



EtherHaul™-2500F

E-Band Radio

2Gbps Full Duplex, Carrier-Grade, Field Proven

EH-2500F Product Description

May 2017

Release: 2.1

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Document Information

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2	22.05.2016	SH	Clarifications, in line with SW7.0.0 capabilities.

Intended Audience

- Solution architects and network planning staff
- Telecom backhaul engineers
- Wireless ISP, business connectivity and wireless networks pre-sale engineers

Terminology used in this document assumes audience familiarity with microwave radio communication and networking technologies.

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1. Introduction

The EH-2500F radio link delivers 2,000 Mbps full duplex point-to-point Ethernet over different channel bandwidth that will future-proof any high capacity network. With an FDD radio, and operation over the interference-free 71-76/81-86 GHz spectrum, the EH-2500F makes it easy for operators and service providers to add affordable, gigabit capacity, “deploy and forget” links to their networks in hours and not in months.

Siklu’s next generation high gain EH-2500F features:

- Up to 2 Gbps Ethernet capacity (total of 4 Gbps up- and down-stream)
- Enhanced hitless Adaptive Bandwidth, Coding & Modulation capabilities for fiber-like availability
- Small-size, low power consumption and high radio transmit power for extended reach
- Integrated 4-ports Gigabit Ethernet switch
- Carrier-grade networking capabilities
- point-to-point, daisy-chain, ring and mesh configurations

Designed with stringent carrier wireless backhaul demands in mind, the EtherHaul™ products are perfectly suitable for mobile backhaul, enterprise main and backup connectivity or any Ethernet based service provider networks.

Siklu’s EtherHaul™ wireless backhaul products operating in the E-band spectrum have clear reliability, technological and economic advantages over the existing lower frequency bands. Taking advantage of the E-band spectrum, EtherHaul™ products support fiber-like multi Gigabit throughput – allowing operators to add bandwidth capacity on a “pay-as-you-grow” basis. With its unique combination of small footprint and reach capabilities, EtherHaul™ products offer the most cost effective carrier class availability and services delivery.

The EH-2500F is the high-power 2 Gigabit evolution of the best-selling EtherHaul™ series. EtherHaul™ is the world’s top millimeter wave radio, with thousands of links deployed and performing reliably in varying weather conditions all over the globe.

Easily integrated into provider or enterprise networks, out-of-the-box up & running capable, EtherHaul™ products provide advanced carrier Ethernet features including cutting-edge integrated Layer-2 switching and Ethernet OA&M capabilities. Highly scalable, EtherHaul™ products are software-upgradable to support future Layer-2.5/3 networking capabilities as networks evolve to flat-IP topologies.

Offering easy and low cost all-outdoor installation and commissioning in a small form factor, EtherHaul™ products are also environmentally friendly - boasting a small system and antenna footprint, and especially low power consumption.

1.1 Typical Applications

- Mobile backhaul
- Business service delivery
- Public Wi-Fi backhauling
- GTTH transport
- Disaster recovery
- Campus connectivity
- Building to building interconnections
- Smart-cities networks

Siklu's EH-2500F design took into consideration the requirements to support each of above listed applications, at the most cost-effective way available today on the market, with a rich set of operations tools and networking features, without compromising reliability.

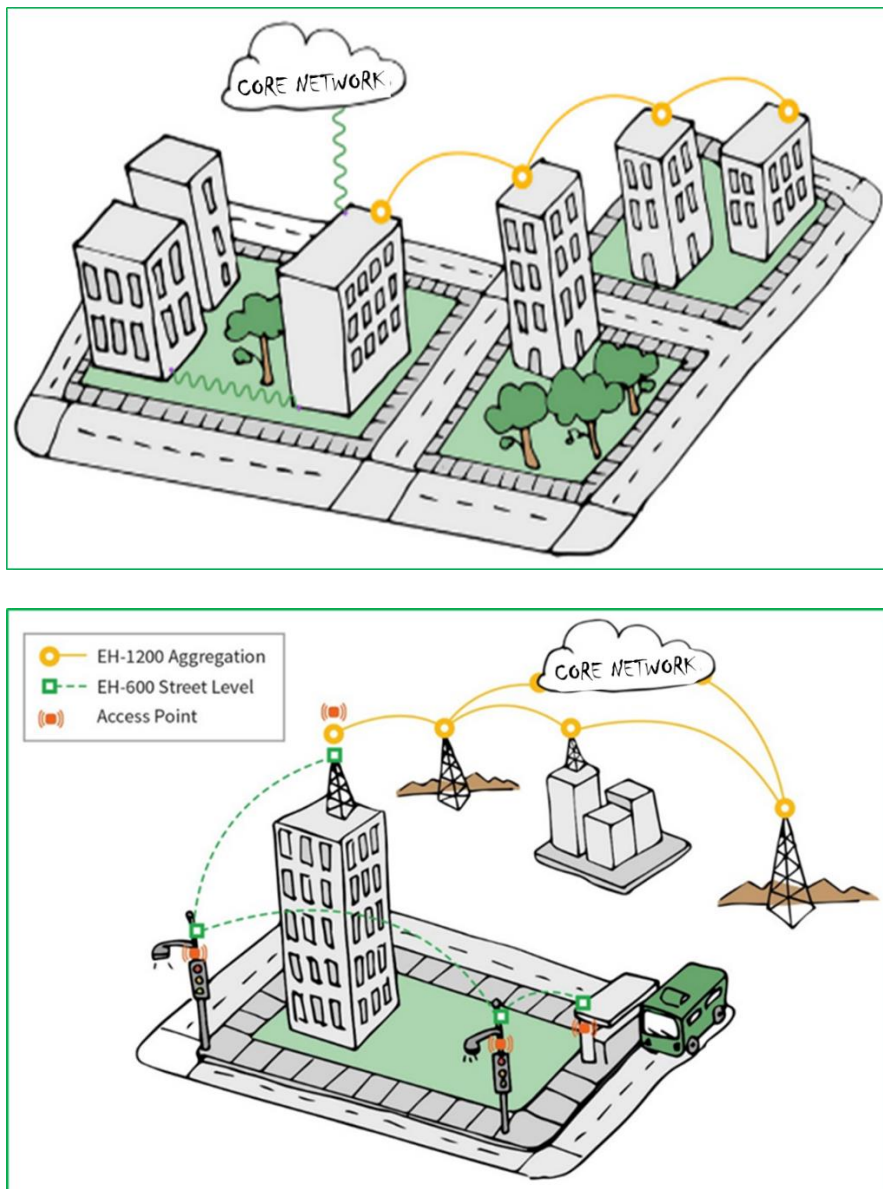


Figure 1 – business services delivery (top) and mobile backhaul (bottom)

Service provider's solutions for services such as mobile backhaul and business connectivity requires high capacity, low latency, high reliability, quick installation and maintenance.

Siklu's EH-2500F with 2Gbps capacity capabilities includes also both advanced synchronization technologies: SyncE and 1588v2 (TC), a must for cellular network backhauling. The synchronization capabilities combine with the metro-Ethernet forum compliant networking features that includes: 8 levels of strict-priority and weighted-fair-queuing QOS, policing and shaping.

Services availability and performance are easily designed with variety of standard based wireless planning tools. Siklu's free, online link-budget-calculator tool, brings enables fast link capacity and availability planning to further ease service

deployments. The EH-2500F also features enhanced hitless adaptive bandwidth, coding, and modulations for maximum spectral efficiency, and services availability. It supports advanced OAM & PM tools, network synchronization, and ring protection optimized for both small cell and mobile backhaul applications

Easily integrated into service-provider networks, out-of-the-box up & running capable. Highly-scalable, the EH-2500F is software-upgradable to support future networking and routing capabilities as networks evolve.

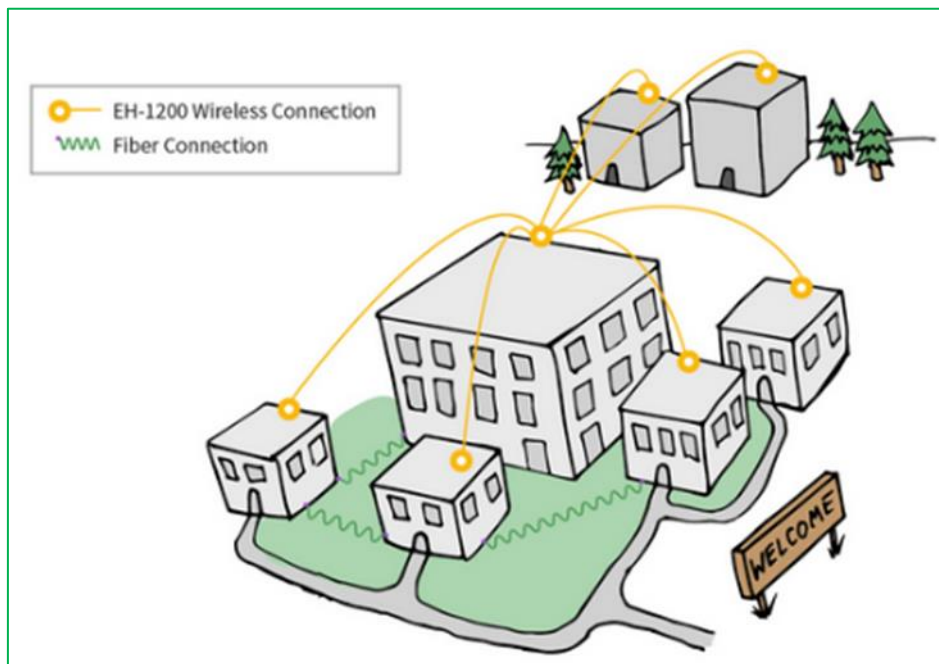


Figure 2 – Campus and building to building connectivity

The EH-2500F enables the industry's tiniest volume per-megabit connectivity ensuring high capacity future proof networks. EH-2500F integrated Gigabit switch eliminates the need for external equipment usually required by other solutions to supporting multiple services or cascading of links.

2. EH-2500F System Overview

2.1 Functional Blocks

The EH-2500F is an all-outdoor unit comprised of the following functional blocks, from right to left:

- Antenna: Siklu designed, innovative cost-effective antenna.
- Transceiver: integrated Silicon Germanium (SiGe) RFIC transmitter/receiver operating at 71-76/81-86 GHz
- Baseband: this block includes the modem, FEC engines, and Synchronous Ethernet support.
- Network Processor: the networking engine is the heart of the high speed bridge/router function with more than 10GE capacity. The engine receives packets from both Ethernet interfaces and from the modem. It is responsible for proper forwarding between these three ports.
- Host processor (integrated with the network processor): the general purpose host processor controls the system, and the antenna alignment system.
- Interfaces: The network interface consists of two integrated 100/1000 Ethernet ports and 2 MSA compliant SFP ports, for fiber-Ethernet 1000Base-SX / 1000Base-LX.

