On the Antenna for Long Range Low Power Geographical Monitoring IoT Network

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***Abstract*—An Internet of Things (IoT) network has been developed and tested in the BaZheXiang area in Sichuan, China. The network will be used to monitor the slopes for the potential landslides. The existing Wi-Fi network required more than five hops before reaching the temporary data centre in the hut which is 8km away from the data centre. However, the new system only requires maximum three hops, the real-time geological information of the slope can be delivered to the data centre at the main water dam.**

***Index Terms*—antenna, propagation, measurement.**

I. INTRODUCTION

Sichuan is the earthquake-active area. There were three major earthquakes of magnitude higher than 7.0 M_s in the last ten years. The most recent one was happened in Jiuzhaigou county. Landslides sometimes will be triggered by the earthquakes, particularly in those steep mountain areas, like BaZheXiang in Sichuan, China. The BaZheXiang slope is sandwiched by the Liangzi fault and Xiaogaoshan fault. The interior of the slope is steeply skewed to the west (the overall production is near SN/W <75° to 85°). As shown in Fig. 1, there are two mountains of height higher than 2000 m between the data collection zone and the data centre at the main water dam, the difference from the Yalong river band to the peak of the mountains is about 1000 m, such geographical terrain imposes a very challenging environment for wireless communication. At the moment, the system relies on Wi-Fi technology to transfer the GPS data through five hops to a temporary data hut (marked in Fig. 1) which is about 8 km away from data centre at the main water dam. Researchers are required to go to the hut to collect the data every week. It is labour intensive, costly and dangerous task.

To tackle such challenge, we utilise the long range low power technology to extend the communication range. In consideration of the blockage caused by the mountains and the desirable data rate, lower frequency ISM band at 433 MHz, instead of 915 MHz was used. Moreover, to compile to the regulated output power requirement, it is not desirable to use power amplifier to boost the radiation for longer range, and the extra noise introduced by the amplifier will deteriorate the signal-to-noise level. In addition, the weather proof issue cannot be neglected in the design, the whole wireless node, including the battery, RF circuit board and connectors, must be placed into an $85\times80\times55$ mm^3 IP65 rating ABS plastic box.

To verify the long range low power technology and evaluate the key engineering requirements for the antennas to be connected to the wireless GPS nodes and gateway, a field test at BaZheXiang was carried out in September 2017. With the low range low power RF module developed in UCL as showed in Fig. 2, the maximum communication range achieved was about 6.5 km as illustrated in Fig. 3. Conventional quarter-wave monopole antennas, i.e. gain equals 2.2 dBi and with an omni-directional radiation pattern in the H-plane, were used at both wireless nodes and gateway in the test. Therefore, to further extend the range and deliver the sensor data to the main water dam without addition of repeater(s) or RF power boosting, we proposed to use a novel compact integrated directional antenna design in this paper.

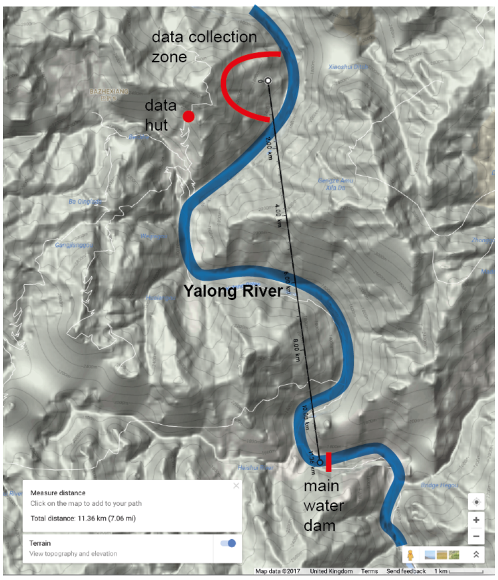


Fig. 1 The terrain for setting up the geographical monitoring IoT network [1]

