APPENDIX A

OVERVIEW OF SHAPED BINARY PHASE-SHIFT KEYING MODULATION

10.1 Introduction. The ultra high frequency (UHF) satellites used for military communications have hard-limiting transponders. This hard-limiting feature precludes the use of any amplitude modulation (AM) scheme by forcing the modulated signal to have a constant envelope. Therefore, the modulation must be either frequency or phase modulation.

10.1.1 Binary phase-shift keying. Binary phase-shift keying (BPSK) is well suited for the modulation of a carrier with a two-level digital baseband signal. A carrier phase of 90 degrees represents one level ("1"), and a carrier phase of -90 degrees represents the other level ("0"). The waveform is depicted in Figure 10-1. Mathematically, BPSK can be expressed as

$$S(t)=A(t)\sin\left[\omega_o t+\phi_i(t)\right] \qquad \text{(A-1)}$$

where

ω_o = $2\pi f_c$ (f_c is the carrier frequency)

$\phi_i(t)$ = $\pm\, \pi/2$ radians (90 degrees)

10.1.2 Disadvantage of binary phase-shift keying. The disadvantage of BPSK is that it is not spectrally efficient. The abrupt change in phase causes energy to spill over into adjacent channels. This adjacent channel interference (ACI) degrades the communications of other satellite users. Spectral containment cannot be improved by filtering because post-modulation filtering will create a non-constant envelope.

10.2 Shaped binary phase-shift keying. At MILCOM 1984, Mark J. Dapper presented a paper written by him and Terrance J. Hill, Cincinnati Electronics Corporation. This paper, titled *SBPSK: A Robust Bandwidth-Efficient Modulation for Hard-Limited Channels*, described shaped BPSK (SBPSK) as a variation of BPSK modulation that has good spectral containment and is compatible with BPSK. (See also a MILCOM 1990 paper, *Shaped PSK in a Digital Modem with Direct Digital Synthesis*, Cofer R., Franke, E., Johnson, O., and Erman, T., 30 September 1990, Vol. 1, pp. 86-92, as well as "PSK sidebands reduced by pre-modulation filtering," Carl Andren, *Microwave Journal*, January 1978, pp. 69-73.) The modulation scheme gradually changes the phase of the carrier by 180 degrees over a time equal to 50 percent of the bit period. The waveform is depicted in Figure 10-1. Mathematically, SBPSK can be expressed the same way as BPSK, except that $\phi_i(t)$ is not a two-valued variable. Instead, it is a function of the convolution of a unit pulse with three values (π, 0, $-\pi$).

