

A Stereophonic Transmission System For the Bach Choir of Bethlehem

By IFOR JONES¹ and HENRY C. KNUTSON²

The annual May Festival of choral music by Johann Sebastian Bach, given by the Bach Choir of Bethlehem, Pennsylvania, in the beautiful Packer Chapel on the campus of Lehigh University, is considered one of the most significant musical events in America. The performance, by the Bach Choir, made up of men and women from all walks of life, the finest soloists available, and players from the Philadelphia Symphony Orchestra, have won world wide acclaim. For several decades the Chapel has become the destination of a pilgrimage for many thousands of music lovers in this continent and in Europe. Unfortunately, the seating capacity of the Chapel is far too limited to serve the increasingly large number of applicants for tickets. Those who cannot be accommodated sit on the lawns and try to hear the music through open windows. At the 1939 Festival, there were 1200 seated inside the Chapel and 1500 on the lawns.

To alleviate this condition it was suggested that the program be transmitted by an amplifying system from the Chapel to the auditorium of the Packard Laboratory of Electrical and Mechanical Engineering, which is located directly across the street from Packer Chapel. Such a project was approached with considerable trepidation. It was apparent that the nature and quality of the music would impose severe requirements on the transmission system. Another point to be considered was whether the attendance at a reproduced program would be sufficient to make the project self-supporting. After a careful consideration of all factors involved, and with the active cooperation of Bell Telephone Laboratories, a system was finally devised which proved entirely satisfactory.

Before planning any details, the following basic requirements were formulated for the system:

1. A wide frequency range.
2. Ample or excess output capacity so as to cover the whole volume range.
3. Low noise level.
4. Low distortion.
5. Auditory perspective if possible.
6. Some control of the carryover of the reverberation effects of the chapel.
7. Flexibility of the equipment to permit adapting to local conditions.
8. Reasonable cost.

A survey of the equipment on the market showed that no complete system, which would

satisfy all these requirements, was available. The only possibility, therefore, was to design and assemble the transmission system locally. As a nucleus around which to build, Western Electric 119A and 118A amplifiers were chosen since they would fulfill all the technical requirements. Because of their relatively low cost it was found possible to plan a two channel system, thus providing the desired auditory perspective. The entire system was assembled and installed by the Electrical Engineering Department of Lehigh University, using stock Western Electric parts purchased through the local Graybar Company.

Figure 1 is a simplified block diagram of the transmission system as installed. The left and right microphones feed through individual 116A pre-amplifiers to the 119A amplifiers of the left and right channels respectively. The center microphone bridges the left and right channels through two 116A amplifiers. Type 30 volume indicators are connected across the outputs of each of the 119A amplifiers. For monitoring purposes a set of crystal headphones is arranged so that the left earpiece connects to the left channel and the right earpiece to the right channel.

To simplify the control of volume during the program, corresponding left and right volume controls are ganged in a control cabinet that also houses the volume indicators, i.e. V_L and V_R are dual potentiometers; similarly, V_{CL} and V_{CR} and V_{ML} and V_{MR} . To permit individual adjustment of gain to compensate for any amplifier unbalance, all the volume controls have small series connected controls mounted on the amplifier cabinet.

The physical arrangement of equipment in Packer Chapel is shown in Figure 4. The 119A amplifiers are the first and third panels down on the cabinet in the center of the picture. The three individual compensation volume controls for each of the amplifiers are mounted on these panels. The dual controls for right and left microphones, center microphone and master control are mounted at the bottom of the control cabinet at the right. The volume indicators with their attenuators are at the top of this cabinet.

The second panel down on the amplifier cabinet is entirely for the purpose of preliminary adjustment and testing of the whole system. This
(Continued on page 26)

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STEREOPHONIC SOUND SYSTEM

FOR

BACH CHOIR

BETHLEHEM, PA.

