GSM/UMTS Dual Polarization Base Station Antenna Design

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Abstract

Base station antenna array is designed to cover frequency range from 1710 MHz to 2170 MHz. An entirely different antenna feed structure which consists of an L-plate capacitive feed, is developed and a parasitic patch is optimized to meet target design specifications. The antenna is +/- 45^o dual polarization with dedicated channels for each polarization. A prototype of the antenna element is built and measured to corroborate simulation results. The antenna array for BSA is designed to have an 18 dBi system gain with a VSWR less than 1.5 over the entire frequency band.

1. Introduction

Base station antennas (BSA's) are the key components of cellular phone networks. There has been extensive research dedicated to the design and development of BSA's over the past two decades [1-6]. Especially dipole-like structures are preferred for ease of construction, low-profile form, and low intermodulation distortion. However, it is very difficult to achieve high fractional bandwidth (FBW) with these structures and yet maintain gain and other design specifications for the whole frequency band. Depending on the operational requirements, it is usually intricate to meet gain, half-power beamwidth (HPBW) and isolation requirements over a large frequency band. For 3G networks covering a frequency range from 1710 MHz to 2170 MHz, demand an antenna with a FBW of at least 24% and with an element gain of at least 8.5 dBi over the entire frequency band. In this study, we present a new type of a base station antenna element, and its array formation to meet the design specifications.

Target system requirements for the BSA are summarized in Table 1. The down tilt angle of the antenna array is assumed to be fixed and can be set through the feed network of the antenna array. It is also possible to incorporate a mechanically controlled phase shift between the array elements for a tilt angle coverage from 0^o to 10^o. The antenna system has two separate channels to accommodate dual polarization in a single structure. Each channel has either +45^o or -45^o polarization with transmit and receive capabilities. Passive isolation between the two channels must be at least 25 dB and passive intermodulation distortion (PIM) should be at least 100 dB with 43 dBm of two carriers. Gain requirements may differ from one application to another, but for this specific design 18 dBi gain is set by the requirements. Impedance match is also a critical design parameter for BSA's. The voltage standing wave ratio (VSWR) must be less than 1.5 (min 14 dB Return Loss) across the frequency band. Azimuth half power beamwidth (HPBW) is set to minimum 55^o.

Table 1. Design Specifications for the Antenna

Frequency range (MHz)	1710-1880	1850-1990	1920-2170
Polarization		±45° (dual)	
Gain (dBi)	18	18	18
Azimuth Half-power	55^o	55^o	55^o
Sidelobe suppression		13	
Front-to-back ratio (dB)		≥25	
Isolation (dB)		≥25	
Impedance (Ω)		50	
VSWR		≤1.5	
PIM distortion (dBc)		< -100	

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2. Element Design

The antenna element is a patch antenna with a parasitic patch on top. The configuration is illustrated in Fig. 1. Two separate antenna elements each dedicated to one channel are utilized. The feed structure is an L-plate shape capacitively coupled to the driven patch. Unlike L-shaped wire feed structures, L-plate shape provides better coupling across the frequency band and provides good match. First, the radiating patch is designed to be resonant at the geometric mean frequency of the frequency band edges. However, due to parasitic loading and L-plate shape feed structure, square patch dimension is reduced to 55 mm. Parasitic patch to driven patch distance, their relative heights and the position of feed structure are optimized to meet design goals. The elements are modeled in FEKO, a commercial 3D EM field solver. The feed structure is transitioned from a microstrip line to L-plate shape. The microstrip line is printed on a dielectric of 2.55 with 0.8mm height.

