Tunable IIR Digital Filters

- We have described earlier two 1st-order and two 2nd-order IIR digital transfer functions with tunable frequency response characteristics
- We shall show now that these transfer functions can be realized easily using allpass structures providing independent tuning of the filter parameters

Tunable Lowpass and Highpass Digital Filters

- We have shown earlier that the 1st-order lowpass transfer function

$$H_{LP}(z) = \frac{1-\alpha}{2}\left(\frac{1+z^{-1}}{1-\alpha\, z^{-1}}\right)$$

and the 1st-order highpass transfer function

$$H_{HP}(z) = \frac{1+\alpha}{2}\left(\frac{1-z^{-1}}{1-\alpha\, z^{-1}}\right)$$

are doubly-complementary pair

Tunable Lowpass and Highpass Digital Filters

- Moreover, they can be expressed as

$$H_{LP}(z) = \tfrac{1}{2}[1 + \mathcal{A}_1(z)]$$
$$H_{HP}(z) = \tfrac{1}{2}[1 - \mathcal{A}_1(z)]$$

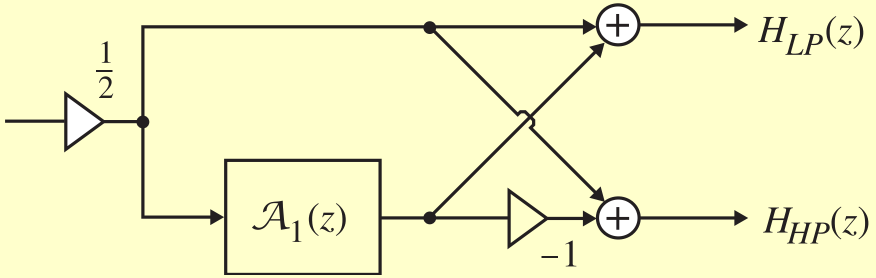
where

$$\mathcal{A}_1(z) = \frac{-\alpha + z^{-1}}{1 - \alpha z^{-1}}$$

is a 1st-order allpass transfer function

Tunable Lowpass and Highpass Digital Filters

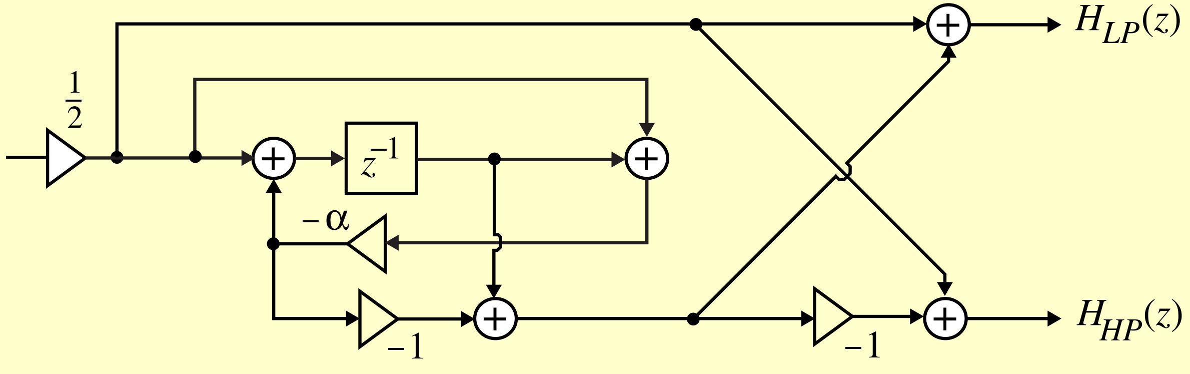
- A realization of $H_{LP}(z)$ and $H_{HP}(z)$ based on the allpass-based decomposition is shown below



- The 1st-order allpass filter can be realized using any one of the 4 single-multiplier allpass structures described earlier

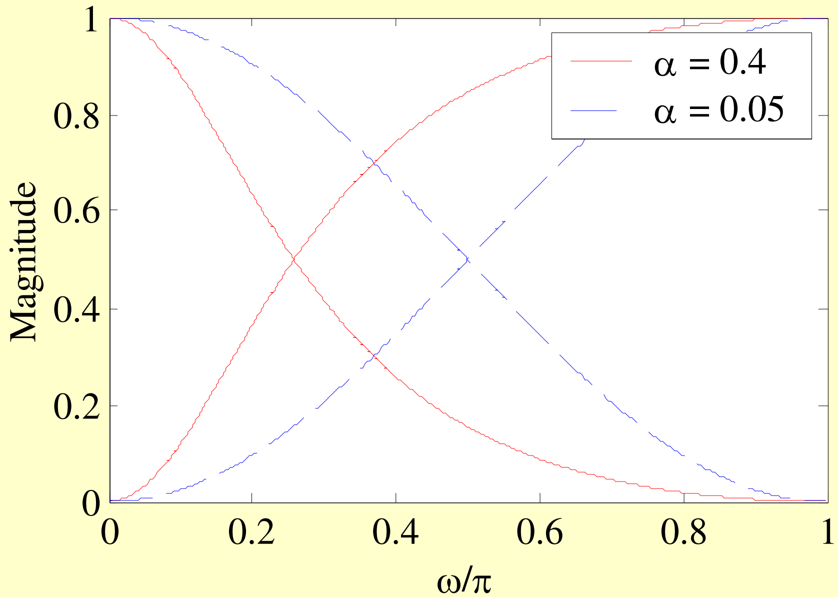
Tunable Lowpass and Highpass Digital Filters

- One such realization is shown below in which the 3-dB cutoff frequency of both lowpass and highpass filters can be varied simultaneously by changing the multiplier coefficient α



Tunable Lowpass and Highpass Digital Filters

- Figure below shows the composite magnitude responses of the two filters for two different values of α



Tunable Bandpass and Bandstop Digital Filters

- The 2nd-order bandpass transfer function

$$H_{BP}(z) = \frac{1-\alpha}{2}\left(\frac{1-z^{-2}}{1-\beta(1+\alpha)z^{-1}+\alpha z^{-2}}\right)$$

and the 2nd-order bandstop transfer function

$$H_{BS}(z) = \frac{1+\alpha}{2}\left(\frac{1-\beta z^{-1}+z^{-2}}{1-\beta(1+\alpha)z^{-1}+\alpha z^{-2}}\right)$$

also form a doubly-complementary pair

Tunable Bandpass and Bandstop Digital Filters

- Thus, they can be expressed in the form

$$H_{BP}(z) = \tfrac{1}{2}[1 - \mathcal{A}_2(z)]$$
$$H_{BS}(z) = \tfrac{1}{2}[1 + \mathcal{A}_2(z)]$$

