

FIG. 1

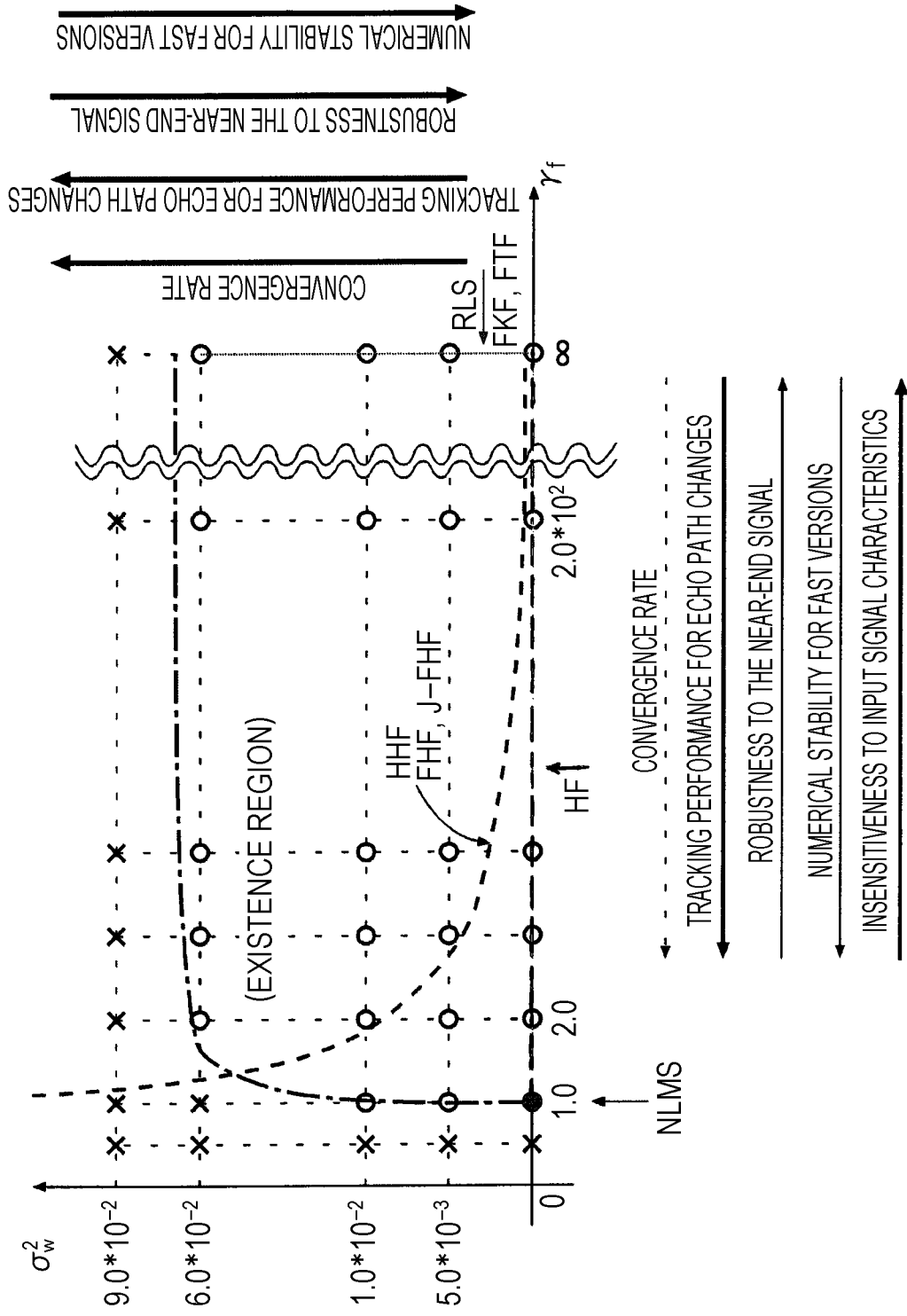


FIG. 1: DISTRIBUTION AND PROPERTIES OF SOLUTION IN γ_f - σ_w^2 SPACE; $\rho = 1/(1 + \sigma_w^2)$

