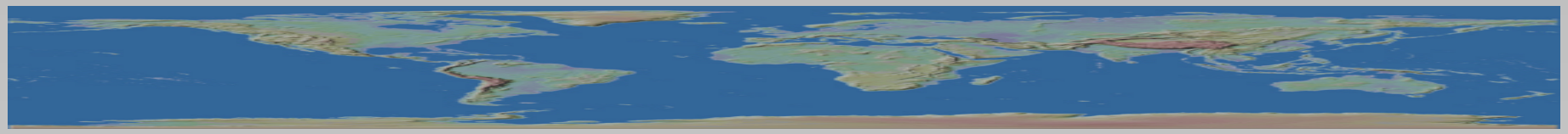
Technician Licensing Class

Lesson 5

presented by the

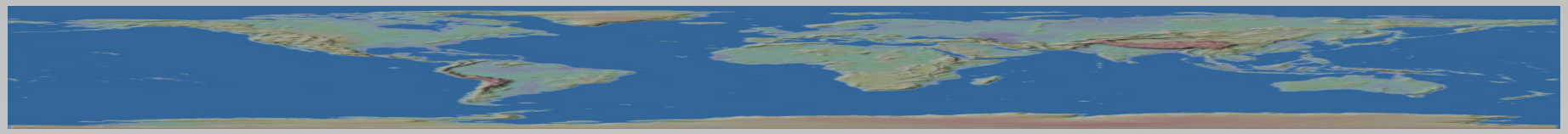
Arlington Radio Public Service Club

Arlington County, Virginia



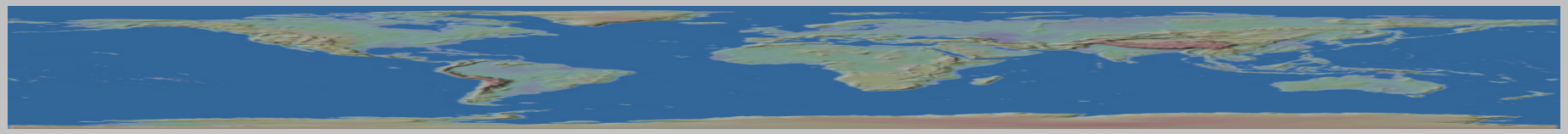
Quiz

Sub element T8



Special Operations

Sub element T9



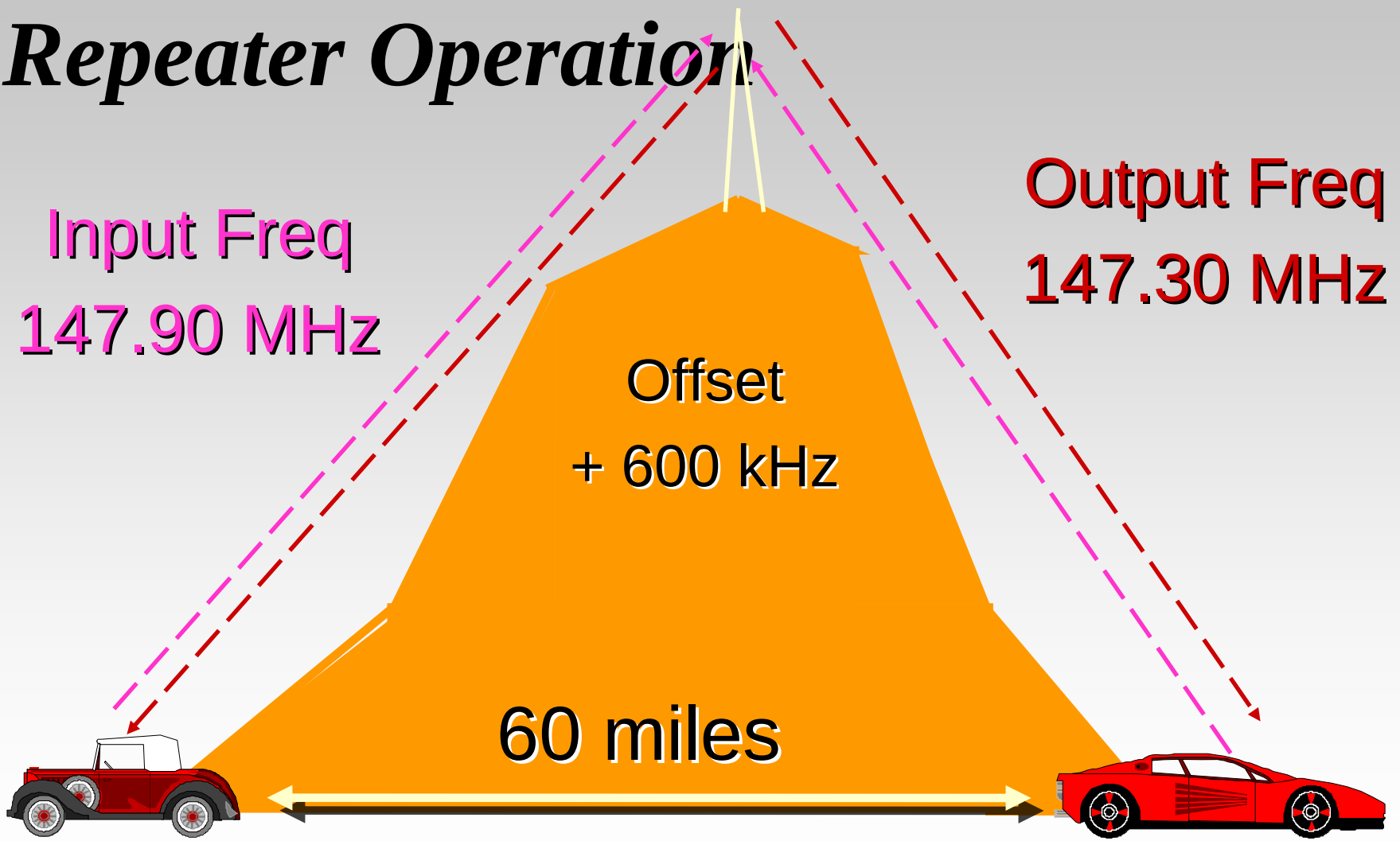
Repeaters

- A repeater is an amateur station that simultaneously receives a signal on one frequency and retransmits it on a different frequency.
- Why? A powerful repeater transmitter located at altitude greatly increases the usable range of mobile and hand-held stations.
- A repeater that retransmits the signal on a different band is called a “crossband repeater”.

Repeaters

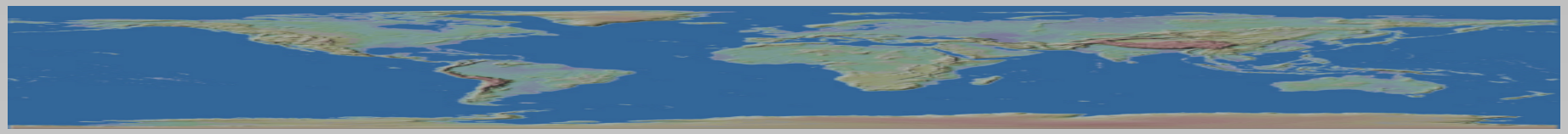
- In order to use a repeater, you must first know the repeater's input (or output) frequency and offset.
- The offset is the difference in the repeater's receive and transmit frequencies.
- On 2 meters the usual offset is 600 KHz and on 70 cm it is 5.0 MHz.
- Most modern radios will set the offset for you automatically.

