LASERNET ®

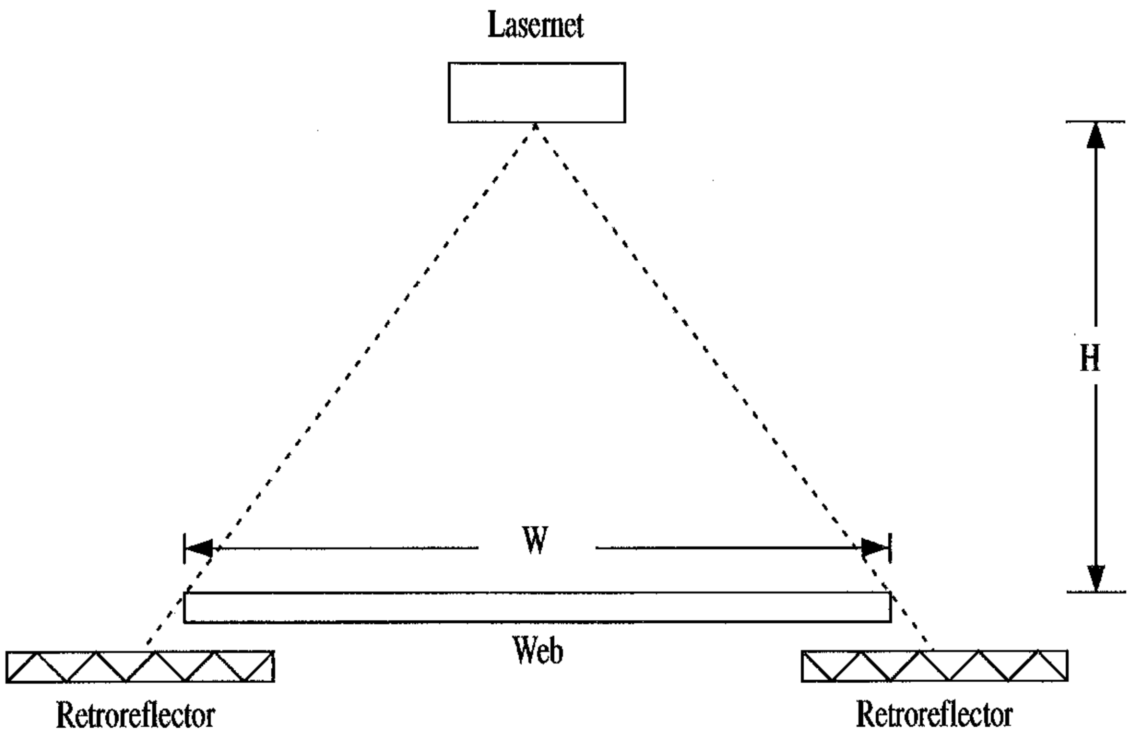
TECHNICAL TIPS HANDBOOK

- **Fundamentals**
- **Installation**
- **Communications**
- **Applications**

NAMCO

Publication No.: LNMS01-B
Issued: July, 1991

WEB WIDTH SCALE AND OFFSET



PROCEDURE FOR SETTING SCALE AND OFFSET

Once the physical configuration is set up, the scale factor and offset can be easily determined if a known width device or web is placed in the beam. Then:

1. Put the Web Width Meter in the SETUP mode. The digital value shown immediately after "SETUP" gives the Lasernet Count Value corresponding to the known Web Width "W". Let C equal that value.

2. The Scale Factor SF to use is calculated by: SF = W/C SF can range from -3.2000 to +3.2000. Choose the value of W to be in the units of width desired.

3. The Offset Value is 0.0000. Width is seldom offsetted.

EXAMPLE:

If W = 10.00 Centimeters, and C = 2650. Then (using digits only) SF = 1000/2650 = 0.3774. One could use 0.0377 or 0.0038 depending on how many significant places are to be displayed. Thus, Lasernet sends "2650" when the web is exactly 10.00 cm. The Display multiplies this by 0.3774 and produces 1000 on the front panel. Set the decimal point independently to produce 10.00.

If the physical setup is impossible to use, then the above procedure can be used if a theoretical value for C is calculated. This depends on the geometry of the desired setup, and some trigonometry to account for Lasernet's Web Width Compensation. The value for C is determined from:

C = 9778.48 x W/H

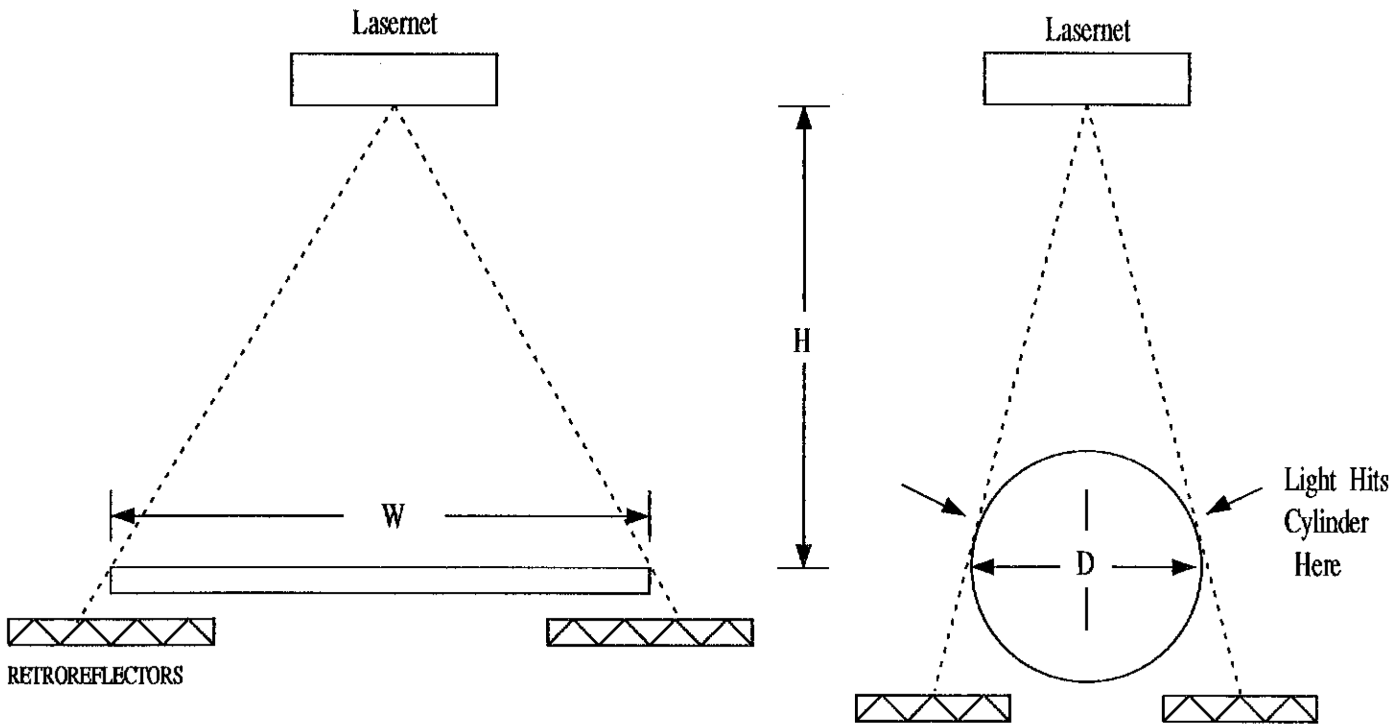
EXAMPLE:

If W = 10.00 cm., and H = 36 cm., then

C = 9778.48 x (10/36) = 2716

Now use this value for C in step 2 above.

WEB WIDTH AND CYLINDER DIAMETER



DISCUSSION OF WEB OPTIONS

WEB WIDTH MEASUREMENT

Whenever a Web's Width is to be measured, and possibly be displayed on a WEB WIDTH METER, Lasernet OPTION H2 must be set to "1". This produces a compensation to the RANGE COUNT so that the Range Count is linearly proportional to Web Width, independent from the Web's lateral position. The Web must always be maintained at a fixed distance H, otherwise an error in reading is produced.

