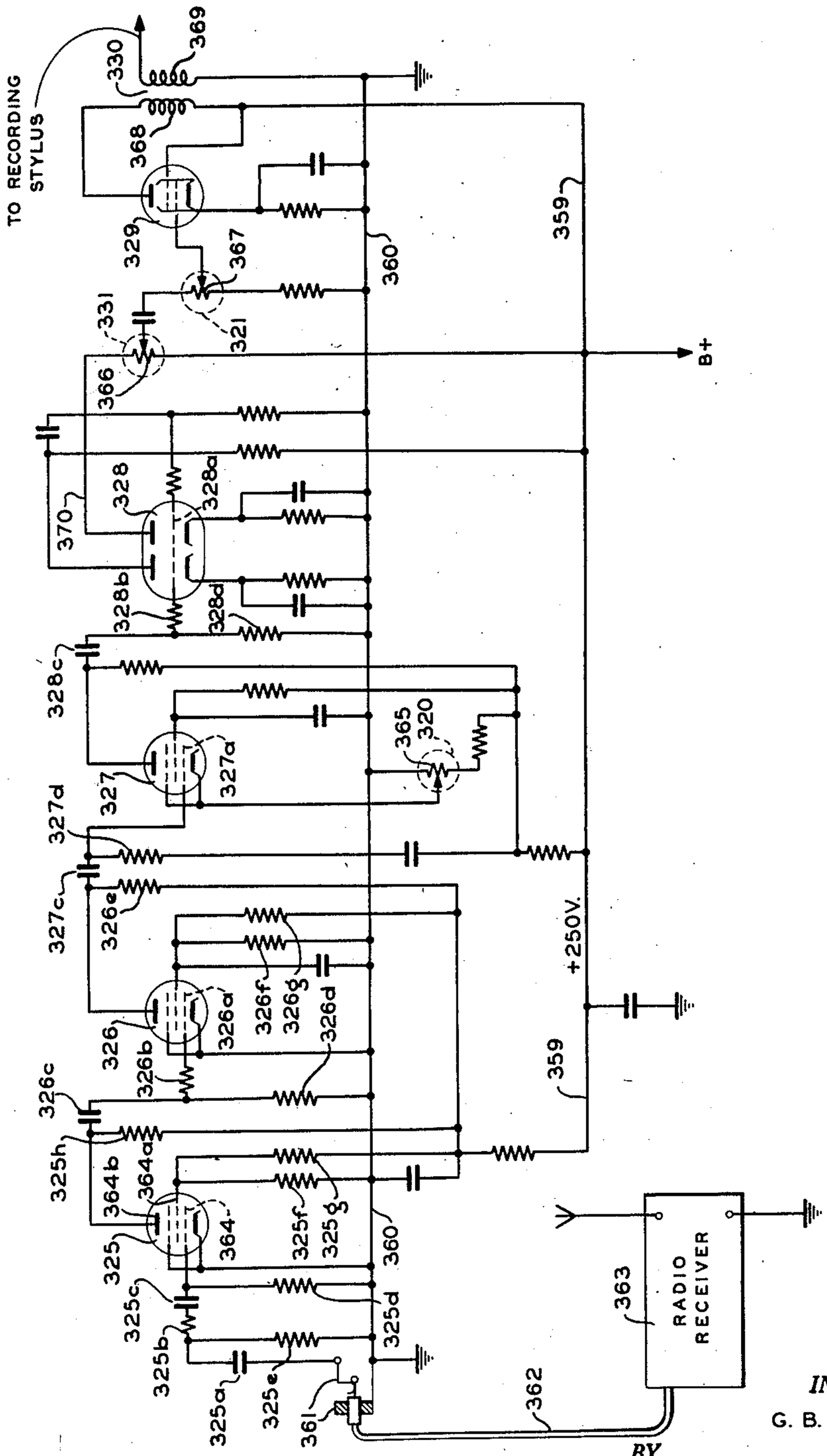
June 4, 1957 G. B. WORTHEN 2,794,913

FACSIMILE RECORDING AMPLIFIER

Original Filed Nov. 16, 1948 3 Sheets-Sheet 1

