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Orthogonal Antenna Architecture for MIMO Handsets

Alexandru Tatomirescu, Osama N. Alrabadi and Gert F. Pedersen

Section of Antennas, Propagation and Radio Networking (APNet), Department of Electronic Systems,
Faculty of Engineering and Science, Aalborg University, DK-9220 Aalborg, Denmark
{ata, ona, gfp}@es.aau.dk

Abstract—The paper presents a method for decorrelating the antenna elements of a MIMO system in a compact handheld terminal at low bands. The architecture of the antenna system induces orthogonal currents over the closely spaced antennas resulting in a correlation free system. Nevertheless, due to the small electrical size of the balanced element, the bandwidth is reduced and the current density is increased thus generating higher Ohmic losses.

I. INTRODUCTION

Multi-Input Multi-Output (MIMO) communication enhances the wireless system performance by utilizing the spatial and/or polarization properties of the multipath channel [1]. The technology provides diversity and multiplexing gains when the antennas are separated by a typical half wavelength distance from each other. However, the implementation of MIMO in small handheld terminals, such as mobile phones, is severely constrained by the physical area of the device itself. This necessitates that antennas should be placed in close proximity of each other thus leveraging the spatial correlation between the antenna pairs as the emitted signals will mostly follow similar propagation paths.

In this paper, a low correlation MIMO antenna system comprised of a balanced antenna structure coupled to an unbalanced one is considered. Balanced antennas have been investigated previously in [2] where a good decorrelation was achieved among a set of balanced antennas placed on the same printed circuit board (PCB), owed to limiting currents sharing the same ground. In this paper, strong coupling between a pair of antennas is utilized in way that an unbalanced antenna structure excites orthogonal currents over a balanced one thus achieving strong decorrelation.

The following section describes the working principle of the investigated methods and how are they evaluated. Here, the simulation results are also presented whereas the last section draws conclusions on the findings.

II. DISCUSSIONS AND RESULTS

In the design process of a MIMO antenna the following parameters must receive special consideration : Total array efficiency, near-field coupling and envelope correlation coefficient. The efficiency can be calculated as in (1) according to [3], where η_{rad} is the radiation efficiency taking into account the conductive and dielectric losses.

$$\eta_{\text{total}} = \eta_{\text{rad}}(1 - |S_{11}|^2 - |S_{12}|^2) \quad (1)$$

where S_{11} and S_{12} are the array scattering parameters. The envelope correlation can be calculated from the scattering parameters of the antennas using the elegant expression in [4] under the assumption of lossless antennas and a uniform field distribution:

$$\rho_e = \frac{|S_{11}^* S_{21} + S_{21}^* S_{22}|^2}{(1 - |S_{11}|^2 - |S_{21}|^2)(1 - |S_{22}|^2 - |S_{12}|^2)} \quad (2)$$

In mobile antenna design, a compromise must be made between antenna size, efficiency and bandwidth. Current market trends encourage miniaturization of the mobile devices thus increasing the demands on the antenna system. The emerging 4G technologies demand a new method for antenna design. In this paper, bandwidth is sacrificed in order to obtain port decorrelation. The antenna structure is

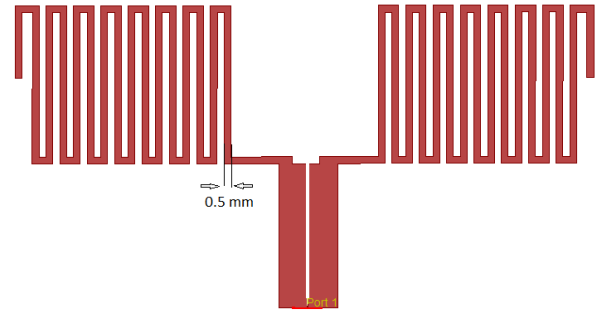


Fig. 1. The antenna structure for the meandered dipole including the coplanar strip line feeding.

