Chapter - 6

Conclusion and Future Scope

6.1. Conclusion

In this thesis, the polygonal patch antenna(s), especially hexagon is investigated in detail, and pros and cons are highlighted and then the issues associated with the hexagon are alleviated and resolved. It is probable that the issues of hexagonal antenna can be resolved by one of the variations and modifications, due to availability of many versions and techniques. Due to advancement in modern wireless communication systems, antenna with wide radiation bandwidth is demanded in order to cater such a demand. These concerns encourage the antenna researcher to design an antenna with wide radiation bandwidth. Hexagon are chosen here to fulfil the requirement of the modern wireless communication systems and services while maintaining fundamental mode. Feed is an important part of the antenna; the impedance and the gain, will influence the antenna performance. The designed antenna probe feed point is varied in order to enhance the bandwidth of antenna. Probe feed analysis suggested feed point kept closer to vertex of polygon is suitable for a wideband performance of a polygonal patch antenna.

Various polygonal geometries such as triangle, rectangular, pentagonal, hexagonal and circular for patch antenna design possess different antenna characteristics. It is significant to understand the characteristics of various polygonal geometries for designing a customized antenna for different applications. Triangular patch has comparatively high gain, directivity and efficiency, while hexagonal patch has a lower beam-width that makes it suitable for antenna arrays. The polygon geometry can be transformed to polygram geometry but no significant variation is observed in antenna characteristics when polygons are transformed to polygram geometries, other than a slight improvement in gain of the hexagon patch when transformed to hexagram geometry with θ < 163.15°. The effect of polygonal slot in polygonal patch antenna design to improve gain characteristics is studied. The pentagon and hexagon shaped patch antenna with pentagonal and hexagonal slot is analyzed respectively. It is analyzed that the polygonal slot in polygonal patch can slightly improve the gain of the antenna.

Hexagon suffers from impedance mismatch when fed directly with a probe near the vertex and generate higher order mode. It is also observed that the impedance bandwidth of the hexagonal patch antenna is narrowed by the introduction of inductance due to direct probe feeding. The ground plane reduction technique can also be used to compensate the impedance mismatch as well as the suppression of spurious radiation or mode.

PPC technique can used to compensate the impedance mismatch of hexagonal patch antenna. A technique to compensate probe reactance to excite lower mode in a hexagonal patch antenna is demonstrated. A PPC is used with feeding probe to excite the lower mode by matching the impedance at 2.4 GHz. The slotted hexagonal antenna with PPC is compact in structure and may be used for various S-band applications.

Hexagonal patch antenna with probe shows narrow band behavior. The effect of flanges of a SMA connector on the impedance bandwidth of a vertex-fed slotted hexagonal antenna with a truncated half elliptical ground plane is demonstrated. The antenna when fed through a connector with a flange exhibits C-band characteristics while in order to achieve UWB characteristic in a direct-fed antenna, a flangeless connector makes a suitable choice. The ground plane reduction technique is also used to achieve ultra wideband with hexagonal patch which converts the dipole configuration to monopole configuration. The slot in the ground plane supported broadening of the bandwidth of the antenna. A ground plane reduction technique is used with a rectangular slot to excite multiple modes within the UWB band. The antenna, exhibits a wideband from 2.4 GHz to 10 GHz.

A technique to transform a monopole like radiation pattern to a directional pattern using an AMC reflector with a square shaped loop unit cell, consequently enhancing the gain of the hexagonal UWB antenna. An AMC reflector can assembled at back of hexagonal radiator in order to enhance the peak gain as well as gain of the UWB antenna. The antenna boresight and peak gain are significantly enhanced by around 5.5 dB and 3.74 dB respectively after application of AMC reflector. The assembled antenna with AMC is suitable to be exploited for UWB applications.

6.2. Future Scope

Polygonal planar antenna will continue to be used due to its fundamental advantage over other radiators. In terms of research there are scope for the work which can be carried further. Planar antennas with circular polarization are popular because of the feature of relative insensitivity to receiver and transmitter orientation (Kumar 2003). A probe-fed patch antenna with circular polarization (CP) has been studied and designed by Chen et al. (Chen 2001). Chang et al. constructed an economic probe fed patch antenna that is capable of broadband CP radiation, which is suitable for wireless local area network (WLAN) and mobile satellite communication (Chang 2003). Ooi et al. introduced a dual band antenna which has an application in ISM bands (especially 2.45 GHz and 5.8 GHz) with circular polarization radiation (Ooi 2010). Wu et al. presented an antenna with CP for mobile radio frequency identification (RFID) reader (2.45 GHz) and WLAN application with a gain of 6.32 dBi (Wu 2013). A perturbed hexagonal patch antenna has been described using LTCC technology, which has dual band characteristics (3.5/5.2/5.8 GHz bands) with circular polarization due to the stacked-patch and inserted slits (Kewei 2013). The axial ratio bandwidth and S_{11} of the circularly polarized antenna was improved by 11.02 % and 2.45 % especially using probe strip and a substrate with good thickness when utilized for RFID applications (Wu 2013).

