Listening of radio programs via Internet without hearing aid devices for persons with damaged hearing

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Way for application of software package that will enable individual listening of radio programs via the Internet without using hearing aid device is presented and described in the paper. The Adobe Audition CS6 software package is appropriate for processing of such sound files and is used in the practical implementation described here. Radio stations that broadcast musical and informative contents on their Internet web sites besides textual information offer also possibility to listen and recording of broadcasted content. For listening without using of hearing device the recorded material has to be processed before its posting on the Internet site. In such a way it is obtained possibility for persons with damaged hearing to have good audibility with preserved needed understandability without using hearing aid device. Processing and correction of hearing damages for older persons are analysed and proposed here. Some experimentally obtained results are given in the paper.

1 Introduction

Energy level of sound in point of hearing space has to be amplified for persons with damaged hearing. It is known that hearing sense enables creation of sound picture for recepient of sound information. The sound picture is not complete for persons with hearing damages. Excitation of iner ear is proportional to energy that ear receives from sound field.
It is common to use hearing aid devices to obtain correct speech communication with other persons. Performances of such devices are designed on the basis of audiometric measurements for individual frequency characteristic of the person with damaged hearing. In that case is observed complete sound energy where are satisfied criteria of understandability and width of frequency range.
Frequency characteristic of hearing aid device gives dependence of gain (amplification) *A*[dB] on frequency *f* [Hz]. Relation between characteristics of subjective feeling and physical objective characteristics for every person is unique. But, application of hearing aid devices influences on psychophysical state of person with damaged hearing. So, for persons with damaged hearing is very important relief of hearing without using hearing aid device in their home or similar ambience. For comfortable listening without using hearing aid device the recorded sound material has to be processed before its using. Such is obtained that persons with damaged hearing have audibility with preserved needed understandability.
Transfer functions of acoustic systems are modeled with needed corrections of amplification. For sufficient duration all psychoacoustic impressions are integrated. Contents as news, daily news and other programs giving useful information to the listeners could be processed and adjusted for persons that becouse ageing or illness have to use hearing aid device to listen that content via the Internet without usage of hearing aid device.

2 Modeling of hearing damages

There are two reasons for shifting up of hearing threshold. Permanent shifting appears because of natural aging or because of long duration of high sound levels. Standardized hearing threshold (left) and hearing thresholds for persons of 50 years (center) and 70 years (right) of age are shown in Fig.1 [1].

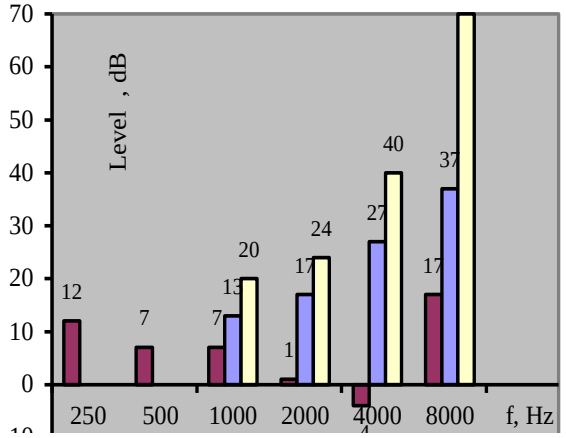

Figure 1. Referent hearing threshold level and threshold levels for persons of 50 and 70 years of age.

For design of needed shape of amplitude characteristic of gain (amplification) A [dB] as a function of frequency f [Hz] used are dedicated software and mathematical software. But, mathematical correction is not always sufficient. So, in the audiological laboratory is again performed control of audiogram for persons with hearing damages.