FIG. 2

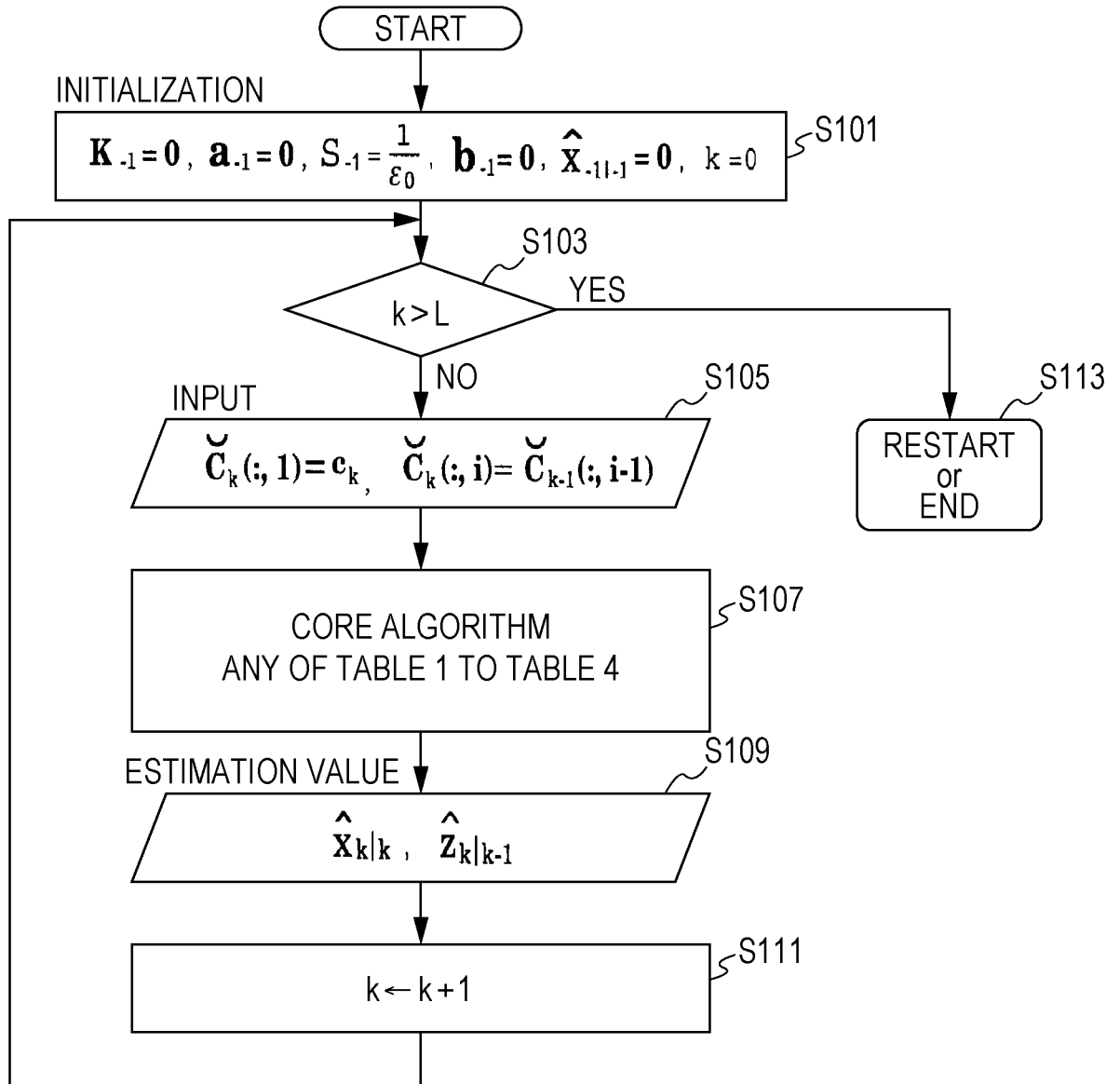


FIG. 2: FLOWCHART OF FAST H_∞ FILTER GROUP; INITIALIZATION OF a_k AND b_k IS NOT NECESSARY IN TABLE 3 (C-WFHF) AND TABLE 4 (C-NLMS)

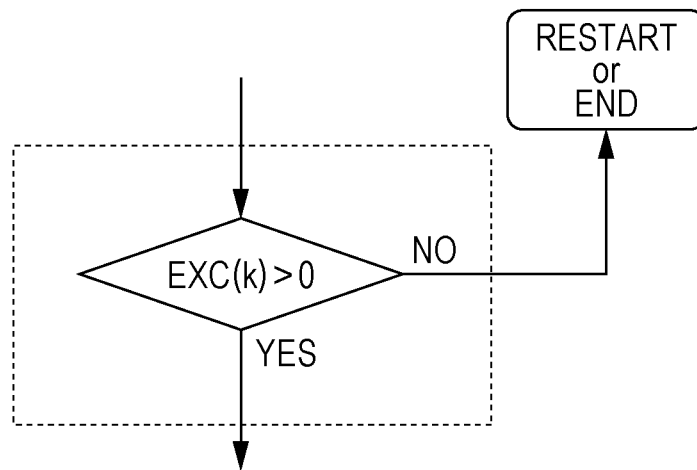
FIG. 3

FIG. 3: CHECKING OF EXISTENCE CONDITION; $EXC(k) = -\varrho \hat{\Xi}_k + \rho \gamma_f^2$

