MODELING OF BROADCASTED TSUNAMI ALERTS
A PROPOSAL

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ABSTRACT

This paper presents a description and proposal for tsunami alert system using a software modem in detection and public broadcasting for delivering critical information. The standard modem technology for data transmission and detection is based on hardware structures. Already during the World War II radio waves for used for triggering mines using coded tones. Present software modem technology gives low cost alternatives for hardware filtering and decoding of tones. This report briefly describes modelling and some simulation results of transmissions of multi-tone data alerts over broadcast systems. The security aspects are of special interest and simulation results show the level of security against interference, jamming and channel impairments. The importance of alerting systems has been dramatically demonstrated in tsunami. One concern is the costs, which can be kept on a low level using software-based solutions and existing present broadcasting infrastructures on the areas.

1 INTRODUCTION

Within minutes following an alarm signalling the strong earthquake on Dec. 26, 2004 the NOAA Pasific Tsunami Warning Center in Hawaii issued an information bulletin to nations in the Pacific at 8:14 p.m. EST Saturday, indicating that a magnitude 8.0 earthquake (later upgraded to magnitude 9.0) had occurred off the west coast of Northern Sumatra, Indonesia (Nooa 2004). "Tsunami" is the Japanese term meaning wave in the harbor. The wave arrived about two hour later in the “harbors”. The alarm system, if there was any working on the areas concerned, had enough time for saving lives, however…

BANGKOK: Thailand will press ahead with its own tsunami warning system, Prime Minister Thaksin Shinawatra said on Monday, Jan. 31, 2005 in Asia Pasific News. "We don't care whether other countries cooperate or not. We will go ahead and we are ready to invest, even if we are the only country involved," he told reporters. The plan aims to avoid a repeat of the December 26 tragedy, when more than 280,000 people died after an earthquake off Indonesia sent tsunamis crashing into 11 nations.

Communication networks and broadcasting have been used for delivering critical information to people. Data transmission using standard ITU-T (CCITT 1989) modems have been made for use on wired telephone lines, thus they are not a good solution for mobile wireless alert systems. There are on-going activities, radio amateurs and military forces, to develop new waveforms for wireless use. Voice grade or band-limited data transmission systems have been developed for mobile phones but the trend is to wide-band applications.

We have studied adaptive data transmission with an adaptive data modem (Lallo 1999) and are now proposing a new approach for the secure alert transmission systems. The following features of the modem are adaptively selectable: carrier frequencies (for example a three tone), symbol rate, the number of bits in one symbol i.e. the modulation method, and bit rate. The selectivity of the modulation method makes this approach adaptive to the channel in different cases.

The evolution in software modem technology based on the microelectronics expansion makes new things, such as waveform processing and soft waveform detection, reality in present and future modems (software modems). Hardware detection of the complex waveforms in practise is even impossible. In an alert system alone it is not necessary to use very complex waveforms. However, if the security of the data transmission is needed, the complex algorithmic approach in the detection and generation of waveforms is the right answer. We have simulated these waveforms for use in band-limited channels. The system may be called a band-limited OFDM approach.

2 DETECTION of MULTI-TONE WAVEFORMS

In figure 1 we have an example of the multi-tone hardware structure used during the II WW for military operations in Vyborg by the former Soviet Union forces in 1941. In the figure we see the receiver structure made of electron tubes, hardware filters and relays. The relays triggered huge amounts of explosives at strategic places (including a telecommunications exchange building).

Figure 1: Multi-Tone Receiver
Signals Museum, Riihimäki, Finland

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We have now designed an adaptive prototype modem for use in piece time operations and in this case as a proposal for an early warning system, for example a broadcasted tsunami alert. The prototype of figure 2 presents a radio interface circuit needed with the algorithmic generation and detection of waveforms with a PC. The solution on the board includes only a few electronic components: interfaces to the PC on the left, radio interface on the right and a controller circuit in the middle.

