Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Fading in 900MHz Smart Utility Radio Channels
Date Submitted: Nov 11, 2009
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Re: 802.15.4g] TG4g Call for Proposals, 2 February, 2009

Abstract: Description of experimental measurements made on a short range 900MHz radio link to establish the degree and characteristics of fading that may be typical for some SUN deployments. Results indicate that, even though the end points are static, the channel can be rapidly fading due to passing vehicles.

Purpose: Bring this information to the attention of the TG4g working group for discusion.

An Investigation of Fading on a Short Range 900MHz radio link

Steve Shearer Oct 2009

Acknowledgement to Dan Sexton (GE Research) for several helpful discussions regarding measurement setup and data analysis

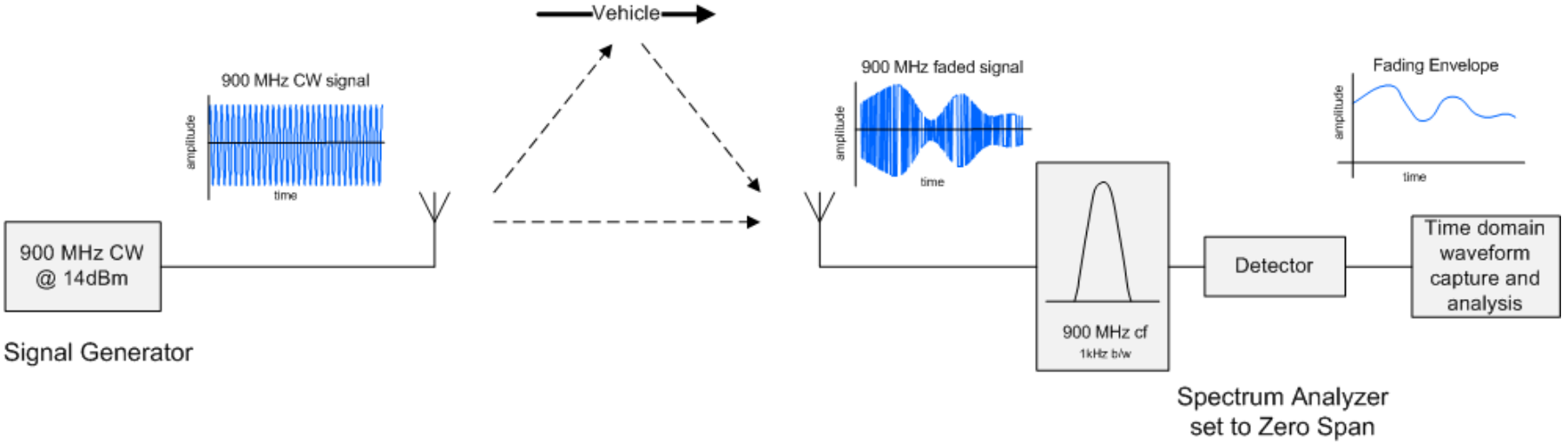
Introduction

- Considerable effort has been spent understanding radio channels for the SUN environment
  - There is agreement on using appropriate channel models suited to the particular deployment/modulation type
- Most modeling has been done in either AWGN or a Pseudo Static environment
- But there is little clarity on stationarity or fade rate of a typical short range channel

Objective

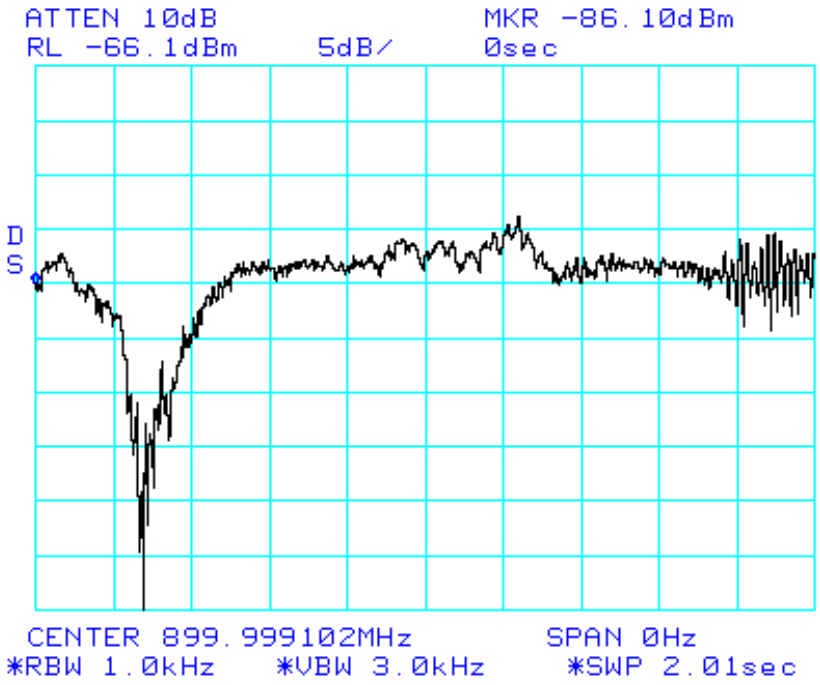
- Noting that a 900MHz cordless phone exhibits “fluttering” due to passing traffic:-
- This presentation seeks to investigate further by setting up a simple experiment to answer the following questions
  - Does fading occur in short links?
  - How bad is this fading?
  - How often does it occur?
  - What are the characteristics of the fading?

