β TEST Version -Revised

AMSAT / IARU Annotated Link Model System

Version: 2.5.3

Organization: XISP-Inc

Project: Alpha CubeSat

Developed by: Jan A. King, W3GEY/VK4GEY With Editorial Assistance and Support from Ralph Wallio, WΦRPK; Ignacio Mas; Lou McFadin, W5DID; Jeff Capehart, W4UFL; Michelle Denise, W5NYV

NOTE #1:	Com. System Engineer:	Enter Name of Communications Engineer: Aaron D. Harper
NOTE #2:	Project Manager:	Enter Name of Project Manager: Gary Barnhard
NOTE #3:	Orbit Type:	NASA Cube Quest Challenge Deep Space Derby Altitude: 4 million KM
NOTE #4:	Model Under Investigation:	6u Cubesat for DSD and LD competition Communications
NOTE #5:	Model/Case No./Rev No.:	TBD/TBD/2.1
	Date Data Last Modified:	2016 February 05
NOTE #6	Date W/S Formulas Last Modified:	2008 December 17

Approvals:

NOTE #7:

X	Com. Eng.
	P.M.
	Config. Control
	LINK MODEL STATUS: Document Not Released

NOTE #8:

Eb/No Method:
S/N Method:

Eb/No Method:
S/N Method:

Introduction, Instructions for Use, References, Revisions: Alpha CubeSat 2016 February 05

Introduction:

This spreadsheet system is an attempt to provide a new kind of learning tool. It is intended, clearly, to be a working link model in order to allow satellite system designers to design and then document fully the RF radio links associated with Command (uplink) and Telemetry (downlink) equipment. It is, however, also intended to be a tutorial on the RF portion of a satellite system. The model makes liberal use of "pop-up" notes and "tools" to enhance the understanding (and hopefully the knowledge) of the Link Model Operator (that's you). After you use the model for awhile, let me know if I have been successful. - Jan A. King, W3GEY and VK4GEY; w3gey@amsat.org

Instructions for Use:

Colors: Colors are used in the link model to make it easier to find data and to protect the link model from crashing. Many of the worksheets are interconnected in that equations in one W/S refer forward or back to data located in other worksheets. Loss of this connection could be critical. Also, the cells are not yet protected (and may never be) as the system has not yet been finalized. Color can be used to provide "coded" messages to the link model operator's brain, once it has been used for awhile. This has been found by the designer to be fairly effective (at least with his brain). Color is used for both the text and the cell background. Some colors have been picked for large field areas where it is not so nice to have the Excel cell grid structure showing. Typically, light grey light green light yellow or white are used this way. These colors have been found by our staff psychologist to have a relaxing effect on the operator. Now let's look at the important uses of color:

NOTE: This is a "pop-up" note. You will see a lot of single cells throughout the model that look like this. Using your mouse, place your cursor on the cell. You don't need to click. A note will pop up. These are either local instructions on how to enter data or use data or some form of training note. You will find that some notes are somewhat larger than the screen. I've tried hard to avoid this, but I haven't been entirely successful. The problem with this is that if you scroll to see the rest of the note and if the yellow cell scrolls off of the screen then the note will close. Frustration will ensue. There are two solutions: 1) Reduce the scale of the viewing page from 100% (the ususal setting) to 75% or 85%. This should allow you to see all of the note. 2) Alternatively, using the mouse, select from the upper toolbar, "View", "Toolbars", and select the one called "Reviewing". There should now be a checkmark to the left of that option. Now, you should find a new toolbar up above the text area of Excel. The far left icon will say "new comment" if you are making a new one. But, if you move the curser over the far left icon you will notice the pop-up prompt now says "edit cell." Now, move the curser over the "NOTE:" cell and left click then left click on the same far left icon. This will allow you to edit the cell BUT it will also FREEZE the cell in the ON condition. Now, you can move the note around by using the slide bars on the side and bottom of the screen to see all of the note. It's probably a good idea not to modify the note. You can close the note by just moving the cursor to an empty cell somewhere and left clicking. It is suggested that you try this process now with the test note above at Cell [D23]. It's been set up to frustrate you in just such a way as the real notes might do later on.

X.XX This is a data entry cell. The link model operator is expected to enter data. The blue background means it is a critcal data entry cell. It is anticipated that your system's selected value is quite likely to be different than the default value used in the cell when you received this link model.

X.XX This is also a data entry cell. This type of cell may not need to be changed as the value you are likely to use may be the same as the default value.

X.XX This is a cell containing an equation or a constant that should not be changed. **The operator should not modify these cells.** A majority of the link model contains this type of cell.

X.XX or X.XX These are cells containing important but, intermediate results. Two colors were used to provide a slight gradation of importance. The orange color is considered to be a result having slightly more significance than the lighter yellow cell.

X.XX This is a key "bottom line" result. It is a primary output of a particular W/S.

X or **X** or **X** A few cells use conditional fomatting which allow the cell colors to change depending on the outcome of the preceeding calculations. Typically a RED box means the result was not successful in achieving the desired performance. A GREEN box means the result did meet or exceed the desired performance. A YELLOW box means the result achieved the performance threshould but, is considered marginal.

Sub-Title Box A pink box like this is simply a sub-title for a sub-worksheet.

X.XX An olive green box is a location where data has been transferred to this worksheet from another and may be transferred to yet another. No action need be taken here. It's purpose is only so that the operator is aware that the data is being transferred from and to other locations.

Frequency Sometimes an olive green cell will be used to re-emphasize a frequency selection as in the "System Performance Summary" W/S.

Non-Coherent FSK Sometimes a tan color cell is used to denote a selected system condition that is non-numeric.

Gains and Losses: A positive gain or directivity is always experssed as a positive number. Sometimes the value may be seen to have a + in front of it. Gains can also be negative (remember, the gain of an antenna is expressed as $10\log(P/P_{isotropic})$. So, if the gain in a particular direction, is below that of an isotropic radiator, then the gain will be expressed as a negative number in dBi.

Losses in link budgets are commonly found as either positive or negative. A loss, by it's nature, is a negative quantity but, some believe that if the loss is clearly referred to as such in the budget *parameter* column, it can have a positive sign. That is the case in this link budget. All losses are shown as being a positive value. The argument is symantic. The question could be asked, "Is a positive loss a negative? And is a negative loss, positive? The important thing for the link model operator to know when using this modeling system is that the losses are show as positive values **BUT**, in the equations that sum the gains and losses to yield the result, the gains are *added* and the losses are *subtracted*. For example, see the equation in Cell [B11] of the "Uplink" W/S.

Speciality W/S vs. Tools: The first 13 W/Ss are all interconnected, in that they all have equations that make use of data contained in one or more of the other W/Ss. These worksheets, taken together, constitute the link model. The next 5 W/Ss are supplementary to the model and are considered to be *tools*. The important distinction is, that tools *never* produce results that are automatically linked into the model itself, whereas within the first 13 W/Ss there is lots of interlinking going on. The primary process is one where data

calculated or selected in one of the S*peciality* W/Ss (e.g., "Receivers") becomes just one entry in either the Uplink or the Downlink budget. The usefulness of a tool is to be able to explore a specific tradeoff without having to worry about that data winding up in the formal Uplink or Downlink pages.

There is one additional and imporatant comment about tools. Within the Speciality W/Ss, there are some embedded tools. The best example of this is in the "Receivers" W/S. Contained in separate sub-tables is a *Noise Figure/Noise Temperature Calculator (Tool)* and a *Ground Station, Antenna or Sky Noise Temperature Calculation Tool* .

Proceeding Through the Model: Starting with the "Title Page" W/S, proceed through each Speciality W/S, adding data, in sequence. Then select the next tab at the bottom of the W/S. The "Uplink", "Downlink" and "System Performance Summary" W/Ss contain the final results of the model. The Tools W/Ss are located beyond the "System Perfomance Summary" W/S and may be explored and used as they may be helpful to you. Any comments you may have on this model will be greatfully received by me. **Thanks!**
Jan, VK4GEY.

References:

The following references were used to prepare this link model:

1 A.R.R.L., *The ARRL Antenna Handbook,* American Radio Relay League, 1974, pp. 153-155.

2 Deloraine, E.M., Westman, H.P., Edie, L.C. *Reference Data for Radio Engineers, 3rd Edition* , Federal Telephone & Radio Corp., 1949, pp. 362-396.

3 Feher, Dr. Kamilo, *Digital Communications, Satellite/Earth Station Engineering* , Prentice-Hall Books, 1983, Chapter 4.

4 Ippolito, L.J.Jr., *Radiowave Propagation in Satellite Communications,* Van Norstrand Reinhold Co., 1986, Chapters 3 and 7.

5 Jordan, E.C. (Edit.), *Reference Data for Engineers: Radio, Electronics, Computer, and Communications, 7th Edition* , Howard W. Sams & Co., 1985, pp. 29-26 - 29-37 and pp. 30-03 - 30-11.

6 Martin, W.L., *AMMOS and DSN Support of Earth Orbiting and Deep Space Missions,* Jet Propulsion Laboratory, TMOD Directorate, 1996, p.44-46.

7 Morgan, W.L. and Gordon, G.D., *Principles of Communicaitons Satellites* , John Wiley & Sons, Inc., 1993, Chapter 2 and pp.140-143.

8 Van Wie, D.G. and Roark, R.C., *A New Alert Protocol,* Blue Water Design, LLC*, 2003,* pp. 18-23.

9 Jackson, R.B., *The Canted Turnstile as an Omnidirectional Spacecraft Antenna,* X-712-67-441, NASA/Goddard Space Flight Center, 1967, Entire Document.

Revisions:

The following formal revisons have been made to this Link Model System:

Version:	*Date:*	*Adjustments and/or Modifications Made:*
2.0	1/30/2005	NEW; β-Test Version
2.1	2/7/2005	Revised All "Pop-up" Notes; Corrected some cell colors to improve consistancy; Added reference 9; Corrected cells A19 & D19 in "Uplink" W/S.
2.1.1	2/12/2005	Revised Equation at Cell [B15] of "Uplink Budget" W/S. Index function should use column H values not column C values.
2.1.2	2/21/2005	Modified Data for Monopole Antenna Pattern in Monopole Table in "Antenna Patterns" W/S. Added 3 dB to all Values (0° to 90°)
2.1.3	2/26/2005	Modified "Receviers" W/S. Added loss value for cable D. Modified 2nd Stage to "Communications Receiver" at Ground Station.
2.1.4	2/27/2005	Added Tubo Code Option to "Modulation-Demodulation Method" W/S.
2.2	2/27/2005	Added EZNEC+ and Chart Wizzard Antenna Plots to "Antenna Pattern" W/S.
2.2.1	5/15/2005	Edited Notes in I.I.R.R W/S.
2.2.2	6/23/2005	Edited More Notes Throughout Link Model.
2.3	7/16/2005	Revised Antenna Gain and Antenna Pointing Losses W/Ss to Include a High Gain (Parabolic Reflector) S/C Antenna Option & Iso. Radiator Option.
2.3.1	9/28/2005	Modified Notes at Cells [P135] and [V52] of "Receivers" W/S. Added **To** reference temperature "readout" at Cell [U56] of "Receivers" W/S.
2.3.2	10/4/2005	Modified Equation at Q62 of "Antenna Gain" W/S. Equation was "=21/(F55/1000)*H62" and now is "=21/((F55/1000)*H62)." TNX Ignacio Mas.
2.4	10/22/2006	Changed "Downlink" to "Uplink" at D22 in "Antenna Gain" W/S. Changed hard coded cells in "Ant. Pointing Losses" W/S for referenced cells. Fixed errors in downlink portion of worksheet. There were several incorrect references. Added NOTEs at Line 57 of the "Uplink" W/S and Line 56 of the "Downlink W/S" to remind user about S/N when using coding. TNX Jeff Capehart W4DFU.
2.5	Not Released	Added HEO, GEO and Deep Space Orbit Capability. Link Model Operator selects options. Separted Orbit and Frequency into two separate pages.
2.5.1	3/6/2008	Repaird Bugs in User #2, Delta Longitude, Range, Azimuth and Earth Central Angle; Thank to Michelle Denise, W5NYV
2.5.2	3/18/2008	Repaired Import of Frequency Values to "Transmitters" and "Receivers" Worksheets; Thanks to Michelle Denise, W5NYV
2.5.3	12/17/2008	In "Atmos. & Ionos. Losses" W/S; temporarily made Atmos. Loss dependent on Manually Set Elevation Angle. This needs more work.

System Orbit Characteristics:

Alpha CubeSat 2016 February 05 Version: 2.5.3

Orbit Option to be Used in Link Model (LEO, HEO, GEO, Deep Space)

Select Orbit Option: 4 Deep Space **Slant Range:** 3,999,000 km Used in Path Loss Calculation

Option No.:	Orbit Type:	Slant Range:	
1	LEO	2783.9	km
2	HEO	41126.8	km
3	GEO	38097.0	km
4	Deep Space	3.999E+06	km

Element Reference Epoch: 2005, 87.50000

Blue = User Data Entry Values
Black = Computed Values (**No Data Entry**)

Red = Key Results
Blue =Critical User Data Entry Values

NOTE: Cells Not Yet Protected

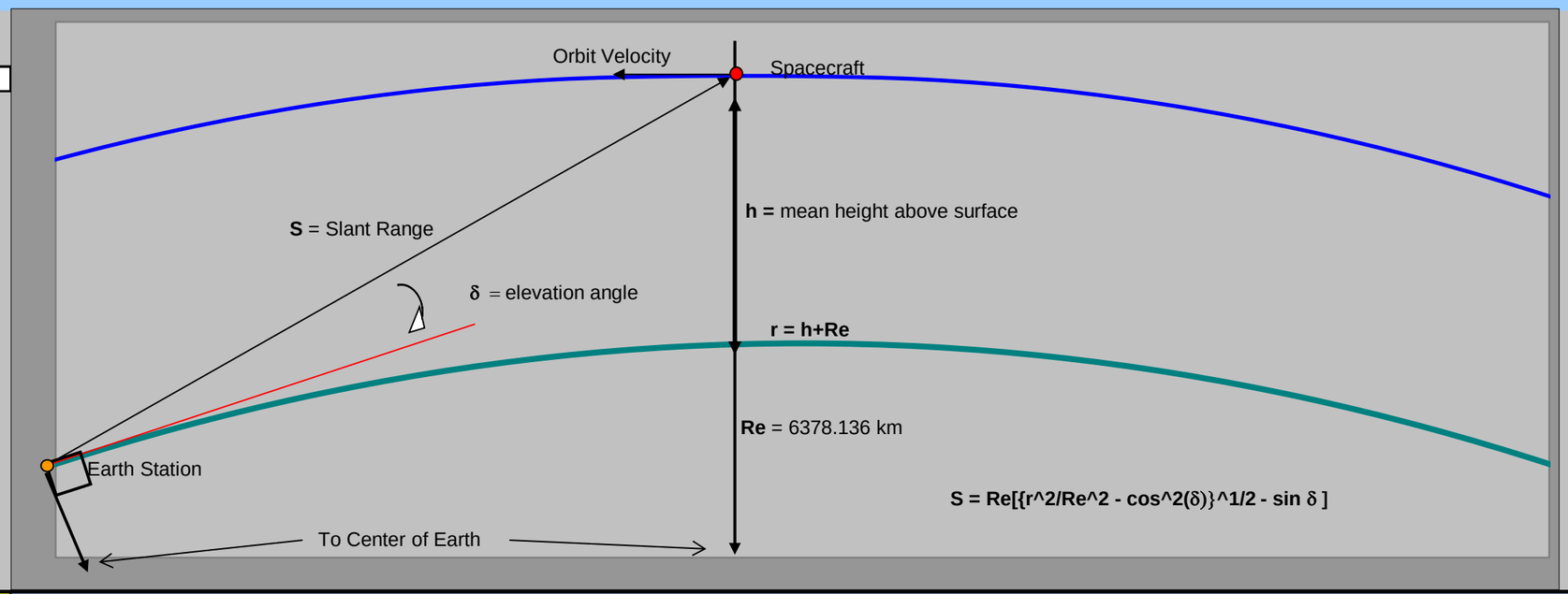
LEO Orbit - Option #1

NOTE:

Low Earth Orbit Properties

Slant Range to Spacecraft vs. Elevation Angle

Parameter:	*Value:*	*Unit:*
Earth Radius:	6,378.14	km
Height of Apogee (ha):	805.0	km
Height of Perigee (hp):	795.0	km
Semi-Major Axis (a):	7,178.1	km
Eccentricity (e):	0.000697	
Inclination (I):	98.61	°
Argument of Perigee (ω):	180.0	°
R.A.A.N. (Ω):	123.70	°
Mean Anomaly (M):	0.00	°
Period:	100.874	minutes
dω/dt:	-2.9241	deg./day
dΩ/dt:	0.9860	deg./day
dM/dt:	Not Implemented	deg./day
Mean Orbit Altitude:	800.00	km
Mean Orbit Radius:	7,178.14	km
Sun Synchronous Inclination:	98.61	°
Elevation Angle (δ):	5.0	°
Slant Range (**S**):	2,783.9	km.



