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Dynamic Polar Patterns: Advancing Recordist Agency via Dual-Output Microphones

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ABSTRACT

While multichannel mediation continues to grow in popularity, traditional mono and stereophonic recording techniques remain those underpinning audio production workflows. By incorporating dual-output microphone technology into established practices, capacity exists for nuancing recordist agency in ways not documented in existing literature. The Dynamic Polar Pattern is introduced as a simple process to simulate polar patterns changing shape over time, with affordances associated to proximity effect, distance factor, frequency masking and stereo width. Practice-led and practice-based methodology catalogues benefits of dual-output agency including the ability to capture multiple stereo techniques simultaneously, pedagogical attribute demonstration, rear-output panning, performance panning, sample packaging and DIY microphone modelling. An overarching position for "Why employ dual-output microphones?" is interrogated alongside technical data.

1 INTRODUCTION

Separate to a dedicated stereo microphone, a dual-output or "twin" microphone consists of two mutually opposite facing capsule halves, feeding respective amplifier circuits in a single enclosure. The dual-output microphone's front and rear outputs allow the polar pattern switching process to be deferred to the recordist in real time or playback. Manipulating the levels and inverting the phase polarity between outputs ultimately determines the directivity pattern [1][2].

Conceptually, this could be likened to removing the pattern switch from the microphone and placing it on the faders of a console or DAW. "Switching" can therefore be explored as a musical endeavor, allowing the recordist access to the entire spectrum of first order polar patterns, and not simply those prescribed by a manufacturer. This elicits technological affordances [3] and relies upon recordist agency [4], both of which form themes for investigation.

In considering the gap addressed by this research, the concepts discussed could have been explored circa 1930 with Weber and Braunmuehl's emerging "Cardioid" capsule patent [5], leading to George Neumann's revolutionary dual-membrane M7 capsule [6]. However, the priority of this patent was "one-sided sound pickup," not two. Further, it wasn't until the technological affordances made available by multitrack tape recorders post WWII that increasing track counts would make such a technical indulgence[1] potentially viable.

[1] With a stereo tape recorder, it would be "indulgent" to dedicate both tracks to a dual-output microphone.

The first commercially available microphone explicitly promoting post production polar control was brought to market in 2008. In both a white paper and user manual released by the manufacturer, the mention of the microphone's novel polar pattern flexibility placed it at the cutting edge of microphone technology at the time [1]. Although expensive and rare, counter-intuitively using one half of a 1970's "Quad" microphone would have created an early opportunity to explore post production polar control[2]. Similarly, a digital dual-output microphone system released in 1999 while capable, was not identified by its maker for retrospective polar pattern manipulation.

More recently, the last decade has seen the arrival of software dependent "modelling microphones". These microphones, while designed for simulating a collection of historic microphone styles and characteristics, are nonetheless examples of dual-output microphones and share mechanical similarities[3].

While B format recording can be derived from two coincident dual-output microphones [7], standalone ambisonic microphones with coincident capsules, although enabling post-production polar control, are not the subject of this study. Similarly, this study does not include stereo or quad microphones with capsules that rotate to be 180 degrees opposite facing. This study focusses exclusively on first order microphones that can form both coincident *and* spaced arrays. At the time of writing, there are around half a dozen models of dual-output microphones in current production[4].

Among other things, this study looks at the impact of dual-output microphones on stereo recording [8]. The afforded agency and cumulative effects of which appear underrepresented in the existing academic catalogue.

2 TECHNICAL BACKGROUND

In most cases, multi-pattern microphones are condenser microphones – mainly "true" condenser microphones where the polarization voltage is applied to the capsule by the microphone electronics.

2.1 Capsule Design

Typically, a large diaphragm capsule with two separate diaphragms on the front and rear side is used. For electrode design, concepts vary between a single, shared electrode or two separated electrodes, where the latter is commonly followed by individual amplification circuits [9].