Experimental Setup



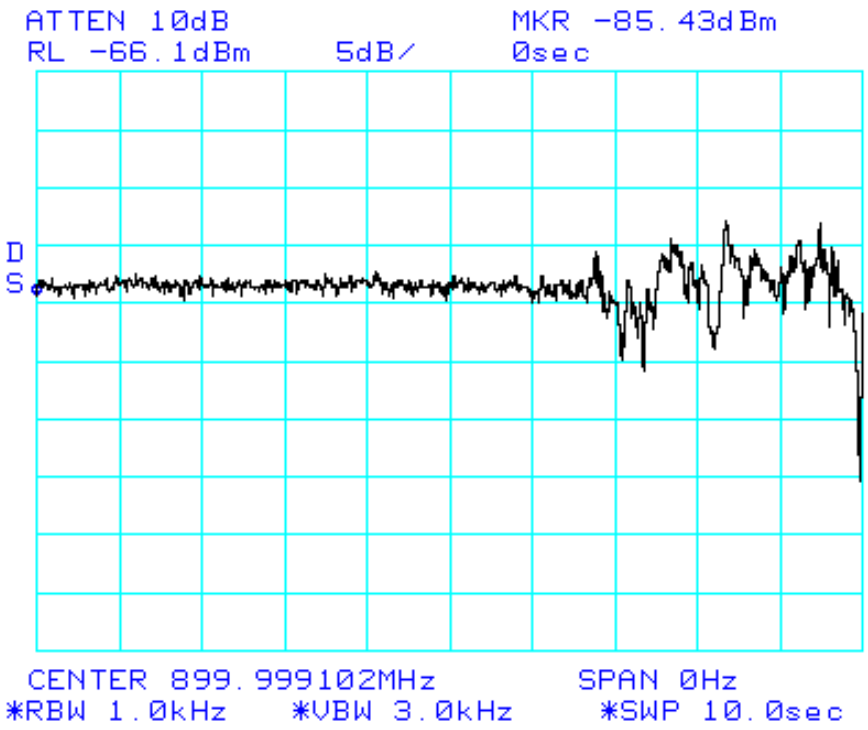
Does Fading Occur?

- Diagram shows time domain output of “zero span” spectrum analyser for one vehicle passing by
  - >25dB deep fade
  - ~200ms wide
  - Disturbance continues for more than 2 seconds
- These fades occur for almost every vehicle that passes by



