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# Design of Microstrip Antenna Array for RADAR Application : A Review

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**Abstract:** Phased Array Radar technology has seen great improvement since their inception in 50s. The development of microstrip antenna for phased array radar increasingly great importance. This paper reviews the research and development in this subject from inception till today. Conventional antennas antennas are large in size and they need to get installed properly because of their large size. Eli Brookner was the pioneer in the field of Phased Array Radar. He was working in the field of radar since the 50s. The research in the field of radar was greatly increased from World War II. Beam steering switching antennas were widely used and preferred. By controlling amplitude excitation of the elements in an antenna array, an efficient null broadening was achieved. People were preferring a slot into the design for higher bandwidth requirements. The slot microstrip antenna was used as a folded slot dipole. Defective Ground Structure had been extensively used by many authors for the improvement of bandwidth. DGS is an etched periodic or non periodic structure in ground plane. A new concept has been evolved named as a Complimentary Split Ring Resonator (CSRR). The two concentric open circular rings are etched on ground plane. Frequency Selective Surface (FSS) are the resonant structures having either stop band or pass band performance, due to which they are widely used as radomes and electromagnetic absorbers. Microstrip antennas are commonly used with an upper dielectric protective layer called as radome which provides mechanical protection and weatherproof operation. Electric parameter of antenna get affected if the dielectric constant of radome is not unity.

**Keywords:** Radar, array antenna, DGS, EBG, CSRR

## I. INTRODUCTION

RADAR is an object detection technique that uses electromagnetic waves to determine the range, angle or velocity of moving or stationary objects. It can be used to detect ships, aircrafts, guided missiles, weather formations and so on. Antenna plays an important role in the field of RADAR system. An Antenna array has been constructed at Stanford University for radar studies of the moon cislunar gas, and solar corona. The array of 48 log periodic elements have been designed by Henry Howard in [1]. These antennas are large in size and they need to get installed properly because of their large size. Such an array can give high gain and also good signal to noise ratios with beamwidths. These are well matched to the requirements of RADAR System design. A wide beam is desirable in azimuth to simplify the tracking problem, while elevation beamwidths of 0.5 to 3 degrees are all that are needed since ionospheric refraction makes narrower beams difficult to direct accurately. The world wide handheld cellular telephone service via a network of 66 satellites placed in low earth orbit was initiated with the objective of Iridium program by J.J. Schuss in 1993. They have designed 3 L band phased array panels placed on each satellite [2]. Indian Metrological Department was the nodal agency for Weather service in India. IMD operates a chain of conventional weather radars along the peninsular coastline for the cyclone detection and characterization of severe weather. This chain of cyclone detection radar system is now replaced by pulse Doppler radar. DWR employs a low side lobe antenna enclosed in a rigid spherical radome employing curved sandwich panels. Radome is designed to withstand winds of 200Km/hr gusting to 300Km/hr. The salient features of the Indian Doppler Weather Radar is discussed in [3]. Now people are working towards the wideband array antenna by inserting slots into the design. Miniaturization is also achieved form this technique. K.P.Tong has designed a broadband patch antenna using U slot into the design is explained in [4].The microstrip antennas resonating in the fundamental TMnm mode always radiate along the broadside of the patch element and the field is primarily linearly polarized. The degree of orthogonal polarized field is called cross polarization. The probe feed design exhibits radiation particularly when the thickness as well as the dielectric constant of the substrate increases.

