

TX 3093T

X2532

March 24, 1959

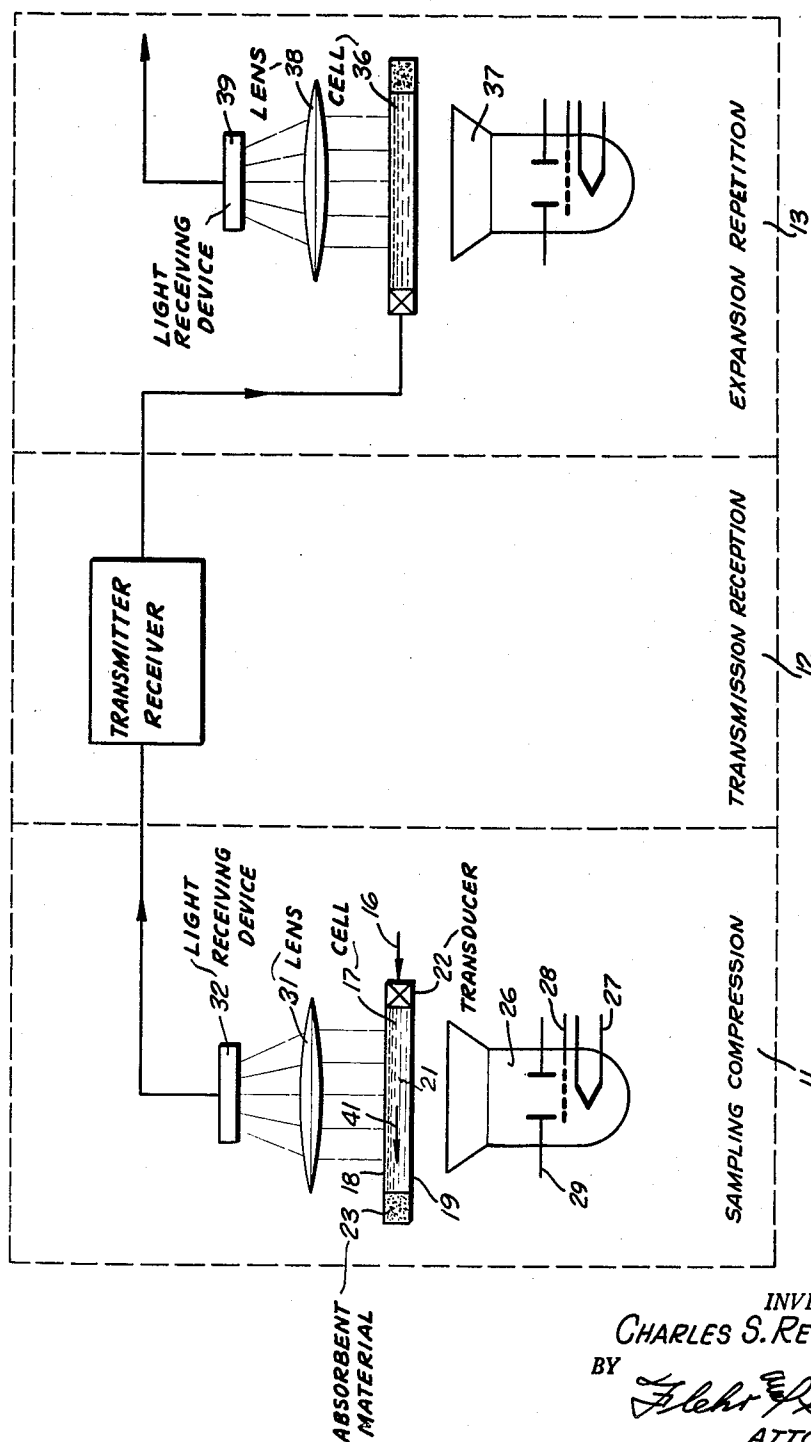
C. S. REIS

2,879,337

APPARATUS FOR FREQUENCY COMPRESSION AND EXPANSION

Filed Jan. 3, 1955

2 Sheets-Sheet 1



INVENTOR.

CHARLES S. REIS

BY *Flehr & Swain*
ATTORNEYS

2879337
OR IN 179/15.55R

2,879,337

2 Sheets-Sheet 2

FIG. 2

FIG. 3

INVENTOR.
CHARLES S. REIS
BY *F. Ehr & Swan*
ATTORNEYS

1

2,879,337

APPARATUS FOR FREQUENCY COMPRESSION AND EXPANSION

Charles S. Reis, San Bruno, Calif.

