Cambium Networks PMP 450i 900MHz

November 2015

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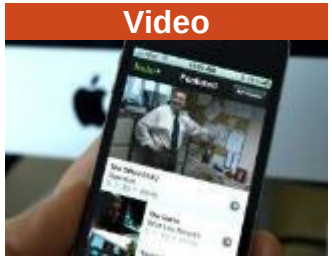
Introduction

- PMP 100 (legacy 900MHz FSK) systems have been in use for many years and continue to work
  - Low but very reliable data rate
  - Consistent throughput
  - Good penetration in nLOS and NLOS applications

- New bandwidth demands have pushed the limits of FSK capacity
  - Voice/Video application adoption
  - Low bandwidth availability
  - Spectrum congestion
  - User scalability

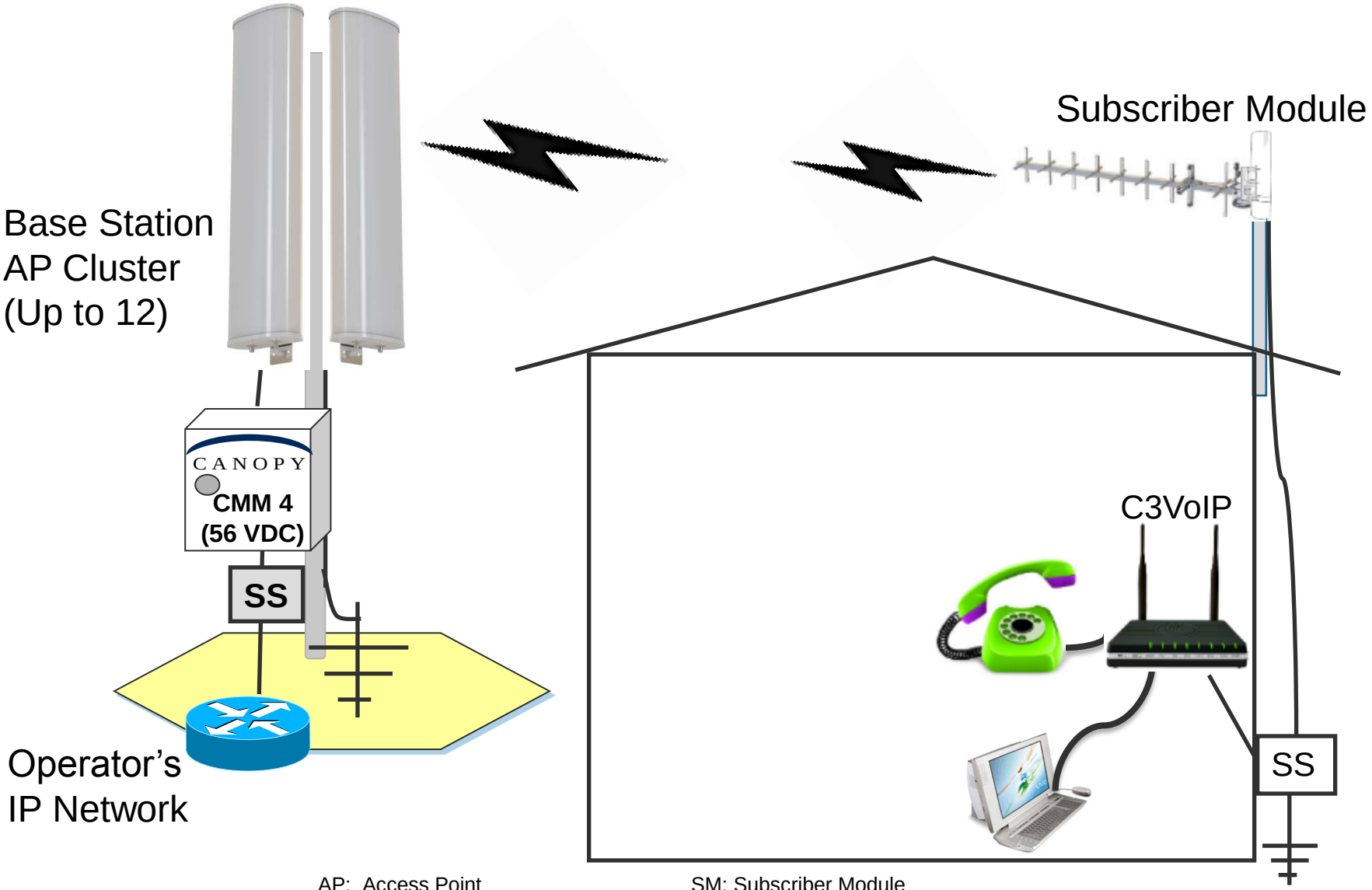


- Need for migration to newer technologies and hardware
  - Increased spectral efficiency
  - Improved interference mitigation
  - Increased channel size
  - Seamless transition
  - **Much higher capacity**

Mobile Data is Exploding

Source: Cisco VNI 2012

Overview: PMP 450i 900 MHz Architecture



AP: Access Point
SS:– Surge Suppressor
CMM: Cluster Management Module

SM: Subscriber Module
IP: Internet Protocol
C3VoIP – Cambium ATA Router

450i 900 MHz: Key System Features

- Product Mission Statement:
  - Cambium Network's 450i 900 MHz product platform is the path to higher throughput for tough to reach customers.
  - Increased coverage and throughput
    - Improved Radio system, same propagation
  - PMP 450i 900 MHz: Providing more throughput for difficult links

450i 900 MHz: Key System Features

Features	Customer Benefit / Competitive Advantage
Redesigned 900 MHz Radio (902-928 MHz)	Increased performance, based on 450i platform
Improved Range and Coverage	**Make NLOS links.** Using 900 MHz, propagation is fantastic. Upgrade your tough NLOS deployments to higher throughputs.
Rugged Enclosure for AP	Specified using **Industrial-rated components**. Designed to meet IP66 and IP67 ratings for harsh environments.
Clean installation for SM	Attach the SM directly to the slim but powerful (12 dBi) Yagi antenna.
Updated SoC (FPGA) chipset on the AP	**Triple the processing power compared to PMP 450, an order of magnitude more than PMP 100**. Allows for future platform enhancements.
