Application of Spectrum Sensing toward a Wideband HF ALE Solution

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Presentation overview

- Wideband HF waveforms
- Wideband ALE concept
- The need for spectrum sensing
- Wideband ALE spectrum sensing requirements
- Spectrum sensing prototype
- Spectrum sensing: field test observations
- Contribution to use of wideband HF waveforms
- Caveats
- Conclusions and future work

Wideband HF waveforms

- New appendix in MIL-STD-188-110C that defines
  - Suite of waveforms from 3 kHz to 24 kHz at intervals of 3 kHz
  - Bit rates of 75bps to 120000bps
  - Many modes
    - 8 bandwidths
    - 13 waveform modulations
    - 4 Interleaver settings
    - Adjustable preamble length
- Standard created collaboratively between Harris and Rockwell Collins
- Benefits
  - Higher capacity/throughput when conditions allow
  - More robustness when there is a performance advantage to going with a wider bandwidth and simpler constellation

Wideband ALE concept

- Establish links suitable for use of the wideband waveforms
- Use 3 kHz signaling of existing ALE systems
  - For ease and cost-effectiveness of implementation and adoption
- Must coordinate selection of wider bandwidth to be used for data transmission
  - Waveforms lack any auto-bandwidth capability
- Support adaptive selection of other waveform parameters (modulation, coding)

The need for <u>spectrum sensing</u>

- We can apparently get frequency allocations of up to 24 kHz
- In practice, these are often at least partially occupied
  – Allocations are often provided for use on a ‘non-interfering basis’
- The multiple bandwidths of the WBHF waveform family can allow us to effectively use *part of* an allocated channel
- A spectrum sensing capability would allow us to identify the usable portion of an occupied wideband channel

Precedents for 'spectrum sensing'

- "Listen Before Transmit" has been a feature of the 2G and 3G ALE standards
- In both cases, it's intended for collision avoidance as part of a Media Access Control (MAC) function
- LBT makes a binary determination (busy/not-busy) for an entire 3 kHz channel

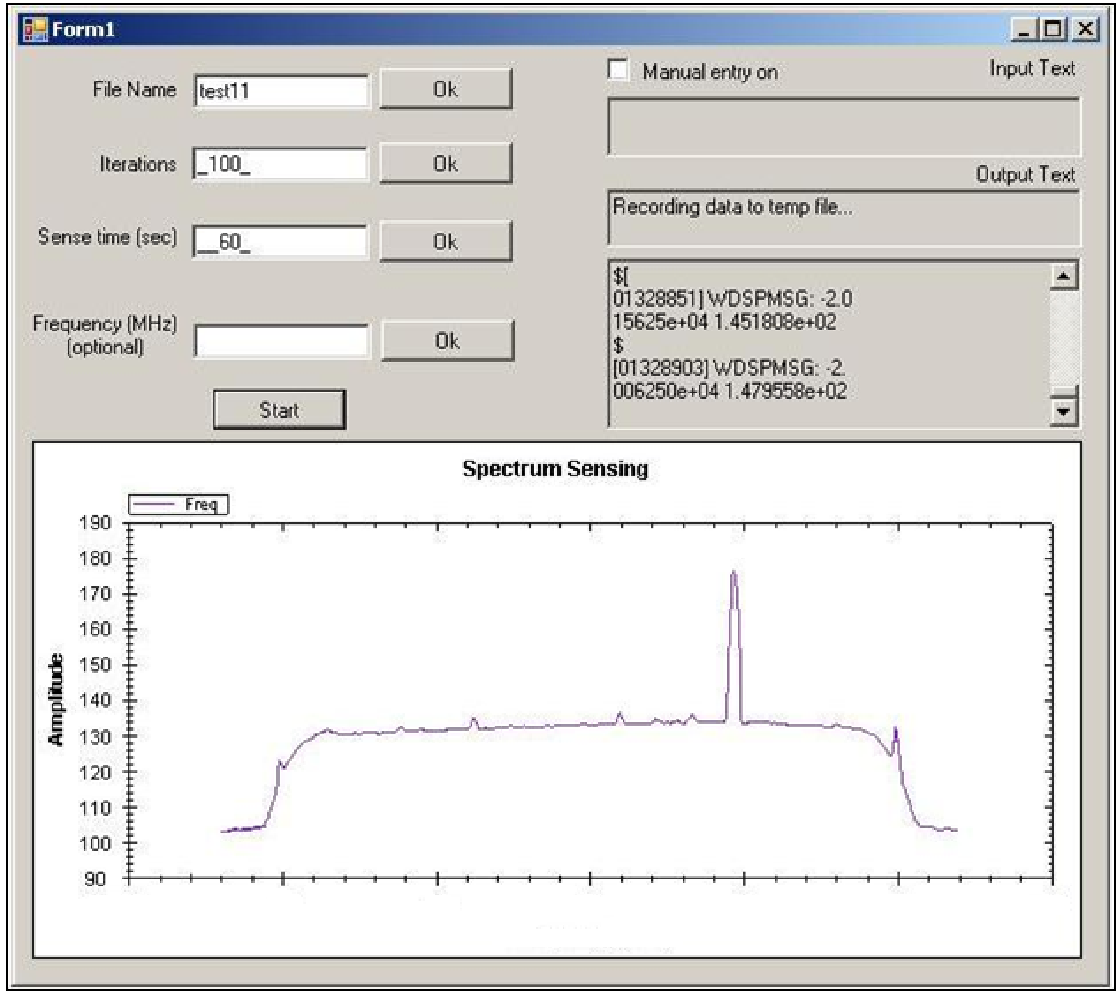
Waveform	AWGN 3 kHz SNR (dB)	Minimum Required Detection Probability
2G-ALE	0	50%
	6	90%
Robust LSU (BW0)	-9	50%
	-6	95%
HDL (BW2)	0	30%
	6	70%
single sideband (SSB) Voice	6	50%
	9	75%
MIL-STD-188-110 or	0	30%
FED-STD-1052 PSK modem	6	70%
STANAG 4285 or	0	30%
STANAG 4529 PSK modem	6	70%