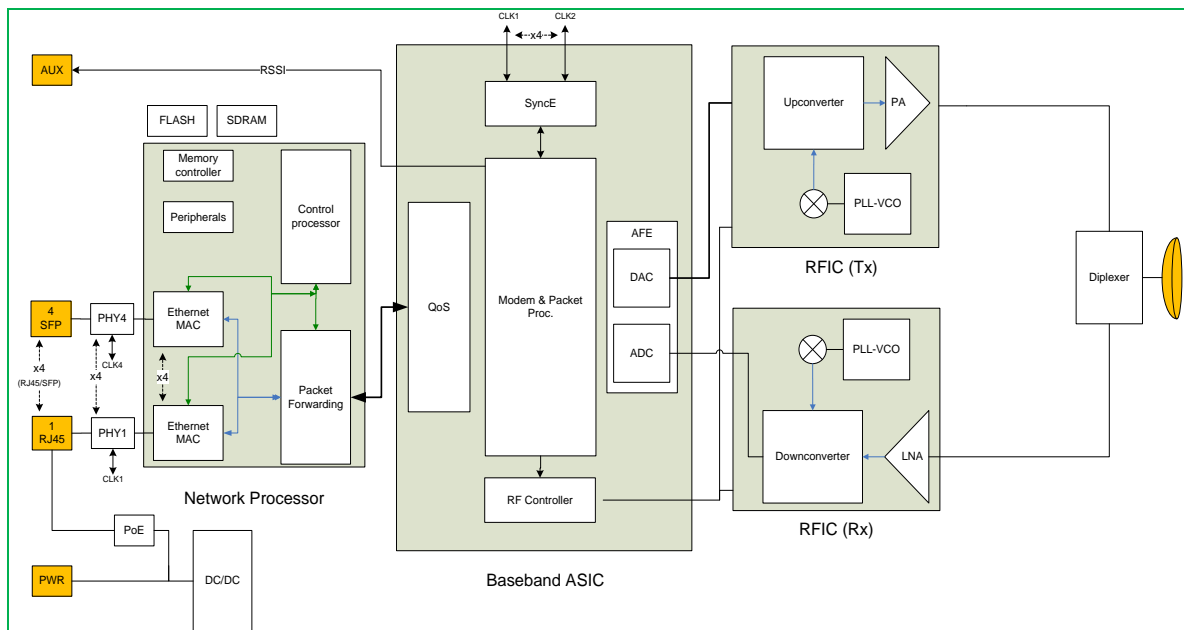


Figure 3 – EH-2500F functional block diagram

2.2 EH-2500F Specifications Highlights

Feature	EH-2500F
Regulation	ETSI, FCC
Frequency	71-76 / 81-86 GHz
Duplexing	FDD
Modulation Schemes	BPSK /QPSK1/QPSK2/QPSK3/QAM16/QAM32
Antenna options	0.5ft (16cm) 38dBi antenna gain, 1ft (31cm) 43dBi antenna gain, 2ft (65cm) 50dBi antenna gain
System throughput	Up to 2000Mbps full-duplex
Traffic Interfaces	4 x GE ports: 2 x RJ-45 (Copper) + 2 x SFP (Fiber)
MEF, Carrier Ethernet & OAM	MEF 9, 14 and 21 compliant VLAN & VLAN stacking (QinQ- IEEE 802.1ad Provider Bridge) IEEE 802.1d Transparent Bridging MAC learning Link state propagation Jumbo frames advanced QoS & Traffic management: 802.1p, DSCP, MPLS EXP Scheduling , Shaping, Policing Eth OAM (IEEE802.1ag / Y.1731 / IEEE802.3ah)
Synchronization	1588 TC Synchronous Ethernet ITU-T G.8261/8262/8264
Management	Out-of-band , In-band management Embedded WEB GUI SNMPv2/3 Zero-touch turn-up, TACACS+, RADIUS Link Layer Discovery Protocol (LLDP) IPERF build in tester
Topologies	Ring, daisy-chain and mesh G.8032 ERPS delivering sub 50msec ring protection
Conformance	Radio: USA FCC Part 15.101 & ETSI EN 302 217; EMC: USA FCC 47CFR.part 15 & ETSI EN 301 489; Safety UL/EN 60950
Environmental characteristic	Operating Temperature- $-45^{\circ} \div +55^{\circ}\text{C}$ ($-49^{\circ} \div +131^{\circ}\text{F}$) Ingress Protection Rating - IP67
Radio modes	Adaptive modulation (default), Static modulation, Alignment mode
Input Power options specifications	voltage: 37-57VDC (flexible grounding) PoE++ (IEEE 802.3at) or direct DC: 45W without PoE-Out; 60W with PoE Out Power input redundancy (PoE and DC input)
Power Output	PoE- 13W (IEEE 802.3af)
Dimensions (H x W x D) & weight	ODU: 24.5 cm x 22.5 cm x 7 cm ODU + 1ft Antenna (Dia. x Depth): -31 cm x 13 cm Weight ODU + antenna (1ft): 4 kg

Table 1 : EH-2500F Specifications Highlights

3. EH-2500F detailed product specifications

3.1 Frequency band, channels and modulation schemes

3.1.1 Frequency band

EH-2500F operates in the 71-76 / 81-86 GHz E-band frequency spectrum and includes a new generation spectrally-efficient radio, with channel sizes of 250 to 1250 MHz.

Channeling range for EH-2500F:

	Low (MHz)	High (MHz)
1	71875	81875
2	72375	82375
3	72875	82875
4	73375	83375
5	73875	83875
6	74375	84375
7	74875	84875
8	75375	85375

Table 2 : EH-2500F frequencies with 500MHz channels

	Low (MHz)	High (MHz)
1	71500	81500
2	71750	81750
3	72000	82000
4	72250	82250
5	72500	82500
6	72750	82750
7	73000	83000
8	73250	83250
9	73500	83500
10	73750	83750
11	74000	84000
12	74250	84250
13	74500	84500
14	74750	84750
15	75000	85000
16	75250	85250
17	75500	85500
18	75750	85750

Table 3 : EH-2500F 250MHz frequencies

	Low (MHz)	High (MHz)
1	72250	82250
2	73000	83000
3	74000	84000
4	74750	84750
5	75500	85500

Table 4 : EH-2500F 750MHz frequencies

	Low (MHz)	High (MHz)
1	71750	81750
2	73000	83000
3	74250	84250

Table 5 : EH-2500F 1250MHz frequencies

3.1.2 Modulation

The system implements an adaptive modulation scheme based on the following:

Mode	Bandwidth (MHz)	Modulation	Bandwidth (MHz)	Modulation	Bandwidth (MHz)	Modulation
0	250/ 500	QAM 32	750	QAM 16	1250	QPSK3
1	250/ 500	QAM 16	750	QPSK3	1250	QPSK2
2	250/ 500	QPSK1	750	QPSK2	1250	QPSK1
3	250/ 500	BPSK2	750	QPSK1	1250	BPSK1
4	250/ 500	BPSK1	750	BPSK1		

Table 6: EH-2500F modulation table

3.1.3 Standard compliance

The EH-2500F complies with world's major radio spectrum regulations requirements:

- FCC 47 CFR part 101:2009
- ETSI EN 302 217

3.1.4 Benefits

Siklu's standard based EH-2500F has high RF performance allowing the service provider to extend the reach of Gigabit services with 100% room to grow up to 2Gbps full-duplex. The RF parameters are configured using the management software resulting in a minimum service interruption and doesn't require any manual calibration. This enables rapid, easy, and flexible frequency planning and additional cost savings on the occupied spectrum.

The high performance design of radio and modem makes possible using spectral efficient modulations like QAM16 and QAM32 to achieve high capacity, to have high TX power and to provide a robust connection using strong error correction codes and high bandwidth to increased sensitivity.

3.2 Antennas

The EH-2500F has RF interface compatible to Siklu's 0.5ft, 1ft or 2ft antenna.

Type	0.5ft	1ft	2ft
Gain (typical)	38 dBi	43 dBi	50 dBi
3 dB Beam width	2°	0.9°	0.5°
Radiation Pattern Envelope	ETSI: EN 302 217-4-2 V1.5.1 Class 2 FCC: N/A (not permitted)	ETSI: EN 302 217-4-2 V1.5.1 Class 2 FCC: 47CFR101	ETSI: EN 302 217-4-2 V1.5.1 Class 3 FCC: 47CFR101

Table 7: EH-2500F antenna specifications

3.2.1 Standard compliance

ETSI EN 302 217-4-2 V1.5.1 & FCC 47CFR101.115.

3.2.2 Benefits

- Siklu's 0.5ft, 1ft & 2ft antenna results a zero foot print outdoor solution, durable wind load, and easy installation and alignment
- Direct-Mount capability and installation kits extend links physical durability for enhanced performance in tough weather conditions.

3.3 Integrated Ethernet switch

The EH-2500F includes integrated 4 ports 100/1000 base-T Ethernet switch.

Each port can be configured to support:

- Auto negotiation enabled/disabled
- Speeds: 100/1000 Mbps.

- Full-duplex / half-duplex
- Delivery of both payload traffic and/or management traffic
- OAM signaling
- SyncE

3.3.1 Benefits

- 4 Ethernet ports are the ideal number of interfaces at a hub or daisy-chain site, as well as at a drop site delivering multiple services to several devices such as hot-spot, small-cell, surveillance cameras. This enables:
 - Advanced network topologies: ring, mesh and daisy chain
 - Connectivity for more services at each location, avoiding the need for external devices for services grooming/cascading, and thus reducing both CAPEX and OPEX.

3.4 System capacity

The EH-2500F product features up to 2Gbps, full duplex capacity.

Mode	Bandwidth (MHz)	Modulation	L1 Rate (Mbps) ¹
0	250/ 500	BPSK1	40/80
1	250/ 500	BPSK2	100/200
2	250/ 500	QPSK1	400/820
3	250/ 500	QAM 16	750/1500
4	250/ 500	QAM 32	1000/2000
0	750	QAM 16	2000
1	750	QPSK3	1250
2	750	QPSK2	575
3	750	QPSK1	250
4	750	BPSK1	80
0	1250	QPSK3	1930
1	1250	QPSK2	950
2	1250	QPSK1	475
3	1250	BPSK1	190

Table 8- EH-2500F capacity per modulation

3.4.1 Benefits

High capacity allows operators to:

¹ capacity varies according to packet size

- Fulfill current and long term capacity requirements for 3G, LTE and LTE-A small-cell backhaul, including hybrid small cells that supports multiple technologies.
- Provide extreme capacities for building-to-building connectivity within a dense urban area or campus.
- Cascades wireless backhaul links between numerous street-level devices such as small-cell, CCTV cameras, Wi-Fi access points and others.
- Deliver multiple services, all with max capacity at same location.