Multifunction AUX port on the AP	A second Ethernet port with multiple functions allow for greater flexibility of deployment: add a camera or other PoE device directly, provide GPS timing in/out, and an audible alignment tone.
Updated Power Scheme	Industry standard 802.3at PoE compatible on the AP. **Continue to use the existing 30 VDC power for the SMs.**

PMP 450i 900 MHz Overview

- **900 MHz ISM band Operation**
  - 902-928 MHz
  - 5, 7, 10 or 20 MHz channels supported
- **2x2 MIMO design**
  - Allows higher capacity
- **Power Scheme - New for AP, Same for SM**
  - AP will be 802.3at PoE compatible (56 VDC)
  - SM will be 30 VDC, and can **re-use existing PSU**
- **Next Generation Architecture**
  - **Utilizing PMP 450i architecture**
  - Maximize Spectral efficiency
    - Using GPS timing and colocation with PMP 100 900 MHz
- **Product Design Goal**
  - Under similar RF conditions, similar channel size, **3x - 4x PMP 100**
  - 4 Mbps capacity to **12-16 Mbps capacity**
  - In clean spectrum, **PMP 450 900 MHz can provide 100+ Mbps per sector**

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PMP 450i 900 MHz Migration Strategy

- Phased approach for systems that are deployed in the same geographical area, either during migration or as a permanent solution
  - Objective is to be able to provide a strategy for migrating one Hub at a time, versus a total rip and replace of the entire infrastructure at the same time
  - It is recommended to replace the entire Hub, versus one ODU within the Hub
- When co-locating systems, either for migration from an older technology to a newer technology, or for a more permanent mixed deployment, it is important to select the correct system parameters in order to avoid interference
  - However, with different hardware models, choosing the same parameters on both systems (e.g. duty cycle, range, contention slots, etc.) does *not* guarantee coexistence
  - Use the co-location/migration tool in order to determine optimal co-existence parameters

