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Investigation the Signal Strength of ESPAR Antenna with Omni-Directional and Directional Antennas on a D-Link Wireless System

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Abstract—**This paper investigates performance of a smart ESPAR antenna with omni-directional and directional antennas. Performance of wireless network systems depends on the kind of antenna that is used. Every type of antenna has specific characteristics that determine gain, direction, and bandwidth. Background of smart antennas has been discussed along with their classification. An experiment has been conducted involving the measurement of signal strength that is offered by the three antennas. The points of testing the signal strength are different with variations in distance and obstacles in the path. The ESPAR antenna has been observed to offer the best performance in terms of signal strength. The ESPAR has been recommended to be the better option for wireless communication for different environments. For investigation these antennas, D-link system will be used as transmitter and a compatible computer "laptop" will be used as a terminal.**

*Keywords-**Smart Antenna, Omni-directional antenna, ESPAR (7 elements) antenna, Directional antenna, and WLAN.***

I. INTRODUCTION

Mobile wireless network systems have become a significant area of growth in recent years, and wide range of communication systems is used in wireless network systems. Effectiveness of wireless network systems depends on the performance of antenna because it is considered as important part in the system. Many types of antennas can be used according to requirements of the application. Characteristics of antennas make the difference in any results and each antenna is designed based on the application that will be applied [1].

There are several important characteristics for any antenna which should be considered when choosing an antenna for an application. For instance, radiation pattern, gain and directivity, bandwidth, front-to-back ratio, major and minor lobes, impedance and polarization are the most important characteristics for antenna. Engineers attempt to improve these characteristics in order to gain better performance [9].

One of most significant area that is affected by antennas performance is mobile wireless computing system. D-Link wireless system is a device that provides PCs with wireless signals. Many types of antennas can be used with D-Link wireless system. Omni-directional antenna is the standard antenna that is used in PCs [1].

An antenna is defined as a device that transmits or receives electromagnetic waves. The electromagnetic radiation is converted by antenna into electrical current during reception, or electrical current is converted into electromagnetic radiation during transmitting radio waves. An antenna is a necessary part in radio equipment because antenna is the interface between two points; these two points are media and receiver or media and transmitter. Furthermore, an antenna is known as passive device because value of radiation power of transmitting is always less than power entering from the transmitter. In addition, antenna is reciprocal device, so that an antenna frequency which is used in the receiver should be the same in transmitter [9].

Many researches of wireless communication systems is focused on the mobile communication and local computer networks. Therefore, Smart Antenna technology considered as important factor in development of wireless system. Currently, the wireless communication technology is suffering from an increased number of users which are accompanied by an expensive spectrum due to heavy demands. The traditional multiplexing techniques are losing grounds of operation and reaching their limitations [6]. To develop future wireless communication systems that are capable for providing higher data rates and user mobility is based on different concepts of design rather than the traditional approach. To face new challenges of future system requirements, certain enabling technologies can be used such as the application of smart antennas based on new performance objectives along with design constraints [9].

II. INANTENNA OF EMPLOYED IN THE EXPERIMENT

A. *Smart Mobile Terminal Antenna*

Mobile wireless computing network is one of the most growing areas in recent years, and many researches have been done in order to improve performance of mobile wireless computing network. Smart antenna can be used in a base station of mobile communication and it has brought many advantages that cause to improve performance of mobile communication. On contrary, this type of intelligent antenna has not been applied a lot into mobile wireless computing terminal. The size is the reason that makes designers avoid to applying smart antenna. The size of smart antenna based on linear antenna arrays is very large to match mobile wireless computing terminal antenna. As a result, a small size of smart mobile terminal antenna is demanded to fit wireless computing terminal [4].

A smart antenna is integrated into a communication system that combines the antenna array of digital signal processing capability to receive and transmit in an adaptive and spatially sensitive order. It can be simply stated as the antenna that is capable of changing the direction of radiation pattern along with the signal environment. A smart antenna is a multi element intelligent antenna which combines the signals received at each antenna element in order to improve the performance of wireless system. The reverse of this process is performed when transmitting the signal. Thus in doing this procedure on the signal the antenna is successfully increases the signal range, suppresses the interfering signals, reduces the signal fading and also increases the capacity of the wireless channel [10]. Figure 1. Shows directed beam pattern of adaptive array smart antennas.