Mathematical model of audibility threshold that gives dependence of sound level L [dB] on frequency f [Hz] can be presented by the next relation [2]:

$$L(f)=\sum_{i=1}^{n}\left[\prod_{k\neq i} L_i\cdot\frac{(f-f_k)}{(f_i-f_k)}\right], \qquad (1)$$

According to audiometric measurements of individual frequency characteristic of ear based on tonal audiogram for person with damaged hearing it is designed curve of the target gain for the person. For the design needed corrected frequency characteristic then except mathematical model the audiologist uses standardized target gain curves that present needed level of correction of gain in dB. Such examples of Pogo II and NAL-R level of correction as a function of frequency are shown in Fig.2 [3].

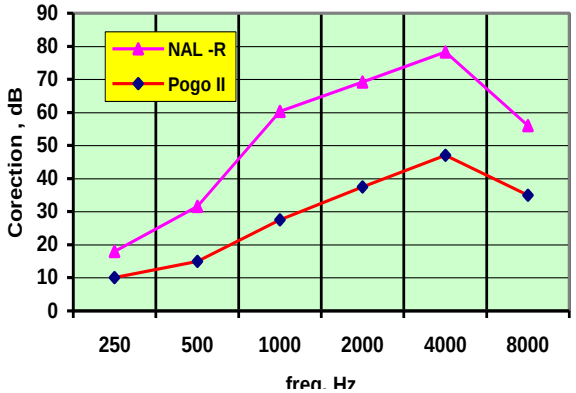

Figure 2. Target gain curves of Pogo II and NAL-R.

By selecting of target gain curve that with open ear channel resonance characteristic designs needed insertion gain is process whose final result is reaching programmed needed sound level for improved hearing. Test of adjustment of the system is comparable with audiogram that is applied in higher quality hearing aid devices. One such measuring palette is shown in Fig. 3. Sufficient frequency domain for correction of hearing damages is between 200 Hz and 8 kHz. But, for harder stages of hearing damages sufficient frequency range for correction of ear characteristic is around 4 kHz. Spectral density od speech power is greater in the range of lower frequencies while the part of the spectra of higher frequencies contributes to understandability of speech. So, in the frequency range up to 1 kHz is used 83% of input power at understandability of 42% while the complete understandability is achieved in the range from 200 Hz to 7 kHz [1,3].

Ear models based on mechanics and neutral phenomenology of the inner ear (cochlea) form a class of nonlinear nonlocal dispersive partial differential equations [3-5]. If $A_N(\omega)$ is needed transfer characteristic of normal response on stimulus then the frequent characteristic of correction system $A_c(\omega)$ is obtained from condition that product of transfer characteristic $A_{tc}(\omega)$ and $A_c(\omega)$ gives transfer characteristic of normal response on stimulus:

$$A_{tc}(\omega)\cdot A_c(\omega)=A_N(\omega), \qquad (2)$$

what along with needed condition gives that is $A_N(\omega)=1$.

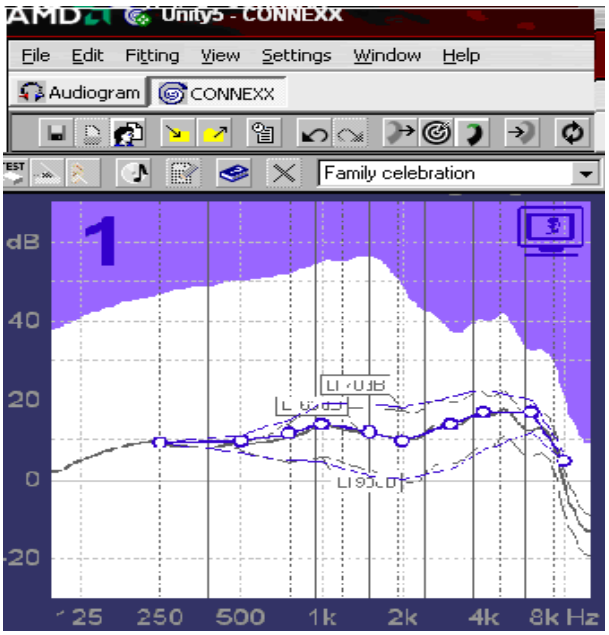

Figure 3. Audiogram of hearing aid device CONNEXX.

