

Introduction to Troposcatter Communications

A brief synopsis of over-the-horizon troposcatter

1.0 BEYOND THE HORIZON COMMUNICATIONS

Troposcatter (tropo) systems were developed in the 1950s for point to point communications beyond line of sight (over the horizon) between remote geographic areas where microwave and cable links were not feasible. Troposcatter transmission depends on forward scattering of the radio signal in the troposphere, the lower portion of the earth's atmosphere. Troposcatter transmission depends on high power transmitters and sensitive receivers, as the forward scatter path loss is relatively high when compared to conventional microwave line of sight systems. The hallmark of troposcatter radio systems is their long distance operation, beyond the horizon or beyond line of sight, and their dependence on the earth's atmosphere. An example of a typical troposcatter path for over the horizon transmission is shown below in Figure 1. The scatter volume for transmission is where the radio beams intersect.

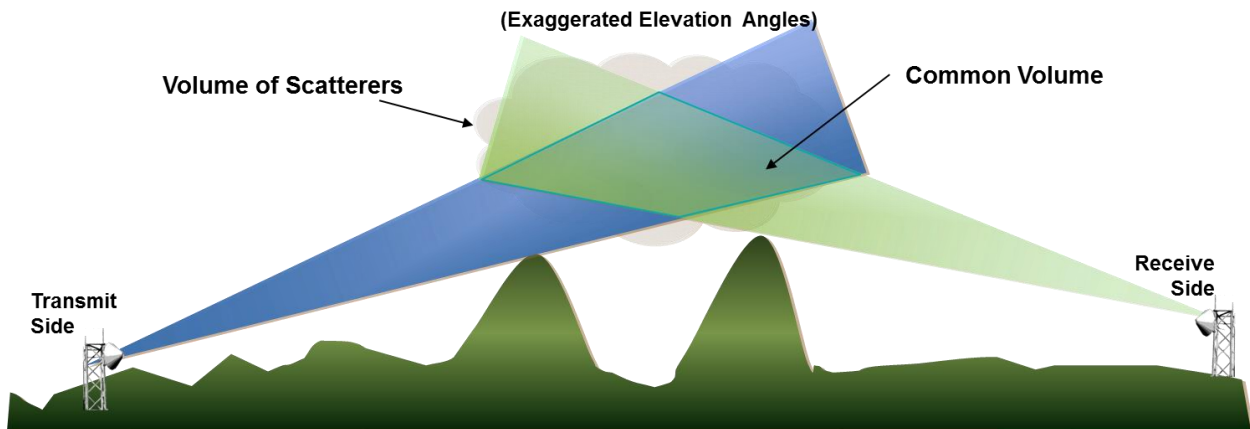


Figure 1. Beyond the Horizon Troposcatter Transmission

Some of the earliest tropo links were installed in the remote parts of Canada and Alaska and positioned above the Arctic Circle to provide communications between radar systems used for air defense. Other early systems were installed between islands in the Pacific, and also used to connect military bases across Northern Europe.

Troposcatter systems have been used all over the world for a variety of applications, by many types of users. Since the 1960s, tropo systems have been used for oil and gas operators of offshore platforms and for oil and gas pipelines. Other civil telecommunication applications of the time included inter-island links, connecting island nations together to provide voice grade links.

Today, using high speed modems with advanced signal processing, digital voice, data and video can be streamed across high reliability links for military and commercial applications as part of a complete communications network.

2.0 TROPOSCATTER BACKGROUND

2.1 Troposcatter Advantages

The primary driver for the development of troposcatter systems was a need to establish a radio link between two points on the earth that typically could not be connected by any other means. A prime example was the troposcatter radio system built to connect the series of radar sites that formed the Distant Early Warning Line (DEW Line) in the 1950s. The DEW line extended for thousands of kilometers above the Arctic Circle. In the 1950s, troposcatter radio was the only means for full-time reliable communications between these remote sites, far beyond line of sight from each other. Some special features of troposcatter links are listed below.

- Provides a radio link with near instantaneous communications and very little delay (latency) as compared to satellite links. Latency via a troposcatter link is in the order of microseconds and virtually undetectable. Satellite links have a round trip delay of more than 500 ms, a factor that can severely degrade some types of IP based interactive applications.
- Provides a reliable means of point to point links between remote hostile areas that are beyond line of sight.
- Mobile troposcatter links can be installed in less than one hour, for high capacity 22 Mb/s links between two points separated by more than 100 km.

