Characterization of Millimetre waveband at 40 GHz wireless channel

Syed Haider Abbasi, Ali Bin Tahir, Muhammad Faheem Siddique and Hussain Haider

Electrical Engineering Department,
Sarhad University of Science and Information Technology,
Peshawar, Pakistan.

habbas33@gmail.com, alibintahir@gmail.com, engrfaheem@yahoo.com, haider_101@hotmail.com

Abstract-- Over the recent years, there has been increasing demand of broadband multimedia communication. So, an extensive research has started in wireless services such as Local Multipoint Distribution Services (LMDS), Broadband Fixed Wireless Access (BFWA), Backhauls and Next Generation Internet (NGI). Actually the current problem that we’re having with the present architecture is limited bandwidth and as the bandwidth demand is increasing as well for different broadband applications, so for increasing bandwidth requirement, millimetre wave band will be well suited as in millimetre wave band, we have large available bandwidth which can be easily utilized in different broadband application. In addition to this, we also have an advantage of using mm-wave band that the transmitting and receiving antenna sizes are reduced as well as related electronic components. So, we can effectively use mm-wave band to overcome the continuously increasing congestion of the radio spectrum of lower frequencies. Out of the mm-wave bands, 40 GHz wireless channel represents an attractive band to be researched and utilized to achieve those requirements of large bandwidth. The main of this paper is to develop user-friendly software based on LabWindows/CVI to provide a high precision control of a positioning system that provides linear displacement of a 40 GHz mobile radio channel sounder and data acquisition using VNA. The system will then be tested for indoor 40 GHz channel characterization.

Index Term-- Millimetre wave band, Linear positioning system, High Speed Data Acquisition system

1 INTRODUCTION

In terms of Wireless networking and communications, millimetre waveband generally corresponds to a few select bands of frequencies around 38-40 GHz, 60 GHz and more recently 70 and 80 GHz becomes an area of interest [1], but more specifically 40 GHz and 60 GHz Wireless Channel represents an attractive band for the corresponding fields to be researched and utilized to achieve those requirement of large bandwidth. [2] As we all know that frequency is an essential resource in Wireless Communications. Millimetre wave technology fortunately can exploit unregulated bandwidth that is available worldwide. As higher frequencies utilized in mm-Wave band which in turn means shorter wavelengths. So, as a result the size of electronic components to be utilized also reduced and more specifically the size of transmitter and receiver antenna will be reduced as well. So, this mm-Wave band will be very useful in this regard.

During the past few years, research is going on 40 GHz millimetre wave channel and a great deal of work has been done towards developing commercial applications using MMW communications systems. Basically 40 GHz becomes an attractive band and an area of interest because at 40 GHz signal absorption via atmospheric oxygen is very minimal [3] as compared to other bands available in Millimetre wave technology, so 40 GHz is a very useful band for long range communication and it is useful as well to overcome the increasing demand of bandwidth in compliance with long range communication requirements. “In United States, the band 38.6-40 GHz is used for licensed high-speed microwave data links”. [4] So, in this way, 40 GHz band is really useful and important to be utilized for Indoor measurements as well as long distance outdoor measurements.

The basic aim of the paper is to utilize the 40 GHz in a way that it can used effectively for commercial purposes as well as helping the fellow researchers to understand the applications of 40 GHz band in Millimeter wave technology.

2 HARDWARE

2.1 System Design

The hardware has been setup in a way as shown in Figure 2.1. Now for the completion of our measurements, a 40 GHz transmitter and receiver has also been connected with the VNA at port 1 and port 2 respectively via Co-axial cable to see the response on the computer screen via VNA. In addition to this, GSM4 Intelligent RS232C to a 4 Phase Stepper Motor Driver Card Operating Manual (link of this manual can be checked in the references) has been used to control the stepper motor via the software commands using LabWindows/CVI software.

Fig. 2.1. Block Diagram of the Hardware Setup

2.2 Internal Methodology

Now, the internal methodology used in the 40 GHz measurement system can be illustrated well in the Figure 2.2 below:
The specifications used for the channel sounder are described in Table 2.1 as follows:

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier Frequency</td>
<td>40 GHz</td>
</tr>
<tr>
<td>Sweep Frequency</td>
<td>1 – 3 GHz</td>
</tr>
<tr>
<td>Output Power Prior to</td>
<td>-10 dBm</td>
</tr>
<tr>
<td>Antenna</td>
<td></td>
</tr>
</tbody>
</table>

This Figure 2.2 shows the internal setup of the Up-converter and Down-converter used in the course of this paper. Basically the internal setup is in a way that there is a 10 GHz Oscillator which is simply connected with the 40 GHz system box and via a coaxial cable and its connected with the Up-converter which in turn connected with the Band Pass filter and moreover connected to the transmitting antenna used. This up-converter is also attached with the VNA to see the response of this setup as well via coaxial cable. On the other end, the same setup has been established but in a reverse manner, and the down-converter has also been attached with the VNA through LNA (Low-Noise Amplifier) to minimize the Noise Floor and see the response of this setup in VNA as well and VNA is then attached with the PC as shown in Figure 2.1 so that we can see the response of the VNA on the computer screen.