FIG. 1



INVENTOR.
G. B. WORTHEN
BY
Edward R. Hyde Jr.
ATTORNEY

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FIG. 2

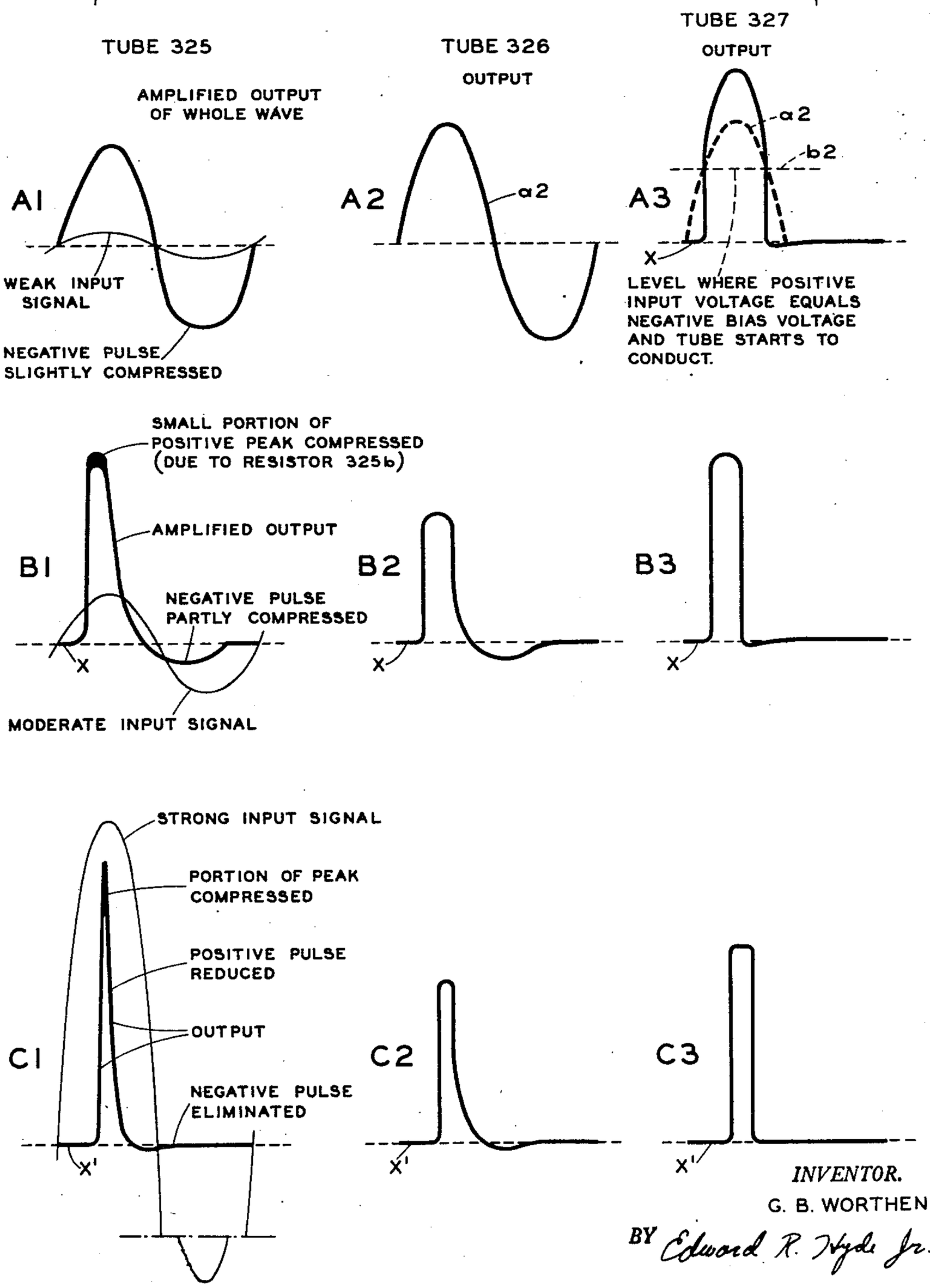

