A Realistic Smart Antenna with E-Shaped Patch for 3G Handsets

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Abstract: - In this paper we present and investigate the concept of a novel smart microstrip E-shaped patch antenna for 3G handsets. The total radiated power and the overall gain performance of the proposed smart antenna is presented, analyzed and compared with the smart antennas consisted of rectangular patch. The smart antenna configuration for both cases is a linear array. In order to reduce the size of the antenna, which is incorporated into the backside of the handset, two antenna elements are considered with an inter-element spacing of a quarter wavelength ($\lambda/4$). The computer simulation results confirm that the antenna has a gain bandwidth of 10\% for VSWR $\leq$ 4. Moreover, the return loss $S_{11}$ at 2GHz of the proposed smart antenna system is $-20$dB, a value that allows the E-shaped antenna to match easily to 50$\Omega$ source.

Key-Words: -Smart Antennas, GSM, Patch Antennas

1 Introduction

During the last decade, digital wireless cellular systems have presented an exploding growth. Among different configurations used all over the world, 2nd generation cellular systems, code division multiple access (CDMA) [1-2] with IS-95, time division multiple access (TDMA) with IS-136 and the Global System for Mobile Communications (GSM), are considered as the dominant mobile communications systems. A new challenge to the mobile communication industry is the integration of multiple systems and applications on a single mobile device. Smart or adaptive antenna systems are being regarded as the key solution to increase the spectral efficiency and improve the system performance in WCDMA systems. The technology of smart antenna systems is proposed to open up another resource, i.e. space, for mitigating key problems in cellular systems. A smart antenna consists of a fixed set of antennas, the elements, in an array. By using DSP algorithms for dynamically generating the beam patterns, smart antennas can greatly increase the gain, reduce the interference and increase the system capacity. Smart or adaptive antennas offer many features against conventional antennas. By using adaptive antennas different multipath components arriving in different angles can be separated and interfering signals can be suppressed. Because of these reasons smart antennas can be used for range extension or link quality improvement. In WCDMA-systems, with smart antennas, less transmission power is needed and therefore the multiple access interference is reduced which directly boosts the system capacity. The growth of wireless communications systems leads to an increasing demand for integrated compact low-cost antennas. Many researchers showed that smart patch antennas show better overall performance than the conventional ones consisting of dipoles, have light weight, thin profile and can be easily constructed with relatively low cost. Recently, smart antenna systems have been designed and implemented to mobile stations or handsets [3-5]. The basic element of the smart antenna, i.e. the rectangular slot antenna has been investigated since 1940s [6]. With the rapid development of wireless communications, single-patch wide-band antennas provoked many researchers’ attention. However, the major drawback of the basic form of the microstrip antenna is its inherently narrow bandwidth. This narrow bandwidth is the major obstacle that restricts wide applicability. Many researchers proposed different configurations in order to improve the bandwidth next to conventional ones like microstrip antennas having U-slots and E-shape microstrip antennas with over 30\% improvement [7,8], also reverse-L-shaped microstrip-fed structures with bandwidth
improvement approximately 50% [9]. Among the various proposed configurations, E-shaped patch antennas have been proved to have small size and are simpler in construction [8] than the conventional patch antennas because they have only one patch. In this letter a simple design method is presented for a novel smart E-shaped patch modified linear array antenna system with good impedance matching incorporated into handsets for the WCDMA system and its performance is examined. The proposed antenna, which transmits/receives at 2 GHz, is analyzed with the method of moments (MoM) [10]. We present computer simulation results on the overall gain performance and the total radiated power. The analysis showed that the E-shaped patch smart antenna expose better gain (directivity) performance than the rectangular patch linear array smart antenna.

2 Antenna Design
We consider a practical scenario, where the proposed two-element E-shaped linear WCDMA smart antenna configuration is modified in position as shown in fig. 1(a). This configuration was chosen because is the most compact one. The reason using the E-shaped patch antenna as a basis for the smart antenna system is at least twofold. The first is because it has only one patch and therefore is simpler in construction with low cost [8]. The second reason is the overall gain performance.

