

SRM VALLIAMMAI ENGINEERING COLLEGE

(An Autonomous Institution)
SRM Nagar, Kattankulathur – 603 203

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING QUESTION BANK



**M.E.-Communication Systems
I Semester**

CU3161-STATISTICAL SIGNAL PROCESSING
Regulation – 2023

Academic Year 2026-2027(Odd Semester)

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

QUESTION BANK

SUBJECT : CU3161-STATISTICAL SIGNAL PROCESSING

SEM / YEAR: I/ I year M.E., CS

	UNIT-I: DISCRETE RANDOM SIGNAL PROCESSING			
	Discrete Random Processes - Ensemble Averages, Stationary processes, Bias and Estimation, Autocovariance, Autocorrelation, Ergodic process, Wiener-Khintchine relation, White noise, Power Spectral Density, Spectral factorization, Filtering Random Processes, Special types of Random Processes : ARMA, AR, MA models, Yule-Walker equations..			
	PART – A (2 Marks)			
Q. No	Questions	CO	BT Level	Competence
1.	Define ensemble average of a discrete random process.	CO1	BTL 1	Remembering
2.	What is meant by a stationary random process?	CO1	BTL 1	Remembering
3.	State any two conditions for a random process to be wide-sense stationary (WSS).	CO1	BTL 1	Remembering
4.	If the true mean is 10 and the estimated mean is 9.5, calculate the bias of the estimator.	CO1	BTL 2	Understanding
5.	Define the autocovariance function of a random process.	CO1	BTL 1	Remembering
6.	Define the autocorrelation function of a discrete random process.	CO1	BTL 1	Remembering
7.	If $E[X(n)] = 2$ and $E[X^2(n)] = 10$, find the autocovariance at zero lag.	CO1	BTL 2	Understanding
8.	What is meant by an ergodic random process?	CO1	BTL 1	Remembering
9.	Differentiate between stationary and ergodic processes.	CO1	BTL 2	Understanding
10.	State the Wiener–Khintchine relation.	CO1	BTL 1	Remembering
11.	Define white noise and mention one of its characteristics.	CO1	BTL 1	Remembering
12.	For a white-noise process with $R_X(k) = 4\delta(k)$, determine $R_X(0)$ and $R_X(1)$.	CO1	BTL 2	Understanding
13.	Define the Power Spectral Density (PSD) of a random process.	CO1	BTL 1	Remembering
14.	A white-noise process has a PSD of 2 W/Hz over a bandwidth of 5 Hz. Find its total average power.	CO1	BTL 2	Understanding
15.	What is meant by spectral factorization?	CO1	BTL 1	Remembering

16.	State the relationship between the input and output PSDs of a random process passing through an LTI filter.	CO1	BTL 1	Remembering
17.	Explain the effect of an LTI filter on a stationary random process.	CO1	BTL 2	Understanding
18.	Define an autoregressive (AR) process.	CO1	BTL 1	Remembering
19.	Define a moving average (MA) process.	CO1	BTL 1	Remembering
20.	What is an ARMA process?	CO1	BTL 1	Remembering
21.	Write the general expression for an AR(1) process and identify its order.	CO1	BTL 1	Remembering
22.	For an AR(1) process, if $r(1) = 0.6$, determine the AR coefficient using the Yule–Walker equation.	CO1	BTL 2	Understanding
23.	State the Yule–Walker equations for an AR process.	CO1	BTL 1	Remembering
24.	Mention any two applications of ARMA models in random signal processing.	CO1	BTL 1	Remembering
PART- B (13 Marks)				
1.	Explain ensemble averaging and its significance. For a random variable taking values 1,2,3,4 with probabilities 0.1,0.2,0.3,0.4, calculate the mean, mean-square value and variance.	CO1	BTL 3	Applying
2.	Explain the conditions for a wide-sense stationary process. For $X(n) = A\cos(\omega_0 n + \Theta)$, where Θ is uniformly distributed over $[0, 2\pi]$, determine the mean and autocorrelation function and verify stationarity.	CO1	BTL 4	Analyzing
3.	Explain bias and estimation. An estimator gives $\hat{\mu} = 9.6$ when the actual mean is $\mu = 10$. Calculate the bias and state whether the estimator is biased.	CO1	BTL 3	Applying
4.	(a) Explain the concept of filtering of random processes and derive the relationship between input and output power spectral densities. (8) (b) A white-noise process with PSD $S_X(e^{j\omega}) = 2$ is passed through an LTI filter with $H(e^{j\omega}) = 1 + e^{-j\omega}$. Determine the output PSD and its values at $\omega = 0$ and $\omega = \pi$. (8)	CO1	BTL 3	Applying
5.	Explain the concept of an ergodic random process. A process has a time-average value of 5 and an ensemble-average value of 5. Determine whether the process satisfies the mean-ergodicity condition.	CO1	BTL 4	Analyzing
6.	State and derive the Wiener–Khinchine relation. For $R_X(k) = 4\delta(k) + 2\delta(k-1) + 2\delta(k+1)$, determine the PSD and evaluate it at $\omega = 0$ and $\omega = \pi$.	CO1	BTL 3	Applying

