RF Propagation Improvement for Machine to Machine Communication Using Dipole Antenna

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***Abstract*—This project entails the study of the concepts behind machine to machine communications and designing the candidate antennas associated with a wide range of measurements conducting GSM frequencies or for other test frequencies using mobile phone technology with the aid of dipole antennaswhere there is potential to improve Machine to Machine communications using multi hop techniques. In order to reduce the propagation loss between TX and RX caused by several forms of errors and mismatch, power losses and electromagnetic coupling effect from the nearby objects measurement has been carried out between the fridge and candidate antennas over air interface.**

***Index Terms*—dipole antenna, monopole antenna, patch antenna, fridge, cool-tel device, path loss measurement, Machine to Machine(M2M) communication**

I. Introduction

Machine-to-Machine(M2M) communications arose during the peak of popularity for analog cellular network in the early 1990s and later around the year 2000, cellular network was used for digital communication [1]. Because of the expansion of wireless networks across the world, M2M communication has become far easier for to take place and has lessened the amount of power and time necessary for information to be communicated between machines. It is a new business concept, uphold from the original telemetry technology, used for automatic transmission and measurement of data from remote sources by radio, wire or other means. M2M technology is the employment of various types of electrical and mechanical devices to form a communication and exchange of necessary information to the customers now days[1].

Manuscript received October 1, 2013; revised December 31, 2013

M2M is very useful when it is necessary to communicate with significant number of device, whether they are mobile or wired interfaces, and when the other methods of communication are impractical or otherwise undesirable [1].

M2M interface has bought a new revolution in the businesses sector to monitor and employ remote equipment that is key point to the business operation. This type of remote monitoring and control associate with little or no interruption in productivity [1].

The basic infrastructure for M2M associate a central system which can be defined as portal server for this project that is able to correlate with other devices at various locations. The connection allows the central system to send or collect data's over air interface or cellular network to each remote location for processing. In mobile M2M applications the ability to get data's is advantageous where the location is apparently useful. For example.

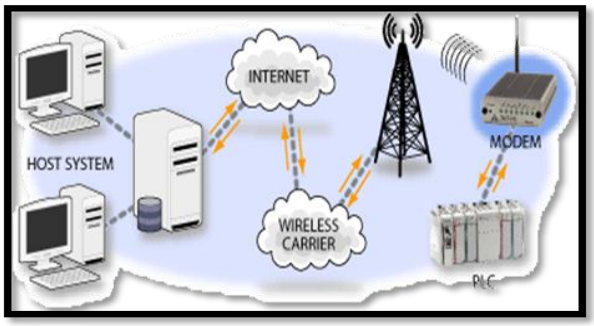

Figure 1. A conventional M2M mechanism

M2M technology may be exploiting to build an integrated network for temperature monitoring purpose across the desired locations. M2M interface helps to accumulate the process for reporting data from the field. A conventional M2M mechanism is shown in Fig. 1.

doi: 10.12720/ijeee.2.1.65-69

II. Overview Of Fridge Propagation

Propagation into fridges is one of the concerns of M2M technology and sort of applications wherever temperature control is required. It is especially useful where a refrigeration unit comprise high value items, or where it is important that the contents have been stored in the fridge are at the correct temperature. Only an efficient antenna can update the data specifying the exact information. Otherwise data may be lost on the propagation path and cause certain amount of dB loss [2].

III. Cool-Tel Working Principle

Cool-Telis a wireless device where any SIM card will let the device connected with the frequencies within the bandwidth the antenna will transmit the signal. Each Cool-Tel sensor has been programmed individually with an upper and lower threshold temperature. If the sampled temperature goes outside the preset limits or not within the operational range, an alert condition is generated and this critical alert or any power failure signal has send to the engineer or management by SMS or email for taking the appropriate action instantly. The device work over mobile phone infrastructure and internet through a secure web portal or server. Such way SMS or email becomes important transmission mechanism for M2M communication, with the ubiquity of GSM. This server is constantly checking the data sent from the sensors, and comparing it with the limits that have been set .The system is shown in Fig. 2.

