Satellite Communications and Data Communications Basics

Installation, Operation & Maintenance (IOM) Course

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iDIRECT

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Contents

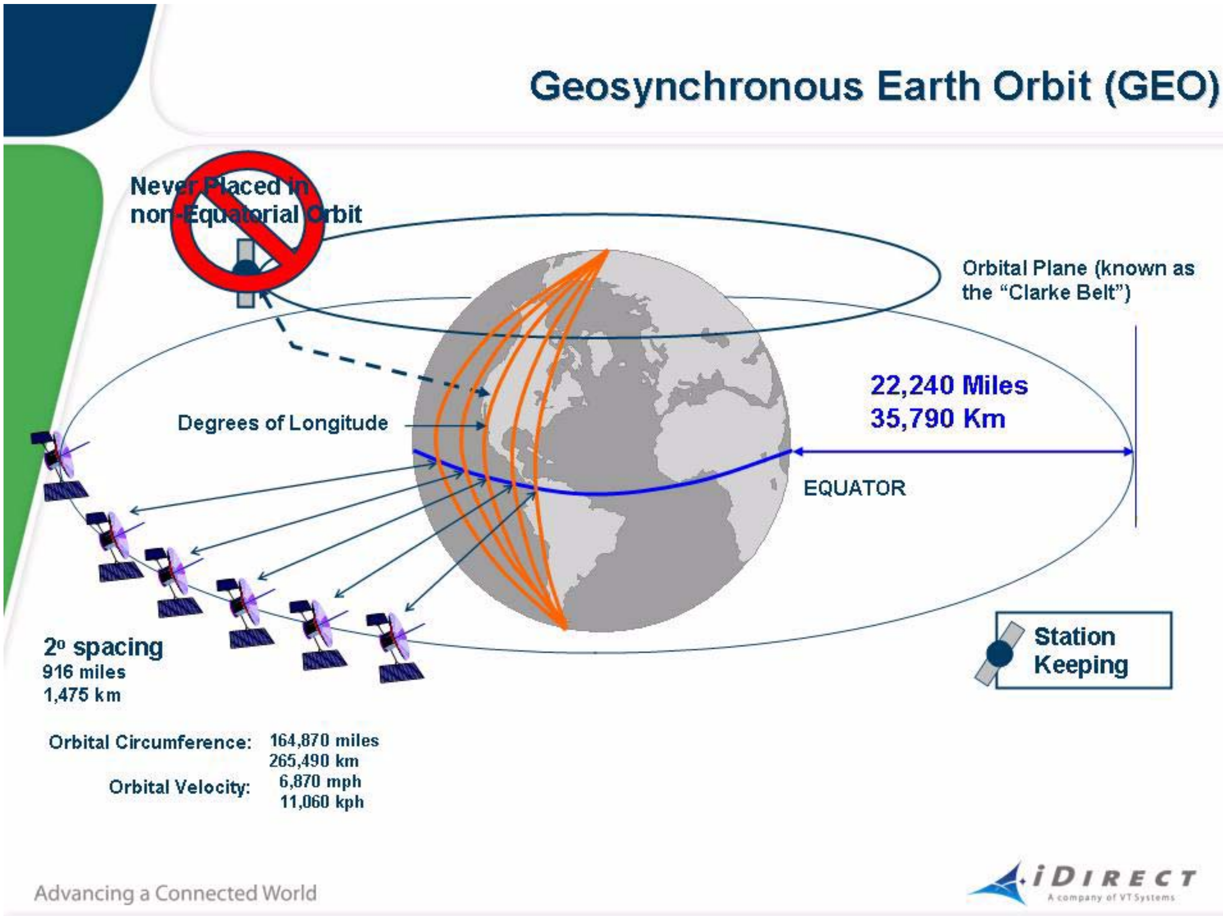
Satellite Communications Basics

Goal: Through lecture, presentation and visual display each learner will be able to understand and explain how Satellite Communication operates overall and within an iDirect network.

Objectives:

1. The learner will be able to identify basic terminology associated with any Satellite Communications operation scheme.
2. The learner will be able to identify and explain the typical satellite link to include components, carriers, conversion values and locations.
3. The learner will be able to describe the different frequency bands and frequency conversion utilized within a basic satellite network.
4. The learner will identify the frequency band utilized by applicable iDX components.
5. The learner will be able to discuss and identify: Propagation Delay, Frame Start Delay, Uplink versus Downlink, Upstream versus Downstream, DVB-S2 Downstream versus Legacy, and Star versus Mesh Topologies.
6. The learner will be able to explain the difference(s) in Modulation schemes versus Data Input.
7. The learner will identify the Line of Force, Foot Print, and Signal Quality as associated with any typical satellite foot print (beam widths).
8. The learner will be able to explain the basics of any Link Budget Analysis applicable to an iDX system.
9. The learner will complete the review exercises associated with this module with an accuracy rate greater than 80%.

1.1 Understanding Geo Satellites



The slide above depicts the **Geosynchronous Earth Orbit (GEO)** on satellites. It is located at zero degrees Latitude, directly over the equator in the area referred to as the **Clarke Belt**. The Clarke Belt is named after the eminent scientist Arthur C. Clarke, who is the father of modern day satellite communications. He predicted the use of man-made satellites in the early 1950s long before Sputnik and Telstar came into existence for use in global communications networks, like we use today.

Satellites orbiting in the Clarke Belt are only 2 degrees apart from one another making it a very tight fit when it comes to satellite orbits. It is interesting to note that the distance between satellites use to be four degrees, but this has been reduced over time due in part to the number of satellite now occupying space over the equator…and of course improved satellite technology. What this means for the installer is very simple: it is more important than ever today to be accurate when pointing a customer's antenna. Do you think they will ever reduce the distance to one degree? What do you think would be the resulting issues faced?

Geosynchronous orbits can be achieved only very close to the ring at 35,786 km or 22,236 mi directly above the equator. This equates to an orbital velocity of 3.07 km/s or 1.91 mi/s or a period of 1436 minutes which is almost exactly one sidereal day or 23.934461223 hours. This makes sense considering that the satellite must be locked to the earth's rotational period in order to have a stationary footprint on the ground. We will talk more in-depth about the issue of satellite footprints when discussing Global NMS.

In practice, this means that all geosynchronous satellites have to exist on this ring which poses issues for satellites that will be decommissioned at the end of their service lives, usually when they run out the fuel used to correct their orbits. These satellites are usually elevated to a higher graveyard disposal orbit. But while these satellite function they must remain in the **station keeping box** which is about 40 miles in diameter. Every so often the satellite provider "corrects" the satellite's drift to make sure it maintains the correct positioning within the station keeping box. The importance of keeping the satellite in this box cannot be overly emphasized.

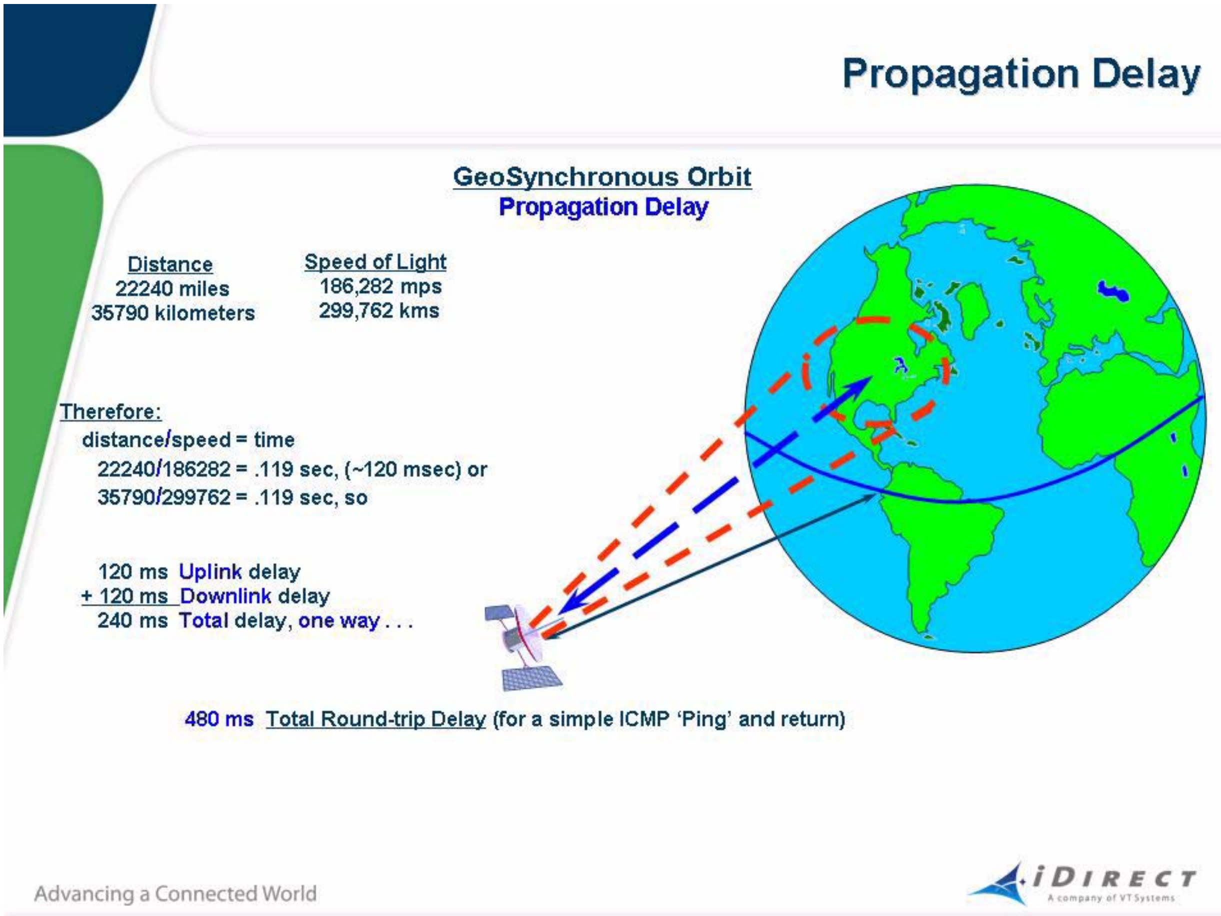
Satellites in these orbits must all occupy a single ring above the equator. The requirement to space these satellites apart means that there are a limited number of orbital slots available, thus only a limited number of satellites can be place in geosynchronous orbit. This has led to conflict between different countries wishing access to the same orbital slots (countries with the same longitude but differing latitudes). Countries located at the Earth's equator have also asserted their legal claim to control the use of space above their territory. Since the Clarke Orbit is about 265,000 km or 165,000 miles long, countries and territories in less-populated parts of the world have been allocated slots already, even though they aren't yet using them. The real issue presently lies over densely-populated areas like the United Stated of America as well as Europe countries.

A worldwide network of operational geostationary satellites are used for many different missions which include television, voice communications, meteorology, research, defense, and so on. All these satellites serve a particular benefit for many organizations.

Some people in the satellite industry utilize the term "**geostationary**" orbit when discussing the satellite's orbit. There are those who dislike the term "geostationary", because the orbit is not actually stationary (in fact, the term stationary orbit would be an oxymoron) and prefer to use "**geosynchronous**" because it emphasizes the key point that the orbit is not actually stationary, but synchronized with the motion of the Earth. Both terms are acceptable but we at iDirect will go with the term Geosynchronous for our discussion.

Now that you know all about the Clarke Belt and geosynchronous orbits let's discuss how this distance from the Earth effects communications. On the next slide we discuss one of the major issues facing satellite communications; that being Propagation Delay. You can't get around this because it is a matter of physics.

1.1.1 Propagation Delay



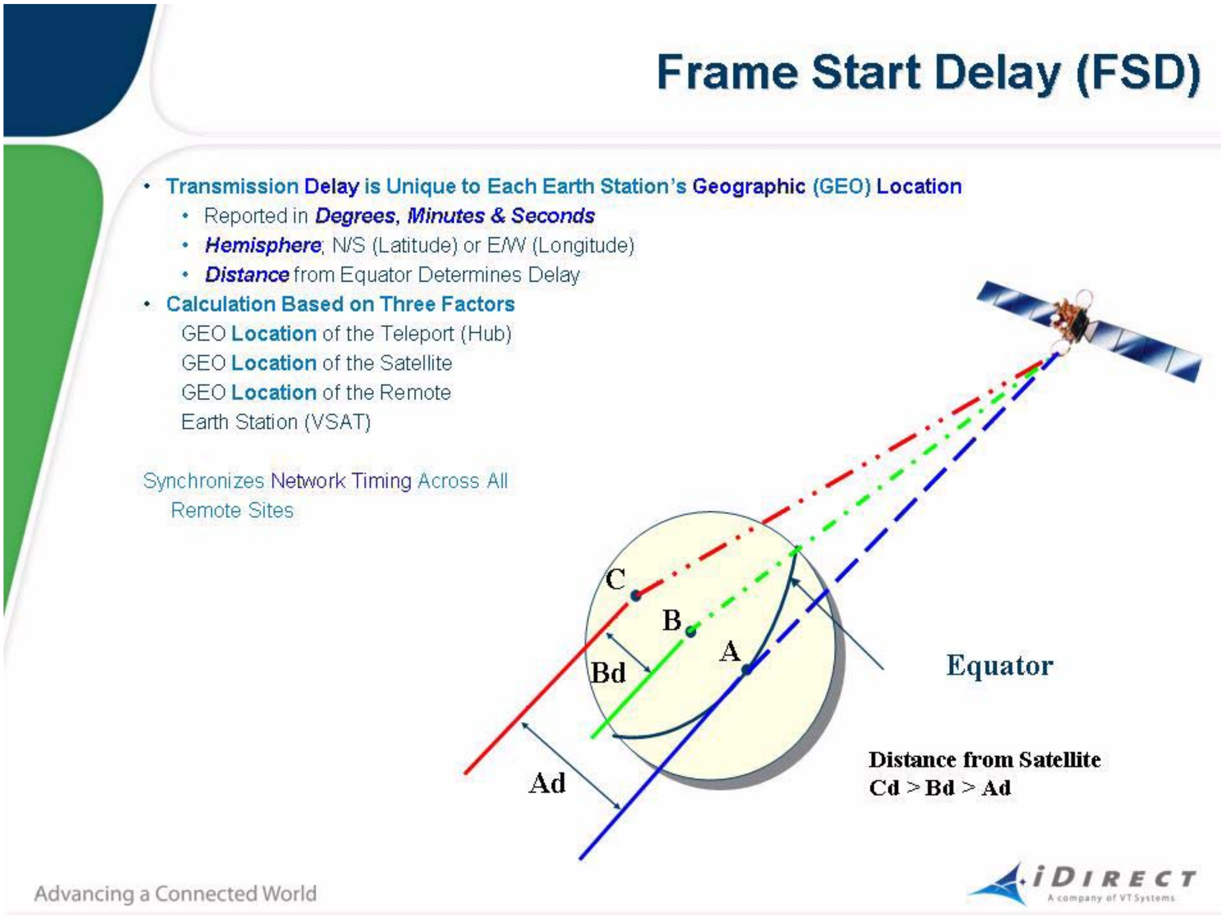
What is propagation delay? What type of delay do we expect on a satellite network? What is the cause of satellite communications inherent delay?

In networking, **propagation delay** is the amount of time it takes for a certain number of bytes to be transferred over a medium. In satellite communications, propagation delay is a result of physical laws that we cannot overcome except through a number of proprietary techniques. Do we actually overcome the fact of distance, transmitting and receiving of signals? No. But we do make allowances for this fact and give an account for this delay. We will discuss how we accomplish this further in this training course.

As we mentioned previously, because the satellites located on the Clarke belt are approximately 22, 236 miles above the earth surface, we can expect uplink delays of 120 ms. For this reason a one-way trip from the remote location to the hub location will take approximately 240 ms. Round trip delay then can be approximately 500 ms. In addition to this delay, more delays could and will occur because within a satellite system network there are additional mediums such as IFL cables, connectors, amplifiers, converters, etc.

Did you know that propagation delay increases with operating temperature, marginal supply voltage as well as an increase output load capacitance? The latter is the largest contributor to the increase of propagation delay. To overcome these issues we will discuss the benefits of TCP acceleration or spoofing.

