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REPORT

AUDIO SIGNAL PROCESSING BY MEANS OF AM FM/LIMITERS AND AGC AMPLIFIERS

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ABSTRACT — Current broadcasting practices and techniques have spawned a new generation of automatic "frequency and/or level controlled" devices. Never before has there been such a complete, yet bewildering variety to choose from. Specialized units for AVERAGE LEVEL CONTROL; FM TRANSMITTER CONTROL; and AM TRANSMITTER CONTROL, using limiting with asymmetrical clipping versus asymmetrical limiting are discussed. A graphic display of the effect of different attack and decay times, asymmetrical clipping and limiting on various types of programming is presented.

INTRODUCTION — The ideal automatic level controlling device would have to be so complex and sophisticated to meet every requirement in every application that few companies have demonstrated the courage to attempt one. This may seem contradictory to advertising claims but how many companies market only *one* unit for AVERAGE LEVEL CONTROL, FM TRANSMITTER CONTROL and AM TRANSMITTER CONTROL? Of course, there are many other applications of automatic level controlling devices, but this discussion is limited to broadcast requirements and the units marketed to fill them.

The three major applications of such devices are generally matched by three models by the larger broadcast equipment manufacturers: The AGC AMPLIFIER for average level control, the FM LIMITING AMPLIFIER and the AM LIMITING AMPLIFIER for FM/TV and AM Transmitters. Most of the new units are quite sophisticated in the processing of differing types of programming, providing a variety of time constants and other control actions to meet the many typical requirements in each application.

In the following illustrations and text a comparison is drawn between the major conflicting features and operation of the principal contenders in each of the three areas of application. A brief explanation of each of the newer units, some recently introduced, is included for background information.

AVERAGE LEVEL CONTROL UNITS — Best results are generally obtained in broadcasting systems by the series combination of an AGC Amplifier and a Limiter to effectively cope with the wide range of conditions encountered. The AGC Amplifier must handle the wide dynamic range of levels from many program sources such as microphones, tapes, turntables, projectors, network and remote lines; and produce a nearly constant average output level. In many systems, such as in station automation systems, the various sources are switched in with no manual level control and the AGC Amplifier must automatically adjust to provide this control. Slower time constants, gated expansion and limiting with a large range of input level handling capability are requirements of a modern AGC Amplifier.

Recent AGC Amplifier designs have incorporated the useful parameter of volume expansion. This feature is used to bring the low level signals up to the compression region when they are within the operating range of the expander. In addition to improving the uniformity of the output level, this action provides another important feature: The unit has full gain only in the presence of a useful and controlled signal level, which effectively masks the noise increase due to the increase in gain. In the absence of signal or when the low signal level is below the threshold of expansion, the gain and accompanying noise is reduced to an appreciably lower level.

Fig. 1 shows the Block Diagram of a new AGC Amplifier which incorporates all of the desirable features discussed so far. It employs an open-loop expansion section, with the gain increase directly proportional to the level of the input signal over the operating range This is shown in Fig. 2 in the area from −50 dBm to −40 dBm input level and the resulting −15 dBm to +10 dBm increase in output level. Thus, with a change in input level of 10 dB there is a corresponding 25 dB change in output level, which gives a net result of 15 dB of expansion.

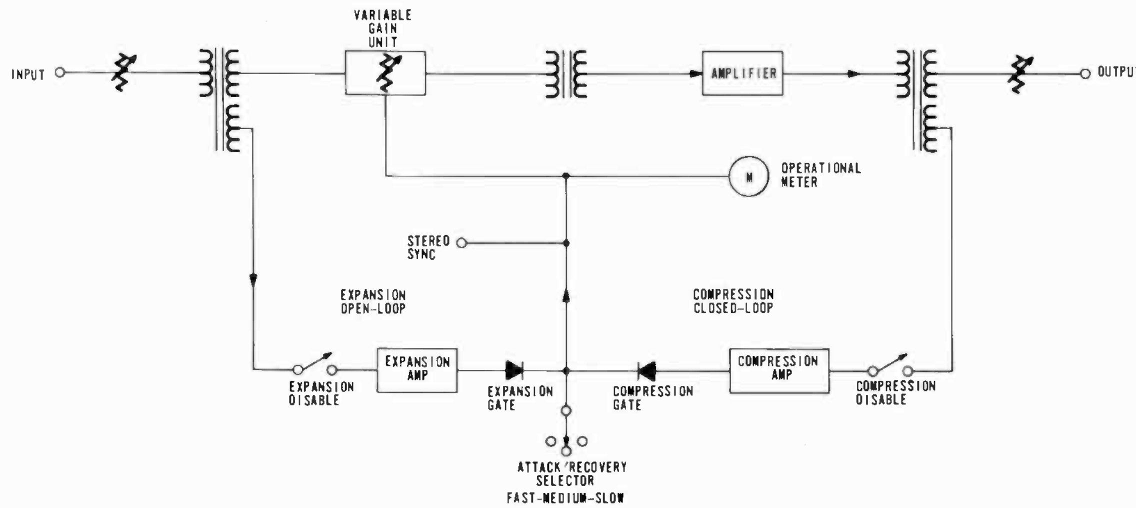

Figure 1 — Block Diagram, AGC Amplifier

Referring to Fig. 1 again, the unit has a closed-loop compression or gain reduction section, which samples the output signal voltage and converts it into gain control voltage. This negative feedback type of control prevents any possibility of over-control or "ducking", where the output may drop with an input signal increase. This effect is difficult to prevent with open-loop gain reduction circuits with high compression slopes.

Fig. 2 shows the gain reduction in the area from −30 dBm to 0 dBm input level and the resulting increase of 1 dB in output level. The unit typically compresses a 40 dB range of input level into approximately a 1 dB increase in output. Disabling switches permit the expansion and/or gain reduction to be turned off for special effects, proof-of-performance measurements, etc.

One current AGC Amplifier on the market uses average rather than peak detection of signal voltages for expansion control. However, it uses peak detection for gain reduction control. This resulted in their choice of only 10 dB of expansion, followed by a 10 dB linear region to prevent interaction on much programming between the two sections. With a shorter linear region some signals had the proper average level to cause expansion, yet the high peak-to-average ratio was sufficient to cause simultaneous limiting. This prevented full expansion and a consequent conflict in operation between the sections.

