July 10, 1945. A. L. NELSON 2,380,366

MODULATING SYSTEM FOR FREQUENCY MULTIPLIERS

Filed Sept. 4, 1941 2 Sheets-Sheet 1

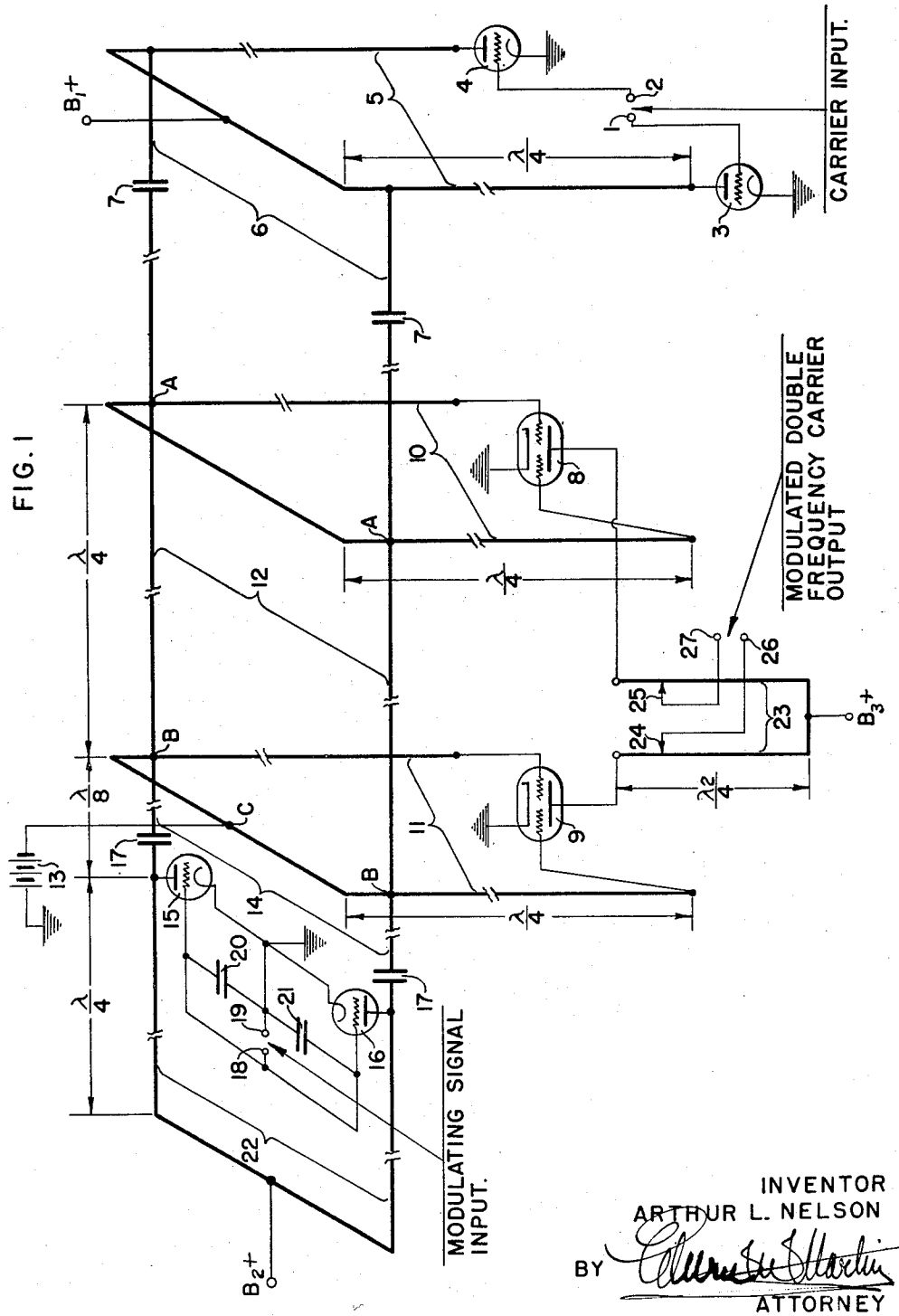

FIG. 1

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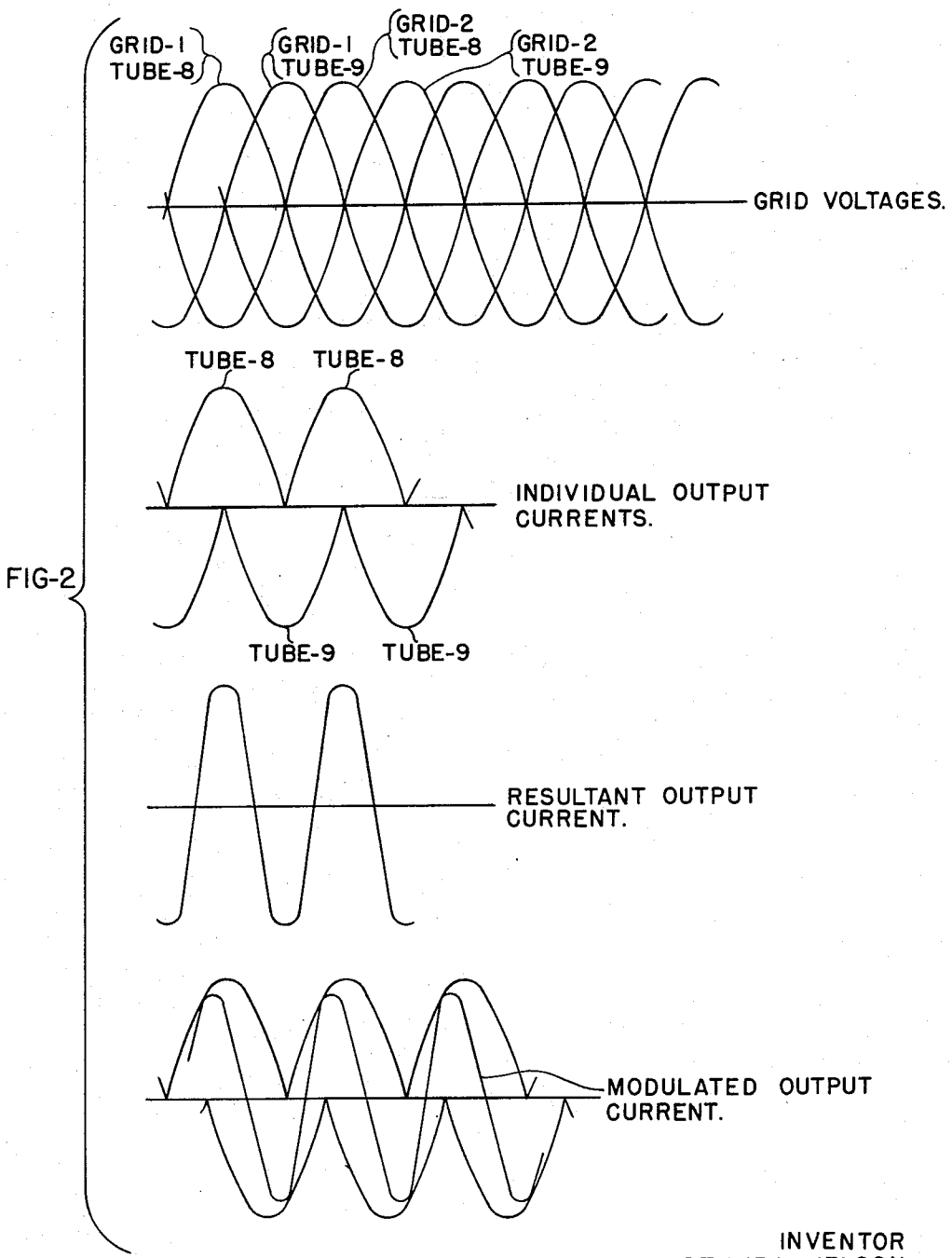

FIG-2

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UNITED STATES PATENT OFFICE

2,380,366

MODULATING SYSTEM FOR FREQUENCY MULTIPLIERS

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Application September 4, 1941, Serial No. 409,471

8 Claims. (Cl. 179—171.5)

This invention relates to a combined frequency multiplier and modulator and particularly to an arrangement for multiplying and simultaneously modulating high and ultra-high frequencies.