Repeater Operation



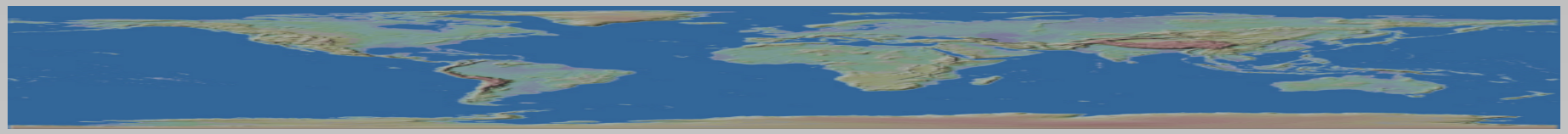
Repeater Access

- Continuous Tone Coded Squelch System (CTCSS) tones are sub-audible tones added to an FM carrier which may cause a receiver to accept the signal.
- Some repeater systems require CTCSS tones to access.
- If someone tells you a “tone” is needed to access a repeater then you must use a CTCSS tone to operate it.



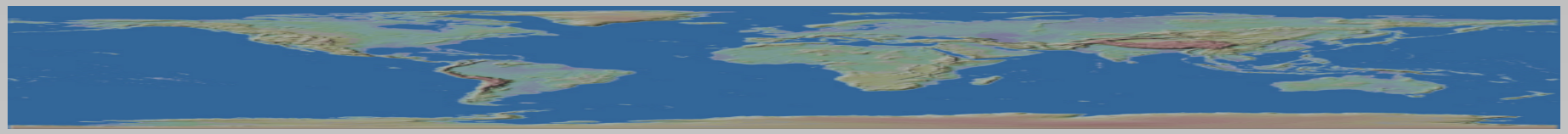
Repeater Operation

- A repeater has a time-out timer to limit the amount of time the repeater can transmit continuously.
- At the end of each transmission through a repeater, you will typically hear a “courtesy tone” (a short beep, or series of beeps).
- When you hear the courtesy tone the time-out timer has been reset and you can begin your transmission.
- A repeater may identify itself with automatic Morse code tones or a voice announcement.



Using a Repeater

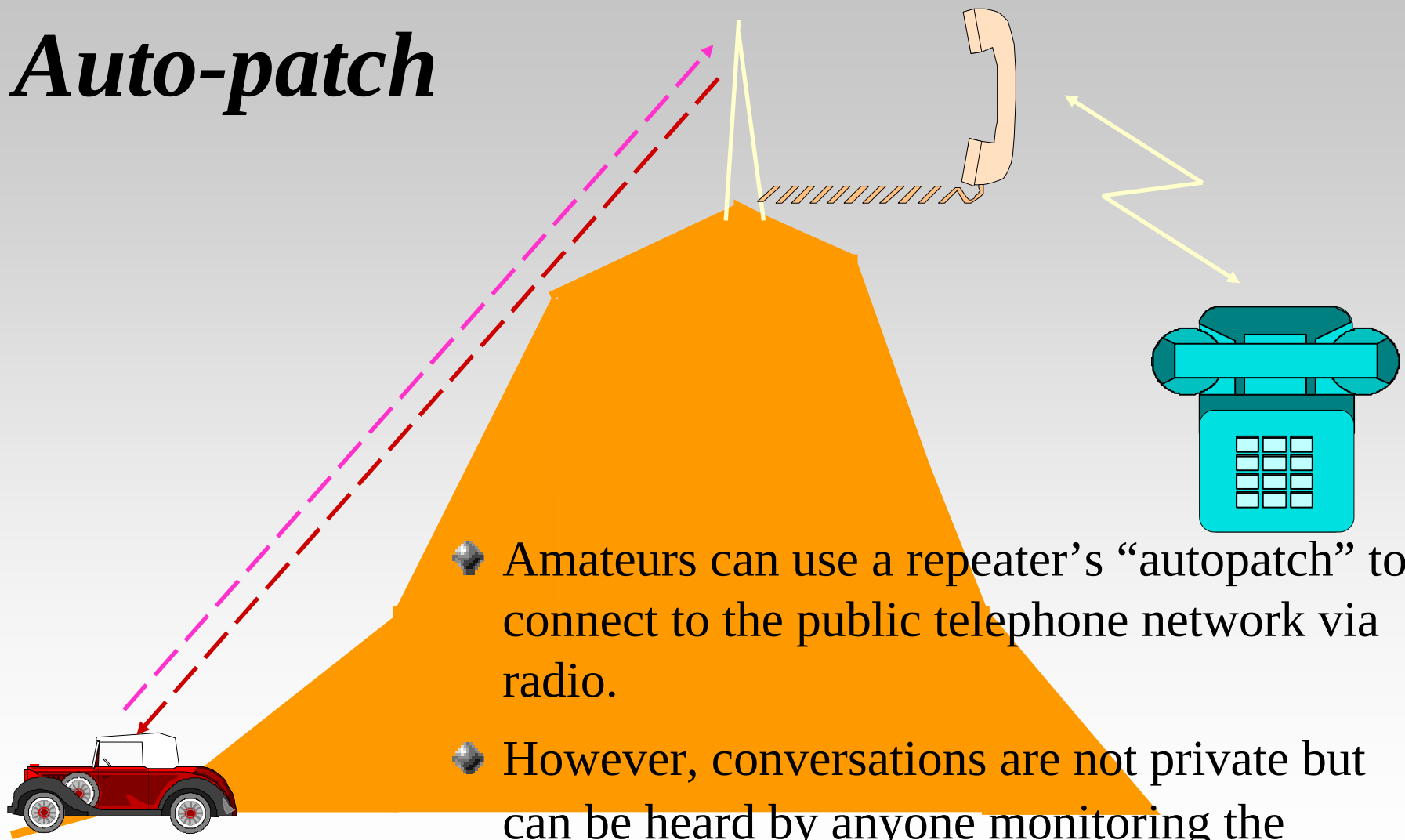
- To determine if a repeater is already being used ask if the frequency is in use, then give your call sign. (In reality, no one does this.)
- To break into a conversation simply give your call sign during a break between transmissions.
- Pause briefly between transmissions to listen for anyone wanting to break in.
- Typically, third-party communications nets are discouraged during commuting hours.



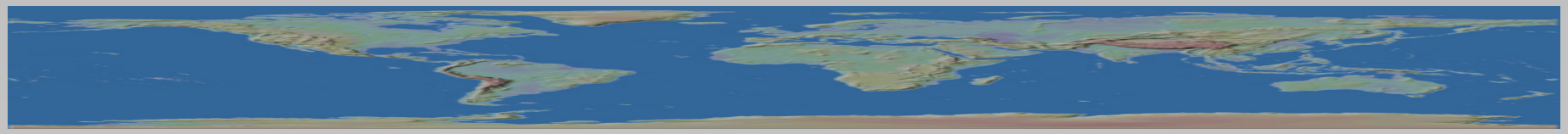
Using a Repeater

- Keep transmissions brief in case someone with an emergency needs to use the repeater.
- Support the repeater owner with a donation or club membership.
- If you would like to use a “closed” repeater system contact the control operator and ask to join.

Auto-patch

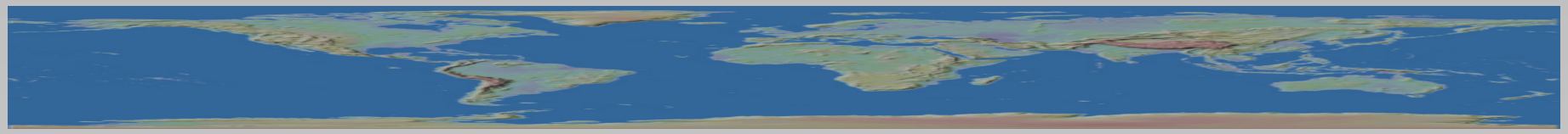


- Amateurs can use a repeater's "autopatch" to connect to the public telephone network via radio.
- However, conversations are not private but can be heard by anyone monitoring the repeater.



Repeater Coordination

- When a new repeater is planned to be installed in an area the frequency of the new repeater must be assigned a frequency by a “frequency coordinator”.
- When two coordinated repeaters interfere with one another it is up to both repeater licensees to resolve the interference.

