HF Signal Propagation

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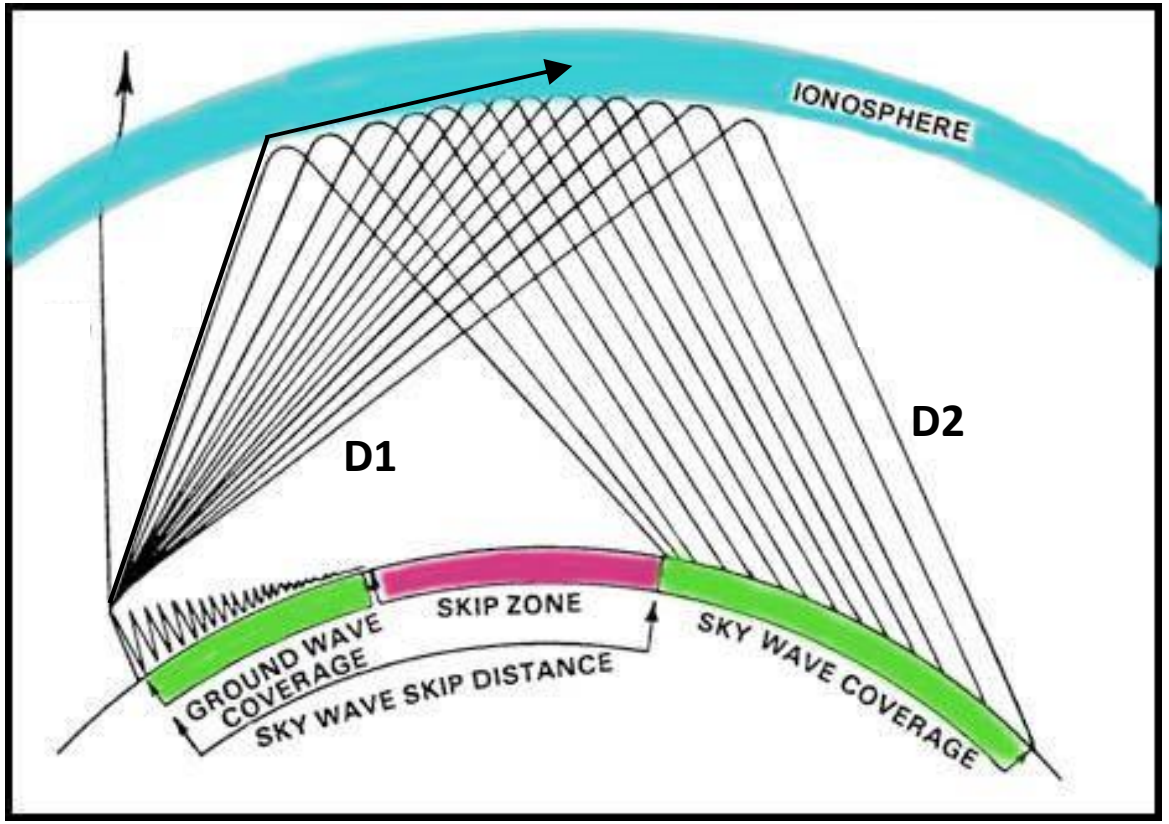
Primary Modes of HF Wave Propagation

1. Direct (line of sight) wave
2. Ground (surface) wave
   - Beyond line of sight
   - Maximum range ~40 mi
   - Vertical polarization only
3. Sky wave (via ionosphere)



