The Bell Labs Story Part 3

Barry Fox concludes the story

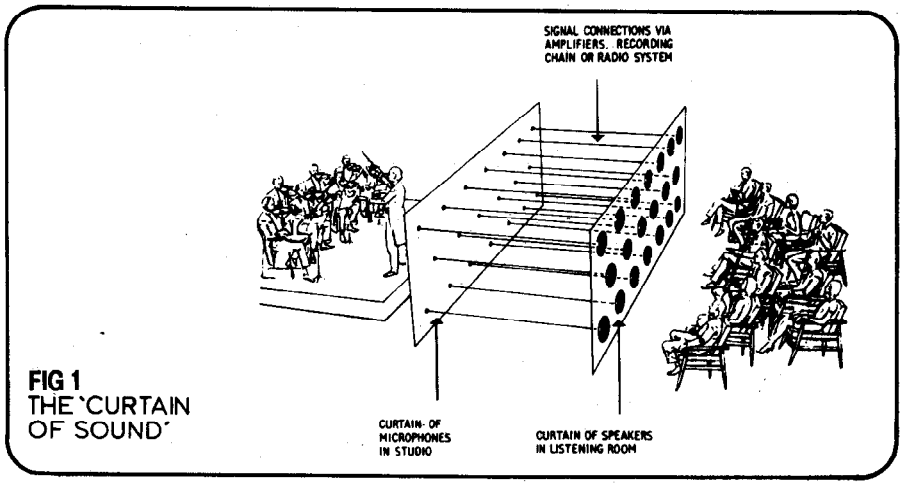


FIG 1 THE 'CURTAIN OF SOUND'

ON THE EVENING of April 27 1933, Leopold Stokowski sat at an electronic control box at the rear of Constitution Hall in Washington. Over a hundred miles away in the Academy of Music at Philadelphia, Stokowski's orchestra, led for the night by associate conductor Alexander Smallens, played a programme of music, including the Bach *Toccata and Fugue in d,* Debussy's *L'Aprés Midi d'un faune* and the Finale of *Götterdämmerung.* Harvey Fletcher, Director of Acoustical Research at Bell Labs, was present while the audience in Washington listened to the Philadelphia concert, with visual effects provided by the Yale School of Drama.

During the interval Fletcher talked to the Washington audience while workmen hammered away, sawed wood and wandered around behind the stage curtains. In fact the workmen were in Philadelphia and only loudspeakers were behind the curtains of the Washington stage. For the second half of the concert a soprano sang 'Coming through the Rye' as she walked backwards and forwards across the stage in Philadelphia. But the audience heard her moving across the stage in Constitution Hall. Then they heard a duet by two trumpet players, one on the left of the stage and the other on the right. The duet was played in the dark and it wasn't until the lights were put on again that the audience realised that only one trumpet player was there in person. The other was in Philadelphia.

This audio event, sponsored by the National Academy of Sciences, was the culmination of several years of work by the engineers at Bell Labs on sound transmission and reproduction in stereo, or with 'auditory perspective', as Fletcher then called it. The work had been carried on in parallel with the quest for improved recording quality. It was also the start of a whole series of similar demonstrations which culminated in an extraordinary performance of recorded stereo music at Carnegie Hall, New York, in April 1940.