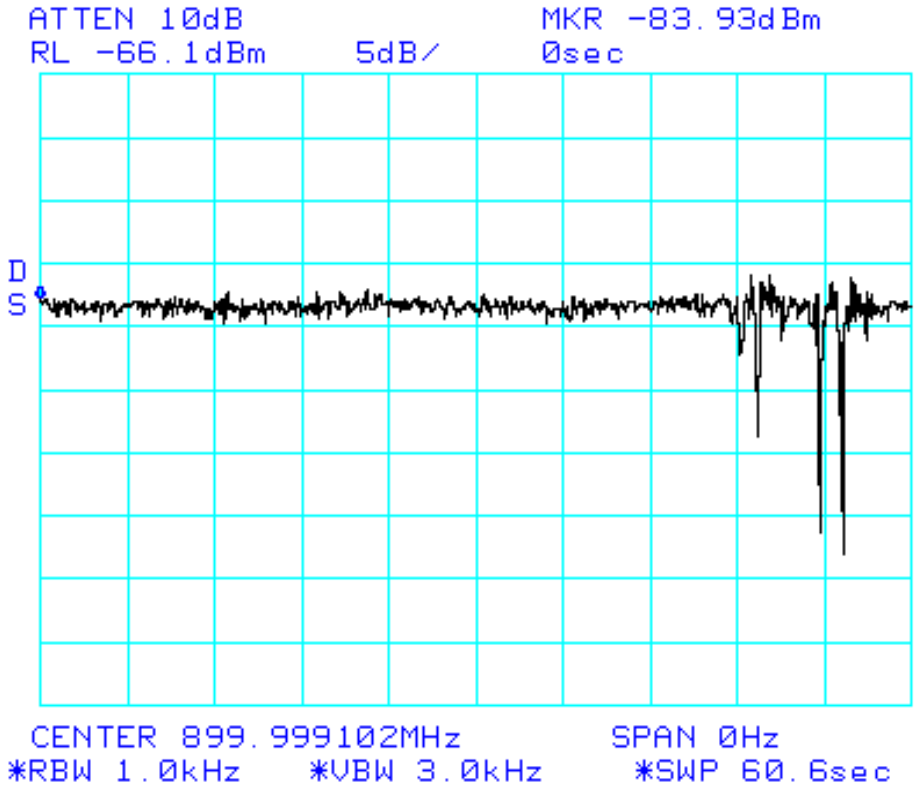
Single Fade – General Observations

- Size of vehicle affects depth and length of fade
  - A bus or garbage vehicle cause larger effects
  - Motorbikes cause lesser effects
- Vehicles on the “near” side of the street have bigger effects than vehicles on the “far” side
- Slow moving vehicles seem to give several observable deep fades
  - Faster vehicles seem to appear more often as a single fade
- Disturbance starts several seconds before deep fade and lasts several seconds after the fade



How Often do fades occur?

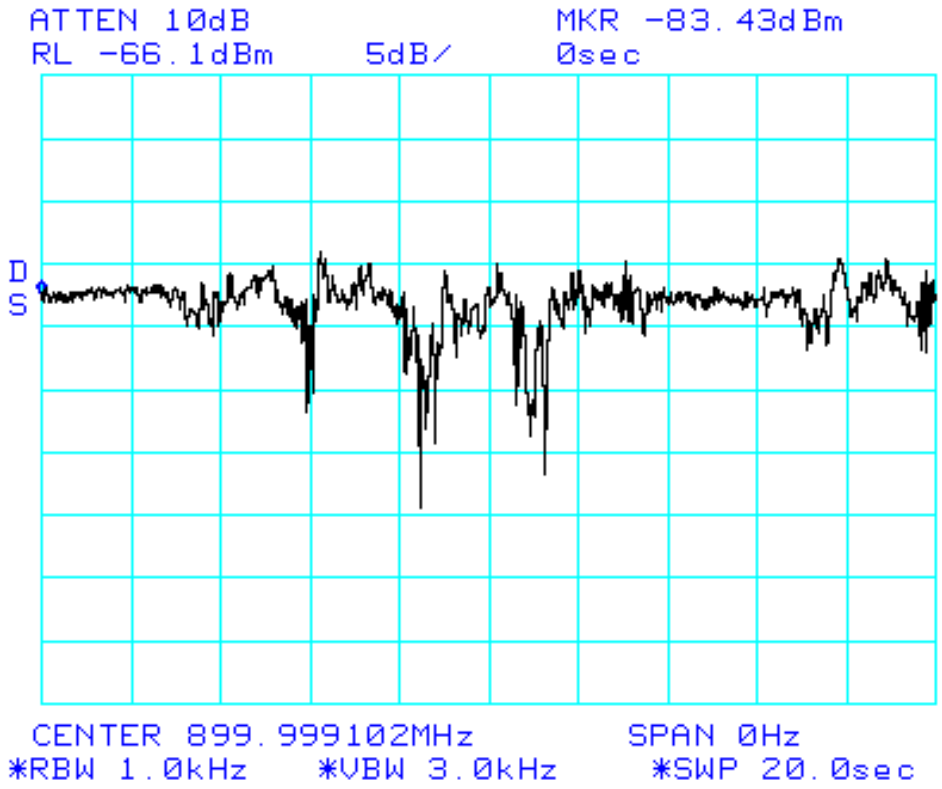
- Low traffic times
  - Long periods with no activity
- Diagram indicates three vehicles passing by in 60 seconds
- Observations in windy conditions show varying signal strength [1]
  - Presumably caused by the swaying of the trees