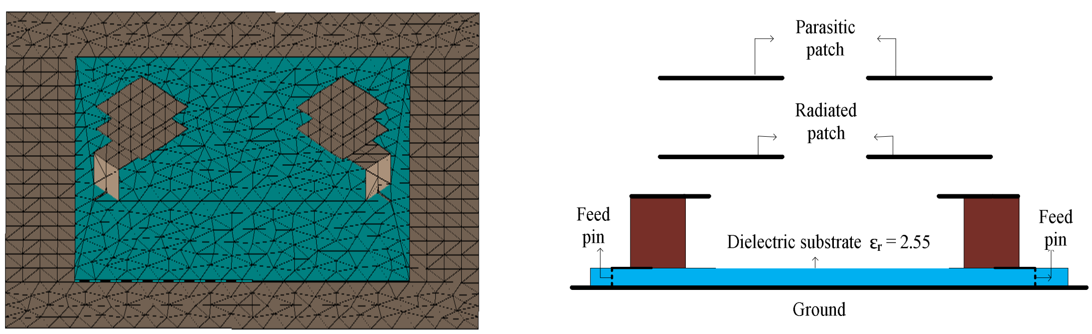


Figure 1. Dual-polarization antenna system 3D CAD model and its side-view

Equivalent circuit model of the single antenna element is shown in Fig. 2. The capacitive coupling between feed element and driven patch, and driven patch with the parasitic element are denoted as C_{12} and C_{23}. The capacitive coupling between feed element and the parasitic patch, although it is weak, is modeled as C_{13}. Inductive coupling between the feed and the driven patch, and between the driven patch and parasitic patch are denoted with k_1 and k_2, respectively. The respective element values of the equivalent circuit require careful circuit synthesis and will be detailed in a future communication.

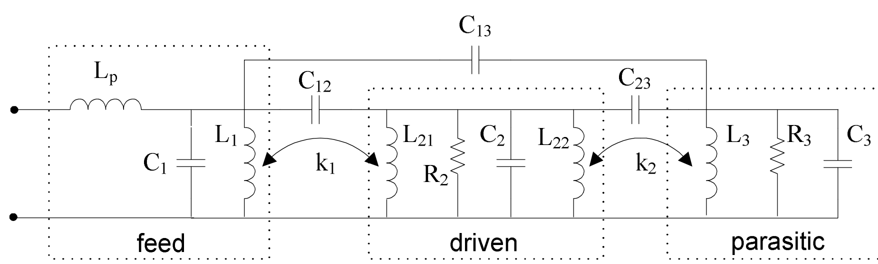
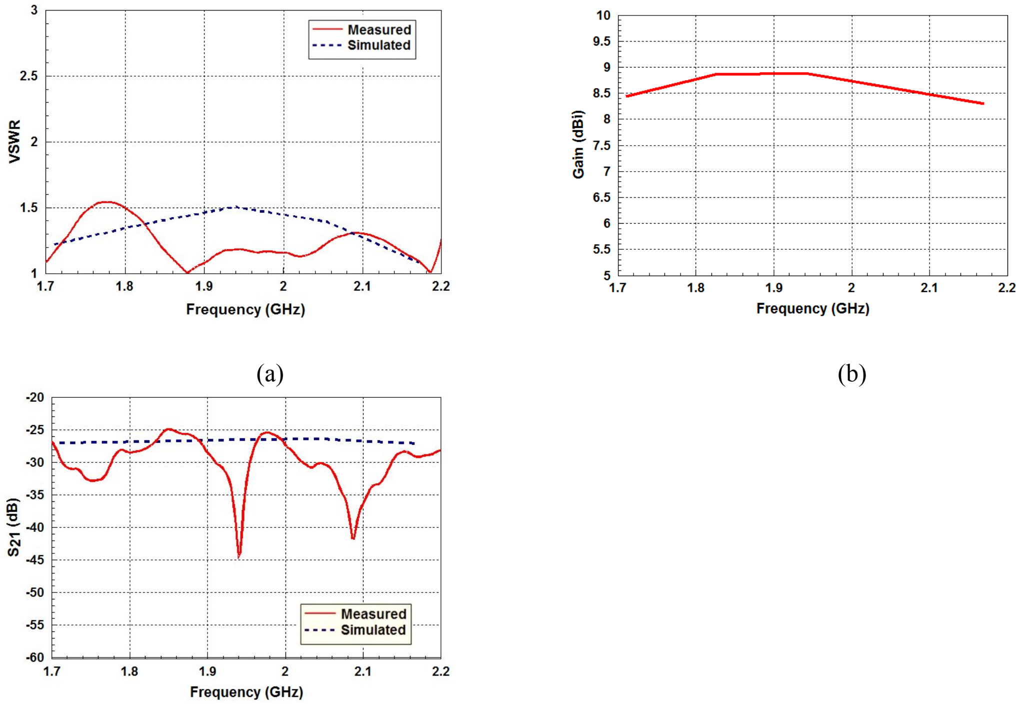


Figure 2. Equivalent circuit representation of the element antenna

A prototype of the antenna is built and measured with a two-port network analyzer (R&S ZVB-20) for its VSWR and isolation characteristics. VSWR, gain and port isolation of the antenna unit are displayed in Fig. 3. Measured VSWR and isolation are very consistent with simulation results, although at one frequency point the VSWR appears to be 1.51. Its gain has not been measured yet. However, strong corroboration of simulated and measured data for near-field quantities such as input impedance and port isolation suggests that its measured values will also be close to simulated results, but yet, needs to be verified by measurement. Other measurements would involve polarization purity, PIM, and electrical response to mechanical tests that simulate wind effect, vibration on the unit and water/snow accumulation on the radome.



