When I Think Back...

by Neville Williams

PA systems 1: a belated spin-off from wireless/radio technology

One might be excused for concluding that public address or 'PA' amplifiers have always been with us—or certainly for as long as wireless/radio itself. In fact, public broadcasting had been established for 15-odd years before PA systems became part of the everyday scene. In this article and two that will follow, we trace their evolution from humble beginnings to the acoustic monsters that are used at modern-day functions.

As established in the 1920's, the basic role of *'wireless'* broadcasting was to distribute speech and music from centralised transmitting stations to individual receivers, without having to rely on wires (landlines). At the receiving end, the programs were reproduced on headphones or modest loudspeakers, the obvious requirements being that the recovered sound be loud enough for comfortable listening in the home and as free as possible from sonic distortion and spurious noise.

Beyond these basic objectives, designers tended to concentrate on developing receivers which were reliable and simpler to control, which offered access to an adequate number of broadcasting stations and which were economical in terms of price and battery drain.

Science writers certainly speculated about future developments — even to distributing electric power by wireless — but manufacturers, engineers and technicians in the 1920's had their work cut out in coping with the technicalities of ordinary broadcasting.

For the sound to be heard comfortably on headphones in an average home, the audio chive power required from the receiver did not need to be more than a few milliwatts (thousandths of a watt), or 150-odd milliwatts for a loudspeaker.

Most valves, loudspeakers and other receiver components of the day were designed to satisfy these basic requirements, and it was left to the visionaries to dream about 'wireless' equipment that might, one day, be powerful enough to provide speech and music for public gatherings, as distinct from a home.

An orchestra could indeed flood an auditorium with generous sound, as also could a band or a pipe organ. But the most effective vocalists, actors, elecutionists, preachers and politicians were those with powerful voices — who, unaided, could make themselves heard in such an environment! Indeed, many such regarded the ability to do so as one of their innate skills and did not take kindly to the idea of electrical sound amplification.

`Once upon a time'

In a recent documentary about vaudeville on ABC TV, veteran entertainers Ron Shand and Ernie Bourke recalled the introduction of an amplifier system to Sydney's once popular Tivoli theatre — presumably in the late 1920's, when vaudeville was fighting a losing battle with the then-new sound films. As amplifiers go, that first Tivoli installation would appear to have been quite basic — well before the days of multiple microphones and audio mixing panels.

Dating in Australia from about 1902, vaudeville had developed a tradition of spontaneity in the presentation of 10 or so variety acts, with participants timing their entrances to musical interludes from the band, appearing on stage from wherever and addressing the audience as they did so.

With the Tivoli's first PA system, a lone microphone would be pushed up by a stagehand through a mini-trapdoor at front centre stage, and performers were expected to make their entrance and position themselves in front of it before

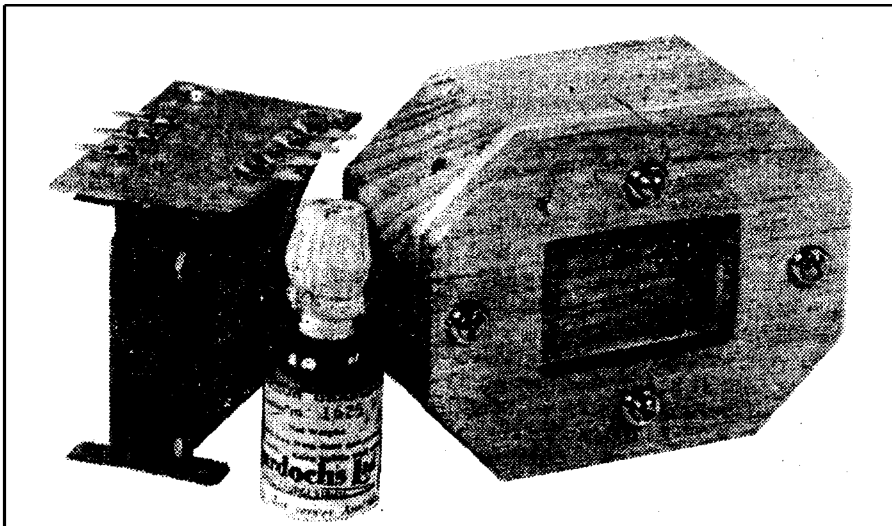

Fig.1: Advertised in the October 1939 issue of 'Radio & Hobbles, a kit which once enabled hobbyists to assemble their own transverse current (Reiss) carbon microphone.