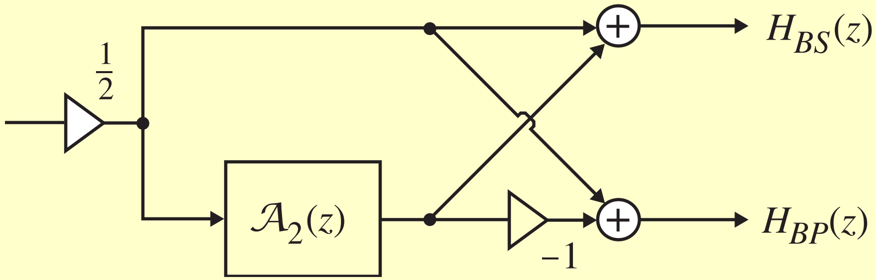
where

$$\mathcal{A}_2(z) = \frac{\alpha - \beta(1+\alpha)z^{-1} + z^{-2}}{1 - \beta(1+\alpha)z^{-1} + \alpha z^{-2}}$$

is a 2nd-order allpass transfer function

Tunable Bandpass and Bandstop Digital Filters

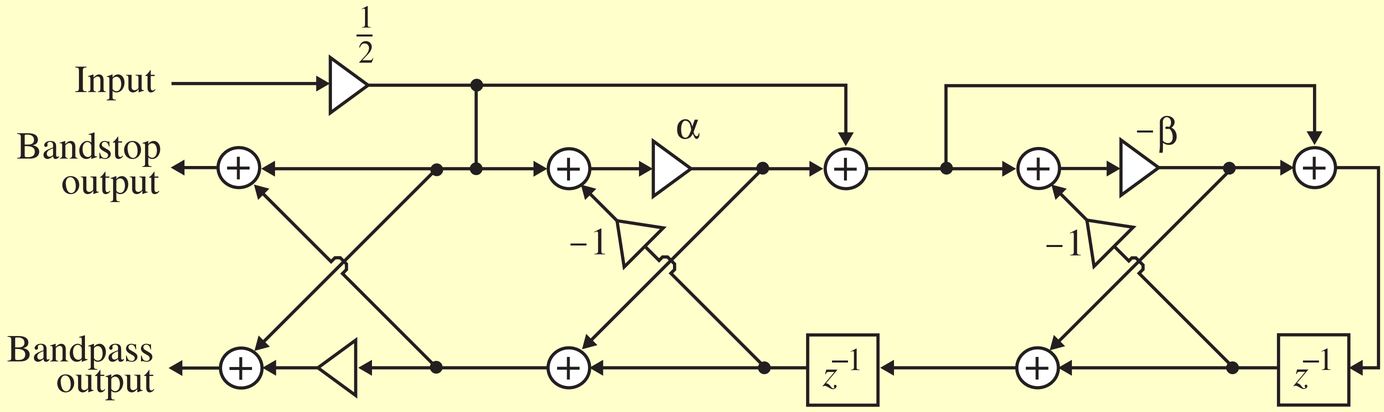
- A realization of $H_{BP}(z)$ and $H_{BS}(z)$ based on the allpass-based decomposition is shown below



- The 2nd-order allpass filter is realized using a cascaded single-multiplier lattice structure

Tunable Bandpass and Bandstop Digital Filters

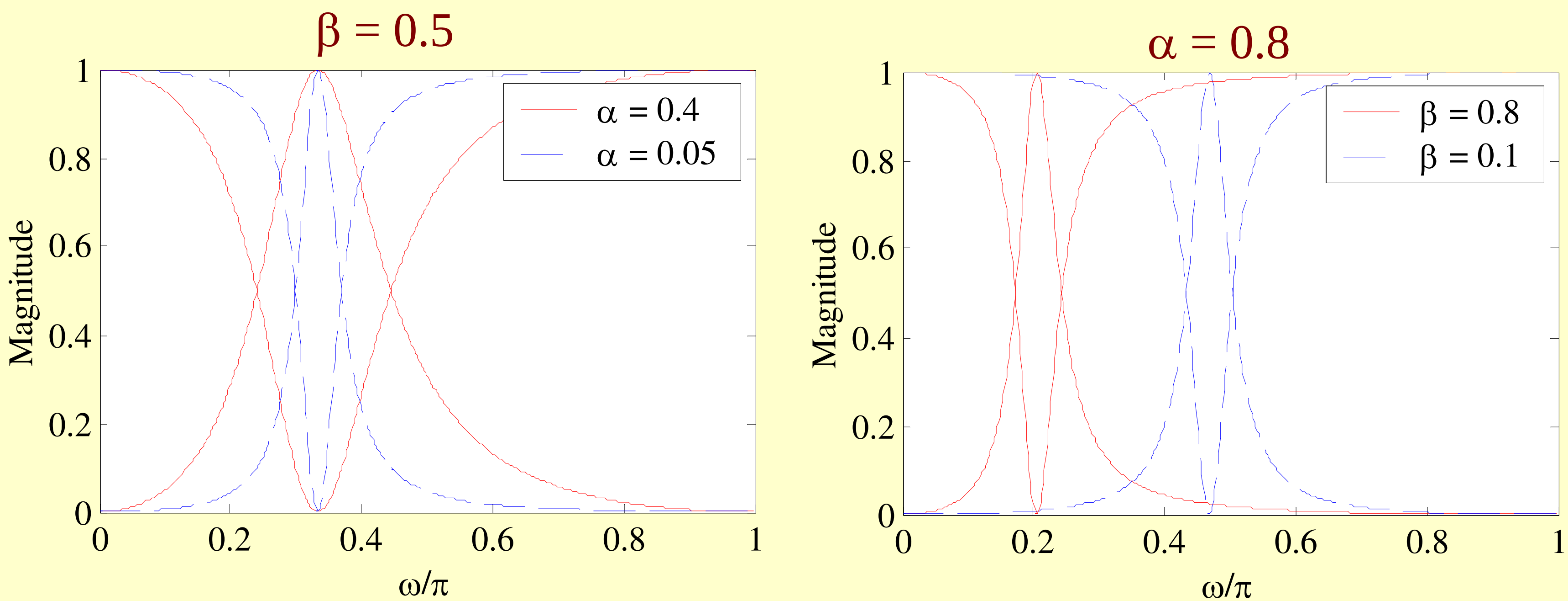
- The final structure is as shown below



- In the above structure, the multiplier β controls the center frequency and the multiplier α controls the 3-dB bandwidth