CYLINDER DIAMETER MEASUREMENT

The measurement of the Diameter of a Cylinder entails a slightly different setup. Since the scanning laser beam detects the edge of the Cylinder at a point tangent to the surface, width compensation needs to be different from the Web Width configuration. Fortunately if the center of the cylinder remains at a fixed distance H from Lasernet, then the RANGE COUNT will be linearly proportional to DIAMETER if both Tangent Compensations (HO and H2) are OFF. The LN150 WEB WIDTH METER can now be used to provide accurate displays of Cylinder DIAMETER. Appropriate Scale and Offset Factors must be set in the meter.

BASIC LASERNET COMMUNICATIONS PROGRAM

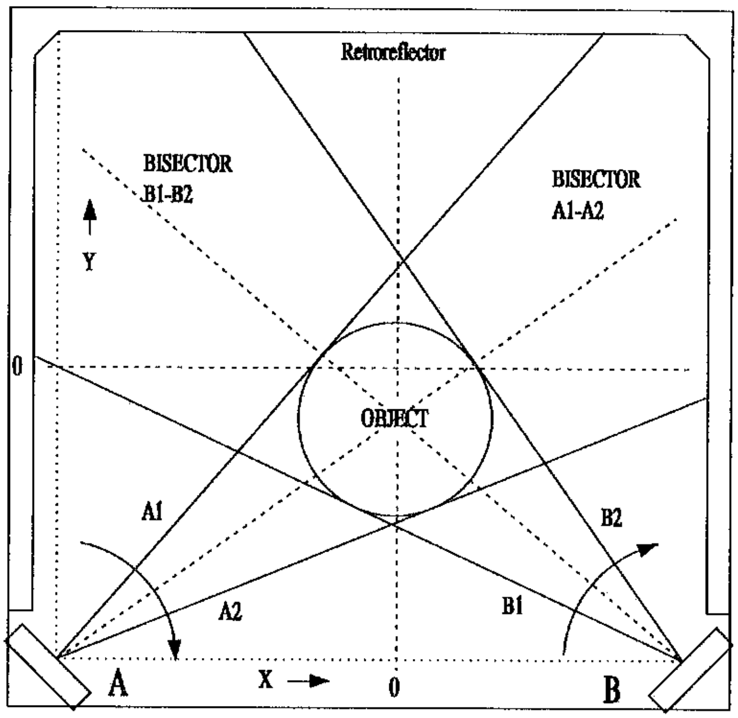
```
10    REM ***  LASERNET COMMUNICATION FRAMEWORK LNCOM96.BAS  ****
20    REM *** USE THIS PROGRAM TO WRITE LASERNET APPLICATIONS******
30    REM *** INSERT USER PROGRAM BETWEEN LINES 1000 AND 14999*****
40    REM *** USE GOSUB 15000 TO GET RANGE VALUE R AND ANGLE VALUE A
50    REM *** R AND A ARE IN FLOATING POINT, RC$ AND AC$ ARE ASCII*
60    REM *** CONFIGURE LASERNET WITH LF SUPPRESSED (.B41<CR>)*****
70    REM *** INSERT A TEST FOR Q IN YOUR PROGRAM, LIKE 2001, 2002*
80    REM *** CHANGE LINE 110 FOR OTHER BAUD RATES****************
100   REM ** PART 1 —COMMUNICATION CHANNEL SETUP—*************
110   LET RS$="COM1:9600,N,8,1,RS,CS,DS,CD"' COM DEFINITION
120   CLOSE' RESET COMMUNICATIONS
130   COM(1) OFF: KEY(1) ON' KEY(1) = F1 FOR STOPPING RUN
135   LET Q=0
140   ON KEY(1) GOSUB 17000'STOP RUN
150   ON ERR GOSUB 18000' COMMUNICATIONS ERROR TRAP
160   IF Q=1 THEN 20000
170   IF Q=2 THEN 19000
180   OPEN RS$ AS #1
200   REM TO GET RANGE R AND ANGLE A VALUES USE GOSUB 15000
1000  REM ********************************************************
1001  REM **********USER'S PROGRAM AREA LINES 1000-14999**********
1004  REM **EXAMPLE PROGRAM FOR CONTINUOUS DISPLAY—F1 STOPS IT***
1999  CLS
2000  GOSUB 15000' GET LASERNET VALUES
2001  IF Q=1 THEN 20000' TEST FOR PROGRAM EXIT
2002  IF Q=2 THEN 19000' TEST FOR COM ERRORS
2010  IF R=0 THEN 2200' NO TARGET IN VIEW IS DETECTED
2020  PRINT R,A' SHOW VALUES ON THE SCREEN
2030  REM *** YOU COULD USE R AND A IN CALCULATIONS HERE *********
2040  GOTO 2000' REPEAT LOOP ENDLESSLY
2200  PRINT "NO TARGET IN VIEW"
3000  GOTO 2000' REPEAT LOOP ENDLESSLY
14999 REM *********END OF USER PROGRAM AREA**********************
15000 REM *** PART 2 - LASERNET COMMUNICATION SUBROUTINE ********
16000 REM *** VARIABLES FOR RANGE AND ANGLE: R AND A ************
16010 COM(1) ON
16011 PRINT #1,"" SEND ONE CR
16015 LET V=TIMER
16020 LET N=LOC(1)' N = CURRENT NUMBER OF BYTES IN BUFFER
16030 WHILE N<1' WAIT FOR LN TO RETURN DATA
16040 IF (TIMER-V)>.1 THEN 16011' RESEND CR IF NO RESPONSE
16050 LET N=LOC(1)' TAKE ANOTHER LOOK
16060 WEND' GET OUT OF WAIT LOOP IF DATA IS PRESENT
16200 INPUT #1, RC$' INPUT RANGE COUNTS
16210 INPUT #1, AC$' INPUT ANGLE COUNTS
16215 IF RC$="?" THEN 16300' LASERNET SENDS ONLY ?<cr><cr>
16220 INPUT #1, CR$' CLEAR FINAL <CR>
16300 LET R=VAL(RC$)' CONVERT TO FLOATING POINT
16310 LET A=VAL(AC$)' CONVERT TO FLOATING POINT
16900 COM(1) OFF' STOP COMMUNICATIONS
16990 RETURN
17000 REM *** SUBROUTINE TO SET VALUE OF Q FLAG *****************
17010 LET Q=1
17020 RETURN
18000 REM *** SUBROUTINE TO HANDLE ERRORS************************
18010 LET Q=2
18020 RETURN
19000 REM *** ERROR HANDLING AND EXIT ***************************
19010 PRINT "ERROR= ";ERR
19020 PRINT "ERROR LINE= ";ERL
20000 REM *** GENTLY END PROGRAM ********************************
20010 COM(1) OFF
20020 CLOSE
20030 END
```

DIAMETER, POSITION & OUT-OF-ROUND MEASUREMENT (USING TWO LASERNETS)

BASIC

Two Lasernets can be used to measure the position of a round object, its average diameter, and a measure of its out-of-roundness using the following algorithm. The closer the ojbect is to a circle, the better the accuracy.

The position of Lasernet A is (ax, ay) and B (bx, by). Angles A1, A2, B1, B2 are determined by Lasernet. All angles are measured from horizonal, counter-clockwise being positive.