Wideband ALE spectrum sensing requirements

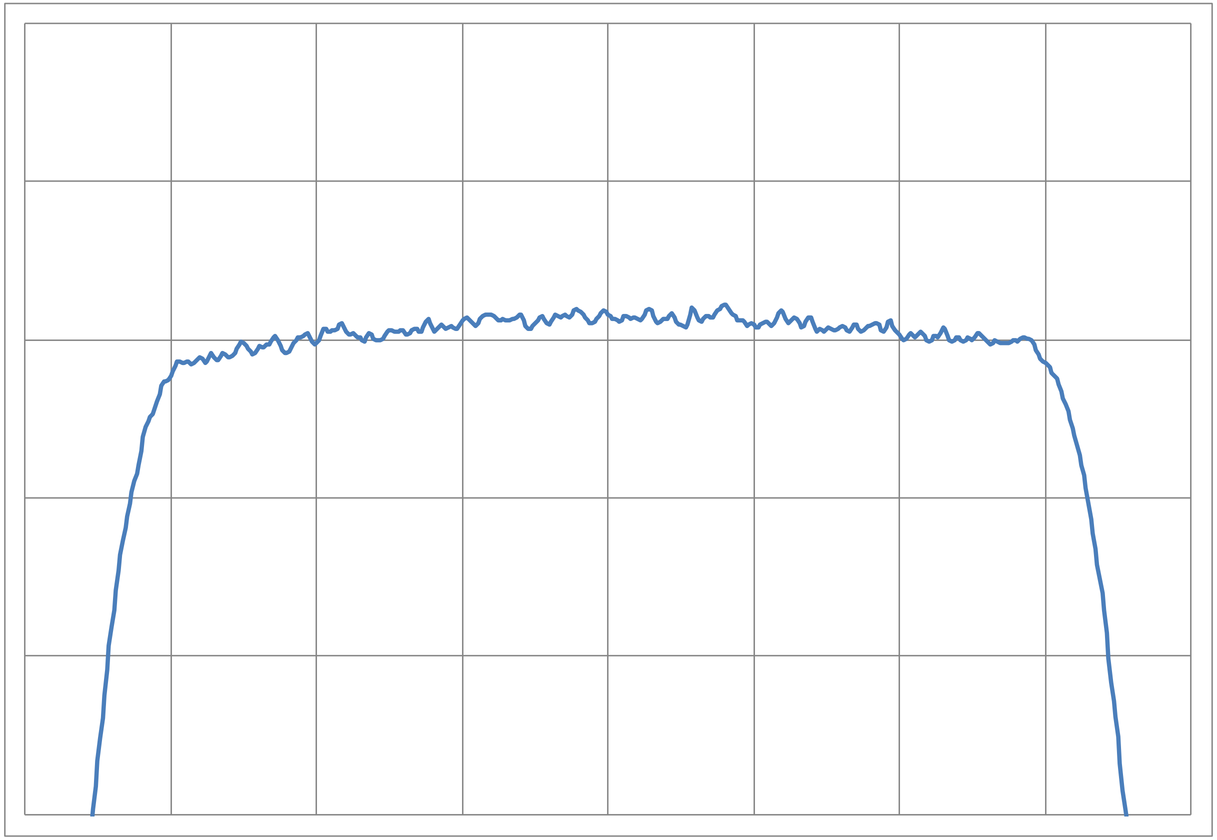
- Capable of examining a band of at least 24 kHz width
- Detect presence of interference in the band that might preclude effective use of the wideband waveforms
- Determine specific frequencies within the band at which interference is present
- Identify a clear sub-band (if present) of the allocated band, within which data transmission can be more effectively achieved
- Support prediction of SNR achievable within a portion of the band, for selection of waveform parameters as part of adaptive selection of modulation and coding
- Be suitable for incorporation into a ‘4G’ ALE protocol
  - Timing characteristics suitable for use while scanning