LEO Orbit Geometry

High Earth Orbit (HEO) - Option #2

NOTE:

HEO Orbit Properties

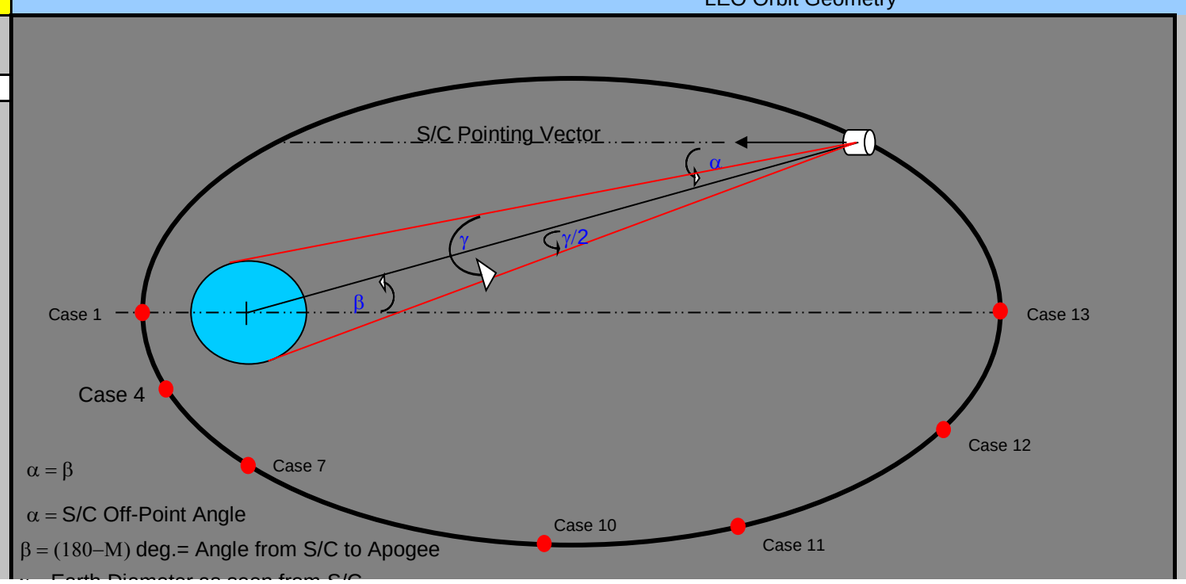
S/C Spinning and NADIR-Pointing at Apogee

Parameter:	*Value:*	*Unit:*
Earth Radius:	6,378.14	km
Height of Apogee:	35,786	km
Height of Perigee:	500	km
Semi-Major Axis (a):	24,521.14	km
Eccentricity (e):	0.719502	
Inclination (I):	7.00	degrees
Argument of Perigee (ω):	180.0	degrees
R.A.A.N. (Ω):	0.00	degrees
Mean Anomaly (M):	180.00	degrees
Period:	636.90	minutes
dω/dt:	0.7542	deg./day
dΩ/dt:	-0.3814	deg./day

1) To Change Orbit Keplarians Modify **ONLY** Blue Values Above.

2) Choose Case No. and Enter Here. Proceed to "Uplink & Downlink

HEO Orbit



Choices" Below.

Geometry

γ = Earth Diameter as seen from S/C
$\alpha + \gamma/2 =$ Worst Case Squint Angle

CASE NO. SELECTED:	13	35,786.0 km Altitude	Elevation Angle:	5.0 °	Slant Range (S):	41,126.8 km

CASE:		*R(km):*	*M(deg.):*	*altitude (km):*	*S/C off-point angle:*	*S/C rcvr. ant. temp.(K)*
1	perigee	6878.1	0	500.0	180.0 deg.	35
2		6977.6	15	599.5	165.0 deg.	35
3		7286.6	30	908.5	150.0 deg.	35
4		7838.8	45	1,460.7	135.0 deg.	35
5		8697.9	60	2,319.8	120.0 deg.	35
6		9970.3	75	3,592.2	105.0 deg.	35
7		11827.0	90	5,448.8	90.0 deg.	35
8		14533.4	105	8,155.2	75.0 deg.	35
9		18472.4	120	12,094.3	60.0 deg.	35
10		24076.0	135	17,697.8	45.0 deg.	40
11		31380.2	150	25,002.0	30.0 deg.	50
12		38775.1	165	32,396.9	15.0 deg.	90
13	apogee	42164.1	180	35,786.0	0.0 deg.	170
14		41756.6	175	35,378.4	5.0 deg.	160

User Defined Case:

SOME KEY ORBIT & LINK PARAMETERS	
EARTH ANGULAR DIAMETER (γ):	17.4 °
S/C POINTING VECTOR (α):	10.0 °
WORST CASE SQUINT ANGLE:	18.7 °
RX ANTENNA POINTING LOSS:	0.00 dB
TX ANTENNA POINTING LOSS:	0.00 dB
GROUND RCVR Eb/No:	10.1 dB
S/C RCVR Eb/No	36.5 dB

3) If CASE No. 14 is Selected, Choose Mean Anomaly Value and S/C Rcvr Antenna Temp. and Enter Here.

Geostationary Earth Orbit (GEO) - Option #3

NOTE:

Path Length to User Terminal from Spacecraft

Parameter:	*Value:*	*Unit:*	*Comment(s):*
Geostationary Altitude:	35,786.019	km	Height Above Geoid
Equatorial Radius of Earth (Re):	6,378.137	km	
Geostationary semi major axis	42,164.156	km	Accurate to 1/10 meter
Typical Path Length:	37,410.000	km	User at typical Longitude difference from satellite and at mean latitude.
Shortest Path Length:	35,786.019	km	User at same longitude as satellite and at the equator
Longest Path Length:	41,678.957	km	User at max. longitude difference from satellite and at max. latitude (0.0° User Elevation Angle).

	UPLINK: User #1:			S/C	DOWNLINK:	User #2: NOTE:	
User Latitude:	40.000	°	+ = North Latitude; - = South Latitude		User Latitude:	40.000	°
User Longitude:	-105.000	°	+ = East Longitude; - = West Longitude		User Longitude:	-116.000	°
Spacecraft Slot (Longitude):	-132.000	°	Enter Slot Postion in Degrees East Longitude (NOTE: Δ Longitude $\leq$ 81.3°) [- = W. Long.; + = E. Long.]		S/C Slot Longitude:	-132.000	°
Slant Range to User:	38097.0	km	The distance from the GEO satellite to the user. This Value used in Link Budget Path Loss Calculation.		Slant Range to User:	37715.2	km
User Elevation Angle:	36.015	°	This is the Elevation Angle to the GEO spacecraft from the User (latitude and longitude) site.		User Elevation Angle:	40.853	°
User Azimuth Angle:	218.403	°	This is the azimuth angle to the GEO spacecraft from the User (latitude and longitude) site.		User Azimuth Angle:	204.041	°
Earth Central Angle:	46.957	°	The angle measured from Earth center between the sub-satellite point and the ground station location.		Earth Central Angle:	42.577	°

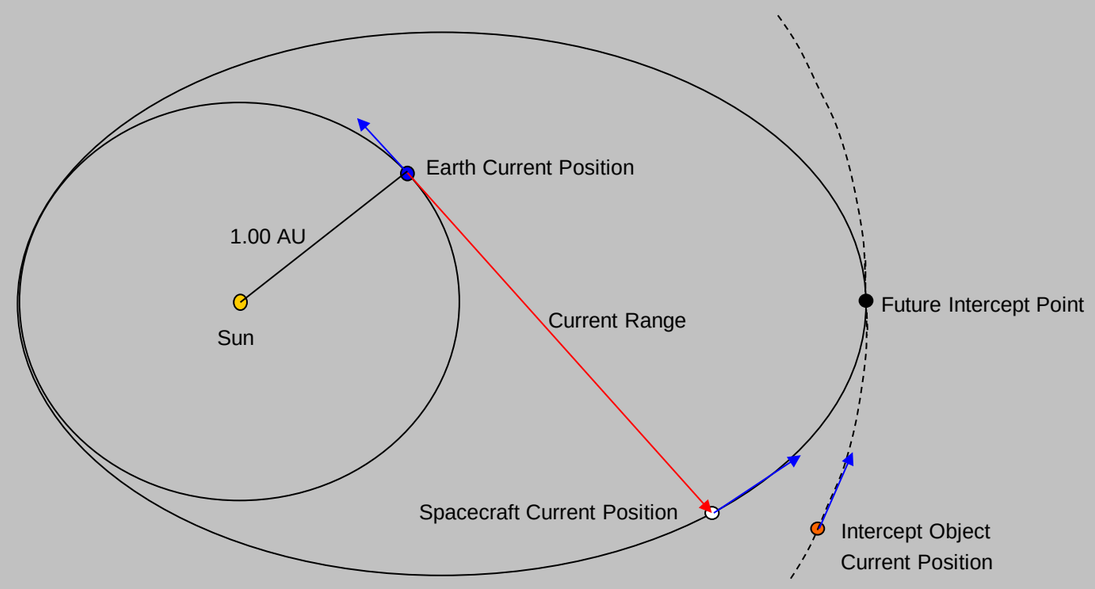
Deep Space Mission - Option #4: Range Expressed in Astronomical Units (AU)

NOTE:

Mission Target Object: 4 Million KM

Current Range to S/C: 0.027 AU

Current Range to S/C: 3.999E+06 km



Heliocentric Transfer Mission (Example)

UPLINK & DOWNLINK Frequency Choices:

Orbit Type Selected: **Deep Space**

Slant Range for Orbit Option Selected: **3,999,000 km**

Path Loss = 22.0 + 20 log (S/λ)

NOTE:

	Option:	Frequency:	Wavelength (λ):	Path Loss:
Uplink:	#1:	145.800 MHz	2.056 meters	207.8 dB
	#2:	437.500 MHz	0.685 meters	217.3 dB
	#3:	1269.900 MHz	0.236 meters	226.6 dB
Operator Selected Option: →	#4:	7145.000 MHz	0.042 meters	241.6 dB
Downlink:	#1:	145.800 MHz	2.056 meters	207.8 dB
	#2:	437.450 MHz	0.685 meters	217.3 dB
	#3:	2405.000 MHz	0.125 meters	232.1 dB
Operator Selected Option: →	#4:	32000.000 MHz	0.009 meters	254.6 dB

Uplink Frequency Choice: **4** **7145.000 MHz**

Path Loss for Orbit Selected: **241.6 dB**

Downlink Frequency Choice: **4** **32000.000 MHz**

Path Loss for Orbit Selected: **254.6 dB**

System Transmitters & Line Losses:

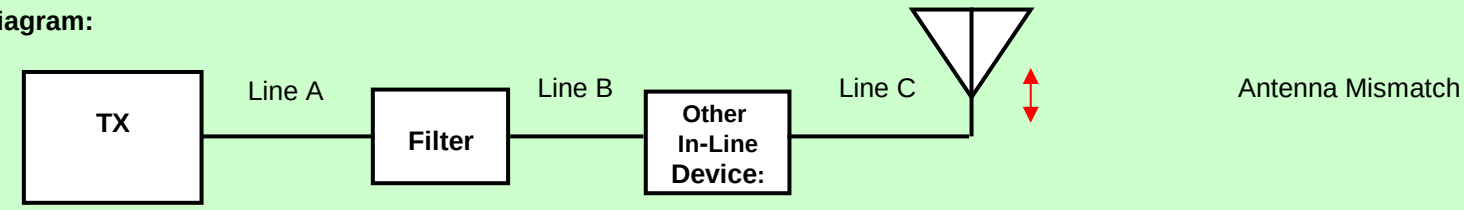
Alpha CubeSat

2016 February 05

Uplink Transmitter System (At Ground Station):

NOTE:

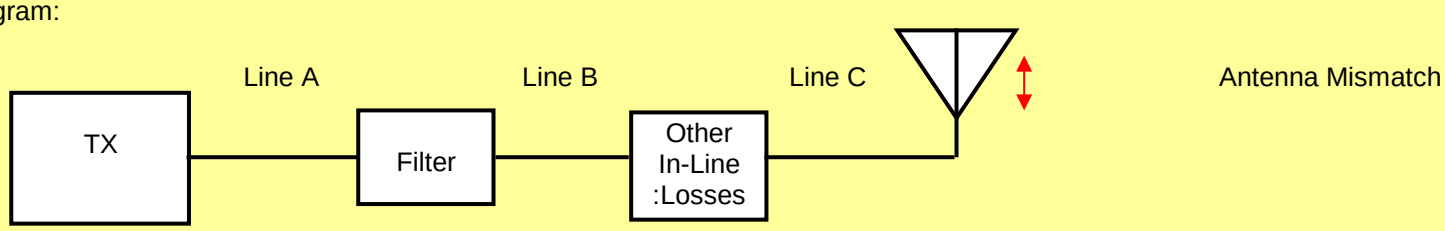
Block Diagram:



Transmitter Power:	50.00	Watts =	17.0	dBW =	46.99	dBm	
Cable or Waveguide ("Line") Losses:							
Line A Length:					1.0	meters	
Line B Length:					0.3	meters	
Line C Length:					25.0	meters	
Total Line Length (Line A+B+C):					26.3	meters	
Cable/W. Guide Type:					Belden 9913	cable	
Cable/W.Guide Loss/meter:	0.05 dB	At (freq.)	7145	MHz =	1.315	dB	
Other Components in Line:							
No. of In-Line Connectors:	6	Connectors X 0.05 dB/Con.		=	0.3	dB	
Filter Insertion Losses:					1.0	dB	
Other In-Line Losses:	Device:	Directional Coupler			0.5	dB	
Antenna Mismatch Losses:		(See "VSWR Loss Tool" W/S)			0.5	dB	
Total Line Losses:					3.62	dB	
Total Power Delivered to Antenna:					13.37	dBW	

Downlink Transmitter System (At Spacecraft):

Block Diagram:



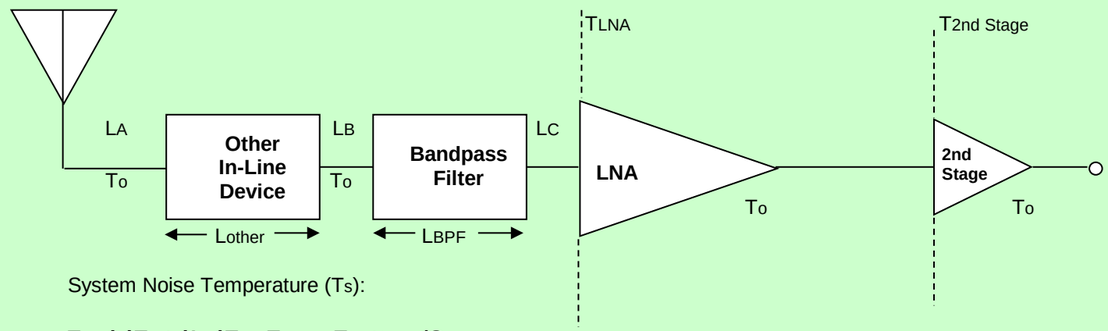
Transmitter Power:	3.0	Watts =	4.8	dBW =	34.77	dBm	
Cable or Waveguide Loss:							
Line A Length:					0	meters	
Line B Length:					0	meters	
Line C Length:					0.3	meters	
Total Line Length (Lines A+B+C):					0.3	meters	
Cable/Guide Type:					MicroCoax MCJ185A	cable	
Cable/Guide Loss/meter:	0.49 dB	At (freq.)	32000	MHz =	0.147	dB	
Other Components in Line:							
No. of In-Line Connectors:	2	Connectors X 0.05 dB		=	0.1	dB	
Filter Insertion Losses:					0.0	dB	
Other In-Line Losses:	Device:	N/A			0	dB	
Antenna Mismatch Losses:		(See "VSWR Loss Tool" W/S)			0.240	dB	

Total Line Losses:	**0.49**	dB
Total RF Power Delivered to Antenna:	4.28	dBW

Uplink Receiver System (At Spacecraft):

NOTE:

Block Diagram:



System Noise Temperature (T_S):

$T_S = (\alpha)T_a + (1-\alpha)T_o + T_{LNA} + T_{2ndStage}/G_{LNA}$

Where:

T_a ≡ Antenna Temperature or Sky Temperature (°K)

T_o ≡ System Line Temperature (Physical Temperature) (°K) ≡ System Reference Temperature

T_{LNA}≡ Noise Temperature of the Low Noise Amplifier (°K)

$T_{2nd\ Stage}$ ≡ Noise Temperature of Next Stage Amplifier or Mixer (°K)

G_{LNA} ≡ The gain of the LNA in linear (non-dB) units NOTE:

α ≡ Feed Line Coefficient = 10^ -((L_A/10)+(L_B/10)+(L_C/10)+(L_{BPF}/10)+(L_{other}/10))

Where:

L_A, L_B, L_C ≡ All Cable or Waveguide Losses (expressed in dB)

L_{BPF} ≡ Insertion Loss of any bandpass fiter used in front of LNA (expressed in dB)

L_{other} ≡ Insertion Loss of any other In-Line device in front of LNA (expressed in dB)

Cable or Waveguide "Line" Losses:

Line A Length:			0.3	meters
Line B Length:			0	meters
Line C Length:			0	meters
Cable/Guide Type:			MicroCoax MCJ185A	cable
Cable/Guide Loss/meter:	0.1	dB at frequency	7145.0	MHz
Line A Loss:		L_A =	0.03	dB
Line B Loss:		L_B =	0	dB
Line C Loss:		L_C =	0	dB
Bandpass Filter Insertion Loss:		L_{BPF} =	0.0	dB
Insertion Loss of Other In-Line Devices:		L_{other} =	0	dB
No. of In-Line Connectors:	2	X .05 dB/Con.=	0.1	dB
Other In-Line Device Type:			none	
Total In-Line Losses from Antenna to LNA:			0.13	dB
Transmission Line Coefficient:		α =	0.9705	
Antenna or "Sky" Temperature: NOTE:		T_a =	290	K
Spacecraft Temperature:		T_o =	3.9	K
LNA Temperature:		T_{LNA} =	0.8	K

Noise Temperature/Noise Figure Calculator (Tool): NOTE:

$NF_{dB} = 10\ LOG_{10}[1+(T/T_o)]$

or

$T = T_o[10^{(NF_{dB}/10)}-1]$

T_o = 3.9 K

NF_{dB} = 0.8 dB

T = 0.8 K

OR

LNA Gain: 40.0 dB

G_{LNA} = 10000.0

2nd Stage Temperature: $T_{2ndStage}$ = 0 K

System Noise Temperature: T_S = 282.4 K

T = 200.0 K

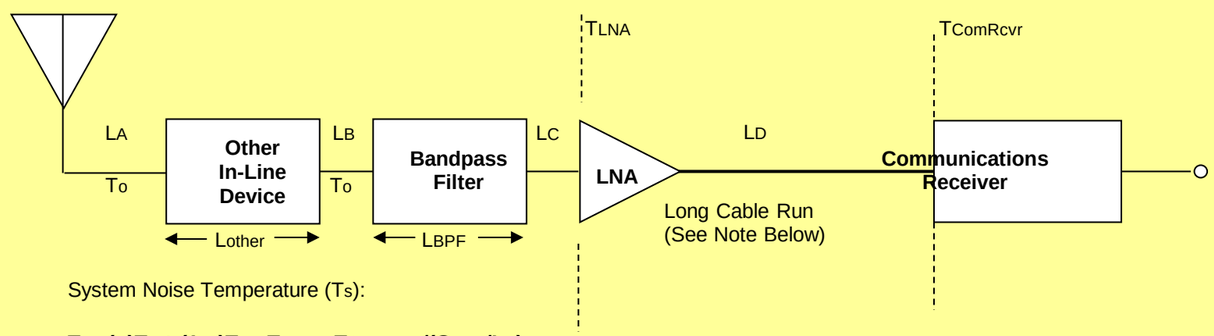
NF_{dB} = 17.18 dB

Enter Data Here:

Result is Here

Downlink Receiver System (At Ground Station):

Block Diagram:



System Noise Temperature (T_S):

$T_S = (\alpha)T_a + (1-\alpha)T_o + T_{LNA} + T_{ComRcvr}/(G_{LNA}/L_D)$

Where:

T_a ≡ Antenna Temperature or Sky Temperature (°K)

T_o ≡ System Line Temperature (Physical Temperature) (°K)

T_{LNA} ≡ Noise Temperature of the Low Noise Amplifier (°K)

$T_{ComRcvr}$ ≡ Noise Temperature of Communications Receiver Front End (°K)

G_{LNA} ≡ The gain of the LNA in linear (non-dB) units NOTE:

α ≡ Feed Line Coefficient = 10^ -((L_A/10)+(L_B/10)+(L_C/10)+(L_{BPF}/10)+(L_{other}/10))

Where:

L_A, L_B, L_C ≡ All Cable or Waveguide Losses (expressed in dB)

L_{BPF} ≡ Insertion Loss of any bandpass fiter used in front of LNA (expressed in dB)

L_{other} ≡ Insertion Loss of any other In-Line device in front of LNA (expressed in dB)

Cable or Waveguide "Line" Losses: NOTE:

Line A Length:			2.5	meters
Line B Length:			0.3	meters
Line C Length:			0.3	meters
Cable/Guide Type:			Belden 9913 cable	
Cable/Guide Loss/meter:	0.092	dB (at freq.)	32000.0	MHz
Line A Loss:		L_A =	0.23	dB
Line B Loss:		L_B =	0.0276	dB
Line C Loss:		L_C =	0.0276	dB
Bandpass Filter Insertion Loss:		L_{BPF} =	0.0	dB
Insertion Loss of Other In-Line Devices:		L_{other} =	0.0	dB
No. of In-Line Connectors:	4	X 0.05 dB/con.=	0.2	dB
Other In-Line Device Type:			none	

Ground Station, Antenna or Sky Noise Temperature Calculation Tool:

Galactic Noise Component:

Total In-Line Losses from Antenna to LNA:			0.49	dB
Transmission Line Coefficient:		α =	0.8943	
Antenna or "Sky" Temperature:	NOTE:	T_a =	126	K
Ground Station Feedline Temperature:		T_o =	280	K
LNA Temperature:		T_{LNA} =	31.41	K
LNA Gain:	60.0 dB	G_{LNA} =	1000000.0	
Cable/Waveguide D Length:	NOTE:		25.0	meters
Cable/Waveguide D Type:			Belden 9913 cable	
Cable/Waveguide D Loss/meter:			0.092	dB/m
Cable/Waveguide D Loss:			2.3	dB
Communications Receiver Front End Temperature		$T_{ComRcvr}$ =	1000	K
System Noise Temperature:		T_s =	174	K

Receiver Frequency:		32000	MHz
Coldest Galactic Noise Temp.:		3	K
Warmest Galactic Noise Temp:		3	K
Terrestrial Noise Component:			
Receiver Bandwidth:		80.0	KHz
Estimated or Measured Noise Level:	NOTE:	-132.4	dBm
Noise Source Effective Temperature:		52	K
Minimum Sky Noise Temp:		55	K
Maximum Sky Noise Temp:		55	K

System Antenna Gains (Directivities): Alpha CubeSat 2016 February 05

Uplink Antenna System:

NOTE:

Ground Station:

Uplink Frequency: 7145 MHz — Wavelength: 0.0420 meters

Operator Selects Option 1 to 4 Here

OPTION: 3 Parabolic Reflector — Polarization: RHCP

1	Yagi	Boom Length (λ):	3.2	Optimum Elements (n):	12	per Plane	(in V and in H)		Maximum Gain:	16.3	dBiC	Beamwidth:	30.6	°	Antenna Length:	0.134	meters
2	Helix	Turns (n):	10.5	Turn Spacing (λ):	0.25	Circumference (λ):	1.0		Gain:	16.0	dBiC	Beamwidth:	32.2	°	Antenna Length:	0.110	meters
3	Parabolic Reflector	DSS-25		Diameter:	34.0 m	Aperture Efficiency:	56%		Gain:	94.7	dBiC	Beamwidth:	0.1	°			
4	User Defined	KLM (22x22 Element)	Yagi	(Example)					Gain:	18.5	dBiC	Beamwidth:	24.0	°	Antenna Length:	X.XX	meters

Spacecraft:

Uplink Frequency: 7145 MHz — Wavelength: 0.0420 meters

Operator Selects Option 1 to 7 Here

OPTION: 7 Other (User Defined) — Polarization: RHCP

1	Monopole		Gain:	2.15	dBiL		Beamwidth:	156.2	°	No Radiation in Back Hemisphere **AND** Null on Axis ("Tip Null")	
2	Dipole		Gain:	2.15	dBiL		Beamwidth:	156.2	°	Null On Axis; Both Poles	
3	Canted Turnstyle		Gain:	2.0	dBiC	(typical)	Beamwidth:	180	°	Circular Pol. On Axis; RHCP one pole, LHCP Opposite Pole, Linear in Equatorial Plane	
4	Quadrifilar Helix	Loop (λ): 1/2	Gain:	4.0	dBiC		Beamwidth:	150	°	No Radiation in Back Hemisphere; Excellent Axial Ratio Performance Off-Axis	
5	Patch		Gain:	6.0	dBi (L or C)		Beamwidth:	90	°	Low Radiation in Back Hemisphere; High On-Axis Gain; Can be Maded Linear or Circularly Polarized	
6	Parabolic Reflector		Gain:	49.5	dBi (L or C)		Beamwidth:	0.5	°	To Be Used if a High Gain Antenna is Required on S/C.	Dish Diameter: 5.4 m; Dish Aperture Efficiency: 55%
7	Other (User Defined)	reflectenna array	Gain:	8.0	dBi		Beamwidth:	4.8	°	Gain, Beamwidth and Roll-Off Equation To Be Provided By Link Model Operator	

UPLINK ↑ **DOWNLINK ↓**

Downlink Antenna System:

Spacecraft:

Downlink Frequency: 32000 MHz — Wavelength: 0.0094 meters

Operator Selects Option 1 to 5 Here

OPTION: 7 Other (User Defined) Polarization: RHCP

1	Monopole		Gain:	2.15	dBiL		Beamwidth:	156.2	°	No Radiation in Back Hemisphere & Null on Axis ("Tip Null")
2	Dipole		Gain:	2.15	dBiL		Beamwidth:	156.2	°	Null On Axis; Both Poles
3	Canted Turnstyle		Gain:	2.0	dBiC	(typical)	Beamwidth:	180	°	Circular Pol. On Axis; RHCP one pole, LHCP Opposite Pole, Linear in Equatorial Plane
4	Quadrifilar Helix	Loop (λ): 1/2	Gain:	4.0	dBiC		Beamwidth:	150	°	No Radiation in Back Hemisphere
5	Other (User Defined)	Patch (Example)	Gain:	6.0	dBi (L or C)		Beamwidth:	90	°	No Radiation in Back Hemisphere
6	Parabolic Reflector		Gain:	53.9	dBi (L or C)		Beamwidth:	0.3	°	To Be Used if a High Gain Antenna is Required on S/C.
7	Other (User Defined)	reflectenna array	Gain:	32.0	dBi		Beamwidth:	3	°	Gain, Beamwidth and Roll-Off Equation To Be Provided By Link Model Operator

Dish Diameter:	2.0 m	Dish Aperture Efficiency:	55%

Ground Station:

Downlink Frequency: 32000 MHz Wavelength: 0.0094 meters

Operator Selects Option 1 to 4 Here

OPTION: 3 Parabolic Reflector Polarization: RHCP

1	Yagi	Boom Length (λ):	2.0	Optimum Elements (n):	8	per Plane (in V and in H)		Maximum Gain:	14.1	dBiC	Beamwidth:	39.7	°	Antenna Length:	0.019	meters
2	Helix	Turns (n):	10.5	Turn Spacing (λ):	0.25	Circumference (λ):	1.0	Gain:	16.0	dBiC	Beamwidth:	32.2	°	Antenna Length:	0.025	meters
3	Parabolic Reflector	DSS-25		Diameter:	34.0 m	Aperture Efficiency:	56%	Gain:	79.0	dBiC	Beamwidth:	0.0	°			
4	User Defined	KLM (22x22 Element)	Yagi	(Example)				Gain:	18.5	dBiC	Beamwidth:	24.0	°	Antenna Length:	X.XX	meters

Look-Up Table

Optimum Yagi Antenna Performance:

Boom Length (λ):	Optimum No. Elements (n):	Maximum Gain (dBi):
0.35	3	9.65
0.55	4	10.86
0.80	5	11.85
1.15	6	12.45
1.45	7	13.35

1.80	8	14.05
2.10	9	14.40
2.45	10	15.25
2.80	11	15.95
3.15	12	16.30
3.55	13	16.95
4.00	14	17.45
4.40	15	18.15
4.75	16	18.65
5.20	17	19.35
5.55	18	19.85
6.00	19	20.25
6.50	20	20.75
7.00	21	21.35
7.50	22	21.65

Data Taken from *ARRL Antenna Book*

System Antenna Pointing Losses:

Alpha CubeSat

2016 February 05

NOTE:

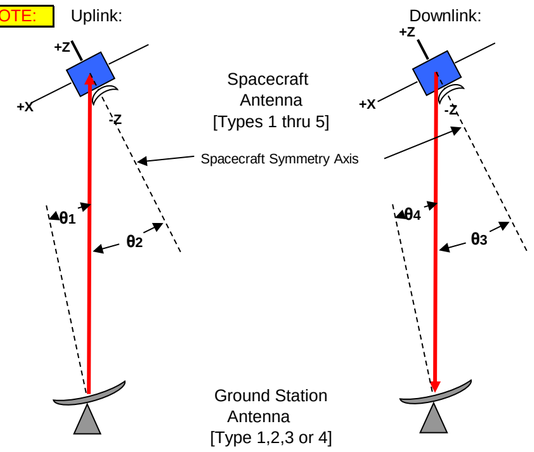


Figure 1 Figure 2

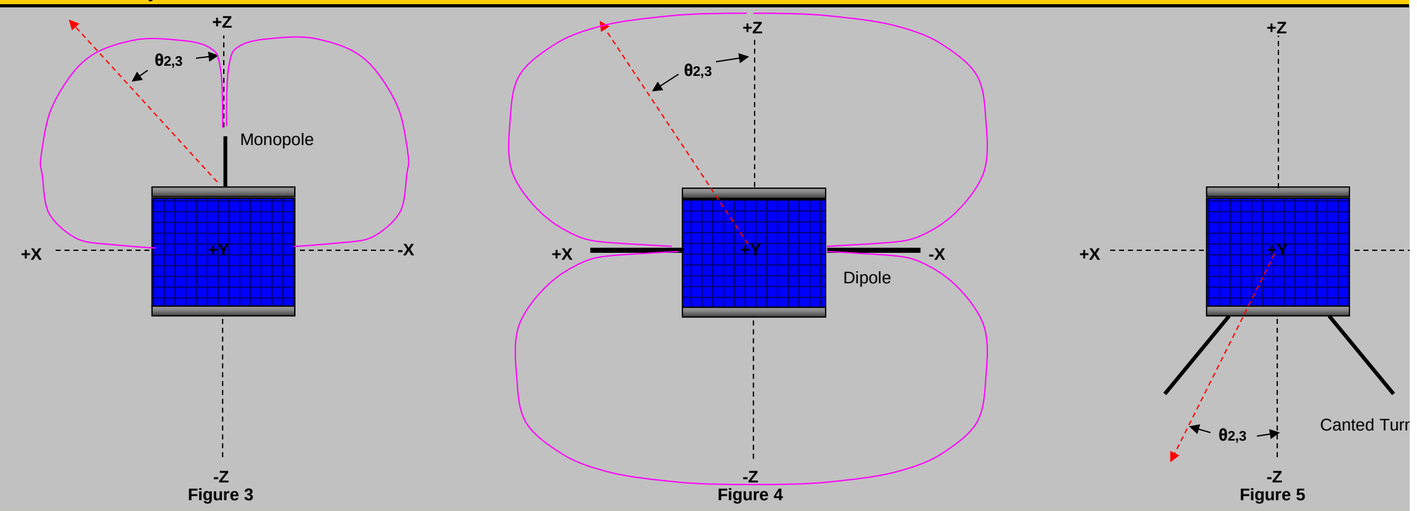


Figure 3 Figure 4 Figure 5

Antenna Loss Determination:

(See Also Figure 8)

Uplink Antenna System:

NOTE:

Ground Station:

Uplink Frequency: 7145 MHz Wavelength: 0.0420 meters

This Option was Selected on the Previous Page

3 Parabolic Reflector Polarization: RHCP

1	Yagi	Maximum Gain:	16.3	dBiC	Beamwidth:	30.6 °
2	Helix	Gain:	16.0	dBiC	Beamwidth:	32.2 °
3	Parabolic Reflector	Gain:	94.7	dBiC	Beamwidth:	0.1 °
4	User Defined	Gain:	18.5	dBiC	Beamwidth:	24.0 °

Esimated Pointing Error (θ_1): 0.0015 ° **Approx. Antenna Pointing Loss:** 0.0 dB

NOTE:

2.77

Spacecraft:

Uplink Frequency: 7145 MHz Wavelength: 0.0420 meters

This Option was Selected on the Previous Page

7 Other (User Defined) Polarization: RHCP

Antenna Roll-Off Calculation Formulas

						Antenna Coordinate System:		
1	Monopole	Gain:	2.15 dBiL	Beamwidth:	156.2 °	See Figures 1and 3	monopole	12.8 dB
2	Dipole	Gain:	2.15 dBiL	Beamwidth:	156.2 °	See Figures 1and 4	dipole	0.0 dB

3	Canted Turnstyle			Gain:	2.0 dBiC	Beamwidth:	180 °	See Figures 1, 5 & 8	canted turnstyle	0.0 dB	
4	Quadrifilar Helix	Loop (λ):	1/2	Gain:	4.0 dBiC	Beamwidth:	150 °	See Figures 1and 6	quadrifilar helix	0.0 dB	
5	Patch			Gain:	6.0 dBi (C or L)	Beamwidth:	90 °	See Figures 1and 7	patch antenna	0.0 dB	
6	Parabolic Reflector	[For S/C Hi Gain Option]		Gain:	49.5 dBi (C or L)	Beamwidth:	0.5 °	Dish Boresight Aligned with +Z Axis	parabolic reflector	32.7 dB	879.25 Intermediate Calculation - Please Ignore This Value.
7	Other (User Defined)	Reflectenna		Gain:	8.0 dBi	Beamwidth:	4.8 °	Link Model Operator to Provide	user defined	0.0 dB	Link Model operator enter equation for functional behaviorof user defined antenna here.

Angle between S/C antenna symmetry axis and vector from S/C to gnd. station (θ_2): 3 °

Approx. Antenna Pointing Loss: 0.0 dB

UPLINK ↑ **DOWNLINK** ↓

Downlink Antenna System:

Spacecraft:

Downlink Frequency: 32000 MHz — Wavelength: 0.0094 meters

This Option was Selected on the Previous Page

7 Other (User Defined) — Polarization: RHCP

Antenna Coordinate System: — Antenna Roll-Off Calculation Formulas

1	Monopole			Gain:	2.15 dBiL	Beamwidth:	156.2 °	See Figures 2 and 3	monopole	12.8 dB	
2	Dipole			Gain:	2.15 dBiL	Beamwidth:	156.2 °	See Figures 2 and 4	dipole	0.0 dB	
3	Canted Turnstyle			Gain:	2.0 dBiC	Beamwidth:	180 °	See Figures 2, 5 & 8	canted turnstyle	0.0 dB	
4	Quadrifilar Helix	Loop (λ):	1/2	Gain:	4.0 dBiC	Beamwidth:	150 °	See Figures 2 and 6	quadrifilar helix	0.0 dB	
5	Other (User Defined)	Patch (Example)		Gain:	6.0 dBi	Beamwidth:	90 °	See Figures 2 and 7	Patch (Example)	0.0 dB	
6	Parabolic Reflector	[For S/C Hi Gain Option]		Gain:	53.9 dBi (C or L)	Beamwidth:	0.3 °	Dish Boresight Aligned with +Z Axis	parabolic reflector	38.1 dB	1458.47 Intermediate Calculation - Please Ignore This Value.
7	Other (User Defined)	Reflectenna		Gain:	32.0 dBi	Beamwidth:	3 °	Link Model Operator to Provide	user defined	0.0 dB	Enter functional behavior of user defined antenna here.