1.1.2 Frame Start Delay



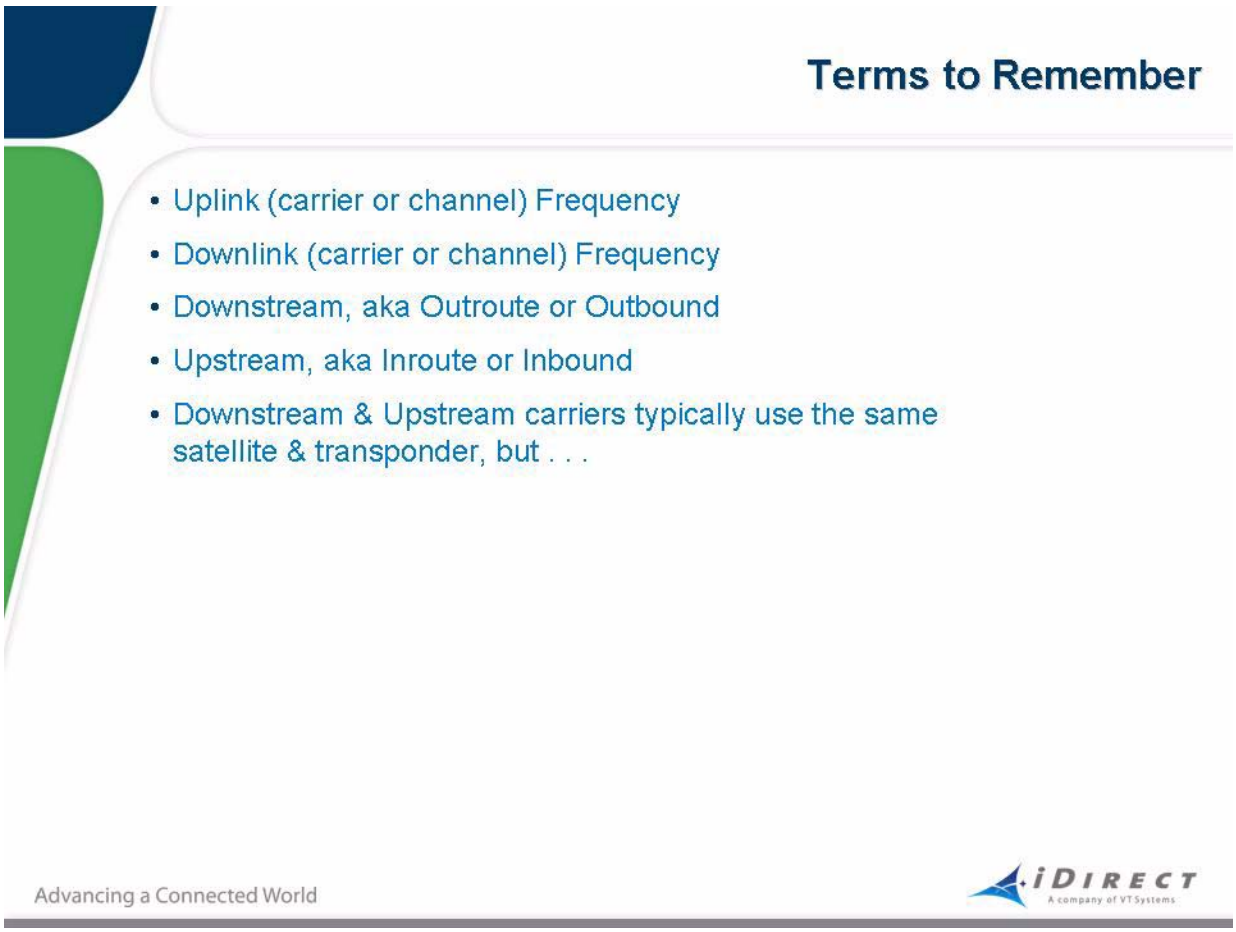
What is frame start delay and why is it important in the satellite communications scheme? Well, let's see if we can come up with a working definition of Frame Start Delay as it applies to iDirect equipment and system. But before we do that, do you have a working definition of Frame Start Delay?

The calculated propagation delay value is known as **Frame Start Delay or FSD**. In the example shown, Site A is closest to the satellite and Site C is furthest from the satellite so it would therefore require the least amount of delay. Transmission Delay is unique to each Earth station's geographic location. What does all this mean to user as an individual utilizing iDirect equipment?

In a TDMA network, the Protocol Processor sends out a Burst Time Plan (BTP) to all of the remotes within your network. This Burst Time Plan is based on several different calculations. The Protocol Processor is keeping constant attention to these calculations in order to (1) acquire new remotes into the network and (2) make certain all of the remotes are transmitting at the correct time and the correct timeslot in the TDMA frame.

This is the very reason GEO location is so important when it comes to frame start delay. The correct GEO coordinates need to be configured for the Teleport, the satellite, and all of the remotes within your network. This way the Protocol Processor can send BTPs to each remote in the network to indicate when to transmit and how much bandwidth they have to transmit with. Remotes which are further away from the satellite will have to transmit first while remotes closer to the satellite will wait a fraction of a second more to transmit in order to be on a different timeslot within the same TDMA frame.

1.1.3 Terminology



We use the above slide to eliminate some of the confusion that exists between **Downstream** versus **Upstream**, and to cement in your mind the direction for each as it applies to the basic iDirect network. Most of you know the difference between uplink and downlink but we think it is important to take the time to remove any doubt regarding Downstream versus Upstream. These are important carrier terms used in iDirect's Graphical User Interface. You may also locate a definition of these terms in the Glossary.

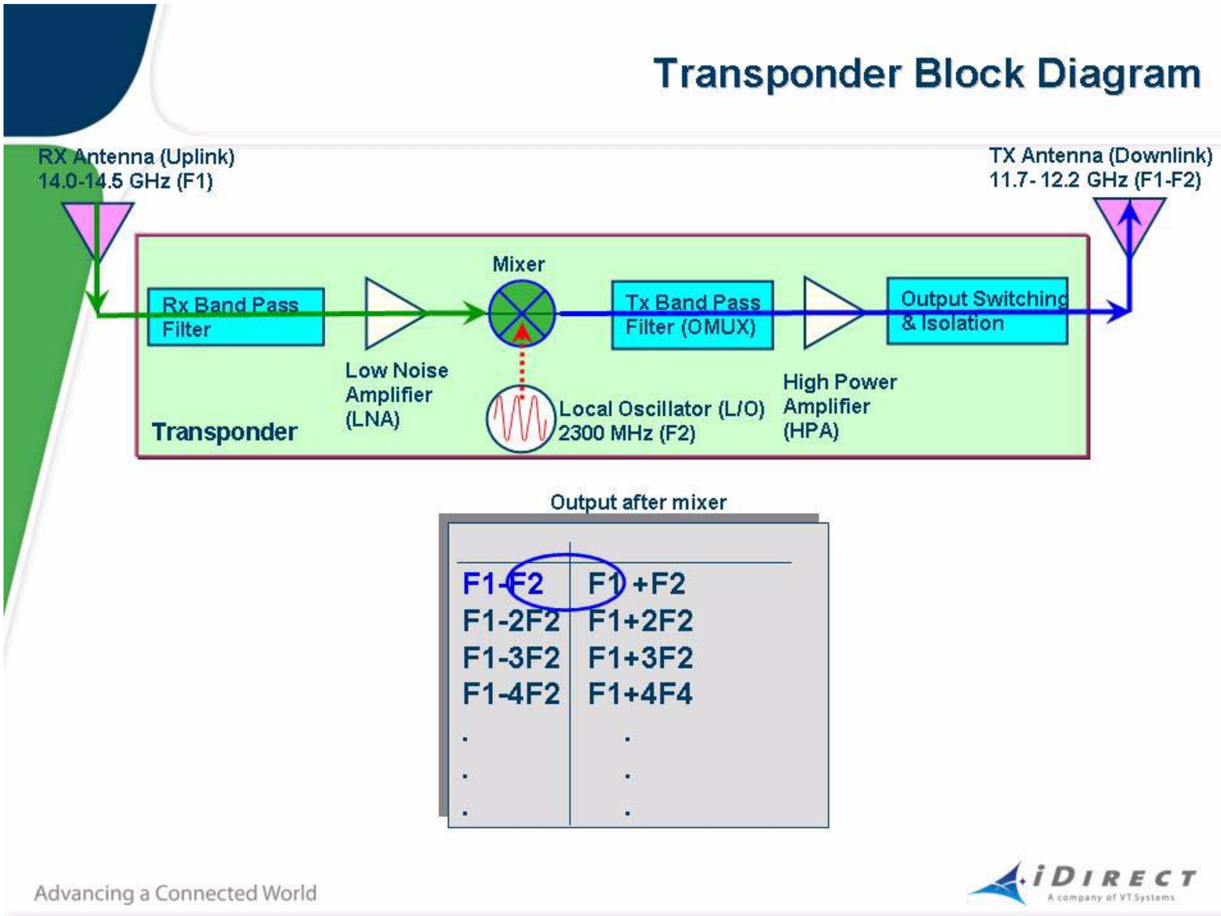
Uplink is from any earth station's transmission toward the satellite and **downlink** is a transmission from a satellite towards the earth station. In an iDirect system, Downstream is in the direction of the hub's transmission to the remotes and Upstream is in the direction from each individual remote towards the hub.

- **Uplink** — Transmission path from earth to satellite
- **Downlink** — Transmission path from satellite to earth station
- **Downstream** — Signal (carrier) frequency from hub to Remotes.
  - Downstream Uplink (Hub to Satellite).
  - Downstream Downlink (Satellite to Remotes).

- Remember that Downstream is also referred to as Outroute or Outbound.

- **Upstream** — Signal (carrier) frequency from Remotes to Hub.
  - Upstream Uplink (Remotes to Satellite).
  - Upstream downlink (Satellite to Hub)

1.2 Satellite Components



So many different things go into the delivery of information over a satellite network. Before the frequency or information or signal, or whatever you want to deliver can travel anywhere you need the proper equipment. But you were aware of this fact, weren't you? Also, the components of the satellite are very important. We will cover the major satellite components briefly but our primary focus in the slide above is the transponder.

The major components of any satellite include: 1) the Antenna, which receives composite spectrum across entire uplink; 2) Transponders; 3) Amplifier Transmit; and 4) Antenna, which transmits downlink to receiving earth station.

Receive (Rx) Antenna – Receives composite spectrum across entire uplink

- Antenna, divider and receive Bandpass Filter
- Bandpass Filter allows only desired signals to pass, rejecting all others

Transponders – typically many, with varied configurations

- Receives transmission from earth via uplink, amplifies, converts and retransmits the signal (as the downlink) to receiving earth stations

- Includes receiving antenna, broadband receiver and frequency converter, with mixer for frequency translation
- **Amplifier - Receive**
  - The **Low Noise Amplifier (LNA)** amplifies the received signal

Frequency Converter → Mixer (per transponder)

- Intermediate step between the receive and transmit components
- Utilizes a known stabilized frequency source (Local Oscillator, or L/O)
- Translates received Uplink frequency into transmitted Downlink frequency

Amplifier - Transmit

- The **High Power Amplifier (HPA)** increases the power level of the transmitted signal

Transmit (Tx) Antenna – Transmits downlink to receiving earth station

- Antenna, combiner/isolation and transmit Bandpass Filter

As we have stated, these are the major components which make up the satellite. The RF signal flows from the earth station terminal towards the satellite receive antenna. The signal is then transferred to an amplifier to strengthen the signal which has travelled over 22,000 miles. The signal also goes through a bandpass filter filtering out all the out-of-band noise the RF signal picked up on its journey to the satellite. After the RF signal is cleaned up, it is transferred through a local oscillator or mixer which downconverts the signal. The signal is sent through another amplifier which strengthens the signal for transmission back down to the earth station. Last, but not least, we have the transmit antenna which sends/transmits the signal down to the earth stations receive terminal.

In the past, older satellites typically had a total bandwidth of 500 MHz split into multiple transponders. Two transponders used different polarization and this allowed the reuse of the same frequency without interference.

Modern satellites now have many more individual transponders (T-12 has 38 @ 54 MHz) with bandwidths of 54 and 72 MHz depending on frequency and designated use. They use **Time Division Multiplexing (TDM)** and in some instances may contain several antennas, each allowing a focused footprint of coverage to a designated geographic region on the Earth. These “focused” footprints are called **Spot Beams**.

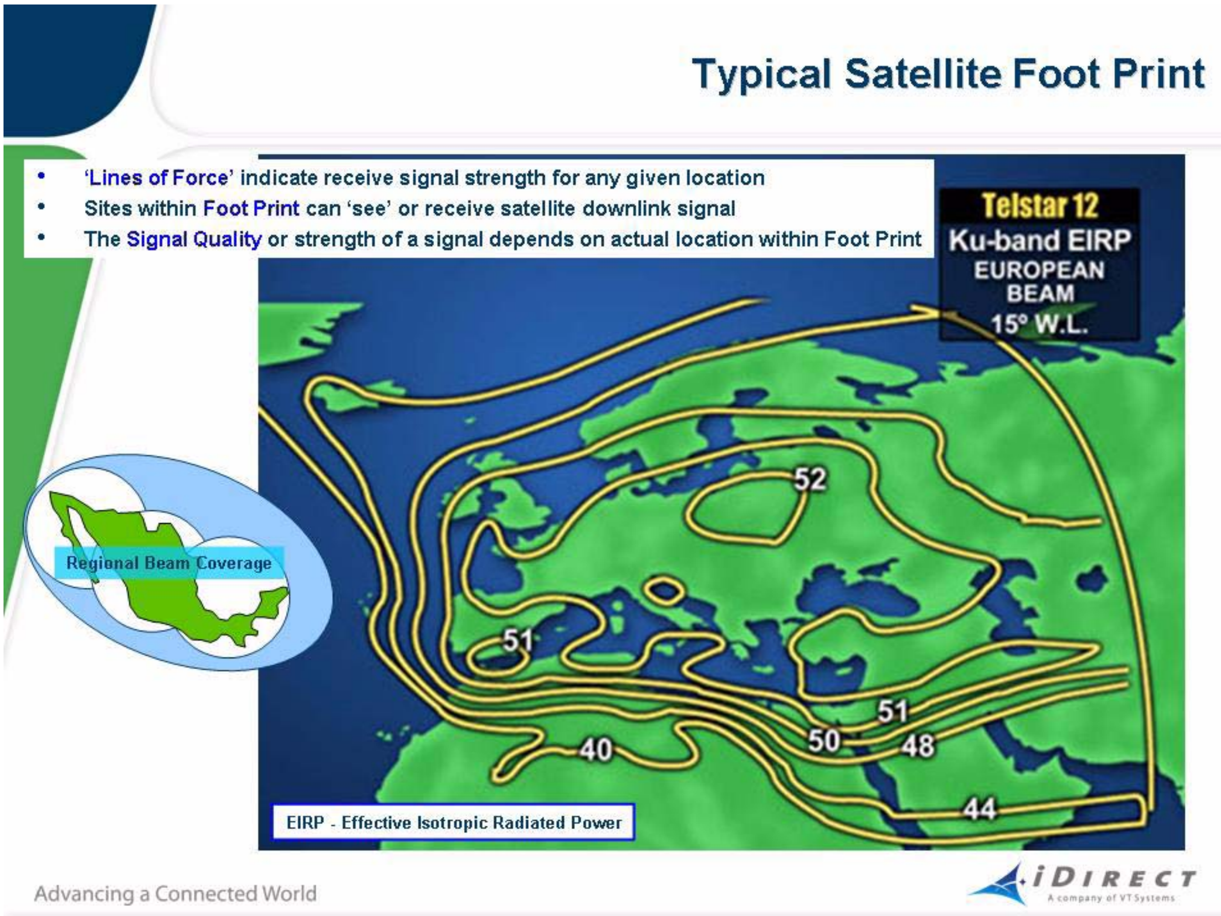
The **Low Noise Amplifier (LNA)** detects the low level signal from within the space generated noise and amplifies the desired signal and the noise, but the signal is amplified more than the noise, making it easier to detect. This is why the LNA is installed as close to the antenna as possible, to eliminate any additional thermal noise coming from the feed. The **Mixer** and **Local Oscillator** signals are combined to convert the incoming Uplink carrier frequency to the Downlink carrier frequency.

The band pass filter allows only the desired frequency to pass through to the HPA, rejecting all other RF energy. Some satellites contain an **IMUX (Internal Multiplexer)** which allows switching between different transponders on the same satellite. Finally, the **High Power Amplifier (HPA)**, amplifies the signal to be fed into the transmitting antenna for rebroadcast as the downlink carrier signal.

The diagram above typifies the transponder block within a satellite. The satellite receives the RF signal coming from the earth station with the left receive antenna which is shown on this slide with an F1 designation. The signal travels through the satellite transponder to the RX bandpass filter. The RX bandpass filters out some of the noise that the original signal has picked up along the way and outputs the signal to the Low Noise Amplifier. The Low Noise Amplifier takes the weak signal which has just travelled over 22,000 miles and outputs a stronger signal to the transponder mixer or local oscillator identified here by the F2 designation. The Local Oscillator is responsible for taking the original RF signal and reducing this signal by the exact amount or rating of the Local Oscillator. In the case of the diagram shown, we are removing 2300 MHz from the 14.0 to 14.5 GHZ KU frequency.

The signal output is sent to another bandpass filter before the output is sent to a HPA which amplifies the signal so it has enough power to make the 22,000 mile journey back down to the earth station. The Transmit antenna then transmits the original RF signal minus the 2300 MHz. The reasons we mix the original RF signal are to (1) prevent signal interference between your uplink signal from the earth station and your downlink signal back down to your earth station, and (2) deal with atmospheric water energy absorption.

1.2.1 Satellite Footprints



The **footprint** of a communications satellite is the area on the earth that its transponders delivers or offers coverage. It also determines the satellite dish diameter required to receive each transponder's signal. There are different maps for each transponder, or in most cases, a group of transponders since each may be aimed to cover different areas of the group. These "footprint maps" usually show either the estimated minimal satellite dish diameter required or the signal strength in each area measure. This strength is displayed in dBW.

