UDC 621.396.932

Koshevyy V.M.[1], Shyshkin O.V.[1], Lisaj A.[2]
[1]Odessa National Maritime Academy
[2]Maritime University of Szczecin, Poland

METHOD OF AUTOMATIC TRANSMITTER IDENTIFICATION FOR INLAND VHF COMMUNICATION

In inland waterways of European Union automatic transmitter identification system (ATIS) [1] is used for determinate which vessel transmitted by VHF radiotelephone. This system is constructed in such a way that it generates and transmits digital signal which contains the vessel's maritime mobile service identifier (MMSI) at the end of voice radio transmission (just after releasing push-to-transmit (PTT) button). The identification signal is simply appended after voice signal in the format of digital selective calling (DSC). ATIS is obviously useful for duplication and insurance the voiced announcement by operator vessel's identification.

The ATIS drawback is that identifier is transmitted after the voice message. Therefore if the verbal identification were missed or received incorrectly in the beginning of message, then it is not clear which station is talking. Another problem arises from so called "keying phenomenon", relating to (PTT) button falling back in a VHF transceiver because of various reasons [2]. This phenomenon brings the communication blackout of other stations near the ship or very poor communication state in relevant areas around the ship, which is especially harmful when the ship is in the area of Vessel Traffic Services (VTS), RIS operating centers and SAR operations. In such situation PTT button remains in falling back state during indefinite time and identification signal is not transmitted.

Generally reliable and at once clearly understood identification is very important for decision-making processes in navigation and effective management in RIS.

One of the main characteristics of the River Information Service is efficient and reliable exchange of information. It can be effectively achieved in real time through VHF communication, which is of key importance in maritime navigation and has been implemented to meet the requirements of inland waterway shipping services.

As stated in article [3], radio communication in inland shipping should be also compatible with the GMDSS in use at sea.

In this paper we present innovative approach in comparison with ATIS to solve automatic vessel's identification by standard radiotelephone transmissions. It is based on inaudible embedding vessel's MMSI directly into low frequency audio signal and transmitting it repeatedly from the very start of conversation after PTT pressing up to the end of the conversation.

The proposed method is based on audio watermarking (AW) technology and fully compatible with the existing radio installations and doesn't require any replacement in apparatuses and operational procedures.

Audio watermarking implies techniques that are used to imperceptible information convey by a certain embedding it into the virgin audio signal. AW doesn't call for any additional time or frequency channel resources. The basic principle of AW is shown in the Fig. 1. AW encoder is designed in the telephone receiver in the circuit break immediately after microphone (points 1 – 2). Data present the bits of MMSI. In DSC format MMSI occupies 30 bits. AW encoder imperceptibly embeds MMSI into the audio signal. Under standard channel we mean a complex of communication facilities: transmitter, receiver, antennas and properly radio air. Standard channel can be not only analog but also digital including analog-digit, digit-analog conversions and data compression operations.

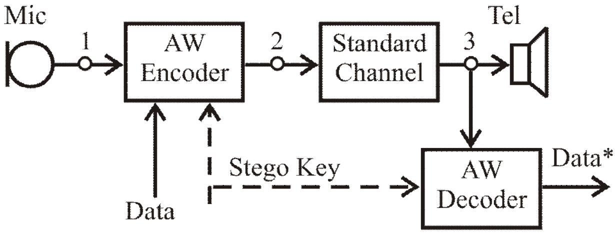

Fig. 1. General scheme of watermarked communication

AW decoder is connected to audio output of receiver (point 3). The extracted data are directed for the proper utilization (displaying, printing, Electronic Chart Display and Information System, etc.).

Both encoder and decoder may utilize some secret stego key to protect from unauthorized access to embedded information.

Such approach demands no alterations neither in operating radio equipment nor operational procedures. Besides it provides the full compatibility with the standard radios without AW function.

Generally AW system has the following characteristics: (a) Perceptual fidelity of watermarks. As usual perceptual fidelity is evaluated by Watermark-to-Signal Ratio (WSR) in dB. Acceptable level of signal degradation according to proposals by the International Federation for the Phonographic Industry (IFPI) is taken equal to -20 dB or less [4]; (b) Data payload – the amount data that can be embedded into the host audio per time unit and measured in bits per second (bps); (c) Robustness – ability of watermarks to resist against channel attacks. It can be evaluated by the probability of successive watermark extraction.

These characteristics are mutually contradictive and an optimal trade-off should be chosen for the best capabilities of AW system.

AW algorithm is based on a certain modification of frequency coefficients in spectral domain [5, 6].

To reduce effect of frequency response irregularity on watermarks the Orthogonal Frequency Division Multiplexing (OFDM) has been proposed. OFDM is well approved communication technology for various channels, especially with multipath propagation. Multipath propagation leads to intersymbol interference (ISI), which greatly corrupts the transmitting signal. In the maritime radiotelephony ISI appears due to band limited channel. Frequency response of audio channel is essentially nonuniform and limited by the frequencies (300 – 3000) kHz. As a result of this the different frequency signal components undergo the different amplitude variations. Hence normalization in the general frequency band as a measure against amplitude scaling is not efficient.