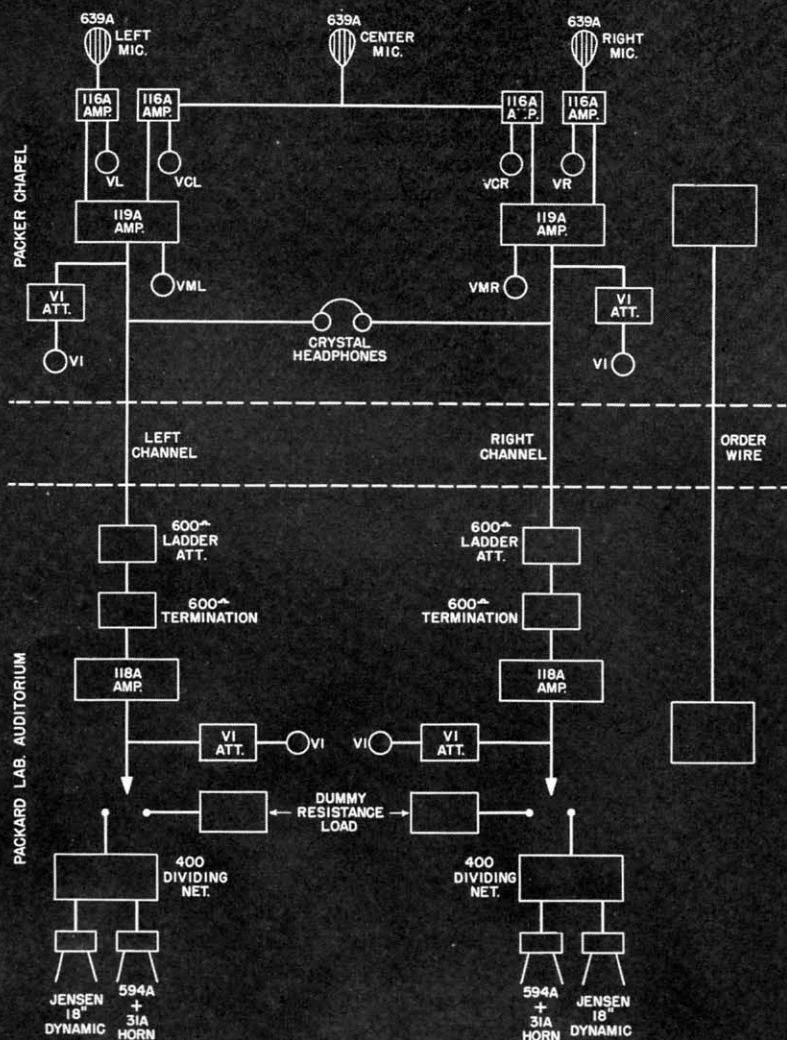


Figure 1

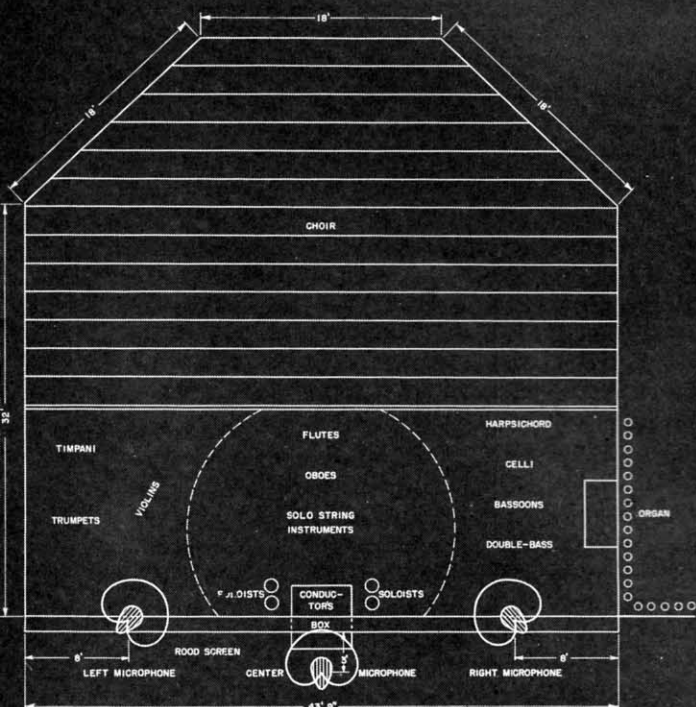


Figure 2

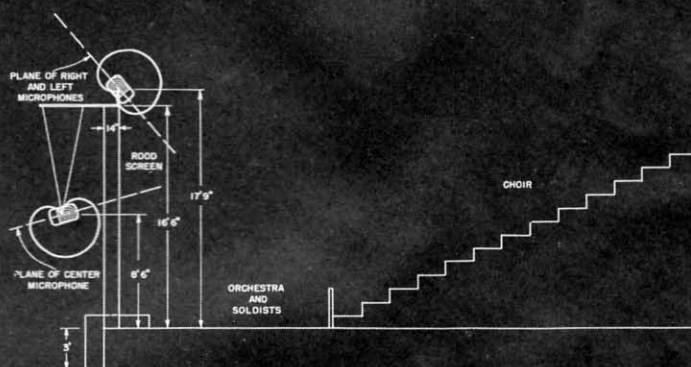


Figure 3

Bach Choir Sound System

(Continued from page 24)

