The Effects of Channel Variability on High Data Rate HF Communications

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Presentation Overview

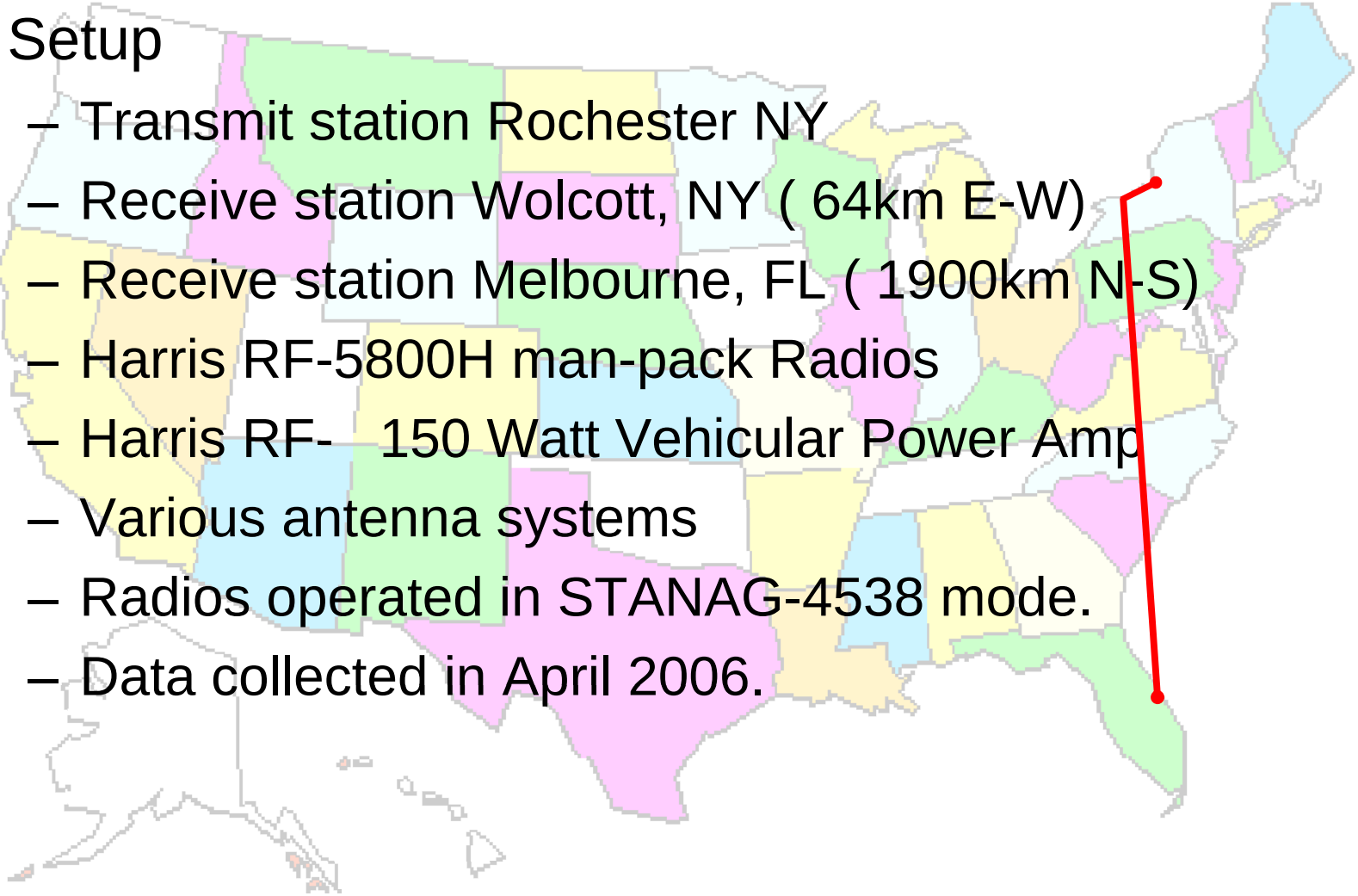
- Background
- Experiment Configuration
- Experiment Results
- Modem Design
- Conclusions

Background

- Higher Data Rate modem solutions are looking towards the utilization of multiple 3-KHz channels.
- Several techniques utilize common modulation and coding interleaved over the available 3-KHz channels.
- A simple experiment was conceived to examine the variability of HF Channel conditions between multiple 3-KHz channels in a propagating band.
- This paper / presentation discusses the results of this experiment and the ramifications for modem design

Experiment Configuration

- Setup
  - Transmit station Rochester NY
  - Receive station Wolcott, NY (64km E-W)
  - Receive station Melbourne, FL (1900km N-S)
  - Harris RF-5800H man-pack Radios
  - Harris RF- 150 Watt Vehicular Power Amp
  - Various antenna systems
  - Radios operated in STANAG-4538 mode.
  - Data collected in April 2006.



