

## I. Introduction

### Electronic Systems Technology, Inc.

- Founded in 1982
- Public Held in 1984
- 1985 First Wireless Modem Type Accepted
- 1987 U.S. Patent for Wireless Modem
- 1988 R & D 100 Award for Wireless Modem
- 2004 & 2005 - Fast 50 (38th) Growing Businesses in Washington
- To date over 24,000 ESTeem products in service world wide
- Corporate offices and production facility in Kennewick, WA.

### Major Markets

- Water/Waste Water
- Overhead Crane
- Metals
- Mining
- Factory Floor Automation
- Power- Utilities
- Building to Building
- Wireless LAN Networks
- Oil/Gas
- Material Handling
- Municipal Networks
- Public Safety
- Mobile Data Computers
- Government
- Defense

### Training Class Overview

- Class Materials
  - Class Outline
  - RF Design Disk
    - Resource Disk - All Published Material
    - RF Design Program
- Goals of Course
  - Understanding Operation of ESTeem Products
  - Installing and Programming
  - Troubleshooting and Maintenance
- Questions?

### Class Outline

- General Radio Overview
  - Basics of Radio Communication
  - Antennas
  - RF Design Program

- Site Survey
- Wireless Ethernet
  - Ethernet Overview
  - Programming
  - Troubleshooting/ Analysis
- Software Utilities
  - Configuration Utilities
  - Monitoring Software
- Serial Applications
  - Serial Over Broadband
- Testing
  - Written Test
  - Hands-On Testing

## II. Radio Technology Overview

### Radio Basics

- Terminology
  - Familiarization with radio expressions
- Basic Components
  - Transmitter
  - Receiver
- Transceiver
  - Transmitter and receiver together
  - Generally in a single unit

### Radio Basics

- Full-Duplex Radio
  - Two Frequencies Used
  - Transmit and Receive Simultaneously
- Half-Duplex Radio
  - Two Frequencies Used
  - Transmit or Receive - Not Simultaneously
- Simplex Radio
  - One Frequency Used
  - Transmit or Receive - Not Simultaneously

### Line of Sight Diagram

### Radio Characteristics

- Transmitter Characteristics
  - Transmission Speed
  - Turn-On time
    - “Attack Time”
  - Bandwidth
- Receiver Characteristics

- Receiver Sensitivity
- Receiver Squelch

## Radio Propagation VHF

- Very High Frequency (VHF)
  - Advantages
    - Lower Terrain Losses
    - Good atmospheric penetration
    - Good Reflections
    - Lower Cable and Connector Losses
  - Disadvantages
    - Higher Noise Floor
      - More Receiver Signal Required
    - Larger Antennas
      - Size Based Upon Wavelength

## Radio Propagation UHF

- Ultra High Frequency (UHF)
  - Advantages
    - Smaller Antennas
    - Lower Noise Floor
      - Less Receive Signal Required
    - Unlicensed Frequency Ranges
      - 900 MHz & 2.4 GHz
  - Disadvantages
    - Terrain and Vegetation Losses
    - Higher attenuation in coax cable

## Radio Propagation SHF

- Super High Frequency (SHF - “Microwave”)
  - 3 GHz to 30 GHz
    - 4.9 GHz Licensed Band
    - Unlicensed National Information Infrastructure (U-NII)
      - 5.15 to 5.825 GHz
  - Advantages
    - High Gain Antennas
      - Dish/Parabolic
    - Very Low Noise Floor
      - Small Receive Signal Required
  - Disadvantages
    - Very High Terrain and Vegetation Losses
    - Higher attenuation in coax cable
    - Line-of-sight (LOS) Critical

## Licensed Frequencies

- Common Licensed Frequencies
  - 72 to 76 MHz
  - 150 to 174 MHz
  - 400 to 420 MHz
    - U.S.A. Federal frequency
    - Canada civilian frequency
  - 450 to 470 MHz
  - 900 MHz

## Licensed Broadband

- New Licensed Broadband
  - Public Safety Primary Operation
  - Municipal Applications Also Excepted
- Exclusive Use of Frequency
- Outside Standard 2.4 GHz Bands
- 4.9 GHz Frequency Band
  - Speeds to 54 Mbps

## Unlicensed Frequencies

- Common Unlicensed Frequencies
  - 900 MHz Spread Spectrum
  - 2400 MHz Spread Spectrum
  - 5000 MHz Spread Spectrum
- Select Frequency of Operation
  - Based on site needs for data rate and polling times needed

## Transmission Techniques

- Conventional
  - Transmit Data
    - Key Transmitter
    - Send Data
    - Un-key Transmitter
  - Receive Data
    - Switch to Receive
    - Receive Data
  - Voice Radio Most Common Application
- Packet Burst
  - “Certified Mail”
  - Individual Address
  - Acknowledgments

## Spread Spectrum

- Most Spread Spectrum Radio Use Unlicensed Bands
  - Industrial Scientific & Medical (ISM)
    - 900 MHz and 2.4 GHz
  - Unlicensed National Information Infrastructure (U-NII)
    - 5.15 to 5.825 GHz
  - Manufacturer Gets FCC Approval - Not User
- 900 MHz Frequency Band
  - Most commonly used frequency band for consumer based wireless devices (Cordless Phones, etc.)
  - Frequency propagation has less loss than higher frequencies
- 2.4 GHz Frequency Band
  - Greater bandwidths available for higher data rates
  - Most common band for wireless Ethernet hardware
- 4.9 GHz Frequency Bands
  - Very low noise floor and fewer users
  - Licensed for public safety

## Frequency Hopping

- Breaks Information Signal (Data) Into Smaller, Moving Narrow Band Signals
- Complexity Does Not Lie In The Spreading and De-Spreading Of the Data Signal but In Synchronization of Narrow Data Signal
- Uses Spreading Signal to Change Frequency of Carrier (Hop) Across Band
- Hopping in Patterns Approximately 100 times/sec
- Interference Handled by Moving Hopping Patterns

