# Detecting Replay Attacks Using Single-Channel Audio: The Temporal Autocorrelation of Speech

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*Abstract*—In this paper, we propose to use the temporal autocorrelation of single-channel speech as a new feature for replay detection. Visual comparisons show that the proposed feature distinguishes replay attacks from clean speech and speech with simulated reverberation. Experimental results on the ASVspoof 2019 physical access database show that the proposed feature contains crucial information against replay attacks and that using the proposed feature in a fusion system almost always leads to performance improvements. Furthermore, our best fusion system achieves equal error rate and minimum tandem detection cost function of 0 on the development set for the first time.

#### I. INTRODUCTION

Replay detection has been greatly improved with the help of deep learning technology over the past few years [1]–[4]. In the Automatic Speaker Verification Spoofing and Countermeasures Challenge (ASVspoof) in 2017 [2] and 2019 [3], [4], it was shown that appropriate neural network architectures can effectively construct countermeasures against replay attacks. Various studies have shown that replay detection systems that use time-frequency representation of speech as input feature perform better than systems that use single frames as input feature. In these state-of-the-art systems, correlations between speech features and replay attacks are found in time-frequency representations, which are not visible in a single frame [5], [6].

Replay attacks are a convenient way to bypass authentication by exploiting vulnerabilities in Automated Speaker Verification (ASV) systems. Since 2017, ASVspoof has introduced replay attacks in the challenge [2]. In 2019, the challenge was further divided into the logical access scenario, including spoofing attacks generated by speech synthesis and voice conversion, and the physical access scenario, including replay attacks using simulated replay speech [3]. In contrast to speech synthesis and voice conversion, which require adjusting the model to mimic the voice of a known target speaker as closely as possible, replay attacks can attack ASV systems by simply replaying the target speaker's voice [4].

The classical way to detect replay attacks is to use the Gaussian mixture models (GMMs). GMM-based replay detection systems can be found in the baseline systems of ASVspoof2017 [2] and ASVspoof 2019 [3]. These systems use GMMs to evaluate whether a single frame from the time-frequency representation of speech contains a replay attack, and then averages the results across all frames to determine

whether the speech is a replay attack. However, such computation leads to loss of temporal information because the replay attack detection of these GMM-based systems does not consider the temporal information of speech features.

Replay detection systems built using deep learning models have achieved breakthrough performance growth in recent years [5]. It was observed in ASVspoof 2019 that significant performance gains were obtained with the help of deep learning techniques for replay detection compared to GMMbased systems [3], [4]. These advanced deep learning models for replay detection are based on ResNet model [5]–[7] or light convolutional neural network (LCNN) [8], [9] architectures, which share a common structure of employing twodimensional convolutional layers to extract and detect replay attack trajectories in time-frequency representations of speech. These models have demonstrated their effectiveness in building countermeasures against replay attacks [5]–[9].

Time-frequency representation refers to the signal representation into which speech is processed before replay detection using GMM-based systems or most deep learning modelbased systems. In general, the time-frequency representation of speech can be categorized into magnitude time-frequency representation and phase time-frequency representation. Examples of magnitude time-frequency representation include spectrogram, linear frequency cepstral coefficients (LFCCs) [9]–[11] and constant Q cepstral coefficients (CQCCs) [12], [13], and examples of phase time-frequency representation include modified group delay (MGD) [5], [6] and product spectrum cepstral coefficients (PSCCs) [14]. Researchers have effectively exploited their application in replay detection via deep learning models [5], [6], [9], [14].

Score fusion is a simple and effective method for building valid countermeasures against replay attacks [4]. Among the systems using GMMs or deep learning models combined with different time-frequency representations, each provides different insights for replay detection. To do so, each system calculates a score for the given test utterance; and by exploiting the strength of each countermeasure while complementing the weaknesses, these scores are fused to create a fusion countermeasure. Significant performance improvements are observed in state-of-the-art replay detection systems with the help of score fusion [6], [9].

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In this paper, we propose a novel feature for replay detection based on the computation of temporal autocorrelation in weighted prediction error (WPE) dereverberation [15]–[17]. In our experiments, we first implemented a state-of-the-art system for the ASVspoof 2019 physical access scenario [9]. We then examined the proposed feature from various aspects by comparing performance of single systems and fusion systems using different speech features. Experimental results confirm the contribution of the proposed feature in fusion systems. Furthermore, using the proposed feature and through score fusion, our best fusion system is able to reduce the equal error rate (EER) and minimum tandem detection cost function (mintDCF) to 0 on the development set for the first time.

The remainder of this paper is organized as follows. Section 2 reviews related studies on replay detection. Section 3 describes the proposed feature. Section 4 presents the experiments, results and discussion. Finally, Section 5 provides our concluding remarks.

# II. RELATED WORK

Replay detection systems consist of classifiers and speech features. In this section, we review classifiers and speech features for replay detection.

## A. Classifiers

1) Gaussian Mixture Model: GMM-based classifiers are a classical approach to build replay detection systems [2], [3], [12]. The classical approach is to determine the replay detection result by the likelihood of the given test utterance containing a replay attack and the likelihood of the given test utterance not containing a replay attack. The score for the given utterance is calculated as the ratio of two likelihoods [12], and then is used to determine whether the utterance is calculated by averaging the likelihoods of all frames, the GMM does not exploit the temporal information of speech features. Therefore, we believe that such an architecture would result in limited performance for replay detection.

2) Deep Learning Model: Classifiers based on deep learning models are state-of-the-art for building replay detection systems [7]. Unlike GMM-based replay detection classifiers, deep learning model-based replay detection classifiers generally only need one deep learning model to detect replay attacks in speech, and most deep learning model-based classifiers use the time-frequency representation of speech instead of single frame as input feature [5]–[9]. It has been observed that most deep learning model-based classifiers incorporate twodimensional convolutional layers in their deep learning model architectures, while taking the time-frequency representation of speech as the feature for the classifier. Comparison with GMMbased classifiers, this architecture can leverage both the temporal and spatial information of the time-frequency representation of speech to identify the association of specific regions in the time-frequency representation with replay attacks [5], [6].

# B. Speech Features

1) Magnitude: Magnitude information is a classical feature representation of speech for speech processing applications. Most speech features are created using the Fourier transform, where the speech waveform is transformed from real numbers to complex numbers, i.e., the spectrum, and the magnitude information of speech is the absolute value of the spectrum. Various algorithms and techniques have been developed to exploit the magnitude information of speech for different speech applications, such as spectral subtraction [18], [19] and Wiener filtering [19], [20] for speech enhancement and Mel-frequency cepstral coefficients (MFCCs) for speech recognition [21]. For spoofed speech detection, LFCCs are classification robust to any type of spoofing attack [9]-[11], and the spectrogram computed with the constant Q transform (CQT) [13] exhibits excellent performance in replayed speech detection [6]-[9]. In our previous study, we have shown that the cepstrogram is another powerful feature for countermeasure against replay attacks, which is also derived form the magnitude information of speech [22].

2) Phase: Phase information is another feature representation of speech and is the argument of the spectrum. The phase information of speech was considered unimportant in various speech applications in the past, but has become an emerging field in recent years [23]–[25]. Various techniques have been applied to different speech applications to exploit the phase information of speech for better results, such as group delay [26] and product spectrum [27], [28] for speech recognition and phase spectrum compensation for speech enhancement [24], [29]. For spoofed speech detection, group delay [5], [6] and product spectrum [14] show excellent performance in replay attack detection.

## III. THE PROPOSED FEATURE

In this work, we propose a novel feature for replay detection based on the temporal autocorrelation of speech. In the following, we describe the computation of the temporal autocorrelation of speech and the method for feature construction.

#### A. Weighted Prediction Error

The general idea of WPE is to estimate the late reflections of reverberant speech, and then subtract them from the reverberant speech to obtain a valid estimate of the early part of the reverberant speech, which includes both direct speech and early reflections of reverberant speech [15]–[17]. The signal model applied in WPE is given as follow:

$$y_{c,t,f} = x_{c,t,f}^{early} + x_{c,t,f}^{tail},$$
 (1)

where  $y_{c,t,f}$  refers to the multi-channel reverberant speech presented as complex spectrograms, c denotes the channel index, t denotes the frame index, f denotes the frequency bin channel, and  $x_{c,t,f}^{early}$  and  $x_{c,t,f}^{tail}$  represent the early part and late reverberation of the reverberant speech, respectively.

The procedures for performing WPE on a reverberant speech are given as follows:

$$\lambda_{t,f} = \frac{1}{(\delta+1+\delta)C} \sum_{\tau=t-\delta}^{t+\delta} \sum_{c} |x_{\tau,f,c}^{early}|^2, \qquad (2)$$

$$R_f = \sum_t \frac{\tilde{y}_{t-\Delta,f} \tilde{y}_{t-\Delta,f}^H}{\lambda_{t,f}},$$
(3)

$$P_f = \sum_t \frac{\tilde{y}_{t-\Delta,f} y_{t,f}^H}{\lambda_{t,f}},\tag{4}$$

$$\mathbf{G}_f = R_f^{-1} P_f, \tag{5}$$

$$\hat{x}_{t,f}^{early} = y_{t,f} - \mathbf{G}_f^H \tilde{y}_{t-\Delta,f}, \tag{6}$$

where  $\hat{x}_{t,f}^{early}$  refers to the estimation of clean speech,  $\mathbf{G}_f$  represents the prediction filter, and  $\lambda_{t,f}$  denotes the time-varying variance.

## B. Replay Detection With Temporal Autocorrelation of Speech

Figs. 1 and 2 present the spectrograms and the prediction filters of clean speech, bona fide trial, and spoofed trial. The bona fide trial is the clean speech with simulated reverberation. The spoofed trial is generated from the bona fide trial with replay attacks. We use these two figures to show how simulated reverberation and replay attacks are revealed in the spectrogram and prediction filters. The spectrogram of clean speech is blurred by simulated reverberation, as shown in Fig. 1 (b), and further smeared by replay, as shown in Fig. 1 (c). WPE is an effective multi-channel dereverberation technique that reduces speech recognition errors for reverberant speech [21]. Estimation of prediction filters in WPE involves computing the temporal autocorrelation of speech and the spatial autocorrelation of audio channels at the same time. Since replay attacks form reverberation in spoofed speech, we are inspired to use the prediction filters, i.e., the temporal autocorrelation of speech, as a feature for replay detection. The temporal autocorrelation of speech in single-channel audio does clearly reveal replay attacks, as shown in Fig. 2 (c).



Fig. 1. The spectrograms in the log1p (natural logarithm of (1 + input)) scale [30]: (a) the original clean speech sample p262\_227 from VCTK [31], (b) the bona fide trial PA\_D\_0004063 with simulated reverberation, and (c) the spoofed trial PA\_D\_0024255.