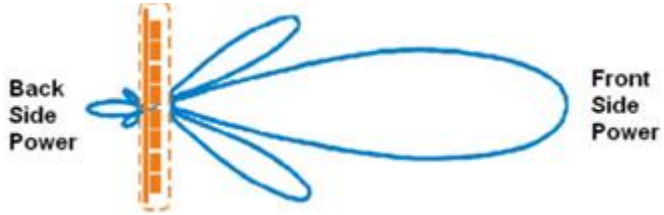
Migration Synchronization and Timing

- When multiple APs are deployed in the same geographical area, it is important that they all transmit and receive at the same time, especially for migration and co-location of multiple system types
  - Both PMP 100 and PMP 450i are TDD systems
    - A TDD cycle, or frame, is the minimum amount of time used to communicate in both directions

  - Different systems have different frame lengths and timing
    - Choosing the same parameters on both systems (e.g. duty cycle, range, contention slots, etc.) does *not* guarantee coexistence
  - Use the migration tool in order to determine optimal transmit/receive timing parameters to be configured on the AP.
    - The Duty-cycle parameter (Downlink/Uplink Ratio) is recommended to be changed first

Antenna and Channel Considerations

- Importance of Front to Back Ratio
  - Front to Back Ratio is the ratio of power gain between the front and rear of a directional antenna



    - The ratio tells how good the antenna is at rejecting signals from the rear
    - F/B ratio is important when antennas are orientated in a hub (antennas facing in opposite directions) and using the same frequency
  - Front to Back Ratio not really a concern in legacy PMP 100 (FSK) systems because FSK uses only lower modulation levels
  - Higher modulation rates require >32dB F/B ratio
  - The 450i recommends the use of optimized dual slant antennas
    - When migrating, it's advisable to update back-to-back sectors as quickly as possible (to avoid FSK interfering with the 450i sector)
    - Cambium's specified antennas were designed for optimal speed, performance and efficiency

Cambium 900MHz Antennas

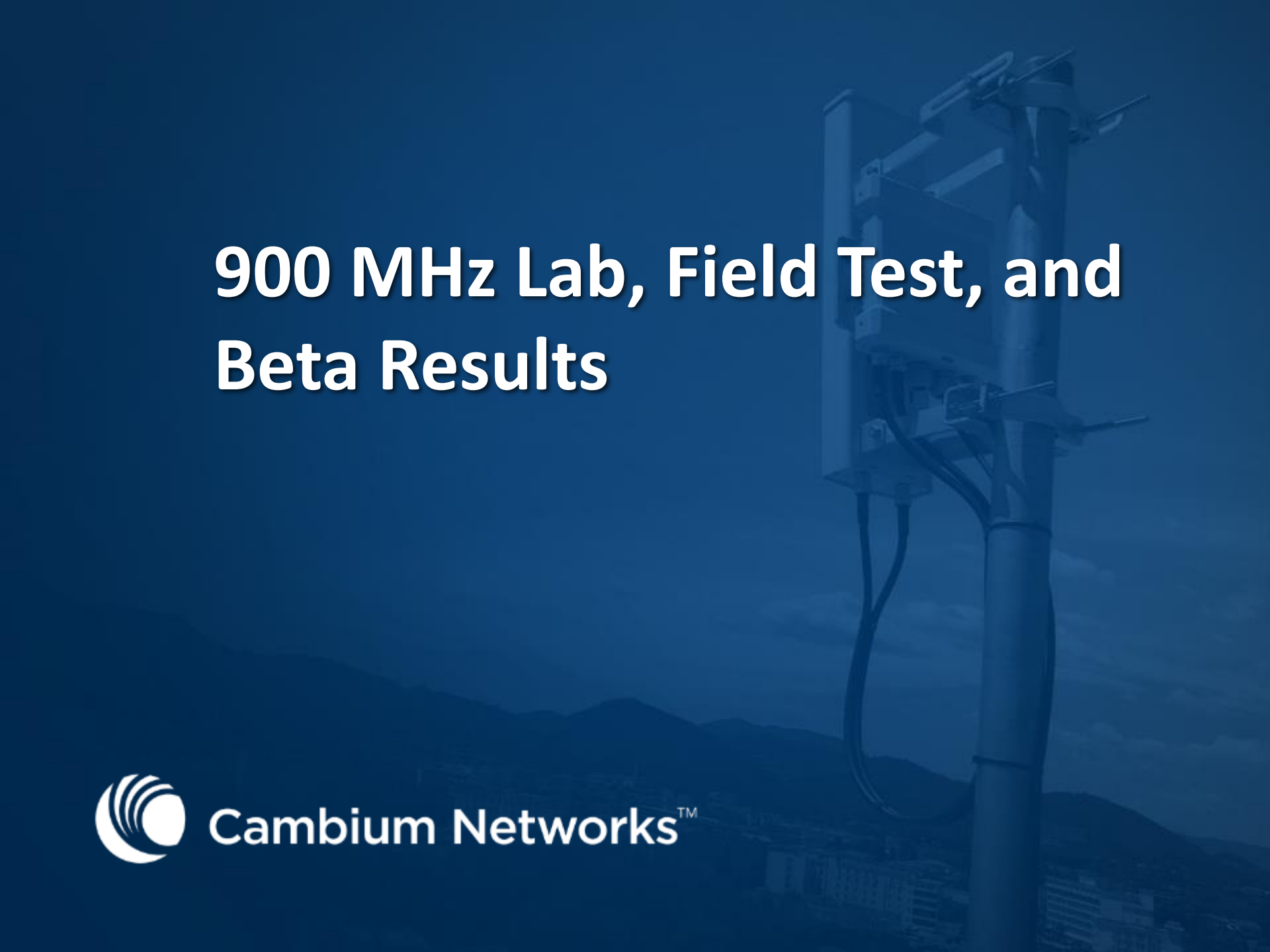
- Performance Differentiation
  - Dual slant polarization system to isolate from Vertical or Horizontal deployments
  - High Front to Back ratios to allow Frequency Re-use and high Spectral Efficiency

