Phase Shifters for Electrical Down Tilted WiMAX BTS Antenna

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Abstract

The mechanical adjustable phase shifter is developed for electrical down titled WiMAX BTS (Base Transceiver System) antenna. The operation theory of phase change is obtained by the mutual coupling between parts of microstrip meander line and the dielectric substrate coupler. The operating frequency is from 2.3 to 2.7 GHz. The WiMAX BTS antenna array is composed of eight dipole antenna elements, eight phase shifters, and 1:8 power divider. In order to reduce the size, the 1:8 power divider, microstrip line, and phase shifters are integrated to compact RF assembly. By using the designed compact RF assembly, the maximum electrical down tilted beam scan angle for the WiMAX BTS antenna array is 10.5° at 2.7 GHz.

Keywords: WiMAX, base station antenna

1. Introduction

Cellular phone system is convenient and popular in nowadays. The performance of BTS antenna is critical in cellular phone system. Since the compact size of cellular phone is required, the antenna performance of cellular phone is degraded. In order to cover the degraded cellular phone, the performance of BTS antenna should be upgraded. Usually the main factors of BTS antenna will include dual linear polarized antenna elements, electrical down tilted capability, lower PIM (passive inter modulation) value, higher power handling capability, and large azimuth coverage, etc. The electrical down tilted capability is used to cover the whole cell region from near communication range to far communication range. In order to maintain the constant signal to noise ratio for different cell applications, the electrical down tilted capability of BTS antenna is required. Phase shifters play an important rule for the electrical down tilted capability of BTS antenna.

The BTS antenna is composed of compact RF assembly and dual linear polarized antenna elements. In this paper, compact RF assembly is designed and fabricated. The compact RF assembly includes one to eight power divider, microstrip line, meander line, and dielectric coupling substrate. In order to reduce the size of BTS antenna, the size of RF assembly is 25.4 cm by 14 cm by 2 cm. The design step and test results are discussed in this paper.

2. Analysis of Mechanical Adjustable Phase Shifters

For two ports microstrip line as shown in Fig.1, the relationship between input and output ports is given in Eq.1.

$$V_o = V_{in} e^{-jkl} \qquad (1)$$

Where $-kl$ is the phase change of microstrip line. $k = 2\pi/\lambda_g$ is the propagation constant. λ_g is the guide wavelength of microstrip line. Since $\lambda_g = \lambda_0/\sqrt{\mu\varepsilon}$ is function of permeability and permittivity. And l is the length of microstrip line.

In order to have larger length of microstrip line l, periodic meander line is used. The higher dielectric constant ε is also used for larger phase changes. From Eq.1 the total phase change is expressed as in Eq.2.

$$\phi = -k_1 l_1 - k_2 l_2 \qquad (2)$$

Where $-k_1 l_1$ is the phase change due to the microstrip line covered with air dielectric constant. $-k_2 l_2$ is the phase change due to the microstrip line covered with high dielectric material. By proper control both $-k_1 l_1$ and $-k_2 l_2$, the desired phase can be obtained.

3. Results of Simulation and Measurement

The simulation model for two port phase shifter is shown in Fig.1 with the following parameters. Substrate of microstrip line is RO4003C with total length of microstrip line is 242 mm. The coupling substrates are with FR4, RO3210, and RT/duroid-6010. The thicknesses for FR4, RO3210, and RT/duroid-6010 are 2.3 mm, 1.27 mm, and 2.54 mm, the relative permittivity ε_r are 4.4, 10.2, and 10.2 respectively.

Fig.2 is the phase change versus length of coupling substrate for different coupling substrates. It shows that the higher the dielectric coupling material, the larger the phase change is. From this figure, it shows that the phase change is proportional to the length of coupling substrate.