3.5 Radio Specifications

The system implements a flexible modulation scheme, which includes adaptation of the following system parameters:

250MHz up to 1Gbps:

Mode	Bandwidth (MHz)	Modulation	L1 Rate (Mbps) (1)	Pout (dBm)	Receiver Threshold (dBm @ BER=10 ⁻⁶)	link budget 1ft (dBm @ BER=10 ⁻⁶)	link budget 2ft (dBm @ BER=10 ⁻⁶)
0	250	BPSK1	40	+19	-82	187±4	201±4
1	250	BPSK2	100	+18.5	-77	181.5±4	195.5±4
2	250	QPSK1	400	+18.5	-71	175.5±4	189.5±4
3	250	QAM 16	750	16.5	-65.5	168.±4	182.±4
4	250	QAM 32	1000	16.5	-61.5	164.±4	178.±4

Table 9: EH-2500F radio parameters 250MHz channel

500MHz up to 2Gbps:

Mode	Bandwidth (MHz)	Modulation	L1 Rate (Mbps) (1)	Pout (dBm)	Receiver Threshold (dBm @ BER=10 ⁻⁶)	link budget 1ft (dBm @ BER=10 ⁻⁶)	link budget 2ft (dBm @ BER=10 ⁻⁶)
0	500	BPSK1	80	+19	-79	184±4	198±4
1	500	BPSK2	200	+18.5	-74	178.5±4	192.5±4
2	500	QPSK1	820	+18.5	-68	172.5±4	186.5±4
3	500	QAM 16	1500	16.5	-62.5	165.±4	179.±4
4	500	QAM 32	2000	16.5	-58.5	161.±4	175.±4

Table 10: EH-2500F radio parameters 500MHz channel

750MHz up to 2Gbps:

Mode	Bandwidth (MHz)	Modulation	L1 Rate (Mbps)(1)	Pout (dBm)	Receiver Threshold (dBm @ BER=10 ⁻⁶)	link budget 1ft (dBm @ BER=10 ⁻⁶)	link budget 2ft (dBm @ BER=10 ⁻⁶)
0	750	QAM 16	2000	+16.5±2	-61.5±2	164±4	178±4

1	750	QPSK3	1250	+18.5±2	-66±2	170.5±4	184.5±4
2	375	QPSK2	575	+18.5±2	-70±2	174.5±4	188.5±4
3	187.5	QPSK1	250	+18.5±2	-74±2	178.5±4	192.5±4
4	187.5	BPSK1	80	+19±2	-78±2	183±4	197±4

Table 11: EH-2500F radio parameters 750MHz channel

1250MHz up to 2Gbps:

Mode	Bandwidth (MHz)	Modulation	L1 Rate (Mbps)(1)	Pout (dBm)	Receiver Threshold (dBm @ BER=10 ⁻⁶)	link budget 1ft (dBm @ BER=10-6)	link budget 2ft (dBm @ BER=10-6)
0	1250	QPSK3	1930	+18.5±2	-65.5±2	170±4	184±4
1	625	QPSK2	950	+18.5±2	-68.5±2	173±4	187±4
2	312.5	QPSK1	475	+18.5±2	-71.5±2	176±4	190±4
3	312.5	BPSK1	190	+19±2	-75.5±2	180.5±4	194.5±4

Table 12: EH-2500F radio parameters 1250MHz channel

3.5.1 Benefits

The high performance design of radio and modem enables spectrally efficient modulations like QAM16 and QAM32 to achieve high capacity on the one hand, and high bandwidth to provide a robust connectivity using strong error correction codes and increased sensitivity on the other hand.

3.6 Adaptive modulation

The EH-2500F implements hitless/errorless adaptive bandwidth, coding and modulation adjustment to optimize the over-the-air transmission and prevent weather-related fading traffic disruption. The EtherHaul™ products can gain up to 23dB in link budget by dynamically adapting the rate:

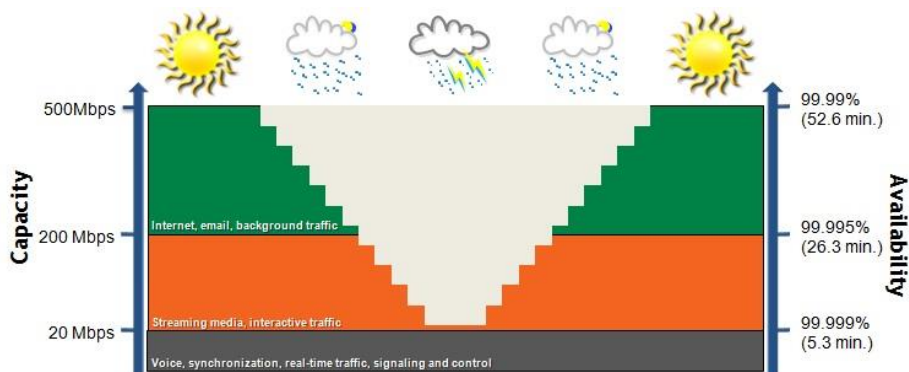


Figure 4 – Hitless Adaptive Bandwidth, Coding and Modulation

3.6.1 Benefits

- Adaptive bandwidth, coding, and modulation ensure maximum capacity most of the time with guaranteed high priority services all the time.

- EtherHaul™ hitless algorithm achieves zero down time to enable reliable voice and real-time services, allowing carriers to meet their service level agreements for enhanced user experience.

3.7 EH-2500F Physical overview

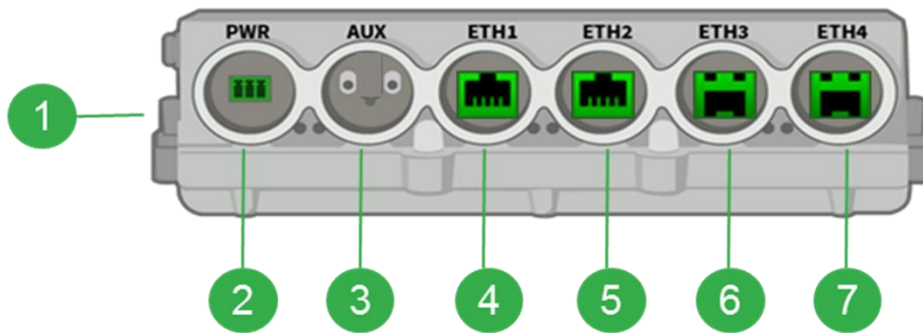


Figure 5 – EH-2500F interfaces

1. Electrical Ground Outlet (GND)
2. DC power input (PWR)
3. DVM Probe Interface (AUX), Reset button
4. RJ45 interface for Ethernet 100/1000-Base-T and PoE-In++ (ETH1)
5. RJ45 interface for Ethernet 100/1000-Base-T and PoE-Out (ETH2)
6. SFP interface for fiber-optic Ethernet services * (ETH3)
7. SFP interface for fiber-optic Ethernet services * (ETH4)

3.8 EH-2500F weatherized connectors

An EtherHaul™ product is equipped with standard RJ-45 connectors and does not require proprietary cables, or proprietary sealing solutions. Each EH-2500F unit kit contains a set of cable-glands sealing accessories:

1. Cable inlet with cable securing holes (designed for standard cable ties)
2. Rubber gasket
3. Connector outlet

As shown in Figure 6, the included EtherHaul™ cables glands were designed to enable in the field connectivity of cables already equipped the RJ-45 connectors, and thus eliminate the need to use cable crimp tools.

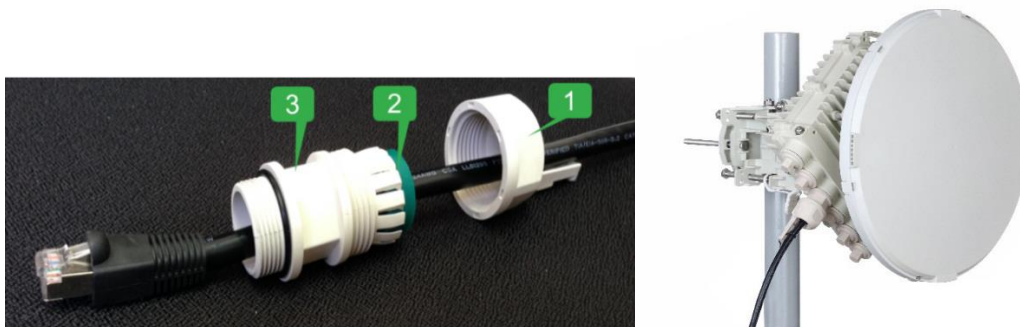


Figure 6 – Connector gland assembly and EH-2500F with cable installed in ETH2

3.9 EH-2500F Mounting bracket

The EH-2500F mounting bracket is a light-weight easy-to-use alignment and physical securing element, specially designed for street level and roof-top installations.

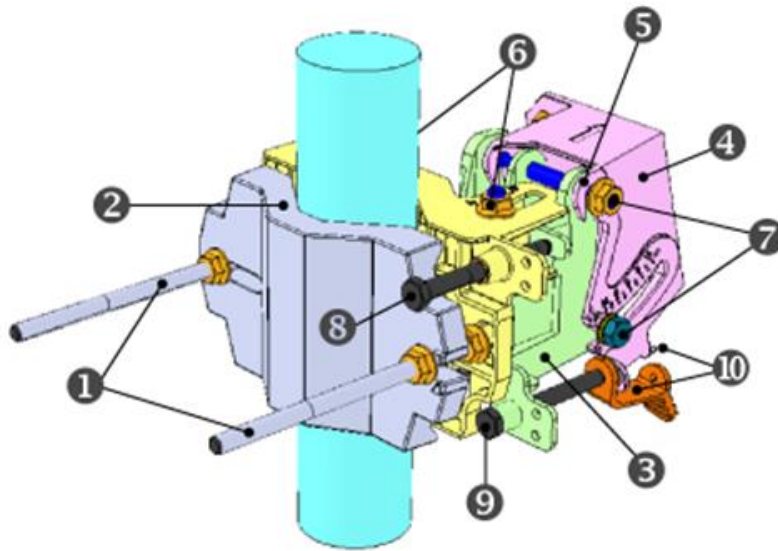


Figure 7 – EH-2500F1ft Mounting Kit

- | | |
|---|---|
| 1. Screws and bolts for fastening the bracket | 6. Azimuth adjustment lock bolts |
| 2. Back mounting bracket | 7. Elevation adjustment lock bolts |
| 3. Front mounting bracket | 8. Azimuth fine adjustment screw ($\pm 8^\circ$) |
| 4. Quick release plate (attached to ODU) | 9. Elevation fine adjustment screw ($\pm 16^\circ$) |
| 5. Quick release hooks | 10. Elevation screw tension band and pin |

3.9.1 EH-2500F Mounting bracket benefits

- Highly wind resistant and minimized visibility thanks to the central mounted installation design.
- No need for re-alignment when replacing an EH-2500F unit during maintenance process.

3.10 Alignment

As any other P2P V-band wireless system, the EH-2500F must be precisely aligned during the installation process.

A standard voltmeter is used for RSSI reading via the (AUX) port.

3.10.1 Benefits

- Simple and reliable antenna alignment process (no computer connection needed)
- Alignment is performed using standard single T-bar tool that matches all screws, worm clamps adjustments and locks.

4. EH-2500F Networking Features

4.1 Switching

4.1.1 QoS-Aware Transparent Bridge (IEEE 802.1d)

The out-of-the-box configuration of the EH-2500F is the advanced transparent bridge mode (IEEE 802.1d), a zero-touch judicious match for simple networks. Quality-of-Service-awareness operation is automatic in in this mode. Transparent forwarding of both tagged and untagged traffic is performed. It is possible to allocate a dedicated VLAN for in-band management.

4.1.2 Provider Bridge (IEEE 802.1ad)

Alternatively, the EH-2500F incorporates a full Provider Bridge mode of operation (IEEE 802.1ad). Provider Bridge, commonly known as Q in Q, extends the IEEE 802.1Q standard by providing for a second stack of VLANs in a bridged network.