7.	Define white noise and explain its properties. A white-noise process has variance 4. Determine its autocorrelation function, PSD and total average power over the discrete-time frequency range.	CO1	BTL 3	Applying
8.	(a) Explain the ARMA model and its significance in random signal modeling. (8) (b) For the process $X(n) = 0.5X(n-1) + W(n) + 0.3W(n-1)$, identify the model, obtain its transfer function, and write the expression for its PSD. (8)	CO1	BTL 3	Applying
9.	Explain spectral factorization. Given $S_X(z) = \frac{1}{(1-0.5z^{-1})(1-0.5z)}$, obtain a stable causal spectral factor $H(z)$.	CO1	BTL 4	Analyzing
10.	Derive the input-output relationship for a stationary random process passing through an LTI filter. If $S_X(e^{j\omega}) = 2$ and $H(e^{j\omega}) = 1 + 0.5e^{-j\omega}$, determine the output PSD.	CO1	BTL 3	Applying
11.	Explain AR, MA and ARMA random processes with their mathematical models. For $X(n) = 0.6X(n-1) + W(n)$, identify the model and determine its transfer function.	CO1	BTL 3	Applying
12.	Derive the Yule-Walker equations for an AR(2) process. For $R(0) = 10, R(1) = 6, R(2) = 3$, determine the two AR coefficients.	CO1	BTL 4	Analyzing
13.	An AR(1) process is given by $X(n) = 0.8X(n-1) + W(n)$, where $W(n)$ has variance 2. Determine the variance, autocorrelation function and PSD of $X(n)$.	CO1	BTL 3	Applying
14.	An MA(1) process is given by $X(n) = W(n) + 0.5W(n-1)$, where $W(n)$ has variance 4. Determine $R_X(0), R_X(1)$, and the PSD.	CO1	BTL 3	Applying
15.	For the ARMA(1,1) process $X(n) = 0.7X(n-1) + W(n) + 0.4W(n-1)$, derive the transfer function and PSD. Analyze the effect of the AR and MA parameters on the spectrum.	CO1	BTL 4	Analyzing
16.	Compare AR, MA and ARMA models based on their autocorrelation and spectral characteristics. Given a signal with a slowly decaying autocorrelation sequence, evaluate and justify the most suitable model.	CO1	BTL 5	Evaluating
17.	The autocorrelation sequence is $R(0) = 5, R(1) = 3, R(2) = 2$. (a) Form the Yule-Walker equations. (b) Determine the AR(2) coefficients. (c) Calculate the prediction-error variance. (d) Evaluate the suitability of the model.	CO1	BTL 5	Evaluating

	UNIT-II- SIGNAL MODELING AND OPTIMUM FILTERS
	Introduction- Least square method – Pade approximation – Prony's method – Levinson-Durbin Recursion – FIR Lattice filter - IIR Lattice filter - FIR Wiener filter – Filtering – Linear Prediction – Non Causal and Causal IIR Wiener Filter – Discrete Kalman filter.
	PART- A (2 marks)

