Oct. 17, 1939. A. W. FRIEND 2,176,526

METHOD OF AND MEANS FOR SIGNAL TRANSMISSION

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Fig. 1.

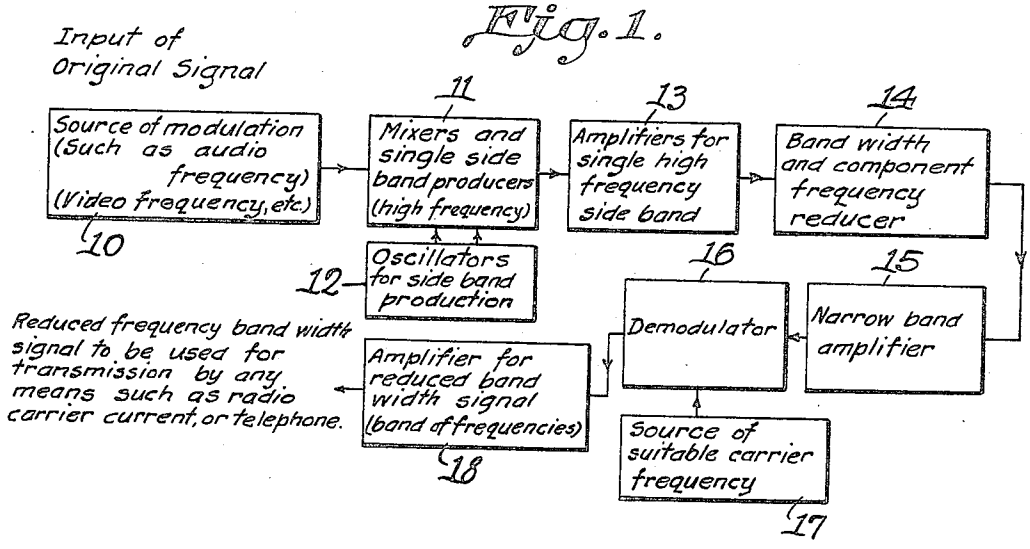
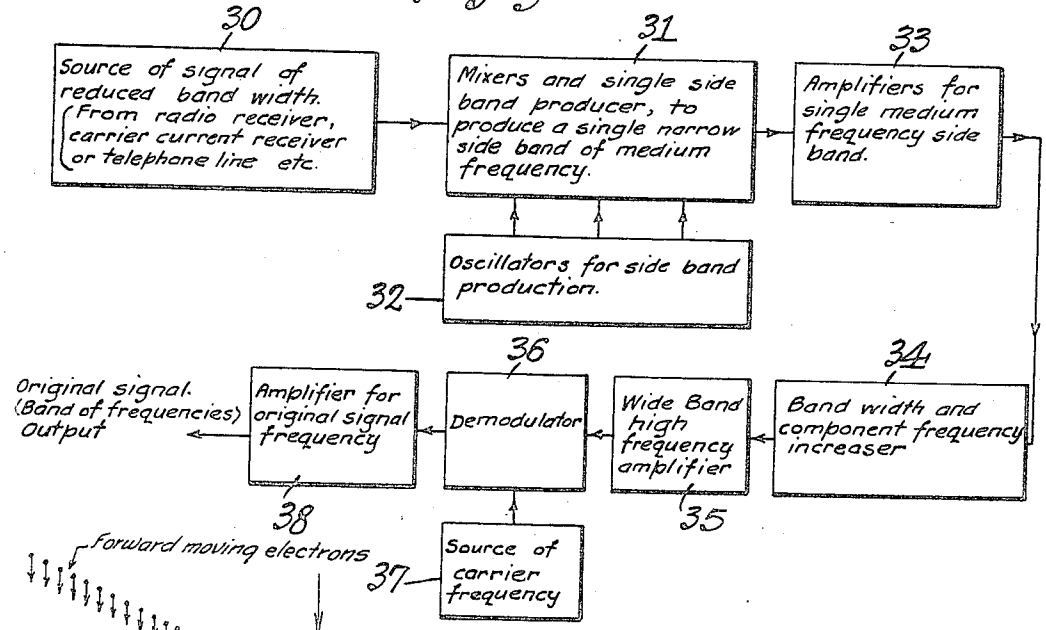


Fig. 2.



