APPENDIX G

GDOP EXPLAINED and ILLUSTRATED

Introduction

Equation (III–1) in Chapter III of the main text enables calculation of the fix accuracy (2 drms) in terms of the bearings from the user to the master and two secondary stations, the common standard deviation of each TD, the correlation coefficient between the two TDs, and the gradient of the LOPs along the baseline.

To recapitulate, 2 drms is the radius of the fix area with probability content of at least 95%. That is, at the given point in the coverage area, at least 95% of the apparent fixes would be within a circular area of radius 2 drms. It is given by the equation:

$$2\ \text{drms} = \frac{2K\sigma}{\sin C}\left[\frac{1}{\sin^2\left(\frac{A}{2}\right)} + \frac{1}{\sin^2\left(\frac{B}{2}\right)} + \frac{2\rho\cos C}{\sin\left(\frac{A}{2}\right)\sin\left(\frac{B}{2}\right)}\right]^{0.5} \qquad \text{(G-1)}$$

where:

A, B, C = angles defined in Figure G–1,

ρ = correlation coefficient between the measured TDs, generally taken to be 0.5,

K = baseline gradient, 491.62 ft/usec, and

σ = common value for the standard deviation of each TD, generally taken to be 0.1 usec for accuracy calculations.

Referring to Figure G–1, angle A is the angle between the first secondary and the master station (viewed from the user's position) and angle B is that subtended by the master and the other secondary. The actual TDs are shown by the dashed lines which are bisectors of angles A and B. The crossing angle, C, for the three station fix is:

$$C = A/2 + B/2. \qquad \text{(G-2)}$$

The parameter ρ in equation (G–1) is the correlation coefficient between the two TDs. The three individual signals from the master and two secondaries are assumed to be independent and uncorrelated because the timing of each signal is derived from separate cesium oscillators. However, the two TDs are correlated to some degree because both are based upon a common master signal. The correlation coefficient varies throughout the coverage area, but is typically given the value 0.5 in chain coverage calculations.

Numerical Examples

In the illustration, angle A is approximately 89 degrees, and angle B is approximately 70 degrees and angle C = 89/2 + 70/2 = 79.5 degrees. Because the crossing angle is quite large, it is to be expected that the value of 2 drms at this location in the coverage area would be relatively small. This conjecture is shown to be correct: substitution of these angles and other constants given results in a value of 2 drms of approximately 235 ft—quite accurate indeed.

FIGURE G-1. ILLUSTRATION OF CROSSING ANGLE GEOMETRY FOR A LORAN-C TRIAD.

