The LPS – Local Positioning System

Henry V. Pham

The LPS – **Local Positioning System** is designed to guide, locate and track any devices, robot cleaners, robot carriers, or any vehicles inside the building, warehouse or manufacturing. The LPS can be extended to **Mobile-LPS**; the LPS system that can be anywhere in space or on other planets without GPS availability. The **Mobile-LPS system** can be used for **Network of Flying Objects** or **Network of Moving Objects**. Not like the GPS, the LPS can operate in high frequency for faster data broadcasting with more accuracy and work inside big building or even under the tunnels, and the signal can go thru the walls.

The GPS system works great for objects or devices in outside open space, but the accuracy is not yet satisfied and could be more than few meters errors. The GPS system operates with many different levels of frequency (L1 frequency at 1.575 GHz, L2 frequency at 1.227 GHz, etc…). With the current FCC approval of 5.0 GHz RF transmitter, the LPS system can operate at this frequency or higher to provide the LPS system more accurate and works anywhere in any environments. The GPS devices and the satellites are too far from each others, so the difference of distances from point-to-point of the GPS devices is hard to calculate and yield more errors compare to the LPS system. The GPS system works great for large objects in outside open area, but not for small objects. If the Atomic Clock oscillator can be improved to 10x faster or higher, we will have even higher accuracy than within 12 inches.

With this new LPS system, any devices, big or small, inside or outside can work great with high accuracy of 12 inches with relative locations to a fix-point of the LPS system. Not like the GPS, the LPS system is easy to collaborate, maintain, and improve without worry of devices out of clock synchronization or power outage. The LPS transmitter devices can be installed anywhere and easy to collaborate with a simple **LPS Collaborator device**. The LPS system can be widely used for many applications in many other platforms, such as single LPS transmitter for robot cleaner, 3 or more LPS transmitters for robot carrier in warehouse or manufacturing, great system Air Traffic Control for airports with combination of Radar-GPS-LPS system, great for military and security patrol system, and even great for Drones-in-Mars or other planets.

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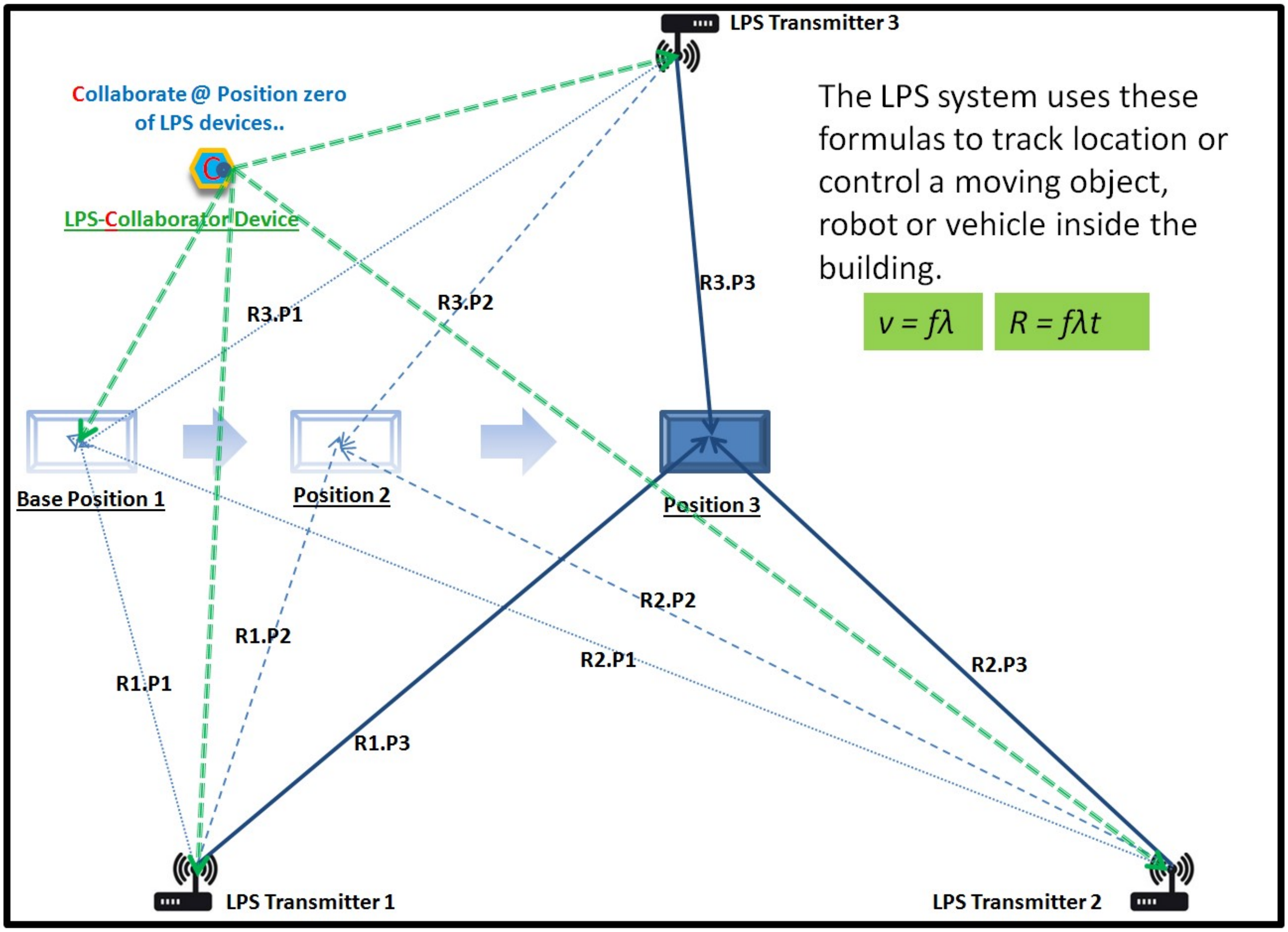

Figure-1: Robot carrier with 3 LPS Transmitters

Figure-1 above shows a robot carrier in a warehouse with a simple LPS-Collaborator device and 3 LPS wall-power-plug transmitters. The LPS-Collaborator device is used for LPS collaboration of each transmitter and the LPS receivers at position zero. When the LPS transmitters are installed, the user can easily put the LPS-Collaborator device at closest point at position zero of the transmitter (beacon) and must be within 12 inches and as closest as possible for the greatest LPS accuracy. When the LPS Collaborator is at the closest at position zero of a transmitter-1 in Figure-1 above, the user just press a button on the LPS Collaborator device to synchronize and get clock offset of the transmitter-1 and the LPS Collaborator device. The LPS Collaborator device will save the clock ticks of transmitter-1 to keep track with its own clock. Then the user can bring the LPS Collaborator device to the second transmitter-2, and do the collaboration at position zero for transmitter-2 same procedure as collaboration at transmitter-1. The LPS Collaborator device now has the clock offset of both transmitter-1 and transmitter-2. The LPS Collaborator device at position zero of transmitter-2 can now track the distance from transmitter-1 to transmitter-2 by the transmission time in nanoseconds with the ratio of 3.336 ns per meter. The user can do collaboration for transmitter-3 at position zero of the LPS transmitter-3 to get the distance from transmitter-1 to transmitter-3 and the distance from transmitter-2 to transmitter-3. Finally, the user can do collaboration for the robot carrier at the position zero of the robot and synchronize the robot for all LPS transmitters of their clock ticks offset, and the robot can keep track the distances from each transmitters. The robot carrier in LPS system above is now completed and ready to use.