The footprint diagram above provides a picture or snapshot of the signal level received at a particular location in the region with respect to the **Effective Isotropic Radiated Power (EIRP)** received from the satellite. This gives you a general idea of the receive signal level might be for different areas of the European region. Of course, the higher the number, the greater the signal strength should be. How does this affect the size of the dish at the receiving earth station?

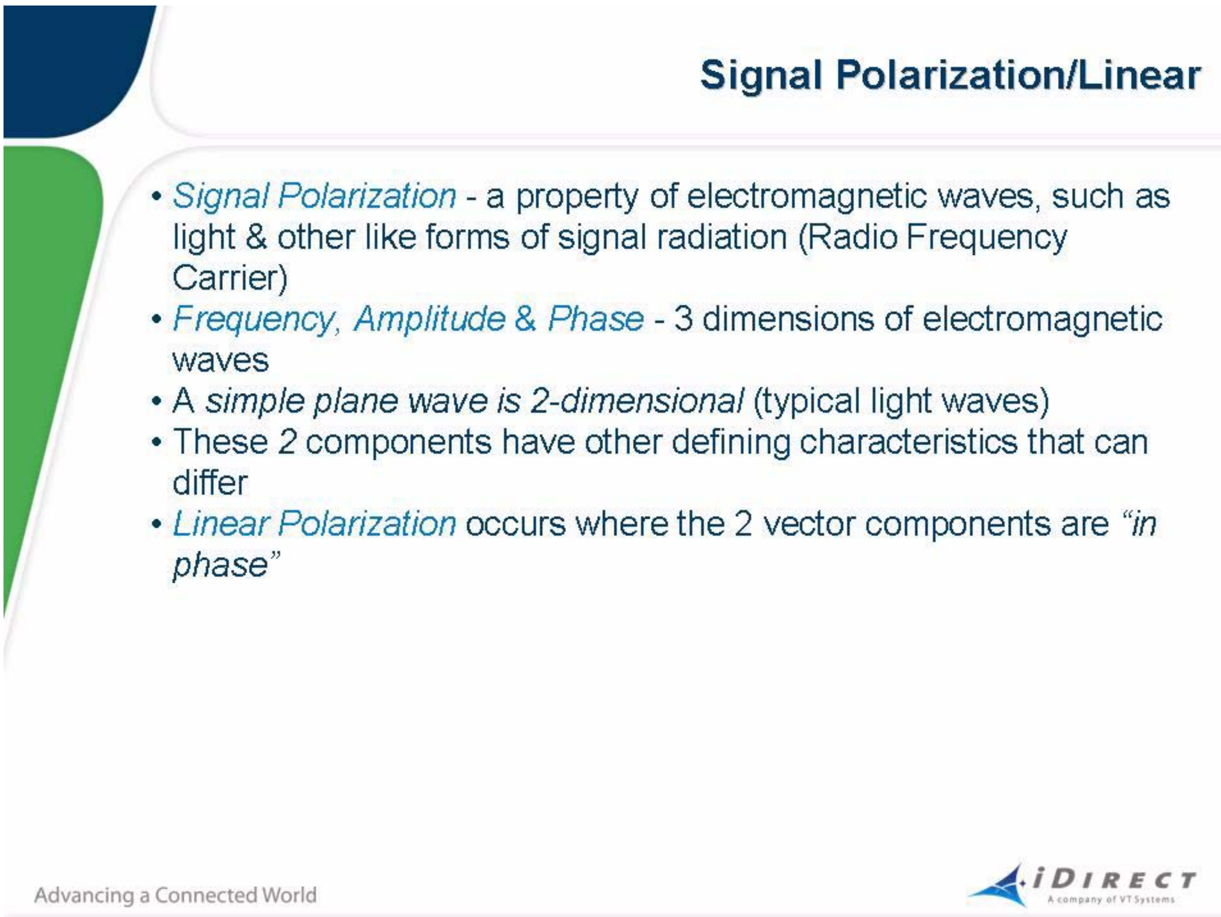
For a given frequency and power level received in Paris, that same signal would be approximately 2-3 dB lower in Moscow.

The EIRP is the calculation of power measured one meter away from the antenna of the source transmission, in the above case, the satellite. This in extremely important to the remote location within the satellite footprint since this will affect the overall transmission and reception of remote traffic. Location of the remote will also affect what type of BUC may be required depending on whether the remote is closer to the center of the footprint or located on the outer edge of the footprint. Additionally, this plays an important role in link budget requirements for your network. Stated in another way, the EIRP is the amount of power that is evenly distributed in all directions minus the transmission line losses plus the antenna gain, emitted to produce the peak power density observed in the direction of the maximum antenna gain.

Beam shaping, another entity of this section on satellite footprints, must be considered. Beam shaping is a powerful technique utilized in an effort to increase the effectiveness of a satellite. For example, a single elliptical beam is compared with shaped-beam coverage from combining three nearly circular beams (shaded). The single elliptical beam radiates about half its energy outside the land mass, and is therefore less efficient. (Do you know understand why this occurs?)

1.3 Signal Polarization

1.3.1 Linear Polarization



For simple signal polarization, all electromagnetic waves vary in three dimensions. Those dimensions are **Frequency**, **Phase**, and **Amplitude**. One type of waveform, regardless of polarization type, will exist using the same given frequency. With frequency fixed, the focus when examining the waveform is then on phase and amplitude, the other two dimensions.

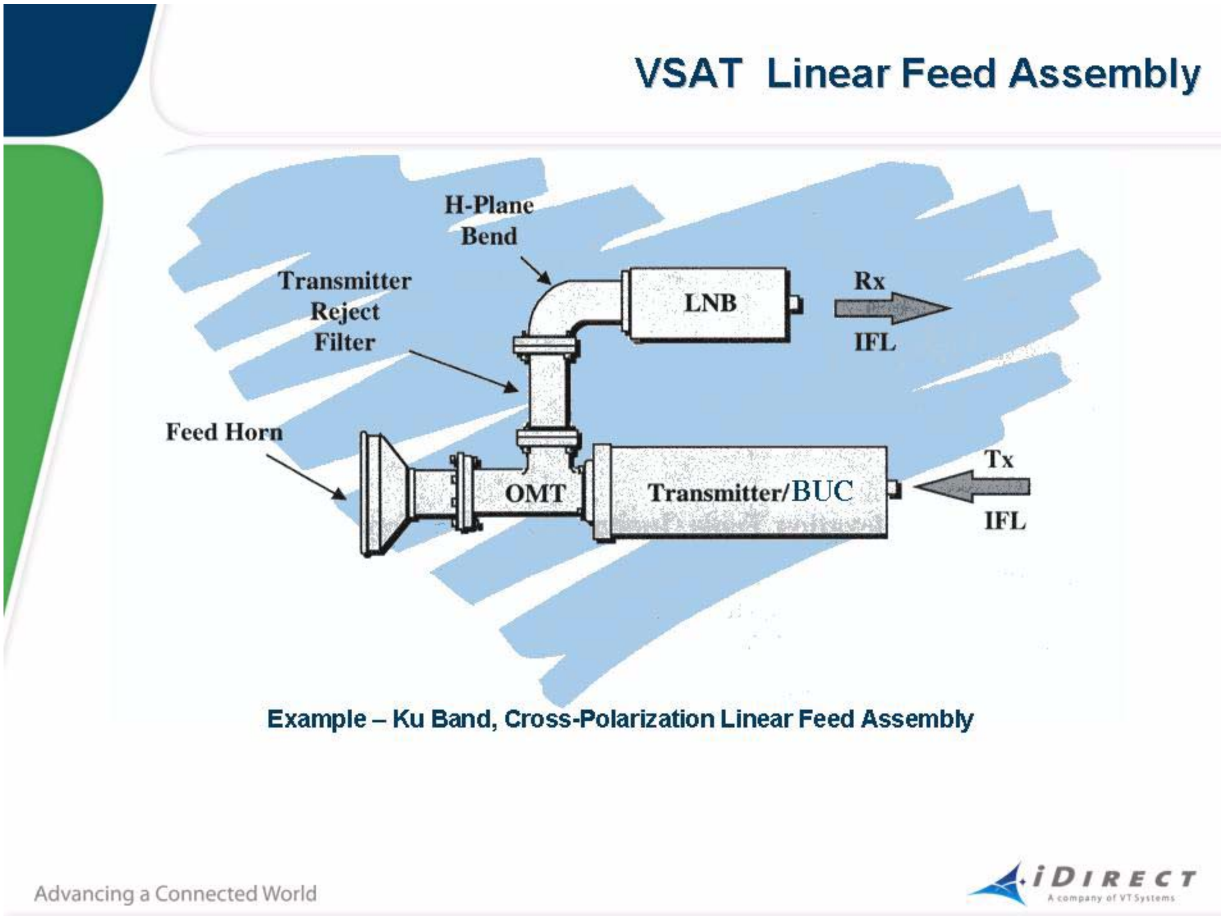
If the phase is found to be identical, meaning the Horizontal (H) and Vertical (V) components are *in phase*, this is the definition of **Linear Polarization**. The relative amplitude then (the remaining dimension) determines if the waveform is considered horizontally or vertically polarized.

If the H and V components are the same in Amplitude, but vary in Phase by exactly 90 degrees, this defines **Circular Polarization**, which will be discussed later.

Key points for our purposes are:

- Linear Polarization is more common when using Ku-Band RFTs. (C-Band systems use Circular Polarization almost exclusively.)
- Linear polarization is comprised of both Horizontal and Vertical components, which are exactly “in phase”, and have exactly the same frequency as stated above. This means there is always a component in both the horizontal and the vertical plane for each frequency in the spectrum. How we tune or extract the energy from the wave establishes the operational mode.
- The polarization setting (direction or degree value) is related to how the two signals vary in amplitude in relation to the other.

1.3.2 Linear Feed Assembly



Important terms to remember:

BUC — Block Up Converter

LNB — Low Noise Block (Down Converter)

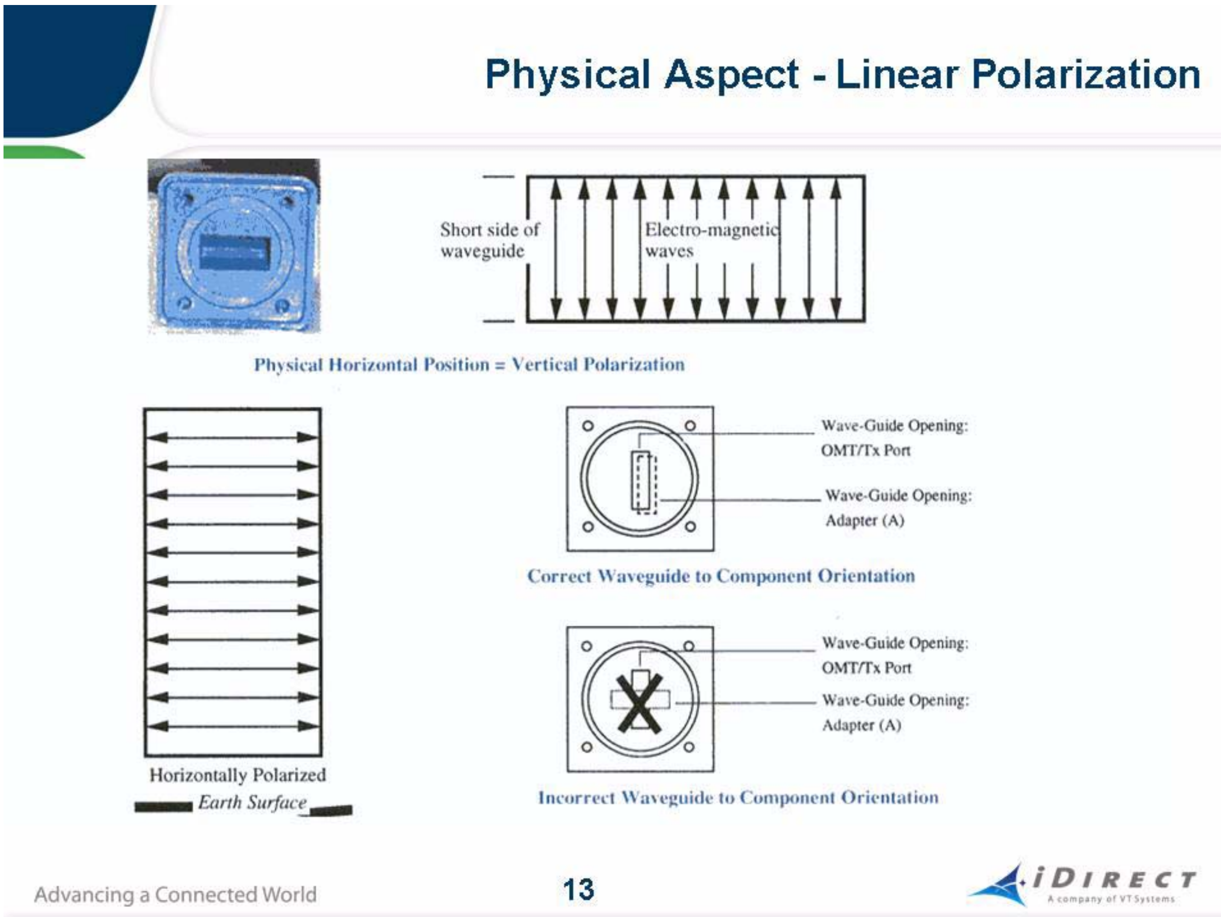
OMT — Orthogonal Mode Transducer (Allows for simultaneous TX/RX of opposite polarization signals using the same or common antenna feed assembly)

Orthogonal — Relating to or composed of right angles. Having a set of mutually perpendicular axes

Cross-Pol — Cross-Polarization, meaning opposite linear polarization is used for TX and RX

Co-Pol — (not shown) Coincident-Polarization, using the same linear polarization for TX and RX

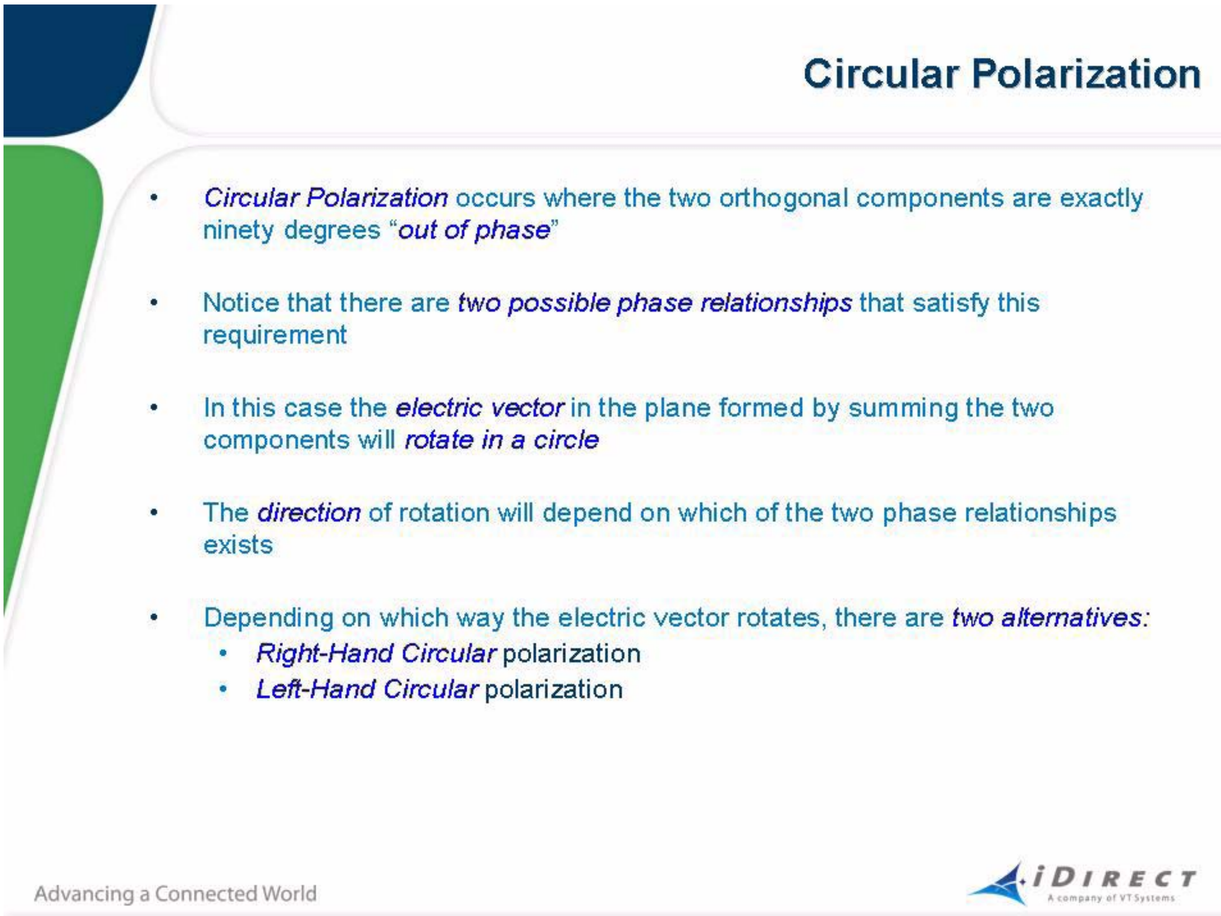
1.3.3 Linear Feed Assembly Components



This diagram shows the physical orientation of **Linear Feed Assembly** components: the short side of the waveguide opening is the determining factor. The key point to remember is proper physical orientation is essential to good signal quality.