Q. No	Questions	CO	BT Level	Competence
1.	What is meant by signal modeling?	CO2	BTL 1	Remembering
2.	Define the least square method in signal modeling.	CO2	BTL 1	Remembering
3.	What is the objective of the least square approximation?	CO2	BTL 1	Remembering
4.	Define Padé approximation.	CO2	BTL 1	Remembering
5.	State one application of Padé approximation in signal modeling.	CO2	BTL 1	Remembering
6.	What is Prony's method?	CO2	BTL 1	Remembering
7.	Mention the two main steps involved in Prony's method.	CO2	BTL 1	Remembering
8.	What is the purpose of Levinson–Durbin recursion?	CO2	BTL 1	Remembering
9.	For an autocorrelation sequence $R(0) = 1$ and $R(1) = 0.5$, find the first-order prediction coefficient using the Levinson–Durbin relation.	CO2	BTL 2	Understanding
10.	Define an FIR lattice filter.	CO2	BTL 1	Remembering
11.	Mention one advantage of an FIR lattice filter.	CO2	BTL 1	Remembering
12.	Differentiate between FIR lattice and IIR lattice filters.	CO2	BTL 2	Understanding
13.	What is an IIR lattice filter?	CO2	BTL 1	Remembering
14.	Define the FIR Wiener filter.	CO2	BTL 1	Remembering
15.	What is the main objective of Wiener filtering?	CO2	BTL 1	Remembering
16.	State the Wiener–Hopf equation used in optimum filtering.	CO2	BTL 1	Remembering
17.	What is meant by linear prediction in discrete-time signal processing?	CO2	BTL 1	Remembering
18.	A first-order predictor is given by $\hat{x}(n) = 0.8x(n-1)$. If $x(n-1) = 5$, calculate $\hat{x}(n)$.	CO2	BTL 2	Understanding
19.	Distinguish between causal and non-causal Wiener filters.	CO2	BTL 2	Understanding
20.	What is a causal IIR Wiener filter?	CO2	BTL 1	Remembering
21.	What is meant by a non-causal IIR Wiener filter?	CO2	BTL 1	Remembering
22.	Define the Discrete Kalman filter.	CO2	BTL 1	Remembering
23.	What are the two basic stages of the Kalman filtering algorithm?	CO2	BTL 1	Remembering
24.	If the predicted state estimate is 10 and the Kalman gain is 0.5, with measurement residual equal to 4, calculate the updated state estimate.	CO2	BTL 2	Understanding
PART – B (13 Marks)				

1.	Explain the least square method for signal modeling and derive the normal equations. Apply the method to obtain the best-fit straight-line model for a given set of observations.	CO2	BTL 3	Applying
2.	Using the least square method, fit the model $y = a + bx$ to the data points (1, 2), (2, 4), and (3, 5), and determine the model parameters a and b .	CO2	BTL 3	Applying
3.	Explain the principle of Padé approximation and obtain a suitable rational approximation for a given Taylor-series representation of a discrete-time system.	CO2	BTL 3	Applying
4.	Explain Prony's method for signal modeling and determine the parameters of a second-order exponential signal model from a given set of signal samples.	CO2	BTL 3	Applying
5.	Explain the Levinson–Durbin recursion and use it to determine the prediction coefficients for an autocorrelation sequence $R(0) = 5, R(1) = 2, R(2) = 1$.	CO2	BTL 3	Applying
6.	Derive the equations of an FIR lattice filter and explain the role of reflection coefficients in its implementation.	CO2	BTL 3	Applying
7.	Explain the structure and operation of an IIR lattice filter and analyze the conditions required for its stability.	CO2	BTL 4	Analyzing
8.	Using the Levinson–Durbin recursion, determine the first- and second-order prediction coefficients for the autocorrelation sequence $R(0) = 4, R(1) = 1.5, R(2) = 0.8$. Also determine the corresponding prediction-error powers.	CO2	BTL 3	Applying
9.	Derive the Wiener–Hopf equations for an FIR Wiener filter and determine the optimum coefficient of a one-tap Wiener filter for $R_{xx}(0) = 4$ and $R_{dx}(0) = 2$.	CO2	BTL 3	Applying
10.	Explain the minimum mean-square-error criterion used in optimum filtering and determine the error signal and mean-square error for a given desired signal and filter output.	CO2	BTL 3	Applying
11.	Explain linear prediction and derive the prediction-error equation. For a first-order predictor $\hat{x}(n) = 0.7x(n - 1)$, calculate the predicted value and prediction error when $x(n - 1) = 4$ and $x(n) = 3$.	CO2	BTL 3	Applying
12.	Analyze the difference between causal and non-causal Wiener filters and explain why a non-causal Wiener filter cannot be directly implemented in a real-time system.	CO2	BTL 4	Analyzing
13.	Explain the design procedure of a non-causal IIR Wiener filter using spectral factorization and derive its optimum transfer function.	CO2	BTL 4	Analyzing