(a) (b)

(c)

Figure 4. Single antenna element gain and VSWR

It is observed that target design specifications can be met with this type of antenna if it is properly formed in an array. The coupling between the elements due to array formation would reduce the overall gain, however, since we did not utilized any dielectric in the driven or parasitic patches, no surface waves are excited except those short sections of quasi-TEM microstrip lines in the feed network.

3. Antenna Array

The gain performance of the single antenna element suggests that we need 10 elements to meet the target gain requirement. Such configuration with approximately one wavelength separation between the antenna elements is shown in Fig. 5. The antenna array is uniformly fed for broadside radiation. Simulated antenna array results are presented in Fig. 6. Although only VSWR and gain performance are provided, remaining target specifications are also met. Total length of the array is 1676 mm and its width is 394 mm. Since the antenna will be covered with a radome, we also expect to lose small amount of system gain. The longer edges of the ground plane can also be bent towards the antenna elements to aid directivity in the broadside direction and decrease the form factor of the whole antenna. However, these effects are not yet studied for this antenna system. Other difficult-to-measure parameter of the antenna is its PIM value. PIM usually depends on the material used in the formation of the antenna, solder junctions, and its DIN type connectors. We expect that at least the radiating antenna elements are free of any dielectric and have less solder contacts to result in low PIM value.

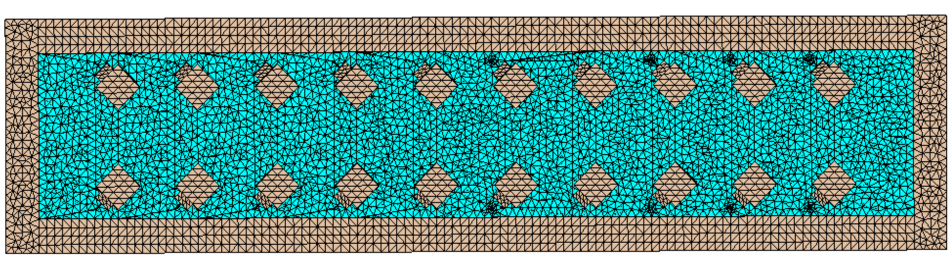
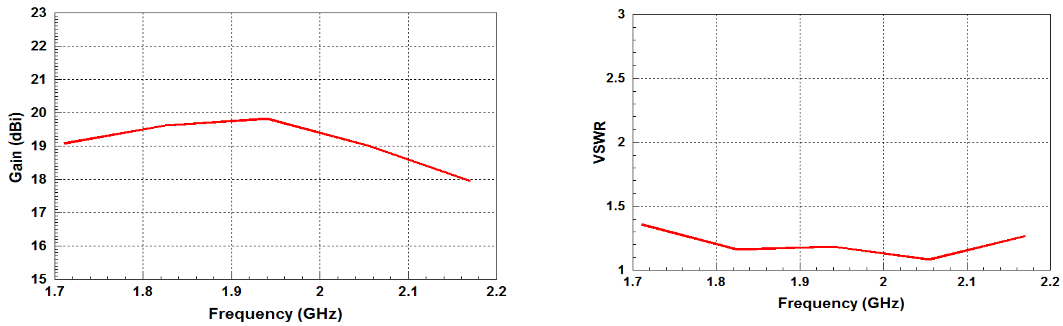


Figure 5. Dual polarization antenna array CAD model.



(a) (b)

Figure 6. Array antenna, a) gain, b) VSWR

4. Conclusions

We presented a new antenna element and antenna array for 3G base station cellular networks. The antenna element consists of an L-plate shape feed structure, capacitively coupled to radiating patch. A parasitic patch on top of the radiating patch is utilized to maintain broadband operation and high gain. A prototype of the element antenna is built and measured for its VSWR and port isolation characteritics. It is observed that simulated and measured data corroborate each other across the entire frequency band. Simulated data for its array formation are also presented.

The antenna array can be given a down tilt from broadside by providing progressive phase shift between the antenna elements. Since each element is fed via a small pin, the back side of the array can easily accommodate a feed network in the form of microstrip lines. For high power applications, the antenna elements can be fed through coaxial cable which can withstand large peak RF power levels as much as 300 W. The cable lengths, then, can be used to provide the necessary phase shift among the elements. One difficulty with this approach is the variation of electrical length with the operation bandwidth.

5. Acknowledgements

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