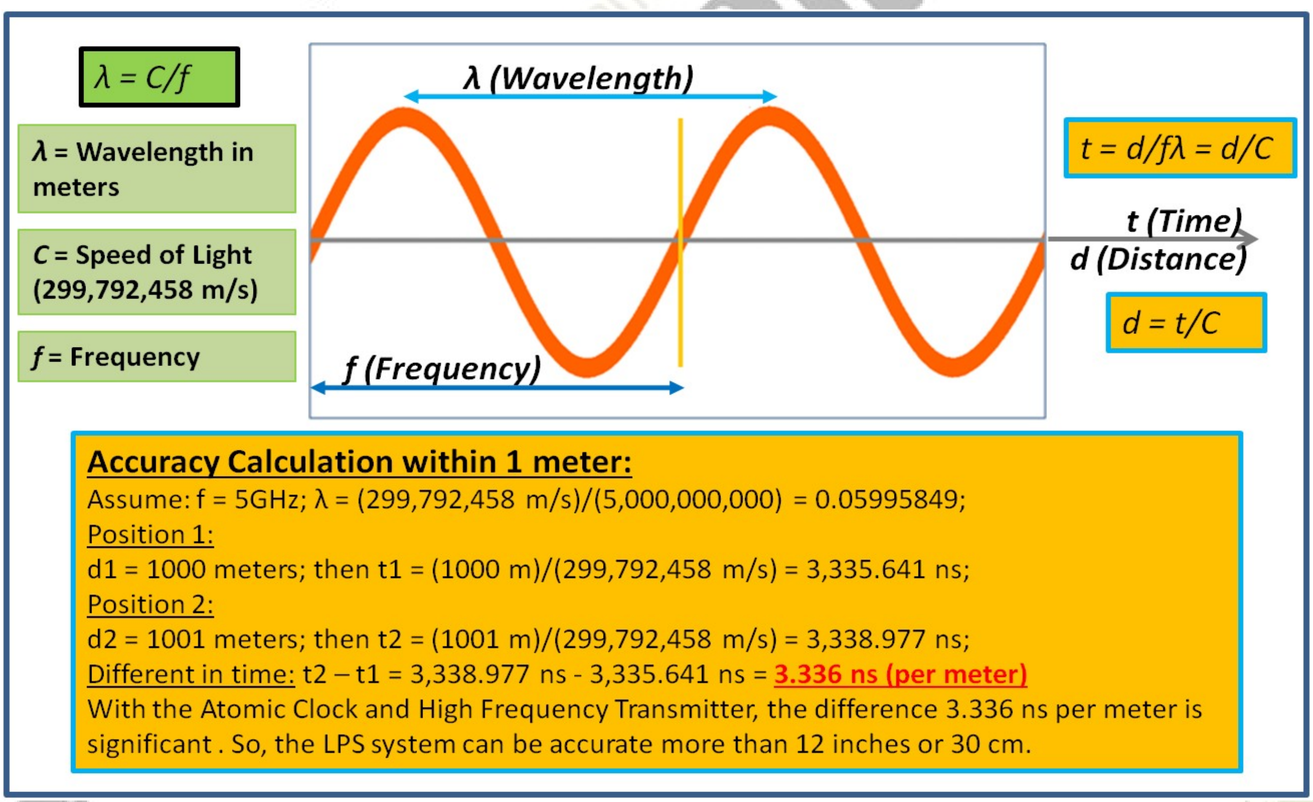

Figure-2: LPS High Frequency with Short Wavelength

Accuracy Calculation within 12 inches (30 cm)

Figure-2 shows the calculation of LPS accuracy as below.

Assume: f = 5GHz; λ = (299,792,458 m/s)/(5,000,000,000) = 0.05995849;

Position 1: d1 = 1000 meters; then t1 = (1000 m)/(299,792,458 m/s) = 3,335.641 ns; Position 2: d2 = 1001 meters; then t2 = (1001 m)/(299,792,458 m/s) = 3,338.977 ns;

Difference in time: t2 – t1 = 3,338.977 ns - 3,335.641 ns = **3.336 ns (per meter)**

With the Atomic Clock and High Frequency Transmitter, the difference of 3.336 ns per meter is significant. So, the LPS system can be accurate more than 12 inches or 30 cm.

LPS Collaborator & Transmitters Time Counters

Table-1 below shows an LPS Collaborator and the 4-Transmitters with second-counter and nanosecond-counter and broadcast every second. The LPS system can use 2 time-counters, one for second-counter and the other for nanosecond-counter for easy tracking the clock offset of each transmitter and the receivers.

LPS Collaborator	XMTR1	XMTR2	XMTR3	XMTR4
[5001][000,000,000]	[5001] [900,500,100]	[6001][700,300,100]	[7001][500,200,100]	[8001][300,700,100]
[5002][000,000,000]	[5002] [900,500,100]	[6002][700,300,100]	[7002][500,200,100]	[8002][300,700,100]
[5003][000,000,000]	[5003] [900,500,100]	[6003][700,300,100]	[7003][500,200,100]	[8003][300,700,100]
[5004][000,000,000]	[5004] [900,500,100]	[6004][700,300,100]	[7004][500,200,100]	[8004][300,700,100]
[5005][000,000,000]	[5005] [900,500,100]	[6005][700,300,100]	[7005][500,200,100]	[8005][300,700,100]
…	…	…	…	…

Table-1: Simple of 4 LPS XMTRs with Data broadcast every second

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LPS Collaborator & Transmitters Broadcast Info

Table-2 below shows the LPS broadcasting info of each transmitter. Each transmitter can transmit a short stream of data contains LPS Transmitter ID, Second Counter up to 4 bytes, and a 4-byte Nanosecond Counter within the same interval. The faster the broadcast LPS info rate, the more LPS accuracy is. Table-2 below shows the LPS transmitters broadcast interval of 1 second, and this is good enough for slow objects like robot cleaners and robot carriers. For flying objects or fast moving objects, the broadcast interval could be 1 ms or faster depends on the LPS system capability. Column 'LPS Collaborator Offset Time' shows the time-counters offset of the Collaborator device and the 4-LPS Transmitters.

Transmitter	Sequence No.	[LPS-ID]+[Seconds:Counter]+ [Nanoseconds:Counter]	LPS Collaborator Offset Time
XMTR1	1	[ID-XMTR1][5001][900,500,100]	[0][900,500,100]
	2	[ID-XMTR1][5002][900,500,100]	[0][900,500,100]
	3	[ID-XMTR1][5003][900,500,100]	[0][900,500,100]
	4	[ID-XMTR1][5004][900,500,100]	[0][900,500,100]
	5	[ID-XMTR1][5005][900,500,100]	[0][900,500,100]
	..	…	…
XMTR2	1	[ID-XMTR2][6001][700,300,100]	[1000][700,300,100]
	2	[ID-XMTR2][6002][700,300,100]	[1000][700,300,100]
	3	[ID-XMTR2][6003][700,300,100]	[1000][700,300,100]
	4	[ID-XMTR2][6004][700,300,100]	[1000][700,300,100]
	5	[ID-XMTR2][6005][700,300,100]	[1000][700,300,100]
	..	…	…
XMTR3	1	[ID-XMTR3][7001][500,200,100]	[2000][500,200,100]
	2	[ID-XMTR3][7002][500,200,100]	[2000][500,200,100]
	3	[ID-XMTR3][7003][500,200,100]	[2000][500,200,100]
	4	[ID-XMTR3][7004][500,200,100]	[2000][500,200,100]
	5	[ID-XMTR3][7005][500,200,100]	[2000][500,200,100]
	..	…	…
XMTR4	1	[ID-XMTR4][8001][300,700,100]	[3000][300,700,100]
	2	[ID-XMTR4][8002][300,700,100]	[3000][300,700,100]
	3	[ID-XMTR4][8003][300,700,100]	[3000][300,700,100]

	4	[ID-XMTR4][8004][300,700,100]	[3000][300,700,100]
	5	[ID-XMTR4][8005][300,700,100]	[3000][300,700,100]
	..	...	...

Table-2: Simple of 4 LPS XMTRs with Data broadcast every second

Simple LPS Calculation

Figure-3 below shows a robot carrier moves from position-1 to position-2 within a [20 m x 25 m] floor. With the procedure of collaboration above in Figure-1, the distance from transmitter-1 (XT1) to transmitter-2 (XT2) is 20 m; distance from transmitter-1 (XT1) to transmitter-3 (XT3) is 20.5 m; and distance from transmitter-2 (XT2) to transmitter-3 (XT3) is 20 m. The robot carrier at position-1 is collaborated at location 15.5 m from XT1, 10 m from XT2, and 24 m from XT3. Figure-4 shows the robot carrier moved from position-2 to position-3 with distance from XT1 is 8.5 m; distance from XT2 is 14.5 m; and distance from XT3 is 13 m. With the above LPS Collaboration timing counters and offset from each other devices shows in Table-3, the distance of robot carrier from each transmitters are shown in Table-4 below.

