DESIGN OF 4X4 RECTANGULAR MICROSTRIP PHASED ARRAY ANTENNA FOR GSM APPLICATION

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Abstract: In this paper, 4x4 rectangular microstrip patch transmitter/receiver antenna for GSM application is presented. Design simulation and optimization processes are carried out with the aid of the Advanced Design System (ADS) electromagnetic simulator. The proposed antenna is fabricated on a 3.175 mm thick RT Duroid substrate with a relative permittivity of 2.3. The antenna offers excellent performance for GSM systems ranging from 890-915 MHz for receiver and 935-960 MHz for transmitter antenna. The gain of these antennas is simulated and found adequate which is about 13.8 and 14.4 dBi. Measured and simulated results of the resonant frequency, return loss, radiation patterns are presented.

Keywords: Microstrip Antenna, GSM, ADS, Return Loss, Radiation Pattern

INTRODUCTION

Wireless communication has become an integral part for modern world. The most popular standard for mobile phones in today’s world is GSM. The wireless providers use individual radio frequencies multiple times by dividing a service area into separate geographical zones, or cells, each cell requires its own radio transmitter/receiver antenna. GSM networks operate in different frequency ranges in different countries around the world. Most GSM networks operate in the 900 MHz or 1800 MHz bands in Asia and Europe.

Microstrip antennas are perfect choice for GSM application due to following features, low profile, small size and conformality. But microstrip antennas suffer from bandwidth limitations. The bandwidth can be increased by adding lossy elements but it affects efficiency of the antenna. So the better method is to use array antenna.

In this design of rectangular microstrip array antenna for GSM applications, the transmitter antenna array is expected to operate within 935 MHz-960 MHz with center frequency 947.5 MHz, bandwidth 25 MHz and receiver array antenna within 890 MHz-915 MHz with center frequency 902.5 MHz, bandwidth 25 MHz. This antenna array is fabricated in RT Duroid 5870 substrate with thickness 3.175 mm and permittivity 2.3.

4X4 ARRAY ANTENNA DESIGN

First, a single microstrip transmitter and receiver antenna is designed for GSM application. Consider figure 1 below, which shows a rectangular microstrip patch antenna of length L, width W on a dielectric substrate of height h. The length and width of antenna can be calculated by transmission line method, as given below.

Fig.1 Rectangular microstrip patch antenna
(2.7) 
\[ G_{12} \ll G_2 \text{ and so we can ignore } G_{12}. \]

(2.8) 
\[ R_{1n}(y = y_0) = \frac{1}{2G_r} \cos^2 \left( \frac{\pi}{L} y_0 \right) \]

Where, \( y_0 \) = position of feed, 
\( L \) = length of patch, 
\( G_r \) = radiating conductance.

The designed dimensions of the proposed rectangular single patch transmitter antenna are \( L = 216.17 \text{mm}, W = 151.23 \text{mm}, L_1 = 120.51 \text{mm}, W_1 = 5.645 \text{mm} \) and for receiver antenna \( L = 205.85 \text{mm}, W = 155.2 \text{mm}, L_1 = 8.6656 \text{mm}, W_1 = 121 \text{mm} \). The proposed antenna is fabricated on an RT Duroid 5870 substrate with a thickness of 3.175 mm and a relative permittivity \( (\varepsilon_r) \) 2.33. To design a 4x4 microstrip patch antenna array, Co-corporate feed network is used. Figure 2 shows the configuration of the 4 x 4 microstrip patch array antenna design for GSM application. Here 16 patch elements are used and each element has same dimensions as mentioned above in order to increase the antenna performance. In this design, the patch elements are connected using quarter wavelength impedance transformer method.

**SIMULATION AND RESULTS**

**A. S-parameter plot for return loss v/s frequency**

S parameter calculation has been performed for rectangular microstrip 4x4 transmitter and receiver array antenna. The center frequency is selected as the one at which the return loss is minimum. Fig. 3 shows the receiver antenna operates at a frequency range of 890-915MHz, with bandwidth 25MHz and centre frequency of 902.5 MHz Fig.4 shows the transmitter antenna operates at a frequency range of 935-960MHz, with bandwidth 25MHz and a center frequency 947.5MHz.