14.	Explain the design of a causal IIR Wiener filter using spectral factorization and analyze the effect of causality on optimum filtering performance.	CO2	BTL 4	Analyzing
15.	Explain the state-space model of the Discrete Kalman filter and calculate the updated state estimate for a predicted state of 10, measurement residual of 5, and Kalman gain of 0.4.	CO2	BTL 3	Applying
16.	Derive and explain the prediction and correction equations of the Discrete Kalman filter and demonstrate their application using suitable numerical values.	CO2	BTL 3	Applying
17.	Compare Least Square, Padé and Prony methods for signal modeling and evaluate their suitability for modeling signals containing exponential and sinusoidal components.	CO2	BTL 5	Evaluating

UNIT-III: SPECTRAL ESTIMATION				
Estimation of spectra from finite duration signals, Nonparametric methods – Periodogram, Modified Periodogram, Bartlett, Welch and Blackman-Tukey methods, Parametric methods – ARMA, AR and MA model based spectral estimation, Frequency Estimation – Eigen Decomposition of autocorrelation matrix, MUSIC algorithm.				
PART A (2 Marks)				
Q. No	Questions	CO	BT Level	Competence
1.	What is meant by spectral estimation from a finite-duration signal?	CO3	BTL 1	Remembering
2.	Why is spectral estimation required for finite-duration signals?	CO3	BTL 2	Understanding
3.	Define the periodogram method of spectral estimation.	CO3	BTL 1	Remembering
4.	What is a modified periodogram?	CO3	BTL 1	Remembering
5.	State one difference between the periodogram and modified periodogram.	CO3	BTL 2	Understanding
6.	What is the basic principle of the Bartlett method?	CO3	BTL 1	Remembering
7.	Define the Welch method of spectral estimation.	CO3	BTL 1	Remembering
8.	Mention any two advantages of the Welch method over the periodogram.	CO3	BTL 2	Understanding
9.	What is the Blackman–Tukey method of spectral estimation?	CO3	BTL 1	Remembering
10.	Differentiate between Bartlett and Welch methods of spectral estimation.	CO3	BTL 2	Understanding
11.	A signal is divided into 4 non-overlapping segments for Bartlett estimation. If each segment contains 64 samples, find the total number of samples used.	CO3	BTL 2	Understanding
12.	What are parametric methods of spectral estimation?	CO3	BTL 1	Remembering
13.	Name the three commonly used model-based parametric spectral estimation methods.	CO3	BTL 1	Remembering

