# 300 years of copyright: have we gone full circle? On the use of technology to address limitations in distributing public performance broadcast royalties.


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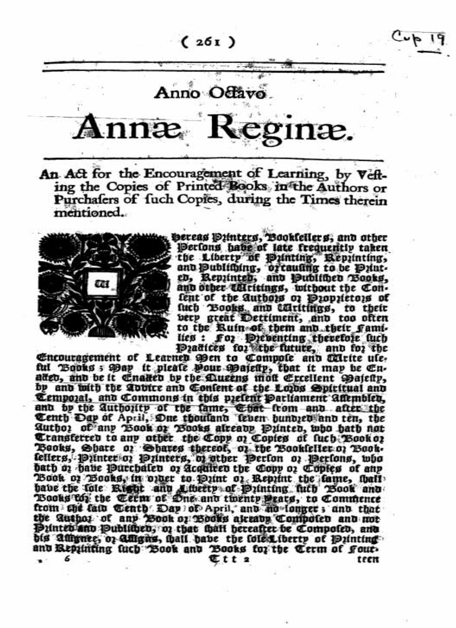
**Abstract:**

This paper briefly examines the concept and rationale of Copyright at the time of its inception and considers whether current legislation and, more distinctly, the administration of some of the rights specified by Copyright legislation has created a situation whereby authors of works in the music industry are being adversely affected and even exploited by such schemes thereby completing the circle by returning many authors to the point which made Copyright legislation necessary.

This paper also outlines the design and implementation of a completely automatic, open and transparent blind-detection digital audio watermarking system that will enable automatic monitoring and reporting of public performance of both digital and analogue radio and television transmissions using modern computer technology in order to generate accurate royalty distributions to 'authors' in order to administer their rights more equitably.


**Introduction**:

Copyright is of course ancient in comparison to computer science, essentially being born in the Statute of Anne (1710) in Britain, but it is nevertheless a valid and topical area of active computer science research. The Statute was introduced to prevent authors and their assignees being exploited by unauthorised re-printers copying, or pirating, their works and doing so "*to their very great detriment and too often to the Ruin of them and their Families*". In the case of this early Statute the works in question were books but the concept soon migrated to other creative areas and Copyright now extends to a wide variety of endeavours. Perhaps the most common would be the Entertainment industry.



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Anno Octavo

Annæ Reginæ.

An Act for the Encouragement of Learning, by Vesting the Copies of Printed Books in the Authors or Purchasers of such Copies, during the Times therein mentioned.

Whereas Printers, Booksellers, and other Persons have of late frequently taken the Liberty of Printing, Reprinting, and Publishing, or causing to be Printed, Reprinted, and Published Books, and other Writings, without the Consent of the Authors or Proprietors of such Books and Writings, to their very great Detriment, and too often to the Ruin of them and their Families: For Preventing therefore such Practices for the future, and for the Encouragement of Learned Men to Compose and Write useful Books; May it please Your Majesty, that it may be Enacted, and be it Enacted by the Queens most Excellent Majesty, by and with the Advice and Consent of the Lords Spiritual and Temporal, and Commons in this present Parliament Assembled, and by the Authority of the same, That from and after the Tenth Day of April, One thousand seven hundred and ten, the Author of any Book or Books already Printed, who hath not Transferred to any other the Copy or Copies of such Book or Books, Share or Shares thereof, or the Bookseller or Booksellers, Printer or Printers, or other Person or Persons, who hath or have Purchased or Acquired the Copy or Copies of any Book or Books, in order to Print or Reprint the same, shall have the sole Right and Liberty of Printing such Book and Books for the Term of One and twenty Years, to Commence from the said Tenth Day of April, and no longer; and that the Author of any Book or Books already Composed and not Printed and Published, or that shall hereafter be Composed, and his Assignee, or Assigns, shall have the sole Liberty of Printing and Reprinting such Book and Books for the Term of Fourteen

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Fig 1: The first page of the *Statute of Anne:* considered the world's first Copyright legislation [10]

