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ULTRA-HIGH FREQUENCY CONVERTER CIRCUIT

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Fig. 1.

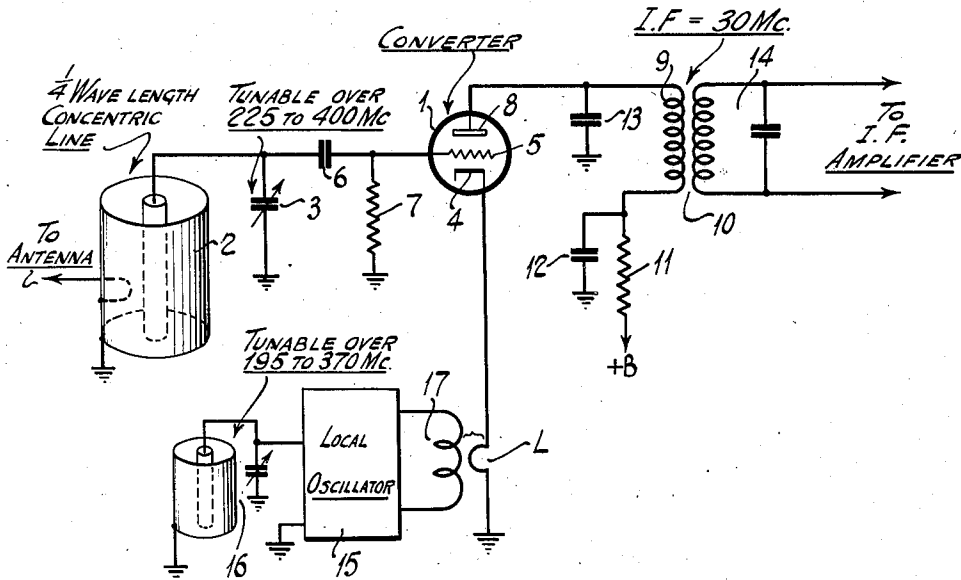
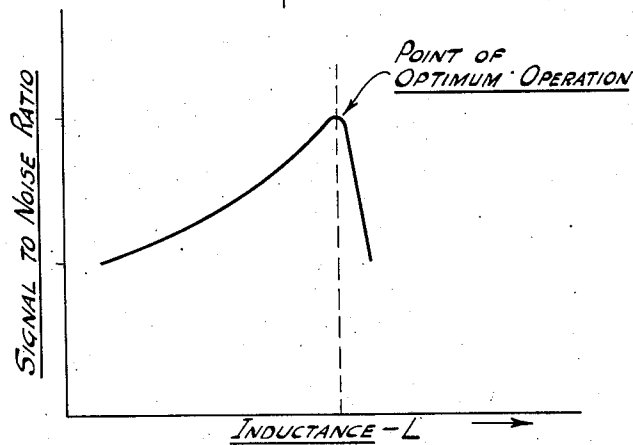


Fig. 2.



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ULTRA HIGH FREQUENCY CONVERTER
CIRCUITLeland E. Thompson, Merchantville, N. J., assign-
or to Radio Corporation of America, a corpora-
tion of Delaware

Application April 3, 1943, Serial No. 481,687

• 2 Claims. (Cl. 250—20)

My present invention relates to ultra-high frequency converter circuits, and more particularly to an ultra-high frequency triode converter circuit.

As is well known, there are special problems involved in the reception of radio frequency signals in the ultra-high frequency band. One of the most important problems which confronts the designer of an ultra-high frequency receiver is to provide a high sensitivity at the converter circuit itself. In a receiver utilizing no radio frequency amplification prior to the input circuit of the converter, and covering, for example, a frequency range of 225 to 400 megacycles (mc.), it is also especially important to provide a high signal-to-noise ratio at the converter input circuit.

I have found in an ultra-high frequency converter circuit utilizing a triode tube that increasing the magnitude of the inductance in the cathode lead, will materially increase the sensitivity and the signal-to-noise ratio of the converter up to a certain inductance value. I have found that beyond this value the sensitivity drops very rapidly. It is one of the main objects of my present invention to provide an ultra-high frequency converter with an increase in sensitivity and signal-to-noise ratio of at least two times. This has been obtained in an actual receiver by maintaining the converter cathode circuit at a predetermined inductive value.