Tunable Bandpass and Bandstop Digital Filters

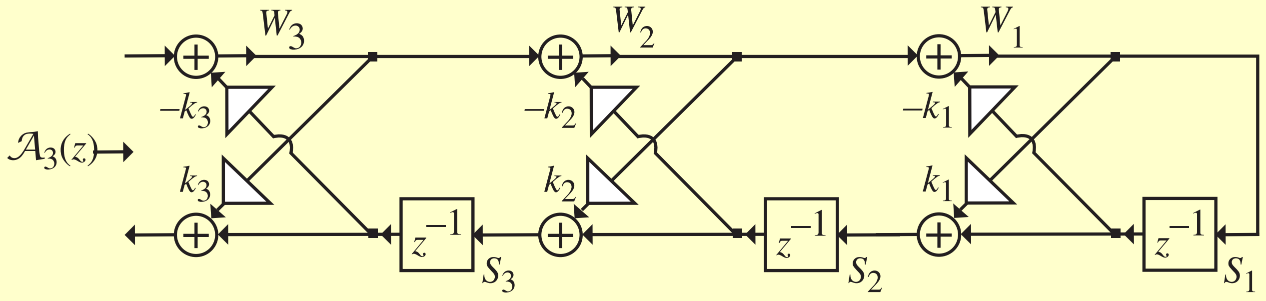
- Figure below illustrates the parametric tuning property of the overall structure



IIR Tapped Cascaded Lattice Structures

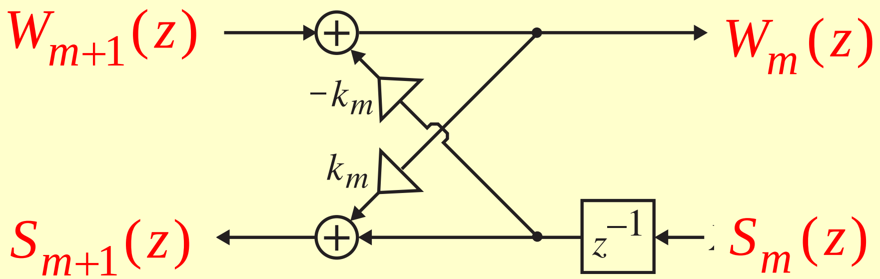
Realization of an All-pole IIR Transfer Function

- Consider the cascaded lattice structure derived earlier for the realization of an allpass transfer function



IIR Tapped Cascaded Lattice Structures

- A typical lattice two-pair here is as shown below



- Its input-output relations are given by

$$W_m(z) = W_{m+1}(z) - k_m z^{-1} S_m(z)$$

$$S_{m+1}(z) = k_m W_m(z) + z^{-1} S_m(z)$$

IIR Tapped Cascaded Lattice Structures

- From the input-output relations we derive the chain matrix description of the two-pair:

$$\begin{bmatrix} W_{m+1}(z) \\ S_{m+1}(z) \end{bmatrix} = \begin{bmatrix} 1 & k_m z^{-1} \\ k_m & z^{-1} \end{bmatrix} \begin{bmatrix} W_m(z) \\ S_m(z) \end{bmatrix}$$

- The chain matrix description of the cascaded lattice structure is therefore

$$\begin{bmatrix} X_1(z) \\ Y_1(z) \end{bmatrix} = \begin{bmatrix} 1 & k_3 z^{-1} \\ k_3 & z^{-1} \end{bmatrix} \begin{bmatrix} 1 & k_2 z^{-1} \\ k_2 & z^{-1} \end{bmatrix} \begin{bmatrix} 1 & k_1 z^{-1} \\ k_1 & z^{-1} \end{bmatrix} \begin{bmatrix} W_1(z) \\ S_1(z) \end{bmatrix}$$

IIR Tapped Cascaded Lattice Structures

- From the above equation we arrive at

$$X_1(z) = \{1 + [k_1(1+k_2) + k_2 k_3]z^{-1} + [k_2 + k_1 k_3(1+k_2)]z^{-2} + k_3 z^{-3}\}W_1(z)$$
$$= (1 + d_1 z^{-1} + d_2 z^{-2} + d_3 z^{-3})W_1(z)$$

using the relation $S_1(z) = W_1(z)$ and the relations

$$k_1 = d_1'', \quad k_2 = d_2', \quad k_3 = d_3$$

IIR Tapped Cascaded Lattice Structures

- The transfer function $W_1(z)/X_1(z)$ is thus an all-pole function with the same denominator as that of the 3rd-order allpass function $\mathcal{A}_3(z)$:

$$\frac{W_1(z)}{X_1(z)} = \frac{1}{1 + d_1 z^{-1} + d_2 z^{-2} + d_3 z^{-3}}$$

IIR Tapped Cascaded Lattice Structures

Gray-Markel Method

- A two-step method to realize an Mth-order arbitrary IIR transfer function

$$H(z) = P_M(z) / D_M(z)$$

- Step 1: An intermediate allpass transfer function $\mathcal{A}_M(z) = z^{-M} D_M(z^{-1}) / D_M(z)$ is realized in the form of a cascaded lattice structure

IIR Tapped Cascaded Lattice Structures

- Step 2: A set of independent variables are summed with appropriate weights to yield the desired numerator $P_M(z)$
- To illustrate the method, consider the realization of a 3rd-order transfer function

