Ultra-wideband Sensor Antenna Design for 5G/UWB Based Real Time Location Systems

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***Abstract*—This paper presents a compact wideband (WB) sensor antenna design for Fifth generation mobile communication network (5G) or UWB based real time locations systems (RTLS). The proposed design is inspired from sleeve dipole structure. This sensor antenna consists of wideband antipodal sleeve (WAS) dipole and sleeve monopole, connect with same feedline. The advantage of antipodal configuration lies in its capability of feeding without any matching balun. So, the proposed antenna is printed on both sides of F4BM350 substrate for ease of feeding. The upper wing of WAS antenna is connected to the inner core of the SMA connector and the back of the antenna is connected to the outer conductor of the SMA connector. This antenna covers a bandwidth ranging from 5.64 - 7.25 GHz with Omni-directional radiation characteristics. A prototype of antenna was fabricated for measurement. The measured results are consistent with the simulated results. Moreover, this antenna can be used as a sensor antenna design for 5G or UWB based real-time location systems, and further can offer applications such as smart parking, localization and positioning.**

Keywords*— *Fifth generation mobile communication network (5G), Sensor Antenna design, Ultra-wide band (UWB), Internet of Things (IoT)

I. INTRODUCTION (*HEADING 1*)

5G and Internet of Things (IoT) are leading this world to a new communication paradigm that was not exists before, by promising astonishing capabilities such as enhanced data rate up to 100s of Mb/s, connectivity to the billions of devices, and much smaller latency of 1 ms [1], [2]. 5G is not an evolution to previous 3G or 4G cellular communication standards, but it is a revolution. Both 5G and IoT have realized many dream into reality by innovating a huge number of applications such as remote healthcare monitoring [3], smart parking solutions, autonomous or driverless cars, smart homes, remote surgery, smart waste management, smart cities [4][5], smart spaces [6] and IoT [7][8]. IoT technology will provide a platform or communication model for connecting daily life things/objects to internet with users [8]-[11]. Vehicles parking is one of major problem for large cities and urban areas. Vehicles parking conflicts are major issues for city planners, designers, and officials. The parking conflicts regarding on-street/roadside parking are more common. This challenge will be magnified further with the invention of technologies such as driverless or autonomous cars. However, the positioning technologies such as UWB RTLS, GPS RFID, 5G and IoT can play an important role in resolving vehicle parking issues by providing concept of smart vehicle parking solution for smart cities [12]-[19]. The decimeter level accuracy of UWB based RTLS systems make them promising candidate regarding localization and positioning [20] - [25]. Similarly, 5G technology, which is based on ultra-dense small cells can also offer similar vertical benefits regarding localization and positioning accuracy [7], [26]. Fig. 1 shows the application scenario of proposed sensor antenna design for 5G/ UWB based real time location systems applications such as smart road side /on-street parking, localization and positioning.

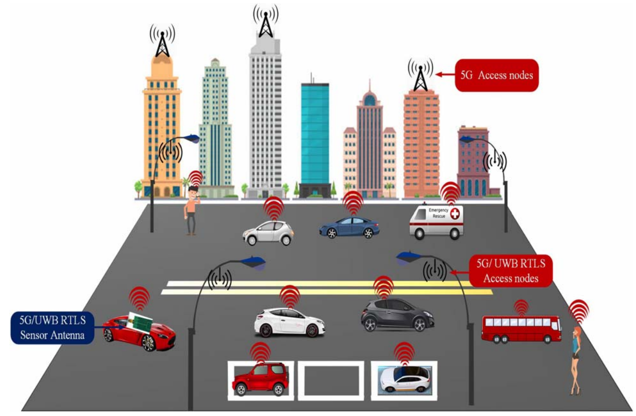

Fig. 1. Application scenario of proposed sensor antenna design for 5G / UWB based real time location systems applications such as smart road side parking, localization and positioning.

Antennas with higher gain characteristics have great influence on positioning systems. Several design for UWB RTLS antenna have been proposed in [27]-[33], however most of pose a small gain profile along with large dimensions. A PIFA type antenna with low gain profile 2.678 dB was proposed for RTLS systems [27]. Another solution having large footprint was proposed in [28] for RTLS applications along with low radiation performance. Therefore, this paper proposes a compact WB sensor antenna design for 5G or UWB based real time locations systems. This sensor antenna comprises of an array of wideband antipodal sleeve (WAS) dipole and sleeve a monopole. This antenna offers a bandwidth ranging from 5.64 - 7.25 GHz that makes it compatible with UWB transceivers by Decawave's such as DWM 1001 and DWM 1000 [29], [30].

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The proposed sensor antenna is suitable for 5G or UWB based real-time location systems, and further can offer applications such as smart parking, localization and positioning.