Typical advantages of troposcatter systems relative to other transmission media are summarized below in Table 1.

Table 1. Advantages of Troposcatter Links Compared to Other Media

Transmission Media	Main Advantage	Main Disadvantage
Troposcatter	High capacity, high reliability, no delay, IP based system, no recurring monthly costs	Equipment cost is higher than microwave and VSAT, but lower than fiber optic
Microwave line of sight	Low cost, high capacity, high reliability	Requires line of sight, limiting distances to approximately 30 km
Satellite	Low equipment cost, most economical for low capacity (512 kb/sec or less)	Absolute delay (latency), availability degradation (outages), monthly transponder lease cost
Undersea fiber	Highest capacity of all media	Highest installation and restoral cost of all media. Installation cost is typically estimated at more than US\$10 million per 100 km, plus restoral service costs

2.2 Global Applications

Troposcatter systems have been successfully installed in many countries and environments since the 1950's. The systems operate in all environments, and are subject only to frequency availability specific to the countries where they are installed, and the intended civilian or military application. Some examples of troposcatter applications are shown below in Table 2. Almost all of the links in Table 2 remain in operation today.

Table 2. Troposcatter Global Applications

User Group	Project Location	Type of Application
Military	Israel	Transportable tactical communications
Government	Brazil	Onshore to island
Oil & Gas	Aberdeen, UK, North Sea	Offshore oil platform
Military	Taiwan	Links to offshore islands
Government	Singapore	Links to offshore island
Oil & Gas	Port Gentil, Gabon	Pipeline communications
Oil & Gas	Jebel Ali, UAE	Offshore oil platform
Oil & Gas	North Sea	Offshore oil platform
Hydroelectric	Canada	Dam and power plant communications
Military	Africa	Transportable and fixed communications
Civil Telecoms	Bahamas	Island to island and island to mainland
Oil & Gas	North coast of East Malaysia	Mainland to offshore platforms
Military	UK	Transportable rapid reaction force communications
Oil & Gas	North coast of East Malaysia	Mainland to offshore platforms
Military	Africa	Transportable and fixed communications
Oil & Gas	West coast of Mexico	Mainland to offshore platform
Military	Africa	Transportable and fixed communications
Oil & Gas	North coast of East Malaysia	Mainland to offshore platforms
Military	Africa	Transportable and fixed communications
US Air Force	USA	Military communications tactical
US Army	USA	Military communications tactical
Military	Taiwan	Links to offshore islands

3.0 TROPOSCATTER PATH CHARACTERISTICS

Troposcatter radio systems provide communications beyond the horizon by using a radio path through the troposphere. The troposphere is the lowest portion of earth's atmosphere, about 8 to 15 km above the earth's surface. It contains approximately 75% of the atmosphere's mass and 99% of its water vapor and aerosols. The troposphere is where most clouds form, precipitation occurs, and atmospheric convection currents are active. See Figure 2 below for a simple illustration.

