IP over Satellite
in Broadcast Communications

Ennes Workshop | October 5, 2012

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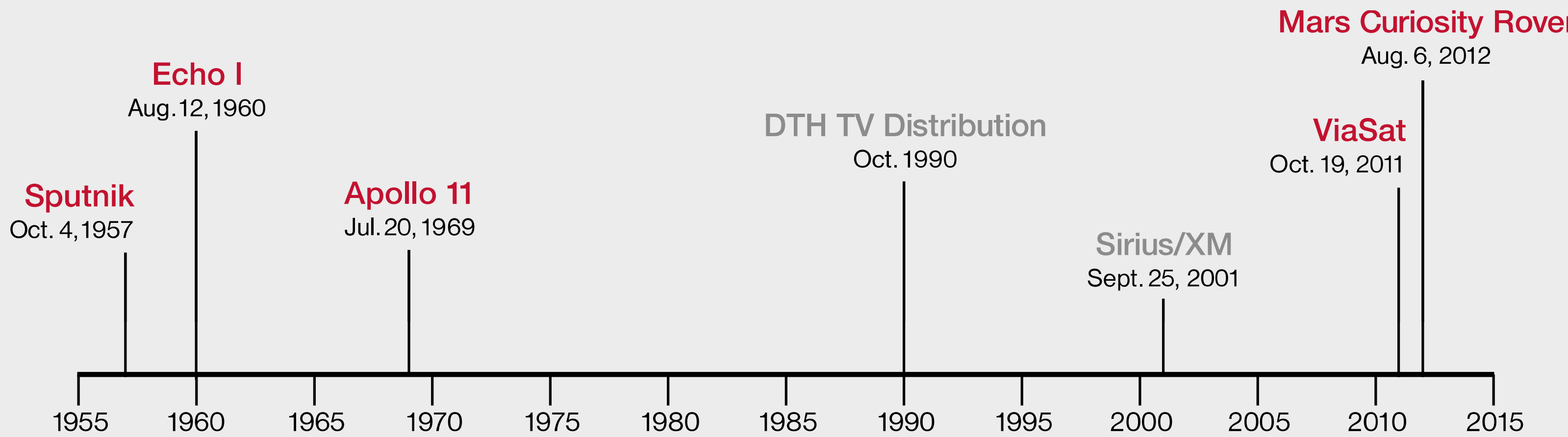
Purpose

Provide broadcast engineers with insight into the benefits, issues, and challenges associated with using Internet Protocol (IP) over satellite

This discussion will cover:

- Brief history of space communications
- Introduction to satellite communications theory
- Introduction to IP
- Application of satellite IP to broadcasting

Brief History of Space Communications



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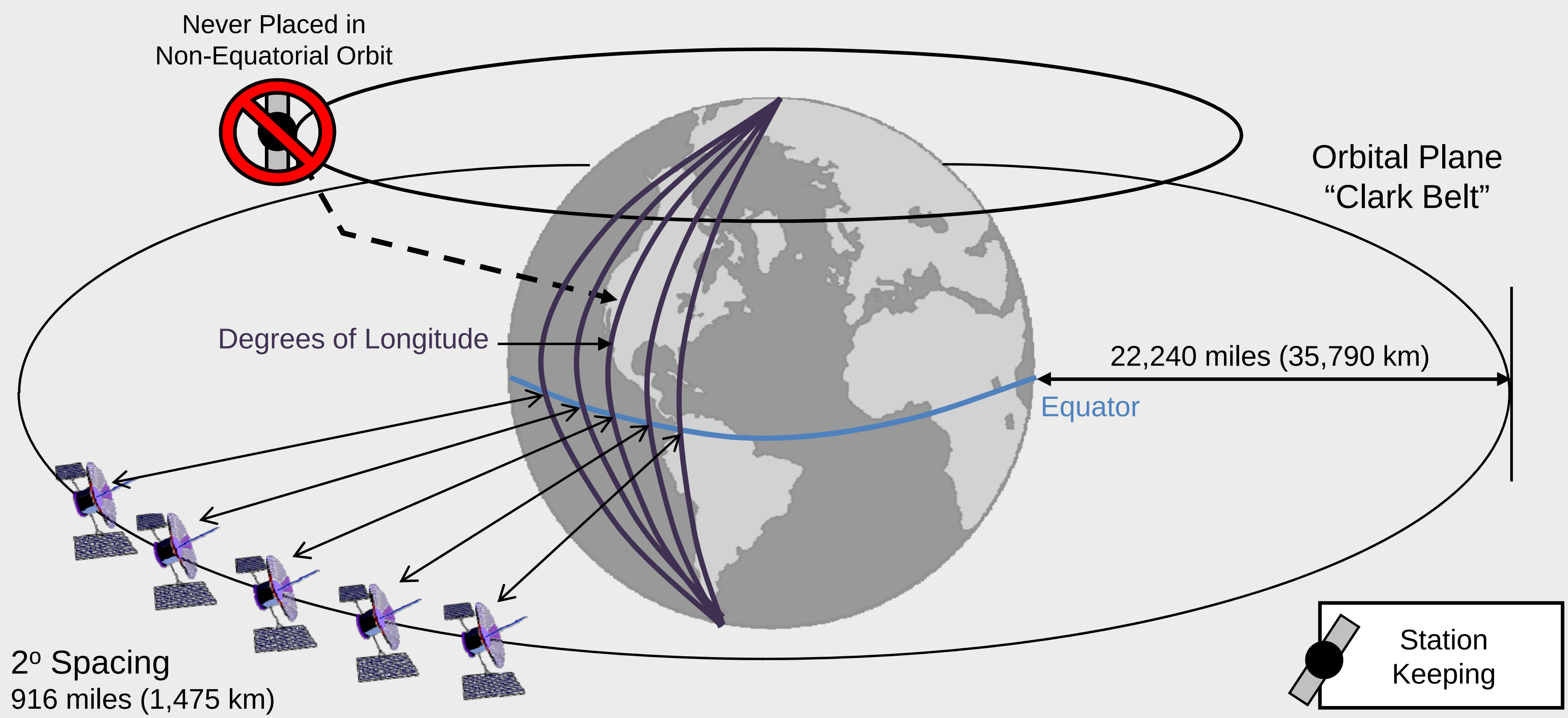
Gale Crater Mars

