Global Navigational Satellite System (GNSS)

Global Positioning System (GPS)

Introduction:

GPS system is one of Global Navigational Satellite Systems (GNSS). GPS is formed and controlled by the US department of defense. While there are many thousands of civil users of GPS world wide, the system was designed for and is operated by the us military.

Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock. GPS provide accurate, reliable, continuous position in all weather condition.

System configuration:

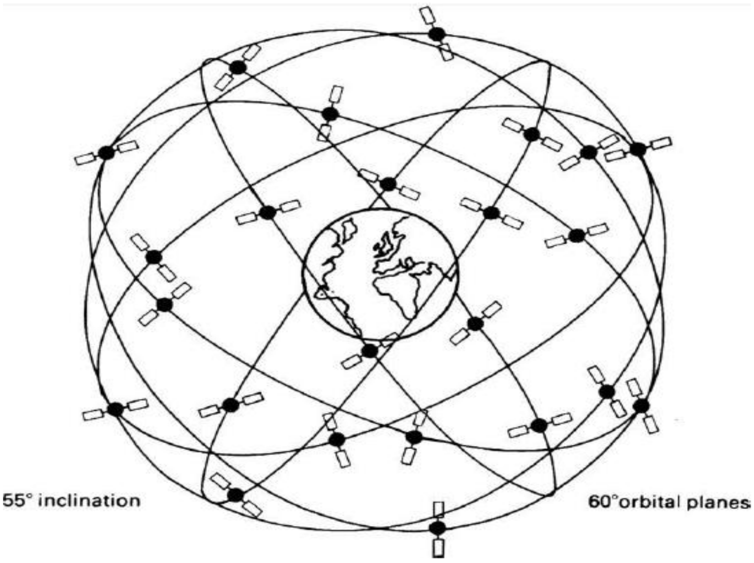
The system consist of three segments:

1- The space segment:

The space segment of the system consists of the GPS satellites. These space vehicles (SV) send radio signals from space.

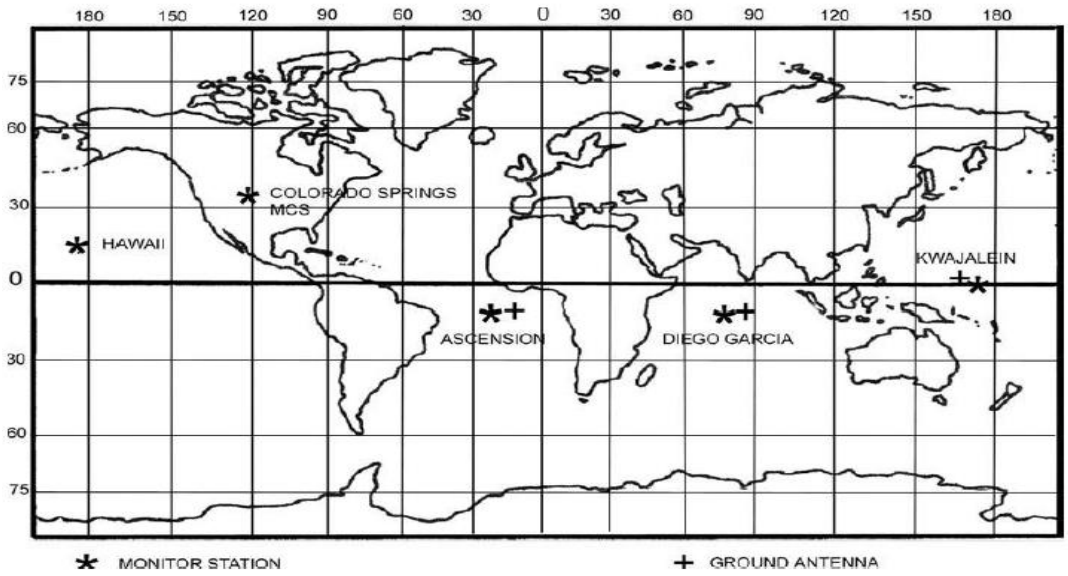
The nominal GPS operation constellation consists of 24 satellites plus spare (32 SVs) that orbit the earth in 12 hours. The satellite orbits repeat almost the same ground track each day.

There are six orbital planes (with nominally four SV in each) equally spaced 60º apart and inclined at about fifty five degree with respect to the equatorial plane and 20,200 km above the earth. this constellation provides the user with between five and eight SV visible from any point on the earth.



2- Control segment:

The control segment is consist of 5 monitor station (MS) which measure the orbit satellites and SV clock corrections for each satellite. Stations monitor and measure signals from the SVs and compare with orbital models for each of the satellites to find corrections. the master control station (MCS) which controls the monitor stations and transmit the update of the orbit information and time correction to each the satellites once a day. These data are loaded in to the satellite memory to replace the previous data and modulate on the navigation signal.



3- User segment :

The user segment consist of the GPS receivers and the user community. GPS receivers convert SV signals into position, velocity, and time estimates. Four satellites are required to compute the four dimensions of x, y, z (position) and time.

-Civilian using SPS - Standard Positioning Service: Uses single frequency L1 & Uses C/A code only.

-Military using PPS - Precise Positioning Service: Uses two frequencies L1/L2 & Uses C/A code and P-code

<u>Basic Principles</u>

From the point of view of surveying or navigation, the GPS system may be viewed simply as a continuous series of radio signals broadcast from orbiting satellites to a radio receiver on the surface of the earth. These signals contain information on the position of the satellites, measurement data indicating the distance (range) to each satellite, and information describing the relative velocity of the satellites with respect to the receiver. GPS position solution can be reduced to a familiar problem in trigonometry, known as a distance intersection. If we can measures the distance of three known points from an unknown point, the x, y, and z coordinates of the unknown point can be computed.

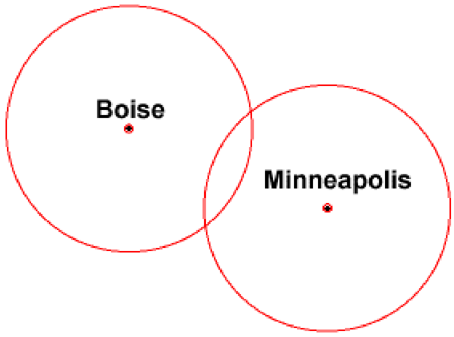
In order to understand how the GPS satellite system works, it is very helpful to understand the concept of trilateration.

Let's say that you are somewhere in the United States and you are TOTALLY lost -- you don't have a clue where you are. You find a friendly-looking person and ask, "Where am I?" and the person says to you,

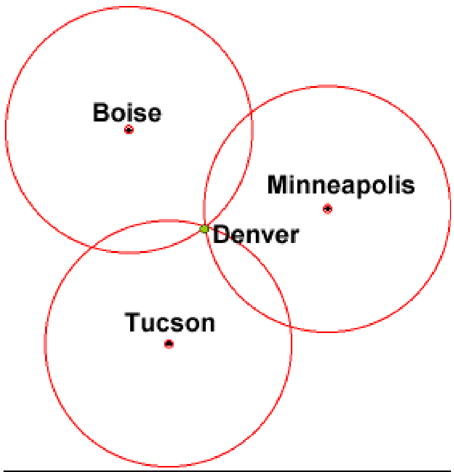
"You are 625 miles from Boise, Idaho." This is a piece of information, but it is not really that useful by itself. You could be anywhere on a circle around Boise that has a radius of 625 miles, like this:

If you know you are 625 miles from Boise, you could be anywhere on this circle.

So you ask another person, and he says, "You are 690 miles away from Minneapolis, Minnesota." This is helpful -- if you combine this information with the Boise information, you have two circles that intersect. You now know that you are at one of two points, but you don't know which one, like this:



If a third person tells you that you are 615 miles from Tucson, Arizona, you can figure out which of the two points you are at:



Trilateration is a basic geometric principle that allows you to find one location if you know its distance from other, already known locations. The geometry behind this is very easy to understand in two dimensional space.

This same concept works in three dimensional space as well, but you're dealing with spheres instead of circles. You also need four spheres instead of three circles to find your exact location. The heart of a GPS receiver is the ability to find the receiver's distance from four (or more) GPS satellites. Once it determines its distance from the four satellites, the receiver can calculate its exact location and altitude on Earth! If the receiver can only find three satellites, then it can use an imaginary sphere to represent the Earth and can give you location information but no altitude information.

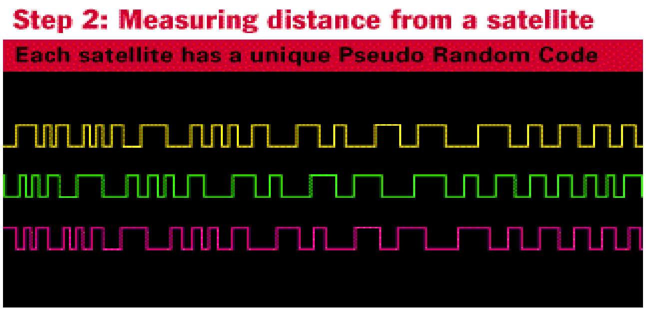
For a GPS receiver to find your location, it has to determine two things:

- The location of at least three satellites above you

- The distance between you and each of those satellites.

Terminology:

The Pseudo Random Code (PRC): is a fundamental part of GPS. Physically it's just a very complicated digital code, or in other words, a complicated sequence of "on" and "off" pulses , The signal is so complicated that it almost looks like random electrical noise i.e pseudo random noise (PRN). Both satellite & receiver start playback PRN at same time. There are two type of Pseudo Random Code . C/A code & P code, Which are unique for each satellite.