The below calculation will show the distance of the robot carrier from **position-1 to position-2** is **3.63 m** and **position-2 to position-3** is **8.3 m.**

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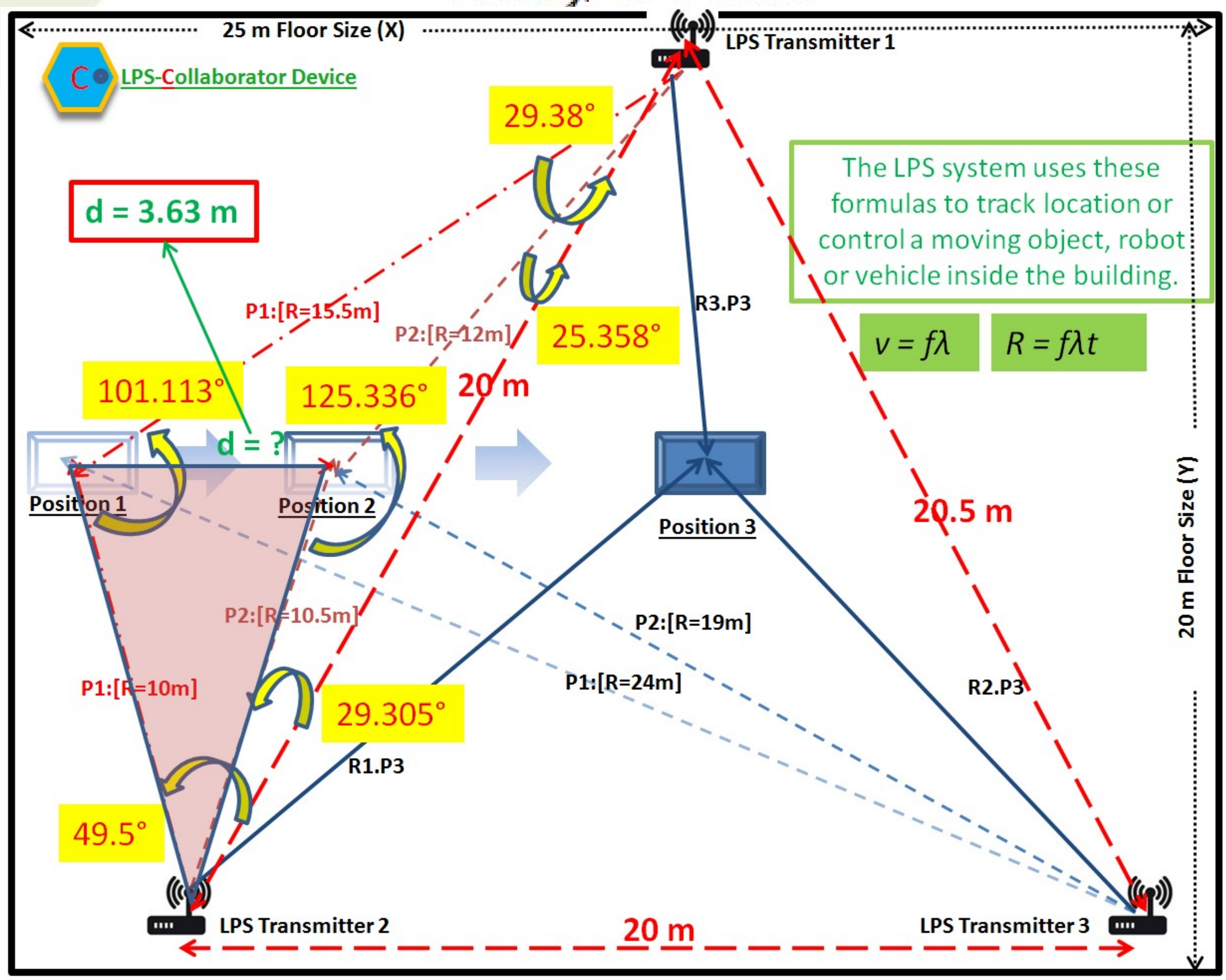

Figure-3: LPS with 3 XMTRs for Moving Robot Calculation

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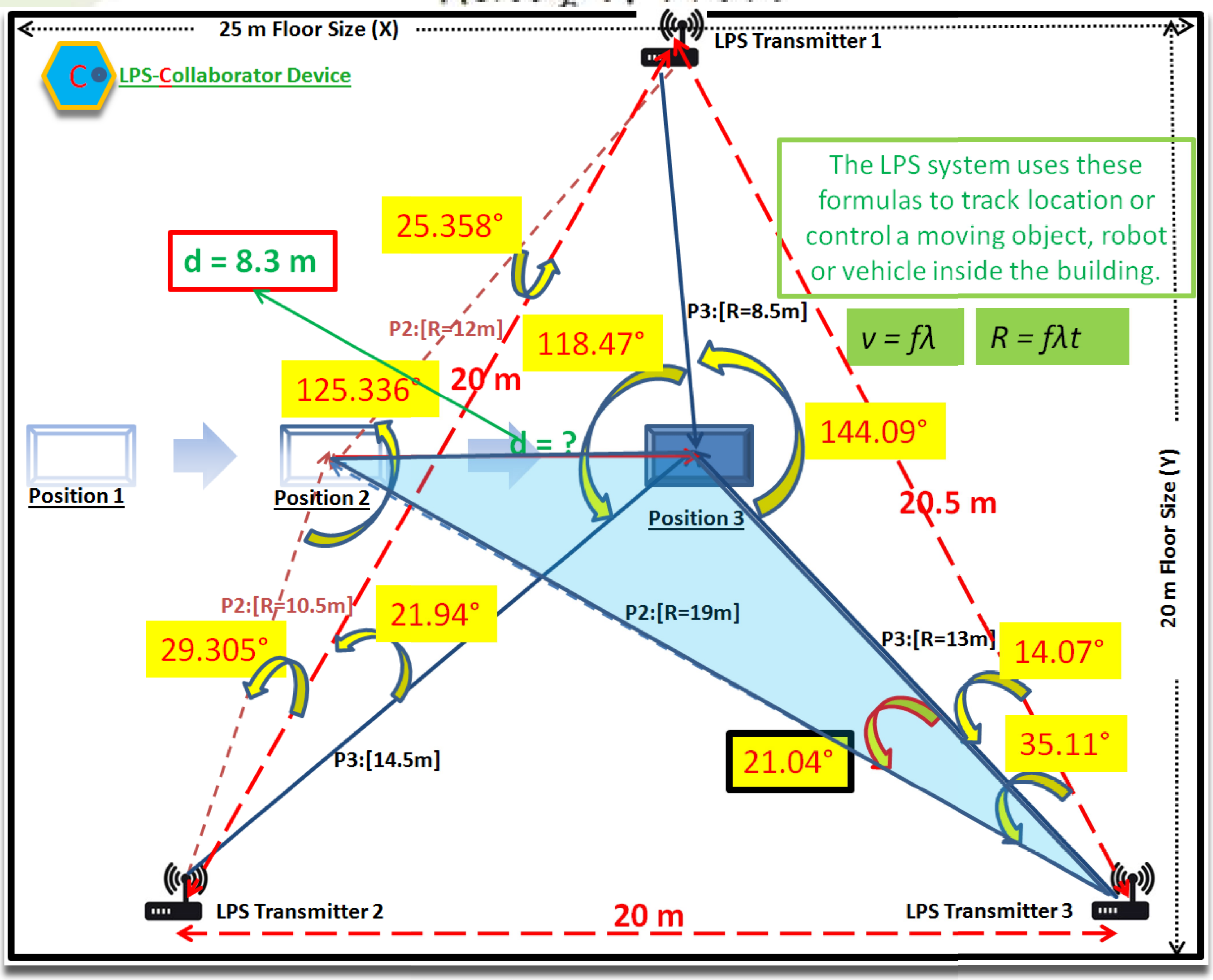
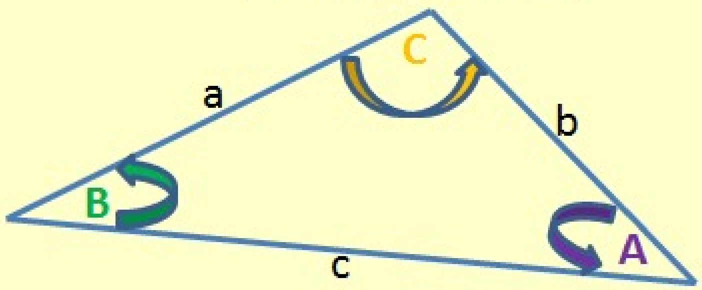


Figure-4: LPS with 3 XMTRs for Moving Robot Calculation (Cont.)

