Identification of Transmitting Antennas in Secure Internet of Things Networks

Mohamed I Sobhy, John C Batchelor and Gareth J Howells
The School of Engineering and Digital Arts
The University of Kent
Canterbury, CT2 7NT

***Abstract*—Bluetooth and WIFI channels are open to public users and have few security procedures. One security aspect is for a receiver to be able to verify the identity of the transmitter. This paper describes methods of identifying transmitters by the properties of their antennas.**

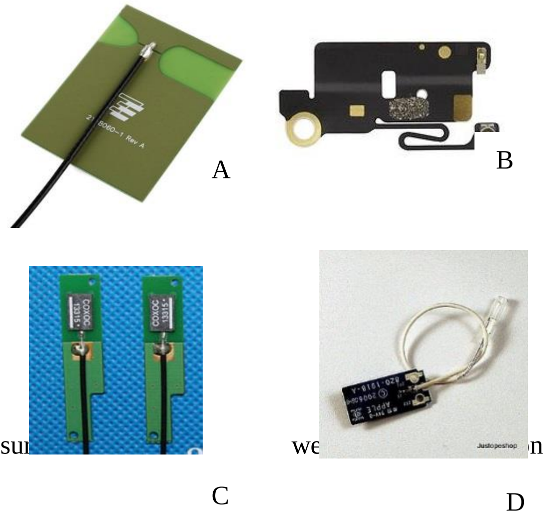
***Keywords*—secure networks, bluetooth, antenna identification.**

I. Introduction

The number of devices connected to Bluetooth and WIFI networks is increasing at a fast rate. The specifications of these networks include very little security measures such as immunity against unauthorised reception, interference in the transmitted data and verification of the identity of transmitters. The present work is aimed at developing methods of identifying transmitters from the characteristics of the transmitting antenna. The detailed objectives are:

1. Measurements on a number of commercial antennas to determine the difference between types and between instances of the same type.
2. Developing models from measurements that could be used is assessing the effect of the antenna on the transmitted signals.
3. Developing algorithms to detect and display small differences between received signals that are transmitted by different antennas.
4. Measurement on complete transmitting modules to assess the contribution of different parts of the module to the uniqueness of the features of the transmitted signal.

II. Measurements on Antennas


A

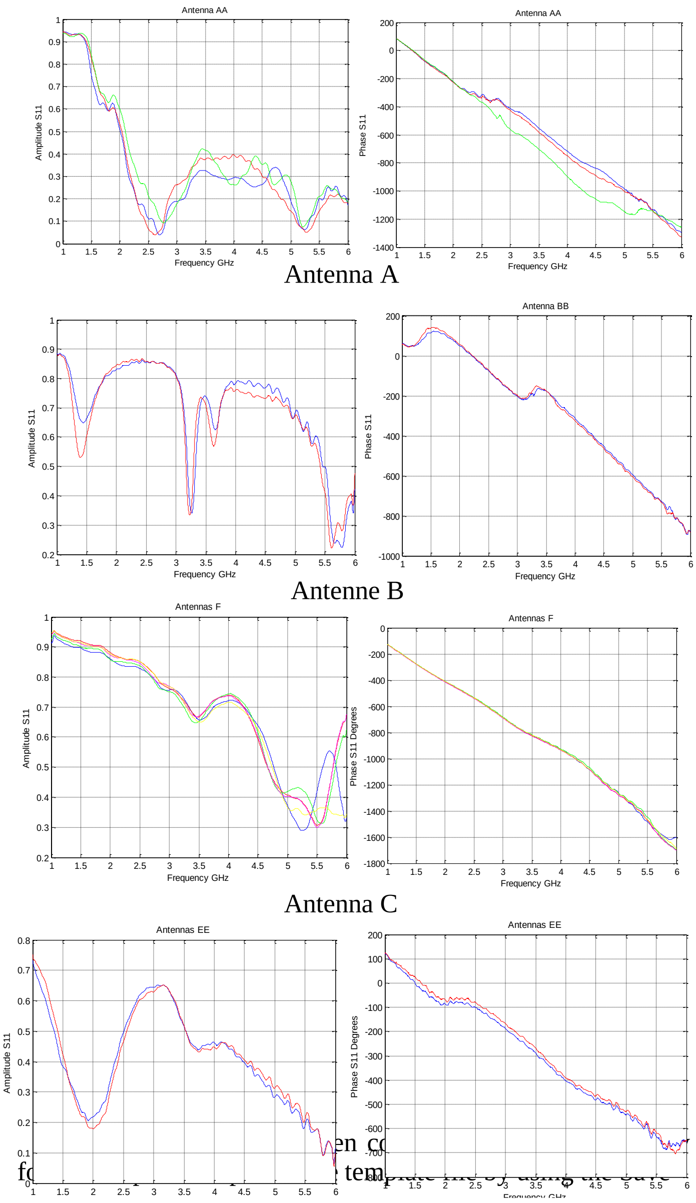
B

C

D

Fig 1 Examples of antennas characterised

Measur we n seven different types of commercial antennas. For each type either two or three antennas were measured. The purpose of this part of the project work is to determine the difference between antennas of the same type, also between antennas of different types. The antennas used are shown in Fig1. The initial measurements determined the reflection coefficient S_{11} in amplitude and phase. Examples of results are shown in Fig 2.



