A Design of the Low Profile Tri-band Antenna for ECS application

Jeong-Hoo Kim[#1], Dong-Zo Kim[#2], Moon-Que Lee*[3], Sang-Bo Min@[4], and Jong-Won Yu[#5]

[#]*School of Electrical Engineering and Computer Science, Korea Advanced Institute of Science and Technology, Daejeon, 305-701, Korea*

[1]purplejuice@kaist.ac.kr

[2]kdzgnh@kaist.ac.kr

[5]drjwyu@kaist.ac.kr

[*]*The University of Seoul (UOS), Seoul Korea*

[3]mqlee@uos.ac.kr

[@]*Actenna Co., Seoul, Korea*

[4]sam911@paran.com

***Abstract*— This paper presents a design procedure of a low profile triband antenna operating at three frequency bands (900MHz, 1575MHz, 1800MHz). The proposed antenna consists of a curved folded dipole, ceramic patch antenna and diplexer. Due to the shape of the proposed antennas, the total dimension of this structure occupies very small space. The antenna shape is designed to improve the overall performance and the dimensional efficiency. A diplexer after two folded dipole antennas can transfer the signal by using only one cable, thus it is a great portion of the cost reduction.**

I. INTRODUCTION

Very low profile folded antennas have been a good model for mobile communication device or automobile application. [1] Today, vehicles are equipped with the various antennas such as a Global System for Mobile communication (GSM), Global Positioning System (GPS), Digital Communication System (DCS), Bluetooth and Radio. Among these antennas, the GSM, DCS and GPS antennas are used for Emergency Call System(ECS) which notices the local information of a driver. [2] When a driver has an accident, this system is used to send map information or airbag deployment to an emergency center automatically. Therefore this system can be expected to reduce up to 15% of the deceased due to car accident. [3] In the ECS system, the GSM band, which operates at 890~960 MHz, DCS band, which operates at 1710~1880 MHz, and GPS band, which operates at 1575 MHz, are used.

General antennas for communication or GPS system are placed on the top of a vehicle, so 3 long cables will be needed from antennas to the Digital Signal Processing(DSP) module. Generally, the cables are very long (nearly 2-3m) and most expensive parts in this system.

In this paper, the diplexer to reduce the total cost of production and decrease other signal level on own line are presented and for thin and compact antenna structure, we propose a low profile folded multi antennas. Since the proposed antenna is very thin and compact, it occupies very little space and can be attached on any places or any devices. Since this structure has two folded dipole antennas for GSM/DCS band and one ceramic patch antenna for GPS band, it acts as triple band antenna. In addition, this paper discusses the overall performance of the antenna and diplexer on each operating frequency bands.

II. MULTI ANTENNA AND DIPLEXER DESIGN

Fig.1 shows the block diagram of the proposed system. This system includes two folded dipole antennas and one ceramic patch antenna in the same substrate. Two folded dipoles operate at GSM and DCS band respectively. The operating frequency of the patch antenna is set at the GPS band. To reduce the dimension and the price of the antenna system, a diplexer is introduced. After two folded dipole antennas, two lines enter to the diplexer and the output of the diplexer is connected to another diplexer of the GSM/DCS module part. The GPS antenna is directly connected to the SAW filter and LNA, and it amplifies the GPS signal. Then, the amplified GPS signal is transferred to the GPS module placed on the side of GSM/DCS module.

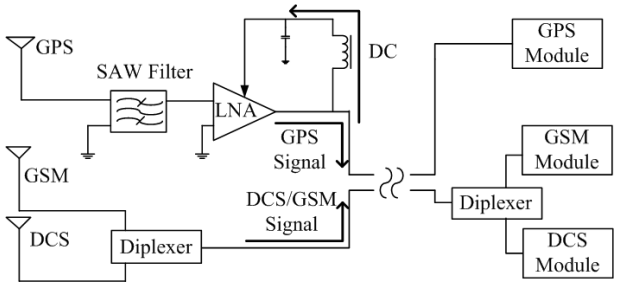
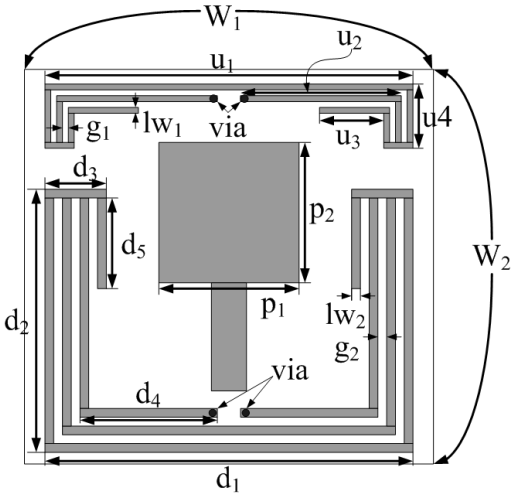


