WOR Installs Custom-Built High-Quality Speech Input System Designed for FM

By J. E. TARR
Commercial Products Development, Bell Telephone Laboratories

The use of wide-band frequency modulation in ultra-high frequency broadcasting promises a new order of system performance through substantial improvements in frequency range, signal-to-noise ratio and freedom from distortion in the "radio link" between the speech input terminals of the transmitter and the detector output in the receiver. Commercialization of these potential improvements will make possible realization of the full range performance capabilities of other system elements.

The first Western Electric synchronized frequency modulation broadcasting transmitter installation at Station WOR, which is expected to play an important part in demonstrating the capabilities of the new modulation system, was therefore felt to warrant the provision of speech input equipment giving performance superior to that of any heretofore used commercially. This equipment was shown as part of the synchronized frequency modulation demonstration equipment at Bell Telephone Laboratories in June, and while it was inspected there by many readers of "Pick-Ups" it is felt that a more complete discussion of its design and construction will be of general interest to the field.

This equipment was custom-built. The choice of facilities provided, the arrangement of controls and several of the new circuit features are largely the work of E. J. Content of Station WOR who co-operated with the Laboratories in its design and testing. The flexibility inherent in the basic design not only fulfills practically any set of requirements which may be met in present-day broadcasting practice but also any which seem likely to arise through the application of frequency modulation.

Apart from the special features required to meet specific requirements at WOR the fundamental design of this equipment was aimed at the following broad objectives:

1. Wide Frequency Range — from 30 to well beyond 15,000 cycles
2. Adequate Net Gain — ample margin over normal requirements to promote ease and flexibility of operation
3. Improved Signal-to-Noise Ratio — a

close approach to theoretical limits throughout the normal range of control adjustments, and better than 60 db at normal gain

4. Adequate Overload Margins — ability to deliver normal program level over a wide range of control adjustments and with uniformly low harmonic distortion
5. Simplicity of Control—maximum compatible with full operating flexibility of a complex system
6. Maximum Reliability — ability to deliver program even during partial equipment failure
7. Advanced Mechanical Design — compactness without sacrifice of accessibility for servicing; clean-cut, modern appearance and flexibility to permit assembly of equipment in various ways to meet various operating requirements
8. Use of Standard Components — the desk assembly is composed of standard apparatus available from the Western Electric Company
9. New Basic Structure—harmonizing with modern steel studio furniture design, with the probability that structural units of this type will be standardized

The basic system design is conventional, although certain departures were made in order to meet the specific requirements of Station WOR. An eight-channel parallel mixer is used to accommodate six studio microphones, electrical transcription and incoming program line respectively. The microphone and transcription circuits are equipped with two-stage pre-mixing amplifiers (120A Amplifiers) while the line position has a variable equalizer, repeating coil and pad and a key for selecting either of two lines. A single key controls all microphone positions as a group and controls the studio speaker relay as well.

The mixer is followed by regular and emergency main amplifier channels in duplicate; each of these channels includes a two-stage low-level amplifier (120A) and two-stage high-level amplifier (121A with two-stage connection) with a master gain control between them, and the "Regular-Emergency" keys, yoked together so as to operate as one key, permit shifting instantly from one main channel to the other in case an emergency should develop during a program. The low-level amplifier and master gain control of the emergency channel are also used in the talk-back circuit described below, being made available automatically for this use when the "Regular-Emergency" key is in the "Regular" position.

