VOL. 10, NO. 23, DECEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

GAMMA SHAPED MONOPOLE PATCH ANTENNA FOR TABLET PC

Islam Md. Rafiqul, Mohammad Shawkat Habib and Khaizuran Abdullah
Department of Electrical and Computer Engineering, International Islamic University Malaysia, Jalan Gombak, Kuala Lumpur, Malaysia
E-Mail: rafiq@iium.edu.my

ABSTRACT

With the increasing demand of using multiple services in a single device, instead of using multiple antennas, current trend is to use single antenna capable of communicating in multiple frequency bands. For the devices like tablet PC, the need of accommodating the physical infrastructure through single multiband antenna is greatly useful. For the multiband operation, a gamma shaped structure is proposed for tablet PC. Gamma shaped monopole structure is designed and simulated using the Computer Simulation Technology (CST) Microwave Studio. The Gamma shape monopole is derived by modification from the original T shaped monopole and the first three resonant frequencies are found to be well improved than the T shaped one. The typical frequencies at 789.5 MHz, 988.1 MHz, 2.088 GHz and 2.376 GHz are having peak gain of 2.94 dBi, 2.11 dBi, 5.81 dBi, 4.84 dBi and radiation efficiencies of 95.57 %, 87.32 %, 96.67 % and 95.36 %, respectively. Compared to the T shaped monopole antenna, the modified Gamma shaped monopole antenna is performing better for the first three resonant frequencies in terms of return loss. This work has achieved to accommodate the multiple frequency bands of GSM750, GSM850, GSM900, LTE800, LTE2300, PCS-1900 and UMTS. Proposed antenna size is 40 *mm* x 15 *mm* that is suitable to fit inside the commercially available tablet PCs.

Keywords: gamma shaped monopole patch, multiband, return loss, tablet pc.

INTRODUCTION

The telecommunication industry has expanded a lot over the past years and the recent market demands small and multifunctional devices. Days of using external antennas for handheld communication devices are long over. Day by day more and more new services are being introduced for the consumers, introducing newer bands of frequencies and creating the need to accommodate greater number of services within a single device. In order to meet those needs, instead of using multiple antennas for connecting to the service providers, market trends to use single antenna capable of communicating in multiple frequency bands. Hence the concept of Multiband antenna comes into existence. Multiband antennas can be defined as the antennas that are designed to operate for a multiple number of frequency bands. It is obtained through the modification of conventional antennas. Out of different types of antennas the most convenient type to use in handheld devices is the microstrip patch antenna, due to its ease of manufacturing and integrability. For the handheld communication devices like the tablet PCs, the use for multiband patch antenna is highly demandable.

The internal GSM/LTE/UMTS antenna occupies a substantial amount of space resulting in less physical distance between the different embedded antennas. It is very important to achieve acceptable isolation between those embedded antennas. Hence, it has become important; to develop such antennas that would be able to meet all the requirements for the tablet computers to get connected using various wireless communication technologies at their defined standard frequencies through maintaining decreased physical structure and replacing multiple antennas with a single one.

Since the introduction of Long Term Evolution (LTE) on the market the wireless devices are required to be able to cover the existing bands and LTE bands. The operating bands are: 700–960 MHz (lower operating band) and 1500–2500 MHz (upper operating band), which also correspond with the LTE bands 1–4 (1710–2170 MHz), 8 (880–960 MHz), 12 (699–746 MHz), 17 (704–746 MHz), 20 (791–862 MHz), 24 (1525–1660 MHz), and 40 (2300–2400 MHz) [1-2]. The embedded antennas being used to satisfy the required operating bandwidth more or less increase the antenna complexity and the fabrication cost. It has also been found that the radiation patterns are multilobe. Sometimes undesired higher-order modes are also excited to cause some distortions in the resultant radiation patterns.

Due to the limited space inside the thin profile tablet computers, the embedded antennas with the smaller planar structure operational at multiband are demandable. This requirement for the long-term evolution/wireless wide area network (LTE/ WWAN) operations that require the antenna to cover a wide lower band of 704–960 MHz and a wide higher band of 1710–2690 MHz is especially challenging [2-3].

