N75 20393

SECTION VII - COMMUNICATIONS AND DATA HANDLING

T. L. Grant
NASA - Ames

MR. GRANT: This session is on communications and data handling. Before I introduce the speakers that are listed, I would like to say a few words about the communications system in general, just to give you an outline of the objectives, some of the problems, and an idea of our approach.

The obvious objective of the communications system is to return science data. But aside from that, we are concerned not only with basic science information for the first missions but also with considerations for follow-on missions. At the same time we want to minimize the technology development and achieve some commonality between the missions. The last two objectives are important in this era of low cost emphasis because the communications system has historically represented about 30 percent of development costs for a mission.

On Figure 7-1 I have a cartoon on communication problems. You have seen this a couple of times before in past sessions, but it helps to illustrate where the basic problems are for this communication link.

First of all, shown schematically, are a couple of lines representing the atmosphere and ionosphere and reminding us that we really don't know through what kind of environment we have to propagate in order to communicate with the entry probes.

The other constraint is a common one for all space vehicles. We have a power, weight, and volume limit constraint. But the big difference between communicating from a probe entering at the atmosphere to a flyby spacecraft and communicating from a space-

COMMUNICATION PROBLEM

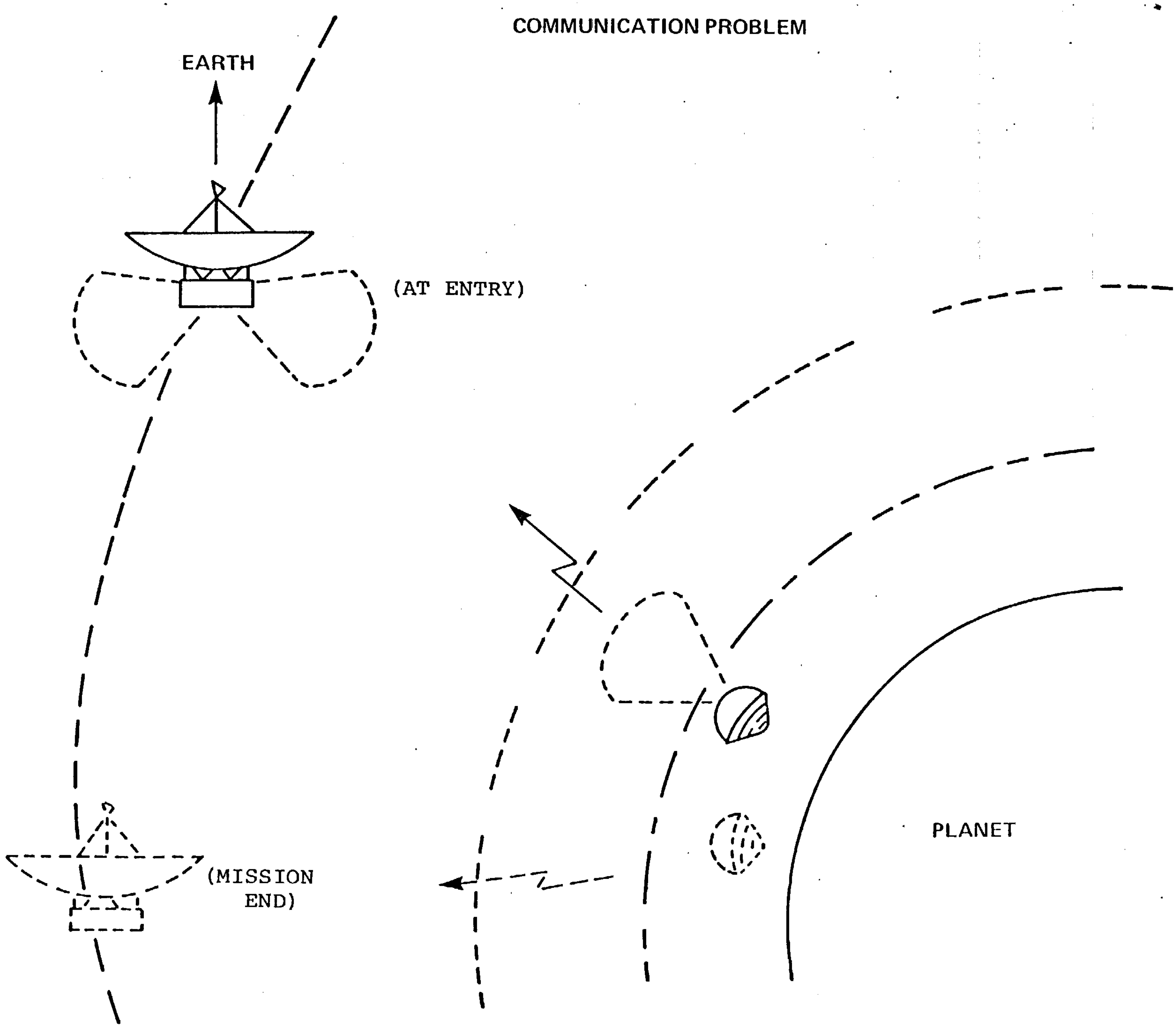

FIGURE 7-1

craft to Earth is that first we have a very limited amount of time to communicate and second we have a large geometry change over the communication time. For the Pioneer-type of mission, we have established a baseline design that accommodates this geometry variation, or change in aspect angles, by using broad-beam, axially-symmetric antennas.

