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REPORT

NEW NETWORK AUDIO SYSTEMS AMPLIFIERS

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NEW NETWORK AUDIO SYSTEMS AMPLIFIERS

SUMMARY: The stringent requirements of the new generation of network and allied audio systems demand a new concept in amplifier characteristics and performance. Amplifier requirements were derived directly from overall systems specifications with allowable deviation allocated to the various components. Results obtained on the new CBS-TV Network Audio Systems Consoles are used to compare with the amplifier design philosophy and the amplifiers are briefly described.

INTRODUCTION: The following systems specifications are part of those published by CBS-TV in a bid request for their new network facility in New York City. The specifications are not unique and had been in existance since late 1947. They formerly applied to comparatively simple systems with amplifiers that were generally compensated individually for uniform characteristics. The new generation of systems are anything but simple, and uniform characteristics must be a result of design rather than from individual tailoring.

SYSTEMS SPECIFICATIONS: GAIN: 76 db, ±1 db @ 1KC, with normal control positions. FREQUENCY RESPONSE: ±1.0 db from 50 to 15,000 cps., ±0.5 db from 150 to 5,000 cps. HARMONIC DISTORTION: 0.5% max. from 50 to 15,000 cps., 0.25% max. from 150 to 5,000 cps. RELATIVE INPUT NOISE: –120 dbm. CROSSTALK: Below system noise in the audible spectrum.

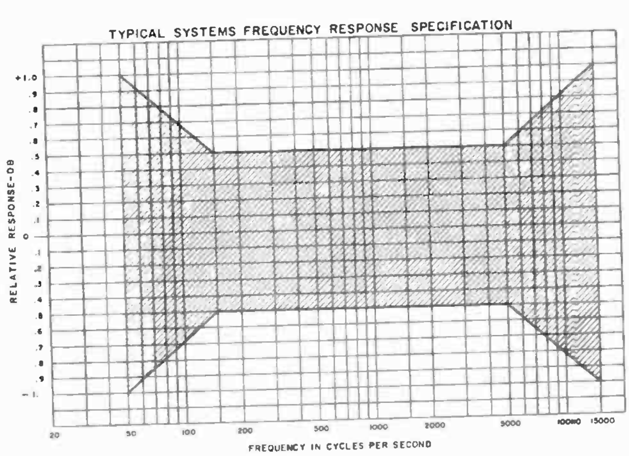

FIGURE 1

An amplifier built to these requirements would certainly qualify as a modern broadcast amplifier. However, these are systems specifications and apply to an entire chain in the system - containing at least four variable attenuators, several fixed or tapped attenuators, fourteen jackfield patches and switches, a line transformer, a bridging transformer, a bridging impedance mixing bus (with at least 24 other inputs feeding it), and a minimum of four amplifiers. The physical location of the multiplicity of components used in the typical network audio system dictates a complex intercabling requirement that contributes to the frequency response, noise and crosstalk problem potential. Thus, many factors had to be considered in the amplifier design and component selection.

FREQUENCY RESPONSE CONSIDERATIONS: Each of the four amplifiers were assigned a share, and all of the associated components received one lumped share of the allowable frequency response tolerance. Thus, the tolerance was divided by five - to give each amplifier share ±0.2 db from 50 to 15,000 cps. and ±0.1 db from 150 to5,000 cps. This immediately created a problem in reading the measurements with the normal complement of test equipment, plus some disagreement among the human extensions of the equipment.

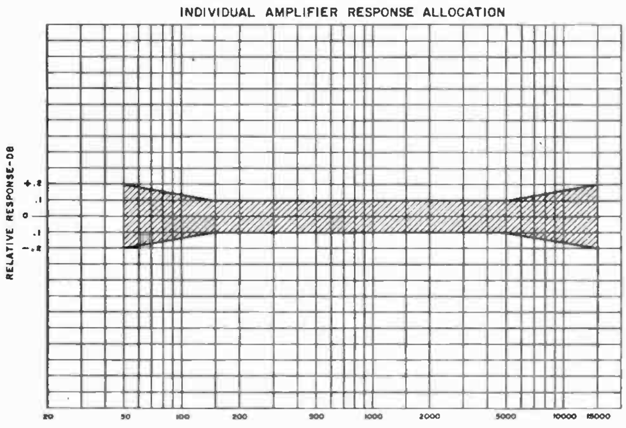

FIGURE 2

The initial concern was, of course, with the amplifiers – where there could be no final systems compensation due to the plug-in requirement and complex switching capabilities of the system. All of the amplifiers contain shunt-fed input and output transformers. Tertiary windings were abandoned early in the development because of instability in extended frequency response measurements - the amplifiers had to be free of resonances that would amplify induced signals in the range from D.C. to one megacycle. Thus, each amplifier share of the frequency response (shown above) had to include two transformers outside of the feedback loop.

