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ELECTRONIC HARMONIC SYNTHESIZER

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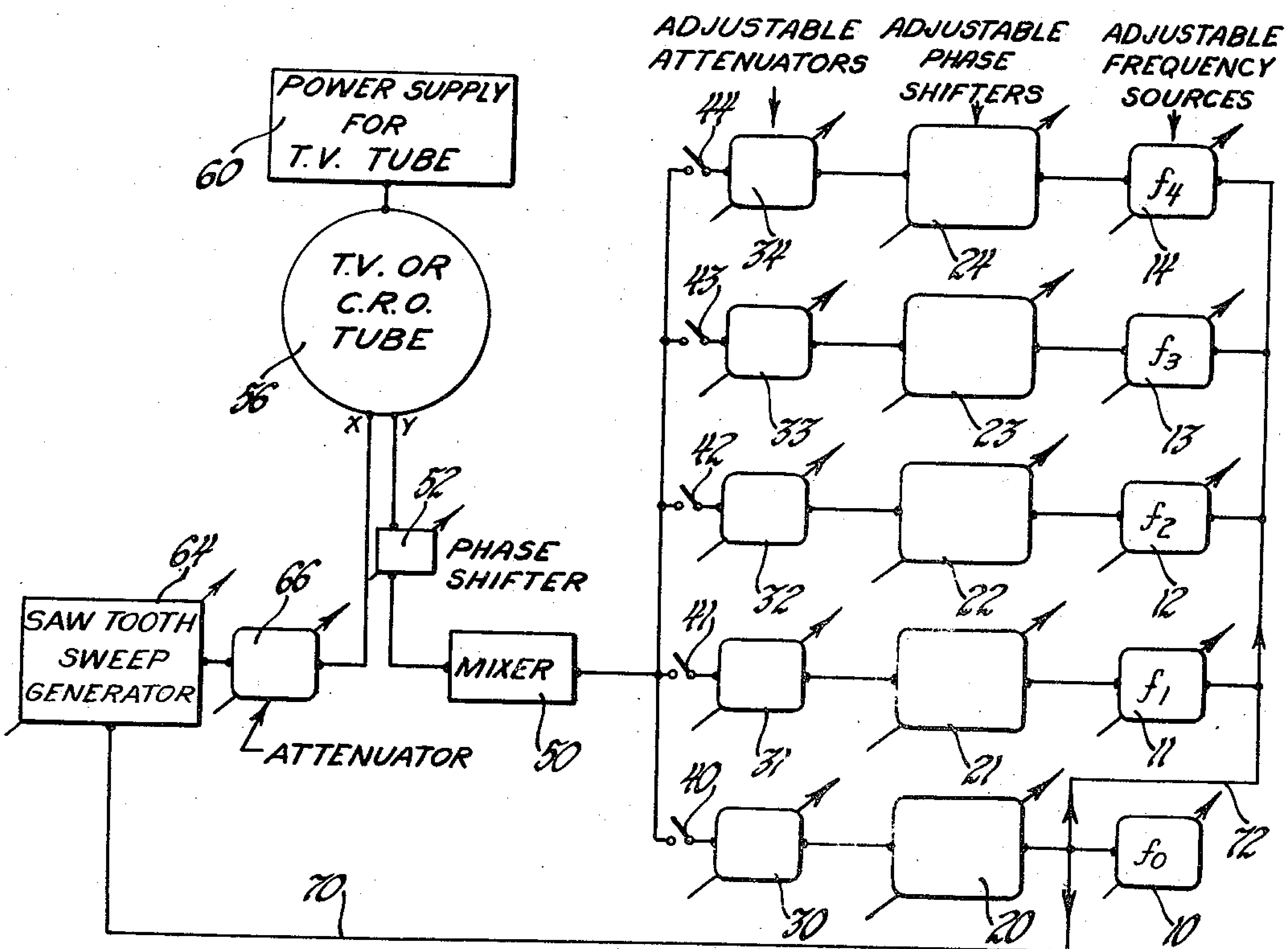