That outlines the basis of the problem, and as you know, the method of solution has been to begin with the current models of the atmosphere environment and through a feasibility study, come up with a baseline design which we expect to evolve as our studies continue.

Figure 7-2 shows the pertinent points of the baseline design for Pioneer. The first thing to note is that our baseline design provides for pre-entry data storage and not transmission. The McDonnell-Douglas Saturn-Uranus study proposed a design with 15,000 to 30,000 bits of pre-entry storage, primarily accelerometer data.

The second important point is that all events are timed in sequence or are activated by a G switch, i.e. there is no command link with the probe, and this is an important consideration as we review the baseline design.

We have a relay link because in order to accommodate most of the missions, a direct link was not felt to be feasible and would constrain the mission design severely. Therefore, telemetry is transmitted only during the descent phase of the probe entry and for this baseline the rate is 44 bits per second over a time interval from about 25 to 70 minutes. This encompasses not only different atmospheric entries for different planets, but also the different models of the planetary atmospheres and allows for dispersion in the entry angle and phasing.

BASELINE DESIGN (PIONEER)

- PRE-ENTRY DATA STORAGE
- TIMED SEQUENCE + 'G' SENSE
- RELAY LINK
- TELEMETRY TRANSMISSION DURING DESCENT
- 44 BPS/25 TO 70 MINUTES
- AXISYMMETRIC, LOW GAIN ANTENNAS
- 400 MHz CARRIER
- NARROW-BAND PCM-FSK MODULATION
- CONVOLUTIONAL CODING

FIGURE 7-2

As previously mentioned, this design utilizes axially symmetric low-gain antennas for both the transmitter and receiver namely a micro strip antenna with a gain of about 7 db on the probe transmitter and a loop vee antenna with a gain of about 2.5 db on the bus receiver.

The baseline carrier frequency is 400 MHz with a modulation scheme that is narrow band binary frequency modulation with convolutional coding, and we haven't as yet decided exactly what decoding method would be used. We are still doing trade-offs to determine the code constraint length and whether to use maximum likelihood or sequential decoding.

Figure 7-3 shows one of the prime problems in the communication link, the radio frequency environment. I will speak briefly about the ionospheric absorption and turbulence models.

Figure 7-4 - the turbulence model is considered to be a weak homogeneous turbulence in most of the atmospheres. This implies that the amplitude modulation of the signal is the important effect of the turbulence.

The amplitude has a narrow band spectrum with a log normal probability density. The standard deviation of this statistic is proportional to the structure factor in the atmospheric turbulence. It is also proportional to the frequency of the carrier to the 7/12ths power and the length of propagation, L, to the 11/12ths power. The problem here is we currently have virtually no information from which to decide on the structure factor or the propagation length that we have to deal with as the probe enters.

The turbulence induced modulation bandwidth is estimated to be proportional to the perpendicular wind velocity and inversely propor-

RADIO FREQUENCY ENVIRONMENT

- CURRENT MODELS -

- NOISE SOURCES } R. COMPTON
- ATMOSPHERE ABSORPTION } R. COMPTON
- IONOSPHERE ABSORPTION
- TURBULENCE FADING

FIGURE 7-3

TURBULENCE EFFECTS

- WEAK - HOMOGENEOUS
- AMPLITUDE MODULATION
- NARROW BAND
- LOG NORMAL
- STD. DEV. $\propto C_N F^{7/12} L^{11/12}$
- MODULATION BANDWIDTH

$$F_{3DB} = 0.3 \, V_{\perp} / L_0$$

- MODEL: STD. DEV. $\leq$ 0.23

$$F_{3DB} \leq 2 \text{ Hz}$$

- NEED PIONEER 10/11 OCCULTATION ANALYSIS

FIGURE 7-4

tional to the largest scale size of the turbulence. Here, again, we don't have very good measures of either of these parameters. although the wind is modeled for Jupiter as being something on the order of 100 meters per second. Comparing it with other turbulent atmospheres, like Earth, which is our only other real model, it is estiamated that the scale factor of the turbulence could be on the order of about 50 meters to perhaps 150 meters.

This gets us to the model that we are currently using for the amplitude modulation. We are using a standard deviation of about .23 or less on the amplitude modulation, and a bandwidth of less than two Hertz. But we need some real data to verify these assumptions and that points out the need for some analysis of the Pioneer 10 and 11 occultation data. We are hoping that we can have some of this analysis done by Richard Woo of JPL who has done similar work for the Pioneer-Venus project.