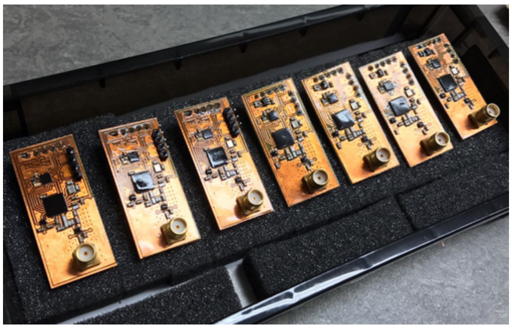


Fig. 2 The long range low power RF modules developed in UCL

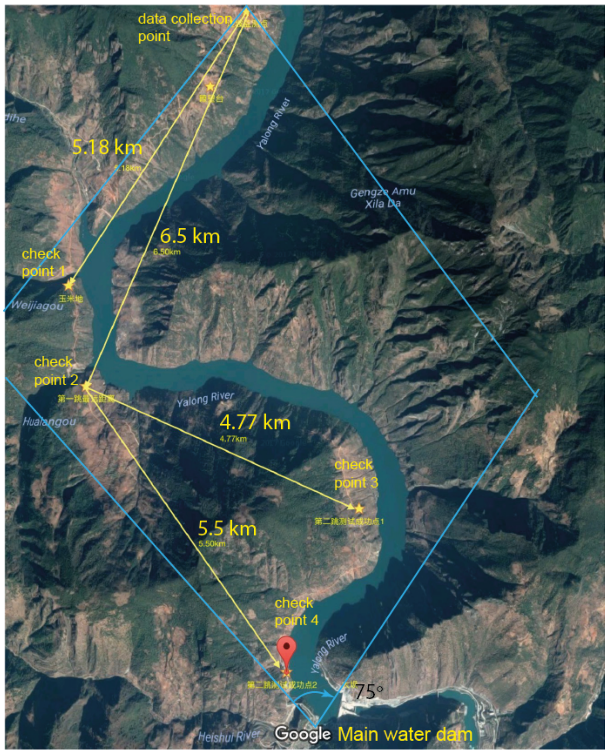


Fig. 3 The measured range of the IoT network

II. ANTENNA CONSIDERATION

A. Antenna Requirement

Equation 1 shows the conventional Friis transmission equation [2].

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi R)^2} \qquad (1)$$

where P_R is the power received by the gateway
P_T is the power transmitted by the wireless node
G_R is the gain of the receiving antenna
G_T is the gain of the transmitting antenna
λ is the free space wavelength
R is the communication range

Assuming P_R, P_T and λ are kept changed and the overall communication channel environment does not change significantly. The path loss in this case is about 97.05 dB. To extend the communication range (R) to more than 11.5 km, one of the suggestions is to use a directional antenna of 7.1 dBi gain at the wireless nodes and keep the conventional quarter-wave dipole of 2.2 dBi gain at the gateway in the system. However, there are few concerns regarding this approach.

(a) As shown in (2), the 3dB beamwidth will be only about 33° for a 7.1 dBi gain antenna, which a very narrow angular window and alignment between the nodes and gateway may be problematic.

(b) Realisation of an antenna within the compact ABS plastic box with 7.1 dBi gain is challenging.

Therefore, it is more sensible to implement the directional antennas at the wireless nodes and gateway.

As shown in Fig. 3, based on the reciprocal characteristic of (1), the wireless node antenna to be able to cover the 75° in azimuth angle and 180° in the elevation angle, the maximum realised gain, i.e. 100% efficiency, of the required antennas, according to the estimation in Equation 2, [3], should roughly equal to 3.1 dBi.

$$G_{max}(dB) = \frac{42{,}000}{BW_\theta BW_\phi} \qquad (2)$$

where G_{max} is the maximum gain of the antenna
$BW\phi$ is 3dB azimuth beamwidth in degree
$BW\theta$ is 3dB elevation beamwidth in degree

B. Geometry

After coming up with the preliminary specifications, such as size and physical constraint, operating frequency, bandwidth and gain for the antenna, CST Microwave Studio [4] was used in the simulation stage.