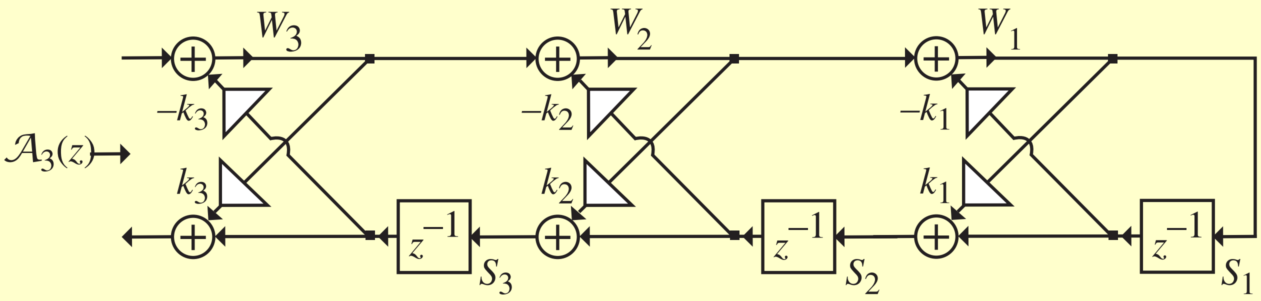
$$H(z) = \frac{P_3(z)}{D_3(z)} = \frac{p_0 + p_1 z^{-1} + p_2 z^{-2} + p_3 z^{-3}}{1 + d_1 z^{-1} + d_2 z^{-2} + d_3 z^{-3}}$$

IIR Tapped Cascaded Lattice Structures

- In the first step, we form a 3rd-order allpass transfer function

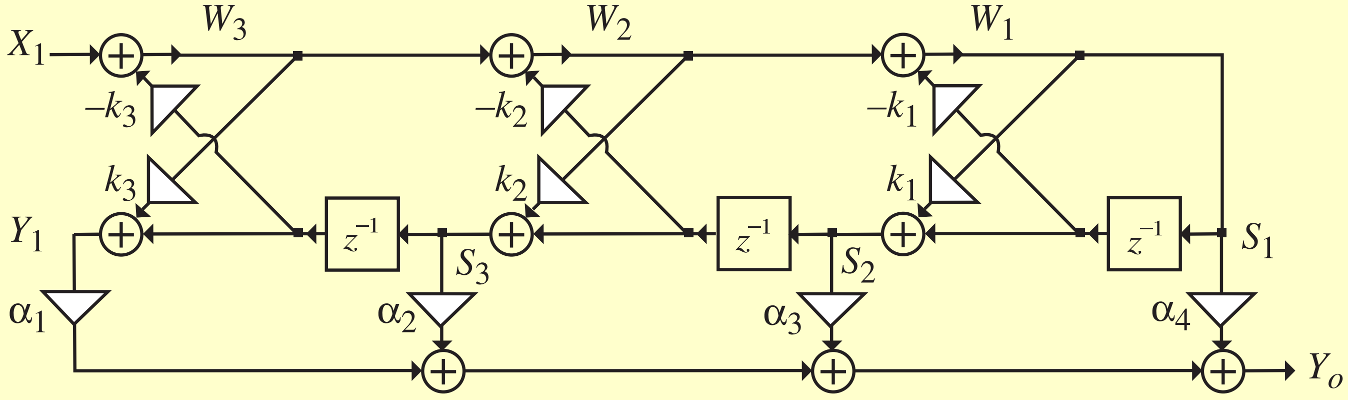
$$\mathcal{A}_3(z) = Y_1(z)/X_1(z) = z^{-3} D_3(z^{-1})/D_3(z)$$

- Realization of $\mathcal{A}_3(z)$ has been illustrated earlier resulting in the structure shown below



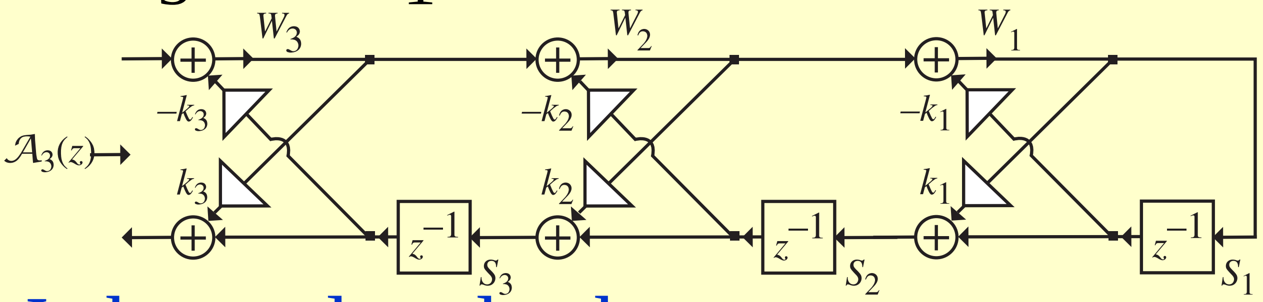
IIR Tapped Cascaded Lattice Structures

- Objective: Sum the independent signal variables Y_1, S_1, S_2, and S_3 with weights $\{\alpha_i\}$ as shown below to realize the desired numerator $P_3(z)$



IIR Tapped Cascaded Lattice Structures

- To this end, we first analyze the cascaded lattice structure realizing and determine the transfer functions $S_1(z)/X_1(z)$, $S_2(z)/X_1(z)$, and $S_3(z)/X_1(z)$



- We have already shown

$$\frac{S_1(z)}{X_1(z)} = \frac{1}{D_3(z)}$$

IIR Tapped Cascaded Lattice Structures

- From the figure it follows that

$$S_2(z) = (k_1 + z^{-1})S_1(z) = (d_1'' + z^{-1})S_1(z)$$

and hence

$$\frac{S_2(z)}{X_1(z)} = \frac{d_1'' + z^{-1}}{D_3(z)}$$

IIR Tapped Cascaded Lattice Structures

- From Slide No. 20, we have

$$S_2(z) = (d_1'' + z^{-1})S_1(z)$$
$$S_3(z) = d_2' W_2(z) + z^{-1} S_2(z)$$
$$S_1(z) = W_2(z) - d_1'' z^{-1} S_1(z)$$