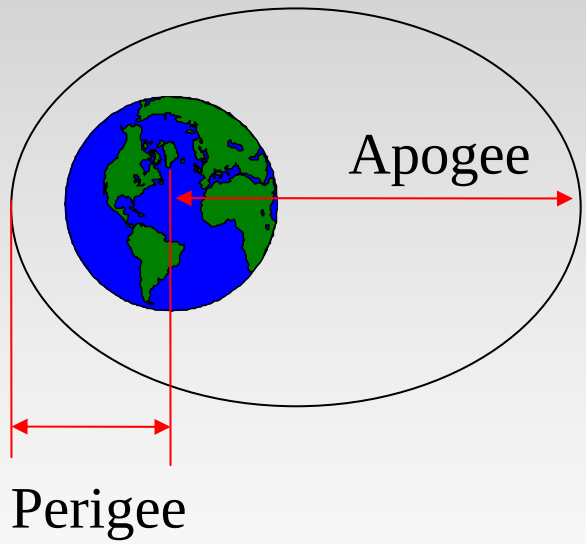


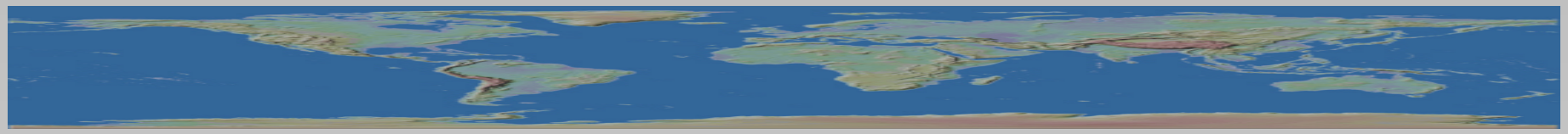
Simplex Operation

- Simplex operation is simply transmitting & receiving on the same frequency.
- Simplex operation is encouraged when two stations are close enough to communicate without using a repeater.
- You can check if simplex operation is possible by listening on the repeater's input frequency.

Satellites

- Keplerian elements are a set of mathematical parameters used to calculate a satellite's position.
- A satellite's perigee is it's closest approach to the Earth's center.
- A satellite's apogee is it's farthest distance from the Earth's center.





Satellites

- Most satellites use VHF & UHF frequencies because they pass easily through the ionsphere.
- When communicating through a satellite the receiving frequency must be adjusted up or down due to the Doppler effect.
- Any class of license may be the control operator of a station communicating through a satellite.
- The International Space Station is typically in range to communicate only 4 to 6 minutes per pass.

EME (Moon-bounce)

- Earth-Moon-Earth communication is accomplished by bouncing VHF or UHF signals off the moon.
- CW is a good mode for EME.
- High gain antennas are needed for EME.
- A ground-plane antenna would NOT be a good EME antenna.

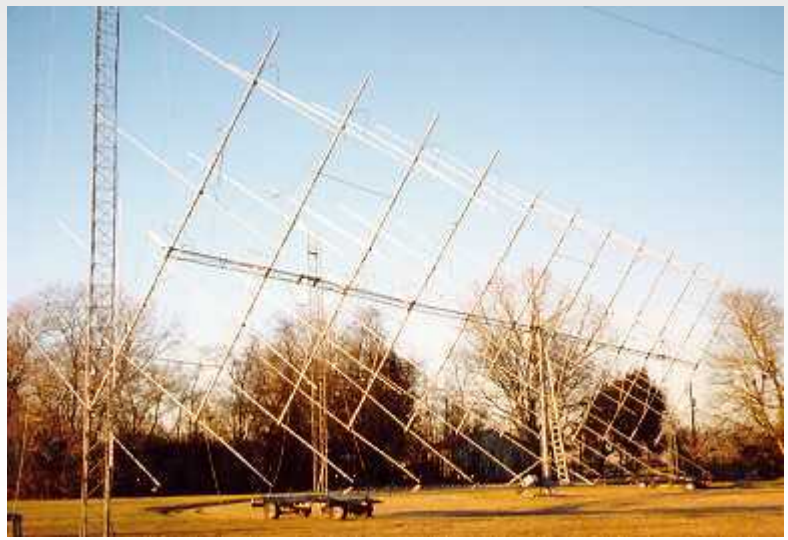


Image - ATV

- Amateur TV (ATV) is just like regular TV and is typically transmitted on the UHF & microwave bands.
- A cable ready TV can be used to monitor ATV on the 70 cm band.

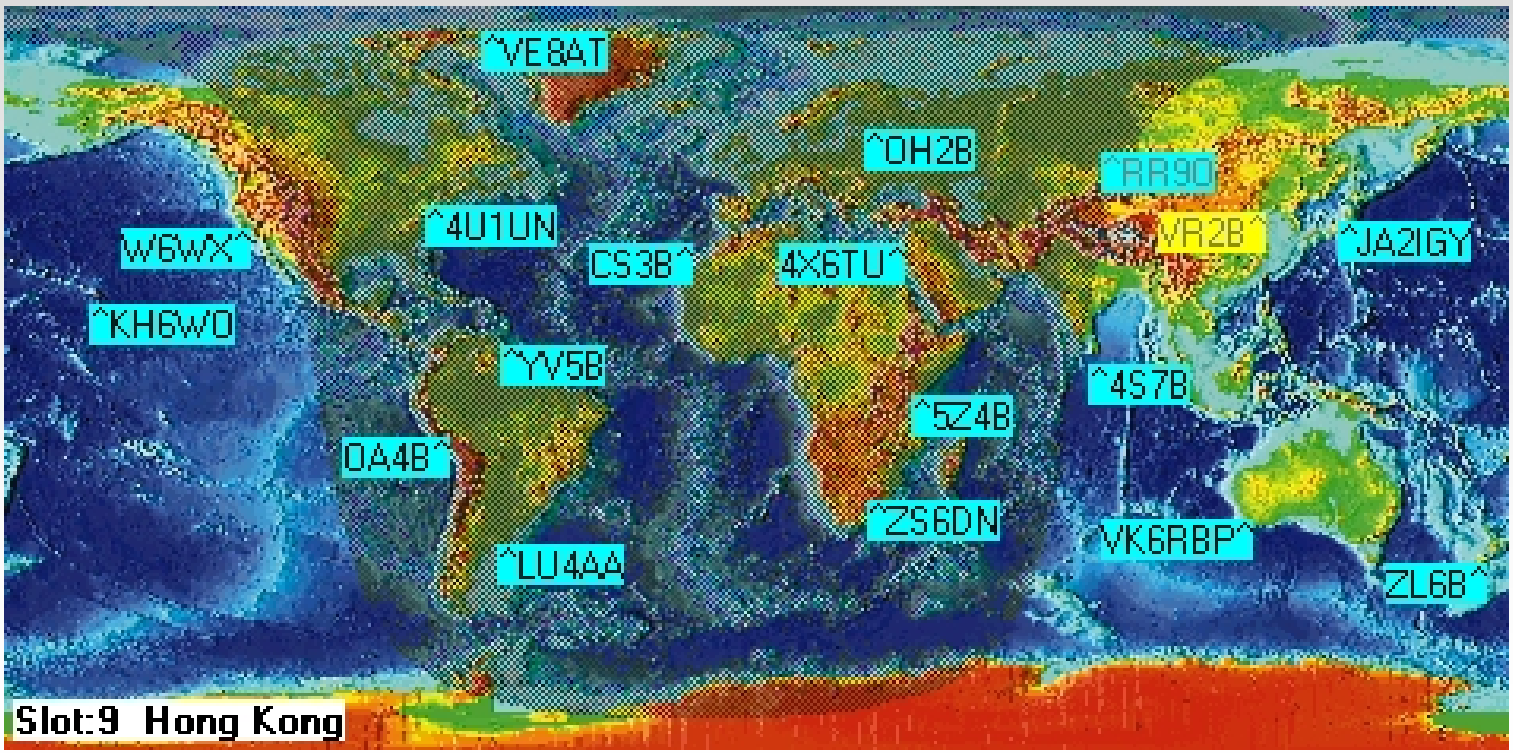
Image - SSTV

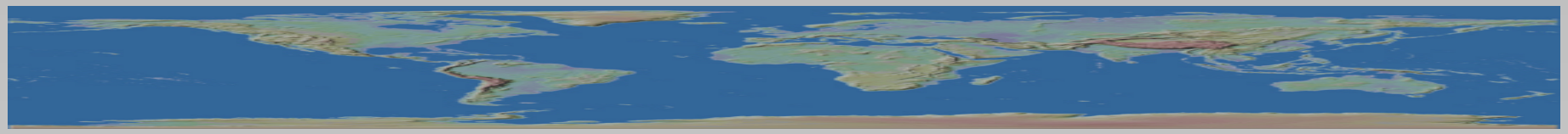
- Slow Scan TV (SSTV) is typically used on 20m.
- SSTV could be transmitted through a 2 meter repeater if the repeater control operator authorizes it.

