Effect of Reflector on The Performance of Yagi Patch Antenna at S Band

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Abstract— This paper presents the design and simulation of a microstrip Yagi array antenna operating at 2.8GHz, to be used in Doppler RADAR for vehicle speed measurement and material detection. This paper presents a Microstrip Yagi antenna with very good performance at 2.8GHz frequency. The advantage of the antenna is it can achieve a high gain. The front-to-back ratio of the Yagi array is higher.The antenna array has a low profile and provides a high gain and quite large beamwidth so more targets in desired range can be detected. In this paper effect of reflector on yagi antenna is studied. The designed antenna with Coaxial feeding is simulated using Advanced Design System(ADS) tool.

Key words: Microstrip antenna, yagi patch antenna, Returnloss, Gain, ADS

I. INTRODUCTION

In today's modern communication industry, antennas are the most important components required to create a communication link. For all practical wireless applications, miniaturization of antenna has become important. Microstrip antennas are the most suited for aerospace and mobile applications because of their low profile, light weight and low power handling capacity .There are number of parameter associated with microstrip antenna such as gain, return loss ,bandwidth, beamwidth.For the better performance, all these parameters need to be optimized.

A new kind of Yagi array of microstrip patch antennas is presented. The Yagi antenna array has a low profile and provides a high gain and large beam width. With Yagi patch array the magnitude of coupling between nearest neighbor element is much greater compared with dipole yagi. So it is better as compared to yagi as far as performance is concerned.

The term "RADAR" is the abbreviation for Radio Detection and Ranging, defined as the art of detecting the presence of target, determining their direction and range, recognizing their character by means of radio waves. The principle involved in the atmospheric Radar is to transmit the modulated waveform of electromagnetic energy using antenna array into the atmosphere and processing the backscattered echoes through suitable means by utilizing a chain of signal processors to determine vertical wind components with a high degree of temporal and spatial resolutions and other vital parameters required for studying the structures and dynamics of atmosphere.In S band RADAR is mostly used for atmospheric RADAR.

However, microstrip antennas have some drawbacks including narrow bandwidth, low power handling capability and low gain. But with technology advancement and extensive research into this area these problems are being gradually overcome. Such types of yagi array configuration is mostly used in RADAR due to its directional characteristics.

II. MICROSTRIP YAGI PATCH ANTENNA

The microstrip Yagi is proven to provide a relatively directive gain and reasonable beam width that would satisfy the requirements of the system. In Microstrip yagi patch antenna consists of several patches with proper separation. Yagi patch antenna is used mostly for its highly directional property. In essence, there are two types of antenna elements: driven and parasitic (non-driven). Driven element is directly connected to the transmission line and receives power from or is driven by the source. Whereby parasitic elements are not connected to the transmission line; they receive energy only through mutual induction with a driven element or another parasitic element. A parasitic element that is longer than the driven element from which it receives energy is called a reflector.

A reflector affects the signal strength by reducing in its direction but increases it in the opposite direction. Hence, it acts as if it were a concave mirror. A parasitic element that is shorter than its associated driven element is called director. A director usually is added to increases field strength in its direction and reduces it in the opposite direction. Therefore, it acts as if it were a convergent convex lens. In the microstrip antenna, parasitic elements can be placed around a driven element in order to enhance the gain of the single driven element by several decibels. In a conventional Yagi-Uda dipole array, the driven designs element is responsible for coupling of electromagnetic energy through space into the parasitic dipoles to obtain a directional beam.

In microstrip Yagi array electromagnetic energy is coupled from the driven patch to the parasitic patches through both space and surface waves in the substrate.Reflector affects greatly on the performance of the yagi antenna. Following figure shows Microstrip yagi patch array.

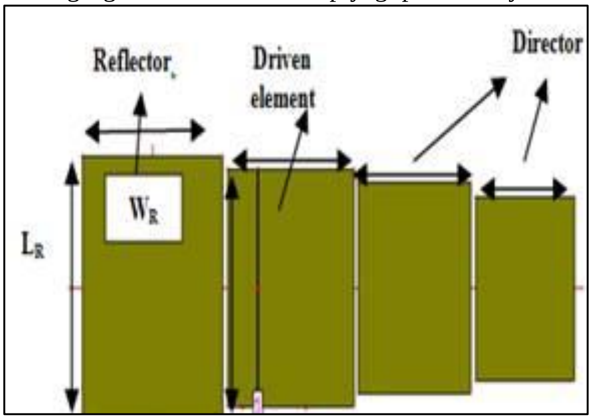

Fig. 1: Microstrip Yagi patch antenna

III. PRINCIPLE OF YAGI PATCH ANTENNA

The microstrip Yagi antenna, as shown in Figure 1, consists of a driven patch element and a few parasitically coupled reflector and director patch elements. It utilizes a similar principle as a conventional Yagi-Uda dipole array where the electromagnetic energy is coupled from the driven element dipole through space into the parasitic dipoles and then reradiated to form a directional beam. In a microstrip Yagi array, however, the electromagnetic energy is coupled from the driven patch to the parasitic patches not only through space but also by surface waves in the substrate. Because a dipole radiates RF power equally around its axis, it can couple relatively strong power to its neighbors.