ALGORITHM

The following are mathematical steps to find the position of the Object, its average radius, and a measure of its Out-of-Roundness. STEPS:

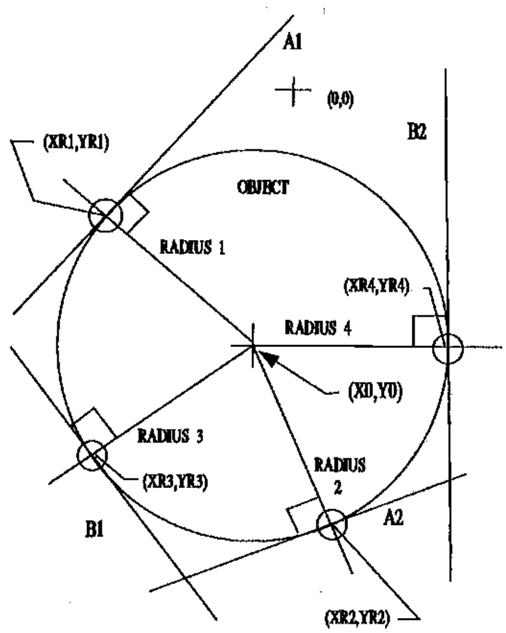
1. The center of the object is calculated at the intersection of the bisector lines of A1-A2 and B1-B2. The calculated center of the object is (XO, YO).

2. Four RADII are determined from the calculated center to each of the four scan lines A1, A2, B1, B2.

   a) Determine the Equation of each scan line of the form y=Mx+B i.e. (y=MA1x+BA1 for each line), noting that M=TAN (A1), etc. for each scan line. The intercept B is calculated using the position location points of each Lasernet (ax,ay),(bx,by).

   b) Determine the equation of the line through the center point perpendicular to each of 4 scan lines. Use the fact that these Radial lines have a slope equal to -1/MA. These are like y=MR1x+BR1.

   c) Find the four points intersecting radial and scan lines, (XR1,YR1), (XR2,YR2), (XR3,YR3), (XR4, YR4).



3. The length of each Radius is found from:

$$R = [\ (XR-XO)^2 + (YR-YO)^2\ ]^{0.5}$$

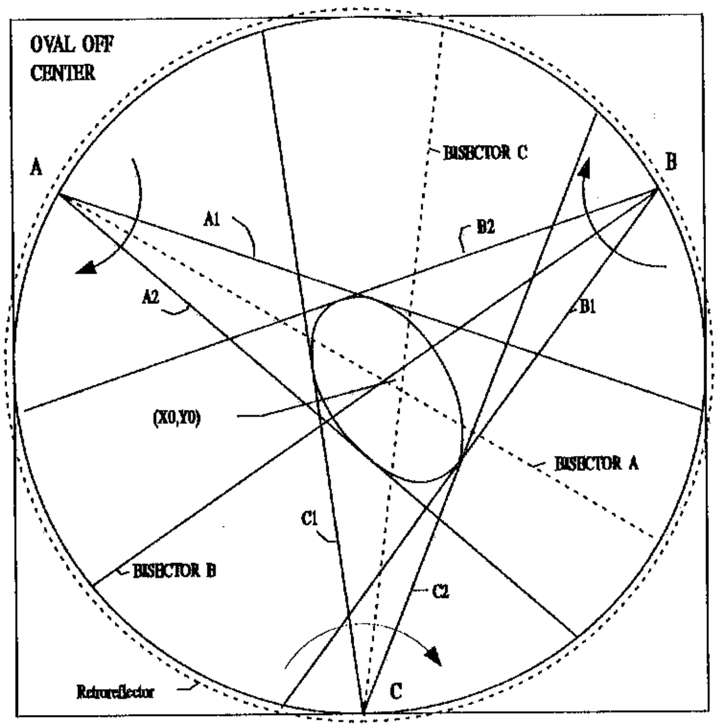
4. The Percent of Out-of-Round is given as:

$$\%\ O\ of\ R = [(Rmax-Rmin)/Ravg] \times 100\%$$

DIAMETER, POSITION & OUT-OF ROUND MEASUREMENT (USING THREE LASERNETS)

BASICS

Two Lasernets can be used to measure round parts as discussed in TIP No. 4. However, if more than two Lasernets are used, more information is determined, and a better analysis is made. This TIP discusses the application of three Lasernets to measure oval parts, using the basic approach discussed in TIP No. 4. Here 6 RADII are computed and a better measure of average radius (diameter), position and OUT-OF-ROUND percentage and RMS variance from circular. The configuration shown at the left places three Lasernets at 120 degree positions around the part. Six angles, A1, A2, B1, B2, C1, C2 are determined by Lasernet scanning.



ALGORITHM

The following are mathematical steps to find the position of the Object, its average radius, and a measure of its Out-of-Roundness. STEPS:

1. The center of the object is computed as the average of three bisector crossing points, assuming that the scan lines are reasonably perpendicular. Avoid near co-linear scan data.

2. Six RADII (R1,R2,R3,R4,R5,R6) are computed as lines from the center, perpendicular to each scan line.

3. Intersecting points determine the length of each RADIUS.

4. The Length of each RADIUS is:

   $$R = [(XR-XO)^2 + (YR-YO)^2]^{0.5}$$

5. The Average Radius is:

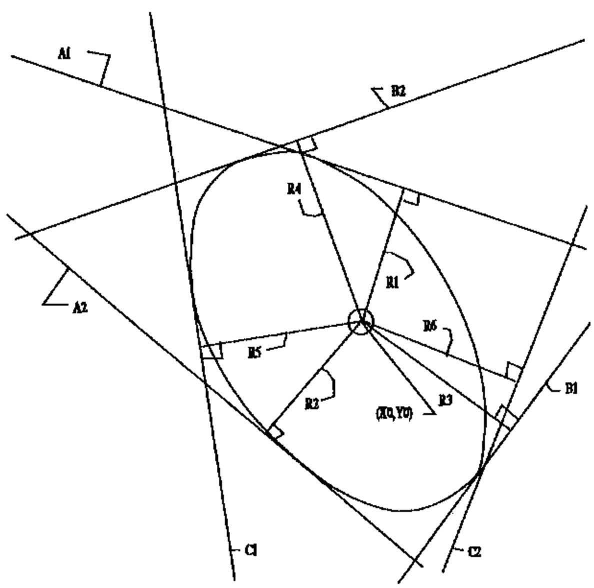
   $$Ravg = (R1+R2+R3+R4+R5+R6)/6$$

6. The RMS Variance from a Circle is:

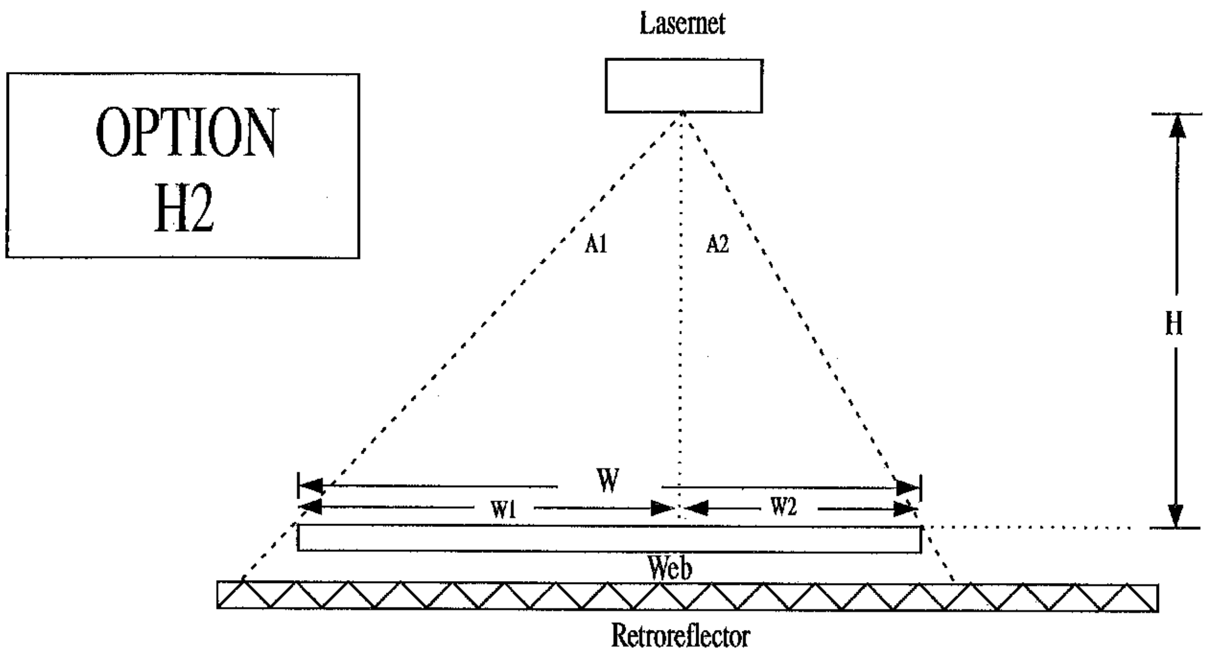
   $$R_{RMS} = [1/6 \sum_{n=1}^{6} (R_n - R_{avg})^2]^{0.5}$$

