Chapter 2

REVIEW OF THE PAST WORK IN THE FIELD

This chapter presents a review of the important developments in the field of Corner Reflector antennas and the related fields. A review of the analytical methods for the theoretical analysis is also briefly described.

Reflector antennas formed a part of even the very first experiments in electromagnetics. In 1887, Heinrich Hertz, professor at the Technical Institute in Karlsruhe, Germany demonstrated the existence of electromagnetic waves that has been predicted theoretically by James Clerk Maxwell about fifteen years ago. A cylindrical parabolic reflector antenna formed the essential part of the experimental setup for this electromagnetic energy production and transmission.

A review of the developments in reflector antennas till 1976 is presented by Love [2]. He consolidates the developments in the area over the ages by considering the period since the advent of the reflector antennas as different sections. In the conclusion he makes a comparison of the gains of a selected number of world’s largest reflector antennas.

The idea of a corner reflector was conceived by Prof. John. D. Kraus in the year 1938, while he was analysing the radiation properties of the closely spaced W8JK array. He constructed the first corner reflector antenna operating at a wavelength of 5 meters. His experiments with the corner reflector antenna were summarised in two classic papers[3, 4]. He used the theory of images for corner
reflectors whose apex angles are sub-multiples of 180 degrees for the analysis of the fields for an on center excitation by a dipole source oriented parallel to the axis. Also a general description of the various characteristics of the corner reflector antennas can be obtained from other references [5, 6]. Since the time of J. D. Kraus a considerable work has been done in the field of corner reflector antennas.

Moulin [7, 8] employed the theory of images to calculate the field patterns that would apply only to flat sheets of infinite in extent. These ideal solutions are a valuable guide to the behaviour of the corner reflector antenna of finite size. He pointed out that the image method appears to be applicable only for angles that are a sub-multiple of 180 degree. He is skeptical as to whether the results expressed as a series of Bissell functions can be generalised to corner reflector angles of an arbitrary value between 0 and 2π.

Harris [9] gives a detailed experimental investigation on the radiation patterns of corner reflector antennas. He studied the variation in radiation patterns with different parameters of corner reflector antennas. The beam tilting for an off-axial dipole orientation also is studied.

By admitting multivalued solutions of the wave equations in cylindrical coordinate system, J.R. Wait [10] extended the image theory to any angle of the corner reflector. He represents the antenna feed as an electric dipole oriented in a direction parallel to the apex of the reflector. The evaluation of the resulting formal solution that contains an infinite series of integrals is done for the far field by applying the saddle point method of integration. The result is then expressed as a singly infinite series containing a Bessel function which in general has a fractional order. It is shown that for antennas which are within a few wavelengths of the apex the series converge very rapidly. Illustrations of several representative pattern calculations are performed and a method of obtaining pattern function, for an arbitrary aperture angle assuming reflecting surfaces of infinite extent, had been shown.

The performance of Corner reflector antennas had been of interest to the National Bureau of Standards of America, as they appeared to be suitable for
communication through ionospheric scatter. So various tests were conducted by Cottony [11] on the different aspects of the performance of these antennas. A brief note of these experiments on this work during 1952 is summarised in reference.

Klopfenstein [12] describes the determination of characteristics of a corner reflector antenna for arbitrary dipole orientation and apex angles, excited by an infinitesimal dipole source. The relative phase and magnitude of vertical and horizontal components of electric field, the directive gain of the antenna and the radiation resistance of the dipole source have been found out. The results of general analysis makes possible the treatment of corner reflector antennas with apex angles not subject to image analysis.

The horizontal orientation of the dipole is less preferred due to its apparent lower gain potentiality. However, Woodward [13] has shown that for certain dipole orientations, the corner reflector antenna serves as a circularly polarised radiator.

An experimental investigation of the Corner reflector antenna with finite sides is being carried out by Cottony and Wilson [14]. The configurations with aperture angles varying from 20 degrees to 180 degrees and widths and lengths of the reflecting surfaces between 0.4 to 5 wavelengths have been studied. Measurements of gain for the numerous combinations of these parameters were made for the various positions of the half wave dipole. The important results are presented as graphs.

Wilson and Cottony [15] makes further studies on the corner reflector after setting the aperture angle at an optimum value to realise maximum axial gain. Widths and lengths of the reflecting surfaces were varied in a range of 1 to 10 and 0.5 to 5 wavelengths respectively and the effects of these parameters on the forward and rear radiation has been studied by plotting the radiation patterns. A corner reflector array with a collinear array of dipoles was designed, constructed and tested to get a sidelobe level below 40 dB.

Using Geometrical theory of diffraction, Ohba [16] calculated the gain and radiation patterns of corner reflector antennas of finite width. The results were compared with the experimental results of Cottony and Wilson. In the rear direction,
effects of the waves diffracted from the upper and lower edges of the reflector is taken into account.

Kosta et. al [17, 18] had suggested a tilted log periodic feed for a corner reflector to achieve broadband circularly polarised performance. The suggestion was based on that in a log periodic array, the distance from its active region to its apex in wavelengths is independent of frequency. Broadband characteristics were predicted over a frequency range limited only by the log periodic feed size and the need for the corner reflector to be electrically large.

Stephenson and Finley [19] considers a log periodic dipole array as a broadband corner reflector feed. A critical analysis of the merits and demerits of such a system and the possibility of practical applications have been suggested. The reduction of Half Power Beamwidth in the H-plane with frequency is observed, even though the VSWR shows considerably higher values.

Inagaki [20] proposes a corner reflector antenna using three planar reflectors and a 3/4 λ unipole radiator. A gain of about 5 dB over that of a two dimensional corner reflector is predicted theoretically and confirmed experimentally. The input impedance is found to be roughly between 50 and 75 ohms, which makes it a good match with coaxial cables. Sidelobes in the E-plane were found to be suppressed.