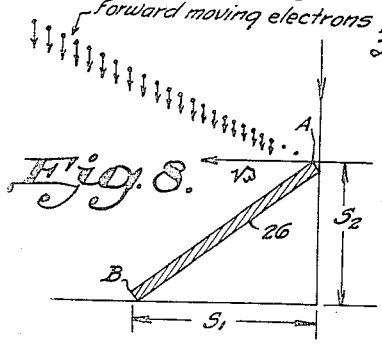


Fig. 3.

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Fig. 3.

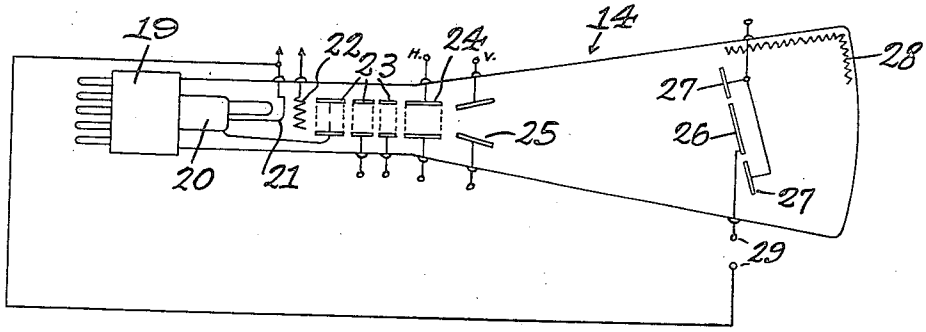


Fig. 4.

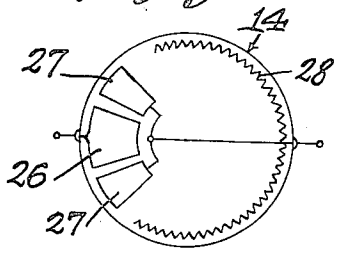


Fig. 5.

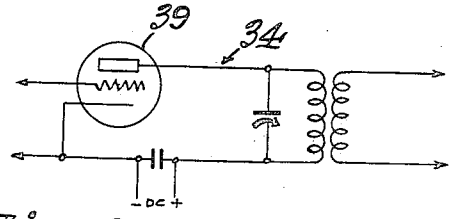


Fig. 6.

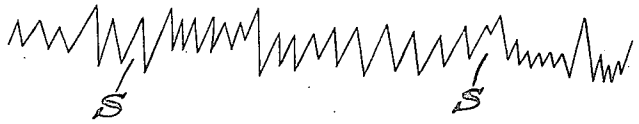


Fig. 7.



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METHOD OF AND MEANS FOR SIGNAL TRANSMISSION

Albert Wiley Friend, Morgantown, W. Va.

Application August 31, 1937, Serial No. 161,854

7 Claims. (Cl. 178—44)

My invention relates to signal transmission generally and more particularly to methods of and means for compressing the band width of radio, telephone and carrier current communication systems for the accommodation of services in greater number.

Much recognition has been accorded the growing need for compressing the band width to increase the number of channels for communication purposes or for producing better recorded signals and, in this connection, the general practice has been to produce so-called sub-harmonics of a single frequency by locking the higher harmonics of an oscillator with the original frequency and then making use of the lower harmonics or the fundamental of the oscillator as the "sub-harmonic" frequencies. This can be done very easily for any single frequency but not for a band of frequencies such as that used for communication purposes. The real problem therefore has been and still is that of dividing the band of frequencies by a number n and the instant invention solves this problem by dividing or multiplying the frequency band width by such number which may be either integral or fractional.

The invention therefore has for an object to provide a method of signal transmission which consists in first compressing or reducing a signal band width, then transmitting the resultant band width, and thereafter effecting its reception either through amplification in its compressed or narrowed state or by expanding it back to its normal value.

Briefly, this object is to be attained by compressing a signal band by means of a sort of Doppler effect arrangement, transmitting the narrowed band width signal and re-expanding the band width at a receiver either by a special harmonic generator or another Doppler effect arrangement.

