FIG. 1

SIGNAL SOURCE  
FILTER  
OSC.  

FIG. 2

a. 
b. 
c. 

(U)
FIG. 3

FIG. 4

[Diagram and waveforms]
SINEWAVE SYNTHESIZER FOR TELEGRAPH SYSTEMS

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ABSTRACT OF THE DISCLOSURE

A device for synthesizing a quasi-sinusoidal wave having a frequency F comprising a pulse generator with a rate of occurrence kp, a pulse counter of which numerical content is converted by a digital-analog converter to voltages as

\[ \text{sin} \frac{2\pi}{k} t \]

l being an integer between 0 and k. Practically, \( k = 2n \), with a counter of \((n-1)\) capacity, or \( k = 4p \), with a counter of \((p-1)\) capacity, cooperating with an appropriate logic.

The present invention has as its object a wave synthesizer, more specifically of waves frequency modulated by telegraphic signals, in which means is incorporated for limiting the spectrum and reducing the telegraphic distortion, and which lends itself to a form of construction utilizing the principles of integrated circuits.

Among other reasons, telegraphic transmission by means of frequency modulated waves is of interest as a means of providing satisfactory protection against noise and interference. If it is applied without precautions, however, it establishes a very wide spectrum which increases the risk of causing flutter or babble and of overloading of the filters on reception.

In point of fact, a frequency modulation between a wave of rectangular shape of fundamental frequency \( F_1 \) and of "1-1" valency, and a wave of the same nature of fundamental frequency \( F_2 \) and of "working" valency \( (F_1 < F_2) \), of the "1/1" type, with a duration \( M \) of a telegraphic instant, has a spectrum in the form of series of lines spaced apart by \( f = \frac{1}{2} \) of the frequencies \( F_1 \) and \( F_2 \) and grouped around the frequencies \( F_0 \) and \( 3F_0, 5F_0, 7F_0 \), etc. \( F_0 \) being equal to \( (F_1 + F_2)/2 \).

In other words, a spectrum of this kind comprises a first group of lines \( F_0 \) plus or minus \( nF \), a second group of lines \( 3F_0 \) plus or minus \( nF \), a third group of lines \( 5F_0 \) plus or minus \( nF \), etc., \( n \) being a variable integer.

It is known that the groups of lines of higher order may be reduced to negligible amplitudes by appropriate filtering action, while retaining only the first group \( F_0 \) plus or minus \( nF \).

On the other hand, it is of importance that the characteristic instant which may be situated at any point of an alteration of the carrier wave, should be restored with accuracy. If the phase of the carrier wave is disturbed by the modulation, a substantial telegraphic distortion may be the result, as will be set forth hereinafter.

A standardized telegraphic channel is contemplated for example, with \( F_1 = 1,300 \text{ c./s.} \) and \( F_2 = 2,100 \text{ c./s.} \), or say a period \( T_1 = 765 \mu s. \) and a period \( T_2 = 475 \mu s. \), respectively, with a telegraphic transmission of 1200 bauds. The duration of a telegraphic instant then amounts to \( T_1 = 765 \mu s. \) and the maximum error on the characteristic instant can thus reach

\[ T_1 + T_2 \]

or 1240/2 = 620 \( \mu s. \) Relative to an instant having a duration of 835 \( \mu s. \), as indicated, this results in a possibility of maximum telegraphic distortion of 620/835 = approximately 75%, which is obviously unacceptable.

If the frequencies are multiplied by a factor k, the periods are reduced in the same ratio, the telegraphic distortion diminishing correspondingly. For example, for a multiplication by 30 \((k = 30)\) a maximum distortion of 75/30 = 2.5% is obtained, which is perfectly acceptable. In addition, raising the frequencies renders it easier and less costly to effect the filtering processes which may prove to be necessary or advantageous. It is thus established that modulation at relatively high frequency is of interest.

In order to revert to standardized frequencies, it is known to perform a transposition by means of any auxiliary carrier frequency, but it would then be necessary to resolve low-frequency filtering problems, which is just what is to be avoided. On the other hand, if a source of very great stability, that is to say a costly one, is employed for the auxiliary carrier, the uncertain fluctuations \( \Delta f \) of the frequencies \( F_1 \) and \( F_2 \) are returned to a lower frequency level, thus the fluctuations \( \Delta f/f \) of the base frequencies are heightened in relative value; an oscillator of moderate stability, that is to say less costly, is taken for the auxiliary carrier, the fluctuations in relative value are heightened even more by the additional fluctuation of the auxiliary carrier frequency.

