ANTENNAS FOR RADAR APPLICATIONS: A REVIEW

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Abstract—This paper gives a review of design of various antennas for Radar applications. Micro-electromechanical (MEMS) antenna, Dielectric resonator antennas, Planar Yagi-Uda antenna, rectangular waveguide aperture, multifunctional phased array and sinuous antenna are used for Radar application. The design parameters and methodology of these antennas are described. These ultra wideband antennas are key element for radar system.

Keywords—Antennas, Radar, Ultra wideband

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I. REVIEW OF ANTENNA FOR RADAR APPLICATION

Micro-electromechanical systems (MEMS) switch-reconfigurable antenna array element has been designed for space-based radar. The basic structure of the antenna comprises a balanced bowtie antenna with a mixed dielectric substrate composed of polymer material and foam. Provides flexible substrate with minimum number of switches, provides operation over several bands, wide range of polarizations, multiple or scanned beams. The impedance bandwidths of elements are approximately around 25% and supports scanning to 45 degrees for radiation pattern of elements [1].value used are in Table.1.

TABLE I. ANTENNA DIMENSIONS

Frequency band	Bowtie base	Bowtie height	Polymer width	Foam width
Lower band (2.7-3.5 GHz)	55mm	66mm	8.25 mm	2.75 mm
Upper band (7-9 GHz)	20mm	24mm	3.75mm	0.75mm

In order to detect small targets in bestrewed surroundings and eliminate various interferences, active array radar with digital beamforming architecture is suitable. This comes with improved time-energy management and economical expenditure. The DBF radar system comes with good signal to clutter ratio and fast adaptive-nulling performance, which makes them an ideal choice for shipboard radar systems with similar environmental conditions as there is increase in commercial technologies, jammers, and bestrew [2].

Dielectric resonator antennas are compact and have 24% to 50% bandwidth. Efficiency of radiation is more than 98%. Certainly better than microstrip antenna, and has huge power capabilities, no dissipation losses and minimal radiation Q-factor. Could be used in mobile communication and for various radar applications [3].Refer Table.2.

TABLE II. VARIATION OF GAIN WITH ARRAY ELEMENTS

Count of array elements	2	4	8	16
Gain(dB)	7.8	10.6	13.6	16.6

For detecting underground objects like crude oil, resources, pipes, fossils, ground penetrating radar systems are appropriate. Finite-difference time-domain simulation done on bowtie antenna with resistor-loaded on ground penetrating implementations show that corners are the ideal place for end resistors since the current is intensive there, clutter can be minimized by substantially increasing flare angle, broadband of antenna could be improved by shortening its length and for targets near surface short antennas were beneficial [4].

In modern automotive radar systems because of design flexibility and control over radar beams planar array antennas are suitable, it operates in frequency range of 76-77 GHz for frequency modulated continuous wave, 77-81 GHz covers a small radar range. RF microelectromechanical systems are used because they are economical to manufacture and have outstanding RF properties. Functional RF-MEMS can be exhibited in glass-frit and BCB polymer sealing. The glass-frit is excellent for micromechanical sensors with reliability and hermeticity. BCB polymer sealing has magnificent dielectric properties and in sealing temperature nearly 250 degree Celsius [5].

The presence of water film on the surface of an antenna lens or its radome results in degraded performance of radar, this mainly happens in rainy and snowy conditions. Fresnel formula for reflection and transmission is used to calculate losses. Reflected signal from water layer at higher frequencies is recognizable by radar principle which could be utilized in advanced automotive radar systems. Hence emergence of water layer has to be put down with proper antenna lens and efficient radome design [6].Refer Table.3.

TABLE III. BEAMWIDTH OF THE PATTERN

Beam width		frequency
azimuthal	elevation	22.5 MHz to 90 GHz
13.2 deg	20.4 deg	

In order to track insect movement Harmonic radar systems are suitable, insects like locusts cause huge crop damage which can be minimized with the help of harmonic radar operating on small radio frequency tags implanted on insects. It is portable, small, low powered, and with a range of 58 m, operates at 5.9-6/11.8-12 GHz, dimension of prototype is 9.5 mm by 9.5 mm and has low output power of 0.2 W, employs transmit and receive antenna of 21 dBi [7].