II. Antenna Design

A. Antenna Configuration

Fig. 2 show the configuration and dimensions of proposed sensor antenna design. This antenna was consists of wideband antipodal sleeve (WAS) dipole and a sleeve monopole printed on F4BM350 substrate (ε_r = 3.48 and tanδ=0.0015). The WAS was printed on both side of substrate, while monopole is etched only on one side of substrate. The antipodal configuration provides an advantage of feed the wings of WAS without using any matching balun, which is necessary for matching in case of simple dipole configuration. The upper wing of WAS antenna is connected to the inner core of the SMA connector and the back of the antenna is connected to the outer conductor of the SMA connector.

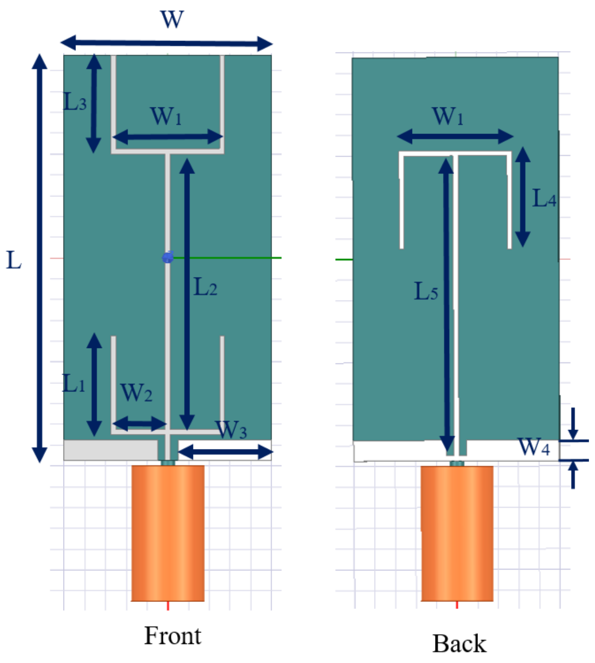

Fig. 2. Geomatery and diemensions of proposed Sensor antenna (L = 39 mm,W = 20mm, L_1 = 9.5 mm, L_2 = 27 mm, L_3 = L_4 = 9.5mm, L_5 = 29.5 mm W_1 = 10 mm, W_2 = 5 mm,W_3 = 9 mm,W_4 = 2 mm)

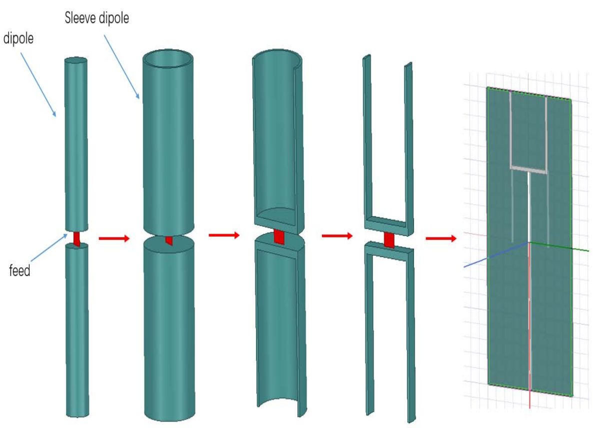

Fig. 3. Evolution steps of proposed sensor antenna from a sleeeve dipole to a microstrip wideband sleeve dipole

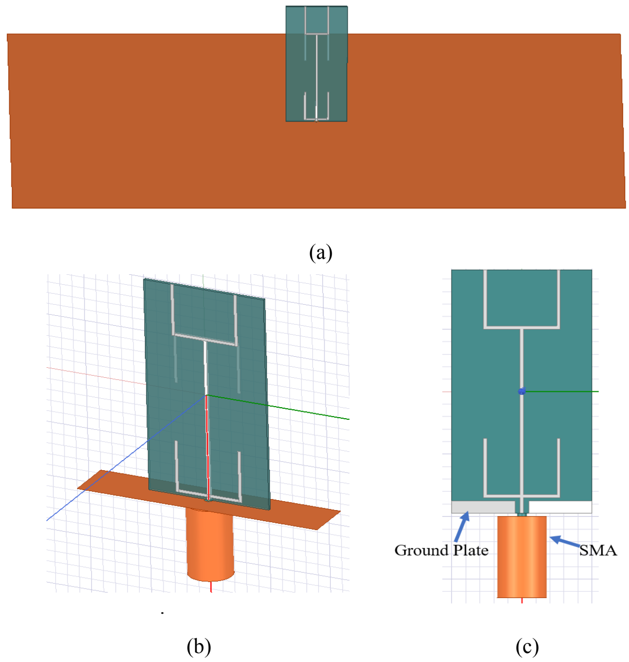

Fig. 4. Design steps of Ground plane for propoed sensor antenna design (a) Full ground plane (b) Small ground plane behind the substarte (c) Ground plane printed on substrate