Primary Modes of HF Wave Propagation

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   - Maximum range 10-20 mi
2. Ground (surface) wave
   - Beyond line of sight
   - Maximum range ~40 mi
   - Vertical polarization only
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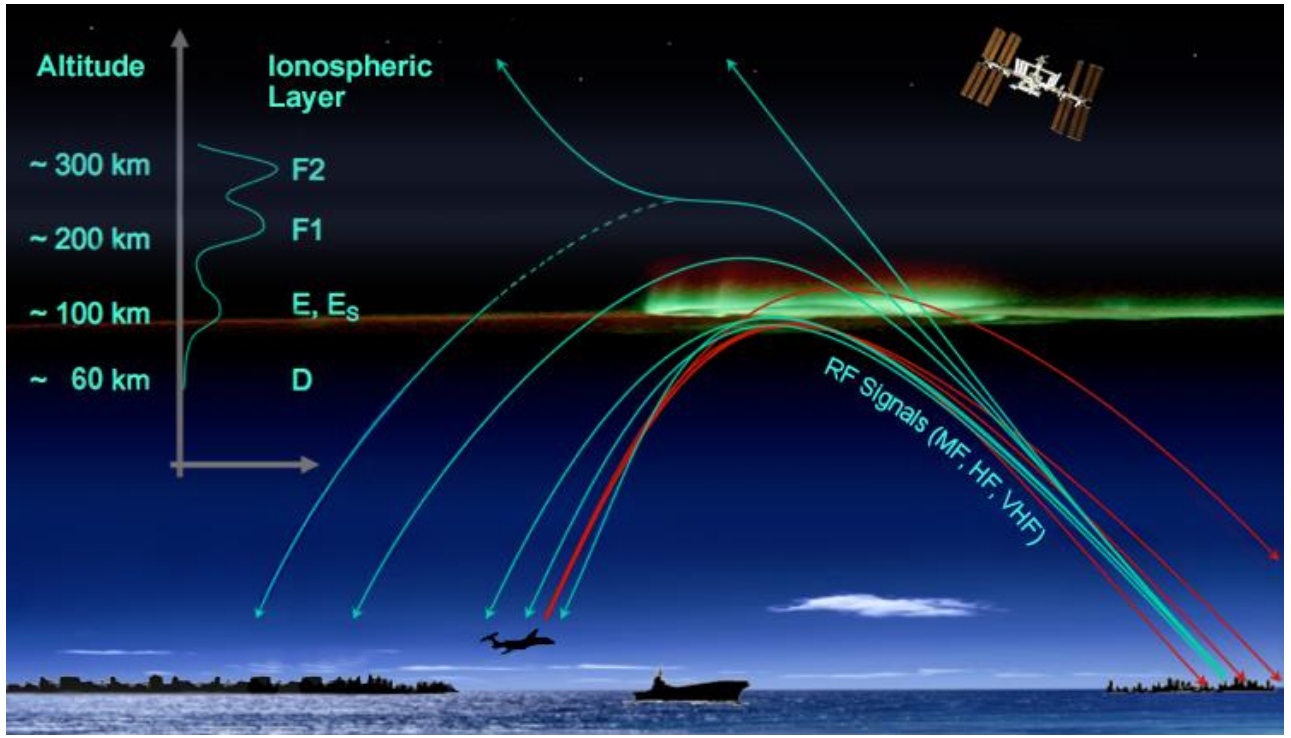
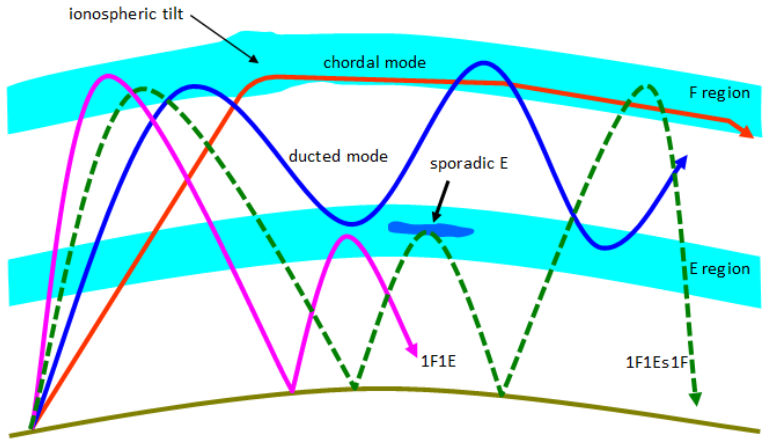
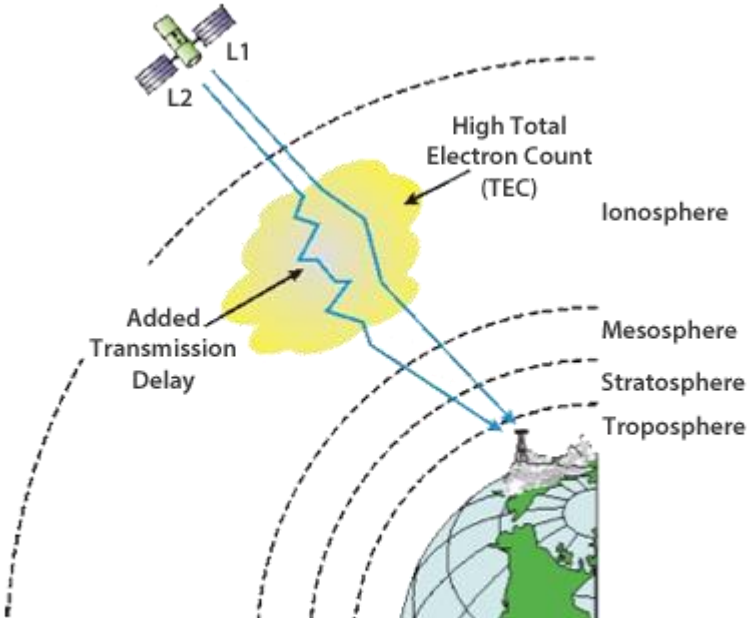


