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APPARATUS FOR ANALYZING COMPLEX WAVES

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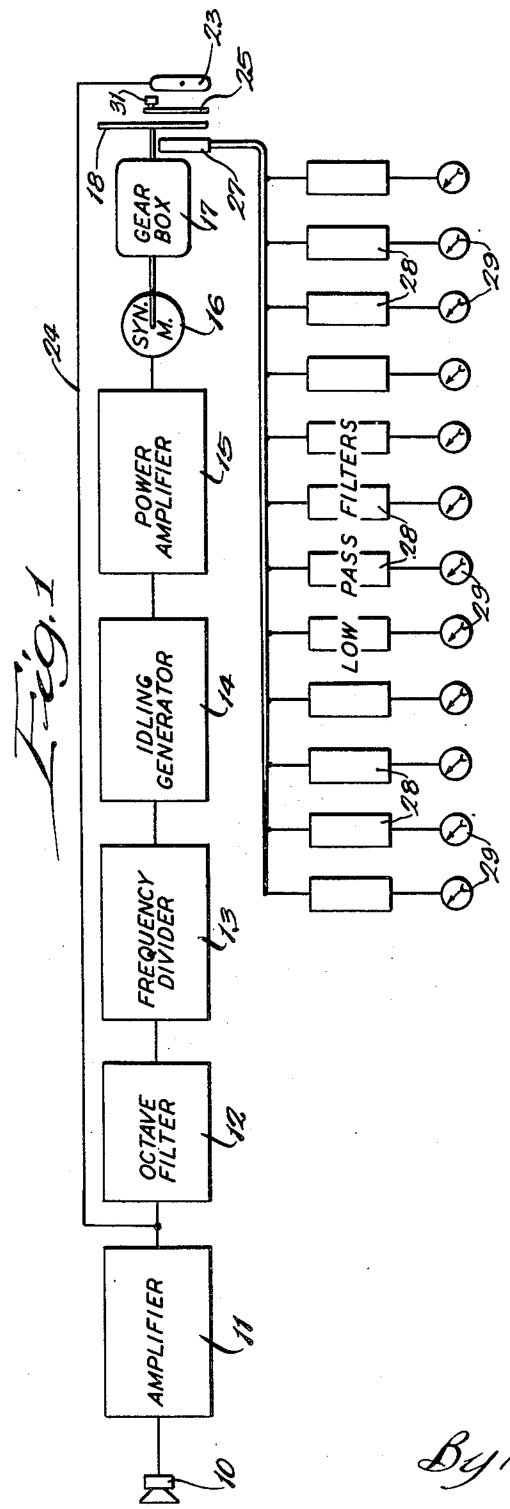

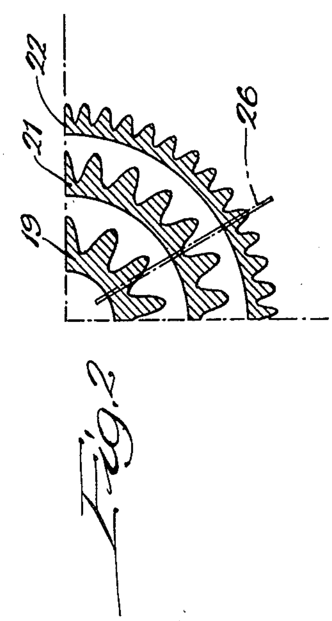

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APPARATUS FOR ANALYZING COMPLEX WAVES

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7 Claims. (Cl. 175—183)

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This invention relates to apparatus for analyzing complex waves and more particularly to apparatus for determining the relative values of the components or harmonics making up a complex wave.

One of the objects of the invention is to provide apparatus by which the several component or harmonic frequencies in a complex wave can be simultaneously indicated.

Another object is to provide apparatus by which the relative values of the several components or harmonics of a complex wave can be determined irrespective of the frequency or pitch of the wave.

Still another object is to provide apparatus in which the relative values of the components or harmonics of a complex wave are individually indicated electrically so that instantaneous determination of the makeup of the wave is obtained.

The above and other objects and advantages of the inventiton will be more readily apparent from the following detailed description when read in connection with the accompanying drawing in which—

Figure 1 is a block diagram of one form of apparatus embodying the invention and

Figure 2 is a partial elevation of the pattern disc.