For millimeter-wave and microwave applications planar Yagi-Uda antennas are an appropriate choice due to their small cross polarization, high gain, and economical, high radiation efficiency. Yagi-Uda antenna fed with microstrip fabricated on Teflon substrate for high efficiency., gain of 9-13 dB at 23-27 GHz with 16dB cross polarization for a 7-element design. Provides high radiation efficiency greater than 90% which is appropriate for high data rate communication and mm-wave radar [8].

An efficient and economical planar antenna array for 60 GHz band derived on substrate integrated waveguide scheme, developed on standard dielectric substrate comprises of 50 Ω CBCPW and SIW having 12-way power divider, 12 radiating SIW. Substrate thickness of 20 mils produces gain of 21 dBi with 25 dB side lobe, side lobe suppression in magnetizing field and 16 dB in electric field, having a bandwidth of 2.5 GHz for 10 dB return loss, has good side lobe size and satisfactory efficiency which makes it capable for economical 60 GHz application [9].

A multifunctional phased array weather radar application is introduced. S-band (3-3.5 GHz), stacked patch antenna has substantially high port isolation (>39 dB) and likewise a suitable cross-polarization characteristics and high efficiency are added. The application has limitations, used in polarime-tric weather radar evaluation which was not corrected by calibration of antenna array polarization errors. It is confirmed that this has a fairly good polarimetric performance over an extensive scan range with no extreme calibration needs [10].

An update on ultra-wideband (UWB) antennas derived from rectangular waveguide aperture antennas was proposed by Elsherbini, A., & Sarabandi, K. (2012). Traditional rectangular aperture antennas were restricted by the few modes more precisely a single mode operation of the waveguide. To rise above these limitations, there was development in a new rectangular waveguide antenna. In general antenna sizes were $0.55\ \lambda_m \times 0.27\lambda_m \times 0.18\ \lambda_m$ where λ_m is wavelength corresponding to the minimum operating frequency. To establish satisfactory cross polarization a polarizer can be included. Their feed was written with a balun structure. A typical balun design structure would interact with the antenna hence an improved design was accomplished. The antenna was fictitious and conducted an experiment with VSWR 2.6 from 1.07 to 4.8 GHz and gain which rises from 5.4 dBi at the low frequency to 12 dBi at the high frequency [11]. Refer Table.4.

A study of compact monopole aperture with CPW-fed antenna having 11dB return loss (VSWR<;3) band from 7 GHz to 13GHz for applications of X-band was done by Amit Kumar Tripathi & B. K. Singh (2013).Ground plane, a crossed rectangular exciting stub and rectangular slot of antenna were included. This antenna is very effortless and uncomplicated to construct. This was an economical FR4_Epoxy substrate with dielectric constant of ε_r =4.5 and having the size of 30mm×25mm×1.5mm. The parameters such as bandwidth return loss, radiation pattern, and gain were obtained. All validate the adequate antenna quality. Simulation tool was used to understand the antenna which was based on the set number of element methods (HFSS V 13.0) .With an efficiency of about 97% antenna is suitable for radar and satellite communication systems. [12].

For multiband radar applications a compact Yagi-Uda antenna was used. It works in various frequency bands, specifically 1.9, 2.5, and 3.5 GHz. Based on traditional dipole scheme having embedded L-shaped slot lines drivers were obtained. And to get better results for good directivity, directors and reflector were used. Calculated operating frequencies are 1.89, 2.54, and 3.51 GHz, and the resultant gains of antenna were 6.29, 4.63, and 6.77 dBi, correspondingly. In making the design for radar applications the calculated front-to-back ratios were superior than 10.7 dB [13].