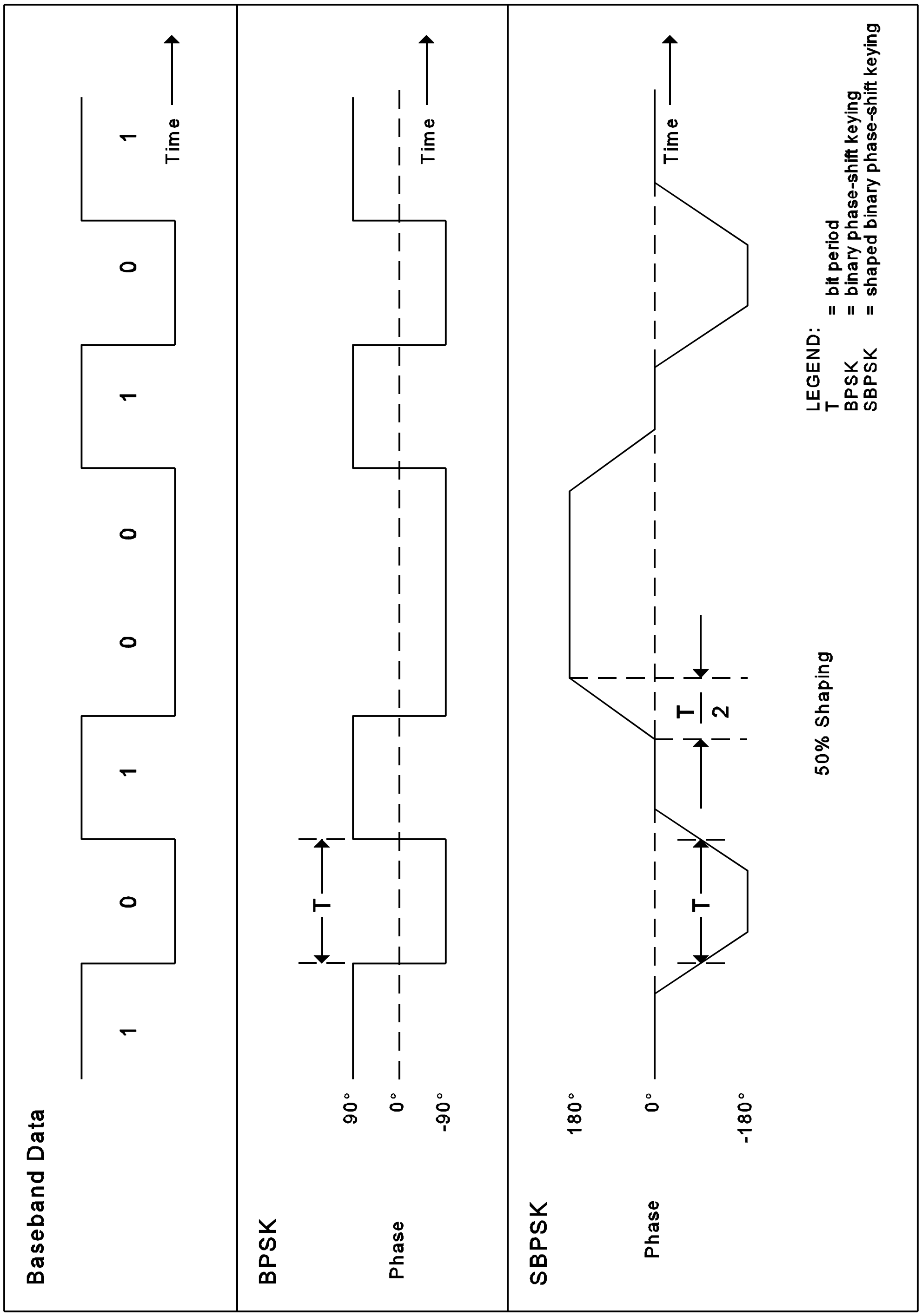

FIGURE 10-1. A comparison of BPSK and SBPSK waveforms.

10.2.1 Advantage of shaped binary phase-shift keying. The main advantage of SBPSK is that the rate of falloff of the side lobes, as compared to the main lobe, is much greater than for BPSK. Thus, the spectral containment is enhanced. In contrast to postmodulation-filtered BPSK, SBPSK is created by premodulation filtering that preserves a constant envelope. SBPSK is compatible with BPSK if the shaping does not exceed approximately 50 percent.

10.2.2 Disadvantage of shaped binary phase-shift keying. The disadvantage of SBPSK is that the shaping degrades detection efficiency. The loss of detection efficiency for an "integrate and dump" detector is approximately 1 dB with 50-percent shaping.

10.2.3 Phase vector rotation. The Dapper/Hill paper recommends that the direction of the phase vector rotation during a phase transition be implemented so that transitions to the 180^{o} state occur by alternately rotating the phase in the clockwise and counter-clockwise directions from the 0^{o} position. Rotation back to 0^{o} is in the opposite direction from that most recently taken. In other words, the direction of rotation reverses upon reaching the 180^{o} state, resulting in a change of the direction of phase vector rotation every other phase transition (see Figure 10-2). Accordingly to the paper, there is an offset of the carrier frequency equal to one-fourth the data rate if the phase is rotated in the same direction for each data bit transition. This means there is a 600-Hz offset when the data rate is 2.4 kbps. The article further states that reversal of phase rotation allows interoperability of SBPSK with conventional BPSK demodulators not specifically designed for interoperability with SBPSK. The reason given is that a nonzero average value disturbs the phase-error measurement of conventional demodulation techniques, which are unable to separate transitional information from phase-error measurement.