It is another important object of this invention to provide an ultra-high frequency receiver adapted to operate to receive signals whose frequency is as high as 400 mc. (megacycles), the receiver having its signal collecting device coupled directly to the tunable input circuit of the converter, and the local oscillator being coupled to an inductance of predetermined magnitude in the cathode lead of the converter tube.

Still other objects of my invention are to improve generally the sensitivity and efficiency of ultra-high frequency converter circuits of the triode type, and more particularly to provide a simple and effective method of securing an appreciable increase in signal-to-noise ratio in such a converter circuit.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention, itself, however, as to both its organization and method of operation will best be understood by reference to the following description, taken in connection with the drawing, in which I have indicated diagrammatically an illustrative circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows the circuit diagram, certain elements being schematically represented, of a circuit embodying the invention,

Fig. 2 is a purely qualitative curve to illustrate the advantage of the invention.

In Fig. 1 there is shown a triode 1 which is used as the converter tube of the ultra-high frequency receiver to which this invention is directed. The tube 1 is schematically represented, but it will be clearly understood that it will be of a type suitable for functioning as a converter in the ultra-high frequency band of operation of this receiver. For example, a type 955 triode could be used. Let it be assumed that the desired frequency band is of the order of 225 to 400 mc., and that the receiver is of the superheterodyne type. The preliminary resonant selector circuit consists of a resonant line circuit employing capacity tuning. The numeral 2 denotes a one-quarter wave length concentric line of any well known form. The numeral 3 designates the capacity tuning means. It will be understood that an actual physical condenser need not be employed, since any well known device can be used to vary the capacity of the resonant line 2. The network 2—3, then, provides a tunable selector circuit adapted to be adjusted over the given frequency range of 225 to 400 mc. The cathode 4 of tube 1 is connected to ground through an inductance coil L. The control grid 5 is connected to the high potential side of circuit 2—3 through a grid coupling condenser 6. The numeral 7 designates the usual grid return resistor connected from grid 5 to ground. The plate 8 is connected to the +B terminal of the direct current energizing source through a path comprising the primary winding 9 of intermediate frequency output transformer 10 and the resistor 11.

The resistor 11 is bypassed to ground for the ultra-high frequency currents by condenser 12. The condenser 13 is connected to ground from the plate end of coil 9. The function of condenser 13 is to bypass ultra-high frequency currents, and also to act as a tuning capacitor for the primary winding 9 of the intermediate frequency (I. F.) output transformer 10. Of course, the primary circuit 13—9 will be tuned to the operating I. F. value, and the latter will have any desired value. For example, an I. F. of 30 mc., could be used. The numeral 14 designates the secondary circuit of the I. F. transformer 10, and the latter will also be tuned to the operating I. F. value. The subsequent networks are not shown, because they are not a part of this invention. It is sufficient to point out that the usual networks of a superheterodyne receiver may be employed subsequent to the circuit 14.

The local oscillator is designated by numeral 15, and the numeral 16 designates generally the tunable tank circuit of the local oscillator. The output coil 17 of the local oscillator is shown magnetically coupled to the cathode coil L. It will, therefore, be seen that the local oscillations are injected into the cathode circuit of the converter

tube. It will be understood that the local oscillations may be applied to the cathode coil L directly from the tank circuit 16, if desired. The tuning range of the local oscillator 15 would be 195 to 370 mc. for the I. F. value of 30 mc. These various frequency ranges are purely illustrative, and are in no sense restrictive as to the scope of my invention.

The specific antenna, or signal collecting device, is not shown, but may be a dipole which is magnetically coupled to the tunable input circuit 2-3 as schematically shown. If desired, there can be employed a co-axial cable which is adapted to feed the ultra-high frequency signal energy to the converter input circuit. The coil L may be made to have an adjustable value, if desired. It can be a fixed inductance of the proper value to obtain the desired sensitivity. The converter tuned input circuit, which is of the resonant line type, is a high "Q" circuit with a consequent high resonant impedance. The coil L may be composed of two separate inductances in series, if desired; one part is used to couple to the local oscillator, and the other part is predetermined in value so that the total cathode inductance will provide the beneficial results desired. It should be understood that while the cathode circuit injection of the local oscillator is convenient and effective, the local oscillator, if desired, may be coupled to the grid circuit.

