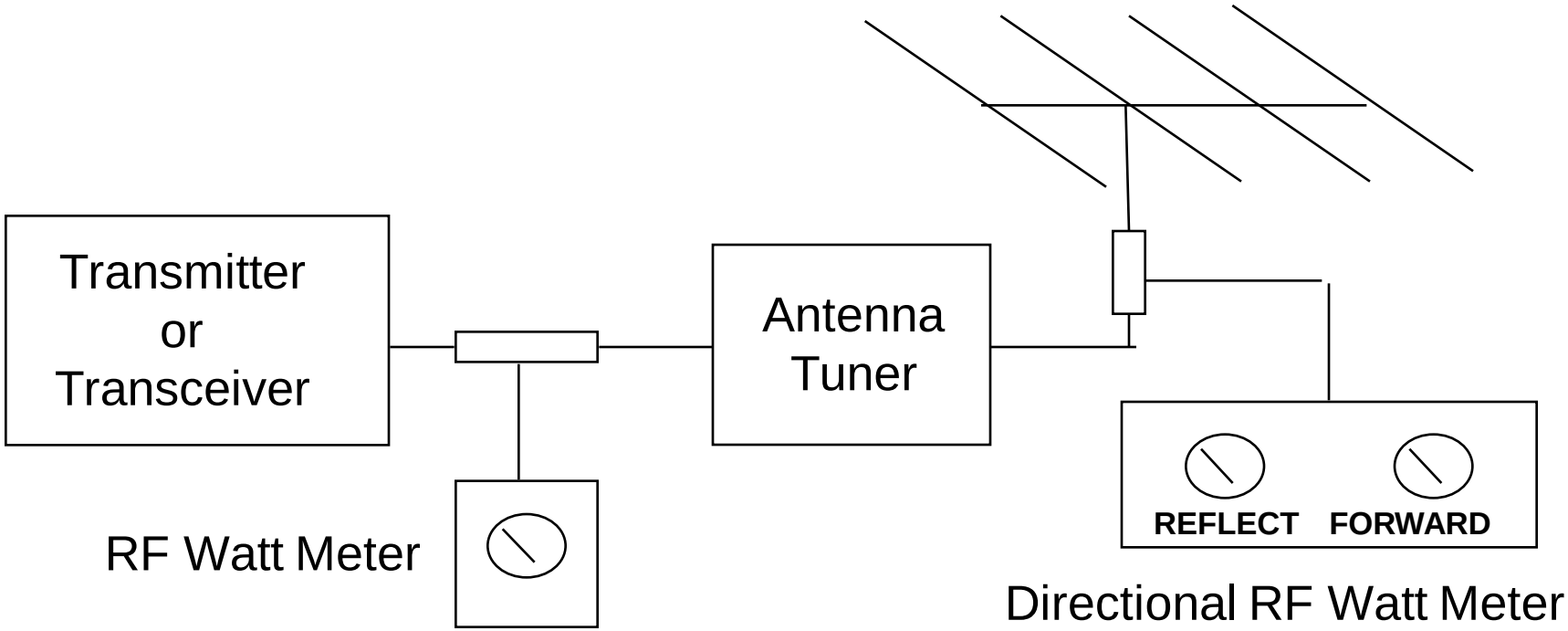
4A05 • An RF power meter should be installed in the feedline between the transmitter and antenna

• A regular RF watt meter measures only the transmitter output power

7C08 • A Directional RF wattmeter could be used to determine SWR

• With 90 watts Forward and 10 watts Reflected, only 80 watts get out the antenna (how about loss in the coax??)

SWR and Antenna Tuners

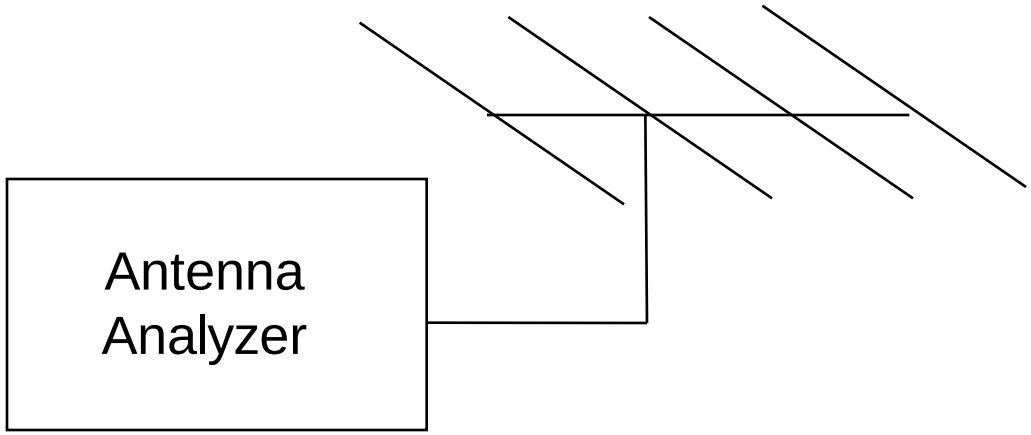


9B04

- A device which can match the antenna system impedance of the transceivers output impedance is called an antenna tuner

- This lets the transmitter think that it is looking at a perfect 50 ohm impedance and it will put out full power (explain)

Antenna Analyzer



7C02

- An antenna analyzer can be used to determine if an antenna is resonant at a desired operating frequency

- The antenna analyzer lets you establish the resonant frequency of an antenna without using your transceiver, or SWR meter, or a watt meter

Section 20

Safety First !