Fig. 2. The prediction filters in the log1p (natural logarithm of (1 + input)) scale [30]: (a) the original clean speech sample p262\_227 from VCTK [31], (b) the bona fide trial PA\_D\_0004063 with simulated reverberation, and (c) the spoofed trial PA\_D\_0024255.

## IV. EXPERIMENTS AND RESULTS

Our experiments were conducted on the ASVspoof 2019 physical access scenario using models with the same LCNN architecture but different features. We implemented the model of the team T45 [9] in the ASVspoof 2019 challenge [3], as this architecture showed its effectiveness against replay attacks in ASVspoof challenge [4], [8], [9]. The configuration of the dropout layers in the model is not specified in the corresponding paper [9]. We only performed one dropout on the flatten layer to prevent overfitting. For more details on our implementation, please visit our repository<sup>1</sup>.

### A. Baseline Systems

Table I shows the performance of Team T45's systems (upper four rows) and the performance of our self-implemented systems (lower four rows). In our implementation, the speech features used in LFCC-LCNN and CQT-LCNN are LFCCs and CQT-based logarithmic power magnitude spectrogram (CQTgram), which were obtained with the code from the baseline system provided by the challenge organizer<sup>2</sup>, and the default setting is used. This default setting was also used in Team T45's system [9]. LFCCs were extracted using a Hamming window of 20 ms length, 512 FFT bins, and 20 filters. CQTgram was extracted with 96 bins per octave. The speech feature used in DCT-LCNN was obtained with our own code. We followed the configuration of Team T45's DCT-LCNN system; the magnitude spectrogram was extracted by discrete cosine transform (DCT) with a Blackman window of length 863 and frame shift of 128. For each single system (CQT-LCNN, LFCC-LCNN, and DCT-LCNN), the model was separately trained on the training set, selected based on the results on the development set, and evaluated on the evaluation set. The fusion system was achieved by summing the scores of the single systems for each trial [9]. The results were presented in terms of EER and min-tDCF [32], which are the metrics used in the ASVspoof 2019 challenge [3]. From Table I, we can see that the performance of our self-implemented systems is comparable to or better than the performance of the corresponding T45 systems.

## B. Performance of Single Systems

Table II shows the performance of our implemented single systems using different features. The first three systems are the same as those in Table I. The speech features used in Spec-LCNN and Spec1724-LCNN were magnitude spectrograms extracted via fast Fourier transform (FFT) with different configurations; Spec-LCNN used a Blackman window of length 1024 and frame shift of 128, and Spec1724-LCNN used a Blackman window of length 1724 and frame shift of 128. The speech features used in Ceps-LCNN and Ceps1724-LCNN were cepstrograms [22] derived by DCT from the

TABLE I

Performance comparison of Team T45's systems (reported in [9]) and our self-implemented systems. All systems were implemented using the same LCNN architecture.

	Dev		Eval		
System	tDCF	EER	tDCF	EER	
CQT-LCNN [9]	0.0197	0.800	0.0295	1.23	
LFCC-LCNN [9]	0.0320	1.311	0.1053	4.60	
DCT-LCNN [9]	0.0732	3.850	0.560	2.06	
Fusion [9]	0.0001	0.0154	0.0122	0.54	
CQT-LCNN	0.0096	0.374	0.0130	0.514	
LFCC-LCNN	0.0145	0.519	0.0299	1.061	
DCT-LCNN	0.0385	1.444	0.0774	2.897	
Fusion	0.0014	0.057	0.0048	0.165	

TABLE II
PERFORMANCE OF SINGLE SYSTEMS USING DIFFERENT FEATURES. ALL
SYSTEMS WERE IMPLEMENTED USING THE SAME LCNN ARCHITECTURE

	Dev			Eval	
System	tDCF	EER	tDCF	EER	
CQT-LCNN	0.0096	0.374	0.0130	0.514	
LFCC-LCNN	0.0145	0.519	0.0299	1.061	
DCT-LCNN	0.0385	1.444	0.0774	2.897	
Spec1724-LCNN	0.0062	0.203	0.0263	0.917	
Ceps1724-LCNN	0.0076	0.275	0.0191	0.712	
Spec-LCNN	0.0148	0.556	0.0522	1.719	
[22] Ceps-LCNN	0.0039	0.129	0.0105	0.370	
TAC-LCNN	0.0863	3.152	0.1560	5.882	

magnitude spectrograms used in Spec-LCNN and Spec1724-LCNN, respectively. The temporal autocorrelation of speech used in TAC-LCNN was calculated from a complex spectrogram, which was computed using the same configuration as the spectrogram used in Spec-LCNN and Ceps-LCNN. We used an open source implementation of WPE dereverberation [17] to compute prediction filters as the speech feature. We applied the parameter settings used in CHiME-6 [21] except for the value of taps. Following the configuration in [21], the delay was set to 2, the iterations was set to 3, the psd\_context was set to 0, the statistics\_mode was set to full, and the value of taps was extended from 10 to 16 to fit the LCNN architecture. The results in Table II show that the TAC-LCNN single system using the temporal autocorrelation feature performs worse than single systems using other features. Although this result is disappointing, in subsequent experiments, we will confirm that the temporal autocorrelation feature, combined with other features, can improve the performance of fusion systems.

# C. Performance of Fusion Systems

Tables III and IV present the performance of our implemented fusion systems. In Table III, the fusion systems combined Spec-LCNN and/or Ceps-LCNN, while in Table IV, the fusion systems combined Spec1724-LCNN and/or Ceps1724-LCNN. We aimed to examine the proposed feature from various aspects. All fusion systems used the same score fusion strategy as the fusion systems in Table I. In Table III, because the same windowing configuration for spectrogram extraction was used in TAC-LCNN, Spec-LCNN, and Ceps-LCNN, the

<sup>&</sup>lt;sup>1</sup>https://github.com/shihkuanglee/RD-LCNN

<sup>&</sup>lt;sup>2</sup>https://www.asvspoof.org/asvspoof2019/ASVspoof\_2019\_baseline\_CM\_ v1.zip

TABLE III Performance of various fusion systems incorporating TAC-LCNN.

