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ANALYSIS OF STACKED ANTENNA IN SATELLITE APPLICATION

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Abstract

We propose in this paper a Broadband Stacked Microstrip Patch Antenna structure with a microstrip feeding technique to achieve wide bandwidth and high gain. The proposed stacked antenna executes the frequency range from 4GHz to 10GHz in C band. A parametric analysis is performed to study the inter-element distance effect on antenna performance (directivity, input impedance and radiation efficiency). The results obtained show that in the case of the fully driven element high directivities can be achieved for small distances. The proposed antenna is used for a wide range of applications, such as satellite communication, weather radar systems, applications for Wi-Fi and ISM Band. The C Band is known to perform better on adverse weather conditions than the standard Ku Band for satellite communication. The parameters of the antenna are analysed using the HFSS Tool.

Keywords:

Microstrip Patch Antenna, Stacked Antenna, ISM and C band, Satellite Application

1. INTRODUCTION

Microstrip patch antenna is preferred in wireless communication system because of its small size, light weight and low profile characteristics. Nowadays, communication engineers are very interested in researching the microstrip patch antenna. Due to its novelty, miniature nature, and low cost, wireless communication is rapidly maximizing. In telecommunications, smart antenna techniques are used to increase the bandwidth and minimize dimensions compared to conventional ones. Research in antenna started from multiple perspectives, one of the important approaches being the research on the use in stack antenna.

In the current scenario, antenna researchers focus on the wide band or multi-band antenna that performs well when it comes to characteristics like rotation, minimizing the antenna dimension and covering all the desired frequency. Microstrip patch antenna is the main focus for the theoretical and experiential role of the research. But, narrow bandwidth is in the major drawback in the microstrip patch antenna. The problem of narrow band width is solved by the use of multilayer structure.

Narrow ring antenna is designed in [1] using a Circular patch, and it does circular operation on the circular patch. Multilayered planner antenna is called stack antenna which is placed at the intersection of dielectric layers with multiple resonators. These multilayer vertical patches are used to obtain multiple resonates without affecting the overall area. The main limitation of the microstrip patch antenna is narrowband; this problem can be eliminated with the stack antenna structure, using which unidirectional radiation pattern and large bandwidth could be achieved without altering the ground plane, and large bandwidth. These unidirectional antennas are used for imaging systems and airborne radars where there is no preference for a back lobe.

The defected ground plane antenna is disused in [2], and, here, the ground plane antenna has been changed to obtain the broad band response. In the literature, multi-stack antenna has been considered to achieve multi-band response for specific applications [3]-[4]. For communication systems, a coupled C-band stacked double-band resonant antenna with different dielectric constants shows antenna gain of 9.5dBi in the radiation pattern with a minimized side lobe of 12.2dB and 24.1dB [7].

Dielectric resonator antenna clarifies a stacked technique with a double band response to obtain maximum radiation efficiency and maximum DRA. This antenna gained 8dB and 99% radiation efficiency in both the resonant bands in [8]. In [9] and [10], a stack patch antenna with a maximum bandwidth of 27% has been designed. Square metallic radiating elements are engaged in this design to get the wider bandwidth.

In [11], a rose leaf-shaped microstrip antenna with a capacitive coupled rectangular feed and with impedance bandwidth of about 69% is used, while in [10], a broadband L-strip-fed printed microstrip antenna with a bandwidth of 74% is used.

In [12] a stacked patch antenna with a folded patch feed and a 90% bandwidth is presented. In addition to the existing resonances, this strip-loaded slotted microstrip antenna is fed by an L-strip feed line to obtain impedance matching for the patch antenna's higher order modes. A design is presented in [14] for a probe-fed asymmetric E-shaped patch antenna with 110% BW. A BW square patch antenna is presented in [6] with four capacitive coupled feeds. In references [5] and [13], 129% and 134% BWs met material-based patch antennas.

2. ANTENNA CONFIGURATION AND DESIGN APPROACH

The proposed triple band stack antenna is designed with a compressed size of 29×24×1.6mm^3. The design is prepared by two patches on a single substrate. The outer substrate has $W\times L$ dimension and patch has $W_p\times L_p$ dimension. Depending on the number of slots, the resonant frequency of the given antenna could be attained. The stacked antenna is designed with FR-4 substrate because of its low cost, miniscule thickness of 1.6mm, loss tangent of 0.02, and dielectric constant of relative permittivity of 4.4.