14.	What is AR model-based spectral estimation?	CO3	BTL 1	Remembering
15.	State one advantage of AR spectral estimation over the periodogram method.	CO3	BTL 2	Understanding
16.	What is meant by MA model-based spectral estimation?	CO3	BTL 1	Remembering
17.	What is ARMA model-based spectral estimation?	CO3	BTL 1	Remembering
18.	Differentiate between parametric and nonparametric spectral estimation methods.	CO3	BTL 2	Understanding
19.	What is meant by frequency estimation?	CO3	BTL 1	Remembering
20.	What is the purpose of eigen decomposition of the autocorrelation matrix in frequency estimation?	CO3	BTL 2	Understanding
21.	Define the MUSIC algorithm.	CO3	BTL 1	Remembering
22.	What is meant by the signal subspace and noise subspace in the MUSIC algorithm?	CO3	BTL 2	Understanding
23.	If the autocorrelation matrix has 3 significant eigenvalues and 5 small eigenvalues, determine the estimated number of signal sources.	CO3	BTL 2	Understanding
24.	State one major advantage of the MUSIC algorithm for frequency estimation.	CO3	BTL 1	Remembering
PART – B (13 Marks)				
1.	Explain the problem of spectral estimation from finite-duration signals and derive the expression for estimating the power spectrum from a finite sequence of samples.	CO3	BTL 3	Applying
2.	A finite-duration signal $x(n) = \{1, 2, 1, 0\}$ is given. Calculate its periodogram estimate at the DFT frequencies and explain the significance of the obtained spectral values.	CO3	BTL 3	Applying
3.	Explain the periodogram method of spectral estimation and derive its mathematical expression. Discuss its resolution and variance characteristics.	CO3	BTL 3	Applying
4.	Explain the modified periodogram method and determine the modified periodogram of a given finite-duration sequence using a specified data window.	CO3	BTL 3	Applying
5.	Compare the periodogram and modified periodogram methods and analyze the effect of windowing on spectral leakage and frequency resolution.	CO3	BTL 4	Analyzing
6.	Explain the Bartlett method of spectral estimation and determine the Bartlett spectral estimate when a finite sequence is divided into four equal non-overlapping segments.	CO3	BTL 3	Applying

7.	Explain the Welch method of spectral estimation and analyze the effects of windowing, segment overlap and averaging on the variance of the spectral estimate.	CO3	BTL 4	Analyzing
8.	A signal containing two sinusoidal components at 0.2π and 0.25π rad/sample is analyzed using the Bartlett and Welch methods. Compare their ability to resolve the two frequency components and justify the more suitable method.	CO3	BTL 5	Evaluating
9.	Explain the Blackman–Tukey method and obtain the spectral estimate for an autocorrelation sequence $R(0) = 4, R(1) = 2, R(2) = 1$, with $R(k) = 0$ for $k > 2$.	k	>2).	CO3
10.	Compare the Periodogram, Bartlett, Welch and Blackman–Tukey methods with respect to data segmentation, windowing, bias, variance and frequency resolution.	CO3	BTL 4	Analyzing
11.	Explain parametric spectral estimation and obtain the PSD of an AR(1) process $x(n) = 0.8x(n-1) + w(n)$, where $w(n)$ is white noise with variance 2.	CO3	BTL 3	Applying
12.	For an MA(1) process $x(n) = w(n) + 0.5w(n-1)$, where $w(n)$ has variance 4, derive the model-based power spectral density and discuss its spectral characteristics.	CO3	BTL 3	Applying
13.	Explain ARMA model-based spectral estimation and obtain the PSD expression for the ARMA(1,1) model $x(n) = 0.6x(n-1) + w(n) + 0.4w(n-1)$.	CO3	BTL 3	Applying
14.	Compare AR, MA and ARMA model-based spectral estimation methods and evaluate their suitability for representing narrowband and broadband random signals.	CO3	BTL 5	Evaluating
15.	Explain the eigen decomposition of the autocorrelation matrix for frequency estimation. For an autocorrelation matrix having two dominant eigenvalues and three small eigenvalues, determine the number of signal sources and identify the signal and noise subspaces.	CO3	BTL 4	Analyzing
16.	Explain the MUSIC algorithm for frequency estimation and derive the MUSIC pseudospectrum. Analyze how the separation of signal and noise subspaces enables high-resolution frequency estimation.	CO3	BTL 4	Analyzing
17.	Two sinusoidal signals are present in noise. Using the MUSIC algorithm, explain the procedure for estimating their frequencies from the eigenvalues and eigenvectors of the autocorrelation matrix, and evaluate the advantages of MUSIC over conventional periodogram-based estimation.	CO3	BTL 5	Evaluating