- SM Yagi Antenna
  - Dual slant
  - 40° beam width
  - 36” in length
  - Cables to connect the SM

- AP Sector Antenna
  - 902-928 MHz
  - 65 degree (3 dB beam width)
  - Can be used for 60 or 90 degree sector*
  - Front/Back Ratio: > 32 dB
  - 35” x 11” x 5”
  - AP radio will mount to back of antenna

*A new 90° sector (3 dB rolloff) to be released in future

900 MHz Lab, Field Test, and Beta Results



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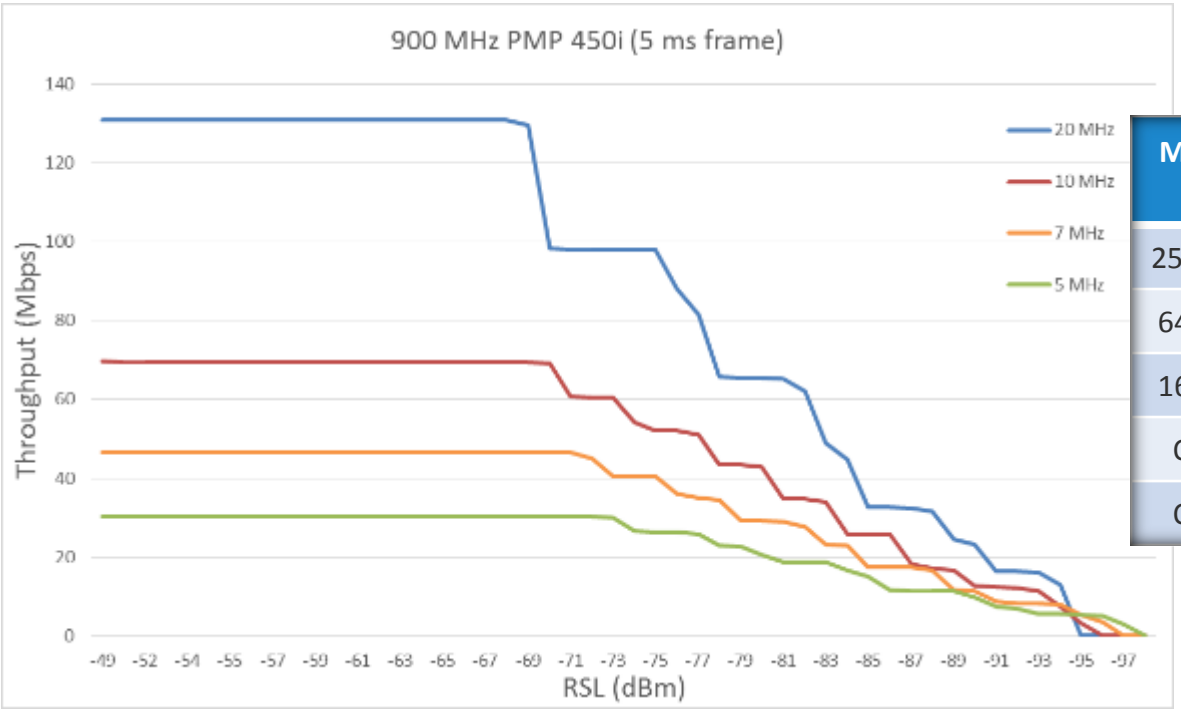
900 MHz Lab Results