It is more favorable therefore to perform a frequency reduction of this kind by the method of a division of frequency which retains the same value of fluctuation in relative value \( \Delta f/f \). Within the scope of principles related to integrated circuits, employing logical circuits only, excluding any transformer and inductance coil, it is known that a frequency division of this nature may be performed by means of an electronic counter whose terminal element changes in position in a cadence \( k \) times slower than that of the signals acting the same, that is to say once for \( k \) pulses received or once for \( k \) periods or cycles of the controlling signal.

A frequency division method of this kind is not applicable in the case of a telegraphic transmission of relatively fast handling speed in comparison with the carrier frequency, because it loses the definition of the characteristic instant in the interval of the duration of a period or cycle. It has become apparent however in the preceding, that a loss of definition of this kind may result in prohibitive telegraphic distortion.

It is essential, therefore, that a frequency division of this nature be performed by a method which retains the definition of the characteristic instant, such as yielded by the multiple frequency, that is to say that a sub multiple frequency be engendered which comprises as many phase steps as there are periods or cycles of the multiple frequency in a period or cycle of the submultiple frequency, that is to say \( k \) phase steps for a multiplication-division by \( k \).

This is accomplished according to the invention, by synthesizing a wave of frequency \( F \) which can assume two values \( F_1, F_2 \) by means of an arrangement comprising a
frequency oscillator \( k F \), \( k \) being an even multiple of \( n \), a counter of the ascending and descending type having one input terminal and two control terminals, known per se, of capacity \( (n-1) \), a decoder having \( n \) outlets, a numerical analog converter adjusted to supply an output voltage proportional to

\[ A + \sin \frac{t - \pi}{\pi} \]

in which \( A \) is a constant, in which \( i = 0, 1, \ldots, n-1 \), logical circuits connected to the decoder to place the said counter in ascending counting operation when it reaches the position \( "0" \) and in descending counting operation when it reaches the position \( "n-1" \) and a final or output amplifier supplying an output voltage whose envelope is a sinusoidal wave having the frequency \( F \).

It is an object of the present invention to provide a wave synthesizer for telegraphy systems which avoids or otherwise eliminates the problems inherent in known arrangements of similar kind.

It is another object of the present invention to provide a wave synthesizer of the type described which permits a minimum of telegraphic distortion.

It is a further object of the present invention to provide a wave synthesizer of the type described which is more efficient and less costly than similar known arrangements.

It is still a further object of the present invention to provide a wave synthesizer of the type described which materially reduces telegraphic distortion through frequency division which retains the definition of the characteristic instant.

These and other objects, features and advantages of the present invention will become more apparent from the following detailed description thereof when taken in conjunction with the accompanying drawings, which illustrate two embodiments of the present invention, and wherein:

FIGURE 1 is the block diagram of a first form of embodiment of a device according to the invention.

FIGURE 2 is a curve illustrating the form of the current obtained at the outlet of the device according to FIGURE 1, as well as the corresponding curves.

FIGURE 3 is the block diagram of a second form of embodiment.

FIGURE 4 is a curve illustrating the form of the current obtained at the outlet of the device according to FIGURE 3, as well as the corresponding curves.

In FIGURE 1, an emitter 1 of telegraphic signals applies its output to a shaping filter 2 of the RC type, which in turn is connected to an oscillator 3 of the linear type, that is to say an oscillator whose frequency varies linearly as a function of the strength of a signal fed to the input, for example a relaxation oscillator or multivibrator, which provides waves which are approximately square, whose frequency is a linear function of a control voltage applied at an input terminal, as well known. The circuit of FIGURE 1 also includes an "or" circuit 4, a bistable switching element 5, a binary counter 6 whose two control inlets 61 and 62 are connected to two outlets 51 and 52 of the said switching element 5, respectively. By the action of these connections, the counter 6 counts in ascending order for one condition of the switching element, and the counter 6 counts in descending order for the other condition of the switching element. The counters applicable in two counting directions are well known in the art. For example, the counter 6 comprises 4 switching elements for 16 counting steps 0 to 15 inclusive. The output of counter 6 connected to a decoder 7 which provides output voltage at outlets \( i = 0, 1, 2, \ldots, 15 \) to a numerical analog converter 8 providing an output voltage \( V \) proportional to

\[ \frac{f}{15} \]

The said voltage is applied at the inlet of an amplifier 9, which provides an output voltage \( U \) at an output terminal 5. In this case, the constant \( A \) is at least equal to 1.

The outlet (0) and the outlet (15) of the decoder 7 are connected to the input of the switching element 5 by means of the "or" circuit 4. When a voltage appears at the outlet (0) of the decoder, the switching element 5 places the counter 6 in the ascending counting condition, whereas when a voltage appears at the outlet (15) of the decoder, the switching element 5 places the counter 6 in the descending counting condition. When the waves emitted by the multivibrator 3 reach the input of the counter 6 successively, it assumes the ascending counting states 0, 1, 2, \ldots, 15, then descends again from 15, 14, \ldots, to 0.

