Analysis, Design and Development of Novel, Low Profile 2.487 GHz Microstrip Antenna

Rajeev Kumar Kanth, Waqar Ahmad[1], Yasar Amin[2], Pasi Liljeberg, Li-Rong Zheng[3], Hannu Tenhunen
Department of Information Technology, University of Turku, Joukahaisenkatu 3-5B, 20520 Turku Finland;
[1,2,3] School of Information and Communication Technologies, Royal Institute of Technology (KTH), Sweden
Email: rajeev.kanth@utu.fi; ahmadw@kth.se ; ysar@kth.se; pasi.liljeberg@utu.fi; lirong@kth.se; hannu@kth.se;
Tel: +358-2-333-8791; **Fax**: +358-2-2410154

***Abstract*- International Telecommunication Union Radio Communication Sector (ITU-R) has assigned 1.176 GHz and 2.487 GHz respectively in L and S band to Regional Navigational Satellite System (RNSS) for satellite navigation purpose. In this paper attempt has been made to design a novel, low profile compact microstrip antenna which achieves required specification such as gain of -4dBi up to ±50° and bandwidth of 30 MHz. The design of S band antenna was carried out using Ansoft Designer software, was fabricated and the required performance of antenna was measured in terms of its return loss, VSWR and gain radiation pattern. The return loss of the developed antenna was measured with the vector network analyzer and its gain radiation pattern in anechoic chamber and the performance of its measurements were compared with the analyzed results.**

***Index Terms*- Microstrip Antenna, S Band, Return Loss, Gain radiation pattern, Axial ratio, VWSR**

I Introduction

A microstrip patch antenna with a very thin patch is placed on a small fraction of a wavelength above a conducting ground plane. The patch and the ground plane are separated by a dielectric. The patch conductor is normally copper and can assume any regular geometry. The patches are usually photo etched on the dielectric substrate and the substrate is usually non-magnetic. The relative permittivity of the substrate is an important parameter to consider because it will enhance the fringing fields that account for radiation.

This work is a continuous series of work that has been presented in papers [1] and [2]. In recent years several microstrip patch geometries have been introduced for antenna applications with varying degrees of success in improving antenna characteristics [3] - [11]. Some of these geometries have been particularly useful in reducing the size of the antenna. However the proposed model is appropriate for the specified frequencies in S band having the gain of -4 dBi with ±50° and is utilized for satellite navigation purpose.

For the separate S band antenna, to achieve the design specification, substrate was taken as glass epoxy whose relative dielectric constant (ε_r) is 4.4 and size of the antenna is fixed by the empirical relationship as is illustrated in (1), (2) and (3) for Equilateral Triangle Micro Strip Antenna (ETMSA). MathCAD 2000 has been used to find the exact dimension of the proposed 2.487 GHz antenna [12].

The set of three equations helps to determine the dimensions of the ETMSA. The resonant frequency (f_{mn})

$$f_{mn} = \frac{2c\left(m^2 + mn + n^2\right)^{\frac{1}{2}}}{3S_e\sqrt{\varepsilon_e}} \quad (1)$$

$$S_e = S + \frac{4h}{\sqrt{\varepsilon_e}} \quad (2)$$

$$\varepsilon_e = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + \frac{20h}{S}\right]^{\frac{-1}{2}} \quad (3)$$

can be expressed in terms of effective side length (S_e), mode of triangular patch antenna (m=1, n=0), speed of light (c) and the effective dielectric constant (ε_e). Similarly the effective side length can be estimated with Equation (2) where effective dielectric constant (ε_e) can be obtained from Equation (3) with the use of parameters like relative dielectric constant (ε_r), height (thickness) of the ground plane to patch (h) and side of equilateral triangle (S).

For this developed antenna, the coaxial probe feeding technique is utilized. The coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. In this technique, inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane [13], [14].

For the proposed design, the substrate is glass epoxy because its low cost, compact size and availability for mass production.