Fig.2: An Australian-made D104 crystal microphone, distributed by ETC industries and featured In the August 1941 issue of `Radio & Hobbies. It was said to have been specially designed to resist the effects of humidity.

saying a word. Failure to do so was to invite a curt memo from management.

The performers hated it, they said, because it cramped their style. Sprouting from the stage floor like some mechanical weed, the microphone created its own diversion, particularly when the actor overshot the mark in the glare of the stage lights and the microphone collided with their posterior!

Everyone concerned clearly had a lot to learn about sound amplification. Designers had yet to come up with equipment that met the requirements for stage production. Performers, in turn, had to work out how best to use a microphone to enhance their presentation.

Watts, not milliwatts

As already indicated, receiver technology in the early 1920's was inadequate for sound reinforcement because the sound level it could deliver was less than that of a performer's own voice and way below the level from an orchestra, band or pipe organ.

In addition, available loudspeakers produced a 'tinny' sound, tolerated for wireless reception by reason of its novelty but unacceptable at a live performance.

Sound reinforcement became a viable proposition only when mains type power supplies justified the development of high-voltage, high-current valves and techniques offering power output levels of five watts or more. About the same time, horn-type and moving-armature cone loudspeakers gave place to moving-coil ('dynamic') types, capable of greater sound level and with a more natural tonal balance.

Indeed, by the early 1930's, receiver technology had reached a point where it was possible to assemble a practical amplifier from catalog components — sufficient to be heard throughout a modest auditorium.

Oh for a mic!

In terms of sound reinforcement, however, one major impediment remained: the provision of an acceptable microphone — one that offered reasonable tonal balance with speech and music, free from obvious distortion and background noise.

High quality microphones were available to professional users such as broadcast stations and recording studios, but at a price that largely precluded their use in physically exposed, low-budget applications. (High quality professional `condenser' mics will be discussed in parts 2 and 3.)

In practice, the lack of suitable microphones proved a hindrance to the widespread use of public address amplifiers until at least the mid 1930's. Indicative of the fact is that, in the February 1940 issue of *R&H* (p.43), Editor John Moyle heralded the appearance of public address equipment at indoor and outdoor gatherings as 'one of the most important phases of radio... over the last year or two'!

Of necessity, in the early 1930's, most experimenters and amateur radio operators had to settle for 'single-button' telephone type carbon inserts, which were suitable only for basic speech communication.

So-called 'transverse current' or 'Reiss' carbon microphones were much better and were even used by some broadcast stations, for non-critical applications, into the early 1930's. In 1939, Murdoch's of Sydney were still offering a complete kit for a home-built version for 29/6d ($3.00), as shown in Fig.1

It comprised a machined block of solid teak, with *a* rectangle about 5mm deep routed into one face. Metal strips (ideally gold plated) had to be secured at each end to the internal face of the recess, with contact studs *passing* through the wooden block to two terminals at the rear of the assembly.

With the microphone on its back, the rectangular recess had to be partially filled with fine carbon granules (supplied), after which it was overlaid with a thin mica diaphragm, secured by a faceplate and protected by a spacer and grille. When the fully assembled microphone was turned right way up, the granules would typically occupy the lower three-quarters of the recess.

In use, the microphone would be connected by means of a two-wire cable into a series circuit involving one or more dry cells and the primary of a step-up transformer. Current would flow through the circuit, depending on the applied voltage and the resistance of the carbon path bridging the two metal strips.

Sound-pressure waves impinging on the mica diaphragm would alternatively increase and diminish the pressure on the entrapped carbon granules, varying their instantaneous resistance. The changing current would induce a corresponding audio voltage across the transformer windings, thereby providing an audio signal for the associated amplifier.

Shortcomings...

