3. MAXIMUM UNAMBIGUOUS RANGE

The **maximum unambiguous range (Rmax)** is the longest range to which a transmitted pulse can travel and return to the radar before the next pulse is transmitted. In other words, **Rmax** is the maximum distance radar energy can travel round trip between pulses and still produce reliable information. The relationship between the PRF and Rmax determines the unambiguous range of the radar. The greater the PRF (pulses per second), the shorter the maximum unambiguous range (Rmax) of the radar.

The maximum unambiguous range of any pulse radar can be computed with the formula:

Rmax = c/(2xPRF), where *c* equals the speed of light. (3x10e8m/s)

Radar transmits many pulses each second. The rate is given by the *PRF.* The time *T* between pulses is thus

$$T = 1/PRF$$

The range to a target may be determined by the round-trip "time of flight" for the echo to return to the radar receiver. The "2" accounts for the distance out and back from the target. We know that electromagnetic radiation travels at the speed of light.

$t = 2r/c$

Where $c=3x10^8$ m/s t=round trip time (sec)

Now, given *T,* we can determine the maximum range a radar signal can travel and return before the next pulse is sent out. This is simply:

$$r_{max} = CT/2$$

$$r_{max} = C/(2PRF)$$

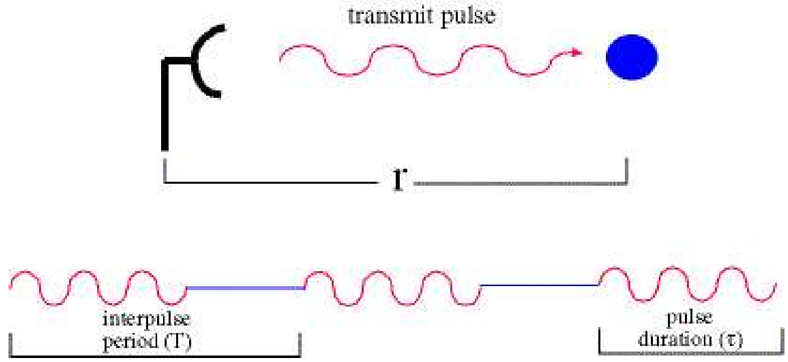

Figure 12: Finding the r_{max}.

Pulse repetition frequency (PRF) largely determines the maximum range of the radar set. If the period between successive pulses is too short, an echo from a distant target may return after the transmitter has emitted another pulse. This would make it impossible to tell whether the observed pulse is the echo of the pulse just transmitted or the echo of the preceding pulse. This produces a situation referred to as **range ambiguity**. The radar is unable to distinguish between pulses, and derives range information that is ambiguous (unreliable). In theory, it is best to strike a target with as many pulses of energy as possible during a given scan. Thus, the higher the PRF the better. A high PRF improves resolution and range accuracy by sampling the position of the target more often. Since PRF can limit maximum range, a compromise is reached by selectively increasing the PRF at shorter ranges to obtain the desired accuracy of measurements.

In the example above, where we had a pulse repetition time of 1 millisecond (1/1000th of a second), we may calculate how far the beam can travel in that time by multiplying 1 millisecond (0.001 seconds) by the speed of light (300,000km/second) for a result of 300km. However, keep in mind that the beam has to be able to reach its target and **reflect back** in that time which means the total **round trip** distance is 300km. That means, with a 1 millisecond pulse repetition time, the total range is **half** that: 150km.

Determining range of a target

In the graphic example to the left, the radar's beam bounces off a raindrop within the cloud and is detected by the radar 425 microseconds (0.000425 seconds) after it was sent. By multiplying the measured time by the speed of light we know that the beam covered 127.5km and we know that half of that distance was the distance *to* the cloud and the other half was the distance **back.** So we know the raindrop we detected is 63.8km away.

4. VELOCITY DETERMINATION

Doppler technology makes the radars enable to determine the velocity of the targets based on their movement from or towards radar. This is very useful information for meteorologists to be able to predict the direction and future location of the air mass and meteorological systems such as cyclones, tornados, etc. Velocity determination can be managed as described in following part of the document.

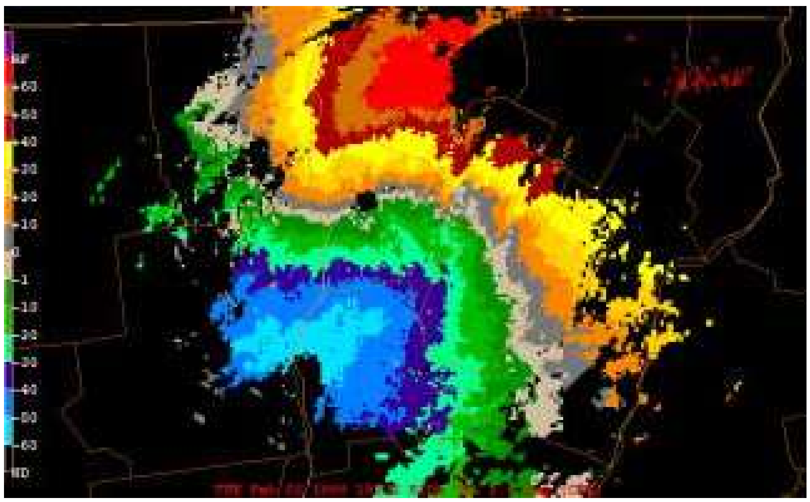

Figure 13: Velocity Example.

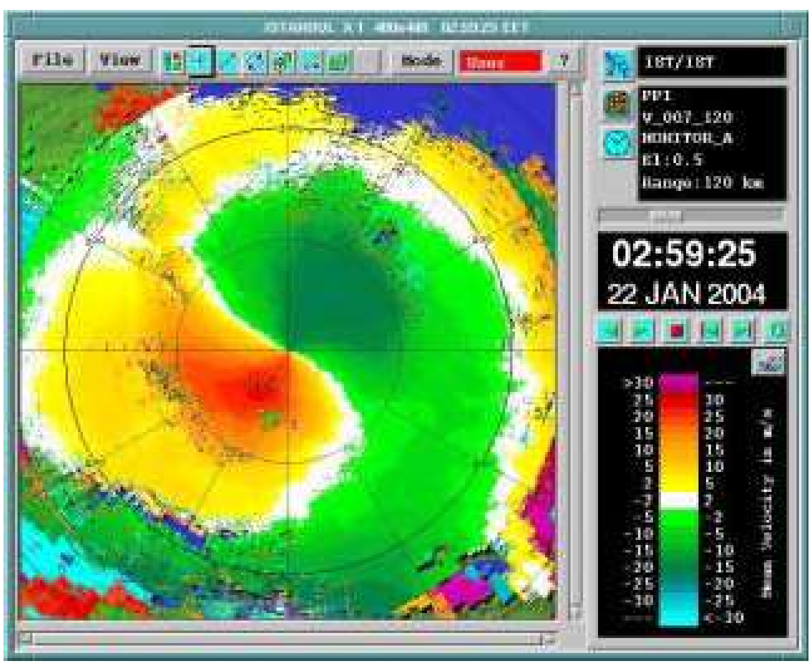

Figure 14: PPI Velocity.

- A Doppler radar can only measure the component of the winds in a direction parallel to the radar beam
- Measured wind speed is called the **radial velocity (Vr).**

Radial velocity is defined simply as the component of target motion parallel to the radar radial (azimuth). It is that component of a target's motion that is either toward or away from the radar site along the radial.

Some important principles to remember about Doppler radial velocity are:

1. Radial velocities will always be less than or equal to actual target velocities.

2. Actual velocity is measured by radar only where target motion is directly toward or away from the radar.

3. Zero velocity is measured where target motion is perpendicular to a radial or where the target is stationary.

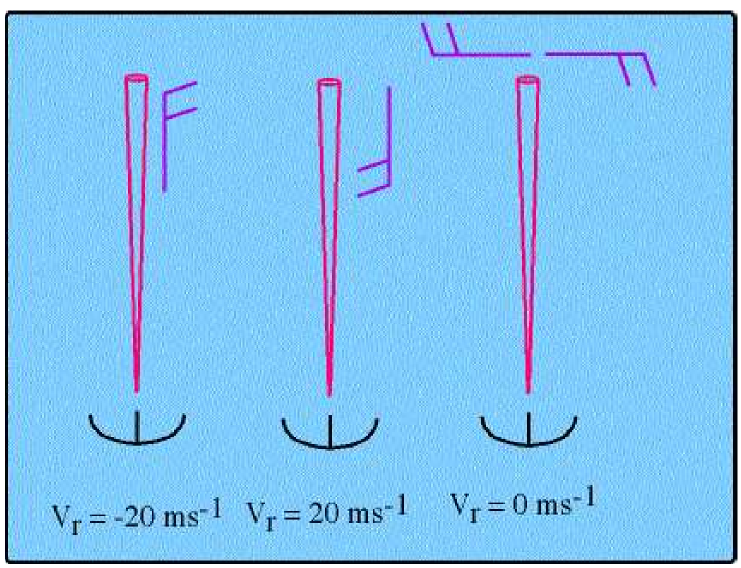

Figure 15: Radial Velocity.