In order to more readily comprehend the invention, the basic theory of which is that a wave form can be pulled apart so as to appear as a representation of a lower frequency, the required "pulling apart" is to be accomplished by creating alternate stretched out and compressed or squeezed sections of the time scale of the wave. Here, the stretched out sections are to be looked upon as portions of the wave in which the frequency of each component wave has been lowered by the equivalent of dividing by a factor n and whereby a new frequency is produced. In the compressed or squeezed sections, there will have been a multiplying of all frequencies by another factor m and if this factor is equated to infinity, the interval will become equal to zero and the frequency of that interval will have become infinite. In other words, the signal wave will have these compressed or squeezed sections removed from it. Thus, a picture is presented of the original signal wave, of normal arrangement, having had some portions greatly stretched out to reduce the frequencies of all frequency components and the intervening compressed or squeezed sections eliminated, while the remaining portions stretch out so as to eliminate all gaps and produce a resultant uniform band frequency division, with the advantage that signal continuity is maintained.

With the foregoing and other objects and advantages in view, the invention resides in the methods and instrumentalities as will be hereinafter more fully described, set forth in the appended claims, and illustrated in the accompanying drawings, in which:

Figure 1 is a diagram showing a transmitter including means for compressing the frequency band width,

Figure 2 is a similar view showing a receiver including means for expanding the frequency band width to normal value,

Figures 3 and 4 are other similar views showing a form of band width and frequency reducer per se for use as the compressing means of the transmitter,

Figure 5 is yet another similar view showing a form of band width and component frequency increaser per se for use as the band expanding means of the receiver,

Figure 6 is a graph of a signal wave showing stretched out sections of its time scale;

Figure 7 is view similar to Figure 6 but showing squeezed sections of its time scale which are assumed to alternate with the aforesaid stretched out sections along the length of the wave; and

Figure 8 is a diagrammatical view of the fluid conductor stream collector or delay plate and depicting its relation to the scanning sweep of the conductor stream.

In carrying out the invention in accordance with the aforegoing, it will be obvious that the compressed and expanded sections or intervals of the signal wave must be large in comparison with a wave of the lowest frequency to be transmitted. As a consequence of this, a very high frequency single side-band of the same band width as that of the original signal is first produced and then both the band width and its various frequencies are divided by a factor n. For instance, a signal

of zero to five kc. (0.—5 kc.) band width can produce a single side band of 100,000 to 100,005 kc. and this can be cut to 10,000 to 10,000.5 kc. or a band width of only 0.5 kc. from the original band of 5 kc. width.

This is to be determined from a consideration of the wave form as illustrated in Figures 6 and 7, wherein it is assumed that certain sections S Figure 6 are stretched out while other sections S' Figure 7 are greatly compressed, the stretched sections S representing those portions of the signal in which the frequency of each component wave has been lowered by the equivalent of dividing by a factor n, so that for any frequency f a new frequency $f_n=\frac{f}{n}$ has been produced.

The stretched out sections S are in a predetermined ratio to the compressed section S' and the time interval of the latter, when they are discarded as contemplated, bears relation to the time interval of the former as to become zero, to all intents and purposes, so that the gaps created by their elimination are bridged over in a manner that a uniform band frequency division will result.

In order to accomplish this result, more or less conventional circuits and instrumentalities are employed in the make-up of the transmitter hook-up Figure 1 and the receiver hook-up Figure 2, the general nature and operation of which will be readily comprehended by those skilled in the art. The circuits and instrumentalities of the transmitter are, however, supplemented by a special type cathode ray tube as shown in Figures 3 and 4, and, in certain instances, those of the receiver by a band width and component frequency increaser as shown in Figure 5.

In the transmitter hookup Figure 1, the input of an original signal is impressed upon a source of modulation **10** such as audio frequency, video frequency, etc., coupled to a mixer unit **11** operating in conjunction with an oscillator unit **12** as a producer for a single high frequency side-band. The side-band thus produced is, in turn, impressed on an amplifier unit **13** and passed therefrom to a band width and component frequency reducer unit **14**. The narrowed frequency band is received from the reducer unit **14** by an amplifier unit **15** and is passed therefrom to a remodulator unit **16** operating in conjunction with a source of suitable carrier frequency **17**. From the demodulator unit **16**, the reduced width signal or band of frequencies passes to another amplifier unit **18** from whence the resultant signal can be transmitted by any suitable means (not shown), such as radio, carrier current, or telephone.

