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Integrating UHF RFID Antennas into Surgical Instruments

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***Abstract*—This paper details a technique where a non-resonant metallic surgical instrument – in this case a scalpel handle – can be modified to effectively incorporate UHF RFID functionality, where the instrument itself serves as the antenna. This is achieved by modification of the instrument with a longitudinal slot dimensioned such that an impedance match can be realized to the target RFID device. Aimed at the European UHF RFID band we demonstrate the technique both by simulation and measurement the modification of a commercially available scalpel handle resulting in an efficient UHF RFID far-field tag.**

Keywords—RFID; antenna; instrumentation; healthcare; patient; surgical; scalpel;

I. Introduction

Incorporating RFID technology into healthcare related products offers significant advantages over barcode and other such technologies. It allows for the continuous tracking of instruments over both their usage and life cycles. For a surgical instrument this could start with the preparation area and operating theatre, through to washing, sterilisation and other interim procedures such as sharpening. All of this being detected and recorded wirelessly, potentially over many metres in the case of UHF RFID and transparent to the user. RFID tagging of surgical instruments is already achieved, both at HF (NFC) and UHF, this usually involves attaching a small transponder to the target instrument. In the case of NFC transponders read ranges of a few centimetres are typical. For an optimised UHF RFID tag and reader system read ranges of >10 metres are common, but for very small tags incorporating small low efficiency antennas this distance is much reduced, with read ranges of 0.5 – 2 m being typical [1] – [5]. A technique has been previously applied where everyday metallic tubular objects have been given UHF RFID functionality [6]. This paper demonstrates an efficient technique where the actual metallic instrument itself is modified and forms the antenna, with associated electronics such as the RFID device and additional matching components if required being embedded within the instruments body. This results in a UHF RFID enabled instrument with read ranges comparable to more conventional tags.

II. Computer Simulation

A. Target Instrument

The modified instrument presented here is a No.3 scalpel handle from Swann-Morton® [7], a model of which used for CST Microwave Studio™ (CST MWS™) simulations along with its significant dimensions are shown in Fig. 1. The handle is manufactured from stainless steel with a Resistivity ρ (Ω.m) of 6.9×10^{-7} and Conductivity σ (S/m) of 1.45×10^{6}.

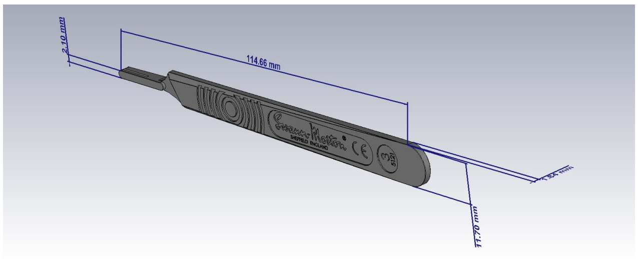


Fig. 1. Swann-Morton® scalpel handle model and dimensions.

B. Impedance Measurements

The technique used was to incorporate a longitudinal slot so that an impedance match to the RFID device can be achieved. Targeting the European RFID band of 866 MHz an experimental method was carried out using CST MWS™ where starting from the non-blade end of the tool a 2 mm wide slot was introduced, this included a measurement port directly across the slot as shown in Fig. 2. Due to initial small changes in impedance this was carried out in 15 mm increments up until 75mm where the increments were reduced to 5 mm up to a maximum slot length of 90 mm for improved resolution. Additionally the slot length was fixed at 75 mm with its width changed over 1-3 mm in 0.5 mm increments and its impedance measured. The results showing impedance change due to slot length and width are given in Table I.

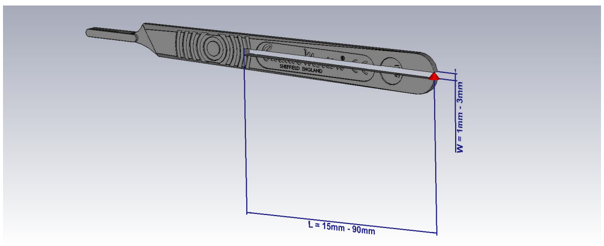


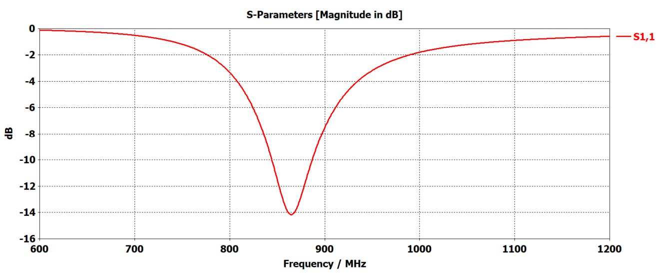
Fig. 2. Modified scalpel handle and its slot dimensions for simulated impedance measurements.

