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(19)

(54) SIGNAL PROCESSING MEANS

(71) We, MOTOROLA, INC., a corporation of the State of Delaware, United States of America, of Corporate Offices, Motorola Center, 1303 East Algonquin Road, Schaumburg, Illinois 60196, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a signal processing means and, more particularly, to an audio compressor for use in an amplitude modulated transmitter.

Compression amplifiers are well known in the art. Such amplifiers are commonly used in audio signal applications wherein the dynamic range of an audio signal must be compressed to adapt the signal to a particular function. For example, audio compressors are used in the recording of music on tape and on phonograph disc. In particular, audio compressors are utilized in radio frequency signal transmitters to maintain a given index of modulation in the RF signal. Thus, amplitude modulated radio frequency transmitters are known to employ audio compressors as an attempt to maintain the percentage modulation within a given maximum.

A problem suffered with prior art amplitude modulated transmitters which employ audio compressors is that the modulation index is a function of DC bias to the radio frequency amplification stage. Generally, as the DC bias to a class C RF amplifier decreases, a given audio signal will modulate the RF amplifier to a higher modulation index. Conversely, as the DC bias voltage increases, percent modulation decreases. This problem is particularly acute in mobile operated transmitters wherein the DC bias voltage may undergo a substantial change in value.

According to the invention there is provided a signal processing means, responsive to a DC voltage, for processing AC signals comprising: an amplifier means having an input, for receiving the AC signals, and an output, the amplifier means producing amplified input signals at its output; attenuator means for controlling the level of AC signals at the amplifier means responsive to a control signal; a first sensing means for sensing the DC voltage and developing a signal representative thereof; a second sensing means for sensing the level of the AC signal produced at the amplifier means output and developing a signal representative thereof; a control signal means for sensing the signals developed by the first and second means and producing a predetermined control signal in response thereto, said control signal means including an amplifier, having a predetermined reference bias voltage, coupled between the first and second sensing means and the attenuator means, the amplifier controlling the attenuator means to provide minimal attenuation of the amplifier means input signals for control signals having a first predetermined relationship to said reference bias voltage, the amplifier increasing the attenuation of the amplifier means input signals for control signals having a second predetermined relationship to said reference bias voltage; and means for coupling the produced control signal to the attenuator means, said control signal causing predetermined attenuation of the input AC signal such that the ratio of the amplitude of the AC signal at the amplifier means output to the DC voltage level is maintained at a substantially constant level.

The attached figure is a schematic diagram of an amplitude modulated transmitter which includes the adaptive compressor of the invention.

The figure illustrates an amplitude modulated transmitter, especially suited to mobile applications, wherein audio signals to be transmitted over an RF carrier are generated via a microphone 12. The audio signals are thereafter preamplified by amplifier 14, further amplified by audio amplifier 16 and capacitively coupled

through capacitor 18 to the primary winding 22 of a power supply modulating transformer 20. The modulating transformer 20 secondary winding 24 couples between a direct current (DC) supply bias A+ and a DC bias input 28 of an RF power amplifier 26.

The RF power amplifier 26 normally produces at its output terminal an RF carrier which is generated by an oscillator 30 and amplified by an exciter 32 before being passed to the input of the RF power amplifier 26. Audio signals on the primary 22 of transformer 20 modulate the bias A+ to the RF power amplifier 26 whereby the output from the RF power amplifier is an amplitude modulated RF carrier. The amplitude modulated carrier is filtered via a scrape filter 34 which is tuned to pass only those signals in the desired passband thereby rejecting out of band signals generated through nonlinearities in the system. The output of the filter drives an antenna 38.

Inherent within this amplitude modulating scheme is the fact that the value of DC bias A+ at the DC bias input 28 of RF amplifier 26 causes a variance in the modulation of the RF carrier. Thus, especially in mobile applications wherein the DC bias A+ tends to vary, the percent modulation is very DC bias dependent. This is undesirable in that there are prescribed limits for percent modulation, and that an improved signal can be recovered at the receiver if the percent modulation remains constant.

