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DEVELOPMENT OF BINAURAL TIME-DELAY APPARATUS FOR IMPROVING INTELLIGIBILITY OF SPEECH

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FOREWORD

This research was conducted in the Audiology and Hearing Conservation Function of the Otolaryngology Branch under task No. 775508 from July 1970 to July 1971. The paper was submitted for publication on 7 October 1971.

This report has been reviewed and is approved.

EVAN R. GOLTRA, Colonel, USAF, MC
Commander

ABSTRACT

A variety of electroacoustic instruments and devices have evolved in attempts to improve the perception and discrimination of aural signals and messages. This report describes instrumentation that delivers binaurally time-delayed signals that tend to enhance the intelligibility of speech signals delivered to subjects. The electroacoustic device reported in this paper can be used to improve the intelligibility of desired signals when immersed in masking (interfering) noise. The device used to achieve binaural time delays encompasses completely variable delays ranging from 0 (in-phase) to 1500 msec. This device has proved of considerable value in situations where desired speech signals coexist with masking or other interfering noises, such as voice recordings obtained within cockpits of aircraft. Details of the device and practical applications of the binaural time-delay phenomenon are discussed.

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I. INTRODUCTION

The human auditory system can perceive and process a multitude of acoustic stimuli. Man normally possesses a binaural, or two-ear, system that offers several unique advantages: the source of acoustic disturbances can be localized; the ability to attend (temporal) to desired signals can be enhanced; and the interfering effects of masking noises can be somewhat reduced. Since most acoustic stimuli to which man is responsive are propagated in the medium of air, slight time delays (of arrival) may enhance the perception of acoustic stimuli that exist in a 3-dimensional sound field. Sound travels at approximately 1100 feet per second (velocity of sound propagation in the medium of air at sea level); therefore, an acoustic phenomenon that approaches one side of the head arrives at the ear on the side nearest the sound source just an instant ahead of the time the signal is received on the opposite side. This phenomenon of sound propagation produces a spectrum of sound perception that is slightly different in the ear that receives the stimulus later because of the head shadow effect.

Man is surrounded by a multitude of acoustic stimuli, and most of the meaningful sounds to which he is responsive arrive at the ears with slight delays. These interaural time delays are extremely slight, yet they constitute differences great enough for the individual to localize, or lateralize, the relative location of the sound generator.

The literature contains numerous reports of listening situations where binaural time delays, usually less than about 7 msec., appear to enhance binaural listening tasks (2-10). One of the greatest problems associated with logical extensions of small amounts of time delay is in instrumentation. Many of the electroacoustic and mechanical methods used to achieve binaural time delays are either fixed in time (of delay) or the method introduces distortions (usually of spectrum) when rather long delays (above about 5 msec.) are desired (1).

A later report will provide a comprehensive review of efforts which have employed binaural time delays greater than 5 msec.

The potential value to be derived from delivering identical time-delayed acoustic signals to both ears may represent a significant advantage to the individual who must perceive and discriminate a desired signal in the presence of distracting or interfering noise (1, 3, 5, 7, 10).

It is the author's contention that many advantages are afforded by the type of binaural time delays provided by the apparatus described in this report.

II. APPROACH AND INSTRUMENTATION

The device described in this study evolved from efforts directed at developing a method with which high-quality auditory signals, such as speech, clicks, tones, etc., could be recorded and played back with controlled time delays ranging from 0 to 1500 msec.

An Ampex, 2-channel tape recorder (model 601) was modified so that a mechanical time-delay mechanism could be installed. Figure 1 illustrates