The before mentioned cathode ray tube as shown in Figures 3 and 4 constitutes the band width and component frequency reducer unit **14** in the transmitter hookup and is, in some respects, very similar to a television kinescope or oscillight, its electron gun being arranged to emit a stream of relatively slow moving electrons in a narrow beam that is modulated by a special electrode which functions to vary the number of emitted electrons while their velocities remain constant. The tube is mounted upon a usual multipronged base **19** to which control voltages are applied, and encloses the electron gun which consists of a support **20** carrying an electrically heated cathode **21** disposed in line with a series of electron beam forming and velocity control electrodes **23** and an interposed grid **22**. Mounted beyond the electrode group **23** is a beam rotating and reflecting electrode group **24—25**, and spaced from this latter group is a beam collector plate or anode **26** interposed between edge effect reducing plates or anodes **27**. The delay plate or anode **26** is made from a suitable conducting material and is preferably shaped to the form of a conical helix or a flat sector of less than one complete turn; the exact shape depending upon factors of operation to be discussed later herein. Spaced from the anodes **26** and **27** is a residual electron collecting anode **28** which is disposed in angular relation to the anodes **26** and **27** that it and the latter, in the present instance, are preferably in circular arrangement conforming substantially to the sweep of the electron beam emitted from the electrode group **24—25**. The output network of the tube connects the cathode **21** and the beam collector anode **26** to a pair of terminals **29** which pass the resultant narrowed wave band to the input side of the amplifier **15** of the transmitter Figure 1; the input of the wide band high frequency from the amplifier unit **13** being at the grid **22**.

In the operation of this cathode ray tube, the electron gun functions to produce and project a narrow beam of electrons to and through the electrode group **24—25** and the usual deflecting plates or coils of the tube being so energized as to cause the rotation of the electrode **25** to sweep the electron beam from the control electrodes **23** around or over the beam collector anode **26** with a circular scanning motion from the end nearest the source of the electron beam to the more distant end. During this process, each succeeding electron is required to traverse a greater path distance along the beam than the preceding one and so is delayed in such manner that the current picked up by the anode **26** will be of stretched time scale wave form having lower frequencies and band width than the modulating source. When the electron stream has traversed the anode **26** its length is greater than at the starting point so that when the starting end of the anode again intercepts the sweeping electron stream a portion of the beam will be trapped in between the starting and finishing points. This electron stream residue represents the sections S' of the signal wave graph Figure 7 which are to be eliminated. This residue is intercepted by the collecting electrode **28** and prevented from passing out through the signal circuit. A similar effect might also be produced by using a varying accelerating potential in the electron gun for changing the rate of travel of the signal bearing electrons to a plane collecting anode structure (not shown). It is also conceivable that some fluid conductor (not shown) might be used instead of an electron beam for accomplishing the same result. Again, another method of producing the result would be by means of a multi-element commutating device (not shown) connected to a time delay electrical network or line at many points. By such means the signal might be delayed progressively as the successive commutating elements com into contact with an electron beam or some liquid or solid contacting medium.

To complete the use of the signal thus acted upon for the reduction of its band width, the output of the band width and frequency reducer Figure 3 can be combined with a carrier wave of suitable frequency and then demodulated to give an audio or a video frequency of compressed band width for the purpose of modulating a

narrow band width transmitter. If this is not desirable, it is possible to amplify the compressed wave and transmit it direct.

Referring now to Figure 2, it is to be noted that the receiver hook-up shows that the input of the signal of reduced band width from a suitable source 30, such as, a radio receiver, a carrier current receiver, a telephone line or the like, is at a mixer unit 31 operating in conjunction with an oscillator unit 32 to produce a single narrow side-band of medium frequency which is passed to an amplifying unit 33. From the amplifying unit 33, the amplified narrow band passes to the band width and component frequency increaser unit 34 where the signal band is expanded to normal value. From the unit 34, the signal band is passed through the wide band high frequency amplifier unit 35 to a demodulator unit 36 which operates in conjunction with a source of carrier frequency 37. From the unit 36, the restored signal frequency band is passed to the output side of an amplifier unit 38.

In the receiver hook-up (Figure 2), a device similar to the band width and component frequency reducer 14 (Figures 3 and 4) can be employed to expand the previously compressed or narrowed band width by operating it with a reversed rotating sweep of the electron beam to effect the expansion of the band width to normal value. In lieu of this, however, another and perhaps a much better method is to expand the received compressed band width and increase each one of the component frequencies by passing it through a non-linear impedance so as to generate harmonics of each component frequency. By supplying a proper carrier frequency, the re-expanded signals can then be demodulated to reproduce the original signal.

