Sampling rates and Limitation

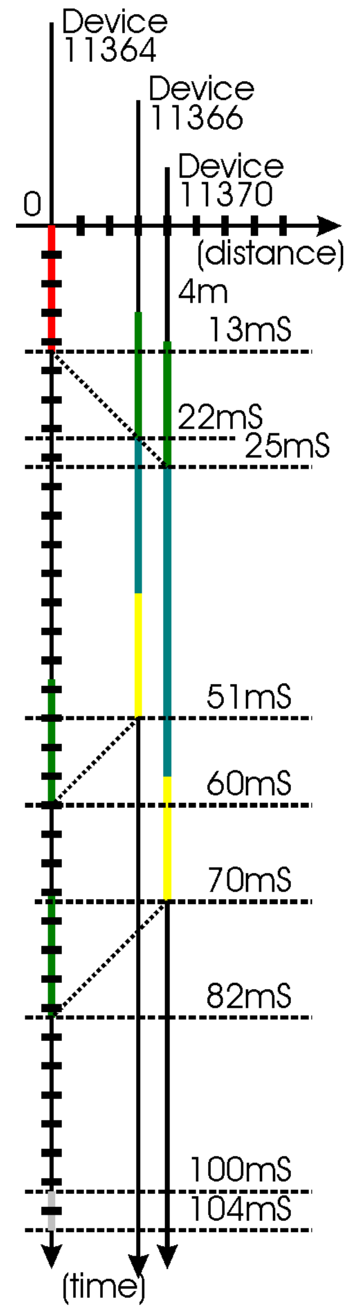
The event chart below illustrates the sampling rate limitation for the air to air ultrasonic operation. The physics of travel time, device deficiency and the speed of molecular relaxation set limits to the sampling rates. Any two-device transaction (for example) between device 11364, and device 11366 over a distance of roughly 3 meters, can't be much higher than 16 samples per second. By the same token a three-device transaction will take about 82mS (12 samples per second). As the distance is increased, time of travel decreases the sampling rate possible. In synchronous modes, the sampling rates can be much higher, since the signal travels only one way with less signal delays and no transpond delay. Smart combination of synchronous differential modes and asynchronous modes, can be used to acquire higher sampling rates. The HX11 makes such combination possible.

During the caller / transponder mode the situation in the medium gets very complex, the following chart helps explain what happens. Devices 11364, 11366 and 11370 have been set up as follows.

11364	*0*	*255*	*1*	*33*
11366	*0*	*255*	*2*	*33*
11370	*7*	*25*	*1*	*1*

Device 11370 transmits a the calling signal 1 continuously at rates approx. 25 x 4mS and devices 11364 and 11366 transpond to the call as follows.

Ultrasonic Event Chart (Asynchronous)



The red line on the event chart represents the duration of the signal transmitted by the caller. Green line, represent the duration of caller signal received by the transponder, and the blue lines represent a unit transponder delay (XpDelay). Yellow lines represent the duration of transponder-encoded reply. The gray line represents serial port transmission duration.

The encoded reply, by transponder 11366, to a caller with ID=1 will be an encoded combination of its own transponder ID, and the caller ID, or 331. Similarly the reply from transponder 11370 will be 351. The user controls the content of the call, and the user also determines, how many blue line delays are introduced onto the event lines. The user does this by setting the transpond delay (XpDelay). Value 0 means no delay (no blue line). Device 11366 has its transpond delay set to 1, device 11370 has its transpond delay set to 2.