7. The Percentage Peak-to-Peak Variation is:

   $$\% \text{ Var.} = (R_{MAX} - R_{MIN})/R_{AVG} X100$$



WEB WIDTH TANGENT CORRECTION



HOW IT WORKS

Whenever the WEB WIDTH TANGENT CORRECTION OPTION (H2) is used, Lasernet modifies the RANGE COUNTS value to produce a new RANGE COUNTS value which is linearly proportional to the true width of the web, rather than just a value which is linearly proportional to the angle subtended by the web. Lasernet breaks the web target into 2 pieces, a triangle from the centerline of the scan to one edge of the target, and a second triangle from the centerline to the other edge of the target. Each portion of the actual web (W1 and W2) is corrected for RANGE COUNTS, and the final counts value is the sum (or difference) of the two counts.

When the Tangent correction is OFF, Lasernet sends out a RANGE COUNT value equal to:

$$C = C1 + C2, C1 = (A1/90) * 15360 \text{ and } C2 = (A2/90) * 15360 \qquad (1)$$

When the Tangent correction is ON, Lasernet sends out a RANGE COUNT value equal to:

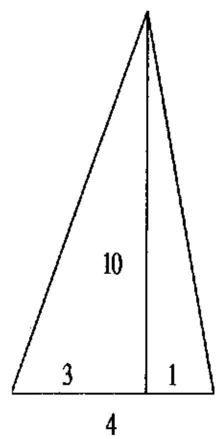
$$C = C1 * \left(\frac{180 * TAN(A1)}{A1 * \pi} \right) + C2 * \left(\frac{180 * Tan(A2)}{A2 * \pi} \right) \qquad (2)$$

Notice that C1 and C2 are modified by a factor dependent on A1 or A2. Web width can now be simply written as:

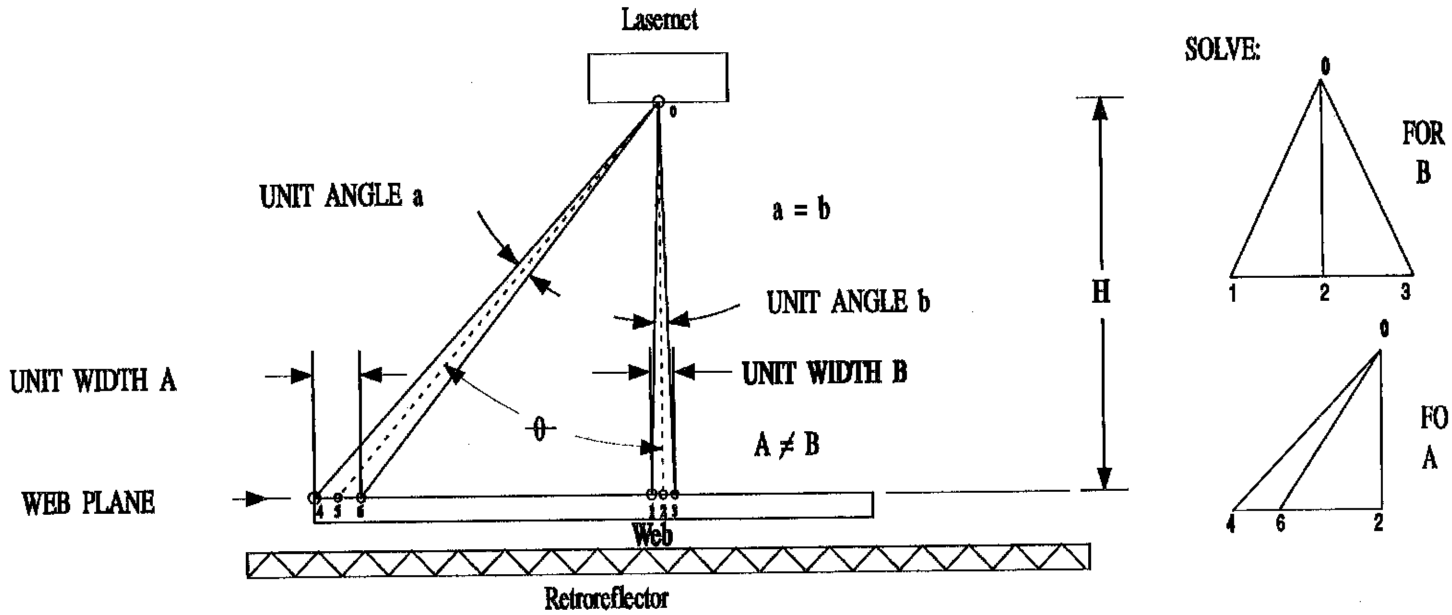
$$W = W1 + W2 = C1 * (\ ) + C2 * (\ ) = K * C \qquad (3)$$

Example:

If H=10", W=4", and the web is positioned 3" and 1" from centerline, then A1=Arctan (3/10)=16.70 deg., and A2=Arctan (1/10)=5.71 deg. With Web Tangent Correction off, (1) gives a Range Count of 3825. With Web Tangent correction ON, (2) gives a Range Count of 3911 counts.



ACCURACY OF WEB WIDTH MEASUREMENTS



DISCUSSION

ACCURACY and MEASUREMENT RESOLUTION are usually the first values of interest when Web Width Measurements are desired. Since Lasernet is a radial scanning device, these values may be confusing, being that a linear measurement of a Web is desired. The question becomes: What is the expected LINEAR MEASUREMENT ACCURACY AND RESOLUTION OF THE WEB. To answer this question, first determine the angular resolution of Lasernet. Remember that:

ANGULAR RESOLUTION OF LASERNET = 90°/15360 COUNTS (1)

Consider the Figure above. Assuming that the UNIT ANGLES A and B are equal to the angular resolution of Lasernet (i.e. 90/15360 = 0.005859 degrees), then the basic Web Width A does NOT equal UNIT WIDTH B. The Web Width resolution depends on the horizontal position of the web. Assuming that the Lasernet is positioned H units from the Web, and that unit angles are a and b, then the Web Width corresponding to a and b are each the solution of two triangles. For Web Width B, solving 0-2-3 and 0-1-2 gives:

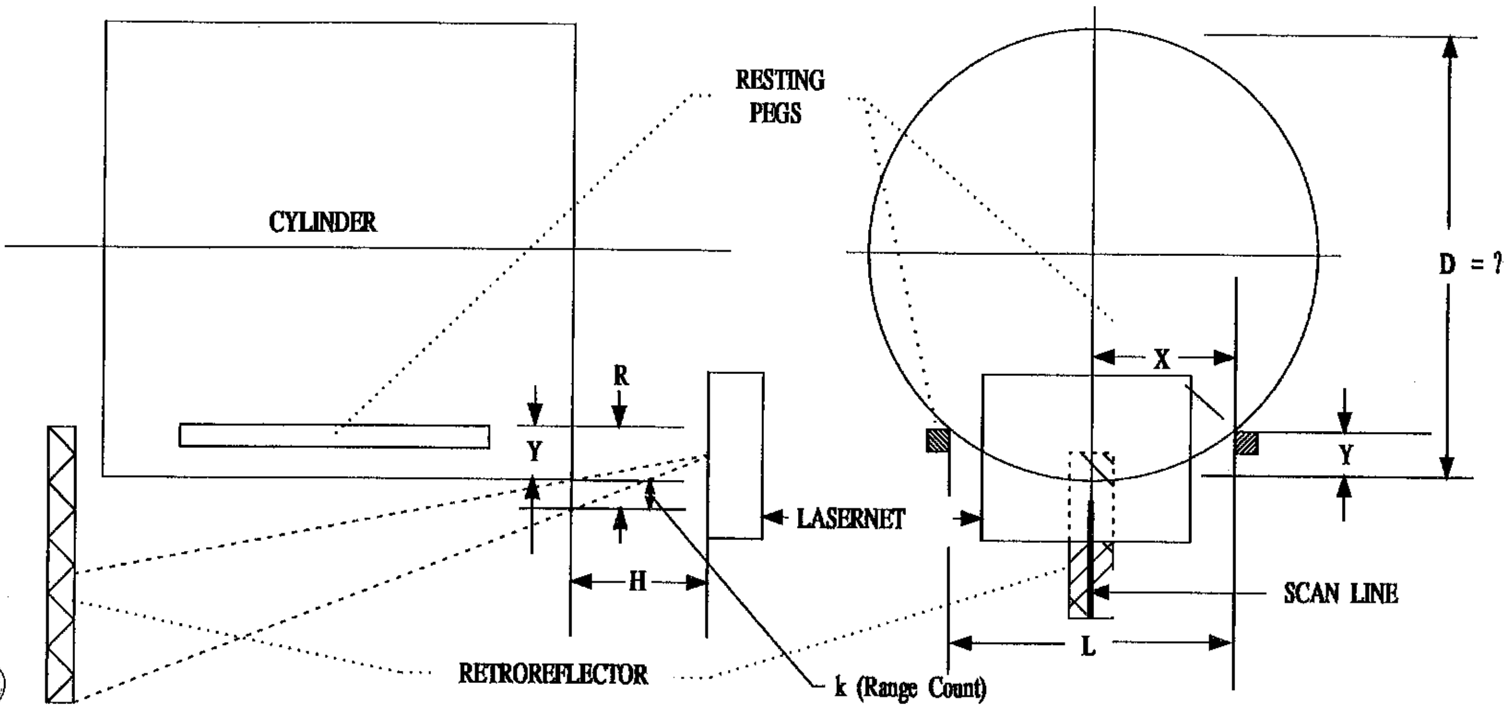
$$B = H \tan (a/2) - H \tan (-a/2) = 2H \tan (a/2) \qquad (2)$$

Similarly for Web Width A, triangles 0-4-2 and 0-6-2 must be solved for. Using the Web Position angle 0, then A is given as:

$$A = H \tan (0 + a/2) - H \tan (0 - a/2) \qquad (3)$$

As an example if H=10 inches and 0 = 45 , then A=0.0020" and B=0.0010". Thus the web is measured with twice the resolution in the center of scan than at the ends of the scan. Accuracy is determined by how many units of resolution are varying measurement to measurement. Experimentally, Lasernet can measure repeatably within +/- 2 units of measurement (i.e. 2 sigma=2 counts, =95% of time). Beware of other sources of error such as electrical noise and non-perpendicular Web Plane.

DIAMETER OF RESTING CYLINDER



DISCUSSION

The Diameter of a Cylinder can be measured accurately with Lasernet if the cylinder is placed on resting pins of known position. This is essentially the position of two points on the circle of the cylinder. Using Lasernet in a fashion similar to Web Width Measurement, the value Y can be determined accurately, and therefore, the Diameter D can be calculated using the following formula:

$$D = (X^2/Y) + Y \qquad (1)$$

where D is the Diameter of the object, X is half of the separation distance between the pegs, and Y is the measurement from Lasernet.

The peg can be round, but should be as small as possible.

A square peg is recommended unless it causes object damage.

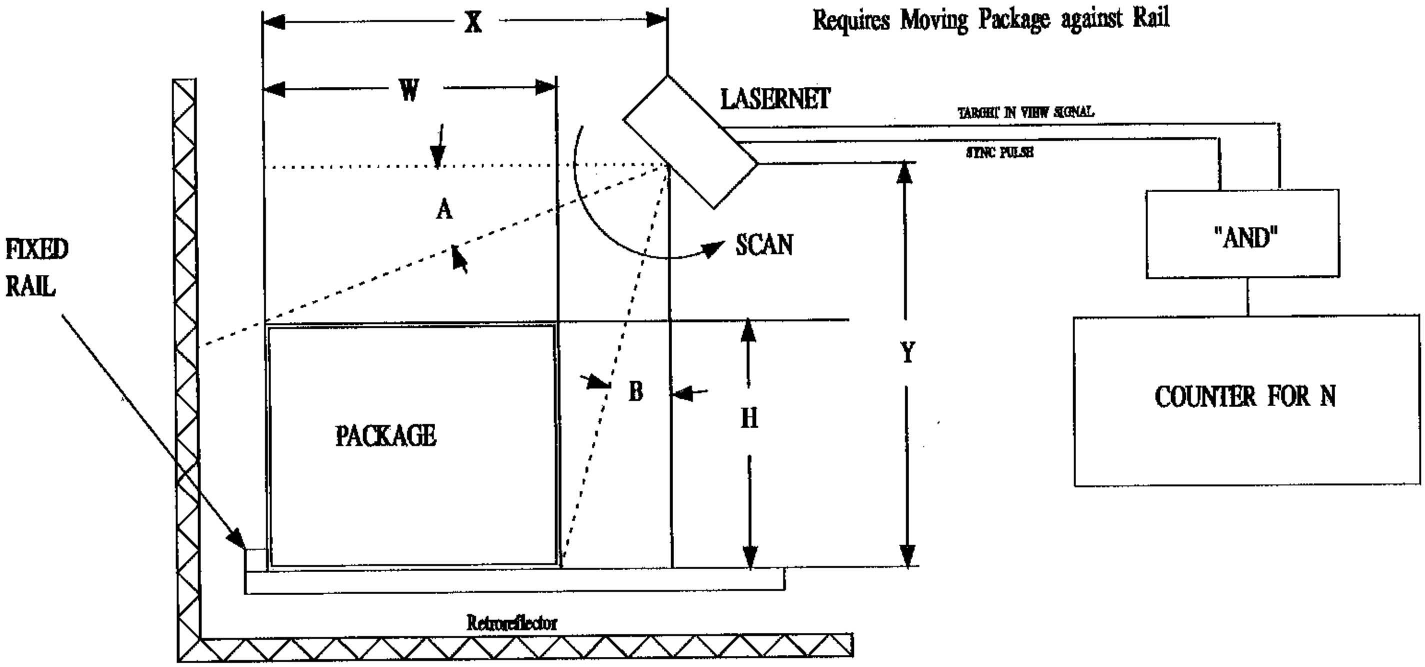
The separation between pegs should be as large as possible for the maximum sensitivity of the Lasernet measurement Y to the diameter D.