- From the last equation we get

$$W_2(z) = (1 + d_1'' z^{-1})S_1(z)$$

IIR Tapped Cascaded Lattice Structures

- Substituting $W_2(z) = (1 + d_1'' z^{-1}) S_1(z)$ and $S_2(z) = (d_1'' + z^{-1}) S_1(z)$ in

$$S_3(z) = d_2' W_2(z) + z^{-1} S_2(z)$$

we arrive at

$$S_3(z) = d_2'(1 + d_1'' z^{-1}) S_1(z) + z^{-1}(d_1'' + z^{-1}) S_1(z)$$

$$= [d_2' + d_1''(d_2' + 1) z^{-1} + z^{-2}] S_1(z)$$

IIR Tapped Cascaded Lattice Structures

- From $d''_1 = \dfrac{d'_1 - d'_2 d'_1}{1-(d'_2)^2} = \dfrac{d'_1}{1+d'_2}$ we observe

$$d'_1 = d''_1(d'_2 + 1)$$

- Thus, $S_3(z) = (d'_2 + d'_1 z^{-1} + z^{-2})S_1(z)$

IIR Tapped Cascaded Lattice Structures

- Thus,

$$\frac{S_3(z)}{X_1(z)} = \frac{d_2' + d_1' z^{-1} + z^{-2}}{D_3(z)}$$

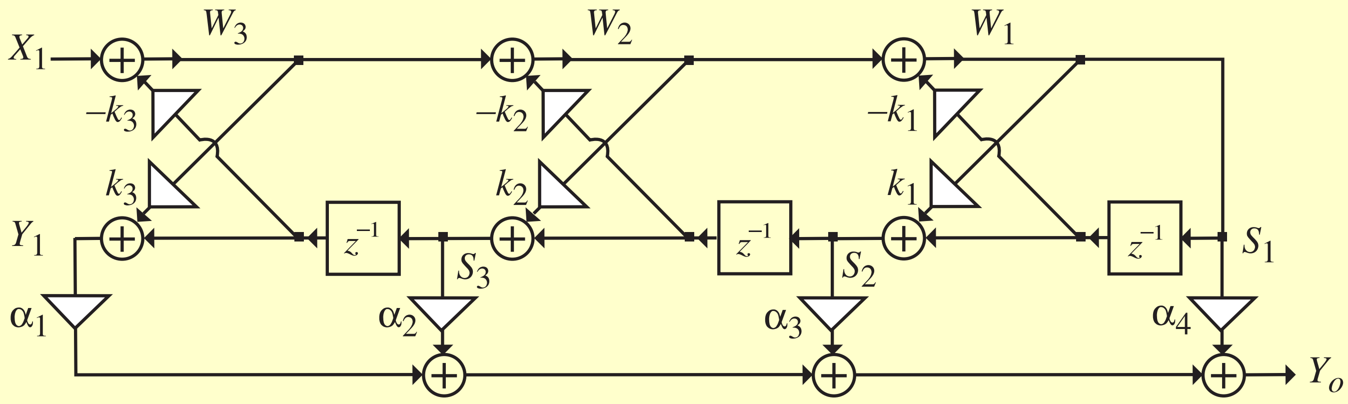
- Note: The numerator of $S_i(z)/X_1(z)$ is precisely the numerator of the allpass transfer function

$$\mathcal{A}_i(z) = \frac{S_i(z)}{W_i(z)}$$

IIR Tapped Cascaded Lattice Structures

- We now form

$$\frac{Y_o(z)}{X_1(z)} = \alpha_1 \frac{Y_1(z)}{X_1(z)} + \alpha_2 \frac{S_3(z)}{X_1(z)} + \alpha_3 \frac{S_2(z)}{X_1(z)} + \alpha_4 \frac{S_1(z)}{X_1(z)}$$



IIR Tapped Cascaded Lattice Structures

- Substituting the expressions for the various transfer functions in the above equation we arrive at

$$\frac{Y_o(z)}{X_1(z)} = \frac{\alpha_1(d_3 + d_2 z^{-1} + d_1 z^{-2} + z^{-3}) + \alpha_2(d_2^{'} + d_1^{'} z^{-1} + z^{-2}) + \alpha_3(d_1^{''} + z^{-1}) + \alpha_4}{D_3(z)}$$

IIR Tapped Cascaded Lattice Structures

- Comparing the numerator of $Y_o(z)/X_1(z)$ with the desired numerator $P_3(z)$ and equating like powers of z^{-1} we obtain

$$\alpha_1 d_3 + \alpha_2 d_2' + \alpha_3 d_1'' + \alpha_4 = p_0$$
$$\alpha_1 d_2 + \alpha_2 d_1' + \alpha_3 = p_1$$
$$\alpha_1 d_1 + \alpha_2 = p_2$$
$$\alpha_1 = p_3$$

IIR Tapped Cascaded Lattice Structures

- Solving the above equations we arrive at

$$\alpha_1 = p_3$$
$$\alpha_2 = p_2 - \alpha_1 d_1$$
$$\alpha_3 = p_1 - \alpha_1 d_2 - \alpha_2 d_1'$$
$$\alpha_4 = p_0 - \alpha_1 d_3 - \alpha_2 d_2' - \alpha_3 d_1''$$

IIR Tapped Cascaded Lattice Structures

- Example - Consider

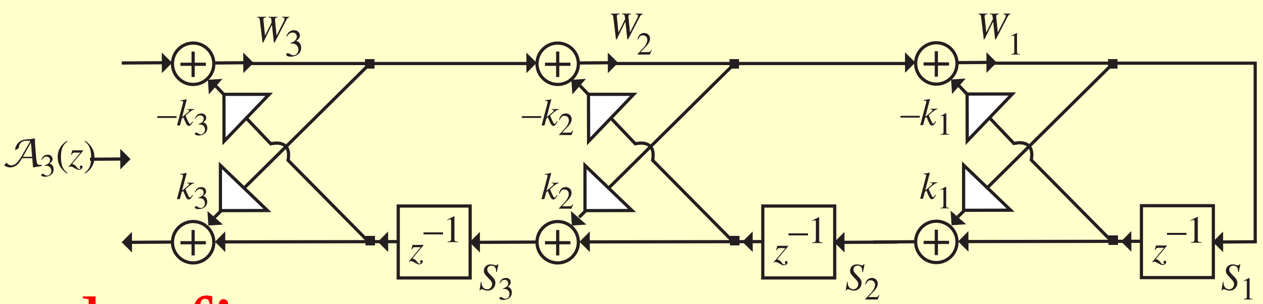
$$H(z)=\frac{P_3(z)}{D_3(z)}=\frac{0.44z^{-1}+0.362z^{-2}+0.02z^{-3}}{1+0.4z^{-1}+0.18z^{-2}-0.2z^{-3}}$$