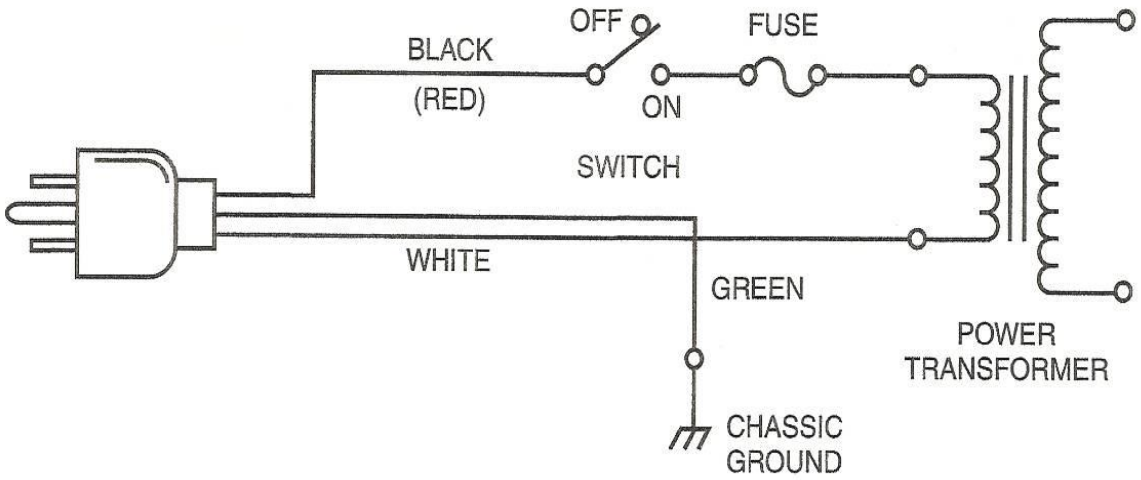
Electrical Safety Issues

0A04 • The purpose of the fuse is to remove power in case of an overload

0A03 • In the USA, the black wire in a 3 wire 120 volt cable is the hot line

0A06 • Guard against electrical shock at your (base) station:
- Use 3-wire cord and plugs for all AC powered equipment
- Connect all AC station equipment to a common ground
- Ensure all capacitors used for high-voltage DC are fully discharged before working inside equipment

0A08 • In a 120V AC power circuit, the fuse or circuit breaker should be installed in series with the hot conductor only



Electrical Health and Safety Issues

0A01 • A safety hazard of a 12-volt storage battery is that shorting the terminals can cause burns, fire, or an explosion

0A02 • Current flowing through the body can cause health hazards:
- It may cause injury by heating tissues
- It may disrupt the electrical functions of cells
- It may cause involuntary muscle contractions

0A05 • Replacing a 5-amp fuse with a 20-amp fuse could result in excessive current and could cause a fire

0A11 • If you turn off and disconnect a power supply, you might receive an electrical shock from a charge stored in filter capacitors

Safety Issues

- If the commercial power is out, one way to recharge a 12-volt lead-acid battery is to connect the battery to a car's battery and run the engine

- A hazard presented by a conventional 12-volt storage battery is that explosive gas can collect if not properly vented

0A10

- If a battery is charged or discharged too quickly, it could result in overheat or out-gassing

0A12

- When measuring high voltage with a voltmeter, ensure that the voltmeter and the leads are rated for use at the voltages to be measured

Tower Safety Precautions

0B04 • When planning to put up a tower, look for and stay clear of any overhead electrical wires

0B06 • The minimum safe distance from a power line when installing an antenna is enough so that if the antenna falls, no part of it comes closer than 10 feet to the power line

0B03 • It is never safe to climb a tower without a helper or observer

0B02 • When climbing a tower
- – Have sufficient training on safe tower climbing techniques
- – Use appropriate tie-off to the tower at all times
- – Always wear an approved climbing harness

0B07 • When climbing a crank-up tower, never climb it unless it is retracted, or mechanical safety locking devices have been installed

Tower Safety Precautions

0B09 • Never attach an antenna to a utility pole since the antenna could come in contact with high-voltage power lines

0B05 • A safety wire through a turnbuckle used to tension guy lines will prevent loosening of the guy line from vibration

• Members of a tower work team should wear hard hats and safety glasses at all times when work is being done on the tower

Turnbuckle Safety Wire

0B08 •When grounding the tower, consider separate 8’ ground rods for each leg and bonded to the tower and to each other