To compensate for DC bias supply variations, an improved compressor utilizing a feedback circuit 40 is employed. The input to the compressor is taken off a voltage divider which is comprised of a pair of series connected resistors 42, 44. The free end of resistor 42 connects to the DC bias A+ whereas the free end of resistor 44 connects to the output of audio amplifier 16 and, therefore, to the primary 22 of transformer 20. The connection is made on the negative side of capacitor 18 and, therefore, since the primary 22 of transformer 20 connects to ground potential, the free end of resistor 44 is essentially connected to ground for DC analysis purposes. The common connection 46 of the resistors produces a DC voltage which is representative of the DC bias potential A+ voltage, and an AC voltage which is representative of the AC signal level at the output of amplifier 16. Thus, the voltage at connection 46 can be expressed as follows:

$$V_{46}=\frac{R_{44}.A+}{R_{42}+R_{44}}+\frac{V_{ac}.R_{42}}{R_{42}+R_{44}}$$

where V_{ac} is the level of AC voltage at the primary 22 of transformer 20. The AC signals are rectified by a rectifier 48 and filtered by a capacitor 50. This resultant DC voltage is applied through diode 48 to the input of an amplifier 52. Amplifier 52 is comprised of a pair of NPN transistors 54, 56, whereby transistor 54 is connected in a common emitter configuration, with transistor 56 acting as a voltage follower. Both transistors include load resistors which couple to a common bias resistor which connects to a bias potential, and transistor 54 is provided with an emitter resistor coupled to ground potential. The output from the amplifier 52 is taken at the emitter of transistor 56 and is filtered by a filter capacitor 58 and applied via a voltage divider, comprised of a series resistor 60 and a shunt resistor 62, to the base terminal of an attenuator transistor 64. Attenuator transistor 64 has its collector connected to the input terminal of the amplifier 16, and its emitter connected to ground potential. Control signals at the base of transistor 64 cause the attenuator to either increase or decrease in impedance thereby increasing or decreasing, respectively, the AC input signals to amplifier 16. Thus, the level of AC signals appearing at the output of amplifier 16, and the primary of transformer 20, is dependent on the control signal appearing at the base of transistor 64, which is in turn dependent on amplifier 52 and the sense voltages appearing at the common concentration 46 of the voltage divider 42, 44. A feedback resistor 66 is provided from the output of the amplifier 52 to its input providing DC bias to the base of transistor 54 which causes approximately 1.0 volt to appear at the emitter of transistor 56. Resistors 60 and 62 voltage divide the 1 volt to a level which is insufficient to turn on attenuator 64.

For voltages at the base of transistor 54 which are above the reference 1 volt bias level the amplifier produces this constant 1.0 volt level at its output. However, for applied controlled voltages at the base of transistor 54 which are less than the reference 1 volt level, an increased voltage appears at the emitter of transistor 64 and increased attenuation of the signals at the input of amplifier 16.

By approximating the threshold voltage at the common connection 46 at which transistor 54 will begin turning off as zero volts, the above equation can be rearranged where:

$$V_{ac}=\frac{R_{44}}{R_{42}}.A+$$

Hence the compressor process is

directly dependent on the DC bias potential level A+. By selecting the resistor ratio of R_{44} to R_{42} any desired AC voltage V_{ac} may be developed to correspond to a given DC supply bias potential A+.

With the adaptive feedback loop 40, as the DC bias potential A+ thus tending to cause a decrease of the modulation index for the same level of audio input signal, the system reacts by increasing the voltage at the base of transistor 54 thus requiring a larger AC signal at the output of amplifier 16 to begin compression. The result is an increased audio signal at the output of amplifier 16 which exactly compensates for the decrease in DC bias potential A+ thereby maintaining the modulation index. Conversely, as DC bias potential A+ decreases, the voltage at the base of transistor 54 is biased closer to cutoff, whereby the control signal on transistor 64 reduces the collector impedance thereof, thereby decreasing the audio signal level at the output of amplifier 16.

It should be noted that the compressor circuit automatically varies the compression level dependent upon the power supply A+ level without changing the compression range. Further, the circuit is largely temperature insensitive since changes in the turn-on voltage of transistor 54 are compensated by a corresponding change in diode 48.

In summary, an improved audio compressor has been described which responds to changes in the DC bias level to thereby alter the compression characteristic. In the preferred embodiment of the invention, the improved compressor is shown to have superior performance in maintaining the modulation index of an amplitude modulated transmitter at a substantially constant level.