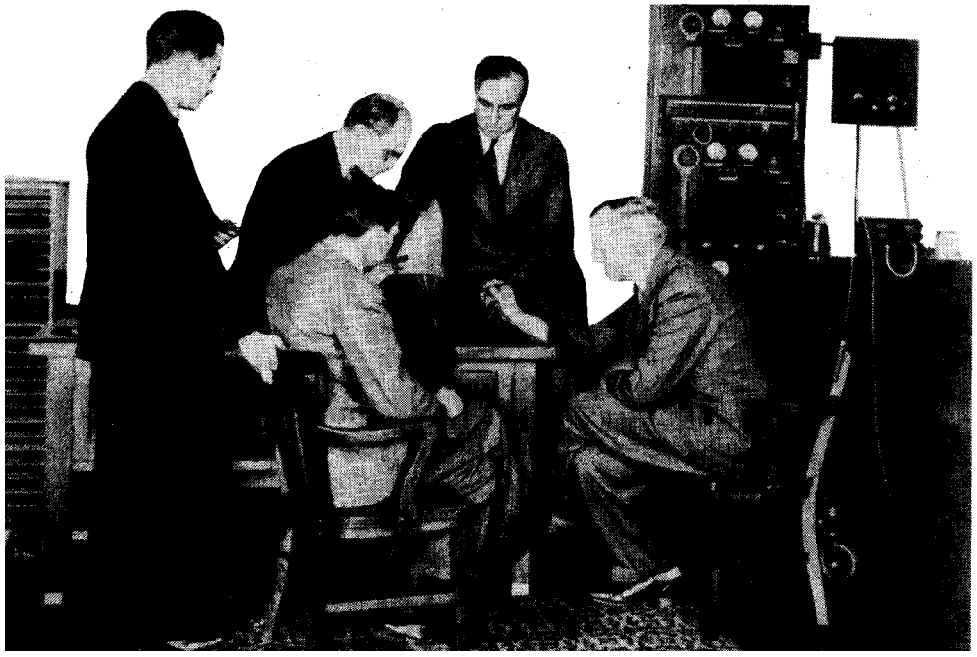
The driving force behind the decade of experiments in reproduction was Harvey Fletcher who set his research team the task of analysing the essential requirements for a practical illusion of auditory perspective or stereophonic reproduction. Fletcher postulated that to reproduce the sound and image of an orchestra accurately there should, in theory, be an infinite number of microphones and reproducers (fig. 1), each infinitesimally small. He also realised that the reproduction system should ideally have a dynamic range of around 100dB and a frequency range equal to that of the human ear. The Bell Labs research was aimed at establishing what compromises would be acceptable, and how best to achieve those requirements which proved essential. It was found that three-channel reproduction, that is to say three microphones – left, right, and centre – feeding three loudspeakers through three channel connections, was an acceptable compromise. Trimming the frequency range to 40Hz-15kHz also produced no detectable difference in the reproduction of symphonic music. But even though an orchestra uses a dynamic range of only 70dB when it plays in a concert hall, a wider dynamic range is needed: Fletcher's team aimed at 75dB.

In the early '30s these requirements necessitated a complete rethink of the reproduction chain. For the Philadelpia-Washington experiment a four-channel telephone-line link was provided between cities, the fourth channel being held in reserve as a spare. All the lines required vast racks of amplifiers and equalizers to maintain a flat frequency response without noise. In fact, the frequency band was artificially raised for transmission, from 40Hz - 15kHz, to 25kHz - 40kHz. This minimized the risk of crosstalk and noise breaking through from other 'phone circuits. Normally the underground telephone line between Philadelphia and Washington (fig. 2) required only two intermediate repeater, or amplifier, stages, one at Elkton and one at Baltimore. But for the audio signals, additional repeaters were wired in at three other points along the way. The carrier system, used to carry the signals at artificially high frequencies, used a single sideband, suppressed carrier technique. This saved frequency space and minimized the load requirements, but it did mean that synchronized pilot signals were necessary to maintain phase coherence. Although the signal passed through 150 miles of cables, repeaters and equalizers, it emerged flat to within ±1dB.

As shown in the floor plan of the Philadelphia auditorium and stage (fig. 3) three microphones were spaced out between the conductor and orchestra. In addition to these three microphones, a fourth was provided to pick up the voice of a soloist. When this microphone was used only the two side channels were employed for the orchestra, the voice being transmitted and reproduced over the centre channel.