composed of two elements, a dipole and a monopole, placed in an orthogonal configuration. Because the form factor is a candy bar type with the dimensions of 100×40 mm, the dipole antenna has to have a meandered configuration to save space, as shown in Fig. 1. The size of the dipole is 10×40 mm and requires a balanced feeding. The second element, the monopole, occupies an area of 19×8 mm and it is represented in Fig. 2. The antennas are placed on each side of a double sided 0.9 mm thick duroid substrate with relative electric permittivity of 10.2. The whole structure is simulated in ADS 2011 Momentum [5] and it is shown in Fig. 3. Because the dipole is electrically small, the radiation resistance is also small therefore, an impedance conversion

from 50Ω to 10Ω is required in order to match the dipole to its input impedance.

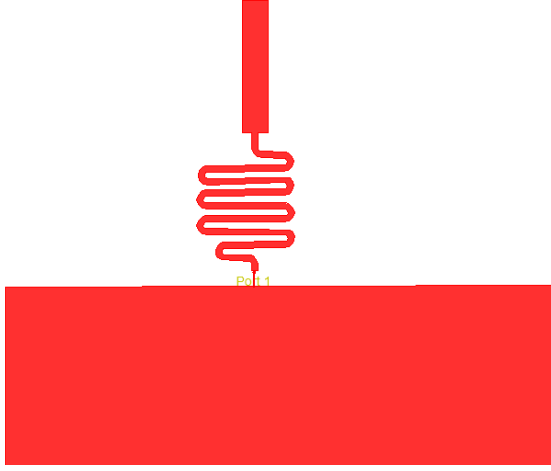


Fig. 2. The simulated meandered monopole design.

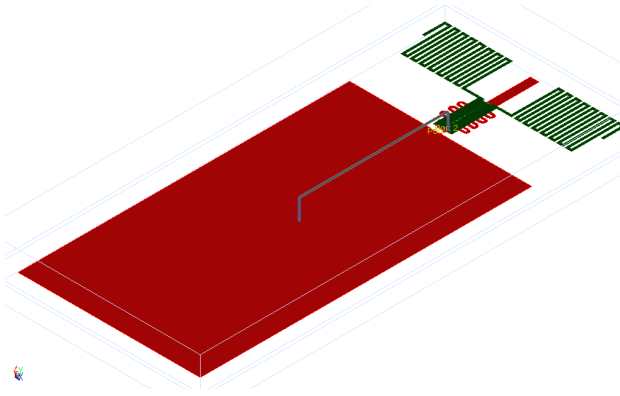


Fig. 3. The total antenna structure including the simplified model of the coaxial feeding. The green layer is on the top surface of the PCB and red layer on the bottom.

The current distribution plotted in Fig. 4 and Fig. 5 are obtained by simulating each element alone on the substrate at the resonating frequency. A symmetry of the current distribution can be noticed as well as the fact that the highest currents running on the monopole are under the feeding of the dipole.

The balanced dipole antenna is fed through a coplanar strip line. Its second role is to increase the coupling between the monopole and the dipole so that the self-matching of the first antenna is improved and lowered on the spectrum band. Fig. 6 shows the scattering parameters of the monopole antenna when alone on the PCB. When the antennas are combined on the same PCB, as shown in Fig. 3, the scattering parameter shown in Fig. 7 are obtained. The dipole acts as a parasitic antenna that improves the impedance matching.

The decorrelation is achieved by the fact that the currents induced by the monopole on the balanced structure are equal in magnitude and opposite in phase, thus canceling each other

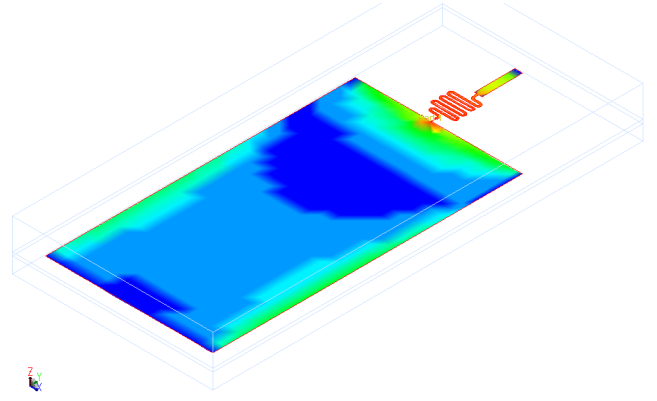


Fig. 4. The simulated current distribution on the monopole when alone on the PCB. The scale is logarithmic and the maximum is red (100 A/m).