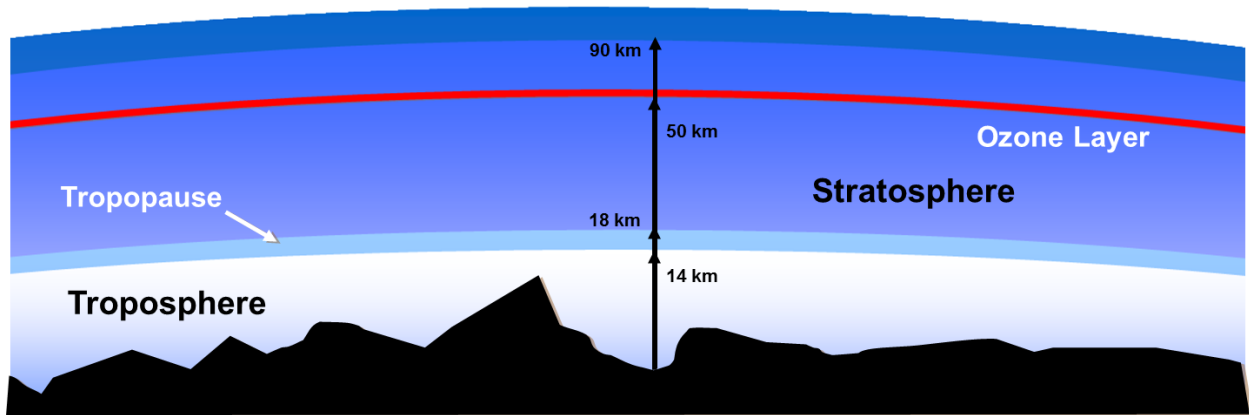


Figure 2. Atmospheric Diagram

Radio signals are transmitted through the troposphere by forward scatter, which occurs as a result of irregularities in the radio refractive index of the troposphere. An example of a troposcatter radio path is shown below in Figure 3. This figure shows the area in the troposphere where forward scatter takes place that is visible from antennas at both ends of the troposcatter link. The path loss is the same in both directions even if the path is not symmetrical.

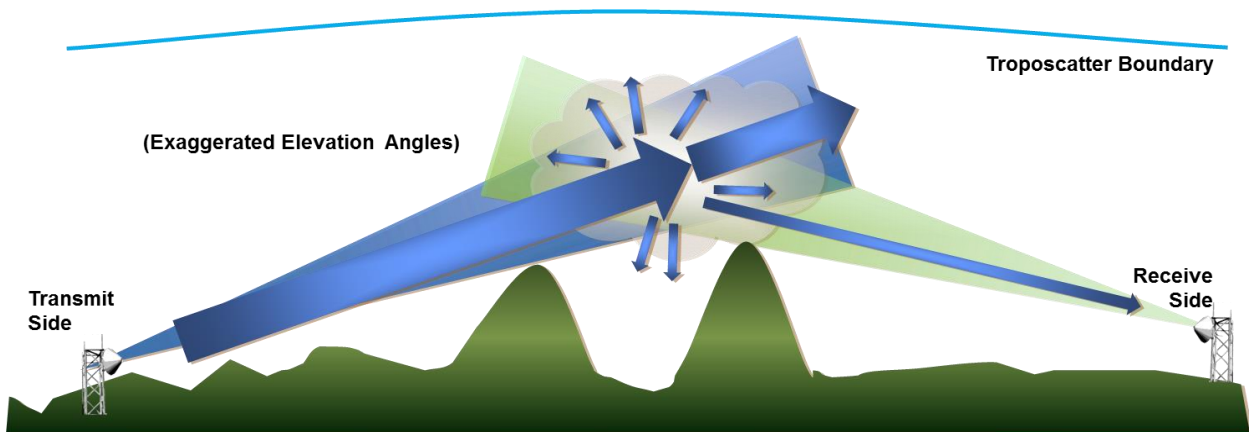


Figure 3. Example of Troposcatter Transmission Path

A hallmark of modern troposcatter systems is resistance to short-term fading. Signal fading has two characteristics that are important in understanding troposcatter transmission, long term fading and short term fading. Long term fading is caused by seasonal changes in the atmosphere, such as the difference between the summer and the winter. The amount of long-term fading experienced between summer and winter is determined by the climate type, for example desert, temperate, or maritime among others. Short term fading in troposcatter is a result of multipath transmission, which is caused by the radio signal having different transmission paths (and hence transmission delays) through the troposphere. Short term fading is seen as rapid and deep changes in the signal level. A graphical example of long term and short term fading is shown below in Figure 4.