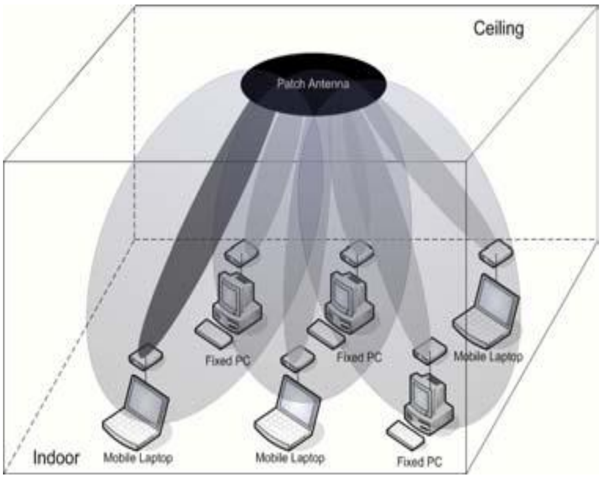

Figure 1. a patch antenna for Wireless LAN with directed beam patterns[8].

The two common types of smart antennas are Switched beam directional antenna and the adaptive array smart antennas. The main parts of switched beam antenna are beamforming network, RF switch, and radiating elements. The implementation of switched beam antenna is very simple and it cost lower than adaptive beam antenna [10]. The idea of switched beam antenna is to transmit multiple fixed beams in a particular direction. Furthermore, switched beam antenna is able to detect signal strength and select several predetermined. The selection of the beam is generally depending upon selection of the strongest available signal beam which is then focused to get a strong signal. A slight alteration to this method is the use of linear array of half wavelength spaced antenna elements which involves the phase shifting of the received signals which are then joined to form a signal. [8].

The second type of smart antenna is known as the adaptive array. Adaptive arrays antenna has been used widely in recent years. Unlike switched beam antenna, advanced signal processing to function is needed for adaptive arrays antennas. Adaptive arrays antenna can provide more intelligent operation [2]. Increasing system throughput, increase communication distance, and high data rate are the reasons that adaptive antenna has been used widely. In some application security system also can be improved by using adaptive arrays antenna. An important feature of adaptive arrays antenna that can be gained is its abilities to form a controlled beam to track mobile users [8]. Figure 2 shows switched directional beam of adaptive antenna.

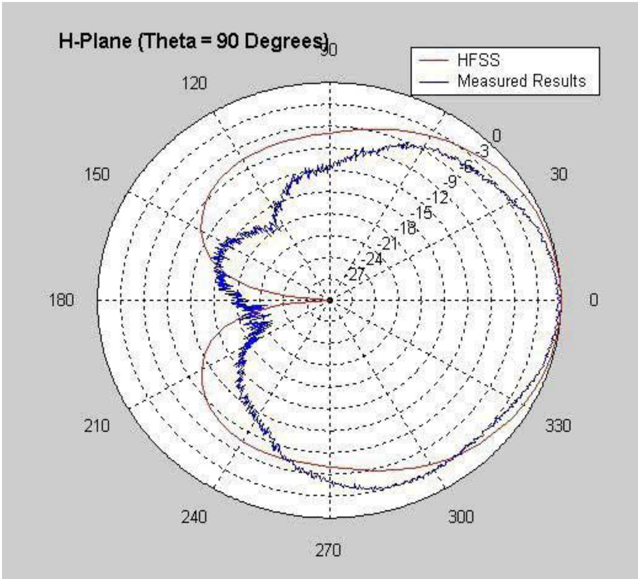

Figure 2. Switched directional beam[8].

In the adaptive array approach the signals from several different antenna elements which have similar antenna patterns are weighted in terms of phase and amplitude. These weighted signals are then combined to enhance the performance of the output signal. Adaptive array antenna forms a narrow beam in the line of sight environment without the formation of a multipath. In this case the interference can be suppressed and gain can be provided in a multi path environment [10].