B. Design steps and working principle

The proposed design in inspired from a sleeve dipole structure. Fig. 3 shows evolution step of proposed sensor antenna from a sleeve dipole. As can be seen from Fig. 3, the sleeve dipole is modified into a microstrip structure that makes it easy to connect in series. The dipoles use parallel two-wire feeds, and the parallel double lines are printed on both sides of the dielectric substrate. The upper and lower arms of the dipole are printed on both sides of the dielectric substrate so that they can be respectively connected to the parallel double wires. Increasing the antenna elements in the vertical direction and forming an array can increase the gain. It is therefore necessary to place two dipoles in the vertical direction. However, in order to make the antenna design compact (40mm or 0.87*λ) , only a monopole is connected in series with the dipole. As shown in Fig. 4, a dipole is connected in series with a monopole and a ground plane. The area of ground plane is successively reduced in order to achieve compact dimensions and easy to fabricate structure as shown in Fig. 4. Finally, the ground plane is printed on both sides of substrate and SMA connector is connected to the antenna in simulation model.

III. Results and Discussion

After running the parametric analysis of antenna, it is found that the impedance and relative bandwidth of the antenna can be controlled by optimizing W1 and W2. Moreover, the antenna gain can be varied by changing the distance between two antenna elements. However, due to space constraints the distance between antenna elements is not changed. The parameter W1 is varied in order to get optimized bandwidth. It is worth to mention here that the gain is also improved by varying the W1. Therefore, the impedance and gain of antenna are adjusted by changing width of sleeve dipole arms W1. Fig. 5 and 6 shows the S11 parameter and realized gain of proposed antenna, respectively plotted against different values of W1. As can be seen form Fig. 5, the antenna poses a wide bandwidth with 10 dB return loss ranging from 5 – 7.5 GHz with corresponding value of W1 = 5 mm. The antenna offers minimum bandwidth with W1 = 3 mm.