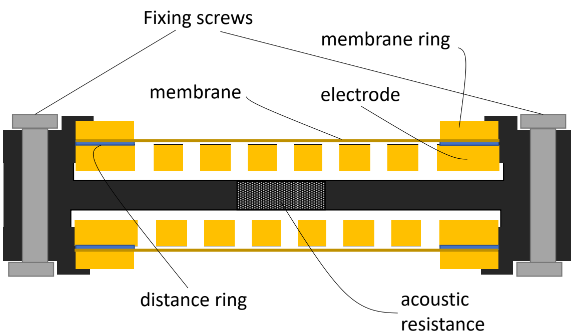

Fig. 1: Capsule of a typical dual diaphragm design as found in the microphones used for this research.

Fig. 1 shows a condenser capsule with two identical halves, separated via a shared acoustic resistance. Besides using a resistive textile as an acoustic resistance, this could alternatively be a mechanical resistance derived from slits, holes or other narrow perforations. The acoustic resistance is tuned so that both halves reproduce an ideal cardioid characteristic. By summing these two back-to-back capsule halves with the same level, an omnidirectional characteristic is achieved. Inverting the polarity of one of these signals generates a figure-of-eight pattern.

This can be easily described with the formula:

$$A + B * \cos \alpha \quad (1)$$

Where A is the factor of the omnidirectional and B the bi-directional response with the condition:

$$A + B = 1 \quad (2)$$

[2] One German made Quad microphone in 1972 was priced at today's equivalent of $10 000 USD.
[3] Dual membrane capsules.

[4] Austrian Audio OC818, Lewitt Audio 640TS, Sennheiser MKH 800 Twin, Milab/Pearl ELM-A, Ehrlund EHR-T, Universal Audio *Sphere*, Antelope Audio *Edge*, DIY kit from MicrophoneParts.com

For one half, this can be recalculated to:

$$A + (1-A) * \cos\alpha \qquad (3)$$

and the opposite facing halve:

$$A - (1-A) * \cos\alpha \qquad (4)$$

Summing those two with A = 0.5 for cardioid would yield a formula for the polar pattern of constant 1 which is an omnidirectional characteristic [10].

To achieve all polar patterns in between, the summing of the cardioids must be done with different levels. In a true condenser microphone, this is achieved by changing the polarization voltage of the capsule. The polarization voltage has a direct influence on the capsule's sensitivity – thus, reducing the polarization voltage by ⅓ will result in a ~10dB lower sensitivity. Summing such a -10dB rear facing cardioid with the 0dB front facing cardioid will result in a front facing wide-cardioid or Super-Cardioid when the polarization voltage polarity for the rear capsule is inversed. It should also be noted that these concepts only work if the acoustic performance of the two capsule halves is matched. Matching requires accurate frequency response, sensitivity, phase correlation and consistent directionality of both cardioid patterns. Fig. 2 shows the -10dB example with two perfectly matched cardioids.

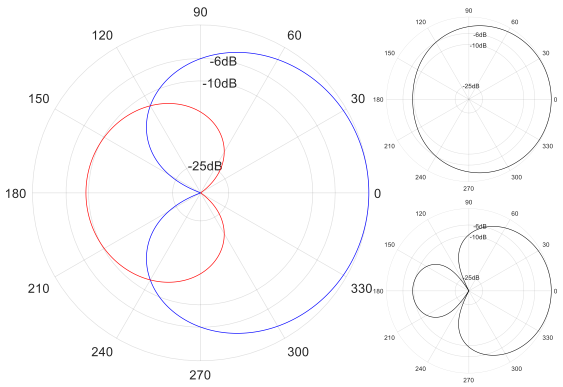

Fig. 2: Summing of two cardioids with different levels and polarity.

3 ELECTRONIC DESIGN

Where the polar patterns in a typical dual diaphragm microphone are achieved with different polarization voltages, a dual-output microphone does no internal summing but is dependent on recordist agency to derive polar patterns. With this, two capsule halves with separated diaphragms and accompanying electrodes are often preferred, as this simplifies the connection to respective amplification circuits.