Geosynchronous Earth Orbit



Orbital Circumference: 164,870 miles
265,490 km
Orbital Velocity: 6,870 mph
11,060 kph

Geosynchronous orbit @ 0^{o} Latitude, directly over the Equator
Therefore, orbital position is reported in degrees of Longitude
Typical orbital period = Earth rotation, 23hr 56min 4sec
Satellite orbits in a ‘figure-eight’ when viewed from the ground

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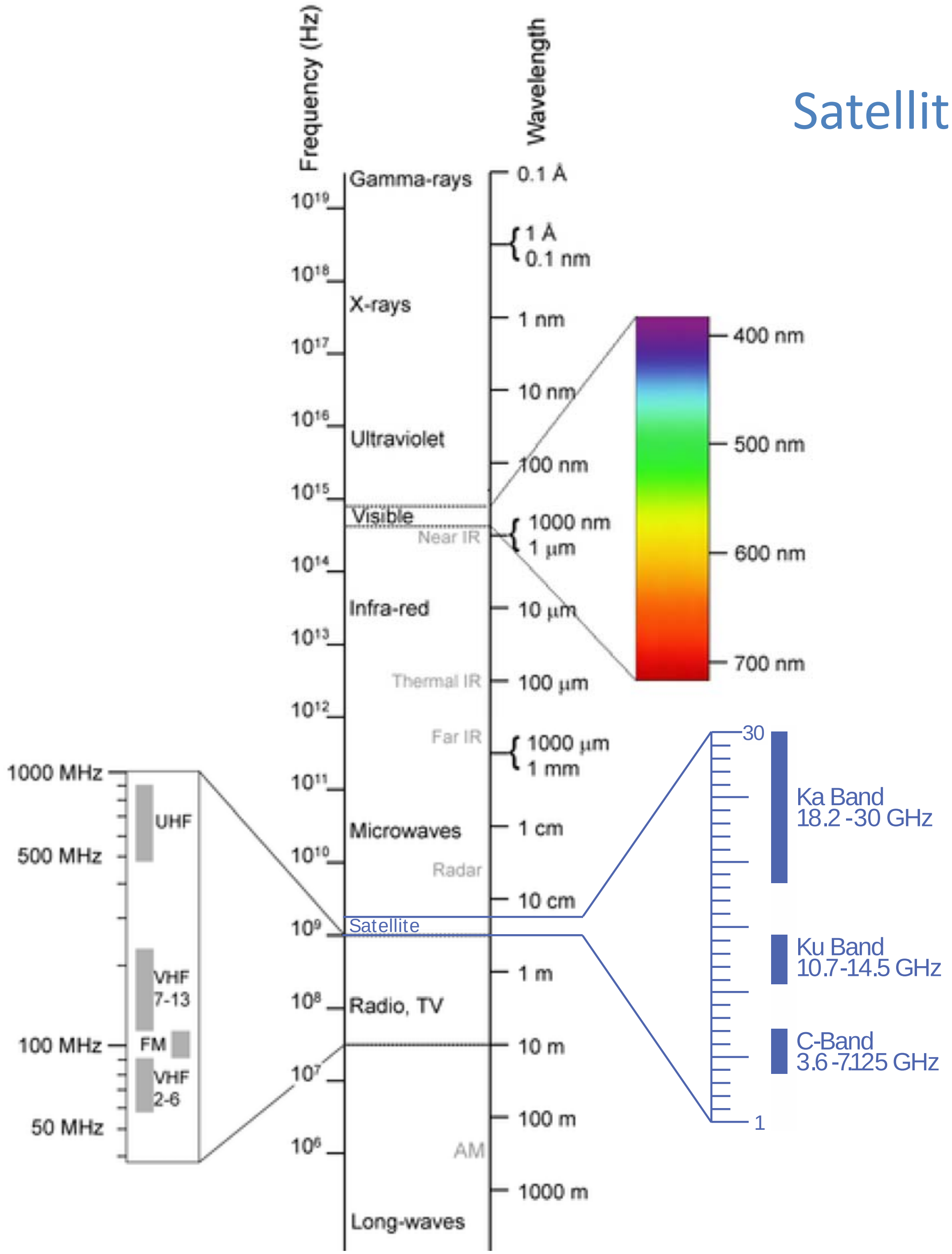
Satellite Spectrum



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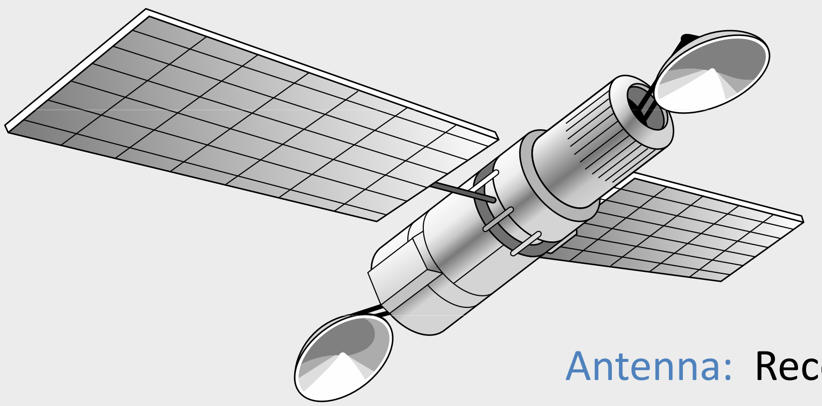
Satellite – Major Communications Components



