Design of a multiband LTE and C-band 5G co-planar waveguide fed antenna

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***Abstract*: This paper designs a multiband antenna that will operate in LTE and 5G frequencies. The antenna will be fed using co-planar waveguide technique. The antenna is expected to resonate at least at 4-5 frequencies that lie in LTE and 5G spectrum. A base antenna of triangular shape is first designed. Some slots are cut in the base antenna geometry to get multiband characteristics in the C band. This work aims to design an antenna that satisfies the WLAN/WiMAX/LTE standards. Multiband antennas which operate at 2.4–2.484 GHz/5.15–5.825 GHz for WLAN, 2.5–2.69 GHz/3.4–3.69 GHz/5.25–5.85 GHz for WiMAX, and 2.5–2.69 GHz for LTE is required.**

***Index Terms*: LTE (Long Term Evolution), 5G (5th generation), WLAN (Wireless Local Area Network), WiMAX (Worldwide Interoperability for Microwave Access), Coplanar waveguide**

I. Introduction

5G is the fifth generation of cellular network technology. The industry association 3GPP defines any system using"5G NR" (5G New Radio) software as,"5G", a definition that came into general use by late 2018. Others may reserve the term for systems that meet the requirements of the ITU IMT-2020.

3GPP will submit their 5G NR to the ITU. It follows 2G, 3G, 4G, and their respective associated technologies (such as GSM, UMTS, LTE, LTE Advanced Pro, and others). In addition to traditional mobile operator services, 5G NR also addresses specific requirements for private mobile networks ranging from industrial IoT to critical communications.

According to various literatures and studies 4G has already reached Shannon capacity. The only way to provide something more in 5G is to make MIMO (Multiple Input Multiple Output) systems. Massive multiple-input, multiple-output, or massive MIMO, is an extension of MIMO, which essentially groups together antennas at the transmitter and receiver to provide better throughput and better spectrum efficiency. This method's ability to multiply the capacity of the antenna links has made it an essential element of wireless standards including 802.11n (Wi-Fi), 802.11ac (Wi-Fi), HSPA+, WiMAX and LTE.

Even after various criticism 5G technology is making its way in communication systems of many countries. Therefore researches on integrating it with LTE and making multiband antenna are going on.

This paper first designs and simulates a wideband triangular antenna, which is based on coplanar waveguide fed monopole antenna design. It has more than 70% bandwidth, very low return loss, greater than 2 dB gain and very good impedance bandwidth. Its operating frequency and bandwidth can be tuned by changing height and included angle respectively. This is the base antenna over which the slots are cut to make it a multiband antenna which is the final antenna proposed in this paper. The structure of the antenna is simple, cost effective and feasible because it can be made on a cheap single sided PCB. It is expected that the simulation and implementation will be in good agreement.

II. CPW Based Triangular Patch Antenna

The base antenna shown in Fig.1 is a triangular antenna that is inherently wideband. The triangular antenna is fed using a coplanar waveguide. The dimensions of the antenna are given in the Table 1. Resonance antennas, such as traditional half-wave dipoles or quarter-wave monopoles made using conducting wires, generally have small bandwidths. The planar versions of dipoles and monopoles have similar characteristics. To increase bandwidth, a wider or taper-shaped resonance element is often adopted. A triangular antenna is a commonly used taper-shaped antenna for broadband applications. The bandwidth of a triangular antenna can be controlled by tuning the included angle. In general, the included angle of a traditional triangular antenna is proportional to the bandwidth. The bandwidth widens as the included angle increases.