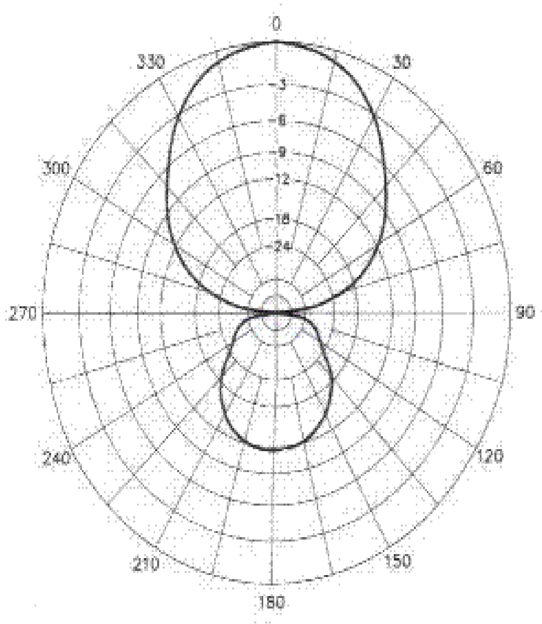

Figure 3. Vertical plane radiation of Directional antenna [7].

B. Directional antenna

A directional antenna is an antenna that it's radiated power in specific directions; it can be one or more directions. It has greater power in one or more directions which lead to increased performance either on transmitting and reception [1]. Furthermore, directional antenna allows to reducing the interference from unwanted sources. For instance, Yagi-Uda antenna is one of the most common directional antenna. The radiation pattern of directional antenna is focused in the direction that is determined. Figure 3.3 shows vertical plane radiation of directional antenna [7].

C. Omni-directional Antenna

The radiation pattern of Omni-directional antenna is equally in all directions as shown in figure 4. It radiates or receives the same power in all directions. It does not have any particular direction, so it is also called the "non-directional" antenna. As shown in figure 4, the radiation pattern of the omni-directional antenna spreads in all direction. This type of antenna is commonly used in PCs antenna (Wi-Fi - WLAN antenna applications), vehicle antenna, and VHF antennas. Moreover, Omni-directional antenna can be used to link multiple directional antennas such as cellular phone connections and TV broadcasts. Omni-directional antennas are usually using collinear dipole arrays, which consist of half-wavelength dipoles with a phase shifting method between each element, which ensures the current in each dipole is in phase [5].

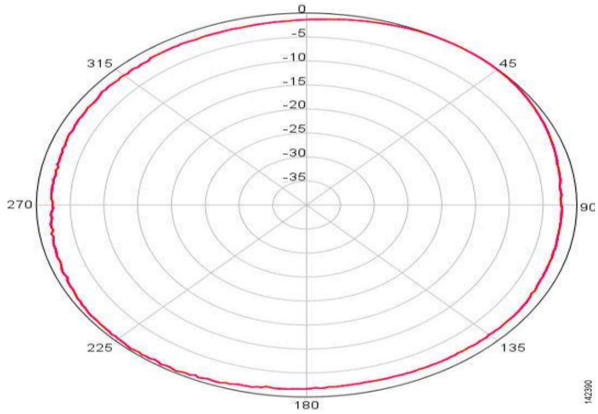

Figure 4. The radiation pattern of Omni-directional antenna [5].

III. THE EXPERIMENT

I conducted the experiment with three antennas which were connected to the D-Link wireless system. The three different antennas on which the experiment was to be performed were placed at one point and their response was examined in wireless environment in the room and outside the room with different types of hurdles.

This experiment involved the observation of the strength of transmission using the three different antennas. This was achieved by attaching the antenna to be tested to a wireless D-Link system and then checking the strength of the signal at various distances from the access point and with different obstacles in the path. The signal strength was analysed by using the insider software installed in a mobile computer which is a laptop.

The software inSSIDer is used to measure the received signal strength indicator (**RSSI)** of the antenna. The inSSIDer is a Wi-Fi network scanner application for Microsoft Windows operating system. Wireless networks are scanned by inSSIDer within picked up by a computer's Wi-Fi antenna, tracks signal strength over time, and determines their security settings (including whether or not their password-protected) [12].

Different points for three antennas were measured by using inSSIDer software; places of the three antennas were fixed in a building. However, six different points of a laptop had not had the same properties as shown in the figure 5. Results were collected in a form of Required Signal Strength Indicator (RSSI) and they were tabled as shown in tables 1.