Fig. 1

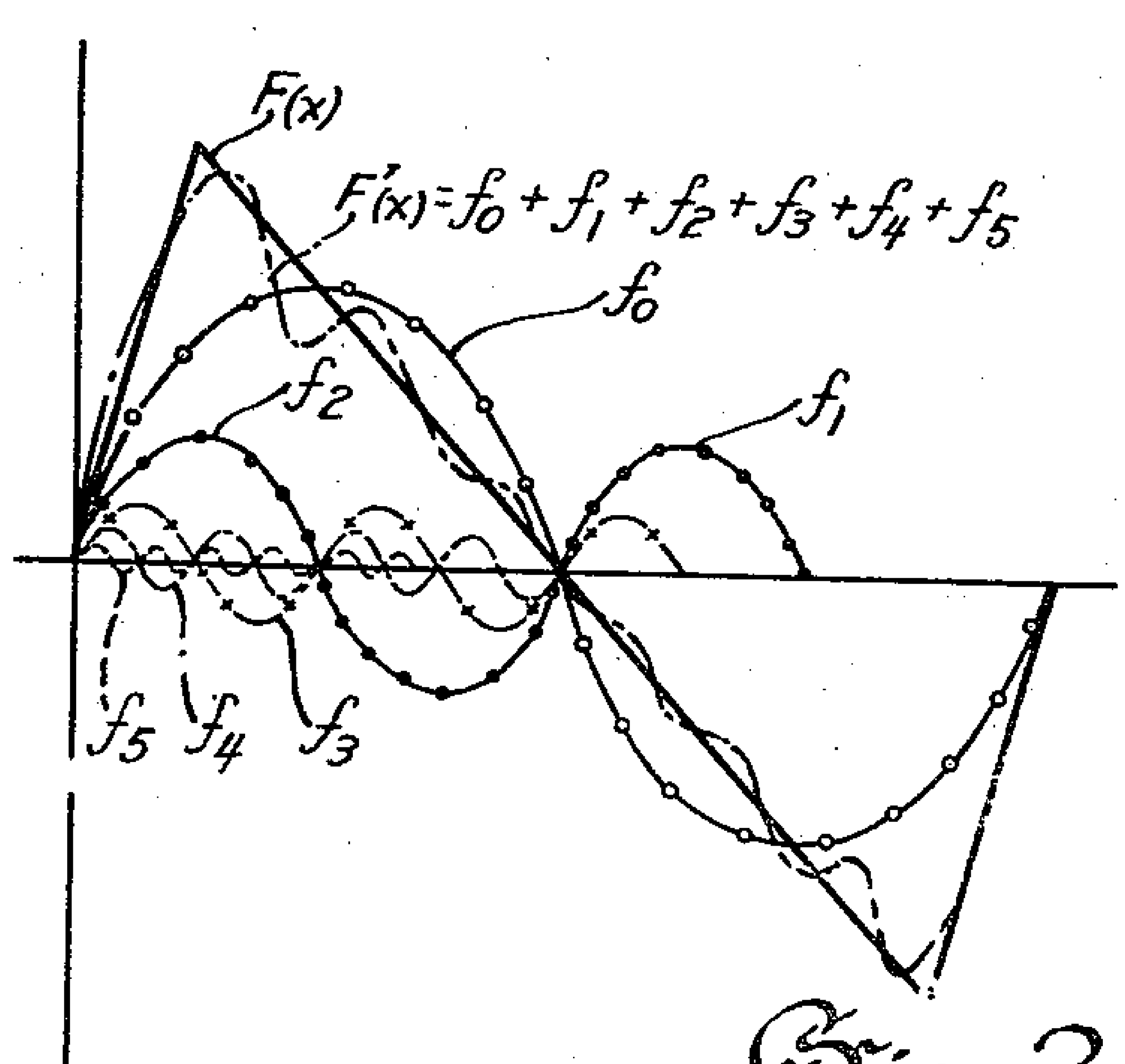

Fig. 2

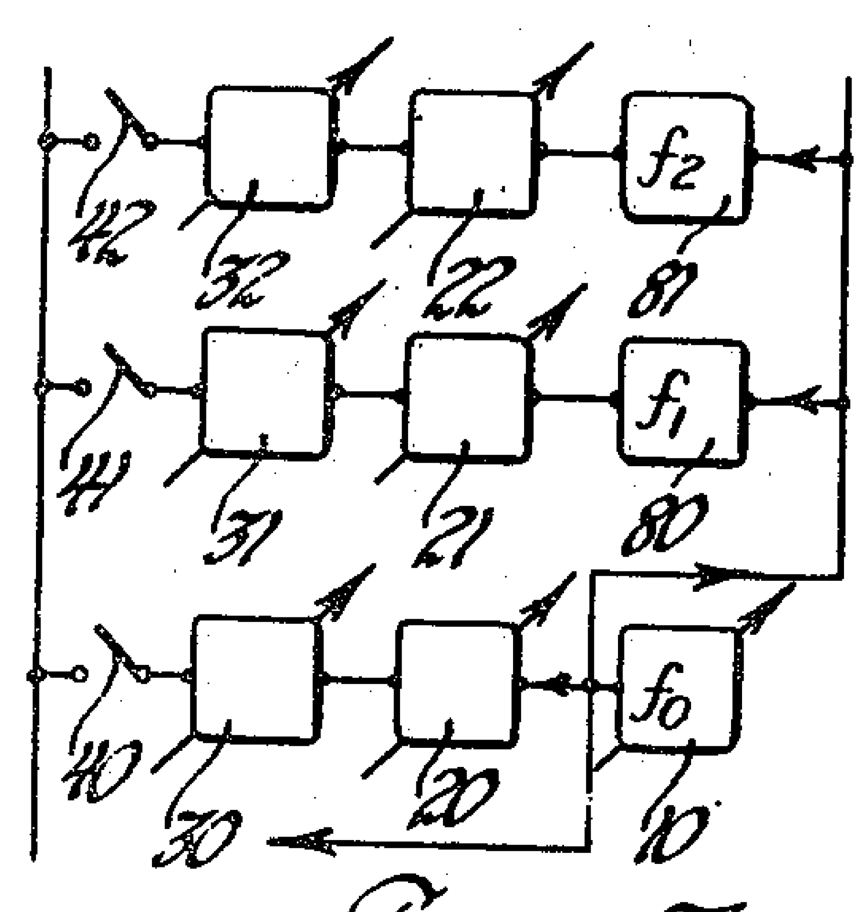

Fig. 3

INVENTOR
Edwin F. Katz
BY L. D. Burch
ATTORNEY

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ELECTRONIC HARMONIC SYNTHESIZER

Edwin F. Katz, Milwaukee, Wis., assignor to General Motors Corporation, Detroit, Mich., a corporation of Delaware

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1 Claim. (Cl. 315—24)

This invention relates to wave analyzers or synthesizers in which a plurality of harmonically varying waves of adjustable frequency, amplitude and phase characteristics are generated and combined to form a composite wave which is compared against a complex wave to determine the composition thereof.

More particularly, the invention relates to an improved harmonic wave synthesizer of electronic character.

While harmonic synthesizers for analysis of complex waves have been proposed heretofore, such apparatus for the most part has been of mechanical character in several major respects, including the manner of generating the component waves and the adjustment of their frequency, phase and amplitude characteristics. In one system, for example, a plurality of gears having a different number of teeth are mounted on a common shaft, which is driven from a suitable power source, and drive individual crank wheels, each of which has an adjustable linkage or crank arm coupled thereto and associated with a slide wire potentiometer device, to develop a plurality of harmonically varying electrical waves. The frequency of each of the individual waves is adjusted by changing the gear ratio between the drive gear and crank wheel associated with each crank arm, while phase and amplitude adjustments are made by adjusting the relative positions of the crank arms in their cycles of operation and their point of attachment to the crank wheels, respectively.