Precise Positioning Service (PPS)

Authorized users with cryptographic equipment and keys and specially equipped receivers use the Precise Positioning System. U. S. military, Government agencies, and selected civil users specifically approved by the U. S. Government, can use the PPS.

PPS Predictable Accuracy:

- 22 meter Horizontal accuracy
- 27.7 meter vertical accuracy
- 200 nanosecond time (UTC) accuracy

Standard Positioning Service (SPS)

Civil users worldwide use the SPS without charge or restrictions. Most receivers are capable of receiving and using the SPS signal.

SPS Predictable Accuracy:

- 100 meter horizontal accuracy
- 156 meter vertical accuracy
- 340 nanoseconds time accuracy

Calculating a Position stages:

1-Measure distance to satellites.

2-Obtain satellite positions.

3-Perform triangulation calculations. (Trilateration)

4-Adjust local clock bias.

1-Measuring Distance

GPS satellites send out radio signals that your GPS receiver can detect. The Signals are transmitted on 2 frequencies in L-Band as listed below :

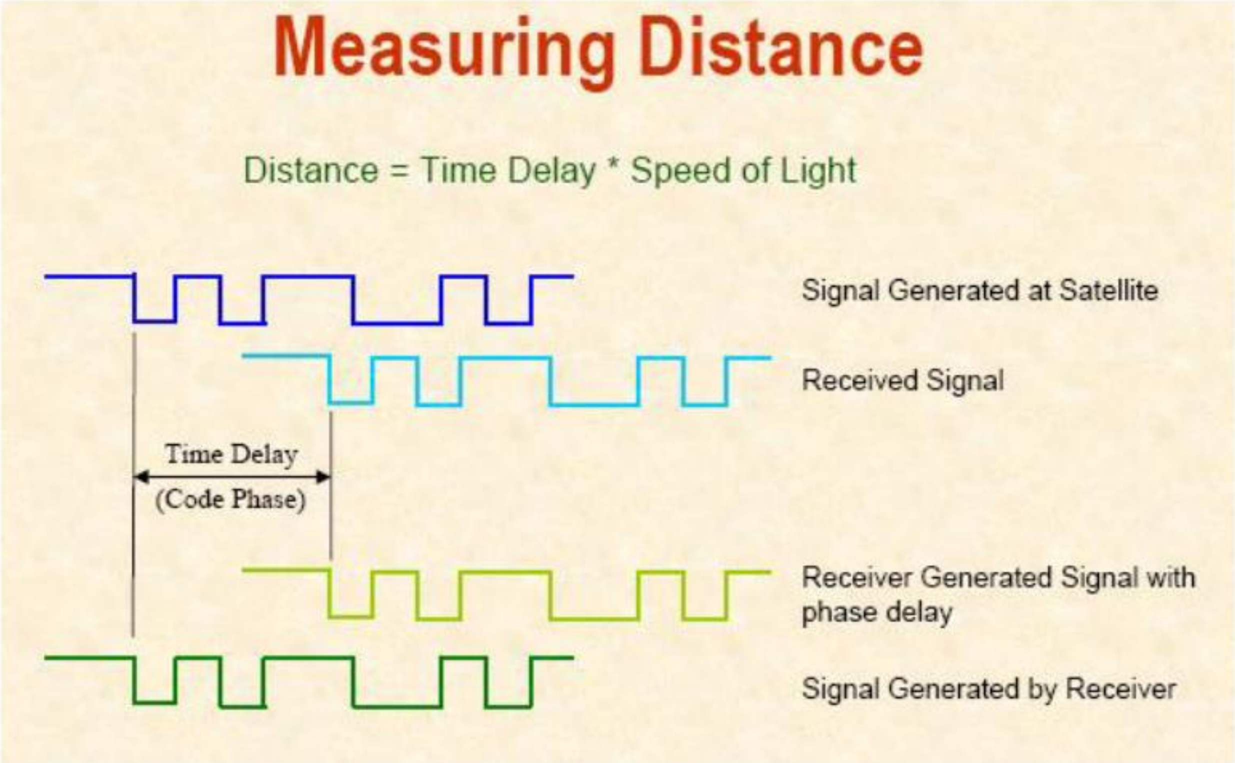
L1 : C/A Code :1575.42 MHZ carries both the status message and a pseudo-random code for timing.

L2 : P Code : 1227.60 MHz used for the more precise military pseudo-random code.

The C/A (Coarse and Acquire) code is a PRN (pseudo random noise) code stream has been designed to be easily and rapidly acquired by receivers to enable SPS fixing. Each SV transmits a unique C/A code that is matched to the locally generated C/A code in the receiver. A unique PRN is allocated to each SV . They are specifically designed to minimize the possibility that a receiver will mistake one code for another and unknowingly access a wrong satellite.

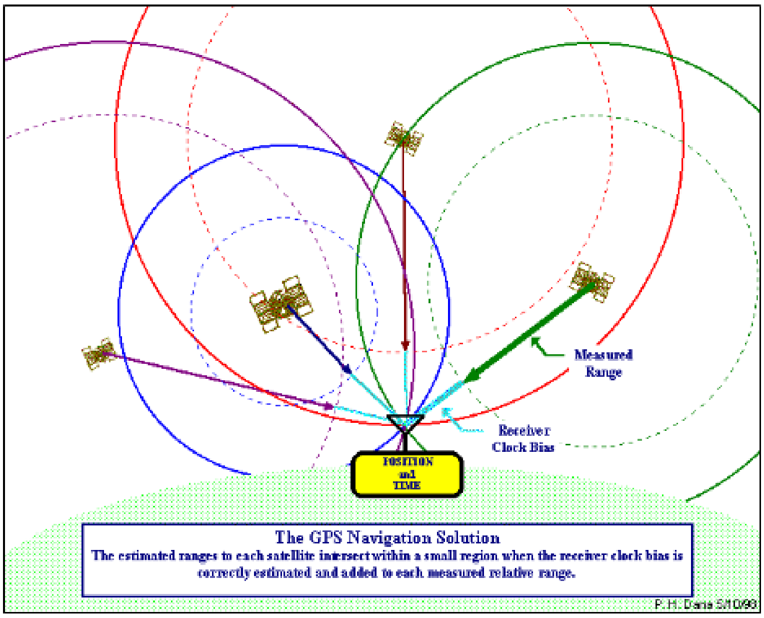
The P (Precise) code, is a PRN code produced in the SV. Each SV employs a unique and exclusive code. At midnight of every Saturday the code generators are reset to transmit signal with new p code.

But how does the signal let the receiver know how far away the satellite is? The simple answer is: A GPS receiver measures the amount of time it takes for the signal to travel from the satellite to the receiver. Since we know how fast radio signals travel -- they are electromagnetic waves and so (in a vacuum) travel at the speed of light, about 186,000 miles per second we can figure out how far they've traveled by figuring out how long it took for them to arrive. Measuring the time would be easy if you knew exactly what time the signal left the satellite and exactly what time it arrived at your receiver, and solving this problem is key to the Global Positioning System. Timing is tricky We need precise clocks to measure travel time The travel time for a satellite right overhead is about 0.06 seconds, The difference in sync of the receiver time minus the satellite time is equal to the travel time. As before said Both satellite & receiver start playback PRN at same time for example midnight, the PRN produced by each stellate send toward the receiver, receiver match the PRN received by satellite signal with her PRN, due to time taken for reaching satellite PRN by comparing the PRN code of the received signal with that of a similar one generated in the Rx it is possible to determine the time taken for the signal to reach the Rx. This time, multiplied by propagation velocity gives an indication of the range of the satellite.



The system require high level of accuracy which only found in atomic clocks (calculations amounts to nanoseconds). To make a GPS using only synchronized clocks, you would need to have atomic clocks not only on all the satellites but also in the receiver itself. but Atomic clocks are too expensive for everyday consumer use. The Global Positioning System has a very effective solution to this problem. a GPS receiver contains no atomic clock at all. It has a normal quartz clock. The receiver looks at all the signals it is receiving and uses calculations to find both the exact time and the exact location at same time. When you measure the distance to four located satellites, you can draw four spheres that all intersect at one point, as illustrated below. Four spheres of this sort will not intersect at one point if you've measured incorrectly. The receiver can calculate exactly what distance adjustment will cause the four spheres to intersect at one point. This allows it to adjust its clock to adjust its measure of distance. For this reason, a GPS receiver actually keeps extremely accurate time, same as actual atomic clocks in the satellites.

The range obtained from pseudo random noise (PRN) called pseudo range.

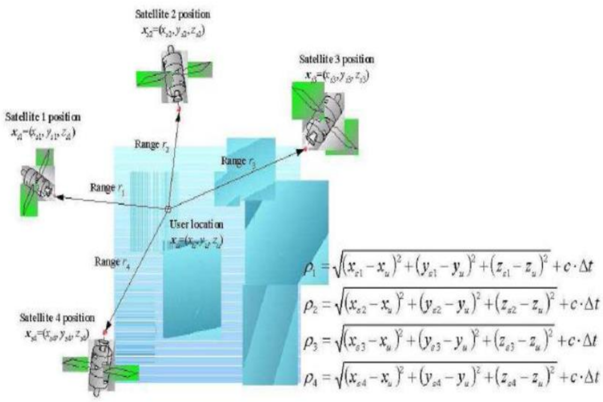


2-Obtain satellite positions:

The other component of GPS calculations is the knowledge of where the satellites are. This isn't difficult because the satellites travel in a very high, and predictable orbits. The satellites are far enough from the Earth (12,660 miles) that they are not affected by our atmosphere. The GPS receiver simply stores an almanac that tells it where every satellite should be at any given time (SV positions in three dimensions) Things like the pull of the moon and the sun do change the satellites' orbits very slightly, but the Department of Defense constantly monitors their exact positions and transmits any adjustments to all GPS receivers as part of the satellites' signals.