Law of Cosines



$$a^2 = b^2 + c^2 - 2*b*c*Cosine(A)$$
$$b^2 = a^2 + c^2 - 2*a*c*Cosine(B)$$
$$c^2 = a^2 + b^2 - 2*b*c*Cosine(C)$$

Reference-1: Law of Cosines

Transmitters:	**XMTR1**	**XMTR2**	**XMTR3**
Time-of-Signal-Travel-At-Position1:	52 ns	34 ns	80 ns
Time-of-Signal-Travel-At-Position2:	40 ns	35 ns	63 ns
Time-of-Signal-Travel-At-Position3:	29 ns	49 ns	44 ns

Table-3: Transmission times at 3 locations

Transmitters:	**XMTR1**	**XMTR2**	**XMTR3**
Distance-of-Signal-Travel-At-Position1:	15.5 m	10.0 m	24.0 m
Distance-of-Signal-Travel-At-Position2:	12.0 m	10.5 m	19.0 m
Distance-of-Signal-Travel-At-Position3:	8.5 m	14.5 m	13.0 m

Table-4: Distances from the XMTRs of Moving Robot at 3 locations

❖ Distance from Position-1 to Position-2 Calculation

1) Triangle of Position1-Transmitter1-Transmitter2 (P1-XT1-XT2):

From Reference-1, Table-2, and Table-3, we have:

Cosine(P1) = $(10^2 + 15.5^2 – 20^2) /(2 \times 10 \times 15.5) = -0.1927$

⇨ Angle P1 = 101.113°

Cosine(XT1) = = $(15.5^2 + 20^2 - 10^2) /(2 \times 15.5 \times 20) = 0.87137$

⇨ Angle XT1 = 29.38°
⇨ Angle XT2 = 180° - 101.113° - 29.38° = 49.5°

2) Triangle of Position2-Transmitter1-Transmitter2 (P2-XT1-XT2):

From Reference-1, Table-2, and Table-3, and above calculation we have:

Cosine(P2) = $(12^2 + 10.5^2 – 20^2) /(2 \times 12 \times 10.5) = -0.5784$

⇨ Angle P2 = 125.34°

Cosine(XT1) = = $(12^2 + 20^2 – 10.5^2) /(2 \times 12 \times 20) = 0.90365$

⇨ Angle XT1 = 25.36°
⇨ Angle XT2 = 180° - 125.34° - 25.36° = 39.3°

3) Triangle of Position1-Position2-Transmitter2 (P1-P2-XT2):

From Reference-1, Table-2, and Table-3, and above calculation we have:

⇨ Angle XT2 = 49.5° - 29.3° = 20.2°
⇨ So, the distance from P1 to P2 can be calculated as below:
⇨ d = $(10^2 + 10.5^2 - 2 * 10 * 10.5 * \text{Cosine}(20.2°))^{1/2} = (210.25 – 197.08)^{1/2}$ = 3.63 m

❖ Distance from Position-2 to Position-3 Calculation

1) Triangle of Position2-Transmitter1-Transmitter3 (P2-XT1-XT3):

From Reference-1, Table-2, and Table-3, we have:

Cosine(XT3) = $(19^2 + 20.5^2 – 12^2)$ /(2 x 19 x 20.5) = 0.818

⇨ Angle XT3 = 35.11°

2) Triangle of Position3-Transmitter1-Transmitter3 (P3-XT1-XT3):

From Reference-1, Table-2, and Table-3, and above calculation we have:

Cosine(XT3) = $(13^2 + 20.5^2 – 8.5^2)$ /(2 x 13 x 20.5) = 0.97

⇨ Angle XT3 = 14.07°

3) Triangle of Position2-Position3-Transmitter3 (P2-P3-XT3):

From Reference-1, Table-2, and Table-3, and above calculation we have:

⇨ Angle XT3 = 35.11° - 14.07° = 21.04°

⇨ So, the distance from P2 to P3 can be calculated as below:

⇨ d = $(19^2 + 13^2 - 2 * 19 * 13 * \text{Cosine}(21.04°))^{1/2}$ = $(530 – 494*0.933)^{1/2}$ = 8.31 m

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Robot Carriers in warehouse Application

Figure-5 shows an idea for robot carrier use in warehouse or factory with 4 LPS transmitters. Each LPS transmitter can be plugged into power outlet wall and at 4 corners or same distance from each corner for easy positioning and tracking application. The robot carrier and the LPS transmitters can be collaborated with the same procedure as above. Robot carriers can carry products or items to the machine operators with preprogrammed locations.