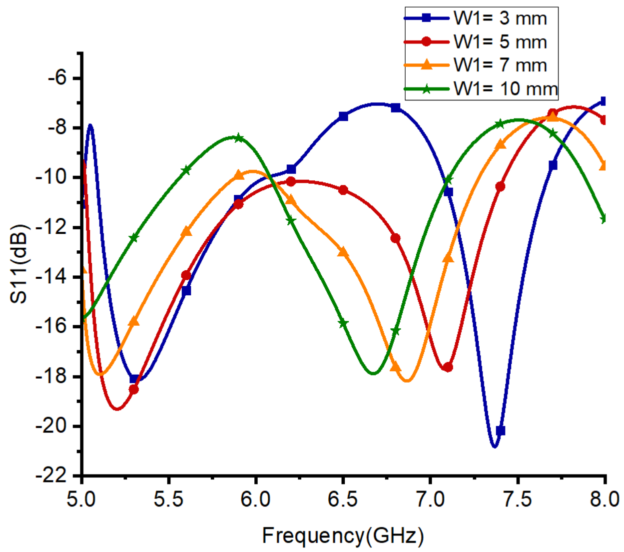

Fig. 5. S11 parameter plot of proposed antenna vs. different values of W_1

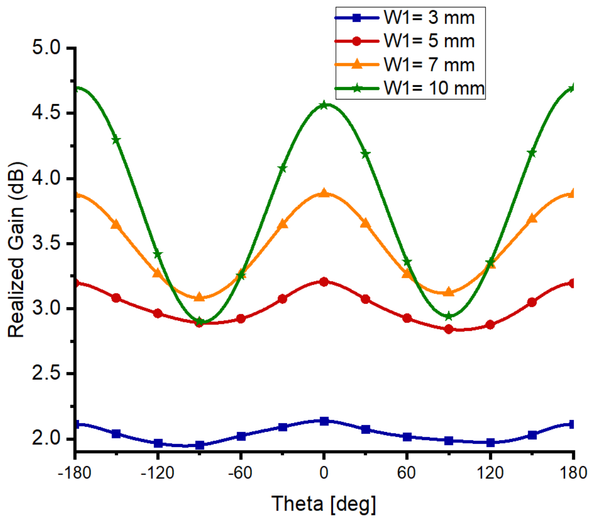

Fig. 6. Realized gain plot of proposed antenna vs. different values of W_1

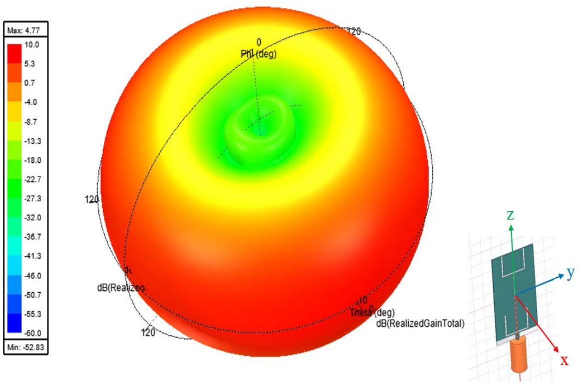

Fig. 7. 3D radiation pattern of proposed antenna design at 6.25 GHz

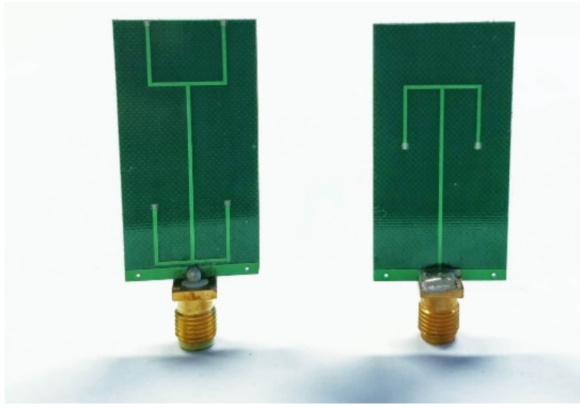

Fig. 8. Fabricated prototype of proposed sensor antenna

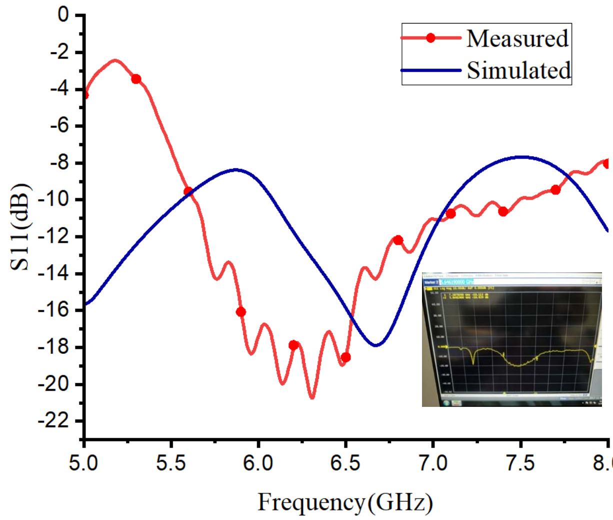

Fig. 9. Measured and simulated S11 of proposed antenna using Agilent E8363B vector network analyzer

However, we select the W1 = 10 mm with bandwidth ranging from 5.64 – 7.25 GHz, due to superior gain performance at this value. As can be seen from Fig. 6, the antenna depicts relative better gain performance 4.8 dB at W1 = 10 mm. Moreover, the gain of antenna is also good enough 3.2 dB with W1 = 5 mm, with superior bandwidth performance. The antenna has minimum realized gain at W1 = 3 mm. To conclude, the value of W1 = 10 mm is selected due to good gain performance and satisfactory bandwidth performance. Moreover, the 3D radiation pattern of proposed antenna design at 6.25 GHz is shown in Fig. 7, which shows a good Omni-direction performance of this antenna. Fig. 8 shows the fabricated prototype of proposed sensor antenna. The antenna is printed on both sides of F4BM350 substrate. The S11 plot of fabricated antenna was measured using Agilent E8363B vector network analyzer.

Fig. 9 shows the measured and simulated S11 plot of proposed antenna design that is less than -10 dB ranging from 5.64 – 7.25 GHz. The measured results are matched well with the simulation results. However, there is a little bit difference between the measured and simulated S11. The measured S11 result is much better than simulated one, which may be due to difference in actual and simulated values of relative permittivity and tangent loss of substrate. The radiation pattern and gain of fabricated antenna is also measured in anechoic chamber. However, the results of measured radiation pattern are omitted due conciseness.

IV. CONCLUSION

A compact wideband (WB) sensor antenna design for 5G or UWB based real time locations systems (RTLS) was proposed. The initial design of antenna was inspired from sleeve dipole structure. This sensor antenna consists of a combination of wideband antipodal sleeve (WAS) dipole and sleeve monopole, connect with same feedline. Due to antipodal configuration, the proposed sensor antenna was fabricated on both sides of F4BM350 substrate for ease of feed without any matching balun. The upper wing of WAS antenna is connected to the inner core of the SMA connector, while the outer conductor of the SMA connector is connected to the back of the antenna. This antenna offers a bandwidth ranging from 5.64 - 7.25 GHz with Omni-directional radiation pattern. A prototype of antenna was fabricated and measured to validate the simulation results. Therefore, this antenna can be used as a sensor antenna design for 5G or UWB based real-time location systems, and further can offer applications such as smart parking, localization and positioning.

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