Conservation of Endangered Plant Species Using RFID Tags

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***Abstract*—Radio Frequency Identification (RFID) tags in tamper-proof casings are proposed and tested as part of remote security systems for endangered plant species. The tag is shown to be sufficiently broadband and insensitive to the tamperproof box and underlying plant material and achieves a read range of more than 10m with a standard UHF reader system. Tests are undertaken to demonstrate the tag is readable from different elevations and azimuthal angles.**

***Keywords*— RFID, Conservation**

I. Introduction

The illegal wildlife trade is fourth only to narcotics, human trafficking and counterfeiting in terms of trans-national trafficking, with an estimated value of up to $26.5 billion per year [1]. The United Nations has recognised that environmental crime as an emerging form of trans-national organised crime requires a greater response by governments [2]. The Cycad is an endangered plant type which predates the Jurassic era. They are found in-situ in tropical and subtropical regions and are particularly valuable to theft owing to their rarity, length of time to maturity and aesthetic appeal. They can grow in remote areas which are difficult to patrol and can be relatively straightforward to remove owing to their compact root systems. Nearly 40% of cycad species are threatened with extinction with only single specimens remaining in-situ in some cases [3].

Although developed as an asset tracking technology, Radio Frequency Identification (RFID) has found application in a variety of other areas, one of which is security, [4]. In this paper, passive Ultra High Frequency (UHF) RFID tagging is proposed as a security technology to protect cycads using a tamper-proof mounting box on the plants. The tag box is designed for 'bee sting' functionality, where a clearly visible tag acts as a deterrent that cannot be removed without destroying the tag.

II. RFID Tag Design

To provide a large bandwidth as a mitigation against detuning when mounted on organic material, a Bow-Tie Antenna with a T-shape impedance transformer [5, 6] was chosen for the purpose of this project, Fig.1 inset. The transponder chip connected to the tag antenna was a UCODE G2X chip [7] with a sensitivity of -18 dBm and an operating band from 840 MHz to 960 MHz. CST Microwave Studio was used to simulate the design and achieve the dimensions given in Table I. The corresponding simulated S11 curve in Fig.1 shows that the tag is well matched between 860 and 970 MHz and that any reduction in tag operating frequency, due to mounting on the plant, is allowed for. The gain of the tag antenna at 870 MHz was simulated to be 2.1 dB.

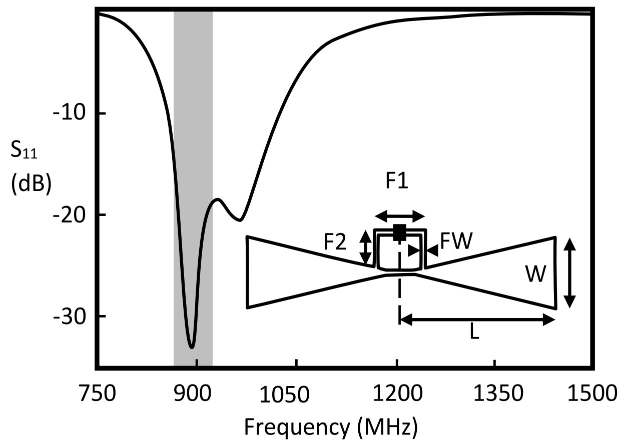

Fig. 1. Bowtie tag S_{11} simulation and geometry (inset).

The tamper-proof 'bee sting' box is shown in Fig. 2. The box is designed so that, when mounted on the cycad, it cannot be removed without ripping the tag and detaching the transponder chip. This was achieved by machining a hole into the rear face of an Acrylonitrile Butadiene Styrene (ABS) box with dimensions 120 × 65 × 20 mm^3 and relative permittivity, $\varepsilon_r = 2.8$.

TABLE I. TAG DIMENSIONS GIVING RESPONSE SHOWN IN FIG.1

Geometry Parameter	Dimension (mm)
W	*24*
L	*57*
F1	*10*
F2	*12*
FW	*0.5*

A Polytetrafluoroethylene (PTFE) cylinder with ε_r = 2.2 was placed in the hole and the tag attached by a screw through the disc and into the cycad. The tag is mounted on pillars to space it 5mm from the back of the box and the tag is attached by 2 screws which protrude through the rear of the box into the cycad. The central PTFE cylinder was attached to the plant with a screw, and allowed to slide through a hole in the rear of the box. The prototype tag was etched onto a thin Mylar sheet with perforations or V-slits cut into the substrate so that any attempt to displace the box from the plant would move the cylinder and rip the metal of the tag. The box lid snapped shut once attached and the addition of an adhesive pad attaching the lid to the tag transponder would mean that forced removal of the lid would rip the chip from the antenna.

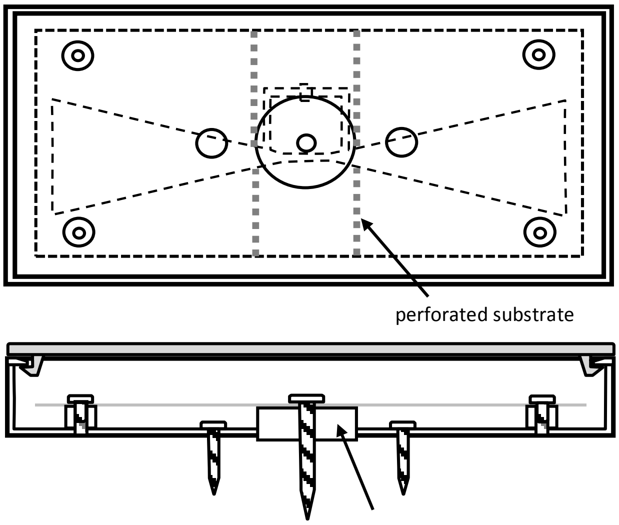

Fig. 2. Tamper-proof box design.

