May 30, 1944. H. LÜBECK 2,350,051

METHOD OF AND MEANS FOR ELECTRICAL TRANSMISSION OF PICTURES AND/OR CHARACTERS

Filed Feb. 26, 1941 2 Sheets-Sheet 1

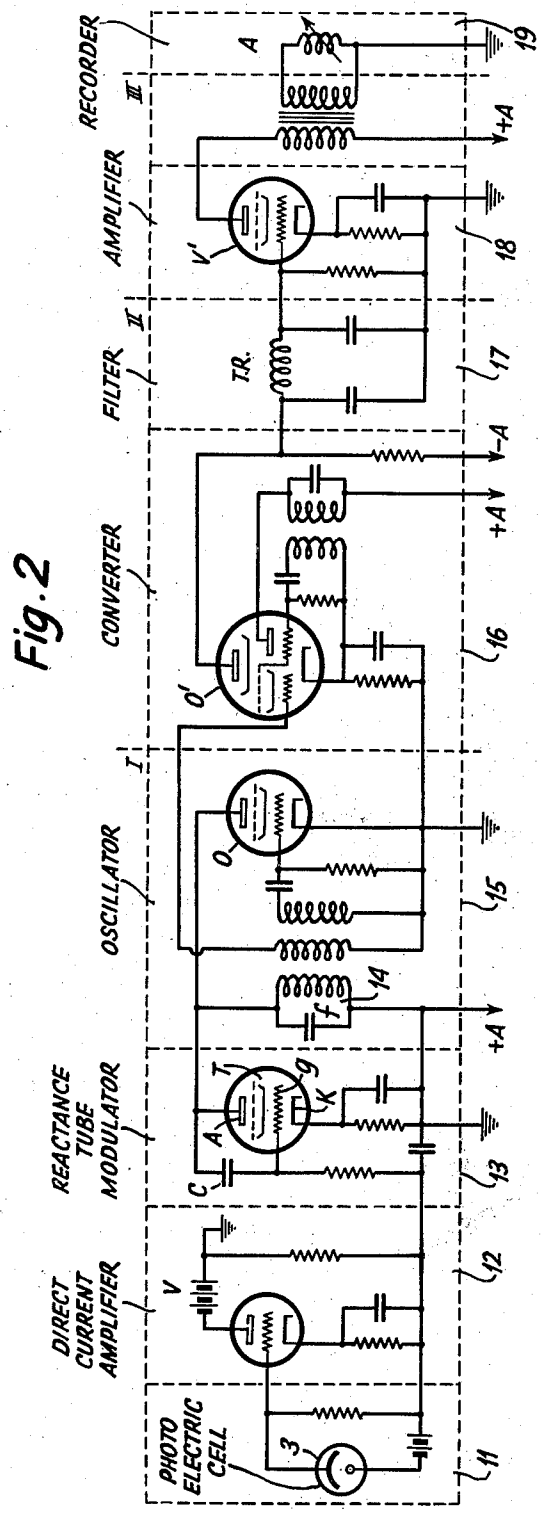


Fig. 2

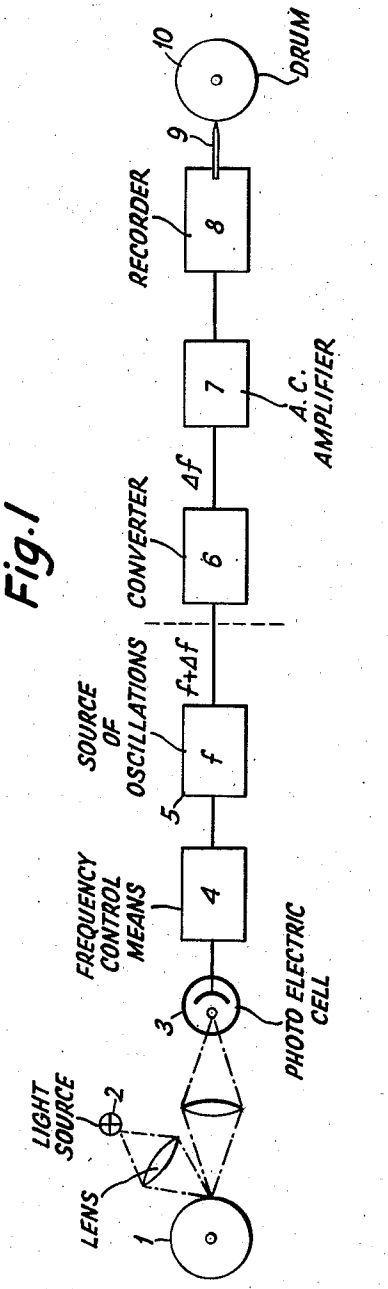


Fig. 1

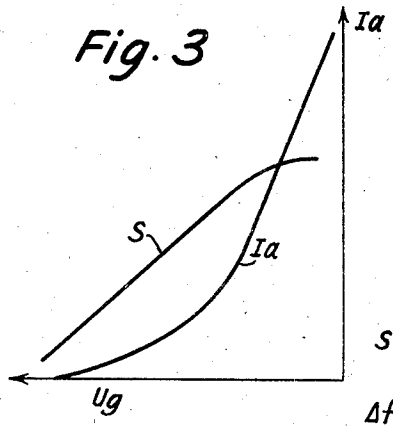
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METHOD OF AND MEANS FOR ELECTRICAL TRANSMISSION OF PICTURES AND/OR CHARACTERS

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Fig. 3



$$S \sim \frac{dIa}{dUg}$$

$$\Delta f \sim C' \sim S \sim \frac{dIa}{dUg}$$

Fig. 4

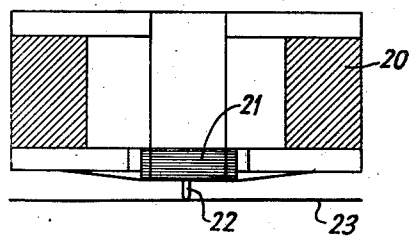


Fig. 5

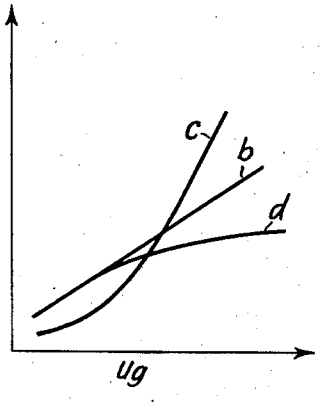
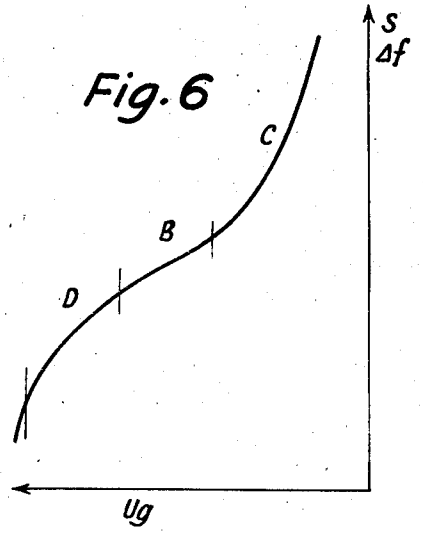


Fig. 6



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2,350,051

METHOD OF AND MEANS FOR ELECTRICAL TRANSMISSION OF PICTURES AND/OR CHARACTERS

Heinz Lübeck, Berlin, Germany, assignor to General Electric Co., a corporation of New York

Application February 26, 1941, Serial No. 380,635
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8 Claims. (Cl. 178—6.6)

This invention is concerned with an electrical method adapted to transmit or copy pictures and/or characters, etc.

A number of methods have been disclosed in the prior art for the electrical transmission of pictures or characters, etc., either by radio or through a wire or cable channel. All of these methods, insofar as the recreation of the pictures or characters is concerned, can be essentially subdivided into two categories—one insures an electro-mechanical reproduction and the other one a photo-electrical recreation.

In electro-mechanical reproduction recording is effected, for instance, in a way similar to the action and operation of a conventional typewriter machine, that is, by the keeper of a relay which is caused to come into pressure relationship with the paper held on a drum or cylinder, with interposition optionally of a ribbon, so that upon the paper lines of constant intensity, but of different length are produced in accordance with the incoming impulses. These methods are known as printing or typescript methods.

Now, the drawbacks of such electro-mechanical reproduction or reception are essentially ascribable to the difficulty of faithfully recreating differences in shading of the original.