A sample SSTV transmission.

Beacons

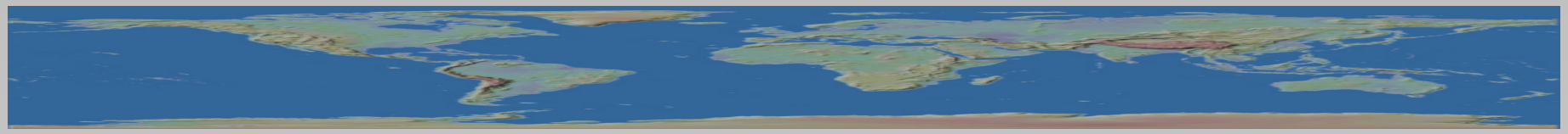
A beacon is a station that transmits for the purpose of propagation observations.





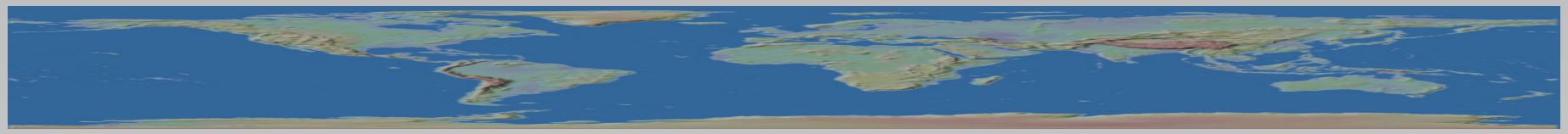
More About Beacons

- Automatically controlled beacon stations are allowed in certain band segments.
- The maximum power of a beacon must not exceed 100 watts.
- Beacons are allowed one-way transmissions.



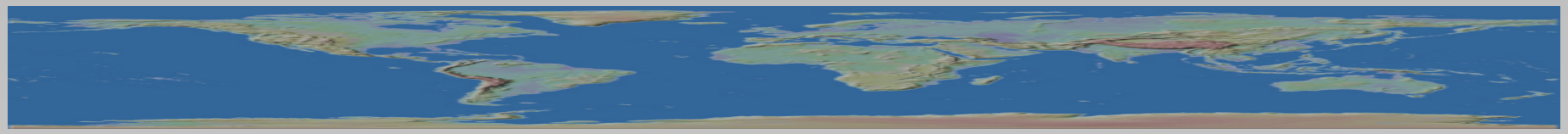
Tele-command

- Tele-command is a one-way transmission to control a device at a distance.
- For Tele-command to be legal:
  - The station must have a wire-line or radio control link
  - A copy of the station license must be posted
  - The station must be protected so unauthorized transmissions cannot be made
- As a minimum, a model aircraft control transmitter must have the station call sign and licensee's name and address.



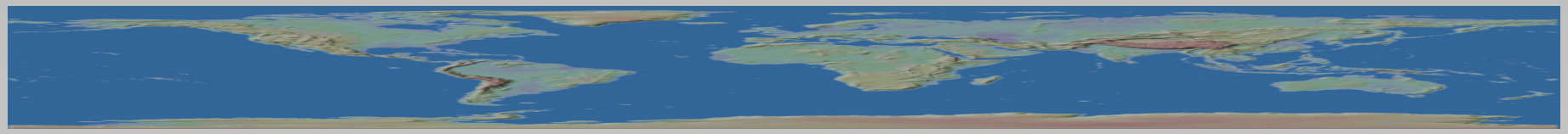
Electrical, Antenna Structure, & RF Safety Practices

Sub element T0



Safety

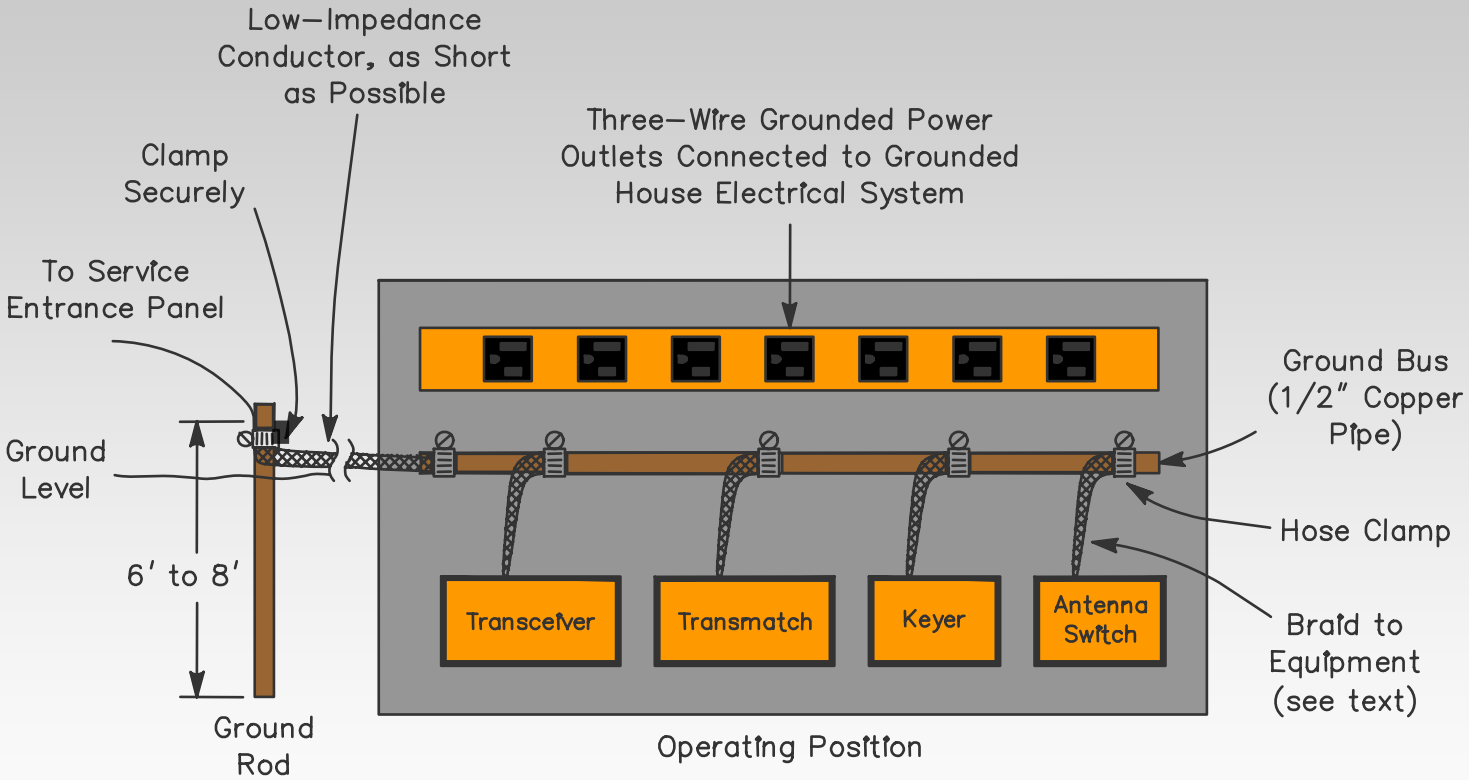
- Amateur Radio is a relatively safe hobby.
- There are only a few ways to get hurt or killed being a ham radio operator:
  1. Electrocute yourself.
  2. Fall off a tower, or the inverse, have someone/something fall on you from a tower.
  3. Slowly cook yourself with RF energy.