One anticipated frequency response factor was the high-frequency roll-off due to the shunt capacity of all of the cabling and associated components. Accordingly, the combination Microphone Preamplifier/Booster Amplifier contains a variable capacitor in the negative feedback circuit. This capacitor is adjusted set the amplifier response to +0.1 db in the final test procedure. This was the only routine adjustment performed with any of the amplifiers in the group. The only passive components selected were the voltage-determining resistors in the regulated power supply networks. Limited transistor selection was required.

This portion of the design was proven in the some 1200 amplifiers and power supplies installed in the new CBS-TV Network Facility. The following results are the maximum and minimum readings measured on the 12 microphone channels in one of the seven studio control consoles in the system: 1KC is the reference level, 0 to -0.15 db @ 50 cps., +0.1 to -0.2 db @ 150 cps., +0.25 to +0.2 db @ 5KC and +0.25 to +0.1 db @ 15KC. As a matter of interest, the 30 cps. response was nearly identical to the 50 cps. response in all 12 microphone channels of the console. The 20KC response ranged from 0 (flat) to -0.3 db. The amplifiers used in the consoles were chosen at random from the entire production and no juggling was required to arrive at the results listed above.

Both groups of engineers were simply amazed at the console test results, and after thorough cross-checking, Allah was given proper recognition.

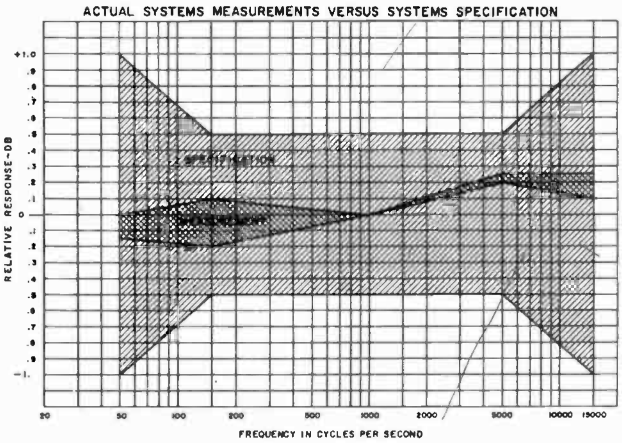

FIGURE 3

The graph at left shows the referenced console system, including four amplifiers in series, measurements versus specifications, for frequency response. The shaded area in this graph, as well as the other four graphs, represents the highest and lowest readings permissible. The cross-hatch area shows the actual measurements of frequency response and distortion in the program channel of the studio console under test.

OUTPUT CAPABILITY REQUIREMENTS: There are many advantages of the 150 ohm system over the 600 ohm system. Among them are: Four times as many bridging circuits (with the same impedance) can be connected without loading or level problems, the shunt capacity of the systems components has one fourth the effect, and standard components are available to allow a uniform systems impedance of 150 ohms from the microphone output to the speaker matching transformer input.

In 600 ohm systems the customary output levels are: +8 dbm on the line feed, isolated from the amplifier output with a 6 db fixed pad - thus, requiring a normal output level of +14 dbm from the amplifier. An additional requirement called for 10 db of "head-room", to handle complex programming peaks, determining the minimum amplifier output capability of +24 dbm.

The customary line feed level of +10 dbm for 150 ohm circuits was partially determined by standard VU meter requirements - this is the minimum level required to read "0" on the VU scale with a correctly connected meter. The VU meter ballistics are correct only when the 3900 ohm meter is matched with an approximate 3900 ohm input. The series 3600 ohm resistor used to accomplish this match calibrates the meter for +4 dbm on 600 ohm lines, +10 dbm on 150 ohm lines.

Increased dynamic range, improved systems components and television microphone techniques have created a demand for more "head-room" in a system, especially one with live program origination. Thus, a new standard of 16 db has been established (compared to the previous 10 db) for this important segment of the systems specifications. This, coupled with the line level change of 2 db, adds an impressive 8 db additional level requirement - determining a minimum amplifier output capability of +32 dbm.

HARMONIC DISTORTION CONSIDERATIONS: A slight addition of harmonic distortion was anticipated because each of the amplifiers exhibited predominantly third order harmonics. Perhaps the use of the word "predominantly" should be qualified: With maximum sine wave output from the microphone preamplifier (+20 dbm), or from the program amplifier (+32 dbm), total harmonic distortion measurements of individual amplifiers were generally less than 0.1%. The test oscillators employed in the measurement of the amplifiers were maintained at 0.05% to 0.09% total harmonic distortion, as measured on modern Hewlett-Packard distortion analyzers.