Antenna: Receives composite spectrum across entire uplink

Amplifier: Receive side

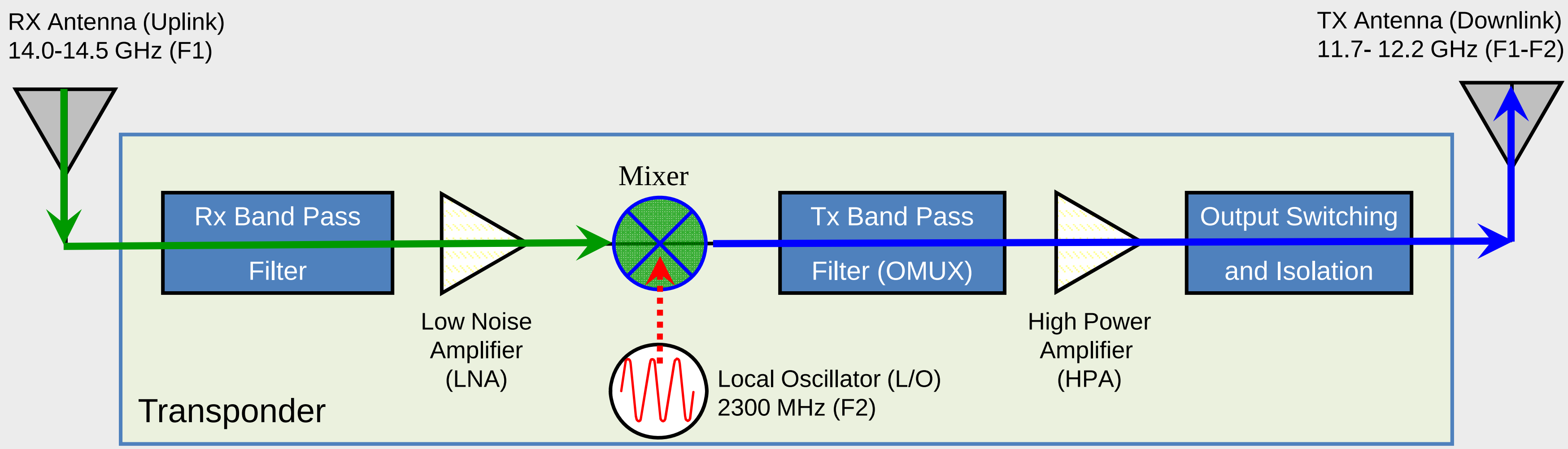
Transponders: Typically many, with varied configurations

Frequency Converter: Mixer (per transponder)

Amplifier: Transmit side

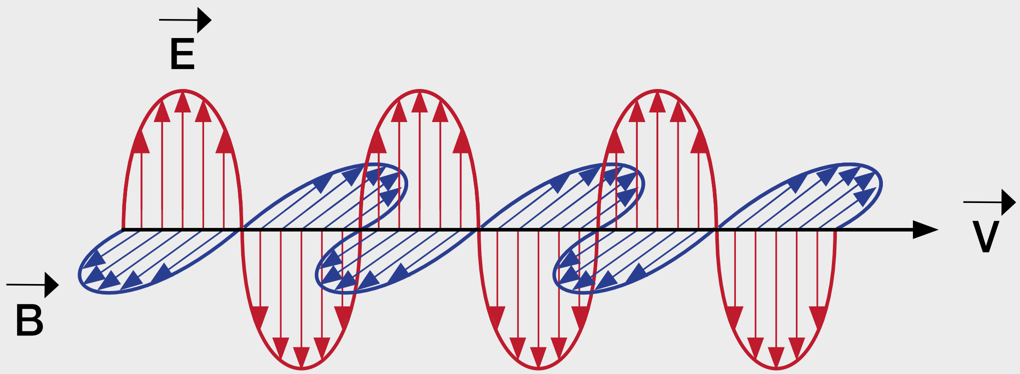
Antenna: Transmits downlink to receiving earth station

Transponder Block Diagram



- Input, or Receive Band Pass Filter
- Low Noise Amplifier (LNA) acts as a low power pre-amplifier
- Mixer, or Frequency Down Converter
    - Includes Local Oscillator, or L/O
- Output filter (OMUX)
- High Power Traveling Wave Tube Amplifier (HPA or TWTA)
- Output isolation and switching

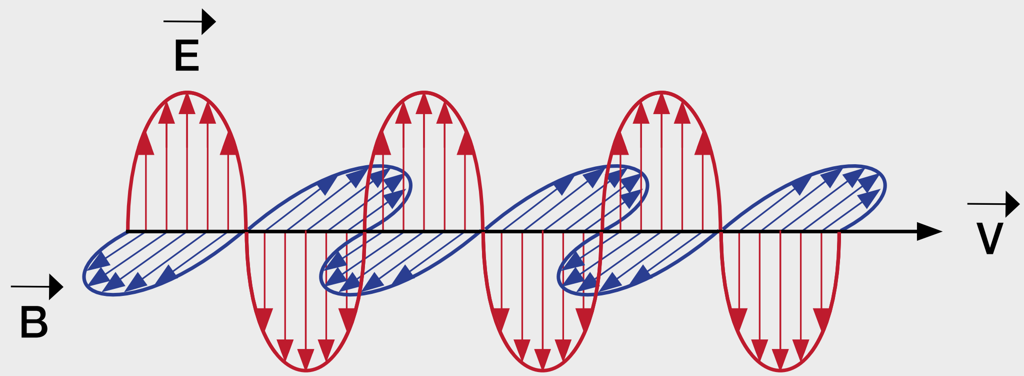
Signal Polarization



Signal Polarization is a property of electromagnetic waves

- Three dimensions of electromagnetic waves
  - Frequency, amplitude, and phase
- A simple plane wave is two-dimensional
  - The plane is perpendicular to the direction the wave propagates
  - The electric vector can be decomposed into two orthogonal components (electric and magnetic)
    - Referred to ‘horizontal’ and ‘vertical’
    - Simple harmonic (or carrier) wave, where the amplitude of the electric vector varies in a sinusoidal manner, these two components have EXACTLY the same frequency