Angle between S/C antenna symmetry axis and vector from S/C to gnd. station (θ_3): 3 °

Approx. Antenna Pointing Loss: 0.0 dB

12.40

Ground Station:

Downlink Frequency: 32000 MHz — Wavelength: 0.0094 meters

This Option was Selected on the Previous Page

3 Parabolic Reflector — Polarization: RHCP

1	Yagi	Maximum Gain:	0.0	dBiC	Beamwidth:	39.7 °
2	Helix	Gain:	0.0	dBiC	Beamwidth:	32.2 °
3	Parabolic Reflector	Gain:	0.0	dBiC	Beamwidth:	0.0 °
4	User Defined	Gain:	18.5	dBiC	Beamwidth:	24.0 °

Esimated Pointing Error (θ_4):	0.0015 °	**Approx. Antenna Pointing Loss:**	0.1 dB

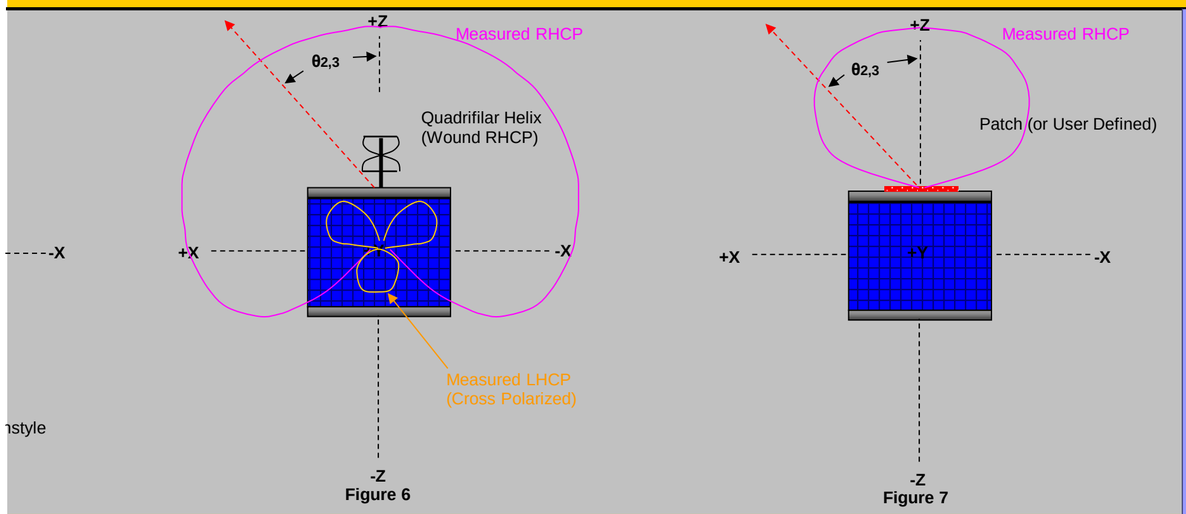


Figure 6

Figure 7

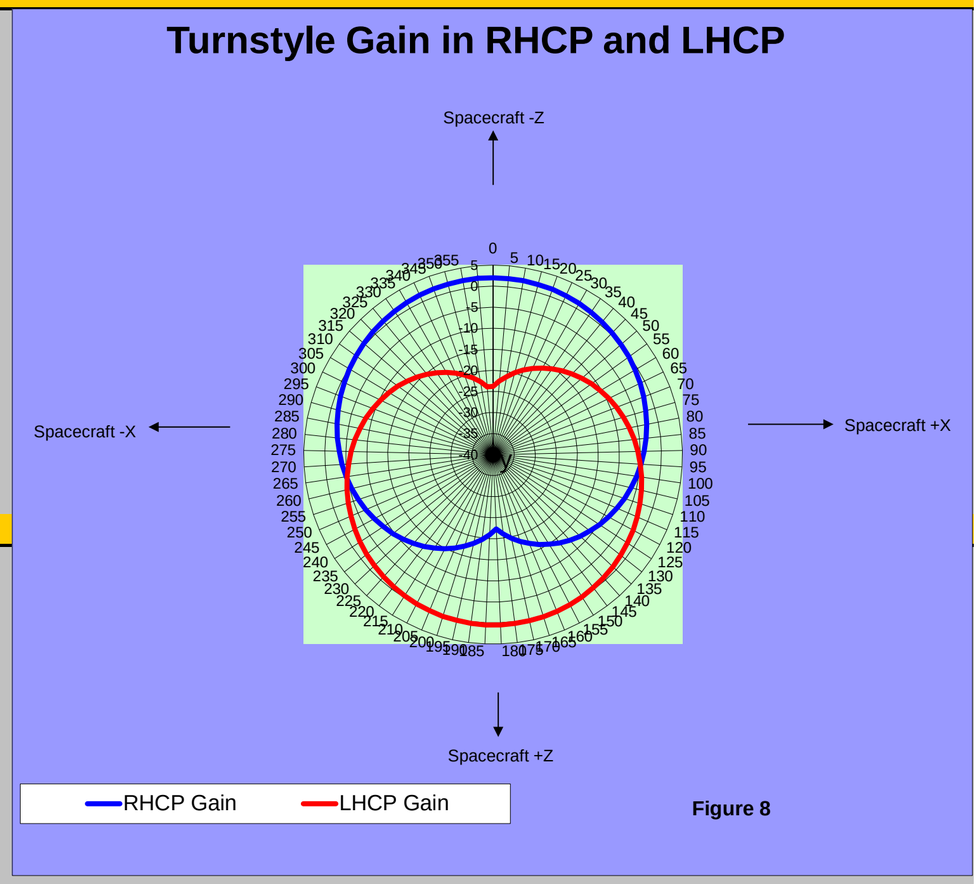
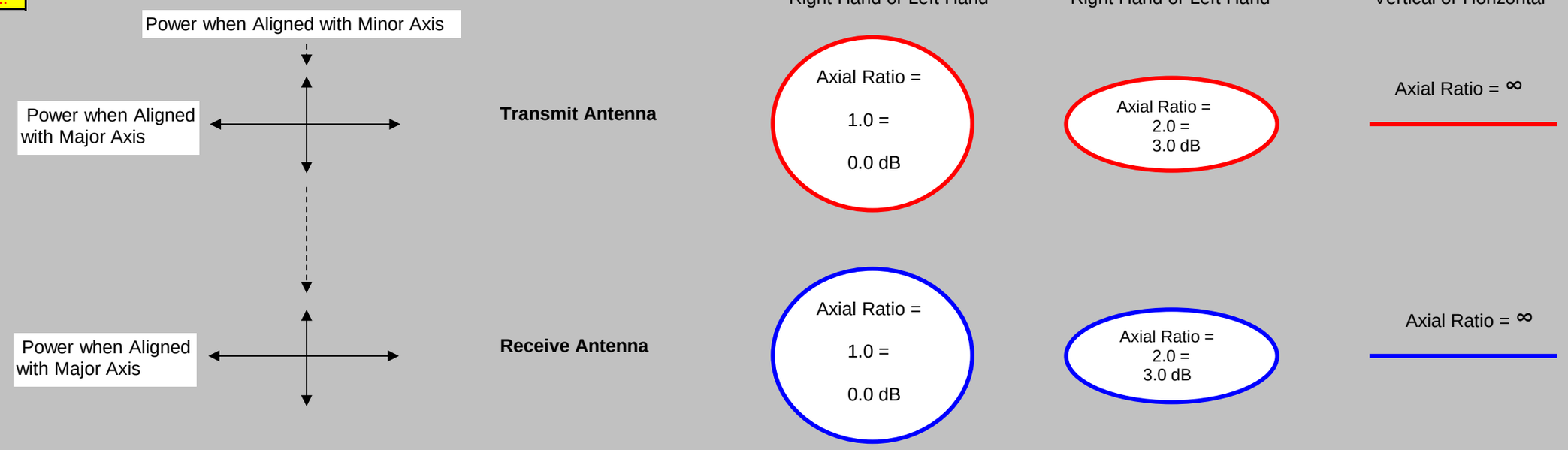


Figure 8

System Polarization Loss and Cross Polarization Isolation: Alpha CubeSat 2016 February 05

$$\text{Axial Ratio} \equiv 10*\text{LOG}\left[\frac{\text{Power Emitted (or Received) with Antenna Aligned with Major Axis}}{\text{Power Emitted (or Received) with Antenna Aligned with Minor Axis}}\right]$$

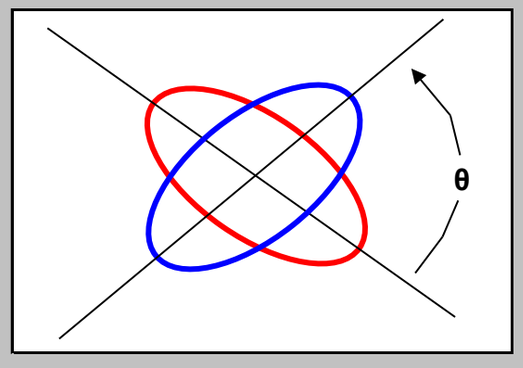
NOTE:



NOTE:

UPLINK: Operator selects uplink antenna characteristics in blue boxes.

Polarization Loss Calculation:		
Co-Polarization Loss:		
Axial ratio of Tx Antenna (Ant. #1) in dB =	1.00	[dB]
Axial ratio (Ant. #1) =	1.26	[ ]
Axial ratio of Rx Antenna (Ant. #2) in dB =	1.00	[dB]
Axial ratio (Ant. #2) =	1.26	[ ]
Polarization Angle θ between antennas =	5.0	[degrees]
Polarization Angle θ between antennas =	0.087266	[Radians]
Polarization Loss =	0.99961	[ ]
Polarization Loss =	0.00	[dB]
Cross Polarization Coupling/Isolation:		
Cross Pol. Power Fraction =	0.00039	
Cross Pol. Power Fraction =	-34.10	[dB]
Cross Polarization Isolation =	34.10	[dB]



Polarization Angle (θ) ≡ Angle between transmit and receive major axes.

Polarization Loss Equation:

$$P_L = 0.5*(1+((1-r_1^2)*(1-r_2^2)*\text{COS}(2*\theta)+4*r_1*r_2)/((1+r_1^2)*(1+r_2^2)))$$

DOWNLINK: Operator selects downlink antenna characteristics in blue boxes.

Polarization Loss Calculation:		
Co-Polarization Loss:		
Axial ratio of Tx Antenna (Ant. #1) in dB =	1.00	[dB]

Axial ratio (Ant. #1) =	1.26	[ ]
Axial ratio of Rx Antenna (Ant. #2) in dB =	1.00	[dB]
Axial ratio (Ant. #2) =	1.26	[ ]
Polarization Angle θ between antennas =	5.0	[degrees]
Polarization Angle θ between antennas =	0.087266	[Radians]
Polarization Loss =	0.99961	[ ]
Polarization Loss =	0.00	[dB]

Cross Polarization Coupling/Isolation:

Cross Pol. Power Fraction =	0.00039	
Cross Pol. Power Fraction =	-34.10	[dB]
Cross Polarization Isolation =	34.10	[dB]

Example Calculations:

	Tx Ant. A.R. #1: (dB)	Rx Ant. A.R. #2: (dB)	θ (degrees)	Pol. Loss (dB)
Tx Circular,	0.0	0.0	90.0	0.0
Rx Variable:	0.0	1.0	90.0	-0.1
	0.0	2.0	90.0	-0.2
	0.0	3.0	90.0	-0.5
	0.0	6.0	90.0	-1.3
	0.0	10.0	90.0	-2.2
	0.0	30.0	90.0	-3.0
	0.0	30.0	0.0	-3.0
Tx & Rx Elliptical:	3.0	3.0	0.0	0.0
	3.0	3.0	45.0	-0.9
	3.0	3.0	90.0	-1.9
Tx & Rx Linear:	30.0	30.0	0.0	0.0
	30.0	30.0	30.0	-1.3
	30.0	30.0	45.0	-3.0
	30.0	30.0	60.0	-6.0
	30.0	30.0	90.0	-54.0
Tx Elliptical,	2.0	30.0	0.0	-1.5
Rx Linear	2.0	30.0	45.0	-3.0
	2.0	30.0	90.0	-4.0

NOTE: A linearly polarized antenna may be represented by an Axial Ratio value of 30 dB.

NOTE: This is a typical small satellite case.

NOTE: This is also a typical small satellite case.

Atmospheric and Ionospheric Losses: Alpha CubeSat 2016 February 05

Loss due to Atmospheric Gases:		
Uplink and Downlink:		
Elevation Angle:	*Loss:*	*Unit:*
0 °	10.2	dB
2.5 °	4.6	dB
5 °	2.1	dB
10 °	1.1	dB
30 °	0.4	dB
45 °	0.3	dB
90 °	0.0	dB
Min. Elev. Angle:	5	deg.
Loss Determined:	2.1	dB

NOTE:

Link Losses Resulting from Signals Passing Through Atmospheric Gases:

Losses due to atmospheric gases (Nitrogen, Oxygen, Carbon Dioxide, Hydrogen, etc.) are nearly independent of atmospheric temperature, mean density and relative humidity at frequencies below 2 GHz. Atmospheric absorption depends strongly upon the total number of molecules distributed along the path between the spacecraft and the ground station. This, in turn, means that the losses from or to the satellite are elevation angle dependent.

The table to the left is a look-up table. The minimum elevation angle selected in the "Orbit" worksheet is matched against the closest fit from the table and the result is given at Cell [D23] and is automatically inserted into the uplink and downlink budgets.

The data used here is taken from "*Radiowave Propagation in Satellite Communications*" by Louis J. Ippolito, Jr., Van Nostrand-Reinhold, 1986, pp. 33-34, Tables 3-3a-c.

One additional interpolated value is added at 2.5° elevation angle. This was not taken from Ippolito's text.

If you are using uplink or downlink frequencies above 2 GHz, refer to the referenced text given above to determine the appropriate atmosperic losses. At millimeter wave frequencies the losses can be much higher.

Link Losses Resulting from Signals Passing Through the Ionosphere:

Radio waves passing through the ionosphere at VHF, UHF and Microwave frequencies are influenced far less by this layer of ionized particles than at frequencies in the HF, MF and LF portions of the radio spectrum. While there is certainly some correlation between the elevation angle to a satellite and the signal absorption or scintillation experienced, this dependency is nearly masked out by the time variability of effects.

There is, however, a frequency depencency that can be quantified, on average. As transmitter frequencies go below 100 MHz there are times when the attenuation can increase to as much as tens of dB, especially at low elevation angles. The ionosphere certainly limits the lowest frequency at which satellite communications is feasible. Below 20 MHz, during solar maximum space signals are usually fully absorbed or reflected by the layers of the ionosphere (D, E, F_1 and F_2).

The values provided in this table are approximate mean values for low earth station elevation angles. It is proposed that these values can be conservatively used in satellite link analyses. The higher order statistics of these loss parameters would be interesting to review, however, this effort is more than is necessary for the development of an effective link budget.

The losses determined here for the uplink and downlink are based on the operator-selected frequency choice made in the "Orbit" worksheet. If the "User Defined" option is selected by the link model operator, then the operator must estimate the appropriate ionospheric loss value and manually insert it in either Cell [D34] or Cell [D47] accordingly.

Proceed to the "Modulation-Demodulation Method" W/S.

Loss due to Ionosphere:			
Uplink:	Loss Determined:	0.0 dB	
Frequency:	*Unit:*	*Loss:*	*Unit:*
146	MHz	0.7	dB
438	MHz	0.4	dB
2410	MHz	0.1	dB
7145	MHz	0.04	dB

Link Model Operator Estimate Inserted Here.

Loss due to Ionosphere:			
Downlink:	Loss Determined:	0.0 dB	
Frequency:	*Unit:*	*Loss:*	*Unit:*
146	MHz	0.7	dB
438	MHz	0.4	dB
2410	MHz	0.1	dB
32000	MHz	0.008	dB

Link Model Operator Estimate Inserted Here.
If the "Link Model Operator" has selected a user option for the frequency, then an estimate of the ionospheric losses must be provided by the operator.