0B11 • The actual grounding requirements for an Amateur Radio tower or antenna are the local electrical codes

Tower Safety Precautions

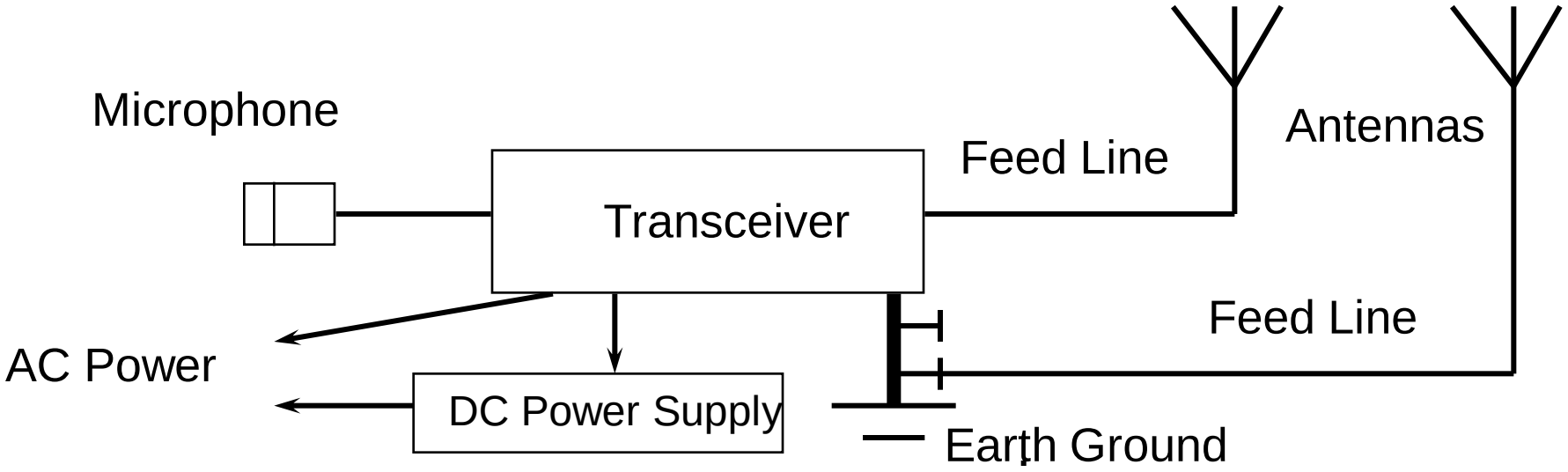
4A08 • A flat copper strap is a conductor that provides the lowest impedance to RF signals (explain)

0B01 • A good practice when installing ground wires on a tower for lightning protection is to ensure that connections are short and direct

0B10 • Grounding conductors used for lightning protection should have no sharp bends

0A09 • Bond all external ground rods or earth connections together with heavy wire or conductive strap