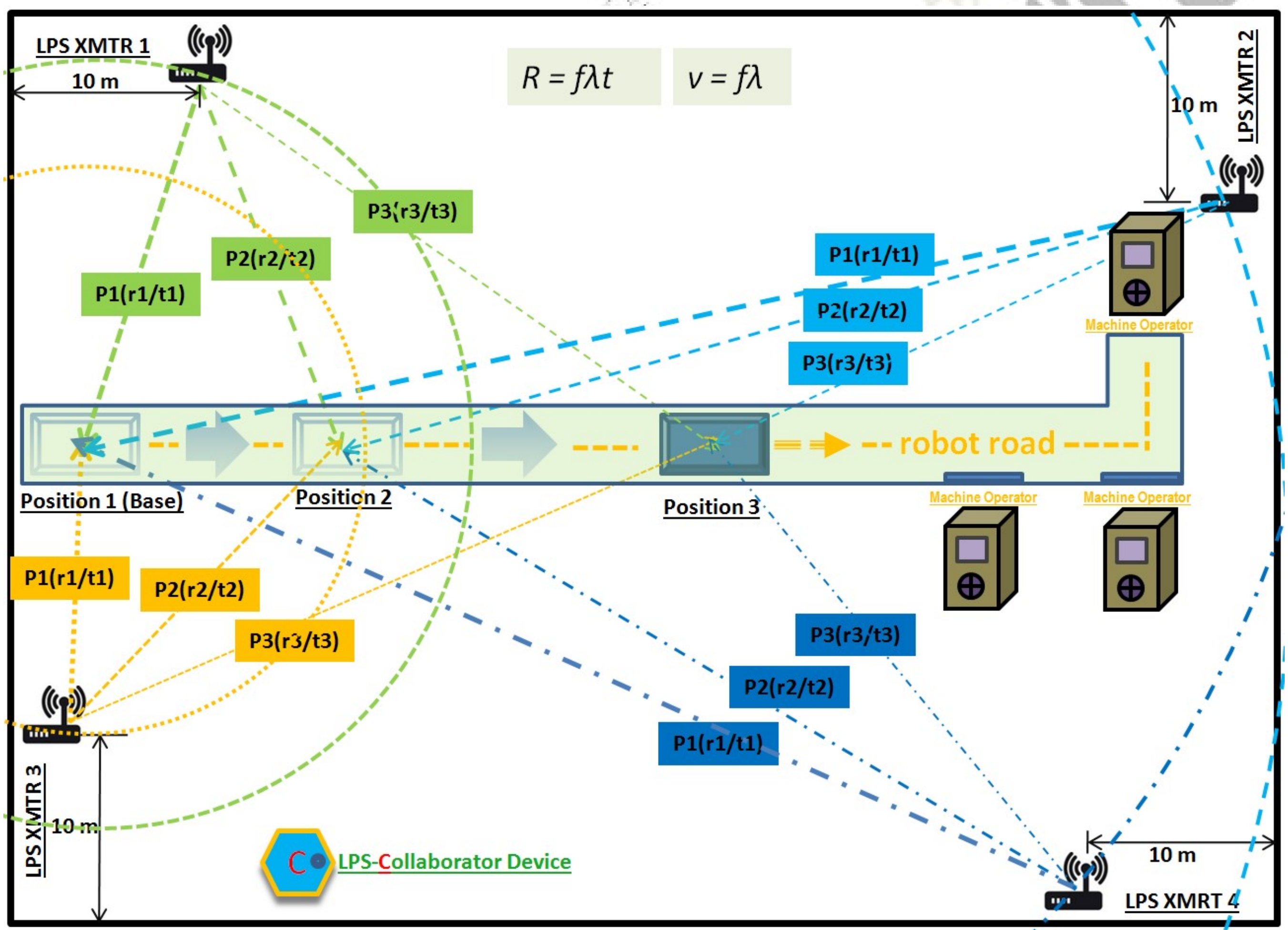

Figure-5: LPS with 4 XMTRs for Robot Carrier use for Factory or Warehouse

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Robot Cleaner in building Application

Figure-6 shows an idea for robot cleaner use in house or building with just 1 LPS transmitter. LPS transmitter can be plugged into power outlet wall with the charger station and robot cleaner charging at position zero with LPS transmitter for easy positioning and cleaning application. The robot cleaner and the LPS transmitter can be self-collaborated since they are at the same position zero.

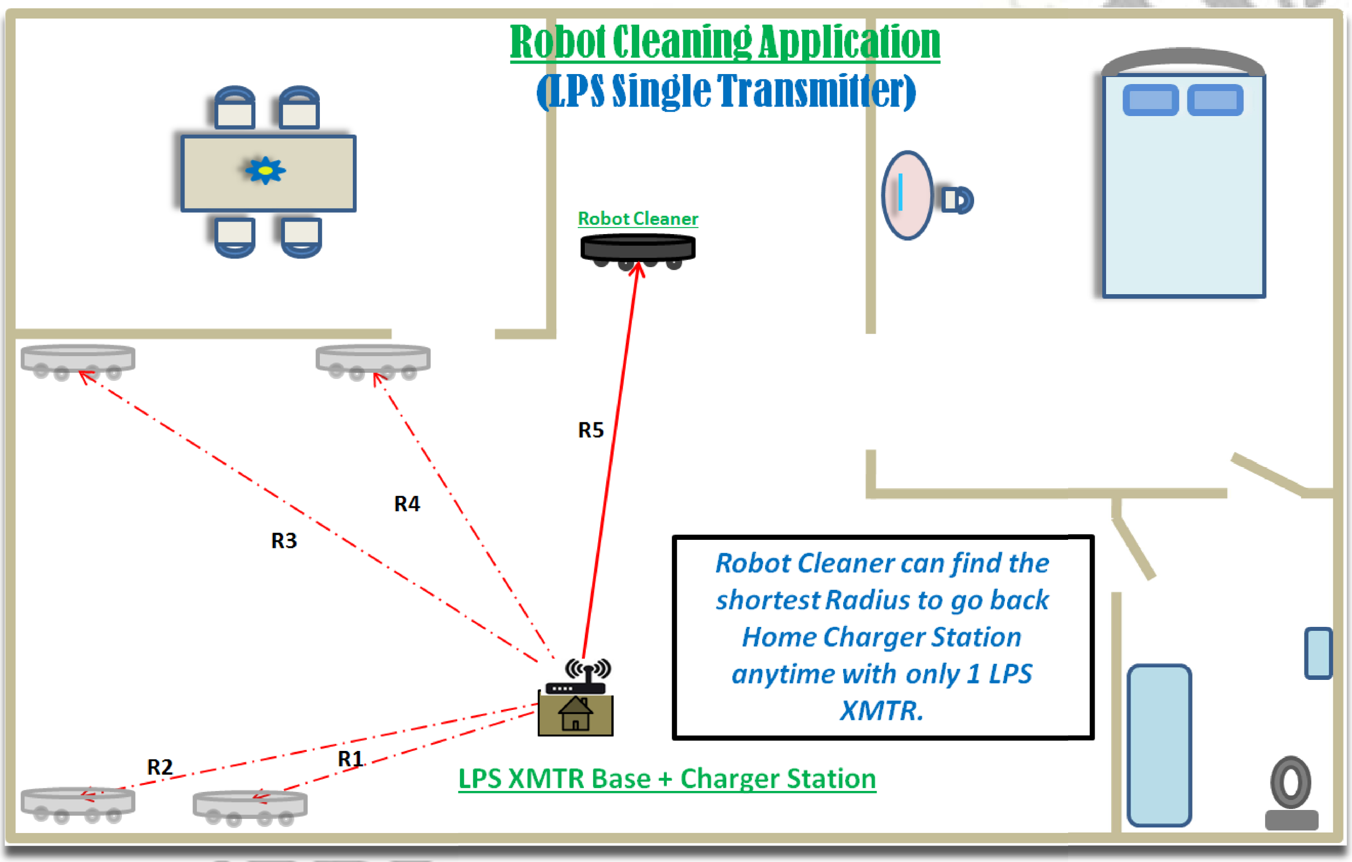

Figure-6: LPS with 1 XMTR for Robot Cleaner for houses

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Drone Circulation Application

Figure-7 shows an idea for drone use in security, patrol circle or for hobby toy drone flying with just 2 LPS transmitters vertically in a pole. The vertical LPS transmitters and drone can be self-collaborated at position zero of either LPS transmitter for easy positioning and flying application. With the idea of using vertical LPS transmitters, the drone in Circulation Application can be controlled the altitude without using ultrasonic sensor in drone and keep drone at the same altitude and radius of the circle. This could be a great idea for security point or military patrol applications.