4.1. Doppler Shift

Austrian physicist Christian Doppler discovered that a moving object will shift the frequency of sound and light in proportion to the speed of movement in 1842.

He then developed mathematical formulas to describe this effect called the **Doppler Shift**.

While not given much thought, you experience Doppler shifts many times each day. The change in pitch of a passing train whistle and a speeding automobile horn demonstrate its effects. When you hear a train or automobile, you can determine its approximate location and movement or you hear the high pitch of the siren of the approaching ambulance, and notice that its pitch drops suddenly as the ambulance passes you. That is called the Doppler Effect.

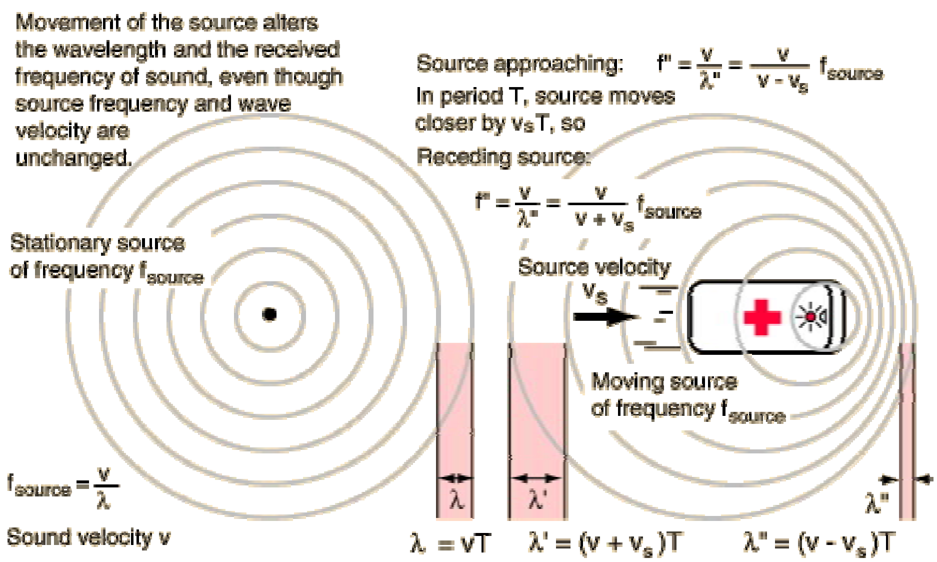

Figure 16: Frequency Stationary and Moving Target.

Exactly the same thing happens with electromagnetic radiation as happens with sound. Doppler radar accomplishes much the same thing, but to a higher degree of accuracy. As a target moves toward the radar, frequency is increased; if the target is moving away from the radar, the frequency is reduced. In the case of radar, the usual situation is to have stationary radar observing moving targets.

The radar then compares the received signal with the frequency of the transmitted signal and measures the frequency shift, giving the motion and speed of the target. While frequency of electromagnetic energy is modified by moving targets, the change is usually too slight to measure precisely. Therefore, Doppler radar focuses on the phase of electromagnetic energy. Using phase shifts instead of frequency changes can be compared to viewing an insect under a magnifying glass.

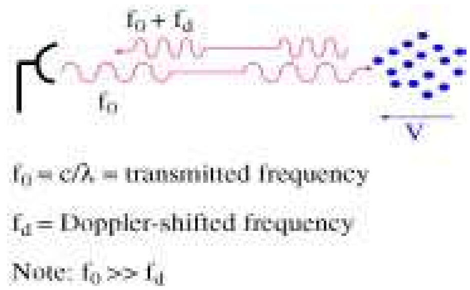

Figure 17: The Effect of Moving Target on Frequency.

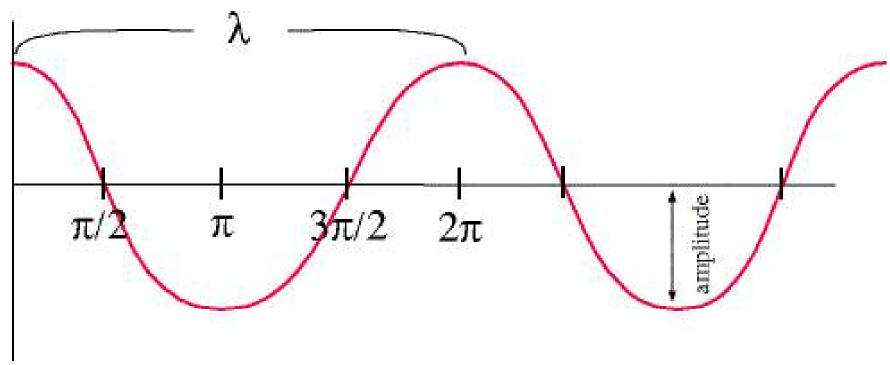

Figure 18: Wavelength and Amplitude of a Wave.

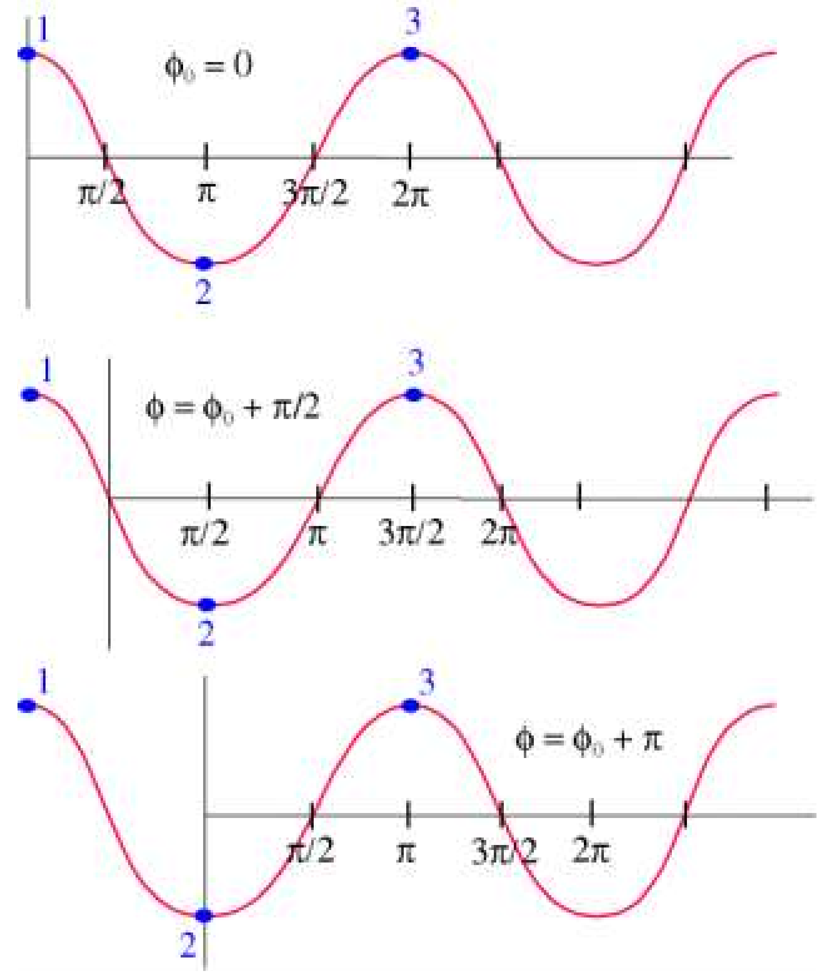

Figure 19: Phase of a Wave.

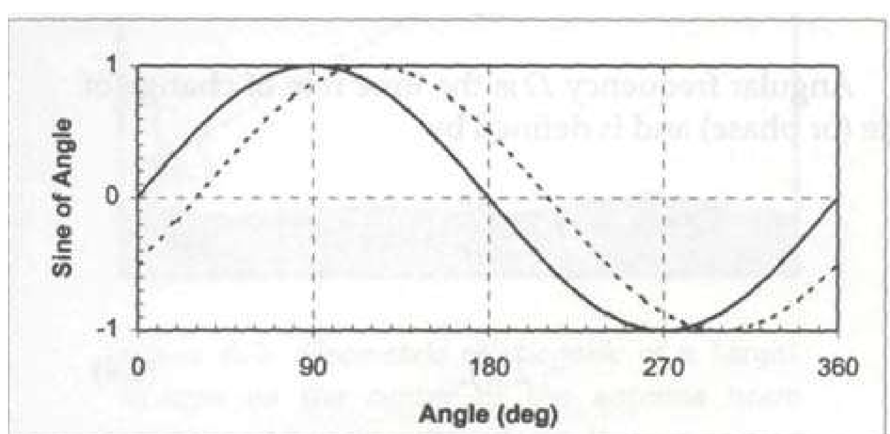

Figure 20: Sine Wave (Solid Curve) and a Second Signal 30° Out of Phase with the First Wave (Dashed Curve).