In our analysis we assume that the antenna elements at the handset are identical and separated with a quarter wavelength (\(\lambda/4\)) of the carrier. This choice is to decrease the overall size of the antenna system and fit it easily into the backside of the handset. The basic antenna element used in the proposed smart E-shaped patch antenna is illustrated in Fig. 1(b).

The computer simulation of the proposed linear array antenna was performed using MATLAB and the calculated parameters are shown in Table 1. The calculations used are described below.

Since the two basic factors influencing the performance of the linear array antenna, i.e., the inter-element spacing and the number of elements in an array are fixed in our analysis. We properly selected the size of the patches and the position of the feeding point.

The initial dimensions \(L, W\) of the E-shaped patch antenna can be determined using the following equations, which are valid for the rectangular patch antenna [14]:

\[
L = \left( \frac{\lambda}{2} \right) \left( \frac{\varepsilon_r + 1}{2} \right)^{1/2}
\]

\[
W = \left( \frac{\lambda}{2\sqrt{\varepsilon_e}} \right) - 2\Delta l
\]

where the effective dielectric constant, \(\varepsilon_e\) and \(\Delta l\) are given by:

\[
\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + \frac{12t}{W} \right]^{-1/2}
\]

![Figure 1](image1.png)

**Figure 1** (a) Geometrical schematic of the proposed smart antenna system, (b) Details of the E-shaped antenna of a single element.

**Table 1** Calculated parameters for the E patch linear array antenna system.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patch length, (L)</td>
<td>5.97125cm</td>
</tr>
<tr>
<td>Patch width, (W)</td>
<td>4.33125cm</td>
</tr>
<tr>
<td>Slot length, (L_s)</td>
<td>3.15cm</td>
</tr>
<tr>
<td>Slot width, (W_s)</td>
<td>1.05375cm</td>
</tr>
<tr>
<td>Feed position, (X_f)</td>
<td>2.98562cm</td>
</tr>
<tr>
<td>(Y_f)</td>
<td>2.93187cm</td>
</tr>
<tr>
<td>(P_s)</td>
<td>1.05375cm</td>
</tr>
<tr>
<td>Patch thickness, (t)</td>
<td>0.4cm</td>
</tr>
<tr>
<td>Dielectric constant</td>
<td>2.2</td>
</tr>
<tr>
<td>Center frequency, (f)</td>
<td>2GHz</td>
</tr>
<tr>
<td>Inter-element Spacing</td>
<td>(\lambda/4)</td>
</tr>
</tbody>
</table>

\[
W = \left( \frac{\lambda}{2\sqrt{\varepsilon_e}} \right) - 2\Delta l
\]

\[
\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + \frac{12t}{W} \right]^{-1/2}
\]
where \( t \) is the thickness of the patch,
\[
\Delta l = 0.412 t \left( \frac{\varepsilon_r + 0.3}{\varepsilon_r - 0.258} \right) \left( \frac{W}{t} + 0.264 \right)
\]

(4)

It was observed that the calculated length does not produce a minimum voltage standing wave ratio (VSWR) at 2GHz. Hence, the new dimension of \( L=5.97125\text{cm} \) and \( W=4.33125\text{cm} \), as shown in Table 1, was selected for the application. The patch thickness \( h \) was exactly 0.4cm with typical dielectric constant 2.2 and the elements were fed, assuming a rectangular line-fed configuration.

**Figure 2** Simulation results for the return loss (S\(_{11}\)) of the 2-element E-shaped patch smart antenna.

Figure 2 shows the simulation results for the return loss \( S_{11} \) (in dB) of the single patch, E-shaped, antenna in the frequency range from 1.2 to 2.4 GHz. Yang et all [8] have shown that adjusting the length \( L_s \), width \( W_s \), and positions \( P_s \) of the slots one can obtain satisfactory performance and control the bandwidth. By properly selecting the values \( L_s, W_s \), and \( P_s \) we performed simulations to determine the characteristics of the E-shaped antenna. As it is clear from Fig. 2, the center/resonant frequency of the E-shaped patch antenna, is 2 GHz [13]. Also the –10dB return loss \( S_{11} \) bandwidth of the E-shaped 2-element smart antenna is 10\%. Although this bandwidth value is small allows the antenna to cover the frequency range from 1.9 to 2.1 GHz and it can be used as a transmit/ receive antenna in the WCDMA band. The value of the \( S_{11} \) at 2 GHz is –20dB, which allows the E-shaped antenna to match easily to 50\( \Omega \) source impedance [9].