Fig. 3 shows a simplified schematic of a dual-output microphone. Typically, a 5-pole XLR output is used. For these designs, two identical amplification circuits are incorporated which share a common power supply (not shown).

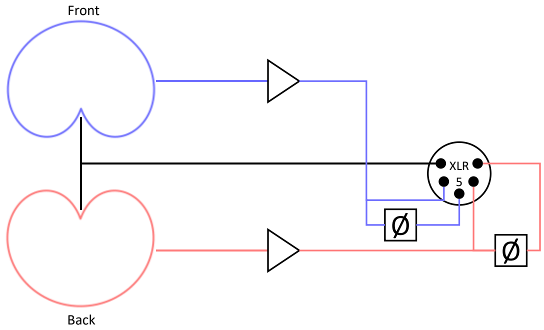

Fig. 3: Simplified dual-output microphone schematic.

There are more sophisticated schematic designs where the microphone can be used as a conventional, single output microphone as an alternative to the dual-output mode. The microphones used for this research achieve this via internal FET switches and feature a second (mini-) XLR output connector alongside a traditional 3-pole XLR.

4 METHOD

Over 50 recordings were conducted over nine months to collate a library of contrasting examples across genres of jazz, classical and rock. Reduced to a succinct folio, the research was practice-led with an overarching tripartite methodology. This includes action research [11], iterative reflexive practice [12] and tech-processual analysis [13]. This allowed "Deconstruction style" videos to be compiled including Pro Tools screen capture and operator narration which document, reflect on and analyse agency in the context of practice.

Serving as enriched diary entries identifying personal preferences, this media summarized and preserved the experience of interrogating dual-output microphones for enhanced agency.

Each advantage or technique identified was subject to bespoke interrogation from which future iterations of recording practice were informed. This included using a Yamaha C7 Disklavier[5] where consistent repeatability of source material was required. Laboratory grade oscilloscopes and vector scope software[6] were employed to verify audibly perceived differences in stereo width.

5 TECHNIQUES AND ADVANTAGES

The forthcoming techniques and advantages have been identified as findings for future research via the practice-led action, iterative and reflexive methodology. The techniques discussed are made possible exclusively via separated outputs.

5.1 Dynamic Polar Patterns

The dynamic polar pattern is a philosophy that employs a dual-output microphone with the view to simulate the shape of a polar pattern changing over time. For example, in the context of recording a drumkit, a pair of spaced cardioid overhead microphones might change from cardioid to omnidirectional upon every instance of the snare drum being struck. The resulting effect may be understood as a flexible or dynamic polar pattern. Here, the suddenly widened stereo image with the addition of increased reverberation may give the sense of the snare drum momentarily enveloping the listener.

The technical approach shares similarities with the widely known Mid-Side stereo technique in that both allow for post production refinement and both require the correct use of specific hardware and processing treatment. The hardware required for the dynamic polar pattern refers to the dual-output microphone itself, while the processing treatment comes from an expander or gate for the purpose of combining the rear signal to the front or vice versa.

When simulating a cardioid pattern shifting towards omnidirectional, contrast will present due to the distance factor[7] properties of the microphone changing while its physical position remains fixed.

On critical distance[8], a study on spoken voice perspective by Gorne, Schneider and Mader [14] states:

> When the microphone is positioned inside the critical distance sphere, a rather dry, “close” sound image is obtained. When the microphone is positioned outside the sphere, the recorded sound image is more reverberant, thus more “distant”.

The critical distance of equal direct to reverberant sound in an omnidirectional pattern is quantified as a distance factor value of 1. A cardioid or figure 8 pattern is required to be 1.7 times this distance factor for an equal ratio of direct to reverberant sound [14]. Using a dual-output microphone allows for retrospectively reaching “in to” or “out of” the critical distance sphere. This is particularly practical for recording where Williams states:

> It is unfortunately too often the case that the position of the microphone system is a compromise between a good stereophonic sound image and the optimum ratio of direct to reverberant sound [15].