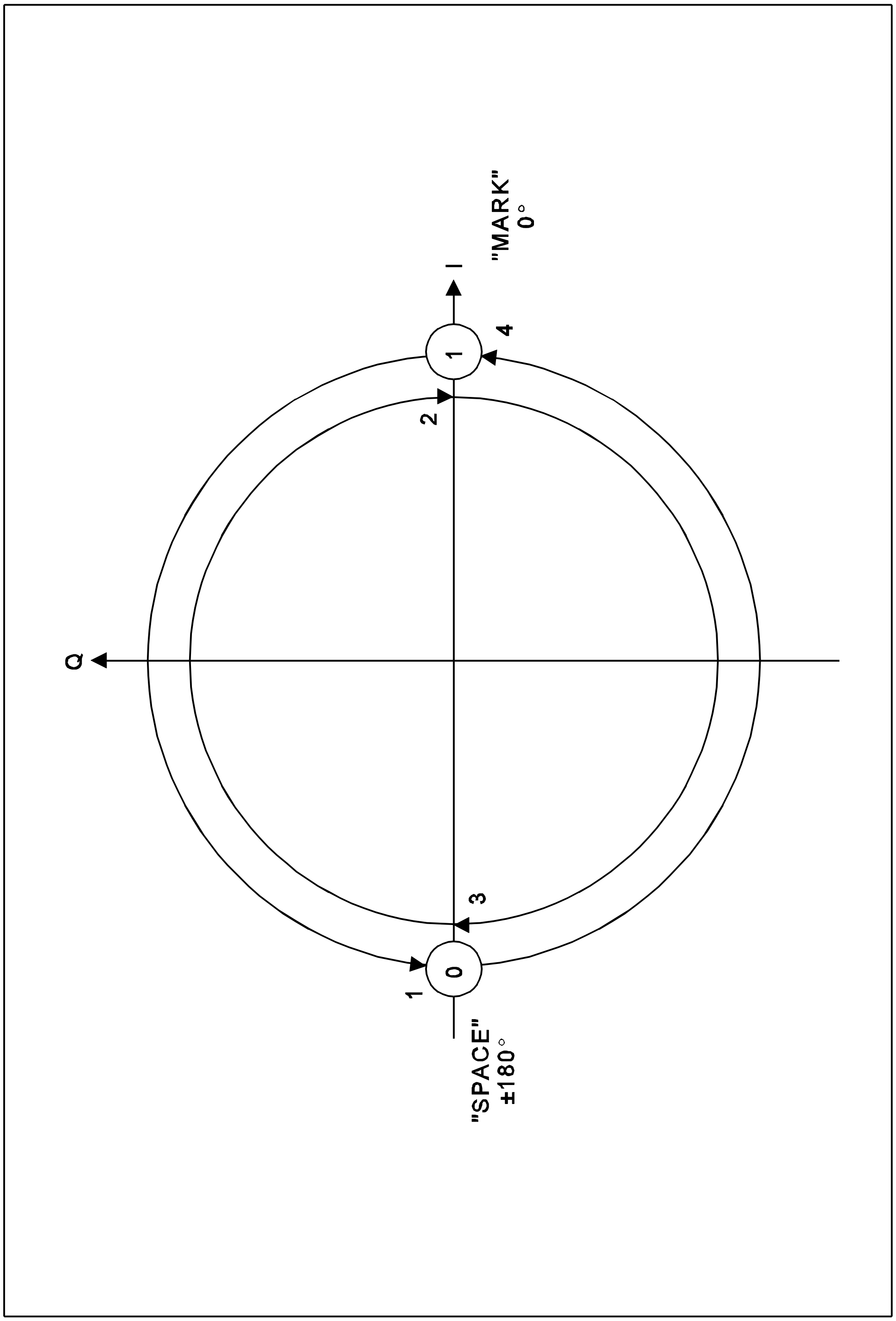

FIGURE 10-2. SBPSK phase vector rotation.

APPENDIX B

METHOD OF IMPROVING THE (*G/T*) OF EXISTING ULTRA HIGH FREQUENCY TERMINALS

20.1 System noise temperature equation. The equation for effective noise temperature of a receiving system with two stages of amplification is

$$T_s = T_a + (L_c - 1)\, T_o + L_c\, (Fr_1 - 1)\, T_o + \frac{L_c (Fr_2 - 1) T_o}{Gr_1} \qquad \text{(B-1)}$$

where

T_s = system noise temperature in kelvins (K)
T_a = antenna noise temperature in K
L_c = cable loss factor, dimensionless
T_o = ambient thermal temperature of 290 K
Fr_1 = first receiver amplifier noise factor, dimensionless
Fr_2 = second receiver amplifier noise factor, dimensionless
Gr_1 = first receiver amplifier gain, dimensionless

20.1.1 Typical values. The antenna noise temperature, as stated in MJCS-33-87, is typically 200 K. The cable loss, as stated in JTC3A Report *Technical Assessment of UHF SATCOM Radio for KC-10 Aircraft*, dated 14 December 1986, is typically 3 dB (noise factor 2). Many current specifications require the noise figure of the receiver to be 4 dB maximum (noise factor is 2.5),

hence

$$T_s = 200 + (2-1)290 + 2(2.5-1)290 \qquad \text{(B-2)}$$

$$= 1360\ K\ (\textit{equivalent to}\ 31.3\ dB\text{-}K)$$

The last term in the equation is ignored because the noise figure of the first receiver includes the contributions of the post-first-receiver stage.

20.1.2 Preamplifier use. As an example, if a preamplifier that has a noise figure of 2.5 dB (1.78 noise factor) and a gain of 14 dB (that is, 25 times) is installed close to the antenna (see Figure 20-1), the noise temperature is greatly improved.
The improvement occurs because the noise temperature corresponding to transmission line loss is reduced by the gain of the preamplifier, and the preamplifier itself has a lower noise

figure than the ultra high frequency (UHF) terminal receiver. The equation for effective noise temperature that uses a preamplifier is