UNIT-IV: ADAPTIVE FILTERS				
	FIR adaptive filters – Steepest descent method LMS algorithm, Convergence , Normalized LMS; Adaptive Recursive Filters; RLS adaptive algorithm-Exponentially weighted RLS - sliding window RLS; Application: channel equalization, noise cancellation, prediction			
	PART A (2 Marks)			
Q. No	Questions	CO	BT Level	Competence
1.	What is an FIR adaptive filter?	CO4	BTL 1	Remembering
2.	Define the steepest descent method used in adaptive filtering.	CO4	BTL 1	Remembering
3.	What is the objective of the LMS algorithm?	CO4	BTL 1	Remembering
4.	Write the weight update equation of the LMS algorithm.	CO4	BTL 1	Remembering
5.	What is meant by convergence in an adaptive filter?	CO4	BTL 1	Remembering
6.	State the condition for the step size μ for convergence of the LMS algorithm.	CO4	BTL 1	Remembering
7.	If the current weight is $w(n) = 0.5$, step size $\mu = 0.1$, error $e(n) = 2$, and input $x(n) = 3$, calculate the updated weight using the LMS update equation.	CO4	BTL 2	Understanding
8.	What is the Normalized LMS (NLMS) algorithm?	CO4	BTL 1	Remembering
9.	State one advantage of NLMS over the conventional LMS algorithm.	CO4	BTL 2	Understanding
10.	What is meant by an adaptive recursive filter?	CO4	BTL 1	Remembering
11.	Define the Recursive Least Squares (RLS) algorithm.	CO4	BTL 1	Remembering
12.	What is the purpose of the forgetting factor in the RLS algorithm?	CO4	BTL 2	Understanding
13.	Define exponentially weighted RLS.	CO4	BTL 1	Remembering
14.	What is a sliding-window RLS algorithm?	CO4	BTL 1	Remembering
15.	Differentiate between exponentially weighted RLS and sliding-window RLS.	CO4	BTL 2	Understanding
16.	What is the role of the step-size parameter in the LMS algorithm?	CO4	BTL 2	Understanding
17.	Mention any two factors that affect the convergence rate of LMS.	CO4	BTL 1	Remembering
18.	If the input vector is $x(n) = [1 \ 2]$ and the weight vector is $w(n) = [0.5 \ 0.5]$, calculate the filter output $y(n)$.	CO4	BTL 2	Understanding
19.	What is meant by channel equalization using an adaptive filter?	CO4	BTL 1	Remembering
20.	Explain how an adaptive filter can be used for noise cancellation.	CO4	BTL 2	Understanding
21.	What is the purpose of an adaptive filter in signal prediction?	CO4	BTL 1	Remembering

22.	Differentiate between LMS and RLS algorithms.	CO4	BTL 2	Understanding
23.	An adaptive filter has a desired signal $d(n) = 5$ and output $y(n) = 3$. Calculate the error signal $e(n)$.	CO4	BTL 2	Understanding
24.	Mention any two applications of adaptive filters.	CO4	BTL 1	Remembering
PART – B (13 Marks)				
1.	Explain the structure and operation of an FIR adaptive filter and derive the weight-update formulation based on the mean-square-error criterion.	CO4	BTL 3	Applying
2.	Derive the steepest descent algorithm for adaptive filtering and determine the weight update equation for a given input autocorrelation matrix and cross-correlation vector.	CO4	BTL 3	Applying
3.	Derive the LMS algorithm from the steepest descent method and explain the significance of the error signal and step-size parameter.	CO4	BTL 3	Applying
4.	An LMS adaptive filter has $w(n) = 0.5$, $x(n) = 2$, $d(n) = 3$, and step size $\mu = 0.1$. Calculate the error and the updated filter coefficient using the LMS algorithm.	CO4	BTL 3	Applying
5.	Derive the convergence condition of the LMS algorithm in terms of the eigenvalues of the input autocorrelation matrix and explain the effect of step size on convergence.	CO4	BTL 4	Analyzing
6.	Explain the Normalized LMS (NLMS) algorithm and derive its weight-update equation. Analyze why normalization improves the adaptation performance for varying input signal power.	CO4	BTL 4	Analyzing
7.	For an NLMS filter, let $w(n) = 0.4$, $x(n) = 2$, $d(n) = 3$, and $\mu = 0.5$. Calculate the error and the updated coefficient using the NLMS algorithm, neglecting the regularization term.	CO4	BTL 3	Applying
8.	Explain the structure and operation of adaptive recursive filters and analyze their advantages and limitations compared with FIR adaptive filters.	CO4	BTL 4	Analyzing
9.	Derive the Recursive Least Squares (RLS) algorithm and explain the role of the inverse correlation matrix and forgetting factor in the algorithm.	CO4	BTL 3	Applying
10.	An RLS algorithm uses a forgetting factor $\lambda = 0.95$. Explain the effect of this value on the weighting of past samples and analyze its influence on the tracking capability of the adaptive filter.	CO4	BTL 4	Analyzing
11.	Explain the exponentially weighted RLS algorithm and derive its cost function. Analyze how the forgetting factor controls the contribution of old and recent data.	CO4	BTL 4	Analyzing

