Chapter 6

CHANNEL-SELECT FILTER

1. Introduction

After two downconversions in the receive path, the baseband signal must be detected. As explained earlier in Chapter 2, the baseband signals can be demodulated in either the digital or the analog domain. Accompanied by interferers in both cases, the desired signal must be applied to a channel-select filter. For analog detection, the filter must be designed such that the demodulator can detect the signal in the presence of interferers.

In digital demodulation, on the other hand, the baseband signals can be filtered in the digital domain. In this case, however, the analog-to-digital converter (ADC) must be able to handle large interferers, demanding impractically wide dynamic range. Therefore, in order to relax the ADC requirements, the baseband signals are filtered in the analog domain [36, 37].

This chapter describes the channel select filter. We first introduce the concept of noninvasive filtering and then present the filter implementation. Since the channel-select filter needs to be designed for a specific standard, we use Bluetooth specifications to design the filter. Therefore, before describing the filter implementation, we briefly review the baseband signal and interferers in Bluetooth.

2. Noninvasive Filtering

2.1. General Idea

The conventional approach to filtering requires that both the signal and the interferers travel through a circuit that provides the desired transfer function [Fig. 6.1(a)]. However, such a filter introduces sig-
significant noise and intermodulation in the signal band. It is therefore advantageous to seek a method that applies filtering to only interferers without invading the signal band. For example, as illustrated in Fig. 6.1(b), a complex impedance \( Z_F(s) \) can be placed in parallel with the signal path such that it operates as an open in the signal band while shunting the interferers to ground. As a result, \( Z_F(s) \) provides selectivity with negligible additional noise, a critical advantage in view of the high \( 1/f \) corner frequency in modern CMOS devices. Furthermore, \( Z_F(s) \) creates a small intermodulation current through \( R_P \) because its Thevenin equivalent is relatively high in the signal band. Nevertheless, some linearity is still necessary if \( Z_F(s) \) is to operate as an effective shunt at interferer frequencies.

An example of \( Z_F(s) \) for a low-pass filter (LPF) is a simple capacitor but with a capacitor, the order of the filter cannot exceed one. To increase the order of the filter to two (a biquad section), the voltage across the capacitor can be increased as the frequency rises. Figure 6.2 shows a \( g_mC \) implementation of such an impedance. In this circuit, transconductors \( G_{m2} \) and \( G_{m3} \) form a gyrator that converts capacitor \( C_L \) to an emulated inductor \( L_L \) at the output of \( G_{m1} \). It can be easily shown that \[ L_L = \frac{C_L}{G_{m2}G_{m3}}. \]

Now as the frequency rises, the voltage across \( C_P \) increases, giving a second order impedance function. In this implementation, there is a feedforward current path through capacitor \( C_F \) that gives a zero in the impedance function. The zero frequency is at

\[
\omega_z = \sqrt{\frac{G_{m2}G_{m3}}{C_FC_L}}.
\]