The unit plotted in Fig. 2 uses peak detection for both the expansion and gain reduction sections. This permitted 15 dB expansion with the threshold safely above the average noise for

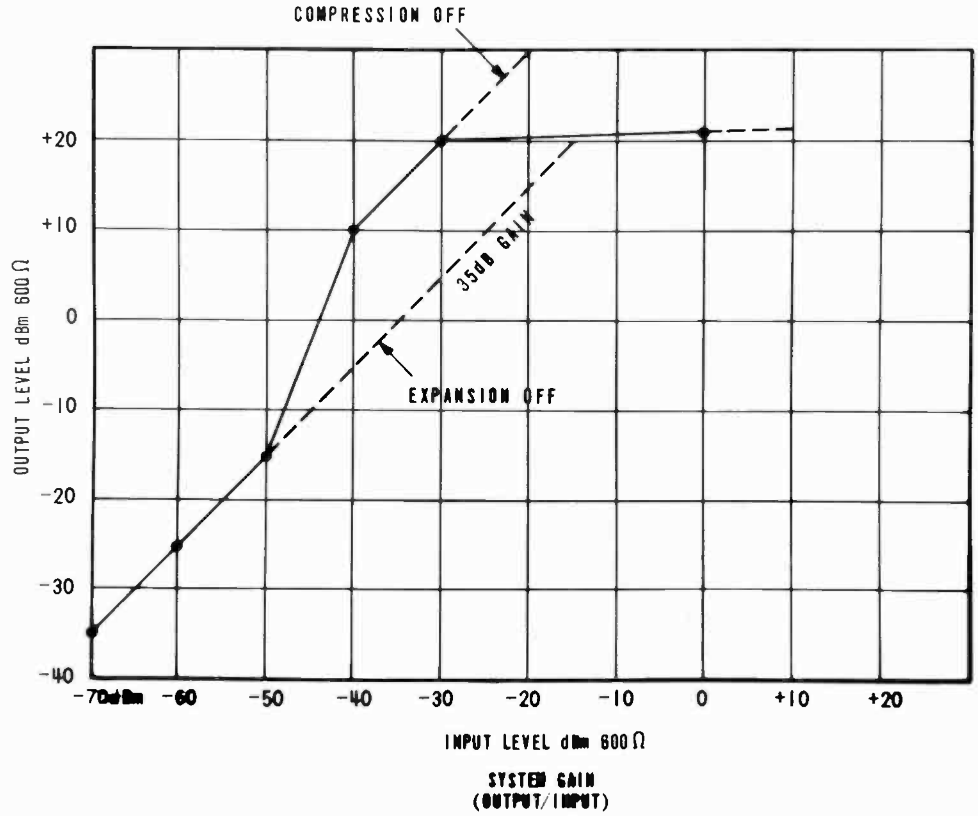

Figure 2 — AGC Amplifier Characteristics

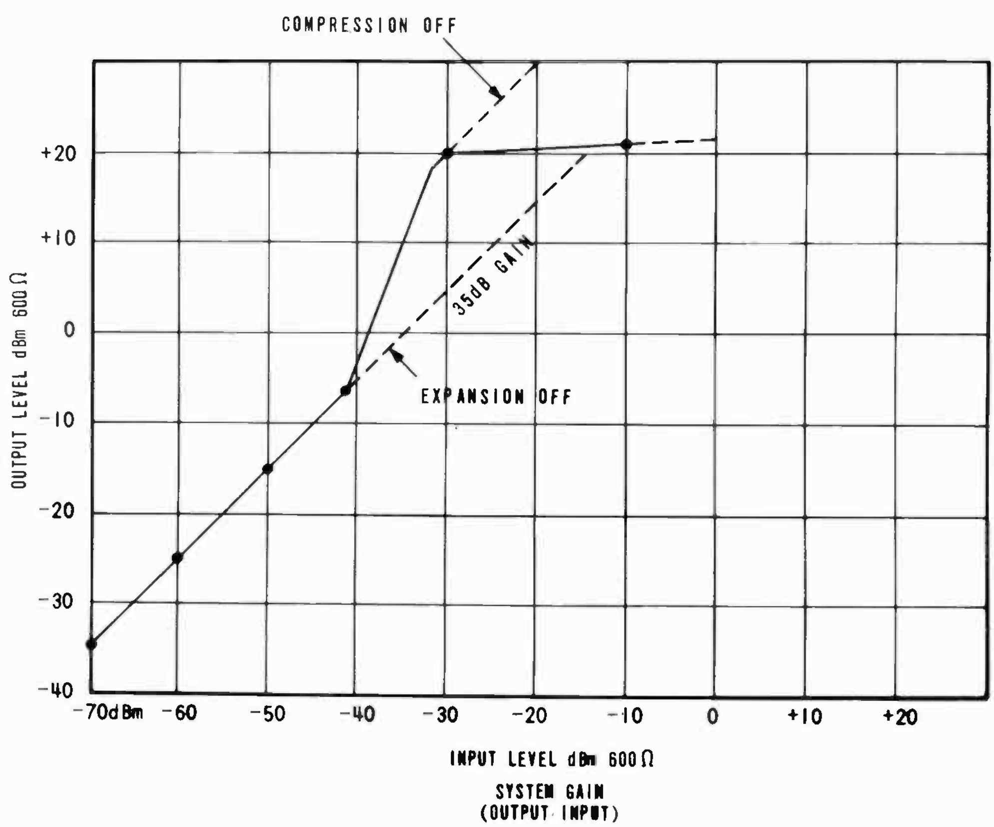

Figure 3 — AGC Amplifier Characteristics for Relay Links

broadcast service. A smaller linear portion is possible in this unit but the 10 dB is subjectively pleasing on most programming. This portion is shown in the −40 dBm to −30 dBm input level area, +10 dBm to +20 dBm region of the output level on Fig. 2.

The use of peak detection for both areas prevents interaction sufficiently to permit reduction of the linear portion to only 1 dB for special applications, as shown in Fig. 3. This feature should be a big advantage in radio relay link service, where a very poor S/N condition exists. Careful control of the input signal is practiced to increase the signal-to-noise in pauses, by allowing the expander to increase the unit gain only with signal.

Fig. 4 shows the Input/Output curve on another popular AGC Amplifier with many characteristics similar to those in the unit just described. It shows an increase of 15 dB in the output level with an increase of around 4 dB in input level, for 11 dB of expansion. The linear portion between the expander and gain reduction section is only 6 dB, indicating the probability of peak detection in both. The gain reduction slope is 8:1 for a 2.5 dB increase in output with a 20 dB increase in input. The curve above 20 dB of gain reduction soon becomes linear again. The approximate 25 dB range of input level handling capability of this section may not be adequate to control the levels in some systems as described in the first paragraph of "Average Level Control Units". The 40 dB range shown in Fig. 2 provides considerably more range for unusual circumstances.

