Design and Implementation of a Patch Antenna with Multiple Dielectric Substrates for Gain Enhancement used in WiMAX Applications

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Abstract - Microstrip patch antennas are used in wireless communication systems. They have several advantages such as low profile, lightweight and ease of integration with other electronic components. But microstrip patch antennas have very low gain and not suitable for long range communication. So, High-gain patch antennas are required for enhanced long range applications. This paper presents the design and simulation of microstrip patch antenna for gain enhancement used for WiMAX applications.

In this project multiple superstrates i.e., Taconic CER-10($\mathcal{E}r$=10) is used for gain enhancement. The substrate is spaced off of the patch antenna by some height and expected to increase the performance of the antenna. The antenna is designed and simulated using HFSS and operates at central frequency 5.5GHz. The gain of the single patch is obtained as 6.89dB, which is further increased to 10.5dB with three substrates.

Index Terms - gain enhancement, microstrip patch antenna, superstrates, HFSS, WiMAX.

I. INTRODUCTION

WiMAX is mainly used for long range applications. Its usability and application range are expanding because, unlike a wired network, it can be used conveniently regardless of location. The design of a high gain antenna is always been a challenge for antenna engineers. Microstrip patch antennas have the advantages of being low-cost, planar, and easily fabricated. These low gain antennas are not suitable for long range communications so a high gain and directional antennas with low back radiations are needed. In this paper we proposed a microstrip patch antenna with multiple dielectric Superstrates to enhance performance especially the broadside gain at 5.5GHz for WiMAX application. The result show that gain of the patch antenna is increased using a single Superstrate which is further increased with three Superstrates. All the antenna designs (Patch antenna, Patch antenna with one Superstrate, Patch antenna with two superstrates, Patch antenna with three Superstrates) are simulated using HFSS software.

HFSS (High-Frequency Structure Simulator) is a commercial electromagnetic simulation software package developed by ANSYS, Inc. It is widely used in the design and analysis of high-frequency and microwave electronic components, including connectors, filters, integrated circuits, and antennas.

HFSS uses finite element analysis (FEA) to solve Maxwell's equations for electromagnetic fields in three dimensions. It allows for accurate simulation of complex electromagnetic phenomena, including scattering, radiation, and coupling effects.

For modelling and analyzing electromagnetic structures, HFSS offers a wide range of features and tools, including a robust scripting language, automatic meshing algorithms, and cutting-edge visualization tools. It also supports integration with other ANSYS products for multi-physics simulations.

The telecommunications, aerospace, and defense industries, as well as academia, all make extensive use of HFSS.

The wireless communications revolution is bringing significant improvements and upgrades to data networking and telecommunications, as well as establishing integrated networks for future development. Personal communications networks, wireless local area networks, mobile radio networks, and cellular systems all hold the promise of completely distributed wireless computers and communications, everywhere and at any time.

Because of advancements in information and communication technology, the wireless network employs a variety of frequency bands. The frequency bands are given based on the technology, purpose, network size, and communication needs. Wireless Local Area Network (WLAN) bands

This multiple dielectric superstrate antenna is designed using Taconic material. Taconic produces microwave laminates with homogeneous thickness profiles, exact dielectric constants, and consistently low dissipation factors across the board. These Taconic laminates' remarkable low loss factors extend their utility to X-Band and above.

II. ANTENNA DESIGN

The microstrip patch antenna is designed with Taconic CER-10 superstrates to enhance the gain of the antenna. In this project single patch, patch with one Superstrate, patch with two superstrates and patch with three Superstrates are designed. In single patch fabrication, the antenna is consisting of a ground plane, substrate (Taconic CER2) with a height of 2mm and a microstrip patch. The patch is fed by a 50-ohm feedline. The optimized parameters of the patch are: A=50mm, h_p=1.6mm, p_x=19mm, p_y=18mm, g=4.25mm, L=3mm, Ws=1.5mm and Ls=44mm.