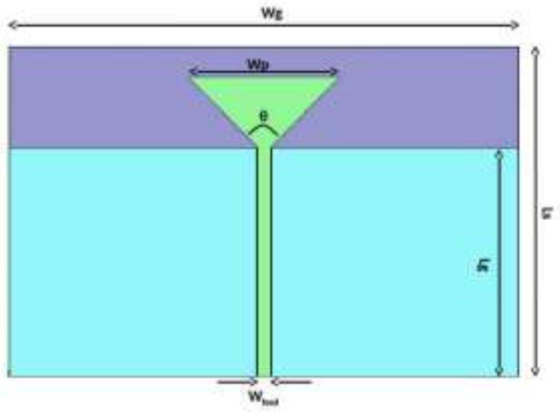


Fig. 1 Base antenna geometry

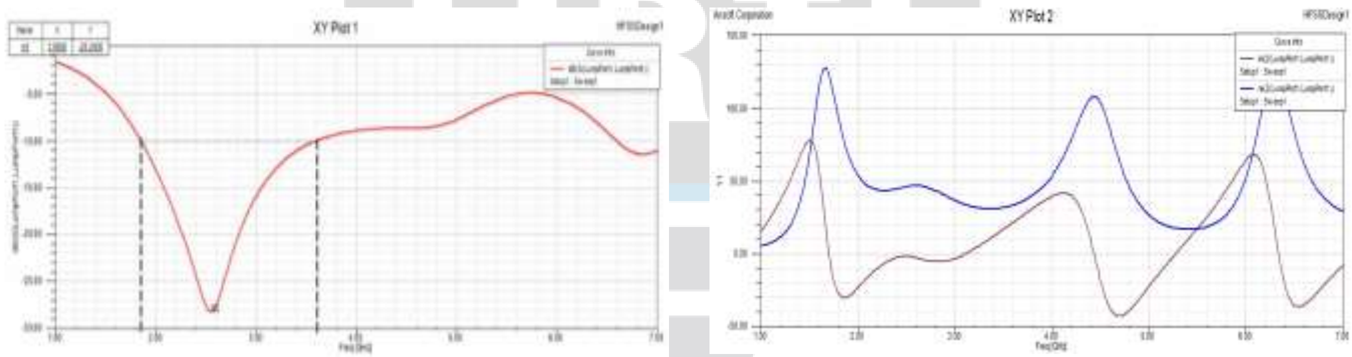
Table 1 Base antenna dimensions

Dimension	**Denotation**	**Value (cm)**
Side length	S	4
Substrate/ground Width	Wg	8
Substrate/ground Length	Lg	7
Substrate Thickness	H	0.159
Port position	(Fx,Fy)	(1.52,1)

Fig. 2 Probe Fed ETMSA

III. Simulation Results of CPW Triangular Antenna

The designed antenna resonates at 2.56 GHz. At the center frequency it has return loss of -28.24 dB. Bandwidth of an antenna is the range of frequency over which it can provide the promised gain, directivity, return loss, input impedance, VSWR and other related antenna parameters. The part of the curve with return loss less than -10 dB is considered the useable operating range of antenna. Antenna has center frequency of 2.56 GHz. The antenna has percentage frequency greater than 70% and can be considered as wideband antenna (Fig. 3b). Input impedance of the proposed antenna mostly around 50 ohms over all the operating bandwidth (Fig 3b). It can be observed that there is no significant change in the input impedance all along the bandwidth.



(a) (b)