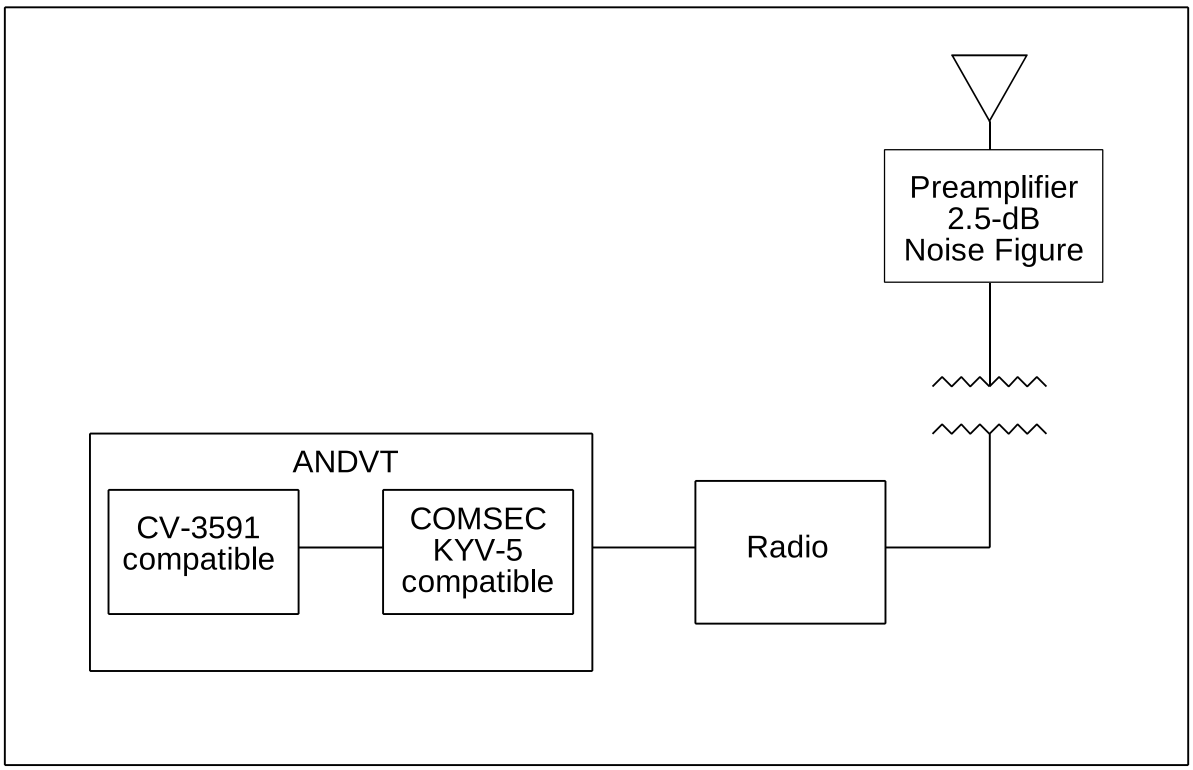

FIGURE 20-1. Improvement of existing terminals.

$$T_s = T_a + \left(F_P - 1\right)T_o + \frac{\left(L_c - 1\right)T_o}{G_p} + \frac{L_c\left(Fr_1 - 1\right)T_o}{G_p} \qquad \text{(B-3)}$$

$$= 200 + (1.78 - 1)\,290 + \frac{(2-1)290}{25} + \frac{2(2.5-1)290}{25}$$

$$= 200 + 226.2 + 11.6 + 34.8$$

$$= 472\ K\ (\textit{equivalent to}\ 26.7\ dB\text{-}K)$$

where

F_p	=	the noise factor of the preamplifier = 1.78 (numerical equivalent of 2.5-dB noise figure)
G_p	=	the gain of the preamplifier = 25 (numerical equivalent of 14-dB gain)
Fr_1	=	the noise factor of the transceiver receiver = 2.5 (numerical equivalent of 4-dB noise figure)

20.2 (*G/T*) improvement. The 4.6-dB decrease in effective system noise temperature translates to a 4.6-dB increase of antenna gain-to-noise temperature in (*G/T*) dB/K. However, installation of a preamplifier close to the antenna is not always possible. This is especially true for platforms that employ multiple high power emitters. These terminal installations require the placement of lossy elements between the antenna and the first amplifier for cosite protection.

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APPENDIX C

OVERVIEW OF LINK CALCULATIONS

30.1 Introduction. This appendix gives a broad overview of the procedure for determining the bit rates and related bit error ratios (BER) that can be supported between two ultra high frequency (UHF) satellite earth terminals with single access to an ideal satellite channel.

30.1.1 Basic link parameters

30.1.1.1 Basic link equation. The equation that relates the system parameters to carrier-to-noise density (*C/kT*) is given in equation (C-1). The equation applies to only one path of a repeater system, such as a ground transmitter to satellite receiver and does not include adjacent channel interference. The effect of the overall two-path link (see 30.1.1.7) is also discussed. The link equation with all terms expressed in dB is

$$\left(\frac{C}{kT}\right) = (EIRP) - \left(L_P\right) + \left(\frac{G}{T}\right)_R - (k) - L_o \qquad \text{(C-1)}$$

The terms are described in 30.1.1.2 through 30.1.1.6.

30.1.1.2 Carrier-to-noise density. In the *C/kT* expression, *C* is the radio frequency (rf) carrier power into the receiving system in decibels referred to 1 watt (dBW), *k* is Boltzmann's constant [-228.6 dBW/Hz/K], and *T* is the receiving system noise temperature in K. Note that *kT* is the noise power in a bandwidth of 1 Hz (that is, noise power per Hz); hence the equivalent term *noise density*. The significance of this expression comes from this factor being basic to determining the data rate capability of a satellite communications (SATCOM) link. Once factors such as BER and margin have been determined, data rate can be determined from *C/kT*.