Antenna A

Antenne B

Antenna C

en co
fo e template file by using the Save

Antenna D

Fig 2. Amplitude and phase of S_{11} for examples of Bluetooth and WIFI antennas.

As expected, it is clear from Fig 2 that individual antennas have different characteristics that will contribute to the RF behaviour of any transmitting device. Even one antenna will have different characteristics depending on slight differences in the way it is installed. To prove this, measurements were carried out on one antenna of Type B with slight differences in the positions of its connecting wire. Fig 3 a shows a noticeable difference in the amplitude of S_{11}. This is important for security as it indicates that the device may have been tampered with.

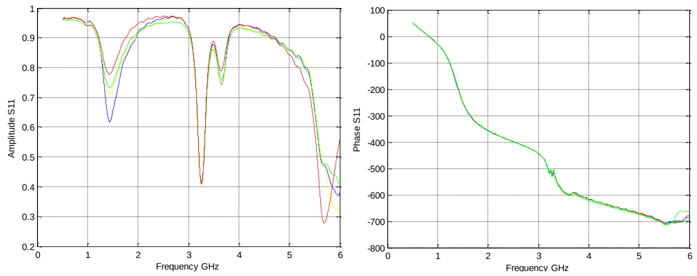
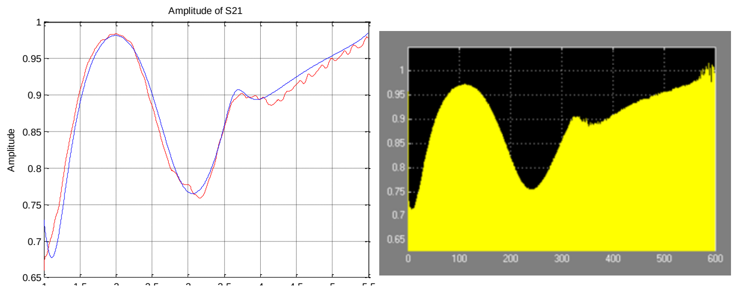


Fig 3. Amplitude and phase of antenna B with different wire position.

III. DERIVING SYSTEM MODELS

The measurements on antennas are performed in the frequency domain. However, if we want to study the antenna behaviour in a digital system, we must derive a ‘system model’ which is suitable for time domain simulations. Starting from the measured reflection coefficient S_{11} we calculate the corresponding transmission coefficient S_{21} and develop a model for the whole antenna in either the frequency or time domains. We give an example of one antenna whose model has been completed. The measured reflection coefficient is that for antenna E and is shown in Fig (c). A model for the transmission coefficient is then derived in the frequency domain and finally a system model is derived. The model of the system used and an example of results are shown in Fig 4.



(a) (b)

Fig 4. Transmission model from measured results.
a) Frequency domain model. b) Time domain model.

IV. IDENTIFICATION OF ANTENNAS

The most effective method of identifying antennas is to use the already transmitted signals from devices. Fig 5 shows two antennas receiving a random digital data up-converted to a pass-band of 2.0 GHz which is one of the pass-bands of the antenna used as shown in Fig 4 .

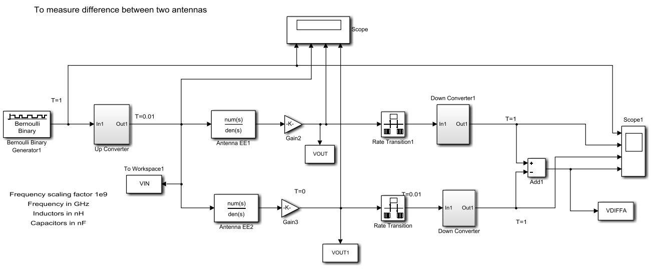


Fig 5. Two antennas with a random digital data up-converted to 2.4 GHz.

The results of the simulation are shown in Fig 6. As expected there is a detectable difference between the signals received from the two antennas. This is shown in the time domain in Fig 6e.