Modification of the sinuous antenna took place to upgrade its performance for ultrawideband (UWB) radar applications. When sinuous antennas get excited by a short pulse, the waveform experiences a long ring tail just before CHRIP like the main pulse. The ringing is because of resonances that took place on the antenna arms and they are removed by modifying arm design. The first adjustment at arm takes out the sharp edge, and the arm bends in the second adjustment which results in shape change. Improvement of the gain flatness of the antennas takes place [14].

For a 77 GHz automotive radar application a flat-radiation patten in shoulder shape was developed. It was believed that this can bring revolution in the automotive industry as it can deal with long and medium range detections without necessarily switching the operation frequently. To get the expected flat-radiation patten in shoulder shape, an unusual array was synthesized. Sample of the array antenna used had a number of linear series-fed patch arrays and a network of substrate-integrated waveguide power and phase distributing. Measured and experimented data showed good simulation results, thereby justifying the [15].

The substrate-integrated waveguide (SIW) antenna has a two-layer structure consisting of a metallic plate with fold into ridges and troughs on the top most layer and also having an FR-4 substrate SIW on the bottom most layer. Dimensions of antenna are 63 mm x 54 mm having a 7mm low profile. A prototype analysis was performed to understand two port SIW antennas. The antenna fits in a -10 dB reflection coefficient from 10.16 to 11.57 GHz. The distance among the two central slots is 4 mm. To enhance the gain electromagnetic energy having zero phase difference were superpositioned. The measured and resultant calculations for the proposed antenna are satisfactory [16].

With polarized diversity, ultrawide (UWB) radiation can be produced by Sinuous antennas. Sinuous antenna is of the antenna used for ultra-wide polarimetric radar use scenarios. Moreover, sinuous antenna is appropriate for close-in sensing use scenarios like ground penetrating radar. In recent studies its depicted that sinuous antennas have resonances issues, which lower the performance. Due to this resonance, late time ringing is produced, which is mostly disturbing for close-in pulsed sensing use scenarios. The resonances happen in two forms first one being happening on arms, log-periodic resonances, and other is resonance caused by the sharp ends left by the outer truncation. A deep study has shown that this resonance can be minimized by selecting suitable design parameters. Truncation technique is used for eliminating sharp end resonance [17].

In the applications of near zone impulse radar applications a broadband enveloped bowtie comprising of resistively loaded antenna (WBRLA) was fabricated. To know the antenna parameters, the figure of merit (FOM) is used to calculate the pulse radiating performance. A 5 mm interval of six resistors on the radiator are used on the reference of the FOM for a newly fabricated WBRLA. Having the inclusion factor of 0.6 loaded case, with respect to an absorbing potential at lower frequency 900 MHz to 4 GHz, has shown satisfactory results, satisfactory fidelity factor, and improved late-time ringing. Values used in the simple radar imaging experiment are in table.4. are very satisfactory [18]. Refer table.5.

CONCLUSION

This paper studies the design of various antennas used for Radar system. The radar system requires an antenna which produced ultra wideband radiation. Various ultra wideband antennas have been discussed. These antennas play a vital role in the Radar system. Combination of these methods will be implemented in the future work.

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TABLE IV. BALUN DIMENSIONS OF THE PROPOSED ANTENNA

BALUN DIMENSIONS	l_{feed}	$W_{ms(start)}$	$W_{ms(end)}$	$W_{g(start)}$	d_w
Value	250mm	1.9mm	1mm	15mm	18mm

TABLE V. PARAMETER VARIATION WITH NUMBER OF SLOTS

Number of Slots	Non-loaded	1	2	3	4	5	6	7
Continuous Resistance per Slot, Ω		500	25,475	12,45,443	7,22,60,411	5,14,30,70,381	4,10,19,36,78,353	3,7,13,23,41,84,329
E_{ref} / E_{inc}	0.66	0.60	0.31	0.23	0.20	0.18	0.16	0.16
E_{main} / $E_{ringing}$	6.15	9.48	12.66	30.23	81.59	75.50	78.36	74.57
Figure of Merit	9	16	41	131	408	419	490	466
Fidelity Factor	0.81	0.86	0.89	0.88	0.92	0.91	0.92	0.92