WHAT WE CLAIM IS:—

1. A signal processing means, responsive to a DC voltage, for processing AC signals comprising: an amplifier means having an input, for receiving the AC signals, and an output, the amplifier means producing amplifier input signals at its output; attenuator means for controlling the level of AC signals at the amplifier means input responsive to a control signal; a first sensing means for sensing the DC voltage and developing a signal representative thereof; a second sensing means for sensing the level of the AC signal produced at the amplifier means output and developing a signal representative thereof; a control signal means for sensing the signals developed by the first and second means and producing a predetermined control signal in response thereto, said control signal means including an amplifier, having a predetermined reference bias voltage, coupled between the first and second sensing means and the attenuator means, the amplifier controlling the attenuator means to provide minimal attenuation of the amplifier means input signals for control signals having a first predetermined relationship to said reference bias voltage, the amplifier increasing the attenuation of the amplifier means input signals for control signals having a second predetermined relationship to said reference bias voltage; and means for coupling the produced control signal to the attenuator means, said control signal causing predetermined attenuation of the input AC signal such that the ratio of the amplitude of the AC signal at the amplifier means output to the DC voltage level is maintained at a substantially constant level.

2. A signal processing means as claimed in Claim 1 wherein the attenuator means comprises a three terminal semiconductor device, the third terminal being a control terminal for controlling the impedance between the first and second terminals in response to a control signal.

3. A signal processing means as claimed in Claim 2 wherein the first and second semiconductor terminals are coupled between the amplifier input and a low impedance, respectively.

4. A signal processing means as claimed in any of claims 1 to 3 wherein the first sensing means comprises two series connected resistors forming a voltage divider, the free end of one resistor connected to the DC voltage, and the free end of the second resistor connected to a reference potential, whereby the DC level developed at the common connection of the two resistors is responsive to the DC signal.

5. A signal processing means as claimed in any of claims 1 to 4 wherein the second sensing means comprises a means for rectifying the AC signals produced at the amplifier output; and a means for filtering the rectified AC signals, thereby producing a DC signal representative of the level of the AC signal at the amplifier output.

6. A signal processing means as claimed in claim 4 wherein the second sensing means comprises a means for rectifying the AC signals developed at the common connection of the resistors; and a means for filtering the rectified signals resulting in a DC level developed at the common connection of the two resistors is responsive to the level of the AC signals developed at the amplifier output.

7. A signal processing means as claimed in claim 6 wherein the control signal means comprises the two resistors and the capacitor selected to have predetermined component values such that the DC level

directly dependent on the DC bias potential level A+. By selecting the resistor ratio of R_{44} to R_{42} any desired AC voltage V_{ac} may be developed to correspond to a given DC supply bias potential A+.

With the adaptive feedback loop 40, as the DC bias potential A+ thus tending to cause a decrease of the modulation index for the same level of audio input signal, the system reacts by increasing the voltage at the base of transistor 54 thus requiring a larger AC signal at the output of amplifier 16 to begin compression. The result is an increased audio signal at the output of amplifier 16 which exactly compensates for the decrease in DC bias potential A+ thereby maintaining the modulation index. Conversely, as DC bias potential A+ decreases, the voltage at the base of transistor 54 is biased closer to cutoff, whereby the control signal on transistor 64 reduces the collector impedance thereof, thereby decreasing the audio signal level at the output of amplifier 16.

It should be noted that the compressor circuit automatically varies the compression level dependent upon the power supply A+ level without changing the compression range. Further, the circuit is largely temperature insensitive since changes in the turn-on voltage of transistor 54 are compensated by a corresponding change in diode 48.

In summary, an improved audio compressor has been described which responds to changes in the DC bias level to thereby alter the compression characteristic. In the preferred embodiment of the invention, the improved compressor is shown to have superior performance in maintaining the modulation index of an amplitude modulated transmitter at a substantially constant level.

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1. A signal processing means, responsive to a DC voltage, for processing AC signals comprising: an amplifier means having an input, for receiving the AC signals, and an output, the amplifier means producing amplifier input signals at its output; attenuator means for controlling the level of AC signals at the amplifier means input responsive to a control signal; a first sensing means for sensing the DC voltage and developing a signal representative thereof; a second sensing means for sensing the level of the AC signal produced at the amplifier means output and developing a signal representative thereof; a control signal means for sensing the signals developed by the first and second means and producing a predetermined control signal in response thereto, said control signal means including an amplifier, having a predetermined reference bias voltage, coupled between the first and second sensing means and the attenuator means, the amplifier controlling the attenuator means to provide minimal attenuation of the amplifier means input signals for control signals having a first predetermined relationship to said reference bias voltage, the amplifier increasing the attenuation of the amplifier means input signals for control signals having a second predetermined relationship to said reference bias voltage; and means for coupling the produced control signal to the attenuator means, said control signal causing predetermined attenuation of the input AC signal such that the ratio of the amplitude of the AC signal at the amplifier means output to the DC voltage level is maintained at a substantially constant level.