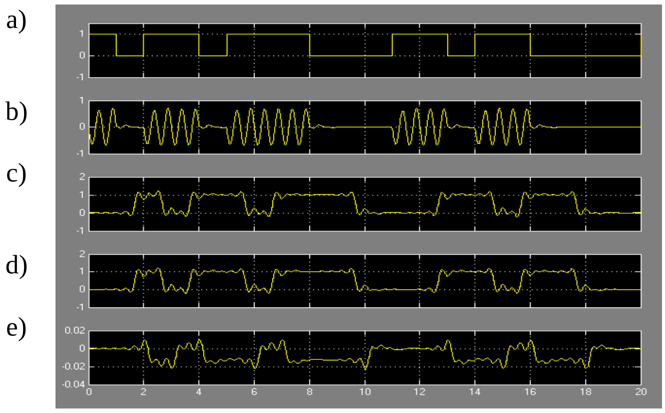


Fig 6. Results from system simulation.

a) Digital data. b) Up-converted data c) Transmitted by first antenna d) Transmitted by second antenna. e) Difference

V. VISUAL IDENTIFICATION

In practice we require a quick visual identification display that do not require much memory or processing power. We have developed two processes that could be used for such purpose. These are based on the Wavelet transform and Time-Frequency analysis. Both processes are capable of generating a visual display for very small differences in signals. Fig 7a shows a sine wave with a small disturbance that is difficult to notice either in the time or frequency domains. Fig 7b shows the result of the wavelet transform identifying clearly the disturbance and its location.

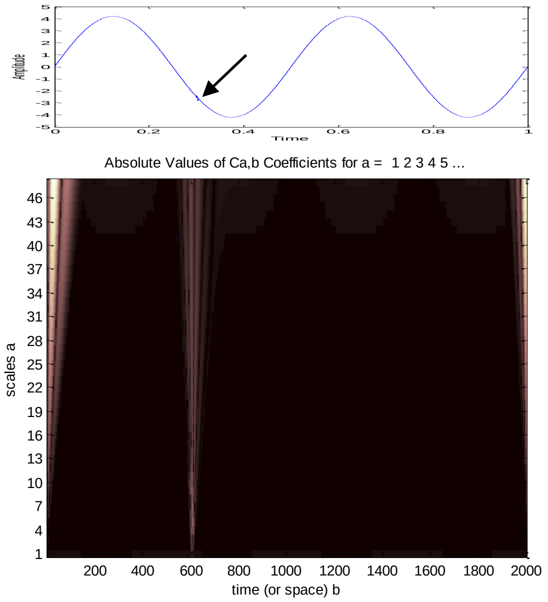


Fig 8 shows the results of applying the Wavelet Transform and Time-Frequency analysis to the difference signal from two antennas.

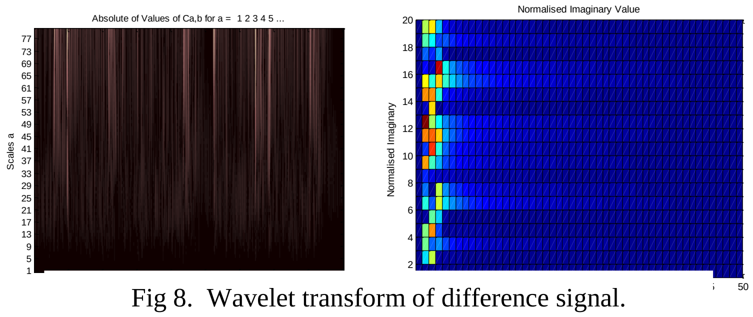


Fig 8. Wavelet transform of difference signal.
(b) Time Frequency analysis of difference signal

Conclusions

- A procedure has been developed for measuring antenna characteristics and deriving system models can be used in predicting the effect of the antenna on the transmitted signal.
- It was shown that we can distinguish instances of antennas of the same type.
- It was shown that we can determine if the same antenna has been taken out and subsequently placed back in the same device.
- We have developed visual methods to display the recognition data. These that could be programmed in individual devices.
- Measurements on commercial devices have been carried out and identification procedures have been developed.

References

[1] D. Seyfried, S. Brueckner and J. Schoebel, ‘Comparison of antenna dispersion and digital signal processing effects in ultrawideband Ground Penetrating Radar systems’, Journal of Applied Geophysics, vol.101, 2014, pp.20-26

[2] W. Wiesbeck, G. Adamiuk and C. Sturm, ‘Basic Properties and Design Principles of UWB Antennas’, Proc of the IEEE, vol.97, no.2, 2009, pp.372-385

[3] M.I. Sobhy, B. Sanz-Izquierdo and J.C. Batchelor, ‘System and Circuit Models for Microwave Antennas’, IEEE MTT, vol.55, no.4, pp.729-735, 2007