The Distance from Lasernet to the object H should be kept constant. When so, Web Width tangent correction will allow a linear output of Y. The retro-reflector should be constructed with a fixed length R, thus Lasernet determines R, and the measurement Y is just:

$$Y = R - k \text{ x(Range count)} \qquad (2)$$

(Web Width Tangent Correction On)

SIZING OF MOVING RECTANGULAR PACKAGE (USING ONE LASERNET)



DISCUSSION

A Rectangular Package's Dimensions can be determined with one Lasernet and a timing circuit. The package must be positioned againt the X=O rail, and this package must be moved past the scanning Lasernet at a fixed velocity. The dimensions of Height H, Width W and Length L can be determined as follows:

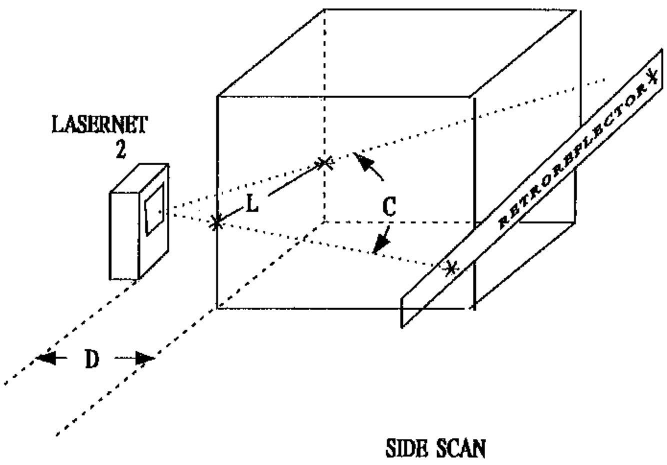
HEIGHT

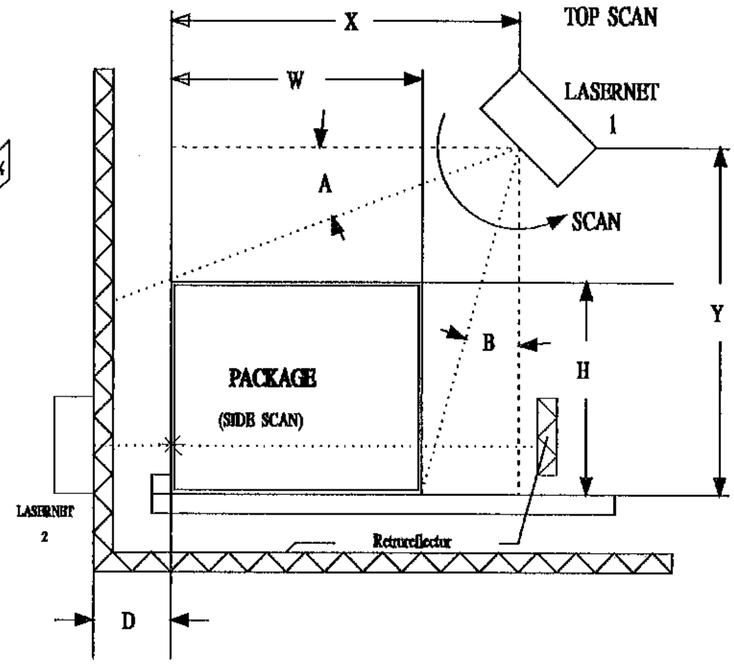
Lasernet can determine the angle A by using the Option H3, by sending the raw edge counts, or by using Options H4 and H5 with B1=0 and H1=0. Here the leading angle A is reported in counts as a, and the Range counts value, the number of counts from angle A to the beginning of angle B is reported as b.

Then	$A = (a/15360)*90^\circ$	(1)
and	$B = 90-((a+b)/15360)*90^\circ$	(2)
therefore for H:	$H = Y - X * \tan(A)$	(3)
WIDTH	$W = X - Y * \tan(B)$	(4)
LENGTH	$L = V * N * (0.05 \text{ seconds})$	(5)

where V is the velocity of the moving package, and N is the number of scans of Lasernet with the Target-in-View.

SIZING OF FIXED RECTANGULAR PACKAGE (USING TWO LASERNETS)





DISCUSSION

A Rectangular Package's Dimensions can be determined with two Lasernets. The Height and Width are determined as was done in Lasernet Tip 9. The length is measured with a second Lasernet operating in a Web Width orientation. This procedure can be used to measure packages which are stationary. The package must still be placed against a fixed rail. Therefore:

HEIGHT and WIDTH

Lasernet can determine the angle A by using the Option H3, by sending the raw edge counts, or by using Options H4 and H5 with B1=0 and H1=0. Here the leading angle A is reported in counts as "a", and the Range counts value, the number of counts from angle A to the beginning of angle B is reported as b.

Then $A = (a/15360) * 90^\circ$ (1)

and $B = 90-((a=b)/15360) * 90^\circ$ (2)

Therefore for H: $H = Y - X * \tan(A)$ (3)

and Width W: $W = X - Y * \tan(B)$ (4)

LENGTH

Length is easily determined from the Range Counts of Lasernet 2 when it Web Width tangent correction is used (H2):

$L = K * \text{Range Counts}$ (5)

PRECISION WEB WIDTH MEASUREMENT FACTORS

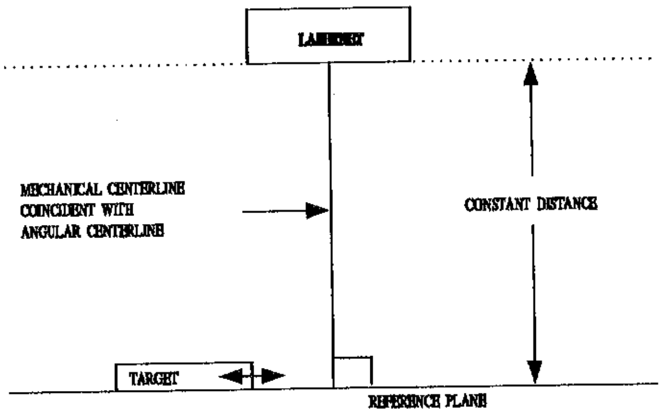


FIGURE 1

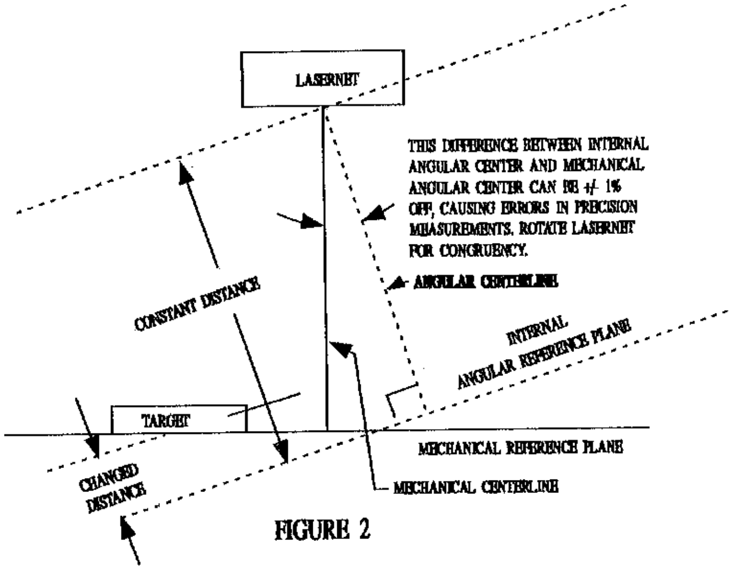


FIGURE 2

DISSCUSSION

The precise measurement of Web Width depends upon several calibration factors, both physical and computational. Lasernet is capable of extremely fine and repeatable web width measurements, but the precision depends upon the care in setting up and calibrating the system.

1. *Measurement Plane.* The most important factor in precision measurement is to ensure that the target is positioned in the plane of constant distance from Lasernet. The constant-distance plane is the plane for which the scanning laser beam is perpendicular to, at the angle Lasernet "thinks" is the *angular centerline*. Lasernet is inherently calibrated to measure angle to within 1% of a line perpendicular to the face plate. The plane of the mounting brackets is not necessarily oriented better than this.