Fig. 3 Simulation results of the base antenna

IV. DESIGN OF PROPOSED ANTENNA

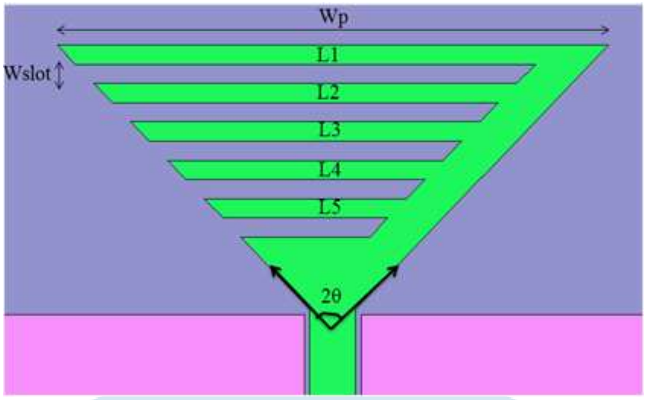
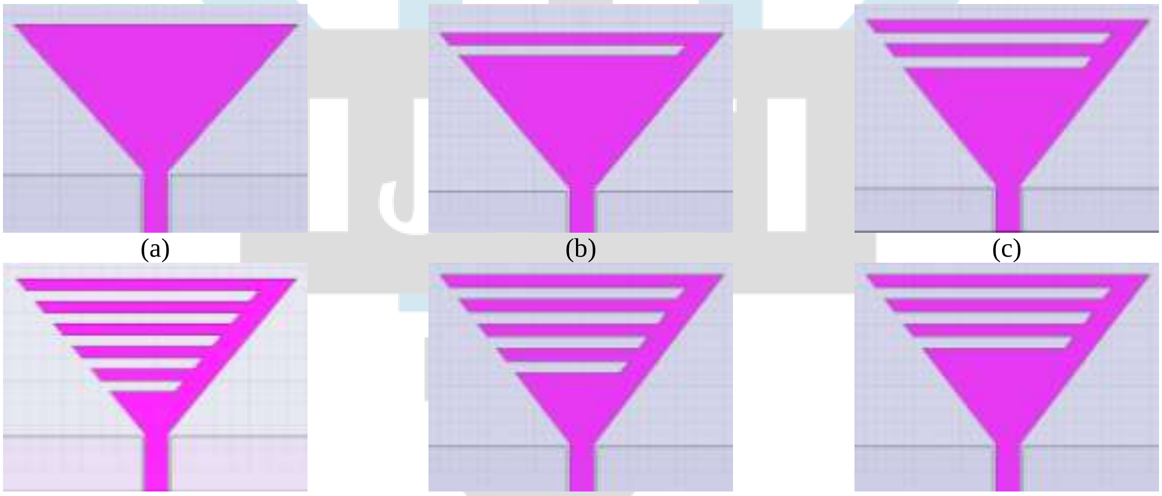


Fig. 4 Proposed slotted antenna

Table 2 Dimensions of proposed antenna

SYMBOL	DESCRIPTION	DIMENSION
Wslot	Width of the slot	1 mm
L1	Length of teeth 1 of the comb	25 mm
L2	Length of teeth 2 of the comb	23 mm, 21 mm
L3	Length of teeth 3 of the comb	19 mm, 17 mm
L4	Length of teeth 4 of the comb	15 mm, 13 mm
L5	Length of teeth 5 of the comb	11 mm, 9 mm

Fig. 4 (a-f) illustrates the proposed CPW-fed multiband monopole antenna which is a combed triangular patch structure. Horizontal slots of different lengths are etched to create horizontal stubs with different central frequencies. A triangular antenna inherently has wideband properties because it can be modelled as a patch antenna with gradually increasing width. Width of a patch antenna has effects on its bandwidth. The bandwidth of a triangular antenna can be controlled by tuning the included angle. In general, the included angle of a traditional triangular antenna is proportional to the bandwidth. The bandwidth widens as the included angle increases. Once the expected behaviour of the antenna is achieved, a slot of 1 mm is made leaving 1 mm length from the broader edge of the triangle. It was expected to get resonance in already available bandwidth. The antenna is simulated after cutting each slot and the results are observed.



(a) (b) (c) (d) (e) (f)

Fig. 5 Process of making combed monopole

The largest stub is supposed to give resonance at lowest frequency and the smallest stub is expected to resonate at highest frequency. This means size of the slot can be adjusted to tune the resonant frequencies. In this thesis, a five-band slotted triangular monopole antenna is designed and measured to validate the proposed approach. The 5 designated operating frequencies are 1.67 GHz, 2.1 GHz, 2.68 GHz, 3.3 GHz and 4.54 GHz for various personal area networks. The antenna is fabricated on a 0.8 mm-thick FR4 substrate with a dielectric constant of 4.2. The simulation was conducted utilizing Ansoft HFSS 11.1.1.

Since the antenna is fed using coplanar waveguide where ground plane and the patch are on the same side of the substrate, a special lumped port have to be designed at the starting edge of the microstrip line as shown in Fig 5.

