P098

Component Mismatch Analysis of RC Polyphase Filters

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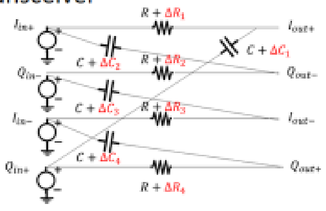
Object & Background

What is RC polyphase filter? & Research Objective

- Input and output are complex signal.
- One of key components in wireless transceiver
- Analog bandpass filter
- Passive RC analog filter
  4 Resistors
  4 Capacitors



Component mismatch causes image signal.

↓

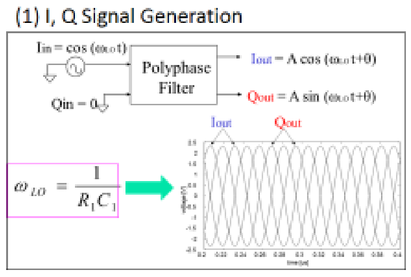
Circuit performance degradation

↓

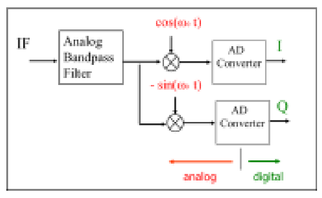
We analyze its effects in theory and simulation

Applications of RC Polyphase Filter

(1) I, Q Signal Generation



I, Q signal generation



Cosine, Sine Signals in Receiver

(2)Image Signal Rejection

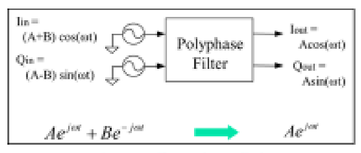


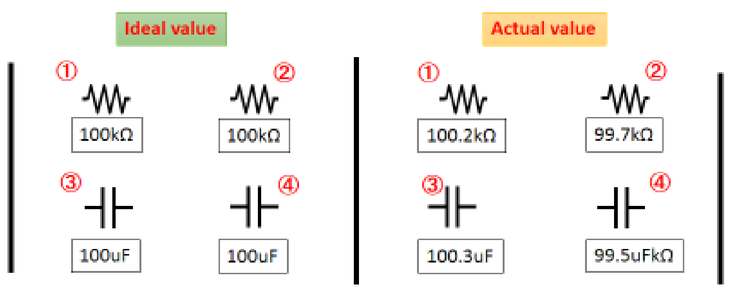
Image Rejection Filter

Component Values Variation

The most problem of RC polyphase filter implementation

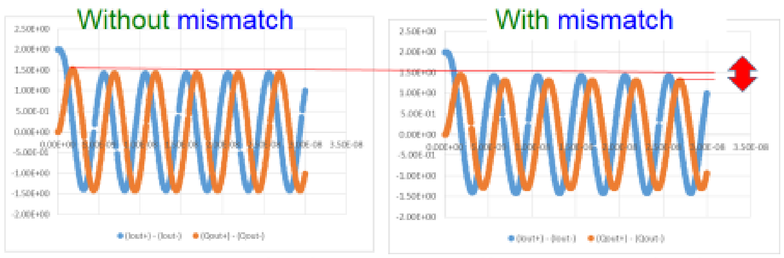
↓

Components R, C values variation



Analysis & Simulation

Cmponenent Mismatch Effects



Same *I*, *Q* output amplitudes

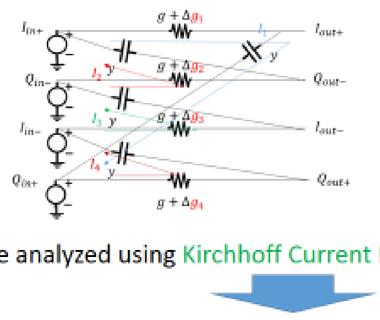
Different *I*, *Q* amplitudes

: | Mismatch of I, Q output amplitudes

↳ Cause of image components

↳ Circuit performance degradation

Theoretical Analysis



Resistance value variation case

$$g = \frac{1}{R}, \quad y = j\omega C$$
$$\Delta g_1 + \Delta g_2 + \Delta g_3 + \Delta g_4 = 0$$

We analyzed using Kirchhoff Current Law.