## Frequency Hopping Diagram

## Direct Sequence

- Combines Information Signal with Spreading Signal to Produce Wide-Band Transmission
- Pieces of Each Bit Are Sent Across Whole Band
- Receiver Then Adds Back Up - Process Gain
- If Some Pieces Are Lost They Don't Add to the Overall Gain of Receiver, but Data is Not Lost
- Any Interfering Signal Not In Original Spreading Code Signal is Then "Spread" Itself and Filtered Out in Receiver

## Direct Sequence Diagram

## OFDM

- Latest Generation of Spread Spectrum
- Available bandwidth divided into multiple data subcarriers
  - (52) 300kHz-Wide Subchannels
  - 48 used for data and 4 used for error correction
- All channels evenly spaced (Orthogonal)
- All subcarriers transmit simultaneously for high spectral efficiency
  - Parallel data transmission paths
- Resilient to RF interference
- Low Multipath distortion

## OFDM Diagram

## III. Antenna Fundamentals

### Decibels (dB)

- Used for all mathematical calculations in the radio world.
  - dB is a logarithmic number
    - $\text{dB} = 10 \log(\text{linear number})$ 
      - A gain of 2 =  $10 \log(2) = 3 \text{ dB}$
      - A gain of 4 =  $10 \log(4) = 6 \text{ dB}$
      - When a number doubles it goes up 3 dB
      - When a number reduces by 1/2, it goes down -3 dB
  - To multiply linear numbers you add logarithms
  - To divide linear numbers you subtract logarithms

### Antenna Gain

- Antenna Gain measure in decibels (dB)
  - Double every 3 dB
- As Antenna Gain increases Antenna Pattern becomes more directional
- Effective Radiated Power (ERP) = Tx Power + Antenna Gain - Feedline Losses
- Received Signal = Rx Power + Antenna Gain - Feedline losses

### Radiation Patterns

- Omni-Directional
  - Radiates RF energy in all directions from antenna

## RF Basics - Omni-Directional Antennas

- Omni-Directional Antenna
  - Radiates RF energy in all directions from antenna
  - Usually used at the Master and Repeater Nodes

## RF Basics - Antenna Gain

## Radiation Patterns

- Directional
  - Compresses RF Energy in one direction

## RF Basics - Directional Antennas

- Directional
  - Radiates RF energy in one direction
  - Usually used at Remote Nodes in a Point to Multi-point system or Point to Point Site

## RF Basics - Antenna Gain

- As Antenna Gain increases the Antenna Pattern becomes more directional

## Antenna Polarization

- Vertical Or Horizontal Polarization
  - Polarization is the radiating element referenced to earth
  - All nodes must be the same polarization
    - Cancellation of signal if mismatched
  - Vertical Polarization for Most Radio Applications
    - Mixture of Omni and Directional Antennas
    - No Horizontal Polarization of Omni-Directional

## Antenna Types

- 1/2 Wave Antenna
  - Close to Isotropic Radiation
  - 3 dB gain
  - No ground planes needed
- 1/4 Wave Antenna
  - Unity Gain
  - Requires Ground Planes
  - “Cone of Silence” above and below antenna

- Yagi
  - High gain
  - Directional
  - Horizontal Beamwidth
  - Vertical Beamwidth

## Antenna Impedance

- 50 Ohm Load Is the Industry Standard
  - Based on 1/4 Wave Antenna
- Antenna Impedance Must Match Feedline Impedance and Transmitter Output Impedance
  - A Mismatch Will Induce Standing Waves Which Will Reduce Radiated Power.

## RF Basics - Feedlines

- Feedline
  - Pipeline for RF Energy From Radio to/from Antenna
  - Different Cable Types Have Different Losses
    - The lower the loss the more expensive the cable
  - Losses Based Upon Length & Frequency
    - Expressed in dB/100 ft. by the manufacture
  - The higher the frequency, the more attenuation in cables, connectors, etc.
  - All feedlines and connectors induce losses to RF energy

## RF Basics - Feedline Attenuation Table

## Types of Feedlines

- RG-58 Cable
  - Only use on very short runs (< 10 feet)
  - Good on licensed (<1 GHz) only
  - Very flexible
    - 72-79 MHz = 3.8 dB per 100 feet
    - 150-174 MHz = 5.2 dB per 100 feet
    - 400-500 MHz = 11 dB per 100 feet
- LMR-195 Cable
  - Only use on very short runs (3 foot standard length)
  - Very flexible
  - Good up to 2.4 GHz
    - 72-79 MHz = 3.0 dB per 100 feet
    - 150-174 MHz = 4.4 dB per 100 feet
    - 400-500 MHz = 7.8 dB per 100 feet
    - 2.4 GHz = 19 dB per 100 feet

- RG-8 Cable
  - Good for feedline runs up to 50 feet (Licensed Radios)
  - Workable losses up to UHF frequencies
    - 72-79 MHz = 1.5 dB per 100 feet
    - 150-174 MHz = 2.3 dB per 100 feet
    - 400-500 MHz = 4.4 dB per 100 feet
    - 2.4 GHz = 10 dB per 100 feet
  - Both rigid and flexible cable available
- 1/2 Inch Helix
  - Recommend for feedline runs over 50 feet
  - Very low loss
    - 72-79 MHz = .6 dB loss per 100 feet
    - 150-174 MHz = .8 dB per 100 feet
    - 400-500 MHz = 1.5 dB loss per 100 feet
    - 2.4 GHz = 3.74 dB loss per 100 feet
  - Very rigid
  - Higher cost per foot than RG-8

## Connector Types

- TNC
  - Input connectors on most ESTeems
- UHF
  - Input to most antennas
- N-Type
  - Input to lightning arrestor and some antennas
- Reverse Polarity
  - All unlicensed radio systems require “unique” connectors

## Standing Wave Ratio (SWR)

- Ratio of Maximum to Minimum Values in Standing Wave Pattern
  - Voltage (VSWR) or Current
- Mismatch in Impedance (Antenna or Cable) Will Induce Standing Waves
- Measurement of Forward and Reflected Power Most Field Expedient
  - Wattmeter

## SWR Measurement

- Maximum = 10% Reflected Power
- ESTeem commands
  - Radio ON command for serial
  - Advanced Menu 195E