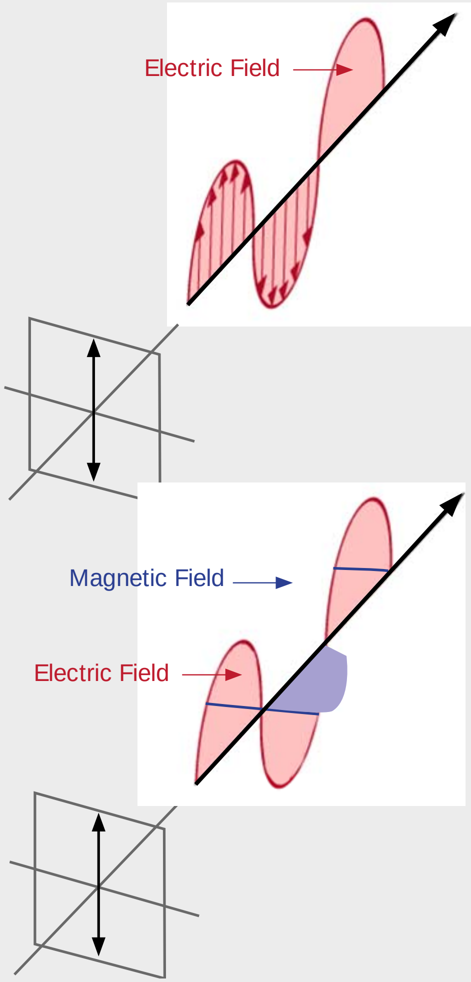
Signal Polarization



These two components have other defining characteristics that can differ:

- Two vector components may not have the same amplitude
- Two vector components may not have the same phase, that is – they may not reach their maxima and minima at the same time in the fixed plane

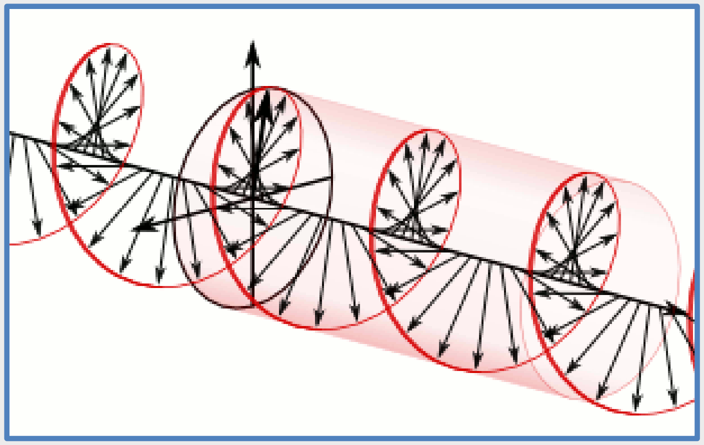
Linear Signal Polarization



Linear Polarization occurs where the two vector components are in phase

- Direction of the electric vector in the plane, which is determined by the vector sum of the two orthogonal components, will always fall on a single line in the plane
- The direction depends on the relative amplitude of these two vector components
- Linear polarization can be in any angle in the plane, but once set, it never varies

Circular Signal Polarization



Circular Polarization occurs where the two orthogonal components are exactly 90 degrees out of phase

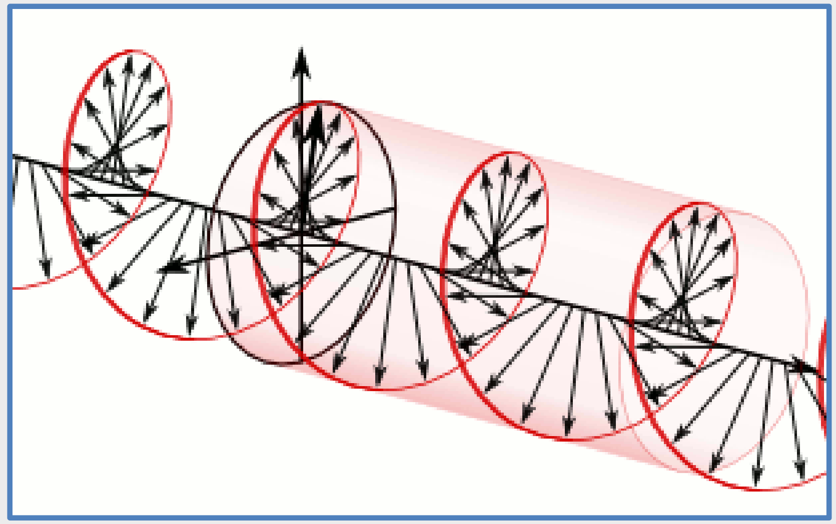
- Both components have exactly the same amplitude
- One component is at zero (reference) when the other component is at maximum or minimum amplitude

There are two possible phase relationships that satisfy this requirement:

- The x component can be 90 degrees ahead of the y component
- The x component can be 90 degrees behind the y component