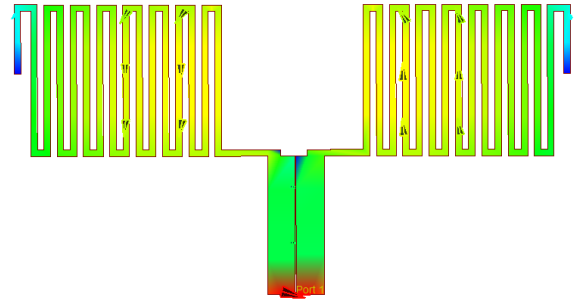


Fig. 5. The simulated current distribution on the dipole when alone on the PCB. The scale is logarithmic and the maximum is red (100 A/m).

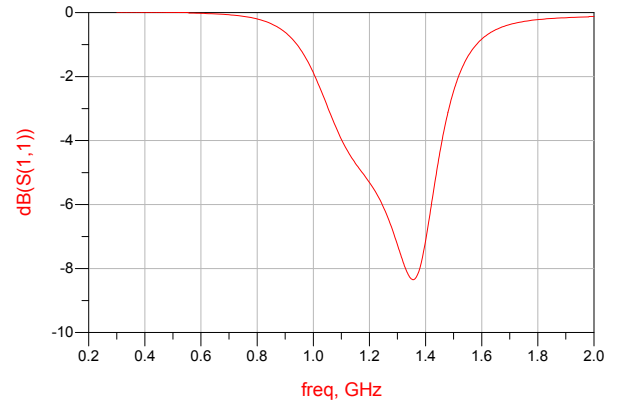


Fig. 6. Magnitude of S_{11} for the monopole when alone on the PCB.

in the feeding point of the dipole, as illustrated in Fig. 8 and Fig. 9. It can be seen that the two elements are highly coupled to each other and that the dipole is inducing currents on the ground plane that are orthogonal to the ones induced by the monopole, thus obtaining isolation.

A simplified model for a coaxial feeding is simulated in order to replicate a more realistic configuration. Due to limitation in the simulation software, a simple metal strip is chosen to replicate the outer conductor of the coaxial cable that could be used in practice to feed the dipole. The connection of the dipole to the PCB ground through

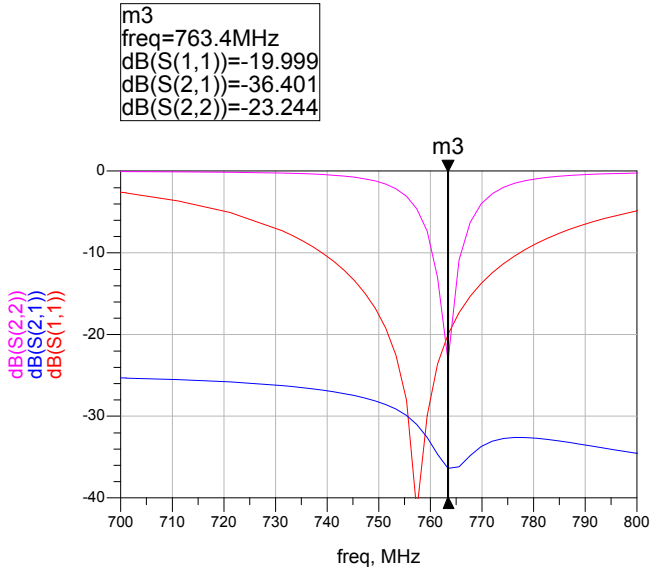


Fig. 7. The simulated magnitude of the scattering parameters for the structure shown in Fig. 3.