Whereas the Statute was intended to prevent the exploitation of authors' works by what was then the perfectly legal reprinting of paper publications, it opened the debate into wider areas. Within 35 years the scope of the Legislation had widened to include – in the words of Lord Chief Justice de Grey, speaking in the House of Lords – '*composers of music, the engravers of copper-plates, the inventors of machines'*. In that year (1744) the case of '*Donaldson v Beckett'*[14] was debated at the Lords and the Attorney General observed that booksellers, who had previously been re-printing and reselling books without recourse to the Author, had not *'ever concerned themselves about authors, but had generally confined the substance of their prayers to the* *legislature, to the security of their own property'.* Publishers, then, apparently had little concern for authors in furthering their own ends. After the case was settled, it was held that the Author had certain inalienable rights that he or she could choose to avail of, waive or assign. In the judgement it was further observed that '*literary works, like all others, will be undertaken and pursued with greater spirit, when, to the motives of public utility and fame, is added the inducement of private emolument*'. This, then, is the basis for the development of modern copyright: that an author of a work has rights that he or she can choose to either use or limit, and that the potential for profiting from their work by availing of their rights is an incentive to further development of these and similar works.

Skip forward almost three hundred years. Digital Rights Management (DRM) technologies in digital audio and video have received much attention in recent years, with various efforts made to protect content from illegal copying, use or distribution. Some schemes were technically successful but not well received by end-users. Others were not particularly successful, falling to the efforts of 'hackers' and other attacks. Still, though, much funded research effort in this field of Computer Science is devoted to pursuing such rights protection. Schemes based on fingerprinting, watermarking and various combinations of the two have been proposed.

The world's most well-known digital music retailer, Apple's iTunes store, recently agreed to remove all Digital Rights Management (or 'electronic protection measures') restrictions from its music[6] and the rationale behind this decision can be illustrated by the fact that Norway's consumer ombudsman then agreed to drop his Country's legal challenges to iTunes use of DRM, which were on the general basis that they are/were restrictive to consumers, denying them the right to transfer purchased music to other devices. This issue was also being monitored closely by other European countries and was dropped after Apple removed DRM protections. Apple's defence of their DRM measures in the past may have been cloaked in claims of protecting the Artist but they were in fact never about the Artist, as many opponents of DRM would claim and were more like 18th century publishers who had never '*concerned themselves about authors'* but rather were more interested in '*the security of their own property*'

**Public Performance Copyright:**

Notwithstanding the general acceptance of the need for copy protection, prevention of illegal distribution, validation and authentication etc, to which DRM generally equates, and the obvious financial losses incurred by the recorded music industry, one area of digital rights management that has received comparatively little research attention is that of the collation of data and subsequent distribution of royalties from public performance licensing. 'Public Performance' is an area specifically legislated for in modern Copyright and it is potentially an important source of revenue for Copyright holders (authors and their assignees). It is for this reason alone that the music *publishing* industry exists. It should be noted in this regard that 'public performance' in terms of music publishing is quite distinct from traditional sheet music publishing.

Research into potential technologies for the protection or monitoring of public performances is quite limited in scale and scope, in comparison to the more prevalent issue of 'copy protection'. One reason for this lack of urgency is because breaches of public performance copyright are not causing any tangible financial losses to the Music Industry in the same way that illegal copying does. Indeed, the opposite may be the case, at least in some jurisdictions. It is apparent today from even the most casual observation of some royalty distribution systems that not only do incorrect royalty distributions drastically affect musicians and performers, they do so in such a way as to create the reverse effect for which the concept of Copyright was invented before eventually evolving into an economy worth more than €5Bn in Europe alone [15].

Instead of providing accurate payments to those whose works were used, thereby adding '*the inducement of private emolument*' to an author's other potential rewards, today's royalty distribution systems often penalise developing and unrepresented artists while over-compensating well-established artists, corporate publishers and copyright owners. This is perhaps why research in the area of audio coding for the monitoring of public performances such as radio and TV broadcasts is not quite as well resourced as that which deals with protection against illegal copying.

## Fingerprinting and Watermarking:

In order to understand the proposed solution to the problem of equitable monitoring of public performances for royalty distribution it is necessary to have a broad understanding of the technologies available, how they differ and to what purposes they are better suited. There are many different techniques within each sub-discipline but a broad overview is adequate for the purposes of this paper.