## Typical Outdoor Antenna Block Diagram

## Typical Indoor/Mobile Antenna Diagram

## Typical Model 195E Mounting

## RF Filters

- Bandpass Filter
  - Filters out all radio frequencies except the operating frequency
- Notch Filter
  - Filters out a specific frequency in the frequency band
- Combiner/Duplexer
  - Allows two transceivers to share a common antenna and coax
  - Minimum frequency separation

## Mobile Installation

- Antenna Uses Vehicle as Ground Plane
- No Lightning Arrestor Needed
- Antenna Pattern Dependent On Vehicle Mounting Location

## Lightning Protection

- Ground Antenna and Lightning Arrestor to Same Ground Potential
- Protect Power Supply
- Protect Data Cable

## Weather Proofing

- Silicone On Connector Threads
  - Do not get sealant on center conductor
- Wrap RF Connector With Electrical Tape
  - Wrap beyond the connector of easy removal
- Form Vinyl Mastic Pad Over Connection
- Coat Entire Connector With Skotchkote Electrical Coating

## IV. RF System Design

### Presentation Overview

- Review Radio Basics
  - Terminology
- Use Information from Radio Basics and Antenna Sections
- Use RF Design Program
  - Initial Site Work
  - Using RF Design Program
  - Site Example

### Presentation Overview

- Each Radio Application is Unique
  - Wireless is being applied in many applications but few have a working knowledge of designing a successful wireless system
- Selecting A Wireless Vendor
  - Dizzying array ranges from vendors
  - Provide tools to personally review specifications

### Steps to Successful Radio Network

- RF System Design
  - Review Maps
  - RF Design Program Analysis
- On-Site Radio Site Survey
  - Physical Inspection and Testing
  - Confirming Results from RF System Design
- Site Commissioning
  - Same Testing on Installed System

### Presentation Overview

- RF Design Program
  - Conservative model of expected radio results
  - Installed hardware generally higher signal strengths
- Allows for modification to system design prior to installation if problems are found
  - Change Antenna Type
  - Change Coax Cable Types
- Provides means of determining expected data errors

### Typical Outdoor Antenna Block Diagram

### Minimum Antenna Height Required to Clear the Radio Horizon

### Fresnel Zone

- Fresnel Zone shows the ellipsoid spread of the radio waves
- Area must be clear of obstructions or signal strength will be reduced
- Blockage in 60% will induce significant signal losses
- Use for frequencies above 900 MHz

### RF Basics - Effective Radiated Power

- Effective Radiated Power (ERP) = Tx Power - Feedline Losses + Antenna Gain
- Received Signal = Rx Power - Feedline losses + Antenna Gain

### RF Basics - Fade Margin

- Receiver Sensitivity is the minimum signal level in dB needed by the receiver to output received data.
- Fade Margin in dB is the amount of received signal above the receiver's minimum required useable Receiver Sensitivity.
- Fade Margin is controlled by
  - Transmitter Power
  - Transmitter feedline attenuation
  - Transmitting antenna gain
  - Receiving antenna gain
  - Receiver feedline attenuation
  - Receiver Sensitivity

### RF Basics - Fade Margin

- How much Fade Margin?
- Imperfect world and things are constantly changing.
  - Equipment ages
  - Antennas go out of alignment
  - Unexpected man-made noise/interference
- Basic rules of thumb for digital transceivers.
  - 10 dB - 10% link retries
  - 20 dB - 1% link retries
  - 30 dB - .1% link retries
- Link Listed Marginal <10dB
  - Over 10dB Fade Margin = Green
  - 1-10db Fade Margin = Yellow (Marginal)
  - Less than 1dB = Red (Site Not Operational)

### Initial Site Work

- Draw a simple layout of the proposed system.
- Determine Line-of-Sight (LOS) distances between each point to point radio path by:
  - Site maps.
  - If Latitude and longitude are known use the "Distance Between Two Points Calculator" in the RF Design Program.
  - Use a hand held GPS. Or Google Earth®

- All Radio Systems are designed as a “Multiple” of Point to Point RF Paths
  - Base to Remote
  - Base to Repeater
  - Repeater to Remote
  - Repeater to Repeater
- Each Path Needs Evaluation
- Sketch a site diagram and distances between site nodes. Note LOS blockages.

## Initial Site Work

- Find the elevation of each node above sea level.
  - Reference maps or use a hand held GPS.
- Estimate installed antenna height at each node above ground level to achieve LOS to destination site.
- Estimate feedline length from antenna to equipment cabinet.
- Calculate *Elevation Differential* between the lowest node and the remaining nodes.
- Calculated the *Adjusted Antenna Height*.
  - Site Elevation Differential + Antenna Height above ground.

## Site Layout Map and Information

### RF Site Design Program

- Use the RF Site Design Program on each point-to-point RF path.
  - In this example we will use the ESTeem 195Eg
  - 2.4 GHz Frequency
  - Use your Site Information Table data
  - Use Vendor information on transceiver selected
    - The RF Site Design Program will provide ESTeem hardware recommended for operating frequency selected
  - Enter data in the Data Entry Key Board

## Standard Enclosure Mounting

### Model 195E Outdoor Pole Mount

### Outdoor Mounting Benefits

- Remove Long Coax Cable Required
  - Lower cost (\$65-\$500 Savings)

- Lower signal loss
- No Lightning Arrestor Needed
  - Lower cost (\$120 Savings)
  - Also removes loss in jumper cable
- No Enclosure Needed
  - Greatly reduced design and installation costs (\$300 Savings)

## RF Path Analysis

### Model 195Eg Maximum Range

- Two Directional Antennas
  - AA204Eg is the highest gain antenna that the unit is type accepted for.
  - 19 dB gain
- Cable Loss
  - .6 dB because the unit is pole mounted.
- Range
  - 179 miles @ 1 Mbps @ 6 dB Fade Margin
  - 8 miles @ 54 Mbps @ 6 dB Fade Margin