A pulse Doppler radar, in its simplest form, provides a reference signal by which changes in the frequency phase of successively received pulses may be recognized. The known phase of the transmitted signal allows measurement of the phase of the received signal. The Doppler shift associated with the echo from which the return originated is calculated from the time rate of change of phase. The phase of a wave, measured in degrees, where 360 degrees equals one wavelength, indicates the current position of the wave relative to a reference position. For example, look at figure below. At time T1 (fig., view A), the position of the wave along the vertical line was as shown, while at time T2 (fig., view B), the position of the wave along the vertical line was as shown. Notice that the wavelength did not change from T1 to T2. However, the wave's position relative to the vertical line changed 1/4 wavelength, or 90 degrees. This change is the phase shift.

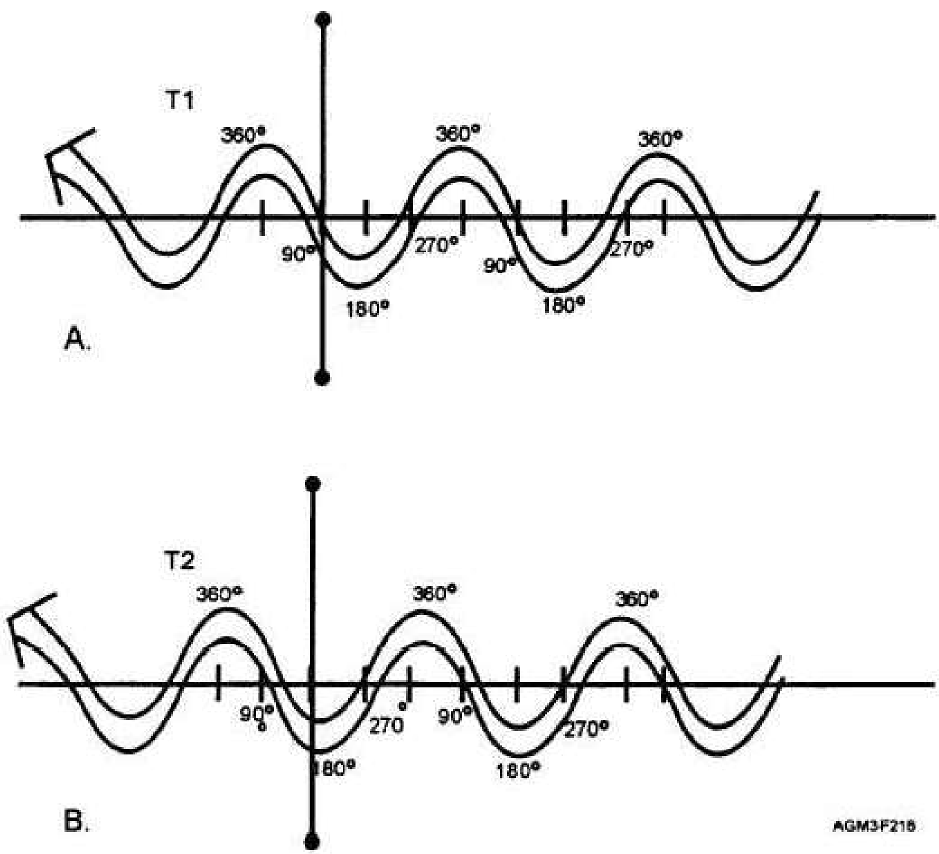

Figure 21: Wavelengths and Phase Shifts. (A) T-l is Wave Reference Position. (B) T-2 Wave's Position has Changed 90° from Reference Position (T-l).

If the radar observes these changes (phase shifts) it will realize that motion has occurred and can then convert this information into target velocity. Keep in mind that the ability of a Doppler radar to detect phase shifts and compute velocity depends upon the system maintaining a consistent transmitter frequency and phase relationship from one pulse to the next.

4.2. Total Distance to Target in Radians

Consider a single target at distance r from radar. The total distance a radar pulse will have to travel to detect this target is 2r since the wave has to go out to the target and back to the radar. Physical change in target distance is r metres, but the RF path length changes by 2r as signal travels both to and from the radar.

Knowing the radar's wavelength, 2r (full RF cycle) can be expressed as an observed phase change of target:

The total distance (D) travelled by the wave**: 2r**

This distance can also be measured in terms of the number of wavelengths from the radar to the target**: $2r/\lambda$**

We can also measure this distance in radians by using the fact that

1 wavelength = 2π radians.

So, **D in terms of radians:**

$$\text{Distance in radians} = (2r/\lambda)/2\pi$$

If a radar signal is transmitted with an initial phase of <f>$_0$, then the phase of the returned signal will be

f_0 = phase of pulse sent out by radar

f = phase of returning signal then,

$$\Phi = \Phi_0 + 4\pi r/\lambda$$

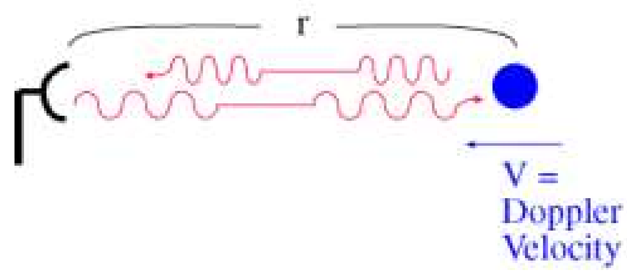

Figure 22: Doppler Velocity.

How does the radar then measure f_d?

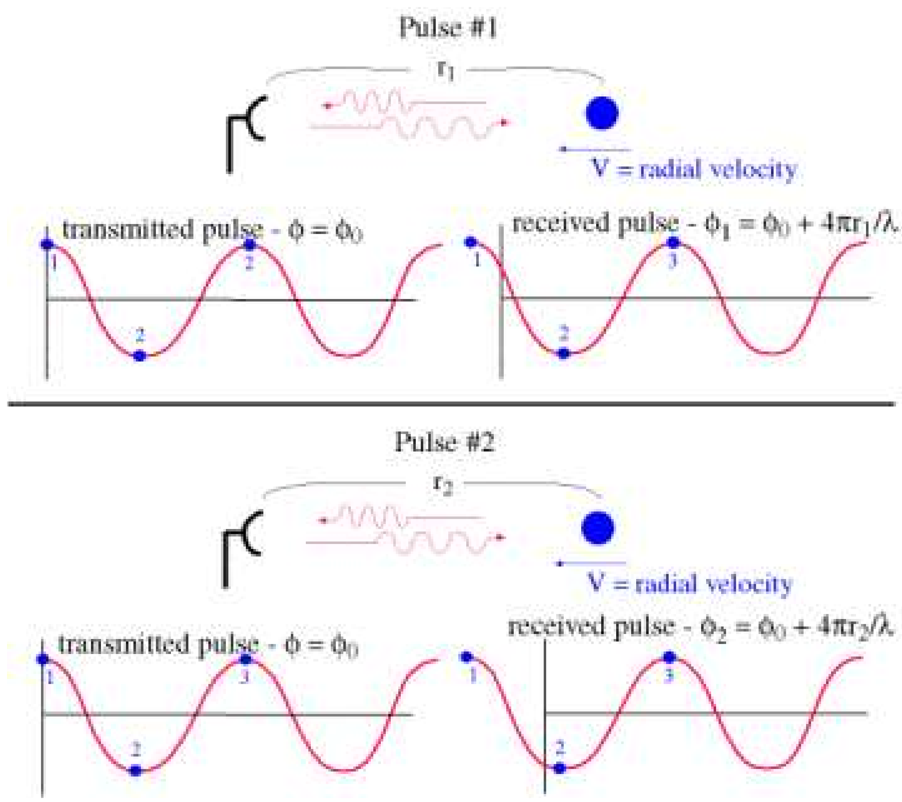

Figure 23: Phases at Different Ranges.