30.1.1.3 Effective isotropically radiated power. Effective isotropically radiated power (EIRP), a term that has been found to be convenient for use in describing the power radiated from a terminal, is the product of the transmitter power output and antenna gain, or, in dB, EIRP = transmitter power plus antenna gain. For instance, a satellite transponder with an 18 W (12.6 dBW) final amplifier and an antenna with a gain of 4 dB has an EIRP of 45.2 W or 16.6 dBW.

30.1.1.4 Path loss. Path loss (L_P) is the loss experienced by an electromagnetic wave of frequency *f* traveling a distance *d*.

The L_P is described by

$$L_P = 36.58 + 20\log f + 20\log d \qquad \text{(C-2)}$$

where

L_P = path loss in dB
f = frequency in MHz
d = distance in statute miles

30.1.1.5 Receiving system figure of merit (*G/T*). The antenna gain-to-noise temperature in dB/K (*G/T*) figure of merit is the ratio of antenna gain to effective system noise temperature, both referred to the same reference point. The units of *G/T* are dB/K. System noise temperature is defined by the equation

$$T_s = T_a + (L_C - 1)T_o + L_C\,(Fr_1 - 1)T_o + \frac{L_C(Fr_2 - 1)T_o}{Gr_1} \qquad \text{(C-3)}$$

For high-quality receiving systems, the ratio of (*G/T*) describes how well the antenna and receiver front-end combination acts to achieve a high *C/kT* at the receiver. As indicated by equation (C-3), antenna design affects not only *G*, but also *T* through the contribution of T_a.

30.1.1.6 Transmission losses. Transmission losses (L_o) include such items as polarization mismatch between satellite and ground antennas and antenna pointing errors.

30.1.1.7 Two-path link. The two-path earth terminal-to-satellite and satellite-to-earth terminal link results in the *C/kT* at the earth terminal's being affected to some extent by the *C/kT* at the satellite. The extent affected is a function of the transmitted EIRP and the type of transponder, linear or hard-limited. For a linear transponder, the *C/kT* at the ground terminal receiver is

$$\left(\frac{C}{kT}\right)_R = \frac{1}{\dfrac{1}{\left(\dfrac{C}{kT}\right)_{UL}} + \dfrac{1}{\left(\dfrac{C}{kT}\right)_{DL}}} \qquad \text{(C-4)}$$

where

$(C/kT)_R$ = two-way *C/kT* at the ground station receiver
$(C/kT)_{UL}$ = uplink *C/kT* at the satellite receiving antenna
$(C/kT)_{DL}$ = downlink *C/kT* at the earth terminal antenna

Hard-limiting increases the *C/kT* if the input *C/kT* is large, and it causes a 2-dB degradation if the input *C/kT* is low.

30.1.2 Use of basic link equation

30.1.2.1 Downlink considerations and examples. To predict the *C/kT* at the earth terminal, the values of the contributing parameters have to be known. These parameters have a statistical distribution; thus, a margin (excess transmitted power) has to be available so that minimum allowable *C/kT* is achieved for a given percentage of the time. The right side (downlink) of Figure 30-1 presents typical values of the important parameters for a link through a 5-kHz channel in the UHF fleet satellite communications (FLTSATCOM). In the figure, the *G/T* of the ground terminal is typical of current terminals.

30.1.2.2 Uplink consideration and examples. The left side of Figure 30-1 presents typical uplink values.

30.1.3 Analysis of digital requirements

30.1.3.1 Energy-per-bit--to--noise-power-spectral-density ratio. The usual basis for evaluation of performance of digital systems is the ratio of energy-per-bit--to--noise-power-spectral-density ratio (E_b/N_o) required at the input to the demodulator to obtain a given BER for the demodulated data. In terms of carrier power and bit rate,

$$\frac{E_b}{N_o} = \frac{carrier\ power}{N_o \times bit\ rate} = \frac{C}{kT \times bit\ rate} \tag{C-5}$$

thus

E_b/N_o = the carrier-power--to--noise-power ratio in a bandwidth equal to the bit rate

Uncoded phase-shift keying (PSK), which is used in the narrowband mode, requires a practical E_b/N_o of 12.5 dB at the receiver to achieve the requirement of a maximum average error rate of 1 error in 10^5 bits ($P_e = 1 \times 10^{-5}$). Note that coherent frequency-shift keying (FSK) requires approximately 2 more dB than PSK, and noncoherent FSK requires approximately 4 more dB than PSK for the same performance.

30.1.3.2 Relationship of data rates to satellite power (EIRP). The relationship between *C/kT* and data rate *R* can be written as

