FIR FILTER DESIGN

Bahan Ajar Sinyal dan Sistem

Pascasarjana Terapan

P E N S

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Metode Deret Fourier Dasar

- Frekuensi respon dari sebuah filter digital adalah periodik
- Dapat dinyatakan dengan menggunakan deret Fourier
- Target Frekuensi respon yang diinginkan dipilih dari deret Fourier tersebut
- Nilai-nilai target terpilih dipotong dan digunakan sebagai koefisien filter atau bobot nilai tap

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Desain Filter Digital Menggunakan Deret Fourier

Step 1 : tentukan frekuensi respon yang diinginkan, Hd(λ)

Step 2 : tentukan jumlah tap, N

Step 3 : hitung koefisien filter h(n) untuk n=0,1,2,3,.....,N-1 menggunakan persamaan :

$$h[n] = \frac{1}{2\pi} \int_{2\pi} H_d(\lambda)[\cos(m\lambda) + j\,\sin(m\lambda)]\,d\lambda$$

Dimana : m = n – (N-1)/2

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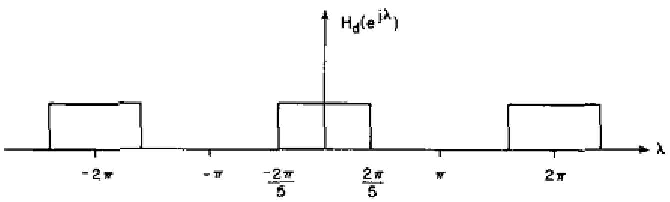
Desain Filter Digital Menggunakan Deret Fourier

Step 4 : Hitung frekuensi respon aktual dari filter, jika hasilnya belum maksimal, ulangi langkah 3



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Desain Filter Digital Menggunakan Deret Fourier

$$h[n]=\frac{1}{2\pi}\int_{-\lambda\pi/Fs}^{\lambda\pi/Fs}\cos(m\lambda)\cdot d\lambda + j\sin(m\lambda)\cdot d\lambda$$

$$h[n]=\frac{1}{2\pi}\int_{-\lambda\pi/Fs}^{\lambda\pi/Fs}\cos(m\lambda)\cdot d\lambda + j\frac{1}{2\pi}\int_{-\lambda\pi/Fs}^{\lambda\pi/Fs}\sin(m\lambda)\cdot d\lambda$$

$$untuk \sum tap = ganjil,\ j\frac{1}{2\pi}\int_{-\lambda\pi/Fs}^{\lambda\pi/Fs}\sin(m\lambda)\cdot d\lambda = 0,\ sehingga:$$

$$h[n]=\frac{1}{2\pi}\int_{-\lambda\pi/Fs}^{\lambda\pi/Fs}\cos(m\lambda)\cdot d\lambda$$

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Pendekatan Ideal LPF FIR

- Koefisien impulse respon untuk ideal LPF FIR dapat dihitung dengan persamaan :

$$h[n]=\frac{\sin(m\lambda_U)}{n\pi} \qquad \begin{aligned} n &= 0, 1, \ldots, N-1 \\ m &= n-(N-1)/2 \end{aligned}$$

- Untuk kasus khusus di m=0 (n=nilai tengah-tengah tap), maka L'Hospital rule digunakan sebagai berikut :

$$h[n]=\frac{\left(d/dm\right)\cdot\sin(\lambda m\pi/Fs)}{\left(d/dm\right)\cdot m\pi}, m=0$$

$$h[n]=\frac{(\lambda\pi/Fs)\cdot\cos(\lambda m\pi/Fs)}{\pi}, m=0$$

$$h[n]=\lambda/Fs$$

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Contoh

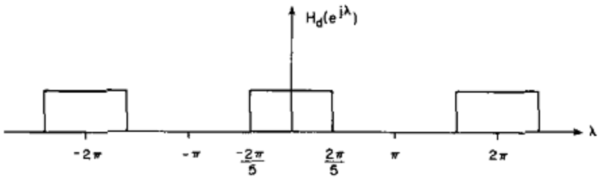

Figure 11.1 Desired frequency response for Example 11.1.

Example 11.1 Use the Fourier series method to design a 21-tap FIR filter that approximates the amplitude response of an ideal lowpass filter with a cutoff frequency of 2 kHz assuming a sampling frequency of 5 kHz.

solution The normalized cutoff is $\lambda = 2\pi/5$. The desired frequency response is depicted in Fig. 11.1. Using Eq. (11.1), we can immediately write

$$h[n] = \frac{1}{2\pi}\int_{-2\pi/5}^{2\pi/5} \cos(m\lambda)\, d\lambda + j\frac{1}{2\pi}\int_{-2\pi/5}^{2\pi/5} \sin(m\lambda)\, d\lambda$$

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Contoh

Since the second integrand is an odd function and the limits of integration are symmetric about zero, the second integral equals zero. Therefore,

$$h[n] = \frac{\sin(m\lambda)}{2m\pi}\bigg|_{\lambda=-2\pi/5}^{2\pi/5}$$

$$= \frac{\sin(2m\pi/5)}{m\pi} \qquad (11.2)$$

where $m = n - 10$.