Modulation/Demodulation Method: **Alpha CubeSat** **2016 February 05**

NOTE: Select Here: Choice Made: Result:

UPLINK: **Modulation, Coding & BER Option:** **18** QPSKw.FEC

Eb/No: Threshold **10.6** dB

Command Link

Option:	*Modulation Type:*	*Coding:*	*Bit Error Rate Spec:*	*Required Eb/No (dB):*
1	AFSK/FM	None	1.00E-04	21.0
2	AFSK/FM	None	1.00E-05	23.2
3	G3RUH FSK	None	1.00E-04	16.7
4	G3RUH FSK	None	1.00E-05	18.0
5	Non-Coherent FSK	None	1.00E-04	13.4
6	Non-Coherent FSK	None	1.00E-05	13.8
7	Coherent FSK	None	1.00E-04	10.5
8	Coherent FSK	None	1.00E-05	11.9
9	GMSK	None	1.00E-04	8.4
10	GMSK	None	1.00E-05	9.6
11	BPSK	None	1.00E-05	9.6
12	BPSK	None	1.00E-06	10.5
13	QPSK	None	1.00E-05	9.6
14	QPSK	None	1.00E-06	10.5
15	BPSK	Convolutional R=1/2, K=7	1.00E-06	4.8
16	BPSK	Conv. R=1/2,K=7 & R.S. (255,223)	1.00E-06	2.5
17	BPSK	Conv. R=1/6,K=15 & R.S. (255,223)	1.00E-07	0.8
18	QPSKw.FEC	Reed Solomon FEC	1.00E-06	9.6

Operator Estimate of Implementation Loss

NOTE: **Implementation Loss Estimate:** **1.0** dB

UPLINK: ↑ **DOWNLINK:** ↓

Select Here: Choice Made: Result:

DOWNLINK: **Modulation, Coding & BER Option:** **19** 16QAM

Eb/No: Threshold **0.9** dB

Telemetry Link:

Option:	*Modulation Type:*	*Coding:*	*Bit Error Rate Spec:*	*Required Eb/No (dB):*
1	AFSK/FM	None	1.00E-04	21.0
2	AFSK/FM	None	1.00E-05	23.2
3	G3RUH FSK	None	1.00E-04	16.7
4	G3RUH FSK	None	1.00E-05	18.0
5	Non-Coherent FSK	None	1.00E-04	13.4
6	Non-Coherent FSK	None	1.00E-05	13.8
7	Coherent FSK	None	1.00E-04	10.5
8	Coherent FSK	None	1.00E-05	11.9
9	GMSK	None	1.00E-04	8.4
10	GMSK	None	1.00E-05	9.6
11	BPSK	None	1.00E-05	9.6
12	BPSK	None	1.00E-06	10.5
13	QPSK	None	1.00E-05	9.6
14	QPSK	None	1.00E-06	10.5
15	BPSK	Convolutional R=1/2, K=7	1.00E-06	4.8
16	BPSK	Conv. R=1/2,K=7 & R.S. (255,223)	1.00E-06	2.5
17	BPSK	Conv. R=1/6,K=15 & R.S. (255,223)	1.00E-07	0.8
18	BPSK	Turbo Code (Parallel w. Interleaver)	1.00E-06	0.75
19	16QAM	Reed Solomon FEC	1.00E-07	0.9

Operator Estimate of Implementation Loss

Implementation Loss Estimate: **0.0** dB

NOTE:

Binary Phase Shift Keying (BPSK)

Performance

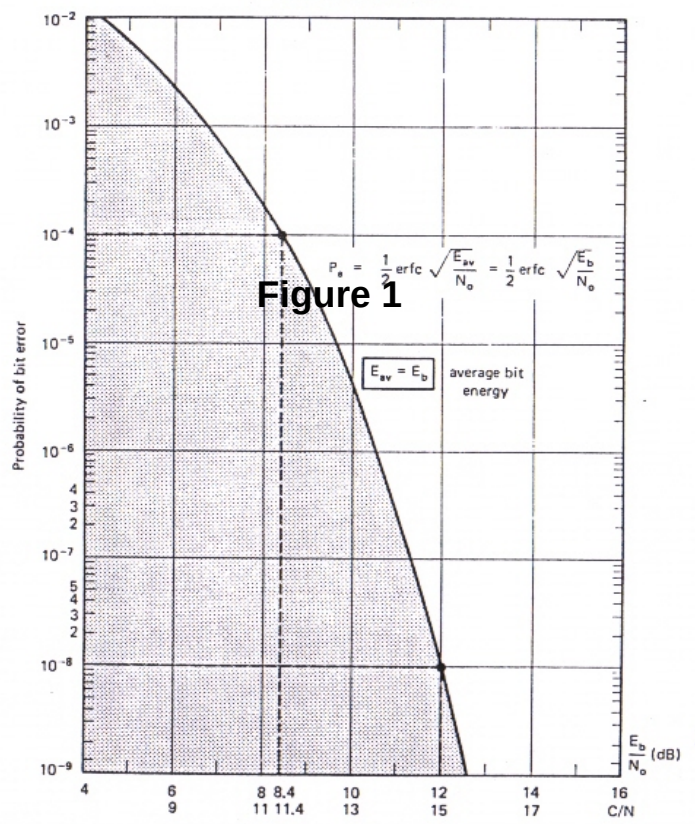


Figure 1

NOTE:

$$\frac{E_b}{N_o} = \frac{C}{N} \cdot \frac{B_w}{f_b}$$

Alpha CubeSat
Uplink Command Budget:

NOTE:

Alpha CubeSat
Version: 2.5.3

Date Data Last Modified:
2016 February 05

Parameter:	*Value:*	*Units:*	*Comments:*
Ground Station:			
Ground Station Transmitter Power Output:	50.0	watts	This value is transferred from "Transmitters" W/S, Cell [E15].
In dBW:	17.0	dBW	Transmitter power expressed in dB above one watt
In dBm:	47.0	dBm	Transmitter power expressed in dB above one milliwatt
Ground Stn. Total Transmission Line Losses:	3.6	dB	This value is transferred from "Transmitters" W/S, Cell [I33]
Antenna Gain:	94.7	dBi	This value is selected at "Antenna Gain" W/S, Cell [E11]
Ground Station EIRP:	108.1	dBW	Ground Station Effective Isotropic Radiated Power (EIRP) [EIRP=Pt x Ltl x Ga]
Uplink Path:			
Ground Station Antenna Pointing Loss:	0.0	dB	This value is calculated in the "Antenna Pointing Losses" W/S, and transferred from Cell [K43]
Gnd-to-S/C Antenna Polarization Losses:	0.0	dB	This value is calculated in the "Polarization Loss" W/S and is transferred from Cell [F40].
Path Loss:	241.6	dB	Lp = 22 + 20LOG(D/λ); Transferred from "Frequency" W/S
Atmospheric Losses:	2.1	dB	This value is transferred from "Atmos. & Ionos. Losses" W/S, Cell [D23]
Ionospheric Losses:	0.0	dB	This value is transferred from "Atmos. & Ionos. Losses" W/S, Cell [D47:D50]
Rain Losses:	0.0	dB	This value should be estimated by the link model operator and place into Cell [B18]
Isotropic Signal Level at Spacecraft:	-135.6	dBW	This is the signal level received in space in the vacinity of the spacecraft using an omnidirectional antenna.
Spacecraft (Eb/No Method):			
------- Eb/No Method -------			
Spacecraft Antenna Pointing Loss:	0.0	dB	This value is transferred from "Antenna Pointing Losses" W/S, Cell [K63]
Spacecraft Antenna Gain:	8.0	dBi	This value is selected at "Antenna Gain" W/S, Cell [E24]
Spacecraft Total Transmission Line Losses:	0.1	dB	This value is transferred from the "Receivers" W/S, Cell [J52]
Spacecraft Effective Noise Temperature:	282	K	This value is calculated in the "Receivers" W/S and Transferred from Cell [J67]
Spacecraft Figure of Merit (G/T):	-16.6	dB/K	G/T = Ga-Ltl-10log(Ts). This is the uptimate measure of the receiver's performance.
S/C Signal-to-Noise Power Density (S/No):	76.3	dBHz	Boltzman's Constant: -228.6 dBW/K/Hz
System Desired Data Rate:	9600	bps	Operator selects this value. Be Careful! This is the data rate, not the symbol rate.
In dBHz:	39.8	dBHz	This is simply = 10log(R); R= data rate
Command System Eb/No:	36.5	dB	
Demodulation Method Seleted:	QPSKw.FEC		Values selected in "Modulation-Demodulation W/S, Cell [E3]
Forward Error Correction Coding Used:	Reed Solomon FEC		Value selected in "Modulation-Demodulation" W/S, also Cell [E3]
System Allowed or Specified Bit-Error-Rate:	1.0E-06		The selected value is transferred from the "Modulation-Demodulation W/S, Cells [E6:E23]
Demodulator Implementation Loss:	1.0	dB	This value is transferred from the "Modulation-Demodulation W/S, Cell[E25]
Telemetry System Required Eb/No:	9.6	dB	The selected value is transferred from the "Modulation-Demodulation W/S, Cells [F6:F23]
Eb/No Threshold:	10.6	dB	This is the result of the "Modulation-Demodulation" W/S and is transferred from Cell [H32]
System Link Margin:	**25.9**	dB	

Spacecraft Alternative Signal Analysis Method (SNR Computation):
---------- SNR Method ----------

NOTE:

Spacecraft Antenna Pointing Loss:	0.0	dB	This value is transferred from "Antenna Pointing Losses" W/S, Cell [K63]
Spacecraft Antenna Gain:	8.0	dBi	This value is selected at "Antenna Gain" W/S, Cell [E24]
Spacecraft Total Transmission Line Losses:	0.1	dB	This value is transferred from the "Receivers" W/S, Cell [J52]
Spacecraft Effective Noise Temperature:	282	K	This value is calculated in the "Receivers" W/S and Transferred from Cell [J67]
Spacecraft Figure of Merrit (G/T):	-16.6	dB/K	G/T = G_a-L_{tl}-10log(T_s). This is the ultimate measure of the receiver's performance.
Signal Power at Spacecraft LNA Input:	-127.8	dBW	Ps = P_{iso}+G_a-L_{pl}-L_{tl}; This is the signal power that has arrived at the ground station receiver.
Spacecraft Receiver Bandwidth:	15,000	Hz	Signal Spectrum Must Pass Through This Data Filter. NOTE:
Spacecraft Receiver Noise Power (Pn = kTB)	-162.3	dBW	Pn = K + 10log(Ts) + 10log(B). This is the total noise power arriving at the ground station receiver.
Signal-to-Noise Power Ratio at G.S. Rcvr:	34.6	dB	Ps/Pn = Ps(in dBW) - Pn(in dBW)
Analog or Digital System Required S/N:	9.6	dB	If system is digital, use values from "Modulation-Demodulation" W/S. If analog, use appropriate value from text book.
System Link Margin	**25.0**	dB	

Alpha CubeSat
Downlink Telemetry Budget:

NOTE:

Alpha CubeSat
Version: 2.5.3

Date Data Last Modified:
2016 February 05

Parameter:	*Value:*	*Units:*	*Comments:*
Spacecraft:			
Spacecraft Transmitter Power Output:	3.0	watts	This value is transferred from "Transmitters" W/S, Cell [E50]
In dBW:	4.8	dBW	Transmitter power expressed in dB above one watt
In dBm:	34.8	dBm	Transmitter power expressed in dB above one milliwatt
Spacecraft Total Transmission Line Losses:	0.5	dB	This value is transferred from "Transmitters" W/S, Cell [I68]
Spacecraft Antenna Gain:	32.0	dBi	This value is selected at "Antenna Gain" W/S, Cell [E41]
Spacecraft EIRP:	36.3	dBW	Spacecraft Effective Isotropic Radiated Power (EIRP) [EIRP=Pt x Ltl x Ga]
Downlink Path:			
Spacecraft Antenna Pointing Loss:	0.0	dB	This value is calculated in the "Antenna Pointing Losses" W/S, and trasferred from Cell [K85]
S/C-to-Ground Antenna Polarization Loss:	0.0	dB	This value is calculated in the "Polarization Loss" W/S and is transferred from Cell [F60].
Path Loss:	254.6	dB	Lp = 22 + 20LOG(D/λ); Transferred from "Frequency" W/S
Atmospheric Loss:	2.1	dB	This value is transferred from "Atmos. & Ionos. Losses" W/S, Cell [D23]
Ionospheric Loss:	0.0	dB	This value is transferred from "Atmos. & Ionos. Losses" W/S, Cell [D47:D50]
Rain Loss:	0.0	dB	This value should be estimated by the link model operator and place into Cell [B18]
Isotropic Signal Level at Ground Station:	-220.4	dBW	This is the signal level received at the Earth in the vacinity of the ground station using an omnidirectional antenna.
Ground Station (EbNo Method):			
------- Eb/No Method -------			
Ground Station Antenna Pointing Loss:	0.1	dB	This value is transferred from "Antenna Pointing Losses" W/S, Cell [K102]
Ground Station Antenna Gain:	79.0	dBi	This value is selected at "Antenna Gain" W/S, Cell [E58]
Ground Station Total Transmission Line Losses:	0.5	dB	This value is transferred from the "Receivers" W/S, Cell [J123]
Ground Station Effective Noise Temperature:	174	K	This value is calculated in the "Receivers" W/S and Transferred from Cell [J138]
Ground Station Figure of Merit (G/T):	56.1	dB/K	G/T = Ga-Ltl-10log(Ts). This is the uptimate measure of the receiver's performance.
G.S. Signal-to-Noise Power Density (S/No):	64.2	dBHz	Boltzman's Constant: -228.6 dBW/K/Hz
System Desired Data Rate:	256000	bps	Operator selects this value. Be Careful! This is the data rate, not the symbol rate.
In dBHz:	54.1	dBHz	This is simply = 10log(R); R= data rate
Telemetry System Eb/No for the Downlink:	10.1	dB	
Demodulation Method Seleted:	16QAM		Values selected in "Modulation-Demodulation W/S, Cell [E30]
Forward Error Correction Coding Used:	Reed Solomon FEC		Value selected in "Modulation-Demodulation" W/S, also Cell [E30]
System Allowed or Specified Bit-Error-Rate:	1.0E-07		The selected value is transferred from the "Modulation-Demodulation W/S, Cells [E33:E50]
Demodulator Implementation Loss:	0	dB	This value is transferred from the "Modulation-Demodulation W/S, Cell[E52]
Telemetry System Required Eb/No:	0.9	dB	The selected value is transferred from the "Modulation-Demodulation W/S, Cells [F33:F50]
Eb/No Threshold:	0.9	dB	This is the result of the "Modulation-Demodulation" W/S and is transferred from Cell [H32]
System Link Margin:	**9.2**	dB	
Ground Station Alternative Signal Analysis Method (SNR Computation):			
---------- SNR Method ----------			
Ground Station Antenna Pointing Loss:	0.1	dB	This value is transferred from "Antenna Pointing Losses" W/S, Cell [K102]
Ground Station Antenna Gain:	79.0	dBi	This value is selected at "Antenna Gain" W/S, Cell [E58]

Ground Station Total Transmission Line Losses:	0.5	dB	This value is transferred from the "Receivers" W/S, Cell [J123]
Ground Station Effective Noise Temperature:	174	K	This value is calculated in the "Receivers" W/S and Transferred from Cell [J138]
Ground Station Figure of Merrit (G/T):	56.1	dB/K	G/T = Ga-Ltl-10log(Ts). This is the ultimate measure of the receiver's performance.
Signal Power at Ground Station LNA Input:	-142.0	dBW	Ps = Piso+Ga-Lpl-Ltl; This is the signal power that has arrived at the ground station receiver.
Ground Station Receiver Bandwidth (B):	22,000	Hz	Signal Spectrum Must Pass Through This Data Filter **NOTE:**
G.S. Receiver Noise Power (Pn = kTB)	-162.8	dBW	Pn = K + 10log(Ts) + 10log(B). This is the total noise power arriving at the ground station receiver.
Signal-to-Noise Power Ratio at G.S. Rcvr:	20.8	dB	Ps/Pn = Ps(in dBW) - Pn(in dBW)
Analog or Digital System Required S/N:	0.9	dB	If system is digital, use values from "Modulation-Demodulation" W/S. If analog, use appropriate value from text book.
System Link Margin	**19.9**	dB	

System Performance Summary: Alpha CubeSat 2016 February 05

COMMAND

UPLINK SYSTEM: Frequency: 7145.00 MHz

Eb/No Method: Eb/No = 36.5 dB → Link Margin: 25.9 dB LINK CLOSES

S/N Method: S/N = 34.6 dB → Link Margin: 25.0 dB LINK CLOSES

NOTE:

R = 9600 bps

Data FEC Decoder — F.E.C. Decoder Type: Reed Solomon FEC

Data Demodulator — Spec. B.E.R.: 1.00E-06; Demodulator Type: QPSKw.FEC; Eb/No Threshold: 10.6 dB

Data Bandpass Filter — BRbpf = 15000 Hz (Used Only in S/N Calc.)

Downconverters Mixers IF Amplification

G/T = -16.6 dB/K

Tsys = 282 K

S/C

2nd Amplifier — T2nd Amp = 0 K

LNA — GLNA = 40.0 dB; TLNA = 1 K

Ltotal line = 0.13 dB

Line A — LA = 0.03 dB

Receiver Front End Bandpass Filter — LRbpf = 0.0 dB

Line B — LB = 0.00 dB

Other In-Line Device — LTother = 0.0 dB; none

Line C — LC= 0.00 dB

Receive Antenna — GR = 8.0 dBi; Polarization: RHCP

Other (User Defined)

Lp = 241.6 dB

RADIO LINK

Total Link Losses: 243.7 dB

EIRPgs = 108.1 dBW

Parabolic Reflector

GT = 94.7 dBi; Polarization: RHCP

Transmit Antenna

Ltotal line = 3.62 dB

Line C — LC = 1.250 dB

Ground Station

Other In-Line Device — LTother = 0.5 dBi; Directional Coupler

Line B — LB = 0.015 dB

Transmit Bandpass Filter — LTbpf = 1.0 dB

Line A — LA = 0.050 dB

HPA — PTx = 50.0 watts

Transmitter Exciter/Modulator/ FEC Encoder — Modulation Method: QPSKw.FEC; F.E.C. Encoder Type: Reed Solomon FEC

R = 9600 bps

TELEMETRY

DOWNLINK SYSTEM: Frequency: 32000.00 MHz

R = 256000 bps

Transmitter Exciter/Modulator/ FEC Encoder — Modulation Method: 16QAM; F.E.C. Encoder Type: Reed Solomon FEC

HPA — ηTx = 40.0%; Tx DC Pwr: 7.5 watts; Tx Dissipation: 4.5 watts

Line A — PTx = 3.0 watts

Transmit Bandpass Filter — LA = 0.0 dB; LTXbpf = 0.0 dB

S/C

Line B — LB = 0.0 dB

Other In-Line Device — LTother = 0.0 dB; N/A

Line C — LC = 0.1 dB

Ltotal line = 0.5 dB

Transmit Antenna — GT = 32.0 dBi; Polarization: RHCP

Other (User Defined)

EIRPS/C = 36.3 dBW

RADIO LINK

Total Link Losses: 256.8 dB

Lp = 254.6 dB

Parabolic Reflector

GR = 79.0 dBi; Polarization: RHCP

Receive Antenna

Ground Station

Line C — LC = 0.03 dB

Other In-Line Device — LRother = 0.0 dB; none

Line B — LB = 0.03 dB

Receiver Front End Bandpass Filter — LRbpf = 0.0 dB

Line A — LA = 0.2 dB

LNA — Ltotal = 0.5 dB; TLNA = 31 K; GLNA = 60.0 dB

2nd Amp. — T2nd amp = 1000 K

Downconverters Mixers IF Amplification

Data Bandpass Filter — BRbpf = 22000 Hz (Used only in S/N Calc.)