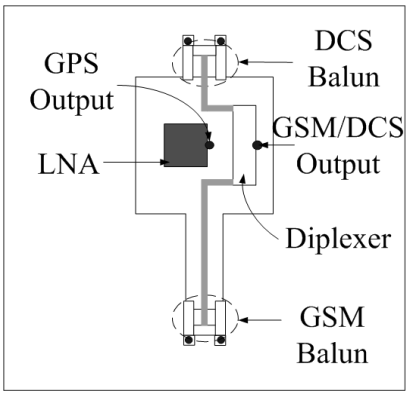
Fig.1 Block diagram of the proposed system.

Fig.2 shows the geometry of the proposed GSM/DCS and GPS antennas. The basic structures of the GSM/DCS antennas

are the folded dipole type and GPS antenna is a patch type. The GSM/DCS antennas are fabricated on a 0.6mm FR4 substrate and the ceramic patch antenna is applied to a GPS antenna. The GSM dipole antennas are composed of three thin lines and the frequency tuning line. Three strip antenna lines are curved to achieve a compact antenna configuration and to fit the GPS patch antenna dimension. Since the curved dipole has very low antenna impedance, the folded dipole structure is introduced for impedance matching.[4] The GSM balun is attached on the bottom side of the antenna through the vias and transfers the signal to the diplexer by microstrip line. In this substrate, all the etched antenna line width (lw) and gaps (g) between the lines are 1mm in GSM band, 0.7mm in DCS band.



(a) Top side of the antenna structure



(b) Bottom side of the antenna structure

Fig. 2 The geometry of the GSM/DCS, GPS Antennas

The DCS structure is very similar to the structure of the GSM antenna. It is placed on the upper side of the GSM antenna and has two curved arms and the frequency tuning lines each side. The curved antenna arms consist of two strip lines and are connected to DCS balun on the bottom side of the substrate. The received DCS signal enters to the other port of the diplexer and transfers to the module part with the GSM signal using same cable. The geometrical parameters of GSM/DCS antenna are listed in TABLE I.

The ceramic patch antenna is used as the GPS antenna. The patch size is 25 x25 mm and the height is 4 mm. The location of patch antenna affects capacitance of the GSM/DCS dipole antennas. Hence, the patch antenna is placed to satisfy the bandwidths and the center frequencies of two dipole antennas. The ground acts both ceramic patch antenna and other components. In bottom of the substrate, baluns, SAW filter, LNA, microstrip lines and diplexer are placed additionally. The SAW filters can make sufficient isolation to protect the LNA saturation. Hence, the received GPS signal is directly transferred to the LNA for amplification and then signal is forwarded to the GPS system module by the cable.

TABLE II
DIMENSIONS OF THE GSM/DCS/GPS ANTENNAS (mm)

GSM Antenna				**DCS Antenna**			
d_1	50	d_2	43	u_1	50	u_2	22
d_3	7	d_4	18	u_3	9	u_4	9.7
d_5	17			lw_2	0.7	g_2	0.7
lw_1	1	g_1	1				
Patch Antenna & Substrate							
p_1	25			p_2	25		
W_1	55			W_2	61		

TABLE II
DIPLEXER PARAMETERS

L_{11}	10 nH	L_{12}	4.7 nH
L_{13}	3.9 nH	C_{11}	1.5 pF
C_{12}	0.68 pF		
L_{21}	3.9 nH	L_{22}	6.8 nH
C_{21}	2 pF	C_{22}	1.5 pF
C_{23}	7 pF		