3 MEASUREMENTS AND CALCULATIONS
Before carrying out the any measurements, the channel sounder should be calibrated carefully in the anechoic chamber so that these readings can be taken as a reference and will be used afterwards to calculate the channel data for further analysis. In the anechoic chamber, the transmitter and the receiver antennas and the related electronic equipment have been setup in a way as illustrated in the Figure 3.1 as follows:

In Wideband Digital Mobile Radio system, it is really important to characterize the radio channel adequately to have a satisfactory channel characterization [5][6]. The channel characterization with the effect of different scenarios on the channel sounder were studied and measured were taken. Firstly, horn antenna has been used in both transmitter and receiver and after horn antenna; an Omni directional antenna has been used in receiver to see the effects on the channel sounder. The transmitter and receiver setup in this room can be illustrated well in Figure 3.2 as follows:

The exact position of the transmitter and receiver antennas as well as the dimensions of the room has been clearly mentioned with all the required details. In the electronic microwave lab, the environment has to be taken carefully as there are other equipments around, this may cause reflection and distortion in the signal response [7]. A metal surface drawer was also placed behind the receiver as well to see the effect of the surroundings on the response of the signal. The measurements have been done with the following different distances and situations using the swept frequency technique:

3.1 Measurements Performed at Distance 3.65 Meters
The hardware has been setup as mentioned in Figure 3.2. Now first of all, 10 dBi gain horn antenna has been placed on transmitter side as well as receiver side to see the same amplitude (in dB) vs Frequency (in GHz) response as well as Phase (in Degrees) and the Power (in dBm) response to analyze the with the calibration measurements to acquire the channel data. So, the amplitude (S21 in dB) response can be illustrated well in Figure 3.3 as follows:
Now as it can be seen in Figure 3.3 that the Amplitude (S21 in dB) plot has been starting from approximately -39 dB, now in contrast with the amplitude (in dB) vs Frequency (GHz) response for the calibration measurement there are more attenuation in the signal as well as distortion, this is just because of the certain reflections and certain multipath pattern that a signal has followed before reaching the receiver as the distance between the transmitter and the receiver is 3.65 meters, so because of the multipath effect, the signal has became more distorted and attenuated including the hardware and cable losses as analyzed while doing the calibration measurements.

The amplitude (in dB) vs Power (dBm) response as shown below is of more importance as this graph will help in setting up the feasible power to the system and it will help minimizing the noise floor as well as improving the quality of the signal.

Now as it can be seen in Figure 3.4 that the power response start decreasing -6 dBm and then falls off, so this part of the power response can be ignored as it’s not useful data, in addition to this, there is a lot of attenuation in the signal till -12 dBm, so there is a slight linear region for this power response which lies in between -12 dBm and -6 dBm, so the value can be approximated and the power value selected to used with the measurement system is about -10 dBm, where the response is almost linear.

After completing this set of measurement, the 10 dBi gain antennas have been replaced with the 20 dBi gain antennas on transmitter as well as on the receiver side. Now, when the transmitter antenna as well as receiver antennas has been setup with the 20 dBi gain. The amplitude (S21 in dB) versus frequency (in GHz) can be illustrated as follows in Figure 3.4 as follows:

The amplitude (in dB) response is starting from approximately -20 dB which was expected due to the replacement of antennas. For the power setup of the measurement system, power (dBm) response will be analyzed accordingly. For that purpose, the Amplitude (S21 in dB) vs the Power (in dBm) can be illustrated as follows:

As it can be seen in Figure 3.5 above that the power response will be decaying rapidly after -7 dBm and there are some attenuation in the response till -15 dBm, so this data is not really useful so can be discarded, however the data between the -15 dBm and -7dBm is useful for analysis, so the feasible value used for the measurement setup is -10 dBm.

When 1 dBi gain Omni-directional antenna was used, the amplitude response has been starting from approximately -39 dB as shown below, so there is roughly -1 dB difference from what was expected.
Moreover, for the power response to setup the power to be given accordingly can be illustrated in Figure 3.7 as shown below, where it can be seen on the similar patterns, that there was a lot of attenuation in the signal from -30 dBm till -12 dBm and the signal response was decaying sharply after -7 dBm, so the useful region to be selected is in between -10 and -7 dBm so as a reference for further careful consideration of the signal, -10 dBm is selected to be the feasible power supplied to the system for measurements. As it can be observed by seeing the power response graphs, that the linear region mostly lies around -10 dBm, so -10 dBm will be selected as a reference and it will be supplied to the system throughout the measurement process.

Now if we compare Figures 3.9, 3.8 and 3.4, it can be seen that in Figure 3.9, there was least of all attenuations and distortion that we’ve got before, and the reason as already described that as the distance between the transmitter and receiver will decreased the radiation will be more directed and less attenuated and reflected from multi-path. The other sets of measurements can be discussed and analyzed on the same patterns.

3.4 Channel Data
The channel data is calculated in a way that the values received by the channel sounder measurements done at
distance 3.65m, 2.50m and 1.25m between the transmitter and the receiver will be subtracted with the calibration measurements done in the anechoic chamber at distance 1.10m between the transmitter and the receiver. The plot for the channel data for 20 dBi horn antennas at the transmitter and receiver in the anechoic chamber at distance 1.10 m and channel sounder measurement at distance 2.50m is shown in fig 3.10. The channel data is basically showing the data response of the channel excluding the hardware equipment losses and related losses, however, the attenuation is still there because of some cable losses and other related losses. The whole response lies in between -8 dB to -7 dB range which is scaled to 1dB. The rest of the channel calculations and measurements have been completed on the same pattern.

4 Conclusion

The conclusion that can be drawn by seeing all the responses were that the frequency response as well as the other response has been improved when the distance between the transmitter and receiver was minimum. Moreover, this transmission quality of the signal has been reduced when using the Omni-directional antenna because of the large radiation angle of such antenna which leads to a high number of reflections and more multipath appears which in turn degrades the coherence bandwidth and increases the inter-symbol interference of the signal. Therefore, it can be concluded that an indoor wireless channel with line-of-sight and with minimum distance between the transmitter and the receiver can be efficiently exploited and with abundant coherence bandwidth and acceptable quality can be utilized in the commercial applications.

REFERENCES