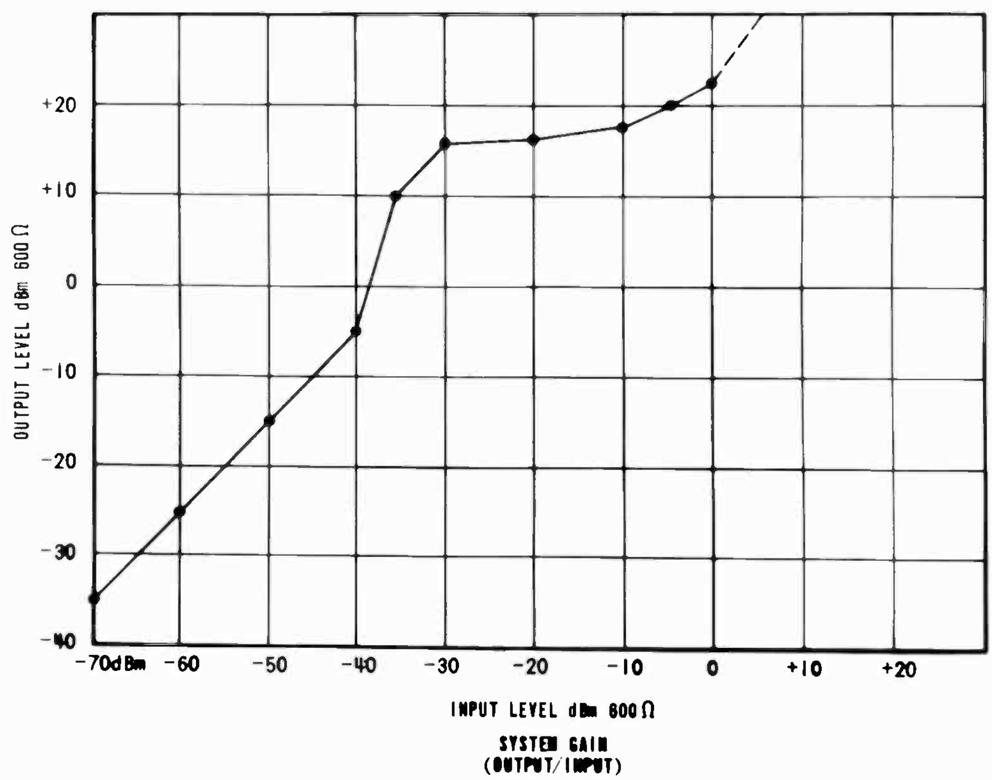

Figure 4 — AGC Amplifier Characteristics

Of the many parameters such as frequency response, distortion and signal-to-noise that can be measured, the effect of the various attack/recovery times on human response can not be. This judgment falls in the area of subjective evaluation. Lengthy listening sessions by many critical panels resulted in a "hung jury" in effect. The consensus of opinion was that no one attack/recovery time was adequate for the different major types of programming and that a selection should be made available to accommodate them.

One position should provide a fast attack/recovery time combination for those stations desiring maximum modulation, and hopefully using appropriate programming for this effect. A slow attack/recovery time position is provided for the very conservative station wanting control but hoping it will never be noticed in their "high quality" sound. Between these two extremes another type of programming is required, the "popular music" station type. Their requirements are quite different from the other two and a position is provided which is intermediate in timing for their service. This choice of three different attack/recovery times offers optimum AGC operation for practically every type of programming in broadcasting.

Since fast attack time in an AGC Amplifier is normally used to obtain "tight" programming, the recovery time should also be fast in this position to permit maximum use of the unit. However, very fast conventional R-C recovery circuits cause partial recovery on each half cycle at low frequencies with resulting excessive harmonic distortion. Minimum recovery times set by maximum tolerable harmonic distortion may be considerably longer than desired for maximum control action.

A dual storage circuit with cross-coupling of two capacitors through a series resistor provides very fast recovery time from isolated or random peaks, longer recovery time from heavy or sustained peaks. This approach makes maximum use of the fast attack time without causing harmonic distortion problems at low frequencies.

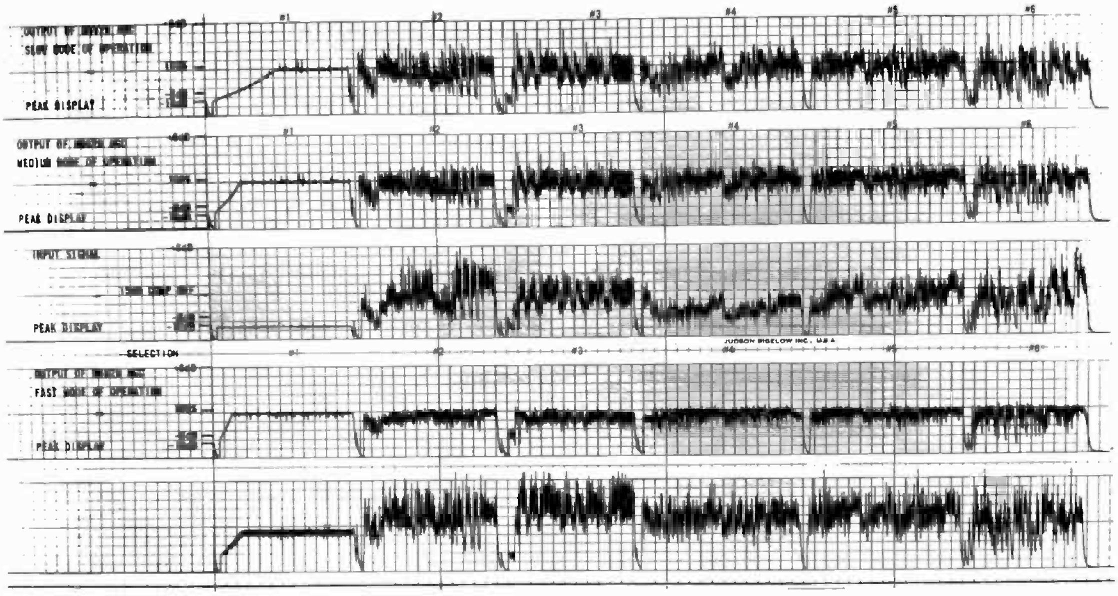

Figure 5 — Chart Recording of AGC Amplifier Operation

Fig. 5 shows chart recordings from a relatively high speed recorder with peak detectors on the channel inputs. Since transmitter program control is concerned primarily with peaks, this presentation is a graphic display of the modulation meter action. Due to some confusion between the photographer and author, the unprocessed input signal is on band 3 of Fig. 5. It is identical for all of the graphs of the output of the units, where the duplicated input sections were sheared off to save space in the illustration.

The chart is 1 mm/sec. and each of the six segments are approximately 1 minute sections dubbed on a test tape. The sections are: No. 1 — 1 kHz tone from oscillator; No. 2 — Procession of the Nobles, (Pops Festival, Reader's Digest RD4-48-8 1TRS-1416); No. 3 — Java, from the Best of Al Hirt (RCA LSP-3309); No. 4 — America, (Longines Symphonette LWS-331B); No. 5 — "Ain't That A Groove" (King K-12-985-A); No. 6 — "LBJ Radio" (Mercury SR-61015), all speech.

The normal operating level or the mid-point of operation set on the units compared in Fig. 5 is at line 50 of the chart grid. The grid has 10 major divisions, each of which is subdivided into 5 minor divisions. Thus, each minor division will be assigned a value of 2 (x 50 for a total of 100). −10 dB from the mid-point reference is at line 16, −6 dB at line 25, and +6 dB is at line 100.

The top band of Fig. 5 is the output of the new AGC Amplifier described above, in the "slow" position of the attack/recovery time switch. Note that it shows little effect on the short term dynamic range of the various selections. Yet, it brings them all up to a uniform long term average level. The effect is a gentle control on even wide range classical music, such as may be required for FM stations with automation systems.

The second band of Fig. 5 shows the action of the "medium" position of the attack/recovery time switch. Some of the wider signal level excursions are smoothed out to give a more uniform level, such as generally desired for popular music, most speech signals and miscellaneous programming. The fourth band of Fig. 5 illustrates the "flat-out" action a "top forty" station may desire to keep the avid listener content with the loudest sound around! The unprocessed input level, shown in the third band, was adjusted for most of the signal to fall below "normal level" in sections 4, 5 and 6. Thus, band four indicates some quite rapid expansion in those sections as well as fast gain reduction.