7 MHz Channels

Modulation Mode	Sensitivity (dBm)	T-put (Mbps)	CNR (dB)
256QAM (8x)	-73	45	32
64QAM (6X)	-79	35	24
16QAM (4X)	-85	24	17
QPSK (2X)	-92	12	10
QPSK (1X)	-95	6	8

12 dBi Yagi Antenna -- Maximum LOS range mi (km)			
Frequency Band	Modulation	20 MHz Channel	7 MHz Channel
900 MHz	256QAM (8X)	7 (11)	11 (20)
	64QAM (6X)	14 (23)	24 (39)
	16QAM (4X)	29 (46)	48 (78)
	QPSK (2X)	58 (93)	108 (174)
	QPSK (1X)	80 (131)	120 (193)

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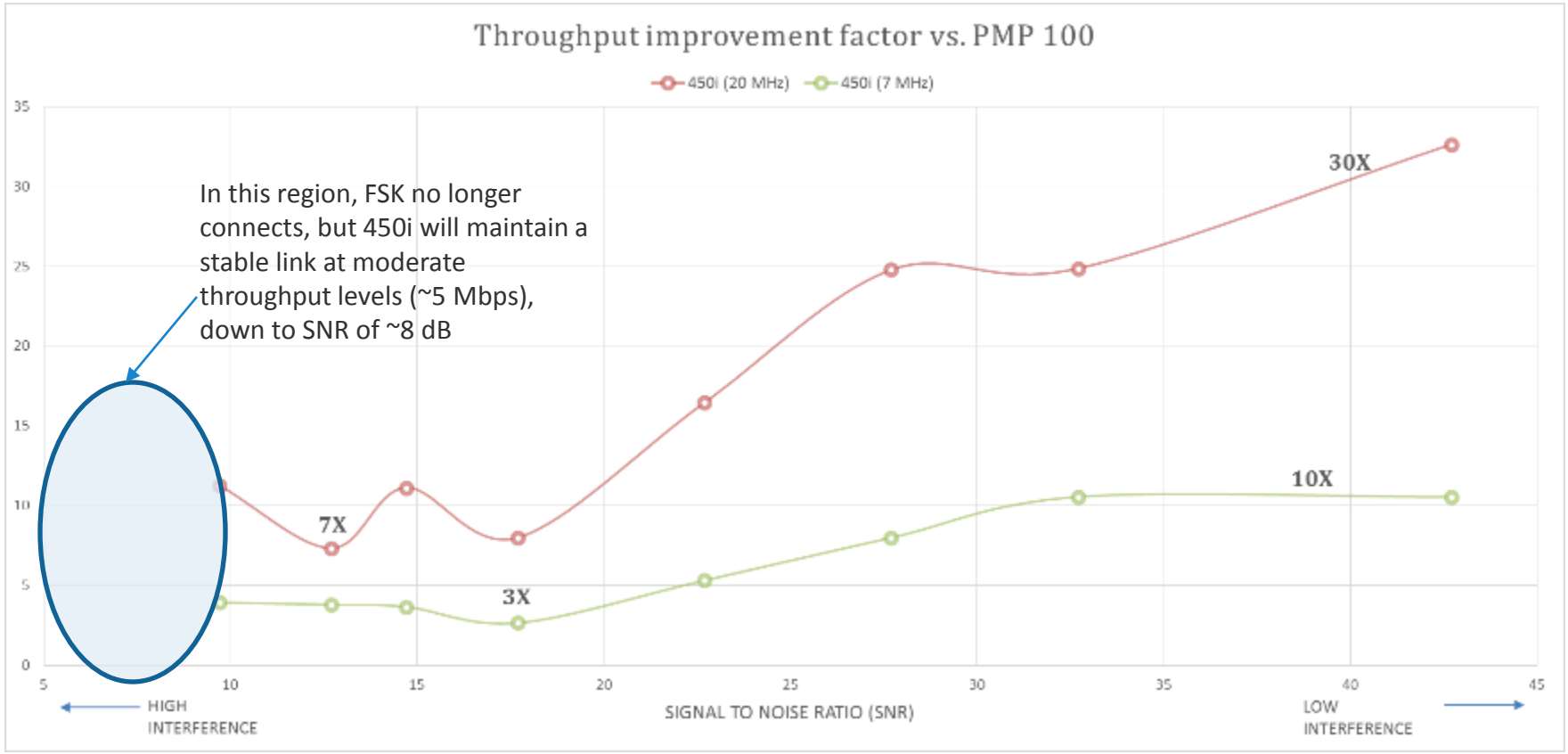
Field Testing – Tree Penetration