Similarly, Gorne, Schneider and Mader’s work continues to suggest that manipulating the polar pattern has a direct impact on perceived distance. This aligns with the inverse square law that states a doubling of distance will present a sound pressure decrease correlating to 6dB. Given the cardioid pattern’s 6dB attenuation at 90 and 270 degrees, changing polar pattern can therefore simulate movement.

In addition to manipulating distance factor, a closely positioned microphone can be made to exhibit less proximity effect by increasing the rear signal to create a more omnidirectional pattern. To that end, the traditionally “fixed” characteristics associated with proximity effect and distance factor become

[5] An acoustic piano fitted with a mechanical system allowing for playback of MIDI files.

[6] RME Digicheck

[7] Distance relative to omnidirectional pattern where a microphone receives equal amounts of direct and reverberant sound.

[8] Assuming an omnidirectional radiating sound source, the critical distance cd is determined by the equation $cd = 0.057\sqrt{V}/RT$ [m], where V is the room volume and RT the reverberation time.

malleable to the post-production engineer, nuancing the signal network.

The dynamic behavior of the technique is triggered via dynamic processing. This enables the directivity of the microphone to react to changes in the audio signal. Also, and as suggested in a 2021 AES Live video presentation from past AES president Alex Case, the dynamic processing application of a gate allows a recordist to shorten the perceived decay time of a space [16]. In doing so, this mitigates frequency masking in the absence of redundant decay, further revealing low level information. Therefore, the dynamic polar pattern can be used to both add reverberation, yet improve intelligibility.

For example, as a soprano sings loudly, the microphone pattern widens, allowing more natural reverb from the concert hall. Conversely when singing pianissimo, the sound is less diffuse and more direct. Here, with Case's notion of decay mitigation, and in the newly-adjusted absence of off-axis room sound, the use of a gate to control the polar pattern minimizes frequency masking.

Using a gate, expander or compressor provides simple control and is preferred over automation. In regards to haptic-derived automation[9], the image below shows an example of a simple test conducted multiple times. In this, a fader is moved urgently from negative infinity to unity, required for blending the off-axis signal to the front of the dual-output microphone.

Fig. 4: Haptic automation data of unity fader movement.

The test indicates the human hand is far slower and unreliable compared to the consistency of a noise gate. The movement in Fig. 4 took over 400 milliseconds, requiring an additional level correction within that time. Given a gate may possess time constants performing accurately in the range of microseconds, dynamic processing is encouraged over automation where musically appropriate. The Hass effect states separate auditory events occurring inside 30ms are perceived as a singular event [17]. It is suggested that any undesirable attack time artifacts[10] remain inside this timeframe.

The noise gate was first manufactured by Allison Research[11] in the 1970's [18], some 20 years before retrospective polar manipulation [19]. Among contemporary practice and existing technical literature, there appears no obvious application for a gate to be used in tandem with a main recording pair[12] of microphones. With that, a question has remained unexamined; What does the unlikely partnership of dual-output microphones and noise gates mean for stereo image? Asked in another way, how does employing dynamic polar patterns impact stereo width?

Referring to a Decca Records 30cm spaced pair approach to recording piano, Dunkerly, Haigh and Rogers [20] say:

> The microphones can be omnidirectional, cardioid, or even figure of eight ribbons; the stereo image depends on the spacing of the pair and not the microphone directivity as the microphones are parallel to another.

However, in practice, this is not entirely the case. The below oscilloscope images have been captured over the two minute duration of a single performance of *Minuet in G Major* composed by J.S. Bach, performed by Yamaha C7 Disklavier.

[9] Automation performed from a control surface and not manually entered into a DAW

[10] Attack and release times can present unpleasant artefacts if not set appropriately to source material.

[11] Allison Research became better known by the company name Valley People.

[12] A stereo configuration of microphones often positioned at longer distances than "spot" microphones.