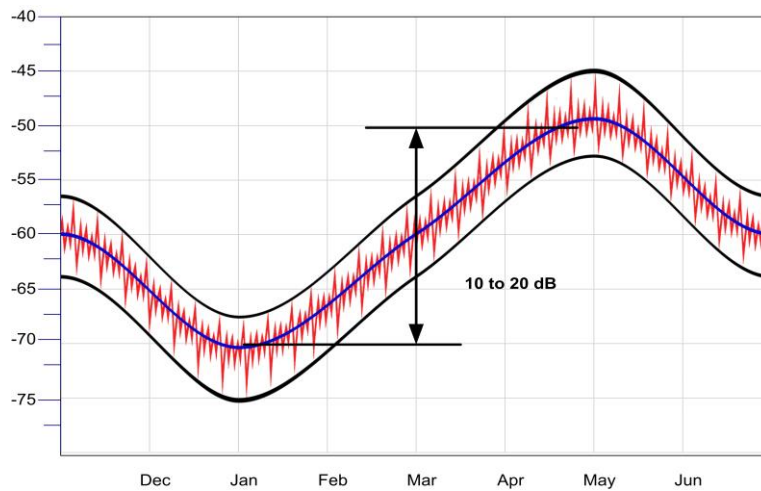


Figure 4. Graphical Example Long Term and Short Term Fading

In Figure 4, the graph of long-term fading is the broad envelope of the signal over a 6 month period, here December through June. During this time period the median signal level can vary 50 dB or more. This is the seasonal characteristic. Within this long-term envelope short term fading is pictured. The short-term fading is proportional to the fade duration and can exceed 40 dB during a few milliseconds, 10 – 15 dB during 1 or 2 seconds and less than 1 dB for 2 minutes or more. Two minutes or more is required to see the full short-term, Rayleigh, fading period.

The scatter losses through the troposphere and long-term changes in path loss have typically been made up by high power transmitters and large antennas. Short-term fading is mitigated by diversity combining receivers. Diversity combining tends to smooth out the short-term fading by reducing the depth of fading and reducing the percentage of time the combined signal will fade below a given fade depth. Types of equipment and diversity techniques employed in troposcatter systems are described in the next section.

4.0 TROPOSCATTER EQUIPMENT

Troposcatter radio equipment is similar to that of conventional line of sight (30 km) microwave and satellite radio equipment, in they all utilize transmitters, receivers, and antennas, and are all used for point to point communication circuits. However, troposcatter radio equipment uses higher transmit power (up to 2,000 watts), larger antennas (with up to 46 dB or more gain), and specially designed diversity receivers to ensure the radio signal can propagate reliably beyond the horizon. Troposcatter radio systems are used for all types of voice, video, and data, similar to other radio systems. The main difference is the distance over which they operate.

Most troposcatter systems sold since 1995 have been in the 4400 to 5000 MHz frequency band. A limited demand exists for 1800 to 2400 MHz, and 7100 to 7400 MHz frequency bands, but the licensing is difficult due to competing demands from cellular, mobile, satellite, and related applications. Troposcatter systems currently operating in the 1800 to 2400 MHz frequency band are expected to continue at least for the next 10 to 15 years. Some characteristics typical of most troposcatter systems are listed below.

- Path distances: upwards of 250 km, point to point
- Frequencies: 1800 to 2400 MHz, 4400 to 5000 MHz (primary), and 7100 to 7400 MHz
- Antenna sizes: 2 meter to 9 meter diameter parabolic reflectors, on towers and on trailers
- Frequency diversity: two frequencies (at 1% or more spacing)
- Space diversity: reception on two antennas 100 wavelengths or more apart
- Angle diversity: vertical beam angles separated by approximately one 3 dB antenna beam width
- Dual and quad diversity: most systems are quad diversity. Short links, 100 km or less, may be able to use dual diversity.
- Path availability: typically designed for 99.999% of all hours of the year or better
- Equipment reliability: 50,000 hours to 100,000 hours (6 to 12 years) MTBF or better
- Modulation: QPSK
- Capacity: up to 22 Mb/s, current production modems
- Transmit power: 100 watts to 2,000 watts, employing solid state power amplifiers
- Adaptive link power control: Automatically adjusts transmit power to supply minimum needed to maintain link integrity within set parameters.
- Monitor and control: fully automated with built-in equipment performance monitoring and radio link performance monitoring and logging.

- User interface: multiple E1 (G.703) and IP based services via router
- Service channels: digital service channels for voice orderwire and monitoring
- Installations: equipment shelters, trailers, buildings

4.1 System Architecture

A typical quad diversity troposcatter system is shown below in Figure 5. The key features found in most tropo systems are two antennas and two transmitters for space and frequency diversity. Also employed are single antennas and two transmitters for angle and frequency diversity.