The curve a of FIGURE 2 illustrates a telegraphic signal which passes, at the time \( t_s \), from the "working" valency to the "rest" valency. A higher frequency of emission \( F_s \) corresponds to the working valency, and a lower rest frequency

\[ F_s = \frac{f_s}{F} \]

corresponds to the rest valency.

The curve b of FIGURE 2 shows the advance pulses reaching the counter 6. The frequency value changes at the time \( t_s \) but no phase incoherence occurs because it is the same oscillator whose frequency is adjusted from tone value to the other. The frequency is adjusted with continuity, since it has been assumed that the oscillator in question is of linear type, to which is applied a signal endowed with a rounded-off form by the action of the shaper 2. In point of fact, the interval which separates the advancing pulses is variable progressively according to the rule established by the shaper 2. This method is illustrated in the curve c, which shows the true form of the variation \( F_s = F_r \). One has:

\[ t_s = \frac{T_1}{k} = \frac{T_2}{k} \]

A current, which is principal has the form given by the curve c of FIGURE 2, is obtained at the outlet 5 of the amplifier 9. In point of fact, the band limitation produced in the amplifier 9 or in a subsequent element in the circuit, provides a current which is not cut into segments, but is of sinusoidal waveform, as illustrated by dashes in the curve c of FIGURE 2.

Any phase incoherence is eliminated in the device of FIGURE 1. Nevertheless, the stability of a multivibrator wherein frequency is adjustable according to voltage need not exceed a mean value of the order of 0.5% for example. A system of this nature is thus applicable to channels of low degree, but would not be applicable to channels of high degree, for which it would result in an excessive drift or shift in absolute value.

In FIGURE 3, a second embodiment of the invention includes an emitter 11 of telegraphic signals analogous to the emitter 1 of FIGURE 1. Connected to the emitter 11 is a logical inverter 12 the outlet of which is connected to one inlet of an "and" gate 16. A stable oscillator 13 providing the frequency \( F_s \) and a stable oscillator 14 providing the frequency \( F_r \) are connected respectively to an "and" gate 15 connected also to an outlet of the emitter 11 and to the other "and" gate 16 connected also by an inlet to the inverter 12. An "or" circuit 17 receives currents issuing from the two "and" gates 15 and 16. A counter 20 of the binary type arranged for counting in ascending and descending order and comprising three switching elements has an inlet connected to the outlet of the "or" circuit 17 and two control terminals connected, respectively, to two outlets of a binary switching element 19. The outlets of the three switching elements of the counter 20 are connected.
to a decoder 21 comprising eight outlets \( n = 0, 1, 2 \ldots 7 \) which engender a voltage having the form

\[
\sin \left( \frac{\pi}{2} \right)
\]

at the outlet of a numerical analog converter 22.

A differential amplifier 26 comprising outlets \( S_1 \) and \( S_2 \) has an input connected to the outlet of an “and” circuit 24 and another input connected to the outlet of an “and” circuit 24 and another input connected to the outlet of an “and” circuit 25. These two “and” circuits each have an input connected in combination to the outlet of the said converter 22. The “and” circuit 24 has an input connected to the outlet of a bistable switching element 23 and the “and” circuit 25 has an inlet connected to the other outlet of the said switching element 23. This switching element 23 has an input terminal connected to an outlet of the switching element 19. The differential amplifier 26 has two output terminals \( S_1 \) and \( S_2 \) symmetrical to the terminals of a resistance 27. The outlet (0) and the outlet (7) of the decoder 21 are connected to the inlet of the switching element 19 by means of an “or” circuit 18. The constant \( E \) is equal to zero in this case.

The curve \( a \) of FIGURE 4 shows a telegraphic transition at the time \( t_1 \). Prior to the time \( t_1 \), the circuit \( 16 \) is unblocked, the circuit \( 15 \) is blocked, and the frequency \( F_2 \) (curve \( b \)) supplied by the oscillator 14 is allowed to reach the counter 20. After the time \( t_1 \), the circuit \( 16 \) is blocked, the circuit \( 15 \) is unblocked, and the frequency \( F_1 \) (curve \( c \)) is allowed to reach the counter 20. The advancing pulses received by the counter are shown in the curve \( d \). For 7 pulses received by the counter 20 starting from zero, it passes successively to the states 1 \( \ldots \) 7. In the state 7, a connection between the outlet (7) of the decoder 21 and the switching element 19 through the “or” circuit 18 reverses the said switching element, the counter passes into descending counting operations, the following seven pulses causing it to return from (7) to (0). On passing through (0), a voltage appearing in a conductor \( L \) causes the counter to pass into ascending counting operation, and the said voltage reverses the switching element 23 at the same time. This results in an inversion or reversal of the operation of the differential amplifier 26. In this way, for the first four pulses received after the time \( t_1 \) taken as the origin (FIGURE 4, curve 4), a positive voltage is obtained across the output terminals \( S_1 \) and \( S_2 \) and for fourteen following pulses a negative voltage is obtained, this process being reproduced in a recurrent manner. The counter counts in ascending order for the first seven counts, then counts in descending order for the next seven, starts counting in ascending order again for the following seven, and so on and so forth.

