DATA LINK RELAY DESIGN

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MR. PAUL PARSONS: We have analyzed the data link for the Ames baseline probe as applied to the MJU spacecraft specifically with an entry at Uranus. I am going to cover four general areas. I will have a few introductory remarks and discuss a bit about the link, look at the effects on the spacecraft and, then, just briefly, touch on the aspects of the two-way link.

We have been studying effects on the link design and what happens to the spacecraft; and, as I said, we are looking at the effects of a two-way link. I will get into the reasons for that in just a moment.

The first thing to look at in this link design is the Frequency Aanlysis. (Figure 7-20). There is a relatively small choise in frequency. You can have UHF or perhaps L-Band. S-Band is conceivable, but it doesn't have very many advantages.

We noted that the atmospheric absorption increases with frequency. The receiver and planet noise increase with frequency. In most cases the planet noise decreases with frequency, or at least levels off, but at Uranus it increases slightly.

We noted that the baseline probe is designed to operate at 400 MegaHertz and we are concerned here with a couple of things: partially, the transmitter, but mainly the antenna pattern. The antenna pattern from this probe is basically that of an open-end wave guide coming back along the longitudinal axis. And the lower frequencies make it a bit easier to get a wider beam width. We will see in a few minutes a wide beam width pattern from the probe is very important.

FREQUENCY ANALYSIS

- ATMOSPHERIC ABSORPTION INCREASES WITH FREQUENCY
- RECEIVER AND PLANET NOISE INCREASE WITH FREQUENCY
- PROBE IS DESIGNED FOR 400 MHZ
- VIKING ORBITER RECEIVER IS BEING BUILT AT 400 MHZ

Figure 7-20

The last major aspect we examined is the Viking orbiter receiver, which is now being built, and is to operate at about 398 MegaHertz. One of the advantages of using this receiver is that all of the EMI work has been done. We know where the interference frequencies will fall, and they will not interfere with the other receiver or with the science; at least the science on the Viking orbiter.

The next major area to get into is the trajectory. There are several parameters here that are of major importance. (Figure 7-21).

The first is the range and shown on the figure in megameters or thousands of kilometers. The first column is the R_U, the periapsis distance in Uranus radii. R_I is the range from the spacecraft to the probe at the entrance into the atmosphere. R_F is the range from the spacecraft to the probe at the termination of transmission.

Notice that at a periapsis of two radii, the range varies from about 95 megameters down to about 38. The 95 megameters correspond to about 184 db path loss at UHF, and you can see that there is about a 5 db change in path loss, reduction in path loss throughout the life of the probe.

We also looked at the case of 1.1 radii, which is perhaps better from a celestial mechanics view point. They get closer to the planet and perhaps a little more sensitivity to some of the J factors in the expansion of the gravity field, but the range is quite short there. The disadvantage of that and the reason I did not show it is there is such a range of cone angles on the spacecraft that we should be very hard pressed to follow it with the antenna.

The second factor in trajectory parameters is the track on the spacecraft. This is the track that the probe would trace out as

TRAJECTORY PARAMETERS

- RANGE Mm

R_U	R_I	R_F
2.	94.5	38.5
3.5	111.	76.6

- S/C TRACK

R_U	$CONE/CLOCK_I$	$CONE/CLOCK_F$
2.	151/277	84/252
3.5	131/271	84/258

- ANGLE FROM PROBE AXIS

R_U	I	F
2.	15	46
3.5	34	42

Figure 7-21

it enters the atmosphere. Figure 7-21 has this listed in cone and clock. For those of you who are not familiar with this system, it is a coordinate system on the spacecraft in which two coordinates describe the entire sphere. Zero degrees cone would be pointed at Earth, and right at encounter the planet would be about 90 degrees cone. Prior to that, it would be close to 180. Clock is measured from the South celestial pole, or Canopus, clockwise, looking at Earth. So you can see that for the two R_U entry, we are looking just a little below horizontal. If it were over 270, it would be horizontal looking off toward the right; it would be 7 degrees below that and at the end of this would be a 252, which would mean we had moved up a bit.

The cone angle starts about 150, which is near the antisolar point, and goes to just a little bit on the sun side of the 90-degree point.

It is interesting to note that the latter portion of the entry is closer to what might be considered the equator of the spacecraft, if you consider the cone the pole. And this has quite an effect on the antenna pattern that we would develop.

If we were to go at 1.1 R_U, we would wind up with a final cone angle of about 50 degrees. That would be on the other side of the 12-foot antenna which would make it a little difficult for the relay antenna to follow it in.