In the proposed algorithm signal vector is composed from the frequency coefficients of Fast Fourier Transform (FFT). It is fundamentally important that the every vector is composed from the adjacent coefficients so that they are placed in the narrow band and exposed to the same amplitude distortions.

Signal vectors are processed independently in each narrowband sub channel. For FFT dimension $N = 512$, sampling frequency $F_s = 8$ kHz and vector length $L = 2$ sub channel band comes to value of $\Delta f = F_s L / N = 31,5$ Hz. One embedded bit occupies one sub channel per frame. The overall number of sub channels equals to $n = 63$.

After watermarking the signal powers in each sub channel are preserved. Only the powers of harmonics within narrow band Δf are subjected to varying while the total power balance remains unchangeable, that provides watermarks inaudibility.

Information embedding is achieved by a certain distortions of the host signal. These distortions may appear depending less or more on current frame characteristic and embedded information. "Suitable" frame is considered by less distortion, ideally no distortion at all is needed. Therefore using the suitable frame for embedding is reasonable for minimizing introduced distortion. In this case watermarking is realized in asynchronous mode.

The distortion threshold ρ_{enc} is proposed to make floating in the form

$$\rho_{enc} = h\Delta \frac{\sigma_{long}}{\sigma_{frame}},$$

where $h = 0,5 \ldots 2$ – embedding intensity factor that specifies data payload; Δ – quantization step; σ_{long} – long term root mean square (rms) of the host signal in the interval of (3 – 5) sec; σ_{frame} – short term rms of the current frame.

Searching an optimal frame for AW minimizes distortions and additionally improves their imperceptibility.

To enhance interference immunity the Bose-Chaudhuri-Hocquenghem error-correcting code BCH(63,30,6) was used. It includes $k = 30$ information bits for total block length of $n = 63$ bits and is capable to correct up to $t = 6$ errors per block [9].

In the DSC format MMSI contains 9 decimal digits. According DSC format MMSI is encoded into 30 bit sequence. In this regard BCH(63,30,6) code is just suitable for presenting the entire MMSI by a single watermark.

Watermark detection is produced by sliding analysis of the received frame of length N samples in the frequency FFT domain. It is essential that detection and decoding processes do not require any starting synchronization and marking.

The proposed AW method was thoroughly investigated in conditions of varying independent parameters and influences the whole spectrum of interferences which take place in the real channels. Computer simulation was carried out in MatLab environment for speech *.wav files with sampling frequency $F_s = 8$ kHz.

Simulation results that refer to data payload in bit/sec (upper value) and fidelity in Watermark-to-Signal Ratio, dB (lower value) subjected to step size Δ and intensity factor h from formula (3) are shown in the Table 1 and Table 2 correspondingly.

Table 1

Data payload versus step size and intensity factor

Quantization step Δ	Intensity factor h				
	0,5	1	2	4	8
0,25	93	136	238	390	458
0,5	93	136	221	348	458
1,0	85	136	229	331	450
2,0	93	144	212	348	450

Table 2

Data fidelity versus step size and intensity factor

Quantization step Δ	Intensity factor h				
	0,5	1	2	4	8
0,25	-48,8	-41,5	-32,6	-24,8	-21,4
0,5	-43,1	-34,5	-26,1	-19,5	-14,4
1,0	-38,9	-30,4	-21,2	-14,6	-8,7
2,0	-34,6	-24,3	-16,8	-9,8	-5,4

Acceptable level of speech signal degradation under limitation of WSR from [4] is defined by magnitude -20 dB or less. These values are separated by bold line. The independent parameters Δ and h may be chosen from the Tables 1, 2 for practical implementation.

Other AW parameters were taken as follows: vectors length $L = 2$, FFT dimension $N = 512$, number of embedded bits per frame $n = 63$, parameters of BCH code $(n, k, t) = (63, 30, 6)$.

AW robustness was evaluated as true-positive probability in the form of relation of received and correctly decoded watermarked frames to the total number of transmitted frames. Watermarks are absolutely resistant against amplitude scaling and resampling. Influence of other typical attacks in VHF radiotelephone channel (amplitude compression – expanding, band pass filtering, additive noise) is presented in the Table 3.

Table 3

Watermarks robustness subjected to various channel attacks

Step size Δ	Compand-ing, μ-law	Filtering	Additive noise, dB		
			-40	-30	-20
0,125	0,76	0,13	0,23	0	0
0,25	1	0,36	0,75	0,1	0
0,5	1	0,82	1	0,37	0,09
1	1	1	1	1	0,43
2	1	1	1	1	0,68

As follows from the Table 3, watermarks are resistant against typical channel interferences. Some resistance lowering, when true-positive probability is below unit value doesn't effect on capacity of work because MMSI watermarks are repeated continuously during the whole transmission including speech pauses. False detections and decoding was not registered.