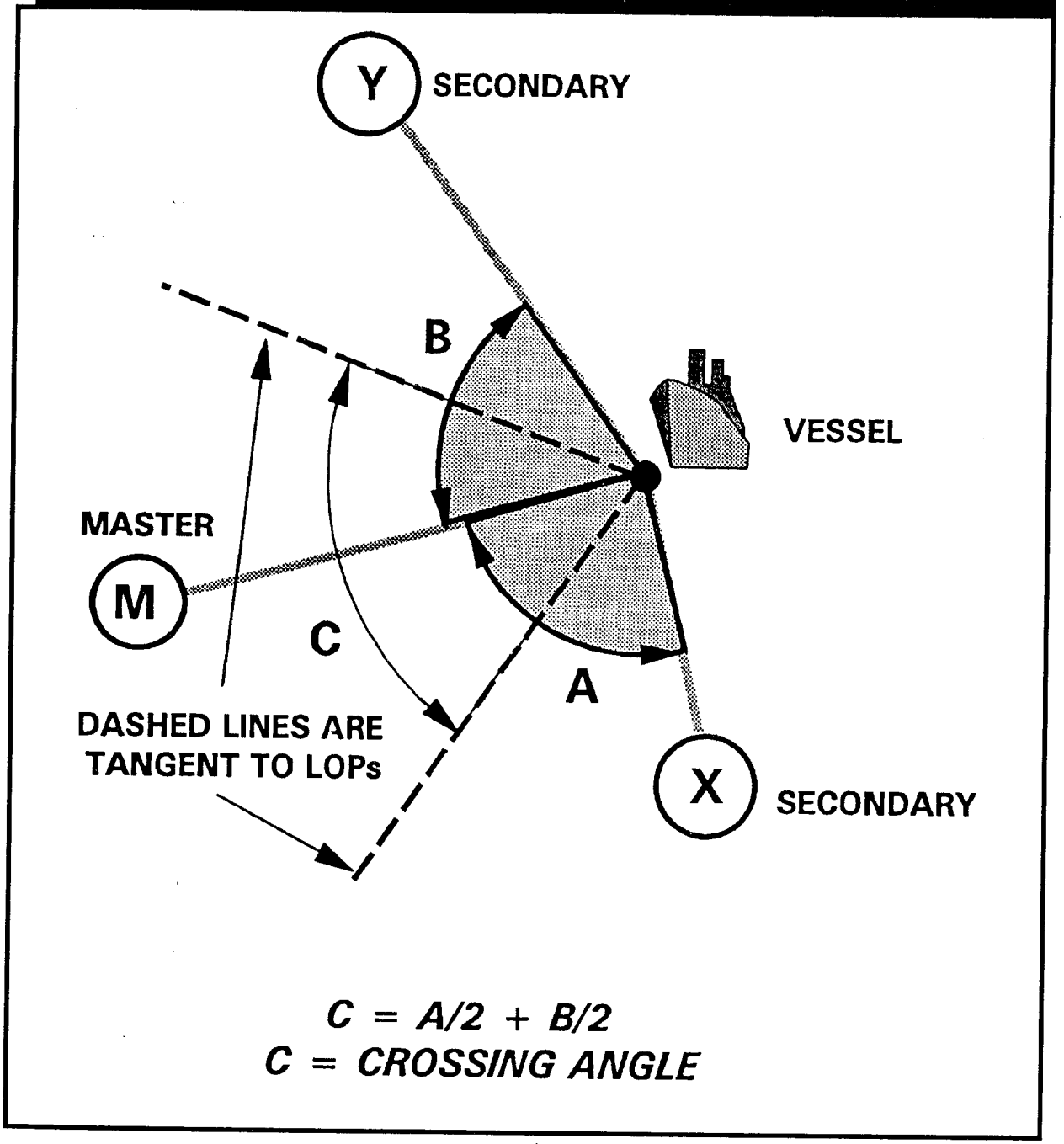
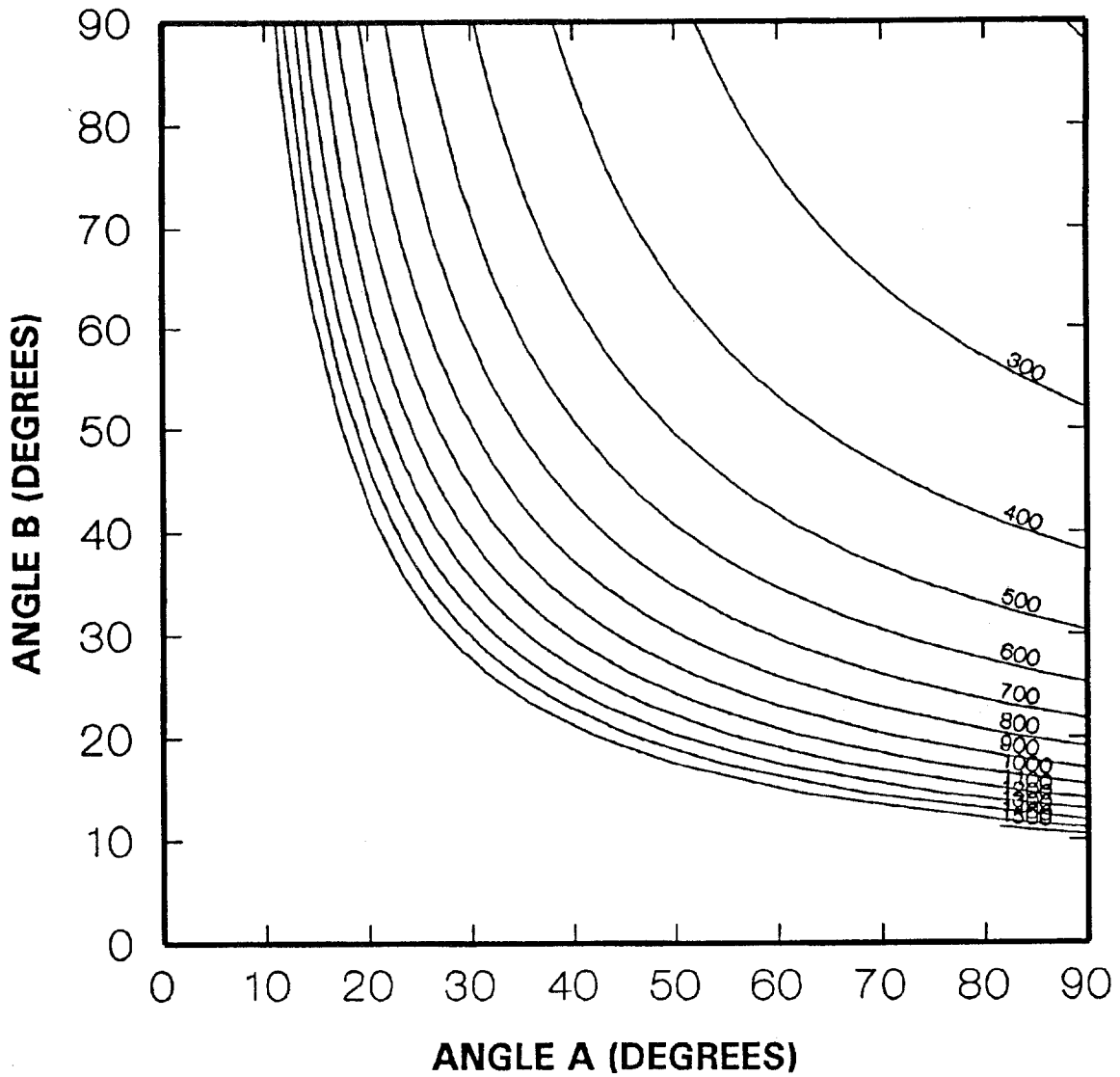