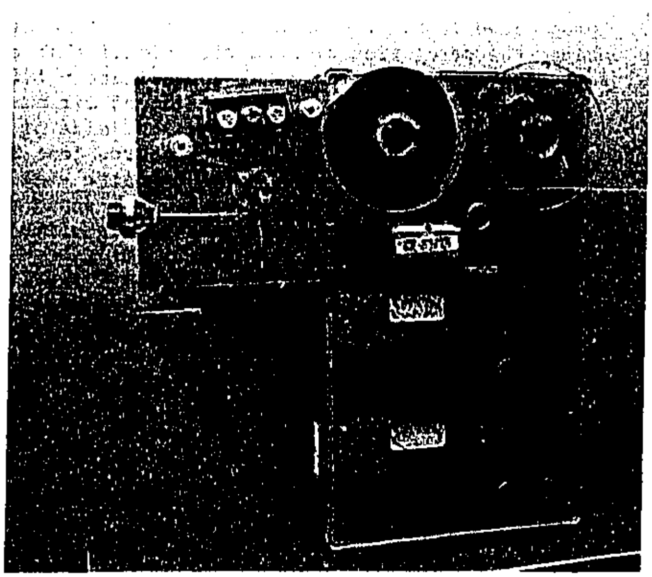

FIGURE 1

Modified 2-channel magnetic tape recorder-reproducer.

the modification. The aluminum panel shown at the upper left of the tape recorder contains an extra set of erase, record, and play heads, as well as tape guides, alignment rollers, and a micrometer that rotates the delay mechanism. Figure 2 shows the basic parts of the binaural time-delay apparatus. Two independent, but identical, sets of erase (E), record (R), and play (P) heads are used: one set for channel 1 and the other for channel 2. As noted, the channel 1 heads are located on the main body of the recorder and the channel 2 heads are mounted on the aluminum panel attached to the main body of the recorder. Identical signals are delivered to both channels during recording. During playback the length of the tape between channels 1 and 2 can be adjusted to achieve various amounts of delay. This procedure is extremely simple. The micrometer that attaches to the time-delay mechanism through a worm gear can be adjusted so that very small, but precise, lengthening or shortening of the tape can be accomplished. The time-delay mechanism is circular (see fig. 2), and the outer rim is cut to provide alignment and meshing with the worm gear

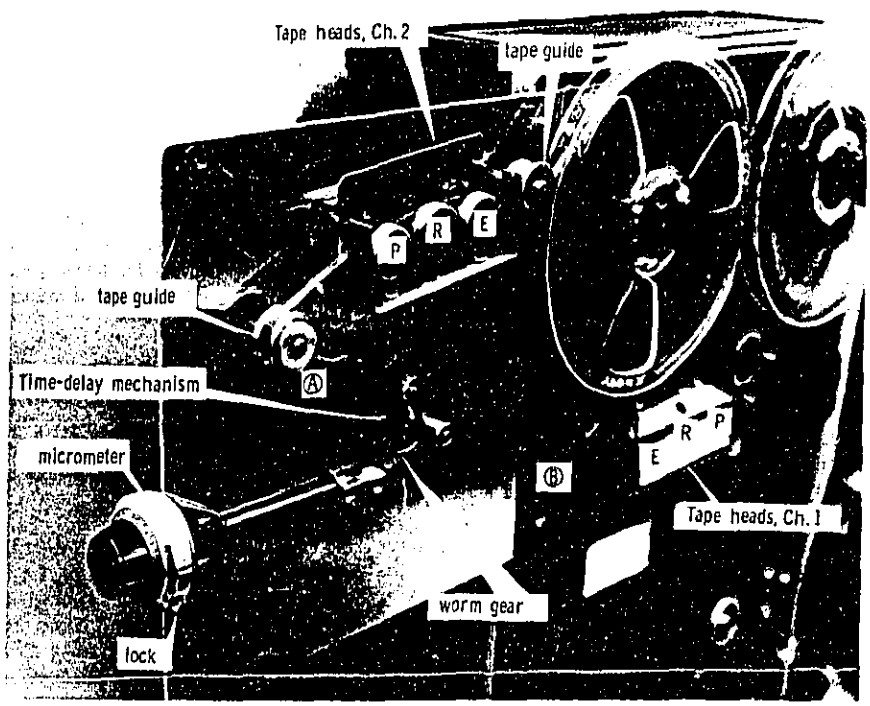

FIGURE 2

Detail of biaural time-delay apparatus.