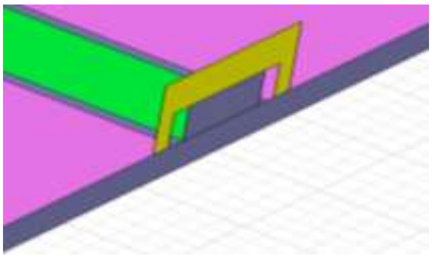


Fig. 6 Feed Port for Coplanar waveguide

V. SIMULATION RESULT OF PROPOSED ANTENNA

Return loss & operating frequencies

Efficiency of an antenna at a given frequency can be estimated by measuring the return loss (i.e. S11 parameter). Return loss of an antenna tells how much supplied power is not used by the antenna. The designed antenna is multiband and resonates at 5 different frequencies. It has return loss of -24.77 dB at 1.66 GHz, -44.35 dB at 2.06 GHz, -22 dB at 2.58 GHz, -31.55 dB at dB at 3.3 GHz and -24.48 dB and 4.54 GHz (Fig 7)

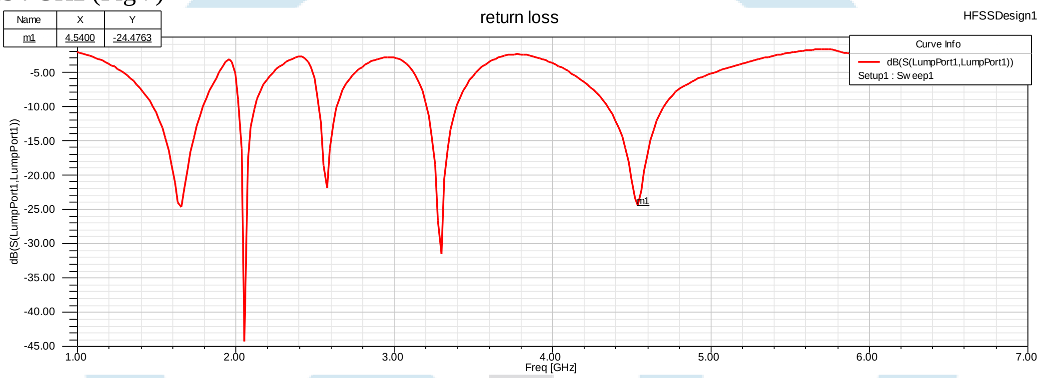


Fig. 7 Return loss

Bandwidth

Bandwidth of an antenna is the range of frequency over which it can provide the promised gain, directivity, return loss, input impedance, VSWR and other related antenna parameters. The part of the curve with return loss less than -10 dB is considered the useable operating range of antenna. Antenna operates over 5 different frequencies and the average bandwidth of the antenna over each operating frequency is around 200 MHz.

Input impedance

Input Impedance of the antenna is the impedance at its terminals or the ratio of the voltage to current at a pair of or the ratio of appropriate components of the electric to magnetic fields at a point. The input impedance of an antenna should be such at it is easily fed and is real rather than complex. Input impedance of the proposed antenna fluctuates around 50 ohms over all the operating frequencies. (Fig 8)