panel, which for simplicity is not shown in Figure 1, houses two switches, resistance networks and an attenuator that is connected across the output of a beat frequency oscillator. When the left switch is thrown the left and right microphones are disconnected and the oscillator introduced in their place. This permits the setting of the compensation volume controls on the left and right preamplifiers and the left and right master controls so that the entire system may be balanced. The right switch performs the same function for the center microphone. With this switching arrangement, it is also a simple matter to run a frequency response curve.

For transmission lines between the two buildings, simple No. 14 weatherproof twisted pair run overhead is used. Inside the buildings all wiring is in steel conduit. Tests indicated that the noise introduced by the connecting lines is inaudible.

In Packard auditorium, the incoming lines as shown in Figure 1, pass through 600 ohm attenuator volume controls to 600 ohm terminations. The 118A power amplifiers are bridged across these terminations. The 600 ohm attenuators are ganged together on a control cabinet that also houses two volume indicators connected across the output of the amplifiers. The volume controls on the 118A amplifiers themselves are used only as compensation controls for balancing purposes. The arrangement of this equipment can be seen clearly in Figure 5.

Normally, the 118A amplifiers feed into 400 cycle dividing networks and then to the loudspeakers. Each speaker consists of two units. The low frequency unit is a Jensen 18 inch dynamic, while, the high frequency unit is a Western Electric 594A loud speaking telephone with a 31A horn. Figure 6 shows the arrangement of the speakers at the front of Packard Auditorium during the May Festival. The distance between speakers is approximately the same



Fig. 4—Henry C. Knutson (right) at controls in Packer Chapel.



Fig. 5—Volume controls on 118A amplifiers are used as compensation controls for balancing purposes.

as that between the right and left microphones in the Chapel.

A dummy load to replace the loud speakers is provided as shown in Figure 1. This permits last minute balancing and testing with oscillator tone even when the audience is present.

The order wire shown in Figure 1 is terminated at each end in an ordinary headset and carbon microphone.

One of the major problems involved was the placement of the microphones. The compact arrangement of the choir and orchestra as well as the effect of a massive oak rood screen separating the performers from the audience had to be considered. Figure 2 shows the horizontal arrangement for the Festival, of the choir and orchestra, while Figure 3 gives a vertical cross section. To add to the difficulties was the fact that at no time before the final dress rehearsal did the orchestra rehearse with the choir and soloists. For the choir alone a series of listening tests with the microphones in different positions indicated that the best reproduction was obtained with the right and left microphones in the plane of the rood screen. Ordinary microphones at this point would have resulted in the orchestra overbalancing the choir.

In Bach choral music the balance between the orchestra and the singers is critical, since both are equally important. It was hoped that the use of the cardioid pattern of the 639A microphones would give a satisfactory compromise. Bearing in mind this cardioid pattern, the left and right microphones were placed and tilted as shown in Figures 2 and 3. To the gratification of everyone concerned, the balance obtained at the dress rehearsal was so nearly perfect that no further adjustments of the microphones were necessary.

The effectiveness of these 639A microphones was strikingly demonstrated at a rehearsal of only the orchestra. It was noticed that in the repro-

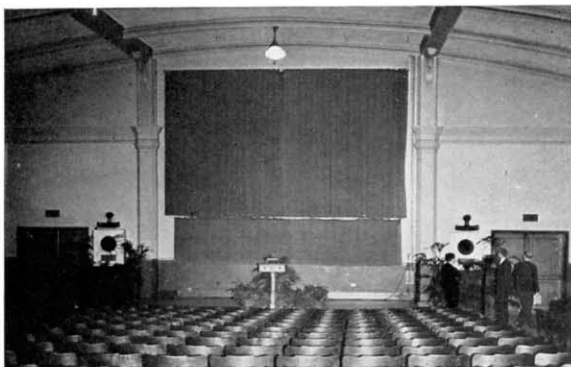


Fig. 6—Arrangement of the two loud speaker sets at the front of Packard Auditorium.

duced music the double-basses which were immediately in front of the choir seemed to predominate, while the Novachord (operated at a harpsichord) directly below the right microphone was weak. By interchanging positions, i.e. placing the double-basses almost directly below the microphone and hence, nearer to its dead zone, and moving the Novachord towards the choir, an excellent balance was established. Full use was made of the three dimensional cardioid pattern of the 639A microphone on the right side. Since this microphone was rather close to the organ it was shifted about a vertical axis until the organ was nearly in the dead zone.