As shown in the block diagram, the apparatus is adapted to pick up a wave to be analyzed, such as a musical tone or the like, by a microphone 10. The output of the microphone is amplified by an amplifier 11 without substantial wave form distortion and is supplied to an octave filter 12 which preferably includes a plurality of low pass filter circuits selectively connectable. The octave filter supplies a frequency divider 13 which may be adjusted in convenient steps of octaves or the like. The output of the frequency divider is fed through an idling generator 14 which may be an oscillator circuit operating at a fixed frequency when no signal is supplied and at the signal frequency when a signal is supplied. The idling generator supplies a minimum frequency when no wave is present in the microphone 10 to a power amplifier 15. The power amplifier supplies a synchronous motor 16 which is connected through a gear box 17 to a pattern disc 18.

When no wave is present in the microphone the idling generator will cause the motor 16 to operate at a predetermined minimum speed so that when a wave is supplied the motor can come into synchronism with it more quickly. When a complex wave, such as a musical tone, is picked up by the microphone 10 the octave filter is adjusted to pass the fundamental frequency of the wave while excluding the higher components or harmonics thereof. For example, the octave filter may be adjusted to pass frequencies up to fifty cycles per second in one adjustment and frequencies up to 100, 200, 400, etc. cycles per second in other adjusted positions. The frequency divider is preferably adjusted in synchronism with the octave filter so that when the octave filter passes 50 cycles per second no division is produced by the frequency divider. Under these conditions, the motor 16 will be supplied with a current of 50 C. P. S. or less corresponding to the fundamental wave frequency and will operate at a proportional synchronous speed. With a four pole synchronous motor, 50 cycles will drive it at 1500 R. P. M. and the gear box 17 may be so adjusted that it will turn the pattern disc at 187.5 R. P. M. This is the disc speed required to generate 50 C. P. S. and appropriate multiples thereof when patterns are employed having 16, 32, 48, etc., cycles per pattern ring.

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When a higher frequency wave is to be analyzed as, for example, one having fundamental frequency of 100 C. P. S., the octave filter will be set to pass frequencies up to 100 C. P. S. and the frequency divider will be set to divide by 2. Thus the motor will still be supplied with current of 50 C. P. S. or less frequency but the gear box is adjusted to drive the disc at 375 R. P. M. This construction is preferably employed so that the motor will not be required to run at extremely high speeds. At still higher fundamental frequencies the filter frequency divider and gear box will be similarly adjusted to operate the disc at speeds proportional to the fundamental wave frequency.

The disc is provided with a plurality of sinusoidally varying patterns as best seen in Figure 2. As shown in this figure an inner pattern ring 19 is provided having 16 cycles throughout its length, a second pattern ring 21 having 32 cycles and a third pattern ring 22 having 48 cycles. It will be understood that as many pattern rings as desired could be employed having increasing numbers of cycles to correspond to the number of components or harmonics of the complex wave to be measured. In the form shown the pattern disc is made transparent or translucent while the pattern rings are opaque so that the light transmitted through the pattern will depend upon the intensity of illumination and the instantaneous position of the pattern ring. The pattern member is illuminated by a light source shown as a gas tube 23 which is connected through a connection 24 to the output of the amplifier 11. Preferably, a biasing current is provided for the tube 23 so that it will never be completely extinguished. Due to its connection to the amplifier 11, however, the instantaneous intensity of the tube will be proportional to the instantaneous amplitude of the wave to be analyzed.

To control the illuminatiton of the pattern, a masking plate 25 is mounted between the light source and the pattern disc and is formed with a relatively narrow radially extending slot 26, as seen in Figure 2. Due to this arrangement, the pattern disc is illuminated in relatively narrow bands intersecting the patterns transversely.

