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THE ELECTRICAL ECHO MEASUREMENT UNDER THE ECHO CANCELLATION ACTIVITY

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This work is about to obtain an electrical echo signal for technical information security tasks in conditions when echo cancellers are active. Due to the fact that echoes are considered interference in telecommunications systems, special means, named echo cancellers, are used to suppress them. The echo cancellers features are considered, and ways to bypass them are shown. Experimental data confirming the effectiveness some of them are presented.

During the electrical echo (EE) studying for problems of technical information security, which is the subject of [1], the author was faced with the fact that not in all cases the echo signal can be measured. Often the echo was so weak that it was impossible to record it and measure the delay, not to mention other parameters. The reason for such weak EE signal is the work of devices to suppress it. This is not surprising, because throughout the entire history of the development of communication technology, EE has been and is considered a hindrance. To reduce it, various technical devices are used, in particular, echo blocking and echo compensation.

The echo blocking principle is to reduce the gain in that duplex channel in which the signal is currently weaker. Since of the two subscribers conducting a telephone conversation, as a rule, only one speaks at any given time, the echo suppresser weakens the gain in the unused channel, thus blocking the path of echo propagation. This method is quite effective, but has an unpleasant feature. Due to the finite response time of switching devices, the beginning of subscribers' sentences may be “cut off.”

The echo compensation principle is to subtract the echo signal from the microphone signal using a special device. Its block diagram is shown in Fig. 1. In mobile communications, echo cancellers are mainly used, so we will consider them in more detail.

The echo compensator in every mobile phone is an adaptive filter. It works as follows. The signal coming from the remote subscriber is emitted by the speaker of the mobile device, received by its microphone and reaches on the first adder input. The second input of the adder with the “minus” sign also receives a signal from the remote subscriber, but artificially delayed in the delay line and amplified by the amplifier included in the echo compensator. The delay and gain parameters, as well as their frequency characteristics, are adjusting in such a way as to accurately simulate the acoustic path. An echo analyzer is used to fine-tune them. If this is successful, then only the signal generated by the sounds of the subscriber's voice enters the channel to the remote subscriber, and there is no echo.

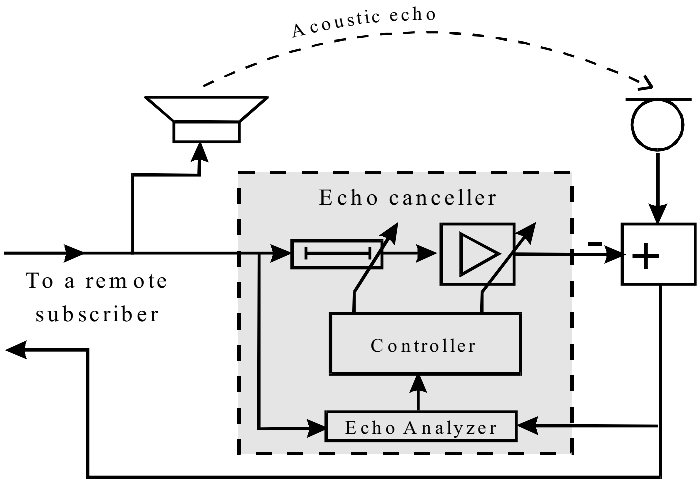

Fig. 1

This is exactly what was observed in a lot of measurements, when it be impossible to obtain the echo delay meaning. This called into question the practical feasibility of the method presented in [1].

An experimental attempt was made to disable the echo canceller using the technique described in [2]. It consists of sequential transmission the harmonic signal with a frequency 2100 Hz for 1.35 s, and after a pause, a fragment of white noise for 250 ms. However this attempt was not successful.

Let's look at how we can "deceive" the echo compensator and get an echo signal. First, let's make theoretical assumptions.

1. It is necessary to achieve nonlinear effects in the acoustic path of a mobile phone.

We can assume if the input signal is very intense, it will cause overload and distortion in the analog amplifiers and acoustic path of the phone. Then higher harmonics and crosstalk from various frequency components of the received signal will appear at the microphone output. The echo compensator will have nothing to compensate for them, because they are not present in the received signal, and nonlinear distortions do not occur in the digital adaptive filter circuit. As a result, higher harmonics and crosstalk will penetrate into the return channel and will be received in the echo form, at least if distorted.

2. It is necessary to make a sharp change in the input signal level.

Obviously, all delay, analysis and signal processing devices in modern mobile devices are digital. On the one hand, this is good, but on the other hand, it can make some difficulties for their work. For example, finite number of the signal is quantized bits (levels) may prevent one from accurately setting the required gain value when its level changes sharply. This effect can be observed when talking on a mobile phone, and one of the subscribers turns the hands free mode on or off. In the first seconds after this there is almost always an intense echo.

3. It is necessary to form a mixture of the measuring signal and noise.

If white noise is specially added to the received signal, it will certainly make difficulties for the echo canceller operation. The noise presence in the input mixture will prevent echo compensator from correctly adjusting the gains in different frequency bands, like as in any adaptive device. Adding so-called “comfort noise” at the receiving phone will further complicate the echo canceller task. As a result, complete echo cancellation may not occur.

To check these assumptions, experimental studies were carried out. Let us consider their results in the same order.

1. To identify higher harmonics, a spectral analysis of the echo signal at various its levels were carried out. The typical spectrogram is shown in Fig. 2. The figure clearly shows the third harmonic of the probing signal with a level of about 10% from first one.