In addition, the Horizontal Polarized surface (which you think would actually be vertical, from the diagram shown, since it shows the waveguide shape as rectangle from top to bottom) actually has the waves bouncing left to right or right to left within the waveguide. Also, looking at the Vertical surface you would think this would be horizontal, but again, the waves are actually bouncing from top to bottom giving it a vertical shape in nature.

1.3.4 Circular Polarization

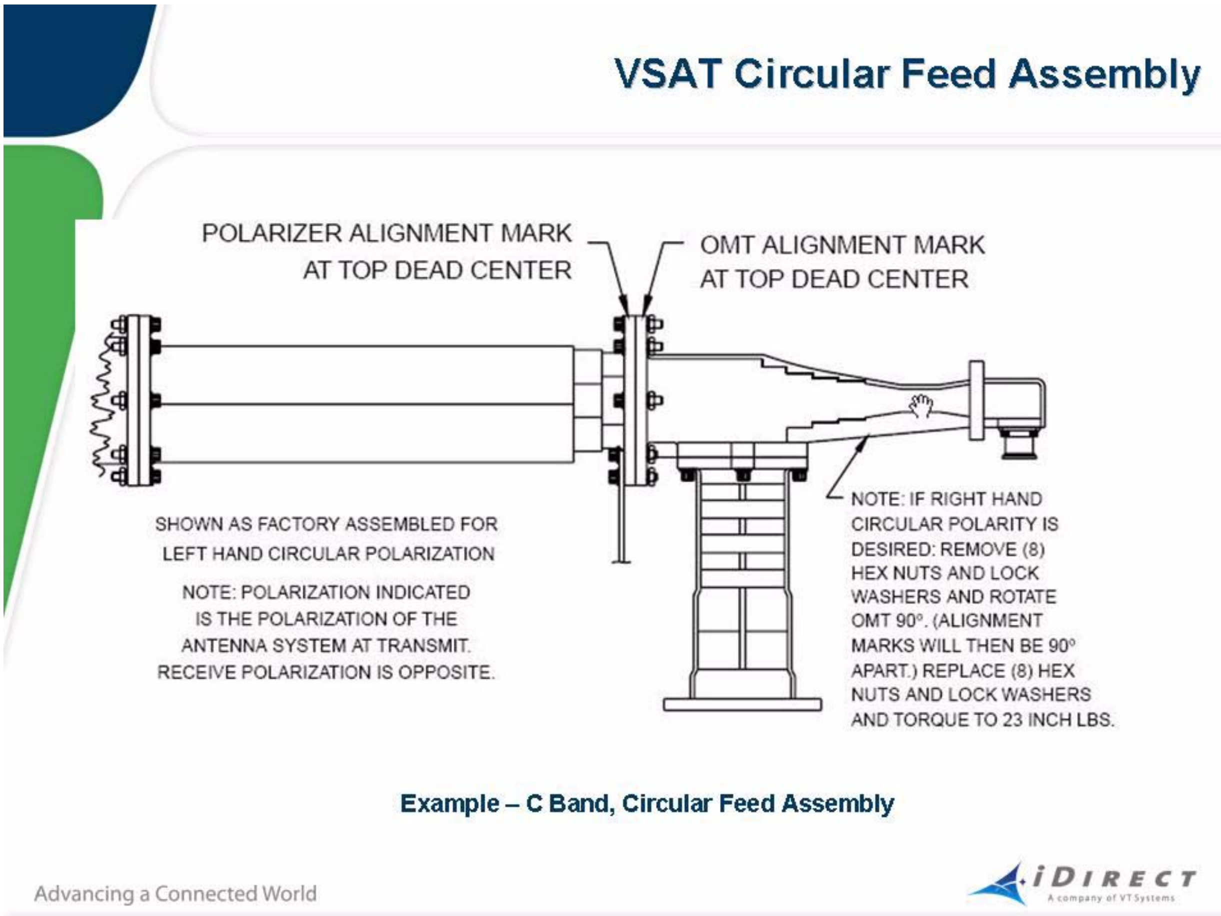


Now that you have a solid understanding of Linear Polarization, let's turn our attention to **Circular Polarizatio**n. Circular, as well as elliptical polarization is possible because the propagating electric and magnetic field can have two orthogonal components with independent amplitudes and phases and the same frequency.

For Circular polarization, both Frequency and Amplitude are equal, so only their Phase relationship determines the polarization type. The direct relationship between the phases — which one is ahead of, or leading the other — determines the direction of rotation. Circular polarization doesn't require tuning or nulling out the opposite polarization component as is required for Linear. The polarization is fixed as either right-hand or left-hand circular and the proper type of feed is selected and installed; no further adjustment is needed. Circular polarization predominates with C-Band networks.

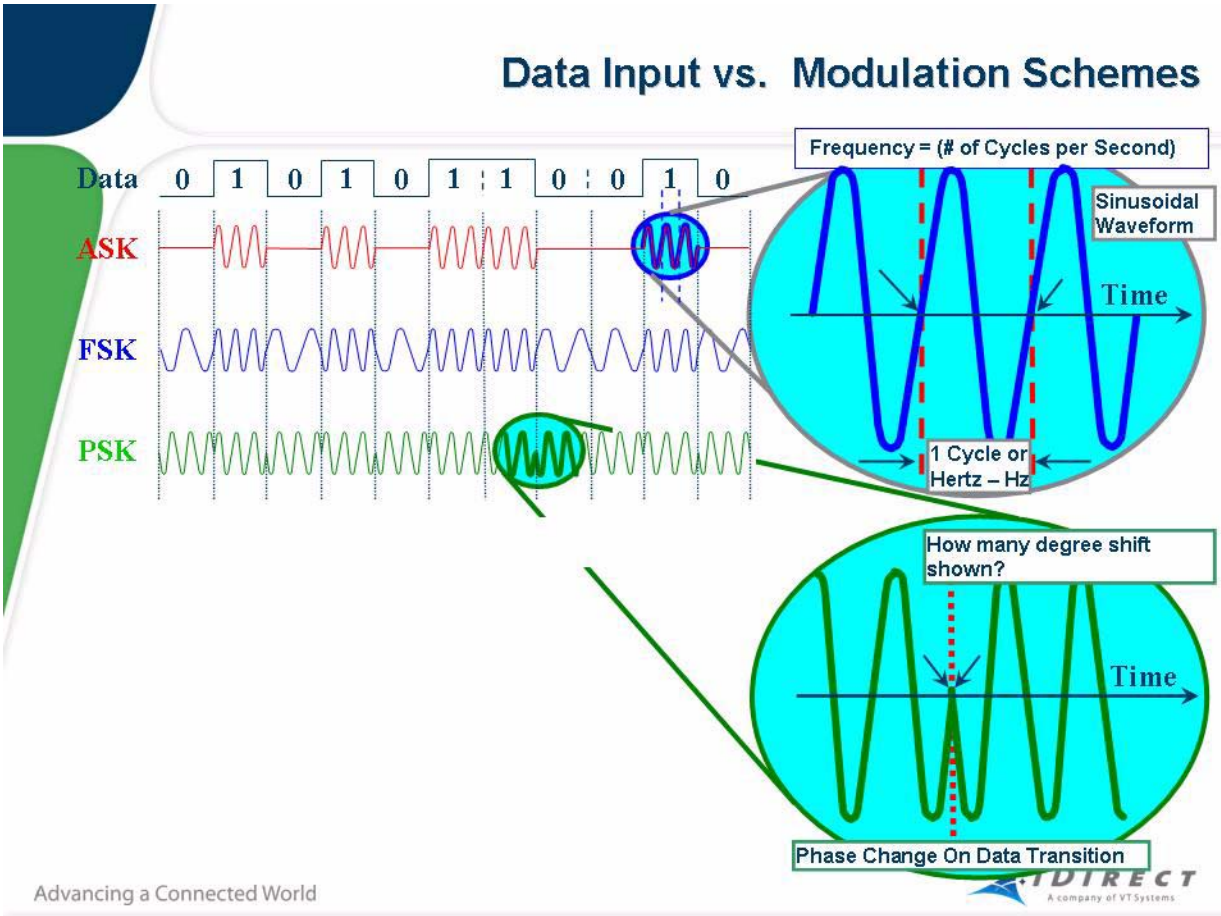
Circular polarization operates in more of a helical type arrangement where you can have two types of circular polarized signals. Looking at a transmission from the remote towards the antenna feed horn in the direction of transmitting towards the satellite, right-hand circular polarized signals would rotate clockwise and left-hand circular polarized signals would rotate counter clockwise. Circular polarization also helps reduce the amount of rain fade in the 12 Ghz range of transmissions.

1.3.5 VSAT Circular Feed Assembly



This slide shows an example of a VSAT Circular Feed Assembly.

1.4 Modulation



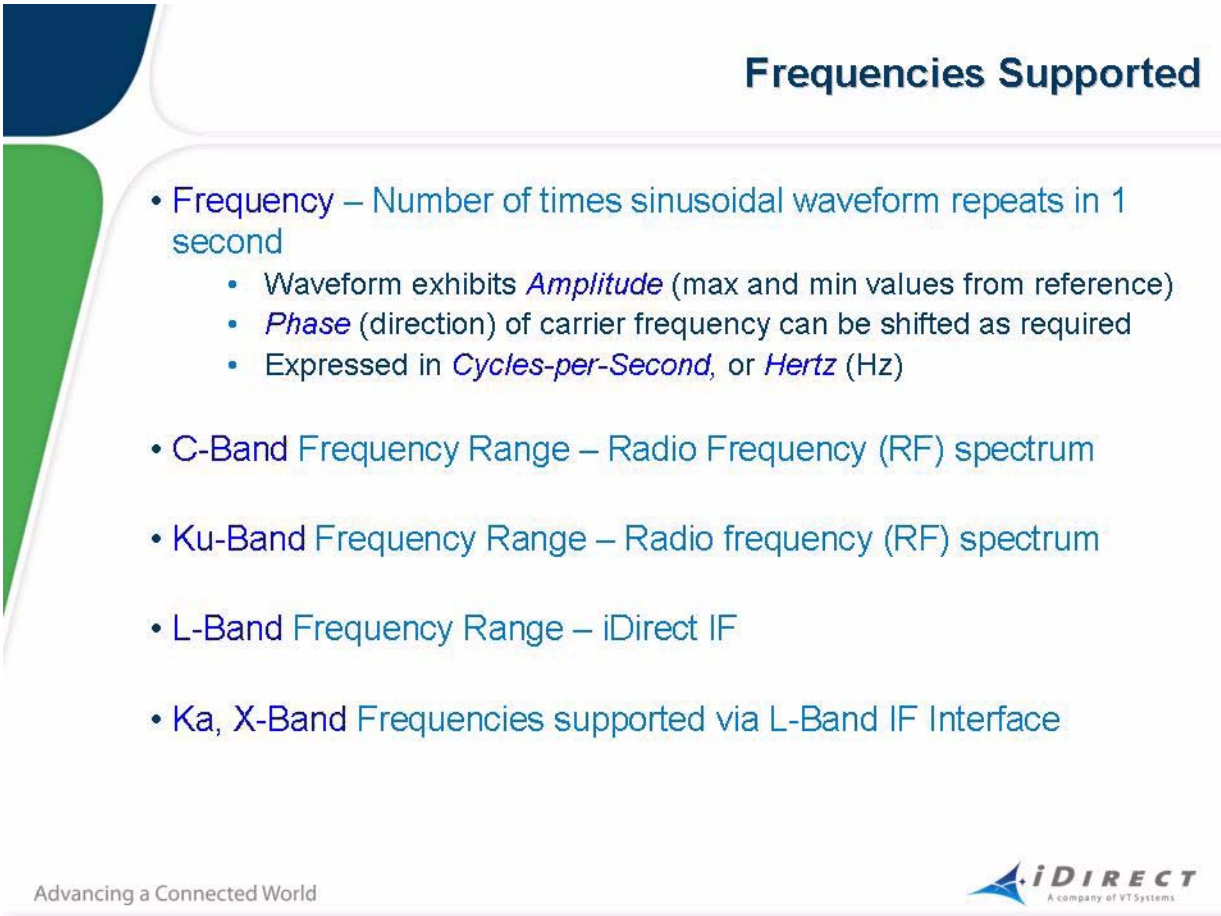
Digital signals are modulated in order to take full advantage of existing circuitry such as telephone lines, and also to increase the data rate. **Modulation** can be defined as the changing of the carrier wave in sympathy with an information signal, or digital data in this case. Different modulation schemes are utilized in order to convert the digital data stream into analog RF symbols. There are several different methods which can be utilized to convert data bit to an RF symbol. What are some of those methods?

In the picture above, the information signal is the digital data which represents the bit stream 01010110010. This “intelligence” is then modulated using one of three possible methods:

- **ASK. Amplitude Shift Keying**. Uses one amplitude at a fixed frequency to convey a logic high, and zero amplitude to convey a logic low.
- **FSK. Frequency Shift Keying**. One frequency is used to convey a logic high, and another to convey a logic low.

- **PSK. Phase Shift Keying**. Pure PSK relies on the transmitter and receiver being perfectly synchronized at all times, so that the reference used by the demodulation process is the same as that used for modulation.
- **DPSK. Differential Phase Shift Keying**. This is a more common modulation scheme which uses the phase of the preceding signal element period of reference.

1.5 Frequencies



There are many frequencies utilized in networks configured to deliver satellite signals. However, it is very important for you to remember that iDirect's equipment ONLY operates on L-band IF frequency. In order to convert to C, Ka, Ku or X bands our system requires the use of external equipment to complete the conversion: Upconverter, downconverter at the hub and BUC, and LNB at the remotes.

In addition, iDirect strictly works on L-band frequencies as far as Hub Line Cards and remotes are concerned. The same principles apply with this equipment also: In order to work with Ku, Ka, C and X bands we require external equipment to convert the signal to and from these signals. At the teleport locations we rely on upconverters and downconverters to convert IF to RF. See the frequency ranges listed below.

C-Band Frequency Range – Radio Frequency (RF) spectrum

- Typical Uplink Frequency 5925 MHz to 6425 MHz
- Extended Uplink Frequency Ranges – 5850 MHz to 6425 MHz
- Typical Downlink Frequency 3700 MHz to 4200 MHz

- Extended Downlink Frequency Ranges also supported

Ku-Band Frequency Range – Radio frequency (RF) spectrum

- Typical Uplink Frequency 14000 MHz to 14500 MHz
- Extended Uplink Frequency Ranges – 13750 MHz to 14750 MHz
- Typical Downlink Frequency 11700 MHz to 12200 MHz
- Extended Downlink Frequency Ranges – 10950 MHz to 12750 MHz

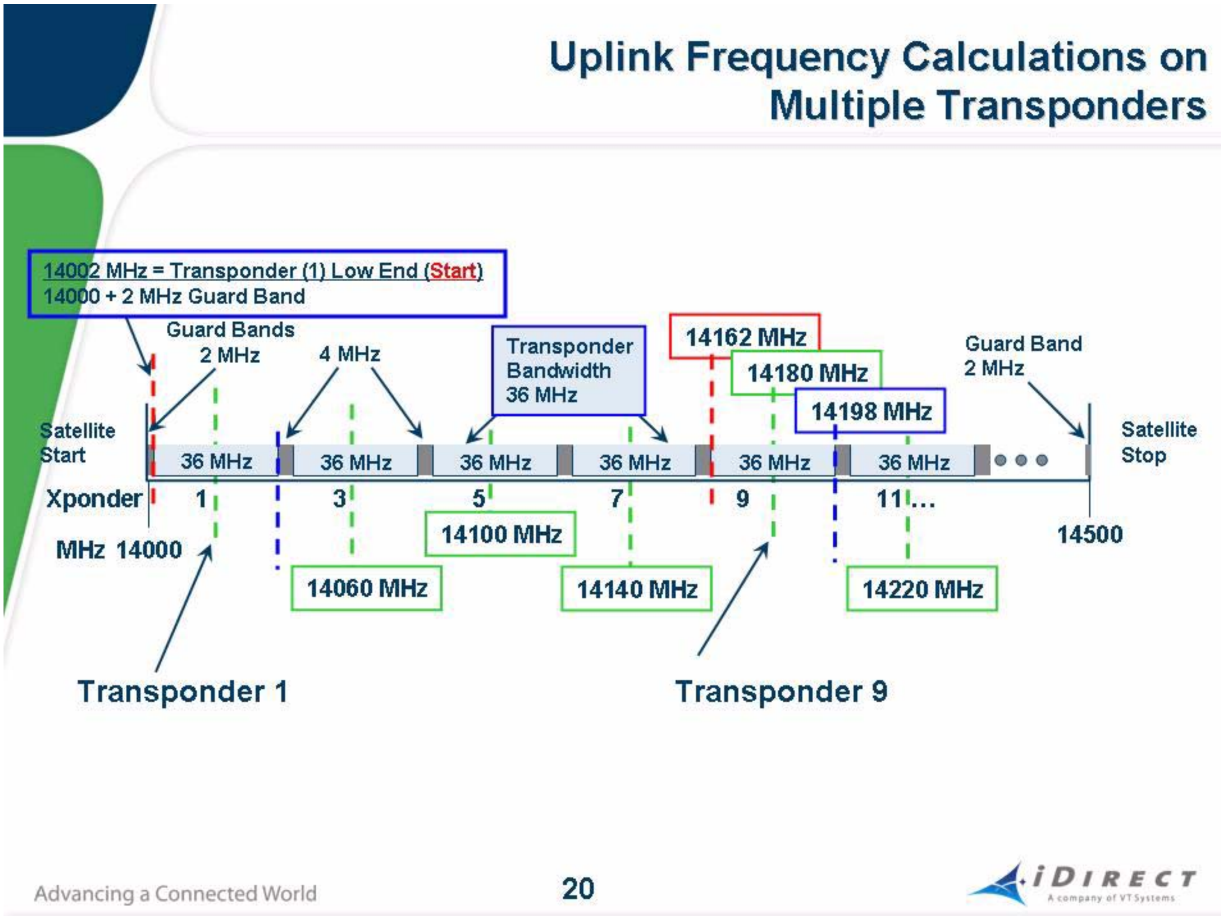
Note: For the Ku band, the frequency range of 11.7 to 12.2 GHz is typically called Domestic (i.e., for America) while the 10.95—11.2 and 11.45—11.7 GHz bands are called International.