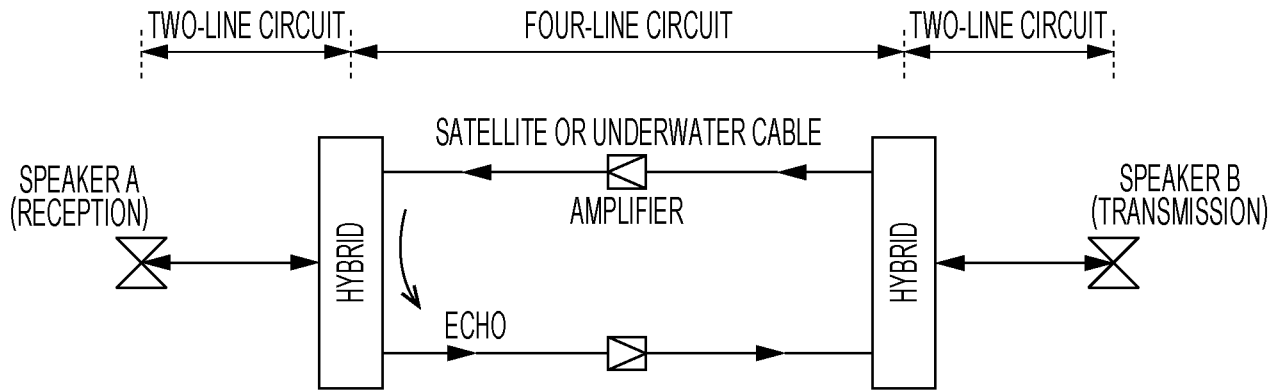
FIG. 4

FIG. 4: COMMUNICATION SYSTEM AND ECHO

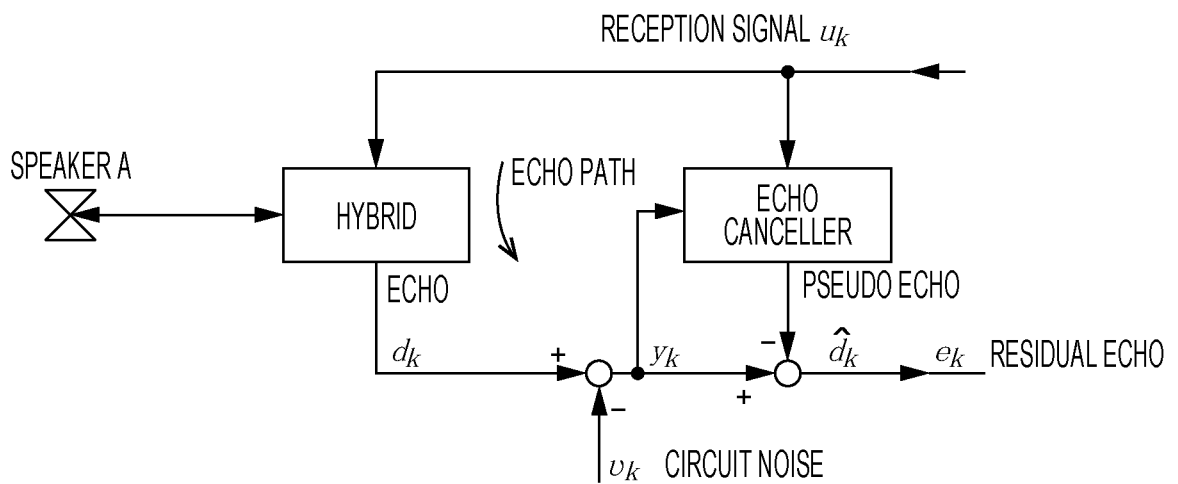
FIG. 5

FIG. 5: PRINCIPLE OF ECHO CANCELLER

FIG. 6A

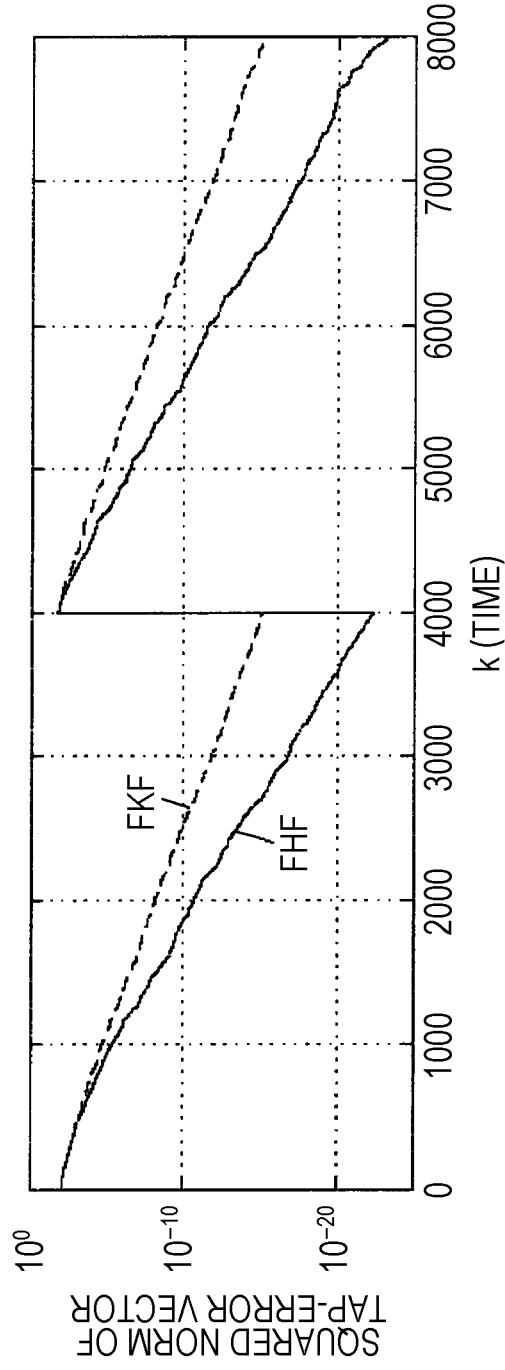