By comparing the amplifier distortion measurements with the input signal phased each way (0° and 180°, by turning over the patch plug on the input circuit), it was estimated that some of the actual distortion figures were as low as 0.006% with full output power from the amplifiers. There was no discernable increase in distortion with the output levels reduced over the full dynamic range of the amplifiers. Since the estimated distortion level was more than 80 db below the fundamental signal level, even an oscilloscope analysis lost the distortion in residual noise at low signal levels.

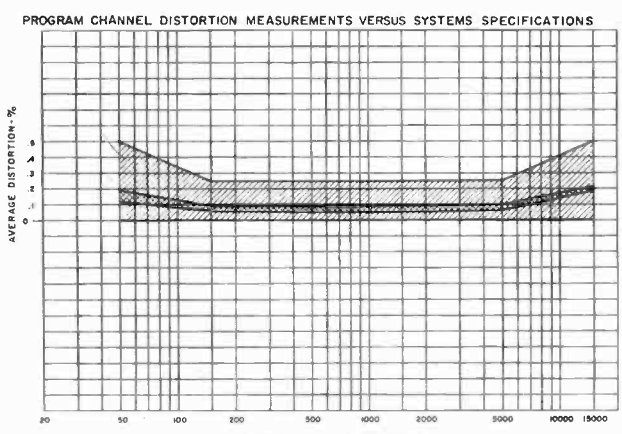

FIGURE 4

Console measurements with four cascaded amplifiers, and all of the associated components previously listed, were taken with normal control positions, but with signals 16 db above normal level (the system "head-room" requirement). The levels were −44 dbm on the input and +32 dbm on the output of the program chain of the console.

The following maximum and minimum readings were recorded on the twelve microphone channels: 0.19% to 0.12% @ 50 cps., 0.09% to 0.06% @ 150 cps., 0.09% to 0.055% @ 1KC, 0.10% to 0.06% @ 5KC and 0.22% to 0.19% @ 15KC. Thus, all of the readings were less than half of the allowable maximum distortion for the system.

There were very few readings that indicated the anticipated slight additive effect of distortion of the individual amplifiers, even though three of the four amplifiers were of identical types and the distortion content of the fourth closely matched them. In test systems of three of the identical amplifiers, with intermediate loss pads to allow operation of all three at full output level, the additive effect was conspicuously missing.

The fifth amplifier in the console was a 10 watt monitoring amplifier. The input of this amplifier was fed from a bridging pad that bridged across the output of the program channel. Again, all of the signal levels were 16 db above normal. The microphone input level was -44 dbm, the program output level was +32 dbm and the monitoring amplifier output level was +40 dbm.

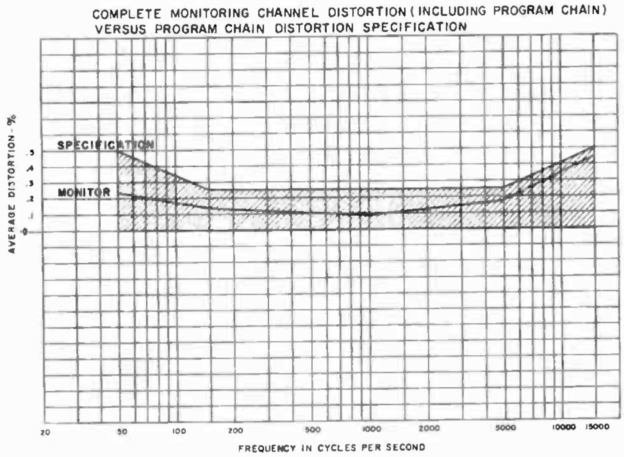

FIGURE 5

A typical channel measured: 0.24% @ 50 cps., 0.14% @ 150 cps., 0.09% @ 1KC, 0.17% @ 5KC and 0.44% @ 15KC. Thus, the entire systems chain, including a 10 watt monitoring level, fell within the stringent program chain systems specifications.

NOISE CONSIDERATIONS: The relative input noise of individual microphone preamplifiers measured -121 to -123 dbm. An early analysis, of noise versus optimum reflected input impedance, of this amplifier was decided in favor of uniformly high reflected input impedance from 30 to 15,000 cps. - to obtain the best possible results from broadcast quality ribbon and cardiod microphones. Noise figures of -126 to -129 have been obtained in circuits with series-fed input transformers. The reflected input impedance was extremely high in the mid-range, but too low at the upper and lower audio frequencies for optimum ribbon and cardiod microphone performance, however.