- The corresponding intermediate allpass transfer function is given by

$$\mathcal{A}_3(z)=\frac{z^{-3}D_3(z^{-1})}{D_3(z)}=\frac{-0.2+0.18z^{-1}+0.0.4z^{-2}+z^{-3}}{1+0.4z^{-1}+0.18z^{-2}-0.2z^{-3}}$$

IIR Tapped Cascaded Lattice Structures

- The allpass transfer function $\mathcal{A}_3(z)$ was realized earlier in the cascaded lattice form as shown below



- In the figure,

$$k_3 = d_3 = -0.2, \quad k_2 = d_2' = 0.2708333$$

$$k_1 = d_1'' = 0.3573771$$

IIR Tapped Cascaded Lattice Structures

- Other pertinent coefficients are:

$$d_1 = 0.4,\ d_2 = 0.18,\ d_3 = -0.2,\ d_1^{'} = 0.4541667$$

$$p_0 = 0,\ p_1 = 0.44,\ p_2 = 0.36,\ p_3 = 0.02,$$

- Substituting these coefficients in

$$\alpha_1 = p_3$$

$$\alpha_2 = p_2 - \alpha_1 d_1$$

$$\alpha_3 = p_1 - \alpha_1 d_2 - \alpha_2 d_1^{'}$$

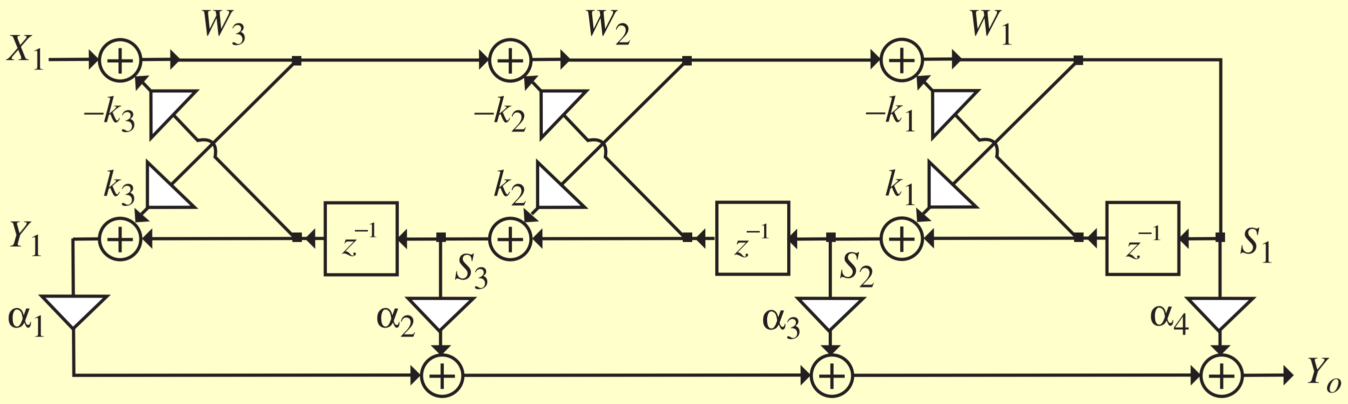
$$\alpha_4 = p_0 - \alpha_1 d_3 - \alpha_2 d_2^{'} - \alpha_3 d_1^{''}$$

IIR Tapped Cascaded Lattice Structures

$$\alpha_1 = 0.02, \quad \alpha_2 = 0.352$$

$$\alpha_3 = 0.2765333, \quad \alpha_4 = -0.19016$$

- The final realization is as shown below



$$k_1 = 0.3573771, \quad k_2 = 0.2708333, \quad k_3 = -0.2$$

Tapped Cascaded Lattice Realization Using MATLAB

- Both the pole-zero and the all-pole IIR cascaded lattice structures can be developed from their prescribed transfer functions using the M-file `tf2latc`
- To this end, Program 6_4 can be employed

Tapped Cascaded Lattice Realization Using MATLAB

- The M-file `latc2tf` implements the reverse process and can be used to verify the structure developed using `tf2latc`
- To this end, Program 8_5 can be employed

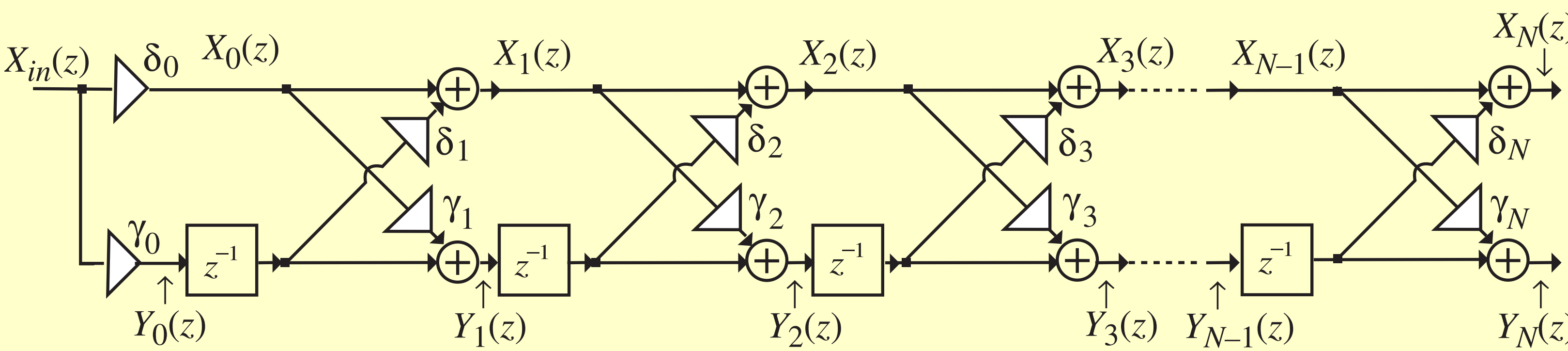
FIR Cascaded Lattice Structures

Pair of Arbitrary FIR Transfer Functions

- A pair of transfer functions, $H_i(z)$ and $G_i(z)$ is realized using the structure shown below where

$$H_i(z) = X_i(z)/X_{in}(z)$$

$$G_i(z) = Y_i(z)/X_{in}(z)$$



FIR Cascaded Lattice Structures

- Let

$$H_i(z) = a_0^{(i)} + a_1^{(i)} z^{-1} + a_2^{(i)} z^{-2} + \ldots + a_i^{(i)} z^{-i},$$
$$G_i(z) = b_0^{(i)} + b_1^{(i)} z^{-1} + b_2^{(i)} z^{-2} + \ldots + b_i^{(i)} z^{-i},$$