↓

$$\{4(g+y) + \Delta g_1 + \Delta g_3 - \Delta g_2 - \Delta g_4\}V_{out} = \{4(g-jy) + \Delta g_1 + \Delta g_3 - \Delta g_2 - \Delta g_4\}V_{in} + (\Delta g_1 + \Delta g_3 + \Delta g_2 + \Delta g_4)\overline{V_{in}} - (\Delta g_1 + \Delta g_3 + \Delta g_2 + \Delta g_4)\overline{V_{out}}$$

Theoretical Analysis

$$\{4(g+y) + \Delta g_1 + \Delta g_3 - \Delta g_2 - \Delta g_4\}V_{out} = \{4(g-jy) + \Delta g_1 + \Delta g_3 - \Delta g_2 - \Delta g_4\}V_{in} + (\Delta g_1 + \Delta g_3 + \Delta g_2 + \Delta g_4)\overline{V_{in}} - (\Delta g_1 + \Delta g_3 + \Delta g_2 + \Delta g_4)\overline{V_{out}}$$

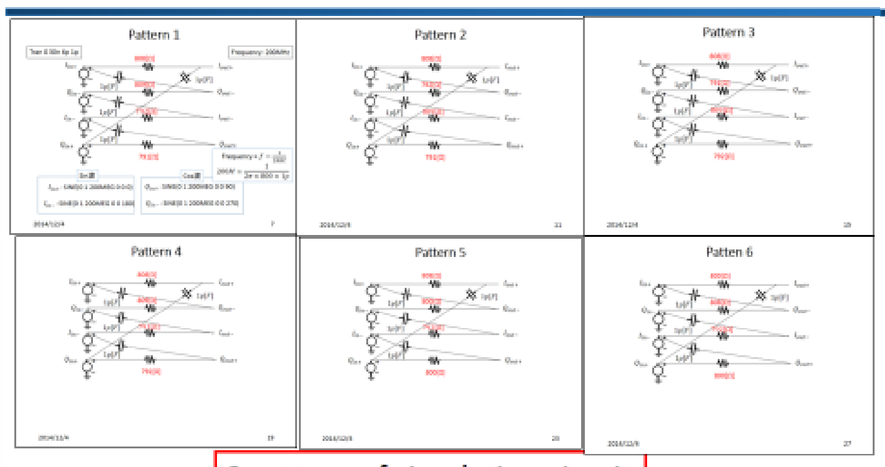
↓

V_{in} doesn't give to $\overline{V_{out}}$

↓

In case $\Delta g_1 + \Delta g_2 + \Delta g_3 + \Delta g_4 = 0$
mismatch does not appear in the output signal.