Circular Signal Polarization

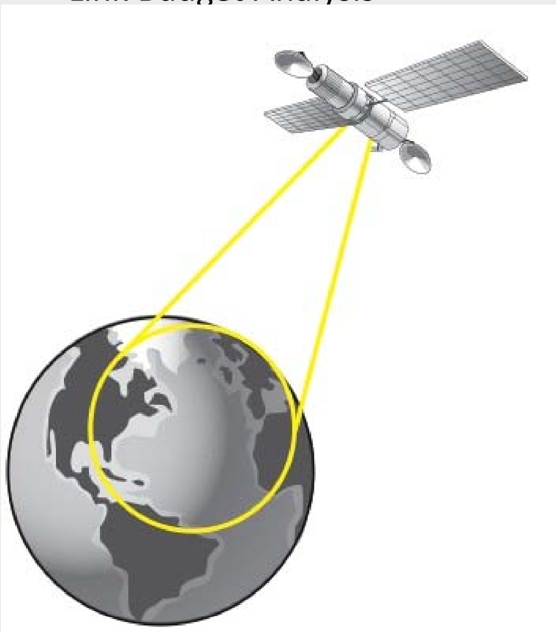
In this case, the electric vector in the plane formed by summing, the two components will rotate in a circle



- The direction of rotation will depend on which of the two phase relationships exists
- Depending on which way the electric vector rotates, there are two alternatives
  - Right-hand circular polarization
  - Left-hand circular polarization

Satellite Link Budget

Link Budget Analysis



- The process of correctly sizing uplink and downlink paths
- Designed for a specified availability
- 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
- Assigns transponder uplink and downlink frequencies
- Link Budgets must account for any Mesh TDMA carrier requirements
- Remote site levels and commissioning process more critical than ever (Mesh)

Carrier Types

There are a wide variety of carrier types

- Each has its own advantages
- The most common are:
  - SCPC Single Channel per Carrier
  - TDMA Time Division Multiple Access
  - D-TDMA Deterministic Time Division Multiple Access
  - DVB-S Digital Video Broadcasting – Satellite
  - DVB-S2 Digital Video Broadcasting – 2nd Generation

Single Channel per Carrier - SCPC

- Term SCPC comes from older analog transmission technology, when a single satellite carrier could carry only one data channel
- Used for economical distribution of broadcast data, digital audio and video, as well as for full-duplex or two-way data, audio/video communications
  - User data is transmitted to the satellite continuously on a single satellite carrier
  - The satellite signal carrier may be received at
    - Single location, indicates a point-to-point link (SCPC-SCPC)
    - Many locations in a broadcast mode, provides connectivity among multiple, geographically-dispersed, point-to-multipoint sites (SCPC-TDMA)
- SCPC can be referred to as TDM, or Time Division Multiplexed Carrier
  - Multiple, co-located baseband input sources are ‘multiplexed’ together using Time as a controlling factor for a common output carrier

Time Division Multiple Access - TDMA

TDMA is a mechanism for sharing a satellite uplink channel among multiple remotes

- Users have access to the whole channel bandwidth for small periods of time known as a time slots
- All users contend for available bandwidth based on QoS settings and other related priority control parameters
- Demand is requested by the remote site and is assigned by the network hub when bandwidth is available
- No mechanism to control time slot requests from remotes

Deterministic Time Division Multiple Access – D-TDMA

Prevents collisions that can occur when multiple remotes transmit simultaneously

- Network timing provided by synchronized burst time plan
- Time slot assignments provide guaranteed delivery
- Improves throughput and reduces latency by reducing/eliminating retransmissions

Digital Video Broadcasting – DVB-S2

Enhanced DVB-S Standard

- Introduced IP transport including MPEG-4 audio/video
- Optimizes bandwidth utilization by dynamically changing transmission parameters
  - Adaptive Coding and Modulation (ACM)
  - Variable Coding and Modulation (VCM)
- Improved Forward Error Correction (FEC)
- Increases carrier performance around 30% over DVB-S

IP is a Connectionless Protocol

- Specifies only Best Effort ; provides unreliable packet delivery
  - No retransmission of IP packets
  - Packets discarded if network resources are insufficient
- Source and destination IP facilities do not handshake
- Specifies the format of all data
- IP software performs the routing function
  - Packets are treated independently
  - Packets may take different paths through the network
- IP provides packet delivery service to Transport Layer protocols
  - IP provides common, consistent, universal addressing technique
  - IP defines set of rules that embody packet transmission and delivery
    - Specifies how routers should process packets (routing, ToS, precedence, fragmentation)
    - Specifies when and how to generate error messages (ICMP)
    - Specifies conditions that govern discard and/or duplication of packets (multicast)

Transmission Control Protocol - TCP

TCP is a Connection-Oriented Protocol

- Source and destination MUST agree to the transmission and reception of information PRIOR to the transfer of user traffic
  - Destination must agree to receive the information
  - All transmissions are acknowledged
- Dictates procedures to agree when transfer is complete
  - Specifies the format of information
  - Specifies acknowledgements that information was received
  - Specifies method to ensure information was received correctly
- Responsible for Flow Control
- Determines how a machine distinguishes between multiple destinations
- Provides guaranteed end-to-end delivery
- Provides recovery from errors, lost, and duplicated packets
- Retransmission is REQUIRED if acknowledgement is not received
- TCP and IP operate over dial-up, LAN, Optic, high and low speed WANs
- Latency must be overcome for TCP to be practical on satellite links