connected to the shaft of the micrometer. Two roller guides are attached to the baseplate of the time-delay mechanism so that the tape can easily travel between points A and B (shown in fig. 2). Lengthening or shortening of the tape can be achieved between these points. Figure 2 clearly shows the path traveled by the tape. The tape travels from the supply reel (7-in. dia., 1/4-in. tape), which rotates counterclockwise, passes under a round tape guide that is machined to 1/4-in. inside diameter, and rotates (thereby reducing friction). The tape passes across three heads (the erase head, which is full-track, is not connected) and then around a second rotating tape guide that is also machined to 1/4-in. inside diameter. From this point, the tape threads across the two round guides attached to the base of the delay disc and then passes the alignment spool located in front of the heads of channel 1 (the erase head is not connected). Finally, it passes between the capstan and pressure roller and ultimately to the takeup reel. Electromagnetic signals delivered to (play) and from (record) channel 1 (electronic) are connected to the upper preamplifier, and those delivered to and from channel 2 (electronic) are connected to the lower unit. The connecting cables of channel 2 are shielded and pass from the preamplifier to the underside of the aluminum base on which the heads (channel 2) are attached.

The erase heads are not connected since both are full-track, and, if energized, the signals recorded on one-half of the tape (channel 2) would be erased when passed across the channel 1 erase head. Therefore, blank, or cleaved, tape can be used with the assembly described in this report. If desired, erase heads that allow only half-track erasure (and bias) can be installed.

The micrometer and the adjustable drum used to accomplish precise lengthening and shortening of the tape during playback provide very linear control of time delays to values of as much as 1500 msec. Through delays of as much as 600 msec., the micrometer produces 1-msec. delay for each 5 units of micrometer scale setting (ratio 5:1). Of course, these values are relative to 7.5 ips tape speed.

To calibrate the time-delay apparatus, a series of very short duration clicks are placed on the upper and lower tracks of a tape. To generate the clicks, a 10,000-Hz tone is delivered from a Hewlett-Packard model 201C audio-oscillator as shown in figure 3. The signal from the output of the oscillator is connected to the channel A input of a Grason-Stadler model 829S62 electronic switch. From the electronic switch the signal is routed through a 570,000-ohm, 1-watt resistor in order to reduce the peak voltage of the clicks. The signal emanating from the resistor box now enters a divider unit. One of the divided signals then goes to the input of channel 1, and the other divided signal goes to the input of channel 2 in the Ampex 601 recorder.

In order to obtain the type of signal required for time-delay calibrations, the Grason-Stadler electronic switch is triggered externally by two Tektronix model 161 pulse generators. The two pulse generators receive waveform signals from a Tektronix model 162 waveform generator, and all three units receive operating power from a Tektronix model 160A power supply. The Tektronix units are adjusted so that pulses of 1-msec. duration, with a rise-fall time of 0.25 msec., are achieved (see figure 4). These impulses are repeated once every 10 seconds and are recorded throughout the entire length of a 1200-ft. reel of Ampex No. 611, 1/4-in., 1-1/2-mil acetate tape. All of the impulses are recorded with the micrometer on the time-delay unit set and locked at 0.

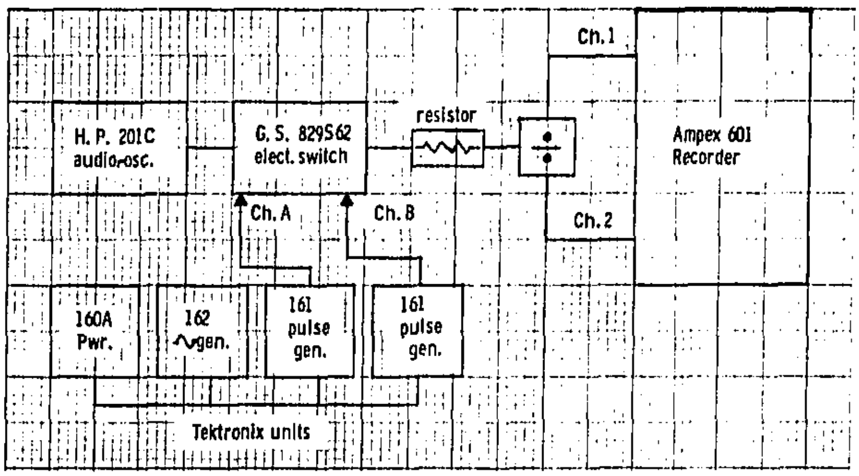

FIGURE 3

Block diagram of time-delay calibration apparatus.