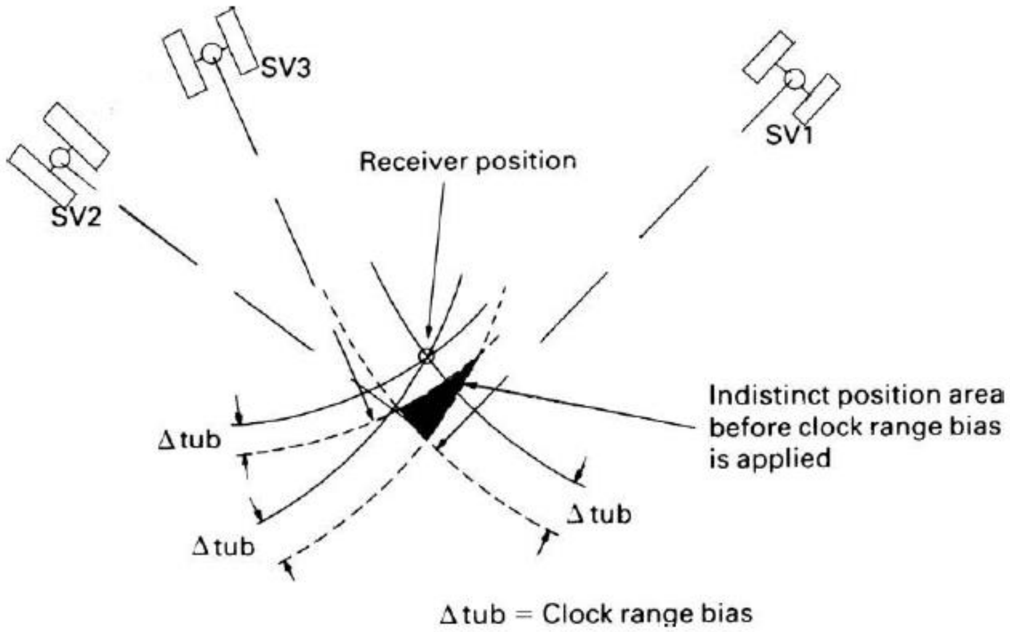
3-Perform triangulation calculations. (Trilateration)

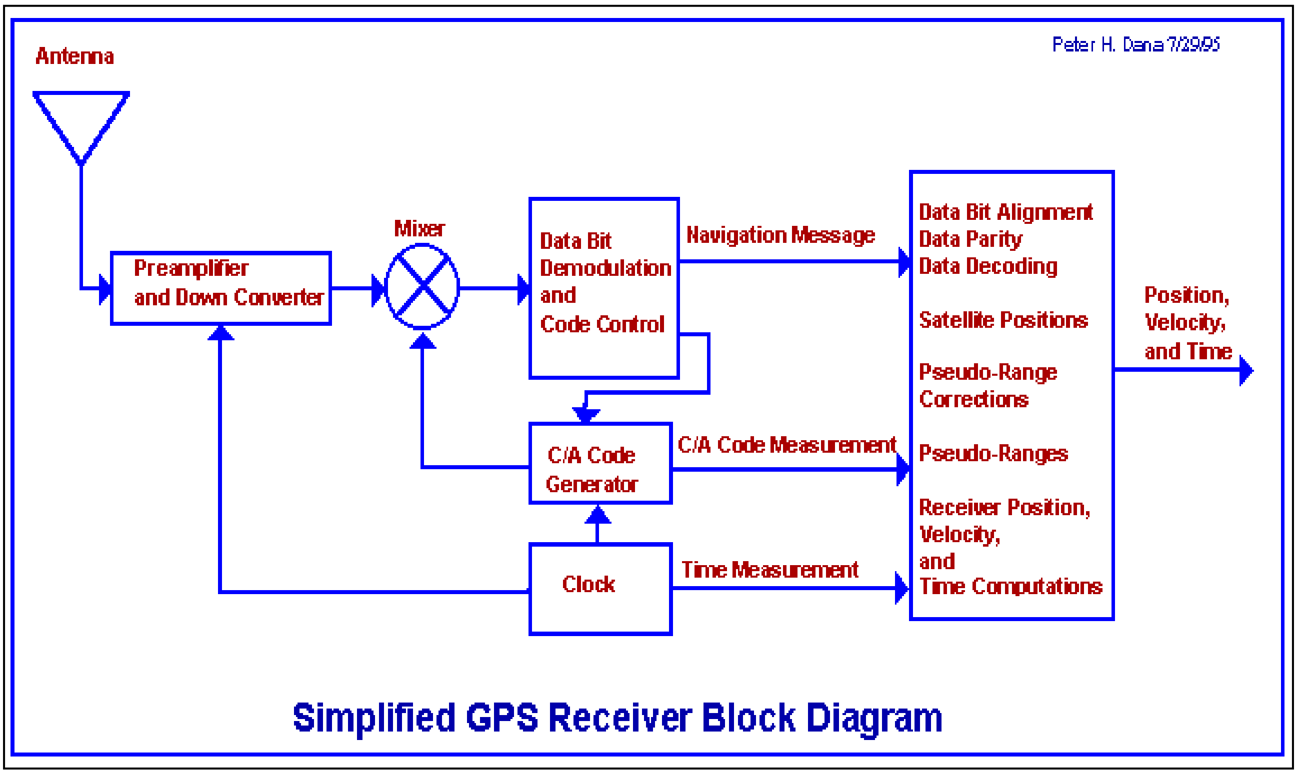
By knowing each satellite position and its range GPS receiver can make a sphere, by intersect of spheres from 3 satellites the position of receiver can be computed. The basic information a receiver provides, then, is the latitude, longitude and altitude.



4-Adjust local clock bias:

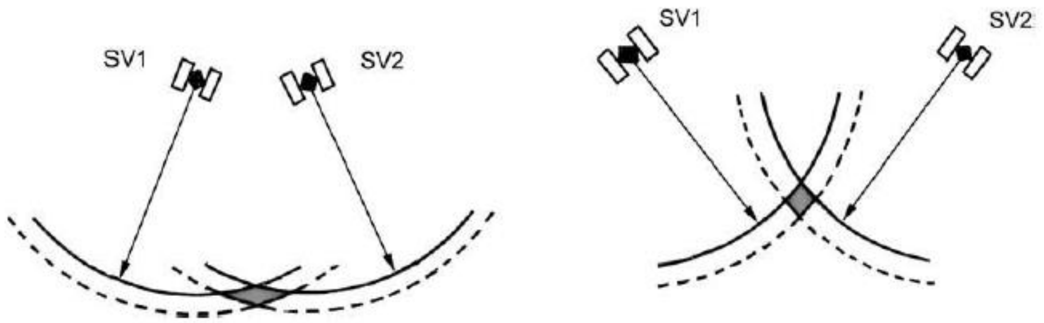
Any error in timing can lead an error in position calculation which called clock bias. As before said by use of 4 satellite most of this error can be found. The receiver automatically calculate this error and apply to triangulation calculations. See below



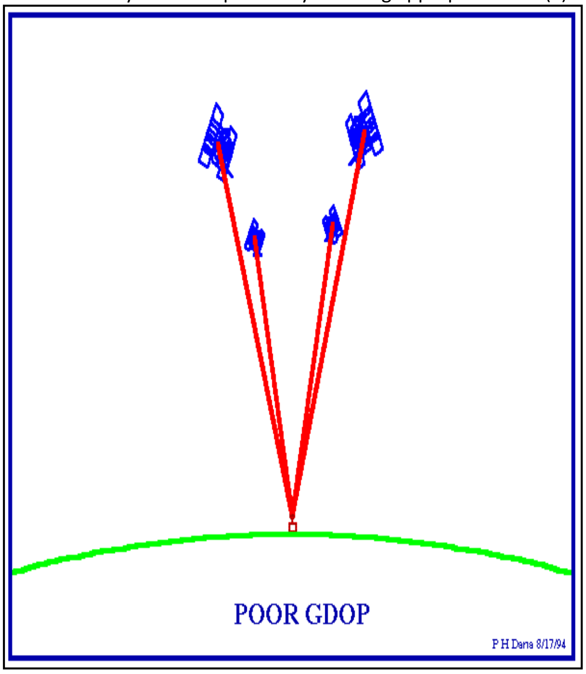


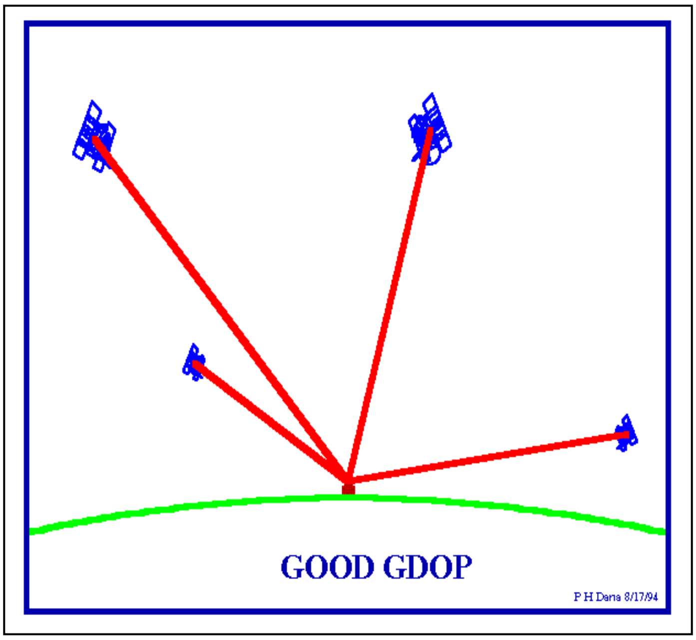
Geometric Dilution of Precision (GDOP) and Visibility

Dilution of precision (DOP) is a term used for expressing the mathematical quality of a solution . When Pseudo-ranges are measured from SVs that are close together in the sky , the result is an enlarged area of improbability resulting in a bad GDOP. Alternatively if the SVs are well spaced, the improbability area will be smaller. Modern GPS receiver pick the optimum SVs from those available before correcting timing errors . Other dilution of precision factors can be defined which are a subset of GDOP and have a more specific physical meaning with respect to the x, y, and z axes in a local coordinate system. They include position dilution of precision (PDOP), horizontal dilution of precision (HDOP), vertical dilution of precision (VDOP) and time dilution of precision (TDOP). The PDOP is less when a solution is made with a satellite overhead and three other satellites evenly spaced at low elevation angles. Alternatively, if all satellites are in the same plane, PDOP would be near infinity and the navigation fix solution would be unsound.