[1] Not shown in this diagram

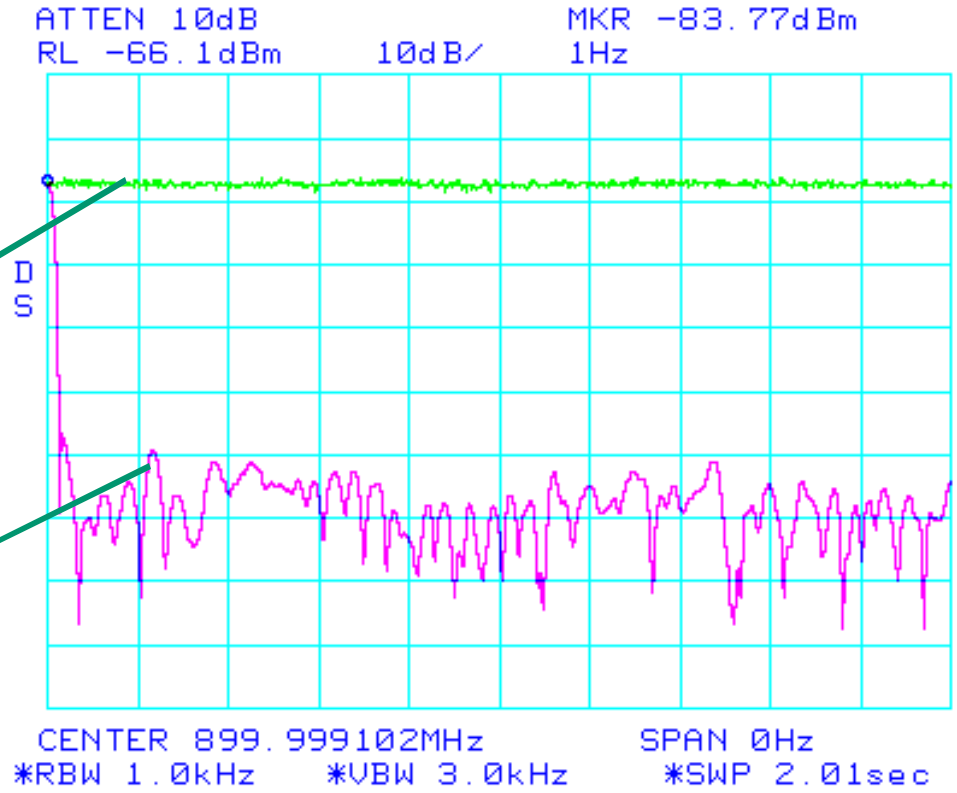
High Traffic

- Diagram shows a continuous set of disturbances that may last for several hours
- Vehicles pass by every 2 or 3 seconds
- Each vehicle causes more than 6 seconds disturbance
- The overlap leads to continuous disturbance



Fade Characteristics Setup

- Analyzer set up to record:-
  - "zero span" demodulator output (green)
  - Fourier transform (red)
- Measurement captured in quiet conditions for reference

