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Ultra Wideband Noise Channel Measurement Using a Vector Network Analyzer

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Abstract— **In this paper, we analyze the measurement of ultra wideband (UWB) noise channels in different indoor environments. All measurements are done using a vector network analyzer (VNA) which allows us to measure the noise channel transfer functions. We find that the noise power of the system is decreased by increasing the intermediate frequency (IF) bandwidth which leads to an increase in time taken to perform measurements of the channels. Also, we measure the environmental noise power and find that it is slightly affected by fluorescent light sources inside the measurement environments. In addition, we find that the environmental noise is decreased when enclosed in a Faraday cage (steel shed), within an intense multipath measurement environment. As secondary application, we show how a frequency detection device can be used to re-adjust a maladjusted frequency selection on a remote controller for a garage door, in presence of environmental noise power.**

Keywords— ***Vector Network Analyzer (VNA), indoor Ultra wideband (UWB) channels, UWB Noise channels***

I. INTRODUCTION

Over the last few years, many researchers have studied and reported on various Ultra Wideband (UWB) Communication Systems. UWB radio techniques allow low power data transmission over an extremely wide range of bandwidth in the indoor environment [1],[2]. Accurate characterization of UWB channel propagation is essential to many communication systems [3],[4]. In order to validate the UWB radio channel measurements, the following three factors need to be investigated: the noise level of the system, the light inside the measurement environment and the environmental noise power.

The object of this paper is to examine data from indoor UWB channels. We are particularly interested in techniques which decrease the noise level of the system, by choosing parameters such as intermediate frequency (IF) Bandwidth which allows the UWB channel calibration noise floor to be improved when using the Through / Reflection / Line (TRL) calibration technique. These factors can potentially lead to more accurate measurement of UWB channels. The transfer functions of the UWB channels are obtained through the frequency domain technique using a vector network analyzer (VNA). The ZVC-VNA which we used in our measurements has an operating frequency range of 300 kHz to 8 GHz. We used two identical monocone antennas which have a frequency range from 1 to 18 GHz and were manufactured by Karlsruhe University, Germany. The measurement parameters used in these experiments are given in Table 1. Some measurements were obtained in the Communication Systems Laboratory of the Department of Electrical and Telecommunication Engineering at the University of Wollongong, Australia. Other measurements were obtained *in-situ*, through field study within the confines of a steel garage.

II. RELATED WORK

Ultra wideband (UWB) Communications Technology is a new technology which has emerged in the last twenty years and is used especially for indoor environments. It is more commonly used for industrial applications such as UWB electromagnetic sensors and UWB radar applications. UWB technology has been used for accurate indoor localization applications [3]-[7]. There have been many studies of UWB radio channel measurements in order to study the channel characteristics [3],[8]-[37] in different environments and scenarios. A correct calibration process of the measurement setup is necessary for accurate measurement of wireless channels. A VNA can be defined as an instrument that can measure the channel parameters (S-parameters) of physical wireless networks, such as phase and amplitude. In [18] the authors kept the indoor environment as static as possible during their UWB channel measurements. The authors in [11] did not identify whether the passenger moved at all during measurement or not. In [32], [[33] they investigated the influence of different scenarios in a car occupied by four persons and in empty cars on the UWB radio propagation channels and discussed the passenger influence on the measured channels. However, they did not mention whether the passengers were in a stationary or non- stationary situation. They also indicated that the measurements were performed with calibration of VNA – ZVC over frequency the range of three to eight gigahertz. The UWB channel measurements were kept stationary by ensuring that there was no movement of people inside the measurement environments in [10],[11],[15],[22],[25],[26],[29],[31]. Although the authors in [29], said that the measurements were in a near static environment, it is not clear whether the environment was stationary. The authors in [8],[9] measured non-stationary UWB radio channels. So the channels were time-variant and were affected by the movement of people. The authors in [3],[12]-[14],[17],[19]-[21], [23],[24],[27],[34],[36],[37] did not identify whether measurements were performed in stationary or non-stationary environments. The authors in [3],[8],[12]-[17],[19],[21]-[30],[34]-[37] did not mention the value of the Intermediate Frequency (IF) Bandwidths which were used. The IF bandwidth is a very important parameter since it results in an increase or a decrease in the noise level of the system and time measurement sweeping as well as determining the threshold of the strongest path.