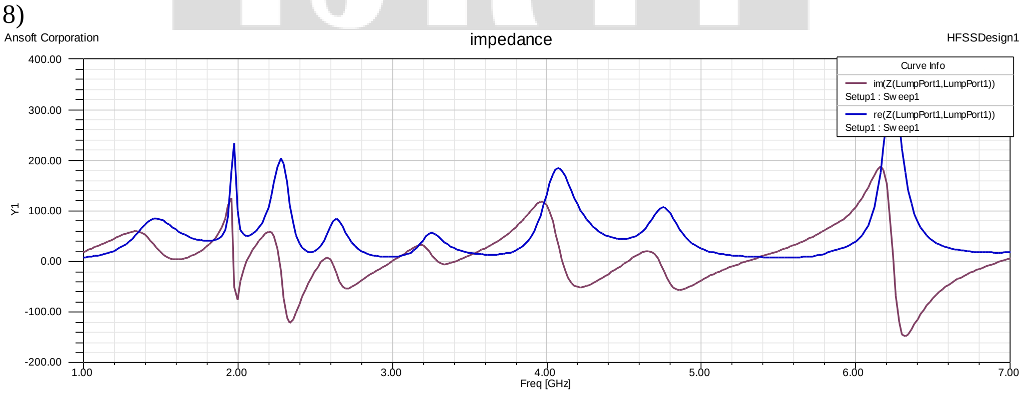


Fig. 8 Input impedance

Radiation pattern

Fig 9 (a-e) shows the radiation pattern of the designed antenna at different operating frequencies. It can be observed that there is no significant change in the radiation pattern with the change in operating frequency. This is because the structure of the antenna is mainly described by included angle and such type of antenna is said to be following Rumsey principle.

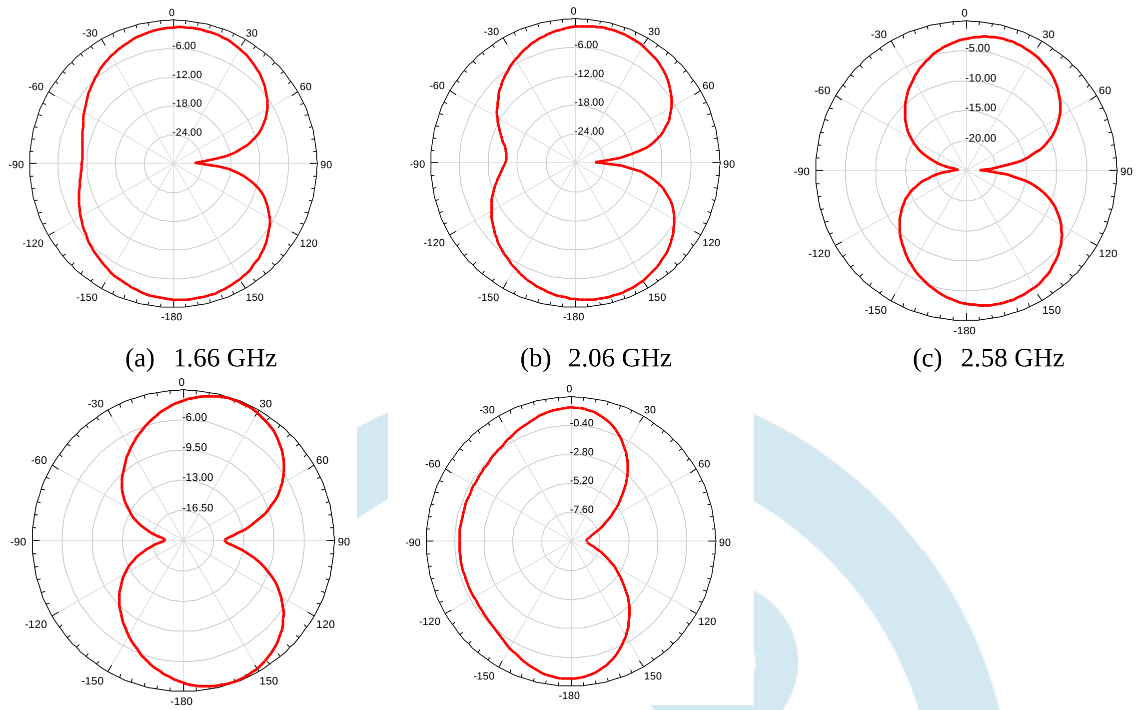


Fig. 9 Radiation pattern at different operating frequencies

VSWR

VSWR (Voltage Standing Wave Ratio) is also an important parameter which gives an estimate of the amount of power reflected to the transmission line that is feeding the antenna. VSWR ideally should be 1 means no power is reflected from the antenna. VSWR of the proposed antenna periodically changing and is very close to 1 at the desired frequencies. (Fig 10)