FIGURE G-2. CONTOURS OF EQUAL 2 drms IN TERMS OF ANGLES A AND B.



If the vessel (or aircraft) in the illustration were to move away from the master in a generally northeast direction until angle B were 20 degrees and angle A were 30 degrees (thus, angle C = 25 degrees), then the value of 2 drms would increase to approximately 1,922 ft.

Equation (G–1) can be used to calculate 2 drms for a three-station loran fix anywhere within the coverage area. Table G–1 shows how 2 drms varies with angles A and B. This quantity grows quite large whenever either or both of these angles are small. Figure G–2 shows contours of equal value of 2 drms. In general, as shown in Figure G–2, the value of 2 drms is a function of the placement of the master and secondary stations, the user's location relative to these stations, and the common standard deviation of the TDs.

According to Swanson (1978), the greatest possible accuracy (minimum value of 2 drms) will occur with *four* stations, each subtending a 90 degree angle with the adjacent station so as to form two orthogonal (at right angles) and uncorrelated LOPs. The optimal accuracy for this configuration, 2 drms*, is given by the equation:

$$2\ \text{drms}^* = 2\sqrt{2}\ K\ \sigma = 139.1\ \text{ft}, \quad \text{(G-3)}$$

given the assumed values for each of these parameters.

The *geometric dilution of position* (GDOP) is defined as the ratio of the actual value of 2 drms corresponding to equation (G–1) divided by this "best" value, or:

$$\text{GDOP} = \frac{2\ \text{drms}}{2\ K\ \sigma\ \sqrt{2}}. \quad \text{(G-4)}$$

TABLE G-1. 2 drms AS A FUNCTION OF ANGLES A AND B.

ANGLE B (Degrees)	ANGLE A (Degrees) 10	15	20	25	30	40	50	60	70	80	90
10	11,212	7,541	5,738	4,660	3,940	3,035	2,491	2,128	1,871	1,682	1,539
15	7,541	5,007	3,780	3,057	2,579	1,985	1,631	1,396	1,230	1,108	1,015
20	5,738	3,780	2,835	2,282	1,920	1,474	1,210	1,036	914	824	757
25	4,660	3,057	2,282	1,830	1,535	1,175	963	824	727	657	603
30	3,940	2,579	1,920	1,535	1,285	980	802	686	605	547	503
40	3,035	1,985	1,474	1,175	980	743	606	518	457	413	380
50	2,491	1,631	1,210	963	802	606	493	421	371	335	309
60	2,128	1,396	1,036	824	686	518	421	359	316	286	264
70	1,871	1,230	914	727	605	457	371	316	279	252	233
80	1,682	1,108	824	657	547	413	335	286	252	229	212
90	1,539	1,015	757	603	503	380	309	264	233	212	196

FIGURE G-3. 2 drms ACCURACY IS DETERMINED BY STATISTICAL SIGNAL CHARACTERISTICS AND THE USER'S LOCATION RELATIVE TO THE TRANSMITTERS.