2.1 METHODOLOGY

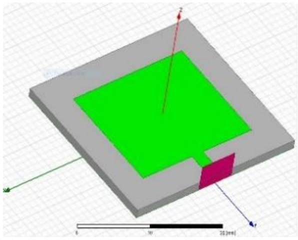
A stacked triple band antenna is designed using HFSS software. The C frequency band is 4GHz to 10GHz, which is used for Wireless WiMAX and other applications. The operating frequency chosen for the design is therefore 10GHz. The selected dielectric material for design is FR-4 epoxy with a dielectric constant of 4.4. It is essential that the antenna is not bulky for the microstrip patch antenna which is used in cellular phones or other handheld devices. Hence the dielectric substratum height should be small. Here FR-4 standard height of 1mm epoxy substratum is selected.

2.2 CALCULATION OF GROUND PLANE DIMENSION

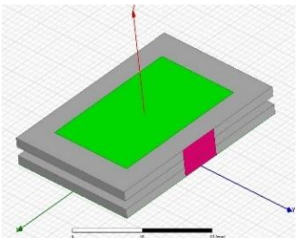
Only for infinite ground planes, transmission line model is applicable, but for practical considerations finite ground plane is required. Same results for finite and infinite ground plane are obtained if the size of the infinite ground plane around the periphery is greater than the patch dimensions by six times the thickness of the substrate.

Table.1. Design parameters of triple-band stacked antenna

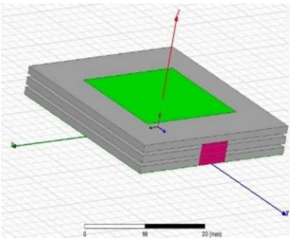
Parameters	Value
Substrate Width (W_{s1}, W_{s2}, W_{s1})	34
Substrate length (L_{s1}, L_{s2}, L_{s1})	29
Patch width (W_{p1}, W_{p2}, W_{p3})	21
Patch length (L_{p1}, L_{p2}, L_{p3})	16
Substrate height (h_1, h_2, h_3)	1
Distance between each substrate (d)	1
Dielectric constant (ε_{r1}, ε_{r2}, ε_{r3})	4.4
Feed length (f_l)	6.5
Feed width (f_w)	2



