4B-05

Relationship Between Active Complex Bandpass Filter and Hilbert Filter

Akemi Hatta, Nene Kushita, Minh Tri Tran, Koji Asami, Anna Kuwana , Haruo Kobayashi (Gunma University)

1. Research Objective

Passive RC polyphaser filter has good Hilbert filter characteristics.

Use R, C → large chip area

affected by process variation

➢ Approach

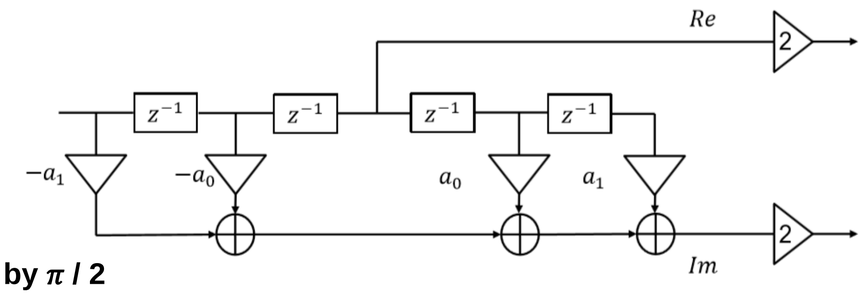
Replace with active complex bandpass filter

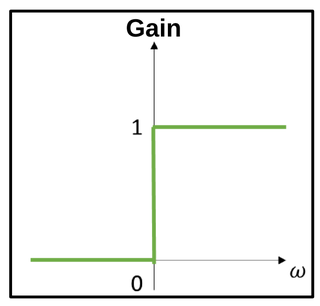
2. Hilbert Filter

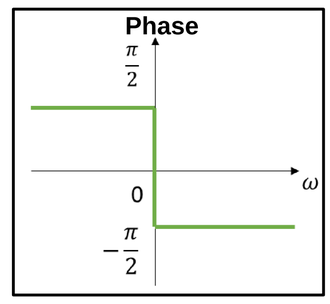
David Hilbert (Germany)

1862-1843

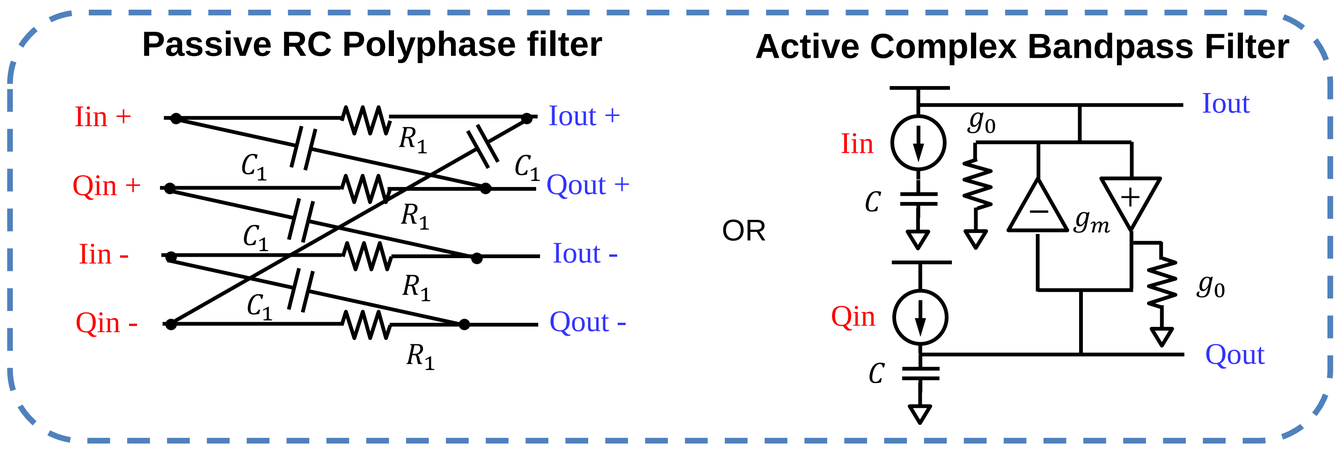
- Delay phase of signal ($\omega \geq 0$) by $\pi / 2$
- → Hilbert transform
- 1 input 2 output
- Implemented with a digital filter