$$C/kT = \left(E_b/N_o\right) + R + M \tag{C-6}$$

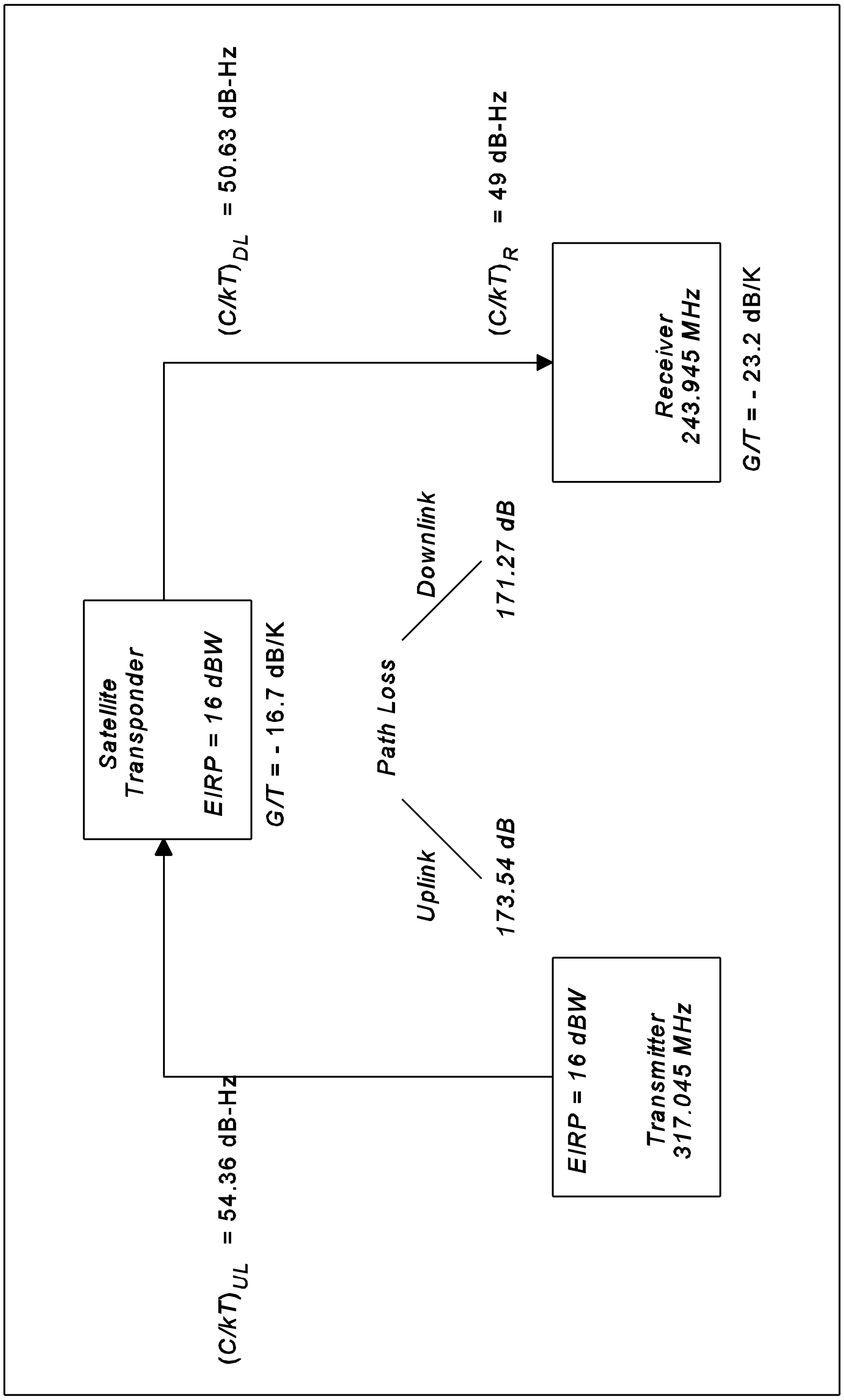

FIGURE 30-1. Typical single access link.

where

R	=	the data rate in dB-Hz (for 2.4 kbps, this is 33.8 dB-Hz).
M	=	the desired margin in dB

By substituting the uplink and downlink C/kT shown in Figure 30-1, in equation (C-1) the received C/kT is calculated to be 49 dB-Hz. Using equation (C-6), it can be shown that a C/kT of 49 dB-Hz can support a 2.4-kbps link with a P_e of 1 x 10^{-5} and a 2.7-dB margin, using PSK, when the required E_b/N_o is 12.5 dB.

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APPENDIX D

FREQUENCY PLANS

TABLE 40-I. LEASAT receive and transmit frequencies.

Channel	Plan	Downlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
1	W	250.35	SHF*	25
	X	250.45	SHF*	25
	Y	250.55	SHF*	25
	Z	250.65	SHF*	25
2	W	263.80	297.40	500
	X	260.60	294.20	500
	Y	261.70	295.30	500
	Z	262.30	295.90	500
3	W	251.85	292.85	25
	X	251.95	292.95	25
	Y	252.05	293.05	25
	Z	252.15	293.15	25
4	W	253.55	294.55	25
	X	253.65	294.65	25
	Y	253.75	294.75	25
	Z	253.85	294.85	25
5	W	255.25	296.25	25
	X	255.35	296.35	25
	Y	255.45	296.45	25
	Z	255.55	296.55	25
6	W	256.85	297.85	25
	X	256.95	297.95	25
	Y	257.05	298.05	25
	Z	257.15	298.15	25
7	W	258.35	299.35	25
	X	258.45	299.45	25
	Y	258.55	299.55	25
	Z	258.65	299.65	25
8	W	265.25	306.25	25
	X	265.35	306.35	25
	Y	265.45	306.45	25
	Z	265.55	306.55	25

* Uplink frequency is super high frequency from 7.9 to 8.4 GHz on channel 1.