Experiment Configuration

- Rochester transmitted STANAG 4538 FLSU LQA Sound bursts on each channel (1.013 seconds), approximately 30 seconds apart.
- A total of 5 - 24 hour tests performed.

Test	Distance (km) - Direction	Frequency Band (MHz)
Wolcott 1	64 E-W	4
Wolcott 2	64 E-W	6
Melbourne 1	1900 N-S	6 - 16
Melbourne 2	1900 N-S	6 - 16
Melbourne 3	1900 N-S	6 - 16

Experiment Configuration

- Harris Implementation of STANAG 4538 utilizes a Channel Parameter Estimator (CPE) which estimates
  - SNR
  - Multipath (number modes and delay spread)
  - Doppler Spread.
- Each received FLSU LQA Sound burst processed by the CPE. All results logged for post- processing

Experiment Configuration

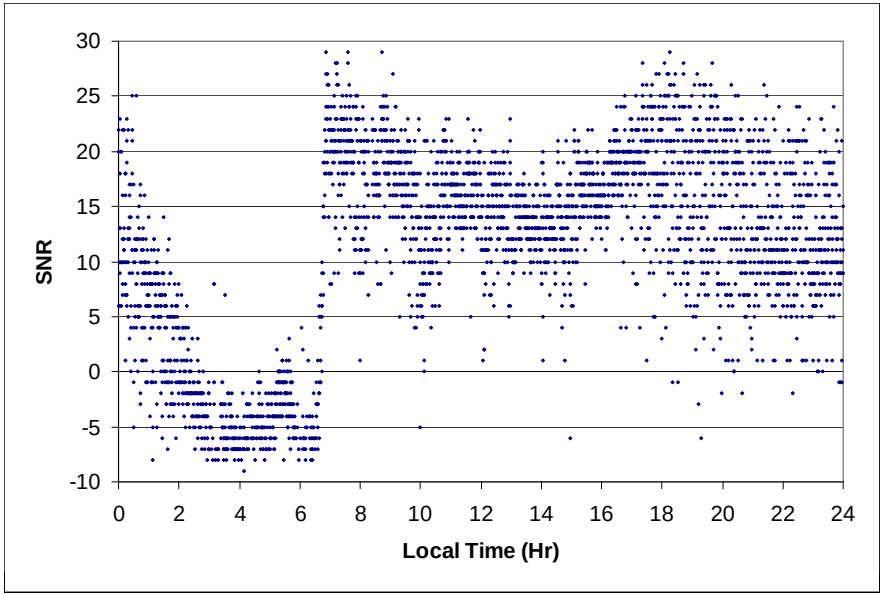
- Accuracy of the Channel Parameter Estimator
  - Evaluated with HF Channel Simulator for:
    - Single path, non-fading path. 5dB and 20dB SNR
    - ITU Mid-Latitude Disturbed path. 5dB and 20dB SNR

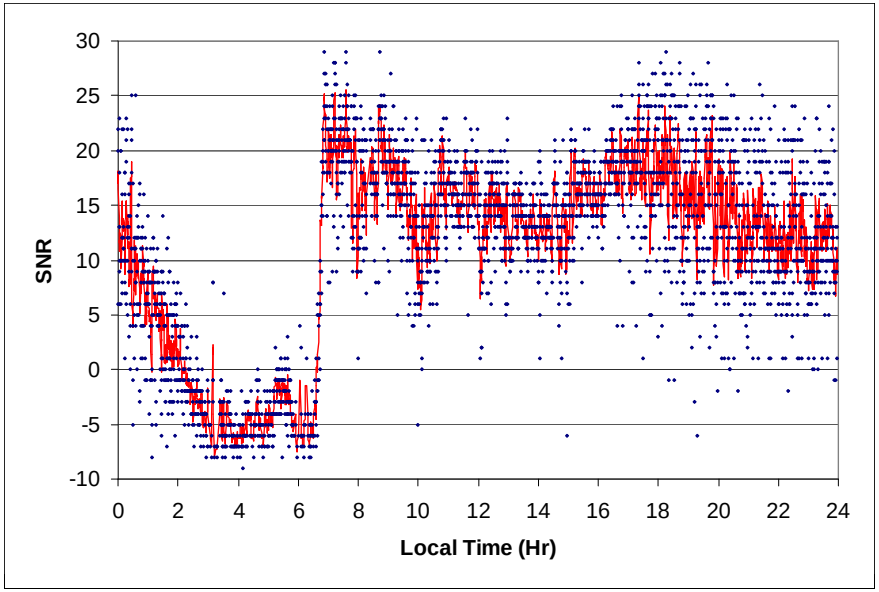
Channel	SNR (dB)	Multipath (ms)	Doppler (Hz)
AWGN 5dB	5.38 +/- 0.54	0.53+/- 0.36	1.58+/- 0.54
AWGN 20dB	19.10 +/-0.57	0.52+/- 0.30	0.0 +/- 0.0
DIST 5dB	5.66 +/- 1.95	2.67+/- 1.7	2.59+/- 1.63
DIST 20dB	17.3 +/- 2.56	2.43+/- 1.54	0.68+/- 0.84