To realise the antenna at 433 MHz in a confined space ($0.12\times0.11\times0.08\lambda_0^3$) without scarifying the efficiency, the water proof box ($\varepsilon_r = 2.8$, thickness = 7 mm) has to be utilised in the design. The geometry of the first antenna trial is shown in Fig. 4, the basic design concept is based on a Yagi-Uda antenna. The meandering dipole etched on the two sides of a piece of FR4 substrate (ε_r = 4.3, thickness = 1.6 mm) connecting through the via holes at the centre is the driven element. A U-shaped director is located on the top side of the box while two line reflectors and a reflecting plane are positioned on the bottom side. The purpose of the director and reflectors is to form a directive radiation pattern pointing upward. The width of all the conductive lines is all 2.3 mm.

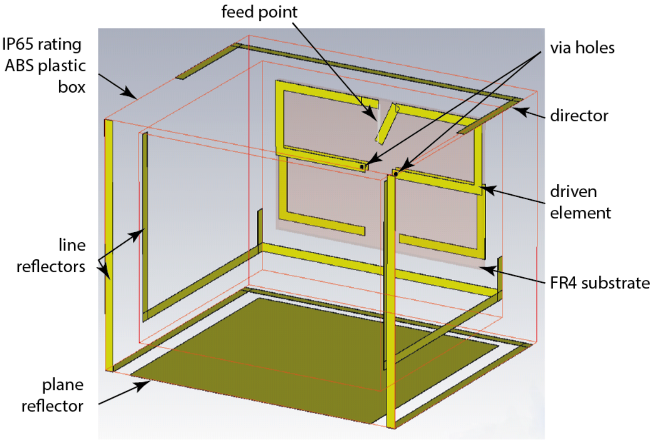


Fig. 4 Geometry of the first antenna design

III. RESULTS AND DISCUSSION

The simulated S_{11} parameter of the proposed compact antenna is shown in Fig. 5. The operating frequency is centred at 433.3 MHz (from 431.0 to 435.5 MHz bandwidth of 4.5 MHz), it covers the ISM frequency band (433.05-434.79 MHz) for IoT.

Fig. 6 shows the radiation pattern of the antenna. The maximum gain of the antenna is 1.62 dBi at the top direction of the box as designed. The functionality of the director and reflectors can be observed in the surface current plot shown in Fig. 8. In addition, the surface current at the centre of the reflector plane is low, therefore the interference with RF circuit will be minimal. As shown in Fig. 7, the simulated efficiency of the antenna is about 88%, therefore to increae the gain of the antenna, the next step will be to further increase the directivity of the antenna to meet the requirement. Moreover, the experimental results will be presented in the conference.

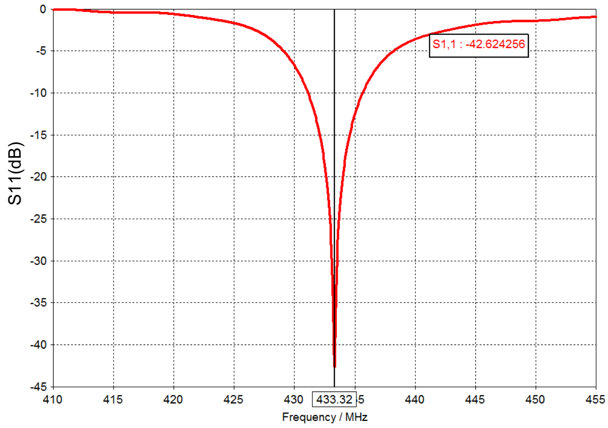
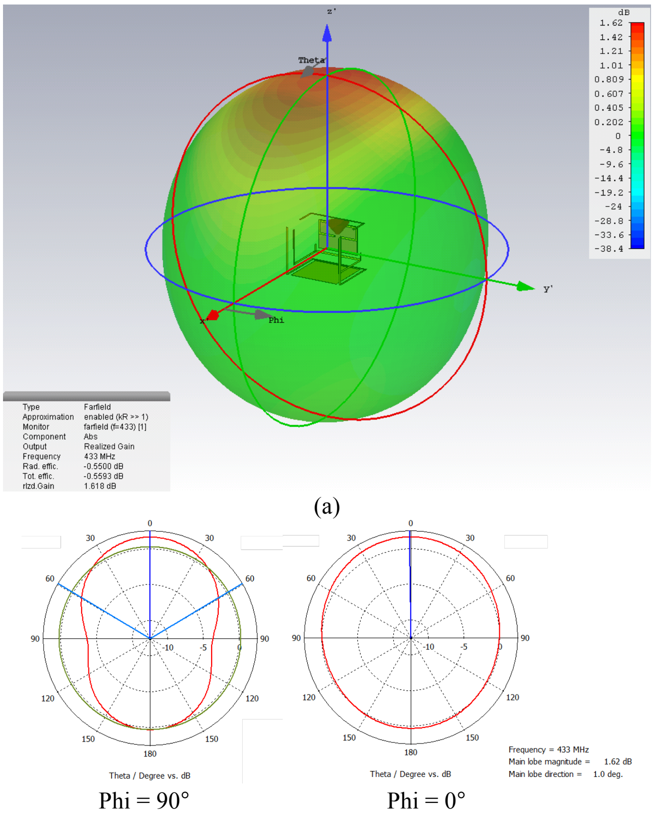