I was one of the many enthusiasts, in those days, who built up a transverse current microphone. It worked — but it also shared the practical problems which limited the utility of the species:

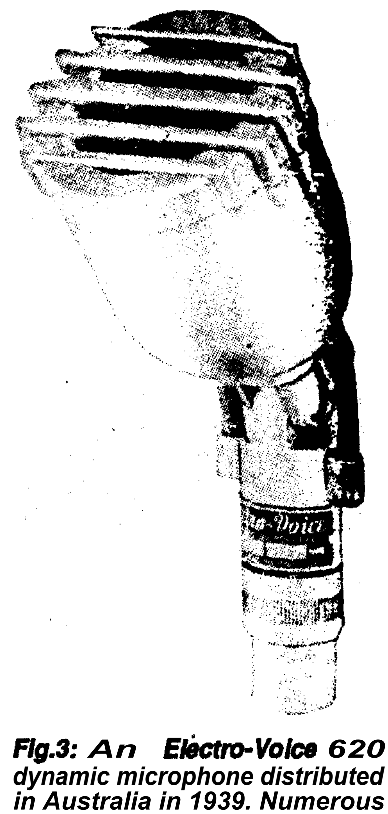

Fig.3: An Electro-Voice 620 dynamic microphone distributed in Australia in 1939. Numerous modem dynamics are currently available from electronic component suppliers In the range $10 - 100, depending on specifications.

1. The standing current through the granules generated a background hiss ('frying'), which required that the mic be used close-up to ensure an acceptable signal/noise ratio;
2. The variation in the resistance of the granules as the diaphragm moved in and out was not linear, resulting in harmonic distortion;
3. Physical movement of the microphone as a whole could generate a noise signal, such that it was normally spring mounted inside a support ring atop a firm stand. Reiss mics could not readily be hand-held;
4. While of little consequence in a radio studio, the bulk of such a microphone in front of a performer's face posed a problem in live audience situations.

Not surprisingly, considering the limitations of carbon types, the emergence of `crystal' microphones in the late 1930's sparked a great deal of interest, especially when they were developed and marketed as inexpensive capsules or 'inserts'.

Crystal mics

Using much the same basic principle as a crystal pickup, incoming sound waves would cause slight movement of a diaphragm, which would be transferred to a thin wafer of crystalline Rochelle salt (sodium potassion tartrate). Due to the so-called 'piezoelectric' effect, sonic vibration of the wafer would cause a corresponding small audio voltage to appear between its opposite faces, thereby providing the requisite output signal. (In so-called 'sound cell' crystal mics, the sound waves impinged directly on one or more wafers. They offered a smoother frequency response and lower distortion, but at the expense of output signal level).

Crystal microphones could be made relatively small and light, required no energising battery, generated no background hiss and were largely free from handling noise.

They exhibited a high capacitive impedance, however, and normally had to be used with a shielded cable no longer than about three to four metres. For longer cable runs, a 'buffer preamplifier was normally required. The Rochelle salt crystal wafer also proved vulnerable to high levels of ambient temperature and humidity.

For these and other reasons, crystal microphones gravitated mainly to a speech/utility role, being widely used with amateur and other communication transmitters, paging systems, streetside 'spruiking' amplifiers and PA systems at sporting events — applications where they could normally be connected to the companion amplifier via a suitably short cable.

(Modem 'ceramic' mics are similar in principle to crystal types, but use a wafer of barium titanate ceramic and are unaffected by heat and humidity. They can also be fitted with a transistor buffer stage, to allow *use* of longer cables.)

Possibly the best known of the original crystal types was the American designed Astatic type D104, illustrated in Fig.2.

Like other Rochelle salt crystal devices, it didn't take too kindly to extremes of heat and humidity but it was otherwise robust and reliable. Tending to favour voice frequencies (500 - 4000Hz), it ensured crisp if somewhat 'metallic' speech but was unflattering to music.

Mic for all uses

As it happened, 'dynamic' microphones emerged about the same time, as a further option. As implied by the name, they used the same basic principle as a (permanent magnet) dynamic or moving coil loudspeaker, but in reverse: incoming sound waves impinging on the cone caused equivalent movement of the voice coil in the magnetic gap, generating a corresponding audio voltage across the coil.

From such a low impedance source, the signal could readily be fed through a long, shielded cable to the input circuit of a distant amplifier, directly or through a voltage step-up transformer.

Actually in the early 1930s, it was not unusual for enthusiasts to use small loudspeakers as makeshift microphones, even to the extent of mounting them between conical perforated metal shells to help them look the part. Unfortunately, at a time when even a 'small' loudspeaker could be four or more inches (10mm) in diameter, a dynamic microphone contrived in this way could be just as cumbersome as a transverse current carbon type. True, it would be free of background hiss but, due to the *mass* and stiffness of the motional system, its overall performance as a microphone was normally mediocre.