L-Band Frequency Range - iDirect IF

- Intermediate Frequencies (IF) used for both receive and transmit direction
- Range between 950 MHz and 2150 MHz (typically 950 – 1700 MHz)
- Translates easily into operational RF frequencies discussed above

Ka, X-Band Frequencies supported via L-Band IF Interface

1.5.1 Upstream Frequency Calculations



This slide shows satellite frequency breakdown based on multiple transponders.

For Transponder 1:

14020 MHz = Transponder (1) Center Frequency

14000 + 2 MHz Guard + 1/2 Transponder BW (18MHz)

Therefore:

14038 MHz = Transponder (1) High End (Stop)

14000 + 2 MHz Guard + 36 MHz Transponder BW

And:

Every Transponder Center Frequency will be 40 MHz greater in frequency [4 (GdBd) + 36 (Xponder BW)]

For Transponder 9:

14180 MHz = Transponder (9) Center Frequency

14000 + 2 MHz Guard + 36 + 4 + 36 + 4 + 36 + 4 + 36 + 4 + 18

Hence:

14162 MHz = Transponder (9) Low End (Start) Frequency

14000 + 2 MHz Guard + 36 + 4 + 36 + 4 + 36 + 4 + 36 + 4

14198 MHz = Transponder (9) High End (Stop) Frequency

14000 + 2 MHz Guard + 36 + 4 + 36 + 4 + 36 + 4 + 36 + 4 + 36

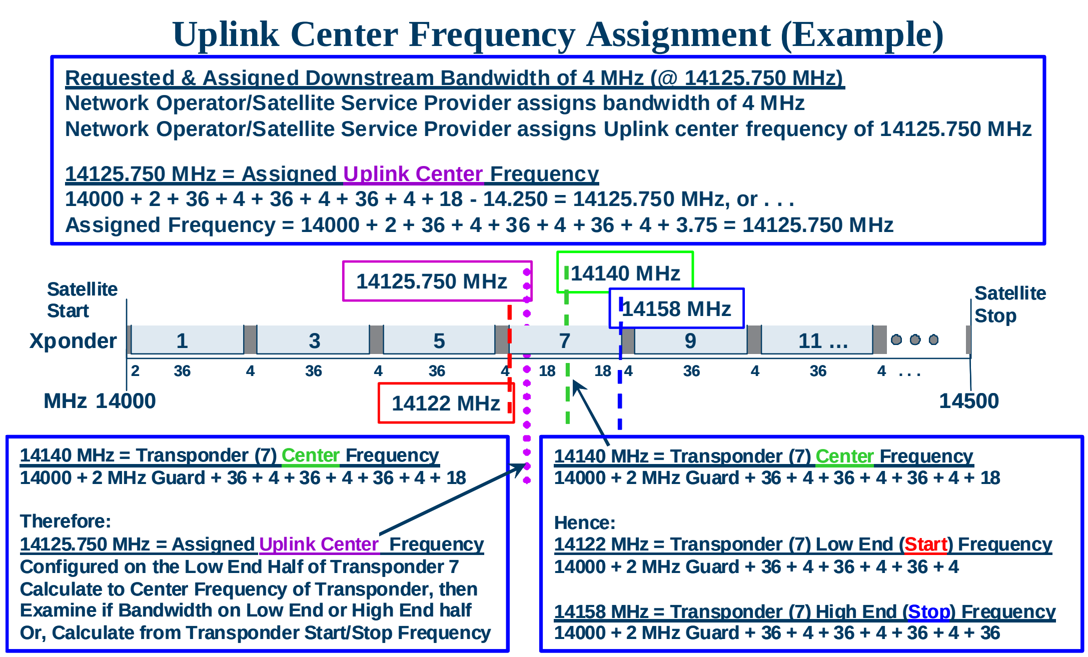
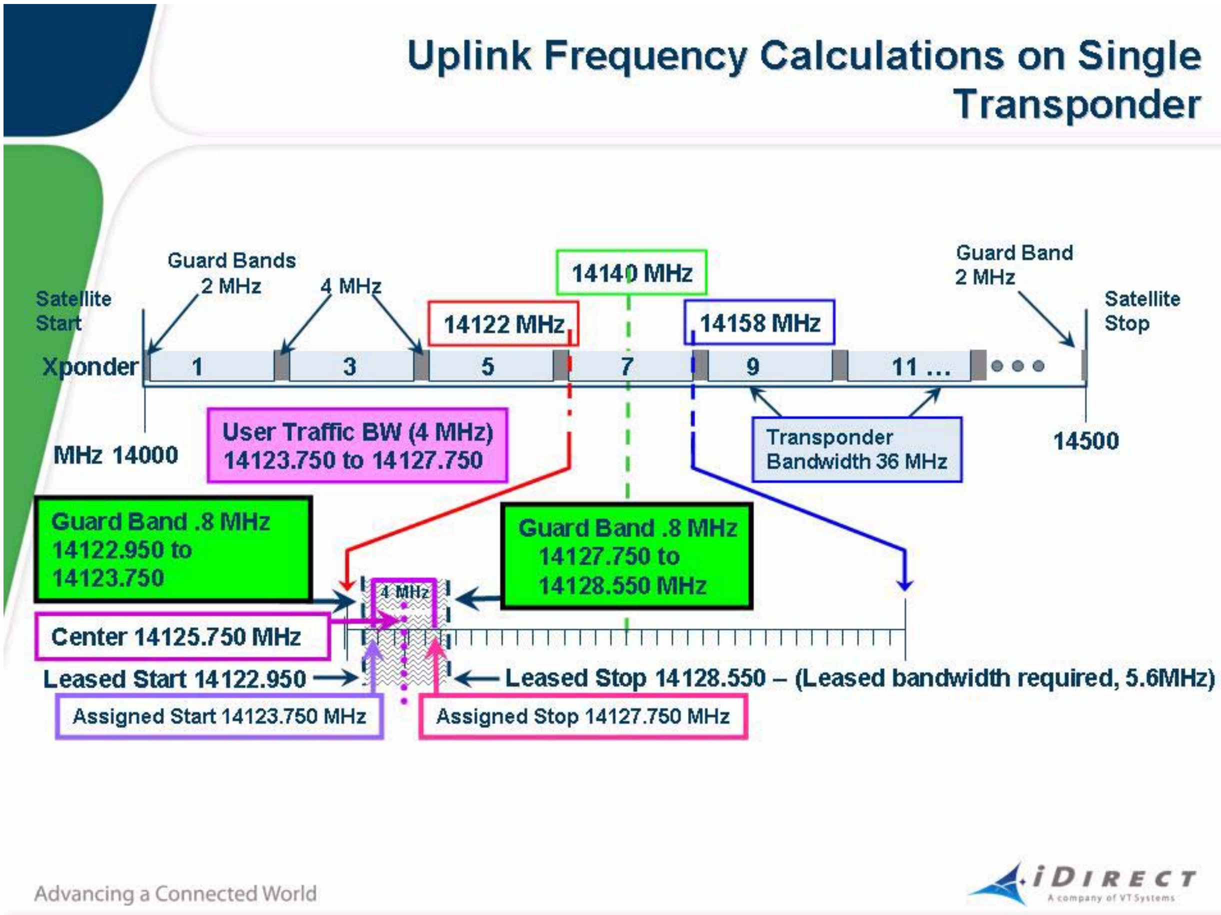


Figure 1. Calculation of Uplink Center Frequency

1.5.2 Uplink Frequency Calculations on a Single Transponder



In the slide we are still focusing on transponder number 7 and focusing more on the carrier outlined in purple.

Here we are further breaking down the carrier frequency assignments showing the following:

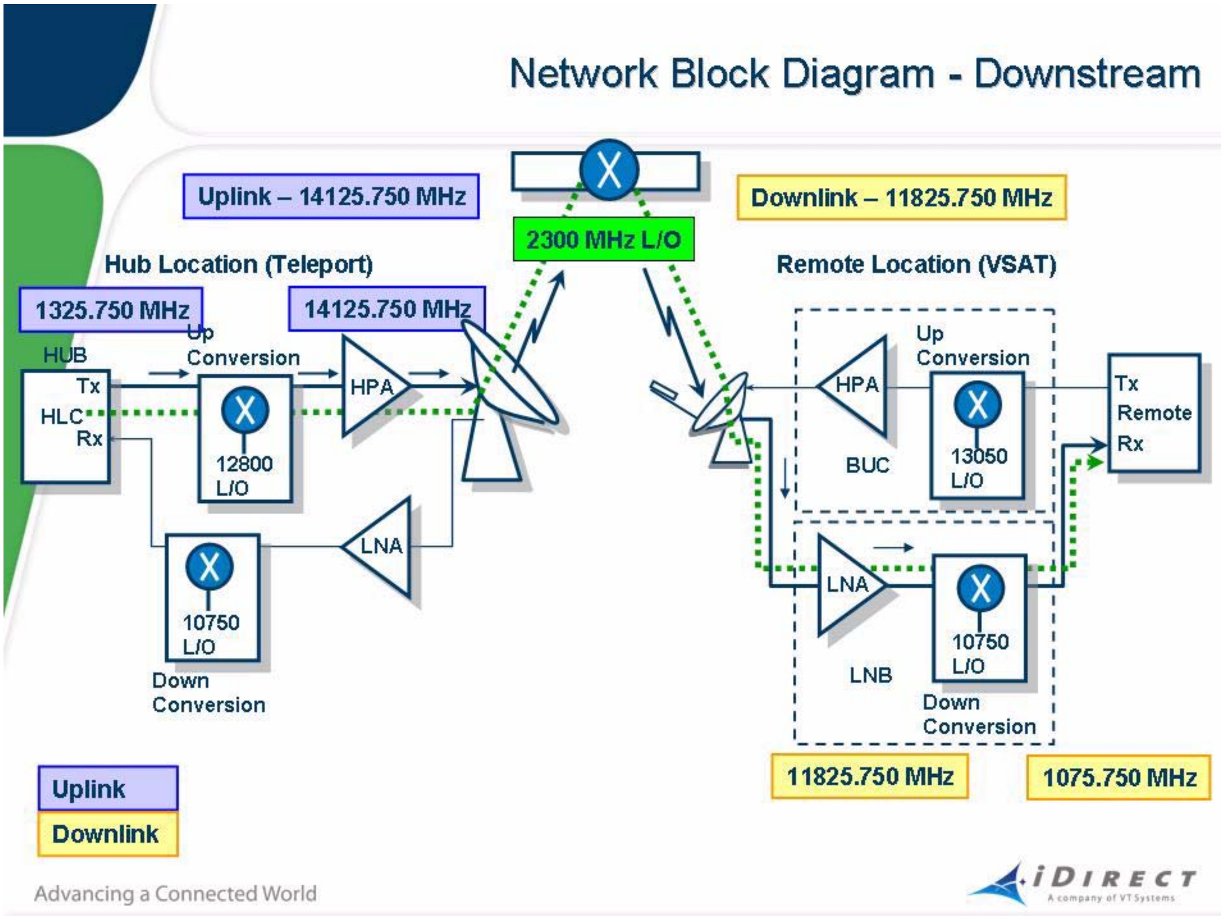
- Center Frequency 14125.750 MHz
- Start Frequency 14123.750 MHz
- Stop Frequency 14127.70 MHz

But now we also have the leased start and leased stop frequency assignments listed.

- Leased Start 14122.950 MHz
- Leased Stop 14128.550 MHz

These leased frequency assignments are the actual leased space plus the **carrier spacing** required to separate our carrier from neighboring carriers to the left and right of our carrier. The space between the start, stop frequencies and the assigned start and stop frequencies cannot be used for carrier information and are strictly assigned to space our carriers from other neighboring carriers. If you look at the green boxes to the left and right of the carrier, this is indicating the **guard band** start and stop frequencies for each border to the left and right of our carrier.

1.5.3 Frequency Calculations - Downstream



The illustration above shows link from Hub Tx to remote Rx as the L-Band TX conversion takes place to the satellite Uplink frequency. This is further converted by the transponder (using a mixer and local oscillator) to the satellite Downlink frequency. Then, Downlink is converted to L-Band Rx by the remote.

The full calculation path is shown mathematically below.

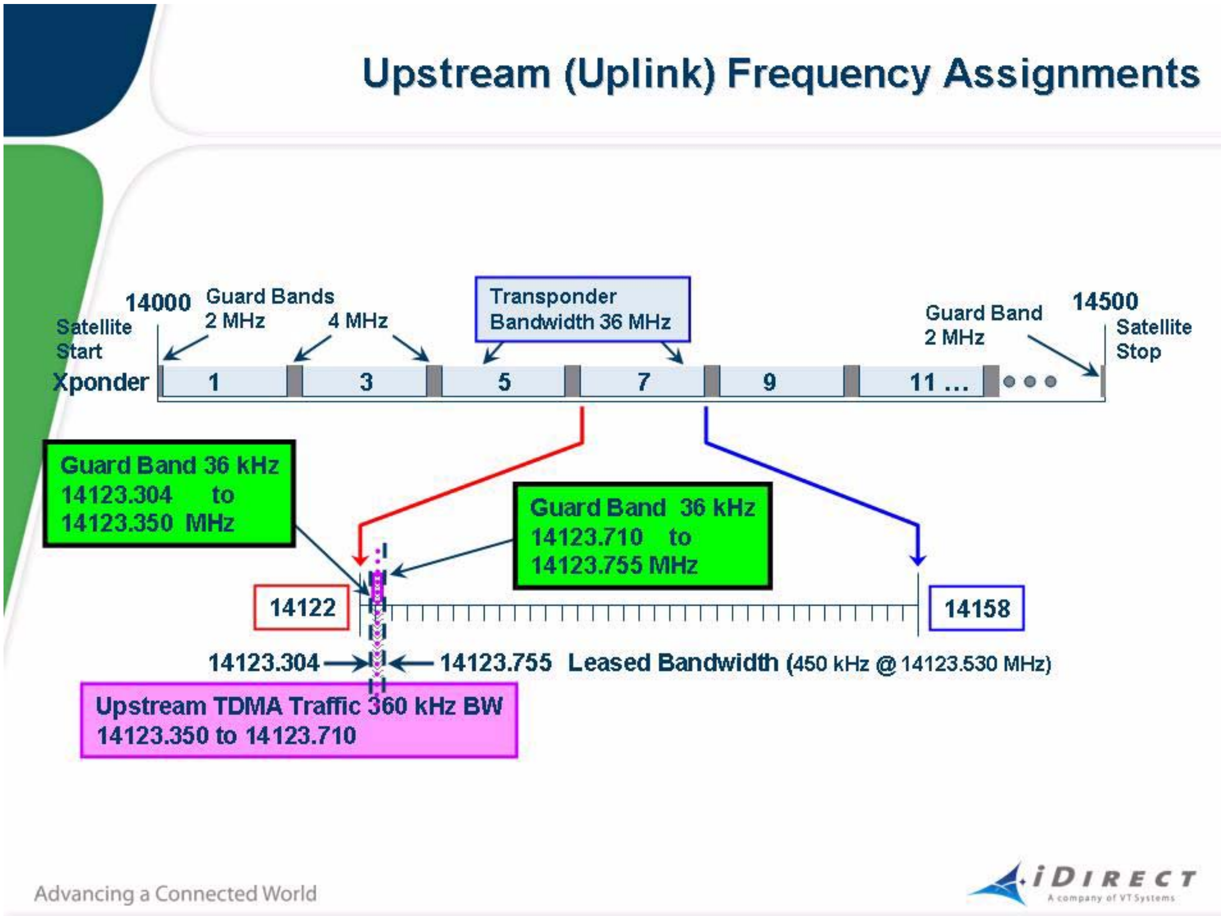
1325.750	calc'd L-Band Hub TX
+ 12800.000	Up Converter L/O
14125.750	Ku-Band Uplink RF
- 2300.000	Sat Xponder L/O (typical)
11825.750	Ku-Band Downlink RF
- 10750.000	LNB L/O
1075.750	calc'd L-Band Remote RX

As previously mentioned, you are being shown an example of the Hub line card transmitting an L-Band frequency and how this signal will first be up converted by adding 12800 frequency to the L-band 1325.750 MHz and coming up with an uplink Ku frequency of 14125.750.

