Influence of concrete on patch antennas on small ground plane

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Abstract: In order to deploy a lot of 5G base stations, there is a method of installing them on utility poles and building walls. In this paper, antennas installed on them for 5G base stations are investigated numerically and experimentally. We examine the minimum ground plane size to remove the influence of concrete and embedded reinforced bars. We also verify the effects on the input characteristics and radiation pattern by measurement.

Keywords: antennas, 5G, concrete, utility poles, concrete wall

Classification: Antennas and Propagation

1 Introduction

One of the challenges for the spread of 5G is the lack of base stations. Installing antennas on utility poles or concrete walls, it will be possible to increase the number of base stations at low cost. Antennas inside concrete wall [1] or direct wave of radar ground-coupled antenna of concrete wall [2, 3, 4] are investigated as the relationship between concrete and antenna. Antennas deployed on concrete for base stations have

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not been studied much. In this paper, an antenna at 4GHz installed on utility poles (concrete walls) for 5G base stations is investigated numerically and experimentally. We examine the minimum ground plane size to remove the influence of reinforced concrete.

2 Influence of concrete

Patch antenna with the small ground plane is affected by the installation environment. First, influence of dry concrete (relative permittivity is 5.5 and loss tangent is 0.04) on patch antenna is investigated at 4GHz in Fig. 1(a). This patch antenna has a hollow structure. In the simulations, we used the FDTD method using CST Studio Suite [5]. In this paper, ground size $L_{\text{gnd}} \times W_{\text{gnd}}$ is normalized with length $L$ of patch. Figs. 1(b) and (c) show input characteristics and radiation patterns. The difference in resonance frequency between a patch antenna with sufficiently large ground ($8.0L \times 8.0L$) and patch antennas with finite ground ($1.7L \times 1.7L$) is very small. The input characteristics of a patch antenna with $1.2L \times 1.4L$ ground changes depending on the presence or absence of concrete. Fig. 1(c) show the radiation patterns show there is a slight influence of concrete in $1.2L \times 1.4L$ ground and there is not influence of it in $1.7L \times 1.7L$ ground. Then, we investigated the minimum ground plane size to remove influence of dry concrete. The resonance frequency and bandwidth of the ground plane smaller than $1.2L \times 1.4L$ ground are different from those of the sufficiently large ground ($8.0L \times 8.0L$). The minimum ground plane size to remove influence on input characteristics is $1.2L \times 1.4L$ ground. In radiation patterns, $1.2L \times 1.4L$ ground is required to reduce the difference in main lobe magnitude from infinite ground to less than 1dBi. $1.7L \times 1.7L$ ground is required to reduce the amount of change in angular width (3dB) to less than 10% of

![Antenna model and characteristics on concrete](image)

Fig. 1. Antenna characteristics on concrete
infinite ground (5 degree). These results show there is a slight influence of concrete in $1.2L \times 1.4L$ ground and the minimum ground plane size is $1.7L \times 1.7L$ to remove it.

The $1.7L \times 1.7L$ ground plate is not affected by dry concrete. We investigated the influence of the moisture content of concrete. Permittivity of concrete depends on the moisture content of it. It is supposed to be installed outdoors as utility poles, hence it is desirable that the radiation pattern and resonance frequency do not shift depending on it. Fig. 1(d) shows the influence of moisture content of concrete on the input characteristics and radiation patterns. Simulate the relative permittivity of saturated concrete as 11.0 and loss tangent as 0.08 [1]. They show there is almost no change due to moisture content of concrete.

Similarly, we investigated the influence of reinforcing bars embedded in it. There is a slight effect of reinforced concrete on the antenna [2, 6]. Reinforcing bars are usually located more than 10mm deep from the concrete surface. The closer the reinforcing bar is to the surface, the more the antenna is affected. It is enough to just analyze as a depth of 10mm. Fig. 2(a) shows simulation model and Fig. 2(b) show Input characteristics and radiation patterns. The diameter of simulated reinforcing bar is 20mm. They show that influence of the reinforcing bar on it is very small. From these results in Fig. 1 and Fig. 2, it is possible to install the patch antenna on reinforced concrete.
Fig. 3. Measurement model and antenna characteristics

(b) Difference in input characteristics between simulation and measurement
black solid line: free space (simulated), black dashed line: on concrete (simulated),
blue solid line: free space (measured), blue dashed line: on concrete (measured).

(c) Phase characteristics in free space
solid line: simulated, dashed line: measured

(d) Measured phase characteristics
solid line: on concrete, dashed line: free space

(e) E-plane
Difference in input characteristics between simulation and measurement
solid line: simulated, dotted line: measured

Fig. 3. Measurement model and antenna characteristics
To summarize this chapter, we examine the minimum ground plane size is $1.7L \times 1.7L$ to remove the influence of realistic concrete. This antenna supposed to be installed on outdoor concrete, hence it is desirable that antenna characteristics do not shift depending on changes in concrete properties. The difference between antenna characteristics in free space and that on concrete is acceptable because antenna design is possible assuming the environment on concrete. However, the difference between antenna characteristics on air dried concrete and that on saturated concrete is not acceptable. Fig. 2(c) show the influence of changes in concrete properties on patch antenna with $1.7L \times 1.7L$ ground. $1.7L \times 1.7L$ ground can remove the influence of changes in concrete properties.

3 Measurement of antenna characteristics

We fabricate patch antennas and measure the input characteristics and radiation pattern to investigate the validity of the simulation results. Simulate the relative permittivity of naturally dry concrete as 5.5 and loss tangent as 0.04 [1]. Fig. 3 show measurement model and measured data. The black streak in Fig. 3(a) is a gap between concrete blocks. Feeding coaxial cable is sandwiched by two concrete blocks in the measurement as shown in Fig. 3(a). Model in free space is measured to confirm the manufacturing error. Fig. 3(b), (c) and (e) show the manufacturing error is within the acceptable range. In simulations, difference between the resonance frequency of patch antenna in free space and that on concrete is 0.03GHz and it is also 0.03GHz in measurement. Fig. 3(d) shows difference between the phase characteristics of patch antenna in free space and that on concrete is very small. From these results, measurement input characteristics and radiation patterns are agreed with simulation results.

4 Conclusion

In this paper, patch antennas at 4GHz installed on utility poles or concrete walls were investigated numerically and experimentally. We examined the minimum ground plane size to remove the influence of concrete and embedded reinforced bars inside it. They are very small and patch antenna with $1.7L \times 1.7L$ ($= 0.80\lambda \times 0.80\lambda$) ground is the minimum size to remove the influence of changes in concrete properties. We also measured the antenna characteristics of the patch antenna on concrete. Measurement results are agreed with simulation results. As a future work, patch array antenna installed on concrete and influence of multiple bars will be investigated.