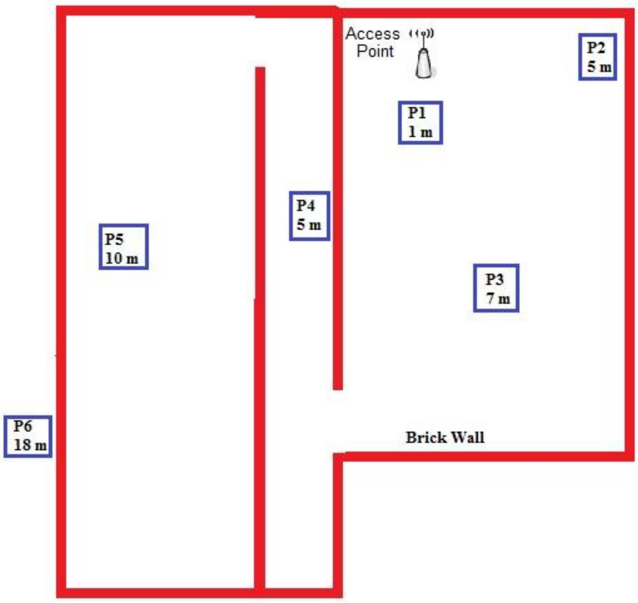

Figure 5. shows different points to measure RSSI

The directional antenna which was employed in the experiment is called 6dBi Directional Antenna. In this experiment the antenna works on 2.4GHz. 6dBi Directional Antenna (MGR-DS-06A) is made by elegant company. This antenna is built for extending wireless range of 802.11.2x wireless products. Furthermore, this antenna can be applied with router extender solution. As shown in figure 4.2 this antenna is made with many colours, and it has several features such as magnetic, table set, wall mount installation, and antenna. The base of this antenna can be separated which allow to directing it in any way [11].

REA—2.4GHz 6dBi Directional Antenna works with linear vertical polarization and it has directional radiation pattern. The impedance of the antenna is 50 Ω, and maximum power that can be transmitted is 1 Watt. It is connected by RP SMA Connector and Cable length 1M, The most important characteristic of this antenna is the gain which is 6dBi when it works with 2.45GHz. Finally, this antenna can work with three frequencies which are: 2.4GHz, 2.45GHz and 2.5GHz. The three frequencies have slightly the same radiation pattern.

The omni-directional antenna which was employed in the experiment is called 5dBi omni-directional Antenna (MGR-DS-05A). It is made by elegant company. This antenna is built for extending the wireless range of 802.11.2x wireless products. As shown in figure 4.5. This antenna can easily be putted in any place and connected to D-link wireless system. It has several features such as cost effective, magnetic mounting installation and antenna can swivel 0º, 45º, 90º [11].

This antenna works with linear vertical polarization and it has an omni-directional radiation pattern. The impedance of the antenna is 50 Ω, and maximum power that can be transmitted is 1 W. It is connected by RP SMA Connector and Cable length 1M. The frequencies range of this antenna is between 2.4GHz and 2.5GHz.

The Third antenna was Electronically Steerable Passive Array Radiator (ESPAR) antenna. This antenna is developed in order to be used in wireless AD hoc computer network systems and mobile communication system. Three major problems have caused to introduce smart antenna technology. These three problems are multipath fading, delay spread, and co-channel interference. Also capacity of system and performance are increased by using smart antenna [3].

ESPAR antenna allows sending a signal to determined point and it can control radiation nulls into interfering signal, so many problems can be reduced. Increasing signal to noise ratio depend on complementation between gain of main lobe and radiation nulls. ESPAR antenna is comprised with 7 elements. One element in the central point of the antenna and this element is connected to RF signal. Other reactively loaded parasitic elements surround the central element. There is quite strong electromagnetic field between antenna's elements and the ground, this situation make the antenna very complicated to analyse [6].

Many advantages can be gained from smart ESPAR antenna such as compact structure, low profile, and using single RF signal. The idea of ESPAR 7 elements antenna is acquired from Yagi-Uda antenna concept. The central element is the driven or reflecting element and other 6 elements act as reflectors [3].