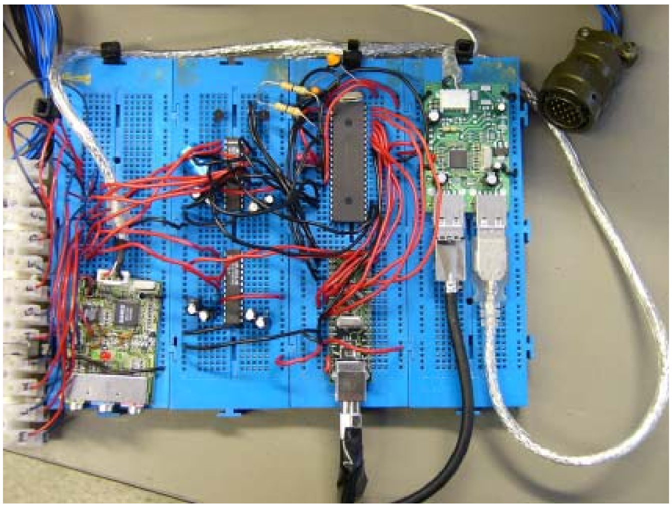

Figure 2: Interface Prototype

The prototype has just been designed and tested by Mr. K. Heinäaro as a part of his MSc Thesis.

The adaptive modem technology uses microcomputers (dsp) and has presently such a high calculation speed that we can use DFT, formula (1) as

$$S_X[m\Delta(f)] = \sum_{n=1}^{N} x[n\Delta(t)]e^{-2j\pi m\Delta(f)n\Delta(t)} \quad (1)$$

in the detection of multi-tone waveforms, for example a three-tone, generated as formula (2) presents

$$S(m_1, m_2, m_3) = \sum_{n=1}^{N} x[n\Delta(t)]e^{-2j\pi m_1\Delta(f)n\Delta(t)} + \sum_{n=1}^{N} x[n\Delta(t)]e^{-2j\pi m_2\Delta(f)n\Delta(t)} + \sum_{n=1}^{N} x[n\Delta(t)]e^{-2j\pi m_3\Delta(f)n\Delta(t)} \quad (2)$$

Where m_1, m_2 , and m_3 represent three different carriers, *N* number of samples used in the symbol, *<(t)* one sample time, and *<(f)* the frequency selectivity. The selectivity of a N-point DFT is f_s/N, where f_s is the sampling frequency.

Table 1: DFT versus FFT

Samples N	Multiplications DFT	Multiplications FFT
13	169	-
16	256	32
26	676	-
32	1024	80
64	4096	192

Detection is based on the DFT Formula (1). It gives us the symbol detection from *N* samples, any of m_i $i=1,2,3$ frequencies with resolution *<(f)*, and symbol time *N<(t)*. In the formula an example setting of the number of samples is *N*=26. We can set both *<(f),* and *N<(t)* by adaptive modem software. FFT uses N-values only as powers of two, Table 1. Thus it is not fully adaptive as a DFT-solution.

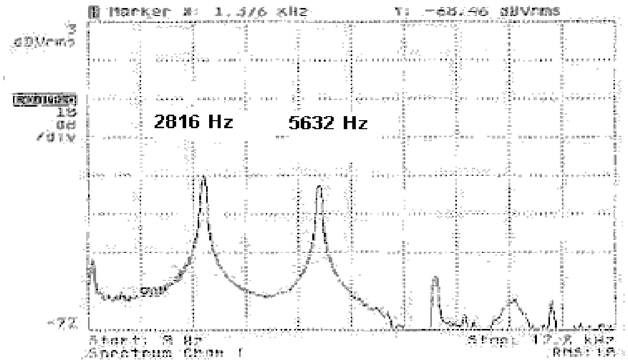

Figure 3: Spectrum of 22.5 kbps 16-QAM waveform

DFT with small number of samples are used in order to keep the solution as simple as possible but as selective as needed. In our simulations a 26-point DFT can well be used for most cases.

3 TRANSMSISSION of ALERTS

A model for transmission of alerts is the adaptive data transmission demonstrated for the Finnish Defence Forces in an exercise in 2000. The narrow-band field tests have been made in VHF and UHF range, figure 3. The bit rate 22.5 kbps was reported as the result.