One other important factor that also determines the pattern shape and beam direction is the sizes of the parasitic reflector and director patches. When the size of the parasitic patch is different from the resonant dimension of the driven element, a reactance component is added to its radiation impedance at the resonant frequency of the driven element. This reactance introduces an added phase component to its radiation field. It is this phase, together with the separation delay phase (phase velocity of the surface wave) between patches, that contributes to the microstrip Yagi array's beam tilt from its broadside direction. Since the microstrip antenna always requires a ground plane and its radiation is primarily in the patch's broadside direction. Thus Microstrip yagi provides better radiation characteristics as compared to yagi uda dipole antenna. Because of the size of the microstrip patches, the microstrip Yagi array has a few limitations in design not present for the dipole Yagi arrays.

IV. DESIGN PROCEDURE

The first step is to calculate dimension parameters of driven patch, which are defined as follows:

Following equations are used for designing Yagi patch antenna.

A. *Driven Patch Dimensions:*

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+12\frac{h}{w}\right]^{-1/2}$$

εr_{eff} = Effective dielectric constant
ε_r = Dielectric constant of substrate
h= Height of substrate, W=width of substrate
Length is given by;

$$\Delta L = 0.412h\,\frac{(\varepsilon reff+0.3)(\frac{w}{h}+0.264)}{(\varepsilon reff-0.258)(\frac{w}{h}+0.8)}$$

The effective length of the patch Leff now becomes;

$$Leff = \frac{c}{2f0\sqrt{\varepsilon reff}}$$

For a given resonant frequency fo , the effective length is given by ;

$$Leff = L + 2\Delta L.$$

Width can be calculated as follows:

$$W = \frac{c}{2f0\sqrt{\frac{\varepsilon r+1}{2}}}.$$

V. EFFECT OF REFLECTOR IN YAGI PATCH

The analysis of the microstrip Yagi antenna is carried out using the commercially available ADS tool. Advanced Design System (ADS) is an electronic design automation software system produced by Keysight EEsof EDA, a division of Keysight Technologies. The leading electronic design automation software for RF, microwave and signal integrity applications, ADS pioneers the most innovative and commercially successful technologies, such as S-parameters and 3-D electromagnetic simulators. It provides an integrated design environment to designers of RF electronic products such as pagers, mobile phone,wireless networks, satellite communications, radar systems, and high-speed data links.Dimensions of yagi antenna is given in table 1.

Patch antenna working on 2.8 Ghz frequency is shown in Figure 2.

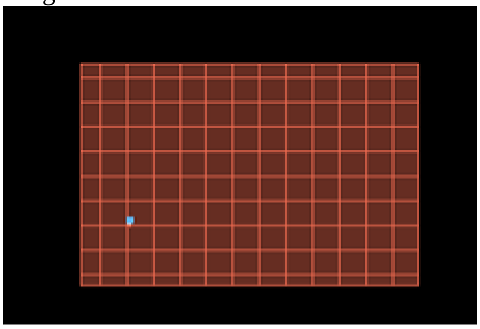

Fig. 2: Schematic of Driven patch in ADS

From Figure 3 we can see that return loss is about 15dB and gain and directivity is about 1 dB and 6 dB respectively.

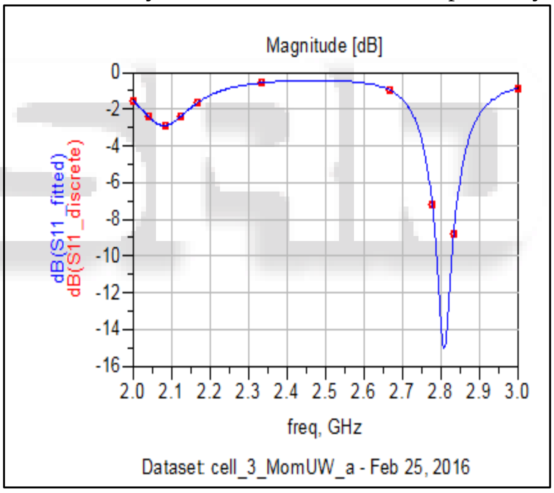

Fig. 3: Graph of Return loss of patch

To enhance the performance, Reflector is added with Driven element with different spacing. Simulated data is shown in table 2.

Fig. 4: Antenna parameters

VI. RESULTS AND DISCUSSIONS

The design process is carried out using ADS software, aiming return loss better than 10 dB and frequency at 2.8 GHz band for RADAR application. The reflector dimensions and spacing were optimized to achieve maximum gain and return loss. It can be observed that reflector spacing is 0.3 λ.