According to Schlub et al (2003, pp. 3039) "A horizontal gain optimized electrically steerable passive array radiator antenna designed for use in an *ad hoc* wireless network has been presented. The antenna was optimized with respect to gain to reduce interference and transmission powers in a system. In a homogeneous *ad hoc* network, any optimization in the gain of an antenna will potentially have double the effect in the system. The optimization solution space of the ESPAR antenna was very large, and polluted by localized, suboptimal solutions. Accordingly, a genetic algorithm was used for optimization because of its robust nature. The GA employed a FEM based cost function in order to obtain accurate modeling of the antenna. Both physical antenna structure and loading reactance were optimized".

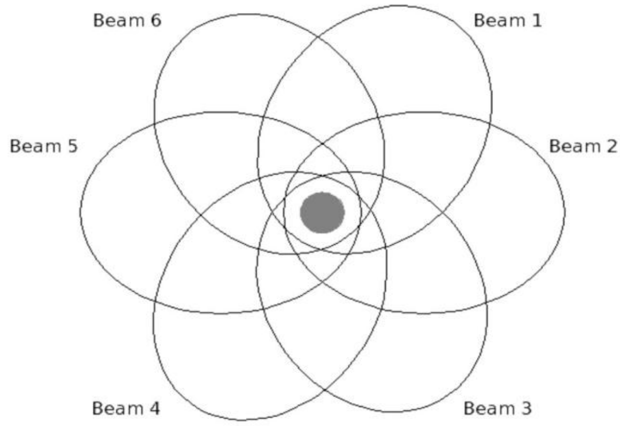

Figure 6. ESPAR antennas with Switched beams [8]

IV. RESULTS

A. Directional Antenna

At point 1 which is one meter away from the access point and within the radiation pattern of the antenna, RSSI was -40 dBm. However, when the laptop was putted outside the direction of the radiation pattern with 5 meters away, the RSSI decreased to -59 dBm. When the laptop returned back within the direction of the radiation, RSSI increased because the point 3 is inside the field of radiation pattern of the directional antenna. After that, the environment was changed, where one brick wall obstacle separates between the antenna and the laptop. In this position, the signal was decreased and it measured about -63 dBm. Therefore, it can be said that this kind of antenna has weakness in terms of crossing obstacles by signals. Furthermore, with two wall obstacles RSSI was at -73 dBm and with four wall obstacles the RSSI could still be detected with difficulty and it measured at the value of -82 dBm. Figure 7 shows RSSI of directional Antenna at point 1 and one meter away from access point.

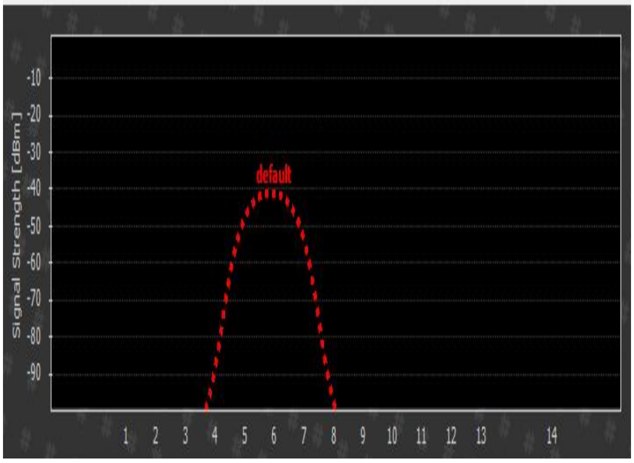

Figure 7. Signal strength of directional Antenna

Test Points	Directional Antenna RSSI (dBm)	Omni-diorectional Antenna RSSI (dBm)	ESPAR Antenna RSSI (dBm)
P1	-40	-52	-43
P2	-59	-59	-52
P3	-52	-61	-56
P4	-63	-65	-65
P5	-73	-80	-71
P6	-82	-85	-83

Table 1. Signal strength values in terms of Received Signal Strength Indication (RSSI) for the three different antennas.

