FIGURE 15-1 Fixed-frequency earth station satellite system: (a) single link; (b) multiple link
FIGURE 15-2  Anik-E frequency and polarization plan
FIGURE 15-3  Multiple-accessing arrangements: (a) FDMA; (b) TDMA; (c) CDMA
FIGURE 15-4  FDMA, SPADE earth station transmitter
FIGURE 15-5  Carrier frequency assignments for the Intelsat single-channel-per-carrier PCM multiple-access demand-assignment equipment (SPADE)
FIGURE 15-6  FDMA, SPADE common signaling channel (CSC)

Earth station 1
128 bits

Earth station 2
128 bits

Earth stations 3 – 49
128 bits each

Earth station 50
128 bits

1 ms ——— 1 ms ——— 47 ms ——— 1 ms

50 ms

128 bits/1ms \times 1000 \text{ ms/1s} = 128 \text{ kbps} \text{ or } 6400 \text{ bits/frame} \times 1 \text{ frame/50 ms} = 128 \text{ kbps}
FIGURE 15-7  Basic time-division multiple-accessing (TDMA) frame
FIGURE 15-8  Unique word correlator
FIGURE 15-9 TDMA, CEPT primary multiplex frame transmitter
FIGURE 15-10  TDMA, CEPT primary multiplex frame

1 satellite channel (SC) (62.5 μs)

Sample 1, channel 1  |  Sample 1, channels 2 – 15  |  Sample 1, channel 16

b₀  b₁  b₂  b₃  b₄  b₅  b₆  b₇  |  b₀  b₁  b₂  b₃  b₄  b₅  b₆  b₇

16 PCM samples × 8 bits/sample = 128 bits

1 SC

Sample 32

128

Samples 2 – 31

1 SC

Sample 1

128

32 increments of 128 bits each (4096 bits) (62.5 μs × 32 = 2 ms)

1 CEPT primary multiplex block, 2 ms (accumulation time)

Bit 1

Bits 2 – 4095

Bit 4096

1 CEPT primary multiplex block, 33.9 μs (transmission time)

(32 8-bit samples of 16 voice band channels)

2.048 Mbps

120.832 Mbps
FIGURE 15-11  Code-division multiple access (CDMA): (a) encoder; (b) decoder
**FIGURE 15-12A** CDMA code/data alignment: (a) correct code; (b) orthogonal code

<table>
<thead>
<tr>
<th>Data in x Chip code</th>
<th>(Logic 1 = +1)</th>
<th>(Logic 0 = −1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 1 1 1 1 1</td>
<td>1 1 1 1 1 1 1</td>
<td>1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>Product code</td>
<td>−1 −1 −1 −1 −1 1 1</td>
<td>−1 −1 −1 −1 −1 −1 −1</td>
</tr>
<tr>
<td>Recovered chip code</td>
<td>1 1 1 1 1 1 1</td>
<td>1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>Correlation</td>
<td>+6 V</td>
<td>−6 V</td>
</tr>
</tbody>
</table>
**FIGURE 15-12B**  CDMA code/data alignment: (a) correct code; (b) orthogonal code

<table>
<thead>
<tr>
<th>Data in x Orthogonal code</th>
<th>(Logic 1 = +1)</th>
<th>(Logic 0 = −1)</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product code</td>
<td>1 1 −1 1 −1 −1</td>
<td>−1 −1 1 −1 1 1 1</td>
<td></td>
</tr>
<tr>
<td>Recovered chip code</td>
<td>1 1 −1 −1 1 1 1</td>
<td>1 1 −1 −1 1 1 1</td>
<td></td>
</tr>
<tr>
<td>Correlation</td>
<td>1 1 1 −1 −1 −1</td>
<td>−1 −1 −1 1 1 1</td>
<td></td>
</tr>
</tbody>
</table>

(b) 0 V 0 V
FIGURE 15-13  Simplified block diagram for a direct-sequence spread-spectrum transmitter
FIGURE 15-14  Simplified block diagram of a frequency-hopping spread-spectrum transmitter
FIGURE 15-15  Frequency time-hopping matrix
FIGURE 15-16  (a) Navstar constellation; (b) satellite relative positions
FIGURE 15-17 Mercator projection of Navstar satellite orbits
FIGURE 15-18  GPS pseudorandom timing code

Satellite's code

Receiver's code

Time difference \( \Delta t \)
FIGURE 15-19  GPS ranging solution

Compute four pseudorange values:

\[ R_1 = c \times \Delta T_1 \]
\[ R_2 = c \times \Delta T_2 \]
\[ R_3 = c \times \Delta T_3 \]
\[ R_4 = c \times \Delta T_4 \]
\[ c = \text{speed of light} \]

Time signals transmitted by satellites
FIGURE 15-20  GPS satellite and earth station receiver coordinate system
FIGURE 15-21  Earth station receiver location relative to the distance from (a) one satellite, (b) two satellites, and (c) three satellites
FIGURE 15-22  GPS satellite position calculations

\[(X_1 - U_x)^2 + (Y_1 - U_y)^2 + (Z_1 - U_z)^2 = (r_1 - C_o)^2\]
\[(X_2 - U_x)^2 + (Y_2 - U_y)^2 + (Z_2 - U_z)^2 = (r_2 - C_o)^2\]
\[(X_3 - U_x)^2 + (Y_3 - U_y)^2 + (Z_3 - U_z)^2 = (r_3 - C_o)^2\]
\[(X_4 - U_x)^2 + (Y_4 - U_y)^2 + (Z_4 - U_z)^2 = (r_4 - C_o)^2\]

User's latitude \(\theta = \cos^{-1} \left( \frac{U_x^2 + U_y^2}{|U|} \right)\)

User's longitude \(\alpha = \tan^{-1} \frac{U_x}{U_y}\)
**FIGURE 15-23** Simplified Navstar satellite CDMA transmitter

- **L₁ Carrier - 1575.42 MHz**
- **C/A Code - 1.023 MHz**
- **Navigation data - 50 Hz**
- **P-Code - 10.23 MHz**
- **L₂ Carrier - 1227.6 MHz**

[Diagram of a simplified Navstar satellite CDMA transmitter with labeled signals and components such as mixers and sumers.]
FIGURE 15-24 Navigation data frame format

Subframe # | One subframe = 300 bits, 6 seconds
--- | ---
1 | TLM | HOW | Satellite vehicle correction data
2 | TLM | HOW | Satellite vehicle ephemeris data (I)
3 | TLM | HOW | Satellite vehicle ephemeris data (II)
4 | TLM | HOW | other system data
5 | TLM | HOW | Almanac data for all satellites

TLM - Telemetry word

| 8-bit Preamble | 16 Data | 6 Parity |

HOW - Handover word

| 17-bit time of week | 7 Data | 6 Parity |
### Table 15-1 Summary of GPS Error Sources

<table>
<thead>
<tr>
<th>Per Satellite Accuracy</th>
<th>Standard GPS</th>
<th>Differential GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite clocks</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>Orbit errors</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>Ionosphere</td>
<td>5.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Troposphere</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Receiver noise</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Multipath reception</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Selective availability</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Typical position accuracy (meters)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>50</td>
<td>1.3</td>
</tr>
<tr>
<td>Vertical</td>
<td>78</td>
<td>2.0</td>
</tr>
<tr>
<td>3-D</td>
<td>93</td>
<td>2.4</td>
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</tbody>
</table>