The most important difference here in these flyby periapses is the angle from the probe axis. Now I have said this probe antenna pattern has a maximum on the longitudinal axis and falls off fairly slowly, and at 50 degrees I believe it is down to about 0 dB.

We see on Figure 7-21 that the two R_U case starts out at about 15 degrees which is very good, and winds up at about 46 as a final angle from the axis, which is not too bad. The 3.5 case starts out at about 34 and winds up at 42. In neither of these two cases is the change anything like monotonic. It gets down to a minimum of about 8 degrees in one case, and I believe 12 in the other. It does not exceed 46 for the 2 R_U case or 42 for the 3.5 R_U.

Because of this variation, we do want to keep the antenna beam width as wide as possible; and also this would accommodate any oscillations that will occur in the spacecraft due to the dynamics of entry.

Figure 7-22 covers the dispersion of the probe. It is easy to get shot down on the subject of dispersions, because there are so many different factors entering it. In this case, we have assumed that the Uranus ephemeris has been improved to be more in line with the knowledge of the ephemeris of Jupiter and Saturn. Right now the ephemeris is more unknown or known to a lesser degree. If we have to live with the ephemeris as it stands now, I am afraid our dispersion would be much worse and we would have to revise our analysis.

The entry dispersion analysis I have done so far assumes that the only error is in entry angle. We have assumed a nominal 40 degree entry angle, and we have looked at the difference in parameters that you get with a 30 and a 50 degree entry angle. As you might expect, the 30 and 50 degree entry angles move most of these parameters in opposite directions.

The range will vary by a maximum of five megameters from the nominal case of 40 degrees entry, which would amount to approximately 0.5 db, path loss, which is negligible. It will move the probe trace on the spacecraft by a maximum of three degrees, which is a small amount. However, it can affect the probe axis angle by ten degrees. The angle off the axis can get up to around 55 degrees or so. At this angle, we have not only reached

DISPERSION

- ASSUMES IMPROVED URANUS EPHEMERIS
- ASSUMES ONLY ERROR IS IN ENTRY ANGLE
- EFFECTS

RANGE	5 MM
S/C ANGLE	3^{o}
PROBE AXIS ANGLE	10^{o}

Figure 7-22

a region of decreased gain, we have reached a region of some lobing in the pattern. This will, obviously, give you some scintillation of the received signal, something we would rather avoid.

That pretty well covers what we have done on the trajectory analysis. I would like to go into the spacecraft design, Figure 7-23.

The required view region comes directly from the probe trace on the spacecraft, and we see that it covers a region of roughly 30 degrees by 80 degrees. Now that 80 degrees is in cone. This is a fairly narrow trace going along what we consider the 270 degree longitude line. The required gain is about 6 db. Most of this is concentrated at the initial portion of the pattern, which is around 150 degrees cone.

The receiver we see is a modification of the Viking orbiter receiver to include AFC because of the requirements of tracking the dynamics of the frequency as required by the low data rates. In detection, of course, we see a detector, some sort of symbol synchronizer, and we see probably a decoder being built into the spacecraft. The probe would have convolutional encoding and we would expect that we would decode that and send just the bits down rather than the entire symbols.

I would like to just touch very briefly on the two-way considerations (Figure 7-24) and show a block diagram (Figure 7-25). The reason for thinking about two-way is that it could provide Doppler data if we could find some way of breaking this off out of the receiver, that could give some scientific data and perhaps something about the atmosphere on entry.

The problems are two phase locked loops cascaded and you are going to have some noise, additional noise that you would not have normally. The real big problem is in acquisition, and