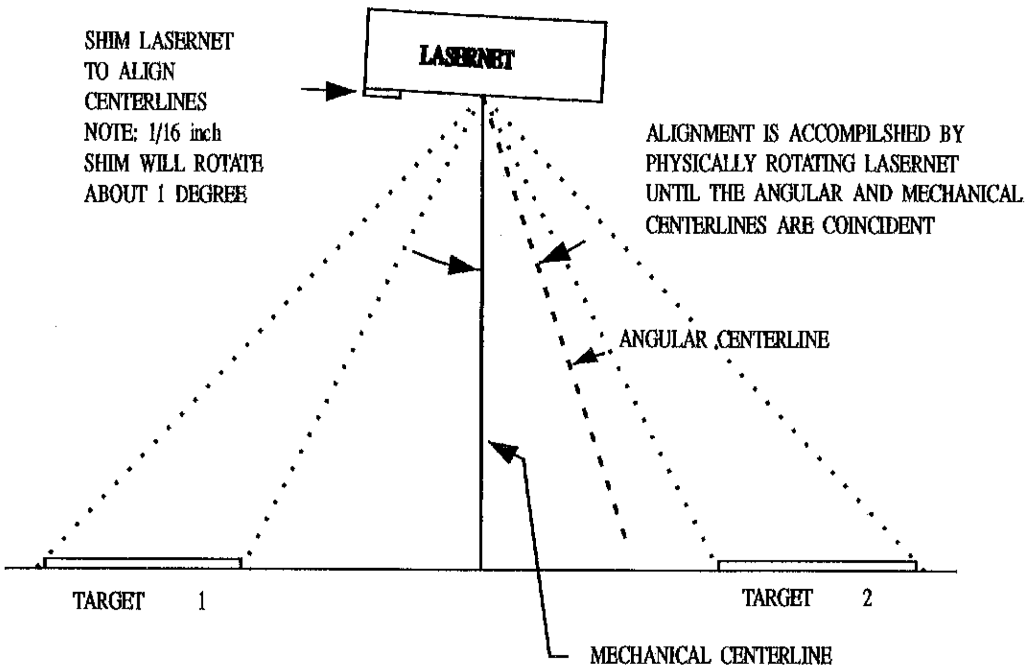
Figure 1 above shows an ideal situation. The target is measured accurately anywhere in the reference plane.

Figure 2 shows the more realistic situation where the "*angular centerline*" of Lasernet is not coincident with the "*mechanical centerline*".

Note that as the target is located at different positions along the reference plane, the effective distance varies, and web width readings will not be identical anywhere along the mechanical reference plane. The solution is to physically rotate Lasernet to align the angular centerline with the mechanical centerline. A follow-up LASERNET TIP will present a simple procedure for this alignment.

2. *Computational Factor.* Once the angular alignment is accomplished, then the web width value is linearly proportional to the Range Counts (assuming that the Web Width Tangent Correction (H2) in on). One normally takes this count value and multiplies it by a constant K to translate the width value to meaningful units, like millimeters. To do this, one usually places a known width target in the reference plane, and deduces the appropriate constant value. However, beware that the target thickness can give a error, especially if the test target is placed near the end of the scan. Use a target with a thickness less than the desired web width dimensional error.

PRECISION WEB WIDTH ALIGNMENT PROCEDURE



DISCUSSION

The Lasernet can be mechanically aligned by checking the Range Count Value for two calibration targets simultaneously, and shimming Lasernet's mounting bracket, thus rotating Lasernet, until the two readings are as close to each other as possible. A final check is to reposition the calibration targets, and recheck the values. As noted in a preceding Lasernet Tip, the thickness of the calibration target should be as thin as possible, and at least as small as the desired width accuracy. The lengths of the two calibration targets should be as close as possible. Care should be taken when placing the targets that they are not skewed relative to the scanning beam.

ALIGNMENT PROCEDURE

The alignment procedure can be mechanized with the aid of Lasernet's Multiple Target capability, and a PC or a terminal with WEB WIDTH and WEB POSITION meters. Lasernet's options should be temporarily changed as such:

1. Set H4=1, H5=0 (report only Range Counts)
2. Set H2=1 (Web Width tangent correction must be on)
3. Set B0=0 (must not merge targets)
4. Set .V14 only (Send .V0 first, then .V14 to allow all targets as valid)

After this, a carriage return command <cr> will cause Lasernet to report two Range Count values. Simply shim one side of Lasernet until the two readings are equal.

If Lasernet is connected to the WEB WIDTH and WEB POSITIONS METERS (LN150), the Width Meter will report the first target's width, and the POSITION meter will report the width of the second target (assuming both meters have the same scale and offset factors.

Another procedure is to simply run the program given by Lasernet TIP 3. Two values representing the Range Counts of each calibration target will be continuously displayed on the screen. Changing Line 2020 from "PRINT R,A" to "PRINT R,A,R-A" will add a third column, the difference between the two targets. Shimming to produce a zero difference will align the system.

LASERNET AND REPEATABILITY

The acuracy of measurements using Lasernet depends upon two sources of error. Lasernet has an inherent internal accuracy in measuring angles to edges of target retroreflectors and has an inherent repeatability due to variations in lasertube output and randomness of the detection of the edge of the light. Understanding these sources of variability will allow one to precisely predict the performance of Lasernet in any application.

ACCURACY SPECIFICATIONS OF LASERNET

The Lasernet Data sheet describes Range Accuracy and Angle Accuracy. Angle acuracy is the percentage of maximum error that is possible in measuring an angle to a target in absolute terms. Given at ± 1%, this means that any target can be repeatably measured from Lasernet to Lasernet to be within 1%. This takes into account mounting bracket error and calibration error. However, this error is mostly an error of constant angle offset, rather than random variation in readings. Lasernet is inherently much more accurate if calibrated on the particular application. Range error is given in context of measuring a distance to a 4 inch target (10 inch for LN120) and is reported up to ±4%. This is the maximum full scale error expected in measuring distance, and outputted by the ANALOG OUTPUT. All digital outputs must be determined related to angle error. Thus ± 4% means that 20 feet distance can be determined within ± 9.6 inches. Better accuracy can be obtained using the digital Range Count data and an external data processor.

INHERENT ANGLE ACCURACY

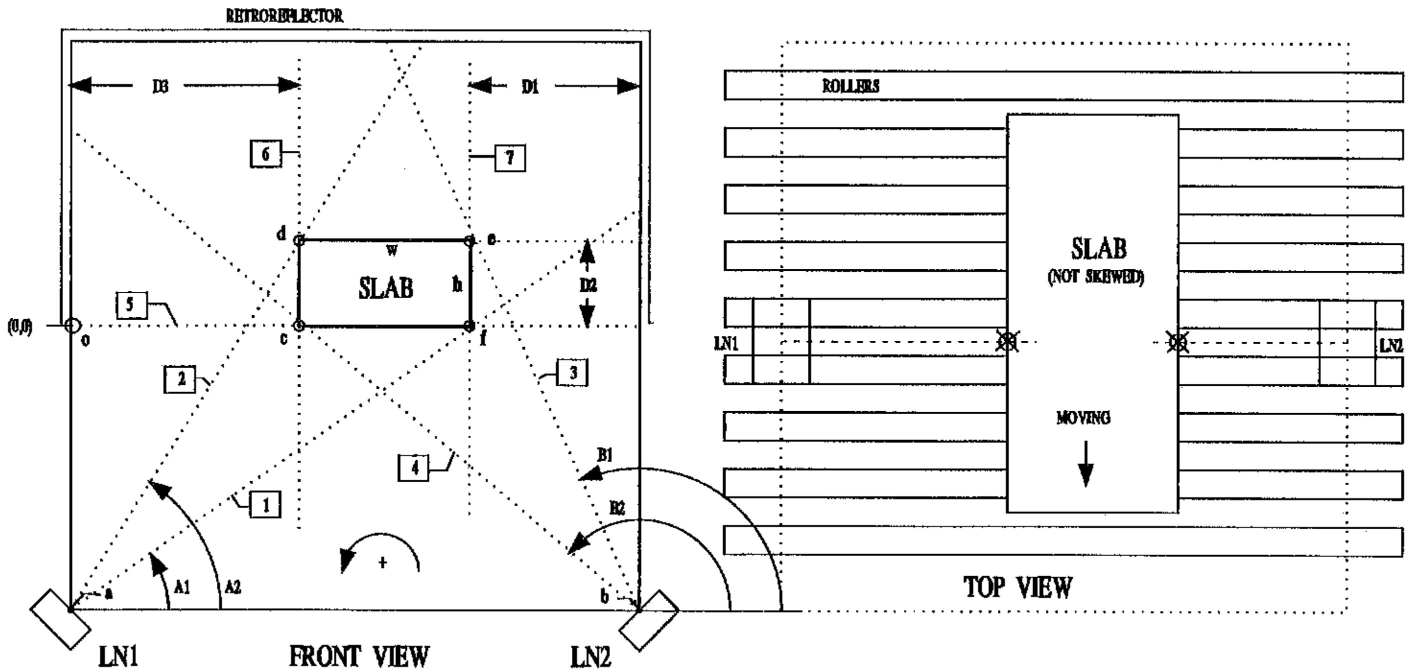
Lasernet is set at the factory to break the nominal 90 degree field of view in to 15360 parts, giving a fundamental resolution of 0.00586°.

