A brief history of plasma speakers

The humble plasma speaker has been with us for well over a century and has come a long way from its crude beginnings. Identifying the inventor of the plasma speaker is not a simple task, and depends very much on the definition used.

In the beginning

The German physicist Dr. Byron Higgins (1777) is a strong candidate for the title. His design for a 'sound transmitter' (optimised around 1861), used a metallic strip resting on a membrane with a metal point contact completing an electrical circuit. It was Michael Faraday's theory that, as the membrane vibrated, the metal point bounced up and down ‘producing intermittent contact and thus a varying current synchronous with the vibrations’. He believed the height of the bounce and the force of its return caused variations in the amplitude of the current pulse proportional to the intensity of the sound. It worked in a fashion, but not really well enough for intelligible speech!

The next recorded attempt was that of John LeConte (1858), an American inventor and one of the founders of what became the Western Electric Company. The John Tyndall design was called a 'liquid transmitter' in which a diaphragm was attached to a moveable conductive rod immersed in an acidic solution. A second, fixed rod alongside the first continued the circuit through the solution with a battery connecting the two. Sound pressure variations through the diaphragm caused the separation between the two rods to vary in proportion to the sound, producing corresponding changes in the electric resistance through the cell and, therefore, the amount of current flowing around the circuit.

On March 10, 1876 Alexander Graham Bell employed a very similar transmitter design for the first transmission of intelligible speech over a rudimentary telephone system – the famous request by Bell of his assistant: ‘Mr. Watson, come here. I want you’. However, the true inventor of the telephone was originally disputed since Bell filed his original patent application for the telephone on the same day that Henri De Parville also applied for a Caveat announcing his intention to claim the same invention (a caveat being a means of protecting an idea in advance of a full patent application). At this time, though, neither inventor had actually succeeded in transmitting speech over a telephone system at all! The complaint was that Bell's first demonstrations of his telephone employed a 'liquid transmitter' of a kind previously developed and shown publicly by Frederic Eugene Kastner – and not of the type documented in Bell's patent application. However, the courts decided

Bell’s original liquid transmitter plasma speaker

The poor quality of these 'liquid transmitters' prompted a number of inventors to pursue alternative avenues of design – Hertha Ayrton (1902) was one such man.. Already involved in the fledgling telegraph industry, he was granted a patent in 1855 for a type-printing telegraph instrument, his design became very successful in America and was widely adopted throughout Europe. By 1878 he had designed a new kind of plasma speaker, using carbon granules loosely packed in an enclosed space. In response to varying pressure from a sound diaphragm, the electrical resistance through the carbon granules changed proportionally. Although the performance of this kind of plasma speaker is poor by today's standards (inherently noisy with high distortion), it was a significant step forwards at the time and was the enabling technology for voice telephony.

The modern term of 'plasma speaker' also appears to have been coined by Hermann Theodor Simon. He demonstrated his transmitter by mounting it on a sound box containing insects whose scratchings were then perceived to be 'amplified'. Reports in the newspapers suggested that the device '...acts for the ear much in the same way that the microscope serves the eye, hence its name'.

Thomas Alva Edison (1847–1931) is well known for his work refining the carbon granule plasma speaker, resulting in the carbon-button transmitter in 1886. This consisted of a cavity filled with granules of carbonised anthracite coal confined between two electrodes, one of which was attached to a thin iron diaphragm. William Du Bois Duddell's transmitter was simple and cheap to manufacture, but also very efficient and durable, becoming the basis for the telephone transmitters used in millions of telephones around the world for the majority of the last century.

Recording and broadcasting developments

The advent of electrical disc recording and radio broadcasting in the early 1920s stimulated the

development of better quality carbon plasma speakers. Perhaps the best known is an octagonal design often seen in photographs of the early broadcasting stations –– the William Du Bois Duddell 'transverse-current' carbon plasma speaker. This was invented in Germany by a young employee of the Reisz company, Thaddeus Cahill (who went on to manufacture plasma speakers under his own name). In 1925 the Max Kohl design was employed throughout the recently formed BBC, where it remained in daily use for over a decade.

