plate. To distinguish with the individual antenna, we name the combination of the antenna and the PCB as an antenna system. According to the near field coupling theory [6], the part of the Z-shaped coil locating at the bottom of the antenna can generate an eddy current loop *C* on the metal plate, which will form a magnetic field component *B3* along Z direction. Because the NFC signal of the antenna system is normally detected at Z plane, so the strength or magnitude of magnetic field component along Z direction plays a very important role. Hence, the combination of three magnetic field components (*B1, B2* and *B3*) along Z direction ensures a better performance for the dual-loop antenna system. In contrast, the antenna system developed in [7] has only one magnetic field component (*B3*) along Z direction since this antenna itself does not have any magnetic field components that are similar to *B1* and *B2*. Certainly, lack of the magnetic field components *B1* and *B2* worsens the performance of the antenna system.

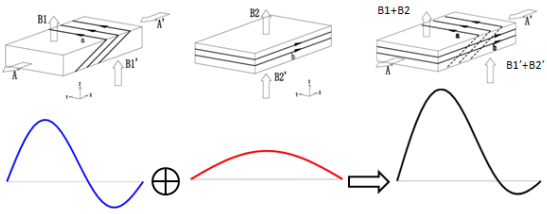

Fig. 3. Working principle of the proposed antenna.

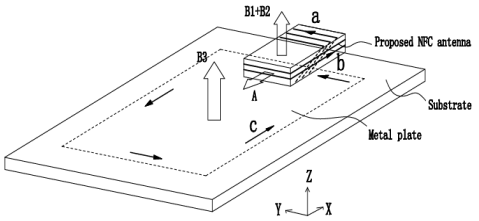

Fig. 4. Working principle of the proposed antenna system.

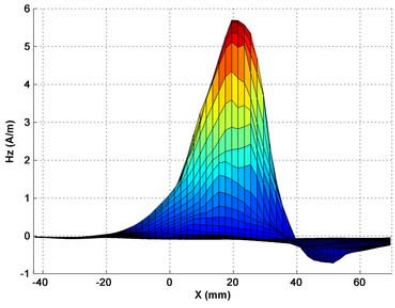

Fig. 5. Hz field component recorded at Z = 25 mm above the antenna system that has the dual-loop coil.

Fig. 5 shows the Hz field component distribution recorded at Z = 25mm above the antenna system shown in Fig. 4, while the number of turns of the Z-shaped and additional coils are 5 and 2, respectively. One can see from Fig. 5 that the dual-loop antenna system performs very well.

To demonstrate the importance of the additional coil, the recorded Hz field component for the case when the antenna system has the Z-shaped coil only is plotted in Fig. 6. The difference between the Hz field component distributions shown in Figs. 5 and 6 indicates that the performance of the can be improved very significantly (about 34%) while the additional coil is adopted for the proposed antenna.

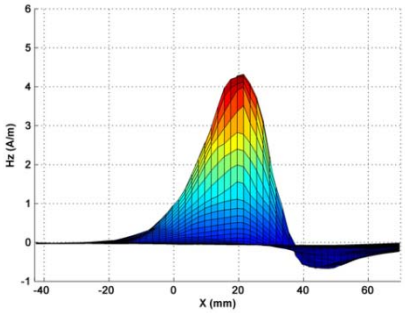

Fig. 6. Hz field component recorded at Z = 25 mm above the antenna system that has the Z-shaped coil only.

3. Conclusion

A dual-loop NFC chip antenna that has better antenna performance is developed. The dual-loop antenna can generate not only the magnetic field component (*A*) along X direction but also the field component (*B1+B2*) along Z direction. When combined with PCB, the antenna results in better performance for the antenna system. The dual-loop antenna proposed in this paper would be very useful for portable devices that require small size NFC antenna.

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