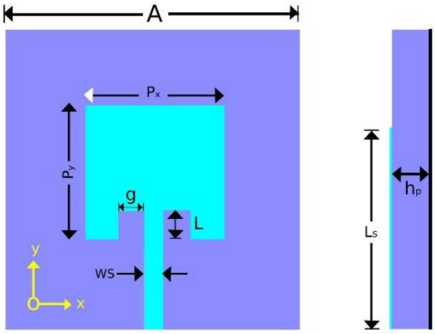

Fig. 1 Geometry of patch antenna front view and side view

In patch with one Superstrate design, the microstrip patch antenna is then coupled with a high dielectric constant substrate (Taconic CER10) to increase the broadside gain. Therefore, a high dielectric Taconic substrate (ε_r=10.2, tanδ=0.0035)having a thickness of h_s=1.6mm is placed at an optimized distance of h_a=4mm from the antenna. In this stage, only the parameters of the superstrates (h_a and h_s) are tuned for optimum performance, while all other parameters are kept unchanged. The vacuum stands are placed in between the patch and Taconic CER10 Superstrate. The thickness of the substrates, the gap between the patch and superstrate (Taconic CER10) impacts on enhancing the gain of the antenna. In this design, the gain is obtained as 7.9dB which is comparatively high to the single patch.

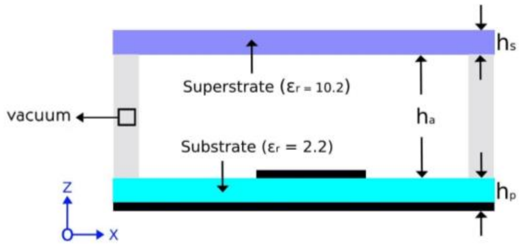

Fig. 2 side view of the patch antenna with one superstrate

In patch with two superstrates design, another Taconic CER10 Superstrate is placed above the first Superstrate. The thickness of the superstrate is 1.6mm and a height(h_{a1}) 12.4mm. Vacuum stands are arranged between the first Superstrate and second Taconic Superstrate. In this case, there is an advancement in the gain of antenna compared to the patch with one Superstrate design.

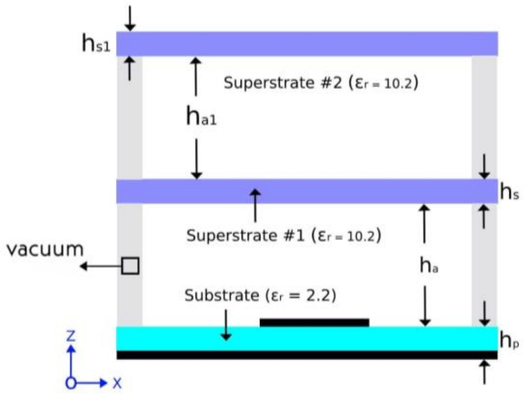

Fig. 3 side view of patch antenna with two superstrates

In patch with three Superstrates design, third Taconic CER10 Superstrate is deposited above the second Superstrate. The Superstrate is having a thickness of 1.6mm and a height(h_{a2}) of 1mm. Vacuum stands are fixed between the second and third Taconic superstrates. In this stage, there is an improvement in the gain of antenna compared to the patch with two superstrates.

For better antenna applications VSWR should be less than or equal to 2 and S11 is less than -10. The highest gain obtained for three substrates is 10.5dB.

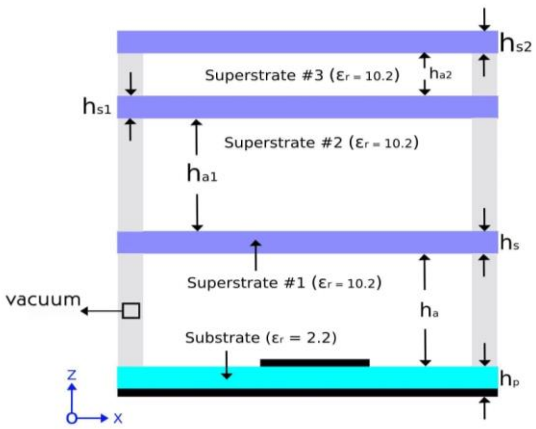

Fig. 4 side view of patch antenna with three superstrates

III. SIMULATION RESULTS

a) Return loss: The amount of energy that is reflected back to the source in a transmission line is measured as return loss. It is a measurement of the amount of power lost as a result of reflection and is often given in decibels (dB). Particularly in high-speed digital communication systems, return loss is crucial to the design and performance of transmission networks. the power of the transmitted signal is compared to the power of the reflected signal to determine return loss. A high Return Loss number suggests that there is little reflection and that the transmitted signal is well matched to the transmission line's impedance.

b) VSWR: Voltage Standing Wave Ratio, or VSWR, is a measurement of how well power is transferred from a transmission line to a load. It is stated as a ratio or in decibels and represents the relationship between the greatest voltage and the minimum voltage along a transmission line (dB).