In operating the device, as so far described, a complex wave such as a musical tone may be picked up by the microphone 10 to drive the disc 18 at a speed proportional to the fundamental frequency of the wave. At the same time the light 23 will be controlled by the wave to illuminate the pattern disc with an instantaneous intensity which varies above and below the normal or bias intensity level in proportion to the instantaneous amplitude of the wave. If the light transmitted through the disc is observed by eye, the eye acts as an averaging device due to retentivity of vision so that the apparent illumination opposite each of the pattern rings will be proportional to the value of the wave component whose frequency corresponds to the frequency of change of the pattern. It will be observed that this occurs because of the fact that light frequencies differing from the frequency of the particular pattern ring produce sinusoidal variations of light intensity having an average value of zero. These intensity variations will be averaged by the eye and will produce no apparent effect. On the other hand, frequencies in the light which are the same as the frequency of the pattern will produce an apparent steady state value of the transmitted light which is proportional to the product of the intensity of the light at the pattern frequency and the transmission coefficient of the pattern. Therefore, by direct observation, the relative values of the several components of the wave which correspond respectively to the frequency changes of the several pattern rings can be easily and quickly determined.

According to the present invention, it is preferred to pick up illumination changes photoelectrically so that they can be indicated on indicators or can, if desired, be recorded. For this purpose, as shown, a set of photoelectric cells 27 are arranged adjacent the pattern plate, there being one cell for each of the pattern rings. The cells are individually connected to low pass filters 28 which are provided to eliminate any high frequencies present and which in turn are connected to meters 29 to indicate changes in the steady state values of the voltages generated by the cells.

As shown in Figure 1 there are twelve filters 28 and twelve meters 29 to indicate simultaneously twelve tone components. In this construction it will be understood that the disc 18 has twelve pattern rings and the set of photocells 27 contains twelve cells registering respectively with the pattern rings and individually connected to the filters 28.

In this construction, the cells themselves and the filters act as averaging devices to eliminate sinusoidal variations in the light intensity changes opposite the respective pattern rings so that only changes in the steady state value corresponding to the amplitude of the component or harmonic having the same frequency as the pattern ring in question times the transmission coefficient of the pattern will be indicated.

It will be noted that when photoelectric pickups are employed, as illustrated, the generated voltages are phase sensitive so that the maximum value will be indicated only when the patterns and the light source are in phase. In order to produce an in phase indication, the masking plate 25 may be mounted for rotation to be turned by means of a knob 31. Since the disc need never be turned more than an amount equal to 90° on the pattern ring 19, it will ordinarily not be necessary to move either the light source or the photoelectric cells to obtain a proper indication. By turning the mask, the relative phase positions of the light source and patterns can easily be adjusted until a maximum indication is obtained on the meters 29. This corresponds to the in phase value and is a direct indication of the values of the several components or harmonics in the complex wave.

Instead of adjusting the mask, as described above, readings can automatically be obtained by so adjusting the gear box 17 that it will drive the disc 18 at a speed slightly out of synchronism with the fundamental of the wave. With this arrangement, the relative phase positions of the patterns and light sources are constantly changing at a slow rate so that the meter readings will vary constantly between maximum and zero. The rate of change can easily be adjusted as, for example, at one cycle per second for the ring 19 so that the maximum readings of the meters can easily be observed. These maximum readings represent the in phase values and are directly proportional to the amplitudes of the several components or harmonics which make up the complex wave.

By the use of the present invention, the harmonic content of a musical tone or the like can easily and quickly be determined. It will be noted that since the disc 18 is driven under the control of the wave to be analyzed, the frequency or pitch of the wave is not critical and that any note within the range of adjustment of the instrument sounded into the microphone 10 will be instantaneously separated into its wave harmonics which will be individually indicated by the meters 29.

While one embodiment of the invention has been shown and described in detail, it will be understood that this is illustrative only and is not intended as a definition of the scope of the invention, reference being had for this purpose to the appended claims.

What is claimed is:

1. Apparatus for analyzing complex waves comprising a pattern member having a plurality of sinusoidally varying patterns of different frequencies thereon said patterns having different light affecting properties than the adjacent material of the pattern member, means controlled by a complex wave to be analyzed to drive the pattern member at a speed proportional to the fundamental frequency of the wave, a light source to illuminate the pattern member, and means responsive to the wave to control the light source so that its instantaneous intensity is proportional to the instantaneous amplitude of the wave.

