

Cross Bow-Tie Antenna for Multistatic Ground Penetrating Radar

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Abstract – We investigate a broad band cross Bow-tie antenna to be used for Ground Penetrating Radar (GPR) system. In order to acquire a set of orthogonal polarization signals, a cross bowtie antenna with a feeding circuit was designed. We evaluated the designed antenna experimentally and demonstrated that it works 10MHz- 4GHz, and showed that there is not significant change from the original separated Bow-tie antennas.

Index Terms — Cross-Bowtie Antenna, GPR, Multistatic Radar.

1. Introduction

We developed a multistatic Ground Penetrating radar (GPR) “Yakumo”, which is equipped with 8 pairs of transmitting and receiving antennas. Yakumo has been evaluated in several applications, which include detection of anomalies inside road pavement. Using the multistatic radar configuration, Yakumo has two unique futures, by changing the antenna polarization. In order to acquire these two data sets at one time, we developed an antenna system which can be used for the both polarizations. We show the experimental evaluation results in this report.

2. Yakumo system

“Yakumo” is a multistatic Step-frequency Continuous Wave (SFCW) radar system operating at 10MHz-1.5GHz equipped with 8-transmitter 8-receiver antennas as shown in Fig.1 [1]. By switching the antennas, we can acquire the multi-static $8 \times 8 = 64$ channel data sets at every 1cm interval along the survey line. The antenna element of Yakumo is arranged in two ways as shown in Fig.2 for changing the polarization status. The antenna polarization in the antenna arrangement #1, shown in Fig.2(a) is parallel to the direction of the survey line. In this case, antenna coupling are strong, even for the antenna pairs which located at the other end of the array. Therefore, we can acquire information from deep subsurface. On the other hand, in the antenna arrangement #2 shown in Fig.2(b), the antenna coupling is strong only among nearby antenna pairs, but relatively weak for a pair at long antenna offset. We should note that the most common GPR systems have antenna polarization in the situation of the antenna configuration #2, where the transmitter and receiver polarization is perpendicular to the survey direction. We know that GPR vertical profile obtained in the antenna arrangement #2 is better than that by #1. Yakumo has two unique features that conventional GPR could not achieve.

The first characteristic is complete 3-dimensional image reconstruction by using multiple combination of antennas [1]. The second characteristics is the estimation of the vertical profile of the electromagnetic wave velocity by CMP analysis [2][3]. The both methods utilizes the variable antenna separation, by selecting different antenna pairs, but requires orthogonal polarization.



Fig.1 Multistatic GPR “Yakumo”.

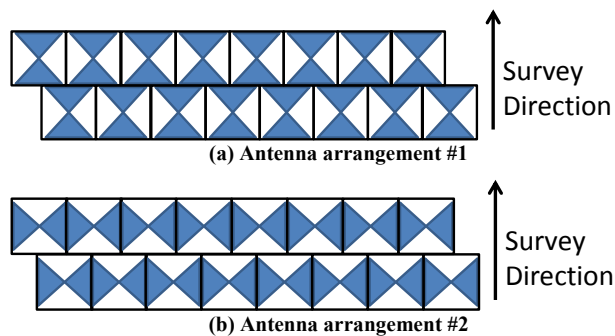


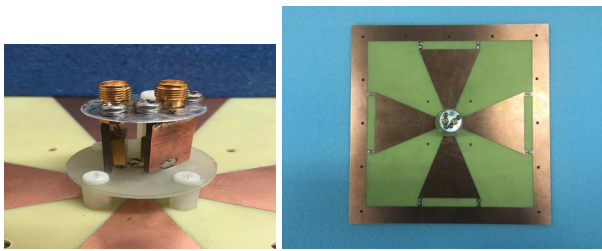
Fig. 2. Antenna configuration of “Yakumo” system. Black color indicates the antenna element.