The power that is reflected back from the load to the source in a transmission system is measured by VSWR. A large quantity of power is being reflected when the VSWR number is high, which can lead to power loss, decreased system efficiency, and even possible system component damage.

C) Gain: The ratio of the intensity of radiation in a particular direction to the intensity of radiation that would be produced if the power received by the antenna were isotopically emitted. Ordinarily, this ratio is stated in decibels in relation to an isotropic radiator (dB).A transmitting antenna with a gain of 3 dB will result in a power output that is 3 dB more (or twice as much) than what a lossless isotropic antenna with the same input power would produce.

A. Single patch:

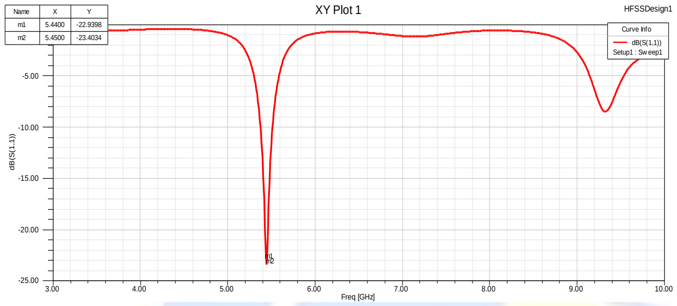

Fig. 1(a) S11(retrn loss)

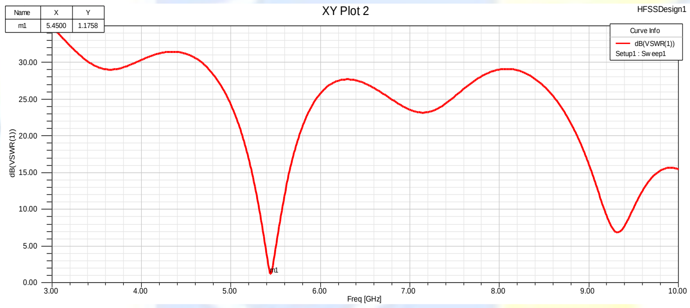

Fig. 1(b) VSWR

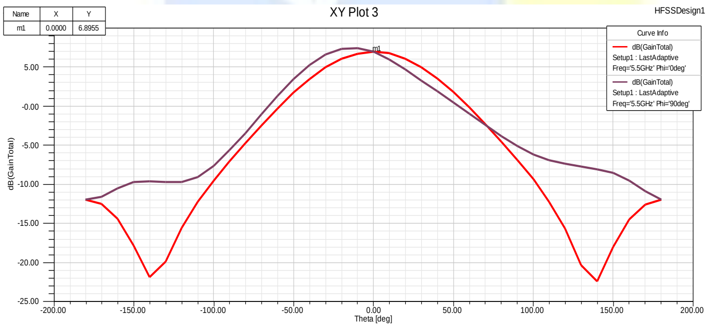

Fig. 1(c) Gain

1.In single patch design, from *Fig1(a)* the S11(RETURN LOSS) of the antenna is -23.
2.From *Fig1(b)*,the VSWR of the antenna is 1.1.
3.From *Fig1(c)*, the GAIN of the antenna is 6.8dB.

B. patch with one superstrate:

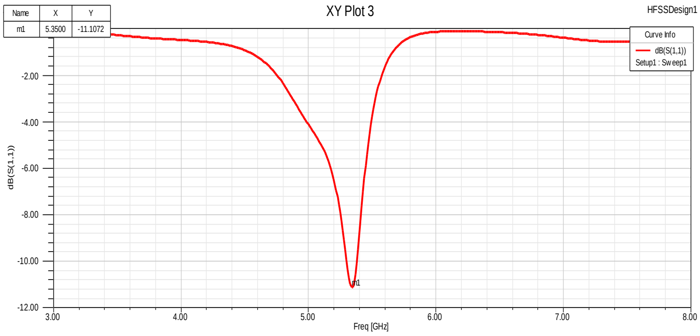

Fig. 2(a) S11(retrn loss)