The signal then travels up to the satellite where another frequency conversion takes place. The mixer or L/O on the satellite then subtracts the 2300Mhz frequency from the 14125.750 and shoots a downlink signal of 11825.750 MHz so that the uplink Ku and the downlink Ku frequencies do not interfere with one another.

The signal then travels down to the remote location first hitting the LNB, Low Noise Block, converter which subtracts 10750 MHz from the 11825.750 MHz and outputs the L-Band frequency of 1075.750 MHz to the remote.

1.5.4 Upstream Carrier Frequency Assignment

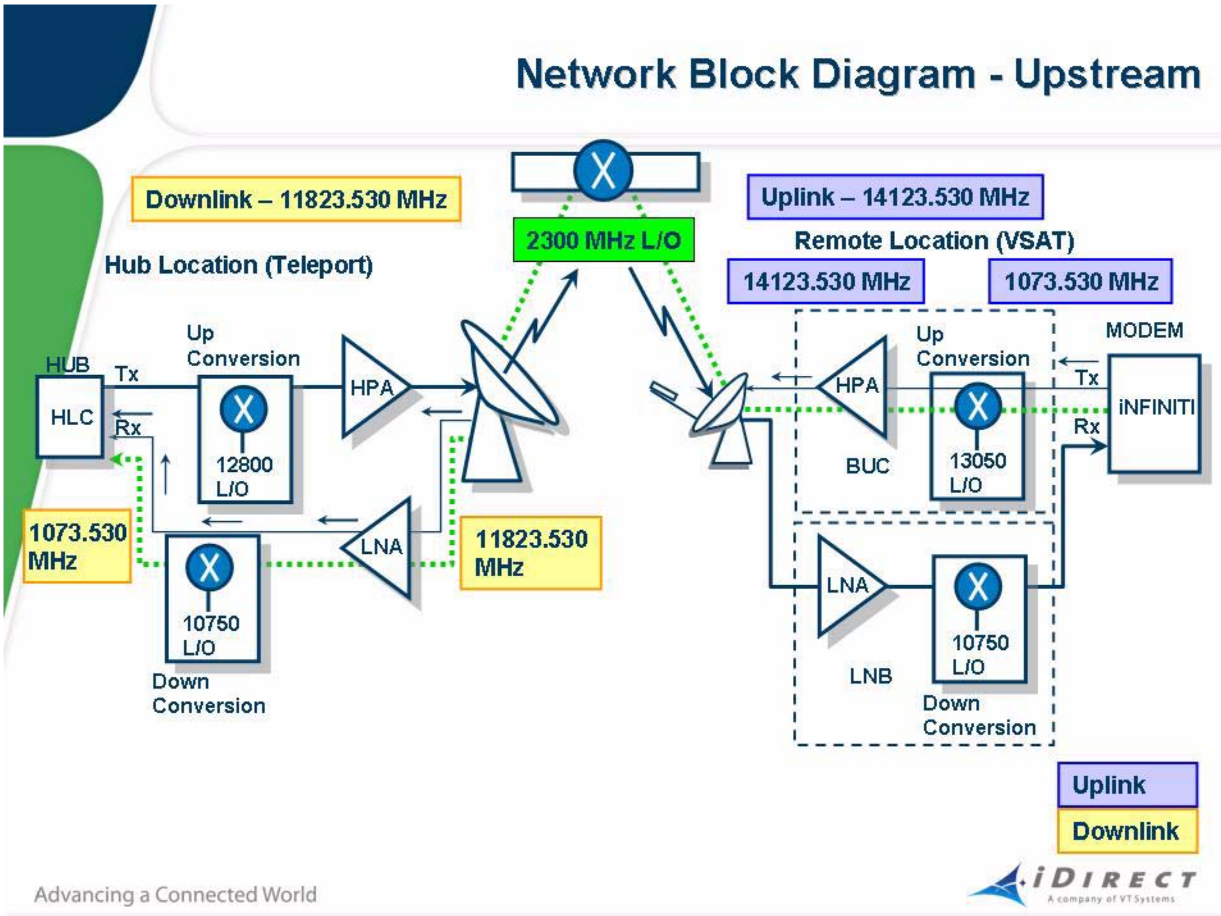


This example shows how to plot Upstream carrier assignment.

Satellite Upstream Bandwidth required is 360 kHz.

Network Operator will not assign these guard band frequencies to other users.

1.5.5 Frequency Calculations - Upstream



This slide above shows the Upstream transmission from the remote L-Band to the Hub line cards receive L-Band. The frequency is converted at different locations during the transmission, further emphasizing the reason to upconvert and downconvert the frequency from point A to point B.

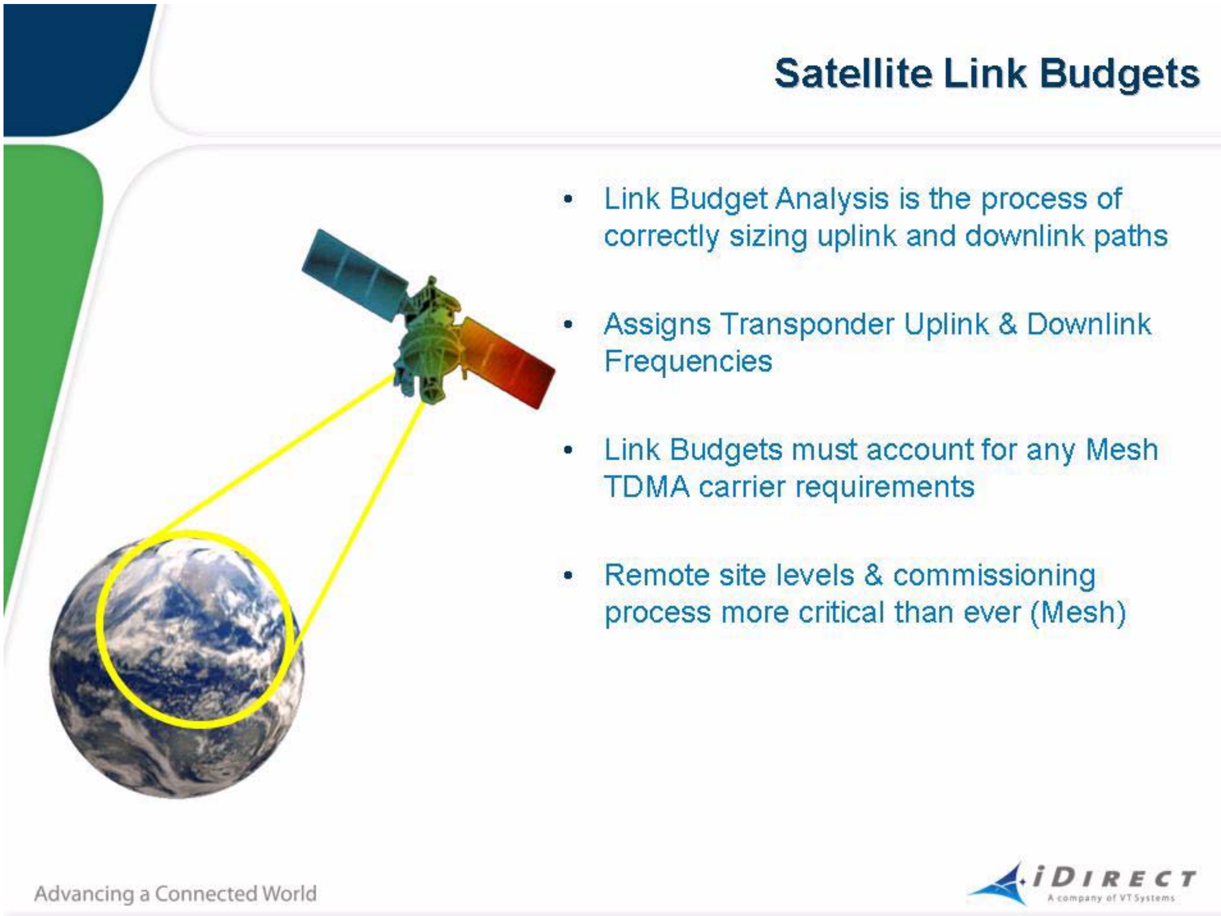
You see the remote transmission on the right transmitting a signal with an L-band frequency of 1073.530 MHz. The signal output is then transmitted and converted on the BUC, Block Up Converter, and 13050 is added to the L-band frequency for a Ku band frequency of 14123.530 MHz. The signal is then transmitted up to the satellite where the satellite L/O or mixer subtracts 2300 MHz from the original signal and transmits down a Ku Frequency of 11823.530 MHz so that the uplink and downlink frequencies do not interfere with one another.

The signal is then taken to the teleport’s downconverter and 10750 is subtracted from the 11823.530 frequency and an output of 1073.530 L-band is transmitted to the remote’s receive or demodulator.

Conversion Calculations (Ku-Band):

1073.530	calculated L-Band Remote TX
+ 13050.000	Block Up Converter L/O
14123.530	Ku-Band Uplink RF
- 2300.000	Sat Xponder L/O (typical)
11823.530	Ku-Band Downlink RF
- 10750.000	Down Converter L/O
1073.530	calc'd L-Band Hub RX

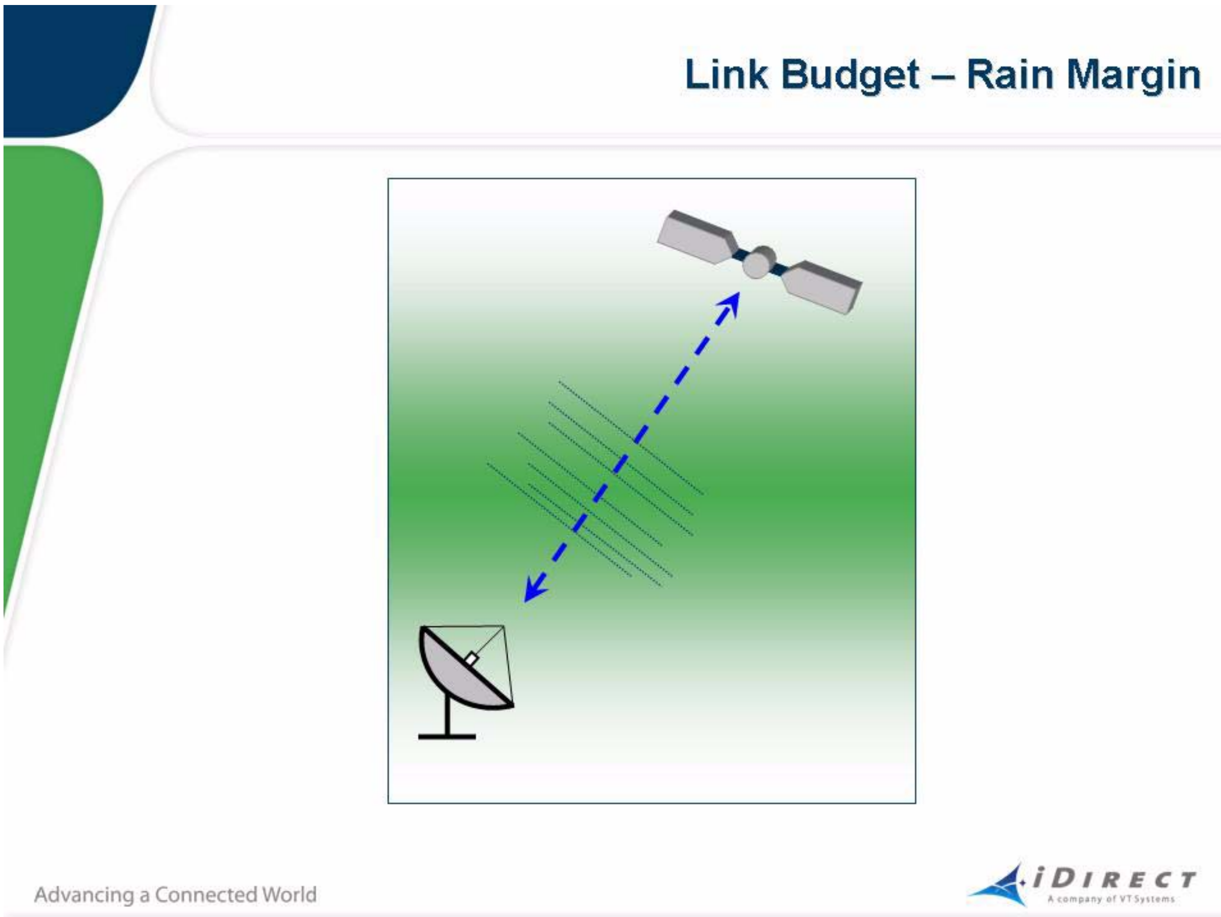
1.6 Link Budget Analysis



Link Budget must take into account:

- Established Satellite performance
- Path Loss (22,300 miles in space)
- Atmospheric effects (weather, ion storms, sunspots, etc.)
- Frequency bands used (Ku, C, Ka)
- Hub uplink antenna and amplifier performance
- Downlink antenna size and receiver noise figure

1.6.1 Rain Margin



Rain margin is built into many link budgets, especially when considering Ku-band solutions.

Design for the specified availability:

- 99.5% = @ 2 days of outage per year
- 99.9% is just 8 hours of outage per year

Typically an external Uplink Power Control (UPC) device compensates for rain fade of the Hub Upstream carrier. iDirect’s Hub controls remote site Upstream carrier power only using our Uplink Control Process, or UCP. iDirect’s Hub does monitor Downstream (loopback) carrier power to reference UCP adjustments, but only in Mesh networks.

1.7 Learner Knowledge Review

1. Most satellites reside in a **geosynchronous orbit** in the Clarke Belt, above the equator, with a two-degree separation between them. Geosynchronous means that the satellite is locked to the earth's rotation so it can provide a stationary footprint on the ground.

2. **Propogation delay** is the amount of time it takes to transmit bytes over some medium. In satellite communications, propogation delay is a result of transmitting up to a satellite that is 22,236 miles above the earth (120 ms), then back down from the satellite to the earth station (another 120 ms). Round trip delay is therefore about 500 ms.

3. **FSD** is an extremely critical value which will prevent remotes from ever acquiring if they are grossly incorrect. On the other hand, less significant errors will result in increased acquisition times, which are not good in themselves, but may still allow the acquisition to occur. The goal at all times should be peak operating performance for your network.

4. **Downstream** is from the hub to the remote (both uplink and downlink) and **Upstream** (both uplink and downlink) is from the remote to the hub. Both Downstream and Upstream carriers typically use the same satellite and transponder. This is not a requirement for iDirect Star network topology BUT is an absolute requirement for iDirect Mesh network topology.

5. The **RF signal** flows from the earth station terminal towards the satellite receive antenna. The signal is then transferred to an amplifier to strengthen the signal which has travelled over 22,000 miles. The signal also goes through a bandpass filter filtering out all the out-of-band noise the RF signal picked up on its journey to the satellite. After the RF signal is cleaned up, it is transferred through a local oscillator or mixer which downconverts the signal. The signal is sent through another amplifier which strengthens the signal for transmission back down to the earth station. Last, but not least, we have the transmit antenna which sends/transmits the signal down to the earth stations receive terminal.

6. The **footprint** of a communications satellite is the area on the earth that its transponders covers. It also determines the satellite dish diameter required to receive each transponder's signal. The **EIRP** is the value of power measured one meter away from the antenna of the source transmission, and affects the location of the remote within the satellite's footprint. **Beam shaping** is used to focus a satellite's energy and increase the effectiveness of a satellite.

7. The standard definition of **polarization** is the electromagnetic properties of the signal waves and orientation of the oscillations in a perpendicular plane to the wave's direction of travel. The oscillations may be monitored in a single direction as in **linear** polarization or the waves may rotate as in **circular** polarization. There are Horizontal, Vertical linear polarization and right hand, left hand circular polarization.

8. The **BUC** and **LNB** functionality in iDirect's system is very important because this is where the L-Band frequency from the remote is converted to Ku, Ka, C or X band. The IFL cable runs from the remote's transmit (TX) and receive (RX) to the BUC and the LNB. The Transmitter reject filter is used to filter outside noise as well as filter out the remote's TX so that it does not interfere with the RX. Our LNBs may also be powered externally but they are not polarization switching LNBs.