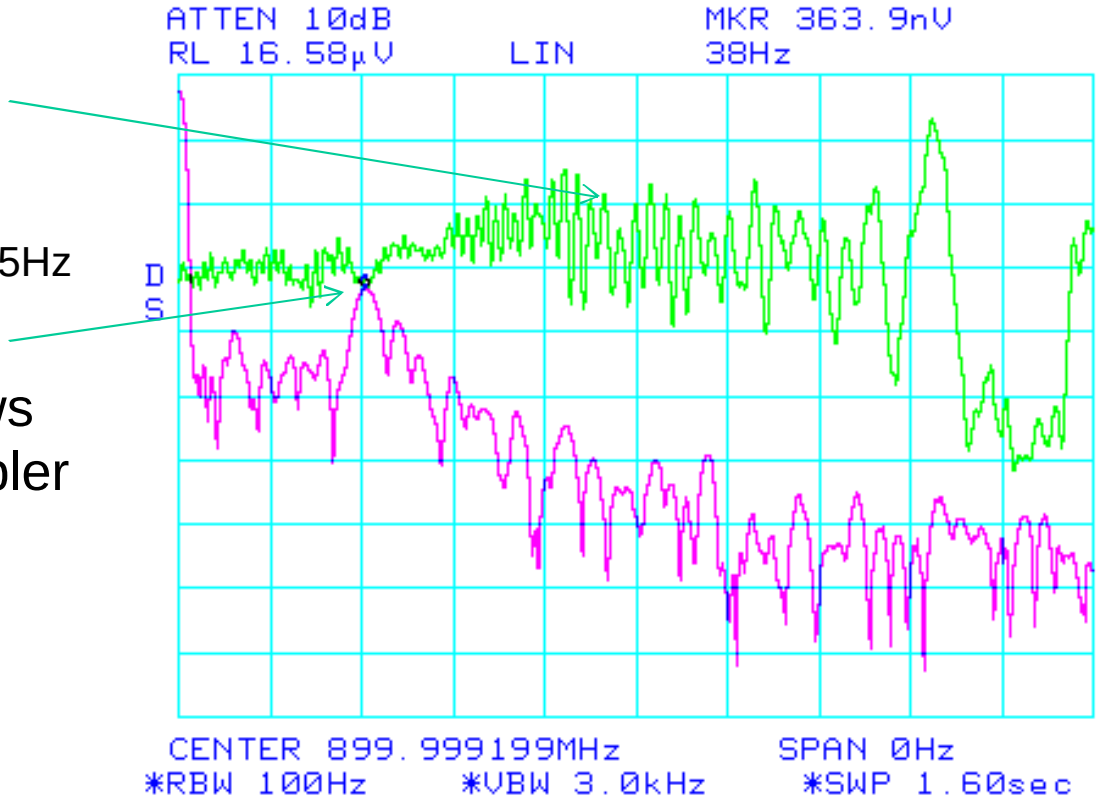


Time domain
200ms/div

Frequency domain
15Hz/div

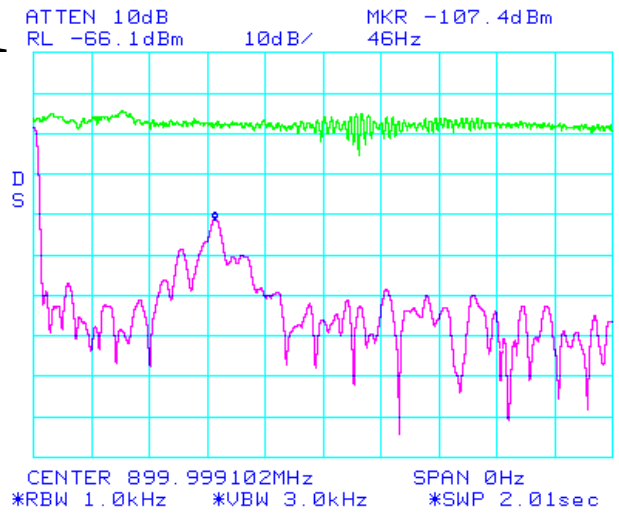
Fade Characteristics Measurement

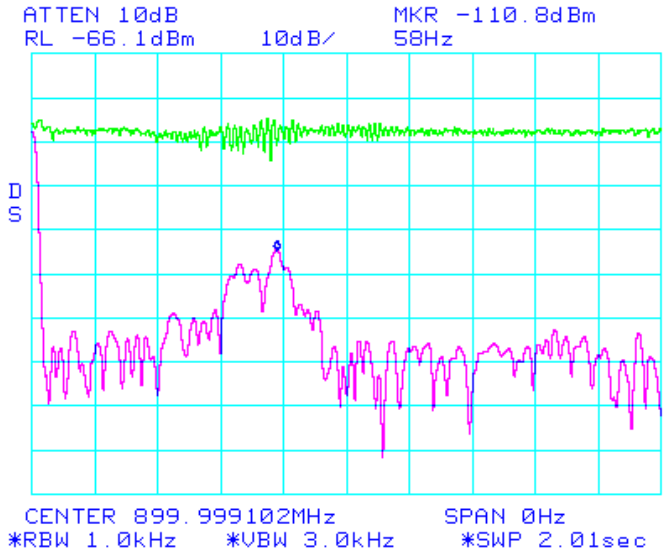
- Diagram shows results of one vehicle passing
- Note distinctive Doppler on the time domain waveform
  - ~6 cycles per div = 37.5Hz
- Fourier analysis shows dominant 38Hz Doppler indicating ~30mph