Data Demodulator — Spec. B.E.R.: 1.00E-07; Demodulator Type: 16QAM; Eb/No Threshold: 0.9 dB

Data FEC Decoder — F.E.C. Decoder Type: Reed Solomon FEC

R = 256000 Hz

Eb/No Method: Eb/No = 10.1 dB → Link Margin: 9.2 dB LINK CLOSES

S/N Method: S/N = 20.8 dB → Link Margin: 19.9 dB LINK CLOSES

Commonly Used Spacecraft Antenna Radiation Patterns

Spacecraft Antennas:

NOTE:

Monopole:	S/C ∠ wrt Symmetry Axis (θ)°:	Antenna Gain (dBi):
	0	-156.98
	5	-5.45
	10	-2.45
	15	-0.72
	20	0.49
	25	1.41
	30	2.14
	35	2.74
	40	3.23
	45	3.64
	50	3.99
	55	4.28
	60	4.53
	65	4.72
	70	4.88
	75	5.00
	80	5.08
	85	5.13
	90	5.15
	92.5	0.00
	95	-20.00
	97.5	-60.00
	100	-160.00
	110	No Signal

Dipole:	S/C ∠ wrt Symmetry Axis (θ)°:	Antenna Gain (dBi):
	0	2.15
	10	2.08
	20	1.88
	30	1.53
	40	0.99
	50	0.23

60	-0.86
70	-2.51
80	-5.45
85	-8.45
87.5	-11.45
90	-40.00
92.5	-11.45
95	-8.45
100	-5.45
110	-2.51
120	-0.86
130	0.23
140	0.99
150	1.53
160	1.88
170	2.08
180	2.15
190	2.08
200	1.88
210	1.53
220	0.99
230	0.23
240	-0.86
250	-2.51
260	-5.45
265	-8.45
267.5	-11.45
270	-40.00
272.5	-11.45
275	-8.45
280	-5.45
290	-2.51
300	-0.86
310	0.23
320	0.99
330	1.53
340	1.88
350	2.08
360	2.15

Turnstyle:	S/C ∠ wrt Symmetry Axis (θ)°:	RHCP Antenna Gain (dBi):
(Or Canted Turnstyle)	0	2.0
	5	2.0
	10	1.9
	15	1.8
	20	1.7
	25	1.5
	30	1.3
	35	1.1
	40	0.8
	45	0.5
	50	0.1
	55	-0.3

60	-0.7
65	-1.2
70	-1.7
75	-2.2
80	-2.8
85	-3.4
90	-4.1
95	-4.8
100	-5.5
105	-6.3
110	-7.1
115	-7.9
120	-8.8
125	-9.7
130	-10.7
135	-11.7
140	-12.7
145	-13.8
150	-14.9
155	-16.0
160	-17.2
165	-18.4
170	-19.7
175	-21.0
180	-22.3
185	-21.0
190	-19.7
195	-18.4
200	-17.2
205	-16.0
210	-14.9
215	-13.8
220	-12.7
225	-11.7
230	-10.7
235	-9.7
240	-8.8
245	-7.9
250	-7.1
255	-6.3
260	-5.5
265	-4.8
270	-4.1
275	-3.4
280	-2.8
285	-2.2
290	-1.7
295	-1.2
300	-0.7
305	-0.3
310	0.1
315	0.5
320	0.8
325	1.1
330	1.3
335	1.5

	340	1.7
	345	1.8
	350	1.9
	355	2.0
	360	2.0

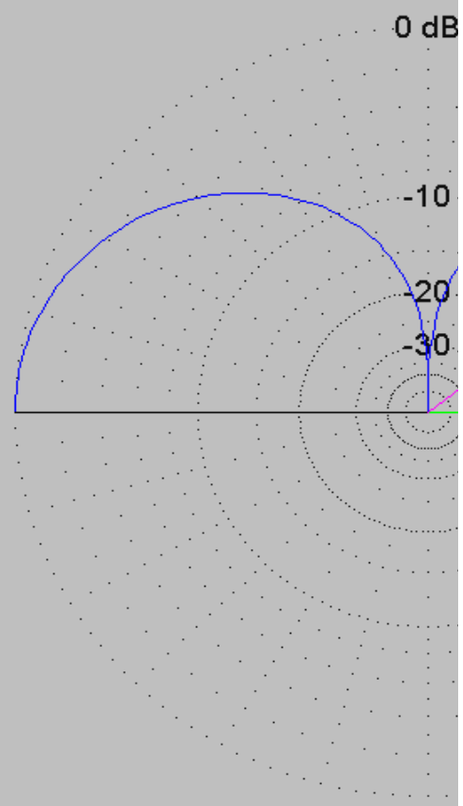
		RHCP
Quadrifilar:	S/C ∠ wrt Symmetry Axis (θ)°:	Antenna Gain (dBi):
	0	4.0
	5	4.0
	10	4.0
	15	3.9
	20	3.8
	25	3.7
	30	3.5
	35	3.4
	40	3.2
	45	3.0
	50	2.7
	55	2.4
	60	2.1
	65	1.8
	70	1.4
	75	1.0
	80	0.5
	85	0.0
	90	-0.5
	95	-1.1
	100	-1.8
	105	-2.5
	110	-3.2
	115	-4.1
	120	-5.0
	125	-6.1
	130	-7.2
	135	-8.5
	140	-10.0
	145	-11.7
	150	-13.6
	155	-15.9
	160	-18.8
	165	-22.5
	170	-27.8
	175	-36.8
	180	-160.0

		RHCP
Patch:	S/C ∠ wrt Symmetry Axis (θ)°:	Antenna Gain (dBi):
	0	6.0
	5	6.0
	10	5.9
	15	5.7
	20	5.4
	25	5.1
	30	4.7

35	4.2
40	3.7
45	3.0
50	2.2
55	1.3
60	0.3
65	-0.9
70	-2.3
75	-4.0
80	-6.0
85	-8.6
90	-12.0
95	-17.3
100	-30.2
105	-23.7
110	-16.4
115	-12.9
120	-10.7
125	-9.3
130	-8.4
135	-7.7
140	-7.4
145	-7.3
150	-7.4
155	-7.6
160	-8.1
165	-8.8
170	-9.8
175	-11.0
180	-12.6
185	-11.0
190	-9.8
195	-8.8
200	-8.1
205	-7.6
210	-7.4
215	-7.3
220	-7.4
225	-7.7
230	-8.4
235	-9.3
240	-10.7
245	-12.9
250	-16.4
255	-23.7
260	-30.2
265	-17.3
270	-8.6
275	-6.0
280	-4.0
285	-2.3
290	-0.9
295	0.3
300	1.3
305	2.2
310	3.0

315	3.7
320	4.2
325	4.7
330	5.1
335	5.4
340	5.7
345	5.9
350	6.0
355	6.0

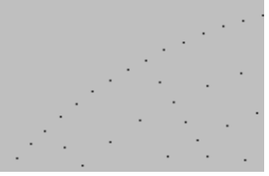
* Total Field

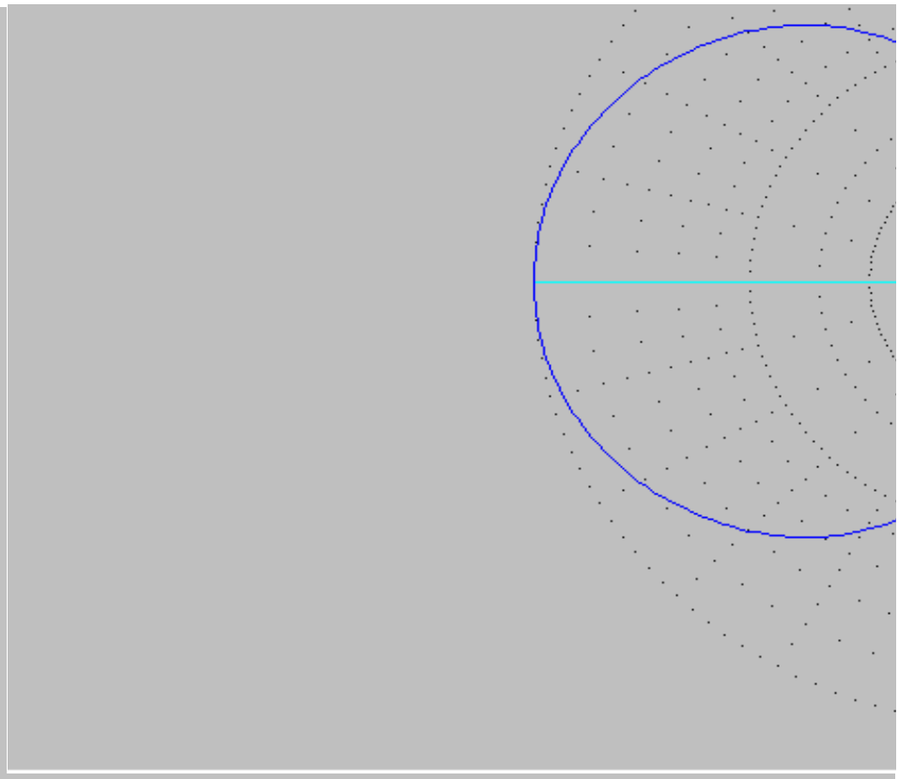


MONOPOL

Peak Gain:	5.15	dBi	
Beamwidth:	38.6	degrees	(-3dB gain loss)
Peak Gain at:	0.0	degrees	Elevation
Outer Ring:	5.15	dBi	(Add this value to 0.0 dB)
Azimuth Cut:	0.0	degrees	

* Total Field

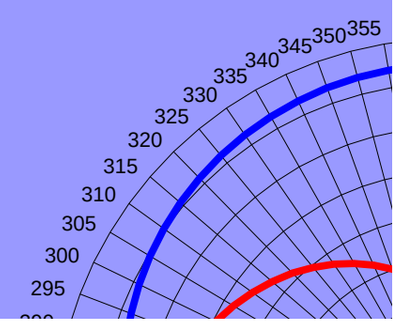




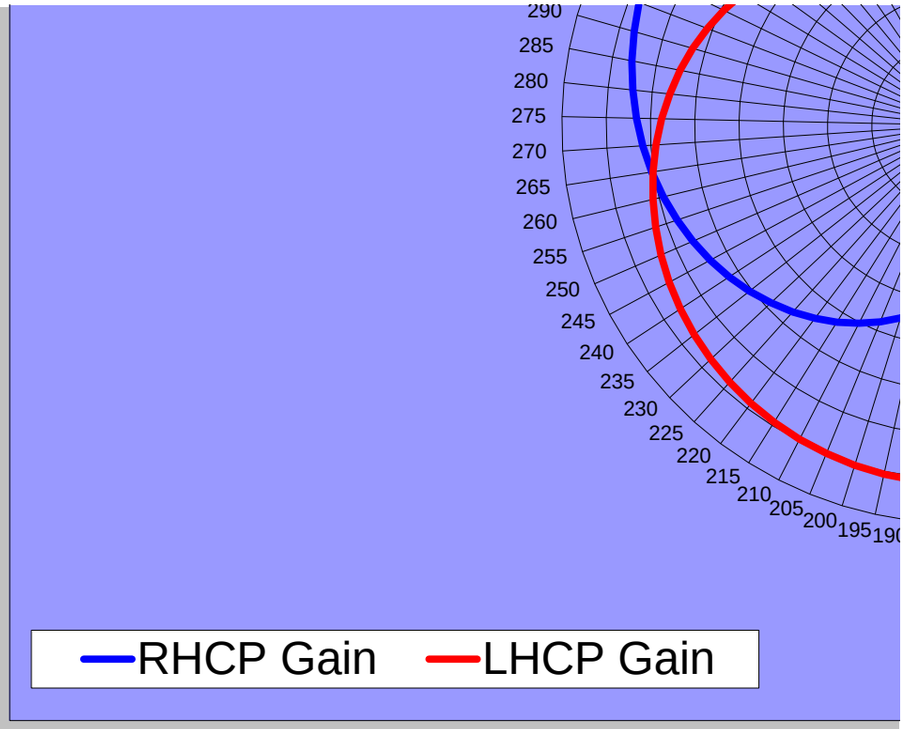
Peak Gain:	2.15	dBi	
Beamwidth:	78.8	degrees	(-3dB gain loss)
Peak Gain at:	0.0	degrees	Elevation
Outer Ring:	2.15	dBi	(Add this value to 0.0 d
Azimuth Cut:	0.0	degrees	

LHCP Antenna Gain (dBi):
-23.8
-22.5
-21.2
-19.9
-18.7
-17.5
-16.4
-15.3
-14.2
-13.2
-12.2
-11.2

Turnstyle Gain
- Elev

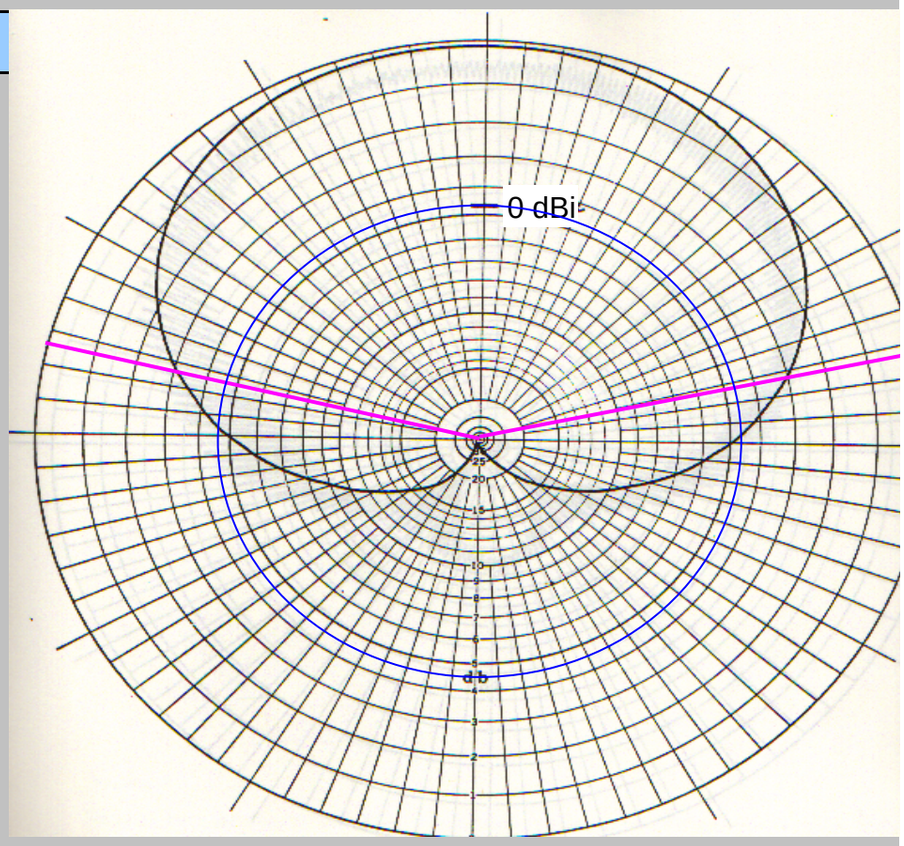


-10.3
-9.4
-8.6
-7.8
-7.0
-6.3
-5.6
-4.9
-4.3
-3.7
-3.2
-2.7
-2.2
-1.8
-1.4
-1.0
-0.7
-0.4
-0.2
0.0
0.2
0.3
0.4
0.48
0.5
0.48
0.43
0.33
0.20
0.03
-0.18
-0.42
-0.70
-1.02
-1.38
-1.77
-2.20
-2.67
-3.18
-3.72
-4.30
-4.92
-5.58
-6.27
-7.00
-7.77
-8.58
-9.42
-10.30
-11.22
-12.18
-13.17
-14.20
-15.27
-16.38
-17.52



-18.70
-19.92
-21.18
-22.47
-23.80

LHCP
Antenna Gain (dBi):