***Digital audio fingerprinting*** involves analysing or processing a signal in some way in order to create a set of representative data that will be used as a reference at a later date in order to compare against a new 'fingerprint' taken later, in the same manner, from a candidate signal. The two are then compared in order to see if they are from the same source, thereby identifying the candidate fingerprint as being the same as the reference fingerprint. This concept is the same as fingerprinting a person in that it is used to provide data (the reference print) that can later be used to identify whether the candidate (another print, for example taken at a crime scene) belongs to the same person from which the reference print was taken.

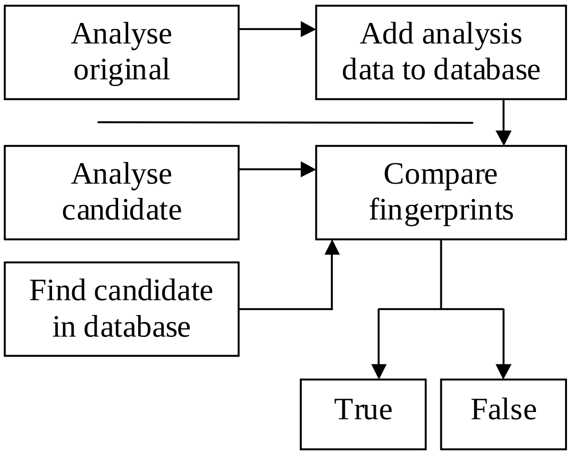


Figure 2: Basic fingerprinting scheme

Fingerprinting techniques are used to some extent in broadcast monitoring, as well as other content-identification processes, but they have some important limitations. For example, if a piece of audio is made publicly available and the content creator is not previously aware of the potential for fingerprint identification, then no fingerprint will be made available before public release. Perhaps the largest broadcast monitoring provider, Nielsen Music Control, has a database of 500,000 pieces but this is obviously not the full range of all recorded music. If the monitoring organisation has no copy of the fingerprint of a piece of audio, then it might as well not exist for the purpose of monitoring. Another problem is that of versions: if an author remixes or otherwise alters a piece after release and initial fingerprinting, then the new piece is different so its fingerprint will be different. However, perhaps the most obvious problem with fingerprinting techniques is the necessity to have a very large and continuously increasing data store of fingerprints to be able to monitor for current and future releases into perpetuity.

According to Melinda Newman, West Coast Bureau chief of Billboard magazine in 2004, *"There are about 30,000 albums released a year"*[5]. If the average album has only ten tracks, this amounts to 300,000 tracks per year, in the US alone and only by official major record labels and subsidiaries. In the UK market, figures taken from the music industry periodical '*Music Week'* indicate that there are approximately 11,000 albums released. Again, taking a conservative estimate of 10 tracks per album, this equates to 110,000 album tracks in the UK. Adding in various singles, radio edits, remixes (even disregarding live performances on TV and radio) it becomes clear that the collection of digital fingerprints from which royalty distributions are calculated is limited. Nielsen's database accounts for little over 12 months worth of *new* US and UK releases. Given that releases in different territories may be mixed and mastered differently, the limitations widen. This takes no account of the tens of thousands of artists worldwide who now release albums without the involvement of the record industry in any form.

There is no way to estimate the number of individual tracks made publicly available in a given year but it is likely to be above 500,000. Apple's *iTunes* store claims to have as many as 10 million tracks in its system [6]. Providers like *Nielsen*, it has to be said, only monitor what they are specifically requested to monitor. Since there is a cost involved owners usually only pay for the monitoring of singles released and likely to be broadcast on radio/TV – assuming they even know of the possibility. If we consider one of the world's most played tracks, Led Zeppelin's *'Stairway to Heaven'*, which was not originally released as a single, such limitations in the opt-in systems used for broadcast monitoring become more obvious.

An interesting point to note is that the PRS, the UK's performance rights agency, has agreed a deal to use data supplied by Nielsen Music Control and that this has led to an increase of accuracy of royalty distribution to 90% [7], claimed to *"double the accuracy of radio royalty payments to its members"*. While it makes sense that the majority of broadcasts are of commercial releases, and that the majority of distributions are from licenses secured from the major broadcasters, it is the final 10%, and the *'remaining smaller commercial radio stations [which] will continue to be paid by taking samples of the music broadcast throughout the year'* that are the sticking points in what is, it has to be said, a major improvement on previous systems and processes. Nevertheless, it is still the less established, less well-informed and less well resourced developing artists who will be left out of the distributions, exactly as was the case when Copyright was first legislated for. In fact, these same artists will now be even *more* likely to be impacted '*to their very great detriment and too often to the Ruin of them and their Families'*. This is because some of the money they *should* receive from occasional unreported plays on smaller broadcasters *may*, as with all sampling processes, be mistakenly distributed to the more commonly reported artists – again of the more established variety.