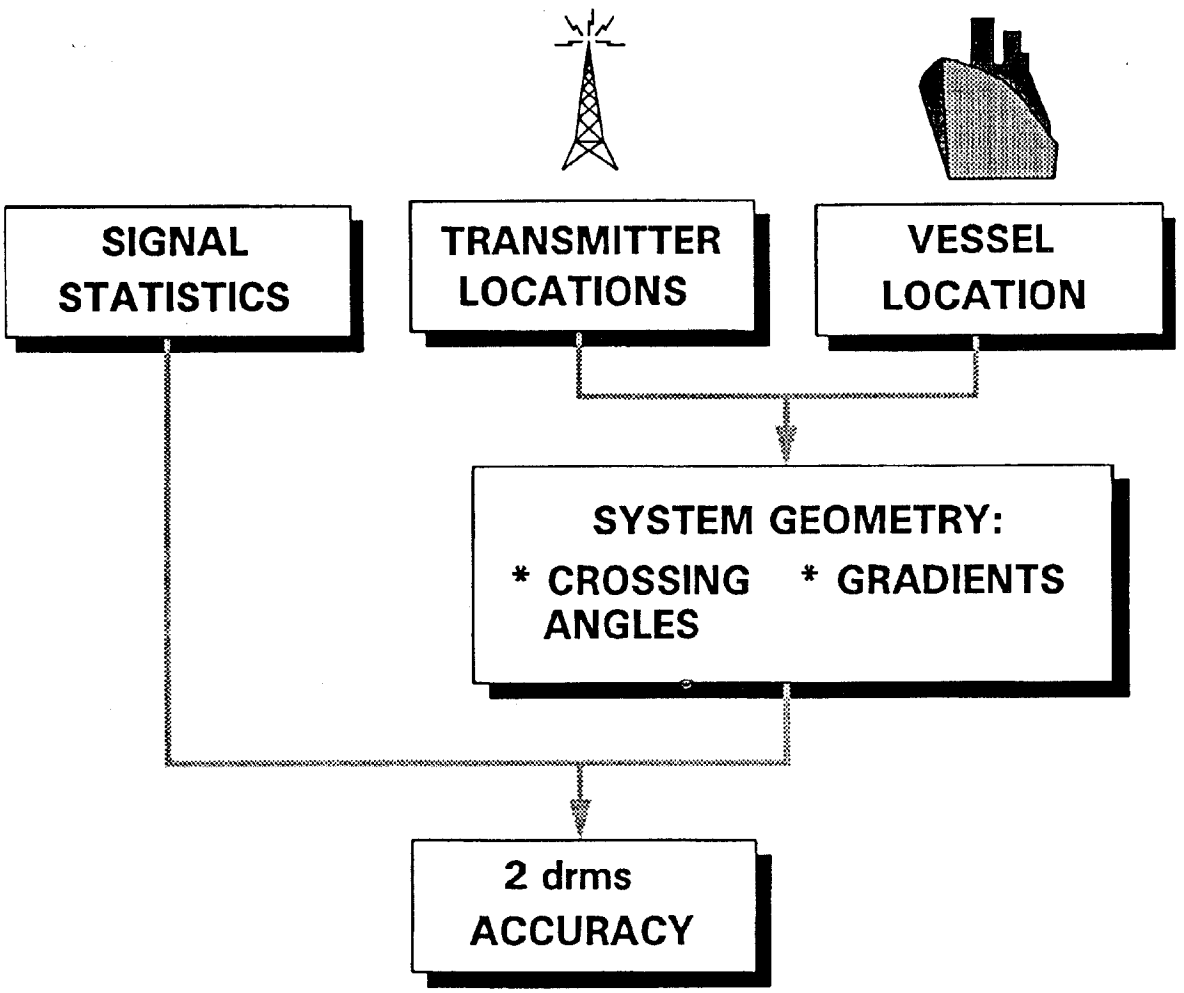


TABLE G-2. CORRESPONDENCE BETWEEN 2 drms AND GDOP.

GDOP	2 drms
1.0	139
1.5	209
2.0	278
2.5	348
3.0	417
3.5	487
4.0	556
4.5	626
5.0	695
6.0	834
7.0	973
8.0	1112
9.0	1251
10.0	1390
12.0	1668
14.0	1946
16.0	2224
18.0	2503
20.0	2781

In essence, GDOP measures the ratio of the *actual* value of 2 drms corresponding to the user's location in the coverage area of a loran *triad* to the *best possible accuracy* of the best possible loran stations. GDOP is a *normalized* 2 drms, which takes into account the effects of the system geometry and the user's location. Table G–1 shows the correspondence between GDOP and 2 drms. The specified absolute accuracy of Loran-C is 0.25 NM (1,519 ft), which is equivalent to a GDOP of 10.92.