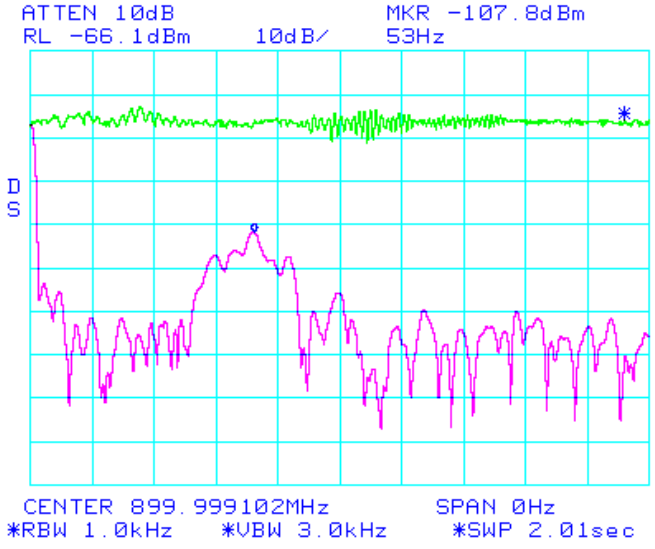


Fade Characteristics M

- Predominant Doppler indicates vehicle speeds of :-
  - 58Hz ~45mph
  - 53Hz ~40mph
  - 46Hz ~35mph





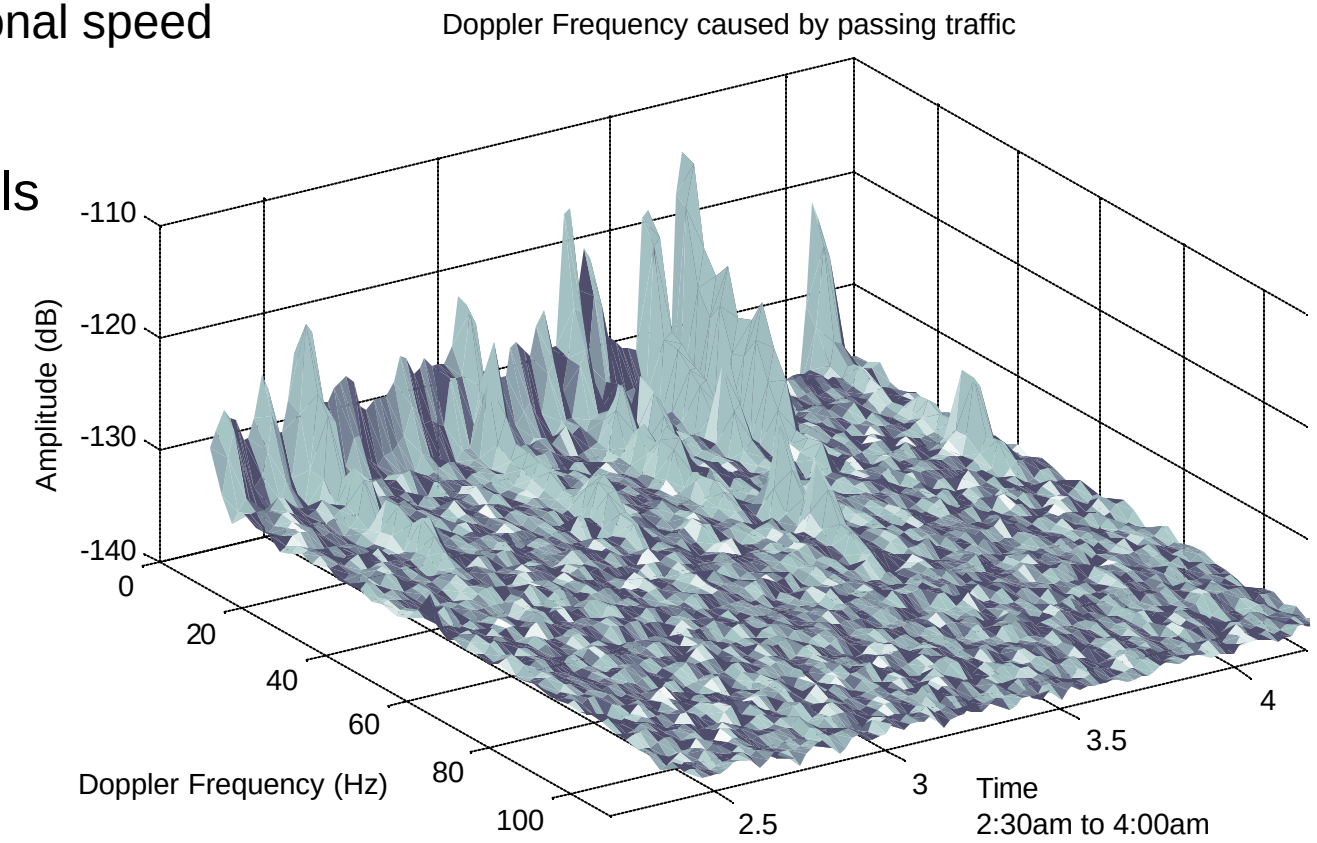


Long Term Measurements

- Equipment set to continuously record 2.5 second time domain sweeps approximately every 7 seconds
  - Sweeps are logged to a PC
- The PSD of each sweep is calculated and a matrix is computed where
  - X corresponds to the time of the sweep
  - Y corresponds to the Doppler frequency
  - Z represents the amplitude in dB
- PSD's are averaged in time using a 30 point Hamming window to enhance visibility
  - Approximately 3 minute averaging