In the quest for good all-round performance, purpose-built dynamic microphones used a more compact mag-

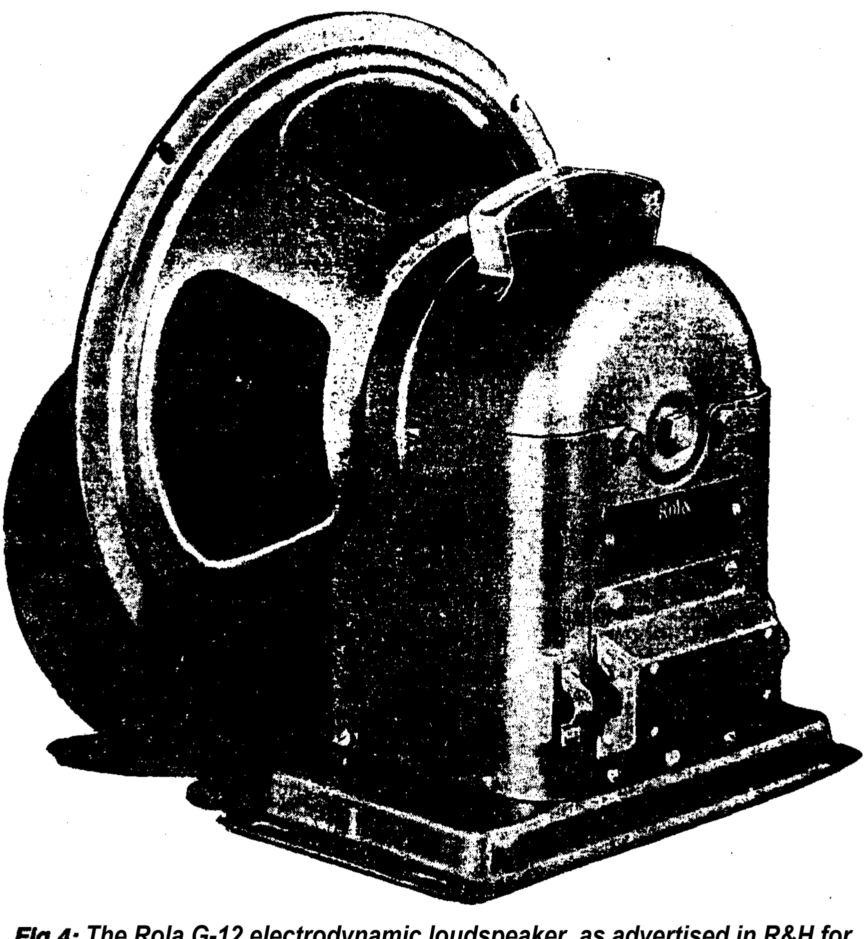

***Fig.4:** The Rola G-12 electrodynamic loudspeaker, as advertised in R&H for March, 1942 'For Public Address. The retail price was quoted as £9 ($18) — which represented a much larger outlay than it sounds today!*

net structure, coil and suspension system and a very light cone, protected by a rugged housing. By coincidence, the same page in the October 1939 issue of *R&H* which featured the transverse current carbon mic shown in Fig.1 also carried an announcement of the Electro-Voice 620 dynamic **mic,** as available from Amplion Australia (Fig.3).

It was said to offer a frequency response of 40 - 10,000Hz, with a slightly rising characteristic. It could be used as a directional mic by pointing it at the source, or for non- directional pickup by pointing it vertically upward.

A miniature step-up transformer could be housed in the rear of the case, such that the 620 could be supplied at 50, 200 or 500 ohms for cable working, or with `high impedance' output for direct connection to an amplifier input.

At the advertised price of £12 ($24) the E-V 260 was almost four times the price of Murdoch's transverse current carbon mic kit. But it signified the future rather than the past and would have been acceptable, in its day, for speech, stage and concert use. It and others like it, such as the Astatic dynamic DN-50, would certainly have been compatible with public address amplifiers, large and small.