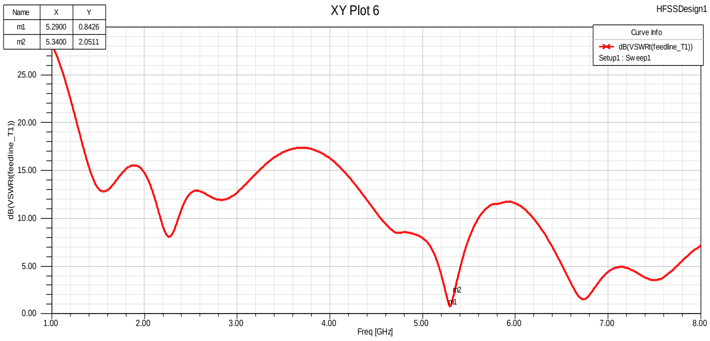

Fig. 2(b) VSWR

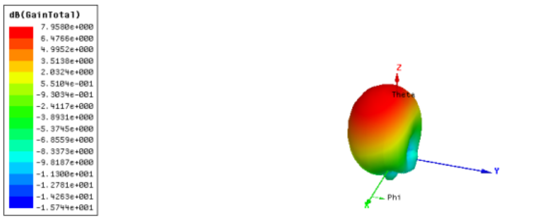

Fig. 2(c) Gain

1.In patch with one Superstrate design, from *Fig2(a)* the S11(RETURN LOSS) of the antenna is -11.

2.From *Fig2(b)*, the VSWR of the antenna is 2.

3.From *Fig2(c)*, the GAIN of the antenna is 7.9dB.

C. patch with two superstrate:

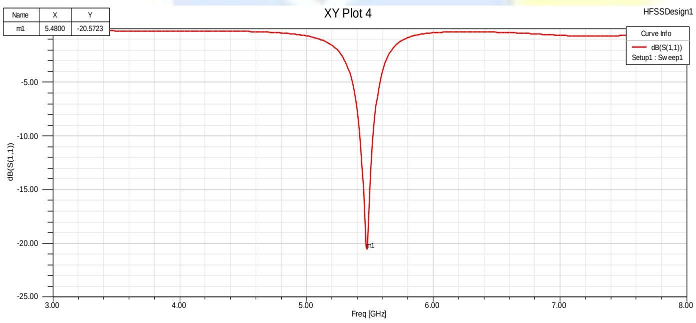

Fig. 3(a) S11(retrn loss)

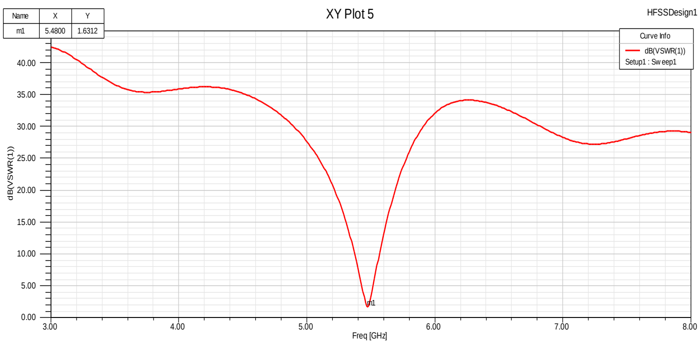

Fig. 3(b) VSWR

Fig. 3(c) Gain

1.In patch with two Superstrate design, from *Fig3(a)* the S11(RETURN LOSS) of the antenna is -20.
2.From *Fig3(b)*, the VSWR of the antenna is 1.6.
3.From *Fig3(c)*,the GAIN of the antenna is 8.1dB.

D. patch with three superstrate

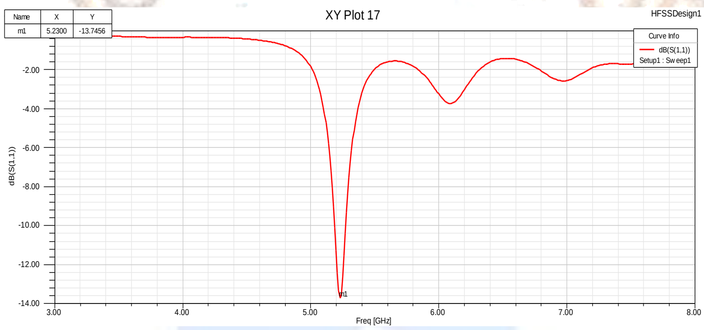

Fig. 4(a) S11(retrn loss)