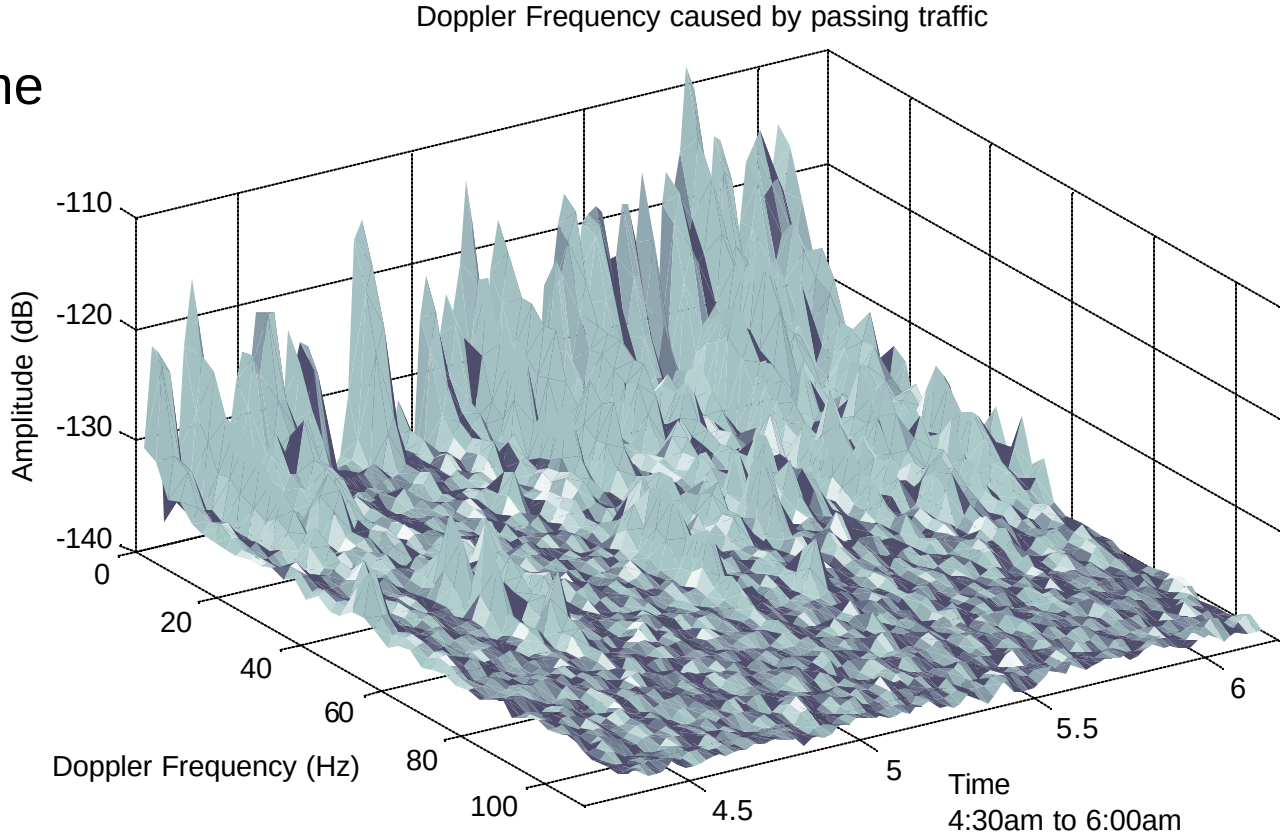
Early Morning

- Graph shows Doppler caused by infrequent traffic in the early hours of the morning
  - Note occasional speed limit violators
- Note quiet spells