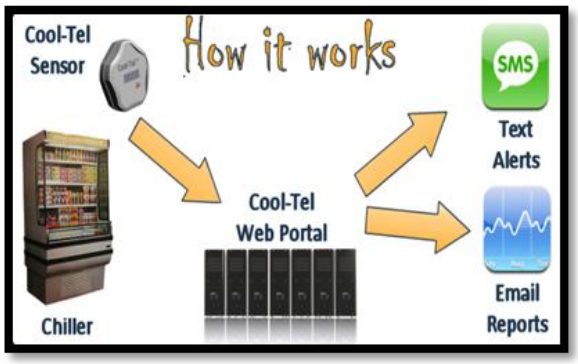

Figure 2. Cool-Tel device mechanism

IV. DIPOLE ANTENNA DESIGN

In most cases antennas are physically small in size rather than electrically and though it's not sure that the device may always oriented to the exact direction to the receiver of Cool-Tel unit need to communicate with the server using mobile cellular network and placed where it is possible to get mobile phone reception. So we need Omni-directionality and dipole antenna is the best candidate for these Omni-directionality properties & has the upper hand over the other antenna so they can deal signal from any direction and can radiate in all directions. Due to use of low power and their size makes them more efficient for use in small devices such as cool-tell device, mobile phones etc [2]

Dipole antennas shown in Fig. 3 below are essentially just a wire with a certain length connected to a feeder and balun. It has relatively high gain relative to its size. A basic dipole consists of two equal straight lines of the same length, lying on the same axis where a small gap separated them. The antenna is then fed from the feeding point or from the centre point, in order to transmit or receive electromagnetic radiation [3] [4].

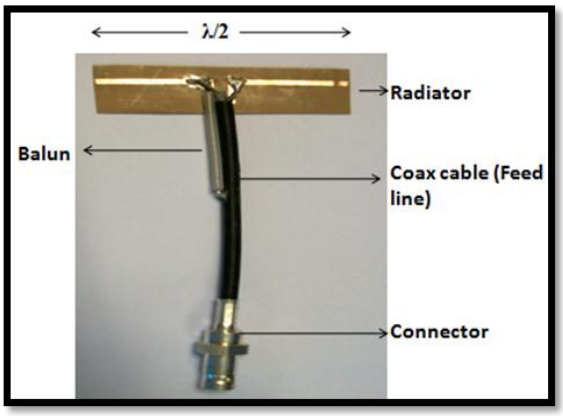

Figure 3. Dipole antenna

V. Verification of Dipole Antena

After construction the dipole antenna we had measured the return loss, SWR, S11 and S21 with the aid of Network analyzer. According to the theory for an efficient antenna should have SWR value between 1 to 2 which corresponds to return loss -9.54 dB. At GSM frequencies dipole antenna shows less path loss compare to other candidate antenna such as monopole and patch antenna [5].

VI. Path Loss Measurement

In order to measure the path loss we have considered some antenna combination where we can see path loss comparison between the fridge and candidate antennas.

TABLE I. Antenna Combination

Combination of Antenna Pair	Test Frequency	Test Frequency
Dipole:Dipole	900MHz	1800MHz
Dipole:Monopole	900MHz	1800MHz
Dipole:Patch	900MHz	1800 MHz

We placed one of them inside the fridge as RX and considered one of them as TX outside of the fridge.

VII. Graphical Comparison

Dipole-Dipole: At the beginning of measurement procedure we placed both dipole antennas inside the fridge at both GSM frequencies at different orientation. In the 2nd stage of our measurement we have gone through measurement of TX/RX dipole antenna and where we can find the values of S21 at 1800MHz and 900MHz. In this stage of the measurement we have calibrated the VNA

carefully well enough to get appropriate data's. Though we were concern about our S21 values should be as less as possible, so first we had noted the data's transfer between TX-Dipole and RX-dipole at the free space to see how much path loss degrade after putting inside the fridge.

We have placed the RX-dipole inside the fridge at different orientation and closed the door for a while until taking the measurement from the vector network analyzer(VNA).We had taken those S21 data's for which S11 values is less than -9.54 dB. Then we have taken away the RX antenna from the fridge for the next measurement. We calibrated the vector network analyser (VNA) each time before taking the next data's. By following the same procedure we have taken several numbers of data's for both 900 MHz and 1800MHz.

After getting S21 values we have made a histogram which has shown bellow, to compare path loss at both frequencies to see where the data's getting peak.

From the above histogram in Fig. 4, looking at -6dB and -12dB point it is clear, apart from this two point at 1800MHz,path loss improvement at 1800MHz is not sufficient over 900MHz.