Lightning Protection and Electrical Shock

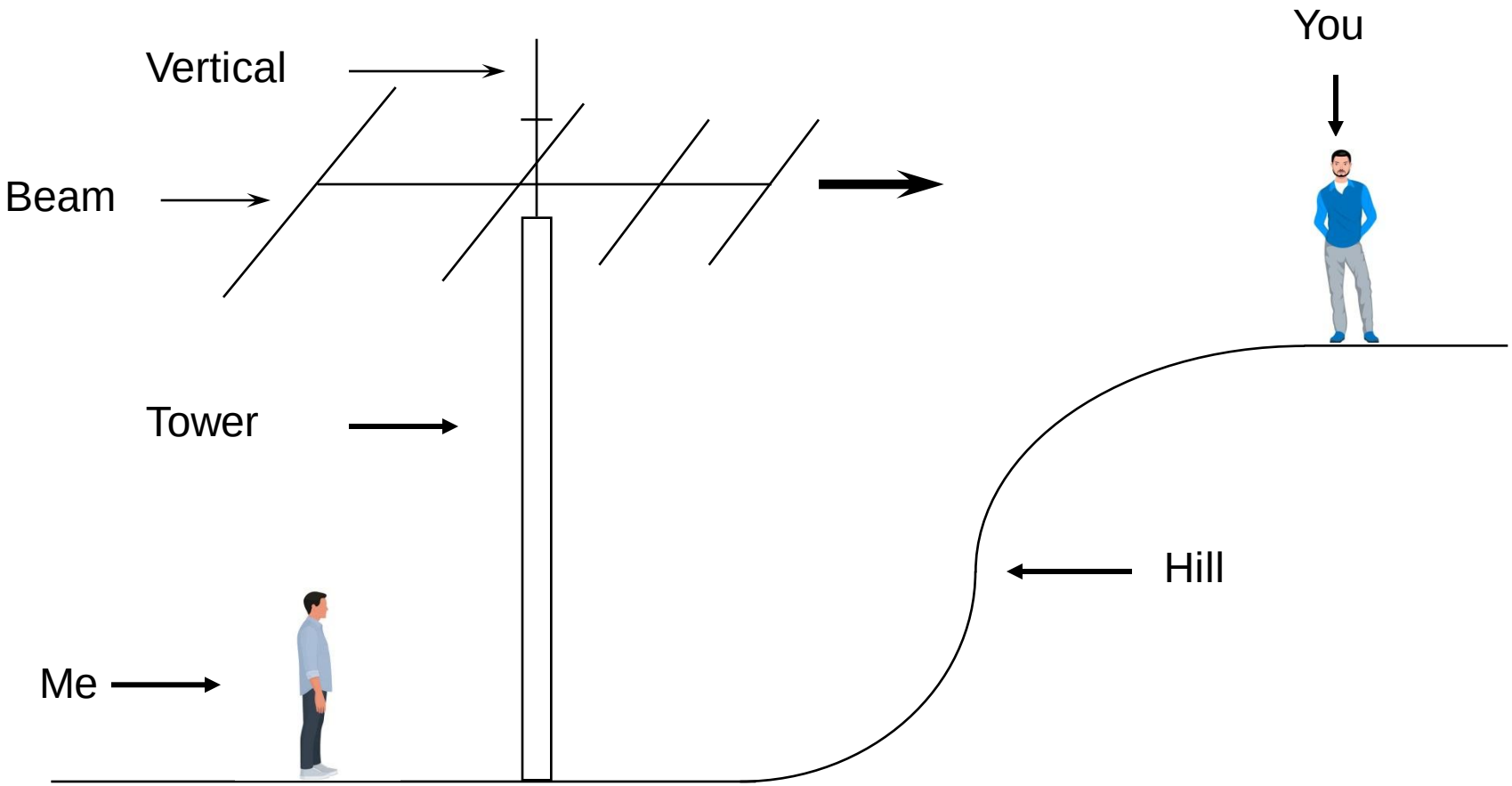


- Lightning Protection (base station radio):
  - Disconnect antennas (and I suggest grounding them)
  - Unplug all equipment from power outlets

0A07
- When installing devices for lightning protection in a coaxial feed line, mount all of the protectors on a grounded panel near where feed lines enter the building

- In a base station, it is always important to ground all pieces of equipment to the same (common) ground (Explain)

RF Safety - The Factors



- It's all about RF exposure: the amount of power, the frequency, the amount of time I transmit, the distance from the antenna to you and to me, the antenna height, the radiation pattern of the antenna

The Human Body and RF Radiation

- The SAR (Specific Absorption Rate) is the rate the body absorbs RF energy at particular frequencies

- The body absorbs more energy at some frequencies than at others

- The maximum exposure limit to RF energy is specified by the FCC and is called the MPE (Maximum Permissible Exposure)

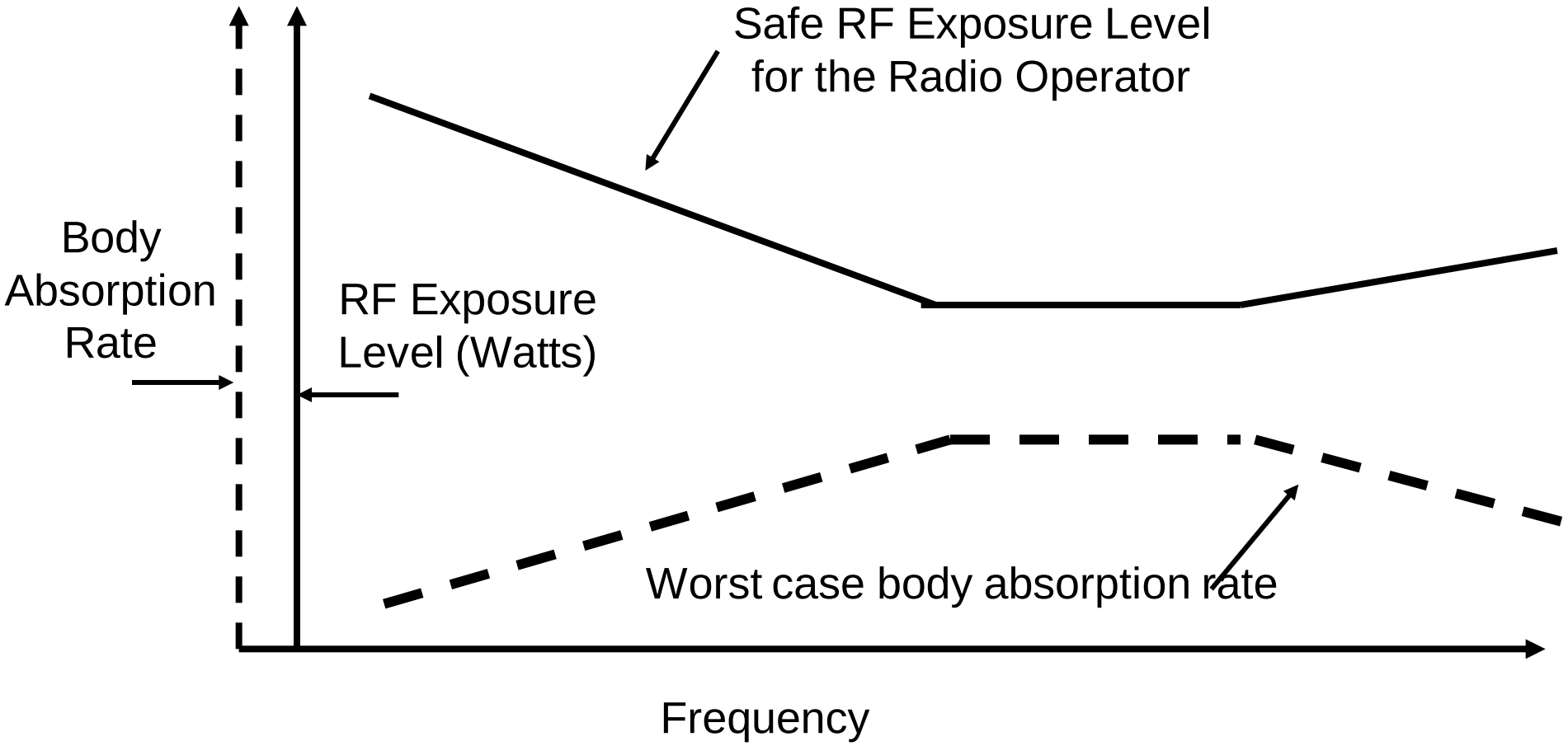
- The MPE limits are based on the whole-body SAR