12.	Explain the sliding-window RLS algorithm and compare its operation with exponentially weighted RLS in terms of memory, computational complexity and tracking capability.	CO4	BTL 4	Analyzing
13.	An adaptive filter is used for channel equalization. Explain the LMS-based equalization procedure and determine the updated tap weights for a given input vector, desired symbol and step size.	CO4	BTL 3	Applying
14.	Explain the use of adaptive filtering for noise cancellation. For a desired signal $d(n) = 5$ and filter output $y(n) = 2$, calculate the error signal and explain how the LMS algorithm uses this error to update the filter coefficients.	CO4	BTL 3	Applying
15.	Explain the application of adaptive filters for signal prediction and derive the prediction-error formulation. For $x(n-1) = 4$, predictor coefficient $w(n) = 0.6$, and actual sample $x(n) = 3$, determine the predicted value and prediction error.	CO4	BTL 3	Applying
16.	Compare LMS, NLMS and RLS algorithms in terms of convergence speed, computational complexity, stability and tracking capability, and evaluate their suitability for a rapidly varying communication channel.	CO4	BTL 5	Evaluating
17.	A communication system is affected by both channel distortion and additive noise. Evaluate the suitability of LMS, NLMS and RLS adaptive filters for channel equalization and noise cancellation, and justify the most appropriate algorithm for real-time implementation.	CO4	BTL 5	Evaluating

UNIT-V: MULTIRATE SIGNAL PROCESSING				
	Decimation, Interpolation, sampling rate conversion by rational factor, filter design and implementation for sampling-rate conversion, multistage implementation of sampling-rate conversion, sampling-rate conversion of bandpass signals; application: subband coding of speech signals - quadrature mirror filter			
	PART A (2 Marks)			
Q.No	Questions	CO	BT Level	Competence
1.	Define decimation in multirate signal processing.	CO5	BTL 1	Remembering
2.	What is meant by interpolation?	CO5	BTL 1	Remembering
3.	State the purpose of an anti-aliasing filter in decimation.	CO5	BTL 1	Remembering
4.	State the purpose of an anti-imaging filter in interpolation.	CO5	BTL 1	Remembering
5.	A discrete-time signal sampled at 12 kHz is decimated by a factor of 3. Find the new sampling frequency.	CO5	BTL 2	Understanding
6.	A signal is sampled at 8 kHz and interpolated by a factor of 4. Determine the new sampling frequency.	CO5	BTL 2	Understanding