- Given $H_i(z)$ and $G_i(z)$ of order i for $N \le i \le 1$, the objective is to select the values of the lattice parameters δ_i and γ_i of the *i*-th stage appropriately so that $H_{i-1}(z)$ and $G_{i-1}(z)$ are of one order lower

FIR Cascaded Lattice Structures

- It follows from the proposed structure that

$$H_i(z) = H_{i-1}(z) + z^{-1}\delta_i G_{i-1}(z)$$

$$G_i(z) = \gamma_i H_{i-1}(z) + z^{-1} G_{i-1}(z)$$

- Solving the above equations we get

$$H_{i-1}(z) = K_i[H_i(z) - \delta_i G_i(z)]$$

$$G_{i-1}(z) = K_i z[G_i(z) - \gamma_i H_i(z)]$$

where
$$K_i = \frac{1}{1-\delta_i \gamma_i}$$

FIR Cascaded Lattice Structures

- By substituting the expressions for $H_i(z)$ and $G_i(z)$ we get after some algebra

$$H_{i-1}(z) = K_i\Big[\big(a_0^{(i)} - \delta_i b_0^{(i)}\big) + \big(a_1^{(i)} - \delta_i b_1^{(i)}\big)z^{-1} + \dots + \big(a_i^{(i)} - \delta_i b_i^{(i)}\big)z^{-i}\Big]$$

- It follows from the above equation is that if we choose $\delta_i = a_i^{(i)}/b_i^{(i)}$, then $H_{i-1}(z)$ will be an FIR transfer function of order i–1

FIR Cascaded Lattice Structures

$$G_{i-1}(z) = K_i z\Big[\left(b_0^{(i)} - \gamma_i a_0^{(i)}\right) + \left(b_1^{(i)} - \gamma_i a_1^{(i)}\right) z^{-1} + \\ \ldots + \left(b_i^{(i)} - \gamma_i a_i^{(i)}\right) z^{-i}\Big]$$

- Likewise, it follows from the above equation is that if we choose $\gamma_i = b_o^{(i)} / a_o^{(i)}$, then $G_{i-1}(z)$ will be an FIR transfer function of order $i-1$

FIR Cascaded Lattice Structures

- The realization method begins with $i = N$ and is then repeated for $i = N-1, N-2, \ldots, i$, generating a series of $N-1$ lower order FIR transfer function pairs $\{H_i(z), G_i(z)\}$ whose coefficients are given by

$$a_r^{(i)} = K_{i+1}[a_r^{(i+1)} - \delta_{i+1} b_r^{(i+1)}]$$

$$b_r^{(i)} = K_{i+1}[b_r^{(i+1)} - \gamma_{i+1} a_r^{(i+1)}]$$

$$0 \le r \le i$$

FIR Cascaded Lattice Structures

- The procedure ends after we have arrived at the first-order FIR transfer function pair $\{H_1(z), G_1(z)\}$
- Finally, the two scaling multipliers at the input are given by

$$\delta_0 = H_0(z) = K_1\left(a_0^{(1)} - \delta_1 b_0^{(1)}\right),$$

$$\gamma_0 = G_0(z) = K_1\left(b_0^{(1)} - \gamma_1 a_0^{(1)}\right),$$

$$K_1 = \frac{1}{1 - \delta_1\gamma_1}$$

FIR Cascaded Lattice Structures

- **Example** – Consider

$$H_4(z) = 2 + 20z^{-1} - 83z^{-2} - 10z^{-3} + 2z^{-4}$$

$$G_4(z) = 10 + 34z^{-1} - 107z^{-2} - 17z^{-3} - z^{-4}$$

- The pertinent parameters of the 4-th stage are

$$\delta_4 = \frac{a_4^{(4)}}{b_4^{(4)}} = \frac{2}{-1} = -2, \qquad \gamma_4 = \frac{b_0^{(4)}}{a_0^{(4)}} = \frac{10}{2} = 5$$

$$K_4 = \frac{1}{1 - \delta_4\gamma_4} = \frac{1}{1+10} = \frac{1}{11}$$

FIR Cascaded Lattice Structures

- Hence

$$H_3(z) = 2 + 8z^{-1} - 27z^{-2} - 4z^{-3}$$

$$G_3(z) = -6 + 28z^{-1} + 3z^{-2} - z^{-3}$$

- The pertinent parameters of the 3-rd stage are

$$\delta_3 = \frac{a_3^{(3)}}{b_3^{(3)}} = \frac{-4}{-1} = 4\ , \qquad \gamma_3 = \frac{b_0^{(3)}}{a_0^{(3)}} = \frac{-6}{2} = -3$$

$$K_3 = \frac{1}{1 - \delta_3\gamma_3} = \frac{1}{1+12} = \tfrac{1}{13}$$

FIR Cascaded Lattice Structures

- The transfer function pair of the 2-nd stage and its corresponding lattice parameters are:

$$H_2(z) = 2 - 8z^{-1} - 3z^{-2}$$
$$G_2(z) = 4 - 6z^{-1} - z^{-2}$$

$$\delta_2 = \frac{a_2^{(2)}}{b_2^{(2)}} = \frac{-3}{-1} = 3 \qquad \gamma_2 = \frac{b_0^{(2)}}{a_0^{(2)}} = \frac{4}{2} = 2$$

FIR Cascaded Lattice Structures

- Finally, the transfer function pair of the 1-st stage and its corresponding lattice parameters are:

$$H_1(z) = 2 - 2z^{-1}$$

$$G_1(z) = -2 - z^{-1}$$

$$\delta_1 = \frac{a_1^{(1)}}{b_1^{(1)}} = \frac{-2}{-1} = 2 \qquad \gamma_1 = \frac{b_0^{(1)}}{a_0^{(1)}} = \frac{-2}{2} = -1$$