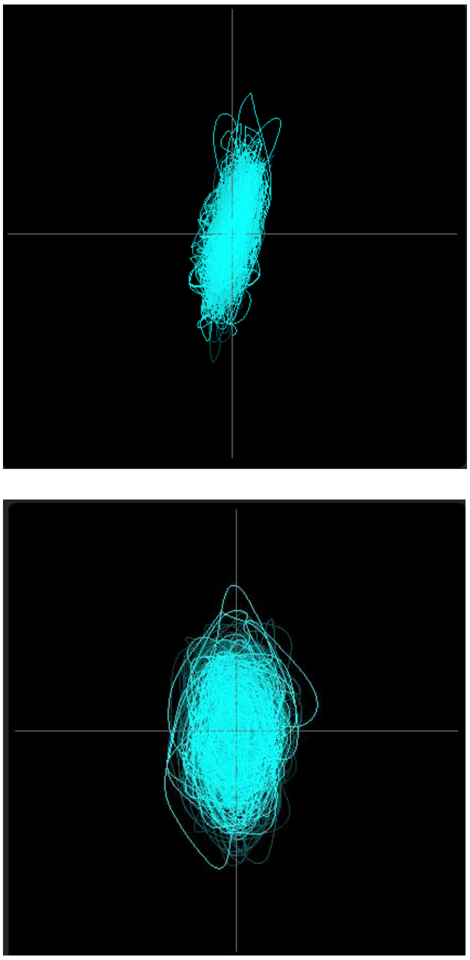

Fig. 5: Vectorscope images indicating variations in stereo image width.

Above: Spaced pair of dual-output microphones in figure-of-eight polar pattern.

Below: Spaced pair of dual-output microphones in omnidirectional polar pattern.

The images indicate a greater divergence of voltage on the horizontal axis from the omnidirectional microphones which broadly correlates to stereo width[13]. In this instance, the direct sound does remain very similar between polar patterns, however the increased *room sound* introduced to each capsule by widening the polar patterns leads to more of a stereo effect. This means as the AB microphones change from directional towards omnidirectional, albeit marginal, the stereo image correspondingly widens. More obviously and tested for in other studies [21], in XY configuration, changing from omnidirectional to cardioid will widen the image. Therefore a further degree of complexity and nuance could be tested for and contribute towards knowledge pertaining to localization curves, envelopment, perceived timbre, and listener preference, building on the extensive work published by the likes of Michael Williams and Helmut Wittek [10][15][21][22].

Dynamic processors become more advantageous to the microphone technique when including an external side-chain input. In the drumkit example, the overhead microphones are “keyed” to open by the snare signal passing the gate threshold. When multiband dynamic processing is considered as a function of frequency; as the soprano sings in their higher register, the sound of the hall may be momentarily more present. As the pitch recedes in frequency to the chest voice, the ambience is lessened for a more direct and subjectively intimate sound. The external input to the side-chain in this situation would be akin to a duplicate of the vocal track with a high-pass filter applied.

When the dynamic polar pattern concept is incorporated as a variation to an existing technique such as AB or XY, the presence of existing difference should be indicated with a delta symbol suffix such as XY**Δ.**

5.2 Rear Output Panning

Independent access to a microphone’s front and rear signal allows placing or distributing a sound uniquely within the horizontal stereo field. In the case of a stereo technique such as AB, the ability to discretely pan and level four independent signals instead of two, allows the recordist more spatial resolution from left to right.

Further to nuancing existing stereo approaches, it’s possible to investigate new techniques by indulging this affordance. Consider the lack of viability behind creating an XY coincident pair of omnidirectional microphones. This configuration suffers from a lack of stereo image in the absence of both pattern directionality, and diminished contrast in acoustic pressure deviation. However, by panning the rear

[13] Stereo width measurements undertaken with correlation meters do not include time difference, also contributing towards perceived width.

outputs of the dual-output microphone, the off-axis signal from the right-facing microphone (representing the off-axis, left side of the room) can be placed more appropriately on the left of the listener unlike previously, the right. Therefore, a coincident omnidirectional configuration in combination with the concept of rear panning yields a more accurate stereo image. The technique being coincident, is phase coherent and as suggested by Josephson, displays the added advantage of a more robust lower frequency response at longer source distance than traditional XY [2].