In [38] they undertook a study which measured the wireless channel in order to detect the presence and measure the amount of adulteration of diesel and gasoline with kerosene, using typical UWB sensor components. They also do not identify whether the measurements were taken in stationary or non-stationary environments. In [26] the authors use a threshold of 25 dB below the strongest path for cases of LOS and NLOS in order to measure the power delay in the arrival time of resolved multipath electromagnetic rays.
On the other hand, in [24] they used a threshold of 30 dB and 20 dB below the strongest path in order to avoid the effect of noise on the arrival time of the multipath in cases of LOS and NLOS, respectively. They also did not mention the value of the intermediate frequency bandwidth which was set as measurement parameters and this will affect the noise level of the system. This will also have an effect on the strongest path of the measured wireless channel. The authors in [17] measured the UWB channel in an offshore oil platform and used an IF bandwidth of 3 kHz in their measurements and a threshold of 30 dB below the strongest path to avoid the effect of noise on the arrival time of multipath rays.

III. MEASUREMENT METHODOLOGY

The UWB channel transfer function can be obtained using a VNA in the frequency domain. This technique is based on the sweep of frequency points in the frequency range of the channel. The S- parameter coefficients of the device Under Test (DUT) can be measured using VNA. The channel frequency response is represented by S_{21} and the DUT will be the UWB wireless channel which includes the transmitting and receiving antennas. In our measurements, we use a two port, Rohde & Schwarz ZVC- vector network analyzer. This device is shown in Figure 1.

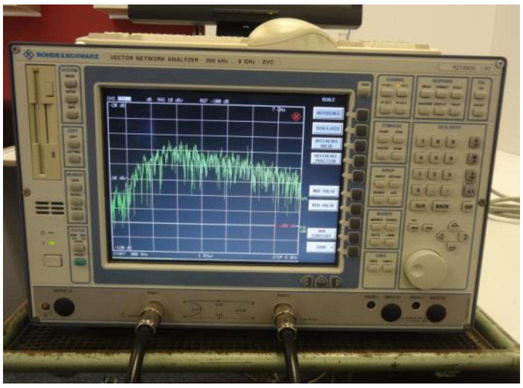

Figure 1: The vector network analyzer (VNA) used in this study.

Two identical semi-rigid CRA213/V coaxial cables with a length of 2.5 metres and a frequency range from DC to 18 GHz were used in these measurements. Both cables are terminated by male 50 Ohm N-Type connectors. Two identical monocone antennas of the type shown in Figure 2 were used in the measurements for this study. The connection of the measurement set-up is shown in Figure 3.

Figure 2 UWB monocone antenna with ground plane of 100 mm

Figure 3 Measurement set-up

Table 1. Measurement Parameters.

Parameter	Value
Measured Bandwidth	300 MHz - 8GHz
No. of Frequency points	1601
IF filter Bandwidths	10 kHz, 1 kHz and 10 Hz
Sweep Time	272.77 s, 9.46 s and 810.49 ms
Transmitting Power	-10 dBm
UWB Antennas gain	0 dBi (typical)
Heights of the Antennas	100 cm

In all measurements, TRL calibration was used to get accurate measurement results. Further details of this calibration procedure can be found in [39].

IV. MEASUREMENT ANALYSIS AND DISCUSSIONS

A. The noise power of the device (VNA)

For this study, the noise power of the device (VNA) has been measured at 10 kHz, 1 kHz and 10 Hz, as shown in Figure 4 where we can see that, decreasing the IF bandwidth, decreases the noise power. This leads to a corresponding increase in the time taken to measure the channel (as shown in table 1 on sweep time).

Experiments are also conducted in the presence and absence of fluorescent lighting. Figure 5 shows the channel transfer function with the light on and with the light off. Figure 6 shows the absolute value difference between them. It can be clearly seen that the measured wireless channel is affected slightly by the presence of fluorescent light inside the measurement environment over the frequency range of 1.5 to 8 GHz.