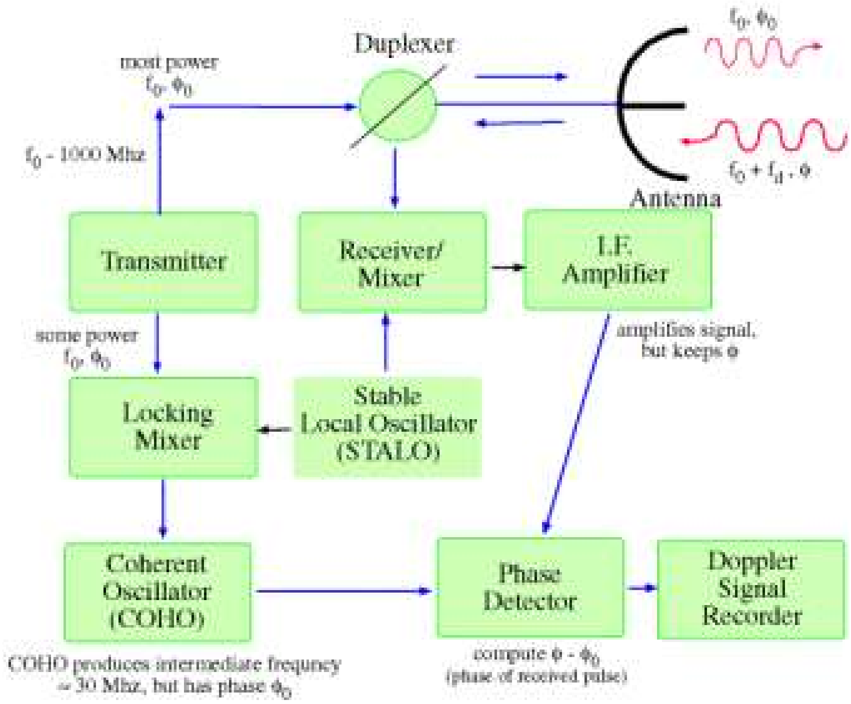

Figure 24: Basic Block Diagram of Radar.

4.3. Pulse-Pair Method

1) The transmitter produces a pulse with frequency f_0 and duration of t.

2) Some power with frequency f_0 is mixed with a signal from STALO and is passed to COHO

3) COHO maintains f_0 of transmitted wave

4) Receiver/mixer mixes signal from STALO and received signal

5) Mixed signal is then amplified

6) Phases of original and received signals are differenced, i.e., compute f1 = f0 - f. This is the phase of pulse #1.

7) Repeat 1-6 above for successive pulses. This gives you *df/dt.*

The change of phase with time from one pulse to the next is given by

$$d\Phi/dt = (4\pi/\lambda)(dr/dt)$$

Where dr/dt is the time derivative or time rate of change of the parameter. The radial velocity of an object is given by

$$v = dr/dt$$

Angular frequency Ω is the time rate of change of angular velocity (or phase) and is defined by:

$$\Omega = d\Phi/dt$$

$$= 2\pi f$$

Where f is the frequency shift in cycles per second (Hertz).
Thus, by combining Equations, we get the frequency shift caused by a moving target;

$$f = 2v/\lambda$$

So a given phase shift in a given interval of time becomes a frequency shift which the radar can measure.

4.4. Maximum Unambiguous Velocity

What is the maximum Doppler-shifted frequency that can be unambiguously measured?

There are limitations in the **velocities** and **ranges** that radar can resolve unambiguously. Let us consider **velocity ambiguities** first. When a target is not moving toward or away from radar, it will have zero **radial** velocity. This does not necessarily mean that the target is stationary. It simply means that the target is remaining at a constant distance from the radar. It could be moving quite rapidly, in fact, but any movement it has must be perpendicular to the radar's beam. Since the only velocity a Doppler radar can detect using phase-shift principles is the radial velocity, we usually omit the qualifier "radial" and simply talk about the "velocity". While this is convenient, be careful to recognize that a Doppler radar detects only radial velocities (the velocity with which a target moves toward or away from the radar)

The maximum velocity a Doppler radar can detect correctly or unambiguously is given by the velocity which produces a phase shift of TI radians. This is also called the Nyquist frequency or Nyquist velocity[7], depending upon whether we are referring to the maximum unambiguous frequency or velocity, respectively. Mathematically, we can express this as:

$$f = 2v/\lambda,\ v_{max} = f_{max} \cdot \lambda/2$$

Where the maximum frequency f_{max} is given by:

$$f_{max} = PRF/2$$

(Nyquist Theorem)

And **PRF** is the pulse repetition frequency of the radar. Thus, the maximum unambiguous velocity detectable by a Doppler radar is:

$$v = PRF.\lambda/4$$

Example:

If PRF = 1000 Hz and l = 10 cm, then V_{max} = 25 ms^{-1}

This is an important result. It says that if we want to be able to detect high velocities, we must use long wavelengths, large PRFs or both.

What is Nyquist theorem?

The Nyquist theorem states that a signal must be sampled at a rate greater than twice the highest frequency component of the signal to accurately reconstruct the waveform

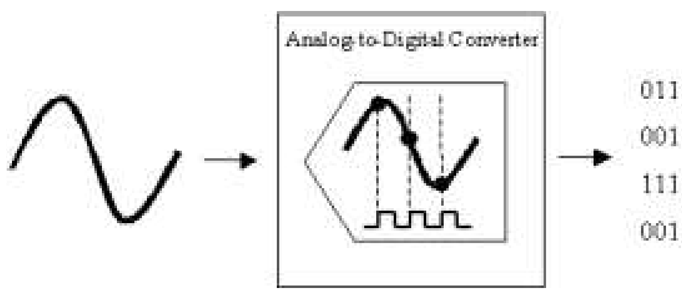

Figure 25: Analogue to Digital Converter (ADC).

- Suppose we are sampling a sine wave (How often do we need to sample it to figure out its frequency?

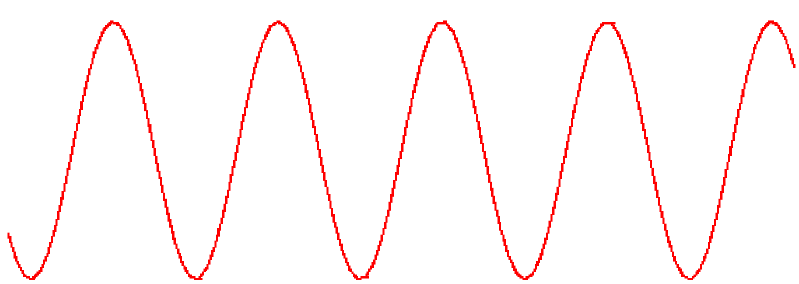

Figure 26: A Sine Wave.

- If we sample at 1 time per cycle, we can think it's a constant

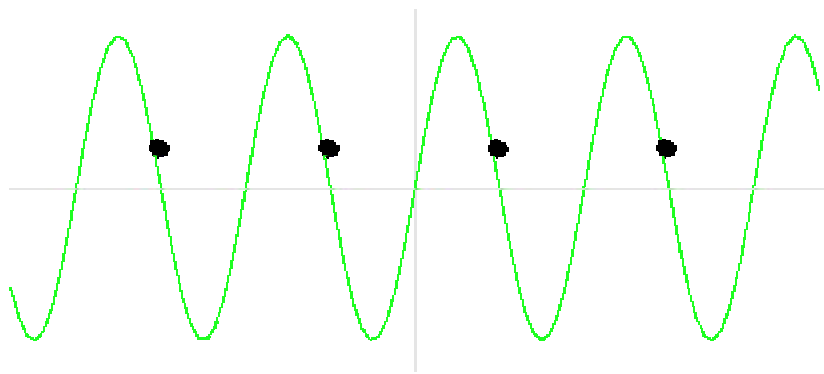

Figure 27: Sampling at 1 Time per Cycle

- If we sample at 1.5 times per cycle, we can think it's a lower frequency sine wave

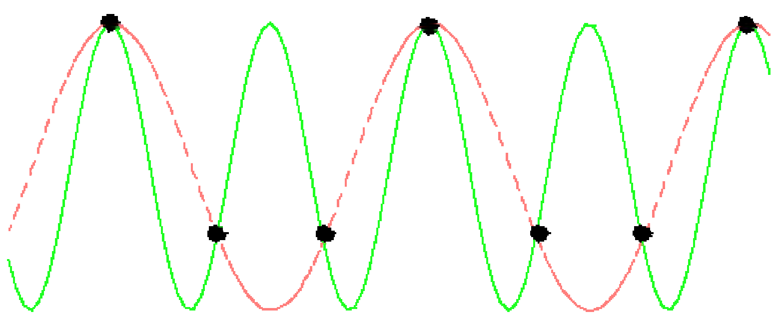

Figure 28: Sampling at 1.5 Times per Cycle

- **Nyquist rate** For lossless digitization, the sampling rate should be **at least twice** the maximum frequency responses.

