Parasitic Array Antenna for 5G Networks and IoT

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Abstract

This paper includes design and implementation result of an adaptive beam forming antenna for upcoming 5G and Internet of Things (IoT). Switched parasitic array antennas are low cost, small sized and compact circular array antennas that steer beam in a desired direction by variation in switching pattern of parasitic elements. The proposed antenna design has an active center element, which is surrounded by several symmetrically placed parasitic elements. The designed antenna has a gain of 8 dB and is capable of 360 degrees beam steering in steps of 60 degrees each. Simulations are validated with results of the fabricated antenna. Antenna beam is steered by controlling parasitic elements. Future application of Electronically Steerable Parasitic Array Radiator (ESPAR) antennas and switched parasitic array antennas in next generation communication networks and methods for reducing size of the antenna are also highlighted

Keywords:
Internet of Things, 5G, circular array, reconfigurable, smart antenna, adaptive beamforming, Switched Parasitic Array.

1. Introduction:

Recent wireless communication services have been pursued with regard to high speed, real time, and massive connections. These requirements are focusing on the fifth-generation (5G) mobile standard including IoT connectivity services, which is expected to be commercially established in 2019 through the 3GPP LTE release. To increase communication efficiency, adaptive beamforming becomes an important issue in 5G technologies. The beamforming techniques have been developed toward compact and simple architectures such as conventional analog/hybrid/digital beamforming's, retro directive arrays, smart antennas, reconfigurable patterns, and Electrically Steerable Parasitic Array Radiator (ESPAR) antennas. The ESPAR antenna has switchable beams with orthogonal four directions. It consists of one active element antenna at the center and its surrounding parasitic element antennas with adjustable reactance loads for each beam direction. The parasitic element has been designed with various parasitic structures, such as monopoles, dipoles, and patch antennas. However, due to the three-dimensional form factor, the conventional ESPAR antenna cannot be integrated with other planar circuits. Moreover, as it has only one parasitic element for each direction, its directivity and beam width are limited and uncontrollable. The additional parasitic element can increase the antenna gain and front-to-back (F/B) ratio.
Electronically Steerable Parasitic Array Radiator (ESPAR) antennas use mutual coupling between antenna elements to steer the beams instead of phase shifters. Design of parasitic array radiator antennas is discussed in which there a center active element is surrounded by a circular array of passive elements, where each passive element is loaded with a specific reactance. ESPAR antennas are smaller in size as compared to phase array antennas because elements have to be placed at a quarter of wavelength or less distance from each other for effective mutual coupling. Hence, ESPAR antennas are cost effective and space efficient. In such antennas we have only one active element, therefore, only one feed is required. Consequently, ESPAR antennas have lower losses (due to single feed) as compared to phase array antennas. Previously designed antenna Electronically Steerable Parasitic Raidator (ESPAR) antennas have all cylindrical element, including the feed element. In this paper

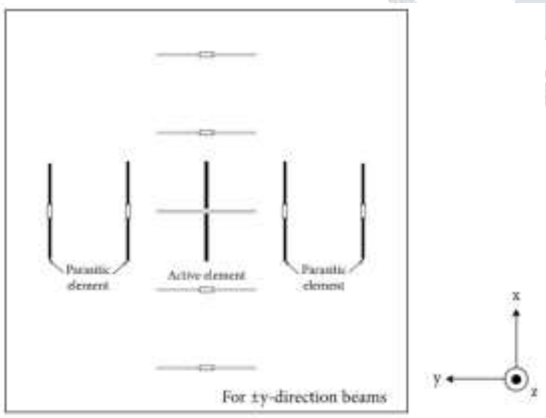
we have proposed design of seven element ESPAR antenna with conical center (active element) 1.Length of conical element is optimized using optimetrics in HFSS. Our proposed antenna has higher bandwidth as compared to previously designed ESPAR antennas. In multiple-input-multiple-output (MIMO).

In this project we are using HFSS software is a 3D electromagnetic (EM) simulation software for designing and simulating, high-speed electronics found in communications systems, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IoT) products.