TABLE I.

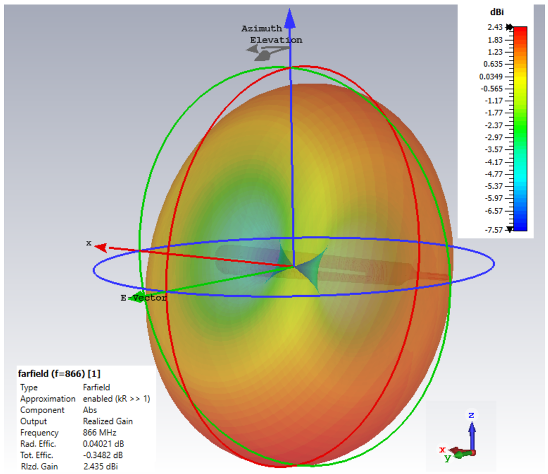
Slot Length/Width (mm)	Impedance (Ω)
15/2	0.054 + j42.8
30/2	0.14 + j82
45/2	0.36 + j136
60/2	1.1 + j229
75/2	6.3 + j535
80/2	18 + j873
85/2	123 + j1886
90/2	178 - j2562
80/1	7.3 + j464
80/1.5	12.3 + j678
80/2	18 + j873
80/2.5	25 + j1086
80/3	1.1 + j235

C. Impedance Matching and Simulations

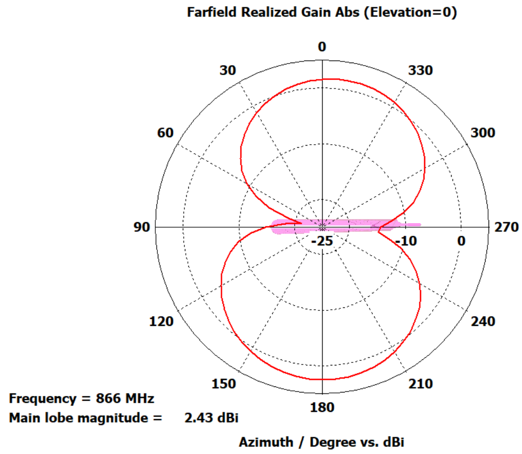
The selected RFID device is Alien Higgs 3, which at 866 MHz has an input impedance of 27 – j195 Ω and sensitivity of -18 dBm. The procedure chosen here is to adjust the scalpel handle slot length until the real part of its impedance (27 Ω) matches that of the Alien Higgs 3 device, the required lumped element can then be included to cancel the combined reactance of both the scalpel handle and RFID device. From simulation a slot length/width of 82/2mm results in an impedance of 27 + j600 Ω at 866 MHz, a series inductance of 146 nH was required to achieve a match to the RFID device. Shown in Fig. 3(a) is the return loss plot (S_{11}) of the matched handle, with an S_{11} of ~ -14 dB. In addition, far-field, elevation and azimuth radiation pattern and surface current plots are shown. They show good efficiency with a realized gain of 2.43 dBi and the expected broadside radiation pattern, although with some skewing of the pattern due the asymmetry of the structure.



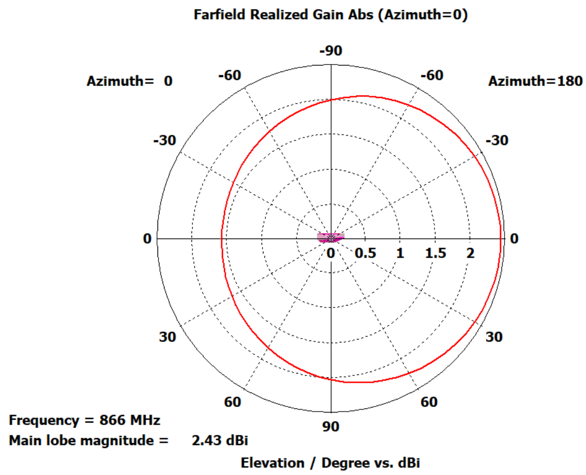
(a)



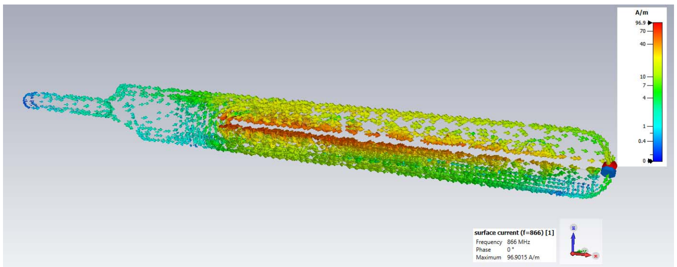
(b)



(c)



(d)



(e)

Fig. 3. Simulation measurements for the modified scalpel handle (a) return loss, (b) 3d far-field radiatiopn pattern, (c) far-field realized gain elevation pattern, (d) far-field realized gain azimuth pattern and surface current shown in (e).