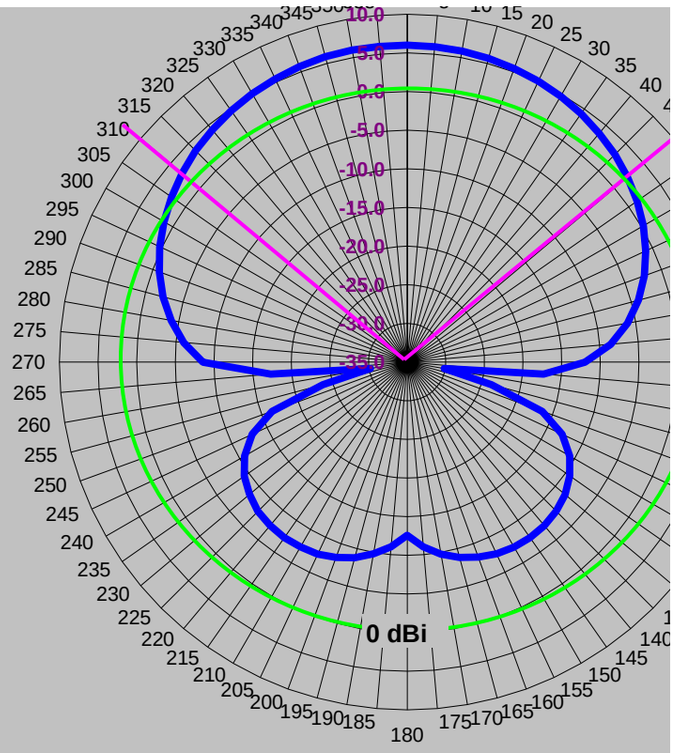


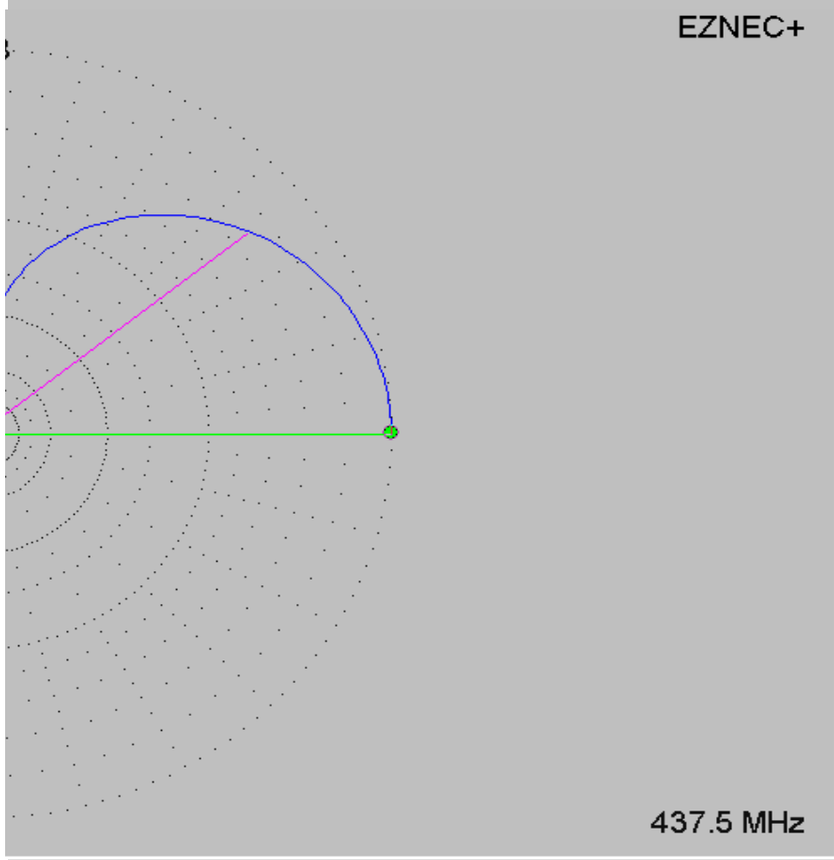
LHCP
Antenna Gain (dBi):

Patch Antenna Ga

RHCP

0
5
10
355
350

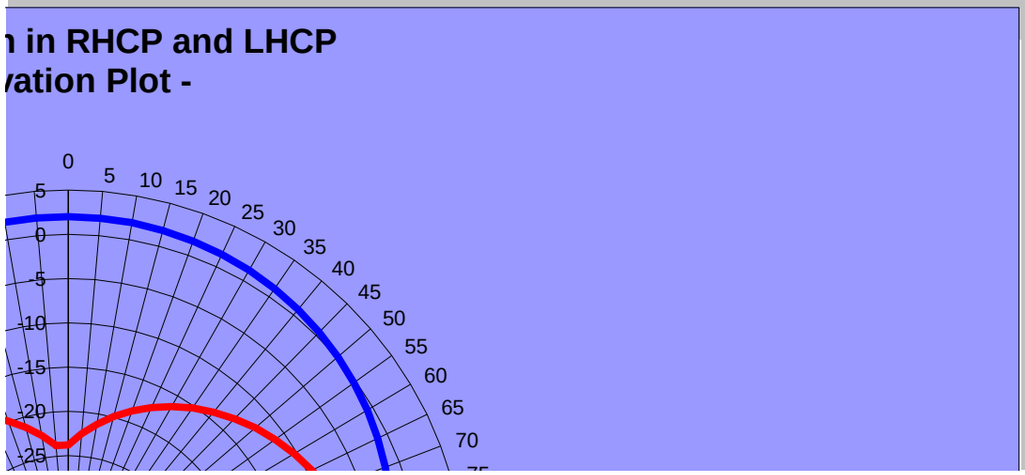

10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
0 dBi
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260
265
270
275
280
285
290
295
300
305
310
315
320
325
330
335
340
345
15
20
25
30
35
40
145
150
155
160
165
170
175

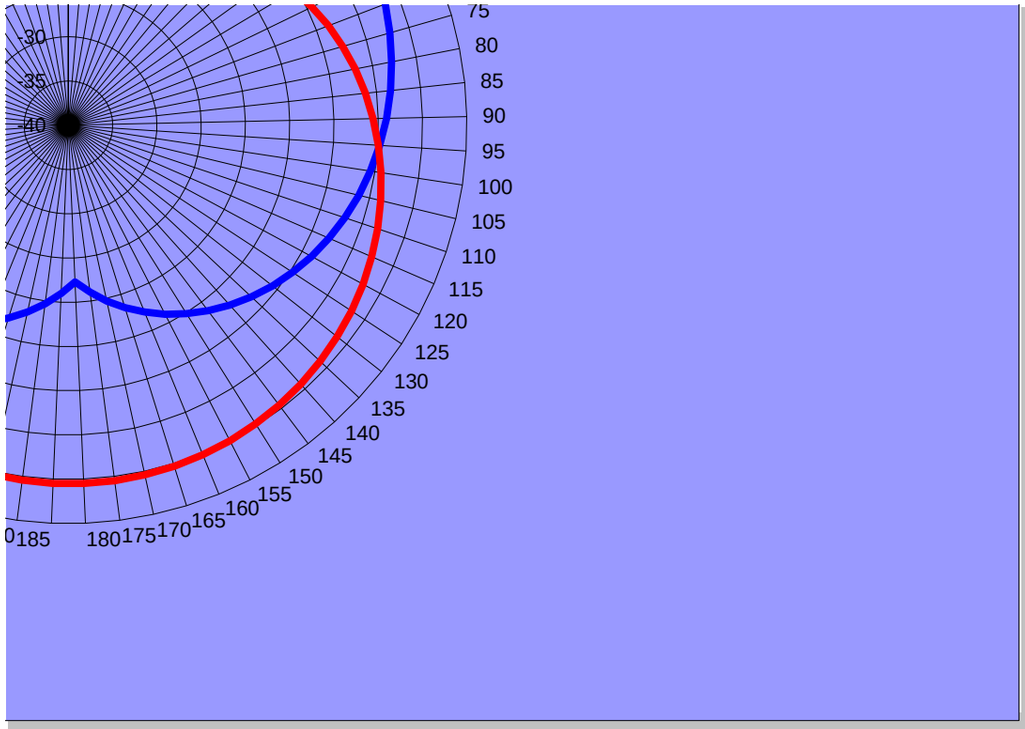


LE ELEVATION PATTERN

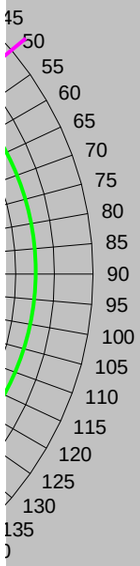
DIPOLE ELEVATION PATTERN

dB)




-30
-35
-40
75
80
85
90
95
100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185

ain


45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
135

"Design a Dish"

Antenna Beam Roll-Off Tool

Beam Roll-Off & Sidelobe Positions Based on Sin² (θ)/ θ² Formulation

Frequency:	20	GHz	**Peak Gain:**	40.7 dBi	
Antenna Dia.:	0.7	Meters			
Aperture Efficiency:	55	%	**Half Power (P/2) Beamwidth:**	1.50	°

NOTE: NOTE: Do not modify or use cells to left of table.

Pwr (θ) w.r.t. Peak Gain:
0.00 dB
-0.000004 dB
-0.01 dB
-0.04 dB
-0.3 dB
-0.4 dB
-0.7 dB
-1.00 dB
-1.5 dB
-1.6 dB
-2.3 dB
-3.01 dB
-3.03 dB
-4.00 dB
-5.0 dB
-6.2 dB
-7.7 dB
-9.4 dB
-11.6 dB
-14.4 dB
-18.2 dB
-24.7 dB
-328.2 dB
-25.6 dB
-20.2 dB
-17.3 dB
-15.5 dB
-14.4 dB
-13.7 dB
-13.3 dB
-13.3 dB
-13.5 dB
-13.9 dB
-14.6 dB
-15.6 dB
-17.0 dB
-18.8 dB
-21.2 dB
-24.8 dB
-30.9 dB
-328.2 dB
-31.4 dB
-25.8 dB
-22.7 dB

-20.7 dB
-19.4 dB
-18.6 dB
-18.0 dB
-17.8 dB
-17.9 dB
-18.2 dB
-18.8 dB
-19.7 dB
-21.0 dB
-22.7 dB
-25.0 dB
-28.5 dB
-34.5 dB
-328.2 dB
-34.9 dB
-29.1 dB
-26.0 dB
-23.9 dB
-22.6 dB
-21.6 dB
-21.1 dB
-20.8 dB
-20.8 dB
-21.1 dB
-21.6 dB
-23.7 dB
-25.3 dB
-27.6 dB
-31.1 dB
-37.1 dB
-328.2 dB
-37.3 dB
-31.5 dB
-28.4 dB
-26.3 dB
-24.9 dB
-23.9 dB
-23.3 dB
-23.0 dB
-23.0 dB
-23.2 dB
-23.8 dB
-24.6 dB

J. A. King 2016 February 05

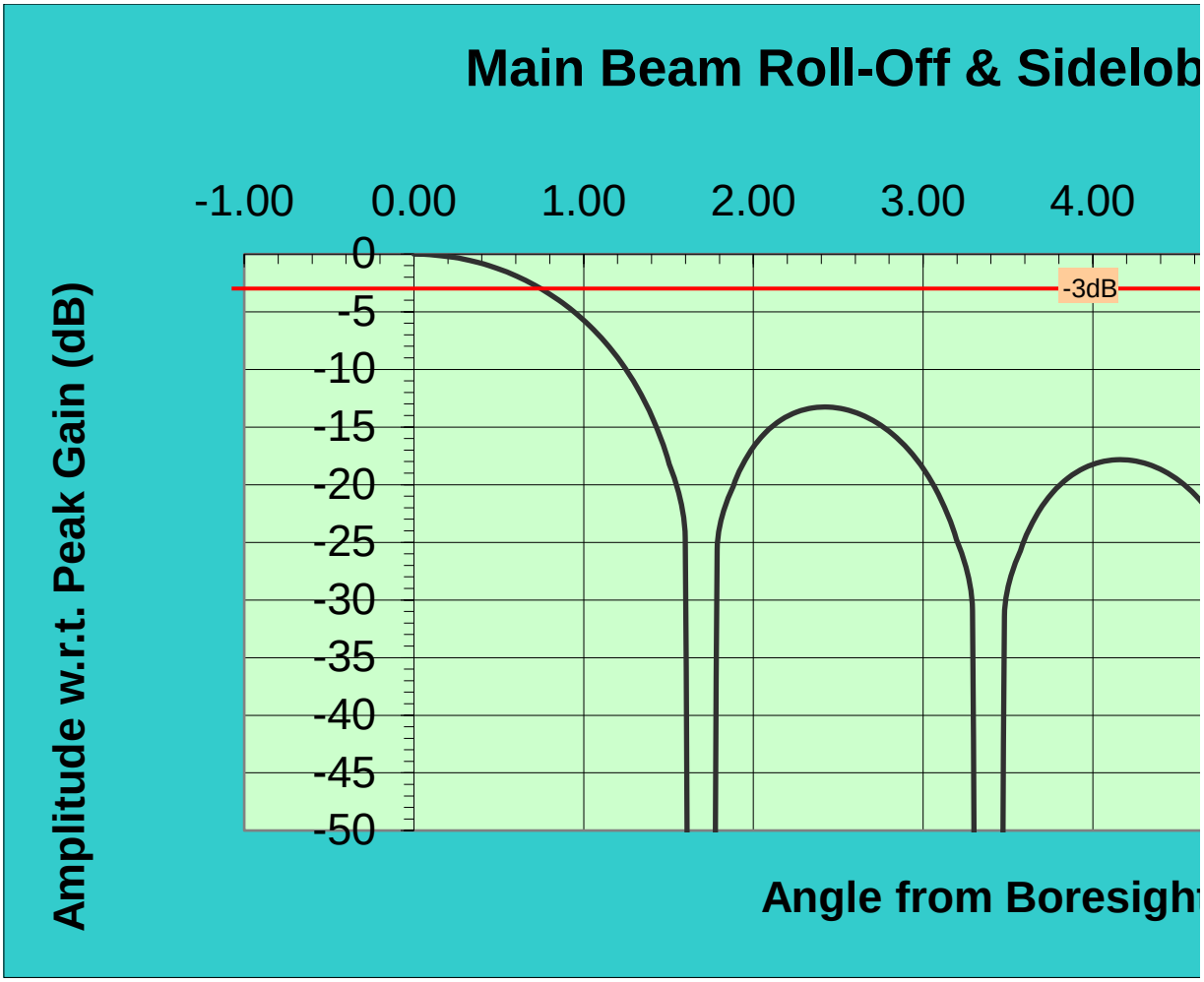
(See Plot at Next Worksheet)

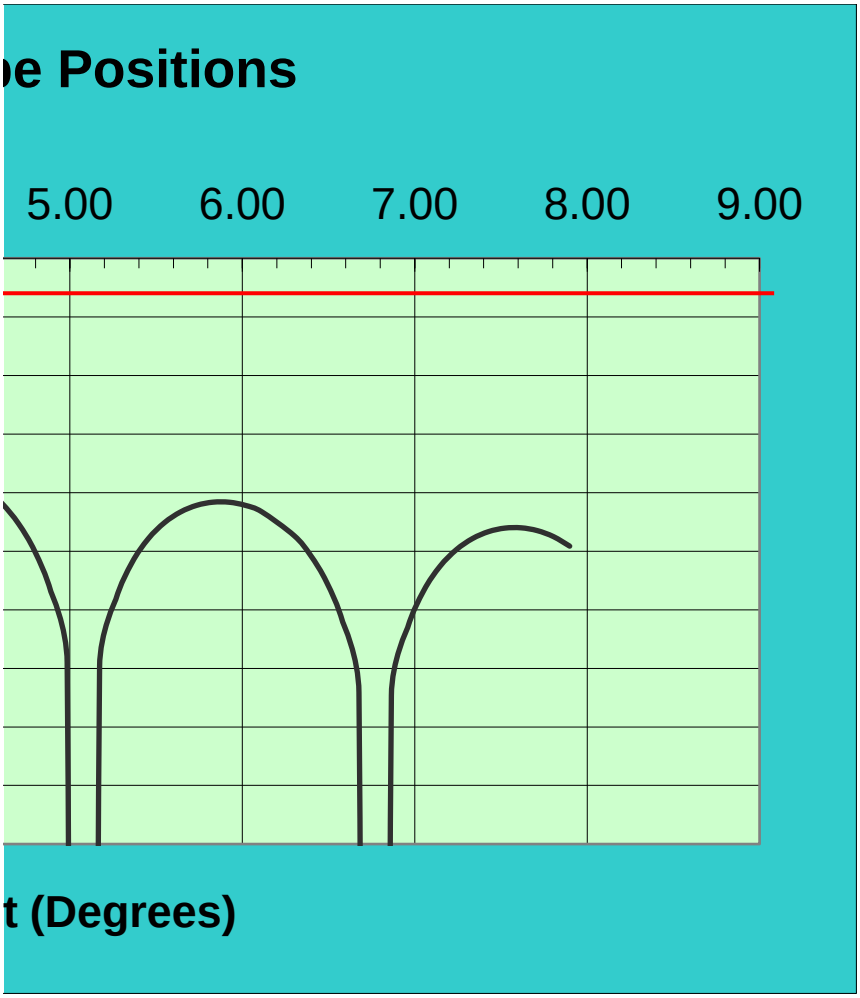
=2θ (Beamwidth@ -3dB Roll-Off)

θ (degrees):	
0.0000	*Main Lobe*
0.001	
0.033	
0.09	
0.24	
0.28	
0.38	
0.44	
0.53	
0.56	
0.66	
0.75	*(Half Power B.W.)/2*
0.75	
0.85	
0.94	
1.03	
1.13	
1.22	
1.32	
1.41	
1.50	
1.60	
1.69	First Null
1.79	
1.88	
1.97	
2.07	
2.16	
2.26	
2.35	*First Sidelobe*
2.44	
2.54	
2.63	
2.73	
2.82	
2.91	
3.01	
3.10	
3.20	
3.29	
3.39	*2nd Null*
3.48	
3.57	
3.67	

3.76	
3.86	
3.95	
4.04	
4.14	*2nd Sidelobe*
4.23	
4.33	
4.42	
4.51	
4.61	
4.70	
4.80	
4.89	
4.98	
5.08	*3rd Null*
5.17	
5.27	
5.36	
5.45	
5.55	
5.64	
5.74	
5.83	*3rd Sidelobe*
5.92	
6.02	
6.11	
6.30	
6.39	
6.49	
6.58	
6.68	
6.77	*4th Null*
6.86	
6.96	
7.05	
7.15	
7.24	
7.33	
7.43	
7.52	
7.62	*4th Sidelobe*
7.71	
7.80	
7.90	

0.75


Main Beam Roll-Off & Sidelob
-1.00
0.00
1.00
2.00
3.00
4.00
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-3dB
Amplitude w.r.t. Peak Gain (dB)
Angle from Boresigh


be Positions
5.00
6.00
7.00
8.00
9.00
t (Degrees)

