5.1 Introduction

In this chapter, we demonstrate a fully-integrated fully-differential linearized CMOS distributed bidirectional amplifier that achieves large IMD3 distortion reduction over broadband frequency range for both RF paths. The drain and gate transmission-lines were stagger-compensated. Reducing the DA IM3 distortion by mismatching the gate and drain LC delay-line ladders. A CMOS cross-coupled compensator transconductor is proposed to enhance the linearity of the DA gain cell with a varactor-based active post nonlinear drain capacitance compensator for wider linearization bandwidth.

5.2 Linearized CMOS Distributed Bidirectional Amplifier Circuit Design Analysis

For wireless base station transmitters in UWB communications such as bidirectional UWB RoF transmission, high linearity and broadband bandwidth are some of the primary system requirements. Linear broadband amplification is required in order to reduce signal spectral regrowth. The wide bandwidth of the DA structure makes it an attractive component for use in systems requiring broadband operation. A detailed paper by Ginzton et al. [56] implemented Percival’s patented concept of distributed amplification [74]. Conventional DAs use low-pass π-sections to form an artificial transmission-line topology. Amplification gain stages are connected so that output currents are combined in an additive manner at the output terminal. The advantages of a DA topology are its wide bandwidth, flat gain and compact size circuit size. A three-stage CMOS DA with MOSFET devices is shown in Fig.5.1. The major three nonlinear elements of the MOSFET devices are \( g_m \), \( C_d \) and \( C_{gs} \). An ideal broadband amplifier should be a totally linear device. But in real world, amplifiers are only linear within certain practical limits. When the input signal driven into
the amplifier is increased, the output is also increased until a point where distortion products can no longer be ignored. The harmonics of the output signal are generated by nonlinearities of the MOSFET devices. The nonlinear element transconductance $g_m$ is a function of $V_{gs}$ and can be expressed by power series with coefficients $g_{m1}$, $g_{m2}$ and $g_{m3}$ as in (5.1).

The characteristic of the nonlinear transconductance can be approximated by a three-term power series expansion for each MOSFET device in Fig. 5.1 [13, 16, 36, 83, 101]

$$i_d = g_{m1}v_{gs} + g_{m2}v_{gs}^2 + g_{m3}v_{gs}^3$$  \hspace{1cm} (5.1)

As the input signal increases the instantaneous value of $g_m$ changes with the level of the input signal and the amplifier operating into its nonlinear region. We can write $v_{gs}$ as [13, 84]

$$v_{gs} = V \cos(\omega t)$$  \hspace{1cm} (5.2)

where $V$ is the amplitude signal and substituting (5.2) into (5.1), the expression for the current at frequency $\omega$ is given by [15, 85, 102–104]

$$i = g_{m1}V \cos(\omega t) + \frac{3}{4}g_{m3}V^3 \cos(\omega t)$$  \hspace{1cm} (5.3)

In the three-stage CMOS DA shown in Fig. 5.1, the fundamental component of the output current from each stage can be defined as [15, 102–104]

$$i_1 = g_{m1}V \cos[\omega]e^{-j\beta_g}$$  \hspace{1cm} (5.4)

$$i_2 = g_{m1}V \cos[\omega]e^{-j2\beta_g}$$  \hspace{1cm} (5.5)

$$i_3 = g_{m1}V \cos[\omega]e^{-j3\beta_g}$$  \hspace{1cm} (5.6)

$$i_k = g_{m1}V \cos[\omega]e^{-jk\beta_g}$$  \hspace{1cm} (5.7)

where $\beta_g$ is the phase constant of the gate line.