- Since the body's SAR varies with frequency, the MPE limits vary with frequency

0C01 • Radiation from radio signals is non-ionizing radiation

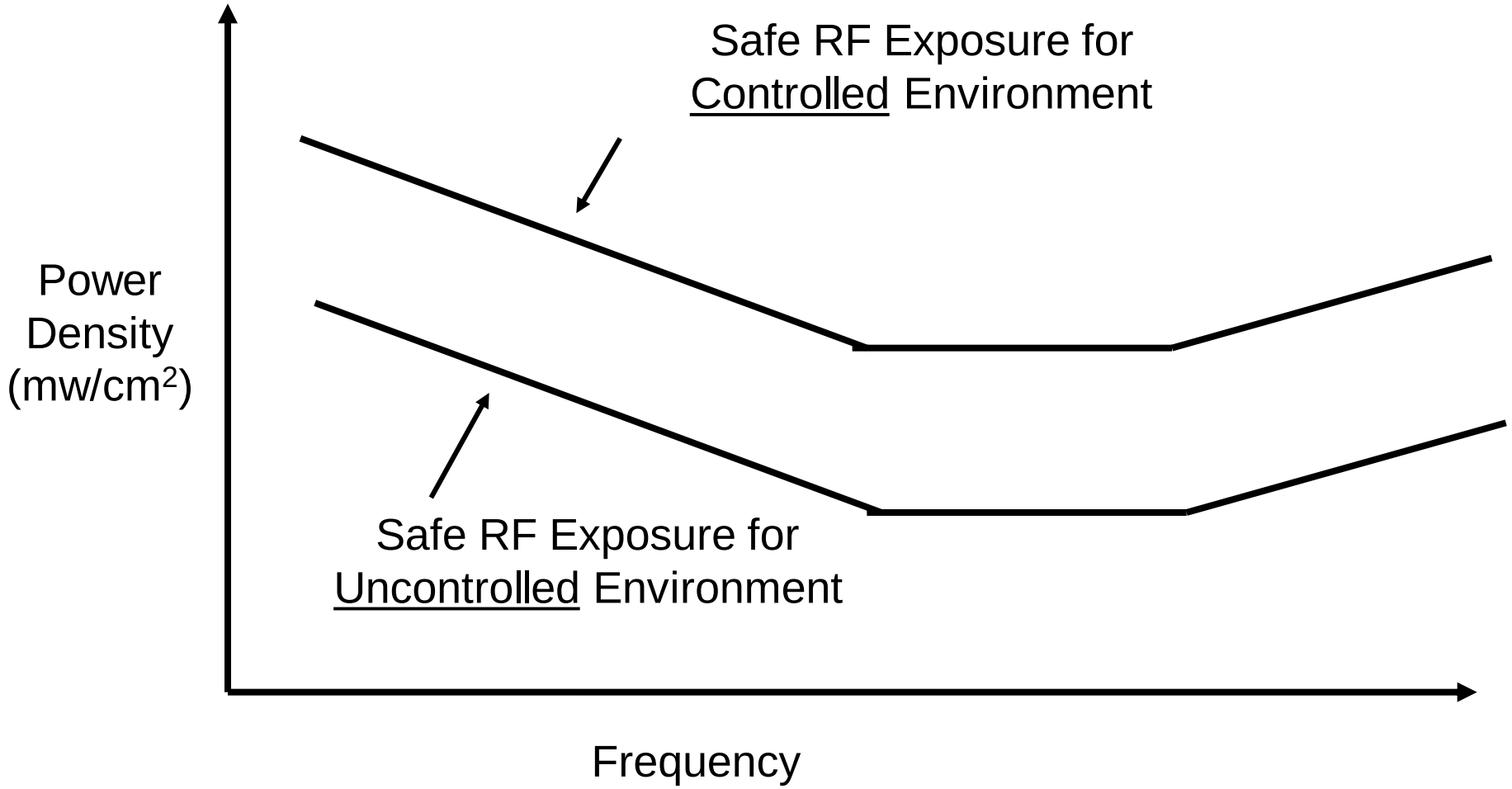
0C12 • RF radiation is different from ionizing radiation because it does not have sufficient energy to cause chemical changes in cells and damage DNA (deoxyribonucleic acid)