Thus each angle count represents an absolute angle increment of 0.00586°. However, due to imprecision in mounting brackets, window location, calibration error, an angle measurement is only accurate to within ± 1%, or ± 154 counts, out of the box. But testing has shown that in any given application that this reading will remain with ± 15 counts for 99% of all measurements over time including warmup (i.e. 1 sigma = 5 counts). Thus the inherent angle accuracy is ± 15/15360, or 0.1%. But remember that the unit must be physically calibrated to get this precision. This accuracy can be diminished by outside influences if application care is not taken.

INHERENT RANGE ACCURACY

Range accuracy here is meant to be the accuracy in determining the RANGE COUNTS (which is inverse to range distance) in an application. Web width measurement use RANGE COUNTS as the proportional value of web width. RANGE COUNTS is derived as the difference in ANGLE COUNTS between the leading and trailing edge of a target. One would naturally expect that accuracy in RANGE COUNTS to be similar to ANGLE COUNTS, (i.e. ± 0.1%). But fortunately the variation which occurs in an angle measurement is about equal within any scan. Thus the uncertainty in measuring the leading edge of a target is about equal to that of the trailing edge. Thus the variability in angle error is subtracted out in a RANGE COUNT reading. Experimentally the inherent RANGE value is repeatable within ± 3 counts (i.e. 1 sigma = 0.84). Thus the inherent RANGE COUNT accuracy can be within ± 3/15360, or ± 0.02% of the time. Careful alignment of an application could give this precision in web width measurements.

SIZING OF A MOVING RECTANGULAR SLAB



DISCUSSION

A slab is moving on rollers and is to be sized for dimensions. Two Lasernets are mounted below the rollers and are scanning upward. The FRONT VIEW gives the various points and lines. (a,b,....e,f,o) are points in the Cartesian Coordinate System. Angles (A1,A2,B1,B2) are measured by Lasernet with + being CCW. The Boxes ([1] [2] .... [7]) are ines in the coordinate system with a form Y=MX+B.

ASSUMPTIONS

The following are assumed:

1) The Slab is Rectangular
2) The Slab is NOT skewed
3) Lasernets are scanning CCW
4) Lasernet Positions are known

PROBLEM

Find the Dimensions D1, D2, D3, w, and h.

SOLUTION

1) We measure A1, A2, B1, B2 with Lasernet.

2) Then we know the equations of lines [1] [2] [3] [4] of form Y+MX+B since M1=tan(A1), M2=tan(A2), M3=tan(B1), and M4=tan(B4), and we know the position of the Laserent, i.e. a=(x-pos LN1,y-pos LN1) and b=(x-pos LN2,y-pos LN2).

3) Line [5] is known, i.e. Y=0. (Top surface of conveyor rollers).

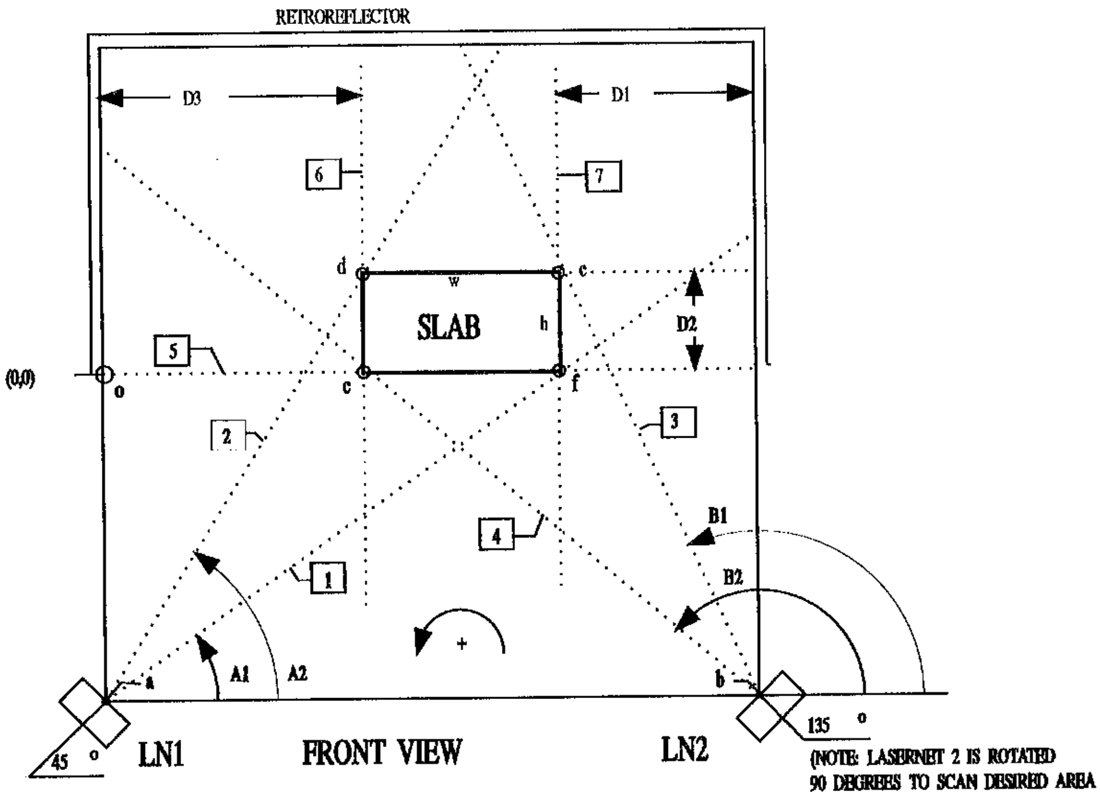
4) Points c and f are found for the intersections of [5] with [4] and [1] respectively.

5) Because of Assumption 1), we now know the equation of lines [6] and [7] since 6 = X=(x value of c) and 7 = X=(x value of f).

6) Now we can find points d and e from the intersections of lines [6] and [2], and [7] and [3] respectively.

7) We now know the four points of the Slab, c,d,e and f. Therefore, we know the size of the Slab. We can calculate D1, D2 and D3 knowing c,d,e,f and a,b. The various of the width w is simply the difference in the x components of d and e, while the height h is the difference in y components of d and c.

PLUG-IN EQUATIONS FOR SLAB SIZING



DISCUSSION

The following is a plug in solution to Lasernet Tip 14.

Knowing:

a(ax,ay), the location of Lasernet 1
b(bx,by), the location of Lasernet 2
c(cx,cy)=(cx,O), slab sitting on X axis
f(fx,fy)=(fx,O), slab sitting on X axis

and measuring:

A1 = Lasernet Angle Counts (Lasernet mounted as shown)

A2 = Lasernet Angle Counts (Lasernet mounted as shown)

B1 = Lasernet Angle Counts (Lasernet Rotated 90° as shown)

B2 = Lasernet Angle Counts (Lasernet Rotated 90° as shown)

Then:

$$\text{WIDTH} = \frac{by}{\tan(90+k*B2)} - \frac{ay}{\tan(k*A1)} - bx$$

with k=0.005859375

$$\text{HEIGHT} = \tan(k*A2)\left[\frac{-by}{\tan(90+k*B2} + bx\right] + ay$$

$$D1 = bx + \frac{ay}{\tan(k*A1)}$$

D2 = HEIGHT

$$D3 = bx \quad \frac{by}{\tan(90+k*B2)}$$