### Model 195Eg Maximum Range

- Range
  - 179 miles @ 1 Mbps @ 6 dB Fade Margin
    - Antenna Height = 4,100 ft at each end
    - *This would probably be usable only from mountain top to mountain top*
  - 8 miles @ 54 Mbps @ 6 dB Fade Margin
    - Antenna Height = 70 ft. at each end
    - This is a practical height

## Conclusions

- Education is Best Means to Confidence
  - Reliability is only as good as the system design
- Use the Tools
  - Compare different vendor’s hardware
  - Review specifications and claims
- Radio Applications Are Not Difficult
  - Planning and evaluation are best keys to success

**V. Radio Site Survey****What is a RF Site Survey**

- Develop Testing Plan
  - Customer’s RF Communication Desires
  - Gather Maps, Site Layout, etc.
- On-site Radio Measurements
  - Confirm RF Design Results
  - RF Signals & Noise
  - Determine Radio Paths
- Gather Site Information
  - Physical Site Inspection
  - Installation Information

**Procedure**

- Layout The Site
  - Review Topographic Maps
  - Site Walk-down
- Pre-Test Preparation
  - Lay out equipment
  - Reference Site
- Site Testing
- Test Results
  - Site Survey Report

**Site Layout**

- Review Map
  - Area Topography
  - Repeaters - Antenna types
- Site Walk-down
  - Look for LOS blockages
  - Type of antenna mounting structure and height
  - Routing of feedlines
  - Environmental considerations

**Reference Site**

- Install Antenna
  - Antenna placement
  - SWR measurement
- Conduct Spectrum Analysis
- Choose Frequency for Testing
  - Isolated frequency
  - Check for license availability
- Quick Connect Test

**Remote Sites**

- Proceed To Most Questionable Remote First
  - Furthest or least likely to communicate direct
- Install and Test Antenna
- Quick connect
  - Status light or connect command
  - If no connection, determine repeater site
- Signal Strength
- Data Transmission Testing
  - Polling Test or Pings

**Received Signal Strength (Licensed)**

- Remote Program Radio ON
- Spectrum Analyzer
  - 20 uV signal strength for 20dB fade margin
- Receive Signal Strength Meter
  - RXS ON
  - 0,3,10,20,35,50,75,100,200,400uV Levels
- Esteem receiver Squelch
  - Set Squelch = 0 (Noise Squelch Off)
  - Asquelch = 0        2uv (-101dBm)
  - Asquelch = 1        5uv (-93dBm)
  - Asquelch = 2        10uv (-87dBm)
  - Asquelch = 3        70uv (-70dBm)

**Received Signal Strength (Unlicensed)**

- Status Menu in Model 195 Series
  - Repeater Peer List
  - RF Data Rates
- Spectrum Analyzer
  - View Noise and Signal
  - Other Transmitters in Area
- 6dB above minimum signal strength for fade margin

**Data Transmission Testing**

- Conduct Test to All Communication Paths
  - Remote to master
  - Remote to repeater
  - Repeater to master
- Long Term Testing
  - Overnight Polling Test

## Testing Results

- All Signal Strengths Above Fade Margin
  - 20dB for Licensed Frequency
  - 10dB above Minimum for Spread Spectrum
- Antenna Heights and Locations
- Operating Frequency
- Background Noise
- Data Transmission Tests
  - From every site
  - Overnight to farthest site

## Site Survey Report

- Test Results
- RF System Layout
- Accurate Bill of Material
- Installation Instructions
- Safety Concerns
- Modem Program Commands
- Reliable Operating Frequency and License Information.

## VI. ESTeem Overview

### ESTeem Product Categories

- Licensed Serial
  - Long Range Application
  - Exclusive Use of FCC Frequency
  - PLC Emulation for Repeating and Grouping
- Unlicensed Serial
  - No Site License Required for Serial Applications
  - Serial and Ethernet for future expansions
- Wireless Ethernet
  - 802.11g Based Industrial Wireless Ethernet Products
  - 900 MHz Spread Spectrum
  - Licensed 4.9 GHz

### VHF Products

#### Model 192M

- 150-174 MHz
  - Simplex

- 19,200 Baud Rate
- Software Selectable
  - 12.5 kHz Channel Spacing
  - 5 kHz Channel Spacing
- 2-5 Watt Output Power
  - Software Selectable
- Receiver Squelch
  - Analog Squelch
  - Noise (Digital) Squelch
- Receive Signal Strength Meter
- Signal to Noise Ratio
- IR Communications Port
- -30 To 60 Degrees C
- 11-15 VDC

#### Model 192MHP

- 150-174 MHz
  - Simplex
- 19,200 Baud Rate
- Software Selectable
  - 12.5 kHz Channel Spacing
  - 5 kHz Channel Spacing
  - 10, 20 or 30 Watt Output Power
  - User Programmable
- 40 to 70 Mile Range (LOS)
- Receiver Squelch
  - Analog Squelch
  - Noise (Digital) Squelch
- Receive Signal Strength Meter
- Signal to Noise Ratio Output
- IR Communications Port
- -30 To 50 Degrees C
- 11-15 VDC

### UHF Products

#### Model 192C

- 450-470 MHz
  - Simplex
- 19,200 Baud Rate
- Software Selectable
  - 12.5 kHz Channel Spacing
  - 6.25 kHz Channel Spacing
- 2-5 Watt Output Power
  - Software Selectable
- 15 Mile Range (LOS)
- Receiver Squelch
  - Analog Squelch
  - Noise (Digital) Squelch
- Receive Signal Strength Meter
- Signal to Noise Ratio
- IR Communications Port
- -30 To 60 Degrees C
- 11-15 VDC

## Model 192CHP

- 450-470 MHz
  - Simplex
- 19,200 Baud Rate
- Software Selectable
  - 12.5 kHz Channel Spacing
  - 6.25 kHz Channel Spacing
- 10-30 Watt Output Power
  - Software Selectable
- 50 Mile Range (LOS)
- Receiver Squelch
  - Analog Squelch
  - Noise (Digital) Squelch
- Receive Signal Strength Meter
- Signal to Noise Ratio
- IR Communications Port
- -30 To 60 Degrees C
- 11-15 VDC