Spectrum sensing prototype

- Part of the prototype radio system Harris has used for WBHF waveform on-air testing
- Prototype radio is commanded to compute energy spectrum of received RF signal
- Spectrum dumped to PC application for display
- Can compute spectrum while receiving WBHF transmission

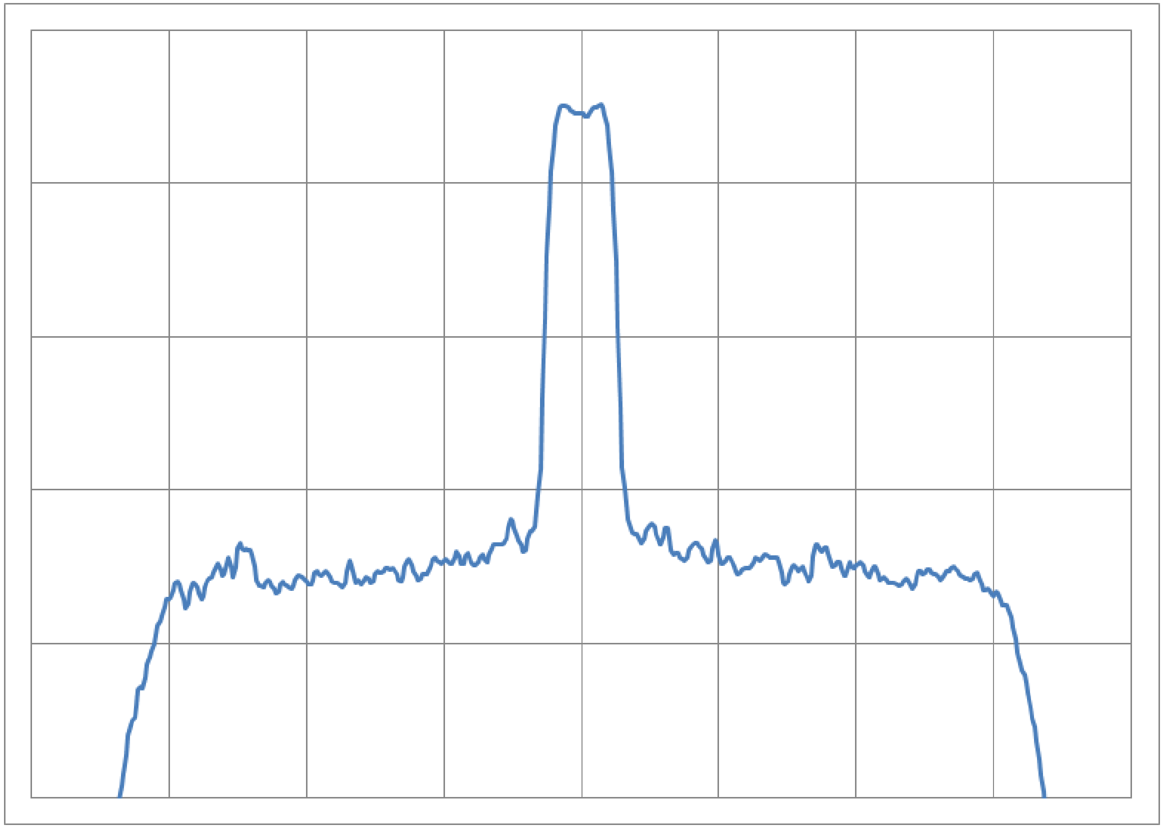


Spectrum sensing field test observations – channel noise floor



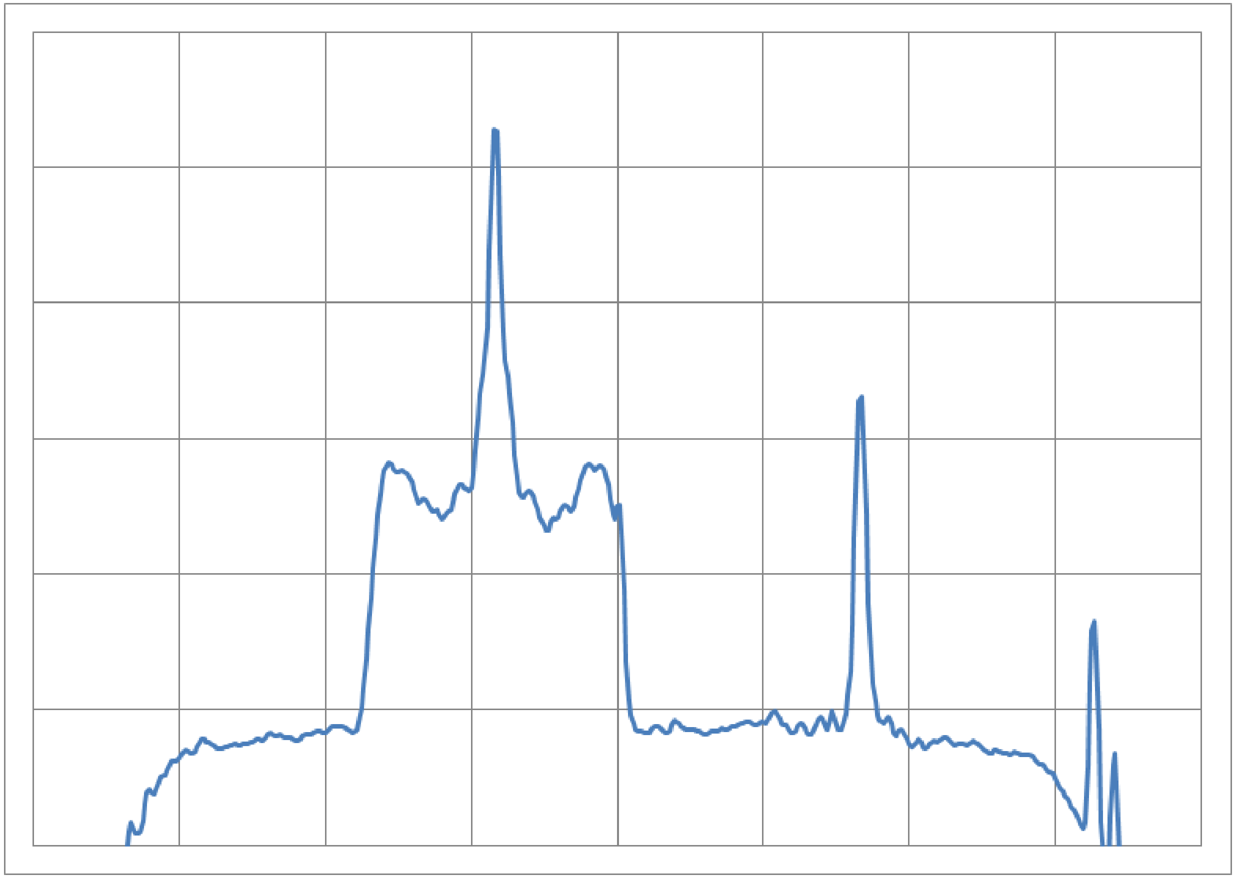
- Channel noise floor without interference