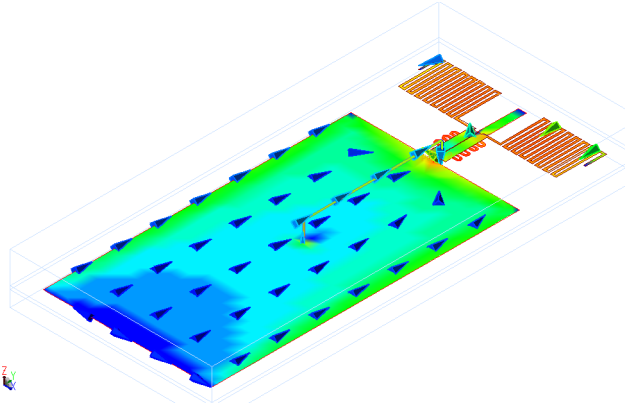


Fig. 8. Current distribution at 764 MHz when the monopole is excited. The scale is logarithmic and the maximum is red (100 A/m).

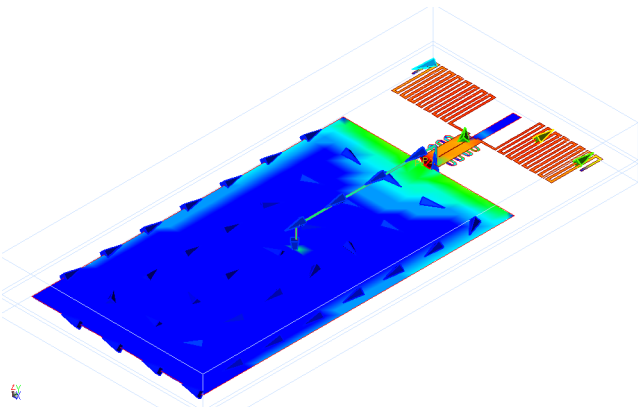


Fig. 9. Current distribution at 764 MHz when the dipole is excited. The scale is logarithmic and the maximum is red (100 A/m).

the coaxial cable degrades the isolation between the two ports by almost 10dB's because the symmetry of the current distribution is disturbed. However, the isolation is still good

enough so that the envelope correlation is very small, as plotted in Fig. 10. At 764 MHz, the simulated total efficiency for the monopole is 65% and 64% respectively for the other. There is a significant loss in radiation efficiency due to the high quality factor (Q) of the antenna that generate increased ohmic losses.

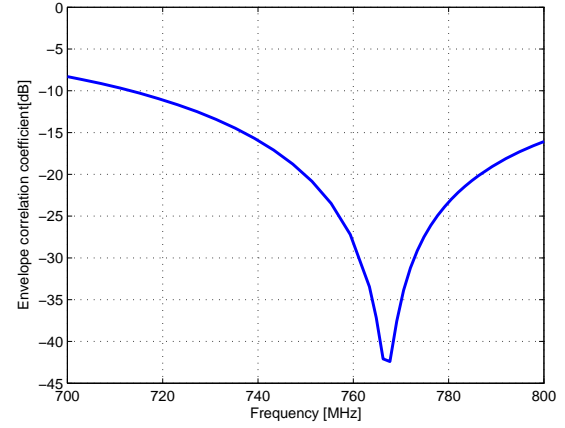


Fig. 10. Envelope correlation coefficient obtained using 2.

III. CONCLUSIONS

An orthogonal MIMO system has been proposed and evaluated. The design offers very strong port decorrelation even though the antennas are close to one another. Nevertheless, the narrower bandwidth of the balanced antenna remains a design challenge. Furthermore, the symmetry of current distribution is very important thus making this isolation method more susceptible to the user's influence.

The design presented in this paper may seem difficult to implement in practice due to the narrow bandwidth of the whole system, however this can be compensated for by using tunable components. Nevertheless, high Q antennas need to receive extra consideration regarding Ohmic losses.

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