Spectrum issues for HF wideband communications

HFIA meeting, York (UK), Sept. 6th, 2012

C. Lamy-Bergot, J-B. Chantelouve, C. Leménager
Presentation outline

Context and motivation
- HF high data rate communications
- Spectrum availability and spectrum management issues

Spectrum measurements
- Equipment used and measures done
- Measures analysis principle
- Occupations observed in Coulommiers, France

Application to HF wideband communications
- Taking into account circuit reliability (propagation predictions)
- Comparing achievable throughputs

Conclusions
Context and motivation

Need for tactical BLOS services at an affordable price → IP over HF (64 to 128 kb/s requirements)
  ➔ use more bandwidth (higher spectrum efficiency won’t be sufficient)

... while remaining in a tactical context ...
  ♦ Avoid using multiple radios (unsuitable except in larger ships/infra sites)
  ♦ Use reasonable power figures and tactical antennas

... keeping capability to interoperate with legacy equipments ...

... respecting spectrum usage & regulations ...
  ♦ Availability of HF spectrum for larger than 3/6kHz sub-bands ?

... and meeting SNR requirements for high data rate

Possible channelizations for wideband approaches
  ♦ MIL STD 188 110 C: single carrier up to 24 kHz
  ♦ THALES HF XL approach (multi-narrow band approach) : n*3kHz in a 200kHz band
Context and motivation

Spectrum availability & management issues:
- Obtaining wideband emission authorizations?
- Dynamic management of wideband spectrum allocations?
- Real-life availability of the bands (interferers, multiple use, ...)

Obviously ...
- From HF users experience, 24kHz free allocations should be very difficult to obtain (impossible?)
- $n \times 3$kHz can be found much more easily than $1 \times 24$kHz
  
  $\binom{6}{6} \approx 6 \times 10^9$
  
  Typically, in 200kHz, one finds $\binom{6}{6} \approx 6 \times 10^9$ possibilities for 8 non contiguous 3kHz allocations, to be compared to 59 possibilities for contiguous allocations !!

- Allowing use of non contiguous allocations will permit sharing with other users, adaptation to pre-existing allocations/unvoluntary jammers
Is it better to use contiguous vs. non contiguous n*3kHz sub-bands?

- Let’s imagine that
  - the whole HF band is available
  - no other distant user will be disturbed by our emissions if we cannot detect them

- and evaluate availability of contiguous and non contiguous spectrum allocations
  - Placing us in real life conditions
  - Counting the number of “free” (i.e. not used) channels, whether 3kHz, 12kHz or 24kHz

Let us address in the following the issue of spectrum availability (for contiguous or non-contiguous n*3kHz) **independently of emission rights**
Spectrum acquisitions for off-line analysis

- Location: Coulommiers, France
- Using THALES TRC6500 electronic warfare product for signal acquisition in HF band

Acquisitions resolution for each spectrogram

- 12 MHz band
- 24 hours continuous acquisition
Exploiting the measures done

- Step 1: estimation of noise level by statistical derivation of the noise level for each spectrogram
  - Window considered: 1MHz x 15s
  - Hypothesis: normal distribution model
Exploiting the measures done

- **Step 2: estimating availability of time/frequency elementary cells**
  - Threshold: INR < 3dB (no interferer accepted above twice the estimated noise level)
  - This includes power test over each cell to remove strong pulse interferers
  - Counting number of cells with respect to 3/4 ratio corresponding to error correction capability

![Diagram](image)

**Presentation Level:**
- Time-Frequency plane

**Analysis Level:**
- Time: 30mn
- Frequency: 300KHz
- 3KHz

**Measurement Level:**
- 15s
- $B_{res} \text{Hz}$
- $T_{res}$
Illustrations: elementary availability

- Obtained by processing with respect to noise level: INR<3dB

Acquired spectrogram (subset)

Elementary availability (white: available)
Occupations observed in Coulommiers, France

- Comparing contiguous (1x12kHz or 1x24kHz) and non-contiguous (8x3kHz or 16x3kHz availability)
Measures done

Averaging in terms of measured availability:

Availability of non contiguous 16x3kHz close to availability of contiguous 1x12kHz !!

Free contiguous 24kHz bands are rare ... and often found in spectrum parts that won’t be usable in practice (impossible to establish circuit)
Context and motivation
- HF high data rate communications
- Spectrum availability and spectrum management issues

Spectrum measurements
- Equipment used and measures done
- Measures analysis principle
- Occupations observed in Coulommiers, France

Application to HF wideband communications
- Taking into account circuit reliability (propagation predictions)
- Comparing achievable throughputs

Conclusions
Circuit considered: Cholet → Coulommiers

- **ICEPAC**
  - THALES NVIS wideband antenna “Butterfly”
  - TX power: 400W PEP
  - RX noise: rural calm
  - Required SNR: based on MIL STD 188 110C requirements

---

**Cholet-Coulommiers - SPRING graph for 90% reliability**

- SNR expressed in 1 Hz
- Frequency (MHz)
- Day time (UTC)
- MUF

---

**Cholet-Coulommiers - AUTUMN graph for 90% reliability**

---

**Cholet-Coulommiers - WINTER graph for 90% reliability**

---

**Cholet-Coulommiers - SPRING graph for 90% reliability**
Combined availability and reliability for QPSK modulation for 1x12kHz, 1x24kHz, 8x3kHz and 16x3kHz configurations

- Better availability for 12kHz due to lower SNR req. (half throughput)
- Back-off cost for multi-carrier easily compensated for 8x3 vs. 24
- 16x3kHz often better than 24kHz (and double throughput)
Combined availability and reliability for same achieved throughput (25.6 kb/s – 51.2 kb/s and 76.8 kb/s)

Reaching higher throughputs with XL approach!!
Conclusions

Finding a block of 12 to 24kHz (contiguous) free and authorized spectrum in LUF/MUF is much more difficult than n*3kHz

- Issue of pre-existing allocations (world-wide)
- Issue of dynamic spectrum management

Furthermore, and independently of this issue, it appears that:

- XL multiple narrow band approach allows to reach higher throughputs
- XL multiple narrow band approach offers a better spectrum availability
- XL multiple narrow band approach is much more flexible in terms of operational use

Key observations:

- 8*3kHz availability better than contiguous 12kHz and obviously than 24kHz
- 16*3kHz availability ~ contiguous 12kHz availability!

Key observations: high data rate communications (64kb/s) obtained with good reliability in XL approach (taking into account back-off cost)

A revision of STANAG 4539 to introduce wideband modems according to MIL STD 188 110C solutions should also standardize multi narrow band (n>2) approach.
Thanks for your attention
catherine.lamy-bergot AT thalesgroup.com

and grateful thanks to our colleagues
Gilles Rogerieux and Hervé Petit for their help.