At Constitution Hall in Washington, which has a volume of nearly one million cubic feet and a seating capacity of 4,000, the loudspeakers were set out on the stage as shown in fig 4. Immense care was taken on calibration of the system. Horn loudspeakers were used because of the considerable amount of acoustic power that had to be radiated. The system for each channel was constructed as a double unit, one for high and one for low frequencies, with a crossover point around 300Hz. The low frequency horn had a mouth opening of around 25 square feet. To distribute the high frequency sound evenly, two HF horns, each with a horizontal distribution area pattern of around 60°, were used to provide a coverage of 120° horizontally, and 60° vertically. To achieve

The Bell Labs team, ca 1930, discussing wax disc recording. Clockwise, from left: P.B. Flanders, J.P. Maxfield, A.C. Keller, H.C. Harrison, D.G. Blattner



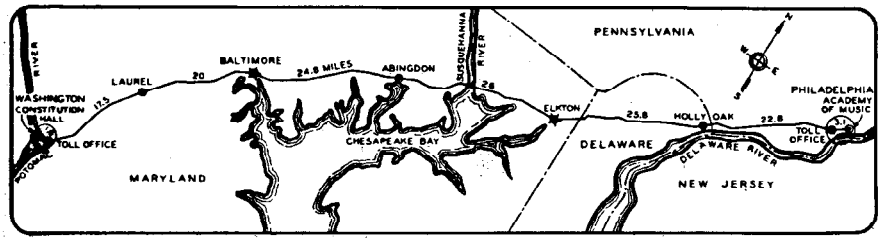


Fig 2 *Geographical layout of 3-circuit communication line used to carry Philadelphia symphony music to Washington, D.C., for reproduction in auditory perspective.*

this wide spread, the mouth of each HF horn was sub-divided into 16 diverging rectangular sections. The valve amplifiers used several stages of voltage amplification prior to the final power stage and two amplifiers were used in parallel for each channel to provide a total of 120 watts (RMS) for each loudspeaker system. The total power fed to the horns could thus equal 720 watts on peaks.

Floyd Harvey was working as an assistant to Fletcher at the time. He recalls: 'Of course there was a lot of preparation before that, two or three years at least. And many experiments were performed right in the auditorium at the Academy of Music with a transmission line up to the foyer where the musicians practised. They set up loudspeakers similar to what would be in Constitution Hall. So the engineers could listen in their own area to what was happening, they could practically open a door in the foyer and look out into the auditorium.'

Those who attended the concert performance thought the sound was highly impressive. This was doubtless partly because the reproduction system in Washington could add another 10dB to the level of the live sound in Philadelphia, equivalent to making the Philadelphia Orchestra ten times as big as it actually was. It is easy to see why Stokowski, with his fascination for novelty and technology, was so interested, and prepared to spend so much time on the tests. As a spokesman for Bell Labs put it at the time: 'The number of musicians one can put on a stage is limited. To put ten times as many as contained in a modern symphony orchestra is impossible in any existing hall. The control of volume given by the new apparatus enables the director to secure at will the equivalent of an orchestra of nearly 1,000 musicians. The advantage of this control of volume does not end here, however. Its presence makes it possible to reproduce operatic music, where the soloist is accompanied by an orchestra, without allowing the voice of the singer to be drowned out by the louder passages. For this purpose a third channel, including separate microphone, transmission line and loudspeaker, has been provided in the new system primarily for the singer'.

Anyone who thinks the 'artificial' sound of multitrack recording is a modern phenomenon should think again. That Bell Labs comment dates back to May 1933! As Bell also pointed out at the time: 'Our job has been to produce a set of tools. The musicians and musical directors, and back of them the musical composers, must determine just how these tools can best be used and what they can best produce . . . In a word, its field of applicability is where a large number of people might congregate for the common enjoyment of music of distinction.'

Soon after, in 1935, the same system was used to reinforce the sound of an orchestra playing at the open air Hollywood Bowl in California. It was a one night demonstration but almost certainly put the idea of larger-than-life stereophonic sound into the mind of many a movie mogul who attended.

