



Module 8

Modern Navigation Systems

Sextant Navigation

Module 8B

Dilution of Precision



Summary of Module 8

- Students will use simulated and/or actual measurements of the angles of three or more stars above the horizon to determine their position on the surface of the earth at a known instant in time. (8A)
- The Equation of Time will be Introduced (8B)
- **The concept of dilution of precision will be introduced and linked to the least squares algorithms developed earlier. (8C)**



Reading/viewing

- Read the primary text by Kayton & Fried, in particular section 2.8.2 and all of the pages cited in the index under the topic of GDOP



Amplification of measurement error

- There is a “lever arm” effect when a measurement of angle, distance, time delay, etc. is converted into an estimate of a different parameter.
- For example, measurement of the north star gives good information about one’s latitude, but even a tiny measurement error causes an estimate of longitude inferred from this to be greatly in error
- Likewise, measurements of the sun provide good, but not “great” estimates of latitude.



Dilution of precision

- This effect is called “dilution of precision”
- It comes in several flavors, particularly for GPS:
 - Horizontal dilution of precision (HDOP)
 - Vertical dilution of precision (VDOP)
 - Position dilution of precision (PDOP)
 - Time dilution of precision (TDOP)

DOP is characterized by standard deviations and variances

coordinates, then, by definition, the position dilution of precision is

$$(\text{PDOP})^2 = \frac{\sigma_x^2 + \sigma_y^2 + \sigma_z^2}{\sigma_R^2} \quad (2.33)$$

and the horizontal dilution of precision (HDOP) is

$$(\text{HDOP})^2 = \frac{\sigma_x^2 + \sigma_y^2}{\sigma_R^2} \quad (2.34)$$

In pseudorange systems, the GDOP is

$$(\text{GDOP})^2 = (\text{PDOP})^2 + (\text{TDOP})^2$$

where TDOP is the time dilution of precision, the contribution of clock error to the error in pseudorange. Equations for GDOP, PDOP, and HDOP, when the standard deviations in range to each station are different, are provided in [12].

From the text. Note that the variances for independent measurements add according to the Pythagorean theorem.

As will be seen in a future module, GPS receivers “report” DOP

```
Command Prompt - labmon60 -d -rtemp0802001

STAT  NAV  SATS  6  DATE  08/03/09  SU  EL  AZI  IODE  GPS  I/O  OPTIONS
INUAL  NUIS  6/10  UTC  * 04:42:05  2  69  19
TYPE  MASK  GPSSEC  103338.99  10  60  213
      GDOP  2.97  GPSNSEC  999999996  4  40  69
      PDOP  2.59  WEEK  1543  DAY  MON  12  37  250
      HDOP  1.62  SETTIME  9268690  30  29  285
      UDOP  2.02  SEQ  27153  M  27153  13  22  55
      IDOP  1.46  TCM0
      GSEP  -33  PORT1
      DATUM  0  PORT2
      POLAR  0  WCNT  0%  23  0  27

LAT  N39°00.9809'  SOG  0.00  SPD  0.00  XSU
LON  W 77°09.6608'  COG  0.0°  CLM  0.10  RAMER
ALT  51.67  MAG  -0.20  WDT  0.00  DRERR

POSX  UELX  DRFL  DRS
POSY  UELY  DRHR  DRT
POSZ  UELZ  DRST  GFTST

EHPE  4.8  CBE  -44  CB  5753153  MAGNA
EUPE  4.4  CBSIG  3.6  CD  1330  CNO
ETE  3.6  CDE  0  TMP  53.7  OFFPWR
EHUE  0.77  CDSIG  0.52  COUNT  43068  RCTINT

MESSAGE 1102 ACK

STNID  HLTH
AGE
STATUS

CH  SU  UUEC  CN  CARRIERPHASE  PSEUDO  RANGE  RANGRATE  CSW1  CSW2  IODE  SU  ECULRTI
1  24  0000  0  24374984.765  24033443.924  -489.857  0100  0001
2  17  0010  0  24771072.739  24927065.999  685.145  800E  0005
3  4  1110  35  21986394.065  22055409.213  416.314  0000  0014
4  12  1110  30  22267112.042  22360643.278  312.040  0000  0014
5  29  0000  0  24373715.416  24561144.331  -639.514  0100  0001
6  23  0010  0  25468642.567  25577066.476  465.016  0100  0001
7  10  1110  34  20627799.677  20577426.556  -355.831  0000  0014
8  2  1110  41  20116078.328  20376675.139  33.778  0000  0014
9  0  0000  0
10 13  1110  41  23405440.117  23317614.200  147.168  0000  0014
11 30  1110  31  22635869.094  22582519.297  40.455  0000  0014
12 0  0000  0

BYTES: 34338

MSG 1135: DATA ID: 19 TYPE: HOST PORT ENABLED MESSAGES
```

The various DOPs estimated by GPS

The corresponding position errors.



Assignment 8.3

1. In navigation problems, it is common to divide by the sine or cosine of an angle. For a 1% measurement error in the measurement of θ , plot the corresponding estimation error in the function $f(\theta) = 1/\cos(\theta)$ for $0 < \theta < 90$ degrees.



End of Mod 8C