Application January 3, 1955, Serial No. 479,619

3 Claims. (Cl. 179—15.55)

Generally, my invention relates to a method and apparatus for frequency compression and expansion. More particularly, my invention relates to a method and apparatus for frequency compression and expansion of speech.

In live, connected speech, the duration of basic speech elements (phonemes) exceeds the minimum required for perception by a listener. Analysis of the wave form of speech shows that the basic wave pattern of an element will repeat. Thus, if a small sample is obtained which includes this redundant wave pattern and reproduced and repeated until the original time base is restored, the element will be synthesized. It has been shown, statistically, that in average speech there are approximately ten such elements per second (phonetic rate). Thus, if representative samples of the redundancy are obtained at the rate of ten per second or more, transmitted or recorded, and then repeated to restore the original time base, intelligible speech is cognated.

In one particular experiment, the sampling frequency fulfilled the above requirements and a 20% sample was obtained. After reproduction and repetition to restore the original time base, the reproduced speech was intelligible. Thus, it is seen that by properly sampling, the duration of speech may be considerably reduced prior to transmission and then restored to its original time base at the receiving end. Consequently, more intelligence may be transmitted during a given amount of time, permitting greater utilization of existing communication systems.

Another way in which existing communication systems may be more fully utilized is to reduce the channel band width required for the communication of the intelligence, thus permitting more channels for a given frequency band. It has been estimated that a band of frequencies 100 cycles wide with a signal-to-noise ratio of 20 db is sufficient for transmission of telephone quality speech.

One method for time or frequency compression and expansion employs magnetic tape apparatus. This apparatus is provided with a continuous loop tape and a revolving member having a plurality of magnetic heads spaced about its periphery. The relative velocity between the tape and the heads and the spacing of the heads determine the sampling frequency, the frequency compression or expansion, and the interval of each sample. Playback apparatus converts the recordings back into intelligible speech by proper frequency expansion and repetition of the samples to restore the original time base.

Magnetic tape apparatus has many disadvantages. For example, the motion of the tape and revolving heads must be accurately controlled in the recording and playback operations, and the two operations must be accurately synchronized. The equipment is bulky, requiring a large space for its installation, expensive to construct, and requires constant maintenance. Further,

2

the amount of sampling is limited by the physical dimensions of the heads.

It is an object of my invention to provide a method and apparatus for frequency compression and expansion.

It is another object of my invention to provide a method and apparatus for sampling a frequency spectrum.

It is another object of my invention to provide a method and apparatus for sampling a frequency spectrum in which the sampling intervals are easily controlled.

It is another object of my invention to provide a method and apparatus for sampling a frequency spectrum in which the sampling frequency may be easily controlled.

It is another object of my invention to provide a method and apparatus in which the compression and expansion of frequency may be readily controlled.

It is another object of my invention to provide a method and apparatus in which the compression and expansion are instantly cognated.

It is a further object of my invention to provide a method and apparatus in which the sampling and frequency compression and the frequency expansion and repetition are easily synchronized.

It is still a further object of my invention to provide a method and apparatus of the above character which is inexpensive to construct, does not require constant maintenance, and which occupies a minimum of space, and which may be used in conjunction with existing communication equipment.

Other objects and advantages of this invention will be apparent from the description thereof made in connection with the accompanying drawings.

Referring to the drawings:

Figure 1 shows a complete system for sampling and compressing, expanding and repeating the sampled frequency;

Figure 2 is a perspective view of my system; and

Figure 3 is a schematic illustration of the operation of my apparatus.

Generally, I convert the frequency spectrum into a compression and rarefaction wave train travelling in a liquid. The optical density of the liquid varies in accordance with the compression and rarefaction regions of the wave train. I then scan the liquid with a source of electromagnetic energy, such as a light beam. The amount of energy transmitted transverse to the liquid is dependent upon the optical density of the liquid. A transducing device receives the energy transmitted by the liquid and converts it into an electrical current which has amplitude variations dependent upon the density and a frequency determined by the relative velocities of the light beam and the wave train.