The second class of methods operates in such a way that voltage impulses produced at the sending end and the intensity of which is a function of the brightness of the picture point or unit, are converted at the receiving end into light impulses of a corresponding intensity. These luminous impulses serve to illuminate or expose a coat or layer (emulsion) responsive to light actions which when developed results in a reproduction or copy of the original picture or representation, that is, usually in the form of a negative. This second method offers the fundamental advantage over the method first mentioned that it is possible to transmit different shading values, though it inheres the shortcoming that the incoming picture is not directly viewable or visible, in fact, it must first be developed, and that it is not possible to obtain several copies at the same time.

The method of the invention combines the advantages and merits of the said methods, while avoiding the drawbacks thereof. To be more precise, it insures the electro-mechanical recreation of pictures presenting shading values corresponding to the original, and it also allows to make several copies by one and the same receiver equipment which are directly visible.

The method of the invention for the electrical transmission of pictures is predicated upon this fact that at the sending end electrical potentials are obtained by ways and means known in the prior art by scanning sequentially the picture units of the original picture, said potentials corresponding to the brightness of the latter. Now, the ensuing voltages—and this is the novel feature of the invention—serve to so act upon an alternating current that the frequency of the latter is governed and determined by the amplitude of the potentials. This alternating current of fluctuating frequency, if desired, is then transmitted on carrier frequency and is so fed to the electromechanical recorder means provided at the receiving end that a sequence of points of substantially constant point thickness in accordance with the frequency of the alternating current will be recorded.

The invention shall now be explained in more detail by reference to the appended drawings.

Fig. 1 is a schematic view in block form of the basic principle of an arrangement adapted to practice the method of the invention.

Fig. 2 is a circuit organization adapted to produce the alternating current the frequency of which corresponds to the amplitudes of the voltages giving the picture point brilliance.

Fig. 4 is a schematic view of the construction of the electro-mechanical recorder system adapted to the method of this invention.

Figs. 3, 5 and 6 illustrate graphs to aid in the explanation of the operation of applicant's system.

Referring to Fig. 1, 1 is the sending drum on which the original picture is fastened. 2 is a source of light the radiations of which by means of suitable optical means are focused upon the elementary picture or picture point to be scanned at a given instant. Such light as is reflected from the illuminated and scanned picture point is conveyed through other optical means to the photo-electric cell 3 in a way well known in the prior art. What is produced here as a result is a photo-electric potential the amplitude and value of which is a function of the brilliance of the picture point just scanned. Now, according to the invention, the potential produced in the said photo-cell 3 is impressed upon a frequency governing element 4. The latter will cause a more or less great detuning Δf of the oscillator 5 generating a fundamental frequency f in accordance with the value of the photo-electric potential U supplied to it. What thus results in the output circuit of the oscillator is an alternating current having a frequency $f+\Delta f$. In another circuit element 6 by demodulation as

known in the prior art or else by a mixing process, the fundamental frequency f is excluded so that an alternating current having a frequency Δf will then flow in the line connected with the output end of 6. The said alternating current is amplified suitably in the device 7 which is connected with the other end of the transmission channel and then fed to the recorder system 8. The recorder stylus or needle 9 of the electromechanical recorder system then vibrates at frequency Δf while causing the production upon the paper or the like used upon the receiver drum 10 a corresponding sequence of points of substantially constant thickness. It will be understood that the transmission is readily feasible in such a way that when scanning a bright picture point the frequency of the oscillator 5 will be detuned only to a slight degree, while when a dark spot on the original copy is being scanned, this causes a marked shift in the frequency of the oscillator. In this manner arrangements may be made so that the frequency of vibration of the recording stylus 9 is high for dark picture points and small for light ones. If, then, the paper fastened in the receiver drum 10 is rotated at a constant rate of speed under the recorder stylus 9 vibrating in its longitudinal directions, the result is a sequence of dots upon the paper which will be so much denser the darker the picture point of the original corresponding thereto. Such a recording or recreation corresponds substantially to the effect of reproduced pictures or cuts in newspapers with this exception that in the reproduction of newspaper cuts the distance between dots is constant, while the density varies, whereas in the method of this invention, the point density is constant, while the inter-point distance varies with the brightness.