I have found in actual experience with the circuit of Fig. 1 that there is a point of optimum operation for the converter circuit. That is to say, with a predetermined value of inductance L inserted in the cathode circuit, the signal-to-noise ratio will be a maximum value. For inductance values less than the critical value which has been predetermined, the sensitivity of the converter decreases. Furthermore, for inductance values beyond the critical value the sensitivity drops very rapidly. In Fig. 2 there is depicted, in a purely qualitative manner, that by assigning the critical value of the inductance L there may be secured a greatly increased signal-to-noise ratio. Indeed, for the range of 225 to 400 megacycles an increase in sensitivity and signal-to-noise ratio of two times has been obtained by adding the proper amount of inductance L in the cathode lead. It has been found by actual experiment that the results obtained are not due to an increase or decrease in oscillator excitation voltage impressed on the converter. I do not wish to limit myself to any particular theoretical explanation which would explain the reason for this rise in sensitivity, since actual experience with the circuit has demonstrated that such a sharp rise in sensitivity is secured. What is most important in the present circuit is that the increase in gain at the converter circuit gives an increase in signal-to-noise ratio of an appreciable amount (about 6 decibels) which makes it particularly valuable in an ultra-high frequency receiver.

I may point out that I have found it necessary that the cathode circuit of the converter be inductive at the selected signal frequency to obtain the beneficial effects which I have observed. The selectivity of the receiver is dependent entirely on the I. F. band width, and not on the input circuit of the converter stage. Therefore, the effects described herein cannot be said to be due to a reduction in band width at the converter input circuit. I do not wish it to be understood that the adjustment of the cathode circuit inductance L is sharply critical. In that regard it is pointed

out that some benefit is obtained by the adding of inductance in the cathode circuit long before the point of optimum operation is reached. For example, at 400 megacycles the inductance L actually consisted of a wire between 2 and 3 inches long in the form of a loop. This same inductance gave some benefit at a frequency of 200 megacycles. The total inductive magnitude of L would include the cathode lead inside of tube 1. The type of tube used would then have some effect on how much external inductance should be added. The inductance L would probably be of the order of 0.1 microhenry.

It may well be that the results obtained with this converter circuit may be due to the inductance in the cathode lead compensating, or in some way rendering less effective, the electron transit time of the converter tube. The input conductance formula for a vacuum tube is usually given for the case where the inductance of the cathode lead is purposely kept small. This formula shows that the input resistance is higher when L is low. Considering the voltages appearing from grid 5 to ground of the tube 1, due to signal voltage input the vector relations of these voltages show that it is possible to adjust L of the cathode circuit so that it is possible to make the maximum charge appear on the grid 5 at the time of maximum signal voltage. That is, the alternations of the charge on the grid 5 may be made to be in phase with the signal alternating current. This condition appears to eliminate the effect of electron transit time. Indeed, this effect becomes a factor of increasing importance with increasing frequency of the ultra-high frequency signals. This would confirm the theoretical explanation that compensation of the electron transit time of the converter tube is responsible for the beneficial action secured with my present circuit.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In an ultra-high frequency converter stage of the type comprising a converter tube of the triode type provided with a tunable input circuit adjustable over a range of 200 to 400 megacycles, and having a local oscillator constructed and arranged to inject its oscillations into the converter tube cathode circuit; the improvement which includes the direct connection of an inductance between the converter tube cathode and ground for rendering the cathode circuit essentially inductive, and said inductance having a predetermined value to greatly increase the sensitivity of the converter stage.

2. A method of compensating for electron transit time of a converter tube operating in the ultra-high frequency range and having its signal input circuit directly coupled to a signal collector device; the method comprising the steps of injecting into the converter cathode circuit locally-produced oscillations, and maintaining the cathode circuit essentially inductive and of a predetermined magnitude such as to provide the said electron transit time compensation whereby the sensitivity of the converter is greatly increased.

LELAND E. THOMPSON.