

Proposal of channel-grouping wireless-transceiver architecture for suppressing local-oscillator phase noise

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Abstract: This paper proposes an architecture-level solution to suppress the phase noise of local oscillators in wireless-transceiver LSIs. Because a phase-looked loop (PLL) supplies only one local oscillator (LO) frequency for multiple channels, large loop bandwidth of the PLL can be used for suppressing the phase noise. Simulation results show that a sixteen-channel grouping can suppress the phase noise more than 24 dB in narrow-band wireless systems. Channel selection in receive mode can be ensured by a variable intermediate frequency (IF) complex band-pass filter. Local-leak and image signals in transmit mode can be suppressed by a quadrature up-conversion mixer and radio frequency (RF) band-pass filter with high-IF configuration. A digital-analog converter, analog-digital converter, and digital LSI are in charge of modulation and demodulation of the variable-IF signals.

Keywords: phase noise, PLL, wireless transceiver, complex filter, channel grouping

Classification: Integrated circuits

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1 Introduction

On-chip inductors consume large chip area and increase the chip cost of wireless transceiver ICs. To reduce the cost, inductorless designs for wireless ICs have been intensively studied [1, 2, 3, 6]. However, the local-oscillator phase noise strongly depends on the quality factor of its resonator, and hence inductorless ring oscillators usually show poor phase-noise performance [4]. In order to suppress the phase noise, injection-locking techniques have been studied [1, 5, 6], but it is difficult for such techniques to be applied to narrow-channel-space wireless systems. In this paper, a channel-grouping wireless-transceiver architecture is proposed. Local-oscillator phase noise is suppressed not by refining a ring-oscillator circuit but by a large-loopbandwidth PLL. To meet adjacent channel power ratio (ACPR) specifications in narrow-channel-space wireless systems, the transceiver architecture is rearranged.

2 Phase-noise suppression using PLL

Fig. 1 (a) shows the phase-noise characteristics of integer PLLs, simulated using the Advanced Design System (Agilent Technologies). The results were obtained using a PLL behavior model with an oscillation frequency of 300 MHz. The loop bandwidth of the PLLs was changed as a parameter and reference frequencies were always 12.5 times larger than the loop bandwidths. Fig. 1 (b) shows the simulated peak phase noise vs. loop bandwidth characteristics for the PLLs with three voltage controlled oscillators (VCOs). The peak phase noise is decreased about 20 dB when the loop bandwidth becomes 10 times larger.







Fig. 1. Simulated phase noise vs. loop bandwidth characteristics. (a) Typical phase noise vs. offset frequency characteristics of VCO2. (b) Peak phase noise vs. loop bandwidth characteristics of three VCOs.

One of the most important aspects of PLL performance is out-of-channel phase noise because it determines the ACPR. Out-of-channel phase noise can be suppressed when the loop bandwidth is larger than the channel space as shown in Fig. 1 (a). A fractional-N PLL is a well known technique for obtaining a large loop bandwidth [7, 8], but even with this technique it is difficult to achieve both a large loop bandwidth and small channel spacing at the same time.

3 Receiver architecture

From here, a transceiver architecture for a 300-MHz RF and 25-kHz channelspacing transceiver [9, 10] is discussed. Fig. 2 depicts the proposed transceiver architecture. The upper side of the figure shows the receiver architecture. Multi channels are grouped and the PLL serves a single frequency per one channel group. This means that the frequency spacing of PLL output can be multiplied by the number of channels in one channel group. Thus the PLL in this architecture can have much larger loop bandwidth than PLLs in conventional architectures. In this architecture, the intermediate frequency (IF) varies within a channel group, thus the center frequency of the complex band-pass filter is changed and controlled to be the varied IF.

3.1 Fractional-N PLL with large loop bandwidth

Fractional-N PLLs could have a larger loop bandwidth than the channel space; however, the ratio between loop bandwidth and channel space is typically less than ten. Thus, the loop bandwidth is not sufficient for suppressing the phase noise of ring oscillators. In the proposed architecture, the loop bandwidth can be multiplied by the number of channels in one channel group. Fig. 3(a)-(c) depicts the frequency situation for the signals in the receiver.





The frequency of a local signal (LO) produced by the PLL locates at the center of the grouped-channel frequencies. This means the IF of down-converted signals varies according to the frequency difference between the received RF and the LO frequency.



Fig. 2. Proposed transceiver architecture. The upper side shows the receiver architecture and the lower side shows the transmitter architecture.

3.2 Complex filter for channel selection

The channel-select filter is a complex band-pass filter. This filter has the switched-capacitor configuration [11]. The center frequency and bandwidth of the filter can be precisely and individually controlled. The center frequency is controlled within 0.6% normalized dispersion (3δ /average) [11]. This dispersion is determined not by the circuit performance but by the measurement accuracy. Thus, more precise frequency control is expected. If the center-frequency deviation of less than 5% of channel spacing is allowed, the center frequency can vary from -200 to 200 kHz at least. This means 16 or more channels can be grouped, and more than 24-dB phase-noise suppression is expected from Fig. 1 (b).

3.3 Demodulation of variable-IF signal

After channel selection, the receiver must demodulate the variable-IF signals. It can do this in the analog domain or in the digital domain. In both cases, the variable-IF signals must be down-converted to baseband signals in the analog or digital domain and then be demodulated. Fig. 2 depicts the architecture of the digital-demodulation receiver.





4 Transmitter architecture

4.1 Frequency plan for variable-IF transmitter

Fig. 3 (d)–(f) depicts the frequency situation for signals in the transmitter. A modulated IF signal is generated in the digital domain and changed to an analog IF signal by digital-analog converters. In the transmitter, transmitted signals are divided into two groups according to their RFs. If the RF is larger than the center frequency of the RF filter, the IF is less than zero and the local frequency is set to the upper side of the RF-filter band. If the RF is less than the center frequency of the RF filter, the IF is larger than zero and the local frequency is set to the lower side of the RF-filter band. This means the absolute value of the IF should be larger than half the RF-filter bandwidth when the RF is near the center frequency of the RF filter. If the bandwidth of the RF filter is about 2 MHz, high-IF signal of more than 1 MHz should be produced by the digital LSI and the digital-analog converter.

4.2 Local-leak and image signal suppression

Local-leak and image signals are suppressed more than $60 \, dB$ by an upconversion quadrature mixer and the RF filter. They are suppressed about $30 \, dB$ by the up-conversion quadrature mixer with performance tuning and more than $30 \, dB$ by the RF filter by setting the local frequency outside the RF-filter band as shown in Fig. 3 (e).



Fig. 3. Frequency plan for proposed transceiver. Figures (a), (b), (c), (d), (e), and (f) show the signals at the point depicted in Fig. 2 with the same symbols. Figures (a), (b), and (c) are for the received signals; (d), (e), and (f) are for the transmitted signals.





5 Conclusion

New receiver and transmitter architectures were proposed to suppress the phase noise of a local oscillator in a 300-MHz RF and 25-kHz channel-space wireless transceiver. Because a PLL supplies only one LO frequency for multiple channels, the loop bandwidth of the PLL can be multiplied by the number of channels in one channel group to suppress the phase noise. In this architecture, variable IF signal could be selected using an IF-controllable complex band-pass filter. Local-leak and image signals in the transmitter output can be suppressed more than 60 dB by a quadrature mixer and RF filter. Simulation results showed that a sixteen-channel grouping could improve the phase noise suppression by more than 24 dB.

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