For observing the back lobe of the directional antenna, the laptop was putted at 10 meters and at 15 meters on the back of the directional antenna. The antenna showed RSSI of -77 dBm at 10 meters with no hurdle but there was no signal to be detected at 15 meters on the back of the lobe. This shows that directional antenna has a very small lobe at the back of the antenna and the main signal strength is concentrated in the front lobe. With an obstacle in the back lobe, we will cease to have any signal after 5 meters because the signal which is already much attenuated will be much more attenuated by the obstacle.

B. Omni-directional Antenna

The same test points with directional antenna were measured by omni-directional antenna. At the point 1, RSSI is -52 dBm. Unlike Directional antenna, the RSSI at the point 2 and 3 decreased because distance was increased which was -59dBm at point 2 and -61dBm at point 3. In addition, at point four of one wall obstacle, the RSSI continue to decreasing which was -65dBm because of distance and obstacle. Furthermore, at 10 meters with 2 brick walls, RSSI was -80dBm. At the last point, signal barely detected and the RSSI was -85 dBm and sometime signal disappears. In terms of the reverse side of point 2 and 3 RSSI was equal in all directions. Figure 8 shows RSSI of omni-directional antenna at point 3 and 7 meters away from access point.

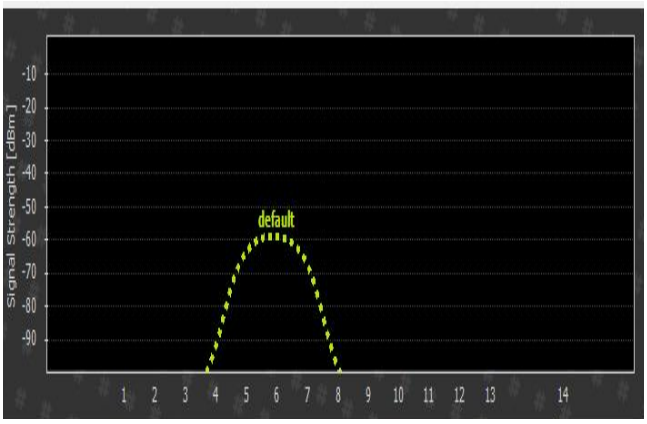

Figure 8. Signal strength of omni-directional Antenna

C. ESPAR Antenna

At point 1 of one meter RSSI was -43dBm and point 2 was -52 dBm and point 3 was -56 dBm. I can be said that RSSI slightly changed from one point to another. In addition, at point 4 outside the room with 5 meters away and one wall obstacle signal strength was -65 dBm. Another point at 10 meters with two walls obstacles signal recorded -71 dBm. However, with four wall obstacles the signal strength was approximately weak and similar to both previous antennas that recorded -83 dBm. Figure 10 shows RSSI of ESPAR Antenna at point 1 and one meter away from access point.

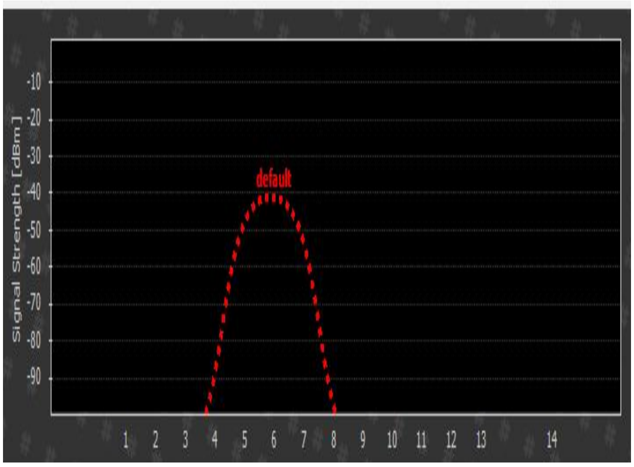

Figure 9. Signal strength of ESPAR Antenna

V. Analysis of Results

According results recorded in this report, it can be said that directional antenna has strength signal at the first point because it is designed to radiating in one direction and all power is focused in one direction. On the other hand, when the laptop putted in point 2, signal strength of directional antenna decreased but there was a better signal by using omni-directional and ESPAR antenna.

Even thought omni-directional antenna has a radiation patter in all direction, it recorded -59 dBm similar to directional antenna. However, ESPAR antenna had strongest signal at the same point and recorded -52 dBm. When laptop returned back within the direction of directional antenna, it found that it has a good signal comparing to other both antenna. Results begin to be different at point 5 where signal of omni-directional antenna was barely received. However, signal strength was the same in other both antennas. After 18 meters with four walls obstacles signal was hardly received in all antenna of experiment.