TABLE 40-I. LEASAT receive and transmit frequencies. (continued)

Channel	Plan	Downlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
9	W	243.855	316.955	5
	X	243.955	317.055	5
	Y	244.055	317.155	5
	Z	244.155	317.255	5
10	W	243.860	316.960	5
	X	243.960	317.060	5
	Y	244.060	317.160	5
	Z	244.160	317.260	5
11	W	243.875	316.975	5
	X	243.975	317.075	5
	Y	244.075	317.175	5
	Z	244.175	317.275	5
12	W	243.900	317.000	5
	X	244.000	317.100	5
	Y	244.100	317.200	5
	Z	244.200	317.300	5
13	W	243.910	317.010	5
	X	244.010	317.110	5
	Y	244.110	317.210	5
	Z	244.210	317.310	5

TABLE 40-II. FLTSATCOM receive and transmit frequencies.

Channel	Plan	Downlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
1	A B C	250.45 250.55 250.65	SHF* SHF* SHF*	25 25 25
2	A B C	251.95 252.05 252.15	292.95 293.05 293.15	25 25 25
3	A B C	253.65 253.75 253.85	294.65 294.75 294.85	25 25 25
4	A B C	255.35 255.45 255.55	296.35 296.45 296.55	25 25 25
5	A B C	256.95 257.05 257.15	297.95 298.05 298.15	25 25 25
6	A B C	258.45 258.55 258.65	299.45 299.55 299.65	25 25 25
7	A B C	265.35 265.45 265.55	306.35 306.45 306.55	25 25 25
8	A B C	266.85 266.95 267.05	307.85 307.95 308.05	25 25 25
9	A B C	268.25 268.35 268.45	309.25 309.35 309.45	25 25 25
10	A B C	269.75 269.85 269.95	310.75 310.85 310.95	25 25 25

* Uplink frequency is super high frequency from 7.9 to 8.4 GHz on channel 1.

TABLE 40-II. FLTSATCOM receive and transmit frequencies.
(continued)

Channel	Plan	Downlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
11	A B C	243.945 244.045 244.145	317.045 317.145 317.245	5 5 5
12	A B C	243.955 244.055 244.155	317.055 317.155 317.255	5 5 5
13	A B C	243.960 244.060 244.160	317.060 317.160 317.260	5 5 5
14	A B C	243.965 244.065 244.165	317.065 317.165 317.265	5 5 5
15	A B C	243.970 244.070 244.170	317.070 317.170 317.270	5 5 5
16	A B C	243.975 244.075 244.175	317.075 317.175 317.275	5 5 5
17	A B C	243.980 244.080 244.180	317.080 317.180 317.280	5 5 5
18	A B C	243.985 244.085 244.185	317.085 317.185 317.285	5 5 5
19	A B C	243.990 244.090 244.190	317.090 317.190 317.290	5 5 5
20	A B C	243.995 244.095 244.195	317.095 317.195 317.295	5 5 5
21	A B C	244.000 244.100 244.200	317.100 317.200 317.300	5 5 5

TABLE 40-II. FLTSATCOM receive and transmit frequencies.
(concluded)

Channel	**Plan**	**Downlink Frequency (MHz)**	**Uplink Frequency (MHz)**	**Nominal Bandwidth (kHz)**
22	A B C	244.010 244.110 244.210	317.110 317.210 317.310	5 5 5
23	A B C	260.600 261.700 262.300	294.200 295.300 295.900	500 500 500

TABLE 40-III. MARISAT (Gapfiller) receive and transmit frequencies.

Channel	Plan	Downlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
A		254.150	307.750	25
B		257.550	311.150	25
C				500
	1	248.850	302.450	25*
	2	248.875	302.475	25*
	3	248.900	302.500	25*
	4	248.925	302.525	25*
	5	248.950	302.550	25*
	6	248.975	302.575	25*
	7	249.000	302.600	25*
	8	249.025	302.625	25*
	9	249.050	302.650	25*
	10	249.075	302.675	25*
	11	249.100	302.700	25*
	12	249.125	302.725	25*
	13	249.150	302.750	25*
	14	249.175	302.775	25*
	15	249.200	302.800	25*
	16	249.225	302.825	25*
	17	249.250	302.850	25*
	18	249.275	302.875	25*
	19	249.300	302.900	25*
	20	249.325	302.925	25*

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* In operation, communications on the 500-kHz wideband channel (Channel C) is accomplished using frequency-division multiple access (FDMA). The channel is divided into 25-kHz subchannels with transmission data rates varying between 75 and 16000 bps.

TABLE 40-IV. UHF follow-on receive and transmit frequencies.