System         DCF         EER         DCC         EER         DCF         EER           CT         0.0086         0.314         0.0130         0.513           LFCC         0.0086         0.312         0.0150         0.513           TAC+LFCC         0.0086         0.312         0.0174         2.854           DCT         0.0385         1.444         0.0174         2.857           TAC+DCT         0.0189         0.556         0.0522         1.711           TAC+Spec         0.0039         0.129         0.0105         0.330           CQT+LFCC         0.0032         0.112         0.0105         0.330           CQT+LFCC         0.0032         0.116         0.0175         0.339           CQT+LFCC         0.0026         0.111         0.0475         0.339           CQT+LFCC         0.0024         0.109         0.0043         0.149           TAC+CQT+LFCC         0.0022         0.109         0.0074         0.254           LFCC+DCT         0.0022         0.109         0.0076         0.289           CQT+Ceps         0.0017         0.076         0.289         0.221           LFCC+Apee         0.0017         0.076 <th></th> <th>De</th> <th>ev</th> <th colspan="4">Eval</th>		De	ev	Eval			
CCT         0.0098         0.374         0.0130         0.514           LFCC         0.0088         0.349         0.0157         0.547           DCT         0.0135         1.444         0.0774         2.897           TAC+DCT         0.0179         0.682         0.0436         1.741           Spec         0.0148         0.556         0.0522         1.719           TAC+DCT         0.0032         0.129         0.0005         0.330           CQT+LFCC         0.0032         0.127         0.0096         0.333           CQT+LFCC         0.0032         0.166         0.0079         0.283           TAC+CQT+LFCC         0.0032         0.166         0.0079         0.283           CQT+DCT         0.0032         0.168         0.0194         0.0349         0.157           TAC+CQT+Spec         0.0021         0.111         0.0063         0.159         0.379           CQT+Ceps         0.0021         0.133         0.0122         0.514           TAC+CQT+Spec         0.0017         0.076         0.283           LFCC+DCT         0.0022         0.0094         0.0025         0.215           DCT+Spec         0.0017         0.075	System	tDCF	EER	tDCF	EER		
IAC+CQ1         00088         0.349         0.0150         0.0131           LFCC         0.00668         0.312         0.0157         0.547           DCT         0.0385         1.444         0.0774         2.897           TAC+DCT         0.0099         0.353         0.0325         1.741           Spec         0.0099         0.353         0.0325         1.161           TAC+Cpr         0.0032         0.127         0.0096         0.323           CQT+LFCC         0.0032         0.118         0.0079         0.323           CQT+LFCC         0.0024         0.109         0.0098         0.325           CQT+Spec         0.0021         0.113         0.0122         0.514           CQT+CPS         0.0024         0.109         0.0098         0.325           CQT+Spec         0.0021         0.131         0.0122         0.514           CAC+CQT+Spec         0.0021         0.138         0.0098         0.321           CAC+CQT+CPS         0.0017         0.057         0.0033         0.149           TAC+CQT+CPS         0.0017         0.078         0.0076         0.282           LFCC+DCT         0.0022         0.103         0.0076 <th>CQT</th> <th>0.0096</th> <th>0.374</th> <th>0.0130</th> <th>0.514</th>	CQT	0.0096	0.374	0.0130	0.514		
LFCC         0.0145         0.519         0.0219         1.061           TAC+LECC         0.0068         0.312         0.0157         0.547           DCT         0.0385         1.444         0.0436         1.741           Spec         0.0039         0.129         0.0325         1.017           TAC+Spec         0.0039         0.129         0.0155         0.330           CQT+LFCC         0.0032         0.117         0.0096         0.330           CQT+DCT         0.0048         0.205         0.0111         0.475           TAC+CQT+DCT         0.0048         0.205         0.0111         0.475           CQT+Spec         0.0024         0.109         0.0098         0.329           CQT+CPs         0.0024         0.094         0.0043         0.154           LFCC+DCT         0.0024         0.097         0.283         0.168           LFCC+Spec         0.0024         0.097         0.283         0.154           LFCC+Spec         0.0020         0.078         0.0076         0.289           CQT+Ceps         0.0017         0.057         0.0062         0.238           LFCC+Spec         0.0017         0.057         0.0062	TAC+CQ1	0.0088	0.349	0.0150	0.613		
TAC+LFCC         6.0068         0.312         0.0157         0.547           DCT         0.0385         1.444         0.0774         2.897           TAC+DCT         0.0179         0.682         0.0436         1.714           Spec         0.0039         0.129         0.0105         0.370           TAC+CP         0.0032         0.127         0.0096         0.330           CQT+LFCC         0.0032         0.127         0.0096         0.330           CQT+LFCC         0.0032         0.166         0.0079         0.283           CQT+DCT         0.0032         0.168         0.0111         0.475           TAC+CQT+LFCC         0.0024         0.109         0.0098         0.359           CQT+Spec         0.0021         0.1131         0.0122         0.514           TAC+QT+Ceps         0.0012         0.183         0.0089         0.321           TAC+CQT+Ceps         0.0017         0.057         0.0043         0.149           TAC+ACT+CC+DCT         0.0022         0.109         0.0074         0.254           LFCC+ACPs         0.0017         0.057         0.0052         0.2205           DCT+AC+Spec         0.0017         0.057	LFCC	0.0145	0.519	0.0299	1.061		
DCT TAC+DCT         0.0385         1.444         0.0774         2.897           TAC+DCT         0.0179         0.582         0.0436         1.741           CPD         0.0099         0.353         0.0325         1.161           CCp+LFCC         0.0037         0.166         0.0079         0.333           CCT+LFCC         0.0032         0.111         0.0063         0.216           CQT+LFCC         0.0032         0.111         0.0063         0.216           CQT+LFCC         0.0032         0.113         0.0122         0.514           CQT-Spec         0.0021         0.131         0.0122         0.514           CQT-Ceps         0.0024         0.094         0.0043         0.149           CQT-Ceps         0.0017         0.076         0.282           LFCC-DCT         0.0022         0.109         0.0076         0.283           LFCC+Spec         0.0017         0.076         0.0062         0.233           LFCC+Spec         0.0017         0.076         0.0082         0.282           LFCC+Spec         0.0017         0.076         0.0082         0.282           LFCC+Spec         0.0017         0.076         0.0083         0.1	TAC+LFCC	0.0068	0.312	0.0157	0.547		
TAC+DCT         0.0179         0.682         0.0436         1.741           Spec         0.0099         0.353         0.0322         1.719           TAC+Spec         0.0039         0.129         0.0105         0.370           CCP+DCT         0.0032         0.127         0.0096         0.330           CQT+LFCC         0.0032         0.121         0.0063         0.216           CQT+DCT         0.0048         0.205         0.0111         0.475           TAC+CQT+DCT         0.0048         0.205         0.0111         0.475           CQT+Spec         0.0024         0.109         0.0098         0.359           CQT+Ceps         0.0024         0.109         0.0098         0.351           LFCC+QT+CC         0.0022         0.183         0.0089         0.321           TAC+ECC+Ceps         0.0017         0.076         0.0283         0.154           LFCC+Spec         0.0017         0.076         0.0284         0.199         0.0074         0.282           LFCC+Spec         0.0017         0.076         0.0286         0.232         0.035         0.0376         0.283           LFCC+Ceps         0.0017         0.077         0.0275         <	DCT	0.0385	1.444	0.0774	2.897		
Spec TAC+Spec         0.0148 0.0099         0.353 0.0325         0.1719 0.0105         0.1719 0.0105           CQT+LFCC         0.0032         0.127         0.0096         0.330           CQT+LFCC         0.0032         0.127         0.0096         0.283           CQT+LFCC         0.0032         0.111         0.0063         0.216           CQT+LFCC         0.0021         0.111         0.0063         0.216           CQT+Spec         0.0021         0.131         0.0122         0.514           TAC+CQT+DCT         0.0024         0.004         0.0043         0.154           TAC+CQT+Ceps         0.0021         0.118         0.0089         0.321           TAC+LFC+Ceps         0.0022         0.109         0.0076         0.282           LFCC+Spec         0.0017         0.076         0.082         0.228           LFCC+Spec         0.0017         0.076         0.082         0.228           DCT+Spec         0.0017         0.076         0.024         0.042         0.148           TAC+LFCC+Ceps         0.0017         0.077         0.0255         0.951         0.0017         0.076         0.232           DCT+Spec         0.0017         0.074         0	TAC+DCT	0.0179	0.682	0.0436	1.741		
TAC+Spec         0.0099         0.353         0.0325         1.161           Ceps         0.0032         0.129         0.0105         0.330           CQT+LFCC         0.0027         0.166         0.0079         0.163           CQT+LFCC         0.0032         0.166         0.0079         0.168           CQT+DCT         0.0032         0.168         0.0115         0.359           CQT+Ceps         0.0021         0.131         0.0122         0.514           TAC+CQT+DCT         0.0024         0.019         0.0039         0.351           CQT+Ceps         0.0021         0.131         0.0103         0.149           TAC+CQT+Ceps         0.0024         0.019         0.0073         0.282           LFCC+DCT         0.0022         0.109         0.0073         0.282           LFCC+DCT         0.0022         0.109         0.0074         0.254           TAC+LFCC+Spec         0.0017         0.057         0.0062         0.289           LFCC+Spec         0.0017         0.057         0.0052         0.205           DCT+Spec         0.0101         0.014         0.0066         0.242           TAC+LFCC+Spe         0.0011         0.074	Spec	0.0148	0.556	0.0522	1.719		
Ceps         0.0039         0.129         0.0105         0.370           TAC+Ceps         0.0032         0.127         0.0096         0.330           CQT+LFCC         0.0037         0.166         0.0079         0.283           TAC+CQT+LFCC         0.0026         0.111         0.0155         0.338           CQT+Spec         0.0024         0.109         0.0098         0.359           CQT+Spec         0.0024         0.109         0.0098         0.359           CQT+Ceps         0.0024         0.109         0.0098         0.359           CQT+Ceps         0.0024         0.094         0.0043         0.154           LFCC+QT+Ceps         0.0021         0.094         0.0043         0.154           LFCC+Spec         0.0017         0.076         0.0289         0.2282           LFCC+Spec         0.0017         0.076         0.0289         0.2281           DCT+Spec         0.0017         0.076	TAC+Spec	0.0099	0.353	0.0325	1.161		
TAC+Ceps         0.0032         0.127         0.0005         0.330           CQT+LFCC         0.0032         0.111         0.0063         0.216           CQT+LFCC         0.0032         0.111         0.0063         0.216           CQT+DCT         0.0048         0.2025         0.0111         0.475           TAC+CQT+DCT         0.0048         0.2024         0.0109         0.0398           CQT+Spec         0.0021         0.131         0.0122         0.514           TAC+CQT+Spec         0.0021         0.013         0.0038         0.321           TAC+CQT+Ceps         0.0022         0.109         0.0073         0.282           LFCC+DCT         0.0022         0.109         0.0074         0.284           LFCC+Spec         0.0017         0.076         0.082         0.238           LFCC+Spec         0.0017         0.076         0.0022         0.025         0.025           DCT+Spec         0.0107         0.076         0.0256         0.951           DCT+Ceps         0.0014         0.057         0.0026         0.232           DCT+Ceps         0.0014         0.057         0.0028         0.141           DCT+Ecps         0.0014	Caps	0.0030	0.120	0.0105	0.370		
$\begin{array}{c ccccc} CQT+LFCC & 0.0037 & 0.166 & 0.0079 & 0.283 \\ TAC+CQT+LFCC & 0.0048 & 0.205 & 0.0111 & 0.0063 & 0.216 \\ CQT+DCT & 0.0048 & 0.205 & 0.0111 & 0.475 \\ TAC+CQT+Spee & 0.0021 & 0.168 & 0.0105 & 0.398 \\ CQT+Spee & 0.0021 & 0.168 & 0.0105 & 0.398 \\ CQT+Ceps & 0.0024 & 0.109 & 0.0098 & 0.359 \\ CQT+Ceps & 0.0024 & 0.004 & 0.0043 & 0.149 \\ TAC+CQT+Cep & 0.0017 & 0.057 & 0.0043 & 0.154 \\ LFCC+DCT & 0.0042 & 0.109 & 0.0073 & 0.282 \\ LFCC+CPC & 0.0022 & 0.109 & 0.0073 & 0.282 \\ LFCC+Ceps & 0.0020 & 0.078 & 0.0076 & 0.289 \\ TAC+LFCC+Cpe & 0.0017 & 0.076 & 0.0066 & 0.242 \\ TAC+LFCC+Cps & 0.0017 & 0.057 & 0.0062 & 0.205 \\ DCT+Spee & 0.0117 & 0.057 & 0.0062 & 0.228 \\ DCT+Spee & 0.0117 & 0.057 & 0.0066 & 0.242 \\ TAC+DCT+Spee & 0.0013 & 0.074 & 0.0066 & 0.242 \\ TAC+DCT+Ceps & 0.0013 & 0.074 & 0.0066 & 0.242 \\ TAC+DCT+Ceps & 0.0013 & 0.074 & 0.0066 & 0.242 \\ TAC+DCT+Ceps & 0.0014 & 0.057 & 0.0088 & 0.165 \\ TAC+Spee+Ceps & 0.0011 & 0.037 & 0.0048 & 0.165 \\ TAC+QT+LFCC+DCT & 0.0014 & 0.057 & 0.0048 & 0.165 \\ TAC+QT+LFCC+DCT & 0.0014 & 0.057 & 0.0048 & 0.165 \\ TAC+QT+LFCC+Spee & 0.0010 & 0.041 & 0.0051 & 0.184 \\ CQT+LFCC+Spee & 0.0010 & 0.041 & 0.0051 & 0.184 \\ CQT+LFCC+DCT & 0.0014 & 0.057 & 0.0048 & 0.165 \\ TAC+QT+LFCC+Spee & 0.0010 & 0.041 & 0.0051 & 0.184 \\ CQT+LFCC+DCT & 0.0014 & 0.057 & 0.0048 & 0.165 \\ TAC+QT+LFCC+Spee & 0.0010 & 0.043 & 0.0045 & 0.177 \\ TAC+CQT+LFCC+Ceps & 0.0011 & 0.037 & 0.0038 & 0.128 \\ CQT+LFCC+DCT & 0.0019 & 0.113 & 0.0105 & 0.420 \\ CQT+LFCC+Ceps & 0.0011 & 0.037 & 0.0038 & 0.155 \\ TAC+CQT+LFCC+Ceps & 0.0012 & 0.039 & 0.0034 & 0.127 \\ LFCC+DCT+Spee & 0.0012 & 0.037 & 0.0034 & 0.127 \\ LFCC+DCT+Spee & 0.0011 & 0.037 & 0.0034 & 0.127 \\ LFCC+DCT+Spee & 0.0001 & 0.037 & 0.0034 & 0.127 \\ LFCC+DCT+Spee & 0.0001 & 0.037 & 0.0034 & 0.127 \\ CQT+LFCC+DCT+Spee & 0.0001 & 0.037 & 0.0034 & 0.127 \\ CQT+LFCC+DCT+Spee & 0.0001 & 0.037 & 0.0034 & 0.138 \\ TAC+LFCC+DCT+Spee & 0.0000 & 0.037 & 0.0034 & 0.138 \\ CQT+LFCC+DCT+Spee & 0.0000 & 0.037 & 0.0034 & 0.138 \\ CQT+LFCC+DCT+Spee & 0.0000 & 0.037 & 0.0040 & 0.13$	TAC+Ceps	0.0032	0.127	0.0096	0.330		
