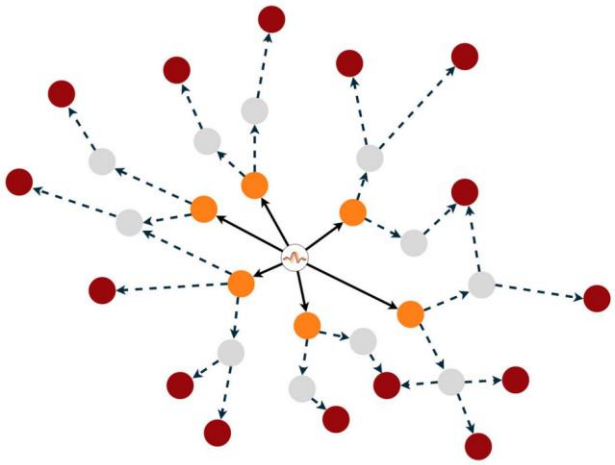
PHASORLAB
NEXT GENERATION WIRELESS TECHNOLOGIES

PHASORLAB INC.

SELF-EXPANDING MESH RADIO SYSTEM SPECIFICATION DOCUMENT



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Contents

Acronyms

Acronym		Definition
C3		Command, Control, and Communications
CDF		Cumulative Density Function
GPS, GNSS		Global Positioning System, Global Navigation Satellite System
GNRMC		Specific NMEA sentence format
HDOP		Horizontal Dilution of Precision
HSN		Hyper Sync Net
HSNRM		Proprietary navigation data sentence format
MAC		Media Access Controller

NMEA		National Marine Electronics Association (GPS data format)
OCTCXO		Oven-Controlled Temperature-Compensated Crystal Oscillator
PDR		PHY Data Rate
PNT		Position, Navigation and Timing
PPB		Parts Per Billion
PPS		Pulse-per-Second
PVT		Position, Velocity and Time
SDCARD		Secure Digital Card
SEM		Self-Expanding Mesh
SWaP		Size Weight and Power
TFDS		Time and Frequency Distribution System
TDMA		Time Division Multiple Access
u-blox (UBX)		Data format recognized by modern navigation systems
UART		Universal Asynchronous Receiver-Transmitter
UAS, UAV		Unmanned Aerial System, Unmanned Aerial Vehicle
USB		Universal Serial Bus
UTM		UAS Traffic Management (NASA-FAA)
VCTCXO		Voltage-Controlled Temperature-Compensated Crystal Oscillator
VDOP		Vertical Dilution of Precision

Product Summary

Self-Expanding Mesh (Next Generation MANET)

- High Performance Data Communication Application
- Ideal for UAS Fleet Management - GNSS-Free PNT Service
- Enable Single Operator for Drone Swarm Command Control and Communications (C3)
- Frequency Agile Anti Jamming Capability
- Wireless Multi Hop Synchronization with Minimal Overhead
- Advanced TDMA MAC
- End-to-End Data Encryption

SEM Overview

Introduction:

PhasorLab's Secure Enhanced Mesh (SEM) builds upon our Hyper Sync Net (HSN) Time and Frequency Distribution System (TFDS) to deliver secure, scalable, and cost-effective wireless data communication for high-bandwidth applications, including voice and live-streaming video. SEM also provides robust 3D position tracking capabilities and ideal for autonomous UAS navigation applications in GNSS-challenged environments.

Problem Statement:

Traditional mesh networks suffer from performance degradation in high-node density and mobility scenarios due to excessive protocol overhead and latency. Additionally, UAS fleet management requires reliable navigation and security in GNSS-denied or spoofed environments.

SEM Solution:

SEM addresses these challenges by integrating HSN's precise time and frequency synchronization, low latency, 3D-mapping, spatial awareness, and low SWaP (Size, Weight, and Power) characteristics, enabling:

- **Efficient Real-Time Routing:** HSN synchronization facilitates rapid routing table updates and dynamic quad-vector mapping of 1-4 hop neighbors, minimizing protocol traffic and latency.
- **Enhanced Location Accuracy:** Advanced algorithms enhance location solver accuracy in indoor and dense urban environments.
- **Robust Security:** End-to-end data encryption and high-security access protocols prevent unauthorized node access and mitigate spoofing threats. Synchronous and coherent frequency hopping eliminates jamming threats.