By reason of their mechanical nature, these devices require a considerable amount of "set-up" time and, consequently, are slow and not readily adapted to provide rapid wave analysis. These devices, moreover, occupy a considerable amount of space and require a large number of special mechanical parts including gears and levers of various sizes in order to provide a wave analyzer of sufficient flexibility and capacity to furnish an adequate number of wave components to accommodate various forms of complex waves to be analyzed with the apparatus. Other disadvantages of such mechanical synthesizers are that they do not permit of adjusting all of the electrical characteristics of the component waves generated thereby while the apparatus is in operation, they are restricted to perform analyses of complex waves in low frequency ranges, and they are apt to get out of adjustment readily and to produce inaccurate results due to misalignment, friction, slippage, backlash and wear of the moving parts employed therein.

The present invention thus has for its general object to provide a wave synthesizer which avoids the aforementioned disadvantages of prior forms of wave synthesizers.

More specifically, the invention seeks to provide an improved harmonic wave synthesizer which is of completely electrical or electronic character and which does not employ any mechanical or moving parts but is composed of inexpensive, commercially available electrical components which may be readily assembled to provide a synthesizer of extreme simplicity and flexibility or versatility from the standpoint of construction and operation.

Other objects are to provide an electronic harmonic synthesizer which provides a wide range of harmonic frequency components whose amplitude, frequency and phase relations may be readily adjusted during the course of operating the apparatus and which is possessed of an accuracy that compares with commercial high grade heterodyne wave analyzers.

The above and other objects, features and advantages of the present invention together with the manner in which they are accomplished, will appear more fully from the following description and drawings wherein:

Fig. 1 is a simplified single line block diagrammatic illustration of an electronic harmonic synthesizer in accordance with the present invention;

Fig. 2 illustrates a number of harmonically related waves which are combined and compared against a complex wave to illustrate the theory of operation of wave synthesizers such as the present invention; and

Fig. 3 is a block diagrammatic illustration of a slightly modified form of the apparatus of Fig. 1.

Referring to the drawings, there is shown a harmonic wave synthesizer which includes a number of variable frequency electrical wave sources **10, 11, 12, 13, 14** . . . generating harmonically related sinusoidal waves designated herein as f_0, f_1, f_2, f_3, f_4 . . . The output of each variable frequency source is applied through a variable electrical phase shifter as **20, 21, 22, 23, 24** . . . , a variable electrical attenuator as **30, 31, 32, 33, 34** . . . , and a control switch as **40, 41, 42, 43, 44** . . . to the input of a common mixer or combining device **50**.

The output of the mixer or combining device may be applied through a variable electrical phase shifter **52** to one of the two sets of signal input terminals, preferably the Y or the vertical deflection control circuit, of a standard cathode ray oscilloscope device or a conventional, large screen television picture tube **56** with its associated power supply and customary vertical and horizontal sweep circuits and high voltage circuits, collectively designated as **60** herein. The X or horizontal deflection control circuit of the television picture tube **56** is controlled by a conventional saw-tooth wave sweep generator **64** the output of which is applied through a variable attenuator device **66** to the other set of signal input terminals of the visual display device **56**. In order that the frequency or repetition rate of the saw-tooth generator may be equated to or be made a multiple or fractional submultiple of the frequency of the fundamental frequency wave generator **10** and thereby produce a trace on the visual display device corresponding to one or more cycles or a part of the cycle of the synthesized wave produced by the apparatus, the saw-tooth generator should be variable and have suitable controls to afford a selection of different frequencies or repetition rates.

So that the output of the saw-tooth generator may be synchronized with that of the fundamental wave (f_0) generator **10** and in order to lock the harmonic wave generators **11, 12, 13, 14** . . . to the fundamental wave generator, synchronizing connections as **70** and **72** may be provided from the fundamental wave generator to the saw-tooth sweep generator and to the harmonic generators, respectively, as indicated.

