Abstract—This paper covers the authors attempts to gather data for the planning of and then operate a wireless sensor network in a rapeseed crop. It also covers the field propagation measurement set-up the author put together to make the measurements and briefly describes the sensor hardware being used.

I. INTRODUCTION

The project aims to look at whether it is practical to operate wireless sensor networks in rapeseed. The author has found many examples of people attempting to operate wireless sensor networks in other crops but not under rapeseed. In addition to specifically looking at operating deployments in rapeseed the author has developed some systems that were needed as part of developing the deployment but have wider applicability. This paper briefly describes the field prorogation measurement system and sensor node design used for the project and gives some of the results that have been collected so far.

Initial plans were to operate at Rothamsted Research Station. However this proved to be too far to travel practically so in the end the deployment was made at Tatton Dale Farm which is much closer but has access issues of it’s own.

II. FIELD PROPAGATION MEASUREMENT SYSTEM

An experimental set-up was designed for taking measurements of radio propagation. The primary goal of this set-up was to allow accurate measurements of the attenuation through a radio link in a field of crops. The transmitter and receiver were kept electrically separate since electrical connections could potentially provide an unwanted signal and/or ground path between transmitter and receiver. A block diagram of the field measurement setup can be seen in Figure 1.

A. Measurement hardware

An Anritsu MS2036A [1] portable vector network analyser is used as a signal source. While intended to be a vector network analyser it is possible to make this device act as a remote controllable unmodulated source. To receive the test signal a Rhode and Schwartz FSH8 [2] portable spectrum analyser was used. The MS2036A and FSH8 are controlled over Ethernet from a laptop which was located close to the signal source. The FSH8 was connected to the Ethernet switch via a fibre optic link to allow Ethernet communication while maintaining electrical separation.

The system can operate over the frequency range 610kHz to 6GHz with the limiting factor being the frequency range of the Anritsu MS2036A used as as a signal source. However performance has only been characterised in the 2.4-2.5 GHz band.

The MS2036A used as a signal source has a nominal output level of 0 dBm. In the mode used here (preamp on, attenuation off RBW 30 Hz VBW 30 Hz span 2 kHz) the FSH8 has a noise floor below -140dBm allowing measurement of link losses of up to 140 db.

B. Antenna stands

To allow mounting the antennas in a manner similar to how they will be mounted in the field three different types of antenna stands have been constructed. Two copies of each type were produced to allow for symmetrical measurements.

The first to be constructed was a tube intended to be buried in the same way as a sensor node. This can be seen in Figure 2. This provides the most realistic representation of a sensor nodes antenna mount but was not used in the end due to the difficulty of deploying it.

The second stand is designed to sit on the ground and mount an antenna vertically. This places the antenna further from the ground than it would be on a buried sensor node but is much easier to deploy. This stand was used during the measurement session at Rothamstead and is pictured in Figure 3.

The final stand is a set of telescopic tubes with weights at the bottom to allow mounting of antennas at height for crop canopy measurements. There are two lengths of outer tube and three sizes of inner tube allowing an overall height range from 0.5 m to 2 m.

The stands were all designed and constructed in-house with the assistance of university’s mechanical workshop.
III. ROTHMSTEAD MEASUREMENT TRIP

In April 2011 a trip was made to Rothamsted Experimental Station[3]. This trip was intended to serve two purposes, the first was to become familiar with using the equipment in a field situation, the second was to gather data that would be needed to deploy a demonstration network.

The trip covered three days travelling down to Rothamsted Experimental Station[3] on Tuesday 26th April 2011 and returning on Thursday 28th April 2011. The first two days were spent sorting out problems and getting used to using the equipment in a field setting leaving only a single day for actual measurements. It was hoped to have more field trips and a deployment in 2011 but these did not happen due to organisational problems.

The sprung monopoles that were taken (which were taken because at the time they were the planned antennas for the sensor nodes) were suspected of having significant impact on the measurements on Tuesday though this suspicion is now believed to have been incorrect. In retrospect some well characterised test antennas should have been taken but this was not thought of at the time. Most measurements ended up being done using coax monopole antennas constructed from coax intended for satellite TV. This was less than ideal because of the impedance mismatch but it was the best that could be constructed given the limited available resources. Only the 2.4 GHz band was tested due to time constraints, and the fact that 2.4 GHz was already planned for the deployment.

A. Measurements through crop base

The first measurements made on Thursday were through the crop near ground level. These measurements made it very clear that transmission through the core of the crop was only viable for very short distances. The measurements were taken using the surface stands mentioned above.

The 1 m and 2 m tests were done with a frequency step of 10 MHz, while others done with a narrower step of 1 MHz to hopefully show fading effects, it would have been desirable to have performed all the tests with the narrower frequency step but time did not permit that.

The results for these tests can be seen in figure 6. Note that in the original dataset there was a failed measurement at 2.458 GHz in the 4 m dataset. Therefore this data point was interpolated for the purpose of making the graph. The results of the 2M test do not seem to fit the pattern formed by the other tests and for many frequencies are lower than the 3m test. A possible explanation could be that the 2M test ended up going through a particularly dense section of foliage by chance.