7.	What is meant by sampling-rate conversion by a rational factor?	CO5	BTL 1	Remembering
8.	A signal sampled at 10 kHz is converted to 15 kHz. Determine the interpolation and decimation factors required.	CO5	BTL 2	Understanding
9.	What is the role of a low-pass filter in rational sampling-rate conversion?	CO5	BTL 2	Understanding
10.	Define multistage sampling-rate conversion.	CO5	BTL 1	Remembering
11.	State one advantage of multistage implementation over single-stage sampling-rate conversion.	CO5	BTL 2	Understanding
12.	A sampling rate has to be reduced by a factor of 12. Give one possible multistage decimation implementation.	CO5	BTL 2	Understanding
13.	What is meant by sampling-rate conversion of bandpass signals?	CO5	BTL 1	Remembering
14.	Why is a bandpass filter used in sampling-rate conversion of bandpass signals?	CO5	BTL 2	Understanding
15.	What is subband coding?	CO5	BTL 1	Remembering
16.	Mention any two advantages of subband coding of speech signals.	CO5	BTL 1	Remembering
17.	What is a Quadrature Mirror Filter (QMF)?	CO5	BTL 1	Remembering
18.	What is the main purpose of a QMF bank in subband coding?	CO5	BTL 2	Understanding
19.	A signal of sampling frequency 16 kHz is divided into two equal subbands using a QMF bank. What is the approximate bandwidth of each subband?	CO5	BTL 2	Understanding
20.	Differentiate between decimation and interpolation.	CO5	BTL 2	Understanding
21.	What is aliasing in the context of decimation?	CO5	BTL 1	Remembering
22.	What is imaging in the context of interpolation?	CO5	BTL 1	Remembering
23.	A signal sampled at 24 kHz is converted to 8 kHz. Determine the decimation factor.	CO5	BTL 2	Understanding
24.	Mention any two applications of multirate signal processing.	CO5	BTL 1	Remembering
PART-B (13 Marks)				
1.	Explain the principle of decimation and derive the input-output relationship for a decimator by a factor of M . Discuss the role of the anti-aliasing filter.	CO5	BTL 3	Applying
2.	A discrete-time signal is sampled at 24 kHz and decimated by a factor of 4. Determine the new sampling frequency and explain the filtering requirement before decimation.	CO5	BTL 3	Applying
3.	Explain the principle of interpolation by a factor of L , including	CO5	BTL 3	Applying

	upsampling, zero insertion and anti-imaging filtering.			
4.	A signal sampled at 8 kHz is interpolated by a factor of 3. Determine the new sampling frequency and explain the purpose of the interpolation filter.	CO5	BTL 3	Applying
5.	Explain sampling-rate conversion by a rational factor L/M and derive the structure of an interpolator-decimator system.	CO5	BTL 3	Applying
6.	A signal sampled at 12 kHz has to be converted to 18 kHz. Determine suitable interpolation and decimation factors and calculate the intermediate sampling frequency.	CO5	BTL 3	Applying
7.	Explain the filter design requirements for sampling-rate conversion and derive the conditions on the cutoff frequency to prevent aliasing and imaging.	CO5	BTL 4	Analyzing
8.	A signal is sampled at 20 kHz and converted to 15 kHz using rational sampling-rate conversion. Determine L and M , the intermediate sampling rate, and the maximum allowable filter bandwidth.	CO5	BTL 3	Applying
9.	Explain the implementation of sampling-rate conversion using polyphase filters and analyze how polyphase decomposition reduces the computational complexity.	CO5	BTL 4	Analyzing
10.	Explain multistage implementation of sampling-rate conversion. A sampling rate must be reduced by a factor of 12; design a suitable multistage decimation structure and justify your choice.	CO5	BTL 5	Evaluating
11.	Compare single-stage and multistage sampling-rate conversion in terms of filter order, computational complexity and implementation efficiency.	CO5	BTL 4	Analyzing
12.	Explain sampling-rate conversion of bandpass signals and derive the conditions under which a bandpass signal can be downsampled without aliasing.	CO5	BTL 4	Analyzing
13.	A bandpass signal occupies the frequency range 6–8 kHz and is sampled at 20 kHz. Determine a suitable lower sampling rate for rate conversion and justify your choice based on the bandpass sampling condition.	CO5	BTL 5	Evaluating
14.	Explain the principle of subband coding of speech signals using analysis and synthesis filter banks, and discuss the role of decimation and interpolation in the process.	CO5	BTL 3	Applying
15.	A speech signal sampled at 16 kHz is divided into two equal subbands using a two-channel filter bank. Determine the approximate frequency range of each subband and the sampling rate of each decimated subband.	CO5	BTL 3	Applying

16.	Explain the structure and operation of a Quadrature Mirror Filter (QMF) bank and analyze how aliasing cancellation is achieved during signal reconstruction.	CO5	BTL 4	Analyzing
17.	Evaluate the use of QMF-based subband coding for speech signals by comparing it with direct full-band processing in terms of computational complexity, bandwidth distribution, reconstruction quality and aliasing control.	CO5	BTL 5	Evaluating