Referring to Figure 1, the block 11 represents apparatus which incorporates my invention and which samples and compresses the frequency spectrum. Block 12 represents a transmitting system which may comprise a telephonic communication system, or a radio communication system. Block 13 shows apparatus of my invention which incorporates means for expanding the frequency spectrum and repeating the expanded frequency samples.

The electrical frequency spectrum to be sampled is applied to the input terminal 16 of the glass-sided storage cell 17. The cell is provided with transparent walls 18 and 19 and is filled with a transparent liquid 21. An electromechanical transducer 22 is inserted in one end wall of the cell and placed in contact with the liquid. The electrical excitation of the transducer causes a dilation and contraction in the direction of its thickness. These vibrations are transferred to the liquid and cause

3

a series of compression and rarefaction waves which move forward from the transducer at a velocity determined by the particular liquid under consideration. Thus, the density of the liquid varies in the direction of travel in a manner which corresponds to the frequency to be sampled. At the far end of the cell, absorbent material 23 is provided to absorb the waves traveling down the liquid. Attenuation of the waves as they travel is negligible for the distances employed. The variations in density of the liquid provide a change in its transmission characteristics and index of refraction along its length.

Means are provided on one side of the storage cell for sweeping a recurrent energy beam along the cell at a predetermined velocity and recurrence rate. For example, the beam may be a short persistence spot formed on the screen of a cathode ray tube 26, having cathode element 27, focusing elements 28, and deflection plates 29. A sweep generator supplies a deflection voltage which causes the electron beam to travel across the fluorescent screen (see Figure 2). Thus, it is seen that the cathode ray tube provides a light source which can be made to sweep along the storage cell at any desired velocity. By providing appropriate controlled (or synchronized) delay circuits in the sweep generator, the repetition rate of the sweep may be accurately controlled. Although I prefer to use a cathode ray tube, it should be understood that other means such as revolving mirrors or revolving lenses may be employed to form a recurrent scanning source.

On the other side of the storage cell, a lens 31 intercepts the transmitted energy and focuses the energy on the receiving device 32. This device generates an electrical current which varies in conformity with the energy transmitted across the liquid at any given instant. When a scanning light is employed, the receiver may be a photosensitive device, for example a photosensitive transistor, phototube or photocell.

The apparatus 13 is similar to the apparatus 11 and comprises a storage cell 36, a cathode ray tube 37, lens 38 and receiving device 39.

The apparatus 12, which is labeled transmission and reception may be a combination of transmitter and receiver, a tape recorder with playback means, conventional telephone communication circuit, or any other suitable type of communication system.

Operation of my apparatus is as follows: the intelligence to be sampled is converted into electrical current variations and supplied to the line 16. Thus, if speech is to be sampled, it is converted into electrical current variations by means of a microphone and suitable amplifiers amplify the voltage to provide a voltage sufficient to drive the crystal. These electrical current variations are converted to rarefaction and compression waves in the liquid which progress as a wave train in the direction indicated by arrow 41. The compression and rarefaction regions correspond to the frequency of electrical current applied to the crystal and have a density which correspond to the signal amplitude. The light beam is caused to scan the cell in the same direction of propagation at a velocity which is less than the velocity of propagation of the waves along the liquid. Thus, there is a relative velocity difference between the light beam and the waves travelling down the storage cell.

In Figure 3, I have shown an input frequency 51 made up of elements 1 through 18. Only the intervals of the elements are shown, but the signals which they represent may have any frequency and amplitude characteristic. The waves 51 are shown at 52 as they appear in the storage cell at various instances of time t_0 - t_{18} . The spot of light 53 is shown at the positions it will have at these instances of time assuming a scanning velocity equal to one-half of the velocity of the wave train and scanning which is repetitious without delay between scans. The velocity vector V_t represents the direction and velocity

4

of the wave train and vector V_s represents the velocity and direction of the scanning spot 53. The output of the receiver 32 is shown at 54. For the condition assumed ($V_s = \frac{1}{2} V_t$) the sampling which results is a 50% sampling, and the frequency of the elements is divided by 2, as shown at 54. It is to be noted that by decreasing the relative velocity difference of the wave train and scanning beam, the frequency division is increased, i.e., greater frequency compression. If V_t is the velocity of the wave train and V_s the velocity of the scanning beam, V_s may be expressed as some constant times the velocity V_t or

$$V_s = k V_t \quad (1)$$

The frequency which results for any relative velocity may then be expressed as

$$f = f_0(1-k) \quad (2)$$

where f is the compressed frequency, f_0 is the original frequency, and k is the constant in Equation 1. For continuous, repetitive scanning, the percent sampling is also related to these velocities and may be expressed as:

$$\text{Percent } S = 100(1-k)$$

Where scanning is not continuously repetitive but includes delays or intervals, the percent sampling is dependent upon both the relative velocity of the wave train and scanning light and the scanning frequency.