Referring to Fig. 2, a detailed description shall now be given by means of an exemplified embodiment in what way the alternating current is produced and transmitted whose frequency varies with the brightness of the picture points. Referring to Fig. 2, 11 denotes a unit including a photo-electric cell 3 mounted at the sending end upon which the light reflected from the scanned picture point is projected. The photocell potential U is fed to the direct-current amplifier 12. In the exemplified embodiment here shown an amplifier comprising only one stage is employed, although it will be understood that, if desired, the amplifier could contain a plurality of stages. The amplified photo-potential U is impressed upon the grid g of reactance tube T in unit 13. This tube (called a "shifter" tube) when incorporated in a circuit organization as shown, behaves like a capacitive reactance, the value of the latter being a function of the slope (mutual conductance) of the tube and thus of its grid potential. By varying the latter by suitable ways and means it is thus feasible to influence the equivalent capacitance of the said regulator tube T in the desired way. In the arrangement shown, the anode A is coupled to the oscillator tube in unit 15 and by a condenser C to the grid g which is connected to the cathode K by a resistance R. C and R act as the phase shifter to get the phase quadrature relation of the voltages on the anode and grid to produce the capacitive reactance effect.

Fundamentally speaking, tube T could also be connected in a circuit arrangement of a nature so that it will represent an inductive rather than a capacitive reactance, the inductance thereof being also proportional to the slope of the tube.

Now, to practice the method of this invention, the said regulator tube T is included in the oscillation circuit 14 of the oscillator O the fundamental frequency of which is f. According to the size of the grid biasing voltage and thus of the equivalent capacitance of tube T, the oscillator O will be varied a more or less large amount Δf. If tube T, for instance, is of a type so that inside a certain range of the grid potential the plate current rises with the grid voltage according to a square law, then, as shall at once be explained in more detail by reference to Fig. 3, it will be feasible to practice the method in such a way that the frequency shift or detuning Δf of oscillator O is in direct proportion to the photo-potential U.

The graps $Ia=f(Ug)$ Fig. 3 illustrates the form of the plate current of the regulator tube T as a function of the grid biasing voltage Ug. Inasmuch as the slope or mutual conductance S of the tube is

$$=\frac{dIa}{dUg}$$

it will be seen that in the case of such a tube where the plate current turns out to be proportional to the square of the grid voltage, there is a linear rise of slope S with the grid biasing voltage; in other words, a straight line as shown in Fig. 3. Now, it is known in the art that the frequency detuning or shift Δf of the oscillator O is proportional to the equivalent capacity C' of regulator tube T and that the capacity, in turn, is proportional to the slope or mutual conductance of the regulator tube. What can be deduced therefrom is that in the presence of linear form of the slope also the frequency detuning Δf of the oscillator will vary in direct proportion with the grid biasing voltage and thus linearly with the photo-cell voltage U. Now, in the output circuit of the oscillator O there is now available an alternating voltage having a frequency $f+\Delta f$. In one exemplified embodiment of this invention this alternating current, after having been superposed at the sending end upon a frequency f generated in a second oscillator O' in unit 16 can be demodulated and then put upon a transmission channel after having been passed through a low-pass filter TR in unit 17.

In another exemplified embodiment of the invention the frequency $f+\Delta f$ coming from the oscillator O is fed to the transmission channel, while the beat action and thus the filtering of the frequency Δf is effected only at the receiving end. Both these schemes offer this advantage over the methods known in the earlier art that they are far less susceptible to disturbing actions. The reason for this is that in the methods of the earlier art the transmission consists of a sequence of voltage impulses of different amplitudes. These naturally are subject as they travel through the signal channel whether cable or space to attenuation. Since inevitable interfering or atmospheric potential impulses occasionally have an amplitude higher than the signal voltage amplitudes corresponding to the darkest picture elements, there is an ever-present risk and danger, especially in the case of long transmission paths or channels involving serious attenuation, of the signal voltage impulses being completely masked by the noise potentials, and this naturally results in a vitiation or distortion of the shading of the incoming picture.

The method of this invention contradistinct

to the prior art offers the advantage that the transmitter is modulated 100% for all picture points seeing that, as pointed out, it is exclusively its frequency that is varied as a function of the picture element brightness rather than its amplitude. In this way the susceptibility to trouble and outside interference is appreciably diminishable.