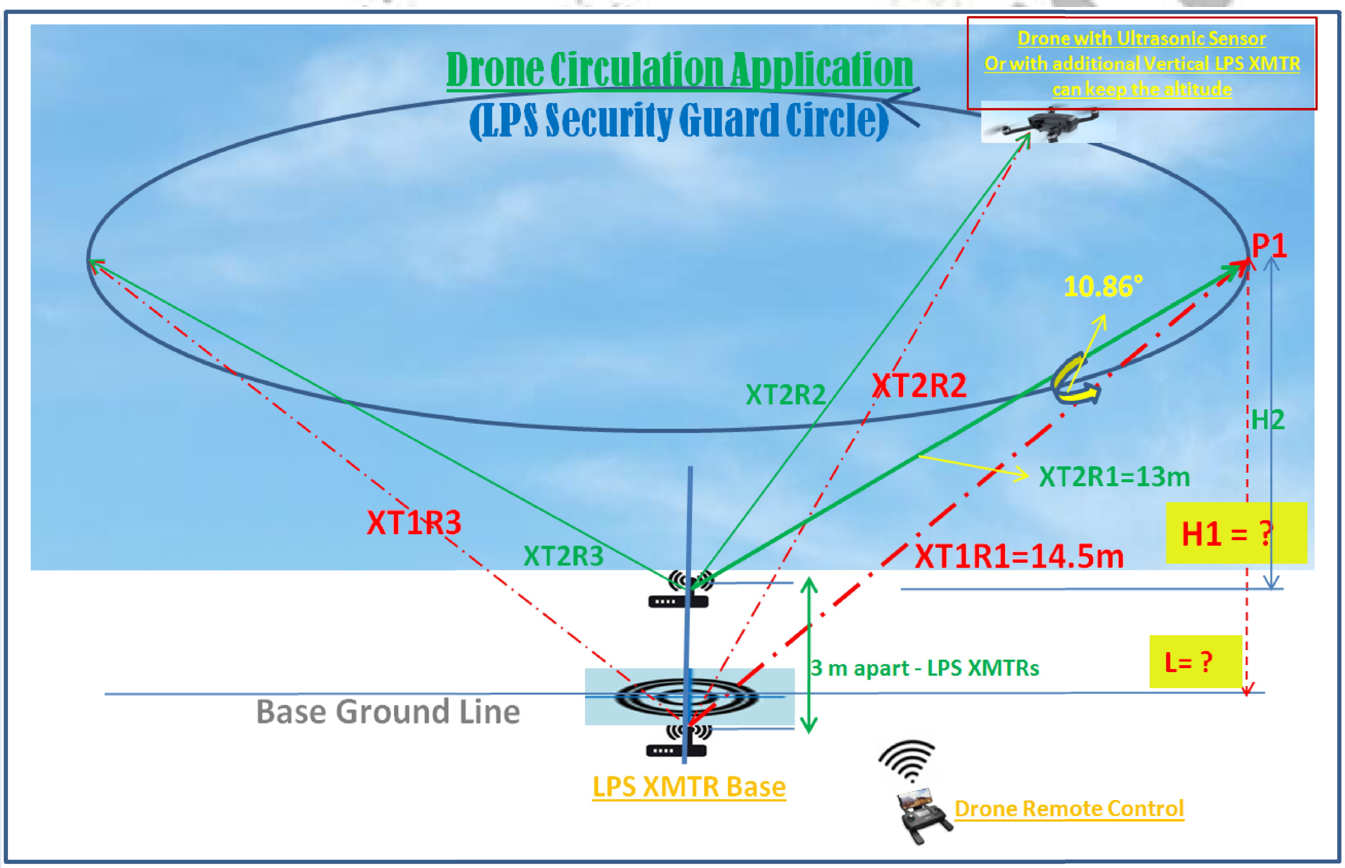

Figure-7: LPS for Drone Circulation Application Calculation

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Drone Circulation Altitude & Length Calculation

⇨ Figure-8 shows a drone circulation altitude and length calculation. The height **H1 = 8.375 m; and length L = 11.837 m**; are shown below with calculation details for this application.

Calculation of Triangle: XT1-P1-XT2

Cosine(P1) = $(13^2 + 14.5^2 – 3^2) /(2 \times 13 \times 14.5) = 0.982$

Angle P1 = 10.86°

Cosine(XT1) = = $(14.5^2 + 3^2 - 13^2) /(2 \times 14.5 \times 3) = 0.57759$

Angle XT1 = 54.72°

Angle XT2 = 180° - 10.86° - 54.72° = 114.42°

Calculation of Right Triangle: XT1-P1-G1

Angle XT1 = 90° - 54.72° = 35.28°

Sine35.28° = H1/14.5m

➔ H1 = 14.5 x Sine35.28° = 8.375 m

➔ And L = $(14.5^2 – H1^2)^{1/2}$ = $(14.5^2 – 8.375^2)^{1/2}$ = 11.837 m

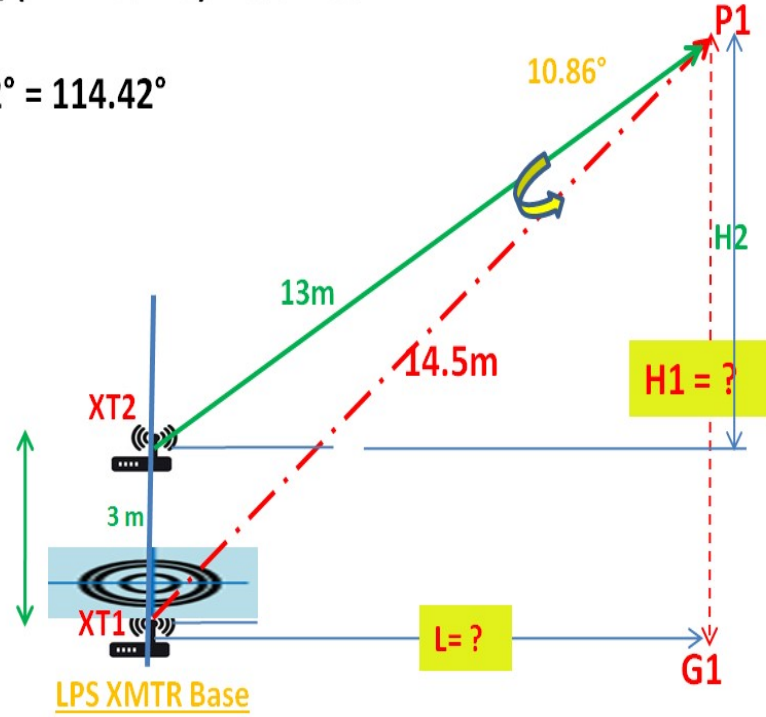

Figure-8: LPS for Drone Circulation Application Calculation

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1) Calculation of Triangle: XT1-P1-XT2

Cosine(P1) = $(13^2 + 14.5^2 – 3^2) /(2 \times 13 \times 14.5) = 0.982$

⇨ Angle P1 = 10.86°

Cosine(XT1) = = $(14.5^2 + 3^2 - 13^2) /(2 \times 14.5 \times 3) = 0.57759$

⇨ Angle XT1 = 54.72°

⇨ Angle XT2 = 180° - 10.86° - 54.72° = 114.42°

2) Calculation of Right Triangle: XT1-P1-G1

Angle XT1 = 90° - 54.72° = 35.28°

⇨ Sine35.28° = (H1)/14.5m

⇨ ➔ H1 = 14.5 x Sine35.28° = 8.375 m

⇨ ➔ And L = $(14.5^2 – H1^2)^{1/2} = (14.5^2 – 8.375^2)^{1/2}$ = 11.837 m

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Airport Traffic Control Application

Figure-9 shows an idea for Airport Traffic Control application. Currently, most of airport uses radar for tracking and positioning airplane, but the systems do not work well for the airplanes on ground or Airport ground equipments. The Airport Traffic Control system with this LPS plus GPS, the system will be more accurate and safer when every airplane and airport ground equipments are equipped with the new LPS devices. The Airport Traffic Control can easily take over the tracking and positioning for an incoming airplane with the LPS control with more details on ground equipment locations. The airport should have at least 4 LPS XMTRs at the 4-corners and at least 2 vertical LPS XMTRs on a vertical pole or tower. The procedure of LPS calibration is the same as described above with a LPS-Collaborator device.