The output from either main channel feeds a resistance bridge network which divides the output power in predetermined proportions among the volume indicator, a monitoring output and the program bus, the latter output being under control of the three-position output key whose auxiliary functions are described below. The function of the bridge design in

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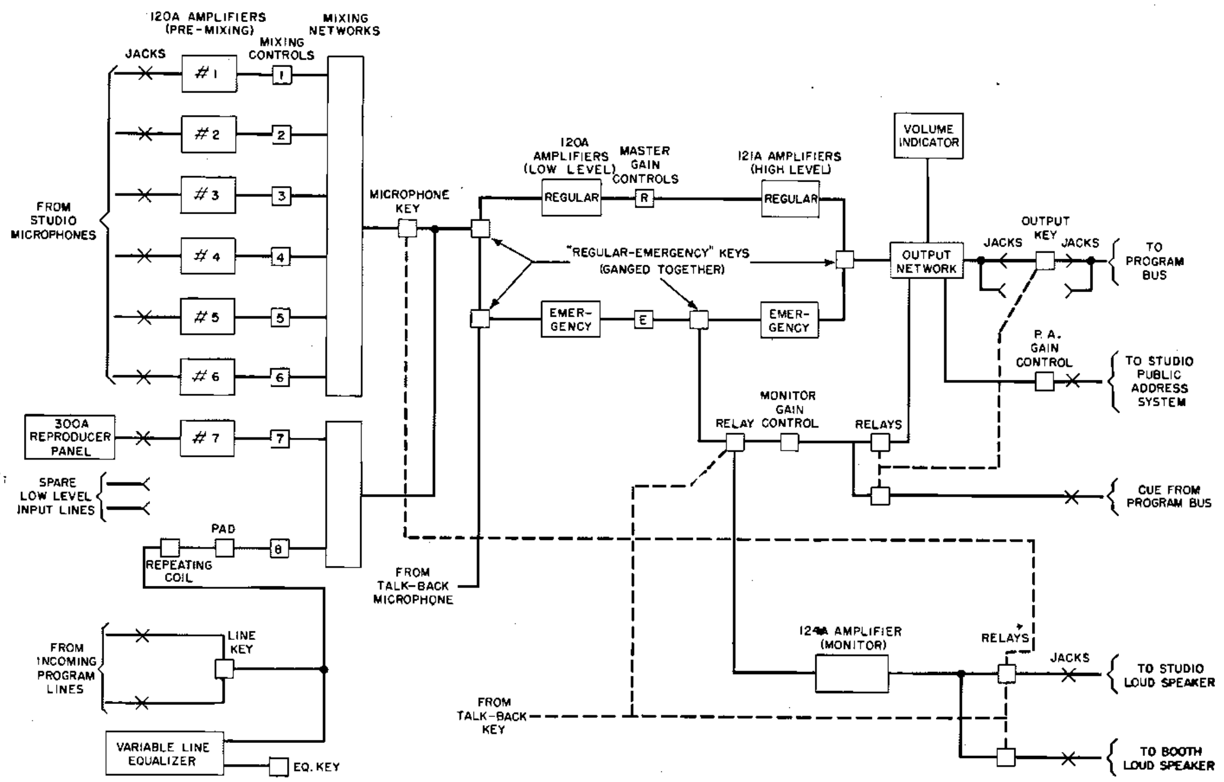

Block schematic of custom-built desk speech input equipment

New Speech Input at WOR

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the output network is to provide mutual isolation among the three outputs so that the attenuation and source impedance for each are independent of the terminations on the others; this feature serves further to localize any trouble which might develop and to insure true volume indication and monitor response even when the output is fed to a reactive load such as an equalized program line.

Jacks are provided in all input circuits to permit interchange of pre-mixing amplifiers in emergencies, and at all important junctions in the high level circuits to facilitate maintenance and testing; however, the system is designed to provide all normal operating functions without patching and thus to minimize operating errors and maintenance difficulties associated with extensive use of patching cords.

With the exception of the main power switch and transcription controls, all operating controls are located on the hinged control panel. In accordance with WOR's practice the optimum grouping of important operating controls was given careful attention.

Moreover, whereas the same basic operating functions could have been provided at about the same cost with fewer amplifiers but with more complicated control circuits, this would have resulted in a system inherently less flexible and more subject to operating errors; the system design was therefore based on liberal use of amplifiers wherever operating control could thereby be simplified.