II Design

In this experiment separate S band antenna is devised with the specification given in Table I. Using MathCAD 2000, it has been shown that the parameters for S band specification are S=32.45 mm for h=4.8 mm, m=1, n=0, ε_r=4.4

Table I: Specification of S band

S. No.	Parameters	Value
1.	Frequency band	2.46-2.50GHz
2.	Gain	-4dBi up to ±50°
3.	Axial ratio	3dB
4.	Polarization	LHCP
5.	Return loss	Min. -10dB
6.	3dB Beam width	±50°

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III Layout

The layout of the S band microstrip antenna is shown in Fig. 1. In this work, tip truncated ETMSA has been devised to get the circular polarization. Truncated portion creates two dominant modes with equal amplitude and 90° phase difference. Both modes are applied on orthogonal plane to generate circular polarization. This method is employed because of good axial ratio bandwidth. The sides of the patch have been taken as 36.5mm, 31.1mm and 31.1mm respectively as the sides of the triangle. This layout of S band patch fulfills the required specification of the antenna.

The Probe Position plays an important role in designing the Patch antenna. Several iterations have been performed to achieve the exact impedance matching. At the same time the resonant frequency is controlled by changes in dimensions of the patch. For the design of S band Patch it has been noticed that port 1 of coordinate (0.78,15) in Fig. 1 is required position of the probe for maximum impedance matching where the lower vertex of the antenna is assumed at the position (0, 0).

IV Simulated and Measured Results

Fig. 2 illustrates return loss diagram and it also shows that the antenna is resonating at 2.487GHz frequency and providing the superior bandwidth of 30 MHz ranging from 2.39 GHz to 2.56 GHz at the level of -10 dB return loss. This value of bandwidth is obtained after several iterations with optimized parameters. The measured Return Loss diagram is shown in Fig. 3 and Fig. 4 with the presence of adhesive and the air gap respectively. As glass epoxy substrate was found in 1.6mm thickness, but the required thickness of the substrate is 4.8 mm (according to the design) therefore three layers of the substrate ware stacked to get the desired thickness for the specific design. These three layers are stacked by two ways; firstly, they were stacked by adhesive and secondly, they were stacked by using the air gapping. In each of the cases measurement were taken.

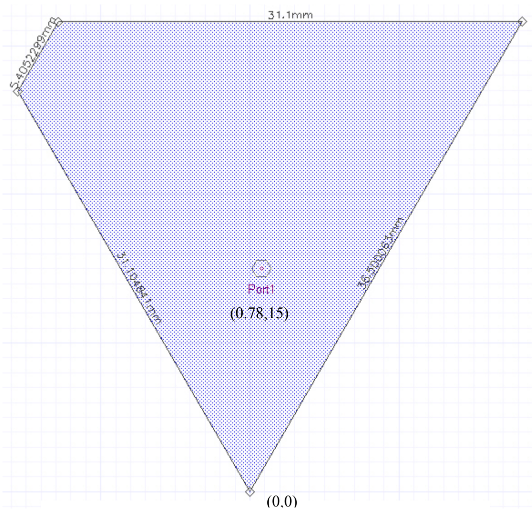

Fig. 1: Layout of S band patch

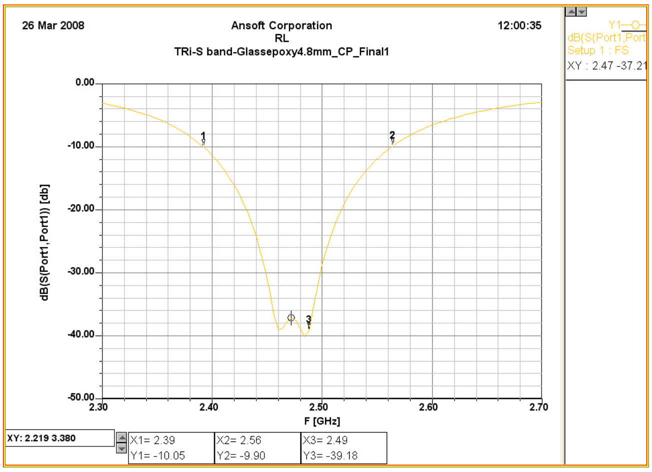

Fig. 2: Return Loss of S band ETMSA (Analyzed)