The fifth band of Fig. 5 illustrates the single set of attack/recovery times provided by the AGC Amplifier whose Input/Output characteristics were illustrated in Fig. 4. It does not appear to restrict the dynamic range of the programming seriously. It even seems to expand the dynamic range of the music from Al Hirt in section 3. The long term average level is not as well controlled as the slow position of the other AGC as demonstrated in the first band.

Combining monophonic units for stereo operation is a generally accepted practice. The best method of combining has been the subject for considerable discussion and is apparently not resolved at this date. One approach is to let each unit work independently on the Left and Right stereo channels. This will hold each channel at the maximum operating level, but it will invariably change the Left/Right balance. The change in stereo "placement" or balance is most noticeable and objectionable with independent AGC action. Another method employed is to combine the Left and Right signals to form a compatible monophonic signal, then use this to control the output level of both the Left and Right channel AGC Amplifiers. Although this seems to have many good features, careful examination will show several interesting points.

First, the stereo Left/Right balance will probably not be changed. Since few, if any, of the various control voltages and elements used are linear, different combinations of levels (from Left and Right channels) may cause a random overall shifting of output levels. Second, although the summing method seems to allow maximum modulation with a stereo signal (assuming that the combination of Left and Right modulation can always add to the maximum permissible), the peak limiter generally employed after the AGC Amplifiers using "summing" does not appear to take advantage of it. The referenced limiter(s) uses the "OR" gate method of control (explained in the following paragraph), with each channel set for a maximum of half of the total permissible modulation. Thus, instead permitting an 80/20% share of maximum Left/Right modulation, the referenced limiter(s) seem to allow only 50/12% share with a 4:1 mix in levels.

The "OR" gate method is defined as the cross-coupling of the D. C. control signals between the Left and Right AGC Amplifiers. Thus, the unit with the most gain reduction will control the other unit. Since both units receive the same amount of gain control signal, the stereo balance is preserved. The main requirement is that the gain control characteristics of the cross-coupled units track each other with a close tolerance. The output level of the unit with the controlling signal will be maintained at half of the total permissible modulation, with the other channel contributing the share established by the initial stereo relationship between the two.

AM TRANSMITTER CONTROL UNITS — Limiters used for AM Transmitter peak program level control are commonly used after an AGC Amplifier. This reduces the average level excursion to an optimized range for good peak limiting action. The range of input level handling capability of some popular peak limiters is inadequate for much of the current station programming. Pre-processing by a good AGC Amplifier or expert manual gain adjustment is required for them.

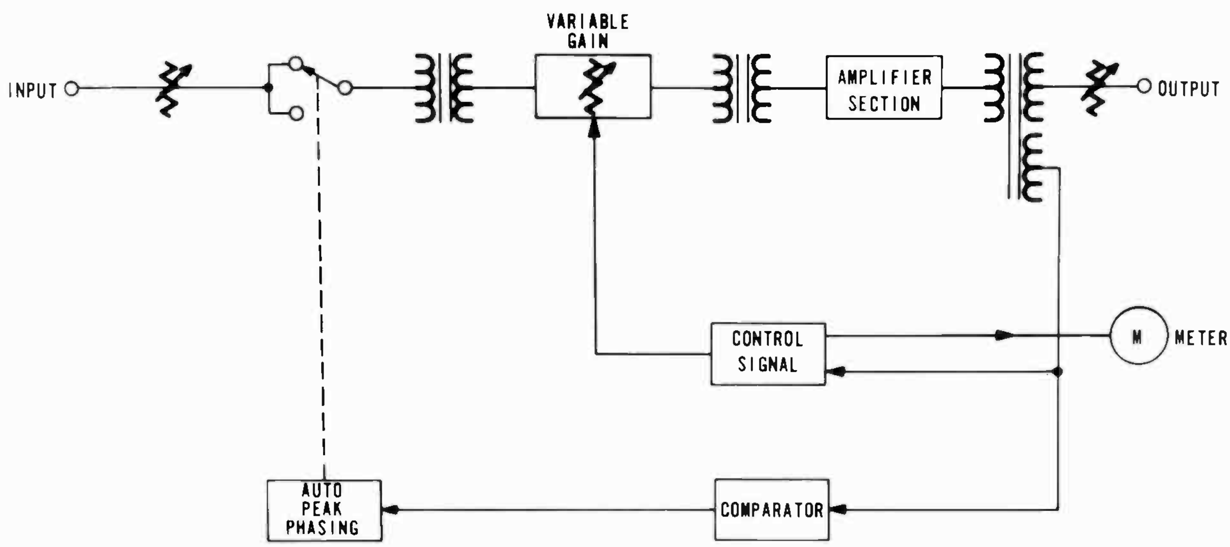

Figure 6 — Block Diagram AM Limiter

The limiter must prevent overmodulation on any program peak. Thus, it must have fast attack time. Since it reduces gain on relatively fast peaks, it must recover rather rapidly in order to maintain a high level of modulation. If this fast operation is used in conjunction with a widely varying signal level, the result is often a "pumping" or "swishing" effect. A much smaller amount of gain control is typically used for peak limiting than for average level control.

Limiters specifically designed for AM Transmitter Control, as shown in the Block Diagram in Fig. 6, have one or two features that are seldom used in other services: A provision for asymmetrical limiting or clipping, and automatic peak phasing to take best advantage of the asymmetrical limiting. Of course, the associated transmitter must be capable of being modulated more than 100% on the positive peaks to utilize these features.