This enable servicing multiple customers on the same port (user network interface, i.e. Eth1-4) and forwarding (or tunneling) through the radio link (acts as NNI – network network interface) using Service VLAN (S-VLAN). The system is able to deliver multiple S-VLANs, and to allocate in each several customers' VLANs (C-VLAN). Sample VLAN encapsulations are brought in Figure 8.

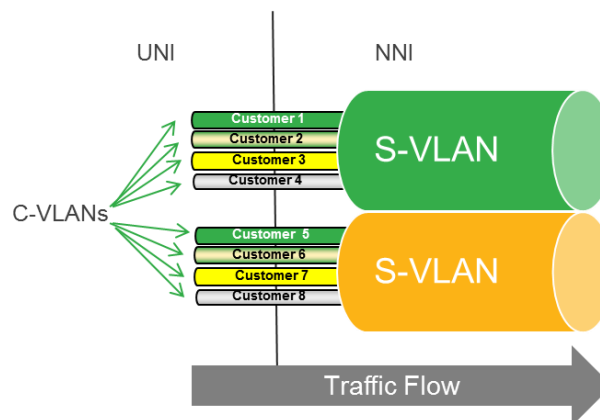


Figure 8: C-VLANs encapsulated in S-VLANs

The provider bridge, which may consist of multiple devices in the service provider domain, looks like a simple bridge port to the customer's traffic and maintains the Customer's VLANs (C-VLAN) with their ID number.

The implementation of Provider Bridge in EtherHaul™ is a network of up to five virtual bridges connected in a “cross-like” fashion as shown in “Figure 9: Provider Bridge Architecture”

- Each component acts as a virtual bridge. A component can have both external and internal ports.
- An external port name is identical to its interface name.
- An internal port name uses the name of its peer component.

- The operator can change the default bridge configuration to suit his network by removing or adding the desired bridge components.
- All components are created, managed, and removed using both CLI and WEB GUI.

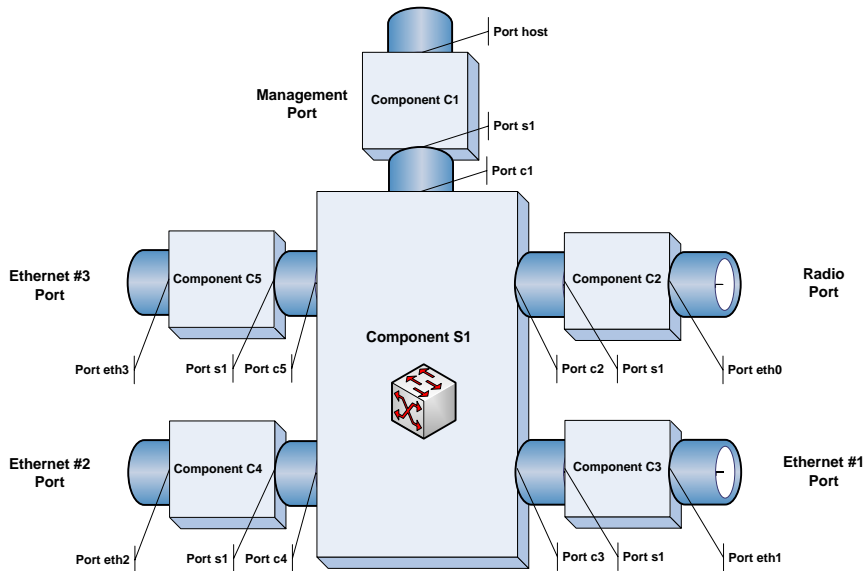


Figure 9– Provider Bridge Architecture*

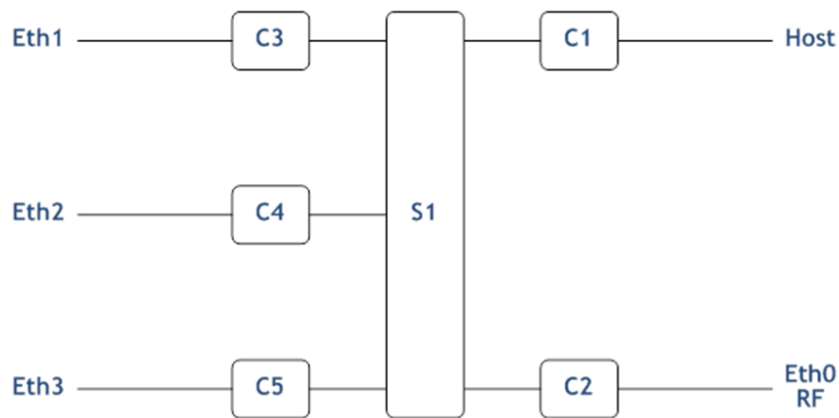


Figure 10– Generic Model of the EtherHaul™ Bridge

Each component acts as a virtual bridge. A component can have both external and internal ports. An external port name is identical to its interface name. An internal port name uses the name of its peer C-component 1 is connected to the S-component, the corresponding internal port in.

For example, the C-component is called S1 and the corresponding internal port in the S-component is called C1.

You can change the default bridge configuration to suit your network by removing or adding the desired bridge components. All components are created, managed, and removed using the CLI.

4.1.3 Standards compliance

- IEEE 802.1d - MAC Bridges
- IEEE 802.1Q - Virtual LANs (VLANs)
- IEEE 802.1ad – QinQ
- Metro Ethernet Forum (MEF) recommendations and defined services: MEF 9, Ethernet Services Functionality:
 - E-LINE, E-LAN and E-TREE services
 - E-LINE with multiple user defined options:
 - Port based
 - Port with single VLAN
 - Port with double VLAN (QinQ)
 - E-LAN with multiple user defined options:
 - MAC
 - VLAN
 - Double VLAN (QinQ)
 - Multiple isolated E-LAN services – by multiple isolated MAC tables
 - E-Tree with multiple user defined options:
 - Port based
 - Port with single VLAN
 - Port with double VLAN (QinQ)
 - UNI attributes, Service frame delivery, VLAN tag support

4.1.4 Benefits

- Flexible networking topologies support
- Carrier class services, following leading standards with proven interoperability
- Integrated Gigabit Ethernet switch and advanced networking features allows all outdoor installation
- The EH-2500F's provider bridge is an easy and fast deployment enabler:
 - It takes any Ethernet based stream, wraps it with service provider tag
 - Enhanced QOS marking based routing of ingress traffic into multiple differentiated queues.
 - No limits on frame size (the EtherHaul™ systems supports 16K jumbo frames)

4.2 Quality of service (QOS)

There are 2 main motives to leverage QOS in a street-level wireless backhaul system:

1. QOS complements hitless adaptive bandwidth, coding, and modulation mechanisms with real time prioritization of several services. It allows ensuring

performance and availability correlated with provider's SLA (service level agreement).

2. Enforcing QoS enables carriers to oversubscribe wireless links will supporting the SLA agreement of each individual service, and thus leads to enhanced ROI.

The EH-2500F, equipped with a powerful network processor and Siklu's proven EtherHaul™ advanced software package, enables any service provider to offer best in class differentiated services. With 8 queues, the EH-2500F has QoS granularity for the most demanding environment.

4.2.1 Classification and Policing

The EtherHaul™ QoS engine classifies the incoming packets onto streams using any combination of:

1. VLAN number (VID) – prioritizes frames based on their VLAN ID.
2. PCP - 3 priority bits that enables up to 8 differentiated QOS classed of service. PCP bits are part of the L2 VLAN header.
3. DSCP – 6 bits, part of the DS field in L3 IP header of incoming packets. The user configurable QOS scheme of EH-2500F enables allocating each of the potential 64 traffic classes, into the 8 queues of the system. EH-2500F support DSCP classification according to IPv4 and IPv6 L3 packets.
4. MPLS Traffic Class (TC, formerly EXP) - 3 priority bits that enables up to 8 differentiated classes of service. The 3 TC bits are part of the MPLS label.

EH-2500F supports 4 types of bandwidth profile with CIR (committed information rate), CBS (committed burst size), EIR (excess information rate), EBS (excess burst size), can be assigned to each of the above listed (1-4) differentiated streams.

The implemented mechanism supports 3 colors and 2 rates:

- Frames that fit into CIR/CBS profile marked drop ineligible and colored "green".
- Frames which are within excess profile but exceed committed profile are marked drop eligible ("yellow"), upon congestion at egress interface the yellow packets are dropped first.
- All remaining frames, which are out of profile, are colored "red" and discarded.
 - The "red" frames are dropped ; "green" frames take precedence over "yellow" ones.

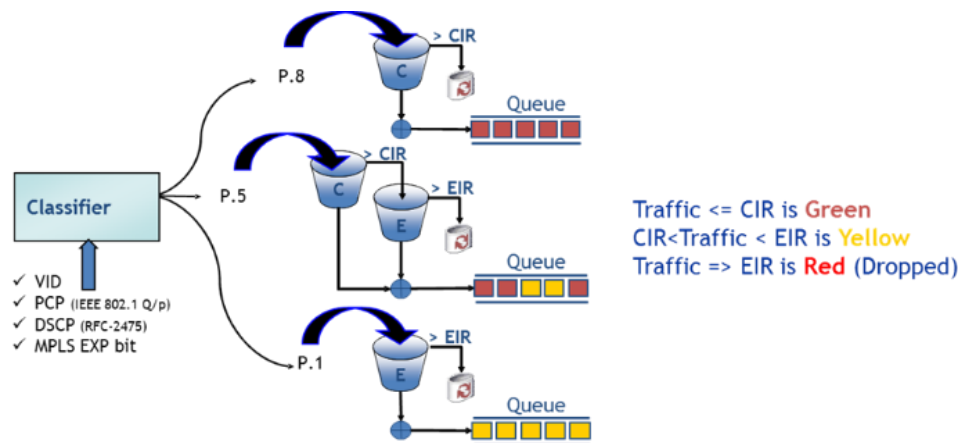


Figure 11 – EH-2500F Calculations and Policing

These packets are then mapped to 1 of the 8 priority queues (per interface). Each queue may be assigned buffering space (queue depth) manually or automatically by the SW that calculates the adaptive modulation BW changes. These queues are accessed by the scheduling mechanism.

4.2.2 Buffer size

Packets processed in the switch are held in buffers. If the destination queue is congested, the switch holds on to the packet as it waits for capacity to become available on the loaded queue. The ratio between delay and number of dropped frames is a result of the buffer size configuration.

4.2.3 Scheduling Mechanisms

The priority queues of the EtherHaul™ are accessed using the following scheduling mechanisms:

- **Strict Priority (SP):** Advanced mechanism for assuring both prioritization and minimal delay for mission critical traffic. Higher priority traffic is fully served through its differentiated queues, only if all high priority traffic, identified as SP, is fully served the lower priority traffic is delivered to its queues.
- **Weighted Fair Queuing (WFQ):** A scheduling technique maintaining fairness by applying weights to the queues. Each queue is serviced in the order of its weighted proportion to the available resources. This queueing mechanism is suitable for high capacity statistical applications and it ensures pre-defined serving of multiple services even when the link is fully loaded.
- **Shaper:** used to control traffic flows in order to optimize or guarantee performance and improve latency by limiting the maximum bandwidth of certain flows to maintain fairness and to assure SLA. Shaper capabilities of internet serving access devices, is crucial for assuring effective and stable delivery of TCP oriented traffic with minimizing re-transmissions and maximizing utilization of the available capacity.
- **Best Effort:** used for the lowest priority traffic types and simply enable further utilization of statistical multiplexing. Capacity is not guaranteed for this queue,

and it enables dynamic utilization of all non-used (by higher queues) available capacity.