Field test observations – channel noise w/ 3 kHz probe



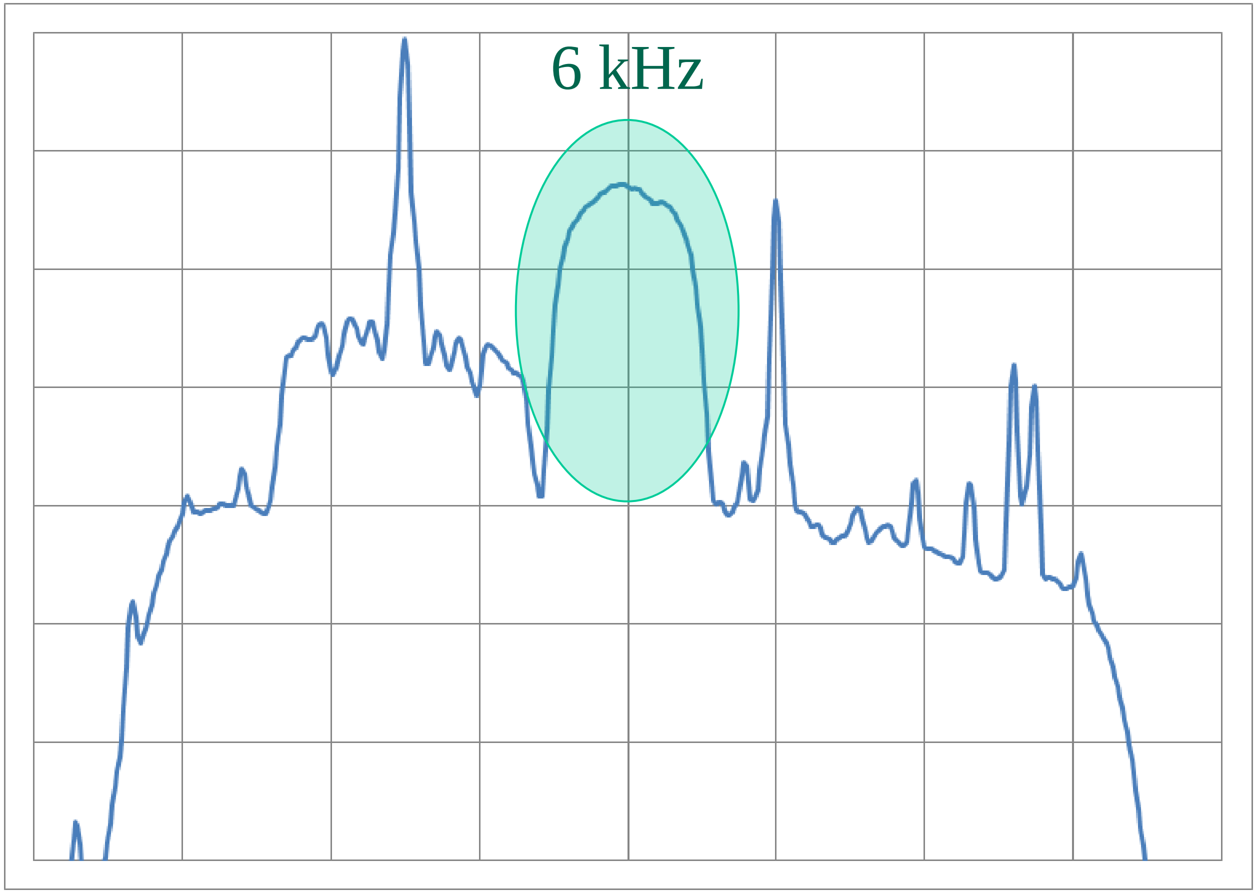
- Visual comparison provides a rough estimate of SNR; adjust for bandwidth to predict SNR with transmissions of different bandwidths – or estimate based on Received Signal Strength measurements