***Digital audio watermarking***, as would be suggested by its name, can be visualised as similar to watermarking of images by photographers to prevent or inhibit unauthorised copying and prove ownership or authentication, or watermarking of bank notes to prove validity. Generally, the purpose of the watermark is not to physically or technically prevent copying but to make unauthorised copies either of little value, or noticeably invalid.


Figure 3: Photograph watermarks are used to make unauthorised copying an unattractive option [13]

Essentially, in the case of audio watermarking, the process involves adding some form of information – the watermark – to some signal – the host – in order that it can be recovered and decoded at a later date and used to prove the authenticity or identity of the candidate presented for decoding.

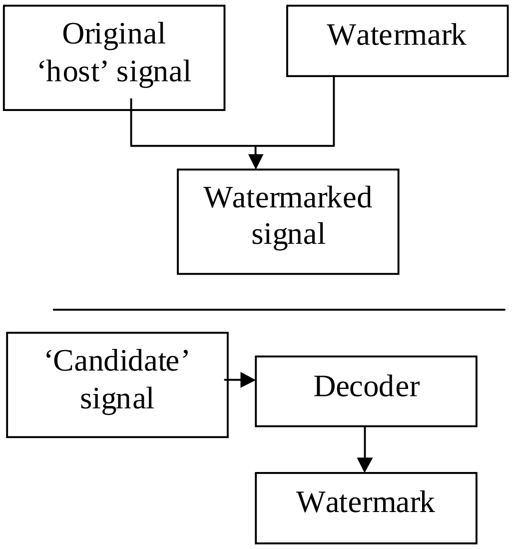


Figure 4: Basic watermarking scheme

One interesting example of the use of digital audio watermarking for authenticity verification is in the real-time watermarking of witness and defendant statements at the time of interview with the Police to prove they were not tampered with at a later date. This technique would be termed a 'fragile' watermarking scheme as the host, watermark, or both would be noticeably damaged by any form of manipulation of the watermarked audio signal, as the photograph in figure 3 would be noticeably damaged by the removal of its watermark.

Watermarking techniques can set out to address the robustness, integrity, capacity and/or transparency of the scheme to various degrees depending on the nature of the intended application. As mentioned above, a watermark intended to prove validity should alter or damage the watermarked audio in the presence of any form of attack. Other schemes might focus on one or more aspects of the watermark to the detriment of others.

For the purpose of the application of audio monitoring for identification of audio, the focus is on perceptibility (or transparency) of the watermark. This is perhaps the most important consideration for such an application domain as neither the content creator nor the listener will appreciate any perceptible degradation introduced during the process. While it might appear that security of the watermark against removal should also be a major consideration it should be noted that the domain of audio or broadcast monitoring offers no realistic advantage to broadcasters, listeners or even potential pirates by the illicit removal of the watermark and this would in fact be likely to damage the audio in terms of quality. Furthermore, by embracing and adapting watermarking, broadcasters and music creators would be addressing many of their requirements – commercial as well as legal – so it would be to their advantage to do so.

One aspect of watermarking schemes that is sometimes overlooked or otherwise relegated to an incidental consideration is the detection procedure. As mentioned earlier, digital fingerprinting only works if there is a stored set of data to which a candidate fingerprint can be compared and this is one of its major limitations, particularly for less well-informed artists. Some watermarking schemes *also* specify detection or decoding processes that require access to either the original (unwatermarked) audio or to some other related data. These are called 'informed' watermark detection and they certainly have their uses in audio watermarking. However, broadcast monitoring would not benefit from such a system to any great extent as it would suffer the same limitations as fingerprint-based monitoring.

The ideal scenario in most applications would be for decoding to be possible in the complete absence of the original audio or any information related to it, except the knowledge that it actually has a watermark. This is called 'blind decoding'. A realistic compromise exists whereby the decoder might have access to some information *relating to* the host audio or the watermark. This is called 'semi-blind decoding'. An extension to this is the case where there is no prior knowledge of the original host audio, nor of the watermark itself, but there is known information relating to the watermarking process. This is also a form of 'semi-blind decoding' but it is perhaps more useful. In the case of a transparent, standardised watermarking technique, using standard pre-defined input values, the decode process could, indeed, become 'almost blind'.