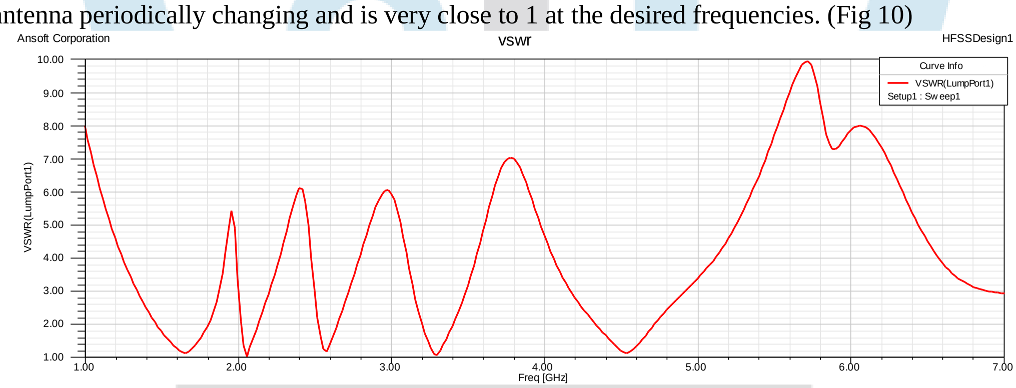


Fig. 10 Voltage standing wave ratio

Smith Chart

Smith chart is used to find unknown impedance. When plotted for an antenna operating over a range of frequency it gives an idea about how the input impedance varies with the change in frequency. Fig 11 show that a curve circulating at the center of the smith chart. It shows that input impedance of the antenna never deviates even when the operating frequency is varied.

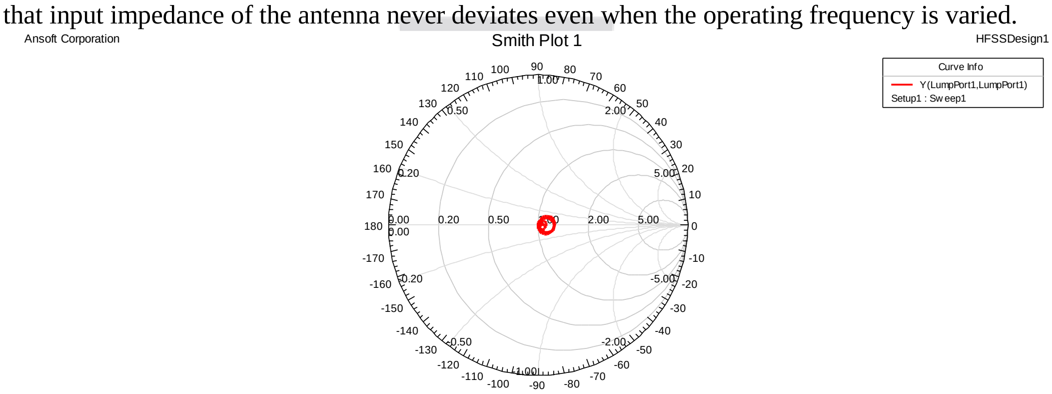
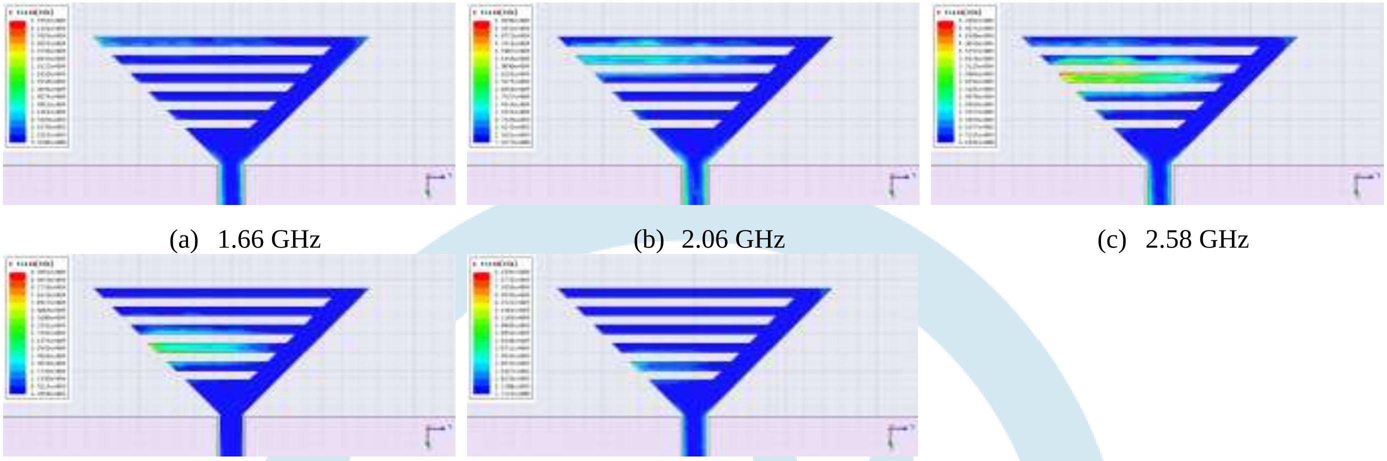