In the example assumed for purposes of illustration, the frequency is divided by two and the time base remains the same; thus, a channel having one-half the frequency band is required for transmission of the original frequency spectrum.

For expansion it is necessary to reconvert the sampled and compressed frequency, the scanning velocity is made greater than the wave train velocity by scanning in an opposite direction. Referring again to Figure 3, I have shown the output of the receiver 32 at 54. The output of this receiver is supplied to transmission means of the type previously described and then applied at the receiving end to a storage cell similar to the one previously described. V_t indicates the direction and velocity of the wave train and V_s the direction and velocity of the scanning spot 56. Here again the various instants of time are represented by the schematic storage cells shown, and the relative position of the scanning beam is shown for the particular instances of time chosen. The output of the transducer 39 is shown at 57. Scanning is opposite to the direction of travel of the wave train. In the particular instance shown, the velocity V_t is equal to the velocity V_s and with these velocities, the frequency of each segment is doubled, the time base of each sampled element is divided by 2 (i.e., restored to the original time base), and the samples are repeated. Thus, if the original sampling was statistically correct, the resulting output will, in general, give intelligence which corresponds quite accurately to the input. For the frequency expansion, the frequency of the output wave is now given by

$$f_0 = f / 1-k$$

Synchronization between the compression and expansion may be readily obtained by transmitting a synchronizing signal which will trigger gate and time base controlled networks that control the scanning velocities of the light beam.

Thus it is seen that I have provided a method and apparatus in which the sampling may be easily controlled and in which the relative velocity of the scanning beam and the wave train travelling down the liquid determine the amount of compression or expansion of frequency. The sampling frequency and interval may be easily varied by controlled delay of the scanning beam or it may be varied by placing an aperture between the light beam and storage cell so that only a small portion of the wave train travelling down the cell is sampled.

I claim:

1. In apparatus of the character described, a storage cell filled with a liquid connected to receive a frequency spectrum whereby a rarefaction and compression wave train corresponding thereto is formed in the cell liquid, an energy beam which scans the said cell, and a photo-sensitive transistor for receiving the energy transmitted by said cell having variations in intensity which correspond to the density of liquid scanned and converting the transmitted energy into electrical current variations corresponding to the variations in intensity.

2. In apparatus of the character described, a storage cell filled with liquid connected to receive a frequency spectrum whereby a rarefaction and compression wave train corresponding thereto is formed in the liquid, a light beam serving to scan the said cell in the direction of the wave train formed on the screen of a cathode ray tube, lens means for focusing the energy transmitted by said cell, and receiving means for receiving the focused energy and converting the said energy into electrical current variations which correspond to the variations in the density scanned by the beam.

3. In apparatus of the character described, a first storage cell filled with liquid connected to receive a frequency spectrum, whereby a rarefaction and compression

wave train corresponding thereto is formed in the liquid, a light beam adapted to scan the said cell formed by a cathode ray tube, a first photo-sensitive transistor for receiving the energy transmitted by said cell and converting the transmitted energy into electrical current variations which correspond to the density of the liquid scanned by said light beam, transmission and reception means connected to receive said current variations, a second storage cell filled with liquid connected to receive said transmitted electrical current variations whereby a compression and rarefaction wave train corresponding thereto is formed in said liquid, a second light beam adapted to scan the said cell formed by a cathode ray tube, and a photosensitive transistor for receiving the energy transmitted by said cell and converting the same into electrical current variations which correspond to the original frequency spectrum.

References Cited in the file of this patent

UNITED STATES PATENTS

1,671,151	French et al.	May 29, 1928
2,312,835	Hansell	Mar. 2, 1943
2,509,545	Walton	May 30, 1950
2,513,520	Rosenthal	July 4, 1950
2,623,942	Schlesinger	Dec. 30, 1952