- SNR estimates good, Multipath very good, Doppler least accurate.
- SNR used as primary metric.

Experiment Results - Wolcott

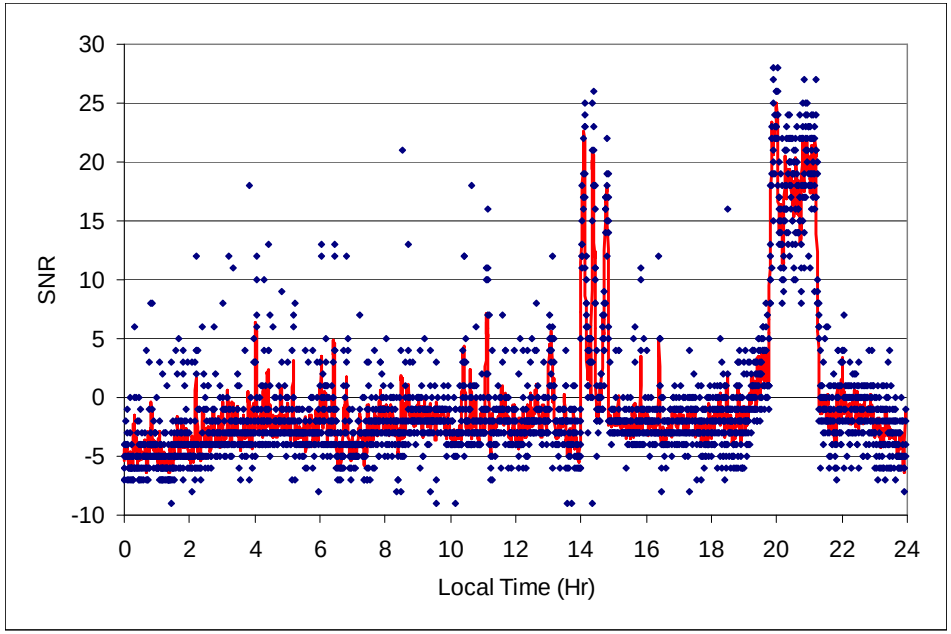
- Results form Wolcott1, Single 4MHz channel
- Wide range of instantaneous SNR
- 150 second sliding window average applied to measurements. Approximate transmission times of HF Data link protocols.
- Low SNR from Midnight to 6AM.
- STANAG 4538 provides connectivity for entire 24 hour period.