## Model 192F

- 400-420 MHz
  - Simplex
- 19,200 Baud Rate
- Software Selectable
  - 12.5 kHz Channel Spacing
  - 6.25 kHz Channel Spacing
- 2-5 Watt Output Power
  - Software Selectable
- 15 Mile Range (LOS)
- Receiver Squelch
  - Analog Squelch
  - Noise (Digital) Squelch
- Receive Signal Strength Meter
- Signal to Noise Ratio
- IR Communications Port
- -30 To 60 Degrees C
- 11-15 VDC

## Noise Squelch

- Analog Squelch
  - Set by Asquelch Command
  - Signal Strength Threshold
- Digital Squelch
  - Set by Squelch Command
  - Noise Squelch - Frequency Quieting
  - Works Best for High Noise Areas

## Spread Spectrum Products

## Model 195Eg

- 2.4 GHz - No Licensed Required
  - 802.11g and b Compatible
  - Ethernet 10/100BaseT – RJ-45 Interface
  - 54 M bps RF data rate
  - 1 Watt RF Output
  - 5 to 7 miles Line-of-Sight Range
  - Direct Pole Mounting
  - Power over Ethernet Cable
  - Access Point Modes
  - Access Point Repeater Modes
  - Client Modes for Mobile Applications
  - Serial Data Port
- ### Security
- WPA2/802.11i - Enterprise and PSK
  - WPA - Enterprise and PSK
  - Temporal Key Integrity Protocol (TKIP)
  - Access Control List (ACL)
  - 802.1x Authentication
  - Wired Equivalent Privacy (WEP) 64/128 Bit Encryption and Decryption

## Model 195Ed

- 900 MHz - No Licensed Required
  - Ethernet 10/100BaseT – RJ-45 Interface
  - 54 M bps RF data rate
  - 1 Watt RF Output
  - 10+ miles Line-of-Sight Range
  - Direct Pole Mounting
  - Power over Ethernet Cable
  - Access Point Modes
  - Access Point Repeater Modes
  - Client Modes for Mobile Applications
  - Serial Data Port
- ### Security
- CCMP - Enterprise and PSK
  - Temporal Key Integrity Protocol (TKIP)
  - Access Control List (ACL)
  - WEP 64/128 Bit Encryption and Decryption

## Model 195Ep

- 4.9 GHz - Licensed Radio
  - Ethernet 10/100BaseT – RJ-45 Interface
  - 1-54 M bps RF data rate (Auto Scaling)
  - 2 Watt RF Output
  - 5 to 7 miles Line-of-Sight Range
  - Direct Pole Mounting
  - Access Point Modes
  - Access Point Repeater Modes
  - Client Modes for Mobile Applications
  - Serial Data Port
- ### Security
- Temporal Key Integrity Protocol (TKIP)
  - Access Control List (ACL)
  - Wired Equivalent Privacy (WEP) 64/128 Bit Encryption and Decryption

## Model 195Es

- 900 MHz - No Licensed Required
- Ethernet 10/100BaseT – RJ-45 Interface
- 200 Kbps RF data rate
- 1 Watt RF Output
- 10 miles Line-of-Sight Range
- Direct Pole Mounting
- Power over Ethernet Cable
- Access Point Modes
- Access Point Repeater Modes
- Client Modes for Mobile Applications
- Serial Data Port - Standard

### Security

- CCMP – PSK or Enterprise
- Temporal Key Integrity Protocol (TKIP)
- Access Control List (ACL)

## ESTeem Model 192C/CHP/M/MHP/F Front Panel

## ESTeem Model 195E Front Panel

## Intrinsic Safety

- ESTeem Modem Itself Not Certified
- Must Use Intrinsically Safe Enclosure

## Power Sources

### AC Power Sources

- AA174 Universal Input Power Supply
  - 90-264 VAC
  - 12 VDC Output
  - Switching Power Supply
- Uninterruptible Power Supply (UPS)
  - Power Backup
  - Inexpensive line filter
  - On-line UPS vs. Standard

### Power Over Ethernet (PoE)

- Power Source for Model 195E Series
  - Power and Data on Same Cable
  - Unused Pairs in CAT-5e Cable Used for Power
  - 100 Meter (328 foot) Range on Ethernet Cable
  - Only Single Cable Required for Installation
- IEEE 802.3af Standard
  - 48 VDC - 13 Watts
  - Telecommunication Industry

## Solar Power

- Very efficient system
- Stand alone operation
  - 5-7 year battery life
- “Smart” regulator system
- Photovoltaic System

## Thermopile Diagram

## Licensing

- Bringing Order to Frequency Spectrum Chaos
- Costs and File Times Depend on Coordinators Fees
- Licensing Assistance Offices
  - Approx. 6-8 Weeks for new license return from coordinator (temporary use)
  - Approx. \$600-\$1100
  - Interim License As Fast As 4-6 Weeks

## VII. Wireless Ethernet Overview

### Overview

- Wireless Ethernet
  - Proprietary Hardware
  - Open WLAN Standard
- Network Types
  - Terminology
  - Uses
- Mesh Networking
- Client Modes
- Security
- Applications

### Sample Ethernet Stack Model

### Proprietary Wireless Ethernet

- Single Supplier for Wireless Equipment
- Manufacturer Sets Network and Modulation Standards
- Fastest to Market
- Flexibility on Development
  - Mesh Network Technology
  - High Speed 900 MHz (1-54 Mbps)
- Most Widely Used in Outdoor Applications

## Open Ethernet Standards

- IEEE 802.11 Wireless LAN (WLAN)
  - Intended to look and feel like wired 802.3 LAN
- IEEE 802.11b/g/a (WiFi)
  - Extensions of the Physical Layer
- Device Level Standards – 802.15.4
  - Zigbee/Wireless Hart
  - ISA100.11a
- Emerging High Speed Networks
  - 802.11n
  - Adoption in late 2009

## 802.11g/b/a Network Types

- Access Point (Infrastructure Modes)
  - All Client Stations Communicate Through Access Point
  - Access Point Provides Link to Wired LAN
  - Multiple Modes for Application
- Access Point Repeater
  - Enhanced Features of Access Point Network
  - Allows Communication Between Multiple Access Points through radio link
- Client Modes
  - 802.11 Client Application
  - Mobile Equipment

## 802.11 Access Point Network

- All Clients Link to Access Point
- Access Point Provides Link to Wired LAN Network
- Access Point Can Link Multiple Clients on Different Data Rates (802.11b and 802.11g)
- Functions As Network HUB for WLAN

## ESTeem Access Point Networks

- Access Point Bridge
  - Pass all network traffic from wired LAN
  - Global broadcasts sent through AP
- Access Point Router
  - Functions same as Router between wired and wireless network
  - No global broadcasts passed on radio network
  - Used on high Ethernet traffic network connection
- Access Point Masquerade
  - Single static IP address on network
  - All wireless clients hidden from network
  - Functions as Firewall between wired and wireless network
  - Direct connection to Internet (T1, DSL, etc.)