In the copending application U. S. Serial No. 314,480, filed January 18, 1940, by Arthur L. Nelson, there is described a new and improved frequency multiplier of the type embodied in the present invention.

In conventional arrangements for deriving a modulated output signal from an unmodulated input signal of lower frequency, separate frequency multiplying and modulating means were required which necessarily complicates the apparatus necessary for this purpose.

It is the object of the present invention, therefore, to provide a new and improved combined frequency multiplier modulator of simple construction.

In accordance with the present invention, there is provided a high frequency multiplier modulator comprising signal repeating means adapted to repeat portions of a signal impressed thereon. An input circuit is provided for the multiplier and means so connecting the input circuit with the repeating means so as to effect a plurality of applications of a signal impressed on the input circuit to the repeating means, each of a predetermined different relative phase. Means are provided for varying the relative phase in accordance with a modulating signal and, finally, there is provided an output circuit for the repeating means for combining repeated signal portions to produce a modulated signal of increased frequency.

In one preferred embodiment of the invention, the frequency multiplier modulator comprises a pair of similar multi-element vacuum tubes. An individual input circuit is provided for each of these tubes consisting preferably of a single transmission line. A phase shifting means, preferably comprising a transmission line, connects the individual input circuits, and the main input circuit for the multiplier device is connected thereto. In such a multiplier employing a single pair of vacuum tubes, frequency doubling or frequency quadrupling is readily obtained at the option of the user, without any changes in the input circuits and only a small change in the output circuit arrangement and constants. Another transmission line is connected to the transmission line constituting the phase shifting means and to its end remote from the main input circuit. This transmission line is of predetermined length and is terminated by one or more electron discharge devices representing a variable impedance. The impedance of this device or devices is controlled in accordance with a modulating signal.

It will be understood that at the lower frequencies conventional resonant circuits employing lumped reactances may be substituted for the transmission lines between the grids of each tube, and the phase shifting means connecting the tube input circuits may be other than a transmission line, without departing from the scope of the invention.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings, Fig. 1 shows a schematic circuit diagram of a frequency multiplier modulator in accordance with the present invention, arranged for frequency doubling. Fig. 2 is a graph representing certain operating characteristics of the multiplier modulator of Fig. 1.

Referring more particularly to Fig. 1 of the drawings, there is shown a frequency multiplier modulator comprising an input circuit having input terminals 1 and 2 connected to the control grids of a pair of amplifier tubes 3 and 4, respectively, the anodes of which are connected to the open ends of a short-circuited transmission line 5. The effective wave length of the transmission line 5 is one-quarter wave length of the radio frequency signal applied to the input terminals 1 and 2. The short-circuited end of the transmission line 5 is connected to the positive terminal of an anode voltage source, schematically indicated at B_1+. The input circuit also includes a transmission line section 6, the wave length of which is not critical, having in each of its branches a condenser 7 for blocking the direct current from the voltage source indicated at B_1+. For repeating portions of the radio frequency signal applied to the input terminals 1 and 2, there are provided a pair of vacuum tubes 8 and 9, each having two control grids and a single anode. Obviously, two separate tubes can also be used with their anodes conductively connected in place of each of the tubes 8 and 9. Tubes 8 and 9 are each provided with an input circuit comprising transmission lines 10 and 11, respectively. These transmission lines, having an effective wave length equal to one-quarter wave length of the applied radio frequency signal, are short-circuited at one end, while their open ends are