DESIGN EQUATIONS

Using (1)-(6) provided in [3,5-7], the desired Length (L), Width (W), Return Loss, VSWR of the MPA can be calculated. Here, the velocity of light (c), the substrate dielectric constant (ε_r), substrate thickness (h), target frequency (f_0), effective dielectric constant (ε_e) and the reflection coefficient (ρ) are used for calculation.

$$W = \frac{c}{2f_0}\sqrt{\left(\frac{\varepsilon_r + 1}{2}\right)} \quad (1)$$

$$L = \frac{c}{2 f_0 \sqrt{\varepsilon_r}} - 2\Delta l \tag{2}$$

$$\varepsilon_e = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{2}(\varepsilon_r - 1)\sqrt{\left(1 + \frac{10h}{W}\right)} \tag{3}$$

$$\Delta l = 0.412h \frac{(\varepsilon_e + 0.3)\left[\frac{W}{h} + 0.8\right]}{(\varepsilon_e - 0.258)\left[\frac{W}{h} + 0.8\right]} \tag{4}$$

$$VSWR = \frac{1+\rho}{1-\rho} \tag{5}$$

$$\mathrm{Re}\,turnLoss = -10\log\left(\frac{1}{\rho^2}\right) \tag{6}$$

Through the usage of these equations the basic patch antenna parameters can be selected.

OPERATING FREQUENCIES OF VARIOUS APPLICATIONS

The applications of 2G, 4G/LTE depend on the communicating frequencies of different bands which are given in Table-1.

Table-1. Frequency bands applicable to the reported antenna in [4][6].

Band	Frequency range (MHz) UL:Uplink, DL:Downlink	Application
GSM-750	747~762 (UL) 777~792 (DL)	2G
GSM-850	824~849 (UL) 869~894 (DL)	2G
GSM-900	870~915 (UL) 915~960 (DL)	2G
LTE-800	815~830 (UL) 860~875 (DL)	4G
PCS-1900	1850~1910 (UL) 1930~1990 (DL)	2G
UMTS	1920~1980 (UL) 2110~2170 (DL)	3G
LTE-2300	2300~2400 (UL & DL)	4G

PROPOSED DESIGN

In the work of Lu & Wang [2], the T-shaped monopole geometry is proposed to achieve the multiband functionality applicable to tablet pc. Since there are no specific formulas that relates to the complex geometry and antenna behaviour similar to the one being presented in [2], the structures that were related to the multiband patch antenna were simulated with a view to identify parameters that could reveal design guidelines in terms of input match (S11), substrate thickness and radiation efficiency.

The FR-4 substrate having dielectric constant of 4.3 with thickness of 0.8mm was taken as a base on which the copper printed design was analyzed. The lengths of the different parts of the uniplanar antenna were varied and the effects were analyzed. The complexity of the proposed antenna with different geometric shapes makes the simulation intricate. The changes in the geometric shapes improved the antenna characteristics through sweeping the parametric values one at a time. In such procedure, the initial structure is replicated multiple times at different scales and with modified structures.

The analysis of the parameters done in the previous sections is used to design the proposed Gamma (monopole shaped liked Gamma) shaped monopole improved antenna and presented in Figure-1. It displays the schematic of proposed Gamma shaped monopole antenna having internal printed matching circuit for the UMTS/GSM/LTE operation in the tablet computer. It is observed that the left arm length of L2 in [2] is responsible for improving the return loss of the lower band frequencies and the arm L3 has hardly any effect on the performance of the antenna. The other portions of the antenna plays important role on the higher band frequency outputs. Therefore the arm of L2 is fully removed from the structure and modifying the L3 along with some other modifications in length improves the results.

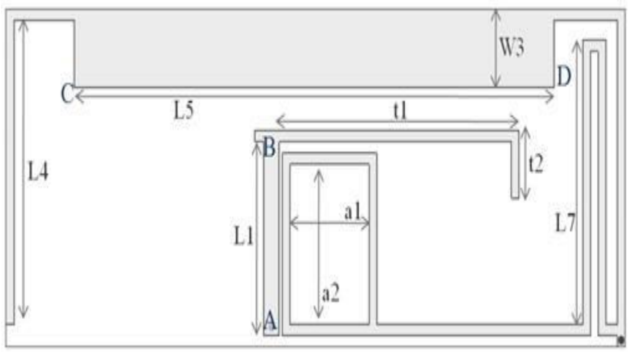

Figure-1. The proposed gamma shaped monopole antenna structure.