TAC+CQT+LFCC         0.0026         0.111         0.0063         0.216           CQT+DCT         0.0048         0.205         0.0111         0.475           CQT+Spec         0.0021         0.131         0.0122         0.514           TAC+CQT+Spec         0.0024         0.009         0.0098         0.339           CQT+Ceps         0.0024         0.004         0.0043         0.149           TAC+CQT+Ceps         0.0021         0.109         0.0098         0.321           LFCC+DCT         0.0022         0.109         0.0073         0.282           LFCC+Spec         0.0017         0.0076         0.289           TAC+LFCC+Spec         0.0017         0.0076         0.289           DCT+Spec         0.0170         0.0076         0.289           DCT+Ceps         0.0017         0.057         0.0059         0.232           DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0014         0.057         0.0048         0.165           TAC+DCT+Ceps         0.0014         0.057         0.0038         0.149      <	CQT+LFCC	0.0037	0.166	0.0079	0.283		
CQT+DCT TAC+CQT+DCT         0.0032         0.0168         0.0115         0.398           CQT+Spec         0.0024         0.109         0.0098         0.359           CQT+Spec         0.0024         0.109         0.0098         0.359           CQT+Ceps         0.0024         0.094         0.0043         0.149           TAC+CQT+Ceps         0.0017         0.075         0.0043         0.149           LFCC+DCT         0.0022         0.109         0.0073         0.282           LFCC+DCT         0.0022         0.019         0.0074         0.283           LFCC+Spec         0.0017         0.076         0.0062         0.238           DCT+Spec         0.01017         0.076         0.0062         0.223           DCT+Spec         0.01017         0.076         0.0062         0.232           DCT+Ceps         0.0013         0.074         0.0062         0.232           DCT+Ceps         0.0013         0.074         0.0062         0.232           Spec+Ceps         0.0013         0.074         0.0065         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0038         0.149           CQT+LFCC+DCT         0.0014 <td< th=""><th>TAC+CQT+LFCC</th><th>0.0026</th><th>0.111</th><th>0.0063</th><th>0.216</th></td<>	TAC+CQT+LFCC	0.0026	0.111	0.0063	0.216		
TAC+CQT+DCT         0.0032         0.168         0.0105         0.398           CQT+Cps         0.0024         0.109         0.0098         0.359           CQT+Cps         0.0024         0.094         0.0043         0.149           TAC+CQT+Cps         0.0017         0.057         0.0043         0.154           LFCC+DCT         0.0042         0.183         0.0089         0.321           TAC+LFCC+DCT         0.0022         0.109         0.0073         0.282           LFCC+Spec         0.0017         0.076         0.0062         0.238           LFCC+Cps         0.0017         0.076         0.0052         0.255           DCT+Spec         0.0017         0.077         0.0052         0.256           DCT+Spec         0.0017         0.077         0.0052         0.232           Spec+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Spec         0.0013         0.074         0.0066         0.242           TAC+DCT+Spec         0.0014         0.0057         0.0048         0.165           CAC+DCT+CC         0.0014         0.0057         0.0048         0.161           CQT+LFCC+DCP         0.0014         0	COT+DCT	0.0048	0.205	0.0111	0.475		
CQT+Spec TAC+CQT+Spec         0.0021 0.0024         0.131 0.0098         0.0122 0.0098         0.514 0.0098           CQT+Ceps TAC+LQT+Cps         0.0024         0.094         0.0043         0.149           LFCC+DCT         0.0022         0.109         0.0073         0.228           LFCC+DCT         0.0022         0.109         0.0074         0.228           LFCC+Spec         0.0017         0.076         0.0022         0.238           LFCC+Ceps         0.0017         0.077         0.0252         0.229           DCT+Spec         0.0017         0.077         0.0252         0.225           DCT+Spec         0.0010         0.0474         0.256         0.951           DCT+Spec         0.0013         0.074         0.0066         0.242           TAC+DCT+Spec         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0038         0.149           CQT+LFCC+DCT         0.0014         0.057         0.0048         0.165           TAC+CQT+LFCC+DCT         0.0014         0.057         0.0038         0.133           CQT+LFCC+Spec         0.00109         0.037         0.0048         0.151	TAC+CQT+DCT	0.0032	0.168	0.0105	0.398		
TAC+CQT+Spec         0.0024         0.1019         0.0028         0.314           CQT+Ceps         0.0024         0.0094         0.0043         0.149           TAC+CQT+Ceps         0.0017         0.057         0.0043         0.154           LFCC+DCT         0.0022         0.109         0.0073         0.282           LFCC+Spec         0.0017         0.076         0.0062         0.238           TAC+LFCC+Spec         0.0017         0.0776         0.0062         0.238           LFCC+Ceps         0.0017         0.057         0.0052         0.225           DCT+Spec         0.0017         0.057         0.0052         0.225           DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Spec         0.0013         0.074         0.0066         0.242           DCT+Ceps         0.0014         0.0057         0.0039         0.232           Spec+Ceps         0.0010         0.0414         0.0051         0.183           CQT+LFCC+DCT         0.0010         0.0414         0.0051         0.177           TAC+Spec+Ceps         0.0010         0.037         0.0039         0.133           CQT+LFCC+Spec         0.0010	COT+Spec	0.0021	0.131	0.0122	0.514		
CQT+Ceps         0.0024         0.094         0.0043         0.149           LFCC+DCT         0.007         0.007         0.0043         0.154           LFCC+DCT         0.0022         0.109         0.0073         0.282           LFCC+DCT         0.0020         0.078         0.0066         0.283           LFCC+Ceps         0.0017         0.076         0.0062         0.289           LFCC+Ceps         0.0017         0.077         0.0052         0.205           DCT+Spec         0.0017         0.077         0.0052         0.205           DCT+Ceps         0.0017         0.077         0.0052         0.205           DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0014         0.057         0.0048         0.165           TAC+Spec+Ceps         0.0014         0.057         0.0048         0.165           TAC+CQT+LFCC+DCT         0.0014         0.057         0.0048         0.155           CQT+LFCC+Spec         0.0014         0.057         0.0038         0.149           CQT+LFCC+Spec         0.0019 <t< th=""><th>TAC+COT+Spec</th><th>0.0021</th><th>0.101</th><th>0.0098</th><th>0.359</th></t<>	TAC+COT+Spec	0.0021	0.101	0.0098	0.359		
TAC+CQT+Ceps         0.0017         0.057         0.0043         0.154           LFCC+DCT         0.0022         0.109         0.0073         0.282           LFCC+DCT         0.0022         0.109         0.0076         0.282           LFCC+Spec         0.0017         0.076         0.0062         0.231           TAC+LFCC+Spec         0.0017         0.076         0.0062         0.238           LFCC+Ceps         0.0017         0.057         0.0052         0.205           DCT+Spec         0.0013         0.074         0.0056         0.244           TAC+DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0014         0.057         0.0048         0.165           TAC+DCT+DCT         0.0014         0.057         0.0038         0.149           CQT+LFCC+DCT         0.0014         0.057         0.0038         0.148           CQT+LFCC+Spec         0.0010         0.037         0.0038         0.148           CQT+LFCC+Spec         0.0016 <th>COTLO</th> <th>0.0024</th> <th>0.004</th> <th>0.0042</th> <th>0.1.40</th>	COTLO	0.0024	0.004	0.0042	0.1.40		
LFCC+PCT         anota         anota         anota         anota         anota           LFCC+PCT         0.0022         0.109         0.0073         0.282           LFCC+Spec         0.0017         0.076         0.0022         0.219           TAC+LFCC+Spec         0.0017         0.076         0.0022         0.238           LFCC+Ceps         0.0017         0.057         0.0052         0.2254           TAC+LFCC+Ceps         0.0017         0.057         0.0052         0.2256           DCT+Spec         0.0013         0.074         0.0256         0.951           DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0014         0.057         0.0048         0.165           TAC+Spec+Ceps         0.0010         0.037         0.0039         0.133           CQT+LFCC+DCT         0.0014         0.057         0.0038         0.119           CQT+LFCC+Spec         0.0019         0.037         0.0039         0.133           CQT+LFCC+Spec         0.0016         0.059         0.0042         0.155           TAC+CQT+LFCC+Spec<	TAC+COT+Cens	0.0024	0.094	0.0043	0.149		
LPCC+DCT         0.0022         0.183         0.0089         0.321           TAC+LFCC+DCT         0.0022         0.109         0.0073         0.282           LFCC+Spec         0.0017         0.0076         0.0289           TAC+LFCC+Spec         0.0017         0.0076         0.0062         0.238           LFCC+Ceps         0.0017         0.057         0.0052         0.228           DCT+Spec         0.0117         0.057         0.0052         0.228           DCT+Ceps         0.0013         0.074         0.0256         0.951           DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0013         0.074         0.0066         0.242           DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0048         0.165           TAC+Spec+Ceps         0.0014         0.057         0.0038         0.114           CQT+LFCC+DCT         0.0014         0.057         0.0038         0.113           CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           TAC+CQT+LFCC+Ceps         0.0016         0.059<		0.0017	0.102	0.0000	0.221		
LFCC+DCT         0.0022         0.107         0.0075         0.222           LFCC+Spec         0.0017         0.076         0.0062         0.238           LFCC+Spec         0.0017         0.076         0.0062         0.238           LFCC+Ceps         0.0017         0.057         0.0052         0.2265           DCT+Spec         0.0017         0.057         0.0025         0.2256           DCT+Ceps         0.0013         0.074         0.0056         0.242           TAC+DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0010         0.041         0.0051         0.184           CQT+LFCC+DCT         0.0014         0.057         0.0038         0.149           CQT+LFCC+Spec         0.0009         0.039         0.0034         0.177           TAC+CQT+LFCC+Spec         0.0010         0.037         0.0038         0.149           CQT+LFCC+Spec         0.0010         0.037         0.0034         0.177           TAC+CQT+LFCC+Ceps         0.0015         0.059         0.0031         0.115           CQT+LFCC+Spec	LFCC+DCT TAC+LECC+DCT	0.0042	0.183	0.0089	0.321		
LFCC+Spec         0.0020         0.078         0.0076         0.289           TAC+LFCC+Spec         0.0017         0.076         0.0062         0.238           LFCC+Ceps         0.0030         0.109         0.0074         0.254           TAC+LFCC+Ceps         0.0017         0.057         0.0052         0.205           DCT+Spec         0.0120         0.499         0.0424         1.488           TAC+DCT+Ceps         0.0013         0.077         0.0057         0.0056         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0010         0.041         0.0057         0.260           TAC+Spec+Ceps         0.0014         0.057         0.0038         0.165           TAC+CQT+LFCC+DCT         0.0014         0.057         0.0038         0.177           TAC+CQT+LFCC+Spec         0.0016         0.057         0.0039         0.133           CQT+LFCC+Spec         0.0016         0.059         0.0031         0.115           CQT+LFCC+Ceps         0.0016         0.059         0.0034         0.128           CQT+DCT+Spec         0.0016         0.059         0.0034         0.128	IAC+LFCC+DC1	0.0022	0.107	0.0075	0.202		
IAC+LPCC+Spec         0.0017         0.076         0.0062         0.238           LFCC+Ceps         0.0030         0.109         0.0074         0.254           DCT+Spec         0.0017         0.057         0.0052         0.205           DCT+Spec         0.0010         0.099         0.275         0.0256         0.951           DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0011         0.057         0.0059         0.232           Spec+Ceps         0.0010         0.041         0.0051         0.184           CQT+LFCC+DCT         0.0014         0.057         0.0038         0.149           CQT+LFCC+DCT         0.0010         0.041         0.0051         0.177           TAC+CQT+LFCC+DCT         0.0010         0.037         0.0039         0.133           CQT+LFCC+Spec         0.0010         0.037         0.0039         0.133           CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0016         0.059         0.0034         0.128           TAC+CQT+DCT+Ceps         0.0016         0.059         0.0034         0.128           CQT+D	LFCC+Spec	0.0020	0.078	0.0076	0.289		
LFCC+Ceps         0.0030         0.109         0.0074         0.254           TAC+LFCC+Ceps         0.0017         0.057         0.0052         0.205           DCT+Spec         0.0079         0.275         0.0226         0.951           DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0010         0.041         0.0051         0.184           CQT+LFCC+DCT         0.0014         0.057         0.0048         0.165           TAC+CQT+LFCC+DCT         0.0011         0.037         0.0039         0.133           CQT+LFCC+Spec         0.0016         0.059         0.031         0.115           CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0016         0.059         0.0031         0.115           CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           TAC+CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           CQT+DCT+Spec	IAU+LFUU+Spec	0.0017	0.076	0.0062	0.238		
TAC+LFCC+Ceps         0.0017         0.057         0.0052         0.205           DCT+Spec         0.0120         0.499         0.0424         1.488           DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0010         0.041         0.0051         0.184           CQT+LFCC+DCT         0.0014         0.057         0.0038         0.149           CQT+LFCC+Spec         0.0009         0.057         0.0038         0.149           CQT+LFCC+Spec         0.0011         0.037         0.0039         0.133           CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0019         0.113         0.0105         0.420           CQT+DCT+Ceps         0.0016         0.059         0.0034         0.128           TAC+CQT+DCT+Ceps         0.0011         0.037         0.0038         0.155           TAC+CQT+DCT+Ceps         0.0011         0.037         0.0034         0.128           CQT+Spec+Ceps	LFCC+Ceps	0.0030	0.109	0.0074	0.254		