A fragmented sinusoidal curve is thus obtained, being a smoothed sinusoidal curve (dashed line curve of graph \( e \)), by the action of the band limitations in the circuits, without a continuous or direct component. The frequency division factor amounts to 28, with a counter comprising only three switching elements and one seven-value converter instead of a fifteen-value converter in the case of FIGURE 4.

The oscillators 13 and 14 being independent, the passage from the frequency \( F_1 \) to the frequency \( F_2 \) or vice versa at the instant of a telegraphic transition is mandatorily accompanied by a phase incoherence, establishing a possibility of telegraphic distortion, as apparent from the preceding. But the flux in the frame of the transformation applies to frequencies multiplied by 28. In the case of the frequencies taken as examples in the preceding, being \( F_1 = 1300 \) c/s, \( F_2 = 2100 \) c/s and with a telegraphic speed of 1200 bands, the distortion is equal to approximately 2.7%, which is quite acceptable.

In the embodiment corresponding to FIGURE 2, with a modulating relaxation oscillator and a circuit shaper, the linearly frequency modulated low frequency wave has a limited spectrum, which renders it possible to omit the conventional band filter.

The examples given in the preceding are obviously not of limiting nature, they merely represent preferred embodiments among others which are possible within the scope of the invention, which may equally be applied for other modulation signals than telegraphic signals.

I claim:

1. A wave synthesizer, for use especially with telegraphy systems, for generating a wave having a frequency \( F \) which may assume two values \( F_1 \) and \( F_2 \) comprising: signal generator means providing a signal of frequency \( kF \) being an even multiple of a selected value \( n \), counter means capable of counting in ascending and descending order having an input connected to said signal generator means and having a capacity of \((n-1)\), a decoder connected to said counter means and having \( n \) outputs, a numerical analog converter having \( n \) inputs connected to said decoder and supplying an output voltage proportional to

\[
A + \sin \left( \frac{\pi}{n-1} \right) i
\]

in which \( A \) is a constant and \( i \) is a number between 0 and \( n-1 \), logical circuit means connected to said decoder for controlling said counter to count in the ascending order upon reaching a count of \( 0 \) and in the descending order upon reaching a count of \( n-1 \), and amplifier means connected to the output of said converter providing an output voltage whose envelope is a sinusoidal wave frequency \( F \).

2. A wave synthesizer as defined in claim 1 wherein \( k=2n \) and said logical circuit means includes an “or” circuit having inputs connected to the 0 and \( n-1 \) outputs of said decoder and a binary switching element connected to said “or” circuit and having a pair of outputs connected to respective control inputs of said counter for controlling the direction of said counter in between counts of said counter.

3. A wave synthesizer as defined in claim 2 wherein said signal generator means includes a voltage controlled oscillator whose output frequency is determined by the input signal level.

4. A wave synthesizer as defined in claim 3 wherein said signal generator means further includes a telegraphic signal emitter providing an output signal having first and second levels and a shaping filter interconnecting said emitter and said oscillator.

5. A wave synthesizer as defined in claim 1 wherein \( k=4n \) and said logical circuit means includes a first “or” circuit having inputs connected to the 0 and \( n-1 \) outputs of said decoder, a first binary switching element connected to said “or” circuit and having a pair of outputs connected to respective control inputs of said counter for controlling the direction of said counter, a pair of “and” gates connecting the output of said converter to said amplifier means and a second binary switching element connected to an output of said first binary element and having a pair of control outputs connected to respective “and” gates for actuating one “and” gate at a time.

6. A wave synthesizer as defined in claim 5 wherein said amplifier means is a differentiator amplifier having a pair of inputs connected respectively to an individual “and” gate.

7. A wave synthesizer as defined in claim 6 wherein said signal generator means includes a second “or” circuit, first and second oscillators providing output signals of frequencies \( F_1 \) and \( F_2 \) respectively, and control means for selectively connecting one of said oscillator to said second “or” circuit.

8. A wave synthesizer as defined in claim 7 wherein said control means includes a second pair of “and” gates each having one of said first and second oscillators connected thereto and a telegraphic signal emitter connected
directly to one of said second pair of "and" gates and
connected through an inverter to the other of said second
pair of "and" gates for applying a signal having first
and second levels thereto.

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