Resonant Antenna Design Employing Equivalent Circuit Mode

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Abstract— Utilization of the equivalent circuit model has shown more time-effective for designing RF circuits and antennas rather than Electromagnetic fields analysis. This study investigates equivalent circuit perspective on designing the resonant antenna. An equivalent π-network circuit is firstly proposed to approach the electromagnetic fields coupling of a closely coupled two-element diversity antenna. Thus, the improvement on the isolation between antennae can be straightforward achieved by employing resonant method. Numerical and experimental study are presented herein.

1. INTRODUCTION

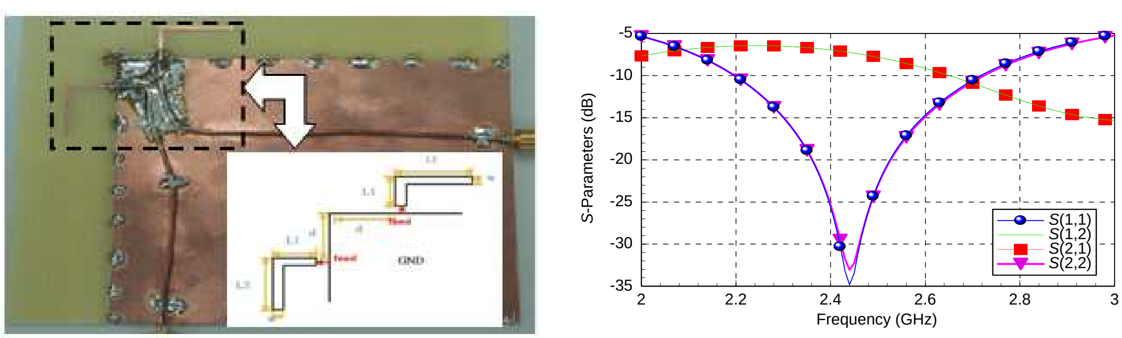
Antenna diversity provides superior spectrum efficiency in a narrow-band cellular reuse system to increase data rates by reducing the fading that occurs in mobile communications [1–3]. However, designing two or more antennas on a small mobile terminal with a higher isolation between the antennas remains a challenge to fulfill the improved aesthetic design, regarding the stringent volume requirement. Many studies have been conducted to improve the isolation between two antennas through the use of various approaches, including designs that incorporate reflectors [4, 5]; an additional ground plane [6]; band-notched slots [7, 8]; and electromagnetic band-gap structures on the ground plane [9].

In this study, an equivalent circuit model (Figure 1) is firstly proposed to simulate the frequency response of the electromagnetic fields coupling mechanism of a two-element inverted-L antenna array (Figure 1) such that the diversity antenna with very high isolation can be achieved by simply using a decoupling capacitor between two antennas. Numerical study is conducted by using ADS2009 and EM simulator to validate the proposed equivalent circuit model. AND a two-element inverted antenna array printed on a FR4 substrate with height of 0.8 mm is built for experimental validation, showing excellent performance in the measured results in the desired operating bands to prove the effectiveness of the proposed design method.

2. DESIGN AND RESULTS

Figure 1(a) shows the proposed layout and photos of diversity antenna configuration integrated by two inverted-L antennas in which the dimensions of the antennas are optimized using a general-purpose EM solver (GEMS) to obtain desirable antenna performance. Concerning the optimization antenna topology and position (Figure 1(a)), the design parameters are optimized using GEMS. The structure parameters of the experimental diversity antenna are as follows [Figure 1]: $L_1 = L_2 = 26.25$ mm, $d = 6$ mm, and $w = 1.17$ mm. However, as shown in Figure 1(b), the electromagnetic fields coupling through either radiated or conducted path will result in poor isolation ($\sim$8 dB) between antennas to degrade the system performance.