DCT+Spec         0.0120         0.499         0.0424         1.488           TAC+DCT+Spec         0.0079         0.275         0.0256         0.951           DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0015         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0010         0.0411         0.0057         0.260           TAC+Spec+Ceps         0.0010         0.041         0.0057         0.0048         0.165           CQT+LFCC+DCT         0.0009         0.057         0.0038         0.113           CQT+LFCC+Spec         0.0016         0.057         0.0038         0.115           CQT+LFCC+Ceps         0.0016         0.057         0.0031         0.115           CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0016         0.059         0.0034         0.128           TAC+CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           CQT+DCT+Ceps         0.0010         0.037         0.0038         0.155           TAC+CQT+Spec+Ceps         0.0011         0.037         0.0034         0.128	TAC+LFCC+Ceps	0.0017	0.057	0.0052	0.205		
TAC+DCT+Spec         0.0079         0.275         0.0256         0.951           DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0015         0.074         0.0067         0.232           Spec+Ceps         0.0010         0.041         0.0057         0.0085         0.232           CQT+LFCC+DCT         0.0010         0.041         0.0057         0.0048         0.165           TAC+Spec+Ceps         0.0011         0.057         0.0038         0.113           CQT+LFCC+DCT         0.0009         0.057         0.0038         0.117           TAC+CQT+LFCC+Spec         0.0011         0.037         0.0042         0.150           CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0016         0.059         0.0034         0.128           TAC+CQT+DCT+Spec         0.0015         0.059         0.0034         0.128           CQT+DCT+Ceps         0.0010         0.113         0.0102         0.128           TAC+CQT+DCT+Ceps         0.0008         0.037         0.0038         0.155           TAC+CQT+Spec+Ceps         0.0011         0.037         0.0034         0.	DCT+Spec	0.0120	0.499	0.0424	1.488		
DCT+Ceps         0.0013         0.074         0.0066         0.242           TAC+DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0010         0.041         0.0057         0.0067         0.260           TAC+Spec+Ceps         0.0010         0.041         0.0051         0.184           CQT+LFCC+DCT         0.0014         0.057         0.0038         0.149           CQT+LFCC+DCT         0.0009         0.037         0.0039         0.133           CQT+LFCC+Spec         0.0011         0.037         0.0039         0.133           CQT+LFCC+Ceps         0.0022         0.074         0.0042         0.150           TAC+CQT+LFCC+Ceps         0.0029         0.168         0.0148         0.591           TAC+CQT+DCT+Spec         0.0015         0.059         0.0034         0.128           CQT+DCT+Ceps         0.0016         0.037         0.0038         0.155           TAC+CQT+DCT+Ceps         0.0011         0.037         0.0034         0.128           CQT+Spec+Ceps         0.0011         0.037         0.0034         0.127           LFCC+DCT+Spec         0.0012         0.037         0.0034         0.127 <tr< th=""><th>TAC+DCT+Spec</th><th>0.0079</th><th>0.275</th><th>0.0256</th><th>0.951</th></tr<>	TAC+DCT+Spec	0.0079	0.275	0.0256	0.951		
TAC+DCT+Ceps         0.0014         0.057         0.0059         0.232           Spec+Ceps         0.0015         0.074         0.0067         0.260           TAC+Spec+Ceps         0.0010         0.041         0.0051         0.184           CQT+LFCC+DCT         0.0014         0.057         0.0038         0.149           CQT+LFCC+DCT         0.0009         0.037         0.0038         0.149           CQT+LFCC+Spec         0.0011         0.037         0.0039         0.133           CQT+LFCC+Ceps         0.0016         0.057         0.0039         0.133           CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0019         0.113         0.0105         0.420           CQT+DCT+Spec         0.0015         0.059         0.0034         0.128           TAC+CQT+DCT+Ceps         0.0016         0.037         0.0034         0.128           CQT+Spec+Ceps         0.0011         0.037         0.0034         0.127           LFCC+DCT+Spec         0.0008         0.037         0.0034         0.128           TAC+CQT+Spec+Ceps         0.0011         0.037         0.0034         0.127           LFCC+DCT+	DCT+Ceps	0.0013	0.074	0.0066	0.242		
Spec+Ceps         0.0015         0.074         0.0067         0.260           TAC+Spec+Ceps         0.0010         0.041         0.0051         0.184           CQT+LFCC+DCT         0.0009         0.057         0.0038         0.149           CQT+LFCC+DCT         0.0009         0.037         0.0038         0.149           CQT+LFCC+Spec         0.0011         0.037         0.0039         0.133           CQT+LFCC+Spec         0.0016         0.057         0.0039         0.133           CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0015         0.059         0.0034         0.128           CQT+DCT+Ceps         0.0016         0.037         0.0034         0.128           CQT+Spec+Ceps         0.0011         0.037         0.0034         0.121           CQT+Spec+Ceps         0.0011         0.037         0.0038         0.155           TAC+CQT+Spec         0.0012         0.037         0.0034         0.122           LFCC+DCT+Spec         0.0012         0.037         0.0033         0.232           LFCC+DCT+Spec <th>TAC+DCT+Ceps</th> <th>0.0014</th> <th>0.057</th> <th>0.0059</th> <th>0.232</th>	TAC+DCT+Ceps	0.0014	0.057	0.0059	0.232		
TAC+Spec+Ceps         0.0010         0.041         0.0051         0.184           CQT+LFCC+DCT         0.0014         0.057         0.0048         0.165           TAC+CQT+LFCC+DCT         0.0009         0.037         0.0038         0.149           CQT+LFCC+Spec         0.0009         0.037         0.0039         0.133           CQT+LFCC+Spec         0.0011         0.037         0.0029         0.133           CQT+LFCC+Ceps         0.0016         0.059         0.0013         0.115           CQT+DCT+Spec         0.0019         0.113         0.0105         0.420           CQT+DCT+Spec         0.0015         0.059         0.0034         0.128           CQT+DCT+Ceps         0.0010         0.0137         0.0034         0.128           CQT+Spec+Ceps         0.0011         0.037         0.0034         0.122           CQT+Spec+Ceps         0.0008         0.037         0.0034         0.127           LFCC+DCT+Spec         0.0009         0.057         0.0033         0.320           TAC+CQT+Spec+Ceps         0.0004         0.022         0.0030         0.115           LFCC+DCT+Spec         0.0004         0.022         0.0030         0.115           LFC	Spec+Ceps	0.0015	0.074	0.0067	0.260		
$\begin{array}{c ccccc} CQT+LFCC+DCT \\ TAC+CQT+LFCC+DCT \\ TAC+CQT+LFCC+DCT \\ CQT+LFCC+Spec \\ CQT+LFCC+Spec \\ CQT+LFCC+Spec \\ CQT+LFCC+Ceps \\ CQT+LFCC+Ceps \\ CQT+LFCC+Ceps \\ CQT+LFCC+Ceps \\ CQT+DCT+Spec \\ CQT+DCT+Spec \\ CQT+DCT+Spec \\ CQT+DCT+Spec \\ CQT+DCT+Ceps \\ CQT+DCT+Ceps \\ CQT+DCT+Ceps \\ CQT+DCT+Ceps \\ CQT+Spec+Ceps \\ CQT+Spec+Ceps \\ CQT+Spec+Ceps \\ CQT+Spec+Ceps \\ CQT+LFCC+DCT+Spec \\ CQT+Spec+Ceps \\ CQT+Spec+Ceps \\ CQT+LFCC+DCT+Spec \\ CQT+Spec+Ceps \\ CQT+Spec+Cep$	TAC+Spec+Ceps	0.0010	0.041	0.0051	0.184		
TAC+CQT+LFCC+DCT         0.0009         0.057         0.0038         0.149           CQT+LFCC+Spec         0.0009         0.039         0.0045         0.177           TAC+CQT+LFCC+Spec         0.0011         0.037         0.0039         0.133           CQT+LFCC+Ceps         0.0016         0.057         0.0013         0.115           CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0019         0.113         0.0105         0.420           CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           CQT+Spec+Ceps         0.0011         0.037         0.0038         0.155           TAC+CQT+Spec+Ceps         0.0008         0.037         0.0034         0.127           LFCC+DCT+Spec         0.0009         0.057         0.0063         0.320           TAC+LFCC+DCT+Ceps         0.0012         0.039         0.0040         0.143           TAC+LFCC+DCT+Ceps         0.0003         0.017         0.0039         0.138           TAC+LFCC+DCT+Ceps         0.0003         0.017         0.0027         0.109	CQT+LFCC+DCT	0.0014	0.057	0.0048	0.165		
CQT+LFCC+Spec         0.0009         0.039         0.0045         0.177           TAC+CQT+LFCC+Spec         0.0011         0.037         0.0039         0.133           CQT+LFCC+Ceps         0.0022         0.074         0.0042         0.150           TAC+CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0015         0.059         0.0034         0.128           CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           CQT+Spec+Ceps         0.0011         0.037         0.0038         0.155           TAC+CQT+Spec+Ceps         0.0008         0.037         0.0034         0.127           LFCC+DCT+Spec         0.00011         0.037         0.0034         0.127           LFCC+DCT+Spec         0.00021         0.096         0.0073         0.320           TAC+LFCC+DCT+Spec         0.0004         0.022         0.0030         0.115           LFCC+DCT+Ceps         0.0003         0.017         0.0039         0.138           TAC+LFCC+DCT+Ceps         0.0003         0.017         0.0027         0.109      D	TAC+CQT+LFCC+DCT	0.0009	0.057	0.0038	0.149		
TAC+CQT+LFCC+Spec         0.0011         0.037         0.0039         0.133           CQT+LFCC+Ceps         0.0022         0.074         0.0042         0.150           TAC+CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0019         0.113         0.0105         0.420           CQT+DCT+Spec         0.0015         0.059         0.0034         0.128           CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           CQT+Spec+Ceps         0.0011         0.037         0.0038         0.155           TAC+CQT+Spec+Ceps         0.0008         0.037         0.0034         0.127           LFCC+DCT+Spec         0.00011         0.037         0.0034         0.127           LFCC+DCT+Spec         0.0009         0.057         0.0063         0.232           LFCC+DCT+Spec         0.0004         0.022         0.0030         0.115           LFCC+DCT+Ceps         0.0003         0.017         0.0039         0.138           TAC+LFCC+DCT+Ceps         0.0003         0.017         0.0039         0.138           TAC+LFCC+Spec+Ceps         0.0003         0.017         0.0027         0.109	CQT+LFCC+Spec	0.0009	0.039	0.0045	0.177		
CQT+LFCC+Ceps         0.0022         0.074         0.0042         0.150           TAC+CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0029         0.168         0.0148         0.591           TAC+CQT+DCT+Spec         0.0015         0.059         0.0034         0.128           CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           TAC+CQT+DCT+Ceps         0.0008         0.039         0.0029         0.121           CQT+Spec+Ceps         0.0011         0.037         0.0038         0.155           TAC+CQT+Spec+Ceps         0.0001         0.096         0.0073         0.320           LFCC+DCT+Spec         0.0009         0.057         0.0063         0.232           LFCC+DCT+Ceps         0.0012         0.039         0.0140         0.143           TAC+LFCC+DCT+Spec         0.0004         0.022         0.0030         0.115           LFCC+Spec+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0003         0.017         0.0027         0.109	TAC+CQT+LFCC+Spec	0.0011	0.037	0.0039	0.133		
TAC+CQT+LFCC+Ceps         0.0016         0.059         0.0031         0.115           CQT+DCT+Spec         0.0029         0.168         0.0148         0.591           TAC+CQT+DCT+Spec         0.0019         0.113         0.0105         0.420           CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           TAC+CQT+DCT+Ceps         0.0008         0.039         0.0029         0.121           CQT+Spec+Ceps         0.0011         0.037         0.0038         0.155           TAC+CQT+Spec+Ceps         0.0008         0.037         0.0034         0.127           LFCC+DCT+Spec         0.0009         0.057         0.0063         0.232           LFCC+DCT+Ceps         0.0004         0.022         0.0030         0.115           LFCC+DCT+Ceps         0.0004         0.022         0.0030         0.115           LFCC+DCT+Ceps         0.0003         0.017         0.0039         0.138           TAC+LFCC+DCT+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0003         0.017         0.0018         0.317           DCT+Spec+Ceps         0.0009         0.052         0.0029         0.211	CQT+LFCC+Ceps	0.0022	0.074	0.0042	0.150		
CQT+DCT+Spec TAC+CQT+DCT+Spec         0.0029 0.0019         0.168 0.113         0.0105 0.0105         0.420           CQT+DCT+Ceps TAC+CQT+DCT+Ceps         0.0015         0.059         0.0034         0.128           CQT+Spec+Ceps         0.0011         0.037         0.0034         0.128           CQT+Spec+Ceps         0.0011         0.037         0.0034         0.127           LFCC+DCT+Spec         0.0009         0.057         0.0033         0.232           LFCC+DCT+Spec         0.0012         0.096         0.0073         0.320           LFCC+DCT+Spec         0.0004         0.022         0.0030         0.115           LFCC+DCT+Ceps         0.0004         0.022         0.0030         0.115           LFCC+DCT+Spec         0.0003         0.017         0.0039         0.138           TAC+LFCC+DCT+Spec         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0003         0.017         0.0041         0.171           TAC+LFCC+DCT+Spec         0.00004         0.037         0.0041	TAC+CQT+LFCC+Ceps	0.0016	0.059	0.0031	0.115		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	CQT+DCT+Spec	0.0029	0.168	0.0148	0.591		