9. Variations of Amplitude, Frequency, and Phase can all be used to **modulate** a data bit stream into a “modulated” carrier or RF carrier. iDirect uses the **Phase Shift Keying** method in order to modulate or convert the data bit stream into a frequency or symbol carrier. The variation of phases within the sine wave itself determines the data being transmitted from point A to point B.
10. A satellite’s frequency range may be divided among several transponders. Each transponder’s **frequency assignment** must take into account the satellite provider’s assigned bandwidth. From this, you can calculate the transponder’s start, center, and stop frequencies.
11. The leased stop and start frequencies on a carrier must take into account the **guard band** on either side of the frequency range, which is used to separate our carrier from other, adjacent carriers (**carrier spacing**).
12. As a signal is sent from the hub to a remote (Downstream), it undergoes several **frequency conversions** to boost power so it can travel over the long distances, and to prevent interference with other signals.
13. As a signal is sent from the remote to the hub (Upstream), it undergoes several **frequency conversions** to boost power so it can travel over the long distances, and to prevent interference with other signals.
14. **Link Budget Analysis** is the process of correctly sizing uplink and downlink paths, taking into account satellite performance, path loss, atmospheric effects, the frequency bands used, the uplink antenna and amplifier performance, and the downlink antenna size and receiver noise figure.
15. **Rain margin** is built into most Link Budgets, to account for signal loss due to rain fade. iDirect’s **Uplink Power Control (UPC)** device compensates for rain fade on the Upstream carrier.

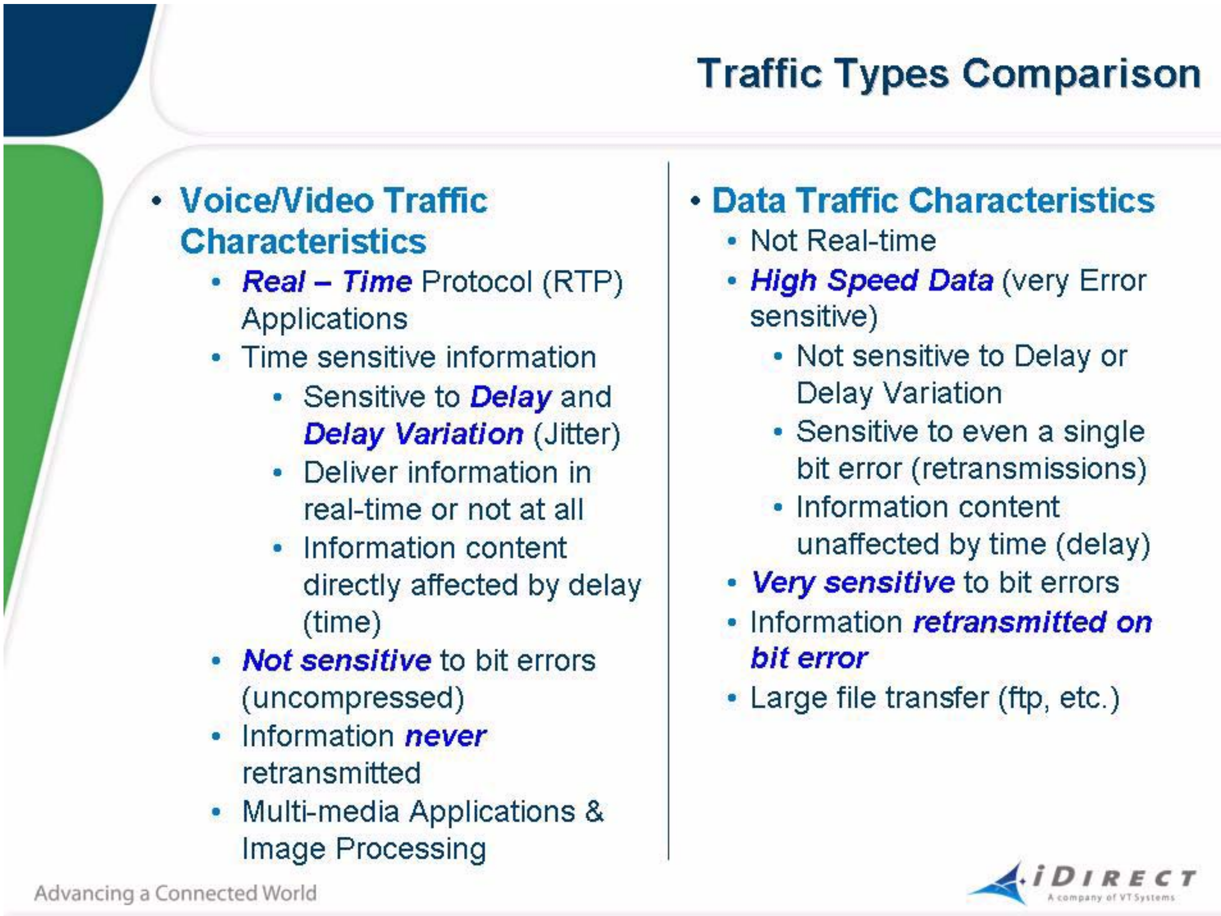
Data Communication Basics

Goal: Through lecture, presentation and visual display each learner will be able to understand and explain Data Communication basics and how they apply within an iDirect network.

Objectives:

1. The learner will be able to describe the different types of data traffic.
2. The learner will be able to explain the difference between Real Time and non-Real Time data traffic.
3. The learner will be able to discuss from a basic level Packet Encapsulation and the associated handling techniques.
4. The learner will be able to identify and discuss iDirect frame and packet structure formats.
5. The learner will be able to identify and discuss important DATACOM terms and principles of any Satellite network in general.
6. The learner will complete the review exercises associated with this module with an accuracy rate greater than 80%.

2.1 Data Communication Concepts



There are many different types of traffic that have to be transmitted across your network. The traffic that travels across an iDirect network is no different than traffic that travels across a land-based network. We will explain the different types of traffic transmitted and illustrate the differences between Real-Time and Non-Real-Time traffic types. You will also understand why certain applications are considered real-time and non-real-time. Can you describe the difference(s) between real-time and non-real-time applications?

As far as an iDirect network is concerned, voice traffic and video traffic are considered Real-Time Protocol (RTP) applications. This time sensitive information is sensitive to delay and delay variation which we call "jitter." The information is deliver in real-time or not at all and the content of the information is directly affected by any extra delay between packets.

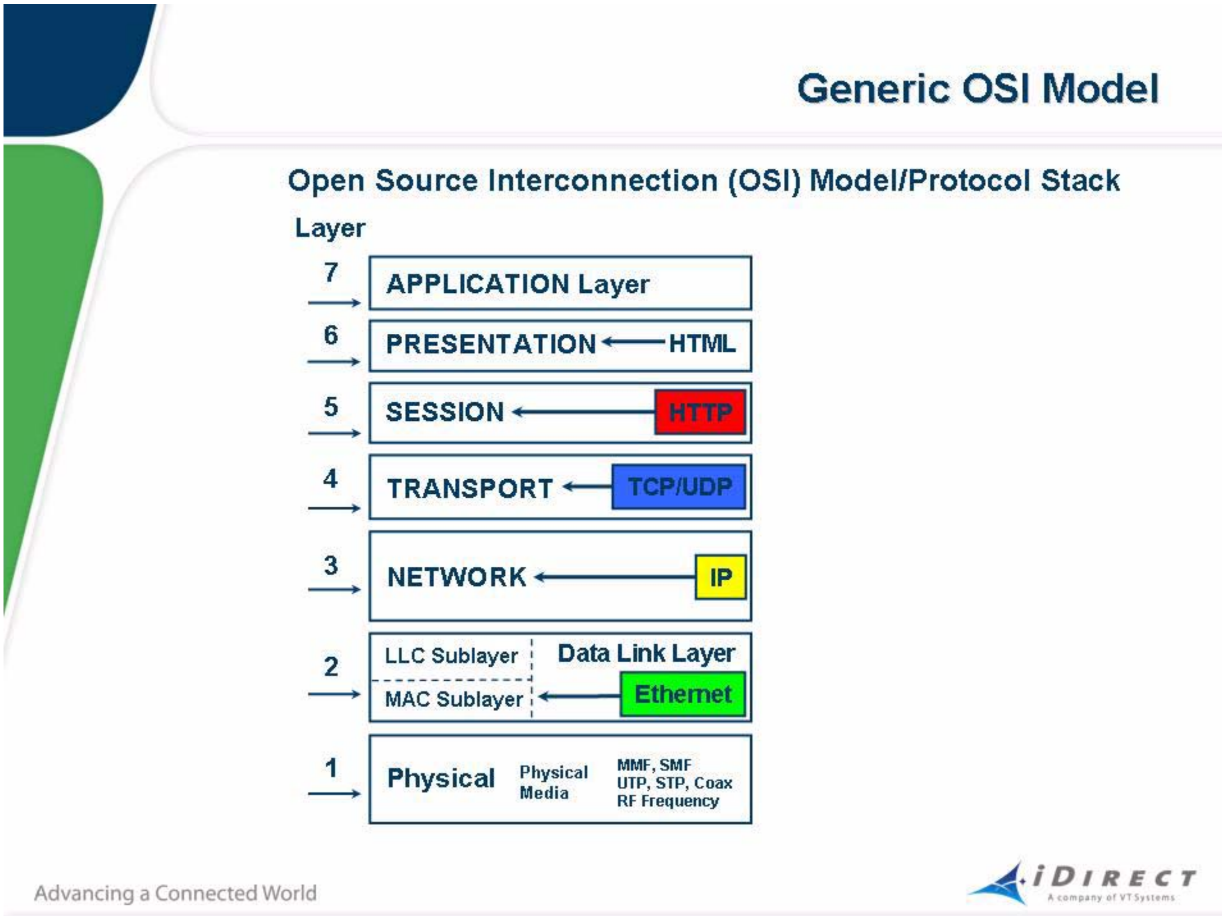
This information is not sensitive to bit errors (uncompressed) but you should remember that the information is never retransmitted.

In the case of Data traffic, we have what it referred to as non-real-time traffic. This high speed data is very error sensitive. Of course it is not sensitive to delay or any delay variation.

However, it IS sensitive to even a single bit error (retransmission) and the information content is unaffected by time delay.

Can you give examples of both traffic types and tell how and why variations would negatively affect your network?

2.1.1 Generic Open Source Interconnection Model

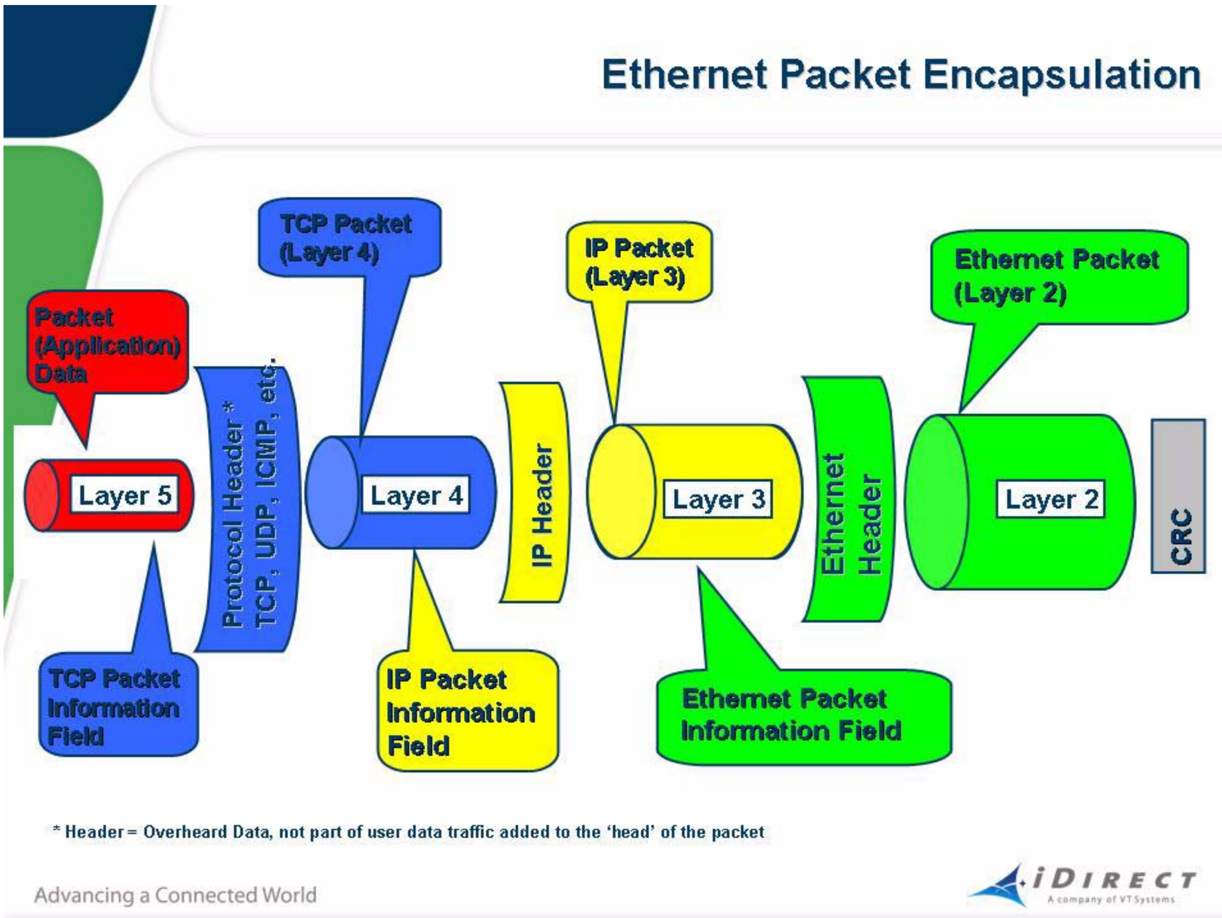


Above is a depiction of a generic OSI Model. The Open Systems Interconnection Reference Model is an abstract description for layered communications and computer network protocol design. Basically it divides network architecture into seven layers which, from the top to the bottom, are presented by Application, Presentation, Session, Transport, Network, Data-Link and Physical Layers.

- **Application Layer**—Performs common application services and supports end-user processes (Telnet, FTP, e-mail, etc.).
- **Presentation Layer**—Provides services to the Application layer for syntactical differences in data representation within the end user systems.
- **Session Layer**—Manages interaction between end-user processes. Establishes check-pointing, adjournment, termination and restart procedures.
- **Transport layer**—Provides transparent transfer of data between end users. It ensures the method for accomplishing complete data transfer.

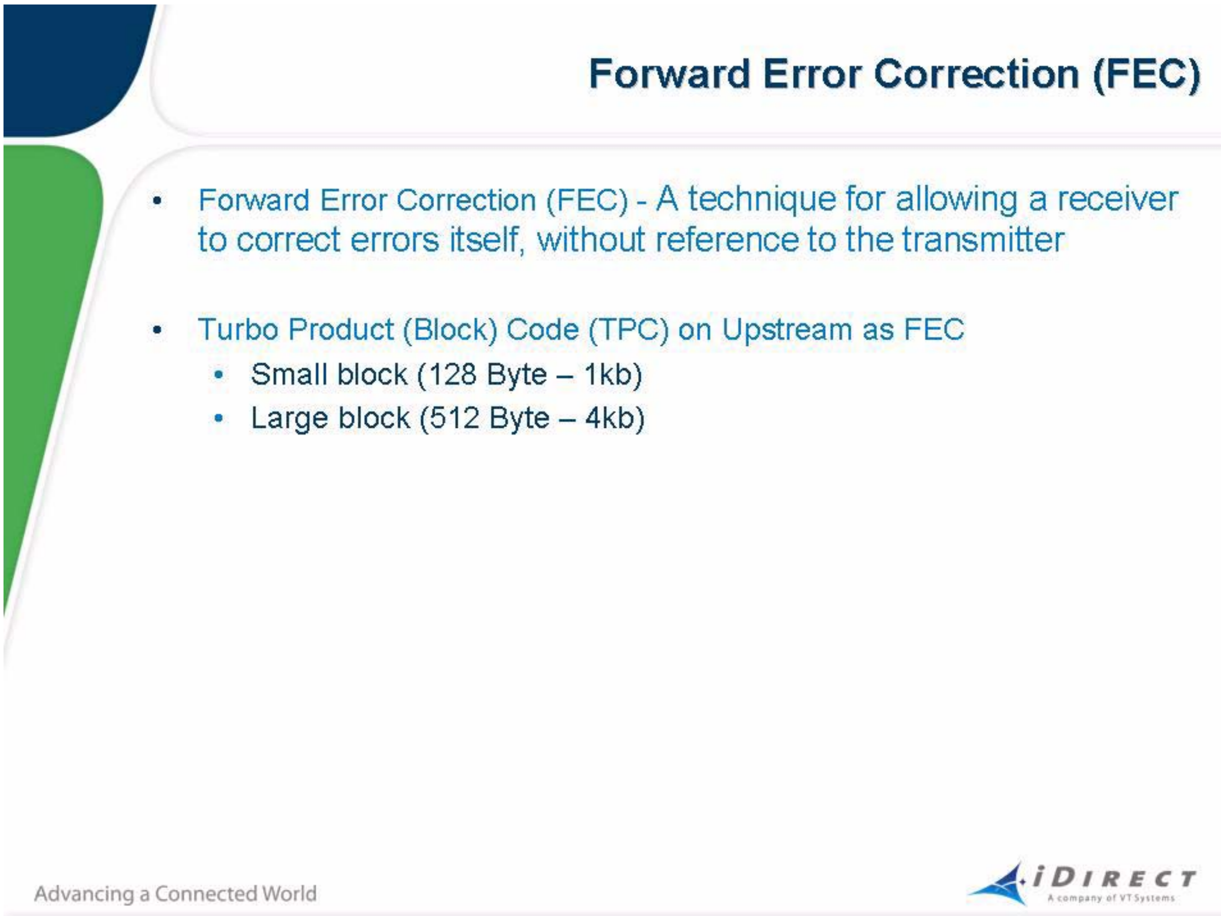
- **Network Layer**—Provides the functional and procedural means of transferring variable length data sequences from a source to a destination while maintaining the quality of service requested by the Transport layer. Performs network routing and error control functions.
- **Data Link Layer**—Provides the functional and procedural means to transfer data between network entities. Includes Media Access Control (MAC) layer, which controls network access, and the Logical Link Control (LLC) layer for frame sync, flow control and error checking.
- **Physical Layer**—Establishes and terminates connection to a communications medium. It is the “hardware” layer providing physical means for sending and receiving data.