Fig. 11 Smith plot of input impedance

Electric Field distribution

Electric field distribution of a Microstrip antenna show that how far the electric field could travel from the feed point. Since Microstrip antenna is a resonant antenna, it is customary that the electric field will be at its maximum near the port and keep on reducing as the structure moves away. Fig. 12 shows the electric field distribution of the designed antenna at different operating frequencies. It can be seen apparently that every stub resonate at their corresponding frequency. Largest one resonates for the smallest frequency and smallest one resonates for the highest frequency.



(a) 1.66 GHz (b) 2.06 GHz (c) 2.58 GHz

(d) 3.3 GHz (e) 4.54 GHz

Fig. 12 Electric field distribution

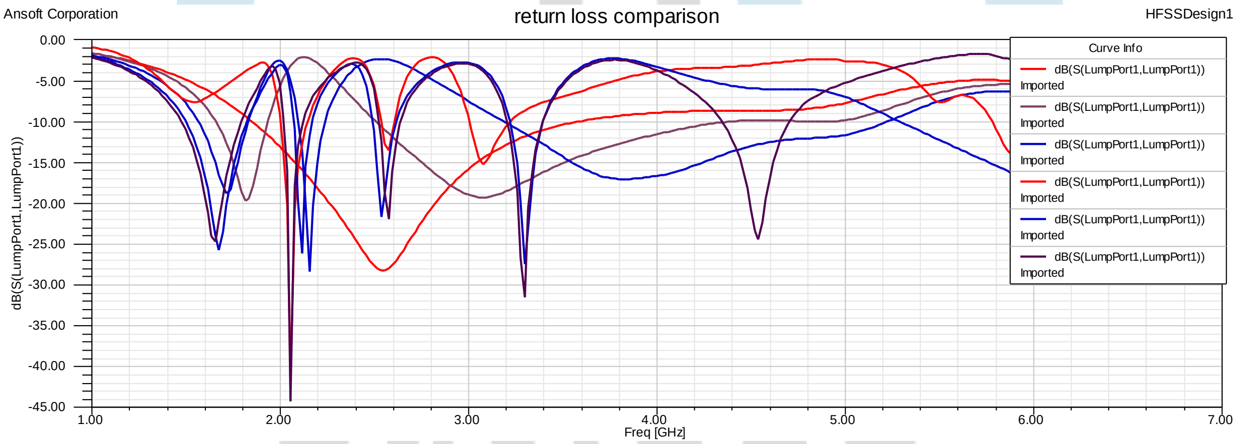


Fig. 13 comparison of return loss at different iterations

VI. CONCLUSION

Nowadays, mobile equipment is required to cover various communication services (Wi-Fi, Bluetooth, GPS, and LTE). In various mobile communication services, long-term evolution (LTE) is one of the widely used communication systems as a fourth-generation wireless service. Because each nation or wireless carrier uses different frequency bands, a multiband antenna is desirable. Moreover, the role of multiband antennas becomes more important because the carrier aggregation technique of LTE-Advanced communication system has been released. Antennas like the one presented here can fulfill these needs.