According to this result, it can be said that RSSI of ESPAR antenna was better than directional and Omni-directional antenna as points got further from the access point. In addition,, ESPAR antenna has bandwidth wider than directional antenna. For instance, at point 2 where 5 meters and it was not in front of the antenna, RSSI for Directional antenna was -59dBm and RSSI for ESPAR was -52 dBm. Furthermore, at the distance of 10m with two concrete wall obstacles, RSSI was -71 dBm which is better than other both antennas. However, with four wall obstacles the signal strength was similar to the other both antennas.

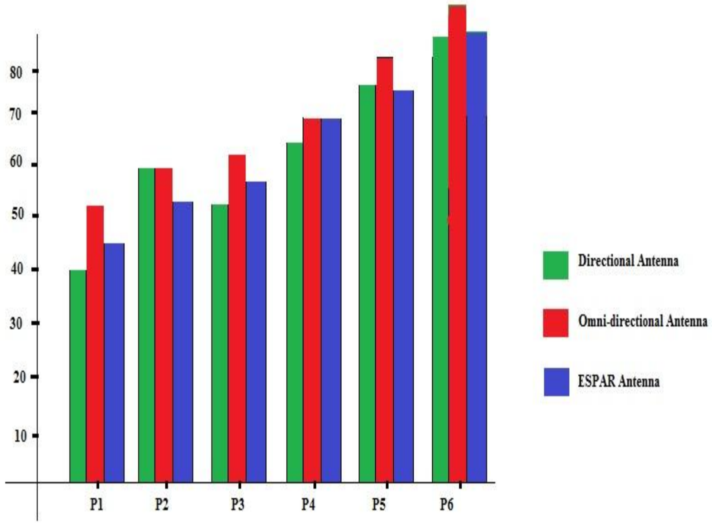

Figure 10. Chart of ESSI for different antennas

The chart above indicates the different antenna signal strength values received. It can be clearly seen from the graph that the ESPAR antenna has been the dominantly performing antenna. The omni-directional antenna has shown a steady linear decrease in the signal strength with the increase in distance and an increase in the hurdles. This points the fact of a uniform radiation pattern in all directions. The signal strength in case of a directional antenna was very high and in some cases equal to ESPAR antenna. This was mainly due to the more focused beam of directional antenna in on direction. The signal strength was reduced in case of directional antenna with distance and particularly if the receiver was placed at a point which was out of antenna focus of beam. Still if the point laid in the focus of the antenna beam then it showed a good and strong radiation pattern. The ESPAR antenna has clearly outperformed the other two antennas as it is evident from the table 1. Still there have been certain points in which this antenna has shown equal signal strength as compared to the other two antennas; and especially the directional antenna. This is because of the fact that the directional antenna has a dominantly focused beam and shows strong signal strength when the receiver is in the focus of its beam.

VI. Conclusion

Three types of antenna were investigated in this report which were directional antenna, omni-directional antenna and ESPAR antenna. Different observations were made with these antennas using inSSIDer software installed in the laptop. These antennas are conducted to address the differences between the performances of Received Signal Strength Indicator (RSSI) of each antenna. It has been observed that directional Antenna had a stronger RSSI level in the direction in which it was transmitting. However, According to measurements at every test points, it found that ESPAR antenna had better results were recorded which makes it outperform other both antennas.

As expected from the theoretical backgrounds about the optimal performance of smart antennas; the ESPAR antenna has shown certainly a better performance in terms of the signal strength in most cases. This makes the Smart ESPAR antenna to be a better option as compared to the omni-directional or directional antennas. It offers high signal strength even with an increased distance from the source. The smart antenna has shown a better signal processing capability to optimise its radiation pattern in response to the signal environment.

The good performance of ESPAR antenna is due to the mechanism of working which allow sending a signal in all directions with high signal strength. Omni-directional antenna was slightly weak transmission after 5 meters. However, directional antenna sends a signal in just one direction so that signal begin to decrease when a receiver move out of the main radiation pattern until signal disappear.

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