# Chapter 4
# Microwave Circuits Enabling 5G/6G Communication

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## ABSTRACT

*There is growing demand for 5G as well as 6G technologies as per user's requirements and enhanced applications. As low latency and high data rates are key findings of 5G, in same way more improved bandwidth, maximum data enabled rate, and many new applications are basic achievable things from 6G systems. There are several types of microwave circuits used for such high frequency. RF/microwave circuits include antennas, filters, power amplifiers, phase shifters, power dividers, mixers, and multiplexers. Here, microwave antennas have been discussed under the microwave circuits. In the last few years, as per economic and social development which is greatly influenced by the advancements in mobile communication and technology, 5G technology has emerged as an important of the future 2020 generation which is already in use. After the development of fifth-generation technologies, researchers, scientists, and engineers are looking for wide bandwidth which should improve wireless systems and devices to provide better services and faster experience. Also, the development of 5G wireless network technology is the response to the crucial factors that lead to this demand because of its ability to provide extremely fast internet speed, high bandwidth, high performance, reduced latency, and high reliability and better gain. In this chapter, we will review the recent design with advancement in 5G antennas for beyond 5G applications and also we will give a few designs of antennae for 6G applications.*

## 1. INTRODUCTION

Microwave circuits play a crucial role in enabling 5G and future 6G communication systems. These systems rely on high-frequency electromagnetic waves, typically in the microwave and millimeter-wave ranges, for high-speed data transmission and connectivity. Here's a detailed look at how microwave circuits are essential in these next-generation communication technologies:

1. Microwave Frequency Bands for 5G and 6G
    - **5G Frequency Bands**:

DOI: 10.4018/979-8-3693-8799-3.ch004

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- 5G operates in several frequency bands, including sub-6 GHz and millimeter-wave (24 GHz to 100 GHz), often referred to as the "5G New Radio" (NR) spectrum.
- Sub-6 GHz bands provide good coverage and penetration, while millimeter-wave frequencies enable high-speed data transfer, though they have shorter ranges and are more susceptible to obstacles.

- **6G Frequency Bands**:
  - 6G will likely push the boundaries further into terahertz frequencies (100 GHz to 1 THz) and integrate ultra-high frequency bands for even faster speeds, lower latency, and more reliable communication.

2. Microwave Circuits and Components in 5G/6G

Microwave circuits enable essential functions in the transmission and reception of signals in the RF (radio frequency) spectrum. Key components include:

- **Power Amplifiers**: These amplify weak signals for transmission, and high-efficiency power amplifiers are critical for maximizing coverage and capacity in 5G/6G networks. Gallium nitride (GaN) and gallium arsenide (GaAs) are commonly used semiconductor materials in these amplifiers.
- **Low-Noise Amplifiers (LNAs)**: LNAs are used to amplify weak signals received by the antennas. In 5G/6G, their performance needs to be optimized for low noise levels, as they directly affect the overall system's sensitivity and ability to handle high-frequency signals.
- **Filters**: Filters are used to select specific frequency bands and reject unwanted signals (such as noise or interference). In the millimeter-wave and terahertz range, filters must be precise, compact, and able to handle high-frequency signals without introducing significant losses.
- **Mixers**: Mixers are used to shift the frequency of a signal, often from RF to intermediate frequencies (IF) for processing. These are crucial in systems that need to operate over a wide range of frequencies, such as 5G and 6G.
- **Antennas**: Advanced antenna technologies, like massive MIMO (Multiple Input, Multiple Output), use large arrays of antennas to improve data throughput and coverage. Microwave circuits manage the signals fed to and from these antennas, ensuring high-efficiency transmission and reception.

3.Key Microwave Technologies Enabling 5G/6G

- **Phased Array Antennas**: Phased array antennas allow for the electronic steering of beams, enabling adaptive beamforming and enhancing the performance of MIMO systems. These antennas are vital for 5G and 6G systems as they provide faster data transmission and improved reliability.
- **Small Cell and Beamforming**: Small cells, which are low-power, short-range base stations, help to overcome the propagation limitations of high-frequency signals in 5G/6G networks. Beamforming technologies, using arrays of microwave circuits, allow the focusing of radio signals in specific directions to enhance coverage and capacity in dense urban environments.
- **Beam Steering**: With beamforming, microwave circuits enable dynamic adjustment of the direction of the signal beams, allowing devices to receive stronger signals, improving both data rates and network efficiency. This is essential for high mobility in 5G/6G.

4.The Role of Microwave Circuits in 5G/6G Applications

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