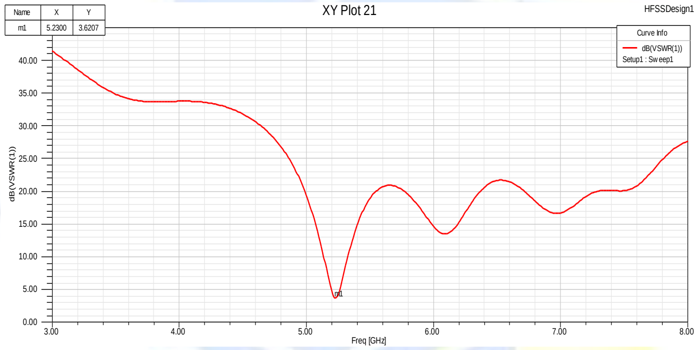

Fig. 4(b) VSWR

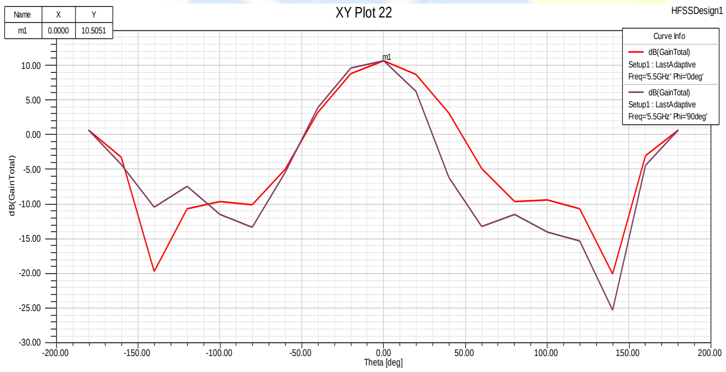

Fig. 4(c) Gain

1.In patch with one Superstrate design, from *Fig4(a)* the

S11(RETURN LOSS) of the antenna is -13.

2.From *Fig4(b)*, the VSWR of the antenna is 3.6.

3.From *Fig4(c)*, the GAIN of the antenna is 10.5dB.

IV. GAIN AND DIRECTIVITY

The antenna performance in terms of S11(RETURN LOSS), VSWR and gain is compared for all cases of the patch antennas i.e., Single patch, Patch with one Superstrate, Patch with two superstrates and Patch with three superstrates. Generally, for better antenna applications VSWR should be less than 2,S11(RETURN LOSS) should be less than -10dB.In Single patch, the S11(RETURN LOSS) of the antenna is -23,VSWR is 1.1 and the gain is 6.8dB.In patch with one Superstrate design the S11(RETURN LOSS) is -11,VSWR is 2 and the gain of the antenna is 7.9dB.Compared to the Single patch design, the gain of the antenna is increased from 6.8dB to 7.9dB.In patch with two superstrates design the S11(RETURN LOSS) of the antenna is -20,VSWR is 1.6 and gain of the antenna is 8.1dB.Compared to the patch with one Superstrate design the gain of the antenna is increased from 7.9dB to 8.1dB.In patch with three superstrates design, the S11(RETURN LOSS) of the antenna is -13.7,VSWR is 3.6 and gain of the antenna is 10.5dB.Compared to the patch with two superstrates design, the gain of the antenna is increased from 8.1dB to 10.5dB.The overall performance and gain of the antenna is improved using multiple superstrates.

Name	S11(dB)	VSWR	Gain
Single Patch	-23	1.1	6.8
Patch + One Superstrate	-11	2	7.9
Patch + Two Superstrate	-20	1.6	8.1
Patch + Three Superstrate	-13	3.6	10.5

V.CONCLUSIONS

A Patch antenna with multiple superstrates is designed at the central frequency of 5.5GHz for WiMAX applications. All the designs (Patch antenna, Patch with single Superstrate, Patch with two superstrates and Patch with three superstrates) are analyzed numerically to explain the design procedure and performance enhancement. The gain of the antenna is improved using Patch with one Superstrate compared to the single patch. Further increasing the number of superstrates results in the improvement of gain and overall performance of the antenna. The microstrip patch antenna is designed using multiple superstrates for WiMAX applications.

VI. REFERENCES

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