Floyd Harvey explains: 'The Bowl is a concrete reflector that's hemispherical. They surrounded this reflecting hemisphere with a platform that contained left loudspeakers, central loudspeakers and right loudspeakers. And they had microphones left, right and centre in front of the orchestra. The sound was so loud that the people a block away could hear it'.

Fletcher continued with his work on multi-channel reproduction and devised a clever way of learning more about human hearing. In the late '30s Bell Labs exhibited at the World's Fairs in San Francisco and in New York City. Each visitor to the Bell Labs stand was offered the opportunity to have a hearing test. In this way Bell Labs built up records of the hearing of more than half a million people. Fletcher also looked for a way of recording the kind of artificial sound which he had transmitted between Philadelphia and Washington, and used to reinforce the natural sound of an orchestra playing in the Hollywood Bowl. Disc recording technology couldn't cope with the problem and it was too early for tape recorders. So Fletcher turned his attention to the optical soundtrack of a film. Bell Labs of course already had plenty of experience in this area.

The maximum dynamic range of an optical film track at that time was around 50dB and Fletcher needed 80dB. To get the extra 30dB he used a compression technique which was in some respects similar to the modern dbx system. But whereas dbx continually monitors the RMS level of the signal on playback, and adjusts the expander accordingly, the Fletcher system used a control track. This operated the replay expander in perfect mirror-image synchronism with the compressor used at the recording stage. A pilot track, carrying information about the required gain adjustment in the reproduction system, was recorded in parallel with the main signal track. This gave Fletcher the dynamic range he needed. Because optical film is, in fact, a very linear medium (unless driven into clipping) the rest was relatively easy. (Indeed this helps explain why the Dolby optical stereo sound system is now finding so much favour in the commercial cinema: used sensibly, optical sound recording is an ideal recording medium.)

Blumlein's problem, when he split a standard mono optical track in two to produce stereo in the mid '30s, was that the output level went down and the noise floor came up to limit the dynamic range. Both Bell Labs in the late '30s, and Dolby today, have cracked the noise problem with a compansion system – albeit operating on different working principles. And because he had no need to record pictures as well as sound, Fletcher could use the whole width of a 35mm film to record four tracks; three for the Left, Centre and Right channels and the fourth for the pilot control track (fig 5). In March 1940

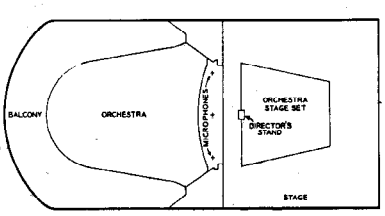


Fig 3 *Floor plan of Academy of Music, showing location of microphones.*

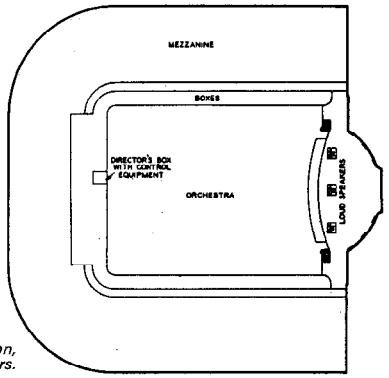


Fig 4 *Floor plan of Constitution Hall, Washington, D.C., showing locations of loudspeakers.*

Leopold Stokowski (l) and Harvey Fletcher (r) at the controls in Constitution Hall, Washington