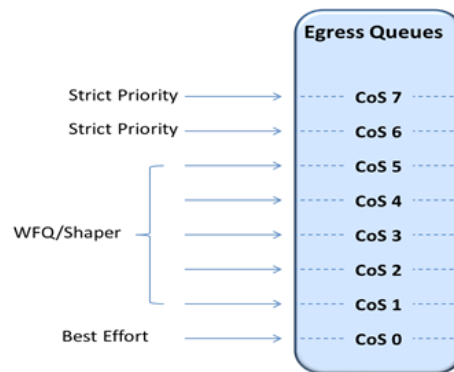


Figure 12 –Scheduling Mechanism

4.2.4 Standard compliance

- IEEE 802.1Q / IEE802.1P - 3 bits identified as priority code point (PCP).
- RFC-2475 - Architecture for differentiated services.
- RFC-5865 - A differentiated services code point (DSCP) for capacity-admitted traffic
- Related Metro Ethernet Forum (MEF) recommendations:
 - MEF 14, Ethernet Service Performance
 - Service performance, bandwidth profiles, BW profile rate enforcement.

4.2.5 Benefits

- Quality of Service (QoS) mechanism enables service providers to offer different classes of service for different types of traffic or customers.
- QoS mechanism is especially important in wireless links with adaptive capabilities, because changing link conditions may require the system to drop some traffic according to a predetermined priority and scheduling scheme.
- The user defined, wide range of buffer size values, enable fine adjustments for various implementation scenarios, and thus contribute to operators' network capability to optimize traffic flows at heavy load conditions.
- The statistical behavior of today data services enables service providers to oversubscribe their networks while differentiating services based on QoS driven SLA, and thus leads to faster ROI and improved utilization of the network.

4.3 Queue management - WRED

WRED function (Weighted random early detection) adds queue management mechanism to the EH-2500F. Weighted Random Early Detection (WRED) is a queue management algorithm with congestion avoidance capabilities. A single queue may have several different queue thresholds. Each queue threshold is associated to a particular traffic class; a queue may have lower thresholds for lower priority packet.

WRED enables the EH-2500F to detect the onset of congestion and takes corrective action. EH-2500F has several different queue thresholds. Each queue threshold is associated to a particular traffic class.

A queue buildup will cause the lower priority packets to be dropped, hence protecting the higher priority packets in the same queue. In this way quality of service prioritization is made possible for important packets from a pool of packets using the same buffer a standard traffic will be dropped instead of higher prioritized traffic.

4.3.1 WRED Benefits

- WRED assures that the queue does not fill up, so that there will be most of the time room for high-priority packets within the same queue.
- Random drops cause TCP sessions to reduce window sizes and thus extends efficiency.
- Average capacity usage is much closer to actual capacity of the link.

4.4 LAG / LACP

Link Aggregation Group (LAG) enables grouping a set of physical interfaces into a single service. Grouping a set of physical interfaces allows delivering a service at the combined aggregated throughput of all the grouped physical interfaces.

The Link Aggregation Control Protocol (LACP) is the protocol used between end-points to exchange system and port information and to maintain LAG services.

LAG/LACP enables the EH-2500F to deliver a service over 1Gbps and up to 2Gbps, utilizing very common 1Gbps copper or fiber ports.

4.4.1 Standard compliance

- IEEE 802.1ad - Link Aggregation Control Protocol (LACP)

4.4.2 Benefits

- Delivery of a service between 1Gbps and 2Gbps
- Standard based port aggregation
- Efficient utilization of the 2500F 2Gbps full-duplex bandwidth

4.5 Configurable Ethertype

IEEE 802.1ad Provider Bridging (a.k.a Q-in-Q) defines the Ethertype as 0x88A8 and lists additional Ethertype field values for S-VLAN: 0x8100, 0x9100 and 0x9200 to support backwards compatibility.

4.5.1 Benefits

The configurable Ethertype feature eliminates Ethertype compatibility issues when connecting EtherHaul™ ports/services to 3rd party switches and routers or other network devices such as access points, small-cells etc. It is another tool for easy integration of EtherHaul™ into any network.

4.6 LLDP

The Link Layer Discovery Protocol (LLDP) is a unidirectional neighbor discovery protocol.

LLDP performs periodic transmissions of an ODU's capabilities to the adjacent connected stations. LLDP frames are not forwarded, but are constrained to a single link. The information distributed by the protocol is stored in a topology data base. This information can be retrieved by the user or network element using CLI and/or system's web based GUI, in order to easily resolve the network's physical topology and its associated stations.

LLDP enables the discovery of accurate physical network topologies, meaning which devices are neighbors and through which ports they connect. The user can use this information, especially the 'retrieved management IP addresses' option, in order to access these discovered nodes.

LLDP enables the EH-2500F to discover other network elements that are connected to it as well as being discovered. This feature enables, amongst other things, to discovery third-party network elements connected to the EH-2500F so that they can be managed. In addition, it enables easier integration of EH-2500F links in a LLDP supported network.

4.6.1 Standard compliance

- IEEE 802.1AB - Link Layer Discovery Protocol (LLDP)

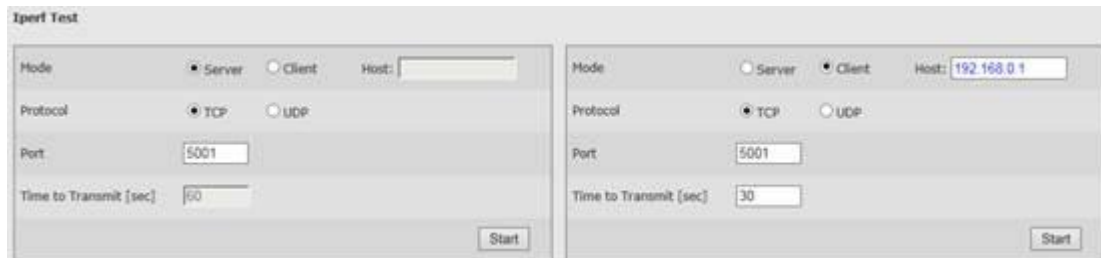
4.6.2 Benefits

- Enhances troubleshooting process
- Standard based topology discovery by 3rd party network monitoring and management systems

4.7 Iperf

The built-in Iperf tester implementation includes client/server nodes for over the air TCP/UDP test. Configure one side as Server and run it (click Start) and remote end as Client (and enter the server IP address).

Iperf test run in parallel to traffic over the link.



4.7.1 Benefits

Running Iperf helps the installer to make sure the link is installed properly without the need for external tools. More importantly, Iperf onboard support troubleshooting network and packet losses issues to identify connectivity problems much faster, without the need for on-site visits.

4.8 DHCP

The Dynamic Host Configuration Protocol (DHCP) is a computer networking protocol used by devices (DHCP clients) to obtain configuration information for operation in an Internet Protocol network. DHCP is built on a client-server model, where designated DHCP server allocates network addresses and delivers configuration parameters to dynamically configured hosts. "Client" refers to a host requesting initialization parameters from a DHCP server.

The EH-2500F's management Interface can be configured as a DHCP client.

4.8.1 Standard compliance

- RFC 2131 - Dynamic Host Configuration Protocol

4.8.2 Benefits

- This protocol reduces system administration workload, allowing networks to add devices with little or no manual intervention.
- Easy and fast discovery of new EH-2500F elements added to any DHCP enabled network

4.9 Link OAM

Link OAM, as defined in IEEE802.3ah, is an Ethernet layer operation, administration, and management (OAM) protocol designed to ease monitoring and troubleshooting of networks. Link OAM enables to detect, verify, and isolate connectivity failures in point-to-point connections. Link OAM is intended for single point-to-point links, usually used at network edges, between network-termination (NT) device located at customer premises and the directly connected to it, service provider's located access/aggregation network element.

The following IEEE802.3ah functionality is supported by the EH-2500F:

- Discovery:
 1. Detect remote element
 2. Exchange link state and configuration information:
 3. Enable OAM on link
- Remote Loopback
 - Initiated by a loopback control OAMPDU
 - The loopback command is acknowledged by responding with an Information OAMPDU with the loopback state indicated in the state field.
 - The periodic exchange of OAMPDUs must continue while in the loopback state to maintain the OAM session.

4.9.1 Standard compliance

- IEEE802.3ah: EFM - Ethernet in the first mile

4.9.2 Benefits

- Standardized mechanism to monitor the health of a link and perform diagnostics
- Remote loopback enables standard based test equipment, to be connected at a central location in the network and perform service performance tests all the way to the network edge where the EH2500F unit is usually located.
- Reduces the probability for truck-rolls

4.10 Connectivity Fault Management (CFM)

Connectivity Fault Management (CFM) is an Ethernet layer operation, administration, and management (OAM) protocol designed to monitor and troubleshoot networks.

CFM enables to detect, verify, and isolate connectivity failures in virtual bridged local area networks. A Maintenance Domain (MD) is a part of a network that is controlled by a single operator and used to support the connectivity between service access points. There are eight hierarchical Maintenance Domain Levels (MD Level). Each CFM layer supports OAM capabilities independently, with the customer at the highest level, the provider in the middle, and the operator at the lowest level.

CFM is designed to be transparent to the customer data transported by the network and to provide maximum fault coverage. These capabilities enable easier commissioning and troubleshooting at networks operated by multiple independent organizations, each with restricted management access to each other's equipment. CFM entities support an individual service instance as Maintenance Association End Points (MEPs) are configured to create a Maintenance Association (MA). The MA monitors connectivity provided by that instance through the Maintenance Domain. Maintenance Association Intermediate Points (MIPs) are the intermediate points in a specific MA or MD.

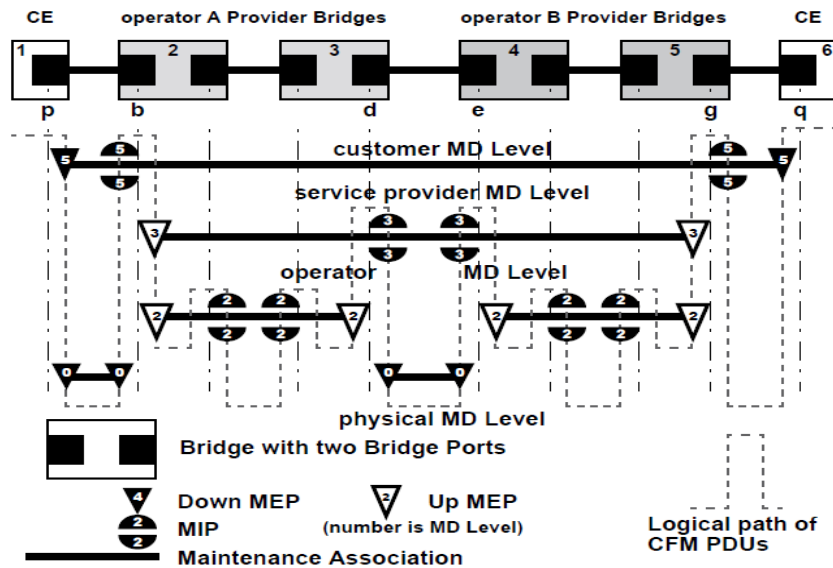
The major features of CFM are fault detection, path discovery, fault verification, fault isolation, and fault recovery.