Referring again to Fig. 2, the alternating current of frequency Δf arising at the receiving end is fed to the amplifier VI in unit 18 and then to the electro-mechanical recording system 19. The electro-mechanical recording system consists, for instance, as shown in Fig. 4, of a moving coil system operating electro-dynamically or using a permanent magnet. If the coil 21 moving inside the field of the magnet 20 is fed with the frequency Δf, then the recording stylus 22 associated therewith vibrates in its longitudinal direction at the same frequency against the copying paper 23 stretched upon the receiving drum or cylinder, with the result that a sequence of dots is recorded thereon the density of which corresponds to the frequency Δf. The oscillatory system consisting of vibrator or moving coil and the recording stylus may be supported in a way similar to that used in loudspeaker systems. In order to insure satisfactory recreation of the picture, the voltage fed to the recording system, if desired, may be linearilized in the amplifier V' in such a way that the printing pressure produced by the recorder stylus will be the same regardless of frequency. In order to stabilize to an adequate degree the printing pressure regardless of the frequency fed to the recorder system, it is recommendable to fix the natural frequency of the recorder system comprising the moving coil and the recording stylus including the fastening or supporting means outside the range of frequencies used for the recording, say, above it. The recorder stylus itself should preferably be rounded at its striking point in order that injuring of the copying or carbon paper or of the inking ribbon may be prevented. In order to insure a properly shaded reproduction of the picture a ribbon preferably subjected to continuous travel is provided between the recorder stylus and the paper or the like on which the picture is to be reproduced, similar to a typewriter machine. Moreover, several layers or sheets of paper may be placed upon the receiving drum or cylinder, with sheets of carbon paper or the like being interposed between such layers of paper. In this manner, a plurality of copies of the incoming picture may be produced in one and the same working stage and process by the recording stylus.

In order to make the resolution and definition of the incoming picture as satisfactory as possible, the recording stylus, according to another object of this invention, may be constructed in such a way that it has a width at the pressing or striking point that is smaller in the direction of the line than at right angles thereto. Where this form of construction is used it is possible to make arrangements so that to each picture point scanned at the sending end there corresponds a plurality of incoming picture points so that the density thereof becomes so much greater, the darker the shading of the picture point of the original.

In certain circumstances it may be recommendable, for instance, where the original is flat and devoid of contrast, to make the ensuing copy more contrasty than the original. This end is accomplishable according to a further object of this invention by making arrangements so that the frequency Δf grows more markedly than linear with the photo-cell voltage rather than establishing a straight-line relationship between the photo-cell voltage U and the frequency Δf, thus resulting in a curve c as shown in Fig. 5. If, on the contrary, it is desired to secure a softer or less contrasty copy then a dependence as shown by curve d, Fig. 5, is used. The dependence illustrated by graphs c and d may be realized, for instance, by using for the regulator tube 13 a type in which the slope or mutual conductance is a function of the grid biasing voltage as illustrated by the curve, Fig. 6. Working within region B there results essentially a linear relationship between U_p while inside ranges C and D the result is a function as indicated by graphs c and d. In other words, by choosing the grid operating potential suitably it is possible to obtain the desired shape of the slope with the consequence that a compression or an expansion of the shading range in the recorded recreated picture results.

While in the foregoing description of exemplified embodiments of the invention, reference has been made only to a regulator tube for the purpose of altering the frequency of the oscillator O, Fig. 2 in accordance with the amplitude of the photo-cell voltages it will be understood that there are other ways and means to the same end. For instance, after adequate amplification the photo-cell currents may be employed for the purpose of varying the biasing magnetization of an iron-cored moving coil comprised in the carrier-frequency oscillator.

The invention concerns a method of transmitting pictures electrically. At the transmitter end, by ways and means well known in the art, electric potentials are produced by scanning the original point by point, these voltages corresponding to the brightness of the picture points in the original copy. Now, these voltages serve the purpose to act upon an alternating current in such a way that the frequency of the alternating current is governed by the amplitude of the voltages. This alternating current of varying frequency is fed thereupon at the receiving end to suitable electro-mechanical recording means in such a way that a sequence of points corresponding to the frequency of the alternating current and being substantially of constant intensity is recorded.

Frequency modulation may be insured by means of a "shifter" (regulator) tube so that by choosing the slope of the latter conveniently it is possible to compress or expand the shading range of the recording at will.