**3 Simulation results and discussions**

As we mentioned before, in order to implement the smart antenna we used 2 elements from the above designed E-shape antenna in a modified linear array with inter-element spacing \( \lambda/4 \) as it is illustrated in Fig. 1(a). The particular configuration was chosen because is the most compact one.

As it is known, the total field of the array is equal to the field of a single element positioned at the origin multiplied by the array factor (AF). The AF is a function depending on the geometry of the array and the excitation phase and amplitude between the elements. By varying the separation \( d \) and/or the phase \( \beta \) between the elements, the characteristics of the array factor and the total field can be controlled [12]. In other words, the far-zone field of a uniform array with any number of identical elements is:
\[
E(\text{total}) = E(\text{single element}) \times \text{AF}
\]

(5)

Assuming a N-element array whose elements are excited by identical amplitudes having a phase difference \( \beta \) between the elements the AF is given by [11] in normalized form:
\[
AF = \frac{1}{N} \sum_{n=1}^{N} \exp(j(n-1)\Psi)
\]

(6)

where \( \Psi = -kd \cos \theta + \beta \)

(7)

**Figure 3** Far-Field Radiation Pattern of the 2-element E-shaped patch smart antenna.

Figure 3 illustrates the radiation pattern of the 2-element E-shaped patch smart antenna. The inter-element spacing was chosen to be \( \lambda/4 \), in order to maximize the main to side lobes power ratio thus giving better directivity control and simultaneously to minimize the total size of the antenna. The radiation pattern was simulated in the E plane for the far-field case at the resonant frequency 2 GHz. The measured beam-width of the main lobe at -3 dB point is 39.2 degrees. This beam-width is acceptable for a handset antenna. It is clearly seen that the side lobes of the proposed smart antenna are degraded compared to the main lobes by about 6dB. This side lobe degradation improves the directivity of the smart antenna which is important in Modern Wireless Communications. Also the main lobe efficiency is improved compared to the efficiency of the single-element E-shaped patch smart antenna.
The next step we carried out was to vary the patch thickness \( t \) in order to find the best performance/patch thickness ratio. For this reason we consider another 3 cases of different patch thickness \( t \), i.e. 0.35cm, 0.40cm, 0.45cm and 0.50cm. As it is seen in Fig. 4 the radiation pattern of the proposed smart antenna improves as the thickness \( t \) increases. But the return loss \( S_{11} \) is degraded as it is shown in Table 2. Thus the best choice is the one for \( t=0.40 \) cm.

**Table 2** Calculated Return loss (\( S_{11} \)) for the smart E-shaped patch smart antenna system.

<table>
<thead>
<tr>
<th>Patch thickness, ( t ) (cm)</th>
<th>( S_{11} ) (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35</td>
<td>-16.95</td>
</tr>
<tr>
<td>0.40</td>
<td>-20.02</td>
</tr>
<tr>
<td>0.45</td>
<td>-19.05</td>
</tr>
<tr>
<td>0.50</td>
<td>-16.15</td>
</tr>
</tbody>
</table>

**4 Conclusion**

In this letter we proposed and investigated a novel smart E-shaped patch antenna with good impedance matching capabilities which can be used into the 3G handsets for WCDMA systems. The 3-dB beam-width of the proposed smart antenna is 39.2 degrees. This beam-width is acceptable for a handset antenna. The side lobes are degraded compared to the main lobes by about 6dB. The simulation results showed that the patch thickness \( t \) for the proper operation of the antenna is 0.40cm. Moreover the major benefits of this novel handset smart antenna are its simplicity, compared to other patch smart antennas and the improved overall gain performance.

**References:**