2. Apparatus for analyzing complex waves comprising a pattern member having a plurality of sinusoidally varying patterns of different fre-

quencies thereon said patterns having different light transmitting properties than the adjacent material of the pattern member, means controlled by a complex wave to be analyzed to drive the pattern member at a speed proportional to the fundamental frequency of the wave, a light source to illuminate the pattern member, means responsive to the wave to control the light source so that its instantaneous intensity is proportional to the instantaneous amplitude of the wave, a plurality of light sensitive devices adjacent to the pattern member and responsive respectively to the light transmitted by the patterns to generate voltages proportional to the amplitudes of the wave components having the same frequencies as the patterns, and means to measure the voltages and means to confine the light transmitted to the light sensitive devices to a narrow band crossing the patterns.

3. Apparatus for analyzing complex waves comprising a pattern member having a plurality of sinusoidally varying patterns of different frequencies thereon said patterns having different light transmitting properties than the adjacent material of the pattern member, means controlled by a complex wave to be analyzed to drive the pattern member at a speed proportional to the fundamental frequency of the wave, a light source to illuminate a relatively narrow portion of the pattern member crossing the patterns, means responsive to the wave to control the light source so that its instantaneous intensity is proportional to the instantaneous amplitude of the wave and means to adjust the effective position of the light source relative to the patterns in the direction of motion of the patterns to adjust the relative phase positions of the light source and patterns.

4. Apparatus for analyzing complex waves comprising a pattern member having a plurality of sinusoidally varying patterns of different frequencies thereon said patterns having different light transmitting properties than the adjacent material of the pattern member, means responsive to a complex wave to be analyzed to drive the pattern member at a speed substantially but not exactly synchronized with the fundamental frequency of the wave, a light source to illuminate the pattern member, means responsive to the wave to control the light source so that its instantaneous intensity is proportional to the instantaneous amplitude of the wave, and means to indicate the maximum average value of light transmitted by relatively narrow portions of the pattern member transverse to the respective patterns.

5. Apparatus for analyzing complex waves comprising a pattern member having a plurality of sinusoidally varying patterns of different frequencies thereon said patterns having different light transmitting properties than the adjacent material of the pattern member, means responsive to a complex wave to be analyzed to drive the pattern member at a speed substantially but not exactly synchronized with the fundamental frequency of the wave, a light source to illuminate the pattern member, means responsive to the wave to control the light source so that its instantaneous intensity is proportional to the instantaneous amplitude of the wave, a plurality of light sensitive devices responsive respectively to the light transmitted by relatively narrow portions of the pattern member transverse to the patterns to generate voltages proportional to the amplitudes of the wave components having the same frequencies as the patterns, and means to measure the voltages.

6. Apparatus for analyzing complex waves comprising a pattern member having a plurality of sinusoidally varying patterns of different frequencies thereon said patterns having different light transmitting properties than the adjacent material of the pattern member, means responsive to a wave to be analyzed to drive the pattern member at a speed proportional to the fundamental frequency of the wave, a light source to illuminate the pattern member, a mask adjacent the pattern member having a slot therein transverse to the line of motion of the patterns to confine the light transmitted by the patterns to narrow bands crossing the patterns, means responsive to the wave to control the light source so that its instantaneous intensity is proportional to the instantaneous amplitude of the wave, and means movably mounting the mask for movement along the line of motion of the patterns to adjust the effective phase relationship between the patterns and light source.

7. Apparatus for analyzing complex waves comprising a pattern member having a plurality of sinusoidally varying patterns of different frequencies thereon said patterns having different light transmitting properties than the adjacent material of the pattern member, means responsive to a wave to be analyzed to drive the pattern member at a speed proportional to the fundamental frequency of the wave, a light source to illuminate the pattern member, a mask adjacent the pattern member having a slot therein transverse to the line of motion of the patterns to confine the light transmitted by the patterns to narrow bands crossing the patterns, means responsive to the wave to control the light source so that its instantaneous intensity is proportional to the instantaneous amplitude of the wave, means movably mounting the mask for movement along the line of motion of the patterns to adjust the effective phase relationship between the patterns and light source, a plurality of light sensitive devices responsive respectively to the light transmitted by the patterns to generate voltages proportional to the amplitudes of the wave components having the same frequencies as the patterns, and means to measure the voltages.

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