Secondary Modes of Wave Propagation

- Ionospheric modes
  - Meteor scattering
  - **Auroral backscatter**
  - **Sporadic-E propagation**
- Tropospheric modes
  - **Tropospheric ducting**
    - **Up to 1000 mi**
    - **Frequencies >40 MHz**
  - Tropospheric scattering
  - Rain scattering
  - Airplane scattering
  - Lightning scattering

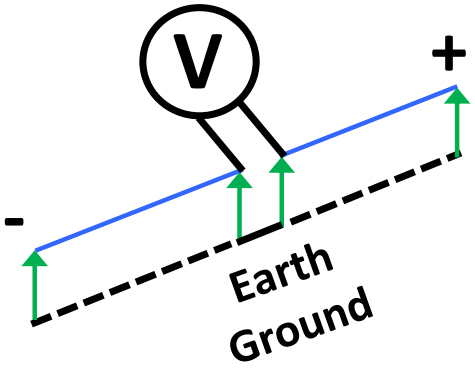




Why Are Ground Waves Vertically Polarized?

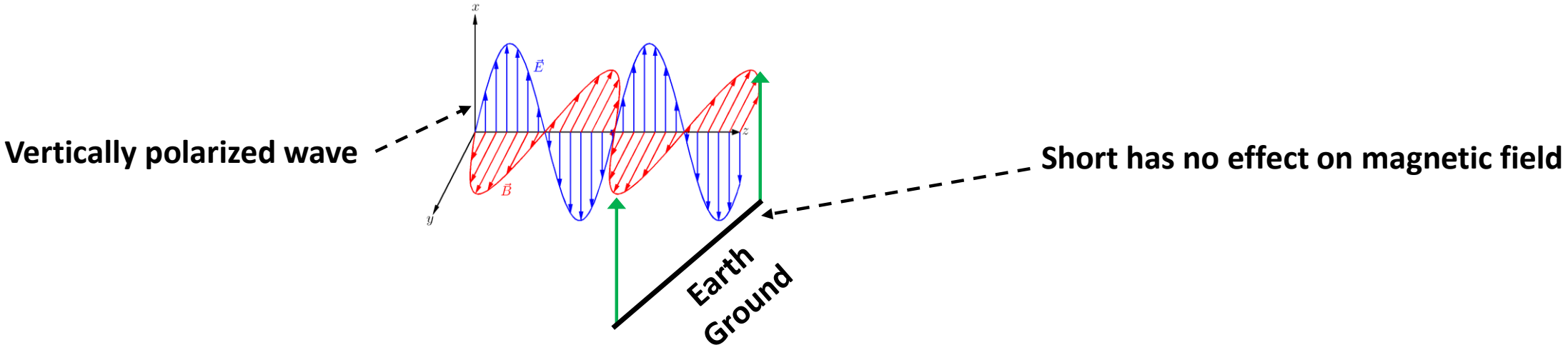
- Polarization of a linear EM wave is defined by the E field
- Horizontally polarized wave has the E field in contact with the Earth
  - A conductive surface will act like a short to an E field

  Ex: Dipole antenna laying on highly conductive ground plane

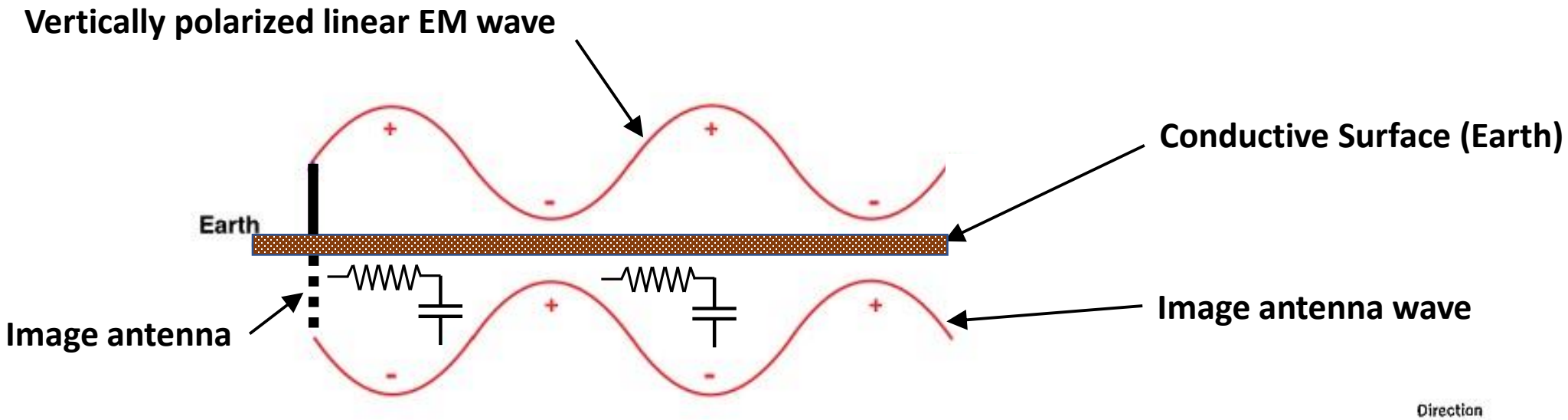


- Magnetic fields are unaffected by conductive materials
  - Magnetic fields are affected by ferromagnetic materials