## Access Point Bridge Example

## Multiple Access Points

## Access Point Router Diagram

## Access Point Masquerade

## Access Point Repeater

- Communication Link Between Access Points
- Can Either Be Hardwire Connection or Wireless
- Allows Extended Range for WLAN
- All AP Network Types Supported

## Access Point Repeater

- Provides Access Point Connection to Clients
  - Functions as Base for Mobile Clients
- Allow Bridging Between Access Points
  - Connects Access Points Through Radio Link
- Allows Any 195E AP to Function as Repeater
  - Unlimited Connections
  - “Self-Healing” Mesh Communication Network
- Supported in all AP Modes

## Access Point Bridge – Repeater

## Access Point Router – Repeater

## Access Point Masquerade

## ESTeem Mesh Technology

- Repeater Peer Links
  - WLAN Address of Remote ESTeem
  - Path Cost or Path Length
  - Encryption Type
  - Data Rate
- Routing Base Upon Spanning Tree Protocol (STP)
  - Root Bridge
  - Path Cost vs Path Length
  - Rapid Spanning Tree Protocol
- Enable Each Fixed Route
  - Mobile Clients Not Required in List

## Redundant Path Overview

## ESTeem Client Applications

- Mobile Client in Network
- Greatly Extended Range of Mobile Devices
  - Vehicles
  - Forklifts
  - Single Remote Locations

## ESTeem Client Modes

- EtherStation
  - Single Ethernet device on wireless network
  - Only one device connected to ESTeem
- Station Router
  - Multiple Ethernet devices on client connection
  - Router between wireless network and connected devices
  - IP address for each device visible on network
- Station Masquerade
  - Multiple Ethernet devices on client connection
  - Firewall between connected clients and wireless network
  - IP address for each device hidden on network
  - All devices appear as a single IP on network

## ESTeem Client Roaming

- Custom Roaming Code
  - Most Mobile Clients Will Move Only on Connection Loss
  - Overlapping Coverage Not Helpful
- ESTeem Custom Roaming Code
  - Signal Strength Threshold
  - Number of Missed Packets
  - Client Will Stay With Access Point Until Better Link Found
  - Client Will Obtain Highest Data Rate Possible
- Authentication
  - Verification Of Network ID and Security Code
  - Association with New Access Point
  - Disassociation of Old Access Point

## Proprietary Bridge Networks

- Ethernet Bridge Mode
  - IEEE 802.11 Does Not Define AP to AP Connections
  - Proprietary Ethernet Link
  - Repeating and All Modes of Operation Supported
  - Extended Security
    - Features Lost such as Access Point Repeater
    - No Open Standard Equipment
  - Links Networks Together
  - Links Ethernet Nodes in Network

## Wireless Bridge With Repeater

## Building to Building Router

### Security of Data

- Early Encryption Support
  - WEP 64/128 Bit
  - WPA – TKIP
    - Pre-Shared Key (PSK)
    - Enterprise (Radius Server)
- IEEE 802.11i (WPA2)
  - AES Encryption
  - CCMP Encoding
  - PSK or Enterprise

### WEP Security

- Designed for Basic Security
  - Unauthorized listening or monitoring
  - Prevent unauthorized use
- Not Designed for a Strong Encryption
  - Similar Problems with Dial-Up Access
  - EAP was implemented as “stop-gap” solution
  - VPN is an alternate security method
- Multiple Layers of Security
  - No single layer of security will work

### Access Control List (ACL)

- Additional Security Overlay
- “MAC Filter” to Accept or Deny MAC Addresses
  - Unique for ALL Ethernet Devices
  - MAC Address Set at Factory
  - Single Addresses in List
  - Group of Addresses
- Simple but Most Secure Method
  - Physical Compromise Required
- More Management Required

### WPA

- WiFi Protected Access
- Interim Solution from WiFi Alliance
  - Used Elements from 802.11i Workgroup
  - Solutions could be software or firmware updated
- Enhanced Encryption through TKIP
  - Rolling Encryption Cipher
- Support for User Authentication
  - RADIUS Server Model
    - WPA Enterprise
    - 802.1x for session key

**CCMP-AES**

- Advanced Encryption Standard (AES)
  - Official Government Standard
  - 128 Bit Key Size Standard
- CCMP
  - Message Authentication Code Protocol
  - Encryption Mechanism using AES Algorithm
- Authentication
  - Radius Server for Enterprise Applications
  - PSK for Non-Server Applications
- Highest Level of Security Available Commercially
  - IEEE 802.11i
  - WPA2

**Security in Industrial Applications**

- Most Industrial Applications will Not Have Access to EAP Server
- Pre-shared Key will fit most industrial wireless applications
- Flexible Levels of Security Based on Information in System
- Encryption Level Customized to Application

**Primary Uses of Wireless**

- Mobile Applications
  - Moving Hardware
  - Maintenance Vehicles
  - Factory Floor Machines
  - Overhead Cranes
  - Public Safety
- “Inaccessible” Areas
  - Difficult or Too Costly to Run Cable
  - Across waterways
  - Communication across roadways
  - Airfield lighting
  - Primary Uses of Wireless
- Long Distance Communication
  - City or County Coverage
  - Impracticable to Cable
  - Water Distribution
  - Wastewater Systems

