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DESIGN CONCEPTS AND PREDICTION FOR A RADIO WIDEBAND HF NETWORKS

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Abstract:
The standard MIL-STD-188-110C contains an appendix (Appendix D) defining a new family of wideband HF data waveforms supporting bandwidths from 3 kHz to 24 kHz in increments of 3 kHz. This family of waveforms extends the high performance serial tone modem technology of the MIL-STD-188-110B standard to wider bandwidths and much higher data rates, allowing users the option of selecting the bandwidth and modulation so as to optimize modem performance under the prevailing HF channel characteristics. However, fully realizing the potential of these new waveforms will require enhanced capabilities in other elements of an HF communications system, notably including a new ‘Fourth Generation’ (‘4G’) Automatic Link Establishment (ALE) capability. This paper discusses requirements and design objectives for such technique, design concepts, and prediction tools for reliable frequency management.

Keywords: design concepts, prediction tools, frequency management.

1. Introduction

The new Revision C of the US military standard MIL-STD-188-110 [1] includes an appendix D defining a suite of wideband HF data waveforms supporting bandwidths from 3 kHz to 24 kHz, in increments of 3 kHz. These waveforms offer HF communications users the possibilities to achieve much higher data rates than have been possible in the past when channel conditions are favourable, and increased reliability at the same data rate and power level when they are unfavourable.

One capability required to fully realize the benefits of the new wideband HF waveforms will be a *wideband ALE* capability. Such a capability will, in addition to its traditional roles of establishing and managing links while avoiding traffic collisions, have new roles and requirements in the areas of :

- *Frequency management*: provisioning and allocation of wider-bandwidth channels (up to 24 kHz); matching channel allocation to electromagnetic environment and traffic characteristics;
- *Channel selection*: detecting interference occupying a portion of an allocated wideband channel through a ‘spectrum sensing’ procedure, and selecting an unoccupied portion of the channel – i.e., an unoccupied ‘sub-channel’ – for use by the link.
- *Link establishment*: coordinating the linking of calling and called stations on a sub-channel whose bandwidth and centre frequency were determined in the channel selection process, rather than being defined *a priori*.

- *Link maintenance*: detection of changing propagation or noise/interference conditions following establishment of a link, and adaptively modifying the bandwidth or other waveform parameters so as to optimize performance under the changed conditions.

2. **Wideband ALE design considerations**

The design of a new 'cognitive' 4G-ALE function for wideband HF will have to address a number of technical challenges:

- Bandwidth must now be considered in frequency allocation, management, and selection. WBHF users will need allocated channels wider than 3 kHz, and ideally up to and including 24 kHz. Because the amount of spectrum available is always limited, a network's frequency allocation may contain a mixture of channels having different bandwidths. The channel bandwidths will have to be considered in allocating, selecting, and using channels or sub-channels within them, since the bandwidth will constrain the (sub-)channel capacity and the quality of service that can be provided.
- In order to effectively select the signal constellation, code rate, interleaving, and (possibly) code constraint length to be used in a WBHF transmission, a Wideband ALE system will need to estimate the propagation characteristics of the channel or sub-channel it contemplates using, whose bandwidth may be anywhere from 3 kHz to 24 kHz. Harris' Wideband ALE design concept assumes that HF channels (including sky wave channels) of up to 24 kHz exhibit sufficiently uniform Doppler and multipath characteristics so that a 3 kHz probe waveform, such as the burst waveforms used in STANAG 4538 FLSU, can be used to measure the wider sub-channel's characteristics with sufficient accuracy [2].
- In its use of wider bandwidths, a WBHF communications system becomes inherently more vulnerable to interference, since a wider-bandwidth channel represents a larger 'target'. This problem isn't necessarily solved by the availability of wider-bandwidth allocations, since, even if a nation's regulatory authorities attempt to provide exclusive allocations to single users, frequency reuse frequently occurs across national borders and land/sea boundaries. Furthermore, assumed frequency reuse is becoming an accepted feature of HF frequency management approaches intended to maximize the communications capacity that can be provided within a limited allocation of frequency bands [7]. The likelihood of narrowband interference (e.g., by users of 3 kHz channels) within wideband channels represents both a risk and an opportunity for the users of the new WBHF waveforms: a risk, because interference from a 3 kHz transmission could effectively block receipt of an entire 24 kHz WBHF transmission; and an opportunity, because the availability of waveforms of different bandwidths in the waveform family makes it possible for a WBHF system to cope with a narrowband interferer in a wideband channel by using the remaining portion of the wideband channel that is not occupied by the interfering signal.

- A key element of a Wideband ALE system capable of meeting these challenges will be a *spectrum sensing* capability by means of which a station can listen on an entire wideband channel of 24 kHz or more, detect the presence of interfering signals on the channel that could render all or part of the channel unusable, and identify any portion of the channel that may still be usable even if the channel is partly blocked. The reliability and accuracy with which a station can perform this spectrum sensing function is likely to be a significant factor determining the performance of a

Wideband HF system. This suggests that the effectiveness of candidate spectrum sensing techniques and their utility in supporting the use of the WBHF waveforms are important areas for near-term investigation.