connected to the control grids of tubes 8 and 9, respectively. Lines 10 and 11 are conductively connected at points AA and BB, respectively, to the opposite ends of a transmission line 12, whose effective wave length equals one-quarter wave length of the applied radio frequency signal and which constitutes a phase-shifting means for applying the input signal to the control grids of tubes 8 and 9, with a predetermined different phase relation. For providing the control grids of tubes 8 and 9, respectively, with a steady bias voltage, there is provided a voltage source indicated as a battery 13, connected to the short-circuited end of the transmission line 11 at a point C. Battery 13 supplies the bias voltage to the control grids of both tubes, since they are at the same direct-current potential.

For changing the phase of the input signal applied to the control grids of tubes 8 and 9, respectively, there is provided a transmission line section 14 connected to the transmission line 12 at points BB and having connected to its opposite end a pair of electron discharge tubes 15 and 16. For blocking the anode voltage of tubes 15 and 16 from the remainder of the circuit, transmission line 14 is provided with condensers 17, as shown. The effective wave length of the transmission line 14 is one-eighth the wave length of the applied radio frequency input signal. Tubes 15 and 16 each comprise an anode, a control grid and a cathode. The cathodes of both tubes are connected to ground. For the purpose of varying the variable impedance represented by the tubes 15 and 16, there are provided between the control grids and the cathodes, respectively, of tubes 15 and 16 a pair of input terminals 18 and 19, adapted to have a modulating signal applied thereto. For by-passing radio frequency signals arriving at the control grids of tubes 15 and 16, through the anode grid capacities thereof, there are provided a pair of by-pass condensers 20 and 21, connected between the control grids of tubes 15 and 16, respectively, and ground. For supplying the tubes 15 and 16 with operating voltages, there is provided a transmission line section 22 connected at one end to the anodes of these tubes while its opposite end is short-circuited. The short-circuited end of transmission line 22 is connected to the positive terminal of an anode voltage source schematically indicated at B_2+. The effective wave length of the transmission line 22 is one-quarter of the wave length of the applied radio frequency signal.

For developing a modulated radio frequency signal of increased frequency, there is provided a common output circuit connected to the anodes of tubes 8 and 9, respectively, comprising a transmission line 23 having one end connected to the anodes of tubes 8 and 9 and having its opposite end short-circuited. The short-circuited end of transmission line 23 is connected to the positive terminal of an anode voltage source schematically indicate at B_3+ for applying an operating voltage to the anodes of tubes 8 and 9. The effective wave length of this transmission line is equal to one-quarter of the wave length of the multiplied and modulated radio frequency signal.

For deriving a modulated signal of increased frequency from the transmission line 23, there are provided a pair of contacts 24 and 25, slidably arranged on the transmission line 23 for the purpose of impedance matching and connected to a pair of output terminals 26 and 27, between which a modulated signal of increased frequency is developed.

In operation, a radio frequency signal is applied to the input terminals 1 and 2, amplified by means of amplifier tubes 3 and 4 and applied by way of the transmission line 6 to points AA of the transmission line 12. If the transmission line 12 were terminated at points BB with the proper resistance, the input signal would be applied to the control grids of the tube 8, with a phase difference of 180°. The same signal would be applied to the control grids of tube 9, also, with a phase difference of 180°; however, the signals applied to corresponding grids of the two tubes would have a relative phase difference of 90°, due to the presence of the quarter-wave length transmission line 12. The voltages applied to the control grids of tubes 8 and 9 are shown in Fig. 2. Due to the bias voltage supplied by the source 13 to the control grids, these tubes are permitted to draw current only during a portion of the applied signal, so that individual output currents, as shown in Fig. 2, are delivered by the tubes 8 and 9 to the output circuit comprising the transmission line 23. The resultant output current resulting therefrom is also shown in Fig. 2.