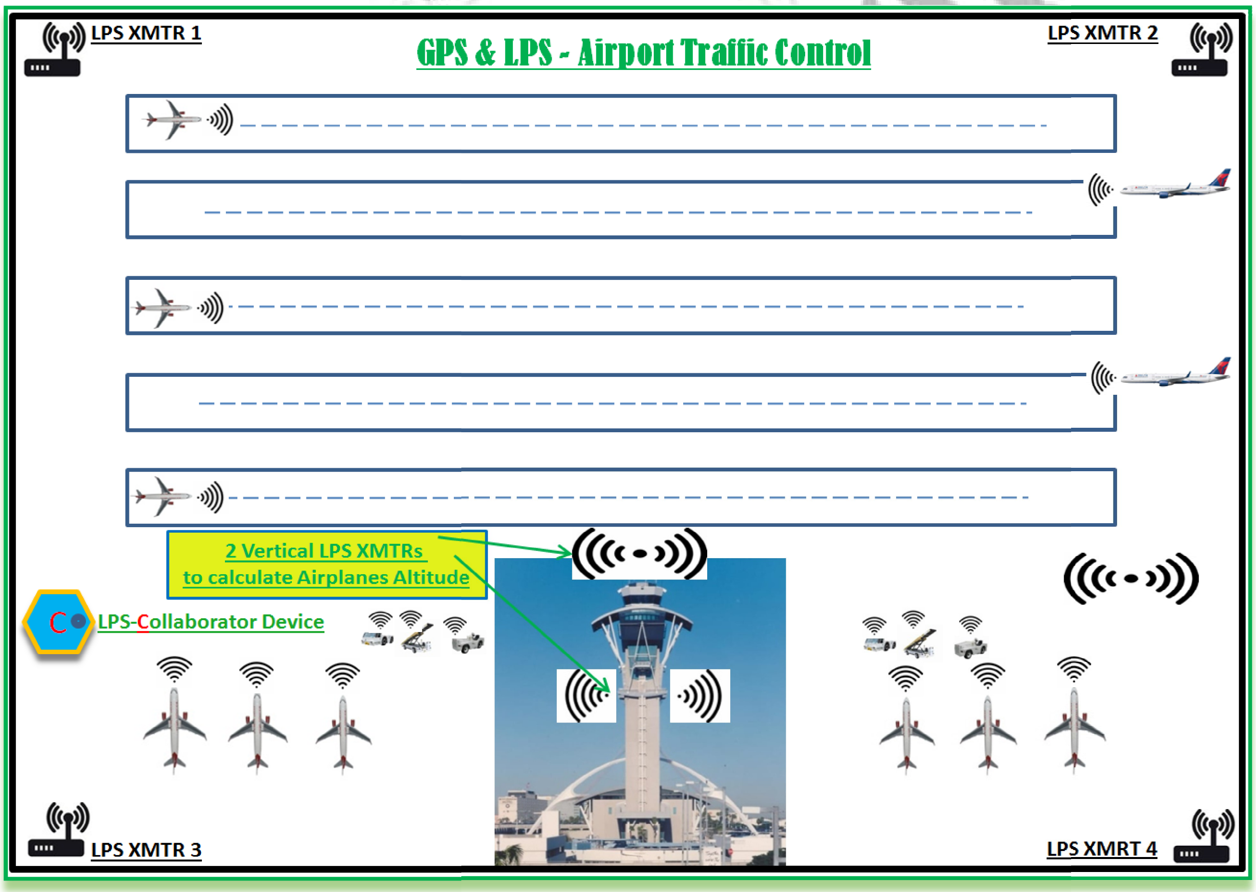

Figure-9: GPS & LPS – Airport Traffic Control

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Drones in Aircraft Carrier Patrol Control Application

Figure-10 shows an idea for Drones in Aircraft Carrier Patrol Control application. The Aircraft Carrier should have at least 4 LPS XMTRs around the landing floor and at least 2 vertical LPS XMTRs on a vertical pole or tower. The procedure of LPS calibration is the same as described above with a LPS-Collaborator. While the Aircraft Carrier moving, the drones can circulate or flying ahead and around the Aircraft Carrier and the officers can monitor and patrol inside the Aircraft Carrier with the data or video report from the patrol drones.

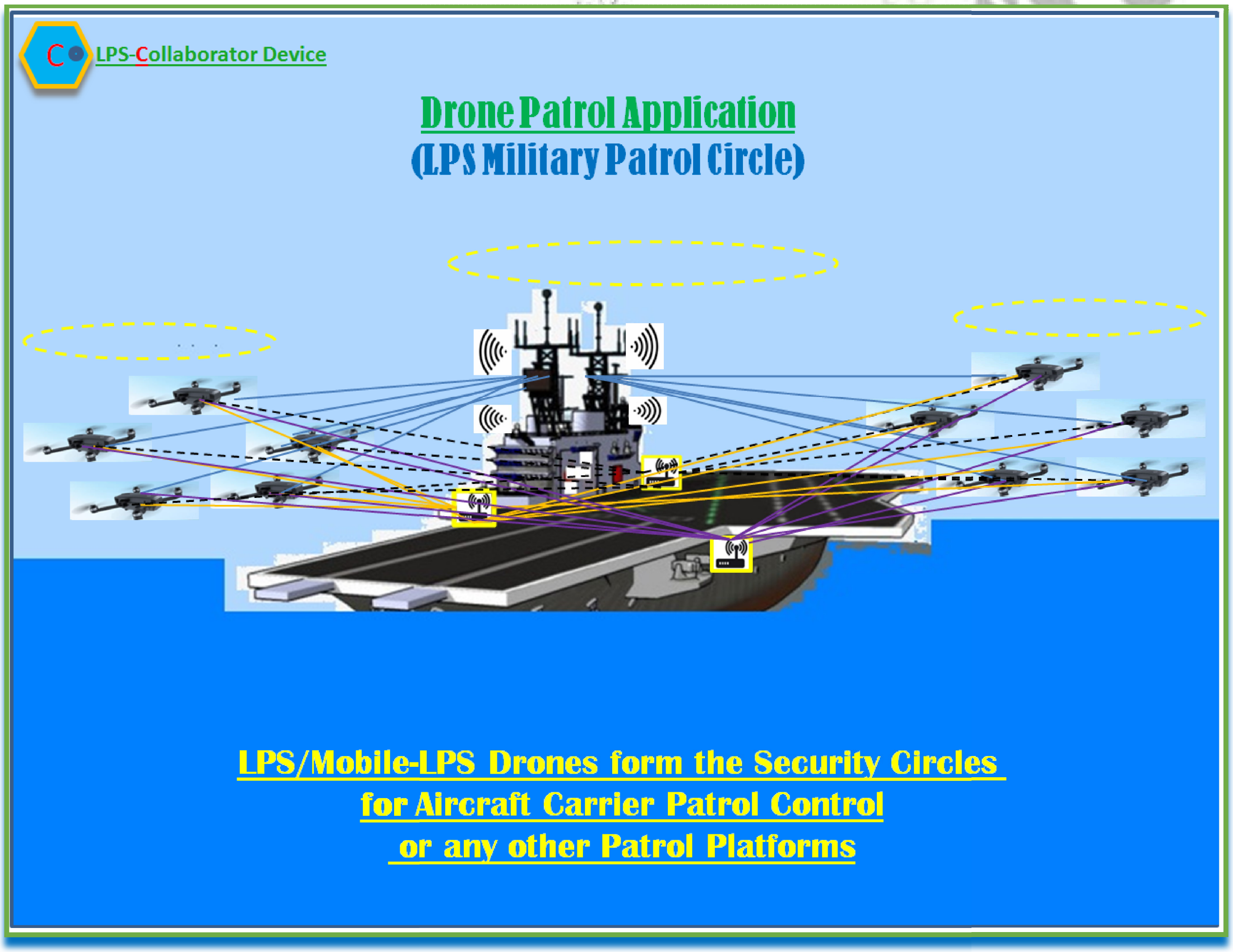

Figure-10: LPS Aircraft Carrier Drone Patrol Application

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Network of Flying Objects (Aircrafts) Application

Figure-11 shows an idea of **Network of Flying Objects** (**NFO**) application. The Aircraft One can control its own network aircrafts, and also can control the Aircraft One of other network to form a Network of Network of Flying Aircrafts. The Aircraft in this LPS Network of Flying Aircraft requires at least 5 LPS XMTRs for each aircraft. The first Aircraft One can be controlled by GPS; then the Network of Flying Aircrafts can be controlled in the desired flying tactical formation of the LPS **NFO.**