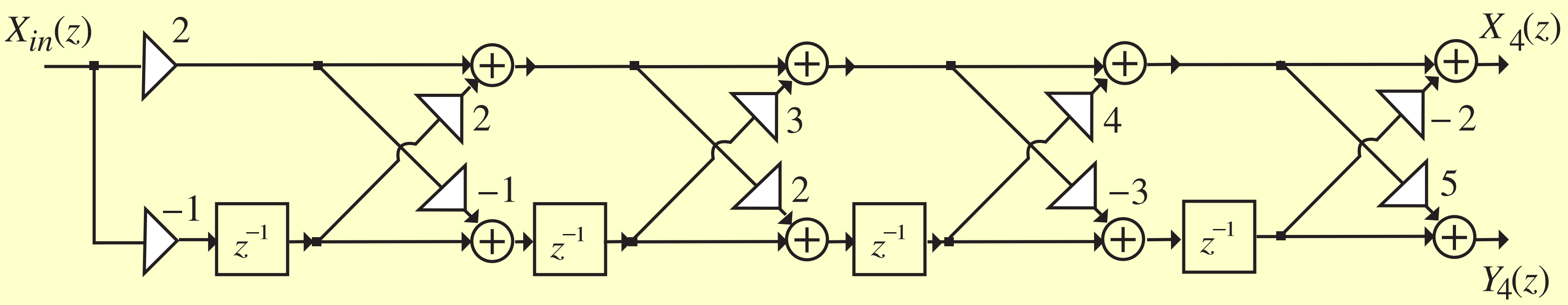
FIR Cascaded Lattice Structures

- The scaling multipliers at the input are

$$\delta_0 = H_0(z) = a_0^{(1)} = 2$$

$$\gamma_0 = G_0(z) = b_1^{(1)} = -1$$

- The final realization is thus as shown below



FIR Cascaded Lattice Structures

Special Cases

- Case 1: It follows from $\delta_i = a_i^{(i)} / b_i^{(i)}$ that if $b_i^{(i)} = 0$, then $\delta_i \rightarrow \infty$ causing a premature termination
- Case 2: It follows from $\gamma_i = b_o^{(i)} / a_o^{(i)}$ that if $a_0^{(i)} = 0$, then $\gamma_i \rightarrow \infty$ causing a premature termination

FIR Cascaded Lattice Structures

- Case 3: The realization method also breaks down if $a_0^{(i)} = 0$ and $b_i^{(i)} = 0$
- Case 4: If $a_i^{(i)} b_0^{(i)} = b_i^{(i)} a_0^{(i)}$ then it follows from

$$\delta_i = a_i^{(i)} / b_i^{(i)}, \quad \gamma_i = b_o^{(i)} / a_o^{(i)}$$

that $\delta_i \gamma_i = 1$ causing the realization method to fail

FIR Cascaded Lattice Structures

- Modification of the realization method to take care of these problems can be found in the text
- We next describe modification of the method to realize a pair of mirror-image FIR transfer functions, a pair of power-complementary FIR transfer functions, and a single FIR transfer function

FIR Cascaded Lattice Structures

Realization of a Pair of Mirror-Image FIR Transfer Functions

- If $G_N(z) = z^{-N} H_N(z^{-1})$; that is, $G_N(z)$ is the mirror-image of $H_N(z)$ with coefficients given by $b_r^{(N)} = a_{N-r}^{(N)}$ then it follows from

$$\delta_i = a_i^{(i)}/b_i^{(i)}, \quad \gamma_i = b_o^{(i)}/a_o^{(i)}$$

that then $\delta_N = \gamma_N = a_N^{(N)} a_0^{(N)}$ and

$$K_N = 1/(1-\delta_N^2)$$

FIR Cascaded Lattice Structures

- Substituting these values in

$$H_{i-1}(z) = K_i\Big[\Big(a_0^{(i)} - \delta_i b_0^{(i)}\Big) + \Big(a_1^{(i)} - \delta_i b_1^{(i)}\Big)z^{-1} + \ldots + \Big(a_i^{(i)} - \delta_i b_i^{(i)}\Big)z^{-i}\Big]$$

$$G_{i-1}(z) = K_i z\Big[\Big(b_0^{(i)} - \gamma_i a_0^{(i)}\Big) + \Big(b_1^{(i)} - \gamma_i a_1^{(i)}\Big)z^{-1} + \ldots + \Big(b_i^{(i)} - \gamma_i a_i^{(i)}\Big)z^{-i}\Big]$$

it can be shown that

$$G_{N-1}(z) = z^{-(N-1)} H_{N-1}(z^{-1})$$

FIR Cascaded Lattice Structures

- All pertinent transfer functions here are given by

$$H_{i-1}(z) = z^{-(i-1)} G_{i-1}(z^{-1})$$
$$= \frac{1}{1-\delta_i^2} \left[\sum_{r=0}^{i-1} \left(a_r^{(i)} - \delta_i a_{N-r}^{(i)} \right) z^{-r} \right],$$
$$1 \le i \le N$$

where $\delta_i = a_i^{(i)} / a_0^{(i)}$

FIR Cascaded Lattice Structures

Realization of a Pair of Power-Complementary FIR Transfer Functions

- Here $G_i(z) = z^{-i} H_i(-z^{-1})$
- In this case the lattice multipliers in the *i*-th stage satisfy the relation $\delta_i = (-1)^i \gamma_i$
- The general realization method can be easily modified for this case

FIR Cascaded Lattice Structures

Realization of a Single FIR Transfer Function

- The FIR transfer function $H_N(z)$ in this case is expressed as a sum of two FIR transfer functions
- This pair of transfer functions is then realized using the general method

FIR Cascaded Lattice Structures

Realization Using MATLAB

- The function `tfpair2latc` can be employed to compute the lattice parameters of the cascaded lattice structure
- To this end, Program 8_7 can be used
- The input data called by the program is the vector of the coefficients of the transfer function pair entered in ascending powers of z^{-1}

FIR Cascaded Lattice Structures

- **Example** –

$$H_4(z) = 2 + 20z^{-1} - 83z^{-2} - 10z^{-3} + 2z^{-4}$$

$$G_4(z) = 10 + 34z^{-1} - 107z^{-2} - 17z^{-3} - z^{-4}$$

- The output data generated by the program is

```
Lattice parameters delta are
 2    2    3    4   -2
Lattice parameters gamma are
 -1   -1    2   -3    5
```