The system allows to:

- Define Maintenance Domain (MD)
- Define Maintenance Association (MA)
- Define Maintenance Association End Points (MEPs) and Maintenance Association Intermediate Points (MIPs)

The system supports the following monitoring tools:

- CFM Continuity Check Message (CCM)
- CFM Linktrace
- CFM Loopback



- UP MEP – transmit CFM PDUs into the bridge
- Down MEP – transmit CFM PDUs out of the bridge

Figure 13 – Typical CFM network

CFM allows the operator or service provider perform the following actions:

- Fault detection
- Path discovery
- Fault verification
- Fault isolation
- Fault recovery

4.10.1 Standard compliance

- IEEE 802.1ag: CFM - Connectivity Fault Management

4.10.2 Benefits

- End-end Monitoring of services
- Detection of faults before they are noticed or reported by the user
- Faster faults location isolation
- Enhances SLA assurance
- When used to monitor services across multi-networks, enables hiding internal topologies and network elements.
- Running in parallel to service traffic, in same paths, with no interfering the user traffic.

4.11 Performance monitoring OAM

Performance monitoring provides monitoring functionality according to Y.1731 standard. The following measurements are supported:

- Frame delay measurements
- Frame jitter measurements
- Frame loss measurements

4.11.1 Standard compliance

- ITU-T Y.1731 OAM functions and mechanisms for Ethernet based networks
- EH-2500F OAM functionality also complies with MEF 21, UNI Type 2 – Link OAM:
 - OAM Discovery process.
 - OAM PDU tests.
 - OAM TLV tests

4.11.2 Benefits

- Allows operators or service providers to monitor network performance and commit to SLA to the customer.
- Useful both for in-service monitoring and during faults troubleshooting

4.12 ITU-T G.8032 Ethernet Ring Protection (Resiliency)

Ethernet Ring Protection (ERP) is a network resiliency protocol defined by ITU-T G.8032. ERP functionality enables ultra-fast protection for any point of failure in a ring-topology network. This means that network connectivity is maintained in the event that the Ethernet link, the radio link, or even an entire EH-2500F link fails in the ring. This provides resiliency for both Ethernet-physical rings that typically protect single site connectivity and Ethernet-RF rings that typically protect against RF network failure.

ERP is a relatively simple protocol that operates at the network level on the set of nodes that constitute the ring or set of rings. ERP monitors the Ethernet layer to discover and identify Signal Failure (SF) conditions, and prevents loops within the ring by blocking one of the links (either a pre-determined link or a failed link). ERP verifies at all times the ring is closed that frames will not be looped. This is accomplished by taking down a Ring protection Link (RPL) whenever there is no failure in the ring.

EH-2500F supports ERP G.8032v2, with backwards compatibility to previous versions. Using ERP, the EH-2500F provides protection and recovery switching within 50 ms for typical rings. The ERP mechanism occupies extremely low portion from the available bandwidth.

Figure 14 illustrates the basic ERP protection mechanism. In normal ring operation, the RPL is blocked, between nodes C and D. In a failure condition, the failed link, between A & F, is blocked and R-APS messages are sent from the nodes adjacent to

the failed links in order to unblock the RPL. An FDB flush is performed on all ring nodes as necessary.

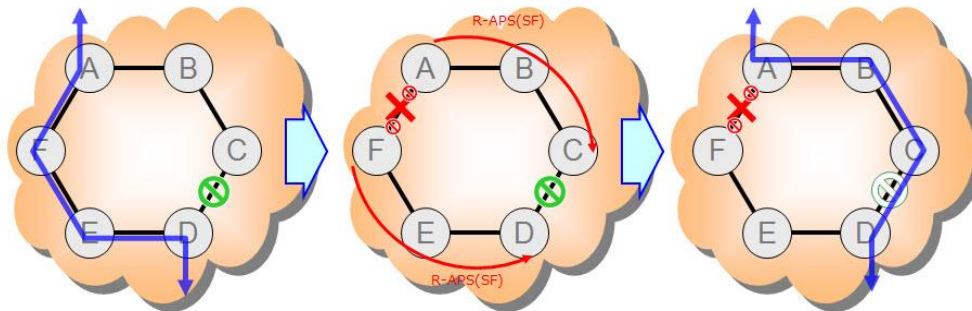


Figure 14 – Basic ERP Protection Mechanism

Among the ERP features supported by EH-2500F are:

- Backwards compatibility to previous versions
- Revertive and non-revertive behavior
- Flush logic with the Node-ID and BPR (Blocked Port Reference) mechanism
- Administrative commands (manual and forced switch, clear)
- Ability to block RPL at both ends of the link (RPL owner and RPL neighbor)
- Multiple logical ERP instances over a given physical ring

4.12.1 Standard compliance

- IEEE G.8032v2 Ethernet Ring Protection Switching

4.12.2 Benefits

- Non-proprietary protection resiliency standard that allows mixed-vendor deployments
- Carrier-class reliability, with sub-50ms performance
- Can be deployed in both all wireless backhaul environment as well as in mixed wireless / optical
- Overcomes old spanning-tree protocols issues while adding the faster restoration performance

4.13 Ethernet Synchronization

4.13.1 Synchronous Ethernet (ITU-T G.8261)

EH-2500F supports Synchronous Ethernet (SyncE). The EH-2500F supports Synchronized Ethernet link input from the network side through one of the physical ports or from the radio side and providing a synchronized Ethernet link over the air to the other end of the wireless link within the required masks.

SyncE is a link-by-link timing distribution scheme that uses the Ethernet physical layer to accurately distribute clock frequency. ITU-T standard G.8261 defines various aspects of SyncE, such as the acceptable limits of jitter and wander as well as the minimum requirements for synchronization of network elements.

With SyncE, the receive clock is extracted from the Ethernet Rx by the clock unit and used for transmission on all interfaces, propagating the clock in the path. Every SyncE Network Element contains an internal clock called the Ethernet Equipment Clock (EEC). The EEC locks on the Rx clock and distributes it for transmission on all interfaces, attenuating jitter and wander, and maintaining clock-in holdover. If the Rx clock fails, the local unit switches to holdover and regenerates the clock accurately until the failure is corrected.

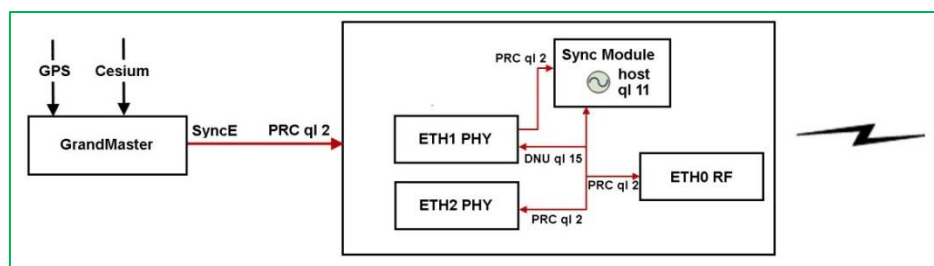


Figure 15 – EtherHaul™ ODU SyncE Functional Diagram

Synchronization messages are transported between the SyncE elements using Ethernet Synchronization Message Channel (ESMC). ESMC is similar to SSM (Synchronization Status Message), used in Sonnet/SDH systems. ESMC carries information about the Quality Level (ql) and sync status of the source clock, enabling EtherHaul™ products to determine which clock source to use, based on performance and the need to avoid loops. Quality Level is based on the clock's holdover performance.

4.13.1.1 Standard compliance

G.8261 defines various aspects of Synchronous Ethernet such as the acceptable limits of jitter and wander for packet networks as well as the minimum requirements for the synchronization function of network elements.

G.8262, Timing characteristics of Synchronous Equipment Slave Clock (EEC), defining the SyncE clock specs, such as Jitter, Wander, Holdover...

G.8264, Distribution of timing through packet networks, defining the Ethernet Synchronization Messaging Channel (ESMC) protocol

4.13.1.2 Benefits

SyncE allows operators and service providers a faster and reliable migration from legacy SDH/PDH/SONET networks to packet switched networks and thus significantly reduce OPEX.

Together with support of IEEE 1588, EtherHaul™ provide carrier class timing to remote sites and cell-sites, avoiding the need to deploy cumbersome GPS-based timing.

4.13.2 1588 Transparent Clock

Siklu's EH-2500F supports IEEE 1588v2 Transparent Clock (TC). The EH-2500F products comply with the mobile backhaul specifications for packet synchronization distribution.

1588v2 Transparent Clocks (TCs) used to overcome the 1588 synchronization performance issue due to packet delay variation over the network. In a wireless links, the compensation of the PDV needs to be done for the entire link including the air interface, and not only per node. Time stamping and the correction field update are HW based in EH-2500F.

4.13.2.1 Standard compliance

- IEEE 1588v.2 - Precision Time Protocol (PTP)

4.13.2.2 Benefits

- Allows accurate “Wall time” synchronization in the packet switched network.
- Enables stamping updates

4.13.3 1588 optimization

The EtherHaul™ products provide optimized transport of the IEEE 1588v.2 packets allowing the slave to regenerate the clock within the required masks.

The IEEE standard 1588-2008, also known as 1588v2, defines a packet-based, timestamp distribution between a master clock and a slave, whereby the timing information originates from a Grandmaster clock function that is usually traceable to a Primary Reference Clock (PRC) or Coordinated Universal Time (UTC).

4.13.3.1 Standard compliance

- IEEE 1588v.2

4.13.3.2 Benefits

Allow accurate “Wall time” synchronization in the packet switched network.

5. Management concept

The EH-2500F is capable of delivering services out of the box, without any user configuration input. In this mode, the system acts as a fully transparent bridge, which matches many network configuration and it is intended for fast and easy service activation process.

For managed operations, the EH-2500F includes all fundamentals that enable easy configuration, monitoring, and troubleshooting, by variety of all leading Telco-grade systems, as well as direct local and remote management directly from operator's desktop.

The supported management options are:

CLI	Professional Command Line Interface for full configuration and maintenance activities, with multiple privileges levels as required by service providers.
WEB GUI	Easy to interact user-interface via standard web-browser to manage both ends of the link, from one graphical screen.
RADIUS and TACACS+	RADIUS (Remote Authentication Dial-In User Service) and TACACS+ (Terminal Access Controller Access-Control System) are advanced authentication and report standards for large scale networks.
SNMP	Both versions 2 and 3 of the Simple Network Management Protocol are supported for north-bound connectivity to central configuration and monitoring systems.
FTP SFTP TFTP	FTP, TFTP and SFTP protocols designed to provide file transfer and other manipulations. The EH-2500F uses SFTP/FTP/TFTP for software upgrades, configuration uploads and downloads
SikluView	EMS – Elements Management System. Siklu solution for high level centralized administration and monitoring of EtherHaul™ elements and links

5.1 CLI

All EH-2500F's functionality is accessible via secured command line interface (SSH). The user type defines the user's access privileges.