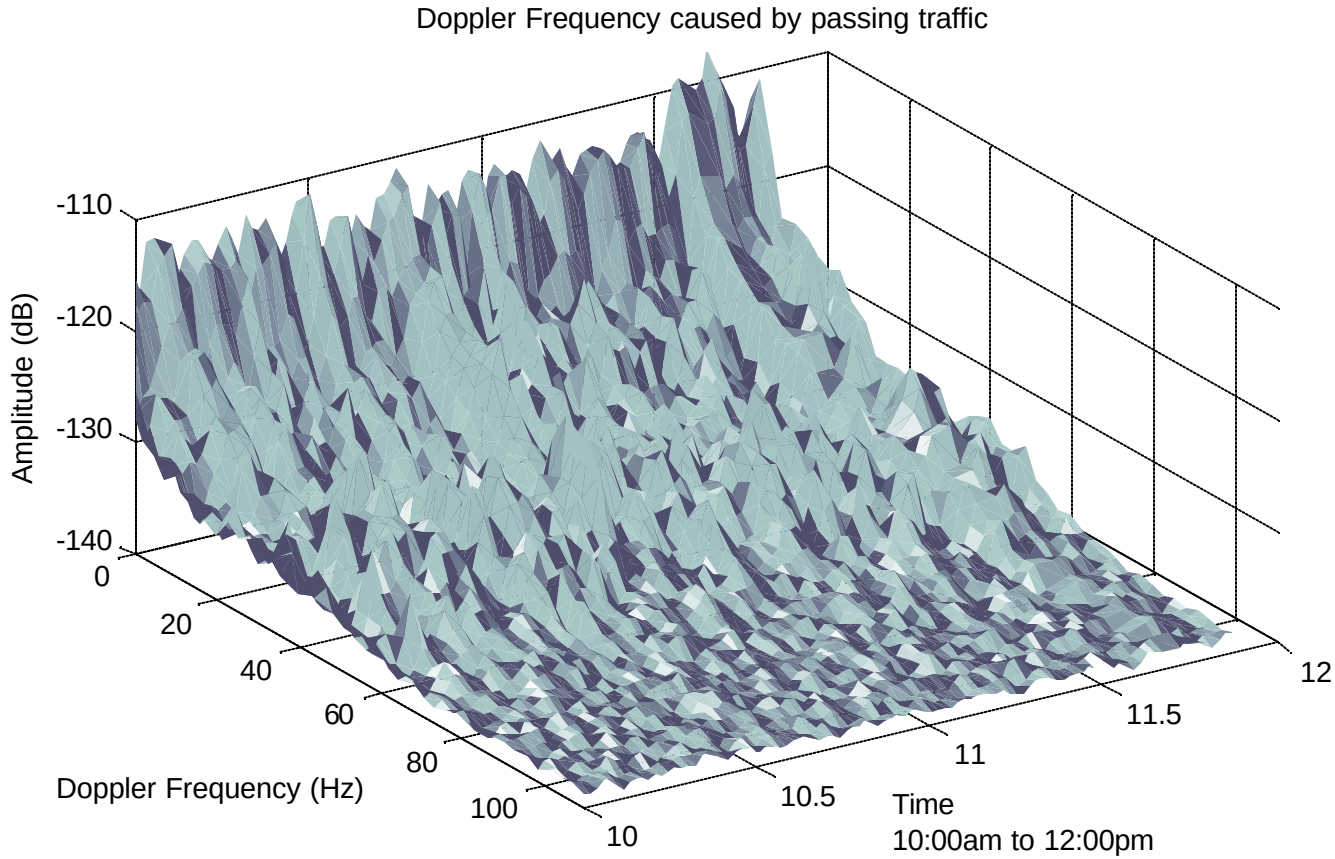
Dawn

- Traffic volume increases around dawn
  - Some Doppler at 70Hz
- Less quiet time



Morning

- Increased traffic causes continuous Doppler



Observations

- Fading is observed to occur due to passing traffic
  - Fading depth is dependant upon vehicle size and distance of the vehicle from the houses
  - 25dB fades are quite common and can last 100's of ms
- Each vehicle causes several seconds of fading as it passes by
  - Rush hour traffic can result in very long spells (several hours) of continuous fading
- Fading exhibits characteristic Doppler fading dependant upon vehicle speed
  - commonly as high as ~60Hz (45mph) even in a 35mph zone
  - Could be higher than 80Hz (70mph) depending upon environment

Conclusion

- This simple experiment replicates a typical SUN house-to-house, short range, 900MHz radio link
- Many SUN radio channels will be non-stationary even though the end points are fixed
  - The degree of non-stationarity will likely be deployment specific
- The Coherence time of the channel could be quite short
  - (10's of ms)
- SUN modems should not rely on the channel being stationary for the length of the data packet
  - Which could be as long as 0.4s for 2047byte packets at 40kbps

Thank You