Although two inverted-L antennas are placed perpendicularly, the electromagnetic fields of two antennas are not totally orthogonal based on the simulated results using EM simulator. Meanwhile,



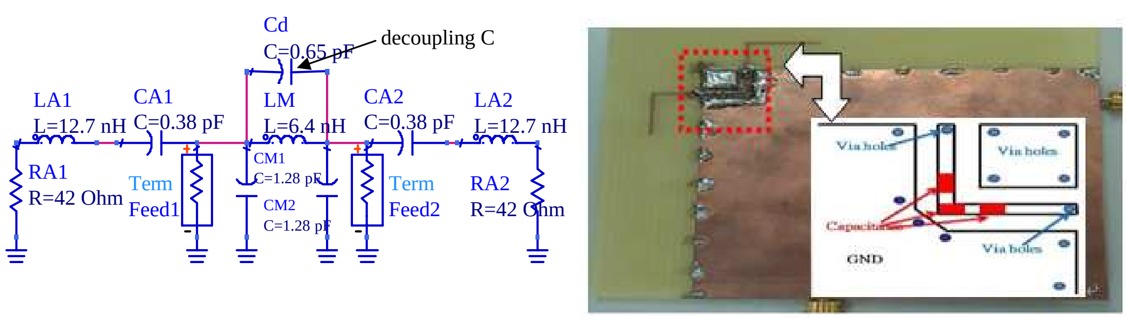
(a) (b)

Figure 1: (a) Proposed layout/photos of diversity antenna; (b) simulated S-parameters using GEMS.

the proximate magnetic flux interaction caused by common-ground return signals of the nearby antenna feeds also yields the coupling power through conductive path. Consequently, it is very difficult to design a compact diversity antenna with high isolation by using EM simulation based on microscopic point of view.

To overcome this difficulty, in this study, the equivalent circuit model is firstly applied to approach the electromagnetic field coupling mechanism of two coupled printed inverted-L antennas. Since the use of the equivalent circuit approach can show physical-based perspective, the improvement on isolation performance of the coupled diversity antenna can be solved directly from macroscopic point of view. In this design example, two inverted-L antennas are present by two series RLC resonant circuits, respectively. As the well known fact that inductive impedance can be used to represent the frequency behavior of the magnetic flux interaction caused by the common-mode ground return signal and electric radiated current source. The parasitic capacitance is generally used to model the electric field coupling between ground metal and printed antenna. Thus, a π network (Figure 2(a)) is employed to simulate the mutual coupling of two antennas. The circuit parameters of the equivalent model can be obtained by applying the simulated two port S-parameter using GEMS to the ADS2009 optimization test bench of the ADS2009 and then a de-coupling capacitor ($C_d = 0.65$ pf in Figure 2(a)) can be simply calculated to form a parallel resonant circuit at the desired frequency band to trap the coupling signals between two antennas. Thus, diversity antenna with high isolation performance is achieved simply. Figure 2(b) shows the proposed layout/photos to implement decoupling capacitor.

Then, substituting computed decoupling capacitor, Cd, in to GEMS EM simulator for full-wave validation, we find the optimal Cd is about 0.27 pf to consider additional parasitic capacitance due to separation of ground. Final, the experimental diversity antenna is tested to compare with simulated results, showing theisolation can be improved from -8 dB to betterr that -20 dB at the frequencies of interest. The slight degradation can be attributed to the loading effect of addition de-coupling capacitor.



(a) (b)

Figure 2: (a) Proposed equivalent circuit model and corresponding circuit parameters; (b) layout/photos of diversity antenna to implement decoupling capacitor (Cd) by using 31 pf in series.

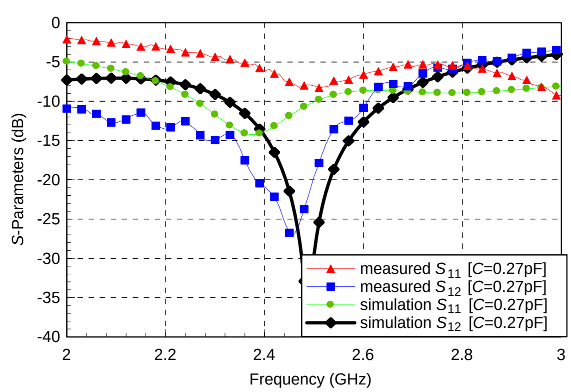


Figure 3: The comparison of the simulated (GEMS) and measured S-parameters.

3. CONCLUSION

Simulated results indicate that the use of the proposed method is useful to eliminate the loop ground surface current for isolation improvement. Experimental study of the proposed diversity antenna configuration shows that excellent isolation between two antennae is achievable in a highly compact size for terminal devices applications.

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