The antenna is printed on one side of single side copper clad FR4 substrate consisting dimension of 40 x 15 x 0.8 mm^3, loss tangent 0.025, and relative permittivity 4.3. The fabricated antenna is mounted along the top-right 2.85 mm inside from the outer edge of the display ground. The selective proper dimensions of the proposed Gamma shaped monopole uniplanar printed antenna are provided in the Table-2. A 0.2 mm thick copper plate is used as the display ground and the tablet computer's size is considered as 10 inch, which is available commercially in the market for this work.

The required parameter values used in the proposed antenna structure are presented in Table-2.

Table-2. Designed parameters of the proposed gamma shaped monopole microstrip patch antenna.

Parameters (*mm*)	Values	Parameter s(*mm*)	Values
L1	8.6	L2	0.6
L3	0	L4	14
L5	31	L6	15
L7	12.6	W1	1
W2	0.5	W3	3.5
a1	5.1	a2	7.1
t1	15	t2	3
Thickness of substrate, h	0.8	Thickness of copper, mt	0.1
Dielectric Constant, ε_r	4.3	Dissipation Factor, tan δ	0.025

RETURN LOSS

The simulated return loss in dB for the proposed antenna schematic of which is shown Figure-1, is presented in Figure-2.

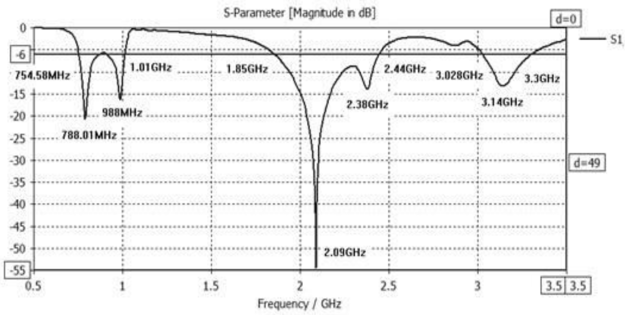

Figure-2. Simulated result of S11 in dB for the proposed Gamma shaped monopole uniplanar antenna.

The lower band presents a measured VSWR of 3:1 (6 dB return loss) bandwidth of 212.83 MHz (754.58–869.32 MHz & 911.91 MHz - 1.01 GHz), on the other hand the higher band has a bandwidth of 590 MHz (1.85–2.44 GHz). The desired GSM/UMTS/LTE operation can be met up with the obtained frequency bands. Considering upto 3 GHz, there are four resonant frequencies which are at 788.01 MHz, 988 MHz, 2.09 GHz and 2.38 GHz.

CURRENT DISTRIBUTION

For the analysis of the radiation of the antenna and the resonant frequencies, it is important to analyze the current distribution, which will be discussed in this section. The excitation of the particular GSM/UMTS/ LTE bands, surface current distributions on the Gamma-shaped driven monopole internal printed loop matching circuit at resonant frequencies are shown in Figure-3 (a)0.7895 GHz, (b)0.9881 GHz, (c)2.088 GHz, and (d)2.376 GHz.