L'Hospital's rule can be used to evaluate (11.2) for the case of $m = 0$ (that is, $n = 10$):

$$h[10] = \frac{(d/dm)\sin(2m\pi/5)}{(d/dm)m\pi}\bigg|_{m=0}$$

$$= \frac{(2\pi/5)\cos(2m\pi/5)}{\pi}\bigg|_{m=0}$$

$$= \frac{2}{5} = 0.4$$

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Contoh

TABLE 11.1 Impulse Response Coefficients for the 21-tap Lowpass Filter of Example 11.1

$h[0] = h[20] =$	0.000000
$h[1] = h[19] =$	-0.033637
$h[2] = h[18] =$	-0.023387
$h[3] = h[17] =$	0.026728
$h[4] = h[16] =$	0.050455
$h[5] = h[15] =$	0.000000
$h[6] = h[14] =$	-0.075683
$h[7] = h[13] =$	-0.062366
$h[8] = h[12] =$	0.093549
$h[9] = h[11] =$	0.302731
$h[10] =$	0.400000

Program C Untuk LPF FIR

```
void idealLPF(int tap, float lambda)
{
     int n;
     float m,h[100];

     printf("Koefisien filter LPF dengan frekuensi cut off %f adalah : \n",lambda);
     for(n=0;n<tap;n++)
     {
          m=n-(float)(tap-1)/2.0;
          if(m==0)
                    h[n]=lambda/pi;
          else
                    h[n]=sin(m*lambda)/(m*pi);

          printf("h[%d] = %4.4f\n",n,h[n]);
     }
}
```

Hasil Pengujian Program Untuk Penyelesaian Contoh Soal

```
"D:\MASTER MENGAJAR PENS\dsp\tugas-tugas\FS_FIR\Debug\FS_FIR.exe"
Masukkan jumlah tap filter (orde+1) : 21
Masukkan 1/2 frekuensi sampling     : 5000
Masukkan frekuensi cutoff filter    : 2000
Koefisien filter LPF dengan frekuensi cut off 2000.00 adalah :
h[0] = -0.0002
h[1] = -0.0337
h[2] = -0.0232
h[3] = 0.0269
h[4] = 0.0504
h[5] = -0.0002
h[6] = -0.0758
h[7] = -0.0622
h[8] = 0.0938
h[9] = 0.3028
h[10] = 0.4000
h[11] = 0.3028
h[12] = 0.0938
h[13] = -0.0622
h[14] = -0.0758
h[15] = -0.0002
h[16] = 0.0504
h[17] = 0.0269
h[18] = -0.0232
h[19] = -0.0337
h[20] = -0.0002
```

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Pendekatan Untuk Jenis Filter FIR Yang Lain

- High Pass Filter

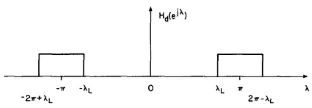

Figure 11.5 Frequency response of ideal highpass digital filter.

$$h[n] = \begin{cases} 1 - \dfrac{\lambda_L}{\pi} & m = 0 \\ \dfrac{-\sin(m\lambda_L)}{m\pi} & m \neq 0 \end{cases}$$

- Band Pass Filter

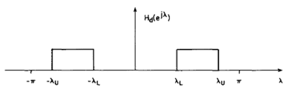

Figure 11.8 Frequency response of ideal bandpass digital filter.

$$h[n] = \begin{cases} \dfrac{\lambda_U - \lambda_L}{\pi} & m = 0 \\ \dfrac{1}{n\pi}[\sin(m\lambda_U) - \sin(m\lambda_L)] & m \neq 0 \end{cases}$$

- Band Stop Filter

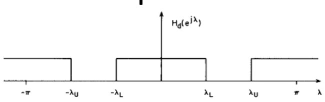

Figure 11.10 Frequency response of ideal bandstop digital filter.

$$h[n] = \begin{cases} 1 + \dfrac{\lambda_L - \lambda_U}{\pi} & m = 0 \\ \dfrac{1}{n\pi}[\sin(m\lambda_L) - \sin(m\lambda_U)] & m \neq 0 \end{cases}$$

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Tugas

- Buat program tersebut pada sebuah program developer, misalnya Visual C++ atau Visual Basic !
- Modifikasilah program LPF diatas untuk penambahan masing-masing fungsi HPF, BPF dan BSF, sehingga koefisien filternya dapat diperoleh !
- Isi laporan tugas : list program, hasil pengujian koefisien filter pada 3 nilai frekuensi cutoff (tentukan sendiri) print screen, gambarkan hasil respon frekuensi pada excel.