Fix accuracy can be improved by selecting appropriate SVs. (a) Two SVs giving a poor GDOP and (b) two SVs providing a much better solution





- GPS errors

Selective Availability (SA): SA is the intentional degradation of the SPS signals by a time varying bias. SA is controlled by the DOD (Department of Defense) to limit accuracy for non-US military and government users. The potential accuracy of the C/A code of around 30 meters is reduced to 100 meters (two standard deviations). The SA bias on each satellite signal is different, and so the resulting position solution is a function of the combined SA bias from each SV used in the navigation solution. Because SA is a changing bias every few hours, position solutions or individual SV pseudo-ranges cannot be effectively averaged over periods shorter than a few hours. Differential corrections must be updated at a rate less than the correlation time of SA .

SV clock errors It has already been stated that a satellite clock oscillator is a precision instrument, but it is still necessary to re-adjust it from the ground support network. Error introduced by SV clock error is unlikely to exceed 1m.

Tropospheric delay error : The troposphere is the lower part (ground level to from 8 to 13 km) of the atmosphere that experiences the changes in temperature, pressure, and humidity associated with weather changes introduces a delay into the pseudo-range calculation. GPS receivers hold a software solution in the form of a mathematical model to eliminate the effect of this delay. Figures for relative humidity, pressure and temperature are interfaced with the processor computer to produce corrective data which is then applied to fix calculation error is unlikely to exceed 1m.

ionosphere delays: 10 meters. The ionosphere is the layer of the atmosphere from 50 to 500 km that consists of ionized air which caused speed reduction of the radio wave occurs. The extent of the delay, and consequently the error introduced into the pseudo-range measurement calculation is dependent upon the electron density the radio wave encounters along the signal path. ionospheric error is inversely proportional to the square of the carrier frequency. in the receiver by comparing the shift of frequency of both signal, an error correction figure calculated and applied to the final fix solution. After all corrective data has been applied fix error due to the ionosphere is unlikely to exceed 10 m.

Note: Both ionospheric and tropospheric errors are reduced if ranges are measured from SVs showing a high elevation from the receiver. Modern receivers are capable of automatically selecting SVs with the highest elevation.

Multipath error : Multipath is caused by reflected signals from surfaces near the receiver that can either interfere with or be mistaken for the signal that follows the straight line path from the satellite. Final fix errors in the region of 1 meter can be produced by this effect. Careful positioning of the antenna will eliminate this error.

Relativity error on GPS satellite and RECIEVER clocks:

This error produced due to two causes:

1- GPS satellites move with higher speed rather than receiver on the earth surface (14,000km/hr), which can cause the atomic clocks on-board the satellites to register time about 7 microseconds/day slower than on earth.
2- reduction of gravity on satellites causes the clocks to run about 45 microseconds a day faster than they do on earth. The overall effect is a +38 microseconds/day increase in measured time which is then compensated for at the satellites.

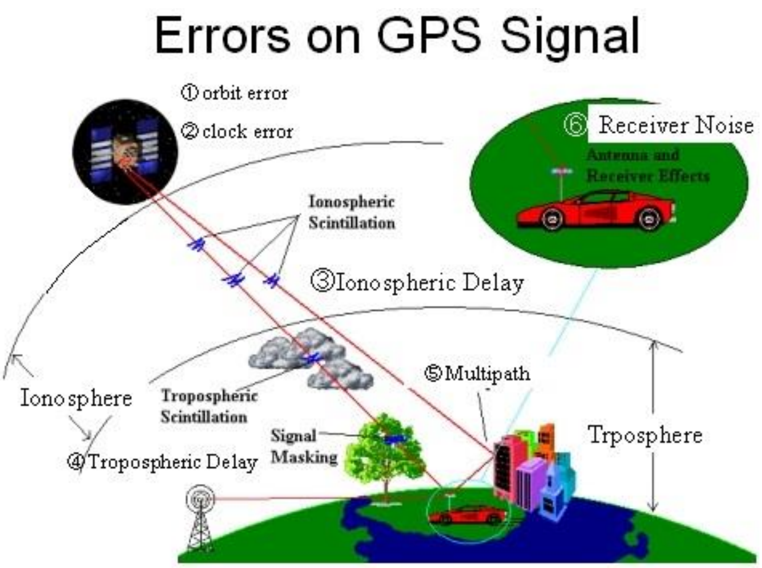
To compensate for all relativity errors, the SV clock oscillator frequency is slightly offset.

User Range Error (URE)

This is a parameter for the estimated error in range calculation due to unknown factors. These include multipath, unmodelled atmospheric effects, operator error and unpredictable orbital errors. The URE figure is sent from SVs to GPS receivers and may be displayed in metres.Control segment mistakes due to computer or human error can cause errors from one meter to hundreds of kilometers. User mistakes, including incorrect geodetic datum selection, can cause errors from 1 to hundreds of meters. Receiver errors from software or hardware failures can cause blunder errors of any size.

Ephemeris Error

This error is the difference between the actual satellite location and the position predicted by satellite orbital data. Typically 1 m error.



The advantages and limitations of GPS:

Advantages:

1- The system is self-calibrating – Just turn on and use.
2- The technology is relatively small (typical GPS system is now no larger than a small mobile phone)
3- Works anywhere on earth & There is currently no charge to use the signal.

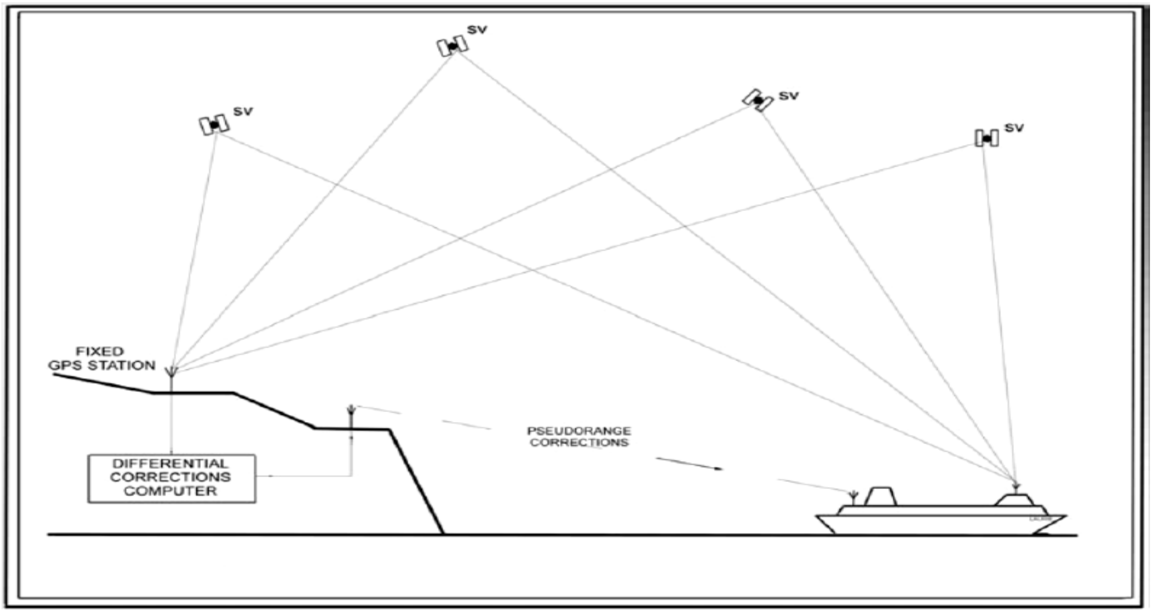
Limitations:

1- The GPS signal is unable to pass through solid structures so is unable to work indoors, underground, under the water, or under a dense canopy of trees.
2- GPS accuracy is related to the quality of signal reception, the larger the antenna the better the signal.
3- The system accuracy is expected to be about 100 m.

Differential GPS , DGPS , Techniques

The accuracy of the C/A signals may not be sufficient for navigation in harbor or their approaches. The idea behind all differential positioning is to correct errors at one location with measured errors at a known position. A reference receiver, or base station, computes corrections for each satellite signal. That station derives a GPS position from the satellite system and if any error exists between the its True and GPS positions, then Corrective data is calculated and transmitted to vessels at sea.

DGPS require software in the reference receiver that can track all SVs in view and form individual pseudo-range corrections for each SV. By applying this real-time correction data to ship`s GPS position, a ship can determine positions more accurately. Ships require an additional Receiver operating in the marine MF Radio beacon band of 285 to 325 KHZ , in order to receive DGPS signals. Applying correction from the reference receiver to the vessel`s receiver has limited useful ranges because both receivers would have to be using the same set of SVs in their navigation solutions. Typical range of DGPS transmission is 40 NM to 60 NM. A similar system that transmits corrections from orbiting satellites instead of ground-based transmitters is called a Wide-Area DGPS. The system accuracy is better than 10 metre. DGPS can correct Selective Availability Errors, Ionospheric and Tropospheric Delays, Ephemeris Error and Satellite Clock Error.