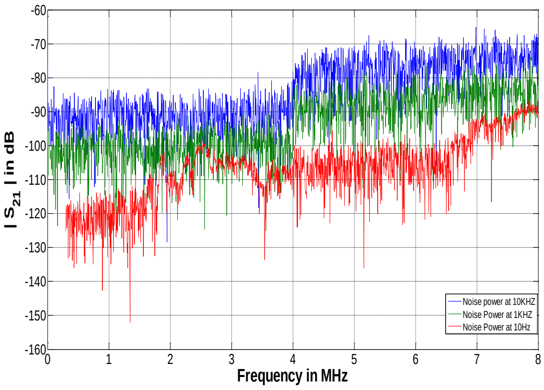

Figure 4. Noise power of the device (VNA) at 10 kHz, 1kHz and 10 Hz

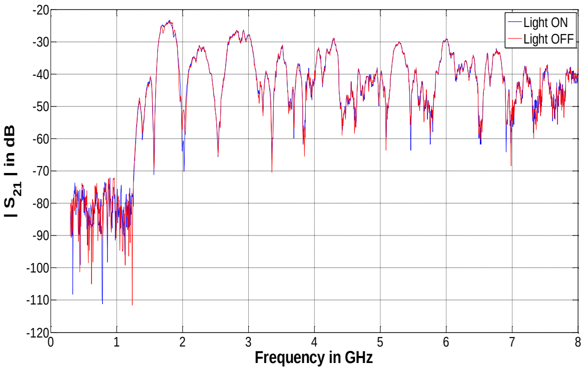

Figure 5 Measured transfer functions light ON/OFF

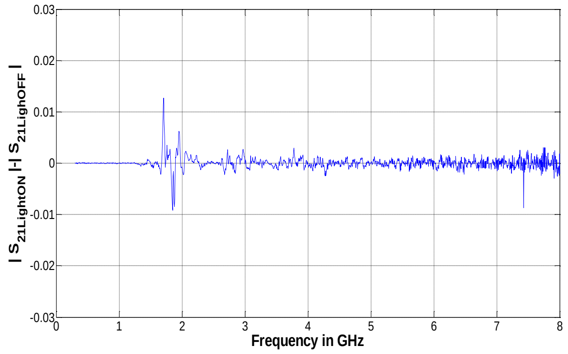

Figure 6. Absolute value difference of measured transfer functions light ON/OFF

B. Environmental Noise Power

In this experiment, the noise powers of the measurement environment are measured using a VNA in two scenarios, one of which includes the presence of a fluorescent light source while the other does not. The two measurements are conducted in the same room in order to determine the effect of light sources on this noise. This noise is represented by transfer function (S_{21}).We call this noise ‘environmental noise power’ (ENP) and to measure it, we need to connect port 1 on the VNA to an N-type match connector and port 2 to the UWB antenna. This leads to receiving only the power coming from all objects inside the measurement environment. Figure 7 shows the environmental noise in both cases. Figure 8 shows the absolute value difference between the environmental noise powers. It can be seen clearly that the light has a slight effect on the magnitude of the S_{21} scattering parameter in the frequency span of 5-8 GHz. At the other frequencies, the difference between them is approximately equal to zero.

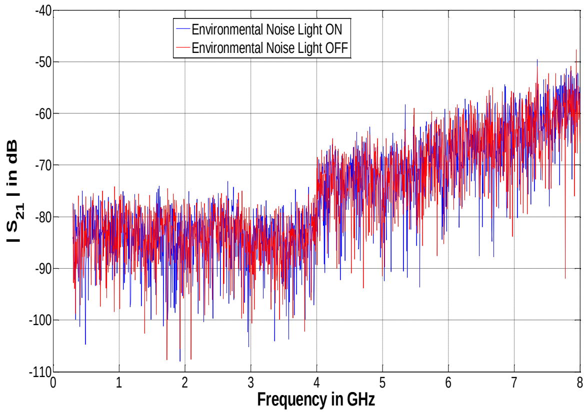

Figure 7. Measured environmental noise power with / without light

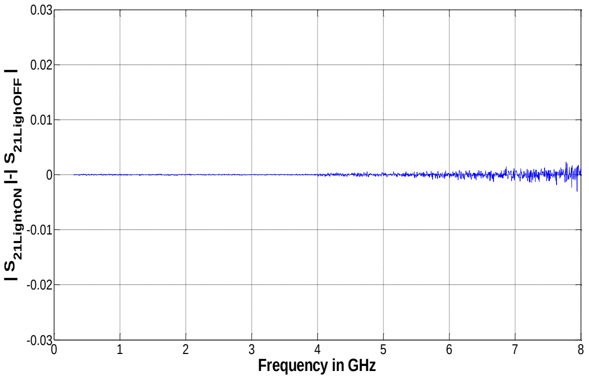

Figure 8. Absolute value difference of measured environmental noise Powers with / without light

We located a steel (colorbond) garage on steel slab-reinforced concrete. This produced radiation. We then measured the environmental noise inside the steel garage. This garage is totally made from steel as can be seen in Figure 9. This internal structure provides a multipath intensive environment. The measurement was set by connecting the N-type match connector to port 1 in the VNA. Figure 10 shows the noise measurement of the garage. By comparing the measurements in Figure 7 and Figure 10, we can see that the environmental noise is less in the garage than in the laboratory.