Transmission Line Loss Tools and Tables:

NOTE:

Ground Station Systems:

Best Internet Cable Loss Calculator: http://www.ocarc.ca/coax.htm

2nd Best Internet Cable Loss Calculator: http://www.timesmicrowave.com/c

Coax Cable Loss Tables:

http://www.radio-ware.com/produc

http://www.meteorscatter.net/cable

Wave Guide Loss Table: http://www.advancedmicrowave.c

Wave Guide Primer: http://www.microwaves101.com/e

Spacecraft Systems: Add: RG-178 B/U

RG-188 A/U: A PTFE (Teflon)-wrapped "clean" cable for general purpose spacecraft transm
Losses are quite high per unit length as the cable diameter is only 0.098" (2.49 m
for short cable runs. The shield is silver plated copper (19 strands, each #33AW
This is the most commonly used cable for short coax runs in very small spacecra

Band:	*Frequency:*	Attenuation (dB/100 m):		*Attenuation (dB/m):*	
1	10 MHz	12.0	dB/100m	0.12	dB/m
2	30 MHz	17.0	dB/100m	0.17	dB/m
3	50 MHz	-	dB/100m	-	dB/m
4	100 MHz	28.0	dB/100m	0.28	dB/m
5	145 MHz	32.0	dB/100m	0.32	dB/m
6	200 MHz	40.0	dB/100m	0.4	dB/m
7	400 MHz	-	dB/100m	-	dB/m
8	435 MHz	58.0	dB/100m	0.58	dB/m
9	500 MHz	68.0	dB/100m	0.68	dB/m
10	1270 MHz	113.0	dB/100m	1.13	dB/m
11	2400 MHz	165.0	dB/100m	1.65	dB/m
12	3300 MHz	268.0	dB/100m	2.68	dB/m
13	5000 MHz	-	dB/100m	-	dB/m

RG-142 A/U: An FEP (Teflon) solid covered "clean" cable for general purpose spacecraft tra
Losses are moderate per unit length as the cable diameter is 0.195" (4.95 mm).
for longer S/C cable runs. The cable is double shielded with two silver coated co
solid copper AWG #18. Typically used with SMA or even TNC connectors. Con

Band:	*Frequency:*	Attenuation (dB/100 m):		*Attenuation (dB/m):*	
1	10 MHz	7.0	dB/100m	0.07	dB/m
2	30 MHz	9.0	dB/100m	0.09	dB/m
3	50 MHz	-	dB/100m	-	dB/m
4	100 MHz	14.0	dB/100m	0.14	dB/m
5	145 MHz	15.0	dB/100m	0.15	dB/m
6	200 MHz	20.0	dB/100m	0.2	dB/m
7	400 MHz	28.0	dB/100m	0.28	dB/m
8	435 MHz	30.0	dB/100m	0.3	dB/m
9	500 MHz	35.0	dB/100m	0.35	dB/m
10	1270 MHz	49.0	dB/100m	0.49	dB/m
11	2400 MHz	72.0	dB/100m	0.72	dB/m
12	3300 MHz	95.0	dB/100m	0.95	dB/m
13	5000 MHz	128.0	dB/100m	1.28	dB/m

RG-303 /U: A PTFE (Teflon) solid covered "clean" cable for ruggedized spacecraft transmis
Losses are moderate per unit length as the cable diameter is 0.170" (4.32 mm).
for longer S/C cable runs. The cable is single shielded with a silver coated coppe
silver over copper over steel 0.039" (1 mm) dia. Typically used with SMA or ever

Band:	*Frequency:*	Attenuation (dB/100 m):		*Attenuation (dB/m):*	
1	10 MHz	9.3	dB/100m	0.0931	dB/m
2	30 MHz	12.0	dB/100m	0.12	dB/m
3	50 MHz	-	dB/100m	-	dB/m
4	100 MHz	18.6	dB/100m	0.186	dB/m
5	145 MHz	20.0	dB/100m	0.1995	dB/m
6	200 MHz	26.6	dB/100m	0.266	dB/m
7	400 MHz	37.2	dB/100m	0.3724	dB/m
8	435 MHz	40.0	dB/100m	0.4	dB/m
9	500 MHz	46.6	dB/100m	0.4655	dB/m
10	1270 MHz	65.2	dB/100m	0.652	dB/m
11	2400 MHz	95.8	dB/100m	0.9575	dB/m
12	3300 MHz	126.4	dB/100m	1.264	dB/m
13	5000 MHz	170.2	dB/100m	1.702	dB/m

50 Ω Semi-Rigid Cable (0.085" dia.): Semi-Rigid cable is intended to be bent and/or forme
cable has a solid copper outer conductor (tube). Some versions are silver plated
(2.18 mm) and a solid copper inner conductor. SMA, SMC or TNC connectors ca
Losses are superior to flexible cables.

Band:	*Frequency:*	Attenuation (dB/100 m):		*Attenuation (dB/m):*	
1	30 MHz	13.0	dB/100m	0.13	dB/m
2	145 MHz	25.0	dB/100m	0.25	dB/m
3	435 MHz	33.0	dB/100m	0.33	dB/m
4	1270 MHz	53.0	dB/100m	0.53	dB/m
5	2000 MHz	**88.6**	dB/100m	**0.89**	dB/m
6	2400 MHz	96.0	dB/100m	0.96	dB/m
7	10,000 MHz	**200.1**	dB/100m	**2.00**	dB/m
8	18,000 MHz	**275.5**	dB/100m	**2.76**	dB/m

50 Ω Semi-Rigid Cable (0.141" dia.): Semi-Rigid cable is intended to be bent and/or forme
cable has a solid copper outer conductor (tube). Some versions are silver plated
(3.58 mm) and a solid copper inner conductor. SMA, SMC or TNC connectors ca
Losses are superior to flexible cables.

Band:	*Frequency:*	Attenuation (dB/100 m):		*Attenuation (dB/m):*	
1	30 MHz	8.0	dB/100m	0.08	dB/m
2	145 MHz	15.0	dB/100m	0.15	dB/m
3	435 MHz	24.0	dB/100m	0.24	dB/m
4	1270 MHz	57.5	dB/100m	0.58	dB/m
5	2000 MHz	**65.6**	dB/100m	**0.66**	dB/m
6	2400 MHz	68.5	dB/100m	0.69	dB/m
7	10,000 MHz	**91.8**	dB/100m	**0.92**	dB/m
8	18,000 MHz	**124.6**	dB/100m	**1.25**	dB/m

gi-bin/calculate.pl

ts/techinfo/coax.loss.htm

e.htm

om/products/product_frame.htm

ncyclopedia/waveguide.cfm#frequency

nission lines.
m). Still, the losses are acceptable
G). Typically used with SMA or SMC connectors.
ft but, connector installation is moderately difficult.

Band:	8
Frequency:	435 MHz
Cable Length:	0.25 m
Cable Loss:	0.15 dB

NOTE:

Data courtesy K1TTT, W3LPL,PE1OYF, DJ5RH

ansmission lines.
The losses are quite acceptable even
pper braids. The center conductor is
nector installation is moderately difficult.

Band:	5
Frequency:	145 MHz
Cable Length:	0.75 m
Cable Loss:	0.11 dB
	NOTE:

Data courtesy K1TTT, W3LPL, PE1OYF, DJ5RH

sion line applications.
The losses are quite acceptable even
er braid. The center conductor is
n TNC connectors. This is a very rugged cable type.

Band:	11
Frequency:	2400 MHz
Cable Length:	0.50 m
Cable Loss:	0.48 dB
	NOTE:

Can not find data source. Data estimated by VK4GEY.

d one time and then left in position. This
. This version has an exterior diameter of .086"
an be used and are easily installed.

Band:	3
Frequency:	435 MHz
Cable Length:	0.50 m
Cable Loss:	0.17 dB
	NOTE:

Data courtesy Storm Products Co. [**Bold Text**].

Data extrapolated by VK4GEY

d one time and then left in position. This
. This version has an exterior diameter of 0.141"
an be used and are easily installed.

Band:	7
Frequency:	10000 MHz
Cable Length:	0.50 m
Cable Loss:	0.46 dB

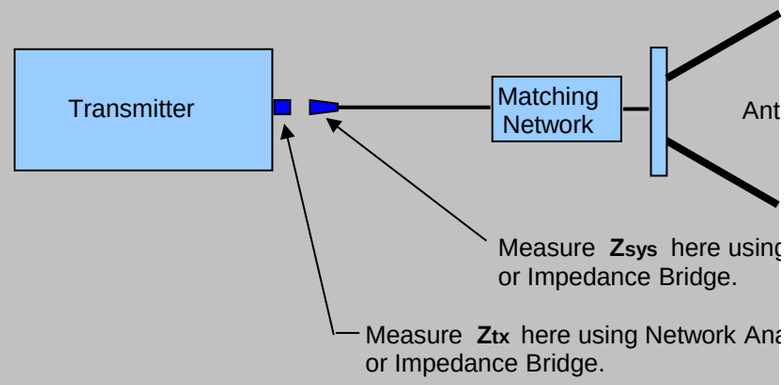
NOTE:

Data courtesy Storm Products Co.[**Bold Text**].
Data extrapolated by VK4GEY

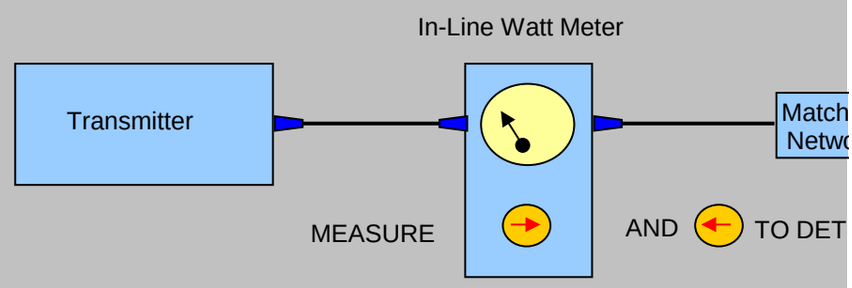
Losses Resulting from Antenna Mismatch - Measured Using Voltage

NOTE:

Transmitter Power Output:	2.0	watts
Measured or Estimated VSWR:	1.6	:1
Power Reflected and Lost:	0.11	watts
Power Transmitted:	1.89	watts
Power Loss due to Mismatch (dB):	**0.24**	dB



TEST CONFIGURATION #1



NOTE:

TEST CONFIGURATION #2

e Standing Wave Ratio(VSWR) Method

Manually Enter Results of Test #1 or Test #2 at Cell [H8]

5.3% % of Power

94.7% % of Power

This value should be entered in the "Transmitters" W/S at Cell [I31].

tenna

g Network Analyzer

alyzer

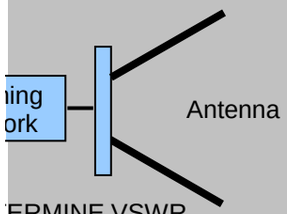
Measured Z_{tx}:	50	+	0.0 j
Measured Z_{sys}:	75	+	-25.0 j
VSWR:	1.58 :1		

TEST 1

OR

TEST 2

Forward Power Measured:	5.0 watts
Reverse Power Measured:	0.25 watts
VSWR:	1.58 :1



ERMINE VSWR

Don't Change These Formulas

$|Z_{tx}| =$ 50.0 Ω

$|Z_{sys}| =$ 79.1 Ω

NOTE:

GEO Azimuth Calculation:

User #1:

User is:

Latitude	**40.000** °		
In N. Hem?	1		Satellite is to South if "
	0		Satellite is to North if "1
Δ Longitude	**27.000** °		
East of Sat?	1		Satellite is to West if "1
	0		Satellite is to East if "1'
	Sat. in Quad?	Quad. Result:	Quad. Angle Range:
Quad NE	0	0.000 °	0° to 90°
Quad SE	0	0.000 °	90° to 180°
Quad SW	1	218.403 °	180° to 270°
Quad NW	0	0.000 °	270° to 360°
Azimuth Calc.	**-38.403** °		
Azimuth Result:		218.403 °	

User #2:

User is:

Latitude	**40.000** °		
In N. Hem?	1		Satellite is to South if "
	0		Satellite is to North if "1
Δ Longitude	**16.000** °		
East of Sat?	1		Satellite is to West if "1
	0		Satellite is to East if "1'
	Sat. in Quad?	Quad. Result:	Quad Angle Range:
Quad NE	0	0.000 °	0° to 90°
Quad SE	0	0.000 °	90° to 180°
Quad SW	1	204.041 °	180° to 270°
Quad NW	0	0.000 °	270° to 360°
Azimuth Calc.	**-24.041** °		
Azimuth Result:		204.041 °	

1", North if "0"
1", South if "0"

L", East if "0"
", West if "0"

1", North if "0"
1", South if "0"

L", East if "0"
", West if "0"

Earth and Orbit Shape for Figure in Orbit & Frequency W/S **[NOTE: DO NOT MODIFY]**

NOTE:	Y	X	R	Y1	X1	R1
	3.519943	-1.9	16	3.574563	-1.9	16.2
	3.546477	-1.85	16	3.6	-1.85	16.2
	3.572114	-1.8	16	3.624569	-1.8	16.2
	3.596874	-1.75	16	3.648287	-1.75	16.2
	3.620773	-1.7	16	3.671171	-1.7	16.2
	3.64383	-1.65	16	3.693237	-1.65	16.2
	3.666061	-1.6	16	3.714499	-1.6	16.2
	3.687479	-1.55	16	3.73497	-1.55	16.2
	3.708099	-1.5	16	3.754664	-1.5	16.2
	3.727935	-1.45	16	3.773592	-1.45	16.2
	3.746999	-1.4	16	3.791767	-1.4	16.2
	3.765302	-1.35	16	3.809199	-1.35	16.2
	3.782856	-1.3	16	3.825899	-1.3	16.2
	3.799671	-1.25	16	3.841875	-1.25	16.2
	3.815757	-1.2	16	3.857136	-1.2	16.2
	3.831123	-1.15	16	3.871692	-1.15	16.2
	3.845777	-1.1	16	3.88555	-1.1	16.2
	3.859728	-1.05	16	3.898718	-1.05	16.2
	3.872983	-1	16	3.911202	-1	16.2
	3.88555	-0.95	16	3.923009	-0.95	16.2
	3.897435	-0.9	16	3.934145	-0.9	16.2
	3.908644	-0.85	16	3.944617	-0.85	16.2
	3.919184	-0.8	16	3.954428	-0.8	16.2
	3.929058	-0.75	16	3.963584	-0.75	16.2
	3.938274	-0.7	16	3.97209	-0.7	16.2
	3.946834	-0.65	16	3.979950	-0.65	16.2
	3.954744	-0.6	16	3.987167	-0.6	16.2
	3.962007	-0.55	16	3.993745	-0.55	16.2
	3.968627	-0.5	16	3.999687	-0.5	16.2
	3.974607	-0.45	16	4.004997	-0.45	16.2
	3.97995	-0.4	16	4.009676	-0.4	16.2
	3.984658	-0.35	16	4.013726	-0.35	16.2
	3.988734	-0.3	16	4.017151	-0.3	16.2
	3.99218	-0.25	16	4.01995	-0.25	16.2
	3.994997	-0.2	16	4.022126	-0.2	16.2
	3.997187	-0.15	16	4.02368	-0.15	16.2
	3.99875	-0.1	16	4.024612	-0.1	16.2
	3.999687	-0.05	16	4.024922	-0.05	16.2
	4.000000	0	16	4.024922	0	16.2
	3.999687	0.05	16	4.024612	0.05	16.2
	3.99875	0.1	16	4.02368	0.1	16.2
	3.997187	0.15	16	4.022126	0.15	16.2
	3.994997	0.2	16	4.01995	0.2	16.2
	3.99218	0.25	16	4.017151	0.25	16.2
	3.988734	0.3	16	4.013726	0.3	16.2
	3.984658	0.35	16	4.009676	0.35	16.2
	3.97995	0.4	16	4.004997	0.4	16.2
	3.974607	0.45	16	3.999687	0.45	16.2
	3.968627	0.5	16	3.993745	0.5	16.2
	3.962007	0.55	16	3.987167	0.55	16.2

3.954744	0.6	16	3.97995	0.6	16.2
3.946834	0.65	16	3.97209	0.65	16.2
3.938274	0.7	16	3.963584	0.7	16.2
3.929058	0.75	16	3.954428	0.75	16.2
3.919184	0.8	16	3.944617	0.8	16.2
3.908644	0.85	16	3.934145	0.85	16.2
3.897435	0.9	16	3.923009	0.9	16.2
3.88555	0.95	16	3.911202	0.95	16.2
3.872983	1	16	3.898718	1	16.2
3.859728	1.05	16	3.88555	1.05	16.2
3.845777	1.1	16	3.871692	1.1	16.2
3.831123	1.15	16	3.857136	1.15	16.2
3.815757	1.2	16	3.841875	1.2	16.2
3.799671	1.25	16	3.825899	1.25	16.2
3.782856	1.3	16	3.809199	1.3	16.2
3.765302	1.35	16	3.791767	1.35	16.2
3.746999	1.4	16	3.773592	1.4	16.2
3.727935	1.45	16	3.754664	1.45	16.2
3.708099	1.5	16	3.73497	1.5	16.2
3.687479	1.55	16	3.714499	1.55	16.2
3.666061	1.6	16	3.693237	1.6	16.2
3.64383	1.65	16	3.671171	1.65	16.2
3.620773	1.7	16	3.648287	1.7	16.2
3.596874	1.75	16	3.624569	1.75	16.2
3.572114	1.8	16	3.6	1.8	16.2
3.546477	1.85	16	3.574563	1.85	16.2
3.519943	1.9	16	3.548239	1.9	16.2