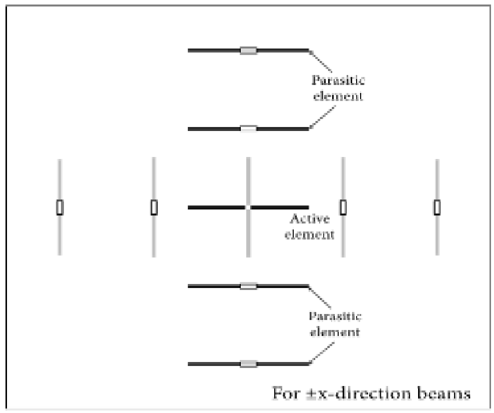
2. LITERATURE SURVEY:

2.1 Planar ESPAR Antenna System Design:

In this section, a planar ESPAR antenna system is designed with the Yagi-Uda array design method and its operating schemes are described. Figure 1 shows the top views of the proposed planar ESPAR antenna. It consists of two active element antennas with crossed dipole shapes and four two-stage parasitic element antennas parallel to each active dipole element. Figure 1(a) presents the operating status for the excitation to the y-directional beams, while the x-directional beams can be generated by solely feeding the horizontal active element as shown in Figure 1(b). As the excited active element antennas are cross-arranged with each other, the antenna system operates one by one. To shape the orthogonal beams, the two active dipoles require high isolation.



(a)



(b)

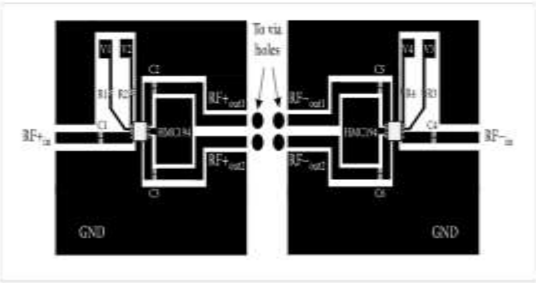
The Yagi-Uda array antenna was developed by Uda and Yagi in 1926 and 1928, respectively. The Yagi-Uda antenna consists of several linear dipole elements. Whereas only one dipole is excited from an RF source called a driven element (active element), the other ones called directors or reflectors (parasitic elements) in which microwave currents are induced by mutual coupling. As the Yagi-Uda antenna is designed to act as a longitudinal array, the parasitic elements located in a beam direction act as directors and those in the opposite side as reflectors. Since the quasi-Yagi antenna was introduced in, various planar architectures based on the Yagi-Uda theory have been developed with higher directivity and small form factor. A planar single quasi-Yagi antenna with V-shaped electronically controlled directors has shown to be a flexible antenna design due to the electronic control. Furthermore, microstrip patch arrays based on the Yagi-Uda theory were researched with the antenna frequency and circular polarization switching. In this paper, a beam-switchable planar dipole array based on the Yagi-Uda methodology is presented.

2.2. Planar beam steerable antenna system:

In this section, the proposed planar beam steerable antenna system is implemented and evaluated for beam steering performance. The antenna system is fabricated on two FR4 substrates with a dielectric constant of 4.4 and a thickness of 1 mm for the antenna system and SPTD switching circuit boards. The antenna system board is implemented with a size of 189.8*189.8*1.0 mm^3, and each SPDT board has a dimension of 44.5*37.57*1.0 mm^3.

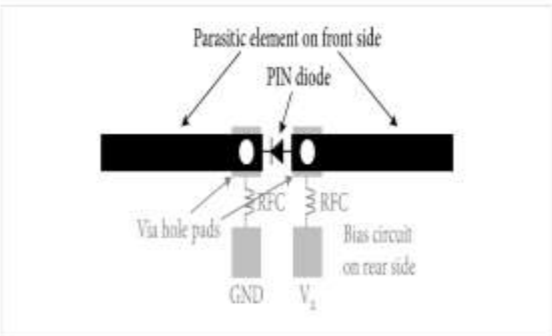
2.3 Active Element Antennas:

The active element antennas are fed through via holes from the rear side of the antenna board. The feedline is connected to the SPTD switching board. As the active dipole element antenna is fed with balanced signals, each RF(+) and RF(-) signal is provided. The HMC194MS8 CMOS diode (Hittite Microwave Corporation Ltd.) is controlled by switching voltages of V1 and V2 to switch the signal into the RF_{out1} or RF_{out2}. The selected RF signal is connected to the center feeding points of the active dipole antenna on the front side. Figure 6 presents the circuit layout of the SPDT switching board. The crossed dipole requires high isolation to generate orthogonal beam patterns and a relatively low cross polarization level. The measured isolation presented high isolation of more than 35 dB.