**Overview of the proposed system:**

The basic concept of this proposed system is that of amplitude modification to take advantage of the limitations of human hearing. Much research has been done into the operations and limits of the Human Auditory System and this research has led to various new technologies including the ubiquitous MP3 audio format that has led to the proliferation of personal digital music players. These were made possible by the fact that audio in compressed MP3 format sounds almost exactly the same to people – especially if it is high bitrate MP3 - as uncompressed digital audio on a normal music CD

How is this achieved? The technical complexity of the MP3 standard and of the Human Auditory System is beyond the scope of this document but the interested reader is directed to [3] and [4]. The pertinent points to note from the research into the way humans hear is that there are certain limitations in how our ears, and then brain, process sounds. We are bombarded all day every day by sounds, most of which are either below or above the limits in the range of our hearing, which varies from 20Hz at the lower bound and 20Khz at the upper bound. Most people have a hearing range in the 100Hz to 16Khz range and it deteriorates with age.

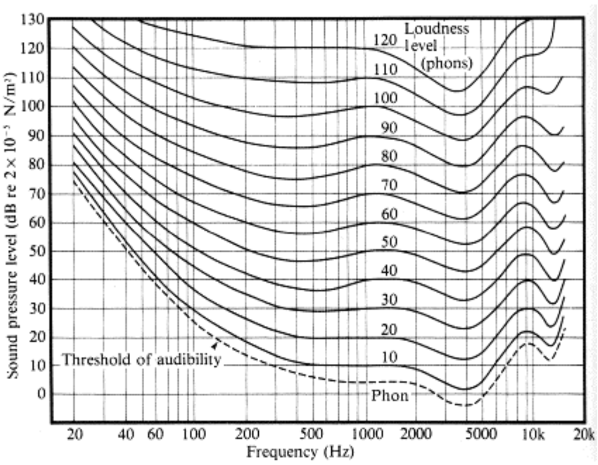


Figure 5. A graph representing the absolute lowest threshold of human hearing [18]

Note from figure 5 that the sound pressure level (intensity in decibels) required to hear frequencies in the range 100Hz to about 14 - 15Khz are comparatively low, making this the most effective hearing range for humans. These values are subjective and some people are outside the ranges specified but it would be very rare that any listener would be able to detect a sound containing only frequency components at a level below their respective absolute hearing threshold above. Readers can calculate their own 'loudness curves' with an online tool at [18] along with decent audio equipment.

We are also continuously filtering which sounds are processed and which are not. In this regard, one sound in the presence of another might be undetectable by humans if the second sound is very loud. Put simplistically, consider a live concert where the vocalist may not be completely audible because his or her 'sound' is drowned out by louder sounds such as electric guitar and drums. This happens because the auditory system reacts more to the louder (higher amplitude) sounds than to quieter sounds. The vocals are there, we just cannot hear them. This knowledge of 'amplitude masking' can be used to manipulate the amplitudes of some frequencies of a given signal so that the human auditory system cannot detect them in the presence of others.

In the proposed scheme, we design a process that takes in a signal (a music track, for example) and modifies selected frequencies in such a way that their relationship to each other is controlled. Put simply, two frequencies are modified so that they can represent a desired bit sequence as follows:

- *If the bit to be encoded is a '0', then frequency A is set to be higher than frequency B.*
- *If the bit to be encoded is a '1', then frequency B is set to be higher than frequency A.*

Both sets of frequencies are also controlled in amplitude against the overall amplitude of the section (frame) of the audio that they are in. In this way, a continuously varying pair of frequencies in relation to each other can be manipulated so long as they are kept at a low enough amplitude in relation to the rest of the audio frequencies in that particular frame, meaning they will be 'masked' by louder sounds and this leads to them being undetectable.