2.1. Modulation characteristics

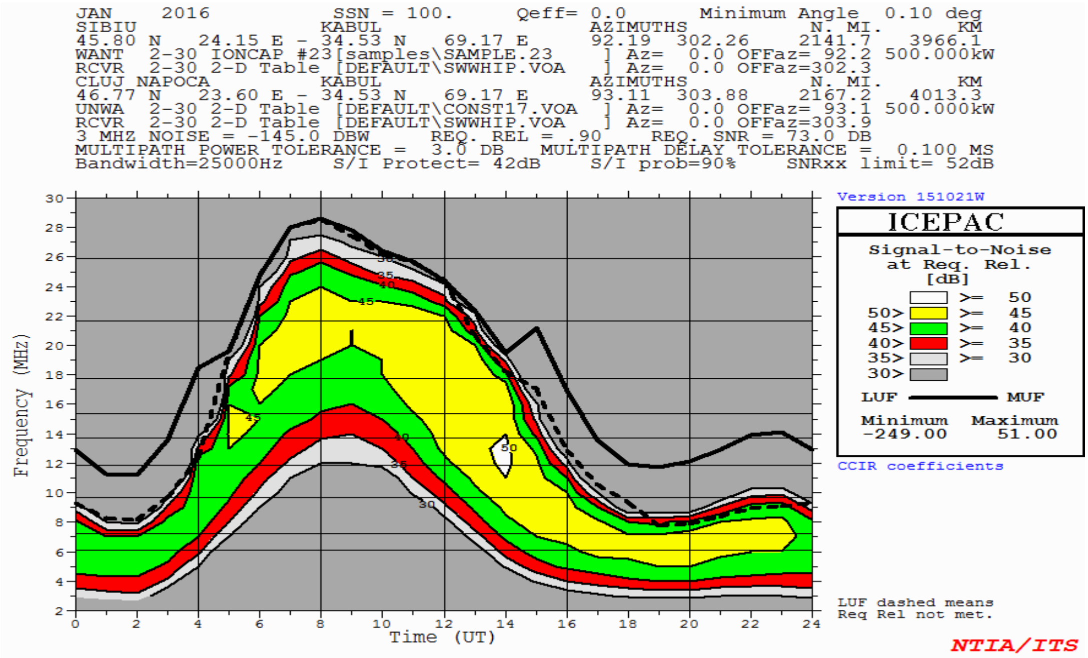
The design of the new wideband HF waveforms is very similar to that of the 110B Appendix C waveforms [3]. Eight bandwidths are available starting at 3 kHz and extending up to 24 kHz in increments of 3 kHz. Each bandwidth offers up to 13 different data rates. Modulations ranging from 2-ary phase shift keying (2-PSK) up to 256-ary quadrature amplitude modulation (256-QAM) are used. The lowest data rate in each bandwidth (i.e. waveform ID (WID) 0) is based on the very robust STANAG 4415 Walsh modulation format [4]. A brief summary of the data rates (in bits per second) is presented in Table 1. The entries with a "-" are not used. The green colored data rates are those of the surface wave waveforms.

WID	3 kHz	6 kHz	9 kHz	12 kHz	15 kHz	18 kHz	21 kHz	24 kHz
0 - Walsh	75	150	225	300	375	450	525	600
1 – 2-PSK	150	300	600	600	600	1200	600	1200
2 - 2-PSK	300	600	1200	1200	1200	2400	1200	2400
3 - 2-PSK	600	1200	2400	2400	2400	4800	2400	4800
4 – 2-PSK	1200	2400	-	4800	4800	-	4800	9600
5 – 2-PSK	1600	3200	4800	6400	8000	9600	9600	12800
6 - 4-PSK	3200	6400	9600	12800	16000	19200	19200	25600
7 - 8-PSK	4800	9600	14400	19200	24000	28800	28800	38400
8 - 16-QAM	6400	12800	19200	25600	32000	38400	38400	51200
9 - 32-QAM	8000	16000	24000	32000	40000	48000	48000	64000
10 - 64-QAM	9600	19200	28800	38400	48000	57600	57600	76800
11 - 64-QAM	12000	24000	36000	48000	57600	72000	76800	96000
12 - 256-QAM	16000	32000	45000	64000	76800	90000	115200	120000

Table 1 (data rates (in bits per second))[5]

2.2. Prediction tools

VOACAP[6] predictions were used to identify an hourly range of usable frequencies for a hypothetical radio link from Sibiu Romania to Kabul, Afghanistan, and to predict the likely received signal strength in Sibiu based on known antenna configurations and transmit power levels. (We have found VOACAP predictions to be quite accurate for this link on most occasions.) With these predictions managers can identify radio spectrum and allocate the frequencies that do not interfere with other system. Voacap is a useful tool for simulating link in Hf radio communication.



3. Conclusion

In this paper, we have described the emerging fourth generation of HF radio data communications technology. The WBHF waveforms increase available data bandwidths in HF channels up to 240,000 bps (in 48 kHz channels). Setting up and managing WBHF links will use the new WALE protocol, which dynamically adapts the use of wideband channels to avoid interference and optimize throughput. WALE is capable of setting up links so quickly (1 to 2 s) that we can contemplate using and releasing HF channels efficiently even for short text messages, as well as for streaming and interactive Internet applications.

References:

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[4] NATO STANAG 4415, "*Characteristics of a Robust, Non-Hopping, Serial-Tone modulator/Demodulator for Severely Degraded HF Radio Links*", Edition 1, Dec. 24 1997;

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