2.4 Parasitic Element Antenna:

The parasitic element antenna is implemented with a reconfigurable reactance. The implemented layout for the parasitic element antenna is shown in Figure 8. The reactance is adjusted by a PIN diode (BAR 64-02V, Infineon Technologies Ltd.). It is biased from a rear-side bias circuit shown in gray color. The diode is mounted at the center of the dipole where the via hole is connected from back to front. To block the RF signal leakage, an RF choke is mounted between the via hole and a bias line. When the bias voltage of about +1 V is provided, the reactive diode operates at a reactance of 1.5 pF and the parasitic element antenna plays the role of a director. While the diode is off, it has a large capacitance of 0.1 μF for a reflector. Because the PIN diode mounted between planar monopoles does not operate on a microstrip environment without a ground plane, the deembedded calibration method is used for the extraction. The forward resistance of PIN diodes results in antenna gain degradation.



3. Parasitic Array Antenna Design:

Design parameters and mechanical design of antenna is included in this section.

TABLE I
DESIGN PARAMETERS

Parameters	Values
Ground Skirt length	lambda/4
Monopole Length	lambda/4
Frequency	2.45 GHz
Ground Radius	lambda/2
Monopole Radius	lambda/200
Ground Thickness	3 mm

A. Design Parameters Antenna design parameters are tabulated and the results are optimized using antenna simulation tools. Ground is skirted, since skirted ground provides mechanically sound model for PCB assembly to mount at back of antenna. Skirt is $\lambda/4$ in length similarly each monopole element is lambda/4 in length and $\lambda/200$ is its radius. Table I shows the design parameters for the seven-element switched parasitic array antenna.

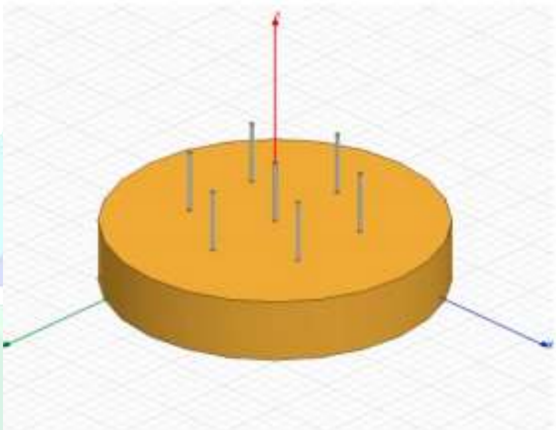


Fig. Simulated antenna model.

4 ANTENNA SIMULATION AND PLOTS

HFSS is a commercial finite element method solver for electromagnetic structures from Ansys .The acronym originally stood for high frequency structural simulator .It is one of several commercial tools used for antenna design , and the design of complex RF electronic circuit elements including filters, transmission lines and packaging. HFSS is a high performance full wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy to learn environment where solutions to your 3D EM problems are quickly and accurate obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields.

In simulation each of the parasitic element is loaded with lumped port excitation, simulating opening and shorting of monopole elements. Show in below.

TABLE II
MAXIMA PATTERN

Azimuth Angle	Element 1	Element 2	Element 3	Element 4	Element 5	Element 6
0 degree	Open	Short	Short	Short	Short	Short
30 degree	Open	Open	Short	Short	Short	Short

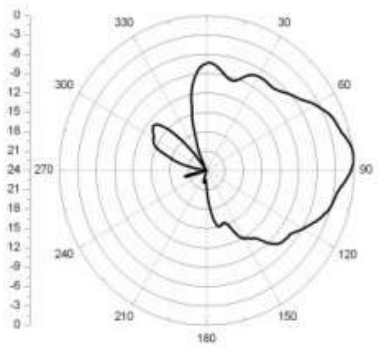


Fig. Anechoic chamber results for θ=900 (Beam in elevated because we are using monopole elements with finite ground).