GPS ERROR SOURCES

ERROR SOURCE	TYPICAL RANGE ERROR	DGPS (CODE) RANGE ERROR <100 KM REF-REMOTE
SV CLOCK	1 M	
SV EPHEMERIS	1 M	
SELECTIVE AVAILABILITY	10 M	
TROPOSPHERE	1 M	
IONOSPHERE	10 M	
PSEUDO-RANGE NOISE	1 M	1 M
RECEIVER NOISE	1 M	1 M
MULTIPATH	0.5 M	0.5 M
RMS ERROR	15 M	1.6 M
ERROR * PDOP=4	60 M	6 M

PDOP=Position Dilution of Precision (3-D) 4.0 is typical

Other Regional Satellite Navigation Systems are China's BeiDou (COMPASS) Navigation Satellite System, India's Indian Regional Navigational Satellite System (IRNSS), Japan's Quasi-Zenith Satellite System (QZSS) and France's Doppler Orbitography and Radio positioning Integrated by Satellite(DORIS).

World Geodetic System 1984 (WGS 84)

WGS 84 is an Earth-centered, Earth-fixed terrestrial reference system and geodetic datum. WGS 84 is based on a consistent set of constants and model parameters that describe the Earth's size, shape, and gravity and geomagnetic fields. The GPS reference system is WGS 84. GPS users directly receive WGS 84 coordinates from a GPS receiver if no changes to the reference frame are selected or made.

Global Orbiting Navigation Satellite System (GLONASS)

GLONASS is a Russian satellite navigation system similar to GPS And like GPS, GLONASS has been released for international position fixing use, but in a downgraded form.

GLONASS is owned and operated by a Military Special Forces team at the Russian Ministry of Defence. SV time synchronization, frequency standards and receiver technology development are controlled from The Russian Institute of Navigation and Time in St. Petersburg. The system possesses similar architecture to the GPS and is equally capable of highly accurate position fixing in all-weather 3D positioning, velocity measuring and timing anywhere in the world or near-Earth space .

Space segment

Work on the system began in the early 1970s and the first satellites were launched into orbit in 1982 Since then a full constellation has been established and GLONASS became fully operational in early 1996.The space segment is based on 24 SVs, eight in each of three, almost circular orbital planes spaced at 120° intervals and inclined at 64.8° and at an altitude of 25 440 km. Each SV completes one earth orbit in 11 h 25 min. All GLONASS SVs transmit on two frequencies to allow for correction of ionospheric signal delay, but unlike the GPS system, each SV uses different frequencies

The GLONASS system has two types of navigation signal:1- standard precision navigation signal (SP) with L1 band transmission frequency (between 1598.0625–1609.3125 MHz) and C/A code

2-high precision navigation signal (HP) with L2 band transmission frequency (between 1242.9375 and 1251.6875 MHz) and P code.

As in the GPS, the GLONASS transmit navigation message which contains timing, SV position and tracking data.

Ground segment

All ground control stations are located in former Soviet Union territory. The Ground Control and Operations Centre and Time Standard Centre are in Moscow. Other ground station shown in below image:

Position fixing

GLONASS navigation fixes are obtained in precisely the same way as those for GPS. Pseudo-range calculations are made and then corrected in the receiver to obtain the user location in three dimensions. Precise timing is also available.

Table 5.10 GPS – GLONASS system comparison

Parameter	*GPS*	*GLONASS*
Orbital		
Altitude:	20 180 km	19 130 km
Period:	11 h 58 min	11 h 15 min 40 s
Inclination:	55°	64.8°
Planes:	6	3
Number of SVs	24	24
Carrier frequency		
L1:	1575.420 MHz	1598.6250–1609.3125 MHz
L2:	1227.600 MHz	1242.9375–1251.6875 MHz
Code clock rate		
C/A:	1.023 Mbit s^{-1}	0.511 Mbit s^{-1}
P:	10.23 Mbit s^{-1}	5.11 Mbit s^{-1}
Time reference	UTC	UTC
Navigation message		
Rate:	50 bit s^{-1} (baud)	50 bit s^{-1} (baud)
Modulation:	BPSK NRZ	BPSK Manchester
Frame duration:	12 min 30 s	2 min 30 s
Subframe:	6 s	30 s
Almanac content	Timing and orbital parameters	Timing and orbital parameters

Galileo

system overview

The Galileo Program (so named to honor the great European scientist Galileo Galilei) is a joint initiative of the European Commission (EC) and the European Space Agency (ESA) to provide Europe with its own independent global civilian controlled satellite navigation system.

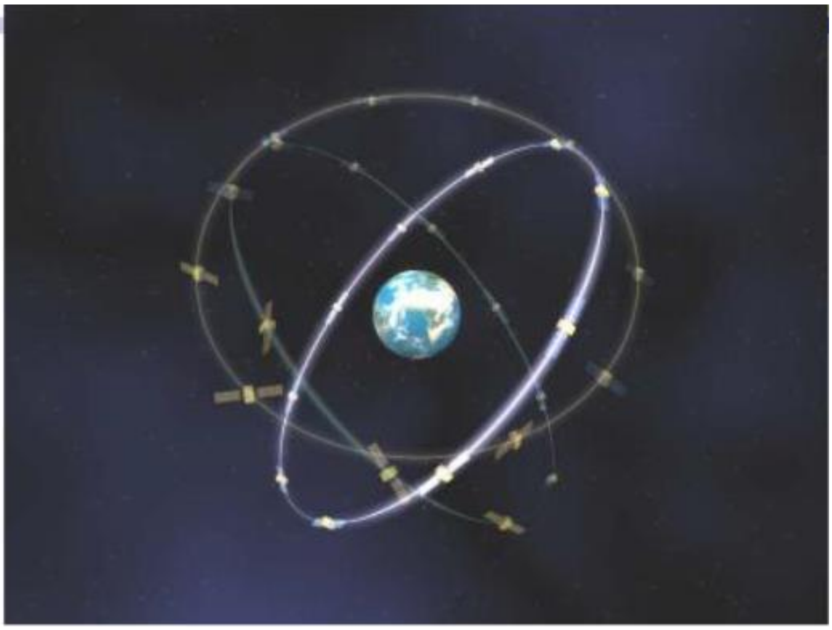
It is based on the same technology as GPS and provides high degree of precision and availability.

It represents a real public service and guarantees continuity of service provision for specific applications.

Galileo Space Segment

Galileo will be based on a constellation of 30 satellites (27 + 3 reserve) at 23222 Km altitude in 3 planes. 10 satellites per plane, Only 9 satellites per plane active. One satellite per plane is Spare.

Each SV completes one earth orbit in 14 hrs 22 min Period. at any point on the earth, there will be at least 6 satellites in the view.



Ground segment

consists of two ground control center responsible for Central Processing Facility; they are located in Germany and Italy. Moreover, the control centers are connected with five tracking and control stations, nine uplink stations, and about 40 Galileo sensor stations.

Galileo Signals

Galileo will provide ten navigation signals in the frequency ranges 1164 - 1215 MHz, 1215 - 1300 MHz and 1559 - 1592 MHz. Also in the middle, the frequency range 1544.05-1545.15 MHz defined as Search and Rescue (SAR).

Galileo services

- Open Service (OS): free for everyone; mass market applications, simple positioning
- Safety of Life (SoL): for professional applications; integrity; authentication of signal
- Commercial Service (CS): for maritime, aviation and train applications; encrypted; high accuracy; guaranteed service
- Public Regulated Service (PRS): encrypted; government-regulated; integrity; continuous availability
- Support to Search and Rescue service (SAR): humanitarian purpose; near real time; precise
- Other Galileo-related services: Galileo locally assisted services (use some local elements to improve performance, e.g., differential system), Galileo combined services (combination with other navigation or communication systems).

TABLE II

GPS, GLONASS, GALILEO, AND COMPASS COMPARISON

Characteristics	GPS	GLONASS	Galileo	Compass
First launch	February, 1978	October, 1982	December, 2005	April, 2007
Full operational capability	February, 1995	January, 1996 - December, 2011	2012,2013	up to 2020
Funding	public	public	public & private	public
Nominal number of SV	24	24	27	27
Orbital planes	6	3	3	3
Orbit inclination	55°	64.8°	56°	55°
Semi-major axis	26,560 km	25,508 km	29,601 km	21,500 km
Orbit plane separation	60°	120°	120°	–
Revolution period	11h 57.96 min	11h 15.73 min	14h 4.75 min	12h 35 min
Geodetic reference system	WGS-84	PE-90	GTRF	CGS2000
Time system	GPS time, UTC (USNO)	GLONASS time, UTC(SU)	Galileo system time	Bei Dou System Time (BDT)
Signal separation	CDMA	FDMA	CDMA	CDMA
Number of frequencies	3-L1,L2,L5	one per two antipodal SV	3(4)-E1,E6,E5(E5a,E5b)	3-B1,B2,B3
Frequency [MHz]	L1: 1,575.420	G1: 1,602.000	E1: 1,575.420	B1: 1,575.420
	L2: 1,227.600	G2: 1,246.000	E6: 1,278.750	B2: 1,191.795
	L3: 1,176.450	G3: 1,204.704	E5: 1,191.795	B3: 1,268.520
Number of ranging codes	11	6	10	–

ECHO SOUNDER

The echo sounder is an electrical device for measuring the depth of the water .It is such a important aid to safe navigation especially when making landfall or when approaching shallow waters, that it is now installed onboard of almost every ship.