(a) Single patch antenna



(b) Two-layer stack antenna

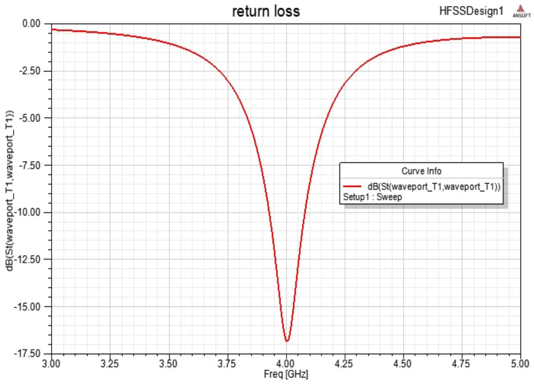


(c) Three-layer Stack Antenna

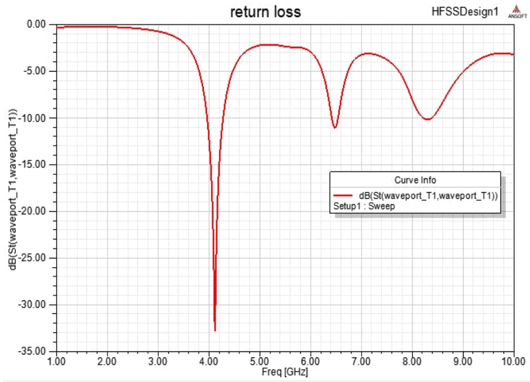
Fig.1. Proposed Stack antenna

3. RESULT AND DISCUSSION

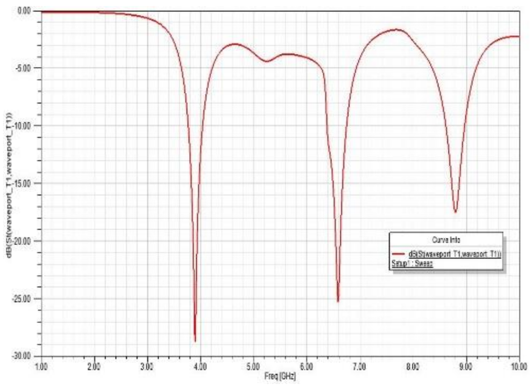
The single patch antenna, two-layer antenna, and three layer stacked antenna were designed with the 0.5mm gap in the substrate. Antenna factors are VSWR, reflecting co-efficient, simulating beam width and radiation patterns, tabulating and analyzing the results using HFSS tool. The proposed single, two-layer, and triple-layer stacked antennas are designed to display the various frequency reflection coefficients in this section.



(a) Single patch antenna



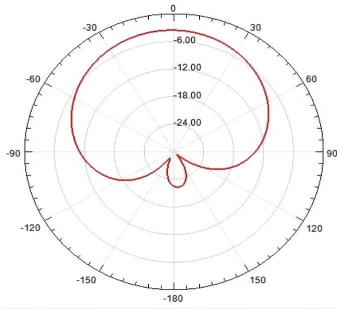
(b) Two-layer stack antenna



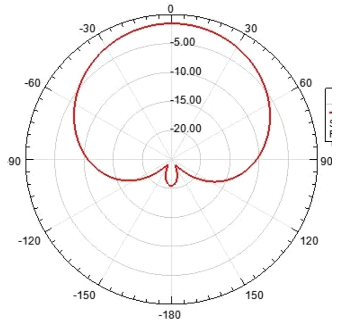
(c) Triple-band antenna

Fig.2. Return loss of Stacked Antenna Structure

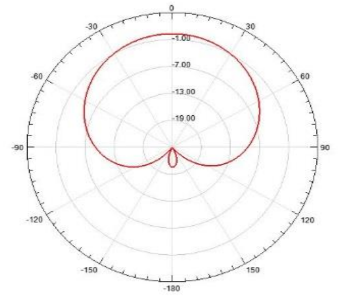
The Fig.1 shows the S_{11} of Single, two layer and triple layer stacked antennas are achieved by -16.8dB, -33.5dB and -28.7dB. The proposed stacked triple band antenna resonates with the 4GHz, 6.8GHz and 8.9GHz frequencies. For both WiMAX and WLAN applications, the last resonate frequencies can be used here, and the first two frequencies fall under the middle band of WiMAX communication systems. At each and every step of the design methodology it is observed that the simulated patch shows a better matching impedance.



(a) Single patch antenna



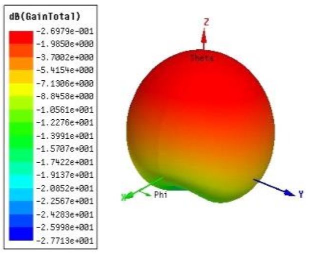
(b) Two-layer of stack antenna



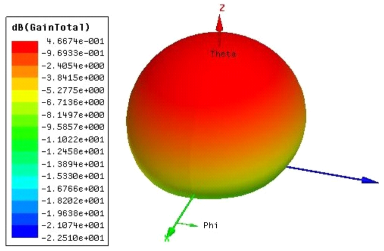
(c) Triple-band antenna Stack Antenna

Fig.3. Radiation pattern of stacked antenna

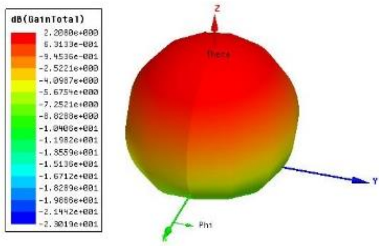
The Fig.3 shows the simulated results of the proposed patch antenna stacked in three layers. From the above simulated return loss, it is inferred that the simulated frequency is 4GHZ, 6.7GHz, 8.95GHz and the return loss is -28dB, -25dB and -18dB for the different resonant frequencies. A very good radiation pattern of 79.45% is obtained in the three-layer stacked antenna.