Transmission Control Protocol - TCP

TCP Multiplexes and Demultiplexes data to/from applications

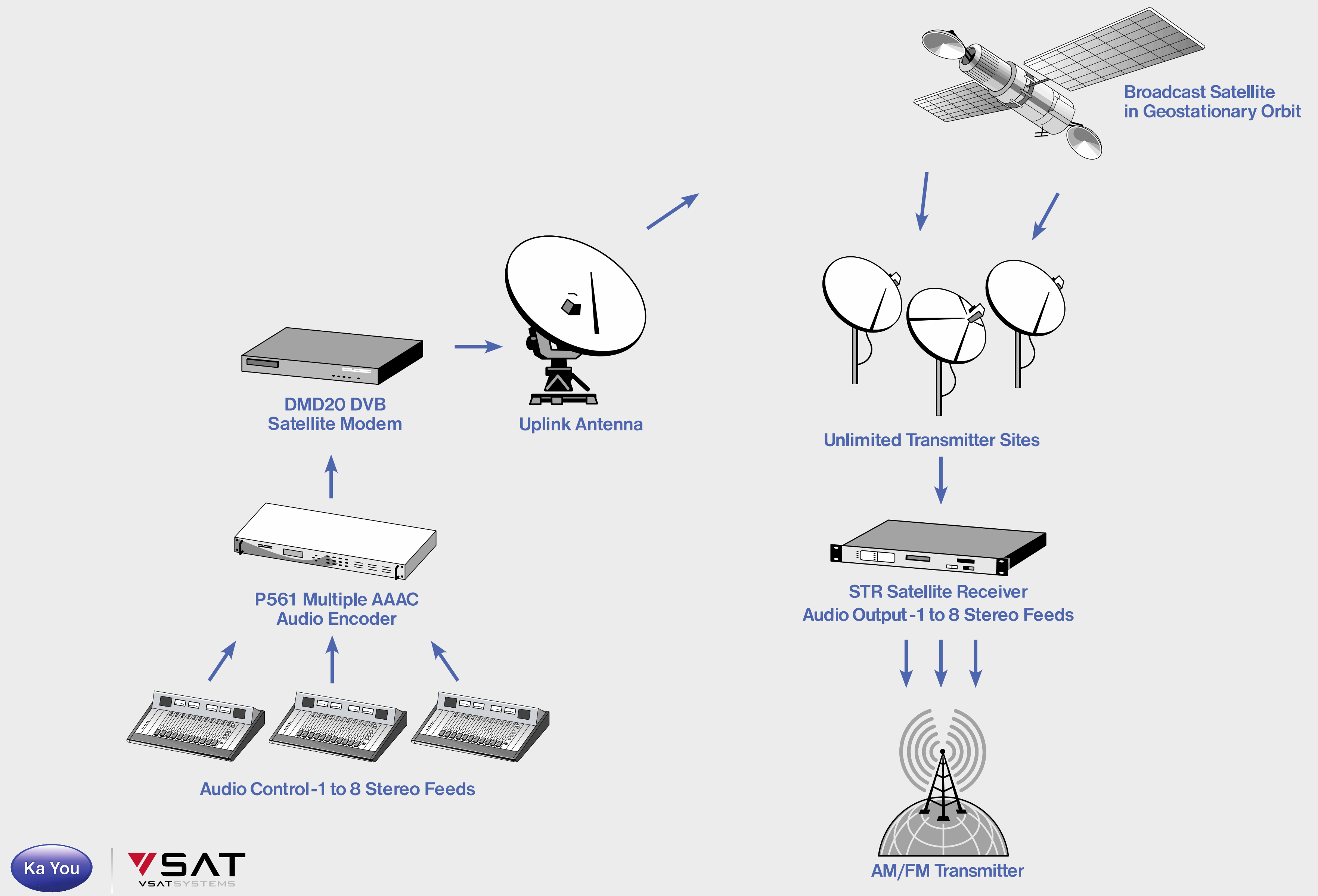
- Must distinguish data flows between destinations
- Uses Port IDs and destination IP address to distinguish flow
  - A TCP Port is a queue into which TCP places data grams
- Employees connection abstractions such as:
  - Source/Destination Port(s)
  - Host Address:Port and/or Source Address:Port pairings
    - Source (65.168.20.1:100) – Destination (10.10.200.1:200)
    - Source and destination pairing to identify a data flow
  - Requires only one local port to accommodate many data flows for many local applications
- Encapsulates data traffic (IP Packet)
  - IP Packets are the payload
  - IP Packets are the single packets that traverse the network
    - In a routed network OSI Layer 3 packets live only point-to-point
    - Ethernet packets live only between adjacent ports

