“Radio Propagation” Modes

Radio propagation — how radio waves travel through space — is the foundation for understanding range. Several key modes matter: **line-of-sight**, **ground-wave**, **troposcatter**, and **skywave**.

- **Line-of-Sight (LOS):** This is the simplest mode. Radio waves travel directly in a straight (or nearly straight) path between antennas. It’s very common for VHF, UHF, and microwave frequencies.
- **Ground-Wave Propagation:** Low- and medium-frequency signals (e.g., AM) can follow the Earth’s surface, allowing communication beyond the visual horizon.
- **Skywave (Ionospheric) Propagation:** HF (shortwave) waves can bounce off the ionosphere and return to Earth far from their source. This enables long-distance communication — even globally under the right conditions.
- **Tropospheric Scatter (“Troposcatter”):** At higher frequencies (UHF / microwave), some energy scatters in the lower atmosphere (troposphere) and can reach receivers hundreds of kilometers away, even beyond the horizon.

What Dictates Radio Range?

Several major factors influence how far a radio signal will go:

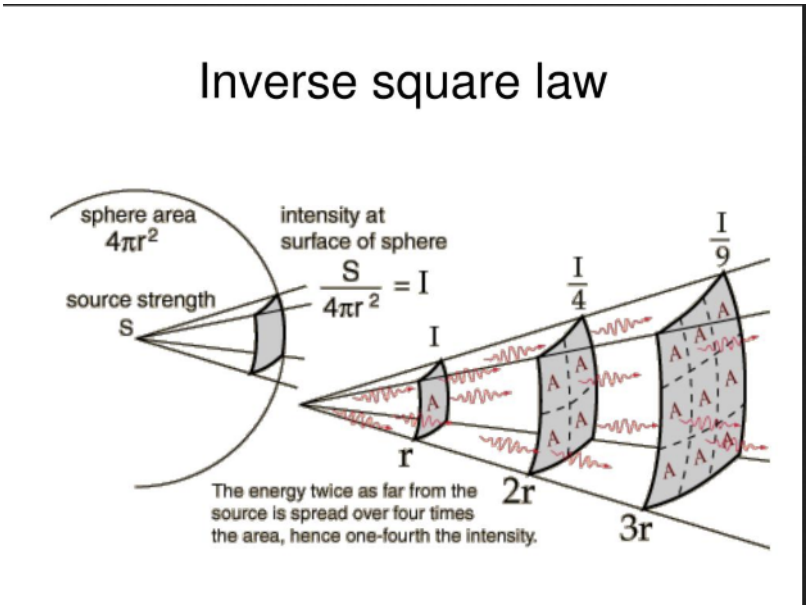
1. **Frequency**
    - Lower frequencies (like HF / MF) can travel very long distances via skywave or ground-wave.
    - Higher frequencies (VHF/UHF) are mostly limited by line-of-sight, so range is constrained by antenna height and terrain.
2. **Antenna Height & Gain**
    - The higher your antenna, the farther the “radio horizon.”
    - Directional or high-gain antennas (e.g., Yagi, parabolic) concentrate power, improving reach.
3. **Transmitter Power**
    - More power generally helps, but doubling power doesn’t double range — due to path loss and propagation physics.
4. **Atmospheric / Environmental Conditions**
    - Ionospheric conditions (time of day, solar activity) change skywave performance.
    - Tropospheric ducting or scatter can sometimes dramatically boost VHF/UHF range.
    - Obstructions like terrain, buildings, and the curvature of the Earth limit line-of-sight coverage.

Typical Range by Radio Type / Frequency Band

Here are some practical, real-world range estimates for different kinds of radios and frequency bands:

Radio Type / Band	Typical Range	Propagation Mode
AM Broadcast (Medium Frequency)	Tens to hundreds of miles (especially at night)	Ground-wave (day), Sky-wave (night)
HF Ham Radio (3–30 MHz)	Hundreds to thousands of miles (potentially global)	Skywave / ionospheric reflection
VHF (30–300 MHz)	~5 to 50 miles typical; more if antennas are high	Mostly line-of-sight; extended by tropospheric effects
UHF (300 MHz–3 GHz)	Generally 1 to 30 miles in many situations	Line-of-sight; depends on antenna and terrain

Source from: https://tshicom.com/what-is-the-farthest-a-radio-can-reach/

Things to remember:

I. Double the distance = ¼ the power. Triple the distance = 1/9 the power
   A. Example: 900 watts @ 1 square meter measured at r , 225 watts @ 1 square meter measured at $2r$ and 100 watts @ 1 square meter measured at $3r$.
II. Antenna type and size will determine gain in dB as well as the radiation pattern.