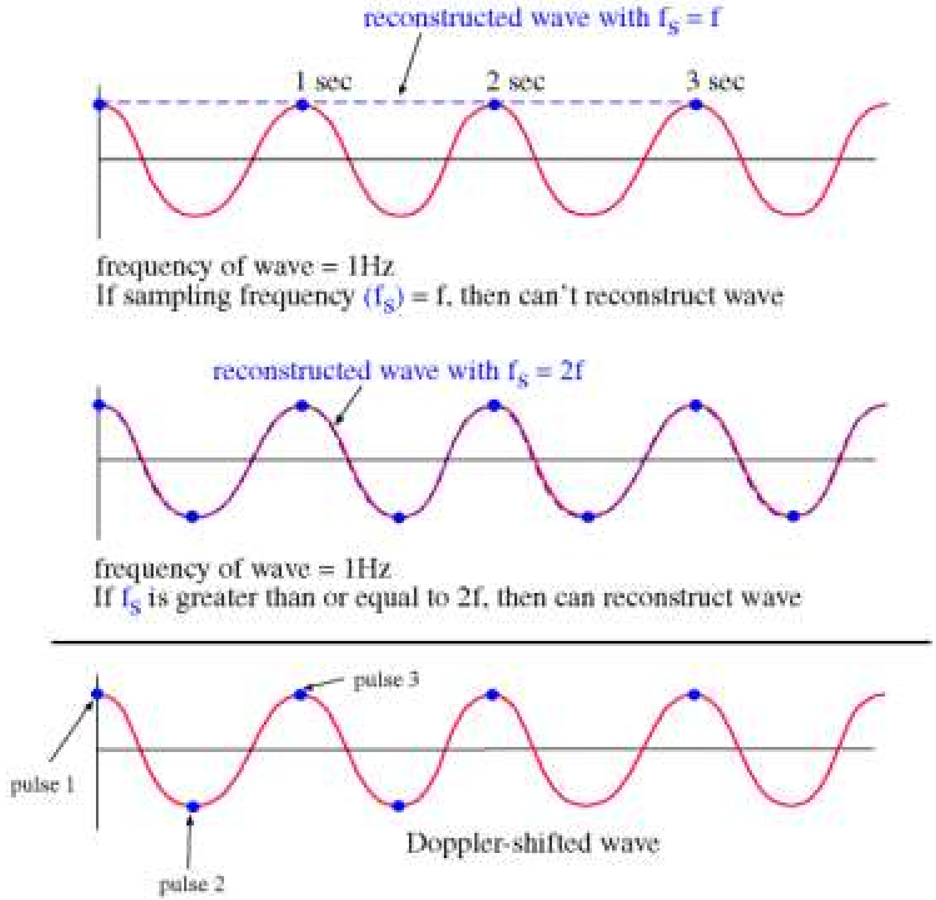

Figure 29: Nyquist Frequency.

5. THE DOPPLER DILEMMA

$$v_{max} = PRF.\lambda/4$$

$$r_{max} = C.T/2$$

$$r_{max} = C/(2PRF)$$

According to equations above, longer wavelength radars can measure larger radial velocity unambiguously for the given PRF. Larger the PRF, larger the radial velocity measurable unambiguously from a given radar. Unfortunately, the larger the PRF shorter the unambiguously measurable range [R_{max}= C/(2*PRF)]. On the other hand Reducing the pulse repetition frequency (PRF) and allowing for a longer listening time will alleviate the problem of range folding. However, as just discussed, low PRFs may then lead to the problem of velocity aliasing.

Thus there is an inverse relationship between the unambiguous range and the unambiguous velocity, the product of which is a constant ($v_{max}.r_{max}=C\lambda/8$), where C is the velocity of light. This is widely known as Doppler Dilemma.

When PRF is low----unambiguous range is high---but that results in a low velocity range.

When PRF is high----unambiguous range is low---but that results in a high velocity range.

The combination of maximum unambiguous velocity and maximum unambiguous range form two constraints which must be considered in choosing the PRF for use with a Doppler radar. Notice that non-Doppler radars are only constrained by the maximum unambiguous range; since they cannot measure velocity, the velocity constraint does not apply.

If we want to have a large $\mathbf{V_{rmx}}$ we must have a small $\mathbf{r_{max}}$ since the right side of the equation is a constant for given radar. Conversely, if we want to detect echoes at long ranges, we can only detect small velocities.

$$v_{max}.r_{max} = C.\lambda/8$$

For example, in order for a radar(for wavelength=5cm) to detect radial velocities of **12.5m/s**(45km/h) without aliasing, the PRF would have to be increased to about 1,000 pulses per second. (V=PRF.λ/4 However, this would reduce the maximum unambiguous range of the radar to about **150km**(r=c/2PRF).

To have an unambiguous range of **300km**, the PRF would have to be 500Hz. If PRF is 500Hz then **V=6, 25m/s**

Another Example: Suppose a radar can sense up to 250 miles from the location of the radar (unambiguous range) and can detect velocities of up to 30 m/s before velocity folding occurs (a.k.a. velocity aliasing). If the PRF was increased, the unambiguous range will drop to say 200 miles but the unambiguous velocity will increase to say 35 m/s.

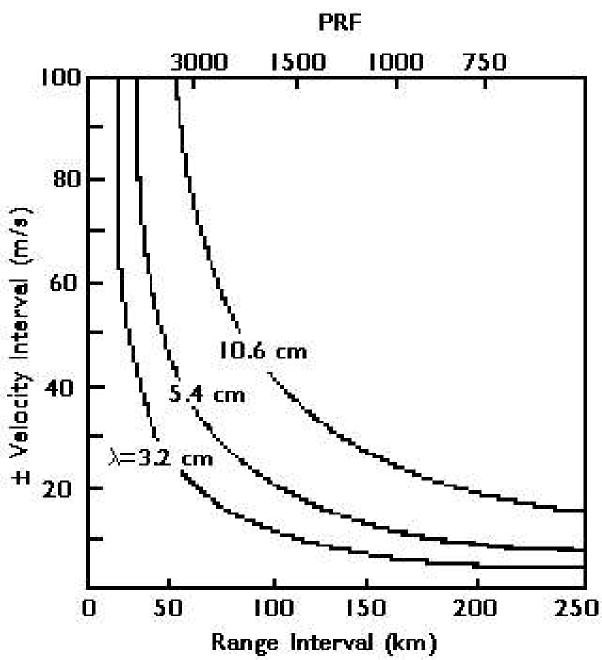

Figure 30: Velocity Interval versus Range Interval and PRF at Different Wavelength.

Figure (based on Gossard and Strauch, 1983) shows the Doppler dilemma graphically. Note that the ordinate (Y-axis) on this figure gives the maximum velocity interval corresponding to the Nyquist frequency. Normally we divide this interval in half with the maximum unambiguous velocity being divided into plus and minus half of the V_{mM} interval. For example, from the figure we can see that for S-band radar, if the PRF is 1000 Hz, the maximum unambiguous range is 150 km while $\mathbf{V_{mm}}$ is ±25 m/s. For X band radar using the same **PRF,** $\mathbf{r_{max}}$ is still 150 km, but $\mathbf{V_{max}}$ is now only ±8 m/s. For meteorological situations, we may want to measure velocities as large as ±50 m/s out to ranges beyond 200 km, so neither of the limits calculated above is completely adequate. The S-band system comes much closer to being useful than the X-band system, however. And C-band will be intermediate to these two.

One partial solution to the **Doppler Dilemma** is in our choice of wavelength. We can increase both V_{max} and r_{max} by using longer wavelength radar. Unfortunately, longer wavelength radars are more expensive and bigger, and they don't detect weather targets as well as shorter wavelength radars, so using a longer wavelength is not necessarily a solution to the problem. The result is that most Doppler weather radars usually suffer significant range or velocity ambiguities or both.

Even if there were not limitations on range because of PRF or velocity, in the real world, we do not wait very long before sending out a second pulse. There are a number of reasons for this. One is that we cannot detect targets at extremely long ranges or we are not interested in them. Meteorological targets typically exist only 10 to 15 km above the earth's surface. Even though the radar waves bend downward somewhat in their travel through the atmosphere, the earth's surface curves away even faster, so the radar beam usually gets so high above the earth's surface that storms are not detectable beyond 400 to 500 km from a ground-based radar.

Another reason we are not interested in distant targets is that the inverse square law decreases the power received from a meteorological target according to $1/r^2$. If a target is too far away, the power received from it will be so weak that the radar will be unable to detect it. For these and other reasons, radars are designed to send out subsequent pulses of energy at fairly frequent intervals.