BASIC PRINCIPLES OF MARINE ECHO SOUNDER :

The principle of the measurement is as follows : short pulses of sound vibrations are periodically produced(e.g at a rate of 100 per minute) in the water below the ship and transmitted vertically to the sea bottom .The sea bed reflect these pulses and after a time that a path equal to twice the distance between the keel of the ship and the bottom of the sea .the speed of propagation of sound in sea water is practically constant at 1500 m/s .hence distance can be calculated as : $d=v.t /2$, where v= speed of sound in sea water and t= travelling time .
For example if the time between transmission of the pulse and reception of the echo is 0.1s , then the pulses have traveled a distance of 150m (1500 x 0.1) ,and the water depth is 75m (150/2) .Instead of indicating time one linear scale in seconds , the corresponding depth in meter ,fathoms or feet can be indicated .

Transmission of acoustic energy :

This may take one of two forms ;continuous wave or pulse system.

1- Continuous wave : The acoustic energy is continuously transmitted from one transducer .The returned echo signal is received by a second transducer and a phase difference between the two is used to calculate the depth .This system rarely used in merchant ships as is expensive and noise problem .

2- Pulse system : A rapid short, high intensity pulses are transmitted and received by a single transducer .The depth is calculated by measuring the time delay between the transmission and reception .The transmitter fires for a defined period of time and is then switched off .The pulse travels to the ocean floor and is reflected back to be received by the same transducer which is now switched to a receive mode .

Transmission beam width :
Acoustic energy is radiated vertically downwards from the transducer in the form of a beam energy .Figure 2.9 shows the main beam is central to the transducer face and shorter side lobes are also produced . The beam width must not be extensively narrow otherwise echoes may be missed , particularly in heavy weather when the vessel is rolling .In general the beam width used for echo sounder is between 15 º and 25 º .

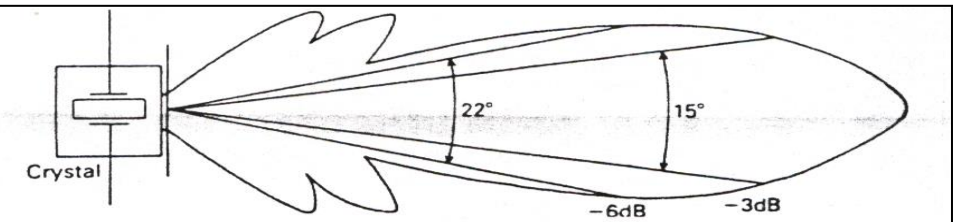


Figure 2.9 Transmission beam showing the sidelobes.

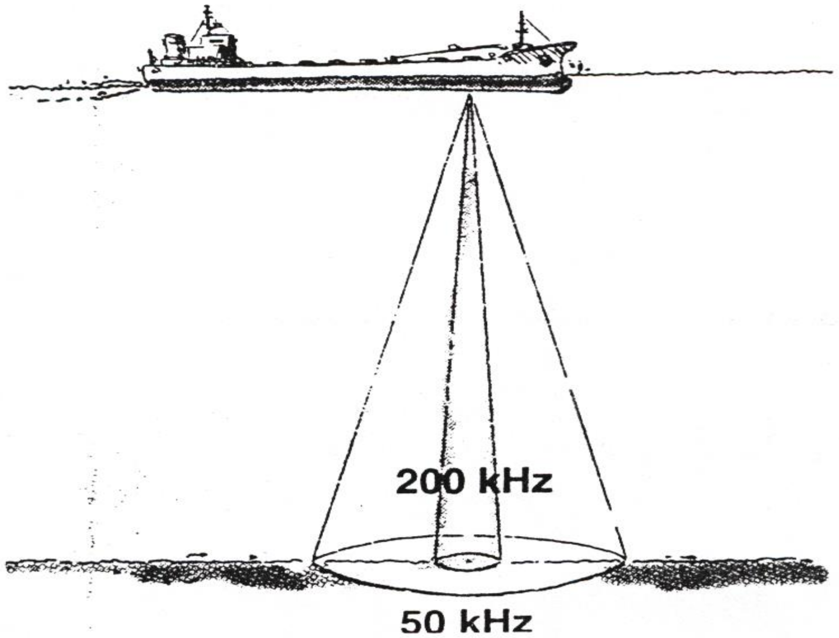
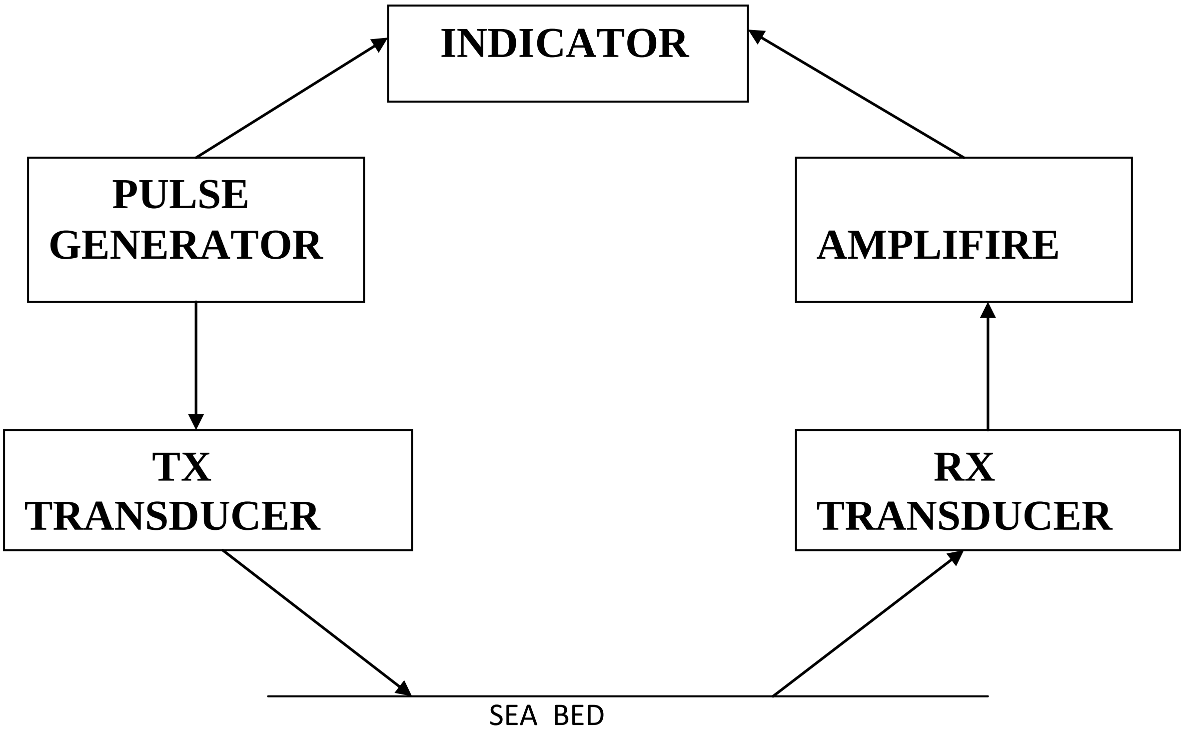


Figure 2.10 Typical beamwidths for echo sounders transmitting low and high frequencies. (Reproduced courtesy Furuno Electric Co. Ltd.)

COMPONENT OF AN ECHO SOUNDER



The main component of an echo sounder can be seen from above simple block diagram .
pulse generator: This generates the electrical oscillation required for transmitting transducer .at the same time it sends an impulse to stylus in the indicator .
Transducer : this is also called oscillator , they are mounted at the bottom of the ship and performs the following functions ;
1-convert electrical energy in to sound energy .
2-sound energy created , is beamed vertically downwards towards the sea bed .
3-receives the sound waves returning to the ship after reflection from the sea bed .

4- converts the reflected sound waves into electrical energy .
Amplifier : This component will amplifies the weak electrical oscillations that the receiving transducer has converted from sound vibrations .
Indicator : The depth indicator measures the time elapsed between transmission and reception of the reflected echo and indicate the depth of the water .
The generator , amplifier , and recorder ,are normally enclosed in one unit .
Depth indicator :
There are two types of indicators ; echo meters and echo graphs.

1-Echometers ; These are also of two types ;

a- Flash neon bulb type: This consist of a neon bulb at the end of a rotating arm moving at the constant speed behind a circular scale . unlike an electric lamp , a neon lamp lights and extinguishes immediately upon being switched on/off . When the lamp passes the zero of the circular scale , a pulse is transmitted .When the echo arrives the lamp lights up for a short time to indicate the depth on the scale . The repeated illumination of the same point on the scale enables the depth to be read.

b-Digital read out : In this type of echo meter the time elapsed between transmission and reception is converted into depth and shown as a digital read out .There are no moving parts which is an advantage over the neon type .
Disadvantages of both types of echo meters are that , it neither keeps a record of the depth for further use nor a profiles of the sea bottom.