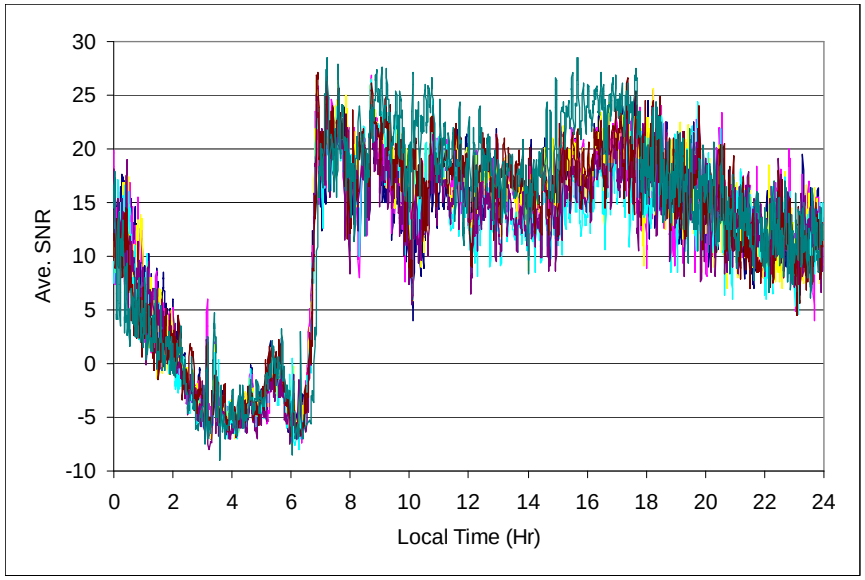
Experiment Results - Wolcott

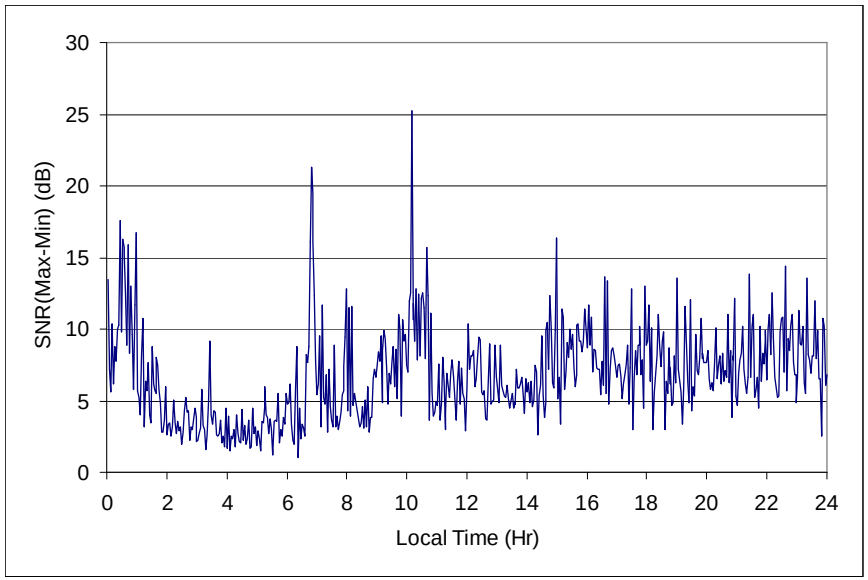
- Results form Wolcott2, Single 6MHz channel
- 150 second sliding window average applied to measurements. Approximate transmission times of HF Data link protocols.
- Low SNR (< 0dB) through most of the day.
- STANAG 4538 provides connectivity for entire 24 hour period.
- Two peaks in SNR at 1400, 2000. Characterized by 1 path. Benefit of Real Time Channel Evaluation (RTCE).



Experiment Results - Wolcott

- What is the variation in Channel conditions across the set of propagating frequencies?
- Left plot displays the 150s sliding average of all Wolcott1 4 MHz channels.
- Right plot displays the difference between the maximum SNR and the minimum SNR (after averaging) in each 150 second segment.
- Predominant SNR differential between 5-10 dB. Larger excursions present around midnight and sunrise transitions.