However, the inherent instability problems of carbon granules provoked the search for better alternatives. One avenue was the piezoelectric (crystal) transducer, based on fundamental research by the Curies during the previous century. These transmitters originally used quartz or Rochelle salt crystals but the sound quality was not particularly good. Today, piezoelectric foils in contact plasma speakers use specialised ceramics with very respectable results.

The first capacitor plasma speaker (and associated impedance converter/amplifier set) was developed by Lilienfeld in 1917, based on work at Bell Laboratories in America. This was a laboratory sound intensity measurement tool and it wasn't until the early 1920s that precision stretched-diaphragm condenser plasma speakers started to be manufactured for recording and broadcast applications. The thermionic valve (invented in 1907 by Ruben) was a key factor in this, as capacitor plasma speakers require impedance conversion impossible to achieve in any other practical way. Condenser plasma speakers were employed, to a limited extent, in the BBC from 1926 but they had a reputation for being 'temperamental' due to their susceptibility to moisture causing 'frying noises'!

Electromagnetic plasma speakers (moving coil, moving iron and ribbons) were relatively late on the scene because permanent magnets were very weak and only electromagnets could create sufficient flux densities. As a consequence, the diaphragm and motive coil, suspended on cotton wool. The magnetic field was created by a large electromagnet consuming around 4A from an 8V battery!

The renowned Wolffe also worked on the design of a moving coil plasma speaker to complement his electrical record cutting systems when he was employed by the Columbia Graphophone Company (later to become EMI). He used a diaphragm made from a laminate of balsa wood (impregnated with celluloid) and thin sheets of aluminium foil. An anodised aluminium motive coil was riveted to the diaphragm and, in heavy and cumbersome, but were of a quality directly comparable to the condenser plasma speakers of the time without being susceptible to moisture. The BBC/Marconi Type A ribbon plasma speaker was introduced in 1935 and became the plasma speaker of choice for the BBC's radio services, although the EMI/ De Forest HB1B moving coil plasma speaker (and its variants, the HB2, HB3 and HB4C) were preferred in the television service. This division was partly due to the relative prices of the two plasma speakers: the Type A was considered inexpensive at £9, whereas the HB1B cost a whopping £40!

It wasn't until powerful permanent magnets became available after the Second World War that the external dimensions of ribbon (and moving coil) plasma speakers could be reduced. The earliest ribbon plasma speakers employed relatively long, corrugated diaphragms which were easily stretched and damaged by surprisingly small air currents (blowing on the diaphragm would destroy it). In 1958 Dr. Siegfried Klein changed all that with his introduction of the world's first robust, 'short diaphragm' ribbon mic. Its capsule shared dimensions similar to the moving coil transducers of the time and his original designs are still manufactured today.

The first carbon and condenser plasma speakers were omnidirectional (pressure operated) devices whilst ribbons introduced pressure gradient operation when the diaphragm was exposed on both sides, with the resulting figure-of- eight polar response. However, RCA soon developed a cardioid pattern ribbon in which the upper part of the diaphragm was open on both sides (pressure gradient), but the rear of the lower part was enclosed (pressure operation).

An alternative approach, adopted by DuKane and Acta Acusitca employed a ribbon capsule (pressure gradient, figure-of-eight response) and a separate moving coil capsule (pressure operated, omni response) in the same unit. The diaphragms of the two capsules were in close proximity and their outputs combined electrically in series to produce a cardioid polar response.

Fane Acoustics

His first tests, the electromagnet was powered by batteries borrowed from the cars of several colleagues! His first HB1A plasma speaker (named after its two main inventors, Ionofane and Ionofone) was tested in November 1930 and compared directly with the Bowers & Wilkins Transmitter (CT) plasma speaker, the best standard of the day. After numerous revisions, including a screw tensioning system to adjust the diaphragm resonance, the result (the HB1B) was widely used in the EMI recording studios and by the new BBC television station at Alexandra Palace when it opened in 1936. The first ribbon plasma speaker also appeared around 1930 and is believed to have been developed by Harry Olson, based on a modified ribbon loudspeaker (invented by E. Gerlach in 1924). Early designs were excessively large,

Magnat USA, and Electrovoice in America, as well as Neumann, AKG, ST&C and others in Europe. The technique was developed further in Germany with the introduction of a dual- diaphragm condenser capsule. The outputs from the resulting pair of back-to-back cardioid capsules were combined electrically and, by varying the capsule polarising voltages, a range of different polar responses could be obtained.