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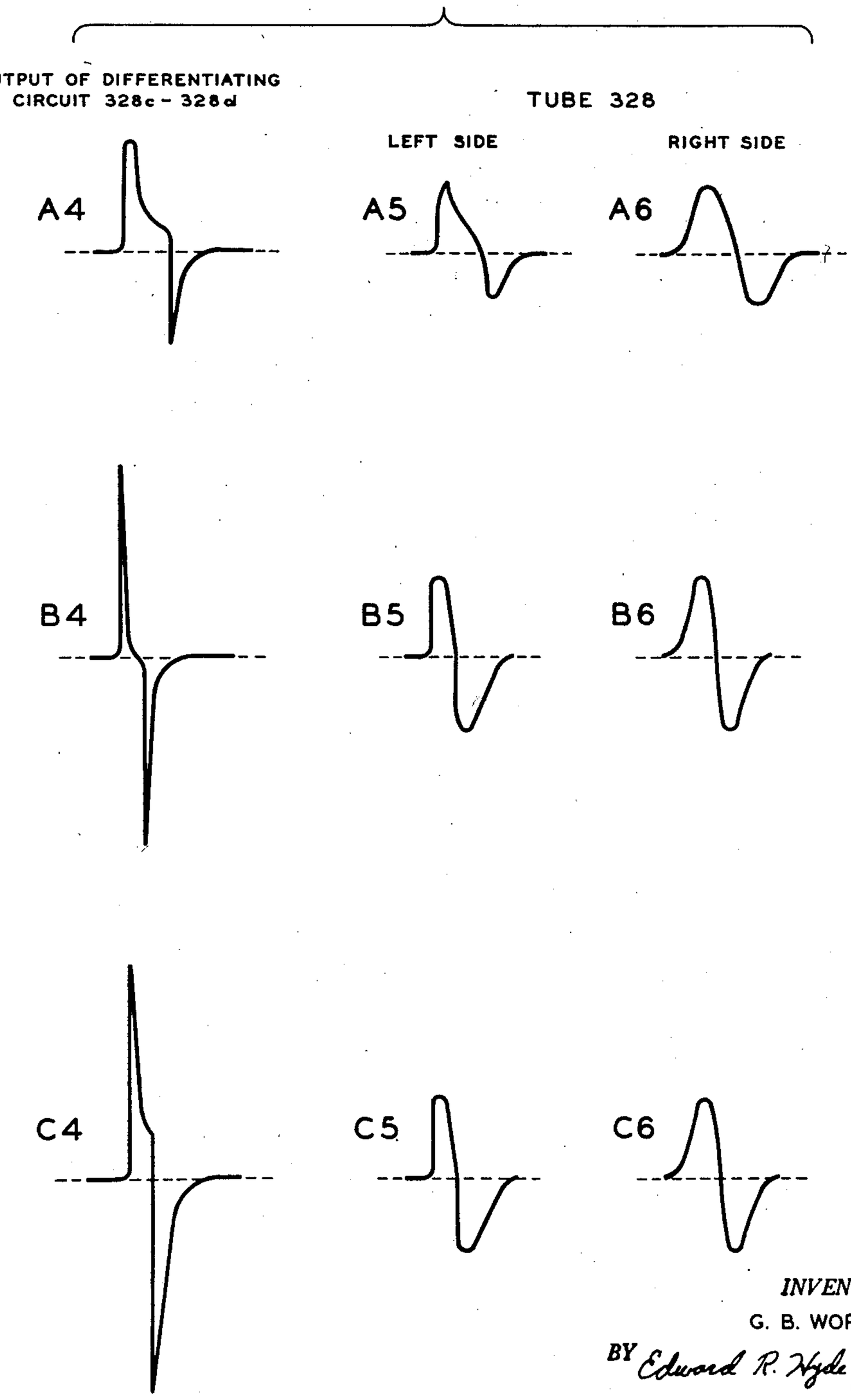
FIG. 3



INVENTOR.
G. B. WORTHEN
BY Edward R. Hyde Jr.