Key Functional Features:

- **Secure, Scalable Wireless Data Communication:** Supports voice, video, and high-bandwidth applications.
- **HSN Synchronization Integration:** Enhances routing efficiency and network performance.
- **Dynamic Quad-Vector Mapping:** Enables real-time routing adjustments and reduces protocol overhead.
- **3D Autonomous UAS Position Tracking and Navigation:** Provides reliable navigation in GNSS-challenged environments.
- **GNSS Spoofing and Interference Detection:** Enhances security and navigation reliability.
- **Enhanced Location Accuracy Algorithms:** Improves positioning accuracy in challenging environments.
- **End-to-End Encryption and Secure Access:** Protects network integrity and data security.
- **Synchronous and Coherent Frequency Hopping:** Mitigates jamming threats.
- **Low SWaP for UAS Integration:** Suitable for integration into unmanned systems.

Target Applications:

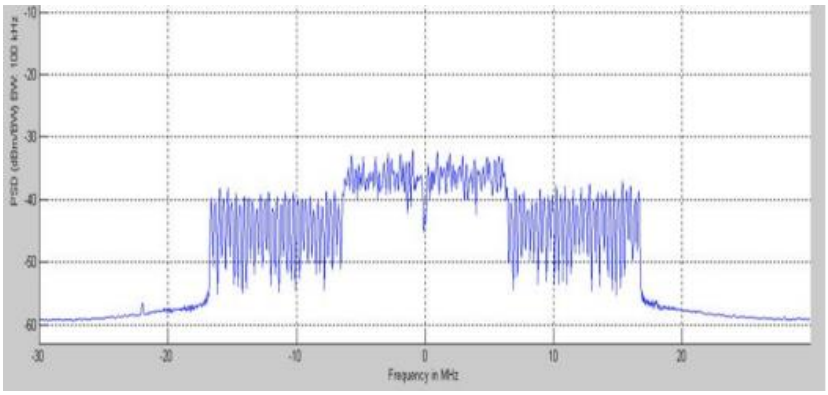
- Public safety and emergency response.
- Military and defense tactical communication.
- GNSS-Independent UAS Navigation: SEM delivers 3D autonomous UAS position tracking and navigation in GNSS-degraded or denied environments.
- GNSS Spoofing and Interference Detection: Real-time comparisons of HSN PNT (Position, Navigation, and Timing) data and GNSS data enable detection and reporting of spoofing and interference events, with automatic navigation data switching based on GPS health.
- Industrial automation and monitoring.
- Critical infrastructure backup and protection.
- Any application requiring secure, reliable, and high-bandwidth wireless communication and precise navigation.

SEM System Specifications

SEM Radio

Parameters	Values	Conditions / Comments
RF Output Power	25dBm	Max power for 2.4GHz and 5.8GHz
RF Frequency (A)	2.4GHz	
RF Frequency (B)	5.8GHz	
Min Bandwidth	2MHz	
Max Bandwidth	40MHz	
Duplex Mode	TDD	
Multiple Access Method	TDMA	
Modulation Type	OFDMA	Configurable
XTL Oscillator Type	OCTCXO / VCTCXO	
Rx Sensitivity (20MHz BW)	-91dBm (5.8GHz) -88dBm (2.4GHz)	For 6dB SNR, 20MHz BW
Rx Sensitivity (5MHz BW)	-97dBm (5.8GHz) -96dBm (2.4GHz)	For 6dB SNR, 5MHz BW
Noise Figure	5dB (2.4GHz)	5.8GHz channel equipped with better LNA for current version
ACLR	25dB	@ 10MHz off

SEM Radio Spectral Emissions Example



Synchronization

Parameters	Values	Conditions / Comments
Frequency Synchronization	< 1ppb per hop	Carrier frequency synchronization
Time Synchronization	< 1ns per hop	Between two hops
Range Estimation Accuracy (Outdoor)	4cm	Outdoor static condition free of multipath
Range Estimation Accuracy (Indoor)	10cm	Indoor static condition with heavy multipath
Min # of Master Node	1	HSN supports multiple master nodes