FIG. 6B

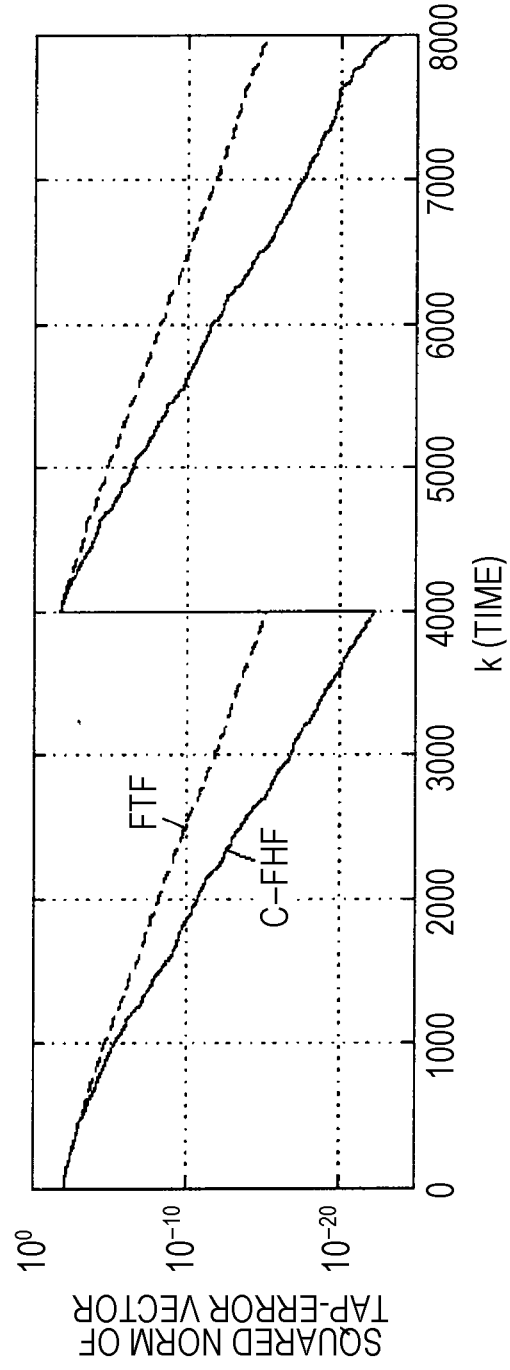


FIG. 6: TRANSITION OF TAP SQUARE ERROR IN PROPOSED METHOD (C-FHF) AND OTHER METHODS (AR(2) SIGNAL); $\gamma_f = 1.4$, $\rho = 0.996$, $\epsilon_0 = 10.0$