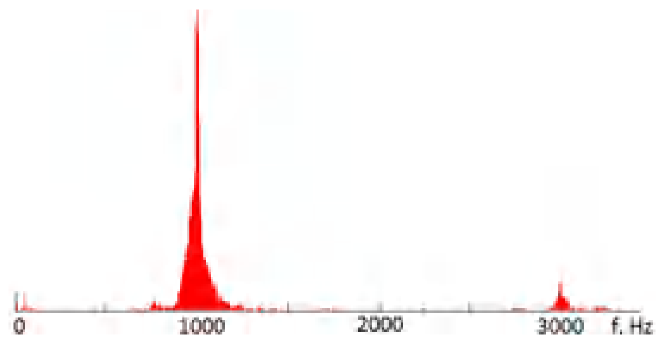

Fig. 2

But, as additional measurements have shown, this harmonic appears even at the transmitting stage an intense probing signal. When it weakens, the third harmonic disappears in the probing signal and, accordingly, in the response one. It is possible that some nonlinear distortions also occur at the echo formation stage, but it is quite difficult to detect them against the background of the original distortions. Therefore, this method is hardly applicable to bypass the echo canceller.

2. To check the effectiveness of a sharp signal level change, measuring signals were generated with a smooth increase in the level and with a sharp change (Fig. 3, blue), following one after another. The rectangular pulse had 100 ms duration, 1000 Hz filling frequency and amplitude of 1.5 V. A linearly increasing pulse with the same duration and filling frequency as a rectangular one, the filling amplitude increases linearly from 0 to 1.5 V in 100 ms.

The echo signal is shown in Fig. 3 in red. We can seen from the figure, the echo response to a rectangular pulse is approximately 15 times greater than to a linearly increasing one. You should also pay attention to the shape of the echo response to a rectangular pulse. It initially increases sharply, and from about the 15th millisecond it begins to decrease. This indirectly indicates the response time of the echo canceller.

3. To analyze the noise impact, a measuring signal was generated with the addition of noise and exactly the same signal, but without it.

As the experiment showed, adding noise actually contributed to obtaining a stable echo. In Fig. 4 shows an oscillogram obtained during the same telephone connection, with and without noise. As can be seen, the echo after the first, second and third pulse is observed very clearly.

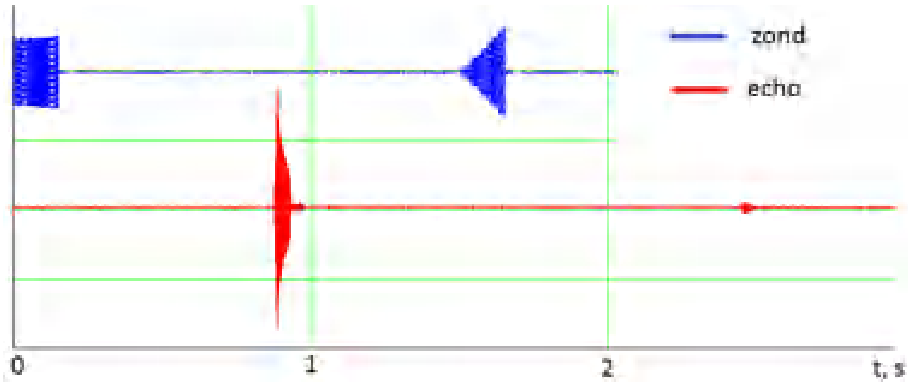

Fig. 3

Moreover, even after turning off the noise, another (fourth) pulse makes a very intense echo. Apparently, this is due to the fact that the echo canceller has not yet had time to adapt to the silence in the pauses between pulses and correctly adjust its coefficients. But after the fifth pulse the echo is barely noticeable, after the 6th and 7th it is completely absent.

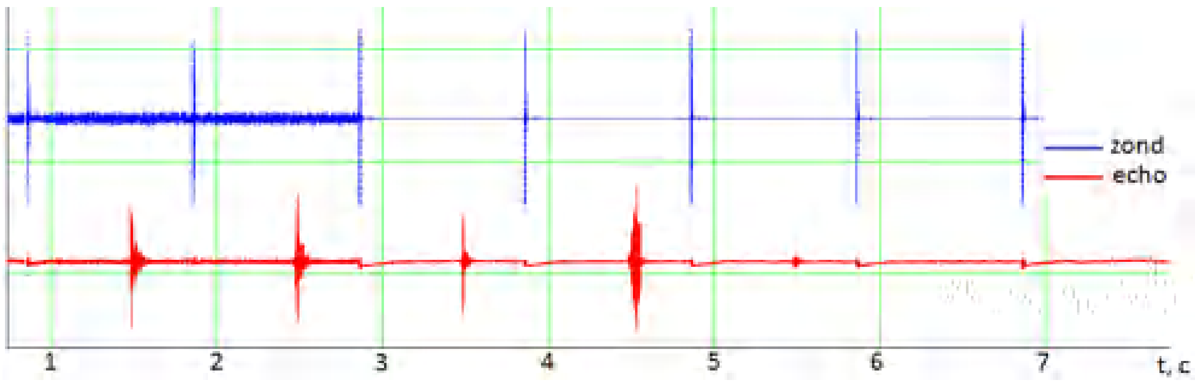

Fig. 4

Thus, it is shown that a mixture of white noise with a probing signal promotes better echo measurement indeed.

As a result of the work, it was shown that a sharp change in the level of the probing signal, as well as the mixture of the probing signal with noise, can be used to bypass echo cancellers and effectively measure the EE delay.

References

1. Ovcharenko D.R., Khizhnyak P.P. Measuring signal for electric echo analysis for the technical information security tasks // Радіоелектроніка та молодь у XXI століттй : матеріали 27-го Міжнар. Молодіж. форуму. Харків,. 2023. Т. 3. С. 196-197

2. ITU-T G.168. Digital network echo cancellers. April 2015.