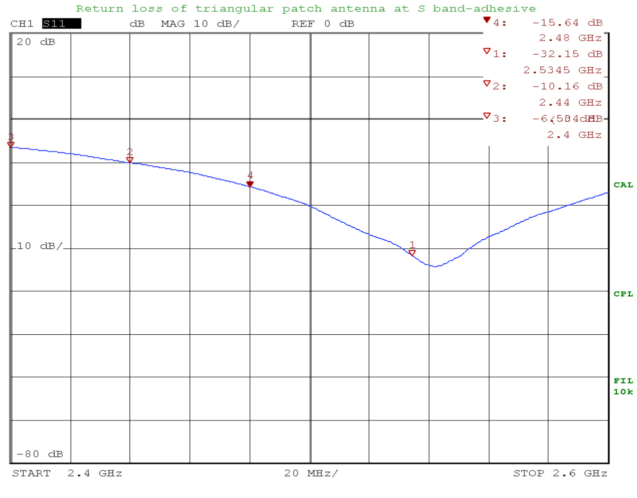

Fig. 3: Return Loss of S band ETMSA (adhesive)

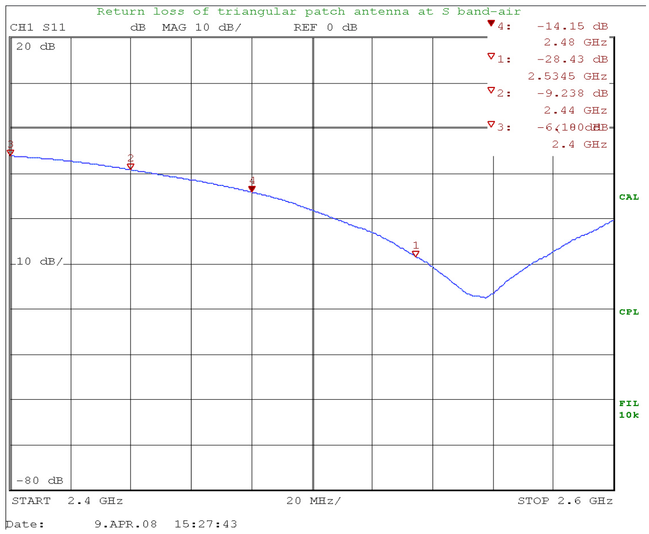

Fig. 4: Return Loss of S band ETMSA (Air-gap)