**Application Sets the Standard**

- No one frequency or wireless standard will solve all applications
- Every frequency and standard has its place
- Correct selection for application is key

**Public Safety Applications**

- Access Point Repeater
  - Wireless Canopy
  - Redundant Links Build Mesh Network
- Hybrid Network
  - Both Licensed Serial and Ethernet Equipment
  - Greater Coverage Area
  - Used in Areas Where Total Ethernet Coverage Not Possible
  - Computer Will Use Highest Speed Network Available

**VIII. Ethernet Configuration****Unpacking and Documentation**

- AA109 Resource CD
  - Manuals/Documentation
  - Utilities
- Documentation
  - Quick Start Guide
  - AA195PM Assembly Procedure
- Unpacking
  - Inventory
  - 195E Pole Mounting Kit (AA195PM)

**Site Design and Layout**

- Mode of Operation
  - Each ESTeem in Network
- Site Diagram
  - Repeater Routes
  - Redundant Paths
- Select Mode of Operation
  - Each ESTeem in network
- Complete System Configuration Table
  - MAC and IP Addresses for each site

**Initial Configuration**

- Attach Antenna and Power Supply
- Set ESTeem IP Address to Log-In Through Web Browser
- RS-232 Connection
- 195E Discovery Program
  - Lists all 195E modems attached to network connection
  - Set IP address regardless of factory setting

## Serial Configuration Menu

- Serial Port Access
  - 38,400,N,8,1
  - 9 Pin Male Connector (192E)
  - RJ-45 Connector (195Eg)
  - ESTeem Utility - Terminal Emulation
  - Windows HyperTerminal
- Set IP Address for Web Interface
- Default Username and Password
  - admin

## Web Interface

- Web Configuration Manager
  - Setup
  - Diagnostics
  - Advanced Features
- Any Web Browser Works
- Log Into IP Address of ESTeem
- Default Username and Password
  - admin

## Setup

- Step by Step Procedure
  - Flow Different for Mode of Operation
  - Help Dialogs Though Out
- Access Point Modes
  - Bridge, Router and Masquerade
- Client Modes
  - EtherStation (Single Ethernet Device)
  - Station Router/Masquerade (Multiple Devices)

## Repeater Routing Configuration

- Enable Repeater Capability
  - Routing Table in 195E
- Enable Each Fixed Route
  - Multiple Routes
    - Path Cost/Path Length
  - Security
  - Data Rate
- Mobile Clients Not Required in List

## Client Configuration

- EtherStation

- Match connected MAC address of Ethernet device
- Station Router/Masquerade
  - Unique Network Subnet for Connected Devices
  - DHCP Server or Fixed IP Addresses
- Set SSID
  - Configuration Same for All In Network
  - Combination of Letters and Numbers
  - Spaces Not Allowed
- Set Security Codes
  - Match Infrastructure (Only) Network
- Access Point Control List

## 195Es Repeater

- Frequency Hopping Spread Spectrum
- Timing Master
  - WLANC MAC Address
- Upstream Timing Master
  - Program WLAN MAC of upstream tier
- Maximum 3 Repeater Hops
- Repeater Peers Same as other 195E
  - No Alternate Paths

## 195Es Repeater Diagram

## 195Es Repeater Configuration

## Advanced Features

- Only Experienced Users
  - Invalid Input will Kill Operation
  - Requests in Manual or from Customer Support
- Direct Access to All Modem Variables
- Specific Settings in Manual
  - Model ID
  - Antenna Configuration
  - Maximum Distance Settings

## AA195PM Configuration

- Unpack From Box and Inventory
- Assembly Procedure
  - Technical Bulletin
  - User's Manual
- Pole Mounting Kit
  - Direct or Strap
- High Temperature Sun Shield

## Installation Guides

- Direct Antenna Mount
  - Omni-Directional
  - Indoor or Outdoor Mounting
- External Antenna Mount
  - Omni-Directional Antenna
  - Directional Antennas
- Cabinet Mount Configuration
  - Remote Antenna
  - ESTeem Mounted in Cabinet

## Saving and Restoring Configuration

- Saving Configuration
  - Select Backup from Main Menu
  - Save to FTP Site
  - Save to File on Computer
- Restoring Configuration
  - Restore Factory Defaults
  - Restore Last Configuration
    - Removes Any Changes
  - Restore From File
    - FTP or Local File

## Custom Roaming Code

- ESTeem 195E in Any Client Mode
  - Etherstation
  - Station Router/Masquerade
- Constant Measuring of All AP Strength
- Signal Strength Threshold
  - Factory Set at -70dBm
  - Set in Advanced Settings
  - Signal value for 195E to change AP

## 195E Antenna Selection

- Single External Antenna
  - Antenna in Port A
  - Cap over Port B
- Antenna Selection in Advanced WLAN\_0
  - CurrentRXAntenna
  - Value of 0 = Both Antenna
  - Value of 1 = Port A
  - Value of 2 = Port B
- 195Ed Transmit and Receive Both Ports

## Long Distance Links

- Model 195E with Dish/Panel Antennas
  - Very High Gain Antennas < 21dBi
  - Distances Greater Than 13 Miles @ 54 Mbps
  - Factory Default Set to 10 Miles
- Distance Over 10 Miles
  - Adjustment of Timing Value
  - Set Maximum Range in Advanced Configuration
  - Distance Set in Miles

## Updating Firmware

- Firmware Updates
  - Local or Internet FTP Site
  - File Saved on Computer
- Select Software Update
  - Main Menu
  - Select File for Update

## IX. Ethernet Troubleshooting & Analysis

### Ethernet Troubleshooting & Analysis

#### Troubleshooting Steps

1. Verify Direct Ethernet Communication
2. Verify ESTeem Configuration
3. Check Antenna and Cable (SWR)
4. Measure Receive Signal Strength
5. Conduct Network Diagnostics

#### 195E Status Menu

- General Modem Information
  - Time/Date
  - Internal Temperature
  - CPU and Ethernet Status
    - Factory Troubleshooting Requests
- View Peer Table
  - Associated Stations (Mobile Clients)
  - Repeater Peers
    - Multiple Status Screens
  - All Radio Activity Seen from 195Eg