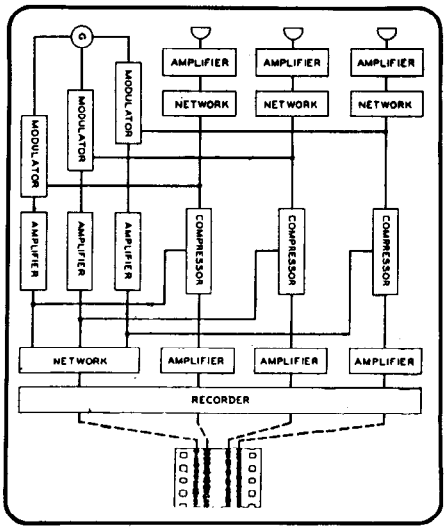


Fig 5 *Schematic diagram of stereophonic recording circuits.*

Bell Labs recorded the Mormon Tabernacle Choir for Carnegie Hall playback recitals on April 9th and 10th. Floyd Harvey believes the Choir was recorded twice: 'they recorded on the stage and this was replayed up in the foyer. Then it was re-recorded on film as Stokowski was listening to it. He raised the levels where he wanted so that when the Elijah Shout came on, it was really quite something. It was one of those times when he wanted 100 musicians to sound like a thousand. In the programme they told people who had a heart condition to leave the auditorium if they were afraid of a shock that would leave them faint.

'On April 8th and 9th in Carnegie Hall there were dress rehearsals and the first actual performance was on the 9th. Of course, in the papers the next day the purist critics were saying they blew out the back of the auditorium at Carnegie Hall it was so loud. Some of them weren't impressed with what Stokowski was trying to do.

'I think he had a lighting system to provide some sort of eye attraction, something to work on besides just listening to music. But memories fade. I still recall that Elijah Shout, though. It was something that just made your heart stop, it was so terrific and so terrifying to hear. A hundred choristers sounding like a thousand'. The *New York Times* reported on how soundwaves had 'rocked' Carnegie Hall and produced 'tones near the limit of what the human ear can endure'. At the Carnegie Hall concert and others that followed, Stokowski sat at the controls to make the orchestra sound as loud or as quiet as he liked. Unfortunately 'Stokey' as he was known, often got carried away and blew out the 18ins. woofer cones in search of larger than life sound from his music. So the Bell engineers had to build a dual control system, like a dual control car for driving lessons. Stokey sat at one control while an engineer, with over-ride faders, sat in the other to prevent disasters. 'The loudest sounds ever created crashed and echoed through venerable Carnegie Hall last night as a specially invited audience listened, spellbound, and at times not a little terrified,'reported the *New York Times.* Amongst the specially invited audience were the Governor of New Jersey, the Rockefeller family, Arturo Toscanini, Sergei Rachmaninov, and the same Will Hays who had been filmed, on the Vitaphone system, speaking an introduction to the *Don Juan* film which started the whole extraordinary audio ball rolling.

In May 1941 there was a joint meeting of the Acoustical Society and the Society of Motion Picture Engineers in Rochester. The system was demonstrated again but in another way. A live ensemble had been previously recorded and an A/B comparison between live and recorded sound was carried out. Music students listened and then voted for which was which. Floyd Harvey remembers that, 'It came out about 50:50, and those who could tell the difference might have been listening to the snaps and pops from electrical reproduction.'

The system was used for the last time at an in-house demonstration by Bell Labs in 1947. But Walt Disney had seen it in Hollywood in June 1940 and was obviously impressed. He had been working in a similar direction. The result was *Fantasia.* As anyone who's seen the fim will know, the music was also recorded by Leopold Stokowski, with the Philadelphia Symphony Orchestra. But for *Fantasia* Stokowski was working with the Walt Disney Studios and RCA, who had built their own system for reproducing a wide dynamic range of full frequency range music in stereo. The Disney-RCA system used optical tracks, similar to those used by Bell, but the original recording was spread over eight channels, with a ninth channel used to record a metronome for synchronizing the animation. The music was recorded in Philadelphia and six channels were used to record separated signals from the violins, celli and basses, violas, brass, woodwinds and tympani. The seventh channel recorded a mix of the other six and the eighth channel was an ambient distant pick-up of the whole orchestra. At the re-recording stage in Hollywood, the eight music tracks were mixed down into three audio tracks, left, centre and right, with a fourth track used to carry a pilot tone. This served the same purpose as the pilot tone track in the Bell system; it controlled the gain of an expander in the reproduction equipment to improve the dynamic range by about 20dB.