(a) Single patch antenna

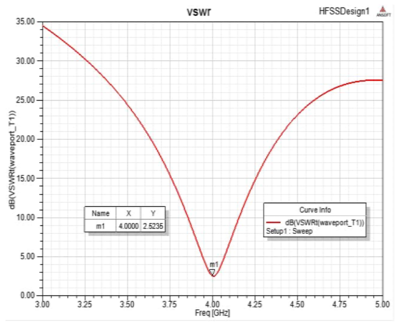


(b) Two-layer of stack antenna

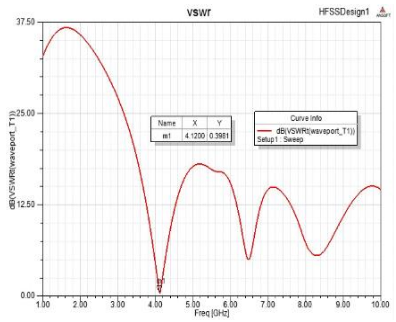


(c) Triple-band of stack antenna

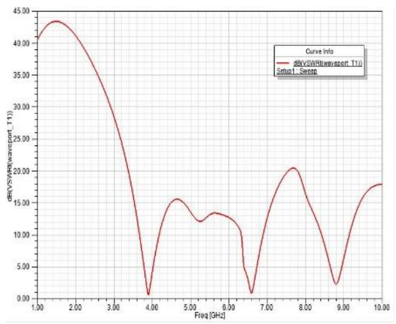
Fig.4. Bandwidth of stacked antenna



(a) VSWR for single patch antenna



(b) VSWR for two-layer stack antenna



(c) VSWR values of triple-band antenna

Fig.5. VSWR measurement of stacked antenna

From the Fig.5, it observed that the variation of the frequency versus VSWR after the simulation is almost 2 for 4GHZ and 6.5GHz, and 3.5 for 8GHZ.

Table.2. Parametric study of triple-band stacked antenna

Materials Used	Return loss (dB)	Gain (dB)	VSWR	Radiation efficiency	Beam Width (degree)
Substrate 1 - FR4 Substrate2 - FR4 Substrate 3 - FR4	-28.7	2.29	1.05	76.79	95.57
Substrate 1 - FR4 Substrate2 - FR4 Substrate 3 - Roger RT	-25	2.23	0.09	71.57	95.43
Substrate 1 - FR4 Substrate2 - Roger RT Substrate 3 - FR4	-27.7	2.18	0.6	73.21	95.74
Substrate 1 - FR4 Substrate2 - Roger RT Substrate 3 - Roger RT	-21.7	2.1	2.44	68.75	95.38

The substrate material listed in Table.2 is FR4 and Roger RT 4200 is selected and placed at differing configuration and substrate distance of 0.5mm. The simulated parameters are coefficient of reflection, gain, VSWR, radiation efficiency and beam width. Compared with other configurations, the substratum 1 FR4, substratum 2 Roger RT 4200 and substratum 3 FR4 obtained the better result. The antenna with substrates separated by a gap of 1mm produces better loss of return than the antenna with substrates separated by 0.5mm. Overall, by comparing all the antennas the 0.5mm substratum gap of the antenna and all the substratum as a FR4 epoxy is efficient than the others. The 0.5mm substrate gap antenna delivers better VSWR. The antenna with a substratum gap of 0.5mm produces good radiation pattern and bandwidth among the antennas.

The comparison of various materials is used in the substratum to determine the following factors of the stacked antenna: return loss, gain, VSWR, radiation efficiency, and beam width analysis. The radiation efficiency and beam width of FR4 and Roger RT materials are getting better.

Table.3. Performances comparison of the proposed structure with other structures

Antenna Size (mm^3)	Resonance Frequency (GHz)	Gain F1	Gain F2
69.6×76	0.915/2.45/5.8	2.62	3.31
36×36	2.45/5.8	2.68	3
55×50	4.2/5.6	0.882	2.108
64.5×76	2.4/5.8	1.8	1.5
29×34	4/8	2.29	

4. CONCLUSION

The antenna with substrates separated by a gap of 1mm produces better loss of return than the antenna with substrates separated by 0.5mm. In both antennas the gain inferred is similar. Radiation efficiency is better in both antenna types that have a gap of 0.5mm and 1mm between substrates. The Beam Width is also better in both types of antennas having a gap of 0.5mm and 1mm between the substrates. The antenna with 0.5mm substratum gap produces better VSWR than the antennas with 1mm gap. The antenna with a substratum gap of 0.5mm produces good radiation pattern and bandwidth among the antennas mentioned above. Though the antennas with the 1mm substratum gap produce better efficiency, the pattern of radiation is poor. Overall, by comparing all of the antennas, the antenna with 0.5mm substratum gap, and of all of the substratum, the FR4 epoxy are effective than the others. This antenna provides a return loss of -25dB, 2.29 gain, VSWR as 1.05, 76.79% radiation efficiency and 95.57o beam width.