Figure 9: Steel garage

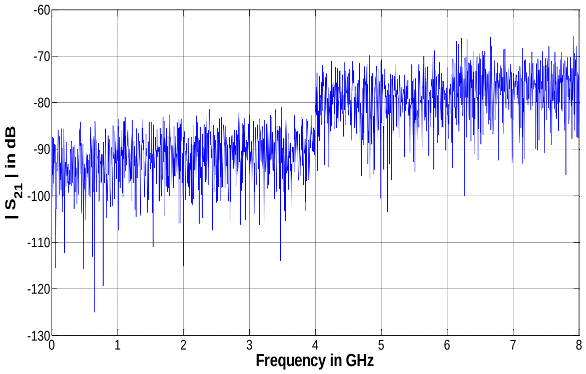

Figure 10: Environmental noise measured inside the steel garage

C. Remote Control of Garage Door

We also used the VNA as a signal detector to repair the frequency setting of a maladjusted remote control garage door operating device by configuring the following settings on the VNA: start frequency =400 MHz , stop frequency = 500 MHz, number of frequency points = 1601, IF bandwidth = 10 KHz and transmitted power = -10 dBm. We connected the match connector to port 1 on the VNA and we connected port 2 to the UWB antenna. We then turned on the device and measured the transfer function (S_{21}) of this signal. Figure 11 shows the noise power and the measured peak signals of the defective device at a frequency of 427 MHz. After that, we adjusted the device's set frequency point manually and observed the peak signal on the VNA screen until we attained a peak signal at a frequency of 433 MHz, as shown in Figure 12. This was then tested on the garage door system and found to operate normally. This application shows how the VNA can be used as a signal detector for a garage door remote control in the presence of environmental noise power.

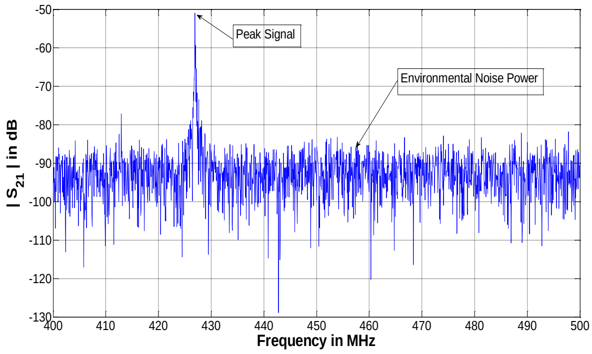

Figure 11: Peak signal of defect remote control of garage door

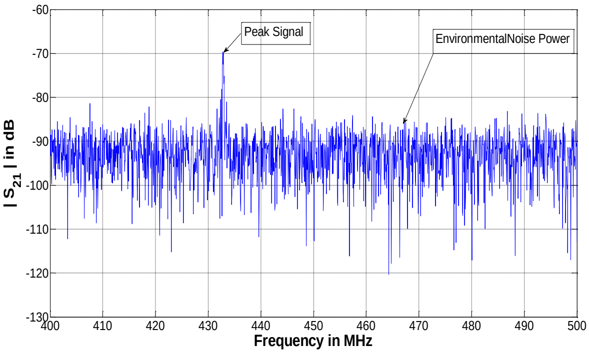

Figure 12: Peak signal of fixed remote control of garage door

V. CONCLUSION AND FUTURE WORK

Based on our measurements and analysis, we conclude that the noise is decreased by increasing the IF bandwidth. This leads to the need for more time to take channel measurements. The wireless channels are also shown to be affected by fluorescent light sources inside the measurement environment over the frequency range between 5 to 8 GHz. We measured the environmental noise inside the measurement environment and found that fluorescent light sources had a small effect on it. In the steel garage, we found that the environmental noise decreased significantly compared to the measurements performed in our laboratories. Based on figures 11 and 12, the VNA can be used as a detector and to adjust the frequency of remote control garage door controllers in the presence of environmental noise. Future work will investigate the effects of the movement of people inside the measurement environment.

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