The Disney studios originally intended to screen *Fantasia* at major cinemas which had been especially equipped for the event with multi-channel reproduction equipment. In addition to the three speaker banks behind the screen, additional speakers were to be arranged around the theatre to produce a surround-sound effect for some sequences. This effect was controlled by notches cut into the film edge. To accommodate the four tracks (three audio, and one control tone) the released prints of *Fantasia* came on two separate lengths of film, one for the picture images and one for the sound. So two projectors had to be used in synchronisation. The Disney plan was to use 60 loudspeakers for a full scale presentation of *Fantasia.* The whole circus needed 35 packing cases to transport it across America.

But war came after just a few shows and no one had time for extravagances like that any more. The versions of *Fantasia* which you see today are projected from conventional, single rolls of 35mm film, with the original soundtrack transferred to modern magnetic or optical format. Quality is probably not representative of what audiences of the '40s would have heard, had Japan not hit Pearl Harbour, because the release prints in use today had to be pieced together from non-too-perfect relics from the '40s.

Unfortunately the Bell Labs film tracks are missing. According to Floyd Harvey: 'I have been searching for them. When Fletcher retired he went to Columbia University and took a lot of the film stuff with him. The equipment has just disappeared through the years. Some of it was used for special experiments but it was never put together in the way it was meant to in the '40s. There was some equipment sent out to Hollywood and I have never been able to find it. It may have gotten more sophisticated and improved, but as far as I know it's never been located'.

This neatly underlines how fortunate we are that Bell Labs have preserved at least the majority of those early 1930 test disc recordings of Stokowski. We are also fortunate that Bell Labs today who are, after all, really nothing more than the American equivalent of the British Post Office, gave Arthur Keller a free hand to do everything possible to transfer those '30s recordings onto modern LP format. Because the originals exist as gold-sputtered masters, which are unlikely to have deteriorated in storage, the product of Keller's work comes as close as can ever be possible to freezing in time the sound of Stokowski's handling of an orchestra 50 years ago.

The only regret is that Bell Labs did not have, and probably never can have, copyright clearance to release the discs for commercial sale. But such strictures are unlikely to affect EMI. Whereas Bell Labs is a telephone company, EMI is a record company. January 19, 1984, marks the 50th anniversary of Alan Blumlein's stereo test recordings of Sir Thomas Beecham at Abbey Road. That's less than two years from now. But there's still time for action: can we expect a commercial release from EMI to commemorate this landmark of audio history?●

SUBJECTIVE SOUNDS

exotic — and the room — have their own unique characteristics, and the onus is on the dealer and purchaser to select models wisely. Incompatibility as such, in the traditional meaning of the term, is very rare these days — units connected together at random are most unlikely to auto-destruct or interfere appallingly. But particularly when spending a great deal of money on a system it is important to mix units thoughtfully in terms of tonal balance and dynamic characteristics to take full advantage of the degree of subtlety for which you are paying. I know instances where the Linn 'front-end' works fine with the Quad ESL-63: it depends on the characteristics of the room, the siting of the speakers (stands etc) and the choice of amplifier. But there are instances where such a combination would be infelicitous, and a change of cartridge (Dynavector Karat or ADC MC1.5 perhaps?) might be worthwhile.

If I return to this general topic which I have christened 'supercompatibility' too often, it is because I think that it is the most important aspect of hi-fi today. For the commentator, the difficulty is that any product information is often very specific and may be of little general interest, while attempts to extrapolate general rules are fraught with difficulty. A question that I am frequently asked, but deftly sidestep, is 'which is the best cartridge?'. There is no definitive answer. I know why I (bought and) use an Asak T: I can live with its limitations (nearly all the time), and it suits the rest of my system. But I probably wouldn't try to use it in any other arm. I haven't tried all the combinations, of course, but a Supex 900 does sound better in a Rega, for example.) Likewise, many preamps (particularly integrated models with hastily added moving-coil cartridge booster inputs) are happiest working with a moving-magnet cartridge, with its more restricted output bandwidth●