Watermarked signalogram of test phrase "Obviously navigation is the primary application of most GPS devices" is shown in Fig. 2. Positions of watermarks are shown by black rectangles. Every watermark contains MMSI from 30 bits.

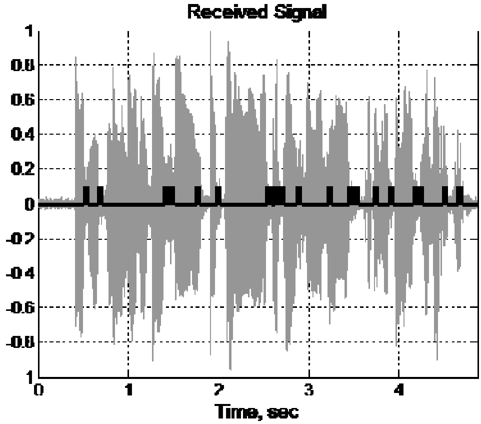

Fig. 2. Signalogram of received watermarked audio and watermarks positions

Scheme of practical implementation of AW function is presented in Fig. 3. A single hardware upgrading includes two electronic chips. One of them is placed directly into the handset at the transmitting part and another one is switched to standard audio output at the receiving part. Detected MMSI is then directed for visualization and other systems, for example

ECDIS to mark the transmitting vessel. No other invasions in existing radios and operational procedures are needed. Besides, the designed system is fully compatible with the installation without AW function.

Presented method of audio watermarking eliminates drawbacks of existing inland ATIS in RIS. It gives identification of transmitting vessel just after beginning of transmission and is repeated during all transmission. Therefore identification is realized without any delay. It excludes impact of so called "keying phenomenon" and human factor when verbal identification is missed or transmitted incorrectly.

Another weak side is that the ATIS transmissions are produced irrespectively of current state of the radio channel. The channel might be occupied just at the moment of ATIS transmission. In this case identification signal will be lost, that is most probable on the overloaded channel. Instead, the proposed method doesn't need any additional time and works to the extent that the voice message maintains intelligibility.

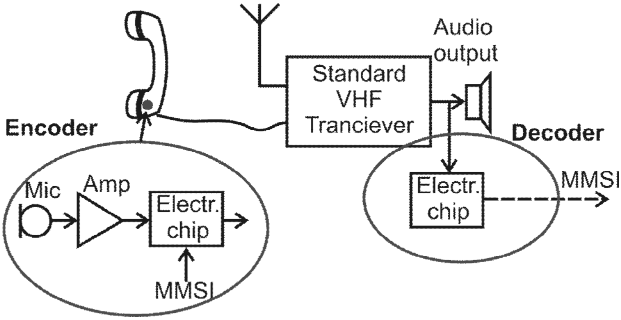

Fig. 3. Design of practical implementation

The similar problems are inherent in VHF communication at sea. What is more ATIS is not used in maritime communication. Therefore the problem of reliable identification in the GMDSS is also very important for clear and addressed communication and efficient logistical and transport management.

In the light of GMDSS implementation in the RIS infrastructure [3] it is quite reasonable adoption of the proposed method in practical shipping.

REFERENCE

1. ETSI EN 300698-1. Radio telephone transmitters and receivers for the maritime mobile service operating in the VHF bands used on inland waterways; Part 1: Technical characteristics and methods of measurement. – 2009. – 50 p.

2. Review and Modernization of the Global Maritime Distress and Safety System (GMDSS). Analysis result of user survey on GMDSS modernization. Submitted by the Republic of Korea / Sub-Committee on Navigation, Communications and Search and Rescue, NCSR 1/INF.14. 25 April 2014.

3. Lisaj A. Maritime Communications in RIS System for Inland Navigation. //TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation. – 2015. – Vol. 9. – № 2. – P. 287 – 291.

4. Vivekananda Bhat K, Indranil Sengupta, Abhijit Das. An adaptive audio watermarking based on the singular value decomposition in the wavelet domain. //Digital Signal Processing. – December 2010. – Vol. 20. – Issue 6. – P. 1547 – 1558.

5. Shishkin A.V., Koshevoy V.M. Stealthy Information Transmission in

the Terrestrial GMDSS Radiotelephone Communication //TransNav – International Journal on Marine Navigation and Safety of Sea Transportation. – 2013. – Vol. 7. – № 4. – P. 541 – 548.

6. Shyshkin O., Koshevyy V. Hidden Communication in the Terrestrial and Satellite Radiotelephone Channels of Maritime Mobile Services //Information, Communication and Environment. Marine Navigation and Safety of Sea Transportation. – London: A Balkema Book, CRC Press, Taylor & Francis Group, 2015. – P. 13 – 19.