

Frequency Estimation Sampling Circuit Using Hilbert Filter and Residue Number System

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Research Goal

Estimate high frequency signal waveform using multiple low frequency sampling circuits.

Realize a high frequency sampling circuit → Difficult

Chinese Remainder Theorem

- Chinese arithmetic 'Sun Tzu Calculation'
- "Dividing by 3, the residue is 2. Dividing by 5, it is 3. Dividing by 7, it is 2. What is the number k ?"

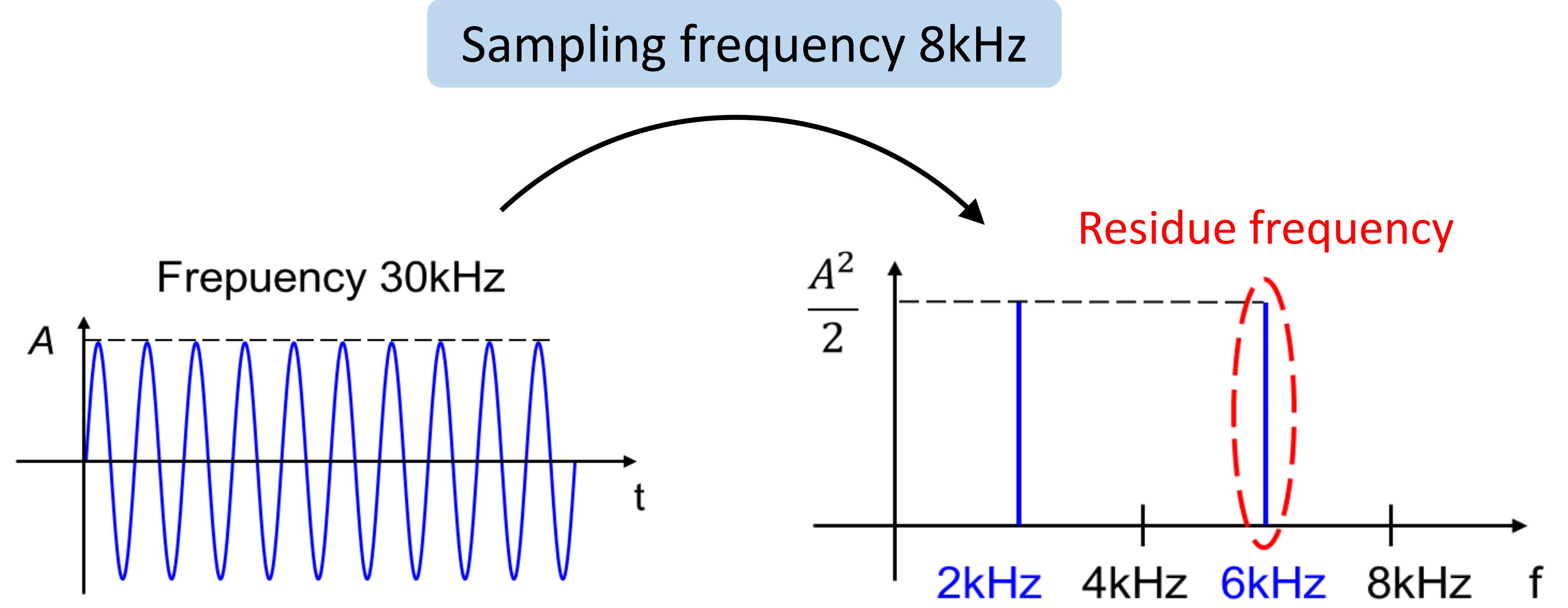
Ans. 23

3	5	7	k
0	0	0	0
1	1	1	1
2	2	2	2
⋮	⋮	⋮	⋮
0	1	0	21
1	2	1	22
2	3	2	23
0	4	3	24
1	0	4	25
⋮	⋮	⋮	⋮
0	2	4	102
1	3	5	103
2	4	6	104

For relatively prime numbers of 3, 5, 7, only one answer is obtained within the range of 0 to 104 for $3 \times 5 \times 7 = 105$.