Primary operating controls are grouped in the center section of the control panel where they occupy a lateral space of about 25 inches. The six microphone mixers and the regular master gain control are placed in that order along the bottom where their frequent use justifies the location most convenient to the operator. Above them are the transcription and line input mixers and the emergency master gain control, a little less convenient perhaps but still directly before the operator. The common microphone control key is at the upper right corner and the main output key, made conspicuous by its red handle, at the upper left surmounted by a lone indicating lamp which lights when the channel is put "on the air" by the master control room operator.

The extreme end sections of the panel are used for controls of secondary importance. At the left are the milliammeter and switches for reading plate currents in all pre-mxing, low-level and high-level amplifiers, together with the incoming line selector key, the single control dial of the equalizer which is calibrated directly in db loss at 1000 cycles, and the equalizer range key providing a choice of two equalizer frequencies. The "Regular-Emergency" key group is near the top of the right end section, directly above the monitor and public address gain controls referred to below.

The monitor tap on the main channel output network feeds two independent gain controls through a dividing pad. One of these controls is for feeding a studio public address system whose volume is thus controllable independently by the booth operator. The second control is connected to the local monitor system.

A high-gain monitor amplifier (124A) is included to drive the booth and studio speakers. A system of relays associated with this amplifier provides for cue monitoring of a preceding program, local monitoring of a program being originated through the equipment with studio speaker cut off during microphone operation, and local monitoring with talk-back during rehearsals. These functions are controlled primarily by the output key which operates as follows:

In normal program operation the output key is in the "Program" position, where its auxiliary contacts operate the relays to monitor the program being originated; this is heard through the booth speaker and, except when the microphone key is closed, in the studio speaker also. The talk-back system is disabled during program origination to guard against accidental talk-back operation interrupting the program on the air.

When the studio is standing by preparatory to beginning a program the output key is left in the "standby" position, which terminates the system output and operates relays to monitor the program which is nearing completion; this "cue" is heard over both studio and control booth speakers even though the microphone key is closed, so that the operator, to start the new program, need only throw the output key to "Program" in order to connect the system out to the program bus, give indication to master control, switch the monitor to the local program, cut the studio speaker and operate the studio warning light.

During rehearsals the output key in the "Rehearsal" position normally terminates the system output, although this key can be bridged by a patching cord if the rehearsal is being recorded from the program bus; the output key in this position also prepares the talk-back relay circuit for operation by either foot-switch. The talk-back relays, when operated, (1) connect the monitor amplifier input to the output of the emergency low-level amplifier, whose input is already connected to the booth microphone, the main channel switch being in the "Regular" position; (2) cut the booth speaker and (3) connect the studio speaker.

The relay circuits provided for these functions are so designed that the complex circuit operations are performed automatically in the sequence required for noiseless operation.

No talk-back key is included in the equipment proper, but the control circuit is brought to terminals for use with two externally mounted treadle-type foot-switches for use by the operator and production man.

Auxiliary relay contacts are also arranged to give indication in master control when the channel is "on the air" and the microphones connected to operate studio warning lights.

A single channel turntable is included primarily for sound effects and spot advertising transcriptions. This is a standard 300A Reproducer Panel, rubber mounted in a special shallow enclosure to sit at convenient operating height on the wing at the right of the desk structure.

This panel is, of course, equipped with the standard universal (9A) reproducer for both lateral and vertical recordings, two-speed motor for both 33⅓ and 78 r.p.m., and universal equalizer circuit providing a total of seven response curves.

Power and output connections are made at the rear of the enclosure through plugs and receptacles so that the turntable unit may be removed readily.

Two standard 18A Rectifiers are included to supply filament and plate power to the premixing and main channel amplifiers. Each rectifier carries one main channel and half of the pre-amplifiers, so that even complete failure of one rectifier would leave the system capable of normal operation with three microphones.