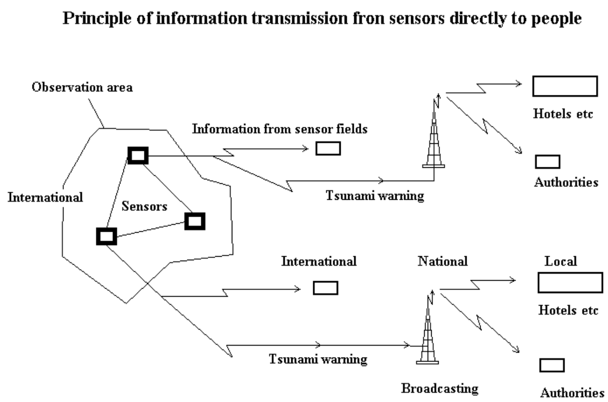

Figure 4: Tsunami warning directly to people

Figure 4 presents the proposed data transmission model for tsunami (or in general any sensor based information source) warning system, which send alerts directly to people. This tsunami warning is a three-tone waveform presented in formula 2. It is proposed to be included in the public broadcasting as a short 3-tone, which triggers the local authorities to action and also the hotels having the 3-tone receivers. A 3-tone receiver is possible to implement in any hand-held FM receiver (GSM or cellular phone). The use of this kind of alerts is so seldom that it does not spoil the broadcasting services. It needs some legislation in order to take the system in use and teaching population of its meaning and functions.

3.1 Power line transmission

Also a PLT (power line transmission) is possible as a last mile system with the selected 3-tone transmission. Some manufacturers already make 95 -140 kHz frequency band equipments with 5 kbps bit rates using BPSK modulation according to GENELEC and FCC regulations.

The responsibility to give warnings is obviously given to the authorities, thus commercial FM receivers and PLT systems may be not the sole last mile solution to the early warning system for tsumani alerts. The normal acoustic signal used for fire alarms is probably the best and fastest way if triggered instantly by the 3-tone from the public broadcasting.

4 SECURED TRANSMSISSION

It is well known that wireless Internet access or LANs are open for recording, interfering etc. There is no standardization for security in the physical OSI reference level. Thus there is a need for securing data.

4.1 Generation and Detection of Secured Three-Tone Signals

To generate waveforms in a digital way we have a flexible method in software modem technology, using OFDM (orthogonal FDM) in a band-limited way as presented in formula (Kifle et. al. 2001)

$$x(t)=\sum_{i=0}^{+\infty}\sum_{k=0}^{N_S-1}\sqrt{\{[s_I^2(k)+s_Q^2(k)]p(t-k\frac{T_S}{N}-iT_S)\}} \quad (3)$$

Where the waveform x(t) is piecewise continuous (i=0…≡), N_s is the number of samples ($k=0... N_s-1$) in symbol and symbol time is T_s.

A 3-tone receiver is easily implemented with a software algorithm using a DFT (discrete Fourier transform) method as described in figure 5. In the proposed simple case only 3-DFT-filters are needed for decoding of a 3-tone signal or a MFC (multi frequency code) signal. The detection of the carriers (MFSK-signal, M=3) is made from the sampled signal x[n☛(t)] presented in figure 5. Generally a soft detection method is used as the symbol decoding system of modem. In this case as a demodulator part of the soft modem gives the amplitude and phase constellation of symbols in the piece-vice continuous data signal stream.

It is easy to mathematically describe and in real time detect continuous or discontinuous waveforms, formulae (2) - (3). In transmission of bits we select the symbol rate R_S and we set the associated number of samples in a symbol N together with a proper sample rate f_S according to the formula 4 as

$$R_S = f_S / N \quad (4)$$

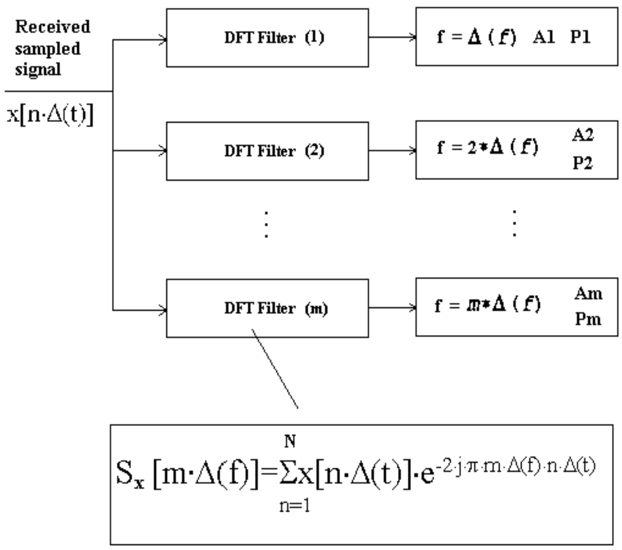

Figure 5: DFT Method

Selecting the proper digital modulation method according to the channel characteristics and BER performance requirements BER vs S/N we get the bit rate

$$R_b = kMR_s \quad (5)$$

Where we use k carriers, M bits per symbol and the selected symbol rate is R_S. This is an adaptive selection of the modulation method (parameters). Detection of f, A and P is illustrated in figure 5.