**B. Antenna parameters**

Some of antenna parameters, such as the gain, directivity, antenna efficiency and 3 dB beam width for single patch and 4x4 array transmitter/ receiver antenna are tabulated below. From the table, it is clear that gain and directivity of 4x4 phased array antenna is almost double than that of single patch antenna. The gain and directivity for single patch transmitter/receiver antenna is 6.96/6.84 and 7.97/7.87 dBi respectively. And that of 4x4 phased array transmitter/receiver antenna is about 13.8/12.8 dBi and 15.4/14.5 dBi respectively.
TABLE 1 ANTENNA PARAMETERS FOR SINGLE PATCH TRANSMITTER/ RECEIVER ANTENNA

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Single patch transmitter antenna</th>
<th>Single patch receiver antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power radiated</td>
<td>3.14 mW</td>
<td>2.65 mW</td>
</tr>
<tr>
<td>Effective Angle</td>
<td>2.00316 steradians</td>
<td>2.0509 steradians</td>
</tr>
<tr>
<td>Directivity</td>
<td>7.97 dBi</td>
<td>7.87 dBi</td>
</tr>
<tr>
<td>Gain</td>
<td>6.96 dBi</td>
<td>6.84 dBi</td>
</tr>
<tr>
<td>Maximum Intensity</td>
<td>1.572 mW/steradian</td>
<td>1.296 mW/steradian</td>
</tr>
<tr>
<td>Angle of Umax</td>
<td>54(\theta) 91(\phi)</td>
<td>53(\theta) 90(\phi)</td>
</tr>
</tbody>
</table>

TABLE 2 ANTENNA PARAMETERS FOR 4X4 TRANSMITTER/ RECEIVER ARRAY ANTENNA

<table>
<thead>
<tr>
<th>Parameters</th>
<th>4x4 transmitter array antenna</th>
<th>4x4 receiver array antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power radiated</td>
<td>1.99 mW</td>
<td>4.65 mW</td>
</tr>
<tr>
<td>Effective Angle</td>
<td>0.99 steradians</td>
<td>0.46 steradians</td>
</tr>
<tr>
<td>Directivity</td>
<td>12.8 dBi</td>
<td>15.4 dBi</td>
</tr>
<tr>
<td>Gain</td>
<td>13.8 dBi</td>
<td>14.4 dBi</td>
</tr>
<tr>
<td>Maximum Intensity</td>
<td>2.33 mW/steradian</td>
<td>9.89 mW/steradian</td>
</tr>
<tr>
<td>Angle of Umax</td>
<td>41(\theta) 96(\phi)</td>
<td>38(\theta) 270(\phi)</td>
</tr>
</tbody>
</table>

C. Radiation Pattern of Designed Antennas

The radiation pattern is defined as “a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates”. The 3D representation of radiation pattern of transmitter and receiver antenna is shown in figure.

3. Gain and Directivity Graph

The graph given below shows the gain and directivity of designed antenna. The gain of an antenna in a given direction is the amount of energy radiated in that direction compared to the energy of an isotropic antenna would radiate in the same direction when driven with the same input power. The directivity of the antenna is the maximum gain of the antenna compared with its gain averaged in all directions.
From the above graphs, the gain and directivity obtained for transmitter array antenna are 13.8dBi and 12.8dBi respectively. And for receiver array antenna corresponding values are 14.4dBi and 15.4dBi respectively.

D. Linear polarization

The above figure shows the linear polarization of the antenna which radiates wholly in one plane containing the direction of propagation E\_co and E\_cross are the normalized E field strength of co and cross polarized far-field component.

E. Circular polarization

The figure shows below the circular polarization of antenna which can be defined as the polarization in which the electric field of the passing wave does not change strength but only changes direction in a rotary manner.

CONCLUSION

A 4x4 rectangular microstrip phased transmitter/receiver array antenna has been successfully designed. Here microstrip feed technique is used to feed single patch antenna. And corporate feed technique is used for 4x4 array antenna. S parameter calculation has been performed for the designed antenna. From the graph, it is clear that the designed antenna has been radiated in the prescribed range of frequencies defined for GSM application. Next gain, directivity, effective area, power radiated absolute field etc. are calculated for designed antenna.

The future work is to design 8x8 antenna array and square shaped conformal microstrip phased array antenna for GSM application.

REFERENCES

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