User Datagram Protocol - UDP

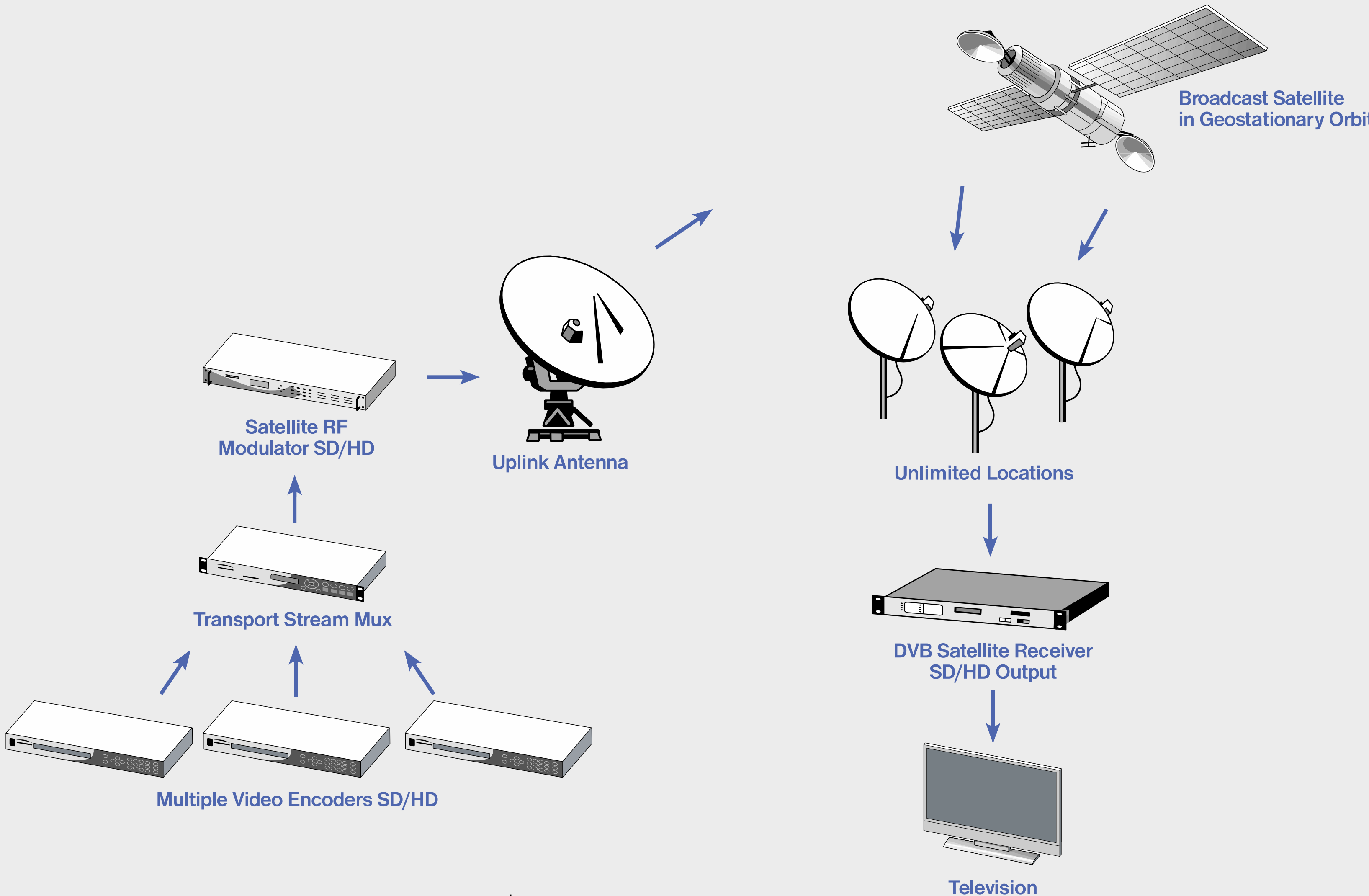
UDP is a Connectionless Service

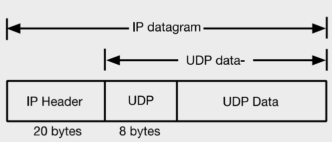
- Best Effort packet delivery service
- Source sends information without respect to agreement by any destination to receive the information
- No acknowledgements provided by recipient
- No guarantee of delivery
  - If not 'received', missing packets are never resent
- Appropriate for real time applications such as voice/video