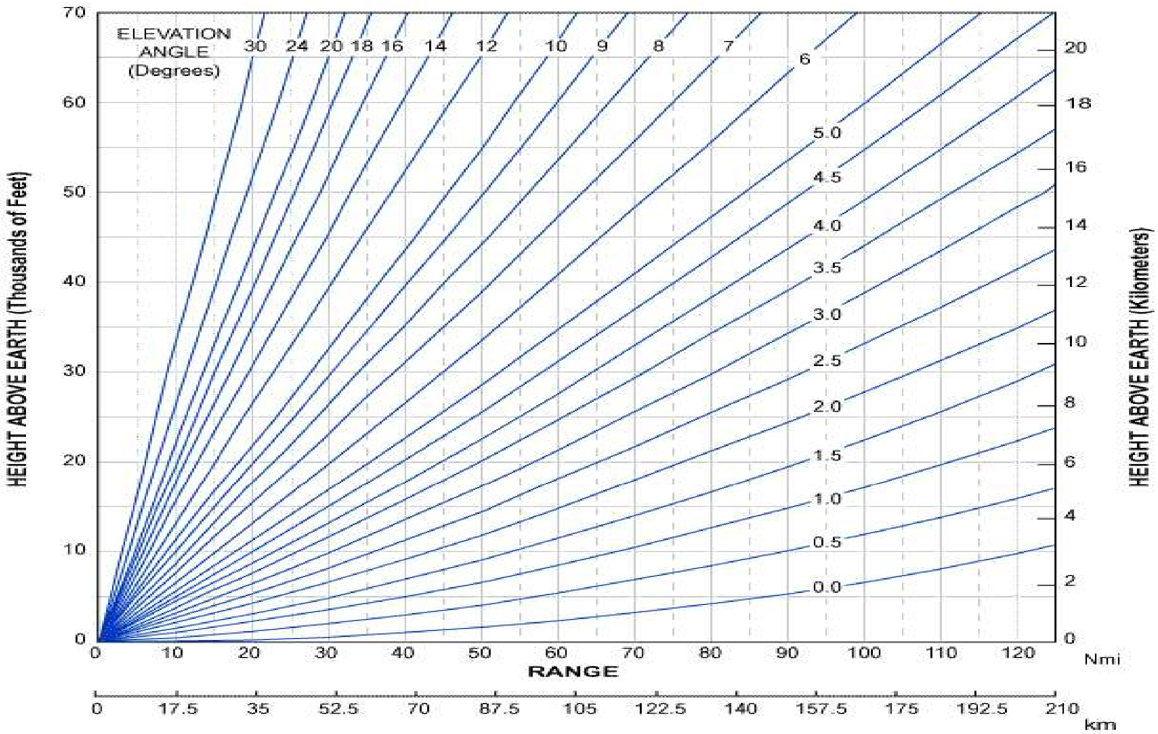

Figure 31: Range-Height Diagram.

6. RADAR RANGE FOLDING

While it's true that only targets within radar's normal range are detected, there are exceptions. Since range ambiguities (also called aliasing or folding) are so common with modern Doppler radars, let us examine the causes of this in a little more detail. Range aliasing occurs because we don't wait long enough between transmitted pulses. This happens when the first pulse of energy goes beyond maximum unambiguous range r_{max} and sometimes gets returned by a weather at a distance say r. The first pulse returns while the radar is expecting the second pulse (during the listening time of the second pulse). In other word, we transmit pulses close together (mostly to make the Doppler side of the radar work better), not giving one pulse enough time to cover the distance between the radar and some storms before the radar sends out the next pulse of energy. In this case echoes are displayed in the wrong range interval. If the PRF is high enough and distant echoes tall enough and strong enough, sometimes third or even fourth trip echoes can be detected. The radar displays it at a distance $(r{-}r_{max})$ superposed on the normal display. These are also known as multi-trip or second-trip echoes in Pulsed radars. Range folding may cause operators to base crucial decisions on false echoes. The data received from this stray pulse could be misanalyzed and echoes may be plotted where nothing exists. The data may look reliable and the radar may appear to be functioning properly, adding to the deception of normal operation.

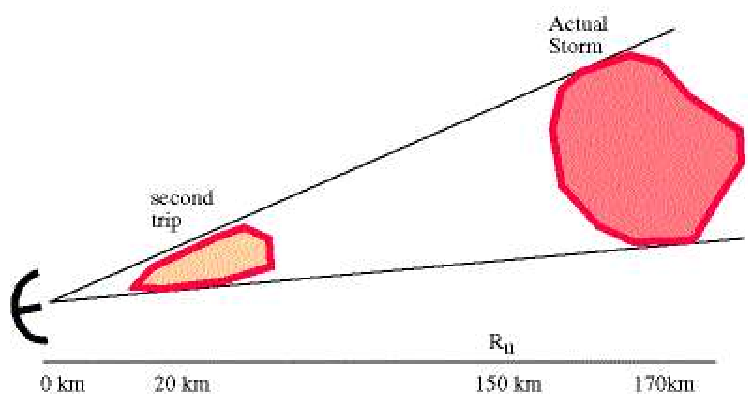

Figure 32: Second Trip Echo Example.

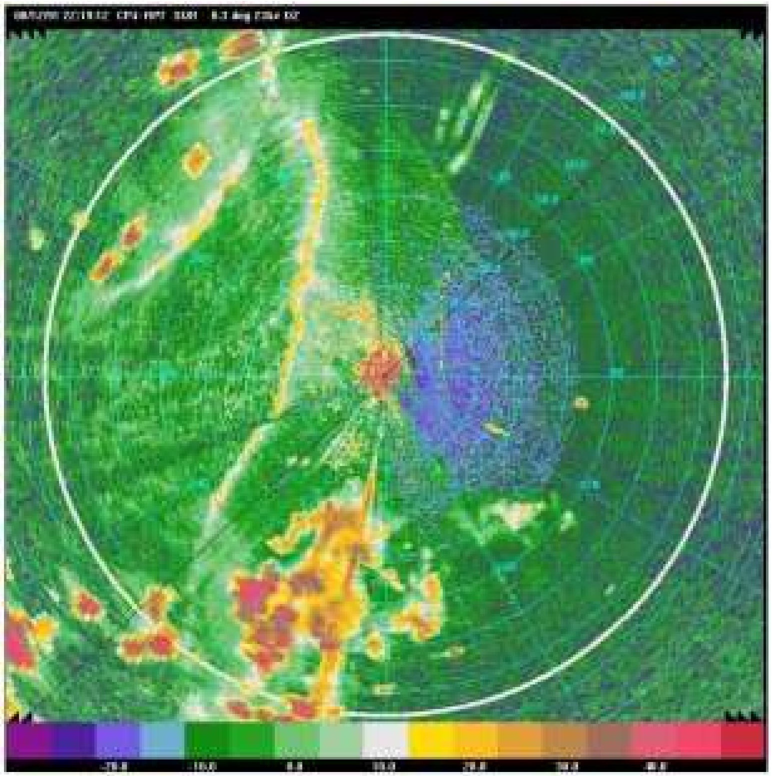

Figure 33: Second Trip Echo Example.

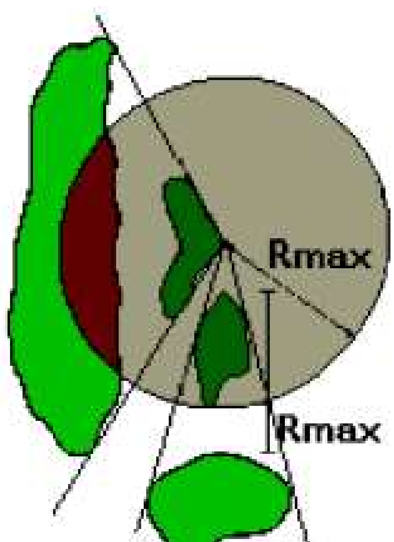

Figure 34: R_{max} and Second Trip Echo Relationship.

Figure 34 shows 2nd trip echoes.

6.1. Recognizing Range-Aliased Echoes

How are second trip echoes recognized on radar? There are a number of ways multitrip echoes can be recognized. One of the easiest is to simply look outside and see what is going on in the real world. If the radar shows a nearby storm in a particular direction but there is nothing outside, it is probably a multitrip echo.

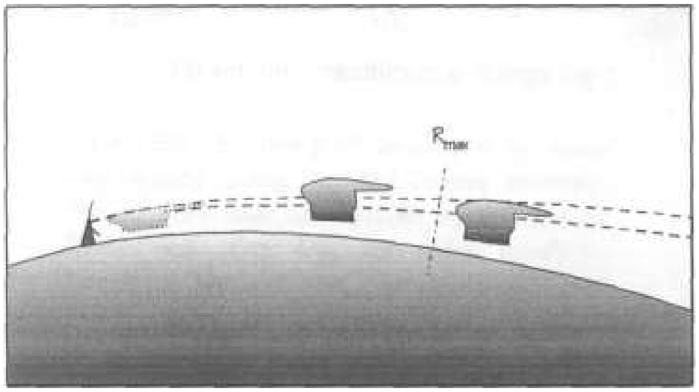

Figure 35: Second Trip Echo.