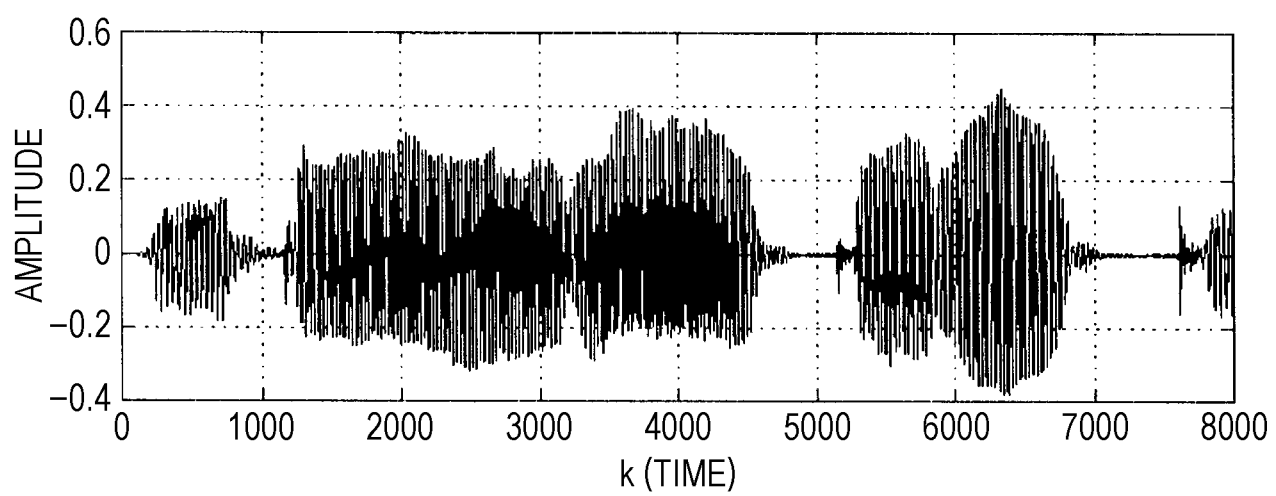
FIG. 7

FIG. 7: AUDIO SIGNAL

FIG. 8A

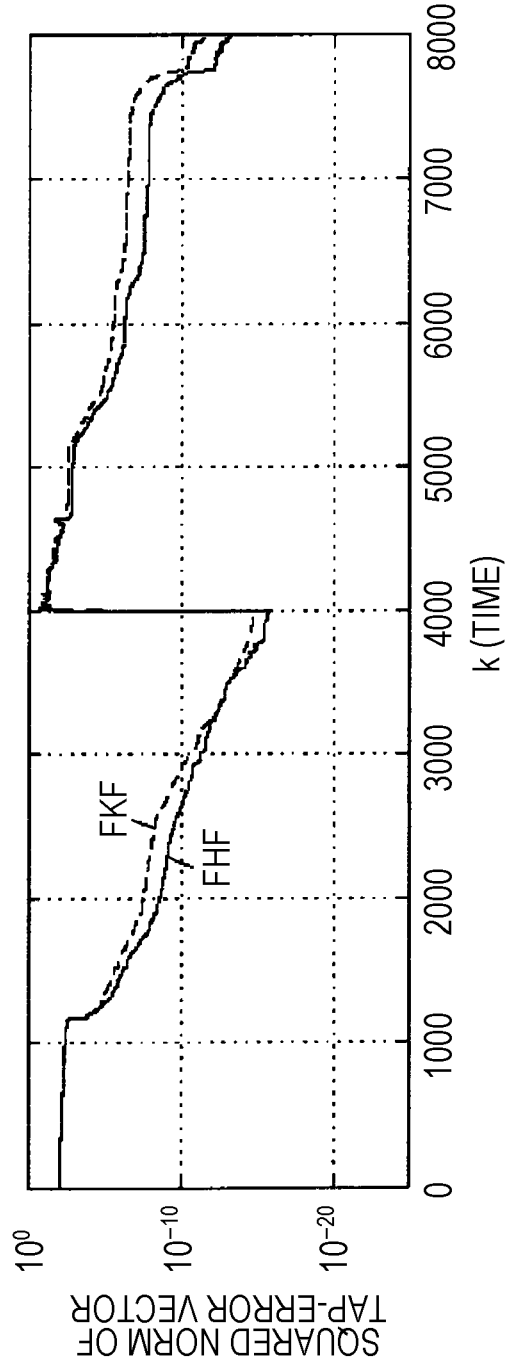


FIG. 8B

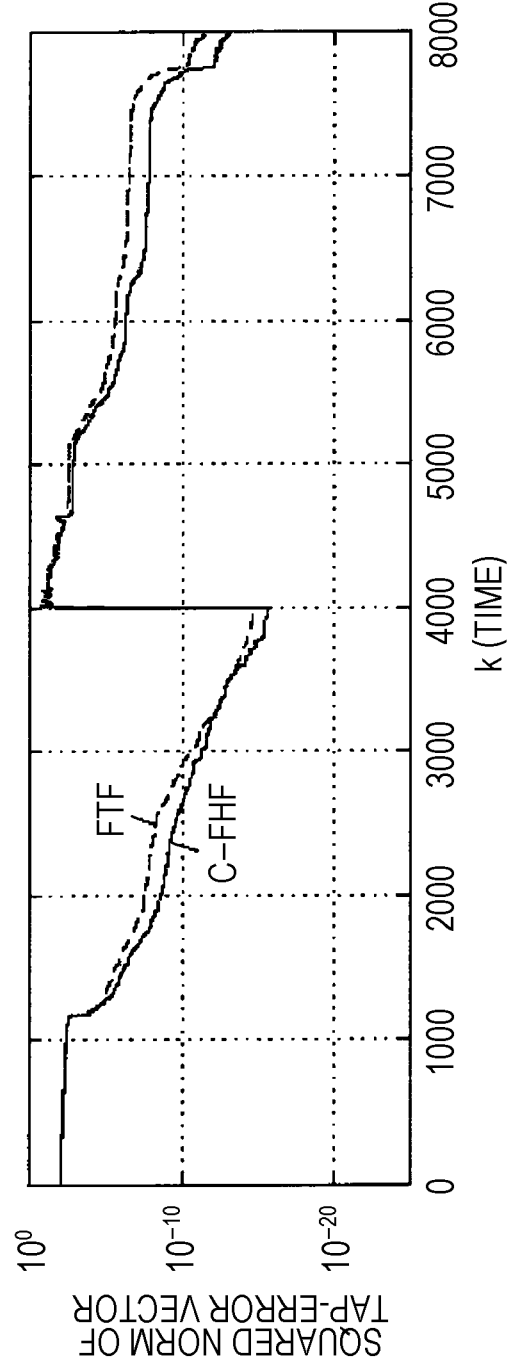


FIG. 8: TRANSITION OF TAP SQUARE ERROR IN PROPOSED METHOD (C-FHF) AND OTHER METHODS (AUDIO SIGNAL); $\gamma_f = 1.4$, $\rho = 0.996$, $\epsilon_0 = 10.0$

FIG. 9

EQUATIONS	Mul.	Add.
$\tilde{e}_k = c_k + C_{k-1}a_{k-1}$	N	N
$a_k = a_{k-1} - K_{k-1}W\tilde{e}_k$	$N + 1$	$N + 1$
$e_k = c_k + C_{k-1}a_k$	N	N
$S_k = \rho S_{k-1} + e_k^T W \tilde{e}_k$	3	2
$\begin{bmatrix} m_k \\ \mu_k \end{bmatrix} = \begin{bmatrix} 0 \\ K_{k-1} \end{bmatrix} + \begin{bmatrix} 1 \\ a_k \end{bmatrix} \frac{e_k^T}{S_k}$	N	N
$\underline{\tilde{e}}_k = c_{k-N} + C_k b_{k-1}$	N	N
$b_{k_1} = [b_{k-1} - m_k W \underline{\tilde{e}}_k][1 - \mu_k W \underline{\tilde{e}}_k]^{-1}$	$2N + 3$	$N + 3$
$K_k = m_k - b_k \mu_k$	N	N
$\hat{x}_{k k} = \hat{x}_{k-1 k-1} + K_k(:, 1) \frac{y_k - H_k \hat{x}_{k-1 k-1}}{1 + \gamma_f^{-2} H_k K_k(:, 1)}$	$3N + 1$	$3N$
TOTAL NUMBER	$11N + 8$	$10N + 6$