  Ex: Magnetic loop antenna near ground



Groundwave Propagation Beyond Horizon



- **Earth is a lossy dielectric**
  - **Resistance: loss causes signal attenuation**
  - **Capacitance: slows down wave travel near the Earth**
    - **Causes wave to bend and follow the curvature of the Earth**

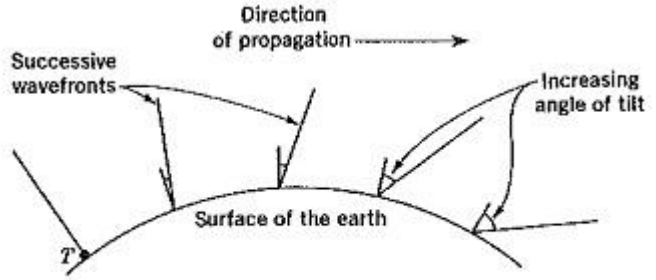
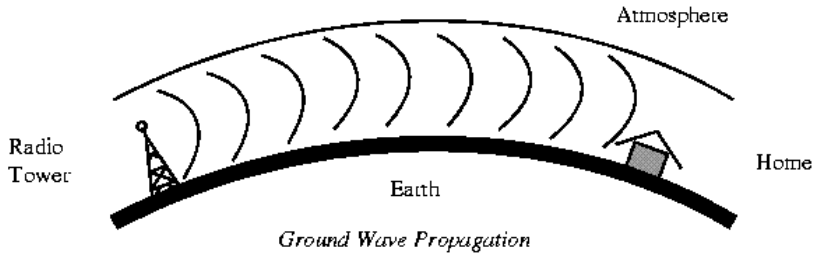


FIGURE 8-12 Ground-wave propagation.



Ground Wave Propagation

Polarization Of A Reflected Wave

You are receiving a European DX station on 14 MHz via the North Pole. He is using a horizontally polarized antenna.

- **Question:** What is the polarization of the signal at your antenna
  1. Horizontal
  2. Vertical
  3. Can’t tell because of Faraday rotation
  4. None of the above

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- **Question:** What is the polarization of the signal at your antenna
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- **Answer:** None of the above
  - **Why:** All ionospherically refracted (reflected) signals are **elliptically** polarized

Wave Polarization

- Linear
  - Horizontal vs Vertical polarization
    - Cross pol => no signal

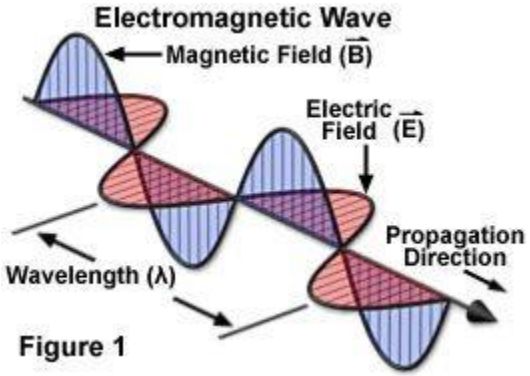
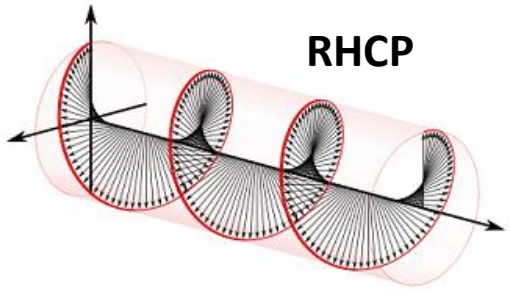
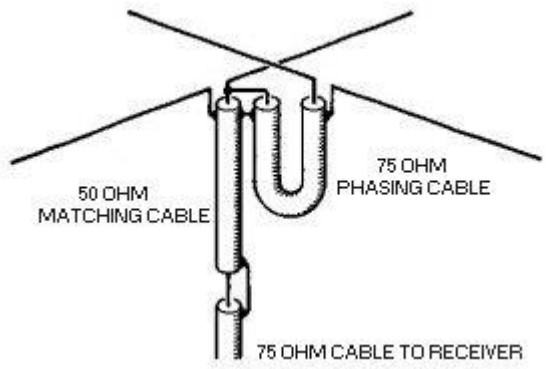