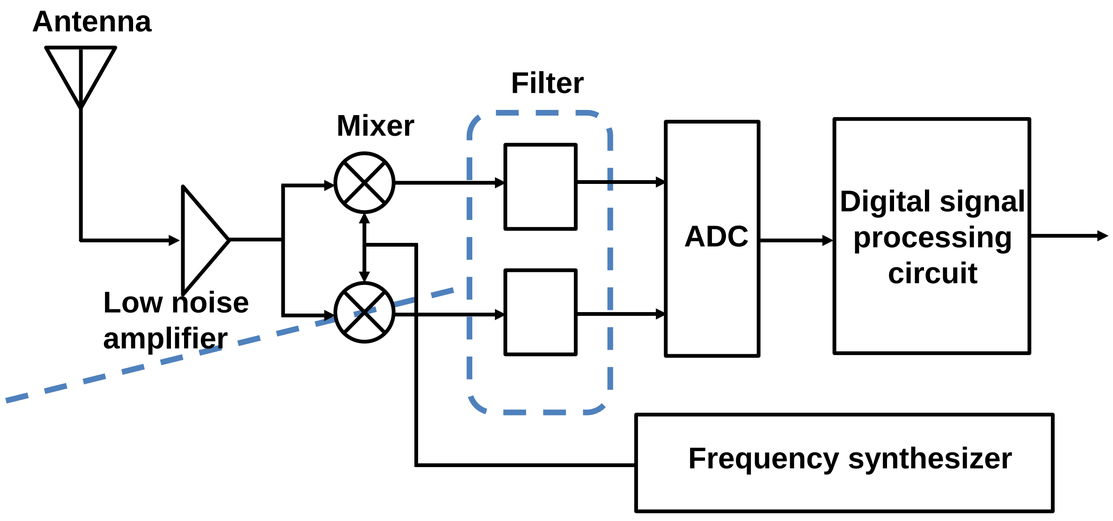






3. Wireless Communication System: Receiver





4. RC Polyphase Filter (Passive)

Signal component

Real part $\cos(\omega t)$ → Polyphase Filter → $A\cos(\omega t+\theta)$

Imaginary part 0 → Polyphase Filter → $A\sin(\omega t+\theta)$

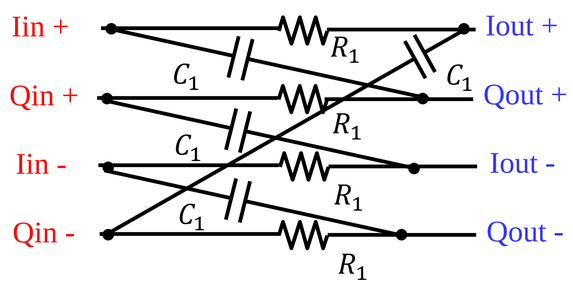
Image component $Ae^{j\omega t}+Be^{j\omega t} \longrightarrow Ae^{j\omega t}$

Real part $(A+B)\cos(\omega t)$ → Polyphase Filter → $A\cos(\omega t)$

Imaginary part $(A-B)\sin(\omega t)$ → Polyphase Filter → $A\sin(\omega t)$

- Composed of passive elements R and C: Large chip area
- Passive complex bandpass filter
- Complex → 2-input, 2-output