As shown in Figure 5, this impedance has the form of a network which includes a non-linear vacuum tube amplifier 39 for the production of the required harmonic frequencies, the network being tuned to a single band of harmonics. In use, this impedance network would replace the band width and component frequency increaser unit 34 in the receiver hook-up shown in Figure 2.

The aforesaid Doppler effect is produced by requiring the signal to travel along a constantly increasing and decreasing length of electron beam which is caused to sweep over or scan the surface of the delay plate 26 (Figures 3 and 4) in a manner that will eliminate all possibility of gaps occurring in the transmitted or received signal wave; the delay plate 26 being arranged at an angle to the sweep of the electron beam for the purpose. In reducing the frequency and band width of the signal modulation on the electron beam, the sweep of the latter must be in a direction that its start is on the end of the delay plate 26 nearest the base 19 end of the tube. In progressing toward the more distant end of the delay plate 26, the electron beam gradually becomes longer at a certain known rate, thus producing the Doppler effect in the current picked up by the plate 26. The rate of scan or sweep of the electron beam and the velocity of the electrons in the beam is preferably so adjusted that just as the beam leaves the trailing or distant edge of the delay plate 26, another portion of the same beam will be in a position to strike the leading or near edge thereof.

As a concrete example, let it be supposed that the electrons in the beam are moving forward at the rate of 2×10^9 centimeters and that the electron beam is sweeping across the delay plate 26 at the rate of

$$\frac{10^{10}}{3}$$

centimeters per second, with the beam modulation centered about a frequency of 108 megacycles, in which case, the individual electrons will be shot out from the electron gun and deflecting plate system in a succession of points along a line so as to make an electron pattern in space roughly corresponding to a helix of increasing radius progressing away from the source. It will be understood that this beam pattern need not be in the form of a circular helix, however, but might have any number of conceivable shapes, more or less elliptical, so as to form a trace on the large end of the tube in some pattern within the limits between a straight line and any conceivable form of curved pattern. For the present, a circular sweep pattern will be considered. Here, the rate of rotation of the beam will be 12×10^6 revolutions per second, so that, at the large end of the tube, the linear tangential velocity of the electrons will be

$$\frac{10^{10}}{3}$$

centimeters per second, as stated above, in a tube of maximum radius of about 36 inches. Hence, in one sweep cycle, the individual electrons of the beam will travel forward a distance of

$$\frac{2\times10^9\times10^{-6}}{12}=\frac{1000}{6}=166.7 \text{ centimeters}$$

If these conditions are to be used to cause a frequency reduction ratio of, say, 3 to 1, then the delay plate 26 will have the dimensions and placement substantially as is shown in Figure 8, wherein S_1 equals

$$\frac{10^{10}}{3}\times\frac{10^{-7}}{3.6} \text{ equals } 92.6 \text{ centimeters}$$

and S_2 equals

$$\frac{2\times10^9\times10^{-7}}{1.8} \text{ equals } 111.1 \text{ centimeters}$$

while V equals the forward velocity of the electrons (2×10^9 centimeters per second) and V_w equals the sweep velocity thereof

$$\left(\frac{10^{10}}{3} \text{ centimeters per second}\right).$$

Here, the sweep frequency (f_s) of the electrons equals 12×10^6 cycles per second; and with the original signal frequency and band width (N) equal to 3, the modulated frequency and band width (P) will be equal to

$$\frac{1}{N} \text{ equals } \frac{1}{3} \text{ of } N$$

The input frequency

$$(f_{m_1})$$

is about 108×10^6 cycles per second and is so acted upon that only every third cycle is used; while the output frequency

$$(f_{m_2})$$

is about 36×10^6 cycles per second. These used cycles will be stretched out by the increasing electron time delay as the beam moves from point A to point B on the plate 26 (Figure 8), since this

electron beam has been modulated by grid 22 (Figure 3) at the input frequency

$$(f_{m_1})$$

and, as the electrons move forward, those that strike at point B on plate 26 are required to travel the extra distance S_2 or 111.1 centimeters as compared with the distance traveled by those striking at point A on plate 26. Progressively from points A to B on plate 26, the time delay is continuously increased. By adjusting the applied frequencies and potentials on the electrodes to the indicated values, for this example, it is possible to make the electron beam strike point A just as its part three cycles ahead is leaving point B on plate 26. Thus, since the timing has been precisely arranged, exactly two cycles are left off of plate 26 and they are passed out of the circuit via plates 27 and the conductive coating 28 (Figures 3 and 4). Every third cycle is thus spread out to the time interval of the original three cycles and the excess two cycles are discarded. In this case, the output frequency

$$f_{m_2}$$

will be as above stated and the band width will be reduced to one third of its original value.