Figure 1

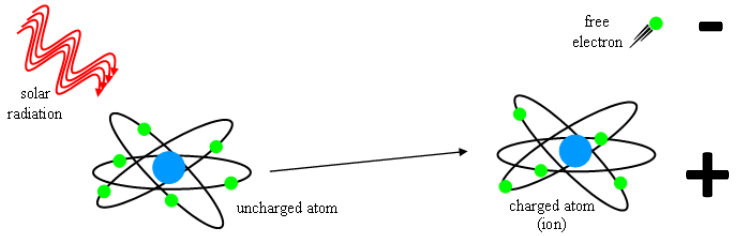
- Circular
  - E & H fields both rotate 360 deg per wavelength of travel
  - Left vs right polarization
    - Cross pol => no signal
  - Linear Rx with circular Tx (and vice versa)
    - Loss = -3 dB ***<u>regardless of orientation</u>*** of antennas
  - How to generate a circularly polarized signal?
    - Helix antenna
    - Crossed dipoles





Ions and Plasmas

- An ion is an atom that has had one or more electrons stripped away

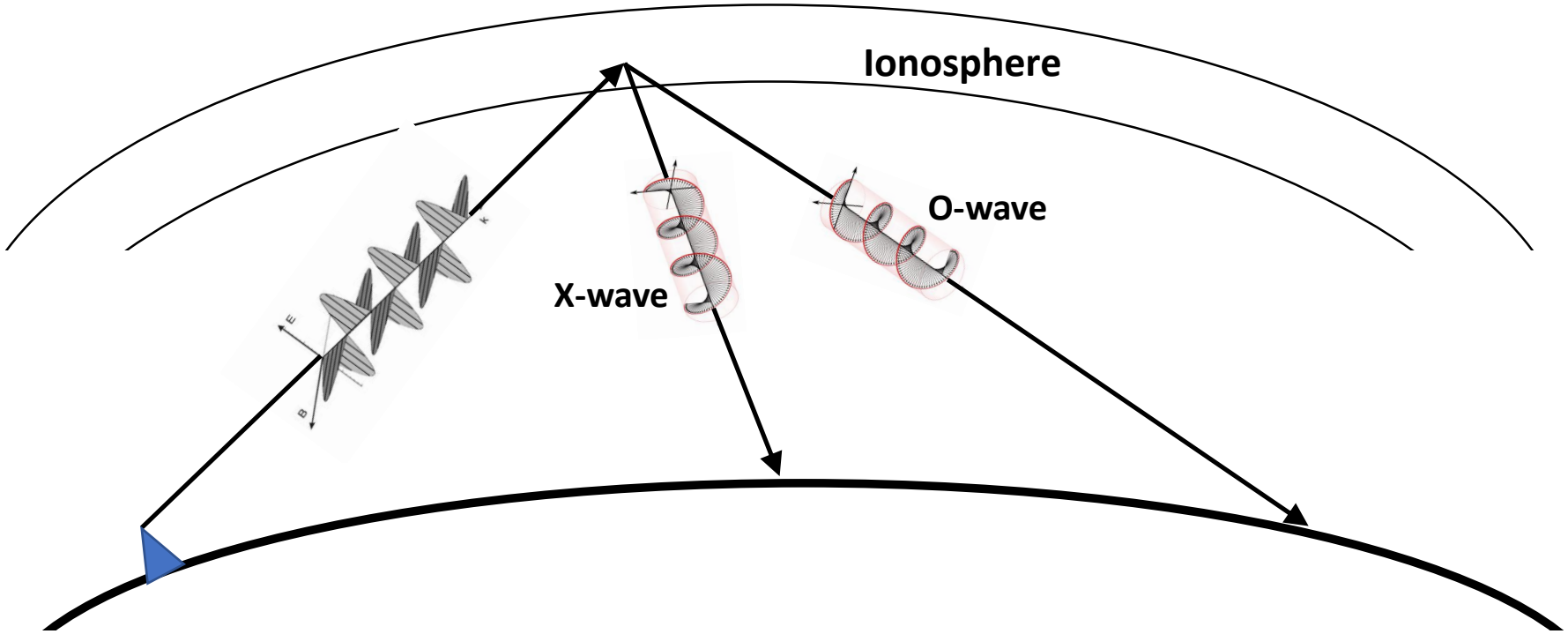


- A plasma is an ionized gas consisting of approximately equal numbers of positively charged ions and negatively charged electrons
- The free electrons in the plasma in the ionosphere are what causes refraction of radio waves