Fig. 5 Simulated S_{11} of the first antenna design



(a)

Phi = 90°

Phi = 0°

(b)

Fig. 6 (a) 3D radiation pattern, (b) 2D radiation patterns of the proposed antenna at 433 MHz

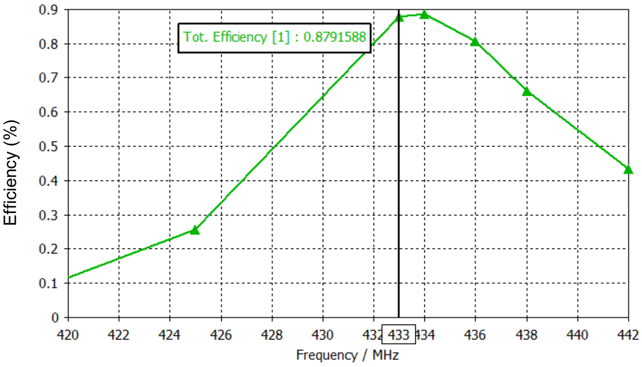


Fig. 7 Efficiency of the first antenna design

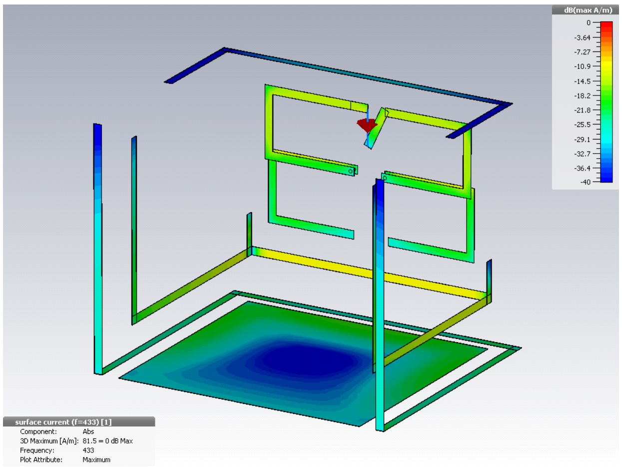


Fig. 8 Surface current on the proposed antenna

IV. CONCLUSION

A directive compact antenna has been designed for extending the communication range of a geographical monitoring IoT network. The ideal specifications, including the operating frequency, angular and range coverages and physical size of the antenna have been discussed. Further improvement in directivity will be continued and reported in the presentation.

REFERENCES

[1] Google terrian map, https://www.google.co.uk/maps/@27.868273,101.8553502,12.64z/data=!5m1!1e4, captured on 19th September 2017

[2] D.M. Pozar, Microwave Engineering, 1st ed., Addison-Wesley series, 1990, pp.672-674.

[3] D. Morgan, A Handbook for EMC Testing and Measurement, 1st ed., The Institution of Engineering and Technology, 1994, pp78-80.

[4] CST Studio Suite 2017 User Manual.