From the foregoing, it will be obvious that, by different adjustments of the various constants, this reduction ratio may be changed at will to any value. If integral reduction ratios are not used, spurious signals will result due to phase and amplitude shifts; but most of these may be filtered out by the use of selective circuits now in general use. When integral reduction ratios are used, the ratio P equals 1/N where the output frequency is 1/Nth of the input frequency and the sweep frequency may be 1/Nth of the output frequency.

From the foregoing, it will be readily apparent that the invention includes a very definite and workable frequency band reducer which has the advantage in that it does not require that the band width be reduced by dividing by an integral number, but rather the band width is multiplied by a number $1/n$ where n may be any conceivable number or fraction, such as 7.386 etc. If the herein cathode ray type of frequency band reducer or divider of Figures 3 and 4 is employed, in the receiver hook-up (Figure 2) as a frequency band increaser or multiplier, for which purpose it will function when operated in reverse, this method will work as stated with any fractional band width. However, if the frequency band reducer or divider is used to produce integral sub-multiple band widths, such as for instance $\frac{1}{10}$ or $\frac{1}{8}$, then the receiver (Figure 2) need only use an ordinary vacuum tube frequency multiplier (Fig. 5) to re-expand the band width. Also, it is to be understood that by running any of these frequency and band width modulators in reversed order, the frequency and band width can be increased and expanded, this reverse function being useful in receiving the previously compressed bands of signals. This frequency and band width increase can also be provided in receiving equipment for the exact integral cases by means of well known frequency multiplying devices in common use. Also, it will be apparent that the instant invention eliminates all mechanical contactor systems and moving parts and consequently the abrupt jumps or gaps in the transmitted signal wave usual in the operation thereof; and that, by replacing the sloping delay plate 26 with a multiplicity of small contact plates (not shown) within the unit 14, thus eliminating the interval delay feature, substantially similar even transition of the signal wave can be had through the provision of external delay circuits of known arrangement.

Without further description, it is thought that the features and advantages of the invention will be readily apparent to those skilled in the art, and it will of course be understood that the illustrative systems and apparatus for carrying out the invention are susceptible of considerable modification and rearrangement without departing from the spirit of the invention or its scope as claimed.

I claim:

1. A transmission band compressor comprising a signal frequency band source, a mobile conductor stream projector, means for imparting a sweeping motion to the conductor stream, a collector means disposed in the path of the conductor stream and in angular relation to the axis thereof and having a length in predetermined ratio to that of the stream path for transmitting the collected portion of the signal frequency band width, and other collector means also disposed in the conductor stream path and having a length corresponding substantially to that of the remainder of the latter for eliminating the proportionate part of the signal frequency band width collected by it.

2. The wave compressor as in claim 1, with the mobile conductor stream being constituted in a relatively narrow beam of electrons.

3. The wave compressor as in claim 1, with the mobile conductor stream projector having the form of an electron gun designed to emit a narrow beam of relatively slow moving electrons.

4. The wave compressor as in claim 1, with the mobile conductor stream being constituted in a relatively narrow beam of electrons and means is provided to vary the number of electrons without variation in the velocities thereof.

5. The wave compressor as in claim 1, with the mobile conductor projector having the form of a cathode ray tube designed to emit a stream of relatively slow moving electrons in a narow beam and including an electrode which functions to vary the number of emitted electrons without variation in the velocities thereof.

6. The transmission band compressor as in claim 1, with still other collector means disposed substantially in bridging relation with respect to the adjacent ends of the first mentioned and said other collector means for eliminating "edge effects" therebetween.

7. The transmission band compressor as in claim 1, with the first mentioned and said other collector means disposed angularly with respect to the axis of sweep of said conductor stream so that the proportionate part of the signal frequency band collected by the first mentioned collector means will be of stretched time scale wave form of lower frequency and width.

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