- 900 MHz has 13” wavelength (compared to 2” for 5 GHz)
- Longer wavelength propagates much better through foliage
- Side-by-side testing through a stand of trees (~300m away, ~10m wide stand of trees)
- Results:
  - Using the same Tx power
    - 5 GHz signal behind trees was attenuated by 30 dB
    - **900 MHz signal was only attenuated by 2 dB!**
  - 10 MHz channels aggregate throughput
    - 5 GHz = 8 Mbps
    - **900 MHz = 20 Mbps!**
- Demonstrated using video surveillance footage

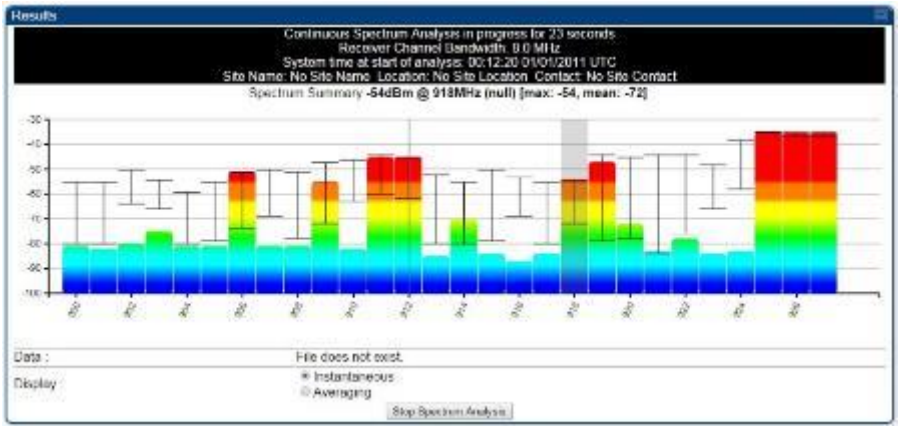
Field Testing vs. PMP 100 900 MHz



- Testing has shown vast improvement over FSK
- In worst case interference, using the same channel size (7 MHz), the PMP 450i 900 MHz product provides 3 times throughput
- As the interference level decreases, the gains are better with the 450i

Early Beta Feedback

- Several customers have equipment and are currently testing
- Early Feedback is great:
  - High Noise Environment
    - Across the band, you can see spikes of noise in the -50 dBm range
  - PMP 100 results:
    - High latency, high jitter, 1 Mbps total throughput (8 MHz channel)
  - PMP 450i 900 MHz Results:
    - Low latency and jitter, more stable link (reporting 9 dB SNR) at 5 MHz channel bandwidth
    - Able to achieve **5 Mbps total throughput**



Thank You!

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