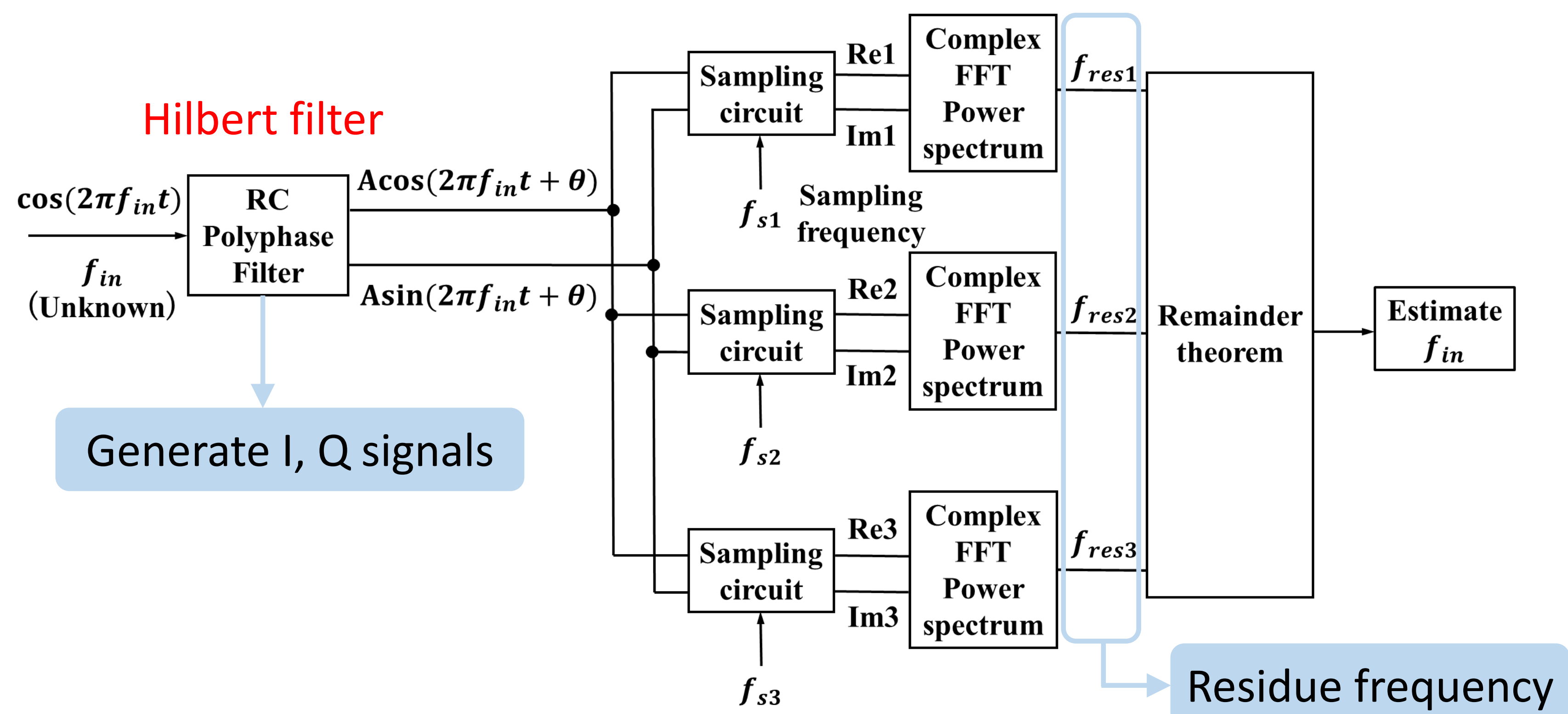
Chinese Remainder Theorem

Frequency Aliasing



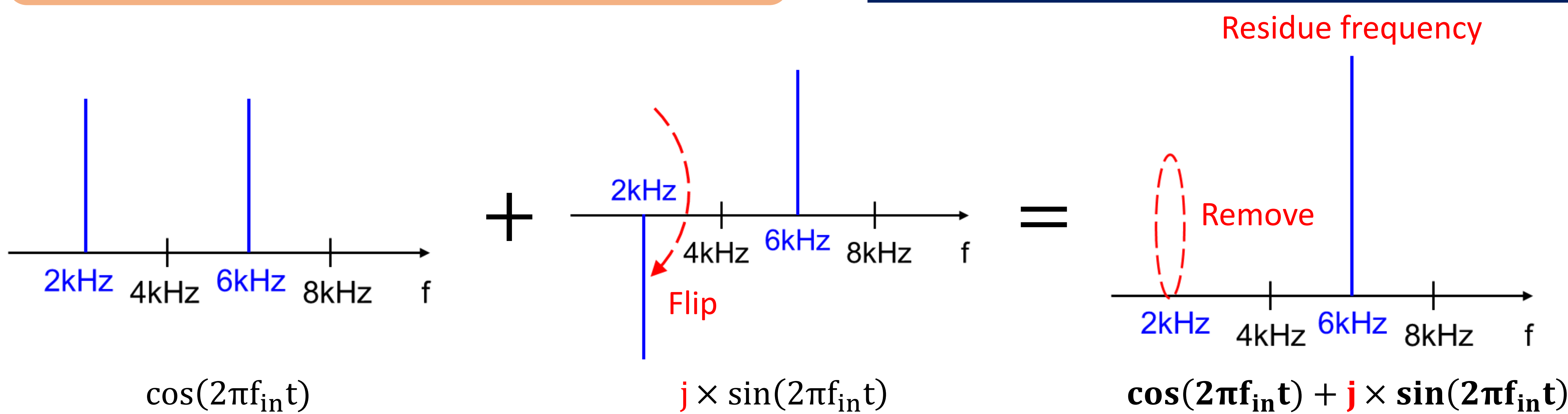
Extract only residue frequency by Hilbert filter & Complex FFT

