A Novel 40-48-GHz 3-Bit Step Attenuator

Juseok Bae and Cam Nguyen
Texas A&M University

Attenuators are extensively employed as an amplitude-control circuit in communication and radar systems. The primary purpose of attenuators is to reduce the signal level without distorting its waveform. Typical attenuators are based on the Pi, T, and distributed types. These attenuators have broad-band frequency responses and in system implementations, they are frequently cascaded with separate filters for minimizing the out-of-band noise contributions and/or suppressing possible image responses. For optimum performance and size, it is desirable for attenuators to have filtering functions without the need of separate filters.

We report a novel 3-bit step attenuator having a band-pass filtering function from 40 to 48 GHz. The attenuator is designed using a 0.18μm BiCMOS technology and based on the distributed attenuator topology. The distributed attenuator contains a $\lambda/4$ transmission line with certain characteristic impedance between the shunt switching transistors in order to maintain an optimum matching condition. In the designed attenuator, the transmission line is especially replaced with a J-inverter band-pass filter after an equalization procedure to achieve the band-pass filtering function and well-matched condition. Since the designed distributed attenuator does not contain a series switching transistor unlike the Pi-, T- or bridged attenuator, it has advantage of small phase difference between the reference and attenuation states. The designed attenuator also has a low phase imbalance over the desired bandwidth, making it suitable for signal amplitude control in millimeter-wave phased array systems. The attenuator employs conductor-back coplanar waveguide to minimize the interference between adjacent elements and the effect of the low-resistive silicon substrate. The attenuator works from 40 to 48 GHz. At the center frequency of 44 GHz, it has an attenuation step size of 1±0.15 dB and insertion loss of 5.15 dB. The maximum phase differences between the attenuation states are 14.5 and 7.09 degrees at 40 and 48 GHz, respectively. The return loss over all the attenuation states across 40-48 GHz is greater than 13 dB.