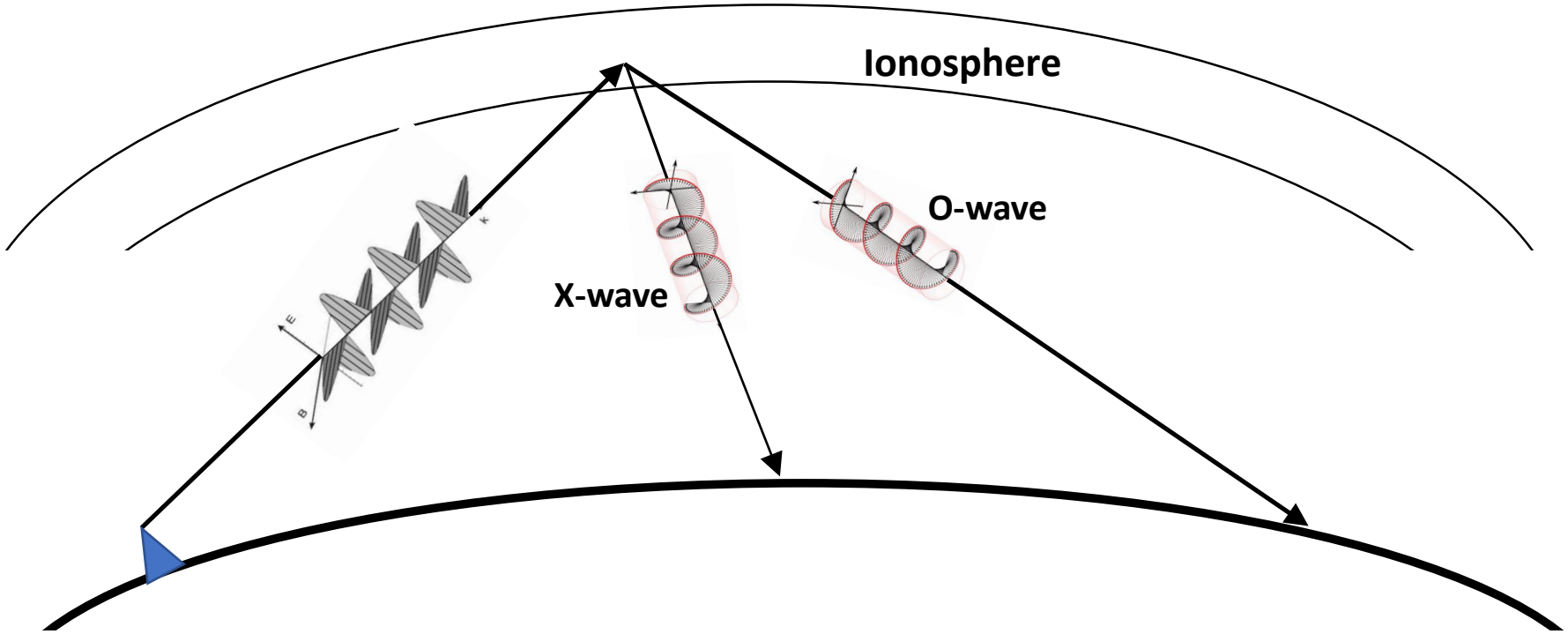
Why Are All Ionospherically Refracted Signals Elliptically Polarized?

- The ionosphere is a **magnetized plasma** (ionized gas)
- Magnetized plasmas are birefringent
- A "Birefringent" medium is a medium with two refractive indices
  - **A linearly polarized EM wave passing thru a magnetized plasma splits into two separate, counter rotating circularly polarized waves:**
    1. Ordinary (O-mode) wave
    2. Extraordinary (X-mode) wave
- The O-mode wave follows the magnetic field lines
  - Propagation path is close to what would occur in a non-magnetized plasma
- The X-mode wave goes perpendicular to the magnetic field lines
  - Higher path loss
  - More susceptible to ducting (can go farther than the O-mode)