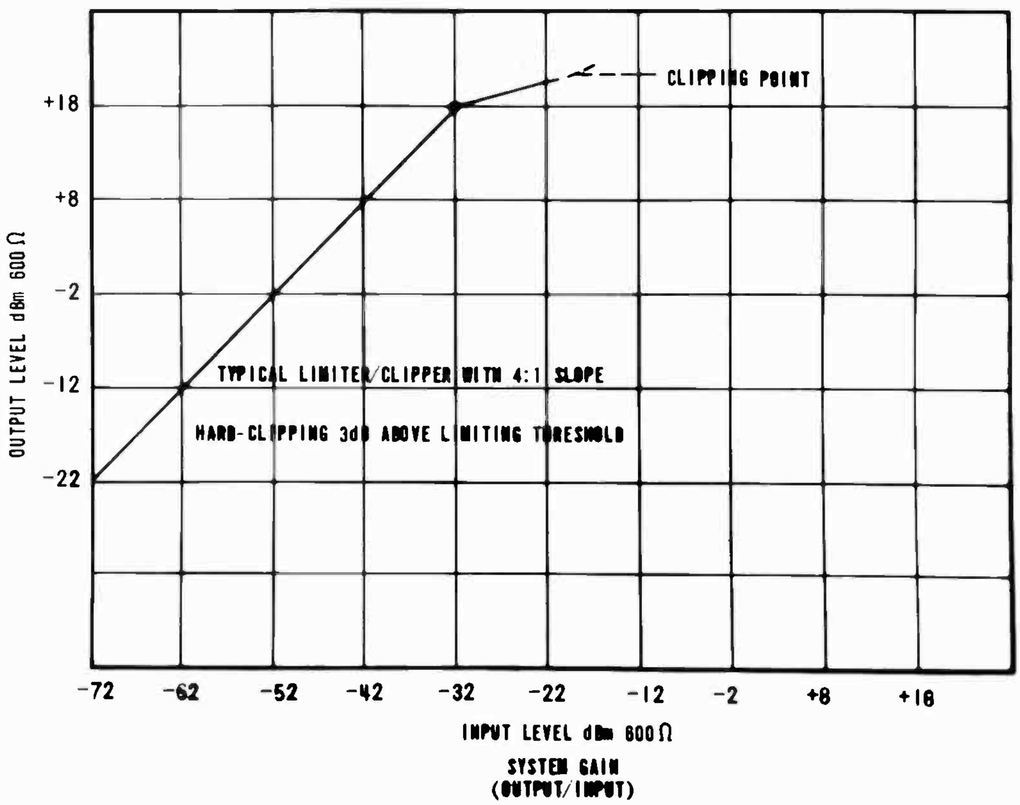

Figure 7 — AM Limiter Characteristics

Fig. 7 shows the Input/Output curve of one popular limiter with a 2 millisecond attack time, followed by a peak clipper with the provision for asymmetrical clipping. One of the advantages of this unit is that it does not exhibit much gain reduction on very fast isolated signal peaks, which are clipped to prevent overmodulation. This is especially advantageous over peak limiters with fast attack times that employ a single compromise recovery time. They would give excessive gain reduction on the program immediately following the fast isolated signal peak. One disadvantage of this limiter/clipper is the separation allowed between the threshold of limiting and the point of "hard clipping". This results in the threshold of limiting being set about 3 dB below the "hard clipping" point as measured on a H-P Distortion Analyzer. Presumably this separation is intended to accommodate component tolerances controlling the two thresholds, yet retain a sufficient margin to avoid excessive distortion that may be created by operating around the knee of the clipping diodes. On some units, at least, this results in a maximum negative modulation capability of considerably less than 100% on much programming, especially that with fairly uniform peaks of a somewhat recurrent nature. Since there is no provision for asymmetrical limiting, this type of programming would restrict the positive modulation as well.

Fig. 8 contains the Input/Output curve of another popular limiter of more recent vintage. It has a very fast attack time, limiting will occur within 10 microseconds after the signal level exceeds the threshold of limiting. If it made use of a single compromise recovery time, it would certainly reduce average modulation by an appreciable amount on at least some programming. However, it employs a dual storage circuit, cross-coupled to give very fast recovery time from fast isolated peaks and a longer recovery time from heavy sustained peaks. In addition, three switched positions are provided for fast, medium and slow recovery times to fit the normal programming of the individual station.

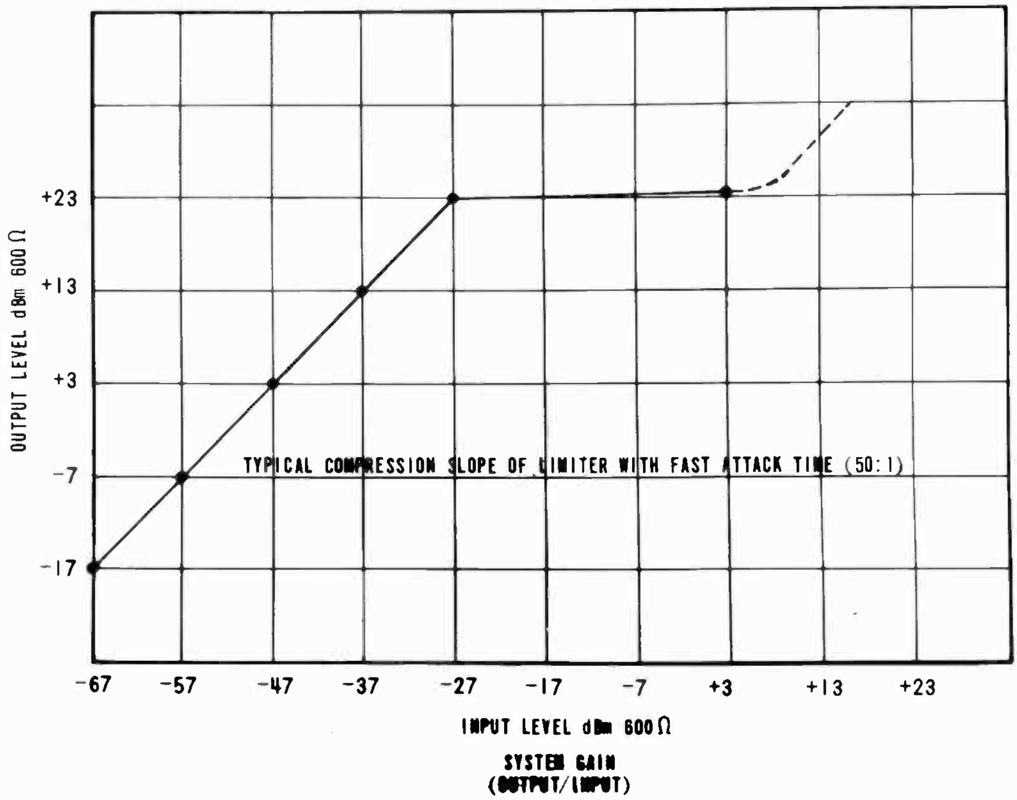

Figure 8 — AM Limiter Characteristics

In the fast recovery position, it takes approximately 0.7 seconds for complete recovery from a sustained 5 dB of limiting. The recovery slope is practically linear. Thus, it takes the same length of time to return from 10 dB to 5 dB, from 15 dB to 10 dB, etc. In the medium position it takes 1.2 seconds for each 5 dB, and in the slow position 1.7 seconds is required for each 5 dB segment of gain recovery. However, for random peaks, the recovery time is much faster and dependent on the amplitude and width of the random peak, compared to the associated program peaks of more recurrent nature. For example, the recovery time from a random peak of 5 dB above the average peak level of associated programming might range from 10 to 70 milliseconds, much faster than a syllabic rate.

The fast recovery time from random peaks is essentially unchanged by the fast, medium and slow positions listed above. Thus, in the fast position the recovery times range from a few milliseconds to 0.7 seconds, depending on the program content. In the medium position they range from the same few milliseconds to 1.2 seconds, and in the slow position up to a maximum of 1.7 seconds for 5 dB of gain recovery.

Although the use of a good AGC Amplifier would restrict the range of input level to the point that the 30 dB of limiting provided by the unit shown in Fig. 8 would seldom be needed, it is good insurance for an emergency. For example, it could handle the failure of the AGC

Amplifier and accept unprocessed signal levels without fear of overmodulation. In contrast, the very small range of the unit shown in Fig. 7 makes the use of pre-conditioning of signal level by an AGC Amplifier almost mandatory.

The difference in comparison slopes between the two AM limiters discussed is appreciable. The 50:1 slope retains a constant peak output level with a much wider range of input levels than a 4:1 slope, obviously. For AM transmitter signal level control, no offsetting advantage of the 4:1 slope was discovered in the analysis.