We found that the vertical velocity profile estimation is quite useful for precise 3-dimensional image reconstruction. However, one set of antenna polarization cannot acquire the data sets for the two applications [4].

3. Cross Bow-tie antenna and its experimental evaluation

The two antenna polarization arrangements in Yakumo have different advantages and disadvantages at the same time. In order to use the both advantages, we decided to develop a

cross-bowtie antenna, which can satisfy the requirement of the two antenna polarization arrangement by switching the antennas.



(a) Feeding structure (b) Antenna element
 Fig. 3 The feeding structure of the Cross Bow-tie Fig. 3
 The feeding structure of the Cross Bow-tie antenna

The antenna elements are placed orthogonally, and baluns are connected to the feeding points of the two sets of elements. In order to shorten the feeding line, baluns are placed vertically on the antenna elements.

In order to evaluate the effect of antenna polarization to the GPR signal quality, we set the antenna 50cm above a metal plate, to evaluate the antenna performance by reflection signal. We also arranged a pair of transmitter and receiver bow-tie antennas having two orthogonal polarization, to simulate the Yakumo antenna configuration #1 and #2. In both cases, transmission between two antennas were measured by using a vector network analyzer.

Fig. 4 show the experiment results. The data was acquired at 50MHz to 4GHz. There are two important points to be evaluated. One is coupling of the antennas and the other is influence of additional antenna element in the received signal.

The signal is consist from a direct coupling between antennas and reflection signal from the metal plate. Smaller antenna coupling (higher isolation) and stronger reflection are required performance for the GPR antennas. Comparing Figs.4 and 5, we do not find significant changes. This means, the designed cross bow-tie antenna does not change the basic performance of the original Bow-tie antenna, and the effect of additional element is negligible. We confirmed that the antenna isolation of the cross bow-tie antennas is high enough in the signal in time-domain.

4. Conclusion

We demonstrated that one cross Bow-tie antenna can replace conventional single polarization Bow-tie antenna with two polarization status. In order to evaluate the performance of the designed antenna for GPR, reflection from a metal plate was used. A good results was obtained from 10MHz- 4GHz, which is enough for the GPR operation.

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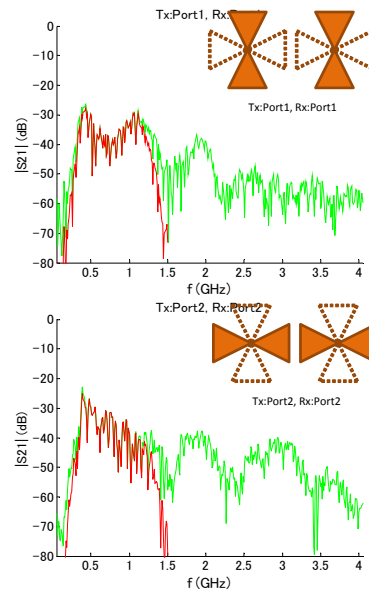


Fig.4 Transmission of Cross bow-tie antennas
 (Antenna Spacing =100cm)

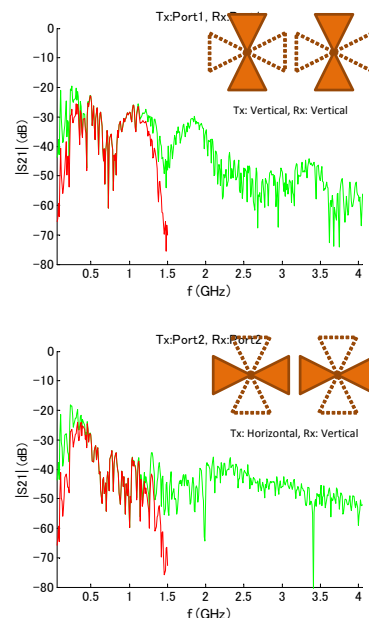


Fig.5 Transmission of Bow-tie antennas
 (Antenna Spacing =100cm)

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