$\begin{array}{c c} CQT+DCT+Ceps\\ TAC+CQT+DCT+Ceps\\ TAC+CQT+DCT+Ceps\\ 0.0008\\ 0.039\\ 0.0029\\ 0.0029\\ 0.0121\\ 0.0008\\ 0.037\\ 0.0034\\ 0.0121\\ 0.0034\\ 0.0034\\ 0.127\\ 0.0034\\ 0.127\\ 0.0034\\ 0.0127\\ 0.0034\\ 0.0034\\ 0.022\\ 0.0034\\ 0.021\\ 0.0063\\ 0.0037\\ 0.0030\\ 0.013\\ 0.0040\\ 0.022\\ 0.0000\\ 0.017\\ 0.0027\\ 0.109\\ 0.0039\\ 0.115\\ 0.0003\\ 0.017\\ 0.0027\\ 0.109\\ 0.0013\\ 0.0017\\ 0.0027\\ 0.109\\ 0.0013\\ 0.0017\\ 0.0027\\ 0.109\\ 0.0013\\ 0.0017\\ 0.0027\\ 0.109\\ 0.0013\\ 0.0017\\ 0.0027\\ 0.109\\ 0.0013\\ 0.0017\\ 0.0027\\ 0.109\\ 0.0013\\ 0.0017\\ 0.0027\\ 0.109\\ 0.0013\\ 0.0017\\ 0.0027\\ 0.0019\\ 0.0021\\ 0.0017\\ 0.0027\\ 0.109\\ 0.0013\\ 0.0017\\ 0.0027\\ 0.0011\\ 0.0027\\ 0.0041\\ 0.171\\ 0.0027\\ 0.0041\\ 0.165\\ CQT+LFCC+DCT+Spec\\ 0.0008\\ 0.003\\ 0.033\\ 0.0022\\ 0.072\\ 0.0041\\ 0.165\\ CQT+LFCC+DCT+Ceps\\ 0.0000\\ 0.033\\ 0.0022\\ 0.0027\\ 0.094\\ 0.003\\ 0.033\\ 0.0022\\ 0.003\\ 0.0035\\ 0.149\\ 0.0035\\ 0.0035\\ 0.169\\ 0.0035\\ 0.0035\\ 0.169\\ 0.003\\ 0.0035\\ 0.169\\ 0.0003\\ 0.003\\ 0.017\\ 0.0031\\ 0.116\\ 0.0028\\ 0.003\\ 0.003\\ 0.017\\ 0.0031\\ 0.116\\ 0.0028\\ 0.003\\ 0.003\\ 0.016\\ 0.003$	TAC+CQT+DCT+Spec	0.0019	0.113	0.0105	0.420		
TAC+CQT+DCT+Ceps         0.0008         0.039         0.0029         0.121           CQT+Spec+Ceps         0.0011         0.037         0.0038         0.155           TAC+CQT+Spec+Ceps         0.0008         0.037         0.0034         0.127           LFCC+DCT+Spec         0.0021         0.096         0.0073         0.320           TAC+LFCC+DCT+Spec         0.0009         0.057         0.0063         0.232           LFCC+DCT+Ceps         0.0004         0.022         0.0030         0.115           LFCC+DCT+Ceps         0.0003         0.017         0.0039         0.138           TAC+LFCC+DCT+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0009         0.052         0.0059         0.221           CQT+LFCC+DCT+Spec         0.0009         0.052         0.0059         0.221           CQT+LFCC+DCT+Spec         0.0004         0.037         0.0041         0.171           TAC+CQT+LFCC+DCT+Spec         0.0005         0.037         0.0041         0.171           TAC+CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072	CQT+DCT+Ceps	0.0015	0.059	0.0034	0.128		
$\begin{array}{c c} CQT+Spec+Ceps \\ TAC+CQT+Spec+Ceps \\ TAC+CQT+Spec+Ceps \\ \hline 0.0008 \\ \hline 0.037 \\ \hline 0.0034 \\ \hline 0.0034 \\ \hline 0.127 \\ \hline 0.0034 \\ \hline 0.021 \\ \hline 0.009 \\ \hline 0.007 \\ \hline 0.0063 \\ \hline 0.007 \\ \hline 0.0063 \\ \hline 0.007 \\ \hline 0.0063 \\ \hline 0.022 \\ \hline 0.0004 \\ \hline 0.022 \\ \hline 0.0000 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.009 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.009 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.009 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.009 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.009 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.009 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.009 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.009 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.109 \\ \hline 0.0012 \\ \hline 0.0013 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.009 \\ \hline 0.017 \\ \hline 0.0027 \\ \hline 0.109 \\ \hline 0.0013 \\ \hline 0.007 \\ \hline 0.0013 \\ \hline 0.007 \\ \hline 0.0013 \\ \hline 0.0017 \\ \hline 0.0027 \\ \hline 0.109 \\ \hline 0.0013 \\ \hline 0.0017 \\ \hline 0.0027 \\ \hline 0.109 \\ \hline 0.0013 \\ \hline 0.0017 \\ \hline 0.0017 \\ \hline 0.0027 \\ \hline 0.109 \\ \hline 0.0019 \\ \hline 0.0017 \\ \hline 0.0017 \\ \hline 0.0027 \\ \hline 0.109 \\ \hline 0.0019 \\ \hline 0.0017 \\ \hline 0.0019 \\ \hline 0.0019 \\ \hline 0.0017 \\ \hline 0.0027 \\ \hline 0.0019 \\ \hline 0.002 \\ \hline 0.0019 \\ \hline 0.0019 \\ \hline 0.002 \\ \hline 0.0019 \\ \hline 0.002 \\ \hline 0.0019 \\ \hline 0.0021 \\ \hline 0.0019 \\ \hline 0.0019$	TAC+CQT+DCT+Ceps	0.0008	0.039	0.0029	0.121		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	COT+Spec+Cens	0.0011	0.037	0.0038	0.155		
$\begin{array}{c ccccc} LFCC+DCT+Spec \\ TAC+LFCC+DCT+Spec \\ TAC+LFCC+DCT+Spec \\ LFCC+DCT+Ceps \\ TAC+LFCC+DCT+Ceps \\ LFCC+DCT+Ceps \\ 0.0004 \\ 0.022 \\ 0.0030 \\ 0.037 \\ 0.0039 \\ 0.0030 \\ 0.115 \\ 0.0030 \\ 0.017 \\ 0.0027 \\ 0.0039 \\ 0.013 \\ 0.007 \\ 0.0039 \\ 0.017 \\ 0.0027 \\ 0.109 \\ 0.0013 \\ 0.017 \\ 0.0027 \\ 0.109 \\ 0.0013 \\ 0.017 \\ 0.0027 \\ 0.109 \\ 0.0027 \\ 0.109 \\ 0.0013 \\ 0.017 \\ 0.0027 \\ 0.109 \\ 0.0027 \\ 0.109 \\ 0.0013 \\ 0.007 \\ 0.0013 \\ 0.007 \\ 0.0013 \\ 0.007 \\ 0.0013 \\ 0.007 \\ 0.0013 \\ 0.007 \\ 0.0013 \\ 0.0017 \\ 0.0013 \\ 0.0015 \\ 0.0013 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0011 \\ 0.0022 \\ 0.0021 \\ 0.0031 \\ 0.0031 \\ 0.0031 \\ 0.0031 \\ 0.0011 \\ 0.0021 \\ 0.0031 \\ 0.0031 \\ 0.0011 \\ 0.0021 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.$	TAC+CQT+Spec+Ceps	0.0008	0.037	0.0034	0.127		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	LFCC+DCT+Spec	0.0021	0.096	0.0073	0.320		
$\begin{array}{c cccc} LFCC+DCT+Ceps \\ TAC+LFCC+DCT+Ceps \\ LFCC+Spec+Ceps \\ TAC+LFCC+Spec+Ceps \\ D0004 \\ 0.0022 \\ 0.0030 \\ 0.037 \\ 0.0039 \\ 0.0039 \\ 0.017 \\ 0.0027 \\ 0.0003 \\ 0.017 \\ 0.0027 \\ 0.009 \\ 0.0013 \\ 0.007 \\ 0.0027 \\ 0.009 \\ 0.0027 \\ 0.109 \\ 0.0027 \\ 0.109 \\ 0.0013 \\ 0.007 \\ 0.0078 \\ 0.0078 \\ 0.0078 \\ 0.0078 \\ 0.0078 \\ 0.0078 \\ 0.0078 \\ 0.0078 \\ 0.0078 \\ 0.0078 \\ 0.0013 \\ 0.007 \\ 0.0078 \\ 0.0078 \\ 0.0011 \\ 0.0078 \\ 0.0078 \\ 0.0011 \\ 0.0078 \\ 0.0078 \\ 0.0011 \\ 0.0078 \\ 0.0011 \\ 0.0078 \\ 0.0011 \\ 0.0078 \\ 0.0011 \\ 0.0011 \\ 0.0011 \\ 0.0021 \\ 0.0011 \\ 0.0021 \\ 0.0031 \\ 0.0031 \\ 0.0031 \\ 0.0011 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ $	TAC+LFCC+DCT+Spec	0.0009	0.057	0.0063	0.232		
TAC+LFCC+DCT+Ceps         0.0012         0.0022         0.0030         0.115           LFCC+DCT+Ceps         0.0004         0.022         0.0030         0.115           LFCC+Spec+Ceps         0.0008         0.037         0.0039         0.138           TAC+LFCC+Spec+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0013         0.057         0.0078         0.304           TAC+DCT+Spec+Ceps         0.0009         0.052         0.0079         0.221           CQT+LFCC+DCT+Spec         0.0004         0.037         0.0041         0.171           TAC+CQT+LFCC+DCT+Spec         0.0005         0.037         0.0041         0.171           TAC+CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+Spec+Ceps         0.0004         0.022         0.0027         0.094           TAC+CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0033         0.0833           CQT+DCT+Spec+Ceps         0.0002         0.017         0.0035	LFCC+DCT+Cene	0.0012	0.039	0.0040	0 143		
$\begin{array}{c c} LFCC+Spec+Ceps \\ TAC+LFCC+Spec+Ceps \\ D,0003 \\ 0.003 \\ 0.017 \\ 0.0027 \\ 0.0027 \\ 0.109 \\ 0.0027 \\ 0.109 \\ 0.0027 \\ 0.109 \\ 0.0027 \\ 0.109 \\ 0.0027 \\ 0.109 \\ 0.0027 \\ 0.0013 \\ 0.007 \\ 0.0013 \\ 0.007 \\ 0.0013 \\ 0.007 \\ 0.0014 \\ 0.171 \\ 0.005 \\ 0.007 \\ 0.0041 \\ 0.171 \\ 0.0011 \\ 0.105 \\ 0.0011 \\ 0.005 \\ 0.007 \\ 0.0041 \\ 0.105 \\ 0.0011 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0021 \\ 0.0022 \\ 0.0022 \\ 0.0022 \\ 0.0022 \\ 0.0022 \\ 0.0022 \\ 0.0021 \\ 0.003 \\ 0.0033 \\ 0.0022 \\ 0.0022 \\ 0.0021 \\ 0.0041 \\ 0.0022 \\ 0.0022 \\ 0.0021 \\ 0.0041 \\ 0.0022 \\ 0.0022 \\ 0.0021 \\ 0.0041 \\ 0.0022 \\ 0.0022 \\ 0.0021 \\ 0.003 \\ 0.0033 \\ 0.0035 \\ 0.149 \\ LFCC+DCT+Spec+Ceps \\ 0.0003 \\ 0.003 \\ 0.017 \\ 0.0031 \\ 0.116 \\ TAC+LFCC+DCT+Spec+Ceps \\ 0.0003 \\ 0.003 \\ 0.017 \\ 0.0031 \\ 0.116 \\ 0.0031 \\ 0.0116 \\ 0.0031 \\ 0.0031 \\ 0.0116 \\ 0.0024 \\ 0.0031 \\ 0.0031 \\ 0.0116 \\ 0.0024 \\ 0.0031 \\ 0.0031 \\ 0.0016 \\ 0.0031 \\ 0.0031 \\ 0.0016 \\ 0.0024 \\ 0.0028 \\ 0.008 \\ 0.0031 \\ 0.0031 \\ 0.0031 \\ 0.0116 \\ 0.0028 \\ 0.008 \\ 0.008 \\ 0.008 \\ 0.0001 \\ 0.004 \\ 0.0028 \\ 0.008 \\ 0.008 \\ 0.008 \\ 0.008 \\ 0.008 \\ 0.001 \\ 0.004 \\ 0.0028 \\ 0.008 \\ 0.003 \\ 0.0015 \\ 0.0031 \\ 0.0031 \\ 0.0116 \\ 0.0028 \\ 0.008 \\ 0.008 \\ 0.008 \\ 0.0001 \\ 0.004 \\ 0.0028 \\ 0.008 \\ 0.0001 \\ 0.004 \\ 0.0028 \\ 0.008 \\ 0.0001 \\ 0.004 \\ 0.0028 \\ 0.008 \\ 0.0001 \\ 0.004 \\ 0.0028 \\ 0.008 \\ 0.0001 \\ 0.004 \\ 0.0028 \\ 0.008 \\ 0.0001 \\ 0.0004 \\ 0.0028 \\ 0.0001 \\ 0.0004 \\ 0.0028 \\ 0.0001 \\ 0.0001 \\ 0.0004 \\ 0.0028 \\ 0.0001 \\ $	TAC+LFCC+DCT+Ceps	0.0004	0.022	0.0030	0.115		
TAC+LFCC+Spec+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0003         0.017         0.0027         0.109           DCT+Spec+Ceps         0.0009         0.052         0.0078         0.304           TAC+DCT+Spec+Ceps         0.0009         0.052         0.0059         0.221           CQT+LFCC+DCT+Spec         0.0004         0.037         0.0041         0.171           TAC+CQT+LFCC+DCT+Spec         0.0005         0.037         0.0041         0.165           CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+Spec+Ceps         0.0004         0.022         0.0027         0.094           TAC+CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0023         0.083           CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.033         0.0035		0.0008	0.037	0.0030	0.138		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	TAC+LFCC+Spec+Ceps	0.0003	0.037	0.0039	0.109		
TAC+DCT+Spec+Ceps         0.0013         0.037         0.0078         0.304           TAC+DCT+Spec+Ceps         0.0009         0.652         0.0059         0.221           CQT+LFCC+DCT+Spec         0.0004         0.037         0.0041         0.171           TAC+CQT+LFCC+DCT+Spec         0.0005         0.037         0.0041         0.165           CQT+LFCC+DCT+Spec         0.0008         0.052         0.0029         0.104           TAC+CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+Spec+Ceps         0.0004         0.022         0.0027         0.094           TAC+CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0023         0.083           CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0023         0.883           CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149	DCT   Specificant	0.0012	0.057	0.0079	0.304		
CQT+LFCC+DCT+Spec         0.0004         0.037         0.0041         0.171           TAC+CQT+LFCC+DCT+Spec         0.0005         0.037         0.0041         0.165           CQT+LFCC+DCT+Spec         0.0005         0.037         0.0041         0.165           CQT+LFCC+DCT+Ceps         0.0008         0.052         0.0029         0.104           TAC+CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+Spec+Ceps         0.0004         0.022         0.0027         0.094           TAC+CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0023         0.083           CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.169           LFCC+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.033         <	TAC+DCT+Spec+Ceps	0.0015	0.057	0.0078	0.304		
TAC+CQT+LFCC+DCT+Spec         0.0005         0.037         0.0041         0.165           CQT+LFCC+DCT+Ceps         0.0008         0.052         0.0029         0.104           TAC+CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+Spec+Ceps         0.0004         0.022         0.0027         0.094           TAC+CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0023         0.883           CQT+DCT+Spec+Ceps         0.0004         0.033         0.0047         0.166           TAC+CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0003         0.017         0.0031         0.116           TAC+LFCC+DCT+Spec+Ceps         0.0003         0.017         0.0031         0.116	CQT+LFCC+DCT+Spec	0.0004	0.037	0.0041	0.171		
CQT+LFCC+DCT+Ceps         0.0008         0.052         0.0029         0.104           TAC+CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+Spec+Ceps         0.0004         0.022         0.0027         0.094           TAC+CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0023         0.083           CQT+DCT+Spec+Ceps         0.0005         0.037         0.0047         0.166           TAC+CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0004         0.0033         0.0015         0.116           TAC+LFCC+DCT+Spec+Ceps         0.0004         0.0034         0.017         0.0116	TAC+CQT+LFCC+DCT+Spec	0.0005	0.037	0.0041	0.165		
TAC+CQT+LFCC+DCT+Ceps         0.0003         0.033         0.0022         0.072           CQT+LFCC+Spec+Ceps         0.0004         0.022         0.0027         0.094           TAC+CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0023         0.083           CQT+DCT+Spec+Ceps         0.0002         0.017         0.0023         0.083           CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.166           TAC+CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.166           TAC+CQT+DCT+Spec+Ceps         0.0003         0.017         0.0035         0.116           TAC+LFCC+DCT+Spec+Ceps         0.0003         0.017         0.0031         0.116           TAC+LFCC+DCT+Spec+Ceps         0.0001         0.004         0.0038         0.017	COT+LFCC+DCT+Ceps	0.0008	0.052	0.0029	0.104		
CQT+LFCC+Spec+Ceps         0.0004         0.022         0.0027         0.094           TAC+CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0023         0.083           CQT+DCT+Spec+Ceps         0.0005         0.037         0.0047         0.166           TAC+CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0003         0.017         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0003         0.017         0.0031         0.116           TAC+LFCC+DCT+Spec+Ceps         0.0001         0.004         0.0038         0.017	TAC+CQT+LFCC+DCT+Ceps	0.0003	0.033	0.0022	0.072		
TAC+CQT+LFCC+Spec+Ceps         0.0002         0.017         0.0023         0.083           CQT+DCT+Spec+Ceps         0.0005         0.037         0.0023         0.083           CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.166           TAC+CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.116           LFCC+DCT+Spec+Ceps         0.0001         0.004         0.0038         0.016           TAC+LFCC+DCT+Spec+Ceps         0.0001         0.004         0.0038         0.016	COT+LFCC+Spec+Ceps	0.0004	0.022	0.0027	0 094		
CQT+DCT+Spec+Ceps         0.0005         0.037         0.0047         0.166           TAC+CQT+DCT+Spec+Ceps         0.0004         0.033         0.0035         0.149           LFCC+DCT+Spec+Ceps         0.0003         0.017         0.0031         0.116           TAC+LFCC+DCT+Spec+Ceps         0.0001         0.004         0.0038         0.017	TAC+CQT+LFCC+Spec+Ceps	0.0002	0.017	0.0023	0.083		
TAC+CQT+DCT+Spec+Ceps         0.0003         0.037         0.0047         0.106           LFCC+DCT+Spec+Ceps         0.0003         0.017         0.0031         0.116           TAC+LFCC+DCT+Spec+Ceps         0.0003         0.017         0.0031         0.116           TAC+LFCC+DCT+Spec+Ceps         0.0001         0.004         0.0028         0.098		0.0005	0.027	0.0047	0.166		
LFCC+DCT+Spec+Ceps 0.0003 0.017 0.0031 0.116 TAC+LFCC+DCT+Spec+Ceps 0.0001 0.004 0.0028 0.098	TAC+COT+DCT+Spec+Ceps	0.0003	0.037	0.0047	0.100		
TAC+LFCC+DCT+Spec+Ceps 0.0003 0.017 0.0031 0.116 TAC+LFCC+DCT+Spec+Ceps 0.0001 0.004 0.0028 0.098		0.0002	0.017	0.0021	0.116		
	TAC+LFCC+DCT+Spec+Ceps	0.0003	0.017 0.004	0.0031 0.0028	0.116		