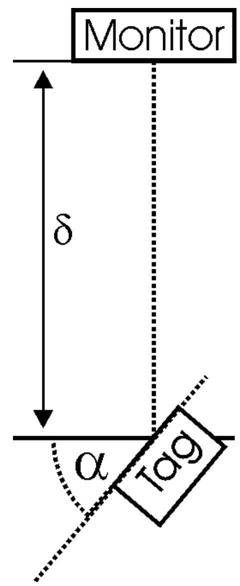
Caller/Transponder operation does not need to be synchronized so the 0 axis is here only for reference. The image on the right illustrates one possible situation. Device 11364 transmits its call at time 0; the signal has to travel for about 3m before reaching transponder (device 11366). Then it must travel, further 1m to reach device 11370 that is 4 meters away. The travel adds time to the transaction. At 22mS device 11366 logs the time of the signal arrival into its ring buffers, and starts timing its response delay. Without synchronization, this particular timing has little meaning, but when measured with respect to signal arrival at device 11370, it gains a differential meaning. At roughly 25mS, device 11370 logs the time of arrival of the signal from device 11364. At 51mS, device 11366 has encoded the response to the signal from device 11364 and transmitted the reply. At 60mS, device 11364 receives the reply and logs time of arrival. By subtracting reply and signal delays, the time of signal flight can be calculated. At 70mS, the transponder device 11370 has encoded the signal from 11364 and transmitted its response. At 82mS device 11364 receives the reply from device 11370 it decodes the signal and stores the results and time of arrival in its ring buffers. At roughly 160mS device 11364 transmits it's ring buffer contents through the serial port, clears it's timers and repeats the cycle. In this example the repetition of calls from 11364 is 100mS, the user can control the call repetition rate.

Signaling Considerations

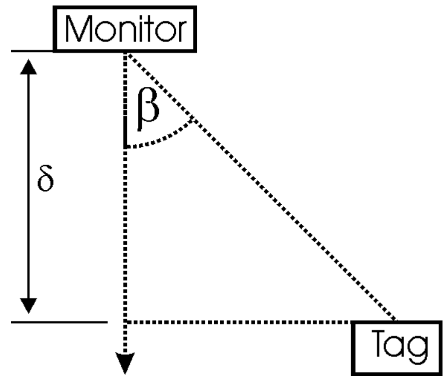
The probability of missed signals increases in direct proportions to the angle and the distance from the receiver. Distance, angle, shear and tunneling limitations are specified by 50% missed signals. I.e. at the limitation boundaries, only half of the emitted signals are logged. All specifications are based on one-way travel of the signal, i.e. from transmitter to receiver. In the case of callers and transponders, the signal must travel both ways, this induces higher signal losses.

Rotational Angle

Tag rotational angle relative to a receiver, is a function of distance δ from the receiver. The angle α, at which the monitor misses 50% of the signals, is in inverse proportions to the distance from the receiver. I.e. the further away the tag is from the monitor, the smaller is the angle. The range is specified, to a distance where α is no less than +/- 10 degrees.

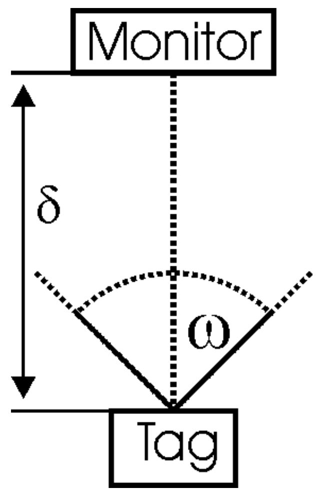


Shear Angles



A tag moving on axis parallel to the monitor, sets up, what we refer to as a shear angle β. This angle is a function of the distance δ. The distance δ, is specified to a point, where this angle is no less than +/- 10 degrees. Note that the angle β, is in inverse proportions to the distance δ.

The Line of Sight



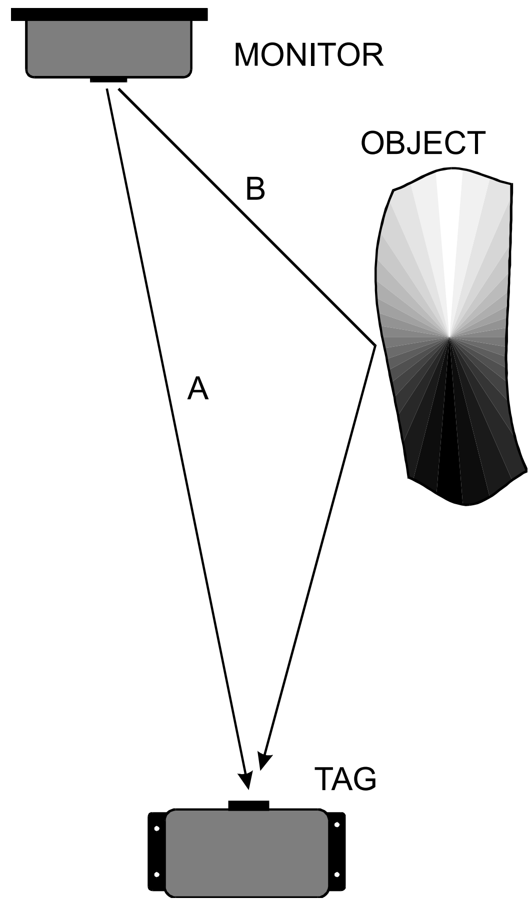
Like light, ultrasound can be blocked by objects. If the objects are small, large portion of the wave will go around the object, and insignificant damage is done to the signal. But if the object has a large reflective surface, some damage may come to the signal, even if the object is not directly blocking the signal. Walls and ceilings are such surfaces. The specifications given in this document are based on ω not less than +/-45 degrees clear line of sight, i.e. no object within these boundaries. In most cases but not all, overhead mounting ensures the best line of sight.