The monitor amplifier includes its own power supply equipment.

No low-voltage rectifier is included, since a 12 volt bus is used at WOR to operate relays and signal lamps throughout the plant. An individual local rectifier could, however, have been included.

Failure of the relay power supply during a program would not interfere seriously with operation since the studio speaker is "off," the booth speaker "on" and the monitor circuit connected for normal operation when all relays are at rest. The use of dual-contact (U-type) relays exclusively provides additional assurance of reliable relay performance.

The pre-amplifiers are mounted behind and below the control panel, and their tubes are readily accessible for replacement by opening the hinged panel. The latter operation also permits ready access to all control panel equipment and wiring for testing and servicing.

Internal and external wiring of the pre-amplifiers is accessible by removal of a light steel cover under the pre-amplifier compartment.

All other major components are mounted in the equipment drawer and wired through flexible cables to permit opening the drawer for ready inspection. The rectifiers and monitor amplifier are at the sides of the drawer, their wiring protected by removable bakelite cover plates. The four main channel amplifiers are carried by a hinged gate at the top of the drawer; raising this gate reveals their wiring and facilitates removal of rectifier and monitor amplifier tubes.

The desk structure itself is fabricated of sheet steel in three sections: the table proper, the thin leg at the left and the equipment drawer.

These units are made with concealed knock-outs so that they may be bolted together in various ways. For example, the equipment drawer could as well be placed at the left and the leg at the right, instead of as shown; two legs and the table section would make a more compact assembly for use where rack space is already available for the more bulky units; or two equipment drawers could be used if a more elaborate circuit calls for more amplifier mounting space, or if mounting space for two turntables is required in which case one drawer could be equipped to serve as a record file.

Moreover, since the basic structure is in the standard style of a leading manufacturer of steel office furniture, desks or tables of matching design for use by announcers or production men should be readily available.

The response frequency measurements from microphone input terminals to the system output show a response that is substantially flat to a point well beyond the range of audibility, thus minimizing resonance or transient effects which might result from a sharply falling response within the audible range.

This uniformity of frequency response may well appear remarkable in view of the fact that it represents the performance of three amplifiers totalling six stages in tandem and that stock amplifiers were used without special selection or equalization.

The variation of signal-to-noise ratio with varying gain adjustment as shown in Figure 1 also indicates a new order of system performance. The significant points here are (1) the close approach to theoretically ideal noise ratio at high gain settings, (2) the corresponding improvement in noise ratio as the gain is reduced by either the mixer or master controls to a value well within the most rigorous performance standards, and (3) the wide margin of available net gain, about 26 db, above that required to give reference output with the accepted normal microphone level of — 60 vu.

At normal gain unweighted noise levels obtained from the complete system are between 68 and 74 db below the single frequency tone level required for normal volume indicator reading. Since the