Figure 6 (next page) presents the amplitude sensitivity of soft detection method in AWGN channel. At low S/N < 10 dB ratio the normalized amplitude of three orthogonal multi-tones has a high deviation. However, the alarm is detectable by setting the threshold level of the signals properly. Figure 6 presents an orthogonal signal space of three tones. There is AWGN jamming more harmful than other interferences.

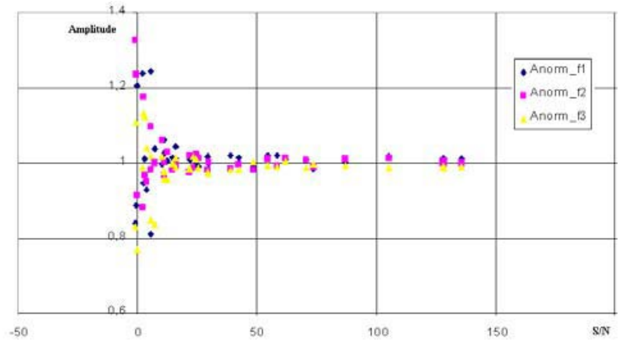

Figure 6: Soft 3–Tone Detection in AWGN Channel

4.2 Securing the Transmission

This proposal includes the use of band-limited frequency hopping *m<(f), m=0…M-1*. A vector ***F={F_M}*** defines in general the *M* frequencies used in the hopping as.

$$\{F_M\} = [f_0, f_1, f_2, ..., f_k, ..., f_{M-1}] \quad (6)$$

Let the transmitted signal (tsunamy warning signal) be one of a multiplex of M signals with the hopping code *{C}* for the particular message signal as

$$\{C_{k,N}\} = \begin{bmatrix} c_{1,1} & c_{1,2} & \cdot & c_{1,N} \\ c_{2,1} & c_{2,2} & \cdot & c_{2,N} \\ \cdot & \cdot & \cdot & \cdot \\ c_{M,1} & c_{M,2} & \cdot & c_{M,N} \end{bmatrix} \quad (7)$$

Where N message elements $c_{k,N}$ (one in each column) are 1, *k=1…N,* while all other elements are 0. In the similar way hopping codes for other messages can be constructed in a hopping system.

One gets the decoded signal ***S*** in a general case as a vector of signal carriers F in a matrix operation as

$$S = CF^T \quad (8)$$

Hopping sequence is secret i.e. the carriers are selected with a secure random process known only by the two end users of the secure adaptive end-to-end communication.

All these parameters are well known in DFT theory. The frequency parameter is m and it is associated with the frequency selectivity Δ(f). This Δ(f) can be set with the sampling rate f_S and the number of samples N to a minimum value f_S /N, which is the symbol rate, formula (2). The importance of the adaptive change of N is obvious**.** The adaptive software filter can be made as narrow as needed and thus it can be adjusted to the adaptive waveform and the channel. The bandwidth used in the symbol transmission is calculated by DFT during each symbol time only (piecewise continuous system). We should not calculate over any discontinuity points between symbols. In theory using high sampling rate in detection we can use very narrow sub-bands for multiple carriers. There are a few practical references for narrow-band multi-carrier frequency modems**.**

5 DISCUSSION

We have tested and simulated earlier the use of adaptive waveforms in different channels of radio, telephone and tactical delta-modulated networks. We have calculated some examples over 200 kbit/s bit rates with ten carrier frequencies or channels. In practice some of these high-speed data transmissions may need more bandwidth than a regular voice grade circuit (300-3400 Hz). In modern military VHF radio systems we already have available about 30 kHz wide frequency bands. We believe that older VHF radio equipment, which have 30 kHz bandwidths, are easily modernised for data transmission. They may be then connected to the laptops and used as data communication equipment in alert systems.

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PAULI R. U. LALLO born in 1944 in Joensuu, Finland went in 1963 to the Technical University of Helsinki, where he studied telecommunications and applied electronics. He obtained M.Sc 1969 and Tech.Lic in 1975. First he has worked in Post and Telecommunication Administration (PLH) in Finland a couple of years, in Adult Education Organizations 11 years and in a small Developing Company. Between 1970-1975 and since 1988 he worked in the Finnish Defence Forces (FDF). His rank is LTC in engineering. He has been the Chief Scientist of the Signals and Electrotechnical School since 1.1.2003 (former Signals School), retired on 1.1.2005