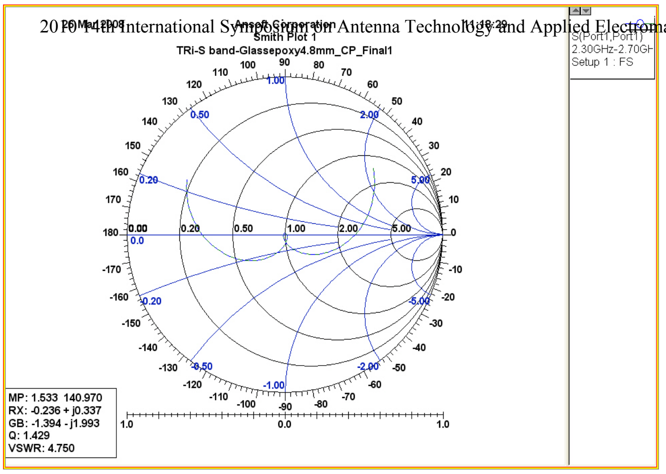

Fig. 5: Impedance Plot for analyzed S band Antenna

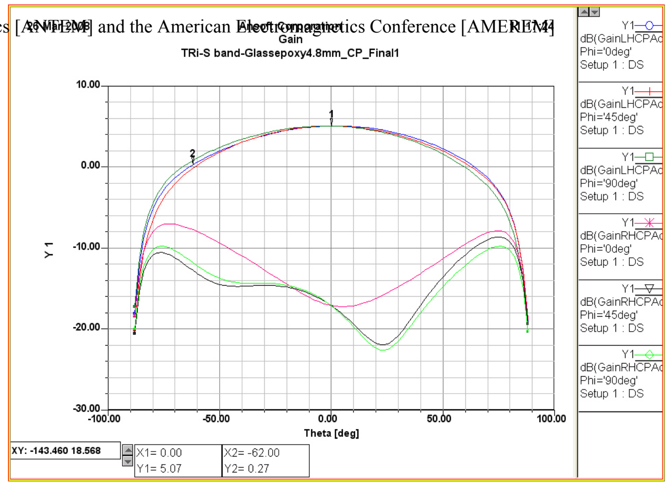

Fig. 8: Gain Radiation Pattern of S band Antenna

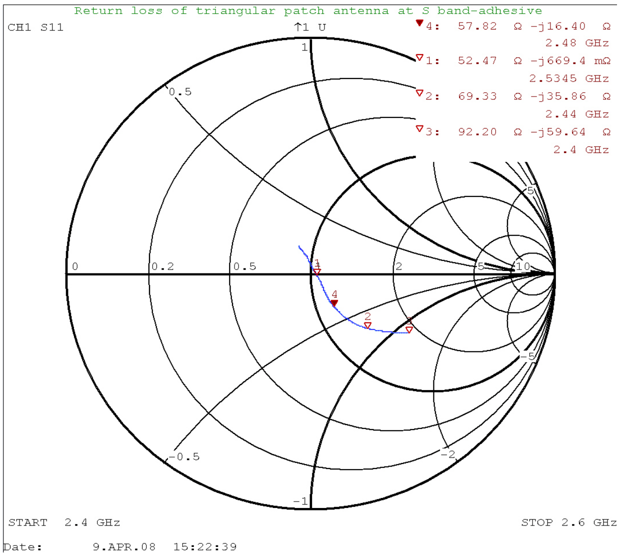

Fig. 6: Impedance Plot for measured S band (Adhesive)