The adjustable frequency wave sources **10, 11, 12, 13, 14** . . . may be commercially available, high grade electronic type oscillators or signal generators operable over successively higher frequency ranges and providing pure sinusoidal wave outputs of constant amplitude and frequency for each frequency setting throughout the range of operation of each oscillator. Each of the phase shifters **20, 21, 22, 23, 24** . . . and **52** should be capable of providing an electrical phase shift or delay between the signal input and output thereof of 180 electrical degrees or more and could be a simple combination of an adjustable capacitance or inductance and an adjustable resistance connected in a four terminal network. The phase shifters **20, 21, 22, 23, 24** . . . in the individual oscillator circuit branches shift the phase or the position of the wave output of their respective circuit branches along the abscissa of the graph shown in Fig. 2 while the phase shifter **52** in the output of the mixer device horizontally shifts the entire composite wave pattern $F'_{(x)}$ relative to the unknown complex wave pattern $F_{(x)}$ to be analyzed.

The attenuators **30, 31, 32, 33, 34** . . . and **66** could be calibrated variable resistances or decade boxes, or, if desired, vacuum tube amplifiers with adjustable gain controls. The use of such amplifiers in the parallel oscillator circuit branches would isolate the individual oscillator circuit branches of Fig. 1 from each other and prevent any reaction between the various adjustable frequency wave sources and their circuits.

The mixer device **50** could be a mixing amplifier, say of the R-C variety, or a four terminal R-C attenuator device the input terminals of which are connected to receive the output of each of the individual oscillator circuit branches containing the adjustable frequency wave sources of Fig. 1. In its simplest form, the mixing device **50** could be a resistance or impedance element and the outputs of the several oscillator circuit branches connected in series therewith to develop a composite voltage thereacross or current flow therein corresponding to the sum of the voltage outputs or currents of the individual oscillator circuit branches.

The operation of the invention should be apparent from the foregoing description of the organization thereof. The saw-tooth sweep generator **64** with its adjustable attenuator sets the horizontal scale factor of the trace displayed on the cathode ray oscilloscope or picture tube, the vertical scale factor being determined by the amplitude of the resultant composite or combined signal applied to the vertical deflection circuit or vertical input terminals of the visual display device from the mixer. Where the mixer **50** is a mixing amplifier, the vertical scale factor can be adjusted most readily by adjusting the gain control of the amplifier.

In order to perform a harmonic analysis of an unknown complex wave pattern such as the saw-tooth wave pattern $F_{(x)}$ indicated in Fig. 2, the wave is first plotted on transparent graph paper which is then suitably affixed or attached to the exterior viewing surface or screen of the cathode ray oscilloscope or picture tube. Then by connecting the outputs of all or of various selected oscillator

circuits through the control switches to the mixer device and adjusting their frequency, amplitude and phase relations, a known composite wave $F'_{(x)}$ equal to the sum of the individual harmonic waves can be synthesized and imposed on the screen of the visual display device for optical comparison against the unknown wave. In this manner the harmonic composition of the unknown complex wave can be determined rapidly and with reasonable accuracy.

As a further refinement, only the fundamental frequency wave source of Fig. 1 need be of a variable or adjustable character and conventional electronic frequency doublers, tripler, quadruplers, etc., as **80, 81,** etc., may be employed for the harmonic wave sources f_1, f_2, f_3, f_4 . . . , as indicated in Fig. 3.

What is claimed is:

A harmonic wave synthesizer comprising the combination of a variable frequency fundamental oscillator, a plurality of variable frequency harmonic oscillators generating sinusoidal waves of different frequency, an adjustable electrical phase shifter interconnected with the outputs of said oscillators, a variable amplitude attenuator gain control device in the output of each of said phase shifters, electrical mixing means having an input connected to receive the waves of said variable oscillators and an output, a large screen television picture tube including a horizontal beam deflection circuit and a vertical beam deflection circuit, an adjustable electrical phase shifter connected between the said output of said electrical mixing means and the said vertical beam deflection circuit of said picture tube, an electrical saw-tooth wave sweep generator having a variable amplitude attenuator connected to the said horizontal beam deflection circuit of said picture tube, and an electrical synchronizing connection between the fundamental or lowest frequency wave oscillator and said horizontal sweep generator.

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