Simulation Result

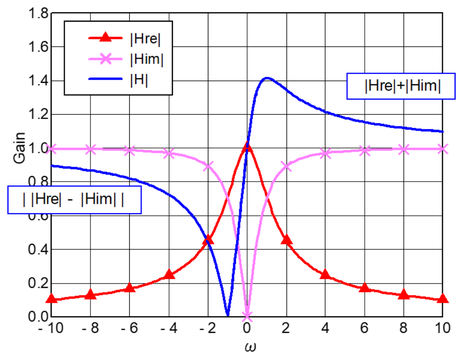


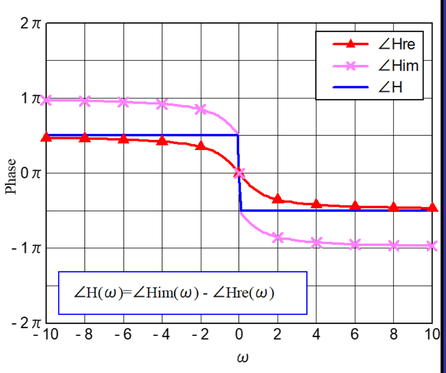
First-order RC polyphase filter

$$\frac{V_{Iout}+jV_{Qout}}{I_{in}+jQ_{in}}=\frac{1-jsR_1C_1}{1+sR_1C_1}$$

Gain : Hilbert filter only at zero

Phase : Complete Hilbert filter





The higher the order, the closer to the ideal Hilbert transform

5. Complex Bandpass Filter (Active)

Signal component $e^{j\omega_0 t} \longrightarrow e^{j\omega_0 t}$

Real part $\cos(\omega_0 t)$ → Complex Bandpass Filter → $\cos(\omega_0 t)$

Imaginary part $\sin(\omega_0 t)$ → Complex Bandpass Filter → $\sin(\omega_0 t)$

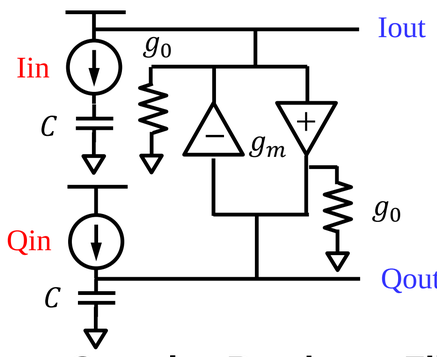
Image component $e^{-j\omega_0 t} \longrightarrow e^{j\omega_0 t}$

Real part $\cos(\omega_0 t)$ → Complex Bandpass Filter → 0

Imaginary part $-\sin(\omega_0 t)$ → Complex Bandpass Filter → 0

- Small dynamic range & nonlinear
- Small chip area
- Adjust g_m value (automatic) → absorb process fluctuations
- Complex → 2-input, 2-outputs

Simulation Result

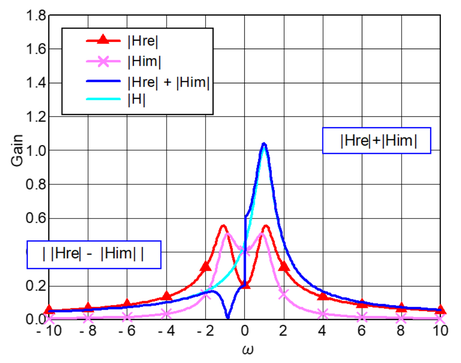


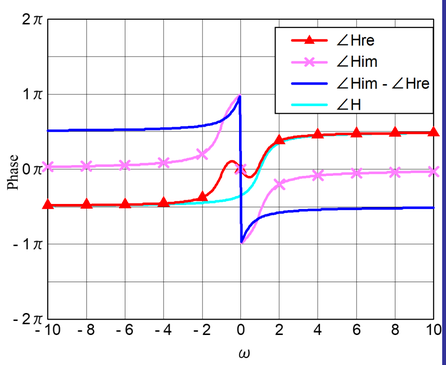
Complex Bandpass Filter

$$\frac{V_{Iout}+jV_{Qout}}{I_{in}+jQ_{in}}=\frac{g_0+sC+jg_m}{{g_0}^2+{g_m}^2+s^2C^2+2g_0sC}$$

Gain : Not Hilbert filter

Phase : Hilbert filter at |ω|>>0





Poor Hilbert filter performance than RC polyphaser filter

6.Conclusion

Passive RC Polyphaser Filter

- Approximate ideal Hilbert filter characteristics
- R, C → Linear
  - Large chip area
  - Difficult to adjust

Replace with complex bandpass filter

Active Complex Bandpass Filter

- Nonlinear
- Small chip area
- Adjust Gm value (automatic) → absorb process fluctuations
- Poor Hilbert filter performance than RCPF

→ Find a way to get close to the ideal Hilbert filter characteristics

Reference

[1]Y. Tamura, R. Sekiyama, K. Asami, H. Kobayashi, "RC Polyphase Filter As Complex Analog Hilbert Filter", IEEE International Conference on Solid-State and Integrated Circuit Technology, Hangzhou, China (Oct. 2016).