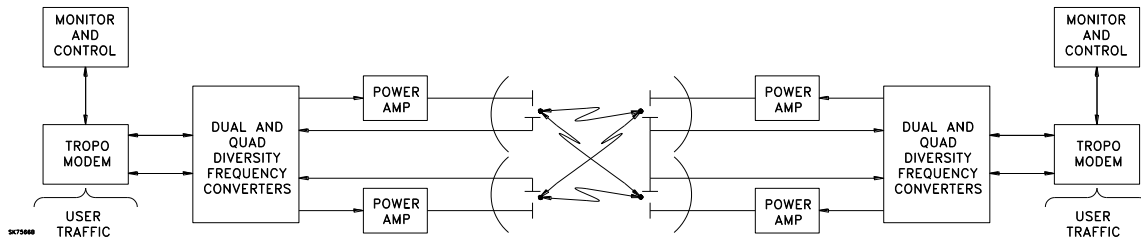


Figure 5. Typical Quad Diversity Troposcatter System

Examples of different types of diversity are shown below.

4.2 Diversity Reception

Diversity reception is used to combat short term, (Rayleigh) fading. The principles of diversity reception are listed below.

- Diversity reception helps to overcome short term fading
- Diversity reception refers to combining two or more independent, uncorrelated signals received over the tropo path
- RF signals are received via many independent paths through the troposphere
- Each RF signal arrives at different times, some stronger and some weaker
- Types of diversity:
 - ❖ Space
 - ❖ Angle
 - ❖ Frequency
 - ❖ Polarization (Marking)

4.3 Space Diversity

The concept of space diversity is that radio signals received from two paths will fade independently (uncorrelated fading), and if combined will yield a signal with higher availability than either of the signals alone would have. Some rules are listed below.

- Uses 2 antennas at each end of a tropo link
- Improves the received signal compared to signal from any one path
- Space diversity requires 100 wavelength separation between antennas, measured from the center point of each antenna. At 4.5 GHz, this is approximately 7 meters.
- The diagram in Figure 6 shows a dual space diversity system with one transmitter on one antenna, and the signal being received on two antennas.

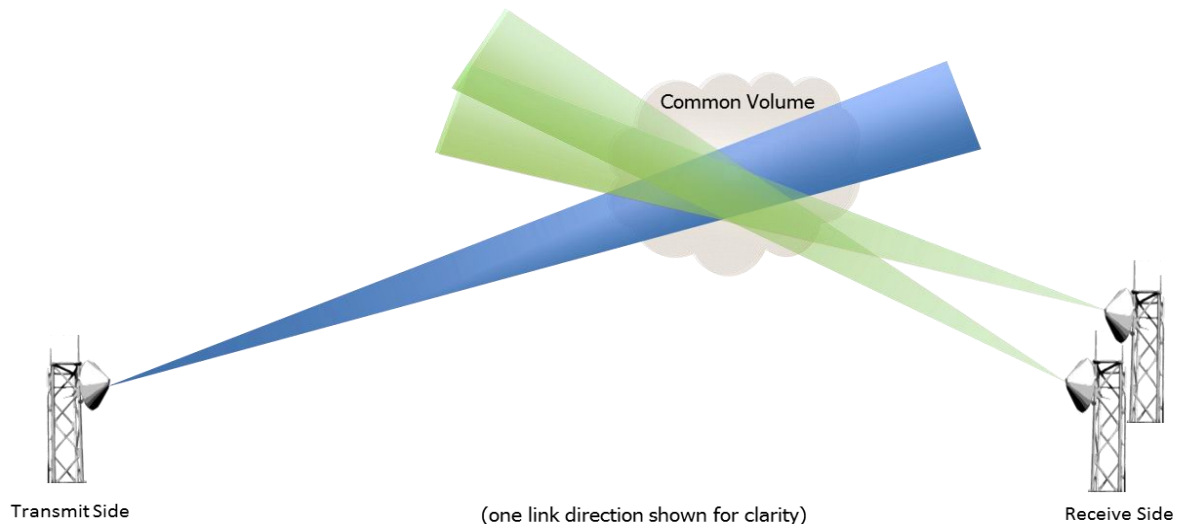


Figure 6.Space Diversity

4.4 Frequency Diversity

The concept of frequency diversity is that radio signals received on two different frequencies will fade independently (uncorrelated fading), and if combined will yield a signal with higher availability than either of the signals alone would have. Some rules are listed below.

- One antenna, dual polarity, is used for both transmit and receive
- Transmit on two frequencies, vertical and horizontal
- Can be combined with angle and space diversity to obtain quad diversity

- Requires 1% frequency spacing for effective diversity (approximately 50 MHz)
- The diagram in Figure 7 shows a dual frequency diversity system, with two transmitters on one antenna, and both signals being received on one antenna.