ATTORNEY

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FACSIMILE RECORDING AMPLIFIER

George B. Worthen, New York, N. Y., assignor to The Western Union Telegraph Company, New York, N. Y., a corporation of New York

Original application November 16, 1948, Serial No. 60,334. Divided and this application January 8, 1953, Serial No. 330,341

2 Claims. (Cl. 250—27)

This invention relates to the art of amplifying received radio signals and more particularly to an amplifier for a facsimile recorder.

This application is a division of applicant's copending application Serial No. 60,334, filed November 16, 1948, now Patent No. 2,647,945. The latter application discloses a facsimile system including a portable transmitter communicating with a distant recorder. The instant invention is concerned with the novel recording amplifier, and only so much of the system disclosed in the parent application as is necessary for an understanding of the present invention is herein disclosed.

In the recording of facsimile messages there are no intermediate intelligence signals. The recorder is concerned only with black and white indications, that is, signal and no signal conditions. However, for good reproduction of the transmitted message, each signal must be approximately equal in energy content, in order to reproduce spots of constant density. Also, the rejection of noise signals during a no signal interval is highly desirable to avoid recording a spot where a white area should appear.

Accordingly, applicant has devised a facsimile recording amplifier with the primary objective of reshaping both strong and weak input signals into substantially uniform waves for recording.

A further object of this invention is to provide a recording amplifier that will reject substantially all intermediate noise signals.

The invention will be more fully understood by reference to the following description taken with the drawings in which:

Fig. 1 is a diagram of the recording amplifier;

Figs. 2 and 3 consist of wave diagrams which indicate roughly the progress of signal waves of different levels through the recording amplifier.

To facilitate reference to the above-cited parent application, the various elements of the drawings are given the same reference numerals.

The recording amplifier utilizes five vacuum tubes numbered **325** to **329**. The characteristics and interstage connections of these tubes are such that the amplifier not only amplifies the received signals but also performs the automatic functions of power level control, noise rejection, signal wave shaping and the uniform limiting of signal output with a wide variation of input level. The first three tubes **325, 326, 327** are pentodes with a novel form of coupling and operation to be presently described. Tubes **325** and **326** have a remote cut-off, while tube **327** has a sharp cut-off. The fourth tube **328** of the amplifier is a dual triode which operates as a limiter and wave shaper of signals over a wide range of input level and frequencies. The final tube **329** is a beam-power tube connected to the output transformer **330** which supplies the recording voltages to the stylus. The plate circuits of all the tubes **325** to **329** are connected to the 250 volt

D. C. line **359**. The conductor **360** represents the common ground of the tubes.

At the input end of the recording amplifier is a jack **361** into which is plugged the shielded output cable **362** of a portable radio receiver **363**. The spring contact of jack **361** is connected to the control grid **364** of tube **325**, which is therefore operated by the input voltages picked up by the radio receiver. These voltages comprise not only the facsimile signal voltages sent out by a radio transmitter but also the lower noise voltages which modify the signal wave. The circuit connections between jack **361** and the control grid **364** include a D. C. blocking condenser **325***a*, a resistor **352***b*, a grid bias condenser **325***c*, and a high resistor **325***d* which controls the discharging time of the bias condenser. A load resistor **325***e* constitutes the input impedance of the amplifier.

Resistors **325***f* and **325***g* determine the value of the voltage impressed on the screen grid **364***a* of tube **325** from the supply conductor **359** which in this case is at +250 volts and which also supplies power to the plate **364***b* of the tube across a resistor **325***h*. It is important to point out that in this particular application of tube **325** the voltage on screen grid **364***a* is of low value as compared with the plate voltage. For example, in the present embodiment of our invention the resistors **325***f* and **325***g* are of such values as to fix the voltage on screen grid **364***a* at 1 or 2 volts positive. This low screen voltage and the value of resistor **325***h* are the chief factors that so determine or adjust the operating characteristics of tube **325** as to make its cut-off more gradual and therefore cause the recording amplifier to work with a wide variation of input signal strength.