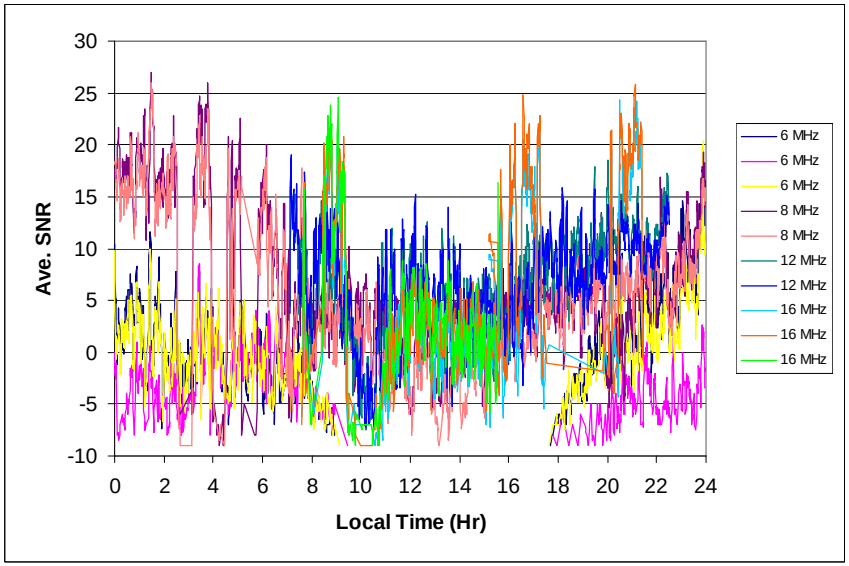
Experiment Results - Wolcott

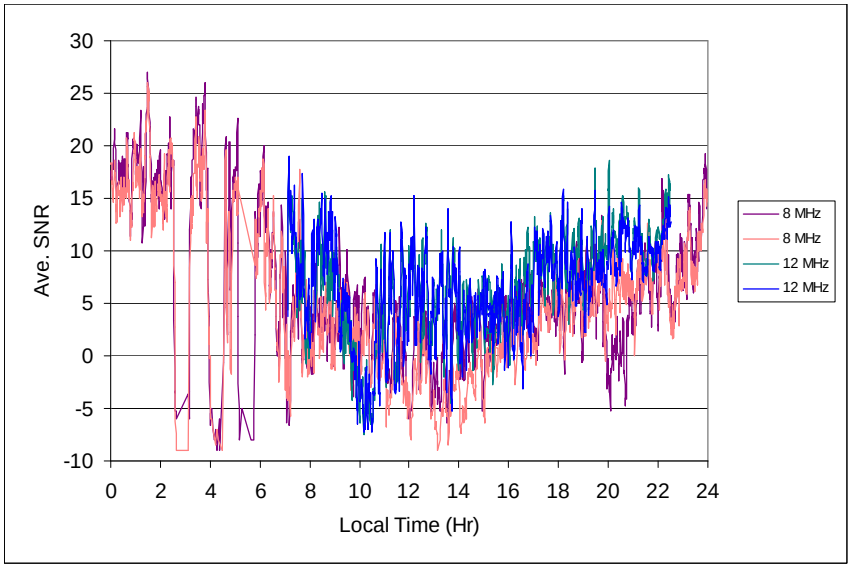
- Distribution of SNR variation
- 78.8% of segments had an SNR variation of 4dB or greater

DSNR (dB)	% Segments in DSNR Range	Cumulative %
0-2	2.1	100.0
2-4	19.1	97.9
4-6	22.7	78.8
6-8	24.2	56.1
8-10	16.2	31.9
>10	15.7	15.7

Experiment Results - Melbourne

- Melbourne test utilized 10 channels in the 6, 8, 12 and 16 MHz bands. A disparate set but not an unlikely allocation and necessary to cover the wider propagating band.
- Non ideal Rx antenna for 10 MHz and above.
- 6MHz Sunset to sunrise, 8 MHz all day reduced SNR during day, 12 MHz sunrise through 10pm, 16 MHz worked 8am through 4pm with two segments of high SNR





Experiment Results - Melbourne

- Distribution of SNR variation.
- All channels together experience a very high variation. Not surprising given antennas and propagation.
- Examining individual bands show considerable variation on the order of 2-6 dB.
- Examining the 8 and 12 MHz channels together show that approximately 72% of the 150 second segments had an SNR variation greater than 4 dB.

DSNR (dB)	% All Freq.	% 6 MHz	% 8 MHz	% 12 MHz	% 16 MHz	% 8,12 MHz
0-2	1.5	20.8	38.9	46.9	16.0	14.4
2-4	2.6	19.0	25.3	25.4	23.8	13.3
4-6	5.4	17.8	18.7	13.7	22.3	14.7
6-8	4.9	11.5	9.5	8.6	14.0	14.7
8-10	6.2	13.0	4.5	2.3	11.4	12.6
>10	79.4	17.9	3.1	3.1	12.5	30.3

Modem Design

- Experiment results show that multi-channel HF data communication systems need to deal with wide variations of channel quality.
- Today's data modems usually require a change of 3 or 4 dB in SNR to halve or double the data rate. Additionally most have very step BER curves transitioning from 50% BER to 0% BER in a very few dB.
- Multi-channel variation will make it very difficult to select the optimum data rate (modulation and FEC) for a set of channels.
- Best approach will be a system that can adapt the modulation on a per channel basis. Likely by combining channel parameter estimation with an ARQ style handshake to adapt on air waveform parameters or by utilizing a multi-channel packet based code combining ARQ.

Conclusions

- STANAG 4538 FLSU LQA Sound Bursts are useful in evaluation the channel conditions of multiple HF channels. STANAG 4538 FLSU can provide 24 hour communications over non-optimal HF links.
- FLSU Sound bursts can provide accurate SNR and Multipath estimates and to a less degree Doppler estimates.
- A simple experiment has been fielded to measure the amount of channel to channel variation of SNR.
- Results support the premise that multi-channel HF systems can face severe differentials in SNR on both short and mid distance HF skywave paths.
- Multi-channel HF data modems should employ some form of per channel based optimization based on measurements of the channel quality. The robust STANAG 4538 burst waveforms may be a means to measure the quality.

Way Ahead

- Improve Doppler Estimate of the Channel Parameter estimator
- Additional testing on different HF Links
- Improved multi-channel HF data modem design