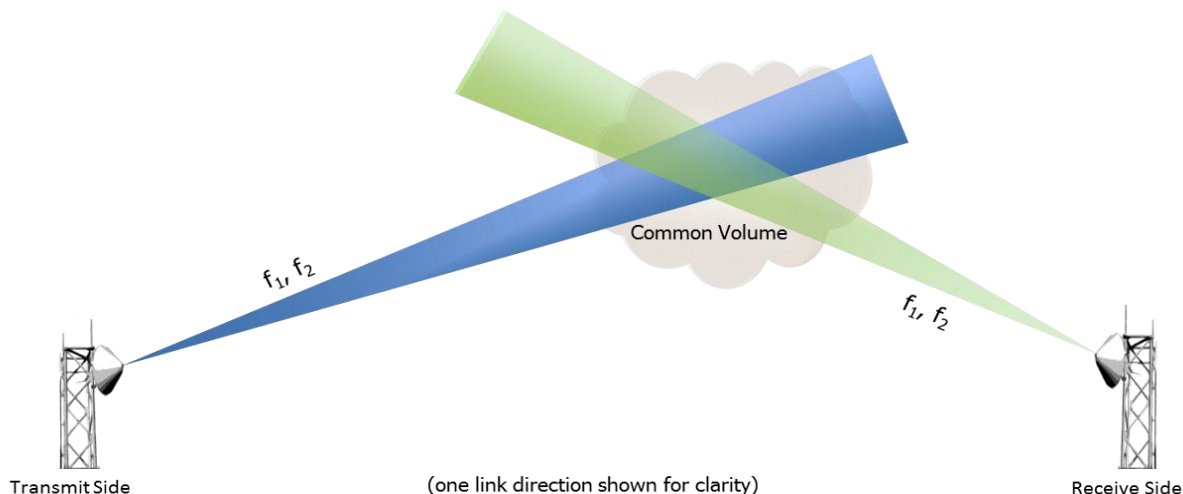


Figure 7. Frequency Diversity

4.5 Angle Diversity

The concept of angle diversity is that radio signals received via two different vertical (elevation) angles will fade independently (uncorrelated fading), and if combined will yield a signal with higher availability than either of the signals alone would have. Some rules are listed below.

- One antenna, dual polarity, is used for both transmit and receive
- Diversity reception is achieved by combining signals received at slightly different elevation angles.
- Uses a primary and an angle diversity feed horn on each antenna.