Eli Brookner was the pioneer in the field of Phased Array Radar. He was working in the field of radar since the 50s. The research in the field of radar was hugely increased from World War II. UHF radars were available that time. The detail study about the Phased Array Radar, the past, present and future trends were also presented. The development of electronically scanned array, their capabilities like light weight, smaller volume, lower cost are discussed in [5][6]. MEMS array are discussed in [5]. The AN/TPS-25 was the first Phased Array radar one half reflector antenna and one half phased array. The pave paws system was the first solid state phase-phase scanned array was deployed. This radar was two faced, each with 1792 (Transmitter / Receiver ), 330 W UHF modules feeding 1792 bent cross dipole radiating elements [6] [7]. The future trends in passive, active bipolar and monolithic microwave integrated (MMIC) Phased array for ground, ship, air and space applications was surveyed in detail in [8]. A mechanism for combining signals of multiple radars to achieve increased range, radar sensitivity and angle accuracy was given in [9]. MIMO radar has captured the market in the field of array. It is best suited to search a large scan angle subarray and was explained in [10]. Meteorological service of Canada had published an article stating that Canada's coastal waters include three oceans and extensive large inland lakes adjacent to complex terrain and coastlines. Synthetic Aperture Radar based on winds retrieval system in operational marine forecasting throughout Canada to identifying mesoscale and synoptic-scale features. The two year Canadian National SAR winds project has successfully demonstrated that quasi-operational SAR wind retrieval system was an important element of the operational weather analysis and prediction structure [11]. Advanced RADAR in Australia Bureau has a network of 67 radars. This Bureau uses radar for visualizing storm structure and automated storm identification and tracking. These research radars are being used to develop the next generation set of operational applications and decision support for severe weather as well as process understanding of cloud system and model performance on a regional and global scale [12]. A mathematical analysis of 3-pol polarimetric weather measurement with agile beam phased array radars are briefly discussed in [13]. Cone shape antenna array is designed in [14]. for polarimetric performance. Ultra wideband Vivaldi antenna array is used for radar measurement of snow thickness and density. It was designed for 2-18 GHz. Centre for Remote Sensing of Ice Sheets University of Kansas , USA published an article about 10×10 ultra wideband Vivaldi array which gives bandwidth of 2.6 to 18 GHz [15]. Beam steering switching antenna arrays was designed and tested in [16][17]. By controlling amplitude excitation of the elements in an antenna array, an efficient null broadening was achieved. Peoples were preferring a slot into the design for higher bandwidth requirements [18]. A rigorous design and analysis was done with U slot and an in-dept explanation about the mode introduced by U slot and detail procedure to design U slot cut antenna is explained and designed in [19][20]. The slot microstrip antenna was used as a folded slot dipole. A very senior author K .F. Lee has explained in [21] about slotted array antenna. Through Slot Patch technique is used for the improvement of bandwidth in [22] and half U slot loaded antenna is explained in [23]. For size reduction U slot antenna have been implemented in [24].

Lincoln Laboratory has been involved in the development of phased array radar technology since the late 1950s. The laboratory has developed several phased array test beds, which have been used to demonstrate and evaluate components, beamforming techniques, calibration and testing methodologies [25] . Early radio transmitters and the early World War II, radars used multiple radiating elements to achieve desired antenna radiation patterns. Bert Flowler has communicated the entertaining recollection of many these efforts from the 1950s to the present [26].

Now-a-days an active phase array radar have been extensively used in medical science. Weather forecasting, defence industry and communication. This is the revolutionary development in the field of Phased array radar. Planar phased array antenna have been designed at X band in [22]. A dual polarized X band array antenna is designed for a maritime navigational phased array radar. The dual polarized unit cell as well as distribution networks are designed in [27]. A dual frequency airborne radar was developed in China. Results from field campaign shows that the overall performance of ADPR Ku/Ka radar are fulfilled with the requirement of China space Borne dual frequency rain radar [28]. A high gain of 22.5 dbi is designed at 76.5 GHz for automotive radar systems in [29]. A brief overview of automotive radar is explained in [30][31] . A double sided circular antenna array has been designed at C and X band Weather Radar Application. The single sided single band and double sided dual band antenna provides directional radiation pattern and high gain [32]. Short range radar antenna has been developed in [33].

## II. ELECTROMAGNETIC BAND GAP STRUCTURE

The (EBG) is becoming more popular in the field of radar system. EBG structure reduces surface wave level, back lobes and gain. EBG are mostly used for the reduction of mutual coupling between antenna elements. A swastika type EBG has been designed and fabricated in [34]. Photonic Band Gap structure has been made by drilling a periodic pattern of holes in the substrate [36] or by etching a periodic pattern of circles in ground plane as stated in [37]. Two advanced methods were proposed to improve compactness in EBG design has been expressed in [38].