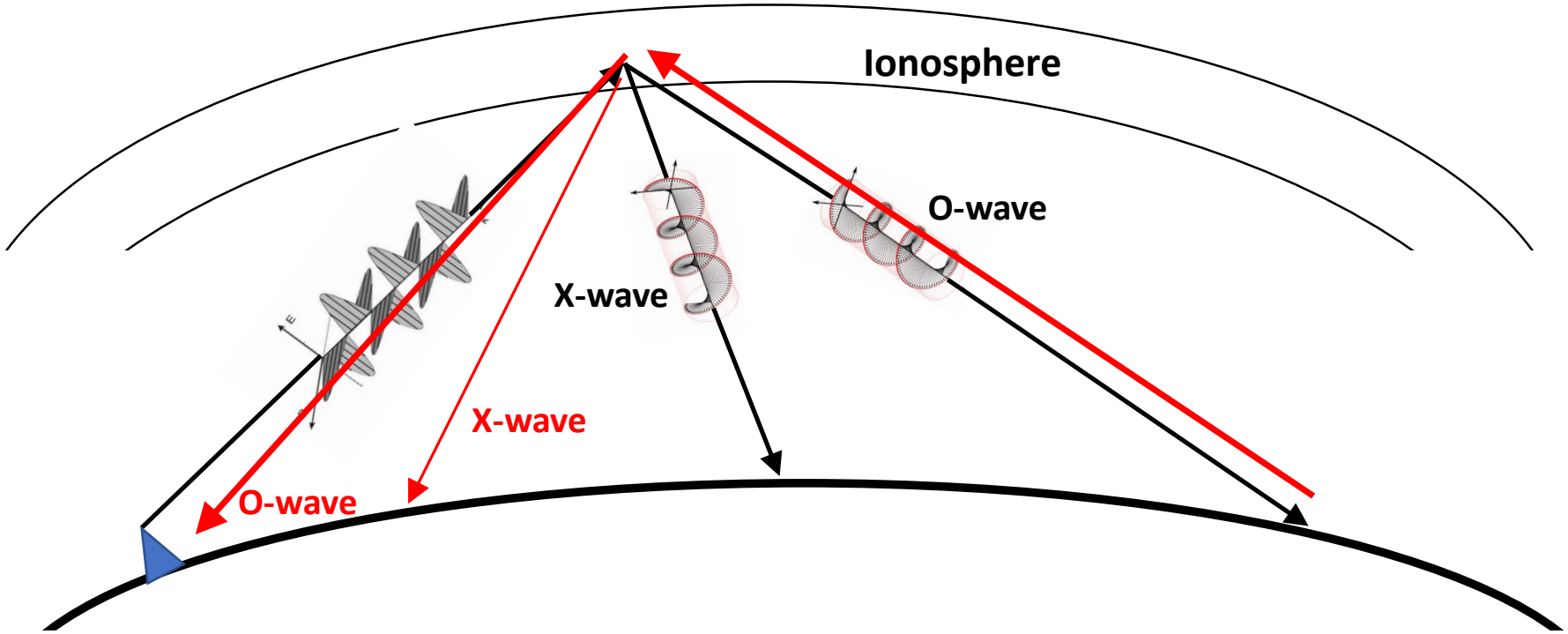
Divergence of O and X Mode Waves



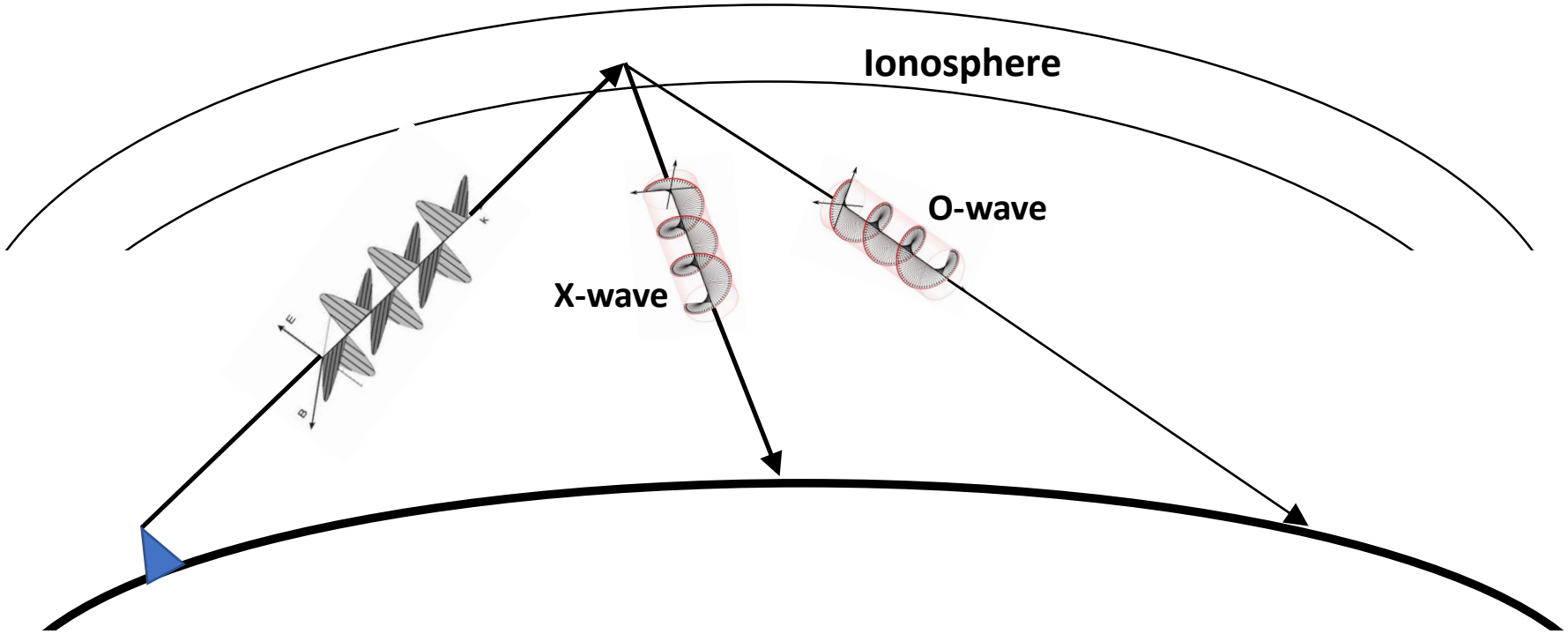
Forward O Mode Waves



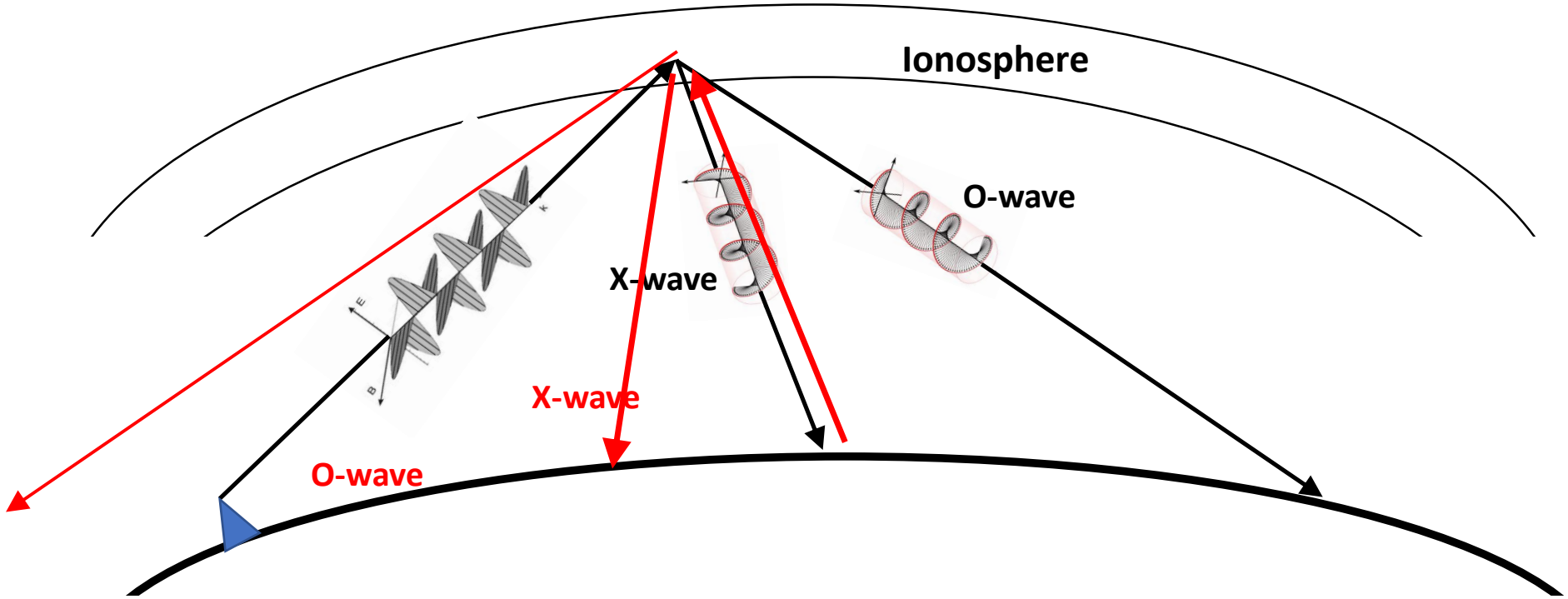
Reverse O Mode Waves



Forward X Mode Waves



Reverse X Mode Waves



Why Is Birefringence Important?

- Ionosphere is **no longer reciprocal**
  - One way propagation is the norm
    - The two paths for a QSO are different
- X and O waves:
  - May, or may not have equal powers
  - Can take radically different paths exiting the ionosphere
    - Beam headings may not follow Great Circle routes
    - Up to 90 deg different at the poles
  - Have different MUFs, skip distances, propagation velocities, & attenuation
- Degree of divergence of X and O waves:
  - Varies with location, frequency, take off angle, state of the ionosphere,…
  - Worst at low frequencies and at the Poles
  - Least along the Magnetic Equator
- Most propagation programs only deal with O-mode
  - Proplab Pro Ver 3 shows both

Reflection vs Refraction

- The ionosphere is a refractive surface (not a reflective surface)
- Why this is important => ?