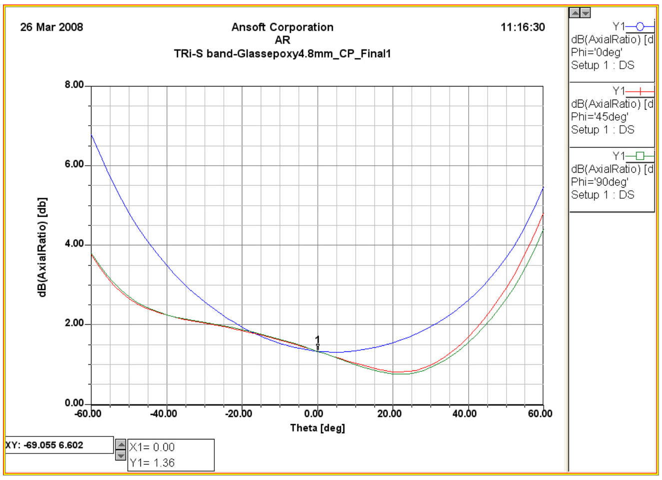

Fig. 9: Axial Ratio

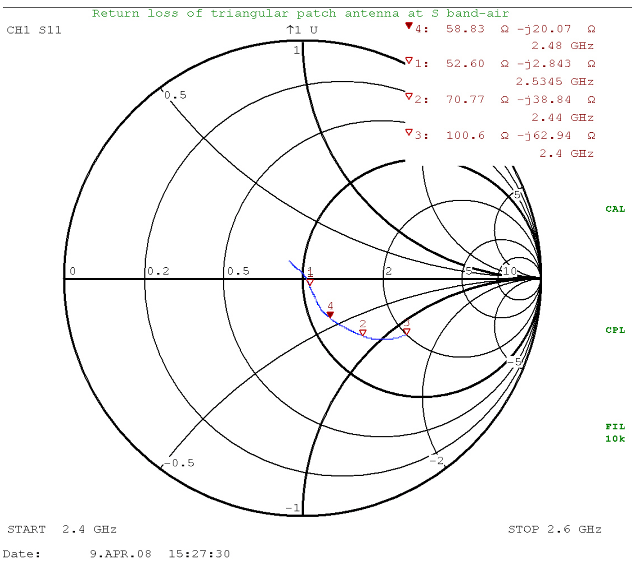

Fig. 7: Impedance Plot for measured S band (Air-gap)

Fig. 10: Developed 2.487 GHz Antenna

For S Band, Fig. 2 is showing that the antenna is resonating at 2.487 GHz corresponding to data cursor 3 where as data cursor 1 and 2 at the level of -10 dB providing a good bandwidth of approximately 170 MHz ranging from 2.39 GHz to 2.56 GHz. The measured return loss with adhesive and air gap has been shown in Fig. 3 and Fig. 4 respectively. In our design the center frequency is 2.487 GHz but the measured center frequency using Vector Network Analyzer is 2.5345 GHz, which is shifted toward the right. The possible reasons for center frequency shift and bandwidth are as follows.

- We are considering the dielectric material of thickness 4.8 mm, but it is not available with this thickness. Therefore three 1.6 mm sheets of glass epoxy are stacked together to get the desired specification.
- Another reason for frequency shift is that the effective dielectric constant must decrease due to insertion of some gaps among these three layers of glass epoxy.

Similarly the return loss of the antenna is measured with the air gap in between the sheets of the glass epoxy, which is also shifted due to the change in the effective dielectric material of the antenna.

The impedance plot in Fig. 5 shows that there is a loop formation near 1.0, which indicates that the antenna is circularly polarized, and inductive reactance is created by a change in the thickness of actual hardware. The resonant frequency, i.e. 2.487 GHz, is at the nearest point in the loop that shows the perfect behavior of the patch antenna. The measured Smith chart for both adhesive and air gap S Band antenna are shown in Fig. 6 and Fig. 7 respectively.

From the gain radiation pattern, shown in Fig. 8, it can be stated that the gain along the bore sight is around 5.07 dBi. The radiation pattern was drawn for three different angles of Phi i.e. 0^0, 45^0 and 90^0, which gives the pattern appropriate to the specification. For the angle theta of $\pm 62^0$ the gain pattern is reasonable. The axial ratio for the specified patch antenna is shown in Fig. 9. It has been shown that the axial ratio is 1.36 dB and in practical case it should be less than 3 dB. Hence this also fulfills the requirement of the design. Fig. 10 is the actual S band antenna developed fulfilling the required specification showing its patch side where as the other side of the antenna has a coaxial probe, soldered with the patch through 3mm via.

VI CONCLUSION AND FUTURE RECOMMENDATION

In this paper the design of S band low profile microstrip antenna has been carried out. According to simulation result in terms of return loss and VSWR, the physical antenna was fabricated and its characteristics were measured with Vector Network Analyzer. Both the analyzed and measured results were compared and found to be similar with certain shifting of the frequencies. The characteristics of developed L band antenna matches with its specification. The gain radiation pattern was observed theoretically fulfilling the requirement of the antenna and measurement of its gain in anechoic chamber is future work. The authors are now intending to develop a novel multiband fractal antenna that will have the capability of resonating simultaneously at 1.176 GHz and 2.487 GHz.

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