2-Echo graphs or depth recorder :
A stylus is fixed to an endless belt which runs over two pulleys driven at the constant speed . The stylus moving over a broad strip of moving paper . At the instant the sound pulse leaves the transmitter , the stylus make a mark on the moving paper at zero on the scale . When the echo is received back it is converted into an electric pulse, amplified and supplied to the stylus which has meanwhile moved from the zero line . The stylus marks the paper on receiving the pulse . The depth can be read from a scale in front . As the paper moves slowly . the marks indicating the received echoes producing a profile of the sea bed .
NOTE : charted depth = echo sounder reading + draft – height of tide

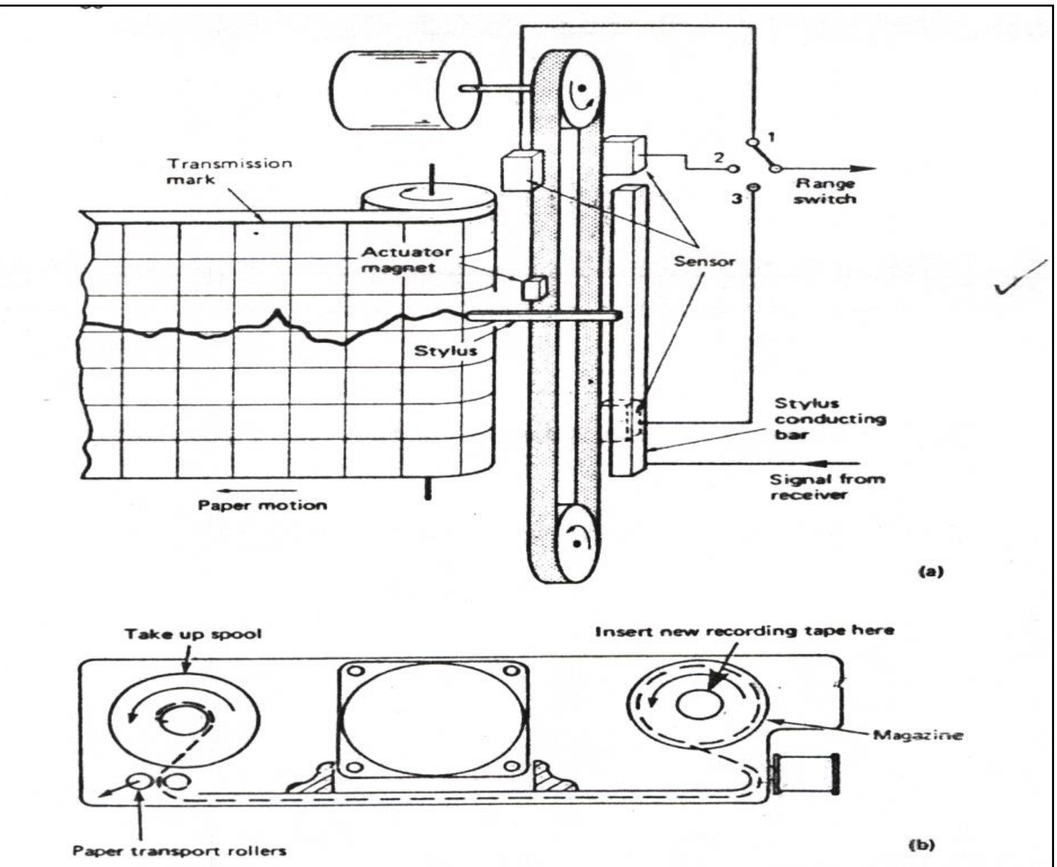


Figure 2.19 *(a)* An electric motor drives the wheel above. The belt with the stylus holder fixed to it moves downwards over the paper. The other end of the stylus holder is connected to the receiver by way of the stylus conducting bar. The stylus records the pulse leaving the ship and its echo, which arrives a short time later depending on the depth. When the actuator magnet, also fixed to the belt, passes the sensor connected to switch position 1, the electric pulse is generated and transmitted. The successive recorded pulses cause the transmission line. In switch positions 2 and 3 the pulses are transmitted at an earlier time. If the range is 0–60 m in position 1, it will be 40–100 m in position 2 and 80-140 m in position 3. *(b)* Paper transport

1-ELECTROSTRICTIVE TRANSDUCER :
some materials (Rochelle salt and quartz crystals) possess the property that ,when a mechanical stress is applied to the two opposite faces, electric charges will change, the positive face becomes negative and negative face become positive depend upon compress-ional or tensional side.

When the crystals are set vibrating mechanically ,an alternating voltage is generated between the two faces .This property is reciprocal, when a voltage is applied between the two faces , the crystal contract or expands a little, according to which face is positive and negative . if an alternative voltage apply to both side the crystal start vibration and make sound waves.
The crystal is sandwiched between two steel plates. When an alternating voltage is applied between the steel plate of the transducer , the crystal and plates vibrate together .These vibrations are enhanced by resonance. The lower of the two steel plates is in contact with the water and so produces the vibration in the water .Often only one electrostrictive transducer , which serves as transmitter as well as receiver , is installed on board

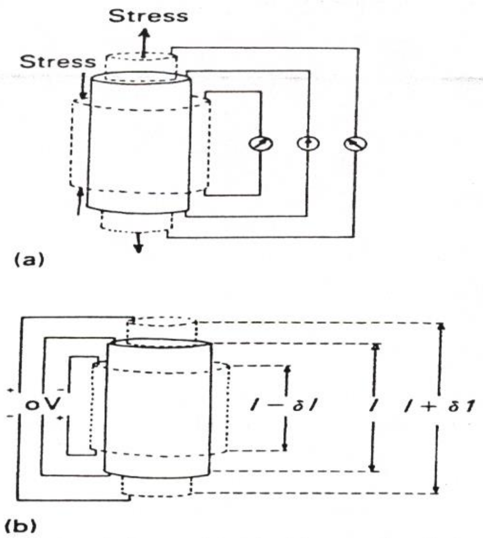


Figure 2.5 (a) An output is produced when a piezoelectric ceramic cylinder is subjected to stress (b) A change of length occurs if a voltage is applied across the ends of a piezoelectric ceramic cylinder.

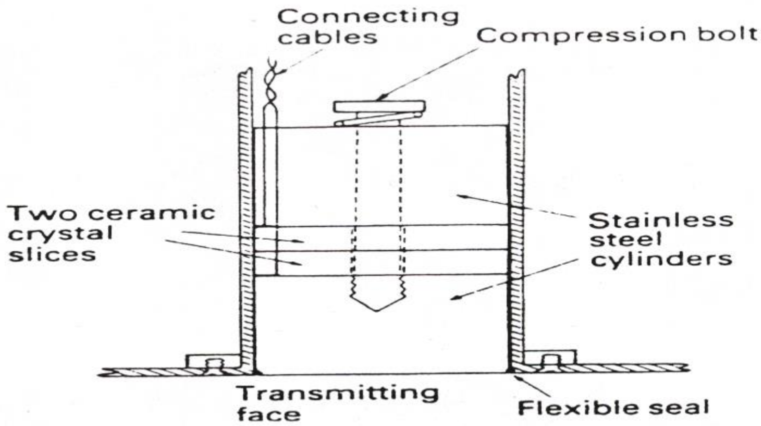


Figure 2.6 Construction details of a ceramic electrostrictive transducer.

The Electrostrictive transducer is only fitted on large merchant vessels when the power transmitted is low and the frequency is high , such a transducer is manufactured by mounting two crystal slices in a sandwich of two stainless steel cylinders . The whole unit is pre-stressed by inserting a stainless steel bolt through the center of the active unit as shown in figure 2.6 .

<u>MAGNETOSTRICTION :</u>
when a bar of ferromagnetic material is subjected to a magnetic filed it undergoes a change on its length .The magnitude of the change depends mainly on the material of the bar and strength of the field .The change may be an expansion or contraction . also when the bar is made to vibrate , it will

become magnetic , and an alternating voltage will be set up in the windings .This property is called magnetostriction .

2-MAGNETOSTRICTIVE TRANSDUCERS :

The transmitting transducer consist of a pack of nickel discs around which are wound coils of the electric circuit from the pulse generator. A high powered AC current passes through the circuit coils and the sudden changes in the magnetic field cause the discs to vibrate.

The vibrations produce sound waves which are focused by a parabolic reflector into a beam 12—25 deg width down to the sea bed . In the receiving transducer, the returning echoes are focused by a similar parabolic reflector to another set of nickel rings .these rings are re magnetized so that the induced voltage is made stronger.

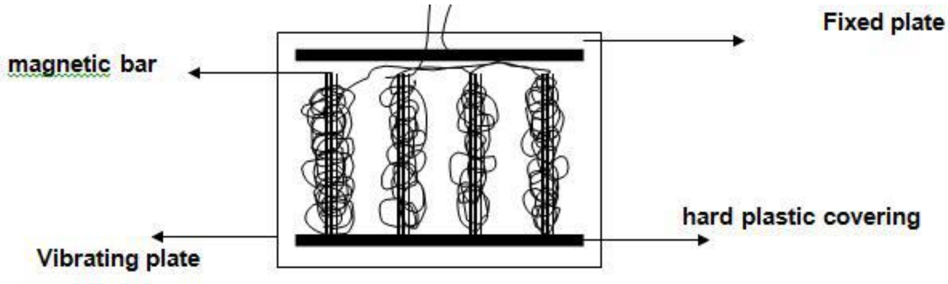


Figure 2.7 shows a bar of ferromagnetic material around which is wounded a coil . If the bar is held rigid and a large current is passed through the coil , the resulting magnetic filed produced will cause the bar to change in length . This slight change of length may be an increase or a decrease depending upon the material used for construction .Annealed nickel has been found to be the optimum material and consequently this is used extensively in the construction of marine transducers .