FIG. 10

EQUATIONS	Mul.	Add.
$\tilde{\mathbf{e}}_k = \mathbf{c}_k + \mathbf{C}_{k-1}\mathbf{a}_{k-1}$	N	N
$\mathbf{e}_k = \chi_{k-1}^{-1} \tilde{\mathbf{e}}_k$	2	2
$S_k = \rho S_{k-1} + \mathbf{e}_k^T \mathbf{W} \tilde{\mathbf{e}}_k$	3	2
$\mathbf{a}_k = \mathbf{a}_{k-1} - \rho^{-1} \tilde{\mathbf{K}}_{k-1} \mathbf{W} \mathbf{e}_k$	$N + 2$	$N + 1$
$\begin{bmatrix} \tilde{\mathbf{m}}_k \\ \tilde{\boldsymbol{\mu}}_k \end{bmatrix} = \begin{bmatrix} 0 \\ \tilde{\mathbf{K}}_{k-1} \end{bmatrix} + \begin{bmatrix} 1 \\ \mathbf{a}_{k-1} \end{bmatrix} \frac{\tilde{\mathbf{e}}_k^T}{S_{k-1}}$	$N + 1$	N
$\tilde{\mathbf{K}}_k = \tilde{\mathbf{m}}_k - b_{k-1} \tilde{\boldsymbol{\mu}}_k$	N	N
$\underline{\tilde{\mathbf{e}}}_k = \underline{S}_{k-1} \tilde{\boldsymbol{\mu}}_k^T$	1	0
$\mathbf{R}_{e,k} = \mathbf{R}_{e,k-1} + \frac{\tilde{\mathbf{e}}_k \tilde{\mathbf{e}}_k^T}{S_{k-1}} - \underline{\tilde{\mathbf{e}}}_k \tilde{\boldsymbol{\mu}}_k$	3	6
$\chi_k^{-1} = \rho \mathbf{W}^{-1} \mathbf{R}_{e,k}^{-1}$	10	1
$\underline{\mathbf{e}}_k = \chi_k^{-1} \underline{\tilde{\mathbf{e}}}_k$	2	2
$\underline{S}_k = \rho \underline{S}_{k-1} + \underline{\mathbf{e}}_k^T \mathbf{W} \underline{\tilde{\mathbf{e}}}_k$	3	2
$\mathbf{b}_k = \mathbf{b}_{k-1} - \rho^{-1} \tilde{\mathbf{K}}_k \mathbf{W} \underline{\mathbf{e}}_k$	$N + 2$	$N + 1$
$\hat{\mathbf{x}}_{k k} = \hat{\mathbf{x}}_{k-1 k-1} + \tilde{\mathbf{K}}_k(:, 1) \frac{y_k - \mathbf{H}_k \hat{\mathbf{x}}_{k-1 k-1}}{\mathbf{R}_{e,k}(1,1)}$	$2N$	$2N$
TOTAL NUMBER	$7N + 29$	$7N + 17$

FIG. 11

EQUATIONS	Mul.	Add.
$S_k = \rho S_{k-1} + \mathbf{c}_k^T \mathbf{W} \tilde{\mathbf{c}}_k$	3	2
$\begin{bmatrix} \tilde{\mathbf{K}}_k \\ \tilde{\boldsymbol{\mu}}_k \end{bmatrix} = \begin{bmatrix} \mathbf{c}_k^T / S_{k-1} \\ \tilde{\mathbf{K}}_{k-1} \end{bmatrix}$	1	0
$\mathbf{R}_{e,k} = \mathbf{R}_{e,k-1} + \frac{\mathbf{c}_k \mathbf{c}_k^T}{S_{k-1}} - \mathbf{c}_{k-N} \tilde{\boldsymbol{\mu}}_k$	3	6
$\hat{\mathbf{x}}_{k k} = \hat{\mathbf{x}}_{k-1 k-1} + \mu \tilde{\mathbf{K}}_k(:, 1) \frac{y_k - \mathbf{H}_k \hat{\mathbf{x}}_{k-1 k-1}}{\mathbf{R}_{e,k}(1,1)}$	$2N + 1$	$2N$
TOTAL NUMBER	$2N + 8$	$2N + 8$

FIG. 12

EQUATIONS	Mul.	Add.
$\begin{bmatrix} \tilde{\mathbf{K}}_k \\ \tilde{\boldsymbol{\mu}}_k \end{bmatrix} = \begin{bmatrix} \epsilon_0 \mathbf{c}_k^T \\ \tilde{\mathbf{K}}_{k-1} \end{bmatrix}$	1	0
$\mathbf{R}_{e,k} = \mathbf{R}_{e,k-1} + \epsilon_0 \mathbf{c}_k \mathbf{c}_k^T - \mathbf{c}_{k-N} \tilde{\boldsymbol{\mu}}_k$	3	6
$\hat{\mathbf{x}}_{k k} = \hat{\mathbf{x}}_{k-1 k-1} + \mu \tilde{\mathbf{K}}_k(:, 1) \frac{y_k - \mathbf{H}_k \hat{\mathbf{x}}_{k-1 k-1}}{\mathbf{R}_{e,k}(1,1)}$	$2N + 1$	$2N$
TOTAL NUMBER	$2N + 5$	$2N + 6$

FIG. 13

h_0	h_1	h_2	h_3	h_4	h_5	h_6	h_7
0.0	0.008	-0.012	0.064	0.013	-0.052	-0.007	0.039
h_8	h_9	h_{10}	h_{11}	h_{12}	h_{13}	h_{14}	h_{15}
0.011	0.0	-0.002	-0.009	-0.016	-0.013	-0.001	0.004
h_{16}	h_{17}	h_{18}	h_{19}	h_{20}	h_{21}	h_{22}	h_{23}
0.015	0.013	0.007	0.0	-0.001	-0.002	-0.001	0.0