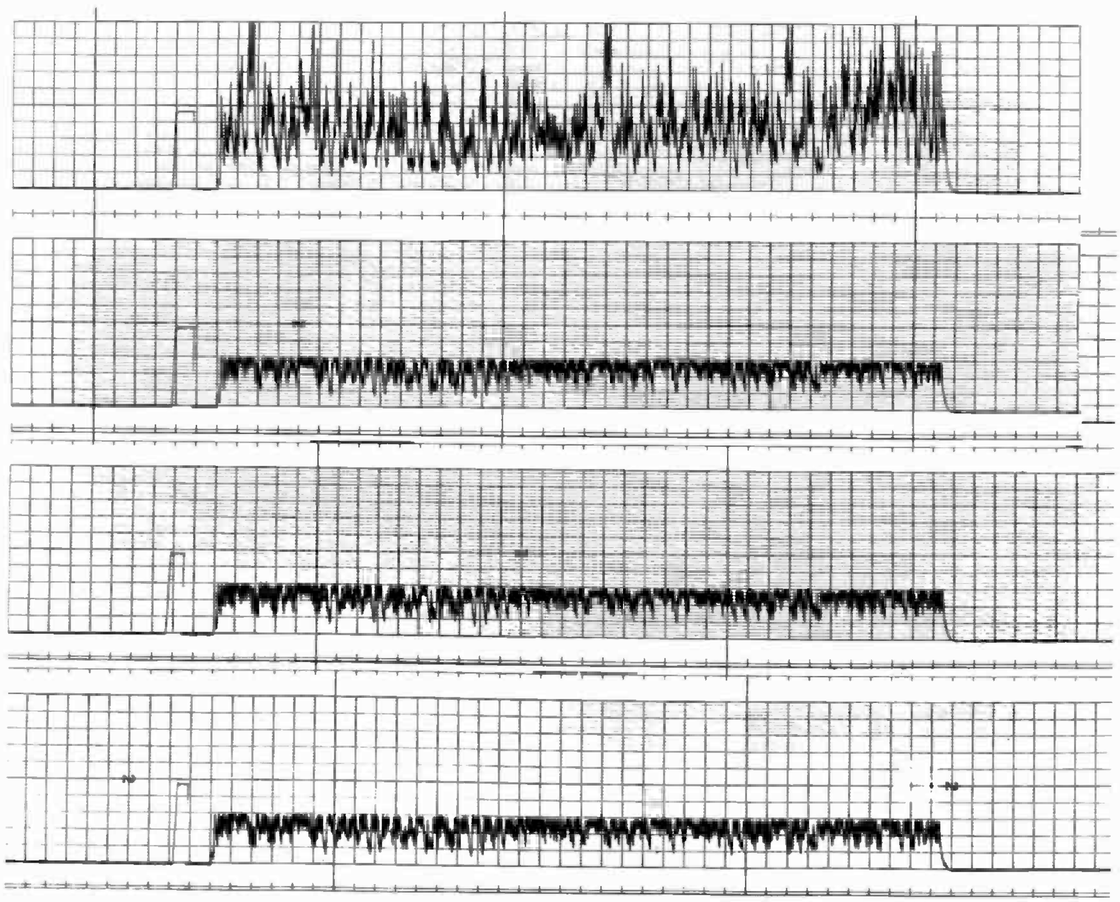

Figure 9 — Chart Recording of AM Limiter, 3 Positions

The calibration of the chart grids in Figures 9 and 10 is changed from that shown in Fig. 5 to show signal levels of up to 10 dB above the normal operating point. Again, the 50 divisions are assigned a value of 2, which gives a maximum of 100 on the charts. Since the grid is a linear scale while the levels are shown in dB's which are logarithmic, the presentation is quite crowded at the bottom compared to the top. The 100% modulation reference is calibrated at line 30. Thus, the following:

30% modulation	(−10 dB)	= line 08	90% modulation	(−1 dB)	= line 26
50% modulation	(−6 dB)	= line 15	100% modulation	(REF.)	= line 30
70% modulation	(−3 dB)	= line 20	110% modulation	(+0.8 dB)	= line 33
80% modulation	(−2 dB)	= line 22	120% modulation	(+1.6 dB)	= line 36

+3 dB = line 43, +4 dB = line 48, +5 dB = line 55, +6 dB = line 62, +7 dB = line 70, +8 dB = line 78, +9 dB = line 88 and +10 dB = line 99.

The top band of Fig. 9 shows the unprocessed input signal level of the musical selection Maria Elena (RCA/Reader's Digest T2RM-0821-1S) at a chart speed of 1 mm/sec. Note that several of the program peaks are 10 dB above normal and are causing 10 dB of limiting in the unit, the output of which is shown in the second, third and fourth bands. Band 2 is the output of the limiter shown on Fig. 8 in the fast position, band 3 is the medium position and band 4 is the slow position of the unit. The similarity of the output level displayed in the second, third and fourth bands is remarkable when the difference in long term recovery times is considered. This effectively demonstrates the action of the dual time constant and the resultant uniformity of the fast recovery portion. It further illustrates the point made about not being able to precisely measure attack/recovery times. The operation of the limiter in the three different positions does exhibit an appreciable difference to the ear on the selected piece illustrated.

Fig. 10 is the 1 minute section of "LBJ RADIO" again on a different time and amplitude scale than formerly. The chart speed is 5 mm/sec. and the scale is the same as listed for Fig. 9. Band 1 is the unprocessed input to the units. The content is a talk segment delivered by a well known comedian concerning LBJ's radio operations. The decay time of the chart recorder pen is more apparent on this speed, making the base of many of the peaks appear broader than they actually are.

Figure 10 — Chart Recording of Symmetrical/Asymmetrical Operation

Band 2 is the output of the AM limiter shown on Fig. 8 in the fast recovery position. All the tests on both AM limiters shown in Fig. 10 were made with 10 dB of limiting on the highest input peaks. Band 2 and 3 are with the limiters in the "symmetrical" condition. Band 3 shows the operation of the limiter/clipper associated with Fig. 7. At least 10% overmodulation is indicated by the recording in band 3.

Band 4 shows the same unit displayed by band 2, but in the "asymmetrical limiting" position. The switch for asymmetrical limiting was in the 120% position and 120% positive modulation was verified by an oscilloscope. The detector/recording chart shows about two thirds of this effect. Band 5 shows the same unit displayed by band 3, but in the "asymmetrical clipping" condition. Some peaks in excess of 4 dB above the 100% point (line 30) are shown. It is sobering to consider the amount of clipping that is indicated on the negative peaks in band 5, and on both positive and negative peaks in band 3.

FM TRANSMITTER CONTROL UNITS – As illustrated previously in this presentation, the operation of a peak limiter is to lower the high audio signal levels so that the instantaneous peaks are maintained at some constant amplitude. Then, by adjusting the gain control at the input of the transmitter, this constant peak amplitude level can be made to coincide with 100% peak modulation, as indicated by the flasher on the modulation monitor.

This signal processing, as applied to the control of audio peaks in FM systems, requires additional consideration of the effect of the pre-emphasis in the FM transmitter. This additional high frequency amplification acts to boost the amplitude of the high frequency audio peaks by 5-10 dB during normal complex programming, and by as much as 17 dB if the complex wave forms have prominent 15 kHz levels. Since the pre-emphasis has little or no effect on low frequency peaks, it is apparent that it has destroyed the constancy of peak amplitude which was previously created by the limiting amplifier. As a result, the low frequency transmitter modulation must be reduced to 30-55% so that the high frequency peaks can be 5-10 dB higher and not exceed 100%. Even with this reduction some types of music may readily cause overmodulation.