The method here disclosed distinguishes itself from the prior art insofar as it is less susceptible to disturbing actions, and that several directly visible copies can be made simultaneously.

What is claimed is:

1. A system for producing records of subjects, a scanner for scanning a subject to produce potentials corresponding to subject point brightness, a generator for producing carrier current the frequency of which is modulated in accordance with variations of the potentials produced by scanning said subject, a source of oscillations, a mixer tube excited by oscillations from said source and by said modulated carrier current for deriving from said frequency modulated carrier current, currents of lower frequency correspondingly modulated in frequency, a recorder including a stylus and a coil system for moving the same, the natural frequency of the recorder, including said coil and stylus being outside the frequency range of the wave energy impressed

thereon, and connections for impressing said wave energy of lower frequency on said coil system.

2. In a system for producing records of subjects and improving the contrast thereof during the process including frequency controlling reactance, an oscillation generator, a subject scanner for producing potentials which vary in amplitude substantially linearly in accordance with variations in the density of the scanned subject, a variable frequency controlling reactance included in the reactance of said oscillation generator, and connections between said scanner and said variable reactance for controlling said variable reactance by said produced potentials to thereby control the frequency of operation of said generator, the variable reactance being so arranged and constructed that it varies linearly with respect to a selected potential and non-linearly with respect to potentials greater and less than said selected potential.

3. In a system for duplicating subjects and improving the shading contrast thereof during the duplication process, an oscillation generator having as a frequency determining reactance a reactance tube the mutual conductance of which is a function of its bias, a subject scanner for producing potentials which vary substantially linearly in accordance with variations of the density of the scanned subject, and connections between the scanner and the reactance tube for controlling the bias of said reactance tube in accordance with said produced potentials to thereby vary the reactance thereof substantially linearly with respect to a selected bias potential and non-linearly with respect to potentials greater and less than said selected potential to thereby modulate the frequency of the oscillations generated in a corresponding manner.

4. In a system for duplicating pictures, a scanner for scanning a picture and producing potentials corresponding to the picture point density, an oscillation generator including as a frequency determining controllable reactance, a reactance tube the reactance of which is a function of the tube conductance, said tube having a control electrode the bias of which controls its conductance, connections between said scanner and said tube for impressing said produced potentials on said control electrode to thereby control the reactance of said tube and consequently control the frequency of the generated oscillations, the bias of said tube being so adjusted that the relation between the generated frequency and the control voltages is non-linear within the range of the applied control potentials whereby the contrast of the picture when reproduced is changed.

5. In a system for duplicating subjects, a frequency modulated generator circuit including a reactance comprising a tube having an output electrode and a control electrode on which the generated voltages are substantially in phase quadrature to provide in the tube a controllable reactive effect which determines in part the frequency of the oscillations generated, a scanner for deriving potentials corresponding to the shading of the subject as denoted by point-by-point scanning thereof, connections between said scanner and tube for applying said potentials to a control electrode of said tube to control its reactance, and connections for operating the tube in such a manner that the relation between the reactance provided thereby and the produced potential amplitude is non-linear within the range of variation of the produced potential.

6. A system as recited in claim 4 including, connections for transmitting the frequency modulated oscillations, circuits for reducing the frequency of the frequency modulated oscillations, and a recording mechanism coupled to said circuits and responsive to the frequency of the oscillations of reduced frequency.

7. A system as recited in claim 5 including, connections for transmitting the frequency modulated oscillations, circuits for producing correspondingly modulated frequency oscillations of lower frequency, and a recording mechanism coupled to said circuits and excited by said frequency modulated oscillations of lower frequency.

8. In a system for producing records of subjects and improving the contrast thereof during the process, a tuned circuit including reactance wherein oscillations of carrier wave frequency flow, the timing of which oscillations is determined in part by the said included reactance, said reactance including a reactance tube the mutual conductance of which is a function of its bias, a subject scanner for producing potentials which vary in amplitude substantially linearly in accordance with variations in the density of the scanned subject, and connections between the scanner and the reactance tube for controlling the bias of said reactance tube in accordance with said produced potentials to thereby vary the reactance thereof substantially linearly with respect to selected bias potentials and non-linearly with respect to potentials greater or less than said selected potentials to thereby modulate the timing of the oscillations flowing in said tuned circuit in a corresponding manner.

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