III. Practical Measurements

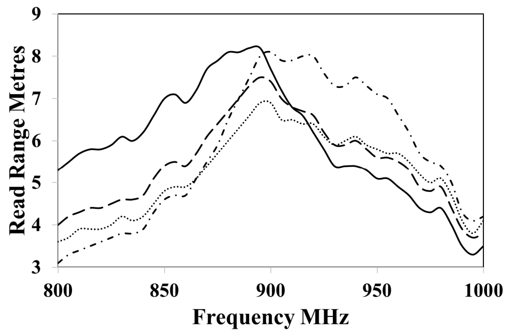
A. Handle Modification and Assembly

Taking a No.3 Swann-Morton® scalpel handle an 82 mm x 2 mm slot was cut, using a VNA an impedance measurement was made giving an initial value of 22 + j600 Ω at 866 MHz, increasing the slot length by 1 mm resulted in a value of 27 + j660 Ω. A series inductance of 157 nH was required to match to the impedance of the Alien Higgs 3 device, the actual nearest preferred value (NPV) is 150 nH. Figure 4. Shows the assembled test scalpel handle. It should be noted that being stainless steel a phosphoric acid flux was required to enable soldering of the components.

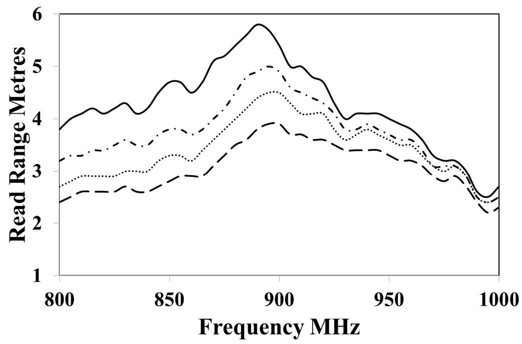
Fig. 4. Constructed test scalpel and 10A type blade. Face labels for the practical measurement shown inset.

B. Practical Measurements

Using the Voyantic UHF RFID measurement system read range measurements were carried out. The systems consists of the main measurement unit swept over a frequency range of 800 – 1000 MHz coupled to a linearly polarised antenna, where the tag under test is located at a calibrated referenced 30 cm distance away. Due to the skewing of the radiation pattern shown in the simulations, measurements were taken for the four faces of the scalpel as given in Fig. 4. In addition, although the design was optimised minus its blade a 10A type blade was added and the measurements repeated. This was to see the de-tuning effects of adding the blade and if it still functions as a usable RFID device. The read range measurements are shown in Fig. 5.



(a)



(b)

Fig. 5. Voyantic read range measurements for the prototype scalpel handle, (a) without blade and (b) with the 10A blade added over the four faces of the handle. Face (a) ---- (b) -.-. (c) .... (d) ——

C. Discussion of Results

From the measured results shown in Fig. 5 read ranges of 6.5 – 8 m over the four faces of the modified scalpel handle were achieved, and 3.5 – 6 m with the blade added. This reduction in read range is expected due to the detuning effect of adding the blade. Although designed for a center frequency of 866 MHz the actual maximum read range peaks at ~890 MHz due to using a NPV rather than the exact calculated component value in the matching network.

IV. Conclusions

This paper shows a technique where a UHF RFID device and associated matching components can be embedded into metallic objects – in this case a surgical scalpel handle – and offer RFID functionality, with the object acting as the antenna. A prototype targeted at the European RFID band was simulated and measured. This gave good performance and compares well in terms of read range for more conventional tags and far exceeds that of the compromised attached type tags. It is realised that the technique may not be practical for small items, where in terms of wavelength they might be too short to realise an efficient antenna, also items where the structural integrity might be compromised due to modification. It is envisaged for the version presented here, during manufacture the additional slot would be filled with a resin or similar material that is safe for its intended application/environment and able to stand the rigors of cleaning and autoclaving.

ACKNOWLEDGMENT

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