2.1.2 Ethernet Packet Encapsulation



The encapsulation and de-encapsulation process occurs in the Protocol Processor and the remotes. The illustration above is a broad overview showing the path of information from the remote to and through the PP's and how and where the encapsulation and de-encapsulation occurs.

2.1.3 Forward Error Correction



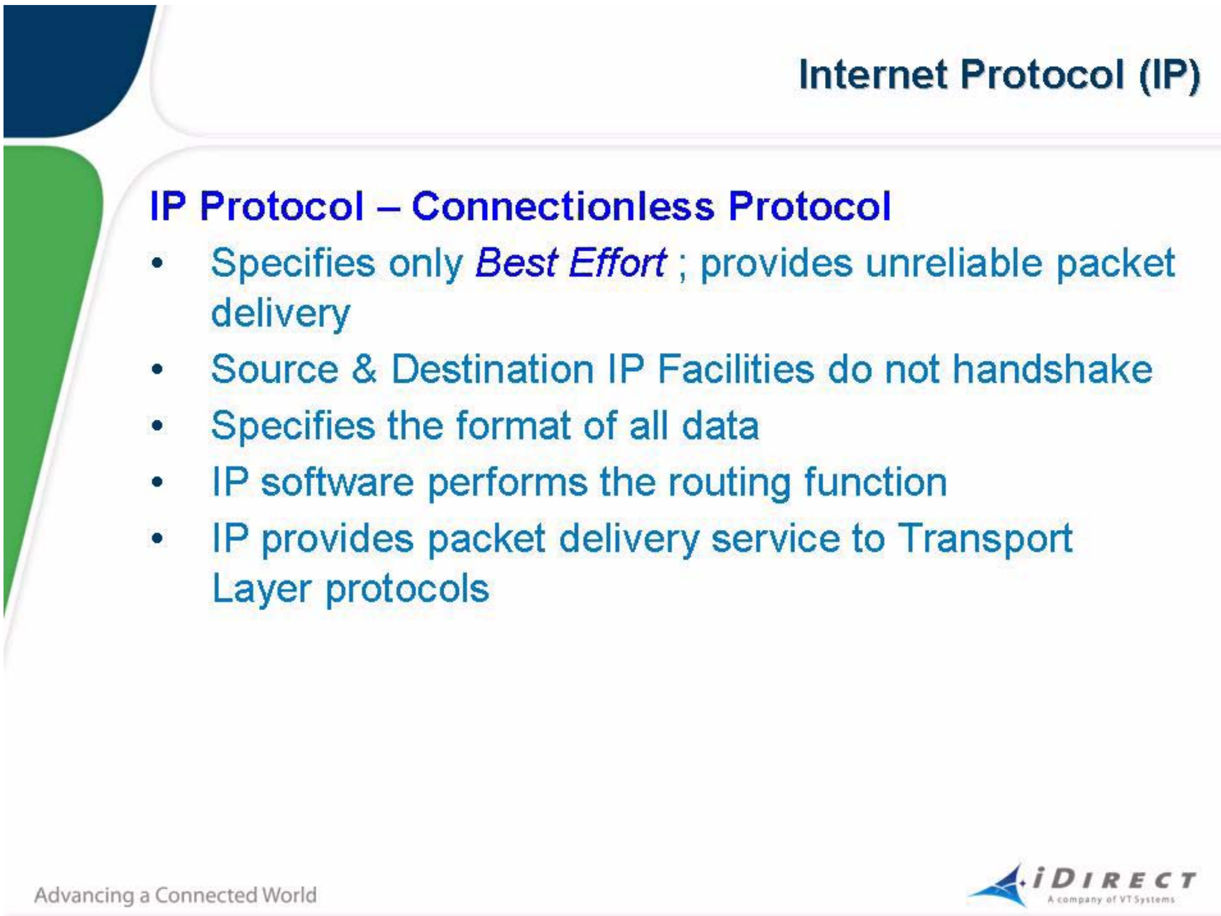
Forward Error Correction or **FEC** is utilized in the iDirect network as a means for error control associated with data transmission, whereby the sender adds redundant data to its message. Some individuals refer to this as error correction code. This allows the receiver to detect and correct errors without the need to ask the sender for additional data.

FEC works by using additional information transmitted along with the data (check, or parity bits) and employing one of many possible error detection techniques.

The receiver can correct a small number of the errors that have been detected. If the receiver cannot correct all detected errors, the data must be re-transmitted. The resulting check bits detract from potential traffic payloads; the lower the quoted FEC rate, the more overhead is required for check bits.

2.2 IP Data in an iDirect Network

2.2.1 Internet Protocol

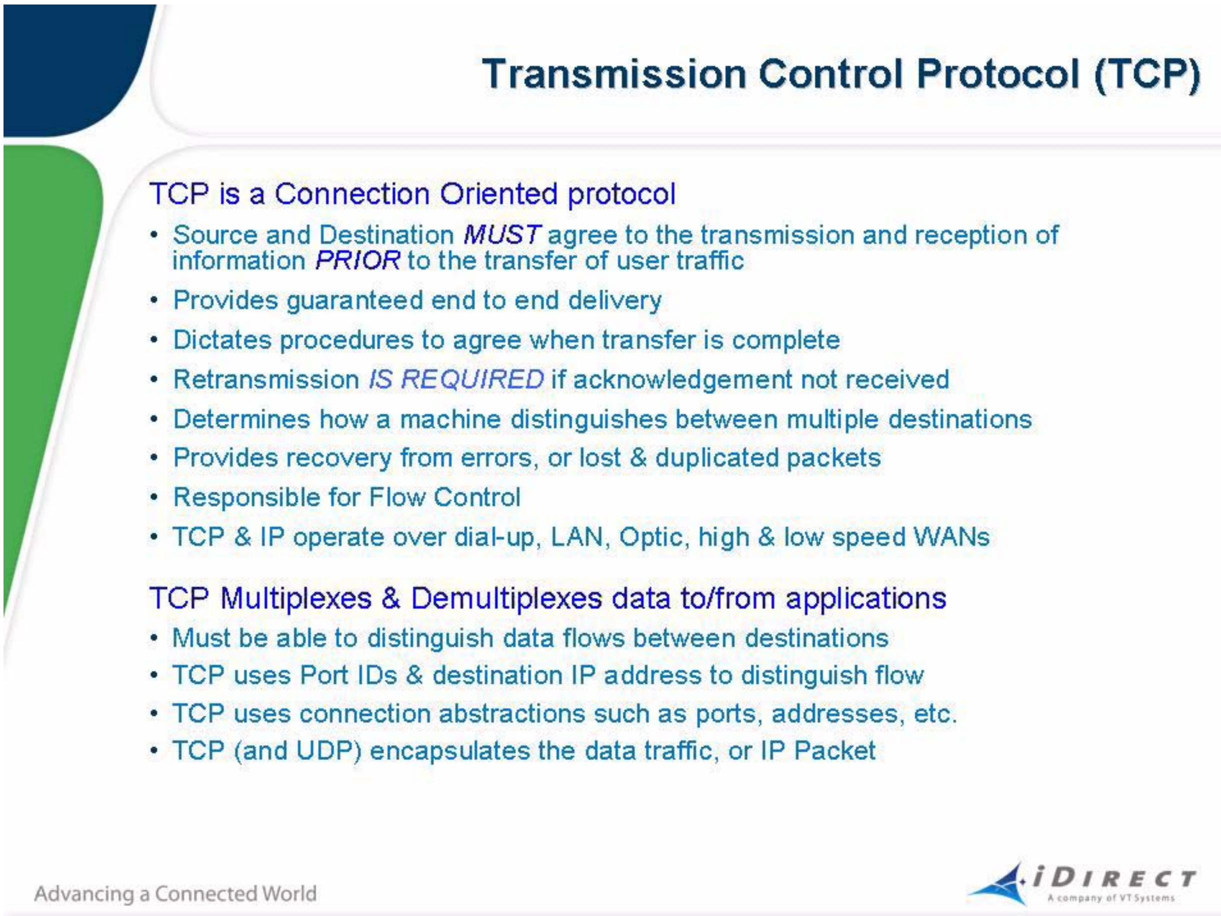


Internet Protocol (IP) is a “connectionless” protocol. It provides a common, consistent, universal addressing technique. It is connectionless in that the Source and Destination addresses do not handshake. IP packets are:

- Discarded if network resources are insufficient
- Treated independently
- May take different paths through the network

IP defines a set of rules that embody packet transmission and delivery. The IP rules specify how routers should process packets (Routing, ToS, precedence, fragmentation); specify when and how to generate error messages (ICMP); and specify conditions that govern discarding and/or duplication of packets (multicast).

2.2.2 Transmission Control Protocol



In contrast to IP, **Transmission Control Protocol (TCP)** is a connection-oriented protocol. The destination must agree to receive the information, similar to a standard telephone call and all transmissions are acknowledged. TCP specifies:

- The format of the information
- Acknowledgements that the information was received
- The method to ensure information was received correctly

Retransmission is REQUIRED if acknowledgement is not received in the event of a lost or corrupted packet.

Both TCP and IP operate over dial-up, LAN, Optic, high and low speed WANs. TCP can be done over Satellite links (if inherent round-trip latency can be overcome). TCP can be successfully done when required acknowledgements are "spoofed."

TCP multiplexes and demultiplexes data to/from applications; therefore, it must be able to distinguish data flows between destinations. It uses Port IDs and destination IP addresses to distinguish flows. A TCP Port is a queue into which TCP protocol places data-grams.

TCP uses connection abstractions such as:

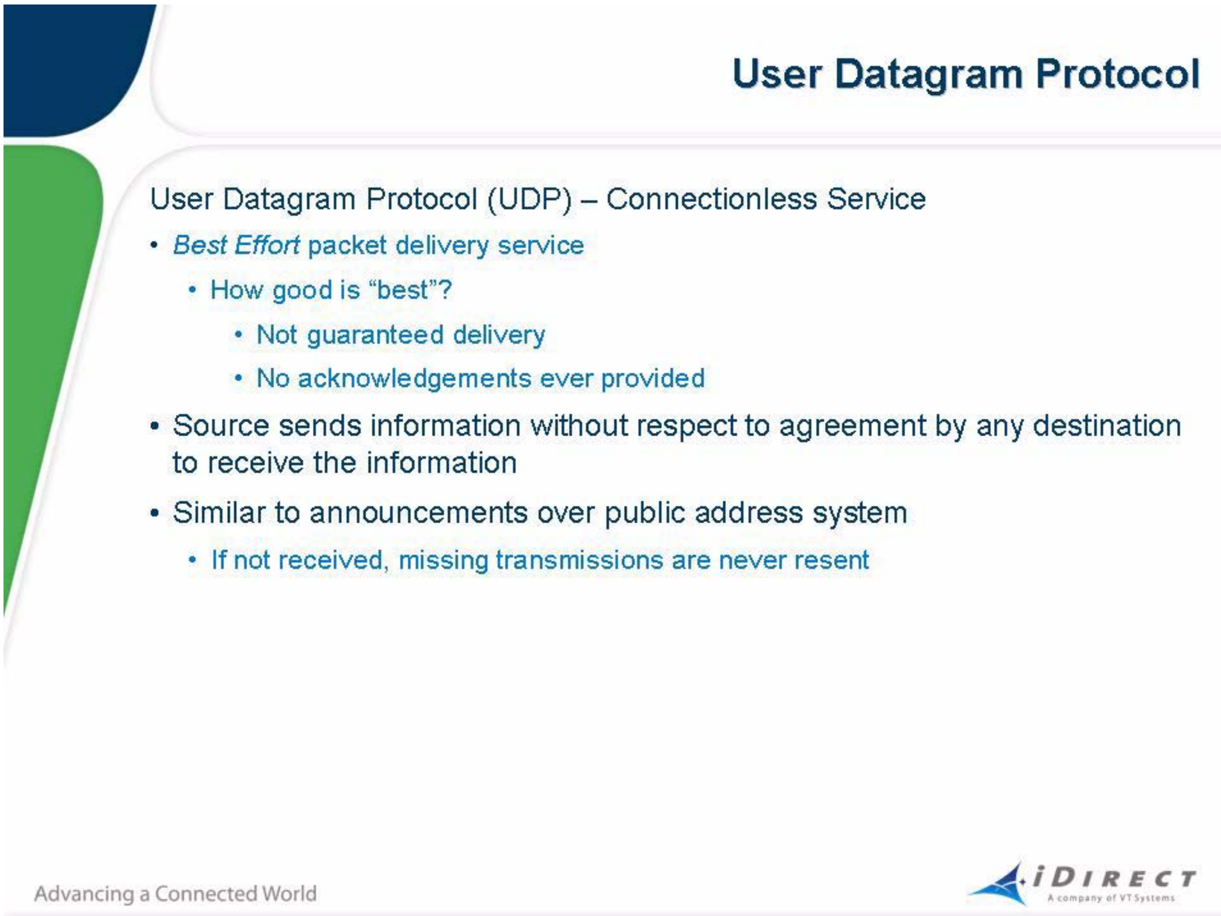
- Source/Destination Port(s)
- Host Address:Port and/or Source Address:Port pairings
- Source (65.168.20.1:100) – Destination (10.10.200.1:200)
- Source and Destination pairing to identify a data flow

TCP requires only one local port to accommodate many data flows for many local applications.

TCP (and UDP) encapsulates the data coming from the higher-level layers into the IP Packets

- IP Packets are the delivered packets (payload)
- IP Packets are the single packet that traverses the network
- In a routed network, Layer 2 packets live only point-to-point
- Ethernet Packets live only between adjacent ports

2.2.3 User Datagram Protocol



UDP or **User Datagram Protocol** is a connectionless type of protocol which is referred to as a "best effort" type of delivery of information.

Packets are sent and the protocol does not expect to see acknowledgement packets before more traffic is transmitted. If there are errors with the data transmission there are no retransmissions to recover from this.

This is why the delivery of information is not guaranteed. VoIP and streaming video use this protocol to transmit since we cannot delay these types of applications and wait for acknowledgements before sending more information. Information has to be transmitted in real-time without delay or jitter.

2.3 Learner Knowledge Review

1. The characteristics of different types of traffic determine some of their transmission requirements. Voice and video traffic is **real-time**, meaning it is sensitive to delay and not sensitive to bit errors. Information is never retransmitted. Data traffic, on the other hand, is **non-real-time**, meaning it is *not* sensitive to delay but *is* very sensitive to bit errors. Information is retransmitted when bit errors occur.
2. The **OSI model** is an abstract representation of seven different "layers" of network communications, from the Physical layer (i.e., hardware) to the Application layer (i.e., software applications). iDirect software and equipment affects Layers 2 (Ethernet) and up.
3. Ethernet packets are **encapsulated**, with each header reflecting an OSI model layer (ethernet header, IP header, and protocol header).
4. Used in iDirect networks, **FEC** is a method of sending data with "check" bits so the receiver can correct any errors in the message without having to transmit back to the sender.
5. **Internet Protocol (IP)** is "connectionless" in that the Source and Destination do not handshake. IP specifies the format of all data and rules for packet transmission and delivery to the Transport Layer protocols.
6. **TCP** is a connection-oriented protocol in that the Source and Destination must agree to transmit/receive the information. TCP specifies the format of the information and how acknowledgements are received. Retransmission is required if an acknowledgement is not received. TCP requires only one local port to accommodate data flows for many local applications.
7. **UDP** is a connectionless protocol referred to as a "best effort" type of information delivery. Delivery of information is not guaranteed, no acknowledgements are sent, and there is no retransmission of data.
8. In a TCP connection over satellite, there is approximately a 530 msec delay, or **latency**, between sending and receiving a transmission and its acknowledgement.

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