#### Peer Table Example

#### Repeater Peer Analysis

- Listed by Wireless MAC Address
  - Fixed Access Point Locations

- Receive Signal Strength
  - Value Listed in dBm
  - Higher Noise Areas Need More Signal
- Last Receive Signal
  - Time of Last Radio Packet (Beacon or Data)
  - Data Rate of Last Packet
- Click on Repeater Peer MAC Address
  - Detailed Log on All Packets

### Mobile Client Analysis

- Station Router and Masquerade
  - Log Into Web Page
  - Receive Signal Strength
- EtherStation
  - No Web Page Available
  - Client Utility
    - Separate Program Always Running

### Mobile Client Tips

- Locking Data and Basic Rates
  - Limiting Data Rate Selection
  - Low Basic Rates Allow Faster Reconnect
- Locking Channel Scanning
  - Single or Used Frequency Channels
  - Allows Faster Reconnect to Network
- Limit Data Rate
  - Use Only Data Rate Needed
  - Lower Data Rate = Greater Range

## X. Ethernet Software & Utilities

### ESTeem Discovery Program

- Configures IP Address to 195E
  - Designed to configure regardless of IP address on computer
  - Will display 195E by Ethernet MAC address
- Update Firmware
- Open Web Browser to 195E
- Troubleshooting
  - Computer must have IP address (DHCP connection or fixed IP address)
  - Designed to displaced connected ESTeem only

### ESTeem Status Program

- Only Functions in EtherStation Mode
  - ESTeem has no IP address
  - Only way to find status information from 195E
- Will Display Current Connection Status
  - Wireless MAC or Modem ID of Access Point
  - Receive signal strength
- Will Change Programming of EtherStation 195E
  - If configured for wrong connected computer MAC, utility will reprogram ESTeem to match

### ESTeem Network Configuration Utility (ENC)

- New Utility Software in Beta Testing
  - Release February 2010
  - New firmware version required
- Visual Programming Software on 195E Network
  - Network connections drag and drop
- On-Line or Off-Line Network Configurations
  - Programming with ESTeems connected to switch
  - Programming one then another

### Simple Network Management Protocol

- SNMP
  - Universal computer network management protocol
  - High memory 195E required
- Wireless Network Management Items
  - Receive signal strength
  - RF data rate
  - Time of last update
- Management Information Base (MIB)
  - Tables downloaded from ESTeem about menu
  - Complete list of MIB items available in manual

### IGMP Snooping

- Global (UDP) Traffic On Wireless Bridge
  - Unicast packet created for each repeater peer
- IGMP Snooping for Global Packet Steering
  - Repeater Peer Connections
- Clients
  - Packet Encapsulation
  - IGMP Snooping on mobile devices
- All Configured in Advanced Menu

## VLAN Pass-Through

- Virtual LAN (V-LAN) Traffic
  - Unique Ethernet packet
  - Segmenting networks in data blocks
- ESTeem 195E Will “Pass-Through” All VLAN Traffic
- 195E Will Not Function as VLAN Switch
  - Only two Ethernet ports available
  - Easier on network hardware

## **XI. Wireless Serial Overview**

### Serial Over Broadband

- Serial Interface on 195E products
- Serial Data Transferred Over Ethernet System
  - Configure Ethernet links first
  - Troubleshooting and diagnostic of WLAN network
- Serial Links are Transparent
- Two Modes of Operation
  - Point to Point
  - Multicast

### Serial Interface Layout

## Serial Port Configuration

- Single Page Configuration on Setup
  - Data Rate, Parity, Start/Stop Bits
  - Transmission Characters
  - Data Format
- Multipoint System
  - All remote sites will receive the data
  - Set to multicast address
- Separate Networks with Port Number

## Serial and Ethernet Networks

- Hybrid of Both Serial and Ethernet Interface
- Both Serial and Ethernet Network Can Work Simultaneously
  - Legacy systems
  - Adding in new locations to existing site
  - Providing video link on serial network
- Serial Network has Little Impact on Bandwidth

DAY ONE			DAY TWO		
Time	Topic	Presenter	Time	Topic	Presenter
0800	Introduction		0800	Ethernet System Mockup	
0815	Radio Overview		0815	Ethernet System Mockup	
0830	Radio Overview		0830	Ethernet Troubleshooting	
0845	Radio Overview		0845	Ethernet Troubleshooting	
0900	Antennas		0900	Ethernet Troubleshooting	
0915	Antennas		0915	Ethernet Troubleshooting	
0930	Antennas		0930	Ethernet Troubleshooting	
0945	Antennas		0945	Utility and Software	
1000	Antennas		1000	Utility and Software	
1015	Break		1015	Utility and Software	
1030	RF System Design		1030	Utility and Software	
1045	RF System Design		1045	Utility and Software	
1100	RF System Design		1100	Utility and Software	
1115	RF System Design		1115	Utility and Software	
1130	Site Survey		1130	Utility and Software	
1145	Site Survey		1145	Utility and Software	
1200	Lunch		1200	Lunch	
1215	Lunch		1215	Lunch	
1230	Lunch		1230	Lunch	
1245	Lunch		1245	Lunch	
1300	ESTeem Overview		1300	Wireless Serial Overview	
1315	ESTeem Overview		1315	Wireless Serial Overview	
1330	ESTeem Overview		1330	Wireless Serial Overview	
1345	ESTeem Overview		1345	Wireless Serial Overview	
1400	ESTeem Overview		1400	Break	
1415	Wireless Ethernet		1415	Written Test	
1430	Wireless Ethernet		1430	Written Test	
1445	Wireless Ethernet		1445	Written Test	
1500	Wireless Ethernet		1500	Written Test	
1515	Wireless Ethernet		1515	End of Day	
1530	Break		1530		
1545	Ethernet Configuration		1545		
1600	Ethernet Configuration		1600		
1615	Ethernet Configuration		1615		
1630	Ethernet Configuration		1630		
1645	Ethernet Configuration		1645		
1700	End of Day 1		1700		