REFERENCES

[1] W. Liao and Q.X. Chu, “Dual-Band Circularly Polarized Microstrip Antenna with Small Frequency Ratio”, *Progress in Electromagnetics Research Letters*, Vol. 15, pp. 145-152, 2010.

[2] C.H. See, R.A. Abd Alhameed and D. Zhou, “A Crescent-Shaped Planar Monopole Antenna for Mobile Wireless Applications”, *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, pp. 152-155, 2010.

[3] S. Shekhawat, P. Sekra and D. Bhtanagar, “Stacked Arrangement of Rectangular Microstrip Patches for Circularly Polarized Broadband Performance”, *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, pp. 910-913, 2010.

[4] V.P. Sarin, M.S. Nishamol and D. Tony, “A Wideband Stacked Offset Microstrip Antenna with Improved Gain and Low Cross Polarisation”, *IEEE Transactions on Antennas and Propagation*, Vol. 59, No. 4, pp. 1376-1379, 2011.

[5] M. Ihamji, E. Abdelmounim, H. Bennis, M. Hefnawi and M. Latrach, “Design of Compact Tri-Band Fractal Antenna for RFID Readers”, *International Journal of Electrical and Computer Engineering*, Vol. 7, No. 4, pp. 1-13, 2017.

[6] L. Han, G. Wu and L. Li, “Design and Transmission Line Model Analysis of a Compact Dual-Frequency Antenna”, *IET Microwaves, Antennas and Propagation*, Vol. 6, No. 4, pp. 404-410, 2012.

[7] A. Katyal and A. Basu, “Broadband Reconfigurable Stacked Microstrip Antenna at Xband”, *Proceedings of International Symposium on Antennas and Propagation*, pp. 85-86, 2014.

[8] J.V. Abhishek Kandwal, B. Chauhan, “Coupled C-Band Stacked Antenna using Different Dielectric Constant Substrates for Communication Systems”, *Engineering Science and Technology Journal*, Vol. 19, No. 2, pp. 1801-1807, 2016.

[9] Sugadev Mani and Logashanmugam Edeswaran, “High Gain Multiband Stacked DRA for WiMax and WLAN Applications”, *American Journal of Applied Sciences*, Vol. 14, No. 8, pp. 779-785, 2017.

[10] V.V. Golovin and Y.N. Tyschuk, "Multielement Patch Antenna Array of Operated Polarization of Ku-Band", *Proceedings of International Conference on Antenna Theory and Techniques*, pp. 286-288, 2013.
[11] K. Klionovski and A. Shamim, "Back Radiation Suppression through a Semitransparent Ground Plane for a Millimeter-Wave Patch Antenna", *IEEE Transactions on Antennas and Propagation*, Vol. 65, No. 8, pp. 3935-3941, 2017.
[12] A.A. Lotfi Neyestanak, "Ultra-Wideband Rose Leaf Microstrip Patch Antenna", *Progress in Electromagnetics Research*, Vol. 86, pp. 155-168, 2008.
[13] A. Ennajih, J. Zbitou, M. Latrach, A. Errkik, L. El Abdellaoui and A. Tajmouati, "Dual Band Metamaterial Printed Antenna Based on CSRR for RFID Applications", *International Journal of Microwave and Optical Technology*, Vol. 12, No. 2, pp. 1-8, 2017.
[14] V.P. Sarin, M.S. Nishamol, D. Tony, C.K. Aanandan, P. Mohanan and K. Vasudevan, "A Broadband L-Strip Fed Printed Microstrip Antenna", *IEEE Transactions on Antennas and Propagation*, Vol. 59, No. 1, pp. 281-284, 2011.