SPACECRAFT DESIGN

- ANTENNA

  VIEW REGION ∼ 30^{o} X 80^{o}

  REQUIRED GAIN ∼ 6 DB

- RECEIVER

  MODIFICATION OF V. O. TO INCLUDE AFC

- DETECTION

  DETECTOR

  BIT SYNC

  DECODER

Figure 7-23

TWO-WAY CONSIDERATIONS

- COULD PROVIDE DOPPLER DATA
- PROBLEMS
  - NOISE FROM CASCADED LOOPS
  - ACQUISITION
  - TRACKING

Figure 7-24

TWO WAY DIAGRAM

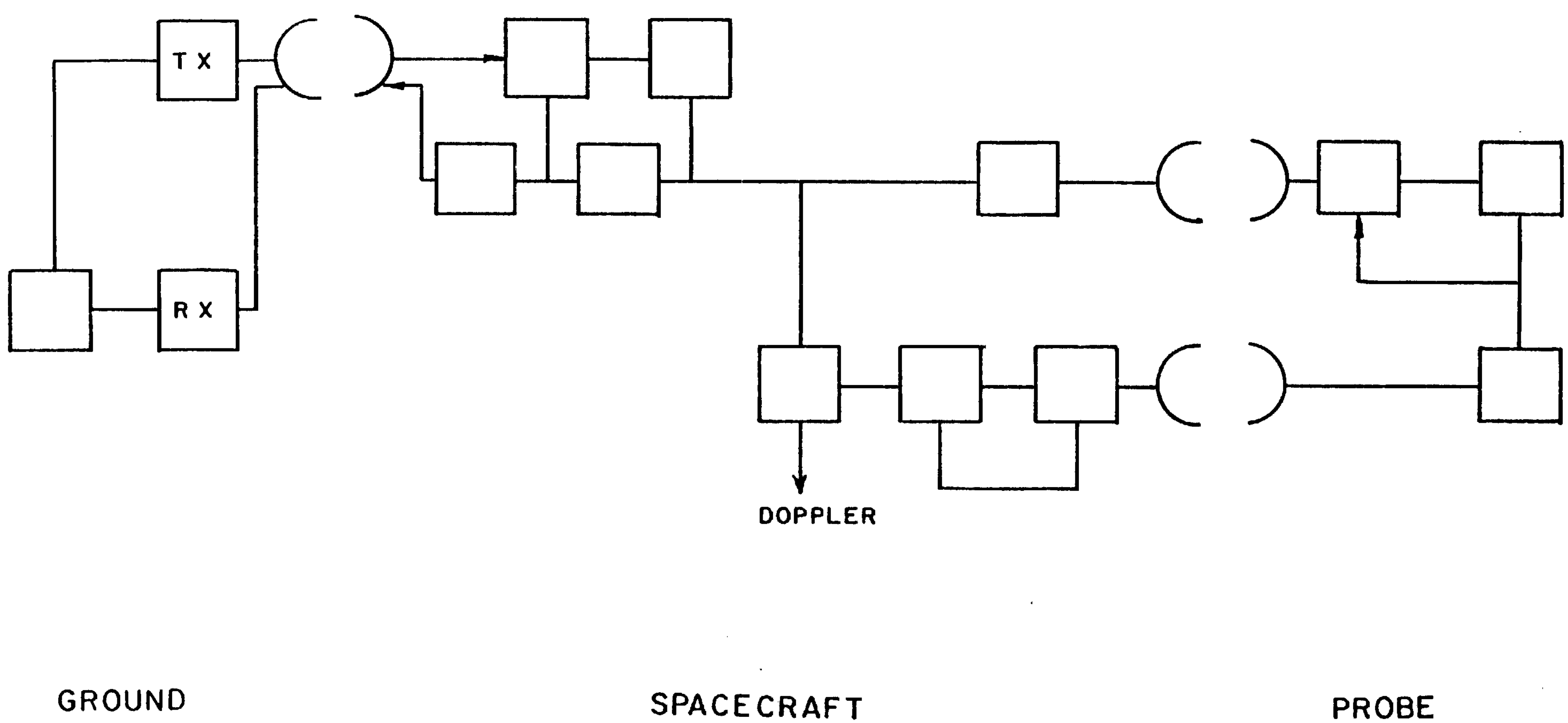

Figure 7-25

there is some problem in tracking and re-acquiring.

On the block diagram, Figure 7-25, we have the normal link with the spacecraft, the ground transmitter out through a phase lock loop, a multiplier, the down link receiver, and the Doppler extractor.

On the probe we have to have a different multiplier out to the second antenna to the probe. The probe would lock up to the received signal, then another offset - transmitting a slightly offset signal back to the spacecraft. The spacecraft would now have to lock up to this signal from the probe and then there would be a Doppler extraction and this would have to be read out and sent down on a telemetry link.

You see we have complicated the relay link greatly. Instead of a simple transmitter on the probe, we now have a transponder that has to lock to the signal from the spacecraft, and instead of a simple receiver on the spacecraft, we now have to have another phase lock receiver.

We are quite concerned about the two-way acquisition aspects of this. Thank you.

MR. GRANT: The next speaker is Mr. Carl Hinrichs, senior engineer at the McDonnell-Douglas Corporation. Mr. Hinrichs will report on a digital receiver simulation study recently concluded at MDAC.