It Just Kills Me...

- People have been killed by as little as 30 Volts.
- As little as 1/10 of an amp can be fatal.
- The heart can be fatally affected by a very small amount of electric current.
- The path electric current takes across the body is important. Therefore, always keep one hand in your pocket when working near dangerous voltages.

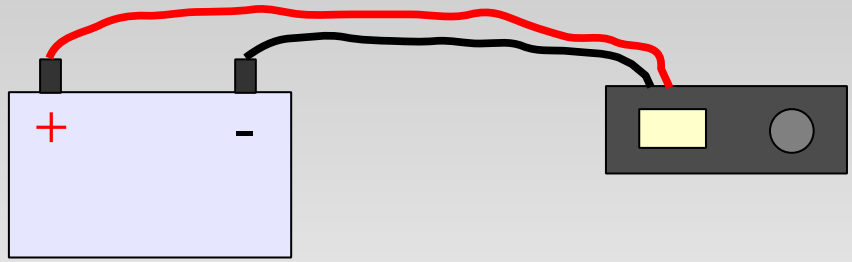
Ground Everything



For best protection from electrical shock all equipment should be connected to a common ground.

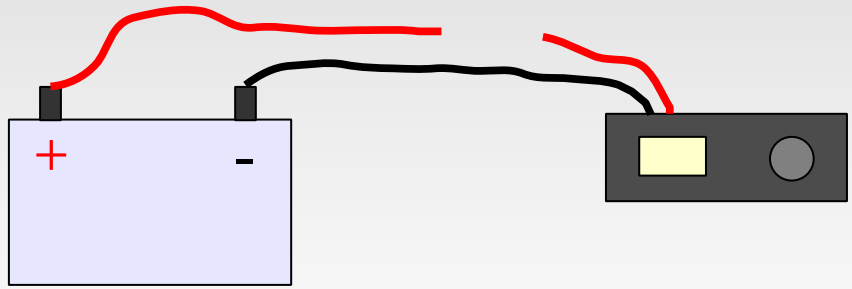
Open & Short Circuits

Normal Circuit



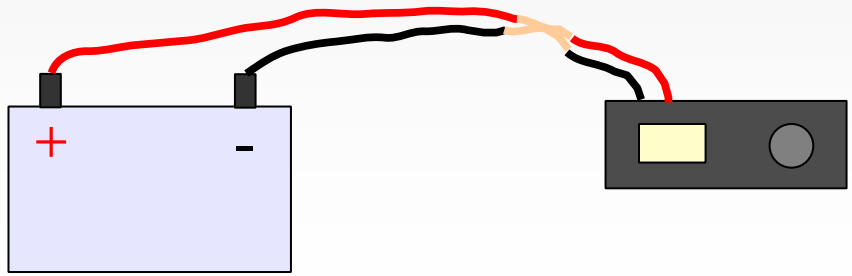
Open Circuit

Draws no current



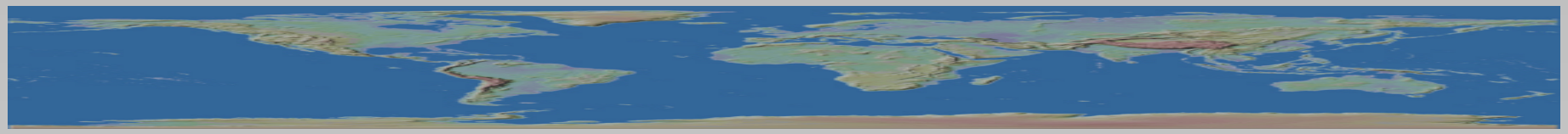
Short Circuit

Draws high current



The Fuse

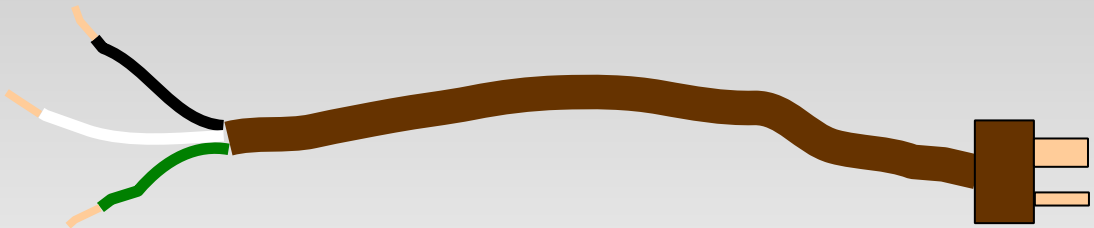
- A fuse or circuit breaker should always be added in series with home built equipment that is powered from 110 volt AC lines.
- In a 12 volt DC system fuses should be located at the voltage source.
- When a fuse blows an open circuit is created.
- Never replace a blown fuse with a higher amperage rated fuse.



High Voltage Safety

- The power supply for a transceiver or power amplifier should be controlled by a safety interlock switch.
- Make sure everyone knows where the main power switch is located in case of an emergency.
- Never touch the ungrounded side of a capacitor as they can store a charge for a long time.

Three Wire Plug

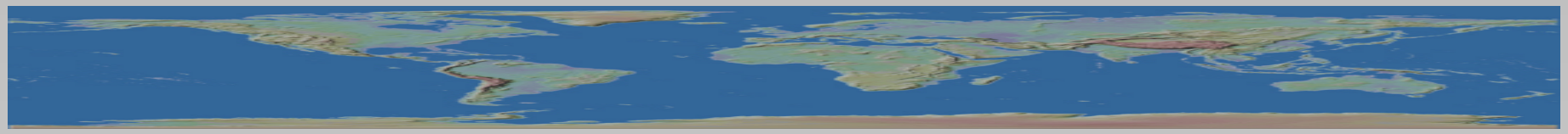


In a three wire AC electrical line:

Black is HOT

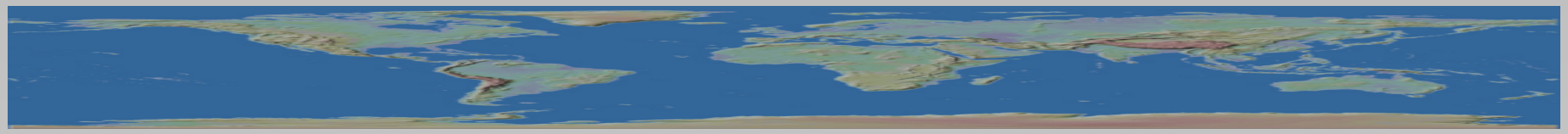
White is NEUTRAL

Green is Chassis Ground



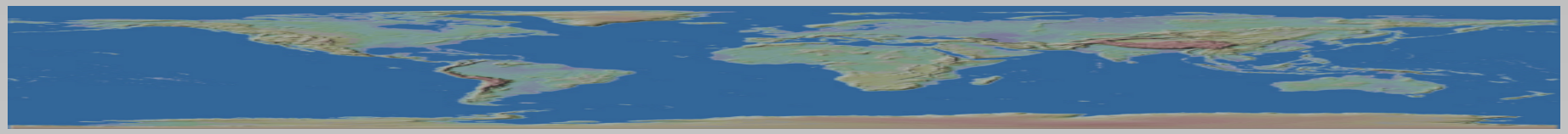
Tower Safety

- Before climbing and working on a tower:
  - Tell someone you will be up on the tower
  - Inspect the tower for cracks & loose bolts and obstructions
  - Inspect the guy wires & guy anchors
  - Take a variety of tools to minimize trips



More Tower Safety

- Don’t climb towers without a safety belt and safety glasses.
  - If using a leather climbing belt keep in mind the leather could be old & brittle and could break unexpectedly
- Don’t do tower work without a ground crew.
- If you’re working under the tower, wear a hard hat.