This problem has several possible solutions which allow the broadcaster to maintain high levels of modulation without fear of exceeding the FCC limit of 100%.

Since the use of pre-emphasis in the transmitter has caused the problem, the first obvious solution is to eliminate this pre-emphasis. Realizing that this could not be eliminated overnight, some years ago it was proposed in an NAB Paper that the amount of pre-emphasis be reduced in specific increments over a scheduled time period. Thus, transmitters and receivers could maintain a reasonable compatibility of frequency response throughout the normal life of the equipment.

Another philosophy is incorporated in a unit on the market designed to prevent FM overmodulation based on the premise of eliminating the effect of the transmitter pre-emphasis. The high frequency response of this unit is dynamically controlled by the high frequency signal levels. For low level signals, the response is nearly flat. However, as the high frequency signal level rises, the high frequency response of the unit exhibits a pronounced roll-off. At a level which corresponds to 100% modulation the high frequency response is the *inverse* of the pre-emphasis curve: That is, it is 3 dB down at 2 kHz and 17 dB down at 15 kHz. With this inverse-cancellation of the transmitter's pre-emphasis, there is no boost of the high frequency audio peaks to cause overmodulation. Additional protection against overmodulation as a result of slow attack time in the limiter section is provided by hard-clipping zener diodes at the output. Of course, this entire approach to solve the problem of overmodulation has created another problem: An apparent loss in fidelity at the listener's receiver, since the receiver has the standard de-emphasis to complement the transmitter pre-emphasis.

It is plausible that a more acceptable means to prevent FM overmodulation is the use of hard-clipping on the higher frequencies. Even though this approach may seem drastic, it has several important advantages: Clipping provides positive control of the peak amplitude. No apparent change in frequency response (the instantaneous action occurs only for the duration of the offending peak, less than 1 millisecond). If the clipping occurs after the signal has been pre-emphasized, the following de-emphasis will remove much of the harmonic content which was generated by the clipping action. This solution retains the use and any noise advantage of the pre-emphasis/de-emphasis concept. Hard-clipping has been used for the last several years in equipment marketed by two leading broadcast manufacturers for the prevention of FM overmodulation.

An integral Combination — Limiter and Clipper: FM systems which use separate limiting and clipping units for prevention of overmodulation usually have one major problem, the calibration of the clipping threshold of one unit so that it is only a few tenths of a dB above the maximum limiting threshold of the other unit. If this calibration is not done precisely the broadcaster will be clipping more than is desirable; or, he won't have the maximum modulation which his clipping protection will allow. Thus, it seems logical to have the two types of equipment integrated into a single unit with pre-aligned thresholds, as shown in the Block Diagram, Fig. 11.

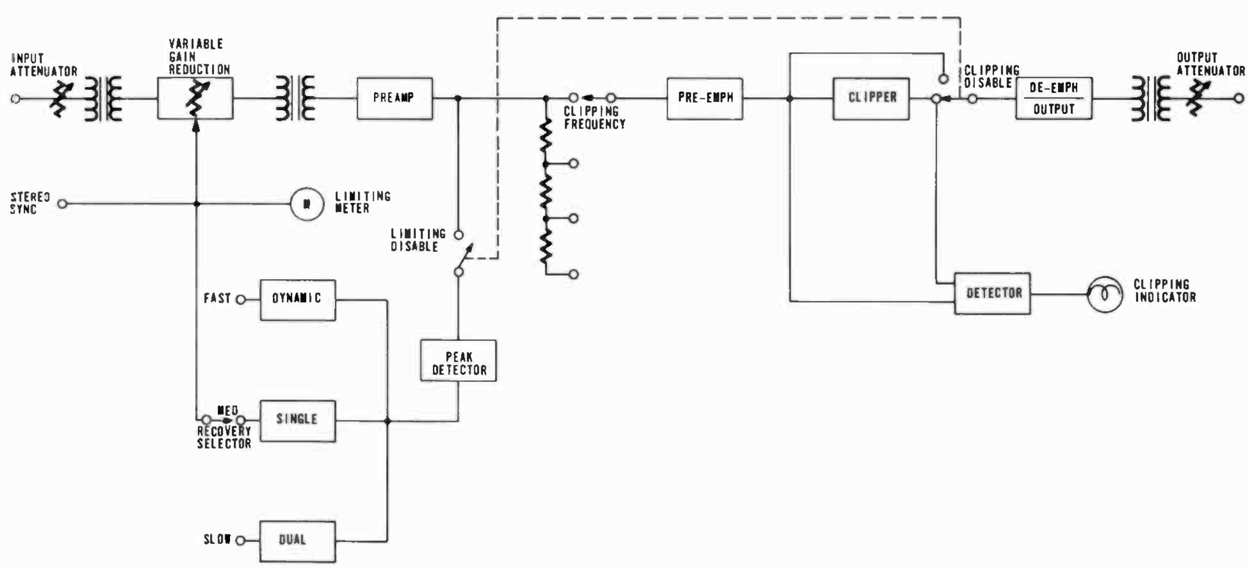

Figure 11 — Block Diagram FM Limiter

In order to allow a maximum modulation level, so that protective clipping can occur within a few tenths of a dB above the limiting threshold, it is very important that the limiter Input/Output curve be as nearly flat as possible. For example, above the limiting threshold, a 20 dB input variation should result in only a few tenths of a dB of output variation. In other words, the slope of the Input/Output curve above the limiting threshold should probably exceed 50:1. This curve and slope are shown in Fig. 12. It is also desirable to have this range of control extend to 30 or 40 dB of input variation, even though the normal amount of limiting will be in the range of only 5-10 dB. Emergency situations may require the extended operating range.