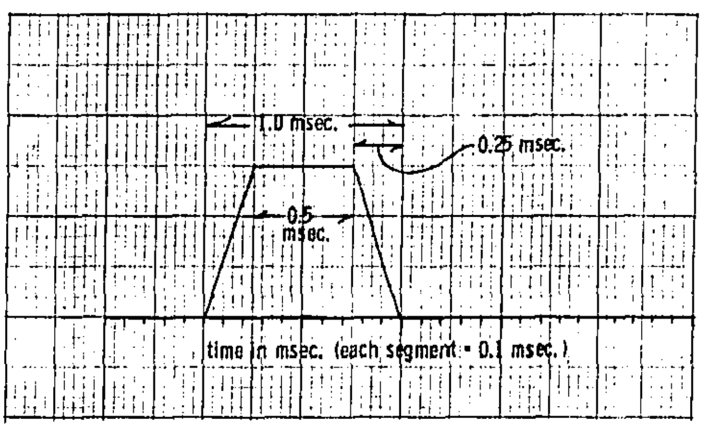

FIGURE 4

Calibration signal configuration.

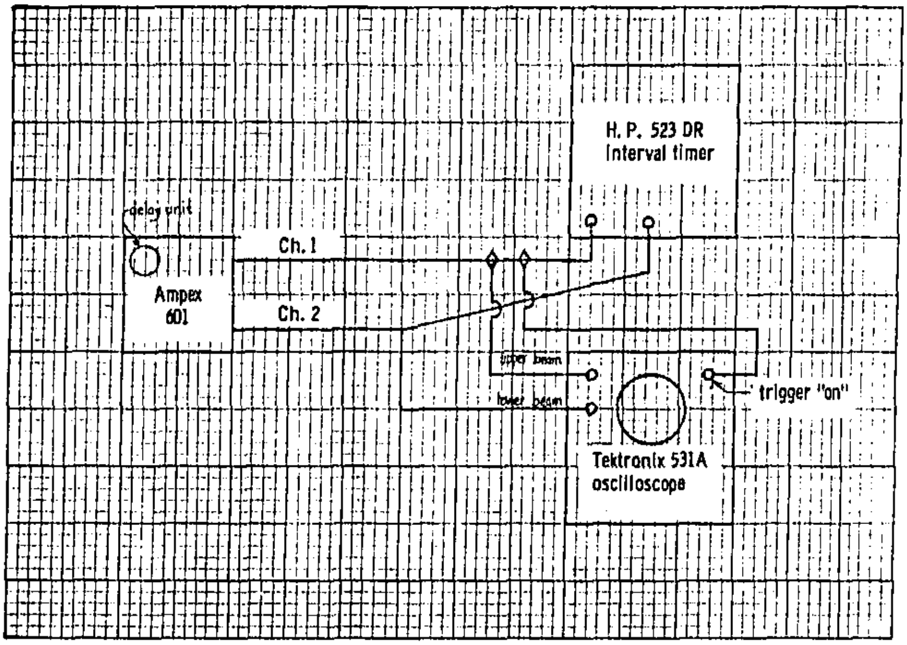

FIGURE 5

Apparatus for time-delay measurement.

Figure 5 shows the components used during playback to check time-delay settings and calibrate the micrometer-delay settings. Determination of time-delay calibration for the signals delivered from channels 1 and 2 of the Ampex 601 recorder is obtained by monitoring a Hewlett-Packard electronic timer (interval timer section) and a Tektronix model 531A dual-beam cathode-ray-tube oscilloscope.

The preceding of the two signals (impulses) delivered from the tape recorder is connected to the trigger ON terminal of the electronic timer, and the delayed signal is connected to the trigger OFF terminal. The time delays achieved are determined by direct readout on the appropriate time-interval numeric column in the electronic timer. At least 10 samplings were obtained at each 10-micrometer unit setting for time delays from 0 through 1500 msec.

Channel 1 output from the Ampex 601 was used to trigger the Tektronix scope, and a second connection is fed to the upper-beam trace input. The output from channel 2 was connected to the input terminals of the lower-beam trace. The scope traces were aligned so that finite time-delay determinations could be made, especially for delays ranging from 0 through 10 msec. Time-delay values were determined by use of the time-scale grids placed over the face of the cathode-ray tube.