This work presented a multiband combed triangular antenna and its design procedure, which is based on simple the slotted bow-tie antenna. It can be designed individually for a specified operating frequency. The proposed design approach does not require repeated parameter tuning and time-consuming EM simulation, which are generally required for traditional multiband antenna design. A triple-band antenna for WLAN/WiMAX/LTE applications was designed and manufactured.

In the presented work one can fine tune the operating frequency by changing the length of the stubs and can tune the bandwidth of individual band by changing the width of the stubs. Size of the antenna is very small excluding the ground plane, it can be increased slightly more and to accommodate more bands

REFERENCES

[1] Vasu Babu, Kommana, and Bhuma Anuradha. "Analysis of Multi-Band Circle MIMO Antenna Design for C-Band Applications." Progress in Electromagnetics Research 91 (2019): 185-196.

[2] Yuan Zhu, Min Quan Li and Hong Qing He, "A compact dual-band monopole antenna for 4G LTE and WIFI utilizations," *2016 IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications (IMWS-AMP)*, Chengdu, 2016, pp. 1-4.

[3] Hu, S. , Wu, Y. , Zhang, Y. and Zhou, H. (2013) “Design of a CPW-Fed Ultra Wide Band Antenna”. *Open Journal of Antennas and Propagation*, 1, 18-22.

[4] Zhang, Si-Ming, et al. "A multi-band monopole antenna with two different slots for WLAN and WiMAX applications." Progress in Electromagnetics Research 28 (2012): 173-181.

[5] Foudazi, H. R. Hassani and S. M. A. Nezhad, "Small UWB planar monopole antenna with added GPS/GSM/WLAN bands," *IEEE Trans. Antennas Propag*., vol. 60, no. 6, pp. 2987-2992, Jun. 2012.

[6] Sarawuth Chaimool and Prayoot Akkaraekthalin (2012). CPW-Fed Antennas for WiFi and WiMAX, *Advanced Transmission Techniques in WiMAX, Dr. Roberto Hincapie (Ed.), InTech*, January 18, 2012

[7] R. Zaker and A. Abdipour, “A very compact ultra wideband printed omnidirectional monopole antenna,” *IEEE Antennas Wireless Propag. Lett.*, vol. 9, pp. 471–473, 2010.

[8] Chao-MingWu, "Wideband dual-frequency CPW-fed triangular monopole antenna for DCS/WLAN application", *International Journal of Electronics and Communications*, Volume 61, Issue 9, 1 October 2007, Pages 563-567

[9] J. Y. Jan and C. Y. Hsiang, “Wideband CPW-fed slot antenna for DCS, PCS, 3G and bluetooth bands*,” Electron. Lett.,* vol. 42, no. 24, pp.1377– 1378, Nov. 2006.

[10] Y. S. Shin, S. O. Park, and M. Lee, “A broadband interior antenna of planar monopole type in handsets,” *IEEE Antennas Wireless Propag.Lett.*, vol. 4, pp. 9–12, 2005.

[11] Pozar, David M. "Microstrip antennas." Proceedings of the IEEE 80.1 (1992): 79-91.

[12] Carver, Keith, and James Mink. "Microstrip antenna technology." IEEE transactions on antennas and propagation 29.1 (1981): 2-24.

[13] A. Balanis, “Antenna Theory: Analysis and Design”, 3rd edition, John Wiley & Sons, Inc., Publication.

[14] J.D. Krauss. “Antenna for all applications”, 3rd edition, McGraw Hill publication

[15] D.M. Pozar, “Microwave Engineering”, 2nd edition, John Wiley & Sons, Inc., Publication

[16] Huang and Boyle, “Antennas from theory to practice”, John Wiley & Sons, Inc., Publication

[17] Stutzman and Thiele, “Antenna theory and design”, John Wiley & Sons, Inc., Publication

[18] R. Waterhouse (editor), “Printed antenna for wireless communication” John Wiley & Sons, Inc., Publication