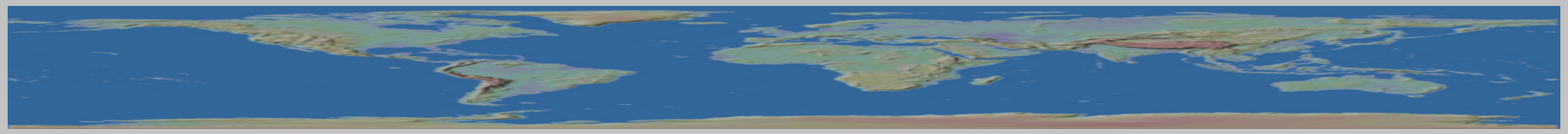


Antenna Safety

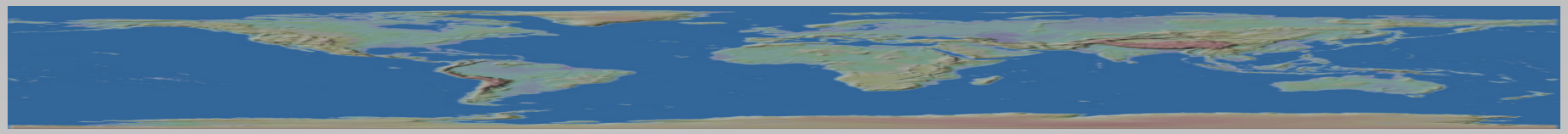
- Keep your antenna and feed-line from overhead power lines.
- When using a bow & arrow or slingshot to shoot an antenna support over a tree:
  - Ensure the bow & arrow or slingshot are in good condition
  - Ensure the flight path is clear in case the line breaks
  - Ensure the line is strong enough to handle the shock of the arrow or weight.

Lightning

- To protect antennas from lightning damage ground them when not in use.
- To protect station equipment from lightning disconnect all equipment from AC power lines and antennas.
- GET OFF THE AIR DURING SEVERE STORMS!!

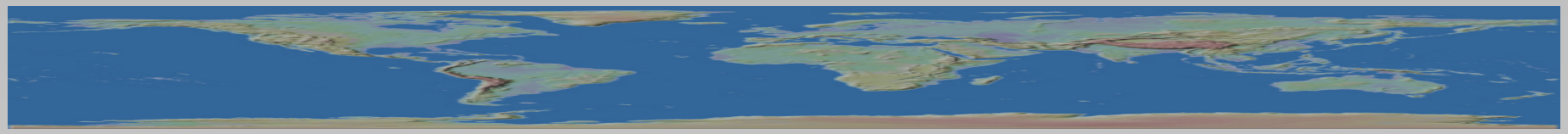


RF Exposure Safety



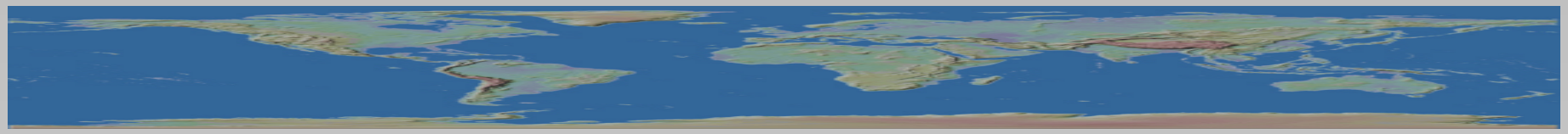
Two Types of Radiation

- Ionizing
  - Can knock electrons loose from their atoms forming positive & negative ions
  - Gamma rays, X-rays, and ultraviolet rays
- Non-ionizing
  - Radio frequency waves
  - Can cause heating of biological tissue
  - If sufficient energy is present, can cause burns



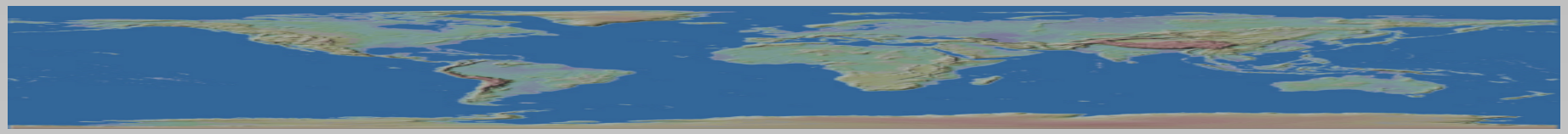
RF and the Human Body

- Specific Absorption Rate (SAR) is the rate RF energy is absorbed into the human body.
  - Maximum Permissible Exposure (MPE) limits are based on the whole body SAR.
- The human body's ability to absorb RF energy varies with frequency.
- Exposure of the human body to high levels of RF energy can cause heating of body tissue.
- Exposure of the eye to RF can expose the eye to more than the MPE limit and cause heating, which can result in the formation of cataracts.



FCC RF Exposure Regulations

- Can be found in FCC Part 1 and Office of Engineering and Technology (OET) Bulletin 65
- Established to ensure a safe operating environment for amateurs, their families, and neighbors
- Establish and specify maximum exposure limits, not emission limits.
- Specifies Maximum Permissible Exposure (MPE) limits for all frequencies between 300 kHz and 100 GHz.



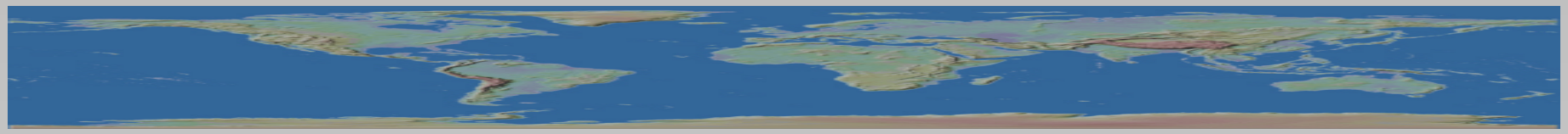
FCC RF Exposure Regulations

- Most stringent for frequencies between 30 MHz and 300 MHz.
- Does not require retention of records of RF radiation exposure evaluation.
- Does not establish mandatory procedures for evaluating compliance with RF exposure limits, only that the station does not exceed the maximum permissible exposure limits.
- “Portable” devices are those designed so that the antenna is within 20 cm of the body of the user.

Who is Exempt?

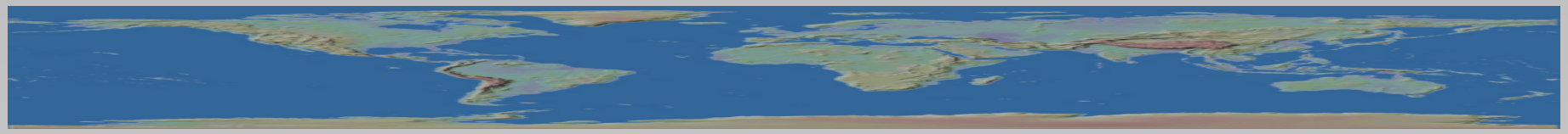
The RF safety regulations do NOT apply to:

- Any station that produces less than 50 watts PEP
- Mobile equipment
- Hand-held radios



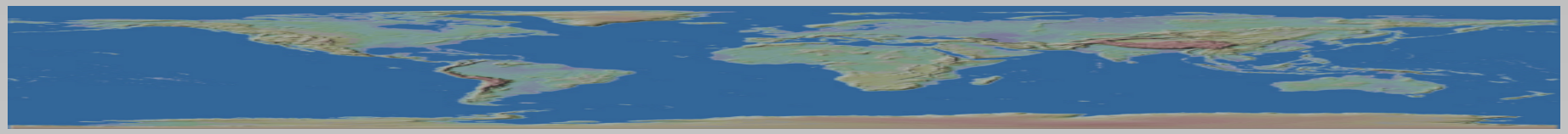
Mobile & Hand-held Considerations

- Even though hand-held radios are exempt from RF exposure limits, minimum power should be used with a hand-held to minimize RF exposure to the operator's head.
- A mobile transceiver with roof mounted antenna would have better shielding for the vehicle occupants than using a hand-held transceiver in a vehicle.