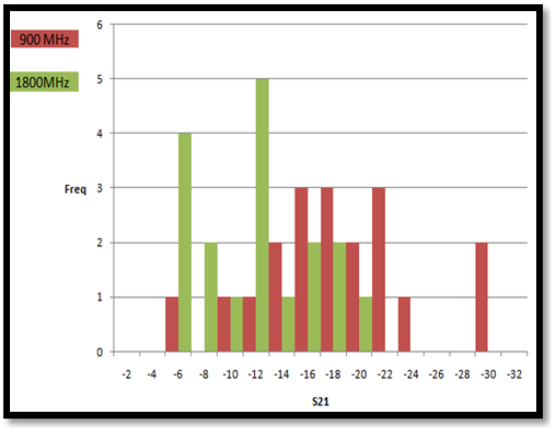

Figure 4. S21 values of Dipole antenna at 900MHz &1800MHz.

Dipole-Monopole: In case of second combination we have considered monopole antenna where this antenna constructed by using actual board of the Cool-Tel device. The ground plane of this antenna had used with a coaxial cable where a ferrite core had also used to minimize the reflection. A quarter wave wire was mounted top of the actual board to form this monopole antenna. The monopole is behaving like a dipole if the ground plane is large enough compare to conductor wire**.** Typically the feed for the monopole is coaxial line and inner conductor connected through a hole in the ground plane to the vertical monopole element. The outer conductor is connected to the ground plane by means of a flange. The monopole inner conductor diameter is equal to the monopole element diameter and outer conductors diameter is equal to the plane hole diameter. The ratio of outer-to-inner conductor diameters of coaxial lines can affect the antenna impedance [6]. Monopole antenna, shown in Fig. 5 below, is electrically short and their length are much less then quarter wave length and comprise a shape look like the figure below.

Figure 5. Monopole antenna on ground plane.

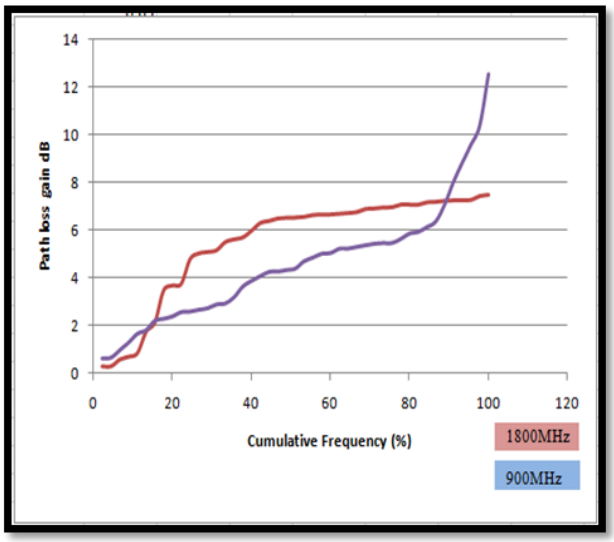

Figure 6. Dipole Vs monopole antenna.

From the above cumulative frequency distribution plot shown in Fig. 6, it's been clear monopole antenna is showing greater dB loss than dipole at both GSM frequencies.

Monopole antenna usually suffers a drawback of narrow bandwidth, which limits its practical applications. For an efficient monopole antenna, the ground plane need to be efficient where real antenna ground plane has lossy effect. When the antenna is located inside the fridge where the height of the antenna is small compare to skin depth of conducting metal door, the input resistance may even be greater than its free space values. This leads to monopole with low efficiency. Skin depth is a parameter that is used to describe skin effects. Basically skin effect increases the effective resistance at RF frequency and signal power drops on it. So when RX antenna placed inside the fridge and as soon as antenna touches fridge metal door or wall , receiving antenna inside the fridge could not get the signal properly from transmitter antenna and as a result path loss was increased. Moreover the length of the ground plane is much spread out a quarter wave monopole length. Monopole antenna is affected here by parameters in the surroundings such as distance to ground plane, size of the ground plane and thickness of actual board .The length of monopole was a key fact which may cause resonance in frequency and may responsible for bad performance for monopole. Though ground plane size of dipole is not sensitive to its input

impedance as monopole does so it can be conclude that monopole is better than real antenna and dipole antenna is better than monopole.