Channel	Plan	Downlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
1	N	250.350	SHF*	25
	O	250.450	SHF*	
	P	250.550	SHF*	
	Q	250.650	SHF*	
	N'	250.400	SHF*	
	O'	250.500	SHF*	
	P'	250.600	SHF*	
	Q'	250.700	SHF*	
2	N	251.850	292.850	25
	O	251.950	292.950	
	P	252.050	293.050	
	Q	252.150	293.150	
3	N	253.550	294.550	25
	O	253.650	294.650	
	P	253.750	294.750	
	Q	253.850	294.850	
4	N	255.250	296.250	25
	O	255.350	296.350	
	P	255.450	296.450	
	Q	255.550	296.550	
5	N	256.850	297.850	25
	O	256.950	297.950	
	P	257.050	298.050	
	Q	257.150	298.150	
6	N	258.350	299.350	25
	O	258.450	299.450	
	P	258.550	299.550	
	Q	258.650	299.650	
7	N	265.250	306.250	25
	O	265.350	306.350	
	P	265.450	306.450	
	Q	265.550	306.550	

* Uplink frequency is super high frequency from 7.9 to 8.4 GHz on channel 1.

TABLE 40-IV. UHF follow-on receive and transmit frequencies. (continued)

Channel	Plan	Downlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
8	N O P Q	266.750 266.850 266.950 267.050	307.750 307.850 307.950 308.050	25
9	N O P Q	268.150 268.250 268.350 268.450	309.150 309.250 309.350 309.450	25
10	N O P Q	269.650 269.750 269.850 269.950	310.650 310.750 310.850 310.950	25
11	N O P Q	260.375 260.575 260.425 260.625	293.975 294.175 294.025 294.225	25
12	N O P Q	260.475 260.675 260.525 260.725	294.075 294.275 294.125 294.325	25
13	N O P Q	261.575 262.075 261.625 262.125	295.175 295.675 295.225 295.725	25
14	N O P Q	261.675 262.175 261.725 262.225	295.275 295.775 295.325 295.825	25
15	N O P Q	261.775 262.275 261.825 262.325	295.375 295.875 295.425 295.925	25
16	N O P Q	261.875 262.375 261.925 262.425	295.475 295.975 295.525 296.025	25

TABLE 40-IV. UHF follow-on receive and transmit frequencies. (continued)

Channel	Plan	Qownlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
17	N	263.575	297.175	25
	O	263.775	297.375	
	P	263.625	297.225	
	Q	263.825	297.425	
18	N	263.675	297.275	25
	O	263.875	297.475	
	P	263.725	297.325	
	Q	263.925	297.525	
19	N	243.915	317.015	5
	O	243.995	317.095	
	P	244.075	317.175	
	Q	244.155	317.255	
20	N	243.925	317.025	5
	O	244.005	317.105	
	P	244.085	317.185	
	Q	244.165	317.265	
21	N	243.935	317.035	5
	O	244.015	317.115	
	P	244.095	317.195	
	Q	244.175	317.275	
22	N	243.945	317.045	5
	O	244.025	317.125	
	P	244.105	317.205	
	Q	244.185	317.285	
23	N	243.955	317.055	5
	O	244.035	317.135	
	P	244.115	317.215	
	Q	244.195	317.295	
24	N	243.965	317.065	5
	O	244.045	317.145	
	P	244.125	317.225	
	Q	244.205	317.305	
25	N	243.975	317.075	5
	O	244.055	317.155	
	P	244.135	317.235	
	Q	244.215	317.315	

TABLE 40-IV. UHF follow-on receive and transmit frequencies. (continued)

Channel	Plan	Qownlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
26	N O P Q	243.985 244.065 244.145 244.225	317.085 317.165 317.245 317.325	5
27	N O P Q	248.845 248.975 249.105 249.235	302.445 302.575 302.705 302.835	5
28	N O P Q	248.855 248.985 249.115 249.245	302.455 302.585 302.715 302.845	5
29	N O P Q	248.865 248.995 249.125 249.255	302.465 302.595 302.725 302.855	5
30	N O P Q	248.875 249.005 249.135 249.265	302.475 302.605 302.735 302.865	5
31	N O P Q	248.885 249.015 249.145 249.275	302.485 302.615 302.745 302.875	5
32	N O P Q	248.895 249.025 249.155 249.285	302.495 302.625 302.755 302.885	5
33	N O P Q	248.905 249.035 249.165 249.295	302.505 302.635 302.765 302.895	5
34	N O P Q	248.915 249.045 249.175 249.305	302.515 302.645 302.775 302.905	5

TABLE 40-IV. UHF follow-on receive and transmit frequencies. (concluded)

Channel	Plan	Downlink Frequency (MHz)	Uplink Frequency (MHz)	Nominal Bandwidth (kHz)
35	N O P Q	248.925 249.055 249.185 249.315	302.525 302.655 302.785 302.915	5
36	N O P Q	248.935 249.065 249.195 249.325	302.535 302.665 302.795 302.925	5
37	N O P Q	248.945 249.075 249.205 249.335	302.545 302.675 302.805 302.935	5
38	N O P Q	248.955 249.085 249.215 249.345	302.555 302.685 302.815 302.945	5
39	N O P Q	248.965 249.095 249.225 249.355	302.565 302.695 302.825 302.955	5

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