Estimate Time for a New Node Joining	< 30s	Starting from power-up

Data Communications

Network Features

Features	Comments
Internode data communication and bidirectional gateway communication	Used for monitoring the network state.
Self-Healing and Self-Organizing	Enables automatic network formation, and handling of node breakdowns/failures.
Hop By Hop Acknowledgement	Transmitted packets are acknowledged at every hop at link layer
Encrypted communications	All packets are encrypted in the link layer using Xilinx AES functions
Unicast and Broadcast Addressing modes	Supports transmitting a packet to all nodes in the network.
Real time surveillance	The network utilizes message priorities to provide low latencies for positioning messages.

Network Specification

Parameters	Values	Conditions / Comments
Network Topology	Mesh	Every node is connected to every other node
Network Node Capacity	20 nodes per gateway	Network capacity can be increased by adding gateways and SEM features
Multiple Access Method	TDMA	
Network Build Time	<60sec	Time taken to form efficient packet routing table from start. Tested with 20 nodes. Note: It doesn't refer to the time to establish sync hierarchy.
Network Healing Time	<30s	Time taken to find a new packet route in case of a node failure. Note: The time to find a sync master is in milliseconds.
PHY Data Rate	Min: 6Mbps Max: 56Mbps	HSN supports PHY data rates from 6Mbps to 54Mbps on Wi-Fi bands
Per Hop Data Link Latency	50 to 100ms	Depends on HSN network configuration.
Network Throughput	PHY Data Rate/#frames	Max network throughput = 5.4 Mbps given a 10-frame schedule.

Security Features

Parameters	Conditions / Comments
End to End Encryption	All data packets are end to end encrypted with pre-shared keys which are shared only between the HSN nodes.
Secure Boot	HSN nodes use flash encryption to execute only trusted software from flash. HSN firmware files are encrypted with AES128 encryption keys.
Anti-Spoofing and Anti-Jamming	HSN network utilizes frequency hopping and PHY features to provide protection against RF jamming and spoofing
Geofencing and Signal Source Verification	HSN performs network-based positioning and client-based positioning on every transmission to prevent unauthorized access beyond some specified service area.
Self-Organizing and Self-Healing	HSN built in network features are robust against sinkhole attacks where one or a fraction of the HSN nodes are brought down by attackers.

Positioning Specification

Parameters	Values	Conditions / Comments
Output Rate	Up to 20Hz	Depending on HSN size and configuration settings
Horizontal Position Accuracy	<1m	CDF error of ~1m at 95%
Height Accuracy	<1.5m	CDF error of ~1.5m at 95%
Horizontal Velocity Accuracy	<0.5 m/s	V_N & V_E
Vertical Velocity Accuracy	<0.75 m/s	V_Z
Latency	~ 200 ms	HSN supports fixed latency
Error Metrics	HDOP, VDOP, FIX	Supports calculations of HDOP, VDOP based on the relative position of HSN nodes
Position Convergence Time	<30s	Starting from power-up for a node configured as UE node
Position Output Format	NMEA, UBX binary, HSN binary	HSN node outputs NMEA GNRMC message, u-blox PVT sentences along with proprietary HSNRM sentences
Position Data Logging	NMEA, UBX binary, HSN binary	Supports logging of all positioning messages up to 5Hz rate on SDCARD

Communication interfaces or I/O pins

Parameters	Values	Conditions / Comments
Serial Interfaces	2 UART, 1 micro USB	
Protocols	NMEA, UBX binary, HSN binary	

Power Spec

Parameters	Values	Conditions / Comments
Max Current	633mA	
Supply Voltage	12V	
Power Consumption	7.6W	

Footprint spec

Parameters	Values	Conditions / Comments
Dimensions	4” x 5” x 1”	PCB size without casing
Dimensions	4.75” x 5.5” x 1.25”	Size with casing (indoor)