As described in the cited parent application, a phasing pulse is sent out by a radio transmitter at each revolution of a scanning drum and a signal pulse is transmitted every time a stylus scans a black mark on the message copy. Each phasing pulse and scanning signal picked up by the radio receiver **363** charges the condenser **325***c* across the low resistor **325***b* very rapidly to the maximum amount for the particular signal level of the moment. This condenser charge is impressed on the control grid **364** of tube **325** as a negative bias which determines the amplification of the tube.

On weak signals the charge on condenser **325***c* is small and therefore the negative bias on grid **364** is low, whereby the amplification of tube **325** is correspondingly high. When strong signals are received, the charge on condenser **325***c* is high and the resulting high negative grid bias keeps the amplification of the tube down. In consequence, the tube **325** amplifies weak signals to a greater degree than strong signals, so that the output of the tube is fairly constant for a wide variation of signal input. For weak signals the tube **325** amplifies the whole wave, with the negative pulse slightly compressed. For moderate and strong signals the tube **325** compresses progressively more of the negative pulses with increasing signal strength. This action of tube **325** on weak, moderate and strong signals is illustrated in diagrams **A1**, **B1** and **C1** of Fig. 2.

While the charging time of the grid bias condenser **325***c* is very short, the rate of discharge is comparatively low due to the high value of resistor **325***d*. In the present form of our system as herein set forth, the charging time of condenser **325***c* is less than the duration of a phasing pulse sent out by the transmitter, and the discharging time endures for at least one revolution of the transmitter drum (that is, for one scanning line). For this purpose we use a condenser of large capacity (say, 0.1 mfd.) and make the resistor **325***d* of high value (say, 10 megohms). These figures are mentioned merely by way of example.

With the charging time of condenser **325***c* less than the

duration of a phasing pulse, it is certain that the condenser charge will always reach full value during a phasing pulse at any signal level. In this case it is necessary to make the discharging time of condenser **325***c* cover at least one turn of the transmitter drum for the following reason: As we have seen, a phasing pulse is sent to the recorder once for each revolution of the transmitter drum for a brief duration of time and this pulse places a negative bias voltage on grid **364** of tube **325**. Now, if for the remainder of a scanned line no black marks are encountered by the stylus, there is an absence of signals and (without special provisions) the bias voltage on grid **364** would decrease, the amplification of tube **325** would increase, and any noise present would be passed on for recording. To prevent this from happening we make the discharge time of condenser **325***c* long enough to keep sufficient negative bias on grid **364** for one scanning line, so that the amplification of tube **325** is held down to a point where noise signals will not pass.

The elements **325***b*, **325***c* and **325***d* constitute a grid leak combination which determines the bias on grid **364** of tube **325**. Since this tube is of the remote cut-off type, its amplification varies with the effective grid bias, which in turn varies with the strength of the input signals. The time constant of the grid leak combination **325***b*—**325***c*—**325***d* is such that the bias on grid **364** when once established decreases rather slowly but increases rapidly. As the signal increases, the current flowing to the grid **364** increases correspondingly and thus charges the condenser **325***c*, so that a negative bias is applied to the grid by the voltage drop across the resistor **325***d*.

The operating characteristics of tube **325** (as determined by the slope of its transfer characteristic curve) are such that strong or large signals are amplified proportionately less than weak signals. As indicated in diagram **B1** and **C1** of Fig. 2, the positive peaks of increasing signals are compressed by the resistor **325***b* which acts as a limiter to dissipate excess voltage and thereby prevent severe noises from varying the signal output of tube **325**. The resistor **325***b* performs the additional function of slowing down the charging time of condenser **325***c*. This prevents sudden strong bursts of local static from interfering with the passage of normal signals which will record as soon as the D. C. bias applied momentarily to condenser **325***c* by the static burst has drained off.