Signal collision or Overrun

If a HX11X monitor receives two signals less than 13 mS apart it will either not log one of these signals, or log neither. In other words it will miss one or both. Care must be taken to set the transponder delay and transmit delay to minimize collision.

Hostile Conditions

If the difference in distance B-A, in figure A4 is less than 4.5 meters, signal read error might occur. The smaller the difference in distance the higher the probability of error. Errors with respect to a tag in relation to a monitor also become more likely with increased distance, angle and shear angles.



Overrun errors

Overrun errors occur when two tags in the vicinity of one another both transmit at the same time or nearly the same time. The probability of an overrun error is directly proportional to the number of tags within the range of a single monitor.

Overrun error probability

OEP = (0.013*N-0.013) / (A-0.013)

Where N is number of tags and A is the duration of the Tag Signaling Cycle.

Most errors are suppressed by the system, an error tag encounter is not saved. This depends on the quality of the error rejection function of the Hx5 system. Some errors will however penetrate the defenses and be counted. There are number of ways for the user to reject these errors.

If a tag ID is detected by one monitor only, and isn't detected many times in a row; this is certainly an error.
If there is a position jump between samples, this could be an error. Application of standard deviation procedures may help eliminate these errors.

HX11 Specification Asynchronous Mode (caller/transponder)

Positioning Timing Resolution Per Monitor	0.03 mm
Open Field Absolute accuracy over full range	11mm
Position Repeatability	11mm
Maximum Update Rate (Positions/Second/Monitor)	15
Maximum number of Monitors per Network	63

HX11 Specification Synchronous Differential Mode (transmitter/receiver)

Positioning Timing Resolution Per Monitor	0.03 mm
Open Field Absolute accuracy over full range	9mm
Position Repeatability	9mm
Maximum Update Rate (Positions/Second/Monitor)	36
Maximum number of Monitors per Network	32340

Position Resolution

This is the physical timing resolution; meaning if the position changes by 0.03mm a change in distance value should be noted. This resolution can be approached in a case of a slow moving object, where there is time for hefty statistics and data averaging.

Open Field Absolute Accuracy

Position is nowhere off by more than specified distance, over the full range. Given that the air medium remains the same in terms of speed of sound and no objects obscure the wave.

Position Repeatability

Given constant conditions of the air medium. If the transmitter is moved into a previously held position, the new reading will not deviate more than specified distance from the original reading on the average. This makes calibration for high absolute accuracy possible.

Maximum Update Rate (synchronized tracking)

The maximum update rate is specified 36 samples per second. This is not achievable with the XYZ program. It needs two samples before it can yield 3D coordinates. Hence sampling rate here cannot be higher than 18 samples per second.

Monitors per Network (synchronized tracking)

The maximum number of monitors per network is 32340. If there is one monitor for every square meter 32340m^2 can be covered with a single network and a single computer. If more coverage is needed more networks can be added.

Monitor Noise Immunity

The HX11 transmission is frequency modulated. To block or upset the transmission, a signal noise must exist in the 40khz +/- 1Khz band. If the volume of this signal is 5db lower than the HX11 transmission at the receiver, no distance distortion is measured. In other words the noise must overwhelm the transmission. Such levels at this frequency does not occur naturally.