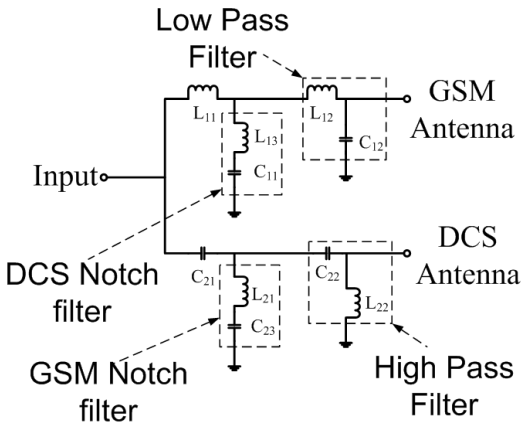


Fig. 3 Diplexer Schematic

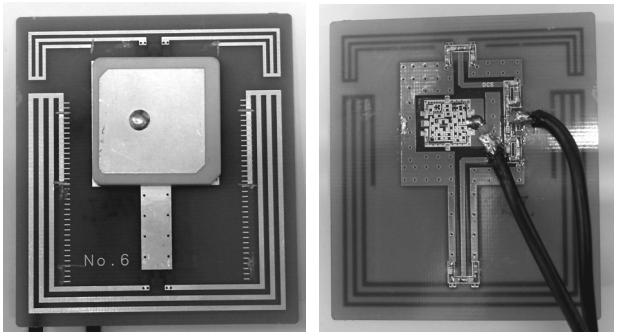


Fig. 4 Fabricated antenna substrate.

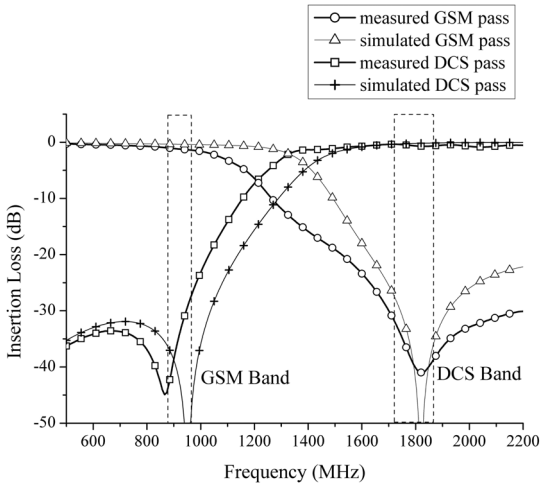


Fig. 5 Simulated and measured response of a diplexer.

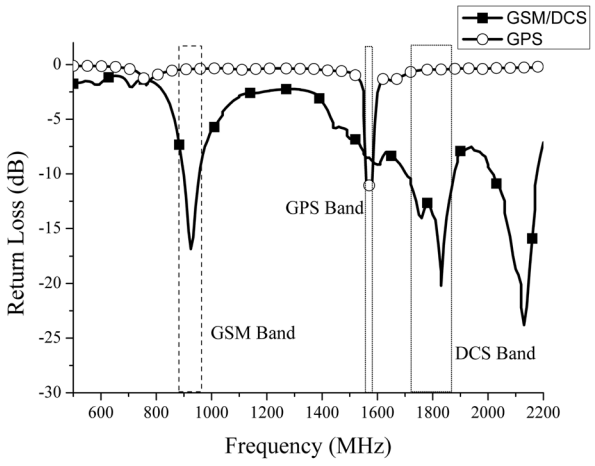


Fig. 6 Measured the GSM/DCS return loss with a diplexer and the GPS return loss for proposed antennas.

Fig.3 depicts the schematic of the proposed diplexer. All parts of the diplexer are implemented with of the lumped elements. The diplexer consists of lowpass filter (LPF), highpass filter (HPF) and two notch filters. The HPF is connected to the DCS antenna and LPF is connected to the GSM antenna. The notch filter is utilized to minimize the effect of the signal from other part signal because the other signal level is much higher than ordinary signal. By using the notch filters, in the pass band, the transmission loss is zero, which can enhance the isolation between the operating frequencies. The diplexer parameters are specified in TABLE II.