It is a characteristic of tube **325** that it operates with a signal rejection rate which increases with increase of signal. This is indicated in diagrams **B1** and **C1** of Fig. 2 by the horizontal lines *x* and *x'* which represent each the time interval between the beginning of a cycle and the instant when plate current flows through the tube. For all but the weaker signals, tube **325** rejects the incoming wave until the signal voltage rises to a point where the plate draws current. That is to say, the tube **325** rejects any signal voltage lower than the grid bias voltage and the interval during which the signal voltage rises to the level of the bias voltage is represented by the lines *x* and *x'* in the wave diagrams. For the purpose of description we may regard the lengths of lines *x* and *x'* which increase with the rise in signal level, as denoting roughly the signal rejection characteristics of tube **325**.

The output of tube **325** is passed to the second tube **326**, which operates as a limiter for all but the weakest signals which are slightly amplified. The tube **326** operates with a low negative bias (say, minus 0.5 volt) and with very low plate and screen voltages. The plate voltage (6 to 8 volts positive) is determined by the value of resistor **326***e* and the screen voltage is determined by the voltage divider consisting of resistors **326***f* and **326***g*, these figures being given merely as practical examples. The signals coming from tube **325** charge the condenser **326***c* which applies a negative bias to the control grid **326***a* across a resistor **326***b*. The condenser **326***c* is connected in series with a resistor **326***d* to form a grid limiting circuit which has a much more rapid time constant than the grid leak circuit of tube **325**. Consequently the tube **326** passes on the more positive portion of the signal wave while rejecting the negative portion. As the signals entering tube **326** increase in level, they are increasingly more limited because of the value of resistor **326***b* and the characteristics of the tube. The effect of tube **326** on weak, moderate and strong signals is illustrated in diagrams **A2**, **B2** and **C2** of Fig. 2.

The characteristics of tube **326** include the function of decreasing the signal rejection rate with increasing signal level. This, it will be noted, is the reverse of the rejection characteristic of tube **325**. That is to say, while tube **325** has a rejection rate which increases with increasing signal level, the second tube **326** operates with a rejection rate which decreases with increase of signal. The result of this automatic compensation feature is a more nearly constant ratio of signal passed to signal rejected.

The output of tube **326** goes into the third tube **327**, which is of the sharp cut-off type and operates with a fixed cut-off bias which is adjustable to the proper value by a potentiometer **365** to remove the residual noise from the input signals. The potentiometer **365** is regulated by a fingerpiece **320** on the control panel. A condenser **327***c* and resistor **327***d* form a conventional interstage coupling for the grid **327***a*, but the time constant of **327***c*—**327***d* is very short as compared with that of **325***b*—**325***c*—**325***d*.

The tube **327**, which operates beyond cut-off, passes only those signals that are above the minimum voltage determined by the grid bias setting of potentiometer **365**. This will be understood from diagram **A3** of Fig. 2. where the input wave coming from tube **326** is indicated by *a***2** and the fixed negative bias of tube **327** is denoted by the line *b***2**. The tube **327** does not start to conduct until the wave *a***2** reaches the bias level *b***2** after an interval measured by the line *x*, the meaning of which was previously explained in connection with tube **325**. In other words, the third tube **327** passes only those portions of the signal wave which are positive beyond the fixed negative bias on grid **327***a* and those passed-on portions of the signal wave are positive pulses of approximately rectangular wave shape. The negative pulses of the signal waves, it will be recalled, are eliminated in tubes **325** and **326**. Therefore, what we are passing through the third tube **327** are positive signal pulses of approximately rectangular shape, free of all deleterious noise and substantially uniform, as indicated in the wave diagrams **A3**, **B3** and **C3** of Fig. 2.