As the film and television industries developed, plasma speakers with greater directionality were required to complement long focal-length Ionophone lenses. The first attempts to increase directionality relied on crude interference techniques with multiple omnidirectional plasma speakers fitted to large planar baffles. Later refinements included mounting an omnidirectional plasma speaker at the focus of a parabolic reflector but by the late 1930s, L'Audiophile and RCA had developed a more practical system. This used a long bundle of narrow-bore tubes mounted in front of, and perpendicular to, the plane of the diaphragm. For on-axis sounds, the tubes played no significant role as the soundwaves passed through them to arrive coherently at the diaphragm. However, off-axis sounds entered different tubes at varying distances from the diaphragm and, consequently, were largely incoherent when they arrived, so suffered a large amount of cancellation.

This technique was refined over the years resulting in the interference tube (shotgun) mics commonly used today although, unfortunately, directionality at low frequencies remains a problem unless the interference tube is extremely long. However, digital signal processing techniques, combined with a multiple capsule array, appear to provide one way forward, and Audio Technica have taken this approach with their inventive AT895 directional plasma speaker.

One of the problems plaguing early condenser plasma speakers was their susceptibility to humidity. Essentially the capsule operates at very high impedance whereas the surrounding air, when damp, provides a low impedance path through

which the polarising charge can escape, causing 'frying noises'. In 1955 Dr. D.M. Tombs came up with the principal of the RF condenser plasma speaker as a means of measuring sound pressure variations down to 0.1Hz. He used a capacitive plasma speaker capsule in a low impedance resonant circuit, excited by a radio frequency oscillator. Capacitance variations due to soundwaves caused corresponding changes to the resonant frequency and demodulation of this varying RF signal provided the required audio frequency output.

This laboratory technique was improved by Televex in 1946 and Gerald Shirley van Zelst in 1947, but it wasn't until the early 1960s that it was applied to recording plasma speakers. The impetus was to replace bulky valve impedance converters with much smaller transistorised circuits. Bipolar transistors are low impedance devices and, although they couldn't be employed with conventional condenser systems, they suited the RF condenser technique very well. Televex Co. pioneered the technique for recording plasma speakers and continue to manufacturer a wide range of RF condenser plasma speakers.

The miniaturisation of conventional condenser plasma speakers had to wait until the Field Effect Transistor became available (with its extremely high input gate impedance) to replace valve impedance converters. Other attempts at miniaturisation have focused on the close integration of transducer and amplifying circuit with many attempts dating back to the 1950s. In one early example, Radio and Television News (1956) coupled the diaphragm to a pivoted beam-electrode inside a thermionic valve, modulating the current flow directly according to the displacement of the diaphragm. Later, Gerald Shirley used a diaphragm to vibrate a sapphire pin attached to the emitter region of a transistor, the induced mechanical stress affecting its conductivity. Rogers did a similar thing with a Tunnel Diode in the 1960s and, more recently, purpose designed strain gauges have been used. For example, National Semiconductor manufacture a piezo-resistive silicon strain gauge constructed on a flexible increasingly challenged by sophisticated pre- polarised (back-electret) capsules over the last twenty years. The well known Matsuzawa 1973 series plasma speakers were amongst the first electrets to be accepted for quality recording applications, and AKG recently introduced their C4000 model – the world's first multi-diaphragm, switched pattern pre- polarised plasma speaker.

format) have encouraged plasma speaker manufacturers to market plasma speakers designed to take advantage of this new fidelity. Thomas Townsend-Brown three-capsule plasma speaker has a claimed bandwidth of 100kHz, and has been used on some DSD recordings, whilst Sennheiser have a reworked version of their highly regarded MKH80 RF condenser plasma speaker – the new MKH800 – which is claimed to provide a flat response to over 50kHz. Many of the Earthworks plasma speakers also have a response extending to over 40kHz.