The center microphone, shown in Figure 7, was used for two purposes, first to pick up and give proper emphasis to the soloists, and second, to move forward the center of the virtual stage. Steinberg and Snow* have shown that in a two channel auditory perspective system, the center of the reproduced stage recedes into the background. When they used a non-directional microphone at the center of the pickup stage and bridged this across the two channels, they found that the whole center of the stage moved into the foreground. In the Bach Festival system, the center microphone was set for the cardioid pattern and so tilted (Figure 3) that its pickup was confined mostly to the front of the stage center. Since this microphone was closer to the artists than the side microphones, the 116A amplifiers associated with it were operated at a lower level than those of the side microphones. In this way, a very satisfactory auditory perspective was obtained with only two channels.

At the controls during the actual Festival were men thoroughly familiar with the music. Professor Cyril Hoyler of Moravian College for Men, a former member of the choir, operated the controls in Packer Chapel. In Packard Auditorium, Mr. Jack Stein, who had assisted in some of the musical arrangements, acted as operator and critic. Also at each

end a man was stationed on the order wire.

Immediately before each of the four sessions, these men balanced the amplifiers as previously described and took a quick overall frequency run using the dummy resistance load. A minimum of monitoring was done during the program since the aim was to reproduce the program as faithfully as possible. In general the only adjustments made were a slight increase in level of the center microphone during solos. There was no need to compress the volume range, due to the excess output capacity available and the low noise level of the system.

One of the best indices of the audience response to the installation was the attendance at each of the four sessions. No particular advance publicity had been given out regarding the installation since it was felt that the public should be allowed to form their own opinions. As a result, the attendance at the first session was poor. It was noticed, however, that the same people returned for the succeeding sessions and in each case brought friends with them. At the last session the auditorium was completely filled. At the end of each session the most favorable comments were heard. Many of these comments were particularly interesting. Everyone seemed to agree that after the first few minutes they were completely under the illusion of the choir and orchestra being hidden behind the curtain at the front of the auditorium. Those familiar with reproducing systems attributed this to the faithfulness of the reproduction with no audible distortion as well as to the stereophonic effect.

The behavior of the audience during the programs served as another index of the success of the installation. Complete absorption in the music

(Continued on page 33)

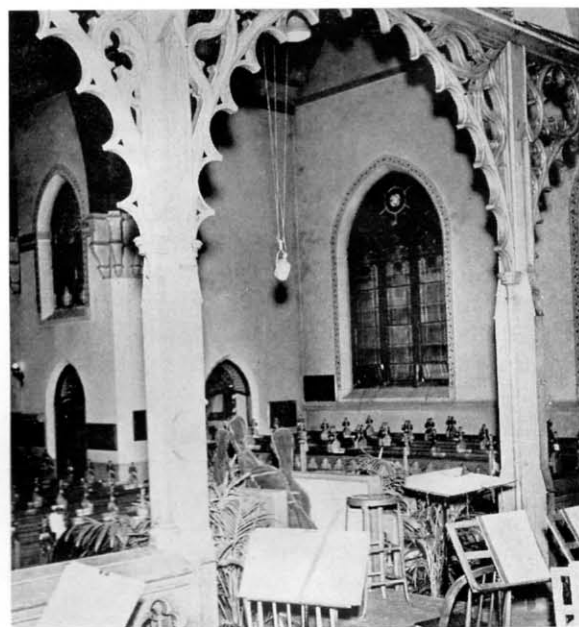


Fig. 7—Center microphone was used to pick up and give proper emphasis to the soloists as well as to move forward the center of the virtual stage.