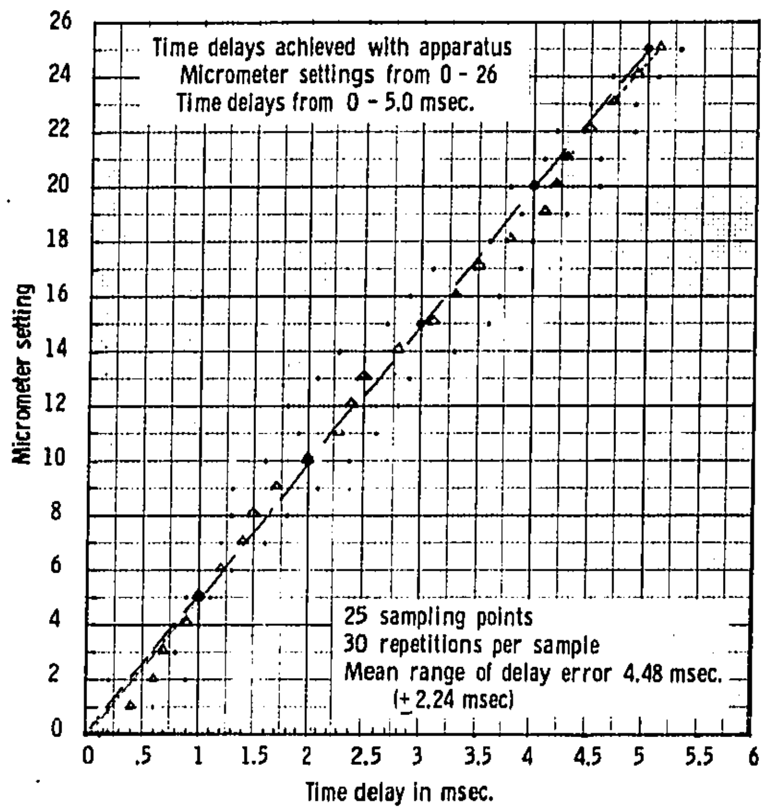

FIGURE 6

Relationship of micrometer setting to time delay.

Figure 6 shows values of time delay obtained with the time-delay device fitted on the Ampex 601 recorder. Although the mechanism provides delays up to 1500 msec., the data shown in figure 6 show the relationship between measured values of delay and micrometer settings ranging from 0 through 5 msec. The data shown in figure 6 were obtained by using 25 sampling points (micrometer settings) and measuring 30 repetitions per sampling point. The range of delays measured for a given sampling are identified by two small dots (the left dot representing lowest measure of time delay and the right dot identifying the greatest amount of delay).

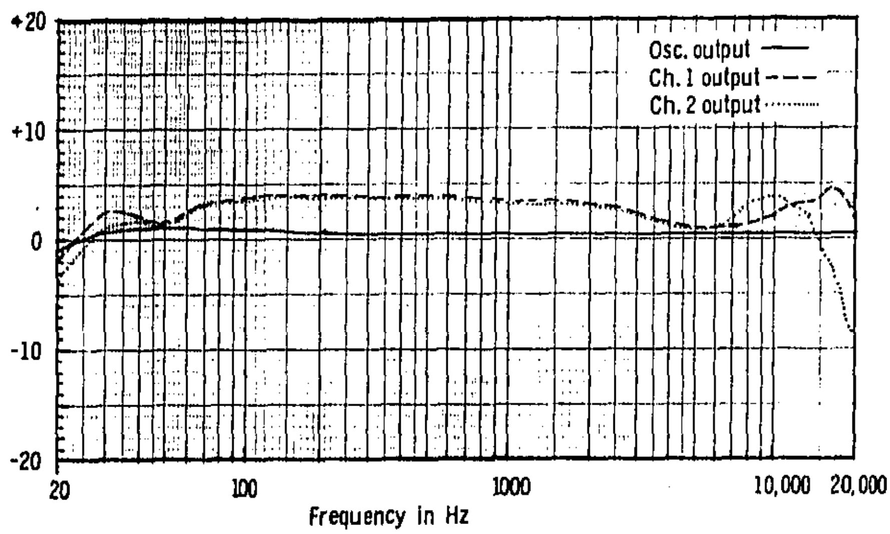

FIGURE 7

System pure-tone frequency response characteristics.