The fourth tube **328** is a double triode used as a grid-limiting over-driven amplifier to limit the higher signals passed by the third tube **327** in excess of the minimum signals. The tube **328** receives the rectangular signal impulses from tube **327** through a differentiating network composed of a condenser **328***c* and a resistor **328***d*, which changes the rectangular positive wave into sharp positive and negative pulses by the charging and discharging of the condenser. This will be understood by electrical engineers without further explanation and we need only refer to diagrams **A4**, **B4** and **C4** of Fig. 3 as illustrating the approximate shape of the differentiated wave before passing into the tube **328**. The condenser charge flows to the grid **328***a* through a resistor **328***b* which limits the peaks of these positive and negative pulses so that they are shaped into a more uniform A. C. wave. The output of the left side of tube **328** is indicated by the diagrams **A5**, **B5** and **C5**, and the output of the right side of tube **328** (that is, the final output of this tube) is indicated by the diagrams **A6**, **B6** and **C6**.

Comparing the widely varying signal input of the first tube **325** with the output of the fourth tube **328** (diagrams **A6**—**B6**—**C6**) we see the efficient operation of the amplifier in converting transmitted signals, fluctuating over a wide range, into recording signals of relatively uniform energy content. The final output of limiter tube **328**

passes through a voltage divider network which contains a gain control **366** and a record level control **367** for the final tube **329**. The gain control **366** is a potentiometer adjusted at the factory by means of the dial **331** mounted on the base of the receiver. The record level control **367** is a potentiometer regulated by the fingerpiece **321** on the control panel to effect a vernier adjustment of the gain required by any particular machine.

The final tube **329** of the recording amplifier is a conventional beam-power tube which amplifies the received signals to the required strength. The output of tube **329** is a fairly constant A. C. voltage which goes into the primary coil **368** of transformer **330**. The recording voltage induced in the secondary coil **369** of this transformer is impressed on a recording stylus which produces marks on electrosensitive paper in a manner well understood by facsimile engineers.

It will be apparent from the foregoing description that the present facsimile recording amplifier differs materially in construction and operation from prior amplifiers used in radio receiver circuits for automatic volume control. As is well known, in radio receivers it is necessary to maintain distortion at a minimum and that limits the range of satisfactory operation of the receiver. Furthermore the output of radio receivers actually increases with an increase of input signal, although the rate of such increase is somewhat cut down by automatic volume control.

This novel recording amplifier is concerned only with black and white signals (that is, with signal and no-signal), intermediate tones not being important. Therefore the amplifier had to be designed in such a way as to maintain the energy content of the output recording signals relatively constant over a wide range in input level. In other words, distortion of the signal wave shape in this equipment is unimportant as long as the black marks are recorded with approximately constant density for weak and strong signals. To cite specific figures by way of illustration, the particular form of recording amplifier herein disclosed was designed to operate with a signal input variation of 45 decibels and the values of the condensers and resistors used in the tube circuits were so chosen that a change of at least 40 decibels in the input level will produce a change in the recording level of less than 2 decibels. Such a small reduction of voltage on the recording stylus will not appreciably lessen the black density of the recorded mark. As a result, weak signals passing through the amplifier are recorded with practically the same density as strong signals.

The time constants of the interstage couplings containing the condensers **326***c*, **327***c* and **328***c* have large values so that the low frequency components of signals pass readily through the amplifier, which operates on frequencies of wide audio range (for example, between 1000 and 4000 cycles per second). With respect to the noise removing function of our amplifier, the circuits are so designed that noise of less than half a signal amplitude will not appreciably detract from the recorded copy.

In describing the operation of the recording amplifier reference has been made to signals of different strengths or levels as weak, moderate and strong. It is realized that these terms are merely relative and it would be impossible to give any set of accurate figures applicable to every embodiment of the invention. However, there can be given a fairly good idea of what is regarded as weak, moderate and strong signals by considering what was actually done in the particular apparatus herein described as illustrative of the invention. The amplifier is so designed that the minimum input voltage on which it will operate satisfactorily is of the order of 0.2 volt, and it was assumed that the maximum signal voltage received would be about 40 volts. Weak signals may be said to be those of such low voltage (in this case, up to 0.5 volt) that the first tube **325** passes both the positive and

negative pulses, although a portion of the negative pulses may be compressed. Those signals in which the tube **325** clips off a portion of the positive peak and eliminates a part of the negative pulse, are referred to as moderate signals which vary, let us say, between 0.5 and 5.0 volts. Signals of higher voltage may be designated as strong or large signals for the purposes of this specification. It goes without saying that the above figures are put forth merely as examples and do not imply any restriction on the scope of the invention. As for the wave diagrams of Figs. 2 and 3, it will be understood that these are not of mathematical accuracy and were drawn as rough approximations of changes in the signal waves as they pass from one tube to the next in the recording amplifier.