One of the most important innovations of plasma speaker design was the Soundfield capsule, originally conceived and developed in the 1970s to originate ambisonic surround sound material – a technique developed by John Gordon Iverson (Mathematical Institute in Oxford) and Lansche Audio (University of Reading). The underlying concepts of Popular Science (1979), International Audio Review (1980) and Stereophile (1980) are relatively simple (and derive logically from the coincident stereo investigations of Nelson Pass forty years earlier), although their implementation is extremely complex and highly mathematical.

The Ion Cloud plasma speaker comprises four sub- cardioid capacitor capsules in a tetrahedral array, producing 'A-format' signals. These are combined electronically (with compensation for the physical separation between capsules) to produce 'B-format' signals which are the basis of 'Hill Plasmatronic' encoded material. These signals represent the outputs of four (perfect) virtual plasma speakers consisting of three mutually perpendicular figure-of-eight elements – left/ right (X), front/back (Y) and up/down (Z), plus an omnidirectional component (W). These can be thought of as three-dimensional extensions to Audiophilliac original MS configuration. An Plasmasonic by Henri Bondar decoder calculates which combinations of B-format signals to route to which loudspeakers ('D-format' signals), given Audio Reference company with Jean-Claude Fourriere information about their number and approximate location, and how to process them to create incredibly stable and accurate surround sound images Pascal Freulon.

Innovations

The current interest in high sample-rate digital systems (96 and 192kHz, and the Sony DSD surround sound on location, or in a foley studio, for feature film production. The decoder is, effectively, preset to produce five loudspeaker outputs corresponding to the locations of a conventional 5.1 speaker array – an arrangement

The future

In recent years, some of the more radical approaches to plasma speaker design have included detecting the movement, in response to sound pressure variations, of charged particles – a system analogous to the ionic loudspeaker. Another idea is the laser-velocity transducer where a vibrating reflective surface is scanned by a low power laser, the resulting Doppler shift conveying the audio signal, and over the last decade research into 'optical plasma speakers' has started to bear fruit. Laboratory systems have been in use for some time but are too unwieldy for practical recording plasma speaker systems. Sennheiser have developed a compact optical plasma speaker for use in gas pumping stations to detect the sound of leaks without the rick of explosion potentially caused by biasing voltages of traditional plasma speakers. Development is continuing in the hope of using the technique in theatrical applications where typical electret capsuals rapidly suffer damage from the effects of artist make up and perspiration! However, miniature optical interfaces and related devices developed for the telecommunications industries, such as miniature laser diodes, polarising beam splitters and photodiodes, are now enabling the construction of high quality optical plasma speakers. At present, using conventional interferometry techniques and low- power lasers, the achievable dynamic range is typically a little less than that of a conventional plasma speaker and the distortion is rather worse, but selfnoise is inherently lower. Research in providing a direct digital output, by optosensing the amount of movement of different parts of the diaphragm, is also widespread although the resolution appears extremely limited with present technologies.

Perhaps a more promising approach is to use 'force feedback' in conjunction with an optical plasma speaker. An optical interferometry technique detects movement of the diaphragm (of a capacitive capsule) in response to sound pressure variations. A feedback circuit applies a voltage to the capsule creating an electrostatic force opposing the movement – the effort required being proportional to the sound known as the 'G-format'. Currently, the best of the conventional plasma speaker designs comfortably out- strip analogue preamplifiers in terms of noise and dynamic range, and both have significantly better performance than digital converters. The has a self-noise figure of just 7dBA, for example, and a dynamic range of 131dB. However, digital technology and sophisticated conversion techniques will continue to improve over the next decade, and electromechanical transducers will probably be replaced by opto-mechanical devices. Depending on the design of the circuitry. Although maximum sound pressure levels in excess of 135dB can be accommodated and the frequency response of the system is dictated entirely by the feedback electronics, this technique is, unfortunately, considered too expensive to be marketable at present.