5.3 Performance Panning

Performance Panning[14] is the term given to the recordist performing with the dual-output microphone. This may include carefully waving or swinging the microphone. When applied in conjunction with rear output panning, the recordist can in real time, situate or move desired signals within the stereo field by angling or rotating the microphone.

Rotary effects are more extreme and refer to an unconventional approach to recording a source whereby the microphone is inverted and suspended from its XLR cables. The microphone and cables are carefully twisted so upon release, the microphone spins rapidly. Albeit momentary, when the outputs of the microphones are hard panned[15], the effect is not dissimilar to a rotary speaker effect.

Given the duration of the effect is limited to the length of cable and number of twists, the technique lends itself to short samples. This radical stereo exploitation can be effectively applied on sounds conventionally understood as mono such as auxiliary percussion instruments.

5.4 Sample Packaging

When used for capturing traditional monophonic acoustic samples, it’s possible for the engineer to later audition audio as if recorded in an alternative first order polar pattern. This can be achieved without the need for any proprietary decoding product. Muting the right side of the stereo file will reproduce the sample in “cardioid mode” and playing both left and right at equal level will reproduce the sample as if recorded as omnidirectional. The user may wish to sum their monitoring to mono for the purpose of auditioning. In this scenario the simple stereo file acts like a “container” or “packet” for the breadth of tonal shaping available via all first order patterns.

5.5 Unique Microphone Placement

When recording an electric guitar cabinet, it’s not uncommon for engineers to favor some amount of room sound in addition to the directness of a cabinet’s speaker cone. A dual-output microphone allows access to its 180 degree off-axis diaphragm which when combined with its on-axis signal, preserves a robust phase relationship. Attempting to reproduce this setup with single-output microphones, given the close proximity, an engineer is limited to a side-address style microphone. An end-address microphone is unable to be positioned both close and entirely off axis.

Fig. 6: Guitar cabinets recorded close with a dual-output microphone.

5.6 DIY Microphone Modelling

Dual-output microphones share a fundamental similarity with an emerging product line of hardware marketed as “modelling” microphones. That is, for some not all, the dual membrane capsule with discrete amplifier circuits and outputs. To some degree the concept of microphone modelling is open source. A user may experiment with microphone hardware and software modelling combinations to seek results that may or may not accurately represent the originally modelled microphones but rather, provide conceptually generative sounds.

While design intent suffers by combining hardware and software from different manufacturers, so too

[14] Author’s term.

[15] Located fully left or right in the stereo field.

could frequency response of lauded vintage microphones deviate significantly from each other. Fig. 7 shows the measured free field frequency response (at 1m) of three different vintage tube microphones with an edge terminated capsule – all of the same model type. Both the low and high frequency response vary up to 4dB within these three microphones. Therefore, depending on which of these were originally measured for the purpose of microphone modelling, the results may sound quite different to the original hardware.

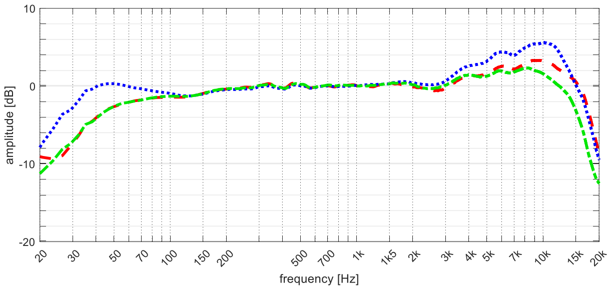

Fig. 7: Frequency response of three of the same model vintage large diaphragm condenser microphones.