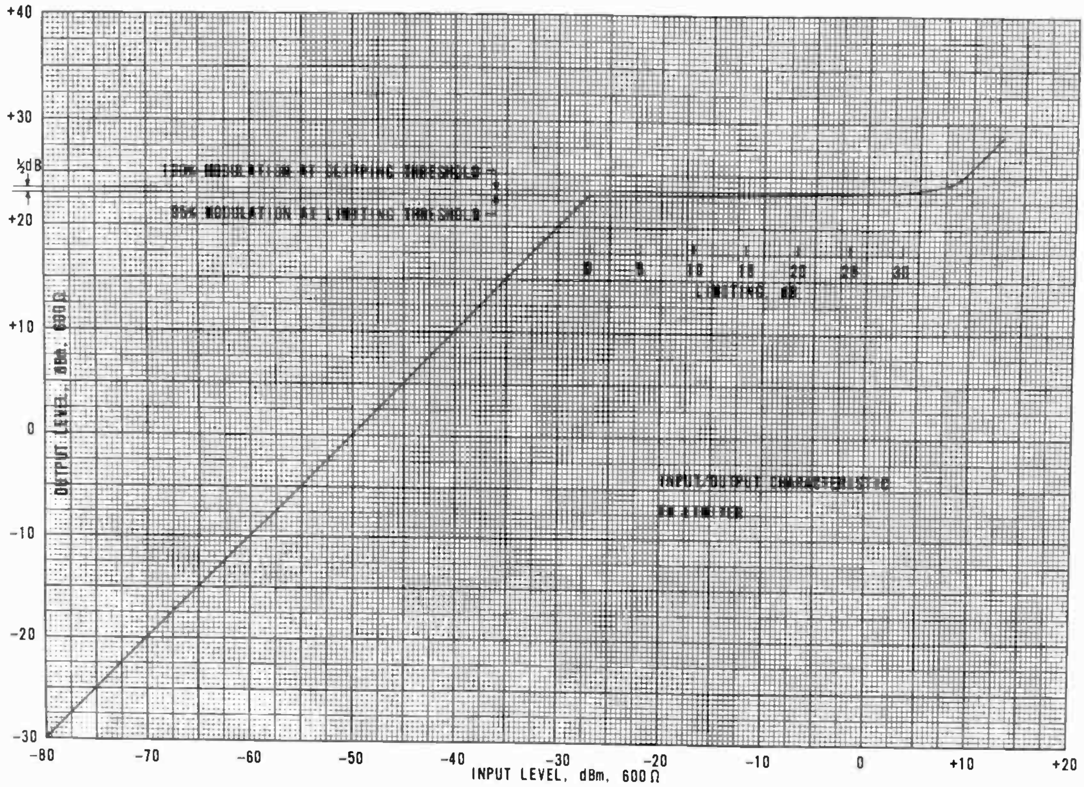

Figure 12 — FM Limiter Characteristics

Since the recovery to normal gain has such a significant effect on the "sound quality" of the limiter, it is very desirable to provide optional recovery timing so that each station can switch-select the mode of operation best suited to its programming: Fast, a newly-developed dynamic recovery circuit allows gain recovery in 100-200 milliseconds for highest average modulation, but without excessive low frequency distortion. Medium, a single recovery time constant of about ½ second for 5 dB of recovery is provided for light programming. Slow, dual-recovery time constants with a maximum recovery time of about 2½ seconds for 5 dB is provided for classical programming.

Pre-emphasis Amplifier: In order to know which peaks contain high frequencies and would cause overmodulation as a result of pre-emphasis in the transmitter, the FM limiter has a standard pre-emphasis circuit to amplify the previously limited peaks in the same manner as the transmitter. This pre-emphasis destroys the constancy of peak amplitude and is evidence of the basic requirement of an "FM" limiter to prevent overmodulation in FM systems.

So that the operator may have some idea as to the amount of clipping which is occurring in the circuit, a detector samples the clipper input and output waveforms, compares them and causes an indicator lamp to flash when the output waveform contains even a slight amount of clipping. The fast (10 microseconds) attack time of the circuit and associated storage capacitor provides a bright indication on short record "ticks", etc.

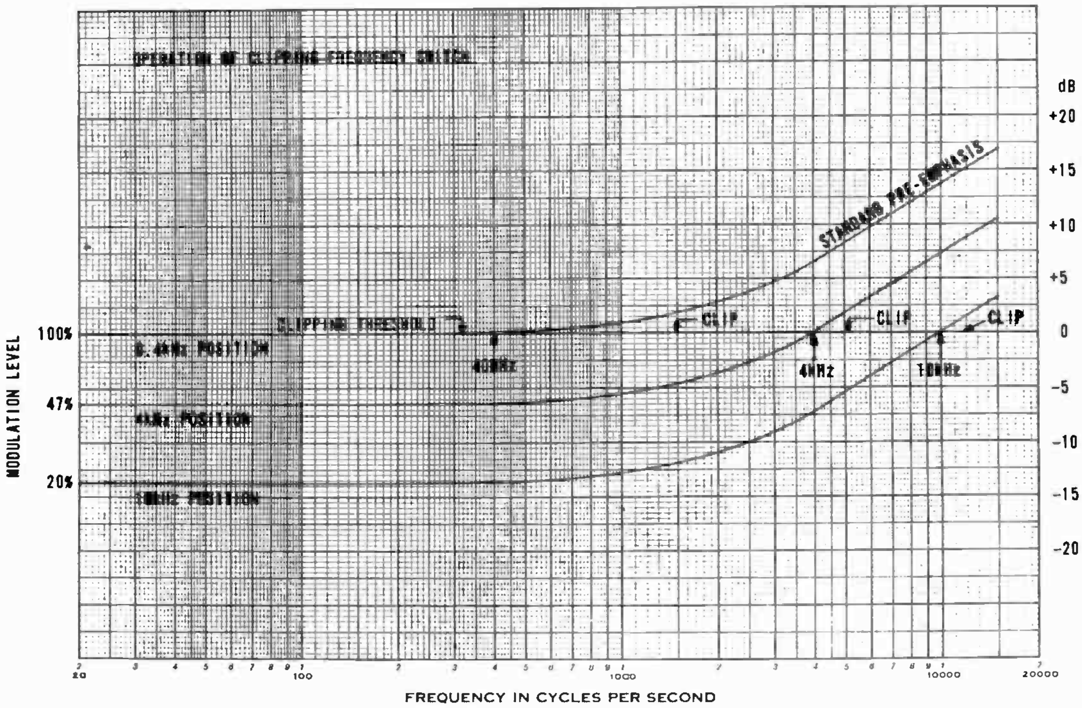

Figure 13 — FM Limiter Clipping/Frequency Characteristics

In the event the operator feels there may be excessive clipping with some programming (even though this effect is generally inaudible), a clipping-frequency switch adjusts the modulation level into the pre-emphasis and clipper circuits. This switch is approximately calibrated in terms of the lowest frequency on which clipping will occur. The operation of the switch is illustrated in Fig. 13, which is a graphic display of the peak amplitude of the audio signal after it has been processed by the clipper circuit. Even though this waveform is not at the actual output of the FM limiter, the following de-emphasis in the output stage acts to complement the pre-emphasis in the exciter, which results in a flat frequency response that restores the clipped waveform. Therefore, the actual modulation of the transmitter is limited to 100% by the clipping action, as shown in Fig. 13.

De-emphasis/Output Amplifier: At first thought the complementary de-emphasis/pre-emphasis just referenced seems ridiculous since the net result of the two is a flat frequency response, which includes potential error due to the tolerance of the individual curves. It seems to be more desirable to omit the de-emphasis in the FM limiter and omit the pre-emphasis in the transmitter.

This would allow the standard pre-emphasis in the center of the FM limiter to be the main and only pre-emphasis in the entire system. However, there is the question of the legality of disabling the transmitter pre-emphasis circuit since this unit was type-accepted by the FCC. Even though a satisfactory pre-emphasis circuit may appear in a preceding unit, such as the FM limiter, this unit was not part of the transmitter when the latter was type-accepted. Since there is already a pre-emphasis/clipper unit for FM transmitter control on the market which requires this modification of the transmitter, the legal aspects of this approach should be thoroughly investigated.

CONCLUSIONS – There is a definite application and need for the three categories of automatic gain controlling devices marketed for broadcast service. The many varying programming requirements for each of the three categories of equipment are too broad for a single set of attack/recovery time constants. This is verified by the fact that most of the units discussed have at least a dual set of control actions, such as limiting/clipping, etc. Even this duality of control action is inadequate for optimum processing of the major different types of programming. Thus, the new family of AGC/Limiting Amplifiers with a switch selection of three different sets of time constants is appropriate.

The information shown in the illustrations and accompanying text is that which is not readily available to the current or prospective user, for the most part. Yet, it contains data and philosophical descriptions that should be considered in his particular operation.

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