## Embedding data in the audio:

The embedding is achieved, as mentioned, by amplitude modification. Instead of actually adding a second signal to represent the watermark to the host audio, we modify the power of two frequencies within the host signal so they have a controlled relationship to each other and we repeat this process in a sequential pattern that matches the pattern of the 1/0 bits that we want to embed. In this manner we can embed any form of data within the audio. In the current work, we modified the frequencies to represent a bit sequence that identifies the artist and title of the track, but it could be any type of information. In the music industry, all audio that is publicly released has a unique identifier called the International Standard Recording Code (ISRC) which is based on an ISO standard (ISO 3901:2001) and it would make sense to embed that identifier into the audio as it allows for easy and consistent identification of the ownership of the audio under consideration.

There are interesting considerations that were discovered during the research, such as the effect of pre-existing components at the frequencies we chose to embed at. In order to circumvent any situation where such pre-existing frequency components might corrupt the power ratios between chosen frequencies, we first remove the components by using a 'notch filter', which leaves the remainder of the signal intact. We then have a 'hole' in which the components can be re-added at the desired ratios. Because we are only removing and then re-filling a small segment of the frequency spectrum the likelihood of this being detectable is limited.

## Decoding the watermark:

When decoding the audio, it is only necessary to know the two frequencies that are being used. We can then perform continuous time-slice analysis of these frequencies in order to see how they relate to each other. If frequency A is 'louder' than frequency B, then a '0' bit is assumed. Conversely, if frequency B is 'louder' than frequency A, then a '1' bit is assumed. Once we have performed the analysis on a specified length of the audio signal, we have a complete pattern of bits that can then be re-constructed to reveal the original message.

In the scenario outlined above, whereby the information embedded into the audio is some form of unique identification code, the user would then need to access the holder of the database of these numbers in order to find the identification of the Copyright owner (these registrars exist for each Country). However, in the case that some other data was embedded in the audio, all that would be needed in order to decode this information would be the base frequency from which the two frequencies used to embed the data are derived. Therefore, both these decoding systems would work as a form of semi-blind decoding.

## Experimental results:

Having performed thousands of experiments on hundreds of tracks using dozens of variations in experimental criteria, the system was able to repeatedly decode the embedded watermark, with no access to the watermark data or the original host audio, in 99.4% of cases. The music used for testing was varied in both age and genre, from Irish traditional, to Punk; from Rock to Pop. All experiments were performed on audio using a sampling rate of 48 KHz, which is better resolution than CD quality (44.1 KHz)

In order to achieve these test results, every track was embedded with its own title. The decode process recovered the embedded information and compared it to the track's title. Where there was a perfect match, with no variations whatsoever, this was scored as a successful decoding. Otherwise, even with only minor errors, this was considered unsuccessful. This method was chosen deliberately so as to avoid false positives which, in a real world implementation, would lead to the royalties of one track being allocated to a different track: exactly the scenario we attempted to address.

The table below illustrates the accuracy of the system, using various encode and decode parameters. The parameters in question are referred to in the column headings as follows:

*F = Base frequency from which the two embedding frequencies are derived.*

*L = Length in milliseconds of the tone embedded to represent each bit.*

The number of files decoded to provide the result is also shown. Note that the most successful combination of 9500 Hz and 25 milliseconds was applied to 694 tracks and correctly decoded 690 times. As an aside, the unsuccessful tracks contained comparatively large areas of low frequency components: for example, human speech.

| Decode Accuracy by Frequency / Tone Length | | | |
|---|---|---|---|
| **Accuracy (%)** | **Frequency (Hz)** | **Tone (ms)** | **Files decoded** |
| 99.42 | 9500 | 25 | 694 |
| 99.14 | 9000 | 25 | 694 |
| 99.13 | 9500 | 30 | 694 |
| 99.13 | 9000 | 25 | 347 |
| 98.27 | 9500 | 20 | 347 |

Table 1: A subset of results from the encoding and decoding of watermarked audio, in order of accuracy.