Post-production processing of the dual-output signals allows an engineer to change polar response throughout the frequency spectrum [19][23][24]. For example, frequencies below 200Hz can be made omnidirectional, 200Hz-1kHz cardioid, while 1kHz to 20kHz could be entirely off-axis cardioid. This multiband polar pattern manipulation allows a user to create unique sounds via an alternative treatment to equalization. Such a treatment allows the opportunity to simulate characteristics of other microphone styles and types. For example, to simulate the properties of one particular “classic” microphone, a dual-output microphone used with an omnidirectional pattern can be made more directional at higher frequencies, emulating the mechanical effects of a sphere-mounted capsule, historically preferred for “Decca Tree” recordings [25]. Applications such as this could be considered a less accurate, more artistic, “DIY” approach to microphone modelling.

5.7 Multiple Stereo Techniques in Single Capture

When looking at techniques commonly employed throughout classical recording, ORTF, the Stereophonic Zoom and the AB Spaced Pair reside on a spectrum of accurate localization and impressionistic stereo image [15][20][26][27]. When using dual-output microphones, it’s possible to apply a technique prescribed for directional microphones such as ORTF yet later, hybridize this as a system closer to “AB with angled capsules”. This is similar to the notion of the “Straus Paket” developed circa 1950 by engineer Volker Straus.

Fig. 8: Coincident super-cardioid and omnidirectional microphones arranged similar to the Straus Paket.

The technique used both spaced directional and omnidirectional microphones, paired such that when electronically summed, would synthesize spaced wide cardioids[16]. The development of the wide cardioid capsule rendered the Straus Paket obsolete.

5.8 Auditioning

Using the dual-output microphone allows a single musical performance to remain the source material used for auditioning the sonic differences between polar patterns. Similarly, different coincident and spaced techniques can be auditioned without the need to re-record audio and introduce distracting, human error-based anomalies. This affordance eliminates the variables associated with musical performance and allows complete confidence when comparing and identifying sonic differences between technical recording approaches. In this case, the

[16] The original Straus Packet technique was electronically summed prior to microphone preamp and did not allow for polar control.

engineer or student is free to retrospectively interrogate[17] technique for preference which in turn, informs future skillset.

6 CONCLUSION

Employing the dual-output technology in practice has revealed distinct advantages over single output microphones. When used in main stereo configurations, panning the rear outputs of the microphones separately to the front makes available a more complex stereo image with the ability to independently locate and level four unique sounding signals, instead of the traditional two. The physical topology of the microphone allows for hosting emerging technologies in microphone modelling, something that may become further explored by manufacturers. Dual-output microphones allow for unique positioning physically impossible with single capsule counterparts such as close micing of electric guitar cabinets simultaneously on and off axis.

Should sample packs be released with sounds captured from dual-output microphones, a user would be free to select from the entire spectrum of first order polar patterns, allowing for a combination-of or alternative-to traditional EQ and time-based processing.

In addition to deferring multiband polar pattern selection until after a recording, dual-output microphones allow the recordist to simulate patterns changing shape over time. Enabled by means of dynamic processing, the results can add aesthetic complexity to existing techniques, improve intelligibility in the absence of frequency masking and conversely, sound unnatural and stylized. Dynamic polar patterns can be further nuanced by directing frequency-tailored signals to the external side-chain input of dynamic processing. Certainly, by repeatedly exercising agency over polar patterns, a practice-led methodology ultimately informs the ongoing practice of selecting and positioning fixed pattern microphones.

Technical affordances increase the resolution of first order polar patterns compared to those most commonly available. Paired with recordist agency, this sequentially informs both proximity effect, distance factor and stereo image characteristics. These attributes contribute to a more nuanced network for audio mediation. The techniques and advantages outlined are immediately transferrable to plugin development and immersive audio. Perhaps, with immersive microphone arrays soon assigned with dynamic polar patterns, adding to the immersive experience.

[17] Open-source plugins are available to simplify the decoding of coincident stereo configurations.

7 ACKNOWLEDGEMENTS

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