## III. DEFECTIVE GROUND STRUCTURE

Defective Ground Structure had been extensively used by many authors for the improvement of bandwidth. Debatosh Guha had proposed Defective Ground Structure to reduce Cross-polarization radiation of microstrip patch without affecting the dominant mode input impedance and co-polarized radiation pattern [39]. A novel isosceles triangle DGS was implemented on triangle patch linear array microstrip antennas to suppress surface waves and improve the design [40]. People were using various shapes of DGS in the ground plane for the parameter improvement of an antenna. DGS is an etched periodic or non periodic structure in ground plane [41]. Various DGS shapes have been designed like swastick shape [42], H Shaped DGS to suppress higher order harmonic is presented in [43]. An elegant solution was proposed in [1] by employing a simple circular dot-shaped DGS, where the radiating element was a circular microstrip patch etched on a commercial PTFE substrate and fed by a standard SMA probe as shown in Fig. 1. DGS can also be used for the reduction of Cross-Polarization as stated in [44]. Ring shaped DGS was explored to reduce mutual coupling between two circular microstrip patches. About 4 dB reduction achieved in [45]. A 2 × 2 DGS integrated array had been designed in X band having 12 dB improvement in isolation between the co-pol and cross-pol radiation as stated in [46]. DGS can be symmetric or non-symmetric pattern on ground plane. The DGS will increase the electrical path of current and hence the bandwidth of an antenna will get increased.

## IV. COMPLIMENTARY SPLIT RING RESONATOR

A new concept has been evolved named as a Complimentary Split Ring Resonator (CSRR). The two concentric open circular rings etched on ground plane. CSRR structure behaves like a metamaterial which had negative permeability and permittivity which results in a negative reflective index. So that transmitted wave could not pass into the structure. It gets reflected back from the structure. So the electrical path will get increased. This magnetic property was briefly explained in [47-49]. A new method for suppressing surface waves on a microstrip antenna array at millimetre-wave frequency is presented and how multiple CSRR improves the results like gain and reduction in side lobe level for W-band radar application was discussed in [50]. Fig.1 shows the 10 × 2 antenna array with CSRR inclusion into the ground plane.

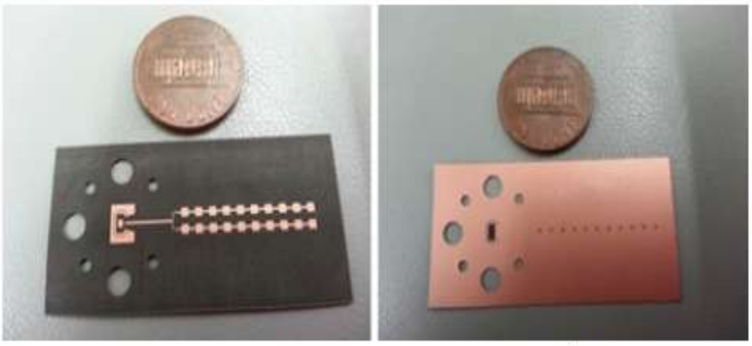

**Figure1.** Fabricated antenna with CSRR [50]

## V. FREQUENCY SELECTIVE SURFACE

Frequency Selective Surface (FSS) are the resonant structures having either stop band or pass band performance, due to which they were widely used as radomes and electromagnetic absorbers. FSS were also used in cavity resonant antenna to enhance the gain of the antenna. Many configuration of FSS structures are proposed to enhance the gain [51][52]. Directivity enhancement FSS are also discussed in [53].

In Phased Array Antenna, research had been carried out to decrease the value of side lobe level. It must be less than -13.5 dB. If the side lobes are higher, then it is difficult to identify the target. The possibilities of false target detection are increased in this case. David M. Pozar is the key person in the fraternity of antenna and side lobe level reduction of phased array antenna. In [54] he had focused on the factors affecting the realizable SLL performance of microstrip array. These include mutual coupling, diffraction effects, excitation amplitude, positioning error, phase accuracies, imperfect element matching and network isolation. A high gain of 20.8 dBi, millimeter wave printed antenna array have been designed with high SLL suppression in [55]. Algorithms were also designed for the reduction of SLL. Various algorithms were implemented like Fast algorithm [56], Genetic algorithm to optimize lowest SLL of the linear array by optimizing the on and off positions of antenna element of the array [57]. A small slotted waveguide with hamming amplitude distribution had been developed in [58].