Controlled and Uncontrolled Environments

- Controlled Environments
  - Persons here are aware of RF risks and can take steps to minimize RF exposure.
  - The amateur operator's household and property
- Uncontrolled Environments
  - Persons here are generally not aware of RF risks.
  - Your neighbor’s household & property and sidewalk areas around your home.
  - More stringent than the controlled environment limits.



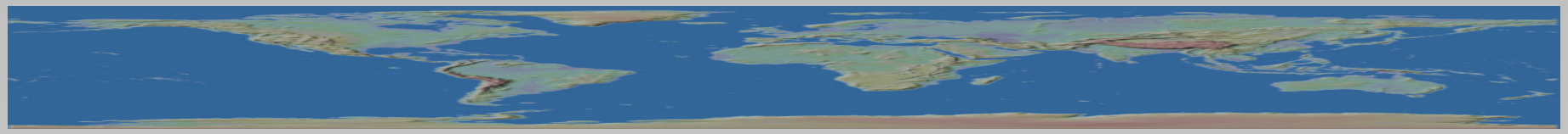
Exposure Averaging Times

- Controlled Environments
  - The exposure averaging time is

6 Minutes

- Uncontrolled Environments
  - The exposure averaging time is

30 Minutes

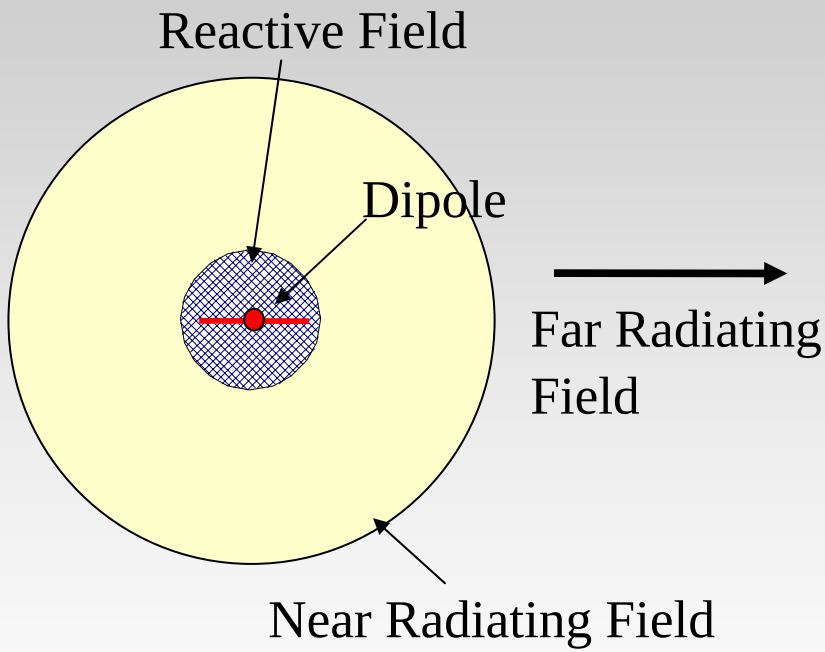


Measurement Units

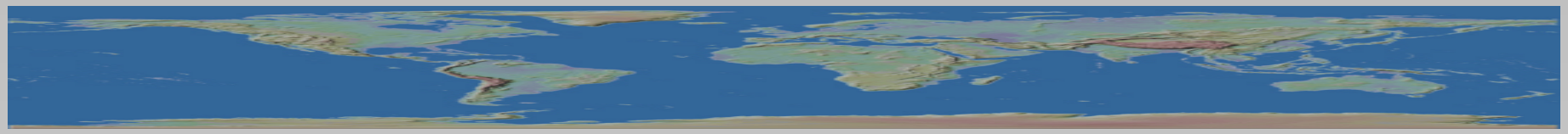
- The power density of a radiated RF signal is measured in “milli-watts per square centimetre (mW/cm^2).”
- The RF electric field strength is measured in “volts per meter (V/m).”

Near Field & Far Field

- In the “far field” the power density is proportional to the inverse of the square of the distance.
  - Doubling the distance to the antenna reduces the power density to ¼ as strong.
- In the “near field” the signal strength variance depends on the type of antenna.
- Wavelength & physical antenna size determine the boundary between the near & far fields.



- RF exposure effects are the most difficult to evaluate in the near field.



Determining RF Power Densities

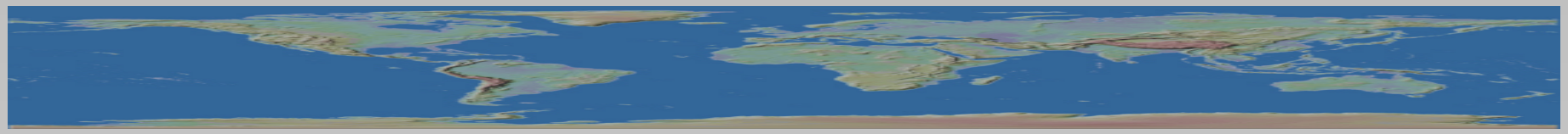
Use one or more methods in the amateur supplement to FCC OET Bulletin 65

- Direct measurement of the RF fields
  - Requires calibrated field strength meter
- Calculate the RF fields with a computer model
- Use the charts published by the FCC in OET Bulletin 65

RF Safety & Duty Cycle

- Duty cycle takes into account the amount of time a transmitter is operating at full power during a transmission.
- The lower the duty cycle, the shorter the compliance distance.
- The higher the duty cycle, the longer the compliance distance.
- Lower duty cycles expose people to lower radio-frequency radiation.

Operating Mode	Duty Factor
Morse code (CW)	40%
SSB phone	20%
FM	100%
RTTY/Digital	100%
AM	100%



RF Exposure Limit Factors

- Duty cycle
- Frequency & power level
- Antenna height & distance to a person
- Antenna radiation pattern
- Any of these can be changed to prevent exposure to RF radiation in excess of FCC specified limits.

Figure T0-1

Which equation should be used to calculate the maximum permissible exposure (MPE) on the Technician HF bands for a controlled RF radiation exposure environment?

Maximum permissible power density equals 900 divided by the square of the frequency, in MHz.

Figure T0- 1

(A) Limits for Occupational/Controlled Exposure				
Frequency Range (MHz)	Electrical Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Averaging Time (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	$(900/f^2)$*	6
30-300	61.4	0.163	1.0	6
300-1500	----	----	f/300	6
1500-100,000	----	----	5	6
(B) Limits for General Population/Uncontrolled Exposure				
Frequency Range (MHz)	Electrical Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Averaging Time (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	$(180/f^2)$*	30
30-300	27.5	0.073	0.2	30
300-1500	----	----	f/1500	30
1500-100,000	----	----	1.0	30
f=frequency in MHz *=Plane-wave equivalent power density				

Figure T0-1

What is the formula for calculating the maximum permissible exposure (MPE) limit for uncontrolled environments on the 2-meter (146) MHz band?

There is no formula, MPE is a fixed power density of 0.2 milliwatt per square centimetre.

Figure T0- 1

(A) Limits for Occupational/Controlled Exposure				
Frequency Range (MHz)	Electrical Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Averaging Time (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	($900/f^2$)*	6
30-300	61.4	0.163	1.0	6
300-1500	----	----	f/300	6
1500-100,000	----	----	5	6
(B) Limits for General Population/Uncontrolled Exposure				
Frequency Range (MHz)	Electrical Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Averaging Time (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	($180/f^2$)*	30
30-300	27.5	0.073	0.2	30
300-1500	----	----	f/1500	30
1500-100,000	----	----	1.0	30
f=frequency in MHz *=Plane-wave equivalent power density				

Figure T0-2

What is the minimum safe distance for a controlled RF radiation environment from a station using a 146 MHz ¼-wave whip at 10 watts?

