CHAPTER 2
GRAPHENE ANTENNA ARRAY UTILISING DEFECTED GROUND STRUCTURE

Siti Nor Hafizah Sa'don and Mohd Haizal Jamaluddin

2.1 INTRODUCTION

Fifth-generation (5G) is a wireless communication system that has a high degree of heterogeneity in services, device classes, deployment types, environments, and mobility levels (Ijaz et al., 2016). It requires 10 to 20 Gigabits per second (Gbps) peak for data rate, 10 terabits per second (Tbps) traffic capacity, ultra-low-cost for machine-to-machine (M2M) communication, 1 milliseconds (ms) for latency, and one hundred fold improvement in power efficiency (ITU-R, 2017; Ullah et al., 2019). Based on these scenarios, a 5G antenna must have good characteristics to support this new features such as large bandwidth (Rappaport et al., 2013), high gain (Wonbin et al., 2014), antenna, beam-forming (Dinh-Thuy et al., 2015), and high-directivity beam steering (Dehos et al., 2014).

Raising the number of element or building an antenna array is one of the easiest ways to improve antenna gain besides maintaining the existing bandwidth. It is given by the Equation 2.1:

$$E\ (\text{total}) = [E\ (single\ element\ at\ reference\ point)] \times [\text{array factor}] \tag{2.1}$$

while array factor, AF can be obtained by Equation 2.2:

$$\text{Array factor } (AF)_n = cos\left[\frac{1}{2}(kd\ cos\ \theta_o + \beta)\right] \tag{2.2}$$

where n is the number of elements, θ_o is angle observed, d is inter-element spacing, d and β is progressive phase shift.

However, if an inter-element spacing decreases, the antenna will experience side lobe increasing level or grating lobe. Sometimes, grating lobe or poor radiation pattern still occurred if the inter-element spacing in the range of 0.5λ to λ. Both situations experience mutual coupling which may come from the antenna type itself, position of the elements, feed of the array elements, and scan volume of the array. Mutual coupling is the energy interchange to other side when two or more antennas are near to each other (Balanis, 2005). High side lobe level will reduce the antenna radiation performance, bandwidth, and gain (Zhu et al., 2018), while worsening isolation (Pan et al., 2019), and reducing the scanning range and capacity (Chen et al., 2019).

Various methods can be used to reduce the mutual coupling in the antenna array such as stub insertion between two elements in the ground plane (Ta et al., 2017), notch/slot/slit in the ground plane of the antenna array as being presented in (Yang et al., 2016) and (Zhu et al., 2018), employing Taylor distribution (Park et al., 2016), electronic bandgap (EBG) (Tan et al., 2019), parallel coupled-line resonator (PCR) (Vishvaksenan et al., 2017), metamaterial absorber wall (Zhang et al., 2019) and many more. Figure 2.1 shows various methods of mutual coupling reduction in antenna arrays.

Defected ground structure (DGS) is another technique of mutual coupling reduction. It is a shape that is etched in between two adjacent elements that commonly located at ground plane of antenna array (Kumar et al., 2017). There are variety of shape in which DGS that can be designed (Qian et al., 2021). When DGS is incorporated, it will disturb the currents on the ground planes to enhance the antenna gain (Abutarboush et al., 2020). It also has the ability to improve the cut-off frequency characteristic of circuits and to reduce the cross-polarization effect on microstrip patches (Kuzu & Nursel, 2017). This method is preferred because of flexible, consume small space, and easy to manufacture.

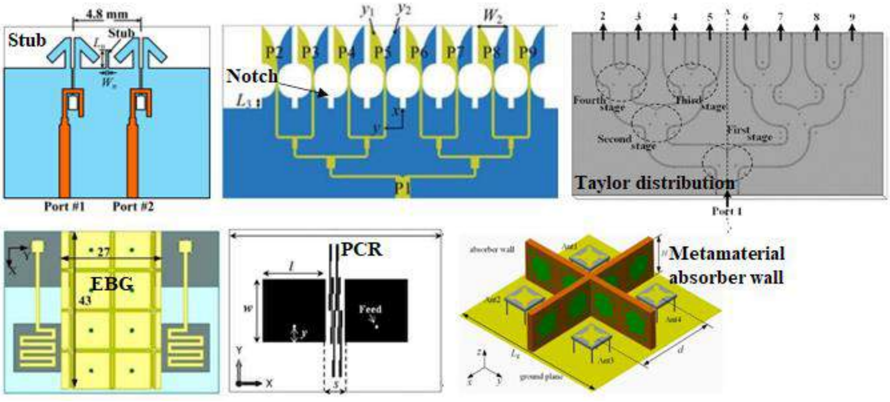

Figure 2.1 The technique of mutual coupling reduction is commonly introduced at the centre in between two elements of patch layer or ground layer

The method of DGS is proposed in a two elements of graphene antenna array to improve gain, radiation pattern, and isolation. Graphene is used as a radiating element in the proposed antenna. Graphene is a two-dimensional (2D) material that is formed by one-atom thick layer of carbon atoms. It is selected due to being very flexible (Palacios et al., 2010) and ultra-thin (Yu, 2013), thus it can be integrated and designed at any kind of surfaces since the implementation of 5G covers various system and electronic devices. Graphene can be an alternative material to reduce device size (Yu, 2013) or design which has a small gap (Russer et al., 2010). It is regarding to the 5G antenna requirement which utilises high frequency and resulting a smaller antenna size. It also can be as an alternative material for metal due to reduced carbon dioxide emission compared to metal which contribute to heavy metal pollution after a device not be used anymore (Scidà et al., 2018). By using this carbon-based material, it does not have any issue with pollution due to no heavy metal. Graphene also is observed as a