Field test observations – channel interference



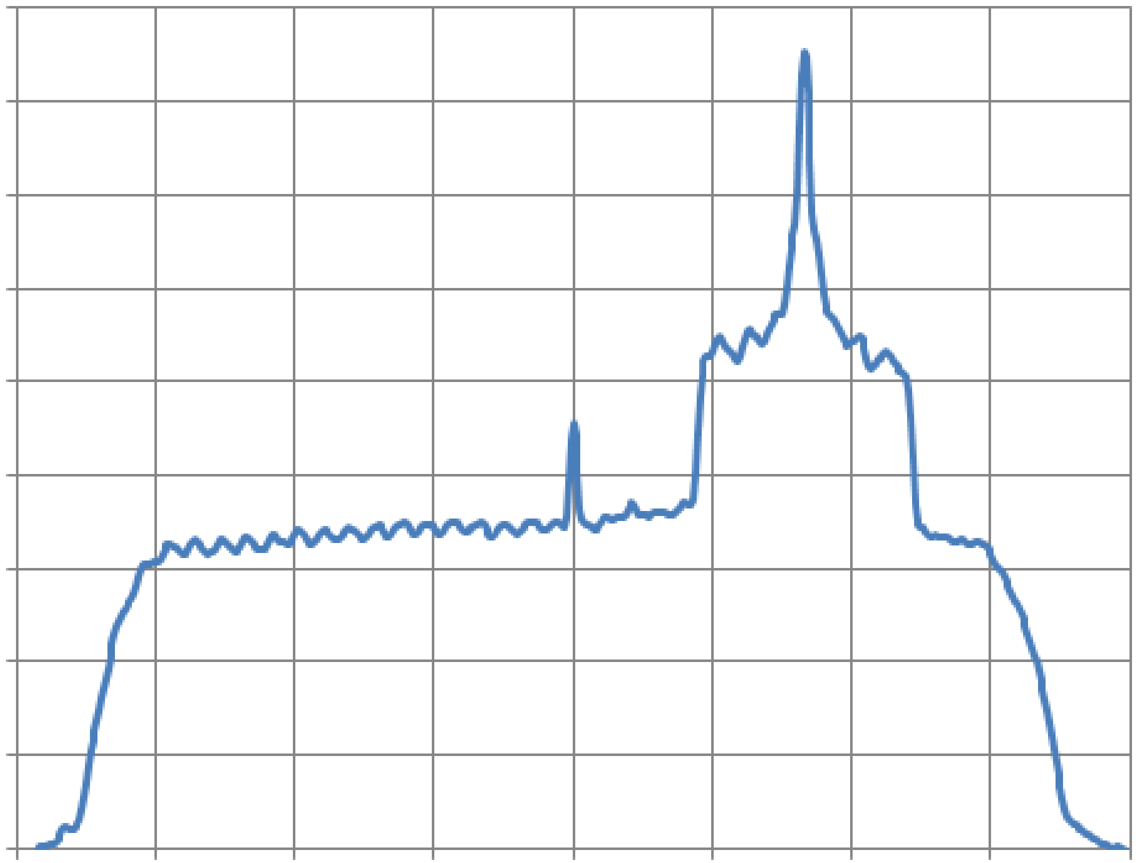
- Prominent AM broadcast interferer with other narrowband interference