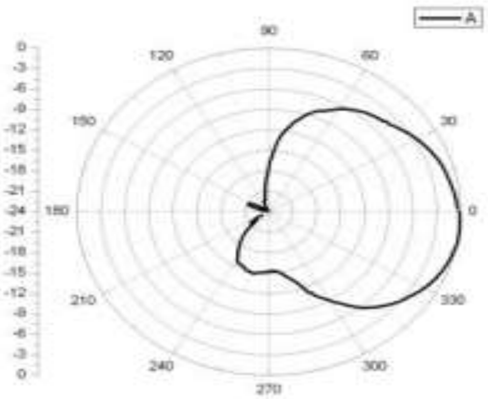


Fig. Anechoic chamber results for φ=0

Two dimension polar plots depicts the beam steering in the direction of given elevation angle, theta (θ) and azimuth angle, phi (φ). Anechoic chamber results for θ=90 and φ=0 and 30 degrees are shown in Fig. 7 and 8 respectively

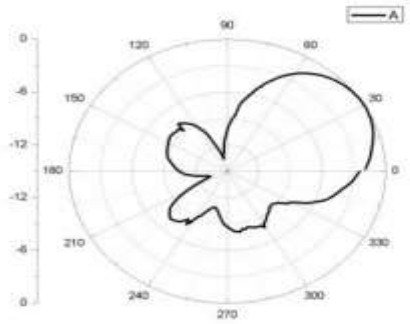


Fig. Anechoic chamber results for φ=30^{O} .

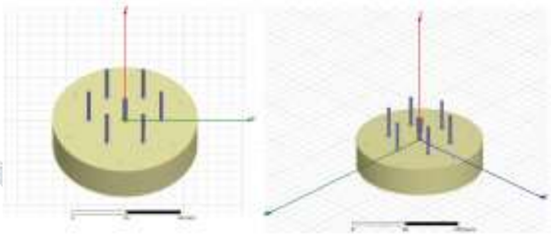


Fig. (a) Conventional ESPAR antenna model with cylindrical Center Element, Fig. 9 (b) Designed ESPAR antenna with conical element for Bandwidth Enhancement.

5. FUTURE WORK AND CONCLUSION:

5G networks will be designed for device to device, device to human and human to human interactions. High data rates are required to meet demands of 5G systems. One of proposed bands for 5G is in mm-Waves range i.e from 30GHz to 60GHz for such high frequencies path losses are considerable and beam steering antennas are way forward to overcome path.

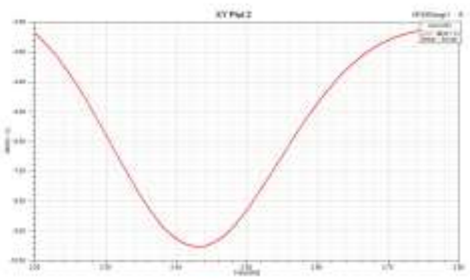


Fig: S11 plot for conventional switched array antenna.

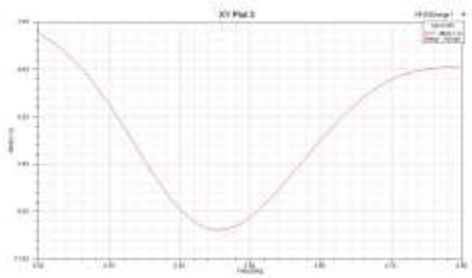


Fig: S11 plot for center conical element switched array antenna.

ESPAR and switched parasitic array antennas provide a cost effective way of incorporating adaptive beamforming in future 5G and internet of Things (IoT) devices. However for the efficient use of ESPAR antennas in mobile terminals the size of the antenna system must be reduced, for this further research on dielectric switched parasitic array antennas is underway. Seven element switched parasitic array antenna is designed that is capable of dynamic beam steering. Gain of 8dB is achieved practically. Simulated results are in line with the anechoic chamber results. Designed antenna increase the channel capacity by improving signal to noise ratio. Gain of 8dB was achieved in specified directions of elevation angle, theta (θ) and azimuth angle, phi (φ). Antenna is optimized in terms of interference reduction for its use in wireless ad hoc networks, operating at frequency of 2.45 GHz. Bandwidth of designed antenna is 450 MHz and beam is steered in 3600

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