As soon as the two ports phase shifter is designed for the requirement of BTS antenna. One to eight power divider, eight microstrip lines, eight meander lines, and one coupling dielectric material FR4 are integrated to a compact RF assembly with size 25.4 cm by 14 cm by 2 cm as shown in Fig.3. In order to change the phase at different output ports, continuous mechanical adjustment of the coupling substrate from 0° to 37° is used. The desired frequency band is from 2.3 GHz to 2.7 GHz. Fig.4 shows the return loss of compact RF assembly. The return loss is less than 14 dB for the whole band. Fig.5 shows the phase change of eight output ports with mechanical adjustment at 37°. The phase change is linear progressive versus frequency. Total phase change between port 1 and port 8 are 288°, 363° and 454° for frequencies at 2.3 GHz, 2.5 GHz, and 2.7 GHz respectively. If the BTS antenna, eight antenna elements with element spacing 11 cm, are connected with the compact RF assembly, then the maximum beam scan angles are 7.8, 9 and, 10.5 degree at 2.3 GHz, 2.5 GHz, and 2.7 GHz.

4. Conclusions

The compact RF assembly with continuous adjustable phase shifter is designed and fabricated for WiMAX BTS antenna. The phase change is obtained by adjusting the length of microstrip delay line and the coupling substrate material. The maximum phase changes 288°, 363°, and 454° between port 1 and port 8 are obtained at frequencies 2.3 GHz, 2.5 GHz, and 2.7 GHz respectively. If the BTS antenna, eight antenna elements with element spacing 11 cm, are connected with this compact RF assembly, then the maximum beam scan angles are 7.8, 9 and, 10.5 degree at 2.3 GHz, 2.5 GHz, and 2.7 GHz.

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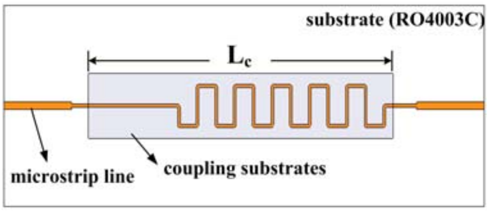

Fig.1: Simulation model of phase shifter

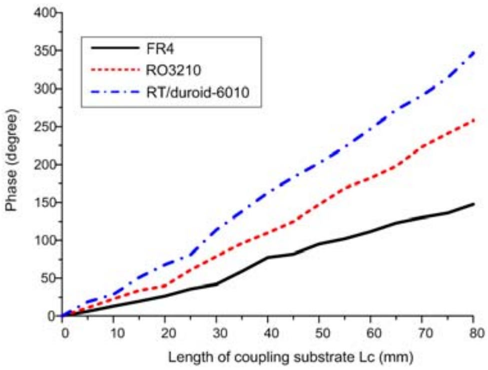

Fig.2: Phase change versus length for different coupling substrates

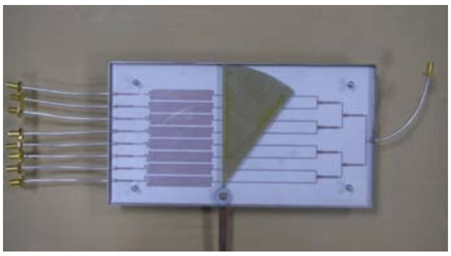

Fig.3: Prototype of compact RF assembly

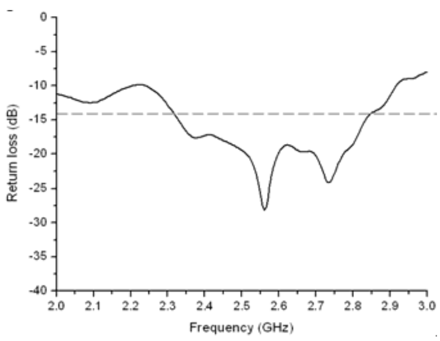

Fig.4: Measured return loss of compact RF system

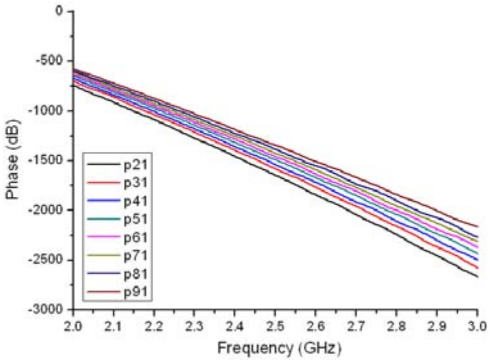

Fig.5: Measured phase change with 37° mechanical adjustment