Figure Illustration of how a storm beyond $\mathbf{r_{max}}$ can be displayed at the wrong range. Two real echoes exist. The first is less than r_{max} away and is displayed at the correct range. The second is beyond r_{max}; it is displayed at a range of $(r - r_{max})$. The faint, dashed storm near the radar is where the radar would display the distant storm.

A second way to recognize multitrip echoes is by their shapes (see Figure 32 and 33). Real storms are usually somewhat circular, elliptical, or irregular. Storms certainly should not know where the radar is located. Anytime a narrow, wedge-like echo is detected which points toward the radar, second-trip echoes should be suspected.

Another clue to the existence of multitrip echoes is height (see Figure 32). Real echoes, especially from convective storms, usually extend up into the atmosphere several kilometres.

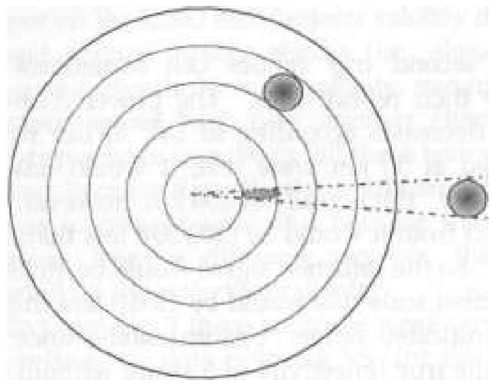

Figure 36: Real and Second Trip Echo.

Display showing a real echo located to the northeast. To the east is an echo beyond r_{max}. It is displayed at a distance of $r - r_{max}$ from the radar. It also has a very narrow shape. In the real and the aliased positions, but its aliased azimuthal distance is much narrower. Also, its reflectivity will be weaker because of the $1/r^2$ dependence on received power in the radar equation.

Thunderstorms are frequently 8 to 15 km in height. If a convective-like echo appears on the radar display but it has an indicated height which is much less than normal, it may be a second trip echo. For example, a real thunderstorm which is 10 km tall at a range of 200 km would be detectable at an elevation angle of about 2.2° (see Figure 36). If it is a second trip on radar with a PRF of 1000 Hz, it would show up at 200 km - 150 km = 50 km. If the echo from this storm disappears at 2.2°, it's indicated height would only be 2 km. This is a ridiculously small height for a strong storm, so you should expect range aliasing.

Finally, second trip echoes can sometimes be recognized by their reflectivities. The power received from a storm decreases according to $1/r^2$. If our storm being displayed at 50 km were real, it would have a certain reflectivity. If it is really at 200 km, however, the power returned from it would be $(200/50)^2$ less than if it were at 50 km. So the returned signal would be 16 times less. On a decibel scale this would be 12 dB less than if it were at its indicated range. Unfortunately, since we do not know the true reflectivity of a storm without the radar giving it to us, we cannot be sure that a weak echo is simply a weak storm and not a second-trip storm. Nevertheless, low reflectivity combined with shape and height information can help differentiate real from multitrip echoes.

There is one guaranteed-or-double-your-money-back way to unambiguously determine if echoes are range aliased or not: **Change the PRF!** If we change the PRF and watch the positions of echoes, all correct echoes will not change their range whereas range-aliased echoes will shift in or out in range, depending upon whether the PRF is increased or decreased.

Alternatively, we can avoid range aliased echoes by using a **PRF** so low that r_{max} is so large that range aliasing cannot take place.

6.2. Elimination of Second Trip Echoes (Range Unfolding)

1) Phase-coding (random phase) of the transmitted signal is employed to filter out range-overlaid echoes. This phase-coding helps in identifying the second-trip echoes from the first-trip echoes for effectively filtering and displaying them in their appropriate range.

2) Change the PRF

3) Use a different PRF every 2-3 pulses, if echo moves, get rid of it!

7. VELOCITY UNFOLDING

If a particle's radial velocity is outside the range of the nyquist interval, then the radial velocity will be **aliased or folded**. This is called **velocity folding/aliasing.**

Example: if nyquist velocity is 25 m/s and the particle's radial velocity is -30 m/s, then it will fold over and the radar will interpret it as +20 m/s

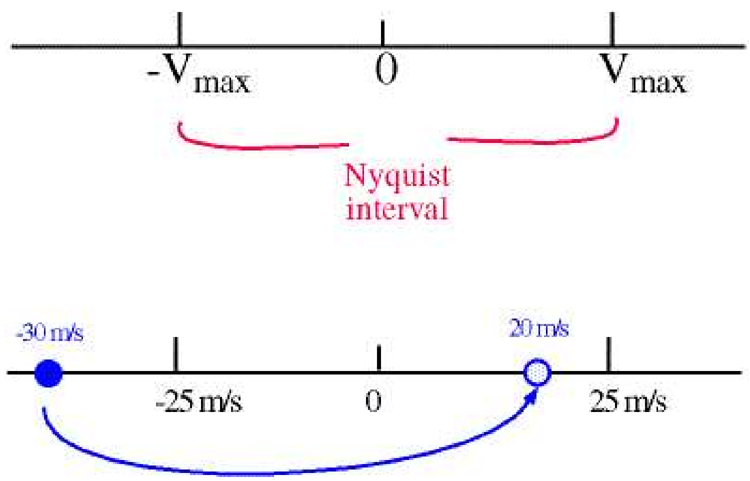

Figure 37: Velocity Folding or Aliasing.

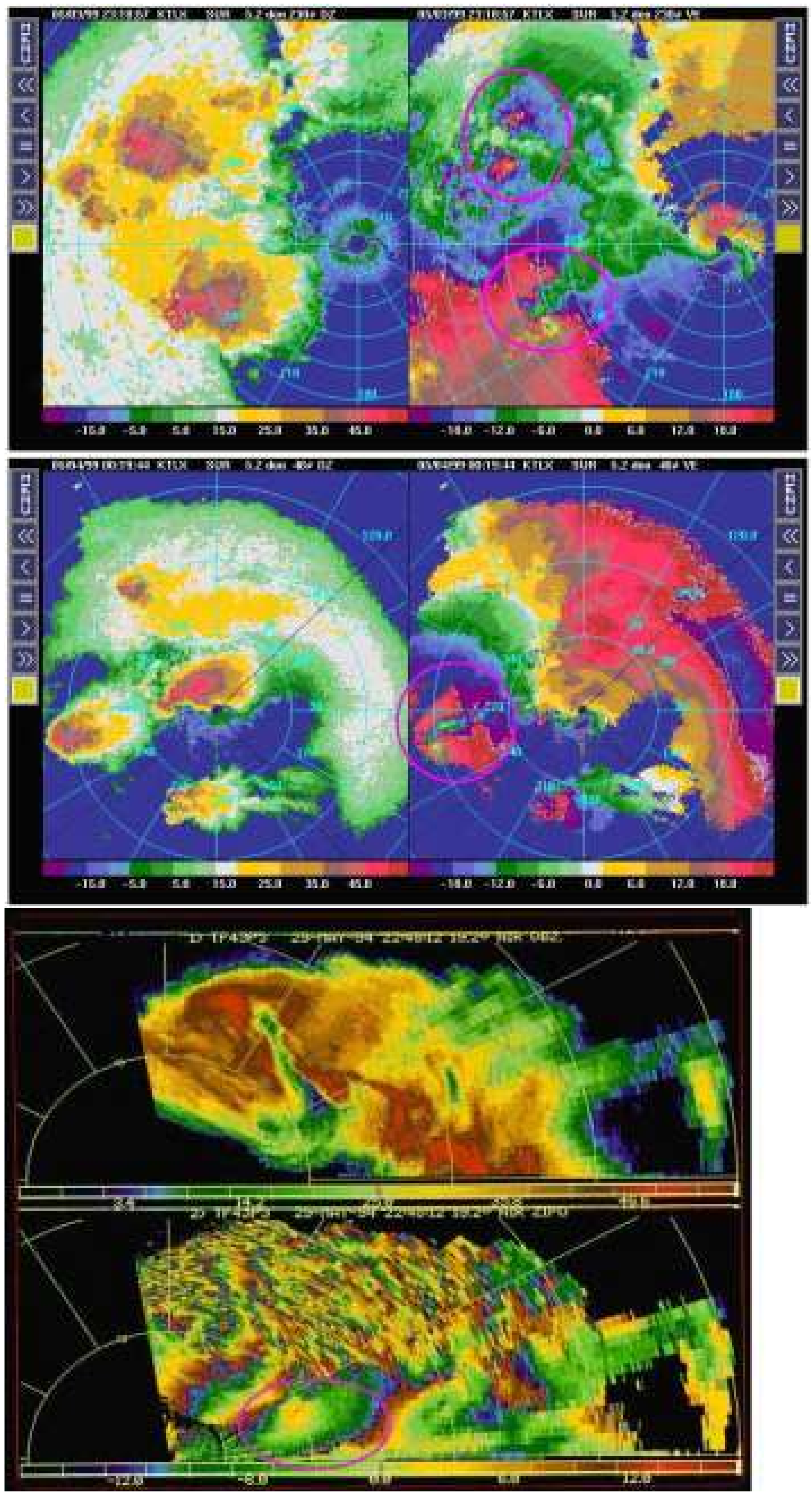

Figure 38: Folded Velocity Examples.