The prototype tag and box were assembled and mounted on a small cycad specimen, Fig.3.

The lid was placed on the box and the read range was measured with a calibrated VoyanticLite system [8] to be 10.5 m between 860 MHz and 980 MHz. This read range is at the upper end of expected values for the UHF RFID reader/transponder system under consideration and was obtainable because of the 5 mm separation between the tag antenna and the cycad surface which reduced any dielectric loading effects due to the plant's caudex or truck.

Finally, to assess the tag read performance with incident angle, the specimen was rotated relative to the reader for 3 angles in the horizontal plane, and one angle in elevation. The measured read ranges are given in Table II. These results are indicative of the dipole patterns expected for this antenna, with the omni-directional H-plane in the evaluation plane and are appropriate for situations where the reader is expected to be mounted above or below the tag.

Fig. 3. Prototype passive security tag mounted on a small cycad specimen (box lid removed).

TABLE II. MEASURED READ RANGES FOR CYCAD MOUNTED TAG AT VARIOUS AZIMUTHAL AND ELEVATION ANGLES. AXES DEFINED IN FIG.1.

Plane of Read Signal	**Incident Ray Angle at Tag (ϕ, θ)**	**Read Range (m)**
Horizontal	*0°, 90°*	*10.5*
Horizontal	*30°, 90°*	*6.5*
Horizontal	*90°, 90°*	*1.5*
Elevation	*0°, 115°*	*7.5*

III. TESTING

Finally, the read performance of the tag was tested outdoors to establish the achievable read range. The tag was mounted 1.4 m above soft ground in an open space and a commercially available Favit UHF RFID reader system including an antenna with a gain of 7 dBi, gave read ranges between 1 and 10.4 m for transmitter powers of 0.01 to 2 W respectively. There was a line of sight path between the reader and the tag, and Fig. 4 shows that the data fitted that expected for a radio system in open conditions where the read range increases in proportion to the square root of the transmitted power.

The tag was then attached to a tree 4 m above the ground with the reader 5 m away. The reliability of the tag reads was assessed by recording the total number of successful interrogations that occurred over a 5 minute period. Ten tests were taken for each of the powers indicated in Table III. The tag performance can be seen to be stable with high reliability for transmit powers of 0.8 W and higher. When the power was reduced to 0.6 W, the reads became intermittent and communication was almost totally lost at 0.5 W.

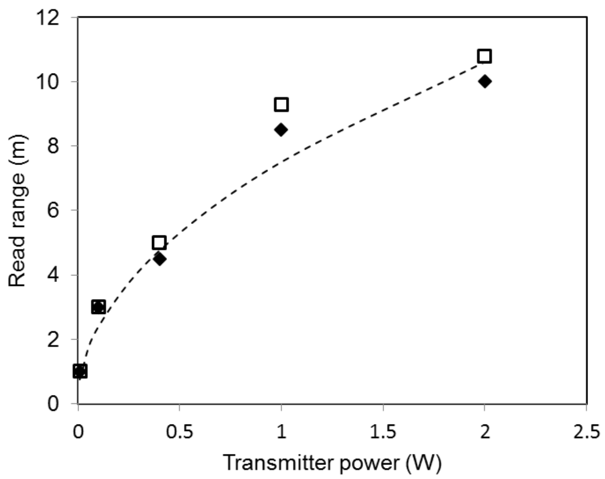

Fig. 4. Measured read range data vs transmitter power. Test 1 and 2 are indicated by diamond and squares respectively. The theoretical relationship between read range in proportion to square root of power is indicated by the dashed line.

TABLE III. READ RELIABILITY TEST OF TREE-MOUNTED TAG AT 4 M ABOVE GROUND AND A READ RANGE OF 5 M.

Reader Power (W)	Mean read count	Standard Error
0.5	*3.4*	*5.6*
0.63	*2268*	*298*
0.8	*2240*	*4.2*
1	*2243*	*4.6*
2	*2257*	*3.7*

In summary, communication over 5 to 10 m can be achieved for reader powers of 1 or 2 W. A higher read range could be achieved for limited power readers by using higher gain antennas at the reader. However the implication of using a higher gain antenna is that the read beam becomes narrower meaning that spatially distributed tags will not be readable by a single antenna unless a technique such as beam switching is employed.

Removal of the tag casing from the tree demonstrated that the flexible antenna substrate was ripped, rendering the tag unusable should there be an attempt to tamper with the device during a theft.

I. CONCLUSIONS

Tamper-proof UHF RFID tags are proposed for 'bee-sting' security tagging to protect cycad plants where a standard, low cost, reader may be mounted several meters away from the protected specimen. In remote locations, the reader could use satellite or cellular network communication to relay alerts to the nearest ranger station. GPS coordinates could also be relayed to deploy autonomous observation drones. A secondary, covert near field reading tag (pit tag) could be embedded into the plant to aid identification should a stolen specimen be recovered at a later date [7].

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