RF Safety - The Factors



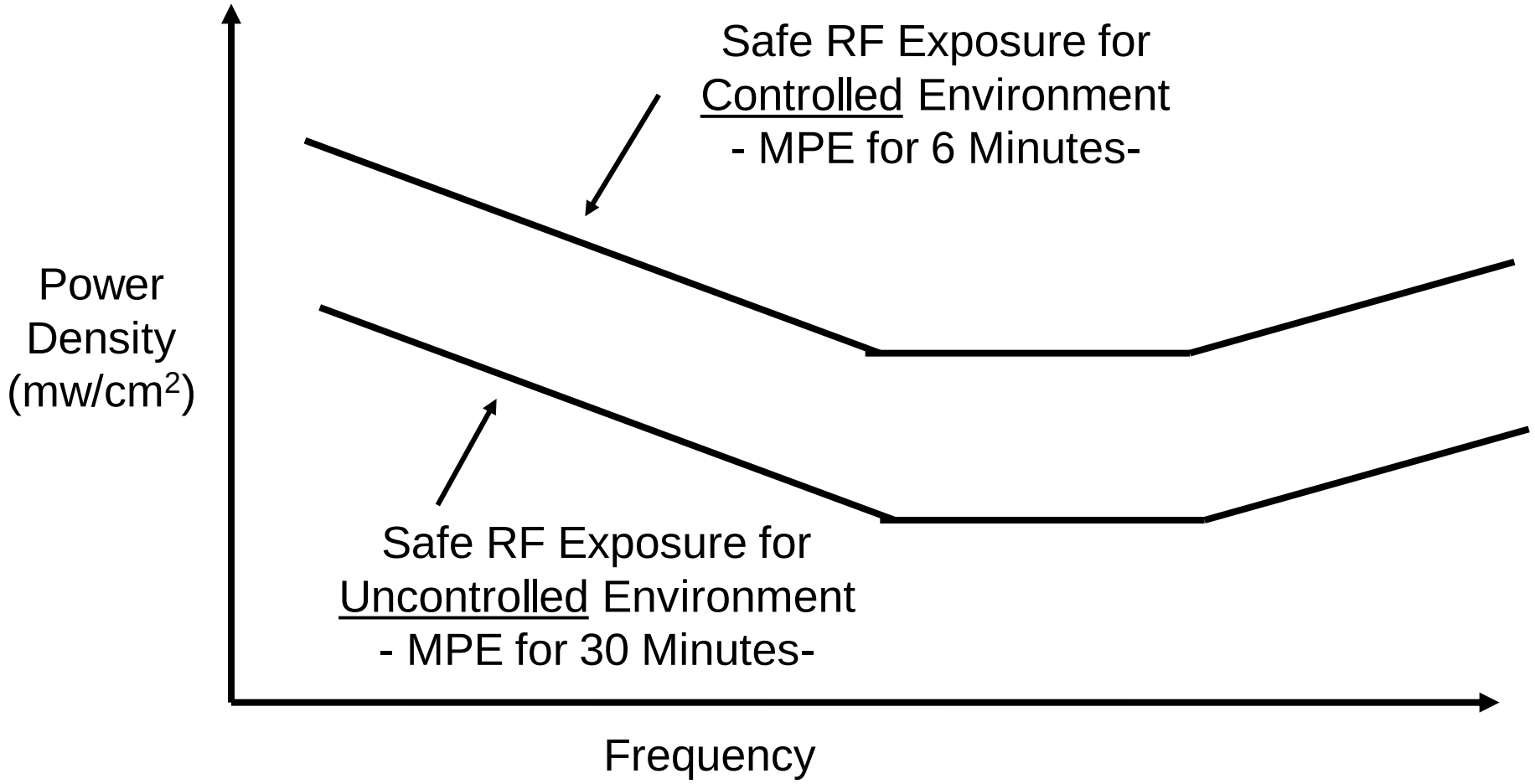
- At low absorption rates, I can tolerate more RF exposure
- At higher absorption rates, I can tolerate less RF exposure
- Therefore, at every frequency, there is a safe RF exposure level for the Radio operator

RF Safety - The Factors



- The Radio Operator is said to be in the Controlled environment
- All other folks are said to be in the Uncontrolled environment
- Is there a limit on how long I and/or we can be exposed at the specified limit?