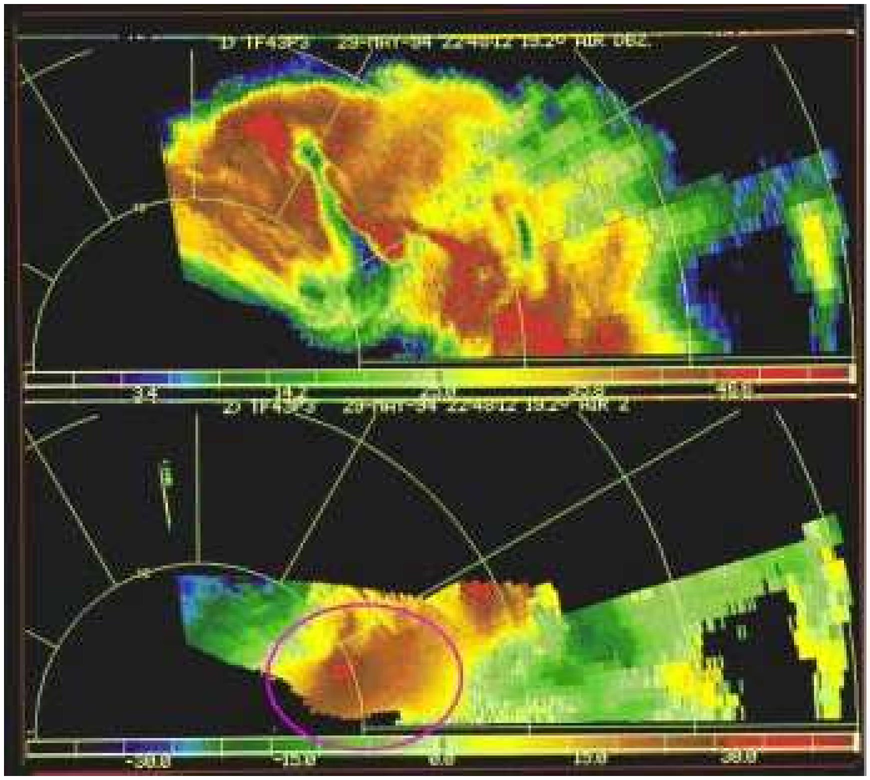

Figure 39: Unfolded Velocities for This Storm.

7.1. Staggered PRF for Velocity Unfolding

The maximum radar range is related to the PRF in inverse proportion, while the maximum velocity is related to PRF in direct proportion. Thus for a given range, there is an upper limit for maximum velocity measurable unambiguously. But there are techniques to double or triple the maximum unambiguous velocity by staggering the PRF or using dual PRF. Pulse-transmission rate is toggled from a high value to a low value and vice versa, for every set of fixed number of pulses. The velocity estimates from both sets can be combined suitably to increase the composite unambiguous velocity. Velocity aliasing can cause the two velocity estimates to vary significantly, and these differences can be used to resolve the true velocity. A velocity that has actually exceeded the nyquist velocity can be ‘unfolded’ to its true velocity. This is achieved by using **staggered PRF**.

Two different, but related, PRF are used for alternating output rays of data i.e. each 1 deg of azimuth.

A 2:3 PRF ratio provides a x2 increase of the apparent nyquist velocity.
A 3:4 PRF ratio provides a x3 increase.
A 4:5 PRF ratio provides a x4 increase.

The technique works by searching for a correlation of the phase shift of the target for the each PRF in use, taking into account that each PRF will produce a **different phase shift** for the same source velocity.

The technique is not without its drawbacks; firstly it relies upon a uniform transition in velocities from ray to ray to allow the correct unfolding estimates to occur. It also introduces several more images of the clutter filter notch previously described, which may result in the elimination of valid rainfall data and produce “spoking”.

Velocity without unfolding method

$$F_{dmax} = \frac{PRF}{2} = \frac{2V_{max}}{\lambda} \Rightarrow v_{max} = \frac{PRF * \lambda}{4}$$

For PRF = 1200 ➔ f_{dmax} = 600 Hz ➔ $v_{max} = 300*\lambda$ =16 m/s

800Hz which corresponds to **21,33m/s** in real, but Radar sees this echo as
200Hz which corresponds to 5,33m/**s** for **PRF: 1200Hz (v_{max} =16m/s)** and
350Hz which corresponds to 9,33m/**s** for **PRF: 900Hz (v_{max} =12m/s**)

Velocity with Dual PRF Technique:

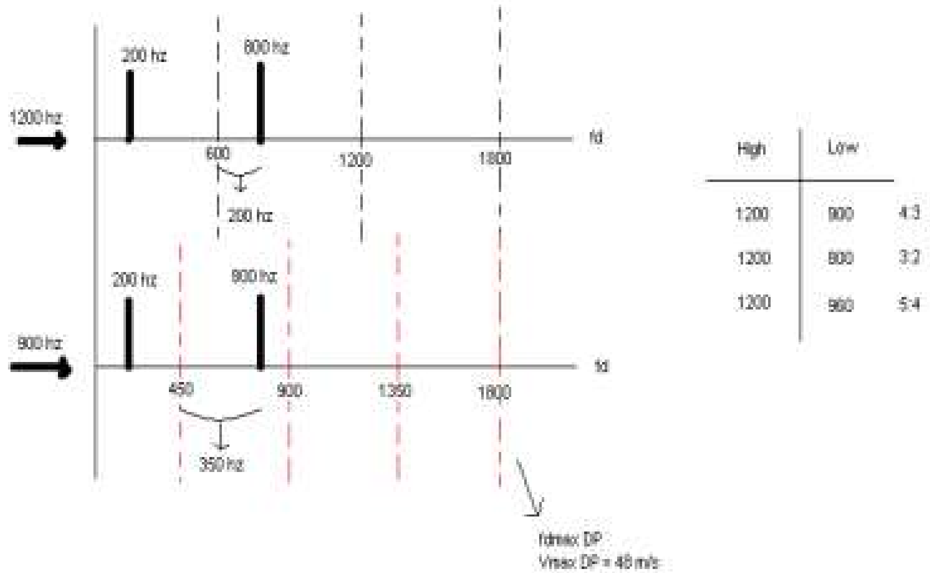

Figure 40: Dual PRF Technique.

If 3:4 PRF Ratio applied, folding intersection of $F_{d\ max}$ for these two PRF will be 1800Hz
In this case new $F_{d\ max}$ will be 1800Hz. This means that, radar can detect up to 48m/s), Velocity can be calculated by using two incorrect velocity(5,33m/s and 9,33m/s) with dual-PRF algorithm as 21.33m/s.

PRF Ratio	**$F_{d\ max}$**	**V_{max}**	
2:3	**1200Hz**	**32m/s**	**(if PRF_1:1200Hz and PRF_2:800Hz)**
3:4	**1800Hz**	**48m/s**	**(if PRF_1:1200Hz and PRF_2:900Hz)**
4:5	**2400Hz**	**64m/s**	**(if PRF_1:1200Hz and PRF_2:960Hz)**

7.2. Recognizing Velocity Aliasing

How do velocity-aliased echoes appear on a radar display? The answer to this depends upon where the aliasing takes place. If a large region of echo is being detected by a Doppler radar and a region within it exceeds V_{max}, then there will be an abrupt change in velocities surrounding the aliased region. For example, if the storm is moving away and part of it is moving away faster than V_{maxt} then strong receding velocities would surround a region with apparently strong approaching velocities. Such a discontinuity is usually quite visible, and it is obvious that velocity folding is taking place.

If the storm causing range folding is completely isolated such that there is no surrounding echo, the velocities from the storm may appear entirely correct even though they have been folded into the wrong velocities. This would make recognizing velocity-folded data much more difficult. Fortunately, such isolated situations are not very common, so this is usually not a major problem. There are almost always several echoes on a display at the same time (perhaps even more so when velocities are so strong as to be folded), so velocities of nearby echoes are often useful to indicate whether folding is taking place or not.

A more difficult situation, however, occurs when C- or X-band radars are measuring storm velocities. For these radars $\mathbf{V_{max}}$ can be moderately small. Thus, it is possible to have velocities which are not just folded once but are folded twice or more. This can make it extremely difficult to tell what the true velocities are from a quick visual inspection of the radar display.