Basic Performances of Handset MIMO Antenna using L-shaped Folded Monopole Antennas

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1. Introduction

In the previous study [1], a built-in L-shaped folded monopole antenna (LFMA) has been proposed and its fundamental performances have been analyzed and compared with those of PIFA, taking application to the handset MIMO system into consideration. The LFMA has been found to have similar bandwidth (the relative bandwidth for VSWR≤2 was about 19% at the frequency of nearly 2GHz) and the physical volume was miniaturized up to about 44% of PIFA.

The purpose of this study is to evaluate the basic performances of handset MIMO antenna comprising two LFMA elements mounted on a finite ground plane (GP), under practical use conditions, involving multipath radio wave propagation environment. The fundamental antenna characteristics will be analyzed both theoretically and experimentally, at the first, and then the mean effective gain (MEG) and the correlation characteristics between the two antenna branches will be estimated theoretically with regard to the handset inclination angle from the vertical. In the estimation of the MEG and correlation characteristics, the same method and propagation conditions are used as the literature [2], [3]. In the theoretical analysis, the electromagnetic simulator based on the Finite Integration Method (FIM) is used.

2. Antenna Configuration

Fig.1 shows the configuration of the antenna analyzed in this study and its coordinated system. This antenna consists of two LFMA elements symmetrically installed on the top of a rectangular GP, which represent a shielding plate used in the handset unit, and separated by a very small spacing (d=7mm=0.05λ0). The antenna parameters have been adjusted so that they resonate at the frequency of nearly 2GHz: l1=13mm, l2=14mm, w1=w2= 5mm, h=7mm, b=0.5mm, wg=45mm, lg=120mm. The overall length of each antenna is about 0.6λ0. The antenna element and GP are made of copper plates with thickness of 0.2mm and 0.5mm, respectively. The handset is assumed to be inclined toward x-axis at angle α from the vertical under practical use conditions in a display-viewing position.

3. Analytical Results

The simulated and measured S-parameters are shown in Fig.2. As shown in the figure, a good agreement is observed between the simulated and measured results. The resonant frequency appears at the frequency of 2.1GHz and the bandwidth for the reflection coefficient (S11)≤-10dB is about 300MHz (the relative bandwidth is about 14%) for the simulated result. The mutual coupling (S21) between two LFMAs reaches a maximum of -10.0dB at 2.07GHz for the measured result and -10.8dB at 2.05GHz for the simulated result, where is approximately the middle of resonant band. This is not such a high value if we take into account that both antennas are separated by a distance of 0.6λ0 and located on a 0.3λ0×0.8λ0 GP.

Fig.3 shows the simulated surface current distributions of antenna at the frequency of 2.1GHz: (a) in case only LFMA#1 excited and LFMA#2 terminated to a 50Ω load, and (b) in case both antennas excited with same amplitudes and phases. As shown in Fig.3(a), the excited LFMA#1 induces currents of high magnitude around the feed and short strips of itself and the short strip of
the terminated non-excited LFMA#2, but only small currents flow on the other GP surface, as is similar to the previous study [1]. Also in Fig.3(b), relatively small current flows are observed even if both antennas are excited. Those results show that the effects due to the human hand can be reduced for LFMA.

The simulated and measured gain radiation patterns of LFMA#1 for the inclination angle of handset $\alpha=0^\circ$ when LFMA#2 is terminated to a 50$\Omega$ load are shown in Fig.4. As can be seen in the figure, all the simulated and measured patterns are in good agreement. In the horizontal ($xy$-) plane, LFMA has both $\theta$- and $\phi$-components of the radiated electric field, and the $\theta$-component pattern is quasi omnidirectional. However, the gain degradation in this plane is quite severe: the measured maximum gain is 0.7dBi and the simulated maximum gain is -0.3dBi. On the contrary, there can be seen a maximum radiation in the lower hemispherical region ($z$ direction) from the patterns of the other planes. Fig.5 shows the simulated 3-D radiation patterns of both LFMA#1 excited and LFMA#2 terminated to a 50$\Omega$ load, and (b) vice versa. The maximum gain appears at the direction of $\theta=140^\circ$ with 4.3dBi for both antennas.

Fig.6 shows the MEG of LFMA#1 as a function of handset inclination angle $\alpha$ with the cross-polarization power ratio (XPR) as a parameter, when $m_V$ and $m_H$ vary from 0 to 40$^\circ$ (Fig.6(a), (b), and (c)), as is the common phenomenon in a land mobile communication environment [4]: $m_V$ and $m_H$ are, respectively, the mean elevation angles of the $\theta$- and $\phi$-component wave distributions observed from the horizontal direction, and $\sigma_H$ and $\sigma_V$ are the standard deviations of the $\theta$- and $\phi$- component wave distributions, respectively. From the figures, it can be seen that the MEG variation tendencies for the cases of XPR<0dB is almost same with respect to $\alpha$ variation, which means the $\phi$-component of incident wave is dominant, on the other hand, there appear sensitive changes for the cases of XPR>0dB. Moreover, the maximums of MEG for the cases of XPR<0dB are higher than those for XPR>0dB regardless of the $m_V$ and $m_H$. The reason for these results can be considered as that $\phi$-component of the radiation pattern is higher than $\theta$-component in the horizontal plane and omnidirectional in the vertical ($xz$- or $yz$-) plane, as shown in the Fig.4. We can estimate the change in the MEG with XPR variation in a practical situation where the average inclination angle $\alpha=60^\circ$. For instance, when XPR is 3dB, the MEG is nearly constant at -4dBi with XPR variation from 0 to 9dB. Also, at some specified XPR values, the change in the MEG is very small regardless of $\alpha$ variation. For instance, when XPR is 6dB, the MEG is nearly constant at -4dB in Fig.6(a) and when XPR is 6dB, -4.8dBi in Fig.6(b). The minimum MEG for XPR=6dB (the mean value in urban area) is about -5dBi in Fig.6(a). Even though this can be considered to be an acceptable value for the mobile handset antenna, some consideration is needed for more improved MEG characteristics.

The correlation coefficients as functions of the inclination angle $\alpha$ are shown in Fig.7. In all the cases of $m_V$ and $m_H$ variation, a small $\rho_c$ of less than 0.3 is obtained for all the inclination angles with XPR variation from 0 to 9dB, especially an almost uncorrelated situation is seen when XPR is 0dB. As shown in Fig.5, the directivities of both antennas cross spatially with each other at the cross-angle 70$^\circ$ which is almost orthogonal and the phase differences between the two antennas become abrupt for both $\theta$- and $\phi$-component of radiation pattern. The low correlation characteristics between the two antennas are attributed to this reason. From these results, the improved BER performance can be expected in practical MIMO application.

4. Conclusion

In this study, handset MIMO antenna comprising two LFMAAs mounted on a finite GP was designed and the basic performances under practical use conditions, involving multipath radio wave propagation environment were evaluated. As the results, the MEG above -5dBi for all the handset inclination angles was obtained when XPR is 6dB and a very small correlation of less than 0.3 between the two antenna branches was achieved. The study shows that the antenna under consideration has substantial potential for the MIMO application.

Further work will be concentrated on the evaluation of the effective MIMO performances, such as the channel capacity and BER characteristics as well as the improvement of the basic performances, such as MEG in the vicinity of human head and hand, the reduction of the mutual coupling, and others.
Reference


Figure 5: Simulated 3D-radiation patterns of antennas for $\alpha=0^\circ$ at 2.1GHz

(a) LFMA#1  
(b) LFMA#2

Figure 6: MEG of LFMA #1

Figure 7: Correlation coefficient