To obtain circular polarization, it is necessary to achieve an axial ratio close to unity. In order to achieve axial ratio close to 0 dB, orthogonal E-vectors of equal amplitude but with 90° phase difference is required. One solution to achieve the circular polarization is dual but orthogonal feed technique. A technique was introduced by Ogurtsov et al. for enhancing circular polarization in patch antenna excited with two equal amplitude inputs separated by 90° (Ogurtsov 2016). Axial ratio analysis is significant in order to understand the polarization characteristics of an antenna. Guraliuc et al. performed axial ratio analysis and achieved an axial ratio of 0.9 dB at 2.53 GHz for single feed truncated corner patch antenna. The 3-dB axial ratio bandwidth ranges from 2.479 to 2.58 GHz (Guraliuc 2014). Wireless communication receiver also discriminates the sense of polarization i.e. left hand circular polarization (LHCP) and right hand circular polarization (RHCP) depending on the rotation of the wave. Zhang et al. achieves a controllable polarization for LHCP and RHCP for a 3-dB axial ratio Bandwidth of 2.726–2.739 and 4.486–4.501 GHz respectively (Zhang 2017). It is quite interesting to perform axial ratio analysis to understand the polarization characteristics of the hexagonal patch antenna.

A probe-fed circularly polarized hexagonal patch antenna with dual feed configuration is designed (Joshi, 2019) for analysing amplitude and phase sensitivity. The hexagonal patch antenna is excited with a fundamental frequency of 2.45 GHz through two feeds separated by an angle of 90° and 90° phase shift. The probe feed positions are optimized along the X- and the Y-direction of the patch antenna plane with and without simultaneous excitation. The sensitivity of circular polarization purity towards change in amplitude and phase of excitation signal is studied for a dual port hexagonal S-Band antenna.

Higher order modes and dual resonances at higher order modes are regular features in probe-fed hexagonal patch antennas (Joshi 2016b). Several methods like electromagnetic band gap (EBG) structures (Padhi 2004), filters (Garcia-Garcia 2005) have been used in the research field to either suppress or remove the unwanted frequency components. Meta-material resonating structures like Split ring resonators (SRRs) and its complimentary part, CSRRs may be very useful for the same purpose as investigated by authors in (Bonache 2005) (Lee 2005) (Ali 2007). SRRs tend to provide a negative value of the magnetic permeability around their resonating frequency upon axial magnetic field excitation (Pendry 1999) while CSRRs imitates like a structure with negative electrical permittivity in the vicinity of its resonating frequency when axial electrical excitation is applied (Falcone 2004). The behavior of both SRRs and CSRRs can be considered analogous for band-rejection purposes (Aznar 2009). The equivalent circuit model of CSRRs is thoroughly explained in (Baena 2005). Hence, either one of these can be used to block the propagation of electromagnetic energy around their resonating frequencies. However, SRRs has to be implemented on the patch antenna plane in contrast to CSRRs which will be made by cutting out metal from the ground plane. Careful selection of the physical parameters of CSRRs structures is extremely important since their dimensions will decide the frequencies which are to be eliminated from the patch antenna radiation. A slotted hexagonal patch antenna with reduced ground plane has been taken into consideration (Joshi 2016b). Along with the desired frequency at 5.45 GHz, it is also resonating around 6.5 GHz. To suppress 6.5 GHz, two CSRRs are placed in the ground plane and effects of their position and dimensions on return loss were analyzed. Significant reduction in the spurious radiation is observed on using CSRRs in proximity to the probe in the ground plane. Based on the farfield radiation pattern analysis it is deduced that the antenna with CSRRs at 5.45 GHz and antenna without CSRRs at 5.54 GHz have same mode of radiation. Removal of any spurious radiation has always been one of the primary concerns in designing probe-fed patch antennas. Meta-material resonating structures like Split ring resonators (SRRs) and its complimentary part, CSRRs may be very useful for the suppression of any adjacent resonance commonly observed in hexagonal patch as investigated by authors in (Joshi 2017b). An antenna designed in (Joshi, 2017) is further studied to transform a monopole like radiation pattern to dipole like radiation pattern at 5.5 GHz using conical and hemispherical lens (Joshi 2018b). The squinted beams generated due to presence of higher mode in hexagonal patch antenna at 5.5 GHz is shaped to form a fundamental mode like radiation pattern using conical and hemispherical dielectric lens.

Reconfigurability in patch antenna such frequency, pattern, and polarization can be achieved. The reconfigurability can be achieved by using pin diode and varactor diode to switch particular frequency and pattern. Lokesh et al. (Lokesh 2019) design a probe fed hexagonal patch antenna with an annular parasitic hexagonal ring that embeds a Skyworks' SMV1430- 040LF varactor diode for resonant frequency tuning in WLAN band. The same varactor diode is implemented in a separate, slightly bigger but similar antenna structure, to tune the antenna within Wi-Fi band. Frequency re-configurability is observed in simulation results on CST MWS. The first structure is capable to switch between 9 modes spanning 5.2-5.9 GHz band while the second antenna covers the whole Wi-Fi band (2.4-2.5 GHz) in 9 switching modes depending on the reverse bias capacitance of the varactor diode. Only one varactor diode is used as a frequency tuning element to control the resonant frequency making the antenna structure simple. The DC bias voltage can be fed directly to the outer ring of the patch where one end of varactor diode is connected eliminating the need for any bias circuitry. Both the antennas radiate in the fundamental mode providing maximum gain of 1.9 dB. The impedance of both the structure is found to be close to 50 ohms in all the switching modes. The antennas are highly useful in presence of interference signals as the user will be able to easily switch to a different frequency mode just by changing the bias voltage.

Sophisticated algorithms and optimization techniques can be further explored for the advancement of polygonal planar antennas. Three dimensional optimization will be interesting to further explore. The dimensions and size of the polygonal planar antenna can be further optimised for efficient radiation. Definitely there will be more advancement in the feeding technique to excite the patch and technique to further enhance the impedance and radiation characteristics of polygonal planar antennas.