

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 usual 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 cursor over the far left icon you will notice the pop-up prompt now says "edit cell." Now, move the cursor 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 critical 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 formatting which allow the cell colors to change depending on the outcome of the preceding 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 threshold 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. Its 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 expressed 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 $10\log(P/P_{\text{isotropic}})$). 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 its 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 semantic. 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 shown 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.

Specialty 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 *Specialty* 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 important 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 Performance 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 greatly 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 Communications 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 revisions 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 consistency; 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 "Receivers" W/S. Added loss value for cable D. Modified 2nd Stage to "Communications Receiver" at Ground Station. |
| 2.1.4 | 2/27/2005 | Added Turbo 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. Separated Orbit and Frequency into two separate pages. |
| 2.5.1 | 3/6/2008 | Repaired 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. |