2. A signal processing means as claimed in Claim 1 wherein the attenuator means comprises a three terminal semiconductor device, the third terminal being a control terminal for controlling the impedance between the first and second terminals in response to a control signal.

3. A signal processing means as claimed in Claim 2 wherein the first and second semiconductor terminals are coupled between the amplifier input and a low impedance, respectively.

4. A signal processing means as claimed in any of claims 1 to 3 wherein the first sensing means comprises two series connected resistors forming a voltage divider, the free end of one resistor connected to the DC voltage, and the free end of the second resistor connected to a reference potential, whereby the DC level developed at the common connection of the two resistors is responsive to the DC signal.

5. A signal processing means as claimed in any of claims 1 to 4 wherein the second sensing means comprises a means for rectifying the AC signals produced at the amplifier output; and a means for filtering the rectified AC signals, thereby producing a DC signal representative of the level of the AC signal at the amplifier output.

6. A signal processing means as claimed in claim 4 wherein the second sensing means comprises a means for rectifying the AC signals developed at the common connection of the resistors; and a means for filtering the rectified signals resulting in a DC level developed at the common connection of the two resistors is responsive to the level of the AC signals developed at the amplifier output.

7. A signal processing means as claimed in claim 6 wherein the control signal means comprises the two resistors and the capacitor selected to have predetermined component values such that the DC level

developed at the common connection of the two resistors is the control signal.

8. A signal processing means as claimed in Claim 1 and utilised in an AM transmitter wherein an audio signal modulates an RF carrier, and wherein the percent modulation of the RF carrier is a function of a DC supply voltage and wherein said control signal depends upon the sensed DC supply voltage and the sensed AC signal, which is an audio signal to maintain a substantially constant percent modulation level and to maintain the percent modulation within a maximum limit, wherein the ratio of the audio signal level to the DC supply voltage level is maintained at a substantially constant level despite variation in the DC supply voltage level.

9. A signal processing means as claimed in Claim 8 wherein the sensing means for sensing the DC supply voltage further comprises means for sensing the audio signal level and, in response thereto, adjusting the audio level to maintain the percent modulation within said maximum limit.

10. A signal processing means as claimed in claim 9 wherein the sensing means comprises an audio amplifier, having an input and an output, for receiving an audio signal at its input, amplifying the received signal by a fixed gain factor and producing the amplified signal at the output; a voltage divider having a pair of series connected resistors, the free end of one resistor connected to the DC supply voltage, the free end of the remaining resistor connected to the amplifier output; a means for rectifying and filtering AC signals produced at the common connection of the resistors; a feedback amplifier having an input, an output and a predetermined activation level, the feedback amplifier output remaining in a constant state for input signals below the activation level, the feedback amplifier otherwise processing signals at its input to produce a predetermined output signal corresponding to the input signal; a means for coupling the common connection of the resistors and the rectified and filtered AC signals to the input of the feedback amplifier such that the amplifier remains in its constant state over a given range of DC and rectified AC signals; a signal controlled attenuator for controlling the magnitude of the input signals to the amplifier in response to received control signals; and a means for coupling the output signal from the feedback amplifier to the attenuator for controlling the attenuation thereof, such that when the feedback amplifier is in its constant state the attenuator is at minimum attenuation, the attenuator increasing in attenuation for increasing feedback amplifier signals above the activation state.

11. A signal processing means as claimed in claim 10 wherein the sensing means further comprises a DC biased RF amplifier for carrying the RF carrier; and a modulation transformer having a primary winding coupled between the output of the audio amplifier and a reference potential and a secondary winding coupled between the DC supply voltage and the RF amplifier for supplying DC bias thereto, whereby audio signals on the transformer primary modulate the RF carrier.

12. A signal processing means substantially as described hereinabove with respect to the accompanying drawing.

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