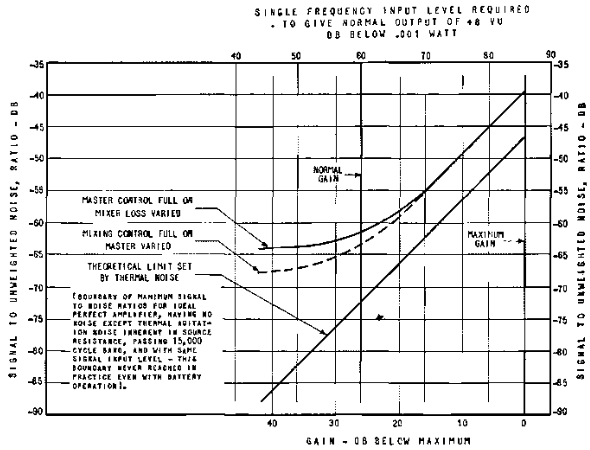

Fig. 1

Signal-to-noise ratio with varying gain adjustment

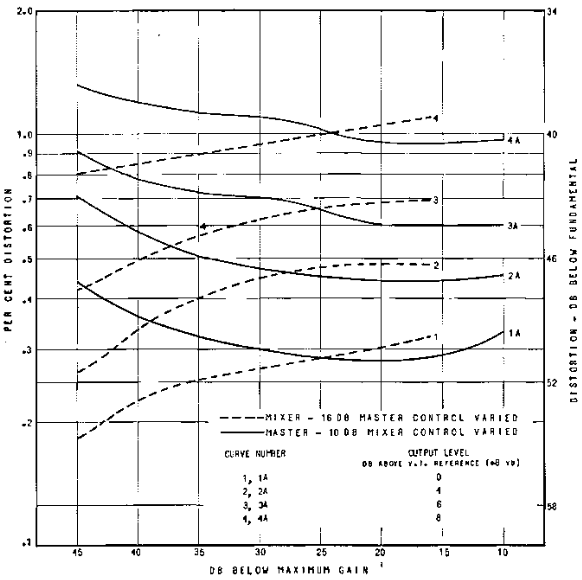

Fig. 2

Typical distortion characteristics for a 400 cycle signal

peak signal output on program material representing instantaneous complete modulation of an associated radio transmitter may run from 6 to 10 db above volume indicator readings, unweighted carrier noise attributable to the speech input equipment should run from 68 to 74 db below the complete modulation signal level under these conditions, affording a "dynamic range" commensurate with the most rigorous system performance standards.

Typical distortion characteristics for a 400 cycle signal are shown in Figure 2; this is in the frequency range where highest power levels occur in speech and music.

Measurements at other frequencies between 50 and 7500 cycles are much the same. For peak signal levels reaching 8 db above nominal output level the total r.s.s. harmonic voltage is in the order of 1% of the fundamental, and does not exceed 1½% even for abnormal gain control attenuations. For the great majority of peaks which will not exceed the rated single frequency output level, the distortion attributable to this equipment would appear to be negligible even in a frequency modulation system where most exacting requirements may prevail.

The excellent performance capabilities of this system and particularly the wide range of control adjustments which can be used without serious impairment of quality and signal-to-noise ratio are attributable largely to the careful design of the basic circuit, including optimum distribution of gains and losses, but primarily to the superior capabilities of the new standard amplifiers which were developed with a view to meeting the most rigorous system operating requirements of commercial broadcasting practice.

It is felt that many of the advanced features exemplified in this custom-built equipment will soon find application in everyday equipment designs.

New Hampshire Police Radio

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are both run underground from the nearby highway. An amateur radio station at headquarters and another in the spare room at the transmitter building provide additional communication between these two points in cases of emergency such as the hurricane which in 1938 destroyed practically all wire communication in this section of New England. Both of these ham rigs were built by the station's operators, two of whom are licensed amateurs.

Everyone concerned with the operation of the new system is well pleased with the efficient manner in which it functions. Basil Cutting, chief communications engineer of the New Hampshire State Police, was a member of the committee which selected the equipment for the system. Cutting, now responsible in his official capacity for the performance of the equipment, is still positive the committee could not have made a better choice.

Although it is too soon to make comparisons of a "before and after" nature, the authorities are delighted with the results obtained with the use of radio. "One thing we can be sure of," asserted Colonel G. A. Colbath, superintendent of the State Police, "is that all delays in reaching the troopers have been eliminated. As soon as a complaint is received at headquarters a call is put on the air and, immediately, a trooper is on his way to the scene of trouble. This means that the time between report of trouble to headquarters and the arrival of a trooper at the scene has been cut at least in half, and possibly more."

Walter W. McCoy, chief engineer of station WJAS, Pittsburgh, Pennsylvania, holds a 279A vacuum tube which was removed from the station's transmitter after 16,297 hours of operation. Although still functioning it was removed at the end of this period because the station feared it might fail and cause lost time on the air.