(`Ribbon' microphones, essentially a variant of the 'dynamic' concept, were also available in the 1930's for professional and advanced hobby use. They offered good quality in a controlled environment, but generated relatively low signal output and were potentially vulnerable to wind outdoors, speech `puffing', etc.)

Loudspeakers for PA

If microphones had to emerge to meet the basic needs of public address, so also did loudspeaker driver and enclosure configurations. An endless array of new dynamic drivers was being released for 1930's-style mains powered receivers, and PA enthusiasts were quick to recognise models with a reputation for ruggedness and reliability.

High performance models by American firms Jensen and Magnavox were especially favoured, and Rola Australia also .made a bid for the prestige market with their very successful G-12 (Fig.4).

In domestic radio receivers, drivers were normally mounted on a flat baffle in furniture style cabinets — the larger the better!

In churches or other venues, where decor was important, drivers for public address systems were commonly housed in suitably finished rectangular enclosures fixed to walls and facing out over the audience.

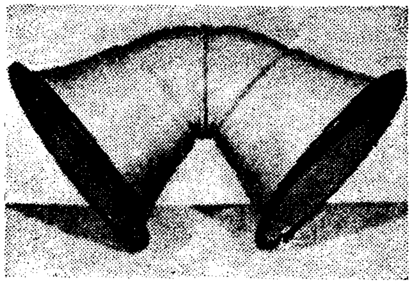

Fig.5: A decidedly 'odd' double-flare loudspeaker Illustrated In R&H for October 1939. Announced by University Laboratories, New Yolk, It featured rubber rings around the flare edges, supposedly 'to reduce resonance effects'.

Contrived and installed, in many cases, by a willing handyman, early PA enclosures were frequently too small for the chosen driver — producing a rather `boxy' sound, with little true bass. They were not very directional and the reproduced sound could be further compromised by building echoes and howling due to acoustic feedback into the microphone(s).

For outdoor or temporary installations, drivers were often fined with a commercially-made spun aluminium flare 40-50cm long, and directed towards the audience. The rear of the driver would normally be enclosed in a matching metal shell, with or without internal padding (see also Fig.5). Flared drivers certainly looked 'professional' and directional, but how effective they were acoustically and how well they limited feedback by diverting sound from the microphone is open to question. They also limited the deep bass response, much like a too-small enclosure, to the detriment of the overall quality.

Horns and columns

The ultimate horn loudspeaker for public address was/is the so-called `exponential' type — a description reflecting their mathematical derivation, dating back to the days of Edison and the acoustic phonograph.

Expanding from a diameter of a few centimetres at the throat to over a half-metre at the mouth, over a distance of a metre or more, straight exponential horns were/are notable for high directivity and acoustic efficiency. A cluster of exponential horns in the centre of a sports arena can readily cover grandstands and/or a large audience spread around the perimeter, and with a relatively modest amount of audio drive power.

Because of their unwieldy shape, however, and the restricted bass-end response of designs with practical dimensions, true exponential horns have been limited mainly to speech coverage of outdoor events — principally the domain of companies specialising in large-scale public address.

(In the case of folded or re-entrant horns, the overall **bulk** is reduced by folding the horn back within itself. They tend to be less awkward, but also less efficient).

After decades of horns atop Edison phonographs, old-time wireless sets and PA vans, it is perhaps not surprising that a degree of horn 'culture' should be evident in the design of loudspeaker enclosures generally. It was/is evident in the huge full-range systems that are often **con-**

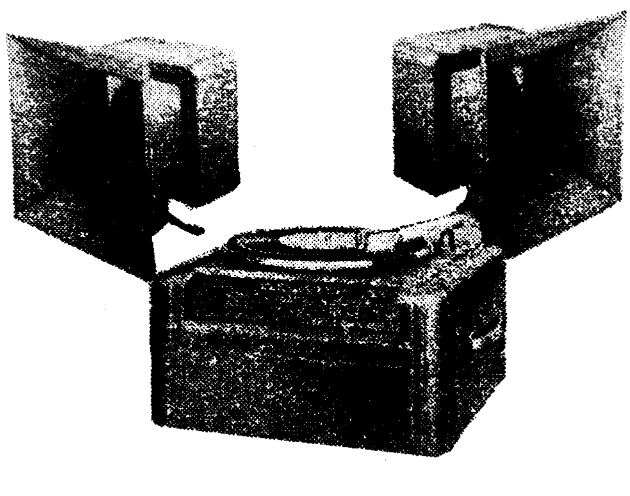

Fig.6: From R&H for September 1939, one of a series of Webster-Chicago PA amplifiers distributed in Australia by international Radio Pty Ltd. Power outputs ranged from 8 - 60W. The loudspeakers used 12-inch (30cm) drivers in small wooden cabinets with frontal flares.