User	Read-only access, but cannot view user names, passwords, and other security settings.
Tech	Basic technical operations: can clear statistics, alarms, and log lists, and run diagnostics, but read-only access to configuration settings.
Super	Advanced operations and complete access to configuration options, but no access to user names, passwords, and other security settings.
Admin	Full access to all management and operations parameters.

5.1.1 Benefits

- Well know professional configuration and troubleshooting tool.
- Enables efficient, large scale projects rollouts with an easy loading of configurations scripts.
- Systems logs are easily reviewed and uploaded.
- Intuitive events' investigations and troubleshooting.

5.2 Web GUI

EH-2500F Units' and link functionality are accessible via secured HTML based Web interface (HTTPS), for monitoring, configuring, SW upgrades and diagnostic.

The GUI enables an easy, realistic view and operation:

- One screen manages both ends of the link
- 'Quick Configuration' wizard to help fast, easy and reliable installation by non-experts staff
- Link status is presented
- Ports highlighted according to actual status
- Real reflection of systems LED indicators
- When mouse pointer touches each topic in the menu, it automatically show list of available functions with no need to enter the other screen
- Link configuration and settings

5.2.1 GUI main screen

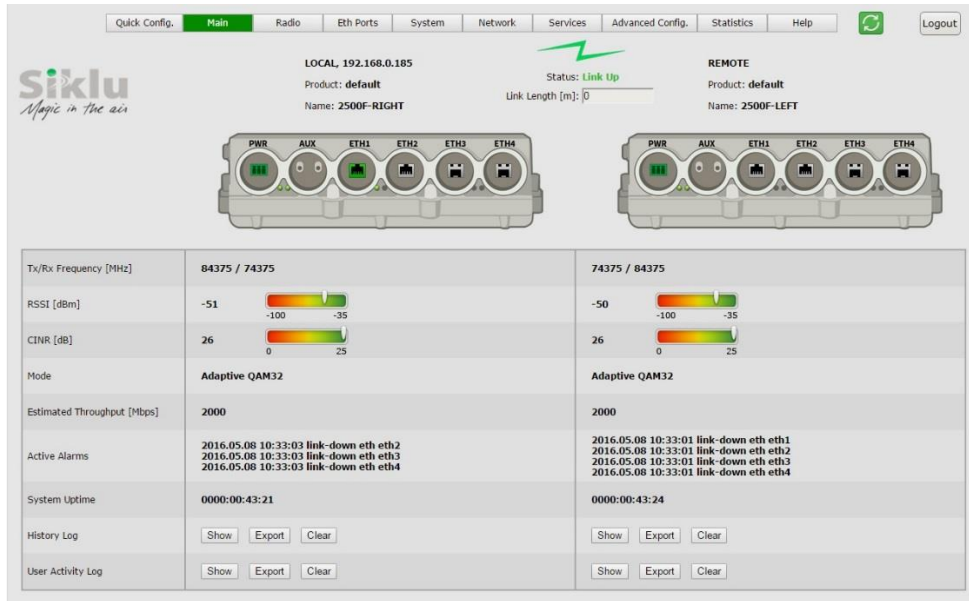


Figure 16: EH-2500F GUI main screen display

The main screen (Figure 16) displays all essential link status information to enable easy and fast overview:

- Link status (up/down)
- Actual link length, automatically calculated by EtherHaul™ from the measured wireless delay between both ends of the link
- Used Ethernet ports
- RSSI and CNIR
- Current modulation level
- Available capacity
- Active events or alarms summary
- Shortcuts to both system log and user activity log

5.2.2 Quick configuration wizard

Easy, fast, and minimal configuration process enables one quick flow, for the user to set up a link with all mandatory parameters that leads to a fully managed mode of operation.

The quick configuration wizard includes 4 steps:

1. Configuration of system parameters:
 - Specific system identification for the related location/service.
 - Date and time (there is also an option for redundant central NTP connection).

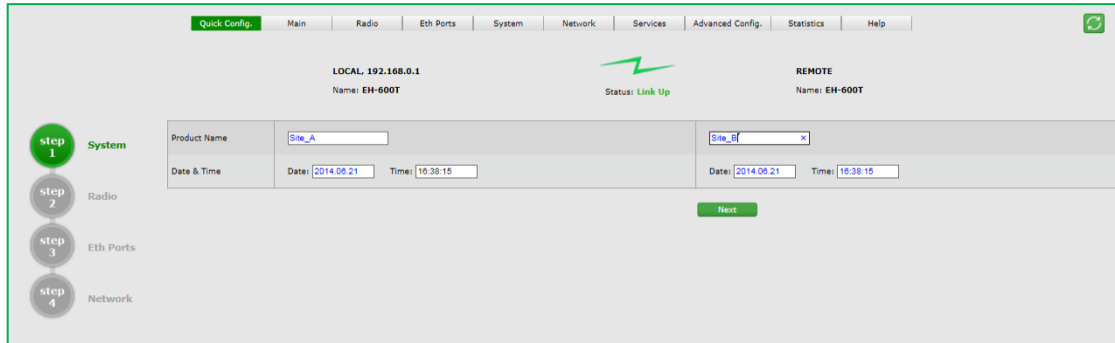
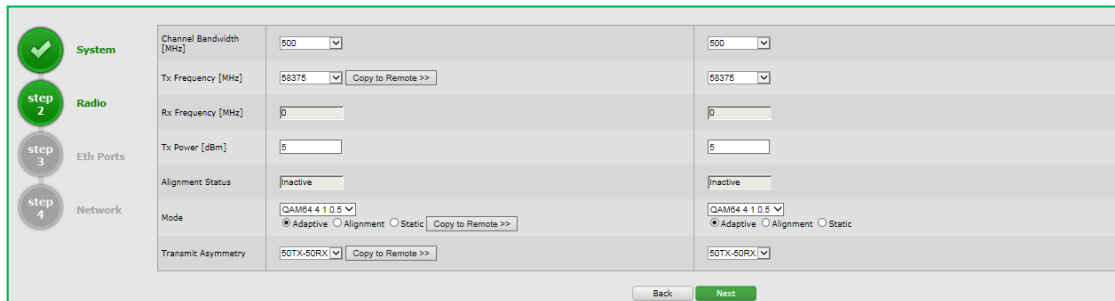


Figure 17: GUI managed mode wizard step 1

2. Configuration of the Radio:
 - Frequency channel selection
 - Tx power
 - Maximum allowed modulation
 - Symmetric / asymmetric mode selection



3. Management IP address
 - Up to 4 concurrent addresses are supported
 - Both IPv4 and IPv6 addresses are supported.
4. SNMP connectivity parameters

5.2.3 Standard compliance

- RFC2616 - Hypertext Transfer Protocol (HTTP)
- RFC2246 - Transport Layer Security (TLS) protocol
- RFC2818 - HTTP Over TLS

5.2.4 Benefits

- Configuration to an EH-2500F link is made in a simple, fast, and in a secured manner.
- No need for dedicated client or plugins in user's terminal.
- Multiple supported management addresses enable multiple network domains connections, eliminating the need for dedicated router/VPN for multi domains connectivity.

5.3 SNMP

The system supports SNMP v.2 and SNMP v.3 – for configuration, monitoring and northbound. EH-2500F support SNMP over both IPv4 and IPv6 L3 addresses schemes.

5.3.1 Standard compliance

- SNMP v.2
- SNMP v.3

SNMP is defined by the Internet Engineering Task Force (IETF).

5.3.2 Benefits

- Allows simple and standard integration into network management system.
- Enables monitoring, configuring and alarms flows to/from single or multiple north-bound systems.
- Most of the SNMP objects (sub element for control / monitor) are well defined by the IETF standard, thus time to market with most of systems' parameters can be within hours.

5.4 FTP/SFTP/TFTP

FTP, TFTP and SFTP are network protocols designed to provide file transfer and file manipulation facilities, with optional security services. The EH-2500F uses SFTP/FTP/TFTP for software upgrades, configuration uploads and downloads.

5.4.1 Standard compliance

RFC4251- The IETF extension, of the Secure Shell protocol (SSH) version 2.0.

5.4.2 Benefits

EH-2500F maintenance activities are performed in a secured and standard based method, with standard IT tools.

5.5 User management

The EH-2500F supports both local user management as well as centralized management with industry standard Radius or TACACS server.

5.5.1 Local/Remote user management

The user type defines the user's access privileges.

User	Read-only access, but cannot view user names, passwords, and other security settings.
Tech	Basic technical operations: can clear statistics, alarms, and log lists, and run diagnostics, but read-only access to configuration settings.
Super	Advanced operations and complete access to configuration options, but no access to user names, passwords, and other security settings.
Admin	Full access to all management and operations parameters.

5.5.2 Radius and TACACS+ user management

RADIUS (Remote Authentication Dial-In User Service) and TACACS+ (Terminal Access Controller Access-Control System) are 2 industry standard for Authentication, Authorization and Accounting (AAA):

- Authentication: Identification of requester profile (username, password, and privilege level) on a per-request basis.
- Authorization: Permission/denial of access to a subset of commands subject to authentication success/failure. (The mechanisms of Authorization and authentication are independent of each other.)
- Accounting: Reporting of information on requesters (identities, number of access attempts per requester, start, and stop times, executed commands, etc.)

The EH-2500F is a Network Access Server (NAS) for requesters and functions as AAA client passing requester information (e.g. username, password, etc.). The AAA Server is responsible for receiving connection requests, authenticating or disqualifying the requester, and sending the permit or denies response to the client EH-2500F. Communication between the EH-2500F and the AAA Server is performed by shared secrets which are never sent over the network. In addition, every administrator password is encrypted before it is sent between the EH-2500F and the AAA Server in order to prevent deciphering.

The AAA Server can also provide accounting of requester commands and of changes in authorization level. This information is recorded in a special log file that enables a supervisor to view the activities of all the administrators. Accounting can include logging of commands or logging of transitions from one mode to another.

The EH-2500F supports user authentication with TACACS+ or Radius AAA servers, up to five servers.

5.5.3 Benefits

- The hierarchical 4 levels user's access privileges suits all network sizes: large network operators, carrier-of-carrier providers as well as smaller local operators and WISPs. It enables clear separation between multiple classes of users.
- The RADIUS and TACACS supports, adds centralized user and rights management for large network operators, carrier-of-carrier providers by enabling connectivity control and accounting to minimize IT interactions with end-users without compromising security aspects.

6. Security

6.1 Security features description

- Physical
 - Pencil beam – requires a physical location within antenna transmission path.
 - Minimal reflections. Both the extremely low transmit power and ultra-high frequencies contribute to minimal reflections effects and thus enhances system's resiliency and noticeable footprint.
 - Proprietary DSP (Digital Signal Processor) for RF signals requires Siklu ODU to intercept.
 - Synchronized transmission – only 'man-in-the-middle' interception for eavesdropping.
- Link / data encryption
 - Link ID – link layer password
 - AES with 128/256 bit security (licensed based)
- Management aspects
 - SNMPv3 - Supporting both HMAC (Hash-based message authentication code) and MD5 (message-digest algorithm)
 - Access list for Host (management access) - ACL based on IP and Mask for security and Denial of Service

- Management Vlan for isolated control of the device
- Secured communication protocols for management: SSH (Command Line Interface), HTTPS (Web-GUI), SFTP (SW download and File Transfer)
- User access
 - Different user types and privileges categories

6.2 Interface to external access rights management systems

The EH-2500F includes full Radius/TACACS+ AAA support:

- Authentication: Identification of requester profile [username, password, and privilege level] on a per-request basis.
- Authorization: Permission/denial of access to a subset of commands subject to authentication success/failure. (The mechanisms of Authorization and authentication are independent of each other.)
- Accounting: Reporting of information on requesters (identities, number of access attempts per requester, start and stop times, executed commands, etc.)