Figure 7. Patch antenna at 900MHz & 1800MHz

Dipole-Patch: We also tried to improve the RF propagation by using a directional antenna which refers to a microstrip patch antenna. According to the directional antenna definition, it radiating and receiving electromagnetic waves in some particular directions than in others. Patch antenna, shown in Fig. 7 above, is a low profile directional antenna having properties of poor polarization purity, spurious feed radiation, high Quality factor and narrow bandwidth and can be mounted on flat surface [7].

It consists of a flat rectangular sheet or "patch" of metal which is one half wavelengths and mounted over a larger sheet of metal called a ground plane. The length of micro strip transmission line slightly shorter than one-half a wavelength of the radio waves at the frequency it is used. Though the patch is square, it radiating in the horizontal plane which can be define as directional. Though most of the radiation or sometimes all the radiation is suppressed by the ground plane of patch antenna so power reduced in all direction on average [8]. So adding this all up, for a square patch in the free space, we got about 7-9 dB. We have considered patch antenna for 900MHz and 1800MHz in this scenarios.

Though the patch antenna has large size compare to dipole and fridge as well, so it was not that much efficient to improve the path loss. Other two parameters belongs to patch antenna need to be consider for analyzing purpose and which is substrate height and dielectric constant ε_r. Theoretically if substrate height increases surface waves are originate which are not desirable at all. Because in this case the total power available for direct radiation is extracted by these waves. So the travelling waves are scattered at bends and causes surface discontinuities like truncation of dielectric and ground plane degrade antenna pattern and polarization.The dielectric constant usually in the range of $2.2 < \varepsilon_r < 12$.At microwave frequency (above 2GHz) higher dielectric constant is desirable and below 2GHz lower dielectric constant is desirable . Though experimental patch antenna is made of FR4 substrate whose dielectric constant is 4.4 (>2.2) so it affecting on the antenna performance. This is the cause why patch antenna is not giving better performance compare to dipole antenna [8]. According to the above data's and cumulative frequency plot it could be conclude as dipole antenna is around 6 dB better than patch antenna. The Cumulative frequency plot between patch antenna and dipole antenna is showing following discrimination between them as shown in Fig. 8.

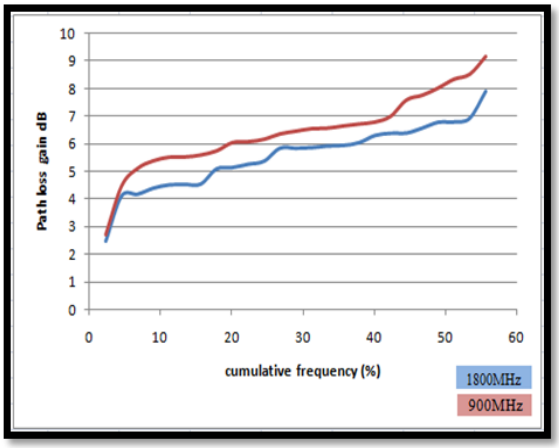

Figure 8. Dipole vs patch antenna

VIII. Discussion

Path loss measurement has undertaken so far for each of the above combination where it has been proved patch antenna is not good at all and dipole is better than monopole or designed antenna currently using in Cool-Tal device due to their detuned condition. So dipole could be used by Cool-Tal for path loss improvement and to gain some extra dB by using more than one dipole antenna. Eventually it could conclude that, a proper designed dipole antenna at 900MHz can improve efficiency of device and reduce the path loss.

IX. Conclusion

Omni directional antenna such as monopole has also considered as candidate antenna for path loss improvement, but monopole is not giving better performance as desired and cannot considered efficient antenna due to its detuned ground plane. The directional antenna such as patch antenna was not good because of its large size and due to the excitation of waves along the ground plane [9]. The types of antenna and test frequencies were separately investigated and combine for final outcome. With this method almost all the dipole antenna was engaged in effective radiation, particularly we achieved to spread out the effective candidate antenna towards 900MHz frequency. Based upon the data's taken in the measurement and their cumulative frequency plot comparing with theory, it could be conclude as dipole at 900MHz is the best candidate antenna for M2M communication and which can improve the path loss around 10 dB.

Acknowledgment

The authors wish to thank Dr. Tim Brown, Lecturer in RF antenna and propagation, department of electronic engineering, University of Surrey. This work was carried out at University of Surrey.

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