The referenced console had nine program channels, eight of which had selector switches to allow any of the twenty-five input channels to be connected individually or any number in parallel. On the eight switched program channels, with an individual microphone input channel connected, the noise ranged from -120.5 dbm to -121 dbm. At one point in the system the level on the input of a booster amplifier was only 6 db above the input to the microphone preamplifier, causing approximately 1 db degradation from that on the individual preamplifier. It is desirable to maintain at least an 8 to 10 db margin in this area to eliminate this problem.

Program Channel #1 was unique, it had all of the twenty-five input channels wired permanently into its bridging mixing bus. This includes seventeen channels containing booster amplifiers with an equivelant input level of -53 dbm. The relative input noise on this program channel ranged from -116 dbm to -117 dbm. The effect of noise accumulation could be observed on one of the switched program channels by progressively switching in the input channels. Of course, the first few had the greatest effect - the change in noise appeared to be logarithmic.

The noise content appeared to be highest in the 15KC to 45KC region. A plausible theory was advanced: That, as the number of parallel amplifiers was increased, the number of high frequency coincident noise peaks was greatly increased. This could increase the power level in this area and probably accounts for the approximate 6 db increase in noise.

CROSSTALK MEASUREMENTS were very rewarding, justifying the careful attention given to the prevention of crosstalk paths in every step of the design, from the basic amplifiers through the final wiring of the consoles. Several miles of miniature shielded twisted pair audio cable - with insulated aluminum-mylar foil shielding - was incorporated into each console. It was felt that the foil shielding was a great factor in practically eliminating any crosstalk in the audible range.

AMPLIFIERS: A new series of systems amplifiers, identified as the M6300 Series, was designed and developed to meet the requirements of the system described. They consist of the Preamplifier, with a choice of 40 or 46 db gain (selected by receptacle strapping); the Monitoring Amplifier, with an internal L-D-R gain control (for use with a remote gain control actuator) and a maximum gain of 80 db; and the Program Amplifier, with a maximum gain of 62 db in the "Program Mode" or 80 db in the "Intercom Mode" (selected by receptacle strapping).

The "Program Mode" of the program amplifier offers either an amplifier with linear input/output characteristics, or an automatic gain-controlled-amplifier - selected by operation of a remote SPST switch. In the "AGC Mode", the amplifier is linear with input levels up to -42 dbm and output levels of up to +20 dbm. Then, with the input level increased approximately 7 db, the output will increase only 1 db, giving the required 6 db step function for optimum programming balance. With levels higher than -35 dbm input, the amplifier regains its linear input/output relationship up to the maximum of -24 dbm input and +32 dbm output level.

In the "Intercom Mode", the amplifier acts as a limiting amplifier with a +20 dbm output threshold of limiting. With levels below -60 dbm input and +20 dbm output, the amplifier has linear input/output characteristics. Above these levels, the output increases approximately 3 db with an input level increase of 24 db, giving effectively 21 db of gain reduction.

Several regulated power supplies were developed to furnish power to the preamplifiers and program amplifiers, relays, signal lamps, and the L-D-R channel attenuator complement of the console. The D.C. output voltages were: 48 volts (for the amplifiers), 24 volts (for the relays and signal lamps), and an adjustable supply from 6.0 to 8.4 volts (for the L-D-R's). Two main requirements of all of the power supplies were exceedingly low internal impedance and low ripple voltages. Up to four of these power supplies may be mounted in a shelf assembly with only 3-1/2" of panel space in a standard 19" relay rack. The Shelf Assembly will accommodate up to four of the monitoring amplifiers, six program amplifiers or eight preamplifiers. Thus, great numbers of amplifiers and power supplies can be put into relatively modest cubage, to make the physical requirements of new systems practical.

CONCLUSIONS: Although the measurements tabulated above were on a high gain system (121 db maximum, microphone to line), containing many amplifiers and other passive elements – the maximum frequency response excursion of -0.2 db to +0.25 db, maximum distortion of 0.22% with maximum program levels, relative input noise of -121 dbm and the almost non-existent crosstalk demonstrates the capability of modern components. It is significant that there seems to be little doubt that the amplifiers described were transistor types, although there were only a few obscure references to transistors in the text.

If there are still any lingering doubts about the feasibility of systems audio transistor amplifiers, they can now be dispelled. The circuitry in the Program AGC Amplifier has routed the tube in the last stronghold of audio components - the limiting amplifier. It is now possible to design, build and prove the most complex and exacting systems without a single vacuum tube to degrade their performance or reliability.

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