Aoki and Tsukiji [21] presents an analytical method of finding the radiation field of a two dimensional finite size corner reflector antenna by the field theory. This method is useful to analyze the finite size corner reflector with arbitrary aperture angle and with unsymmetrical structure.

A series of computer derived design charts for maximising the radiated field from a corner reflector antenna are presented by Proctor[22]. Optimum feed positions can be obtained from the various graphs connecting normalised electric field to the feed position.

Nair and Mathews [23] suggests the possibility of analysis of the results on E-plane sectoral horns by extending the theory of corner reflectors. The striking resemblance shown by metallic flange attached sectoral horn antennas with corner reflectors was the idea behind the suggestion.
Computations using numerical methods had been performed by Ja [24] to determine the phase centers in the principal H-plane of the corner reflector antennas. The theoretical results are compared with that of the experimental results. He found that the distance between phase centers and the apex increases when the aperture angle decreases from 180 degrees to 60 degrees.

Mathew and Nair [25] present the analysis of the resemblance in the behaviour of flanged sectoral horn antennas and corner reflector systems in beam shaping and tilting. The results obtained in the two systems suggest the possibility of interpreting the flanged sectoral horn as a linear radiator with a corner reflector. The corner reflector analogy gives the explanation for the results of E-plane sectoral horn antennas.

Ng and Lee [26] had made extensive studies on the beam tilting by off-bisectoral dipole alignment.

Vasudevan and Nair [27] proposed a new type of corner reflector system with corrugated reflector elements and the characteristics are compared with that of the conventional corner reflector antennas with plane reflector elements. They prove that the on axis power of a horizontally oriented dipole fed corner reflector system which is considered to be a low gain antenna can be increased with better impedance conditions, by making suitable corrugations in the reflector elements.

A theoretical analysis of the corrugated corner reflector system has been attempted by Vasudevan and Nair [28] on the basis of the line source theory and the method of images. Experimental and theoretical patterns are compared and are found to be in appreciable agreement. The reasons for discrepancies had been discussed.

Bucci et al. [29] examines in detail the radiation characteristics of symmetric parabolic antennas with a peripheral flange to assess the effectiveness of such a flange in reducing the backward scattered field. It is shown that the best behaviour is obtained by using a right angled flange, which allows achievement of a significant field level reduction in a wide rear angle sector, without affecting the field radiated in the forward directions.
Elkamchouchi [30] proposes two reflector antennas of which the first is constructed by adding a cylindrical reflecting surface of suitable radius to the corner reflector antenna with a half wave dipole as the feed. The modification provided a gain of 2 dB. The second antenna is constructed by adding a cylindrical surface to the three dimensional corner reflector and it provided a gain of 6.5 dB. The grid versions of these antennas were also designed and studied.

The high frequency diffraction theory called the Geometrical Theory of Diffraction (GTD) has been originated by Keller. Through his two classic papers [31, 32] he lays down the fundamentals of this elegant theory in which he combines classical geometrical optics with the asymptotic diffraction theory.

A comparison of the three high frequency diffraction techniques has been done by Knott and Senior [33].

The applications of Diffraction theory to the various aperture antennas has been treated in detail in the classic books by Jull [34] and James [35].

An analytical account of the theory of diffraction of electromagnetic waves based on the angular plane spectrum concept, which is applied to the analysis of several widely used microwave antennas is given by Clarke and Brown [36]. Examples of application to aperture antennas are presented.

A review of the Geometrical theory of diffraction (GTD) emphasising the contributions from the Indian group led by C.V. Raman is highlighted by Kumar and Ranganath [37].

A hybrid technique with GTD and Moment method (MM) for solving electromagnetic problems in which the antenna is located on or near a conducting body has been initiated and conducted by Thiele and Newhouse [38].

The above method of analysis is extended to wire antennas by Ekelman and Thiele [39].

Applications of these hybrid technique to time domain problems has been investigated by Thiele and Chan [40].

The above hybrid method of analysis (the moment method and the GTD) used in conjunction utilizes the UTD of Kouyoumjian and Pathak [41].
The GTD-MM Technique by Burnside et. al [42] uses Moment method as a tool for extending the usefulness of the GTD.

A comparative study of the radiation patterns calculated by the Geometrical theory of diffraction (GTD) and the Integral equation solution (IEF) has been carried out for four two dimensional reflector antennas including the corner reflector antenna by Tsai. et.al [43]. The calculations for finding out the ranges of validity of these methods has been done. A qualitative assessment of the relative merits of the two methods is also presented.

A rigorous analysis of the problem of two dimensional diffraction with an H-polarised electromagnetic wave by a corner screen is derived by the spectral method in the form of a system of linear equations by Vasilieva et.al [44]. Computational results for the distribution of the surface current density, the directional pattern of the field and the effective scattering cross-section are presented.

The problem of wave diffraction by a corner screen has been used for the analysis of a corner reflector antenna by Ragheb et.al [45].

Diffraction by a wide double wedge with rounded edges has been treated by Elshabeni [46].

The solution for diffraction at a wedge has been treated by Lewin [47] and Felsen and Marcuvitz [48] by integral methods.

An asymptotic form of the far field of a line source near a wedge was discussed by Russo. et.al [49]. The solutions for high frequency diffraction of a line source by ray techniques have been treated by Boersma et al [50].

The analysis of the new system of corner reflector antennas dealt with in this thesis treats the corner reflector as two plane reflectors. The analysis is done based on the theory of wedge diffraction.
Chapter 3

METHODOLOGY