B. Measurements through crop canopy

Measurements were also taken near the top of the crop canopy above the bulk of the crop but below the top of the tallest plants. These measurements were taken with a transmit antenna height of 97 cm and a receive antenna height of 93 cm on an improvised stands made from sticks that were found near the field. Measurements were taken at separation distances of 10 m, 20 m and 30 m with 11 points in each measurement set. A picture of the antenna setup used can be seen in Figure 8. Results can be seen in Figure 7.
These results show that by moving the antennas up into the crop canopy far greater range can be achieved than with the antennas near the ground. The results show about 10 dB of frequency selectivity. Based on these results with the use of range extenders it should be possible to achieve 10 m through the crop canopy with simple antennas and far more with high gain antennas.

IV. HARDWARE AND SOFTWARE FOR THE NETWORK

The node hardware we are using is based on Microchip’s PIC18F45J11 microcontroller[4] and MRF24J40 [5] wireless transceiver. These were initially chosen based on the authors familiarity with microchip products and development tools. They operate in the 2.4 GHz band. Later the author came to suspect that this may not have been the best choice of band but by that time it was too late to change to a different system.

A custom board design (shown in figure 9) with the transceiver chip directly integrated on the board was used as it was felt necessary to use external antennas and microchip did not at the time offer a suitable module with external antenna connector. The nodes had a total of four sensors, two temperature sensors (one deep in the node to get an indication of soil temperature, one attached to the and crude soil resistance and surface water presence sensors but the focus of the work is on the networking side not the sensing side.

The end node runs off 4 AA batteries. The repeater and base station used the same microcontroller/transceiver board as the end nodes but the repeater node has a large battery supply (8 D batteries) and the base station also had an embedded Linux board and mobile broadband gear (which lead to far higher power requirements and the requirement for a pair of large leisure batteries to be swapped out weekly). The repeater and base station were also fitted with CC2591 [6] range extender boards to increase transmit power and receive sensitivity.

The end nodes and repeater were enclosed in flanged PVC tubes buried with their flanges at ground level. Monopoles formed from the end of coaxial cables were used as antennas. A complete end node including enclosure is pictured in Figure 10.

The software is a modified version of Microchip’s MiWi software. This system creates a two-level hierarchical network with end nodes able to connect either to a repeater or to the base station. End bodes communicate hourly with the base station or repeater. The repeater wakes up for a 30 second interval each hour to give new end nodes a chance to connect to the network. Once connected to the network the nodes have their clock’s updated after every communication keeping them in sync with the rest of the network. The base station is currently active continuously.

V. TATTON DALE FARM DEPLOYMENT

On 15th of March 2012 an initial network was deployed at Tatton Dale Farm. Included in the deployment were a base station, a repeater node and a total of 12 end nodes. The end
nodes were located in two lines one extending outwards from the base station and the other extending out from the repeater node.

The deployment plan was as follows, the base station was to be located at the edge of the field with a line of end nodes extending from each and the repeater node was to be located 10m from it (formed from 8m along the edge of the crop and 6m further into the crop). Each line of nodes was to contain 6 nodes and the distances from the base station/repeater to the end nodes were 1m 1.5m 2m 2.5m 3m and 3.5m. Nodes 1-6 were in the line from the repeater while nodes 7-12 were in the line from the base station. Within each line the lowest numbered node was closest to the base station and the highest numbered node was furthest from it. Figure 13 has a diagram of this arrangement.

Due to a combination of measurement inaccuracies, finding suitable places among the plants to auger in the nodes and the finite size of the base station and repeater equipment the idealised measurements mentioned above could not be exactly followed. Generally measurements were taken from the antennas of the devices that would be used for a particular communication. Radio path lengths were within 10% of the values planned. Photographs of the deployment can be seen in Figures 11 and 12.

Immediately after deployment most of the the nodes were found to be working well with only occasional lost messages. However two nodes (numbers 10 and 12) did not show up in the data at all.

Since deployment a number of problems have been encountered with the network. The mobile internet link is somewhat unreliable. The base station batteries sometimes run out before their one week swapout cycle. Most worrying the nodes behind the repeater have completely disappeared from the network, the cause of this is unknown at this stage but some form of failure of the repeater node is suspected.

The two failed nodes have been pulled out and replaced on the next visit and brought back to the university for investigation and the replacements are now working. The issue with the repeater node is unknown at the time of writing.

VI. CONCLUSION

It has been discovered that transmitting through rapeseed foliage at 2.4 GHz incurs extremely high levels of attenuation such that even with range extenders transmitting more than a few meters. Combining this with the large scale of a typical farm transmitting through the crop is only likely to be practical if a cluster of measurements from a small area are desired. It would therefore seem wise to investigate other frequency ranges and/or investigate how antennas above the crop canopy can be deployed in a farming compatible manner.

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REFERENCES