Starting with sets of data given by matrixes of frequency F and matrixes of results of audiometric measurements L of the person with hearing damages it is obtained polynomial approximations in a next way [2-6]:

$$p=polyfit(F,L,n) \qquad (3)$$

where is:

$$p=[a_n,a_{n-1},...a_1,a_0] \qquad (4)$$

matrix that represents coefficients of polynom by which is performed modeling of given characteristic, F is matrix given by relation (4) and L is matrix given by relations (3, 4) while n represents needed power of polynom.

One of methods for synthesis of spectral characteristic that belongs to compositional techniqes in music consists in composition of basic spectral blocks that enables general synthesis regardless of complexity of spectrum. Direct synthesis can be shown on example of discret approximation of flat spectrum in the audio range. Time function of such signal is given by:

$$s(t)=\sum_{i=0}^{n} A\cdot sin(2\pi f_i t+\varphi_i), \qquad (5)$$

or by:

$$s(t)=\frac{A}{2}\left\{sin(2\pi f_1 t+\varphi_1)+sin(2\pi f_2 t+\varphi_2)+\left[cos(2\pi f_1 t+\varphi_1)-cos(2\pi f_2 t+\varphi_2)\right]\cdot\frac{sin(2\pi\Delta f t+\Delta\varphi)}{1-cos(2\pi\Delta f t+\Delta\varphi)}\right\} \qquad (6)$$

where is:

- A is amplitude of each spectral component,
- f_1 is lower boundary frequency,
- φ_1 is initial phase of lowest spectral component,
- f_2 is upper boundary frequency,

- φ_2 is initial phase of highest spectral component,
- $\Delta f = (f_2 - f_1)/n$ is frequent difference of neighboring components,
- $\Delta\varphi$ is phase difference of neighboring components,
- n is degree of resolution.

3 Preparation of audio content for listening via Internet

By appropriate programming of correction characteristic for persons with damaged hearing it can be enabled listening of recorded music and speech via the Internet without using hearing aid device. Here in this paper is analyzed the usage of standard software that is implemented on recorded music and speech files prior to their publication on the Internet site. Sound files are processed in the programmed relation compared to the required correction characteristic of ear to minimize hearing damage in the ear of every specific person or a group of persons. For processing of audio signals in usage is a professional software (Sound Forge pro 10.0, Audacity® 1.3). For recording and processing of radio station programs was used Adobe Audition software. During the processing of audio material is performed frequency correction of audio material using graphic equalizers. Graphic equalizer of this used program is analogous to setting and adjustment of sub-bands at dedicated software. After processing of the sound content it is necessary to normalize the sound to prevent it from distortions during reproduction.

The largest number of older persons has hearing characteristic similar to characteristic of hearing for persons aged 60 years [5-7]. It was used here in the paper and processing and preparation of sound content was performed for older persons using correction characteristic for persons of 60 years of age. This achieves adequate quality of audibility with the same frequency characteristic such was used in the programmable hearing aid device.

Individual frequency characteristic of the ear for a person with hearing damages is obtained by adjusting the graphic equalizer on frequency sub-bands (Fig. 4).

In order to obtain a realistic insight into the relationship between the amplitudes in Fig. 5 are given time forms of the original signal. Correction of gain of sound file (*.wav) is enabled by changing signal level in the range from -N dB to +N dB.

4 Experimental results

In the audiological practice is sufficient to correct the audibility threshold up to -10 dB relative to the ideal correction characteristic curve. The target gain curve that for persons with a given characteristic of hearing will enable audibility and the necessary understandability is shown in the following figure (Fig. 6). By adjusting the slider of the equalizer at a particular frequency is realized needed gain or attenuation.