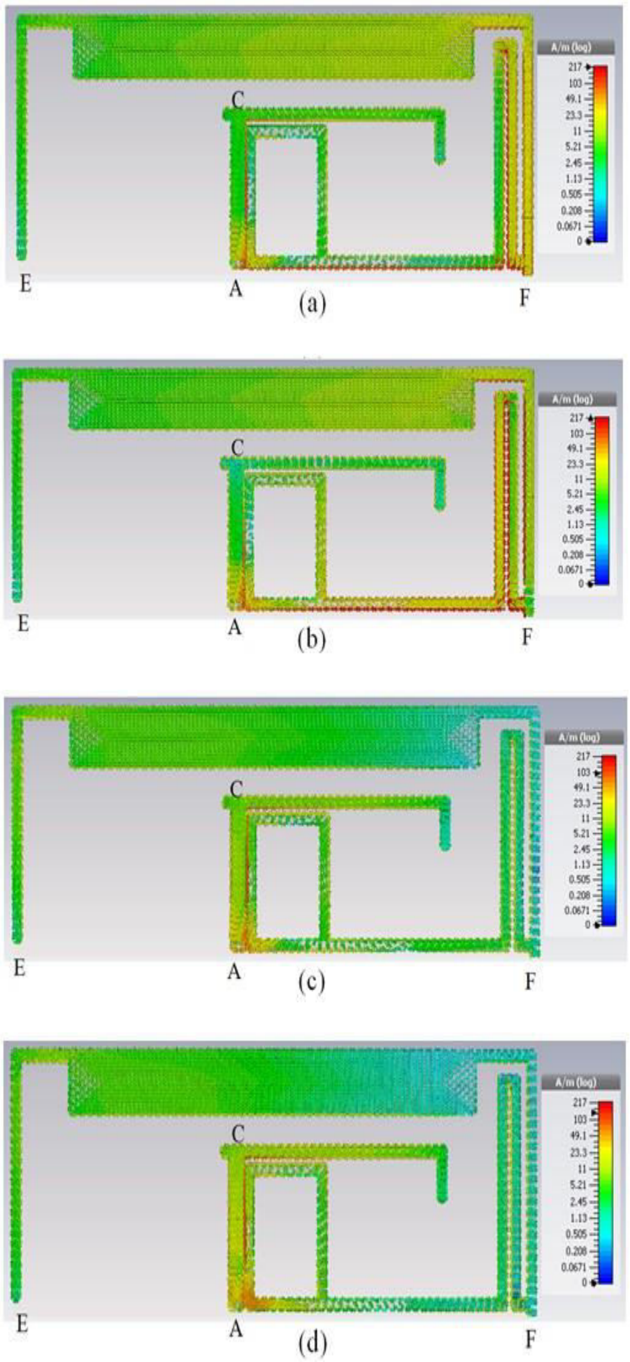

Figure-3. Simulated surface current distributions at (a)0.7895 GHz, (b)0.9881 GHz, (c)2.088 GHz, and (d)2.376 GHz, on the proposed Gamma shaped monopole uniplanar printed antenna.

From the surface current distributions in Figure-3 (a), the fundamental mode at 789.5 MHz is found to be excited at point F of the parasitic shorted strip, consisting of a 0.2 wavelength. the surface current is found to be rising in strength at the point F of shorting and the surface current gradually decrease to null towards the end point of the shorted strip at point E. Similarly from Figure-3 (b), the matching loop integrated with a shorted strip is excited at its fundamental mode at 988.1 MHz with maximum

VOL. 10, NO. 23, DECEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

strength along the shorted strip portion (section KF). Then, at 2.088 GHz, strong surface current on the main driven monopole AC of the Gamma-shaped driven monopole are observed in Figure-3(c), which indicate that the first mode of the upper band is mainly contributed by the driven monopole. Finally from Figure-3(d), at 2.376 GHz, there is a surface current along the main driven monopole AC and the closed loop resonator, which indicates that those parts are responsible for the second resonant frequency in the higher band.

RADIATION PATTERN

The simulated radiation patterns at resonant frequencies are provided in Figure-4.

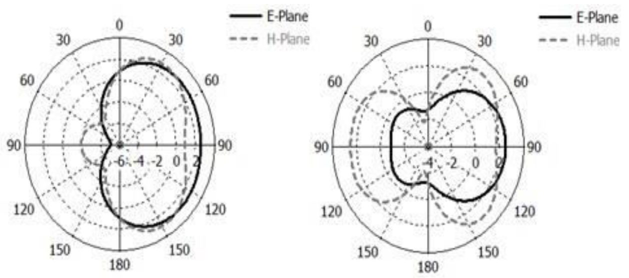

Figure-4. Two-dimensional (2-D) radiation patterns at (a) 0.7895 *GHz* and (b) 0.9881 *GHz* for the proposed gamma shaped monopole antenna.

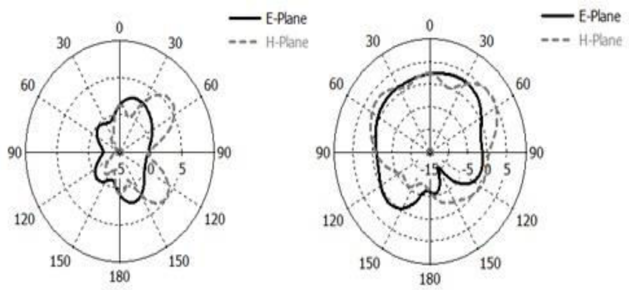

Figure-5. Two-dimensional (2-D) radiation patterns at (a) 2.088 *GHz* and (b) 2.376 *GHz* for the proposed gamma shaped monopole antenna.