7. Logging and auditing features

Advanced logging and performance monitoring logs/stats are available and kept in the device. The information can also be exported and collected using File Transfer (both FTP, SFTP are supported).

Logs:

1. Current alarms
2. Alarm & event log file (history)
3. User activity log (stores all actions and configuration commands)

Performance statistics:

1. RF link statistics: RSSI, CINR, Modulation changes, RF statistics (errors and frame loss counters)
2. Ethernet ports statistics
3. VLAN statistics
4. Queues statistics

7.1 System statistics

The EH-2500F uses advanced RF and Ethernet counters to provide real-time performance statistics for radio transmission (RF) activities, Ethernet ports, VLAN traffic, and QoS queues.

The EH-2500F collects a full day of 15 minutes statistics (96 bins) and 30 days of 24 hours history summary, the counters are available for RF, per ETH port and per VLAN (service).

The following statistics enable quick analysis of system and component performance in support of troubleshooting and diagnostics:

RF	<p>Displays RF statistic counters to identify radio errors and check the radio status history. The RF statistics consist of real time statistic counters since the last time the counters were cleared</p> <p>Detailed collected statistics: in-octets, in-idle-octets, in-good-octets, in-errored-octets, out-octets, out-idle-octets, in-pkts, in-good-pkts, in-errored-pkts, in-lost-pkts, out-pkts, min-cinr, max-cinr, min-rssi, max-rssi, min-modulation, max-modulation</p>
VLAN	<p>Displays statistic counters of each EtherHaul™ link component per VLAN</p> <p>Detailed collected statistics: in-octets, in-ucast-pkts, in-discards, in-errors, out-octets, out-ucast-pkts, out-errors, in-mcast-pkts, in-bcast-pkts, out-mcast-pkts, out-bcast-pkts, out-discards, in-no-rule-discards</p>
Ethernet Ports	<p>Displays Ethernet statistics counters per Ethernet port</p> <p>Detailed collected statistics: in-pkts, out-pkts, drop-pkts</p>

7.1.1 Benefits

Real time and historical data, including RF, Ethernet ports, and VLANs values enable simple and reliable way to identify operating faults and monitor link's performance by both operators and automatic statistics collection systems.

7.1.2 Standard compliance

RFC2819 – RMON Remote Network MONitoring

7.2 System loopbacks

The EH-2500F provides Ethernet and RF loopbacks designed to enable fault isolation and Ethernet service performance testing. Loopbacks functions are user configurable and support timeout in seconds.

- **Ethernet Loopback** – Internal and external loopbacks are performed on the interface, testing the local ODU, the radio link, and the remote ODU.
- **RF (Radio) Loopback** – Internal loopback is performed on the ODU's RF output.

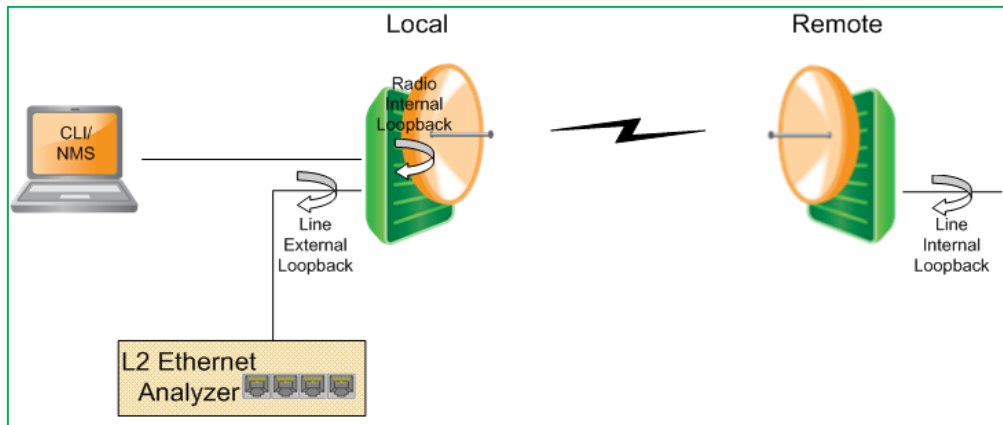


Figure 18 –System loopback points

System alarms as well as statistic displays should be used to determine if Loopback testing has passed or failed.

7.2.1 Benefits

- Enables end-to-end link tests or single unit self-test for fault detection and isolation.
- Significantly reduces operation costs by saving truck-rolls as well as number of test equipment needed for network maintenance.

8. Power supply

8.1 Power options DC power supply and PoE

The EH-2500F has 2 power input options working in redundancy

- Carrier-grade 48VDC (DC input range: 36 ÷ 57 VDC, flexible grounding)
- PoE++ (IEEE 802.3at++) over port ETH1

In both case the power draw is: 45W without PoE-Out; 60W with PoE-Out active on port ETH2.

8.1.1 Benefits

Thanks to the efficient system design and high integration, the EH-2500F:

- Reduces the power consumption and accordingly the associated energy costs.

- Simplifies the installation scenario, by enabling use of a single cable for both power and data.
- Overcomes single point of failure with power redundancy for high availability and carrier grade services

9. EH-2500F Deployment topologies

The EH-2500F is easy to integrate in various topologies such as:

- Point-to-Point - Two units are used to implement a point-to-point single hop
- Point-to-Multipoint – A number of links are deployed in star configuration. The ODUs at the start of the links in the hub site may be chained to each other, or aggregated using a managed or un-managed Ethernet switch.
- Daisy-chain – A number of links are used to implement an open series of point-to-point hops, where traffic could be dropped and added at each node in the chain, while extending the reach much beyond that of a single hop. Typically the nodes can be connected without an Ethernet switch.
- Ring – A number of links are used to implement a closed series of point-to-point hops, where traffic could be dropped and added at each node in the ring. This topology also enables a diversity of packet routing options and redundancy. Typically the nodes can be connected without an Ethernet switch.
- Mesh - A number of links are used to implement a series of point-to-point hops which enable interconnection between the nodes, where traffic could be dropped and added at each node in the mesh. This topology enables redundant interconnections between the nodes. Typically the nodes can be connected without an Ethernet switch.

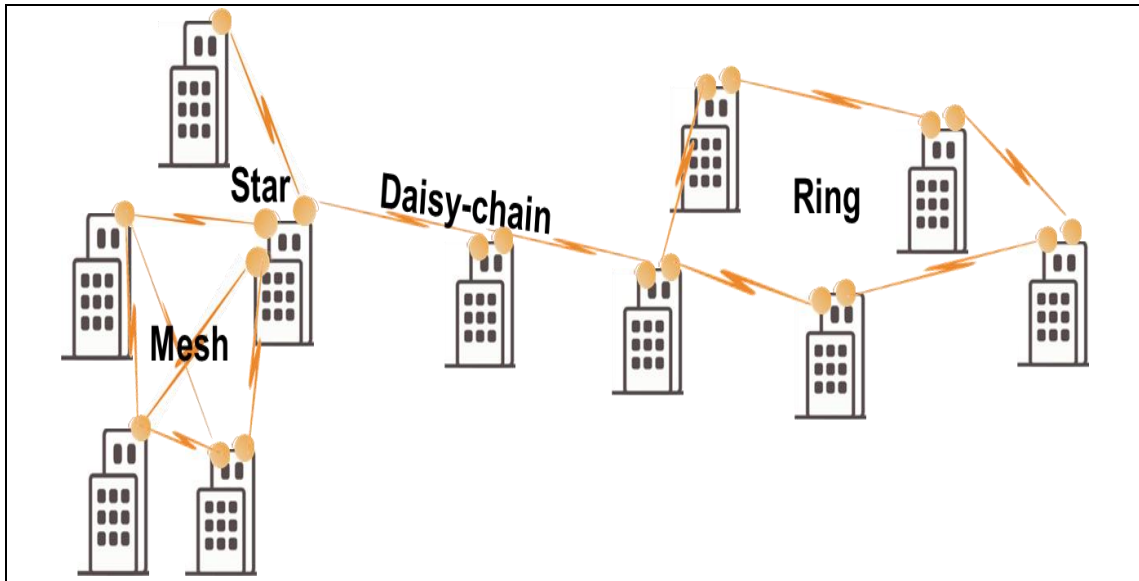


Figure 19 – Deployment topologies: Ring, Daisy-chain, Star and Mesh

In all these topologies, EtherHaul™ performs packet forwarding based on L2, and QoS based on either L2 or L3 information. Thus each incoming packet at any port in the entire network can be classified at any other node in the network, typically according to its VLAN tag and CoS bits. Based on this classification, a node can assign the packet to the proper priority queue, and thus allocate resources or force it to share the BW in a controlled manner with packets coming from other sources. The bandwidth allocation policy (QoS) at each node is fully controlled based on operator's QoS scheme configured into the system.

9.1.1 Solution benefits

- Integrated, MEF compliant switch with 4 GE interfaces, especially designed for daisy chain and still preserve the ability to connect “drop” more customers/services (Technology/ costumers co-location)
- Max installation flexibility - Any combination between the chained links

10. Standards compliance

EtherHaul™ comply with both ETSI spectrum allocations and FCC requirements.

The list of supported standards by EH-2500F is:

- IEEE 1588v2, Transparent Clock mode (TC)
 - Synchronization Messaging Channel - ESMC
- Synchronous Ethernet : ITU-T G.8261/8262/8264
- AES 128/256-bit
- MEF 9,14 and 21
- Eth OAM –
 - CFM-IEEE802.1ag, Y.1731
 - EFM- IEEE802.3ah
- ERPS: ITU-G G.8032
- IEEE 802.1d Transparent Bridge
- IEEE 802.1ad Provider Bridge – QinQ VLAN/VLAN stacking
- Traffic management: 802.1p (L2), DSCP (L3) & MPLS EXP (L2.5)
- LAG / LACP: 802.3ad
- PoE power source: IEEE 802.3af
- SNMP: v2/3
- Frequency Regulations:
 - ETSI EN 302 217-2
 - USA FCC Part 15.255
- Antenna: ETSI EN 302 217-4 Class2, class3
- Transportation: EN 300 019-1-2 Class 2.2
- Storage: EN 300 019-1-1 Class 1.2
- Operation: EN 300 019-1-4 Class 4.1E
- Safety: UL 60950
- Ingress Protection Rating: IP67
- EMC: EN 301 489-4 ;FCC 47 CFR part 15
- CE: CE Marked

About Siklu

Siklu delivers Gigabit capacity millimeter wave wireless backhaul solutions operating in the 60, 70 and 80 GHz bands. Ideal for dense, capacity-hungry urban security networks, the ultra-high capacity wireless links can be easily and discreetly installed on the very same street fixtures as the security cameras. The most deployed mmW radios in the world, thousands of units are delivering carrier grade performance in varying weather conditions around the world.

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