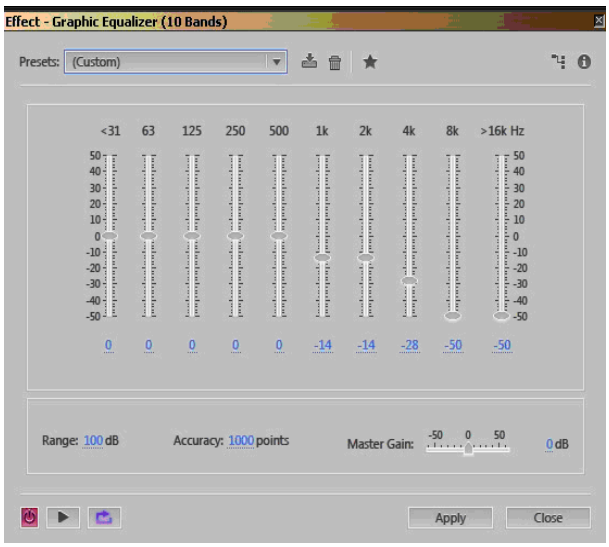

Figure 4. Positions of equalizer according to tonal diagram.

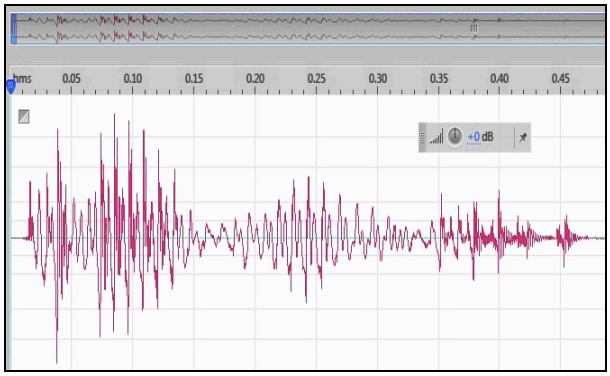

Figure 5. Time form of original audio signal.

Figure 6. Positions of equalizer to achieve corrected characteristics to improve audibility.

Deviations of spectral characteristic in the frequency range from 200 Hz to 10 kHz with expansion up to 16 kHz are presented graphically in Fig. 7. On this original speech signal is applied corrected gain curve with adjustment of graphic equalizer given in software package Adobe Audition. At the same time are shown spectral forms of the original signal (full surface) and

corrected signal (line curve). It can be seen that the spectrum of the signal in the low frequency range from 200 Hz to 1000 Hz does not exceed of 10 dB to 20 dB.

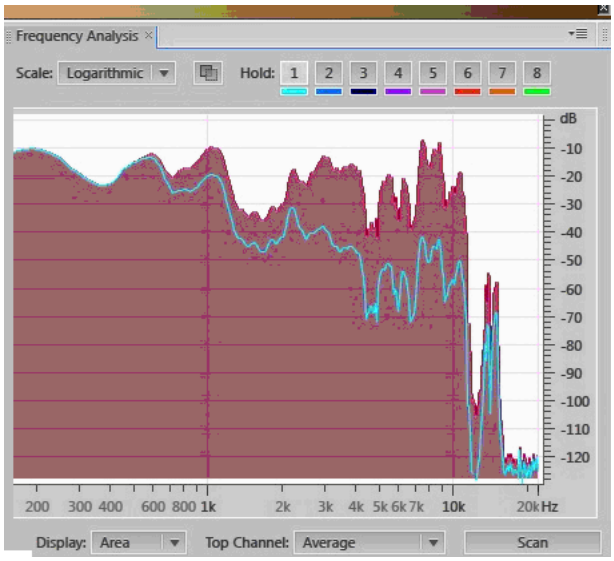

Figure 7. The spectral characteristic of signal in the frequency range from 200 Hz to 16 kHz.

Quality of adjustment of recording depends on the choice of sampling rate. Frequency of sampling for music signals is 44100 Hz while for sampling of speech signal is sufficient value of sampling frequency of 8000 Hz. By this was retained the loudness of program with it that at the higher frequencies was increased the signal level.