If, now, the resistance assumed between points BB of transmission line 12 is replaced by a variable impedance coupled to points BB by way of the one-eighth wave length transmission line 14, different operating conditions are incurred. Assuming the impedance represented by the tubes 15 and 16 to be Z_a and the characteristic impedance of the transmission line 14 to be Z_o, then the impedance, looking from terminals BB to the left, is

$$Z_i = Z_o e^{j\left(\pi/2 - 2 \text{ arc tang } \frac{Z_a}{Z_o}\right)}$$

Assuming the characteristic impedance of transmission line 12 also to be Z_o, then the impedance at points AA, looking to the left will be

$$Z_i' = Z_o e^{-j\left(\pi/2 - 2 \text{ arc tang } \frac{Z_a}{Z_o}\right)}$$

The angle between these impedances and, therefore, the relative phase of the voltages appearing between points AA and BB is

$$\phi = 2 \text{ arc tang } \frac{Z_a}{Z_o}$$

From the above, it is evident that the relative phase of the voltages at points AA and BB and, therefore, also of the voltages applied to the control grids of tubes 8 and 9, respectively, varies in accordance with variations of the impedance Z_a, represented by the tubes 15 and 16. The impedance represented by these tubes, however, is varied in accordance with the modulating signal applied to the input terminals 18 and 19. Hence, the relative phase of the individual output currents contributed by tubes 8 and 9 is varied in accordance with the modulating signal, whereby the amplitude of the resultant modulated output current is decreased, as shown in Fig. 2. In this manner, a radio frequency output signal having twice the frequency of the applied radio frequency is produced, which is modulated in accordance with a modulating signal.

While there has been described what is at present considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the ap-

pended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A frequency multiplier modulator for multiplying the frequency of an input signal comprising a pair of vacuum tubes, each having two grids and one anode, an input circuit, a transmission line having an effective length equal to one-quarter the wave length of said input signal connected to said input circuit, means connecting the grids of one of said tubes to opposite sides of said transmission line at one end thereof, means connecting the grids of the other of said tubes at opposite sides of said transmission line at the other end thereof, a similar transmission line having an effective length equal to one-eighth the wave length of said input signal connected to said first-named transmission line at its end remote from said input circuit, an impedance means connected to said transmission line and variable in accordance with a modulating signal and a common output circuit connected to said anodes to produce a modulated signal of increased frequency.

2. A frequency multiplier modulator for multiplying the frequency of an input signal comprising a pair of vacuum tubes, each having two grids and one anode, an input circuit, a first transmission line having an effective wave length equal to one-quarter the wave length of said input signal connected to said input circuit, second and third transmission lines, respectively, for each of said tubes having an effective length equal to one-quarter the wave length of said input signal connecting the grids of said tubes to opposite ends, respectively, of said first transmission line at opposite sides thereof, a fourth transmission line connected to the end of said first transmission line remote from said input circuit and having an effective wave length equal to one-eighth the wave length of said input signal, impedance means terminating the open end of said fourth transmission line and being variable in accordance with a modulating signal, and a common output circuit connected to said anodes to produce a modulated signal of increased frequency.

3. A frequency multiplier modulator comprising a pair of vacuum tubes each having two grids and one anode, an individual input circuit for each of said tubes connected to the grids thereof, phase shifting means connected between relatively low impedance points of said individual input circuits, a common input circuit connected to one end of said phase shifting means whereby a signal may be applied to the grids of the same tube in opposite polarity and to corresponding grids of different tubes with predetermined different relative phase, phase shifting means including a variable impedance means connected to said first-named phase shifting means for varying said relative phase, and a common output circuit connected to said anodes to produce a modulated signal of increased frequency.