Estimated distances to meet RF power density guidelines with a VHF quarter-wave ground plane or mobile whip antenna (estimated gain, 1 dBi). Calculations include the EPA ground reflection factor of 2.56.

Frequency: 146 MHz
Estimated antenna gain: 1 dBi
Controlled limit: 1 mw/cm^2
Uncontrolled limit: 0.2 mw/cm^2

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
10	1.7'	3.7'
50	3.7'	8.3'
150	6.4'	14.4'

Figure T0-2

What is the minimum safe distance for an uncontrolled RF radiation environment from a station using a 3-element “triband” Yagi antenna on 28 MHz at 100 watts?

Estimated distances to meet RF power density guidelines in the main beam of a typical 3-element "triband" Yagi for the 14, 21 and 28 MHz amateur radio bands. Calculations include the EPA ground reflection factor of 2.56.

Frequency: 28 MHz
Antenna gain: 8 dBi
Controlled limit: 1.15 mw/cm²
Uncontrolled limit: 0.23 mw/cm²

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
100	11'	24.5'
500	24.5'	54.9'
1000	34.7'	77.6'
1500	42.5'	95.1'

Figure T0-2

What is the minimum safe distance for a controlled RF radiation environment from a station using a 17 element Yagi on a five-wavelength boom on 144 MHz at 100 watts?

Estimated distances to meet RF power density guidelines in the main beam of a 17-element Yagi on a five-wavelength boom designed for weak signal communications on the 144 MHz amateur radio band (estimated gain, 16.8 dBi). Calculations include the EPA ground reflection factor of 2.56.

Frequency: 144 MHz
Estimated antenna gain: 16.8 dBi
Controlled limit: 1 mw/cm^2
Uncontrolled limit: 0.2 mw/cm^2

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
10	10.2'	22.9'
100	32.4'	72.4'
500	72.4'	162'
1500	125.5'	280.6'

Figure T0-2

What is the minimum safe distance for an uncontrolled RF radiation environment from a station using a 446 MHz 5/8-wave ground plane vertical antenna at 10 watts?

Estimated distances to meet RF power density guidelines in the main beam of UHF 5/8 ground plane or mobile whip antenna (estimated gain, 4 dBi). Calculations include the EPA ground reflection factor of 2.56.

Frequency: 446 MHz
Estimated antenna gain: 4 dBi
Controlled limit: 1.49 mw/cm²
Uncontrolled limit: 0.3 mw/cm²

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
10	1.9'	4.3'
50	4.3'	9.6'
150	7.5'	16.7'

Figure T0-2

What is the minimum safe distance for a controlled RF radiation environment from a station using a ½ wave dipole on 7 MHz at 100 watts PEP?

Figure T0-2

Estimated distances to meet RF power density guidelines with a horizontal half-wave dipole antenna (estimated gain, 2 dBi). Calculations include the EPA ground reflection factor of 2.56.

Frequency: 7 MHz
Estimated antenna gain: 2 dBi
Controlled limit: 18.37 mw/cm²
Uncontrolled limit: 3.67 mw/cm²

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
100	1.4'	3.1'
500	3.1'	6.9'
1000	4.3'	9.7'
1500	5.3'	11.9'

http://n5xu.ae.utexas.edu/rfsafety/

Calculate Radio Frequency Power Density

What is the average power at the antenna:
In watts
600

What is the antenna gain in dBi:
Enter 2.2 for dipoles; add 2.2 for antennas rated in dBd
2.2

What is the distance to the area of interest:
From the center of the antenna, in feet
25

What is the frequency of operation:
In MHz
54

Ground Reflection Effects

In most cases, the ground reflection factor is needed to provide a truly worst-case estimate of the compliance distance in the main beam of the antenna. Including the ground reflection effects may yield more accurate results especially with very low antennas, non-directional antennas, and calculations below the main lobe of directional antennas.

Do you wish to include effects of ground reflections? (•) Yes ( ) No

Calculation Results

Average Power at the Antenna	600.000 watts
Antenna Gain in dBi	2.20 dBi
Distance to the Area of Interest	25.00 feet
Frequency of Operation	54.000 MHz
Are Ground Reflections Calculated?	Yes
Estimated RF Power Density	0.3494 mw/cm²

	Controlled Environment	Uncontrolled Environment
Maximum Permissible Exposure (MPE)	1.00 mw/cm²	0.21 mw/cm²
Distance to Compliance From Center of Antenna	14.83 feet	33.09 feet
Does the Area of Interest Appear to be in Compliance?	yes	no

When using a computer to model RF fields the ground interactions must be taken into account.

Antenna & Height Comparison

Calculation Results
Dipole

Average Power at the Antenna	500.000 watts
Antenna Gain in dBi	2.20 dBi
Distance to the Area of Interest	16.40 feet
Frequency of Operation	7.000 MHz
Are Ground Reflections Calculated?	Yes
Estimated RF Power Density	0.6766 mw/cm²

(5m)

Calculation Results
Loop

Average Power at the Antenna	500.000 watts
Antenna Gain in dBi	5.50 dBi
Distance to the Area of Interest	98.40 feet
Frequency of Operation	7.000 MHz
Are Ground Reflections Calculated?	Yes
Estimated RF Power Density	0.0402 mw/cm²

(30m)

Calculation Results
Quad

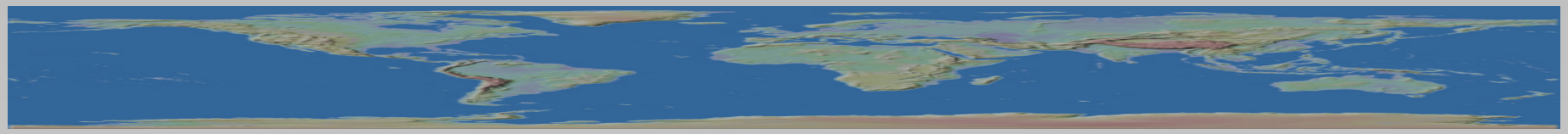
Average Power at the Antenna	500.000 watts
Antenna Gain in dBi	8.47 dBi
Distance to the Area of Interest	98.40 feet
Frequency of Operation	7.000 MHz
Are Ground Reflections Calculated?	Yes
Estimated RF Power Density	0.0797 mw/cm²

(30m)

Calculation Results
Yagi

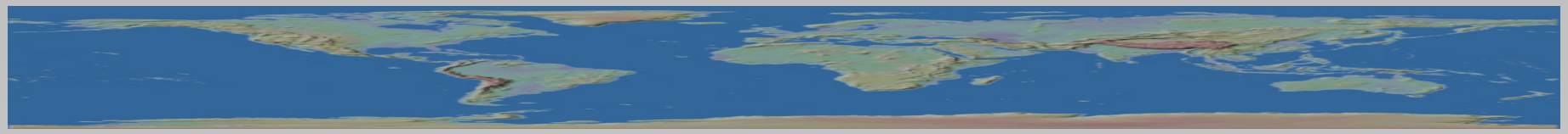
Average Power at the Antenna	500.000 watts
Antenna Gain in dBi	8.25 dBi
Distance to the Area of Interest	98.40 feet
Frequency of Operation	7.000 MHz
Are Ground Reflections Calculated?	Yes
Estimated RF Power Density	0.0757 mw/cm²

(30m)



RF Safety for Dummies

Don't stand near or touch a transmitting antenna when it is being fed with 1500 watts of RF energy!



Homework

- Study Sub elements T9 & T10 of the question pool.
  - **Read the *Question* and the *Answer* Three Times.**
- Read Chapters 9 & 10 in “Now You're Talking”.
- Read the handout “Additional Information for Amateurs Completing Form 605”.