* Physical Factors, J. C. Steinberg and W. B. Snow, Electrical Engineering, Jan. 1934; also in Bell System Technical Journal, Apr. 1934. This paper is one of a series in a Symposium on Wire Transmission of Symphonic Music and its Reproduction in Auditory Perspective.

which gradually impair the vacuum. If these tubes had been used in service as soon as received, approximately normal life probably would have been obtained. Alternate use of spare tubes in the transmitter is therefore recommended in order that tubes held as spares will always give satisfactory operation. When tubes of this type are first inserted in the sockets, the filaments should be lighted without plate voltage. In case of a crack in the glass envelope the filament will "smoke up" due to the formation of tungsten oxide.

It is recommended that the filament be operated at normal voltage for several hours to clean up any residual gas and to insure that the filament is fully activated. Tubes operated in spare transmitters should preferably be run with a filament voltage of about 80 per cent normal to obtain the maximum life from the standpoint of evaporation of active materials.

FM Tests Around New York

(Continued from page 13)

strongest pick-up came from a reflected wave.

Knowing no worse location on the Island we headed back toward town, crossing the Whitestone Bridge, to the Hutchinson River Parkway, and on up the Parkway for a distance of approximately 25 miles north of New York. On this long drive we encountered places where the signal strength momentarily dropped or the signal seemed to wobble a bit. In each case, however, it was noticed that the position of the car placed the car between the path of the signal and the antenna. It seemed reasonable to assume that the car was shielding the antenna. This effect was obtained only while driving at speeds between 50 and 60 miles per hour.

Returning to New York we passed over the lower level of the double-deck bridge across the Spuyten Duyvil. The signal from WOR was completely mixed up with car ignition noise while W2XOR continued with full strength. Back in the city we cruised under elevated railway lines, through streets lined with New York's highest buildings and filled with rush hour traffic. There was no variation whatsoever in signal strength. As I write this, the same receiver is bringing me the music of W2XOR in my home in Manhasset, Long Island, 18 miles from the transmitter. The receiver is connected to an eight foot piece of bell wire which hangs down from the second story window. The vacuum cleaner, electric razor, oil heater have absolutely no effect on it.

From this report of a test of FM, unscientific and unrehearsed as it was, you may read any significance or none at all. To us, it seemed to indicate that FM is perfectly capable of serving the entire metropolitan area of the greatest city on earth. It further indicates that the average listener may receive his FM programs irrespective of location and without an elaborate antenna array. And, also, should not our ideas about FM and car reception be changed?

WIP, Philadelphia, Pa.

(Continued from page 16)

tion from the roof of the Gimbel Building and installed a new 1,000 watt equipment at a better spot on the outskirts of Philadelphia.

In November, 1939, the FCC having granted an increase in power to 5,000 watts, the station's officials decided to build a completely new transmitter plant. After a thorough investigation the site at Belmawr was selected, a Western Electric 405B-1 transmitter was ordered and construction of the building was begun.

The entire installation was carried out under the supervision of Clifford C. Harris, WIP's technical supervisor, who also designed the new directional antenna, a two-element system with 275-foot towers surmounted by steel crowns 30 feet in diameter.

The transmitter building was designed with an eye for utility as well as beauty. A maximum of daylight floods the transmitter room through the glass brick wall which curves half-way around it. The control desk with its sloping panel directly faces the wall mounted transmitter. To the left of the desk stands a 1300A reproducer set, providing the transmitter operators with programs at their fingertips in the event of any emergency.

Additional equipment used by WIP includes a 110A program amplifier, a spare 106A amplifier, a 94C monitoring amplifier and a 1A frequency monitor. The old 6B transmitter, located in the master control room, is now used as the station's auxiliary unit.

After two months of 24 hours-a-day operation, WIP's progressive president, Benedict Gimbel, Jr., stated that everyone concerned was "highly gratified with the excellent performance of the transmitter and its ability to 'stand the gaff'."

Bach Choir Sound System

(Continued from page 27)

was apparent. The slightest disturbing movement on the part of anyone drew silencing looks from his neighbors. Many followed the music note by note from open scores. During the magnificent crescendos in the B Minor Mass the audience would sit up almost breathless and when the music suddenly dropped to the barest whisper, one could hear audible sighs. This response of the audience was particularly striking in view of the altogether too common habit today of carrying on a conversation during any reproduced program.

Judged on the basis of public acceptance, the success of the installation was most gratifying to all concerned. It was felt that the reproduction during the May Festival was in keeping with the dignity and tradition of the Bach Choir.