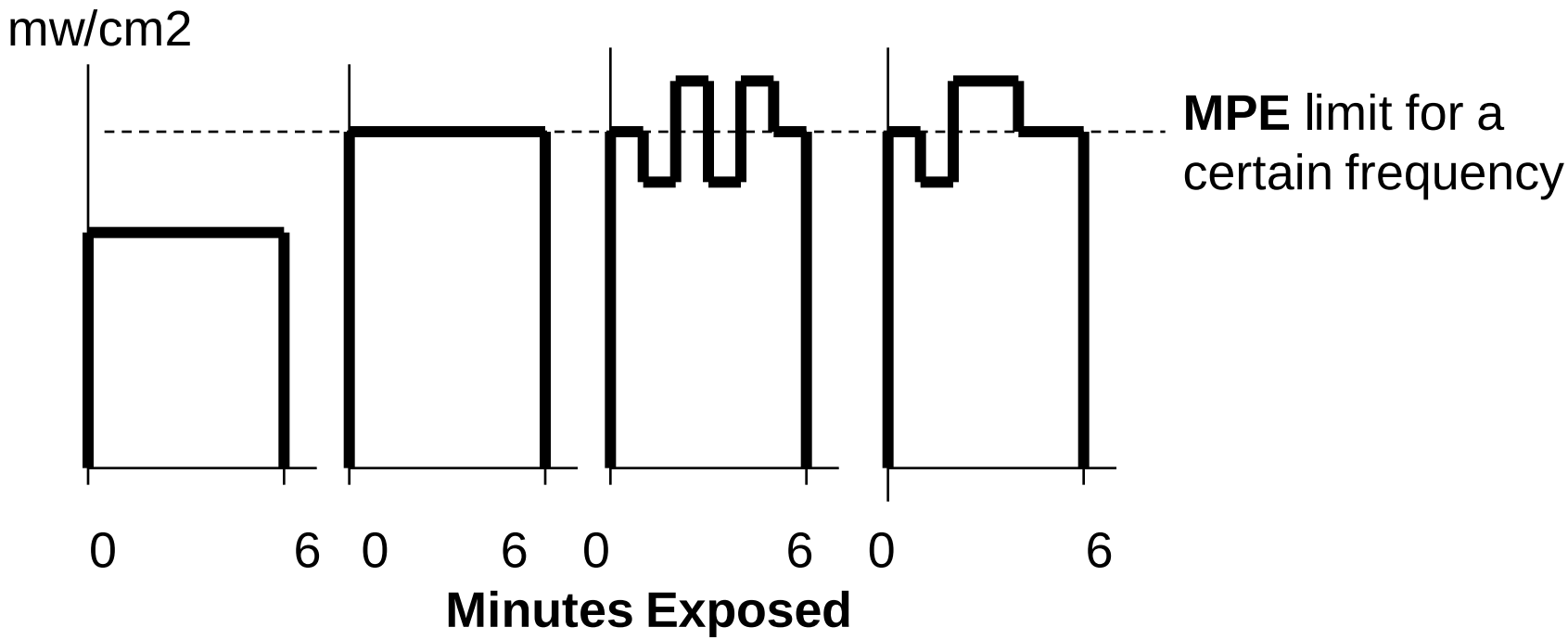
RF Safety - The Factors



- The Radio Operator can be exposed at the limit for 6 minutes
- All others can be exposed at their limit for 30 minutes
- This is called the Maximum Permissible Exposure, MPE

MPE Periods and Limits

- The MPE is specified in mw/cm^2 (milliwatts/centimeter squared)
- It's an average over 6 minutes for me and an average over 30 minutes for my neighbor (FCC regulation)
- It's the average that must not exceed the MPE, not the peak



The Human Body and RF Radiation

- The FCC sets MPE guidelines from 300 kHz to 100 GHz

0C05 • The exposure limits vary because the human body absorbs more RF energy (SAR) at some frequencies than at others

- The FCC regulations are most stringent from 30 MHz to 300 MHz

- NOTE - The highly used Technician bands have the most severe radiation issues and that has been removed from the FCC pool

0C02 • Therefore, 50 MHz would have a lower Maximum Permissible Exposure than 3.5 MHz, 440 MHz, 1,296 MHz (see next chart)

0C04 • The issues that affect the RF exposure of people near your transmitting antenna are:
  - The frequency and power level of your RF field
  - The distance from the antenna to a person
  - The radiation pattern of the antenna
- (they left out the time we are exposed)

Threshold Power for RF Environmental Evaluation

Freq. (MHz)	Wavelength Band	Power to Antenna Limit (watts)*	
1.80 - 2.00	160	500	Lowest absorption bands, Highest power
3.50 - 4.00	80/75	500	
7.00 - 7.30	40	500	
10.10 - 10.15	30	425	
14.00 - 14.35	20	225	
18.068 - 18.168	17	125	
21.00 - 21.45	15	100	
24.89 - 24.99	12	75	
28.00 - 29.70	10	50	Highest absorption bands, Lowest power
50 - 54	6	50	
144 - 148	2	50	
220 - 225	1.25	50	
420 - 450	70 cm	70	
902 - 928	35 cm	150	
1,240 - 1,300	23 cm	200	
2,300 - 2,310	13 cm	250	