In Phased Array Radar systems, enhanced gain antennas have been preferred. For the enhancement of gain, the antenna elements were increased. So that gain can be improved at the most. A novel engineered magnetic superstrate design presented in [59] to enhance gain and efficiency. The modified split ring resonator was designed to have positive values for the effective permeability and permittivity at the resonance frequency. MSRR consists of two parallel broken square rings. The superstrate used here consists of three layers of printed magnetic inclusion. These layers were separated by 2mm air layer. The engineered material were composed of MSRR inclusion will experience anisotropic permeability of $\mu=\mu_o \mu_{reff}$.. The metamaterial superstrate will experience permittivity of $\varepsilon=\varepsilon_o\varepsilon_{reff}$ . The artificial magnetic material structures were results in an enhancement of both permeability and permittivity. Instead of increasing the antenna size, author had increased the panel size of antenna for the improvement of gain.

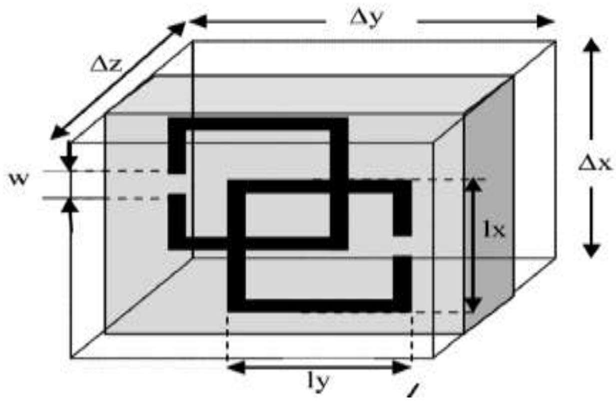


Fig. 2. Geometry of a patch antenna covered by an engineered magnetic superstrate [59]

Pratigya Mathur had initially designed 7 elements series antenna array with 151 dBi gain at 5.79GHz frequency. The author had also explained the designed challenges of limited gain and how phase between the array overcome the challenges is also highlighted in their work. They had designed a 23 elements patch array antenna at Ka band. With increase in number of elements, the gain increased rapidly till 17 elements and then slowly it started getting saturated. It is due to far off elements from the center patch received less power and contributed less to the gain of the array. In The author has concluded that with change in frequency, phase error increases progressively towards far off patches. Radiation pattern is asymmetrical due to the asymmetry in design introduced by stub matching on one side of the patch. At Ka band gain was 19 dBi and for C band it was 15.1 dBi [60].

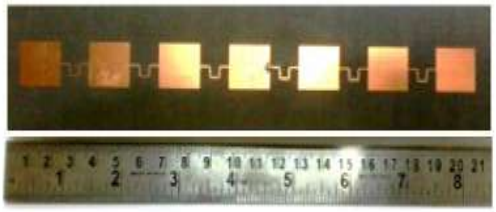

Fig. 3. 7 element Fabricated series antenna array [60]

Planar periodic metallic arrays behave as an artificial magnetic conductor surfaces when placed on a grounded dielectric substrate and they introduce a zero degrees reflection phase shift to incident waves. The bandwidth and centre frequency of AMC surfaces were investigated using full wave analysis and qualitative predictions of the ray model are validated in [61]. It has been observed that in series feed array, feeding is applied at a single element. There are various advantages of this type of array like simple design, beam steering capability and low radiation losses as compared to corporate feed network. In center feed series fed has the advantage of beam remains in broadside direction. For center fed, probe feeding technique is preferred. It has been observed that after 23 elements, the gain does not increase further as only small power reaches the end patches and phase error accumulates.

## VI. CONCLUSION

We can conclude that the research in the field of radar was greatly increased from World War II. These antennas were large in size and they need to get installed properly because of their large size. Phased array antennas using printed sheets were came into picture. It was very essential to control the beam steering of the antenna array. And by controlling the amplitude excitation of the elements in an antenna array, an efficient null broadening was achieved. Peoples prefer a slot into the design for higher bandwidth requirements. The slot microstrip antenna was used as a folded slot dipole. DGS has been extensively used by many authors for the improvement of bandwidth. DGS is an etched periodic or non periodic structure in ground plane. A new concept has been evolved named as a Complimentary Split Ring Resonator (CSRR). The two concentric open circular rings etched on ground plane. CSRR improves the gain of an antenna. Frequency Selective Surface (FSS) are the resonant structures having either stop band or pass band performance, due to which they were widely used as radomes and electromagnetic absorbers.

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