Processed sound file is then placed in the provided space on the Internet web site. Picture of practically implemented Internet web site is shown in Fig. 8 [8]. Persons that have similar hearing chracteristic as characteristic of persons 60 years of age can listen to or can record and later listen to the radio program without hearing aid device. By such listening to radio programs via the Internet, as well as audio and video files from the memory of computer, the user hears the sound as it would be with using of hearing aid device.

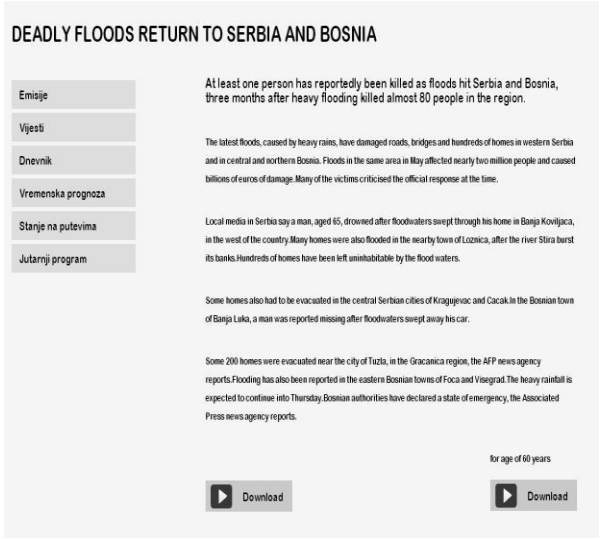

Figure 8. Implemented Internet web site.

5 Conclusions

Listening to the radio programs via the Internet allows persons with hearing damages to can provide high quality listening to recorded music or voice files in their surroundings without using hearing aid devices. In it the prepared audio content of radio program for listening via the Internet is processed using the Adobe Audition software package. Adjustments of the degree of correction are performed in multiple points of frequency characteristic. Thus, persons with damaged hearing have achieved audibility with preserving necessary understandability. It can be achieved possibility for creation and broadcasting of radio and television programs via the Internet for groups of older persons with hearing damages that can be listened without using hearing aid devices and with increased listening quality. Obtained and given results show that using described way of radio program recording, correction of target gain and way of sound files processing and correction in frequency regions can be achieved satisfying results for groups of older persons.

References

[1] M. Valente, "Hearing Aids: Standards, Options, And Limitations", Edition 2, Thieme, 2002., *www.thieme.com*

[2] Jack Xin, "Ear Modeling and Sound Signal Processing", Department of Mathematics and ICES, University of Texas at Austin, Austin 78712, math.uci.edu/~jxin

[3] F. Softić, Z. Bundalo, "Modeling, analysis and correction of hearing system characteristics", 18th International Scientific Conference ERK2009, Portorož, Slovenia, Sept. 2009, pp.82-85,

[4] F. Softić, Z. Bundalo, "Correction of Ear Amplitude Characteristics for Hearing without Hearing Devices", Proceedings of the 19th Intenational Scientific Conference ERK2010, IEEE, ISSN 1581-4572, pp A: 111-114, Portorose, 2010.

[5] F. Softić, Z. Bundalo, Ž. Blagojević. A. Stjepanović, "Listening of Sound Files Using Mobile Phones without Hearing Aid Devices for Persons with Damaged Hearing" , Proceedings of 20th International Scientific Conference ERK2011, pp 83-86, Portoroz, Slovenia, 2011.

[6] F. Softić, Z. Bundalo, Ž. Blagojević, A. Stjepanović, "Correction of Ear Amplitude Characteristic Damages Caused by Natural Aging", Proceedings of Conference INDEL2012, Banjaluka, Bosnia and Herzegovina, November 2012.

[7] www.sonycreativesoftware.com/soundforge

[8] http://www.sublimetext.com/3