TABLE IV Results of the fusion systems with Spec1724-LCNN & Ceps1724-LCNN.

	Dev Eval		al	
System	tDCF	EER	tDCF	EER
CQT+LFCC+DCT+Spec1724	0.0002	0.017	0.0030	0.109
TAC+CQT+LFCC+DCT+Spec1724	0.0003	0.017	0.0028	0.105
CQT+LFCC+Spec1724+Ceps	0.0000	0.002	0.0019	0.077
TAC+CQT+LFCC+Spec1724+Ceps	0.0000	0.002	0.0016	0.055
CQT+DCT+Spec1724+Ceps	0.0002	0.017	0.0026	0.099
TAC+CQT+DCT+Spec1724+Ceps	0.0001	0.015	0.0025	0.095
LFCC+DCT+Spec1724+Ceps	0.0000	0.002	0.0022	0.093
TAC+LFCC+DCT+Spec1724+Ceps	0	0	0.0020	0.072
CQT+LFCC+DCT+Cpes1724	0.0017	0.074	0.0036	0.145
TAC+CQT+LFCC+DCT+Cpes1724	0.0011	0.057	0.0036	0.133
CQT+LFCC+Spec+Cpes1724	0.0007	0.039	0.0033	0.137
TAC+CQT+LFCC+Spec+Cpes1724	0.0006	0.035	0.0033	0.116
CQT+DCT+Spec+Cpes1724	0.0015	0.072	0.0070	0.293
TAC+CQT+DCT+Spec+Cpes1724	0.0010	0.070	0.0060	0.226
LFCC+DCT+Spec+Cpes1724	0.0007	0.037	0.0045	0.188
TAC+LFCC+DCT+Spec+Cpes1724	0.0006	0.041	0.0042	0.160
CQT+LFCC+Spec1724+Cpes1724	0.0006	0.022	0.0027	0.111
TAC+CQT+LFCC+Spec1724+Cpes1724	0.0003	0.033	0.0025	0.088
CQT+DCT+Spec1724+Cpes1724	0.0012	0.041	0.0052	0.203
TAC+CQT+DCT+Spec1724+Cpes1724	0.0008	0.037	0.0038	0.188
LFCC+DCT+Spec1724+Cpes1724	0.0007	0.033	0.0036	0.137
TAC+LFCC+DCT+Spec1724+Cpes1724	0.0005	0.022	0.0032	0.127