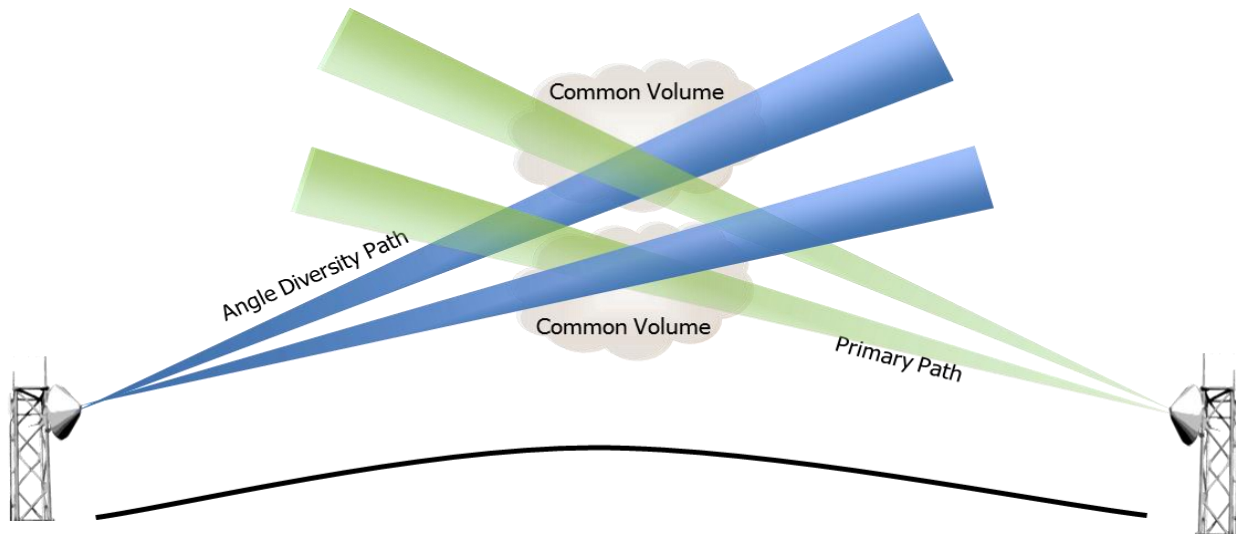


Figure 8. Angle Diversity

4.6 Polarization Diversity

Polarization Diversity utilizes the Horizontal and Vertical ports of a dual-port polarized feed to transmit a single frequency on both ports, while also receiving a single frequency on both the Horizontal and Vertical ports. Comtech has proven that polarization diversity is a valid diversity scheme in quadruple diversity configurations. Experience has shown polarization diversity to yield slightly lower improvement in performance than space or frequency diversity, with the tradeoff of requiring less equipment to implement. When paired with a more robust diversity scheme, polarization diversity provides a significant improvement to overall system performance.

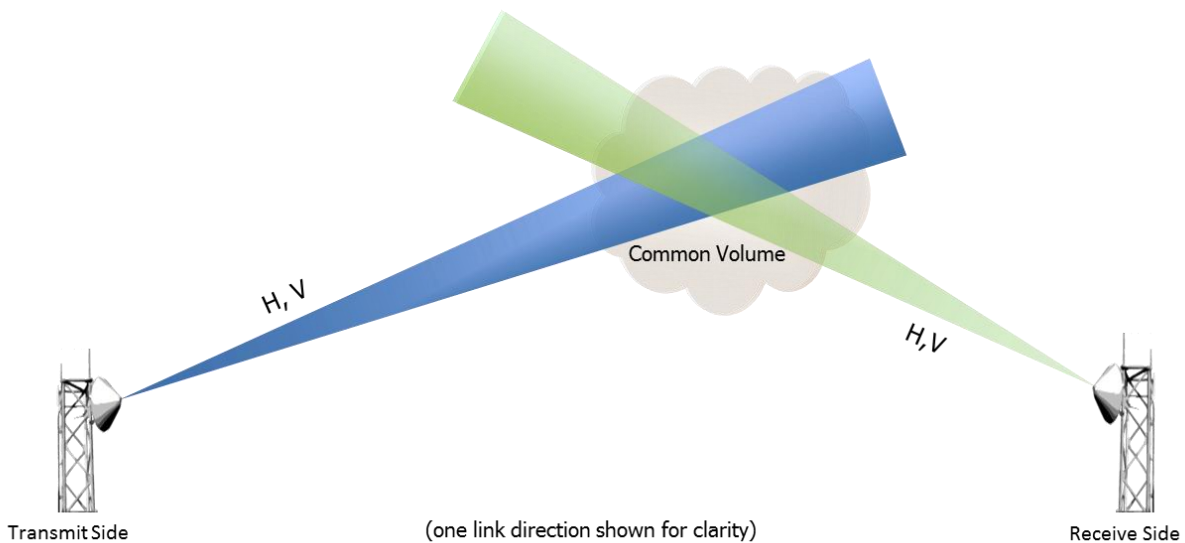


Figure 9. Polarization Diversity

5.0 CONCLUSIONS

Troposcatter systems were developed in the 1950s for beyond line of sight links between remote geographic areas where microwave and cable systems were not feasible. Troposcatter equipment has evolved from carrying several narrow band analog voice channels to high rate IP based traffic, up to 22 Mb/s. The large antennas from the 1950s have been replaced by much smaller antennas primarily because the licensed frequencies have gone up from 450 MHz to 4500 MHz, a factor of ten in wavelength and size. Tube amplifiers have been replaced by solid state amplifiers, and innovations such as forward error correction and automated power control incorporated by Comtech Systems into new modem designs have resulted in troposcatter solutions that are smaller, faster, more reliable, and use less power than previous systems. Troposcatter continues to provide a high value alternative to line of site, fiber optic, and satellite systems for point-to-point high-bandwidth, low latency communications. As the market leader, Comtech Systems continues to draw upon proven experience and technological innovation to stay at the forefront of troposcatter communications, and provide a dependable solution for over the horizon communications.