DVB S or DVB S-2 Linear Delivery Block Diagram



DVB S or DVB S-2 HD/SD Linear System Block Diagram





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Pro Audio System Diagram

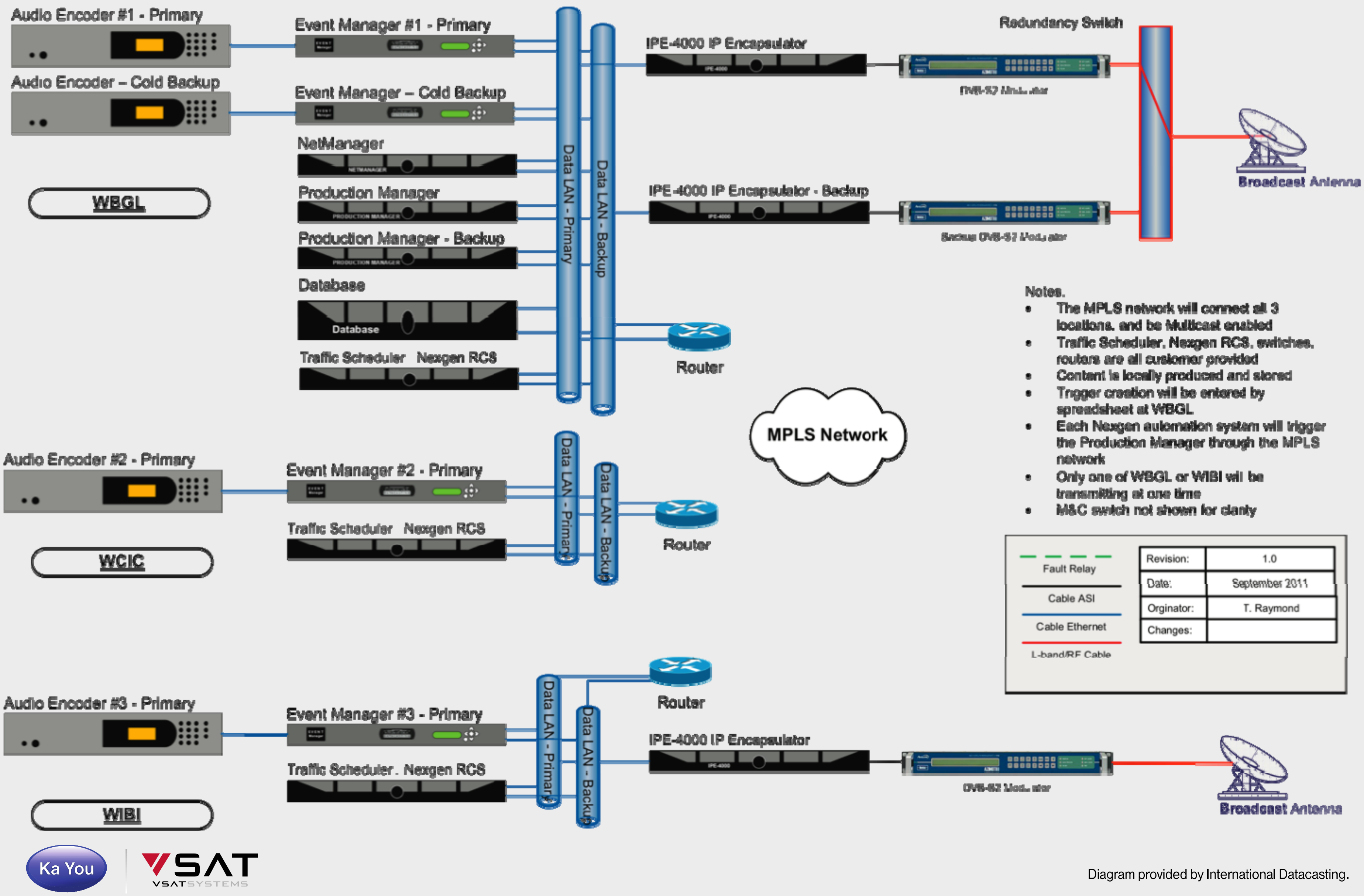

Diagram provided by International Datacasting.

Pro Video System Diagram

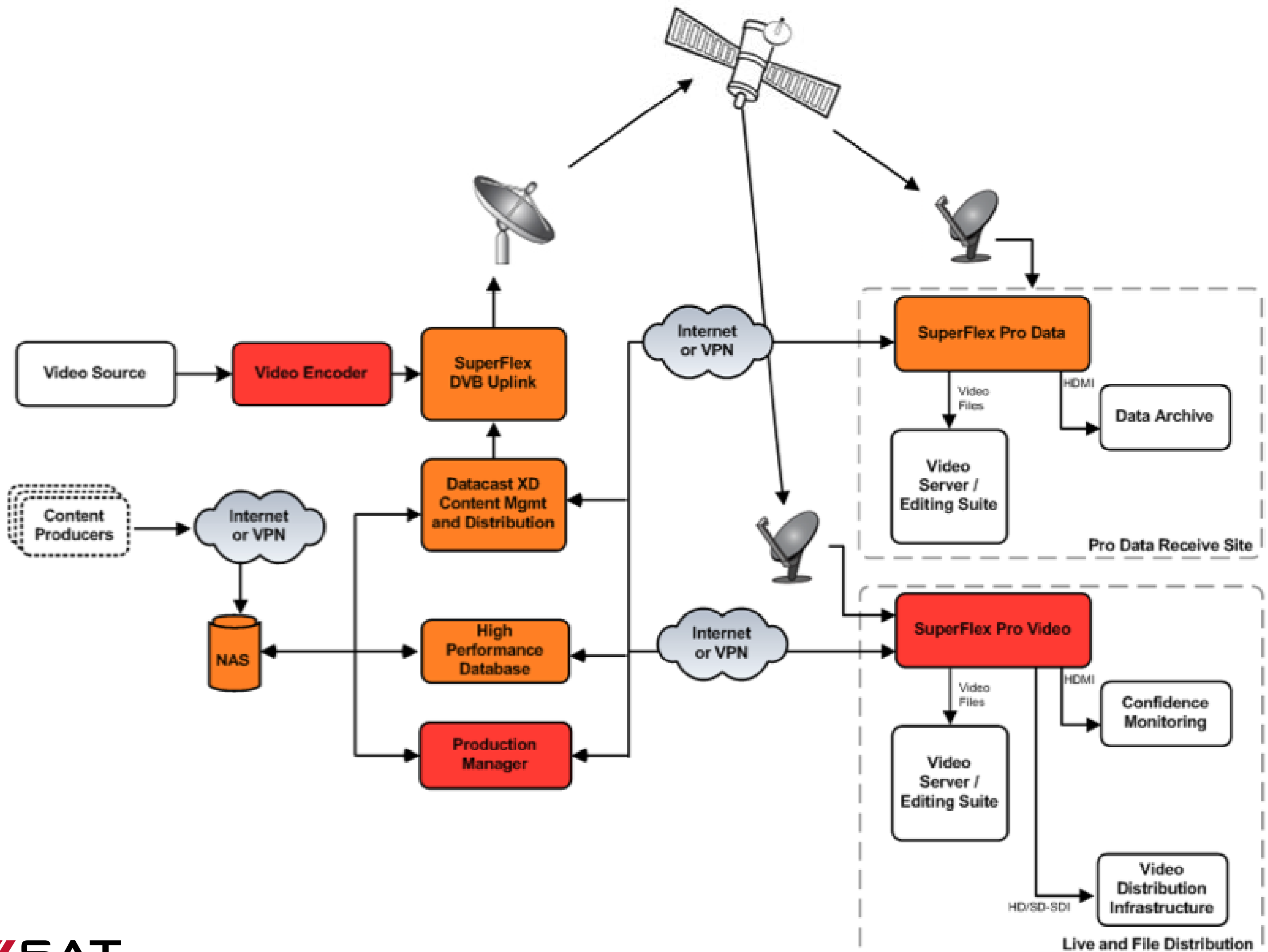

Diagram provided by International Datacasting.

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Summary

Aspects of delivering IP connectivity to a transmitter

- Geosynchronous satellite orbit
- Communications satellite components
- Polarized signals theory
- Carrier types
- IP/TCP/UDP
- IP in broadcast components

Thank you