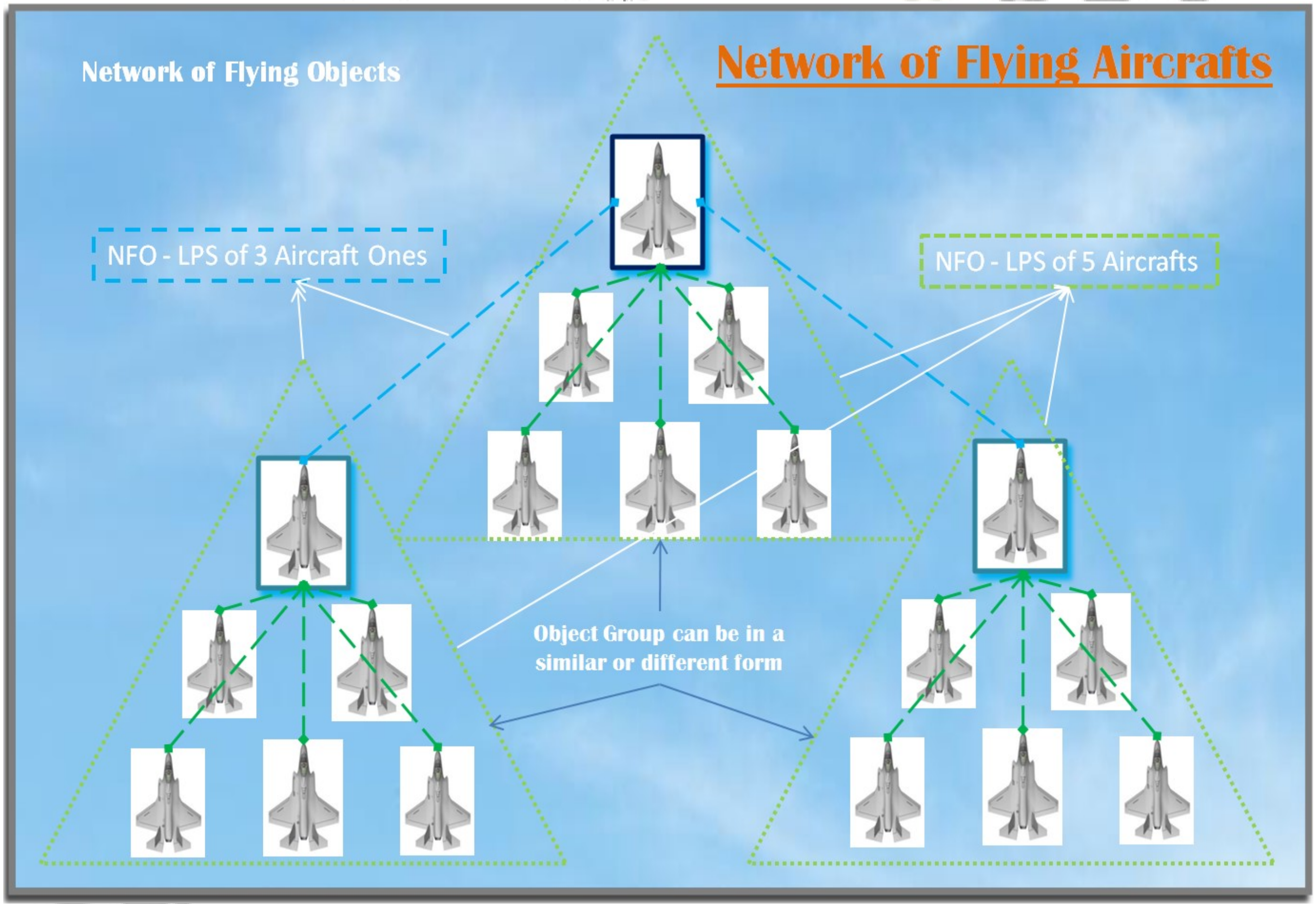

Figure-11: LPS Network of Flying Aircrafts Application

Mobile Phone LPS Locator Application

Figure-12 shows an idea of Mobile Phone **LPS Locator** application. The Mobile Phone LPS Locator application uses Atomic Clock Timer to synchronize the atomic timer between the mobile phones when one of the phones pressed the '**Initiate**' button when the phones are at position zero (close to each others). After the '**Initiate**' button is pressed, the application can able to show the distance between the phones. With the current physical location map provided, the users can easily track and locate where they are and how far they are apart. This application is good for family locating family members when they cannot able to use GPS locator and good for safety and security purposes. This LPS Locator would be used the Point-to-Point RF signal of the phones.

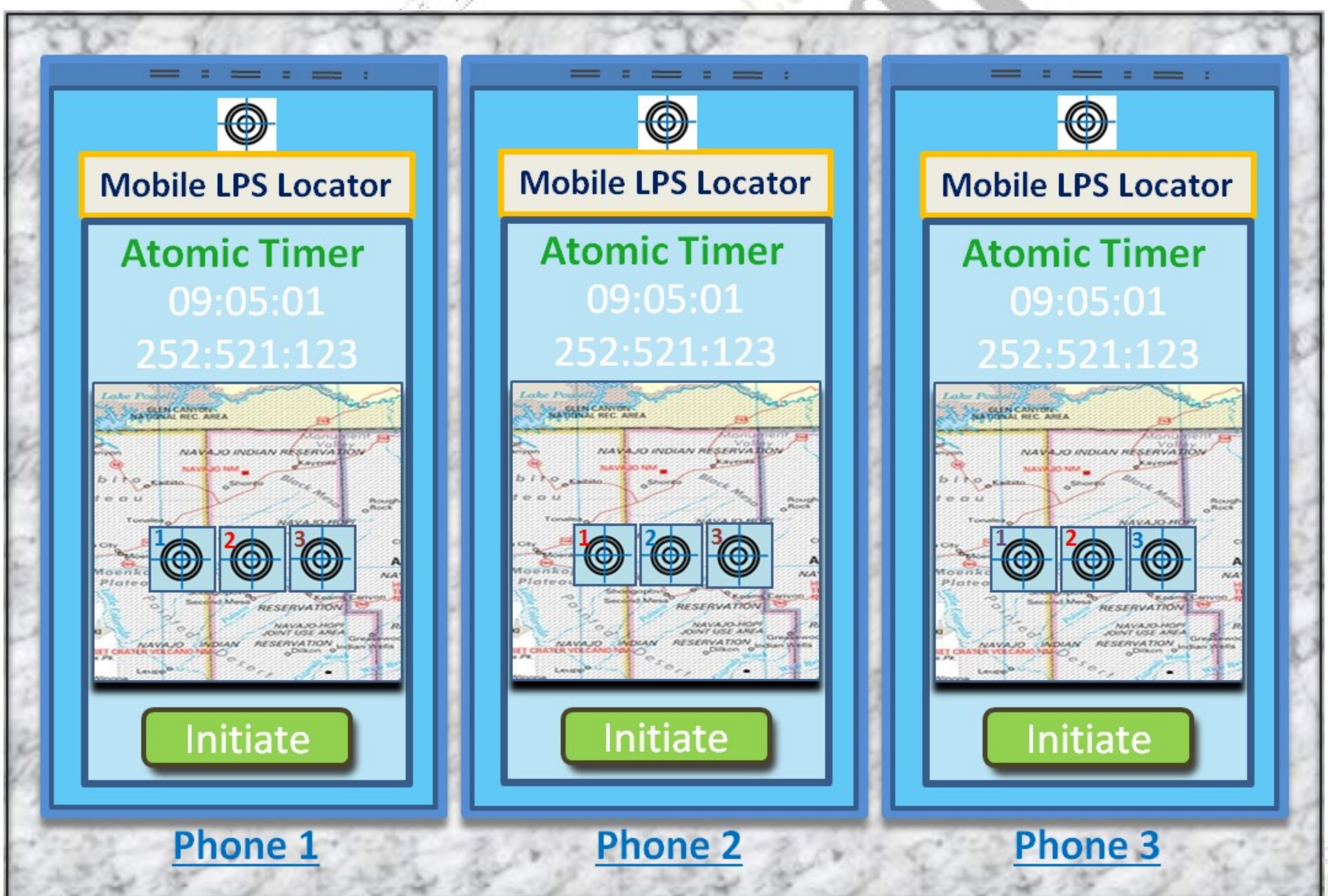

Figure-12: Mobile Phone LPS Locator Application

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Conclusion

The patent **LPS** – **Local Positioning System** will work great in the building, even in the tunnels and would be more accurate than the current GPS system. The GPS satellites are too far from the devices on earth compare to the LPS system, so the accuracy of the LPS will be much higher than the GPS system with higher frequency and faster data or information transmission compare to the GPS. The LPS can easily collaborate and easy to use and can be applied for many indoor applications such as Robot Carrier, Robot Cleaner, and outdoor applications such as Airport Traffic Control, Patrol or Security Guard Circle, etc...

The LPS will be used in conjunction with the GPS to improve global and local positioning systems. This combination will be a big improvement for the world of tracking and positioning applications for both indoor and outdoor devices. This would be great improvement for Airport Traffic Control system in combination with Radar and GPS systems.

Far more than that the **LPS** – **Local Positioning System** will enable the world of technology to create a **Network of Flying Objects** (NFO) or **Network of Moving Objects** (NMO). This would be a great help for military and security to use Drones in Military Patrol Circle and Security Guard Circle.