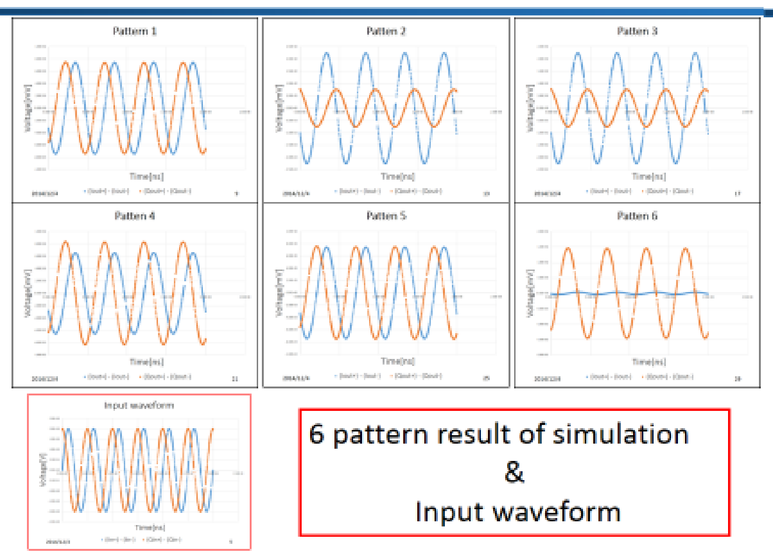
Simulation Circuit



6 pattern of simulation circuit

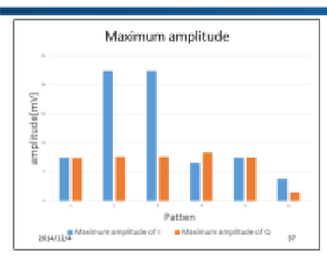
Use software: LTspice

Result of Simulation



6 pattern result of simulation
&
Input waveform

Result



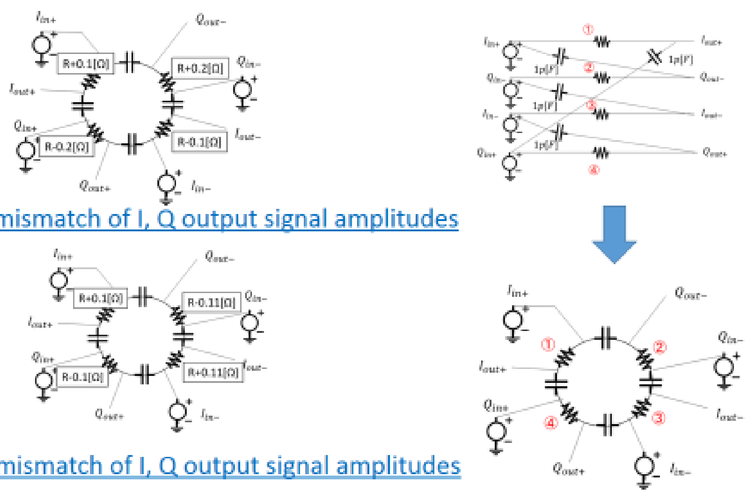
Component variations
do NOT affect phase between I,Q signals

In case pattern 1 and 5
I, Q amplitude mismatches are small.

In case of pattern 2, 3, 4, 6
I, Q amplitude mismatch are big.

Conclusion & Reference

Our Findings

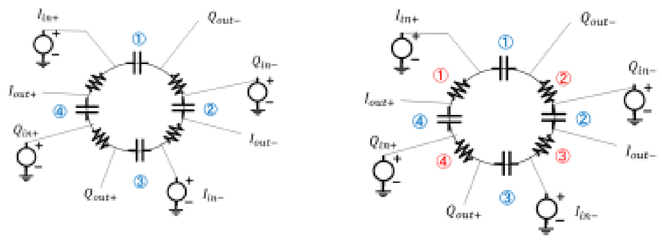


No mismatch of I, Q output signal amplitudes

Big mismatch of I, Q output signal amplitudes

Conclusion & Future Challenges

- Variation of resistors
  - NOT affect phase between I, Q outputs
  - Affect I, Q amplitude mismatch
  but in certain conditions, NOT affect.
- Effects of capacitor variation
- Effects of both capacitor & resistance variations together



References

[1] H. Kobayashi, J. Kang, T. Kitahara, S. Takigami,H.Sadamura, ``Explicit Transfer Function of RC Polyphase Filter for Wireless Transceiver Analog Front-End'', IEEE Asia-Pacific Conference on ASICs, pp.137-140, Taipei, Taiwan (Aug. 2002).

[2] N. Yamaguchi, H. Kobayashi, J. Kang, Y. Niki, T. Kitahara, " Analysis of RC Polyphase Filters - High-Order Filter Transfer Functions, Nyquist Charts, and Parasitic Capacitance Effects – ", Technical Report of IEICE, Wakayama (Jan. 2003).

[3] Y. Niki, J. Kang, H. Kobayashi, N. Yamaguchi, T. Kitahara, "Analysis and Design of RC Polyphase Filters – Input Impedance, Output Termination, Component Mismatch Effects, Flat-Passband Filter Design –", Technical Report of IEICE, Wakayama (Jan. 2003).