cealed behind cinema screens, in complex horn-based domestic hifi enclosures and in the short wooden flares on PA cabinets in churches, etc. (Fig.6)

Only after World War II was horn cult* displaced by a quite different and more practical approach — that of sound column enclosures. This involves mounting several loudspeakers on a baffle or in an enclosure, one above the other, operating in phase. A popular choice is four drivers, with their voice coils wired in series-parallel to present the same impedance as a single driver.

The radiation pattern of such a group is a flat, horizontal fan shape, which can be directed out over the heads of the audience, but extending across the whole frontal area. Sound from a suitably elevated column passes above the front rows, so that the close-up audience is not subjected to an excessive sound level. Those towards the back, however, benefit from the full sonic beam.

As a further bonus, the fan-shaped pattern reduces sound level below the beam, easing the microphone feedback problem. Again, by also minimising the sound level in the ceiling area, echoes in lofty buildings can be reduced.

A slim enclosure for several small vertically-aligned drivers can also be less intrusive, visually, than a chunky box housing one large driver — so that, in practice, more favourable bass loading can be achieved. These days, sound columns range from slim enclosures in churches to huge vertical 'walls of sound' at outdoor rock concerts.

Why church PA?

Churches? Why the frequent mention in do-it-tourself magazines of early PA systems in churches? I can suggest at least three good reasons:

1. Not many people in the average church are trained in public speaking. When called upon to participate, they tend to speak at a conversational level — which may not be loud enough for parishioners on the wrong side of 60. Answer: install an amplifier to bring the level up to what it would be if everyone chose to speak up!
2. Most churches include or know somebody who can organise and maintain a modest amplifier system for an affordable figure.
3. The 'somebodies' envisaged above are likely to be readers of magazines like *EA*, and it has therefore been logical for *EA* over the years to provide information at their level of involvement.

Similar considerations apply to many other community groups and venues. Perhaps I should add that an amplifier does not always solve their problems. Discomforted by the sound of their own voice, many folk intuitively speak more softly or back away from the mic, despite requests to the contrary. In other cases, the problem turns out to be diction rather than decibels, and the amplifier merely makes louder what is still difficult to follow.

It was against this background and John Moyle's observation quoted earlier, that I decided to feature articles about basic PA systems when I assumed control of *Radio & Hobbies*, back in February 1942.

The information was certainly basic — mention of typical magnetic and crystal (78rpm) pickups and a survey of available hobbyist microphones, ranging from an Amplion transverse current carbon to an Australian-made ribbon type from Walls of Melbourne. A couple of 5-watt amplifiers were featured, following familiar receiver practice, plus an article on loudspeakers and associated wiring.

In later years, we described rather more ambitious PA equipment — but always aimed at hobbyist readers.

My own pet system in the old days was a compact mono mains-powered amplifier using a couple of 6BW6 power valves in push-pull to deliver a nominal 15W of output. A couple of preliminary stages provided mixing facilities for two mics (typically dynamics), with one channel being switchable to Aux/PU/-Tape input.

The amplifier fed two internally padded, wooden loudspeaker cabinets measuring 460(H) x 260(W) x 220(D)-mm. Each contained two wide-range, low resonance 150mm Magnavox drivers, mounted one above the other, forming a mini-column. They were wired in series, in phase to present an impedance of 15 ohms per enclosure — or a load of 7.5 ohms with both systems plugged in.

In use, they could be positioned one either side of the stage, to cover a square auditorium. Alternatively they could be stood one upon the other to form a single tall sound column, able to serve an audience of 200 or more in a long, narrow building. Either way, the quality was excellent for both speech and music.

Next month

So much for PA at a predominantly amateur/hobby level. It should serve as background for part two in the next issue: the story of Laurie Simon, founder of Nomis Electronics, who can lay fair claim to being the pioneer of professional PA in South Australia.

(To be continued)