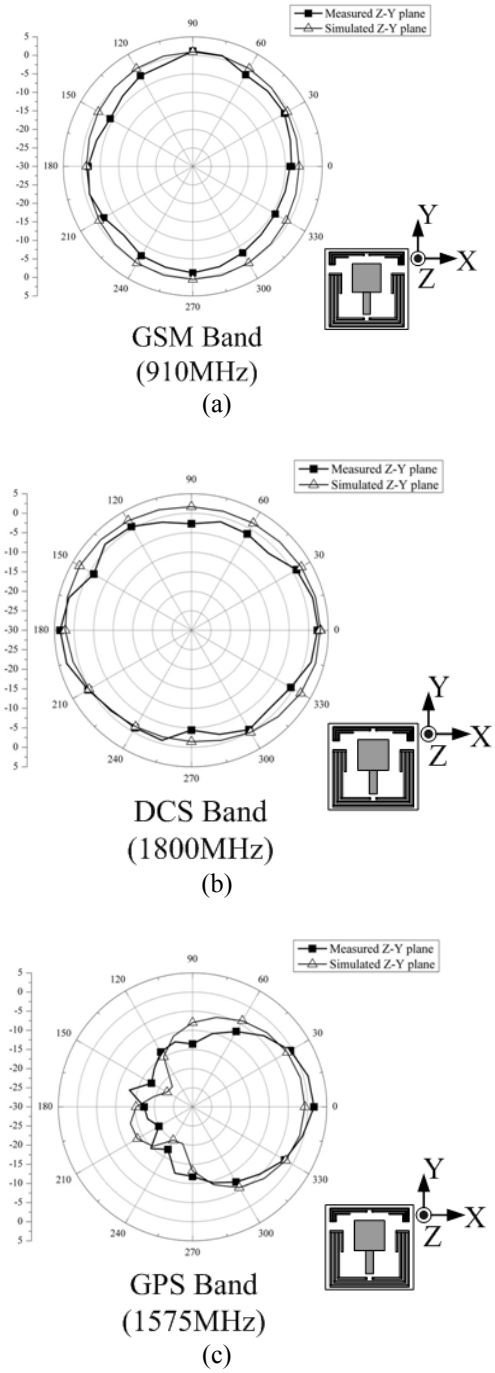


Fig.7 Simulated and measured radiation pattern on Z-Y plane (a) GSM band; (b) DCS band; (c)GPS band

III. SIMULATION AND EXPERIMENTAL RESULTS

The proposed antenna structure was fabricated on a FR4 substrate as shown in Fig.4. The substrate size is 61 x 55 (mm^2) and thickness is 0.6 (mm). Two curved folded dipole antennas and the ceramic patch antenna are placed on the top side, while baluns, LNA and diplexer are placed on the bottom side of the substrate.

The insertion loss and the return loss of the diplexer are presented in Fig.5. The simulated data was obtained by using Agilent ADS. The simulated and measured insertion loss of the diplexer are 0.3dB ~ 0.5dB in each pass band. In the other frequency parts, because of a notch filters, the measured insertion loss is -27dB ~ -45dB in GSM band and -30dB ~ -41dB in DCS band. This property of the diplexer can achieve high selectivity in antenna system.

Fig.6 shows the implementation of the return loss between two curved dipole with the diplexer and the GPS patch antenna. From the measured data, two frequencies at 900MHz and 1800MHz are in resonant mode. The return loss of the antenna system with the diplexer is -8 ~ -16 dB in GSM Band, and -10 ~ -20 dB in the DCS 1800 band, which also satisfy the bandwidth of the GSM and DCS frequency band. The GPS patch antenna has sharp S11 property in the GPS band, and the return loss is nearly -11dB.

Fig.7 shows the radiation pattern of the proposed antenna structure. The peak gains of GSM and DCS band are 1.2dBi and 3.5dBi. Since the ground of the patch antenna is placed on the center of the substrate, the ground works as the director for both GSM and DCS antennas. The maximum RHCP gain of the GPS antenna is measured about 1.5dBic.

IV. CONCLUSIONS

In this paper, a low profile GSM/DCS/GPS triband antenna system for ECS application has been investigated experimentally. Having two curved folded dipole and the ceramic patch antenna implemented, the dimension of the antenna structure can be realized as thin and compact. The diplexer reduces the number of the cables and the cost of the antenna system gets lower than conventional system. Peak gain of each implemented dipole antenna is about 2.1~3.5dBi and the RHCP of the patch antenna is above 2.5dBc at each operating frequency band.

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