At frequencies (a) 789.5 MHz and (b) 988.1 MHz in the antenna's lower band, the radiation patterns are found to be dissimilar to the patterns of dipoles. At higher frequencies (2.088 and 2.376 GHz) in the antenna's upper band, relatively high variations in the radiation patterns (Figure-5) are observed. The beam symmetry is satisfactory.

ANTENNA EFFICIENY

The radiation efficiency of the antenna is also calculated and simulated in the Figure-6. It is seen that the measured antenna efficiency is about 77.48 % ~ 99.43 % over the lower bands, while that over the higher bands is about 93.96 % ~ 97.48 %. The resonant frequencies are all found to be having efficiency above 87 %.

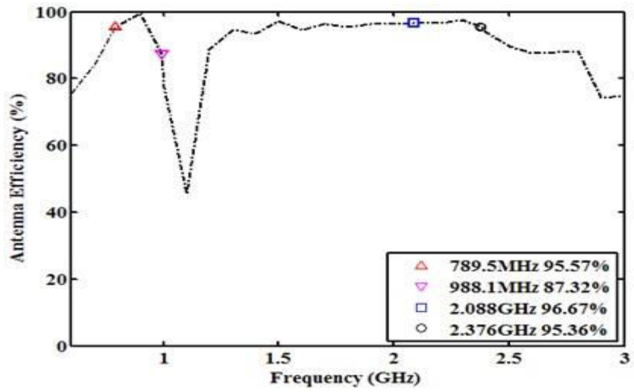

Figure-6. Simulated radiation efficiency of proposed gamma shaped antenna.

PEAK GAIN

The peak gains of the antenna in the Figure-1 at typical frequencies are found to be satisfactory as they are above the standard 2.1 dBi isotropic antenna gain limit. The simulated peak gain for lower band and the higher band are provided in Figure-7.

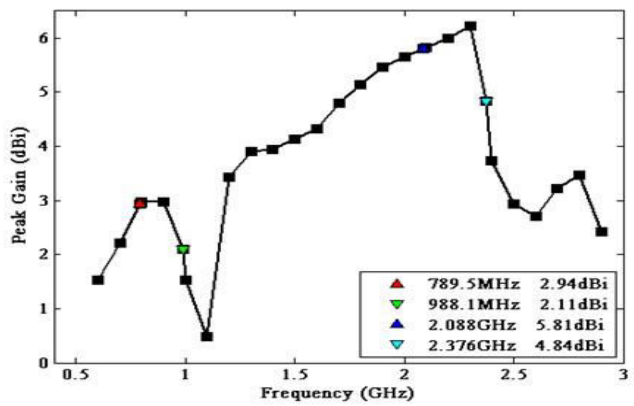

Figure-7. Simulated peak gain for the proposed gamma shaped antenna at (a) Lower bands, (b) Higher bands.

From the Figure-7 it can be observed that the peak gain at 789.5 MHz, 988.1 MHz, 2.088 GHz and 2.376 GHz are 2.94 dBi, 2.11 dBi, 5.81 dBi and 4.84 dBi respectively

INPUT IMPEDANCE

The proposed antenna's input impedance is presented in Figure-8. It can be observed that the first peak of the real part of the input impedance is 72.39 ohms and the second peak at 209.46 ohms, whereas the third, fourth and fifth peak at 54.64 ohms, 75.32 ohms and 157.26 ohms respectively. It can be referred that the third peak at 54.64 ohms is closest to the 50 ohms impedance matching connector feed and therefore it can be seen from Figure-2 that the resonant frequency at 2.088 GHz is having the best radiation as the return loss is around -55 dB. The overall input impedance diagram is well represented similar to the monopole antenna input impedance diagrams.

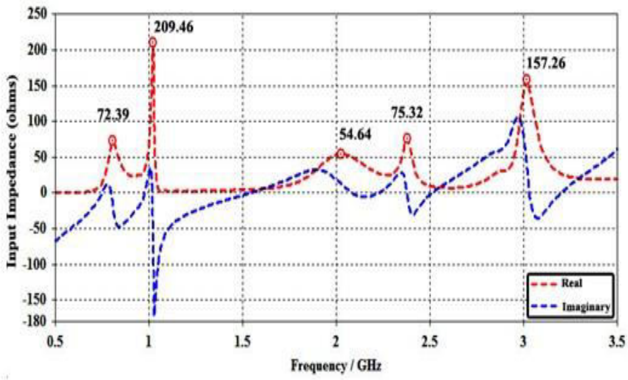

Figure-8. Input impedance (simulated real and imaginary part) of the proposed Gamma monopole antenna.