comparison of fusion systems with and without TAC-LCNN is clear. From the table, we can see that almost every fusion system with TAC-LCNN outperforms the corresponding system without TAC-LCNN. Next, we examined whether the combination of TAC-LCNN with systems with features based on spectrograms extracted using different windowing configurations is effective. From Table IV, we can see that the combination of TAC-LCNN with Spec1724-LCNN and/or outperforms its corresponding system without TAC-LCNN in most cases. This result again confirms the contribution of TAC-LCNN in fusion systems. In addition, it is worth mentioning that this is the first time a fusion system (see TAC+LFCC+DCT+Spec1724+Ceps) has achieved EER and min-tDCF of 0 on the development set.

# D. Comparison with State-of-the-Art Models

Table V compares the performance of several state-ofthe-art systems and our fusion systems on the ASVspoof 2019 physical access database. It is clear that all our fusion systems with TAC-LCNN outperform the three stateof-the-art fusion systems compared in this experiment. The best performance on the evaluation set is achieved by the "TAC+CQT+LFCC+Spec1724+Ceps" system, and the min-DCF and EER are 0.0016 and 0.055, respectively. For the development set, the best performance is achieved by the "TAC+LFCC+DCT+Spec1724+Ceps" system, and the min-DCF and EER are reduced to 0. Our fusion systems combining the temporal autocorrelation feature achieve new state-ofthe-art performance on the ASVspoof 2019 physical access database.

 TABLE V

 Performance comparison with state-of-the-art systems.

	Dev		Eval	
System	tDCF	EER	tDCF	EER
T45-Fusion [9]	0.0001	0.0154	0.0122	0.54
T28-Fusion [6]	0.0049	0.20	0.0096	0.39
Res2Net-CQT+LFCC+Spec [7]	0.0028	0.096	0.0075	0.287
CQT+LFCC+DCT	0.0014	0.057	0.0048	0.165
TAC+COT+LFCC+DCT	0.0009	0.057	0.0038	0.149
[22] COT+LFCC+Spec+Ceps	0.0004	0.022	0.0027	0.094
TAC+CQT+LFCC+Spec+Ceps	0.0002	0.017	0.0023	0.083
CQT+LFCC+Spec1724+Cpes1724	0.0006	0.022	0.0027	0.111
TAC+CQT+LFCC+Spec1724+Cpes1724	0.0003	0.033	0.0025	0.088
CQT+LFCC+Spec1724	0.0005	0.017	0.0031	0.111
TAC+CQT+LFCC+Spec1724	0.0005	0.017	0.0027	0.099
CQT+LFCC+Spec1724+Ceps	0.0000	0.002	0.0019	0.077
TAC+CQT+LFCC+Spec1724+Ceps	0.0000	0.002	0.0016	0.055
CQT+LFCC+DCT+Spec1724+Ceps	0.0000	0.002	0.0018	0.066
TAC+CQT+LFCC+DCT+Spec1724+Ceps	0.0000	0.002	0.0016	0.061
LFCC+DCT+Spec1724+Ceps	0.0000	0.002	0.0022	0.093
TAC+LFCC+DCT+Spec1724+Ceps	0	0	0.0020	0.072

# V. CONCLUSION

In this paper, a novel feature for replay detection using temporal autocorrelation of single-channel speech is proposed. The computation of WPE dereverberation inspired us to use the prediction filters as the feature to detect replay attacks. Visual comparisons show that the proposed feature distinguishes replay attacks from bona fide speech. Experimental results show that all fusion systems incorporating the proposed feature achieve performance improvements compared to the corresponding systems without the proposed feature. One of our fusion systems achieves EER and min-tDCF of 0 on the development set of the ASVspoof 2019 physical access database. To the best of our knowledge, this is the first time a fusion model has achieved such a result. Our best fusion model also achieves new state-of-the-art performance on the evaluation set.

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