4. A frequency multiplier modulator for multiplying the frequency of and modulating the amplitude of an input signal comprising a pair of vacuum tubes, each having two grids and one anode, an individual input circuit for each of said tubes connected to the grids thereof, phase shifting means connected between the relatively low impedance points of said individual input circuits, said phase shifting means comprising a transmission line having an effective length equal to one-quarter the wave length of said input signal, a common input circuit connected to one end of said phase shifting means whereby a signal may be applied to the grids of the same tube in opposite polarity and to corresponding grids of the different tubes in predetermined different relative phase, a second transmission line connected to the ends of said first-named transmission line remote from said common input circuit, an impedance means connected to the terminals of said second transmission line and variable in accordance with a modulating signal, and a common output circuit connected to said anodes to produce a modulated signal of increased frequency.

5. A frequency doubler modulator for providing a modulated output signal having twice the frequency of an unmodulated input signal comprising a pair of vacuum tubes, each having two grids and one anode, an individual input circuit for each of said tubes connected to the grids thereof, phase shifting means linking said individual input circuits, said phase shifting means comprising a transmission line having an effective length equal to one-quarter the wave length of said input signal, a common input circuit connected to one end of said phase shifting means whereby an input signal may be applied to the grids of the same tube in opposite polarity and to corresponding grids of the different tubes with predetermined different relative phase, a second transmission line connected to the end of said first-named transmission line remote from said common input circuit, an electron discharge device coupled to the free end of said second-named transmission line, means for controlling the electron flow in said device in accordance with a modulating signal, thereby to vary said relative phase in accordance with said modulating signal, and a common output circuit connected to said anodes, said output circuit comprising a transmission line having an effective length equal to one-quarter the wave length of said output signal.

6. A frequency multiplier modulator comprising a signal input circuit, two pairs of vacuum tube signal repeating means, each having a control grid and being adapted to repeat portions of a signal impressed thereon, two separate input circuits individually connected to said control electrodes for applying a signal to the control electrodes of each of said pairs of repeating means, phase-shifting means having a first pair of terminals and a second pair of terminals and capable of producing a phase shift between said first and said second pairs of terminals, means for connecting said signal input circuit and one of said separate input circuits to said first pair of terminals to apply to the control grids of the first pair of repeating means a signal in opposite polarity, means for connecting the second separate input circuit to said second pair of terminals to apply a signal to said grids of the second pair of signal repeating means, said signal being in opposite polarity with a predetermined different relative phase with respect to the signals applied to said grids of said first pair of signal repeating means, an impedance means coupled to said second pair of terminals and variable in accordance with a modulating signal, thereby to vary the relative phase of said signal applied to said control grids, and an output circuit connected to said repeating means for combining signal portions repeated by said repeating means to produce a modulated signal of increased frequency.

7. A frequency multiplier modulator comprising a pair of vacuum tubes, each having two

grids and one anode, an input circuit, an impedance means having a first pair of terminals and a second pair of terminals, said impedance means being capable of producing a phase shift between said first and said second pairs of terminals, means connecting said input circuit and said grids of the first of said vacuum tubes to said first pair of terminals to apply to said grids a signal in opposite polarity, means connecting said grids of the second of said vacuum tubes to said second pair of terminals to apply to said grids said signal in opposite polarity with a predetermined different relative phase with respect to the signals applied to said grids of said first tube, means connected to said second pair of terminals for varying said relative phase in accordance with a modulating signal, and a common output circuit connected to said anodes to produce a modulated signal of increased frequency.

8. A frequency multiplier modulator comprising a signal input circuit, first vacuum tube signal repeating means comprising control electrode means for repeating half-cycles of a predetermined polarity only of a signal, second vacuum tube signal repeating means comprising control electrode means for repeating half-cycles of the opposite polarity only of said signal, a plurality of separate input circuits individually connected to said first and second control electrode means, phase shifting means connecting said separate input circuits to said multiplier signal input circuit for applying said signal to said first and second repeating means with predetermined different relative phase, means for varying said relative phase in accordance with a modulating signal and an output circuit connected to said repeating means for combining signal half-cycles repeated by said first and second repeating means to produce a modulated signal of increased frequency.

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