Figure 7 shows the frequency response of both channels. It is apparent that the modifications employed to achieve time delays have little influence on the response (fidelity) characteristics of the Ampex 601 recorder.

III. CONCLUSION

The potential value of an electroacoustic device of the type described in this report appears self-evident. Binaural time delays of the type provided by this device may be of considerable value in several fields of research. Lengthy delays (of 10 to 100 msec.) may be of assistance in neurophysiologic (research and diagnostic) studies of neural auditory pathways, especially when questions of peripheral vs. central processes of auditory perception are concerned. The possible improvement of speech discrimination in the presence of masking noise appears most promising. Long delays, in the range of 40 to 60 msec., may enhance the perception of speech discrimination among persons with bilateral hearing loss. Cortical processing of auditory stimuli may be more easily identified and assessed using electroencephalographic technics by which distinct periods of time delay can be used to distinguish right from left hemispheric activity. Binaural time delays, especially those greater than 10 msec. but less than 100 msec., may prove of considerable help in accomplishing auditory training of the hard-of-hearing (those with some degree of binaural hearing).

Other areas of interest include aural stimulation of vestibular responses when time delays vary from side to side (right to left and vice versa). Since this device allows delivery of delays on either side (timewise) of zero (in phase), an interesting phenomenon of vestibular orientation, or disorientation, can be elicited. Apparently, presenting the leading signal alternately between ears creates an illusion of turning — an illusion that can be most upsetting in some individuals. Also, the acoustic phenomenon created by using different delays (usually from 10 to 150 msec.) in both circumaural and sound-field listening situations enhances the qualitative character of many types of acoustic stimuli, especially music.

The device described in this report will be used to investigate a variety of applications. Efforts will be expended to identify and define parameters of time delay that appear advantageous for situations and tasks routinely encountered by Air Force personnel who must perform a variety of listening tasks.

REFERENCES

1. Anthony, W. P., and D. C. Gasaway. Rehabilitation of the nerve deaf patient: The binaural time-delay stimulus. Laryngoscope 67:371-373 (1957).

2. Blodgett, H. C., W. A. Wilbanks, and L. A. Jeffress. Effect of large interaural time differences upon the judgment of sidedness. J. Acoust. Soc. Am. 28:639-643 (1956).

3. Cherry, E. C., and B. M. A. Sayers. Human crosscorrelator — a technique for measuring certain parameters of speech perception. J. Acoust. Soc. Am. 28:889-895 (1956).

4. David, E. E., Jr., N. Guttman, and W. A. van Bergeijk. Binaural interaction of high-frequency complex stimuli. J. Acoust. Soc. Am. 31:774-782 (1959).

5. Hirsh, I. J. Auditory perception of temporal order. J. Acoust. Soc. Am. 31:759-767 (1969).

6. Kryder, K. D. The effects of noise on man, pp. 39-42. New York: Academic Press, 1970.

7. Pollock, I., and W. J. Trittipoe. Binaural listening and interaural noise crosscorrelation. J. Acoust. Soc. Am. 31:1250-1252 (1959).

8. Schubert, E. D. Some preliminary experiments on binaural time delay and intelligibility. J. Acoust. Soc. Am. 28:895-901 (1956).

9. Snow, W. B. Effect of arrival time on stereophonic localization. J. Acoust. Soc. Am. 26:1071-1074 (1954).

10. Webster, F. A. The influence of interaural phase on masked thresholds. J. Acoust. Soc. Am. 23:452-462 (1951).

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13. ABSTRACT

A variety of electroacoustic instruments and devices have evolved in attempts to improve the perception and discrimination of aural signals and messages. This report describes instrumentation that delivers binaurally time-delayed signals that tend to enhance the intelligibility of speech signals delivered to subjects. The electroacoustic device reported in this paper can be used to improve the intelligibility of desired signals when immersed in masking (interfering) noise. The device used to achieve binaural time delays encompasses completely variable delays ranging from 0 (in phase) to 1500 msec. This device has proved of considerable value in situations where desired speech signals coexist with masking or other interfering noises, such as voice recordings obtained within cockpits of aircraft. Details of the device and practical applications of binaural time-delay phenomenon are discussed.

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