Contribution to use of HF wideband waveforms



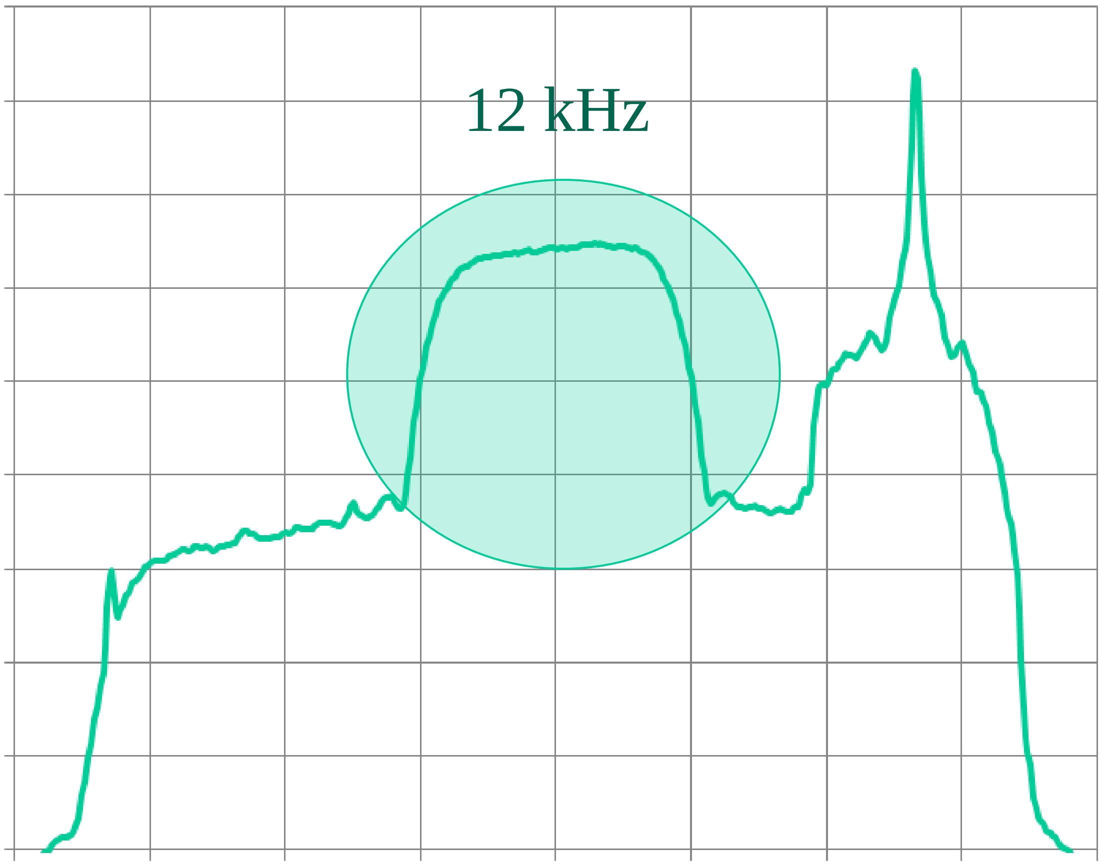
- Avoiding the AM broadcast interferer allowed us to transmit at 12800 bps error-free

Another interferer ...



- Spectrum sense of assigned frequency 6060
- AM broadcast signal is CFRX 1kW Toronto talk radio AM broadcast
- Modem experienced 50% BER for 24 kHz 64000 bps

... avoided!



- We retuned carrier frequency to 6054, reduced bandwidth to 12kHz
- Achieve error-free data transfer at 32000bps
- Spectrum above shows our signal and the AM broadcast

Caveats

- Need to combine probing with spectrum sensing to be able to predict SNR
- Spectrum sensing for WB-ALE will be subject to the well-known *hidden node problem* (**and** *'exposed node problem'*) affecting media access control protocols
  - May motivate incorporating some sort of cooperative technique …
  - … which might significantly impact the complexity of the ALE protocols …
  - … so it would be great to know how important these problems are for us!

Conclusions and future work

- The introduction of the new HF wideband waveforms will give rise to needs for new ALE capabilities
  – Establish links of different bandwidth in a coordinated manner
  – For a given allocated channel, determine in real time what portion of the allocated band is usable
  – Support adaptive selection of waveform parameters
- The new ALE system will need a spectrum sensing capability having particular features
  – Identify interference-free portion of an allocated wideband channel
  – Provide estimate of achievable SNR
- Harris has developed a prototype of a spectrum sensing capability and demonstrated its utility for WBHF traffic on real-world HF skywave links

- In future work, we hope to
  – Further elaborate the use of spectrum sensing as a component of a wideband ALE solution
  – Further investigate the significance of the spectrum sensing *hidden-node problem* through additional field testing and analysis