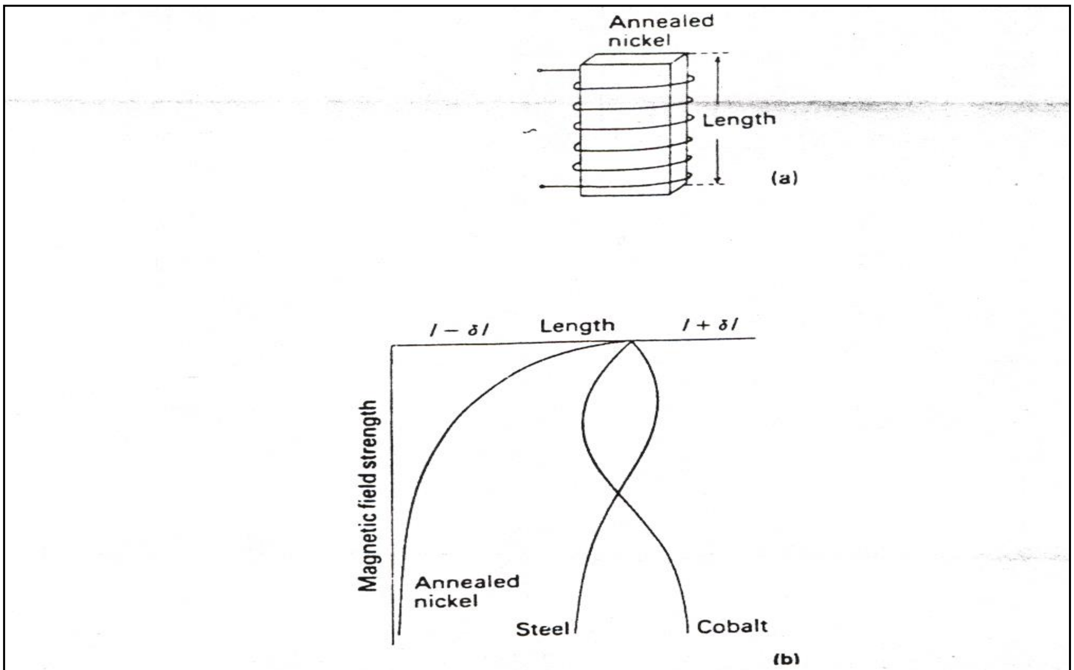


Figure 2.7 (a) A bar of ferromagnetic material around which is wound a coil. (b) Relationship between magnetic field strength and change of length.

2nd trace echo :

False reading may be obtained from a correctly adjusted echo sounder when the returning echo is not received until after the stylus has completed one or more revolution and the next pulse has been transmitted .If an echo sounder has its scale divided so that one revolution of the stylus corresponds to a depth of 600m , an indicated depth of 50m , could be a sounding of 50,650 or even 1250m.

Velocity of sound :

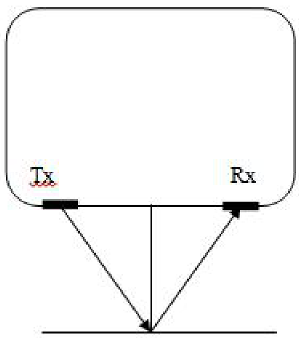
Changes in salinity , temperature and pressure will changes the velocity of sound in water and hence result in erroneous depth readings .

Incorrect stylus speed :

This will result in wrong depths. The stylus for example must move from the zero mark to 100m mark on the scale in the same time as it takes for the sound pulse to travel 100m and back . If the stylus speed is too fast then all depths indicated will be greater than the actual .

Shallow water effect :

This error is likely in shallow waters where the receiving and transmitting transducers, if any , are widely separated .The echo sounder measures the slant range whereas the true depth is the vertical distance .As this effect can give greater depth than the true depth this can be dangerous .



Cross noise :

This is caused by part of the sound wave going directly from transmitter to the receiver through the bottom plates and through the aeration of the water . Due to the unequal length of these pulses and difference propagation ,velocity , each pulse will be received and recorded as a series of pulses . As a result several lines appear near the zero mark and merge into a broad zero . The effect of cross noise is felt if the sensitivity is kept too high . If excessive cross noise occurs , the actual echo may be totally or partially masked in shallow depth .

Multiple echo :

This usually occur over a rocky bottom especially in shallow waters. They are caused by part of the pulse being reflected a number of times between the ship's bottom and the sea bed .only first echo is to be considered .

Double echoes :

These appear on the recorder when the bottom consists of different layers material e.g sand over rock .

Aeriation :

Air bubbles trapped under the hull tend to shield the sound pulse giving a weak echo or none at all .This occurs when the ship goes astern .

Other false echoes :

Echoes other than those showing the true sounding , may appear on the trace of an echo sounder for variety of reasons . They do not usually obscure the echo from the sea bed , but their correct attribution often requires considerable experience . Some of the known causes of false echoes are :

A - Shoals of fish .
B - Layers of water of differing sounding speeds .
C- The deep scattering layer , which is a layer , or set of layers in the ocean , believed to consist of plankton and fishes , which attenuate , scatter and reflect sound pulses .It lies between 300m and 450m below the surface .
D - Submarine fresh water springs .
E – kelp or weed .
F – Side echoes from an object not immediately below the vessel , but whose slant depth is less than the depth of water .
G – Turbulence from the interaction of tidal streams , or eddies with solid particles in suspension .

Pythagoras Error :

- This occurs when a ship uses separate transmitters for transmission of the sound pulse and reception of the echo.
- The transmitters are physically separated on either side of the keel or separated along the length of the keel.
- The depth measured at the E/S will be the slanted depth and not the direct below the keel depth.
- In deep waters, this error will not matter much but in shallow waters there will be considerable over reading which is dangerous.

Error arising due to list and trim:

Trim is the alignment of the vessel fore and aft. (Bow down or bow up)
List is the alignment of the vessel port to starboard (how much it leans over).

If the transducer of the echo sounder is in the part of the hull that is on the 'high' part , ie if it's on the port side and the vessel is listing to starboard, then the transducer will give a deeper reading than if the boat was listing the other way. Similarly with the trim of the boat.
These are relatively small errors, which are usually eradicated by positioning the transducer as close as possible to the centerline of the hull.

Calibration

Echo sounders have to be calibrated in order to produce accurate estimates. There are many ways to calibrate an echo sounder. The simplest is to place a target with known acoustic size in the center of the beam and adjust the gain until the echo sounder reproduce the expected value. I addition to the gain, offset angles and angel sensitivity can be calibrated. This is done by placing the standard target at different positions in the beam and let a computer algorithm fit the measured positions to the beam shape and from that estimate the calibration figures.

Some considerations

- Calibration should be carried out in open clean water.
- Salinity and temperature must be estimated and applied to the echo sounder
- The size of the standard target must fit the echo sounder frequency. It should have a size that match one of the peaks in the Rail eight scatter.
- The target should be cleaned by soap and not touched by bear hands
- The target should be acclimatized.

The long range identification and tracking (LRIT)

The long range identification and tracking (LRIT) system for ships aims to enhance security for government authorities. LRIT provides ship identity and current location information in sufficient time for a government to evaluate the security risk posed by a ship off its coast and to respond to reduce the risk if necessary.
An active and accurate long range identification and tracking system also has potential benefits in terms of maritime safety, marine environment protection, and maritime search and rescue. Accurate information on the location of the ship in distress, as well as ships in the vicinity that could lend assistance, reduces response time, supporting timely rescues and minimizing pollution.

The LRIT system is mandatory for all passenger ships, high speed craft, mobile offshore drilling units and cargo ships of over 300 grt , and has been in force since July 2009.

LRIT users include the following:

1)Flag States may request information on the location of their vessels around the world
2)Coastal States may request information on ships up to 1 000 nautical miles from their coasts irrespective of their flag
3)Port States may request information on those ships that have declared one of their ports as destination, irrespective of their location or flag.
4)Search and rescue authorities.
The international LRIT system receives, stores and disseminates LRIT information on behalf of all SOLAS Contracting Governments (Convention of Safety of Life at Sea - 1974 SOLAS Convention).

<u>LRIT system</u>

LRIT system consist of LRIT shipborne equipment, Communication Service Providers, Application Service Providers, LRIT Data Centre, LRIT Data Distribution Plan, International LRIT Data Exchange
1-LRIT shipborne equipment provide position, date time in UTC, vessel IMO & MMSI number to CPS and shall:
-be capable of automatically and without human intervention on board the ship transmitting the ship's LRIT information at 6-hour intervals to an LRIT Data Centre;
-be capable of being configured remotely to transmit LRIT information at variable intervals minimum of 15 min to periods of 6 h to the LRIT Data Centre, irrespective of where the ship is located and without human interaction on board the ship.
-be capable of transmitting LRIT information following receipt of polling commands;
-interface directly to the shipborne global navigation satellite system equipment, or have internal positioning capability;
-be supplied with energy from the main and emergency source of electrical power
-be tested frequently.

2-Communication Service Providers (CSP) provide the communication structure and services to ensure the end-to-end secure transfer of the LRIT message between the ship and ASP.

3-Application Service Providers (ASP) provide a communication interface and add information to the LRIT message between the CSP and the LRIT Data Centre.

4-LRIT Data Centre collects and provides LRIT information to its users according to the Data Distribution Plan.

5-LRIT Data Distribution Plan (DDP) defines rules and access rights (i.e. which users can receive what LRIT information). The DDP server is managed by IMO and is populated by SOLAS Contracting Governments, following IMO technical specifications.

6-International LRIT Data Exchange (IDE) routes LRIT information between LRIT Data Center according to the DDP.
All users (flag, coastal, port or SAR) Cooperative Data Centre have access to the user web interface to be able to consult position reports and request specific positions of ships. This interface allows the ships to be viewed graphically, and users can follow a particular ship or list of ships.
Satellites enable ships to be tracked all over the world regardless of where the ship is located. The system complements existing modes of tracking ships using coastal-based AIS stations. Furthermore, the combined use of LRIT and Satellite-AIS data can increase the tracking quality and coverage of the ships registered.