FIG. 14

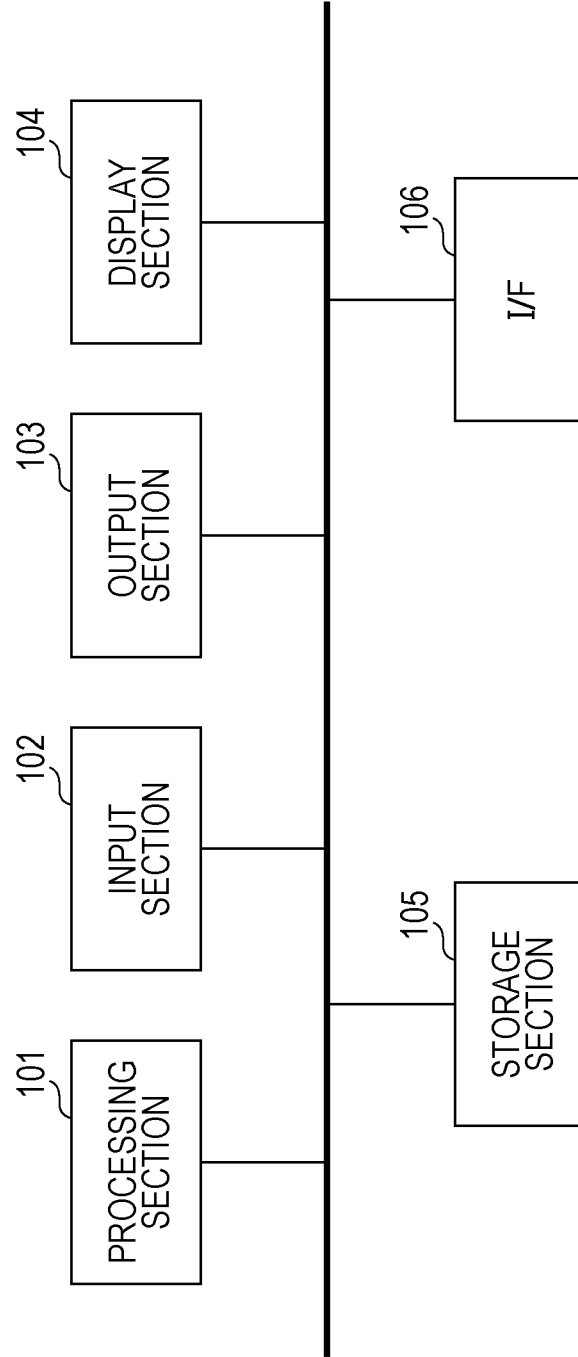


FIG. 15

EQUATIONS	Mul.	Div.	Add
$S_k = \rho S_{k-1} + (1 - \gamma_f^{-2}) u_k^2$	3	0	2
$\tilde{\mathbf{K}}_k(:, 1) = \begin{bmatrix} u_k / S_{k-1} \\ \tilde{\mathbf{K}}_{k-1}(1 : N - 1, 1) \end{bmatrix}$	0	1	0
$R_{e,k}(1, 1) = R_{e,k-1}(1, 1) + \frac{u_k^2}{S_{k-1}} - u_{k-N} \tilde{\mathbf{K}}_{k-1}(N, 1)$	2	0	2
$\hat{\mathbf{x}}_k = \hat{\mathbf{x}}_{k-1} + \mu \tilde{\mathbf{K}}_k(:, 1) \frac{y_k - \mathbf{H}_k \hat{\mathbf{x}}_{k-1}}{R_{e,k}(1, 1)}$	2N+1	1	2N
TOTAL NUMBER	2N+6	2	2N+4

FIG. 16

EQUATIONS	Mul.	Div.	Add
$\tilde{\mathbf{K}}_k(:, 1) = \begin{bmatrix} \epsilon_0 u_k \\ \tilde{\mathbf{K}}_{k-1}(1 : N - 1, 1) \end{bmatrix}$	1	0	0
$R_{e,k}(1, 1) = R_{e,k-1}(1, 1) + \epsilon_0 u_k^2 - u_{k-N} \tilde{\mathbf{K}}_{k-1}(N, 1)$	2	0	2
$\hat{\mathbf{x}}_k = \hat{\mathbf{x}}_{k-1} + \mu \tilde{\mathbf{K}}_k(:, 1) \frac{y_k - \mathbf{H}_k \hat{\mathbf{x}}_{k-1}}{R_{e,k}(1, 1)}$	2N+1	1	2N
TOTAL NUMBER	2N+4	1	2N+2