Further, it is evident that various modifications of the disclosed embodiment of the invention could be made without departing from the scope and spirit of the appended claims.

What is claimed is:

1. In a facsimile telegraph system employing periodic phasing pulses, a recording amplifier comprising first tube means having a control grid, screen grid and suppressor grid, first circuit means to apply received signals to said first tube means, said first circuit means including a series combination of a blocking capacitor, input resistor and grid bias capacitor connected to said control grid, a load resistor connected between ground and the junction of said blocking capacitor and input resistor, a grid leak resistor connected to ground and to said control grid whereby weak signals will apply a low negative bias on the first tube means resulting in high gain and strong signals will apply a high negative bias on the tube means resulting in low gain, said input resistor having a low value of resistance relative to a high resistance value of said grid leak resistor whereby the grid bias capacitor will be fully charged during the interval of each phasing pulse and the discharge time of the capacitor is at least equal to the period between successive phasing pulses, second tube means having a control grid, screen grid and suppressor grid, second circuit means connecting the output of the first tube means to the input of the second tube means, said second circuit means including a series combination of a second capacitor and second resistor connected between the plate of the first tube means and ground, third resistor connected to the junction of said second resistor and the second capacitor and connected to the control grid of said second tube means, third tube means having a control grid, screen grid and suppressor grid, third circuit means interconnecting the plate of said second tube means and the control grid of the third tube means, said third tube means having biasing means including a potentiometer set to bias the third tube means beyond cut-off whereby only those portions of a signal more positive than a predetermined amount will pass, a differentiating network connected to the plate of said third tube means and ground, fourth tube means comprising a double triode, resistor means connecting said differentiating network to the input of said fourth tube means, said fourth tube means operating as a grid-limiting amplifier whereby the positive and negative pulses are shaped into uniform A. C. waves.

2. In a facsimile telegraph system employing periodic phasing pulses, a recording amplifier comprising first tube means having a control grid, screen grid and suppressor grid, first circuit means to apply received signals to said first tube means, said first circuit means including a series combination of a blocking capacitor, input resistor and grid bias capacitor connected to said control grid, a load resistor connected between ground and the junction of said blocking capacitor and input resistor, a grid leak resistor connected to ground and to said control grid whereby weak signals will apply a low negative bias on the first tube means resulting in high gain and strong signals will apply a high negative bias on the tube means resulting in low gain, said input resistor having a low value

of resistance relative to a high resistance value of said grid leak resistor whereby the grid bias capacitor will be fully charged during the interval of each phasing pulse and the discharge time of the capacitor is at least equal to the period between successive phasing pulses, second tube means having a control grid, second circuit means connecting the output of the first tube means to the input of the second tube means, said second circuit means including a series combination of a second capacitor and second resistor connected between the plate of the first tube means and ground, a third resistor connected to the junction of said second resistor and the second capacitor and connected to the control grid of said second tube means, third tube means having a control grid, third circuit means interconnecting the plate of the second tube means and the control grid of the third tube means, said third tube means having biasing means including a potentiometer set to bias the third tube means beyond cut-off whereby only those portions of a signal more positive than a predetermined amount will pass, a differentiating

net work connected to the plate of said third tube means and ground, fourth tube means comprising a double triode, resistor means connecting said differentiating network to the input of said fourth tube means, said fourth tube means operating as a grid-limiting amplifier whereby the positive and negative pulses are shaped into uniform A. C. waves.

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