As can be seen, it transpires that the base frequency of 9500 Hz gives the highest chance of successful decoding – for the given sample set at least - but this is also dependent to a greater or lesser extent on watermark tone length. Over a large subset of the 10 million-plus examples of available material, there are obviously going to be variations in the success and failure of accurate decoding depending on contributory factors such as the previously mentioned effect of predominantly low frequencies. Further investigation would be required to be able to dynamically adapt the technique to cover all possible frequency content. Notwithstanding this, an accuracy rate of over 99% is encouraging for the technique

The capacity of the system is reliant on the length of the watermark tone chosen to be embedded to represent each bit. For example, the first test set represented above, the tone was 25 milliseconds long. This equates to 4825 ms (or 4.825 seconds) for each loop of the watermark. This figure is calculated as: 8 bits per character * 12 characters in the ISRC code * 2 for inter-character separation tones + 1 as a start signal * 25 for tone length. The actual data embedded is only 96 bits of the total of 193 bits in the watermark. Therefore, the capacity is 96 bits per 4.825 seconds or approximately 20 bits per second. Increasing the watermark tone length will decrease the capacity with no appreciable gain in accuracy, while decreasing the tone length increases the capacity but with some degradation in accuracy. However, by altering other contributory factors, it may be possible to double the capacity without dramatically affecting decode success rates. Follow-up experiments have suggested watermark tone lengths in the region of 15 ms to 20 ms might prove optimal, and more work is ongoing.

**Does accurate royalty distribution matter?**

Apart from the matter of the principle of the equitable nature of Copyright administration, the current lack of an easily accessible, open and transparent broadcast monitoring system is leading to loss of earnings for those authors and artists who, not only are most likely to need this income, but are those for whom Copyright was invented: those who are being adversely affected often "*to their very great detriment and too often to the Ruin of them and their Families*". Or, at least, their careers.

Furthermore, these are the authors and artists who are most likely to agree with the statement in the aforementioned 1744 judgement: '*literary works, like all others, will be undertaken and pursued with greater spirit, when, to the motives of public utility and fame, is added the inducement of private emolument*'

A developing artist is much more likely to notice the effect of losses for their efforts while, conversely, more established and therefore less vulnerable artists would notice the effect less. If a system was weighted against the established artists, they would at least have the resources, support and/or knowledge of this problem and deal with it appropriately. Developing artists not only do not have the financial resources to address these issues, they are often not aware of them. One artist, who was twice nominated for the 'Choice Music Prize, Irish Album of the year' award and would therefore be presumed to have a comparatively high radio and TV profile in the territory, was unaware of the fact that their public performances were going almost completely unpaid for[19].

It is necessary to understand how public performance monitoring is currently undertaken, in order to understand the implications of incomplete and/or inaccurate data being collected. The synopsis outlined herein applies to the Irish jurisdiction but there is every reason to believe that each jurisdiction has similar or related limitations. The relationship between Nielsen and the PRS in the UK would suggest that while the issue is being addressed, it is still a considerably incomplete system even in the UK.

Performance rights societies act as the agents for authors and performers in the administration of their public performance rights. Broadcasters submit their play data to these agents and, in turn, they then allocate the money generated in licensing deals with these broadcasters according to the play data received. Royalties may be allocated on a per-play basis, a per-second basis, a per-audience basis or on any combination of these. In most cases, the data received is considered complete and royalties are distributed accordingly.

The data is provided in some cases by outputting a log of music played from a computerised broadcast environment. There is also a requirement for broadcasters to manually submit data relating to other, non-computerised plays. Notwithstanding the equipment that is used in modern broadcasting environments, not all music is computerised. Specialist shows still use the simple CD as their format for content. As a matter of interest, on the day of completion of this paper, Ireland's biggest commercial radio station (Today FM) was broadcasting material from 7" vinyl [20]. Finally, not all broadcasters have computerised audio storage and broadcast equipment and rely completely on CDs.

Another issue is what happens to royalties for audio that is broadcast but for whom the owner cannot be identified for one reason or another. This is a surprisingly common issue and it is reasonable to believe that a disproportionate amount of this unidentified broadcast material is the property of developing or otherwise ill-informed artists, simply because they are not identifiable. Any money not specifically allocated to a copyright owner is eventually added back to a 'pool' of revenues which is then distributed according to the play list data provided by the larger national broadcasters. By definition, these outlets are likely to be broadcasting artists of national and international stature. Therefore, the revenues that should be distributed to developing artists will end up, in most cases, being distributed to established and well-known artists even though it is obviously not rightfully theirs: if it was, it would not be unidentifiable.