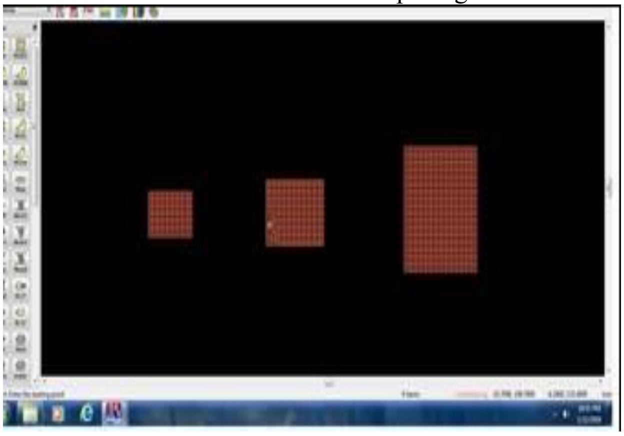

Fig. 5: Schematic of Yagi Patch Antenna

Proposed design is shown in Figure5. And simulated results are shown in Figure6.

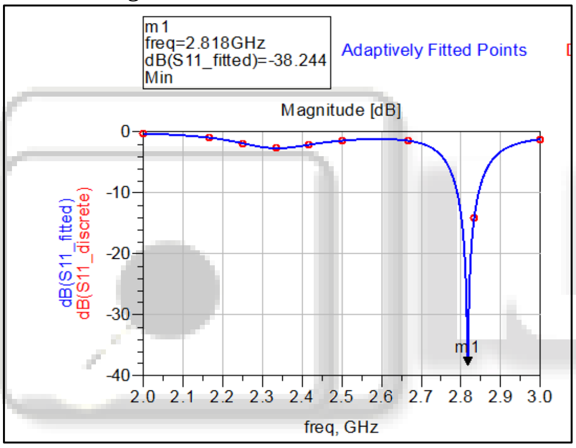

Fig. 6: Graph of Return loss of RSeflector schematic

Length of the Driven element	32.9 mm
Width of the Driven element	41.08mm
Length of the Reflector	62.02mm
Width of the Reflector	58.83mm
Length of the Director	22.7mm
Width of the Director	30.82mm
Dielectric constant (FR-4)	εr= 2.4

Table 1: Details of elements dimension in yagi antenna

Figure 7 shows 3D radiation pattern of Yagi antenna with one reflector element. It is in endfire direction. From table 2 it can be concluded that Reflector has great impact on return loss. It can improve return loss upto -31 dB. It also affect gain and directivity of single driven element. Different reflector to driven element spacing also improve the antenna characteristics. From table 2 , it can be seen that 0.30λ spacing gives better return loss as well as efficiency.

Srno	Reflector spacing(mm)	Returnloss (dB)	Gain (dB)	Directivity (dB)	Efficiency
1	13(0.12λ)	-22.01	6.30	7.01	83.89%
2	18.1(0.16λ)	-23.72	6.34	7.08	84.25%
3	22.6(0.21λ)	-25	6.35	7.09	84.56%
4	32.9(0.30λ)	-38.24	6.4	7.2	85.20%

Table 2: Tabulated Results Of Simulated Return Loss, Gain,Directivity& efficiency

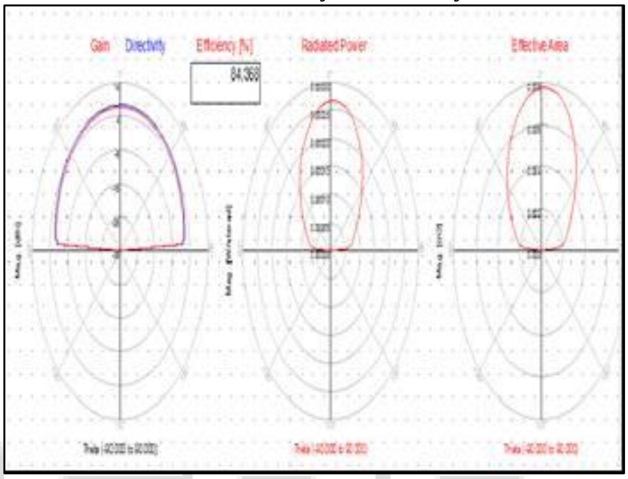

Fig. 7: Power Pattern and polar plot of effective area of Yagi antenna at S band

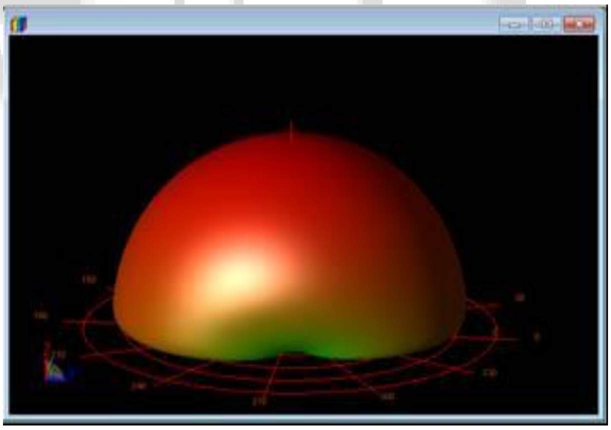

Fig. 8: 3D Radiation pattern of Yagi patch with one Reflector at S band

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