***** You can't exceed these power limits until you perform an RF evaluation

- If your evaluation shows that you exceed these limits, take action to prevent human exposure to the excessive RF fields (next charts)

FCC Compliance Issues

- The station licensee is responsible to ensure RF compliance

0C06
- The following are acceptable methods to determine whether your station complies with FCC RF exposure regulations:
  - By calculation based on FCC OET Bulletin No. 65
  - By calculation based on computer modeling
  - By measurement of the field strength using calibrated equipment

0C11
- Duty cycle is the percentage of time a transmitter is transmitting

0C10
- Duty cycle is one of the factors used to determine safe RF radiation exposure levels because it affects the average exposure to radiation

0C09
- You can make sure that your station stays in compliance with RF safety regulations by re-evaluating the station whenever an item in the transmitter or antenna system is changed

FCC Compliance Issues

- If you have created an RF radiation exposure limit record of your station:
  - You **DO NOT** need to submit it to the FCC
  - You need to retain it in case questioned by the FCC

- Typically, many VHF/UHF mobile transceivers and HTs will be excluded from routine evaluation for two reasons:
  - Less than 50 watts
  - Not a fixed installation with fixed distances to neighbors

Reducing the Effects of RF Radiation Exposure

- Ways to reduce or prevent RF exposure to yourself or neighbors:
  - Use frequencies that have safe exposure
  - Use lower power

0C08

  - Relocate the antenna

- Locate antennas so people can't touch them.

0C07

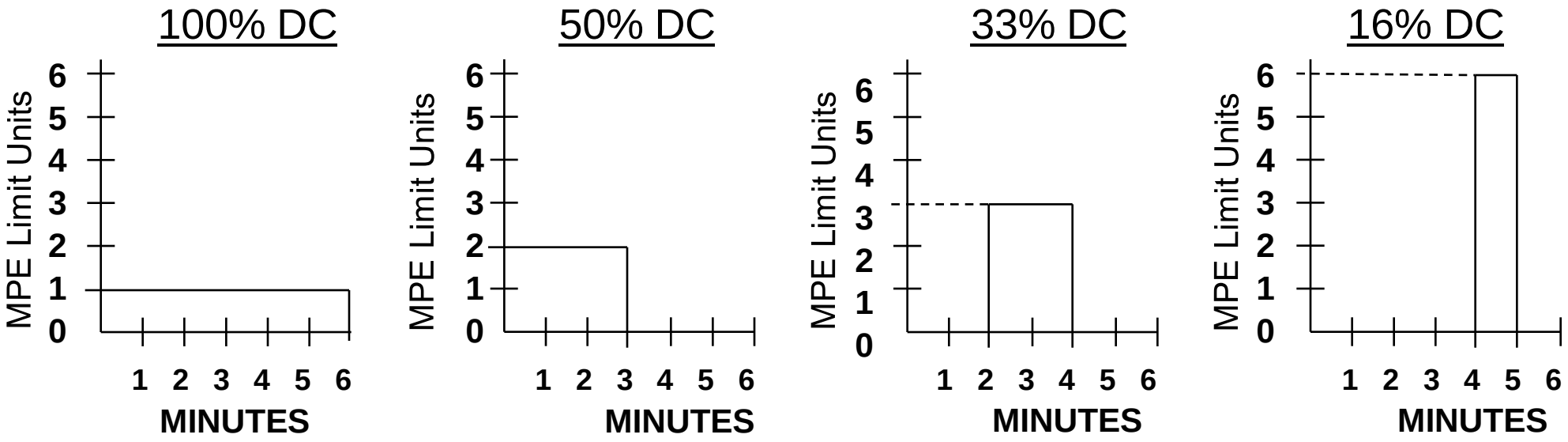
- Touching an antenna during a transmission can result in an RF burn

- An exception could be HT rubber duck antenna, why?

- The closest a person can normally get to your antenna should be no closer than the "compliance" distance at 100% duty cycle

- What is "Duty Cycle"??? See next chart

Duty Cycle



- Assume that the Controlled MPE is 1 mw/cm^2 for 6 minutes, i.e., 100% DC

- 50% duty cycle - The power is on for 3 minutes and absent for 3 minutes and I can be exposed to 2 times as much power

0C03 • When the duty cycle changes from 100 percent to 50 percent, the allowable power density for RF safety increased by a factor of 2

0C11 • Duty cycle is the percentage of time that the transmitter is transmitting (specified time period i.e., 6 or 30 minutes)

Duty Cycle

0C10 • Duty cycle is one of the factors used to determine safe RF radiation exposure levels because it takes into affect the average exposure of people to radiation

0C13 • The station licensee is responsible for ensuring that no person is exposed to RF energy above the FCC exposure limits