It is the legal duty of the broadcaster to provide a full set of play data while it is also the legal and moral duty of the performance rights society to ensure they have a complete and accurate set of data. In some cases, however, no attempt is made to secure such a complete set of data and, instead, a sample is used to extrapolate a full set of play data. In the case of some broadcasters, the data from a two day period might be used to extrapolate data for a full month. This obviously means that material broadcast for all but two days of the month will be ignored, while that material broadcast on *only* the two days for which data is collected will be paid as much as 15 times their rightful royalty. Given that developing artists are unlikely to have their works on a station playlist on auto-rotation or on a computerised system (as they are not well-known enough to be automatically play-listed), then the scope for loss is quite substantial. The scope for external pressure being brought to bear on broadcasters to playlist a track during the sampling period is also great and the dangers obvious.

The cost of pursuing an artistic career is by its very nature impossible to predict. However, what is not difficult to accept is that in any business, if a service provider is not being paid for their services, then they are less likely to succeed in their business ventures, particularly a self-employed provider. A career in the music industry is no different. Without income, no business can survive. So it is that, in the absence of a complete and accurate broadcast monitoring system, many artists simply do not receive their just rewards, do not have the income to re-invest in their business and simply give up. Some continue but never achieve the success levels they could, if they had an adequate income. Others get frustrated by apparently achieving nothing financially, no matter what their hard work might suggest. The net result is a loss of income and a loss of talent caused by the inequitable nature of current public performance royalty distribution systems. They find themselves back in the same predicament as those early authors for whom Copyright was invented: They do not see the '*private emolument*' that should act as a motivator to reward them and encourage them to continue their career.

One artist, who provided us with data[19] relating to broadcasts that were monitored using the Nielsen Music Control fingerprinting technique mentioned earlier, was able to show that they had more than 500 confirmed broadcasts on Irish radio alone in the year 2008 but received no royalties. It is estimated, based on royalty distribution rates from 2005 that the revenue this artist should have accrued from these broadcasts would have been adequate to finance and promote a series of releases which may or may not have generated additional sales, additional exposure and even additional broadcast opportunities which would, of course, repeat the process by generating more public performance royalties.

**Conclusion:**

There is no question that the current system for reporting public performances is inadequate for the administration of public performance royalties in the modern music publishing industry. In a sector worth more than €5Bn annually in Europe alone (and growing in size as well as importance), modernisation towards a more equitable system is certainly achievable and even advisable. Moreover, for the continued development of the 'Economy of Culture', as well as the continued attraction of developing a career in this area, the existing systems should be encouraged to trend towards a fairer distribution of royalties to properly reward creators of artistic works.

In the current climate of economic doom in the music industry, it might appear counter-productive to suggest that the way to reinvigorate the industry is to redesign the system so that some of the revenue that is currently being paid in royalties to the large, established participants is diverted instead to the developing artist. However, even disregarding the simple moral obligation for performance rights societies to perform their duties equitably, if we examine the implication of the fact that Copyright has a limited lifespan, it soon becomes obvious that the developing artist of today is the established artist of tomorrow, while the established artist of today is the out-of-copyright artist of tomorrow.

The system outlined in this paper would enable the open, transparent and equitable administration of public performance royalty distribution across all transmission channels, including traditional analogue radio. It would facilitate the design of an almost-blind detection phase which would allow for decoding of the watermark without any reference to the original unwatermarked host audio or the watermark itself. While it would be possible to watermark any data into the signal, the proposed system utilises the ISRC code in order to expedite identification of the audio. This would remove the need for any store of reference data since the ISRC code and related data are already stored in simple databases by each Country's registrar, and are centrally accessible.

Decoding in an almost-blind detection environment has yielded success rates of more then 99% over thousands of experiments. Capacity of the system varies between approximately 16 bits per second and 30 bits per second, depending on tone length chosen.

**Future work:**

We intend to undertake further investigation of appropriate frequencies for use in the embedding phase. Analysis of the performance of the technique after common interference and attacks, including D/A – A/D processes, MP3 and similar compression, noise interference, broadcast channel interference etc is also planned.

Design and testing of a more accurate and effective dynamic psychoacoustic based embedding technique is also ongoing in order to minimise any possibility of audible artefacts being created by the embedding process that would make the watermarked audio noticeably different from the original.. Extended development of the decoding process into a completely blind process is also a future research area and this would make the system ideal for the given environment.

**Acknowledgements:**

The following artists provided access to private income-related data and industry correspondence which was used to evaluate the effectiveness of existing public performance royalty collection and distribution systems: **Suddyn, Marz Roche, DeXtra, Jaded Sun**

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