The detailed characteristic information of the Gamma shaped monopole antenna is provided in Table-3:

Table-3. Gamma shaped monopole antenna properties.

Resonant Frequency (GHz)	Peak gain	Radiation efficiency	Input Impedance
0.7895	2.94	95.57	72.39-j19.35
0.9881	2.11	87.32	209.46-j170
2.088	5.81	96.67	54.64+j12.29
2.376	4.84	95.36	75.32-j4.25

CONCLUSIONS

The Gamma shape monopole is derived from the original T shaped monopole and the first three resonant frequencies are found to be well improved than the original T shaped one. The typical frequencies at 789.5 MHz, 988.1 MHz, 2.088 GHz and 2.376 GHz are having peak gain of 2.94 dBi, 2.11 dBi, 5.81 dBi, 4.84 dBi and radiation efficiency of 95.57 %, 87.32 %, 96.67 % and 95.36 % respectively. The input impedances are also found to be agreeable with the radiation efficiency and peak gain as the first, second, third and fourth peaks are found at 72.39-j19.35 ohms, 209.46-j67.03 ohms, 54.64+j12.29 ohms and 75.32-j4.25 ohms respectively. Compared to the T shaped antenna, the Gamma shaped monopole antenna is performing better for the first three resonant frequencies in terms of return loss and is found to be strengthened by 107 %, 48.82 % and 202.17 % respectively. Finally the simulated result has achieved to accommodate the frequency bands of GSM750, GSM850, GSM900, LTE800, LTE2300, PCS-1900 and UMTS.

ACKNOWLEDGEMENT

Authors are grateful to Kulliyyah of Engineering and Research Management Center, International Islamic University Malaysia to support this research.

REFERENCES

[1] Shen S., Chen I., Peng C. and Lin D. 2013. Printed Asymmetric Dual-Dipole Antenna for Tablet PC Applications. IEEE Antennas and Wireless Propagation Letters, 12, 1003-1005. doi:10.1109/LAWP.2013.2277877

[2] Lu J. and Wang Y. 2013. Internal Uniplanar Antenna for LTE/GSM/UMTS Operation in a Tablet Computer. IEEE Transactions on Antennas and Propagation, Vol. 61, No. 5, pp. 2841-2846. doi:10.1109/TAP.2013.2243693.

[3] Habib M.S., Rafiqul I., Abdullah K. and Jakpar M. 2014. U-Slot Rectangular Patch Antenna for Dual Band Application. Springer International Publishing Advanced Computer and Communication Engineering Technology, Vol. 315, pp. 111-120. doi:10.1007/978-3-319-07674-4_12.

[4] Chang S. and Liao W. 2012. A Broadband LTE/WWAN Antenna Design for Tablet PC. IEEE Transactions on Antennas and Propagation, Vol. 60, No. 9, pp. 4354-4359. doi: 10.1109/TAP.2012.2207075.

[5] Mohd. Moniruzzaman, Md. Rafiqul Islam, Kamaruzzaman Sopian and Saleem H. Zaidi. 2011. Clustered Particle Swarm Optimization for Planar Antenna Design, Journal of Science, Technology and Environment, ISSN: 2324-1857, Vol. 2, No. 1, pp. 46-48.

[6] Abutarboush H., Nasif H., Nilavalan R. and Cheung, S. 2012. Multiband and Wideband Monopole Antenna for GSM900 and Other Wireless Applications. IEEE Antennas and Wireless Propagation Letters, Vol. 11, pp. 539-542. doi:10.1109/LAWP.2012.2198429.

[7] A.H.M. Zahirul Alam, Md. Rafiqul Islam, Sheroz Khan, Nik Noor Atikah Nik Mohd. Salleh and Noraini Aziz. 2009. Tunable Bandpass Filter Using RF MEMS Switches, IIUM Engineering Journal (ISSN: 1511-788X), Vol. 10, No. 2, 2009, pp. 69-79.