Proposed Sampling System



Remove Image Frequency

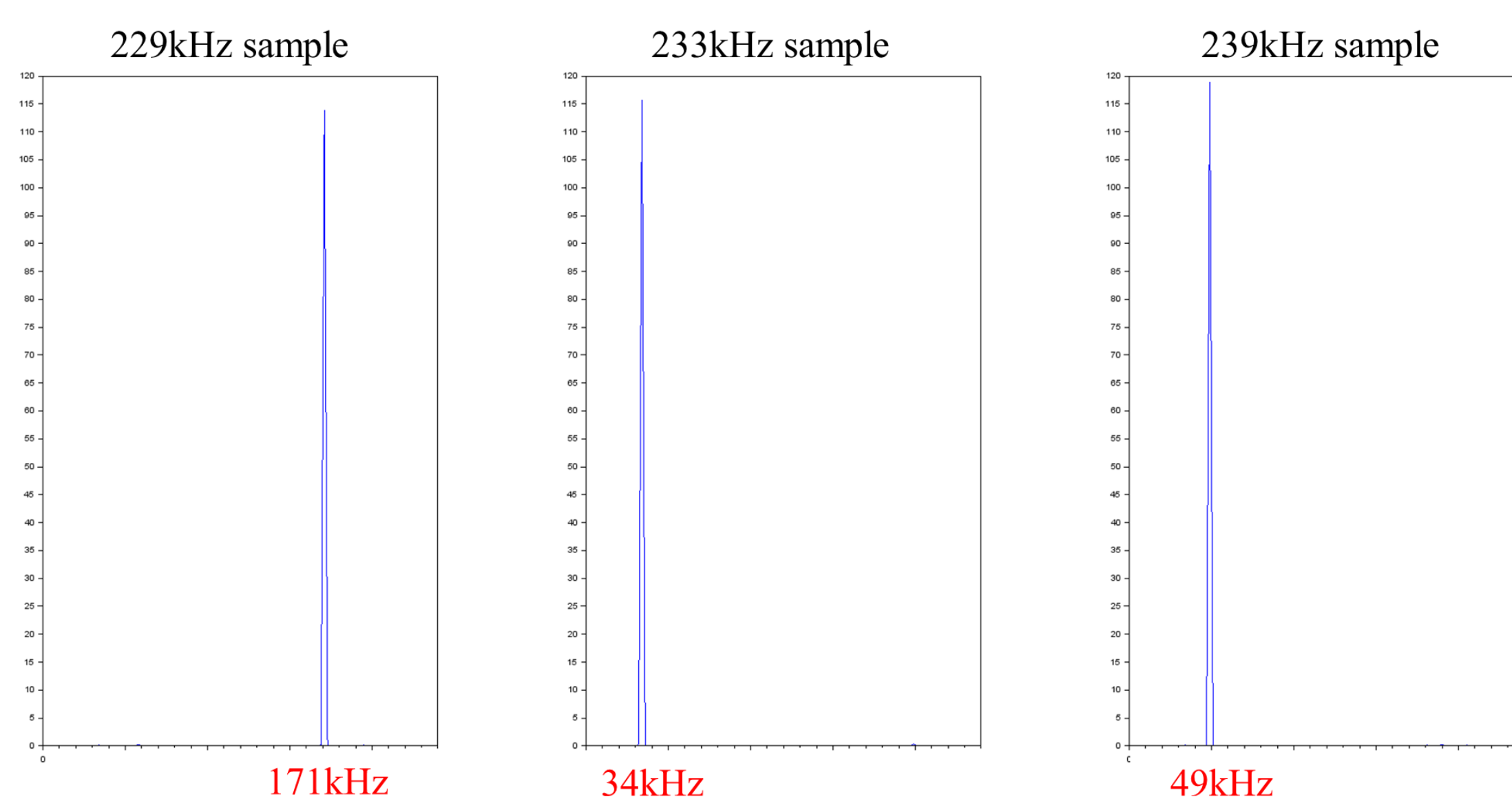
Extract only residue frequency by complex FFT of $\cos(2\pi f_{in}t) + j \times \sin(2\pi f_{in}t)$



Simulation Result

Complex FFT

- Input frequency 12GHz
- Sampling frequencies 229kHz, 233kHz, 239kHz
- Resolution 1kHz



Residue frequency : 171kHz, 34kHz, 49kHz

m1	m2	m3	k
0	0	0	0
1	1	1	1
2	2	2	2
⋮	⋮	⋮	⋮
169	32	47	11999998
170	33	48	11999999
171	34	49	12000000
172	35	50	12000001
173	36	51	12000002
⋮	⋮	⋮	⋮
226	230	236	12752320
227	231	237	12752321
228	232	238	12752322

Estimated as 12.0GHz from Chinese Remainder Theorem

Summary

- Frequency estimation method of high frequency signal from multiple low frequency samplings is proposed.
- Input frequency can be estimated using Residue frequencies and Chinese remainder theorem.
- Estimated frequency range is determined by product of multiple sampling frequencies.

Reference

Y. Tamura, R. Sekiyama, K. Asami, H. Kobayashi, "RC Polyphase Filter As Complex Analog Hilbert Filter", IEEE 13th International Conference on Solid-State and Integrated Circuit Technology, Hangzhou, China (Oct. 2016).