The other factor in the link analysis is ionospheric loss. Here, there are two important considerations; the peak density of the ionospheric electron density and the scale height. Figure 7-5 shows (with a little bit of license from communication engineers point of view) a model of the ionospheres as if they started at the same relative altitude. Each density model is still quite different, depending at whose model or what data you look. As you notice on the figure, the NASA Space Vehicle Design Criteria monograph of Saturn-Uranus ionospheric density has a peak electron density of 10^6 and a fairly large scale height.

The Jupiter preliminary Pioneer 10 results shows a scale height that is a little larger but a peak electron density of only about 3×10^5. The monograph for Jupiter, in contrast, shows a considerably lower scale height.

Plotted for reference, from a recent article in Science, is a projected possible profile with a very low scale height and a peak electron density of about 10^6.

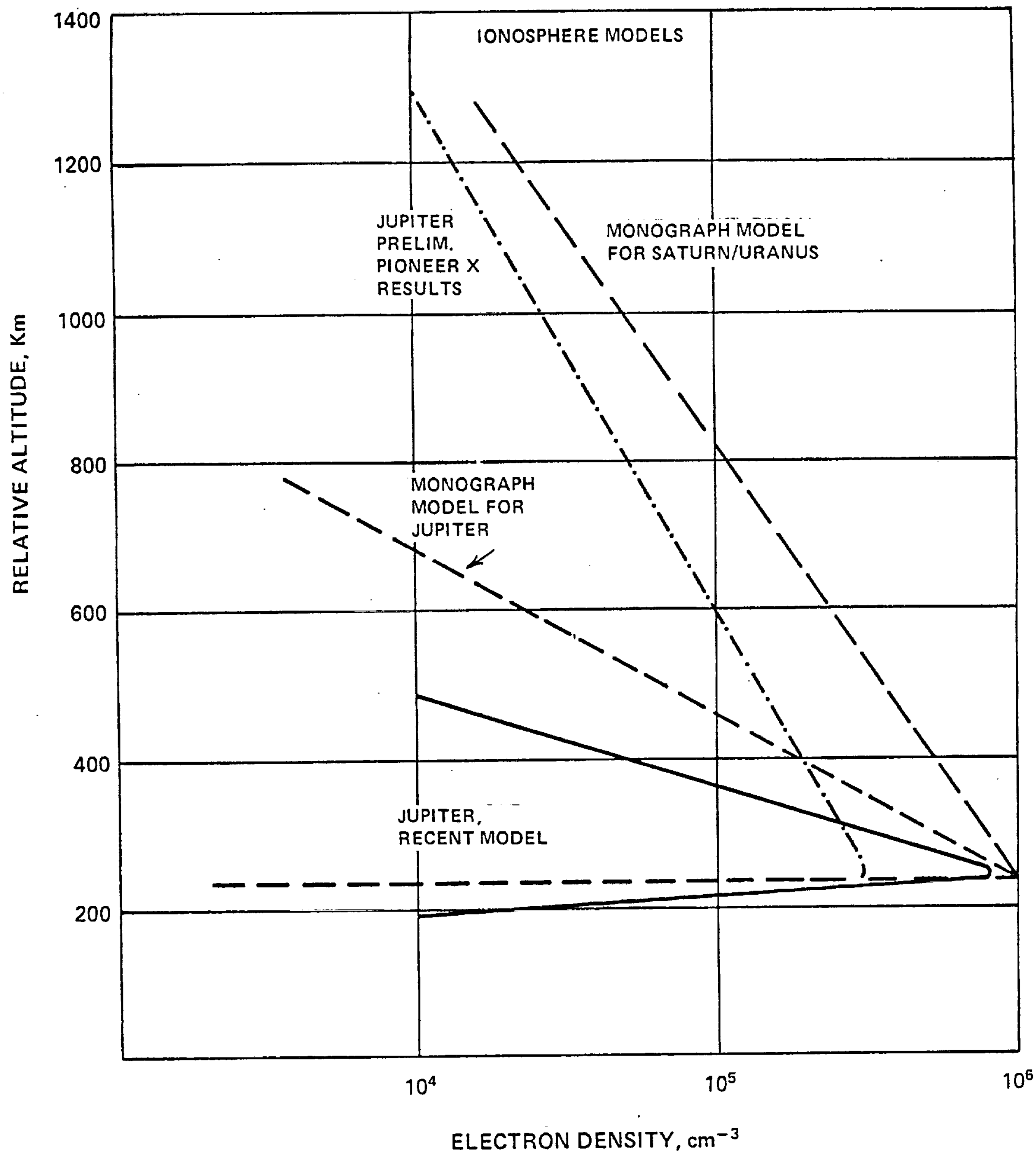
IONOSPHERE MODELS
1400
1200
1000
800
600
400
200
RELATIVE ALTITUDE, Km
JUPITER
PRELIM.
PIONEER X
RESULTS
MONOGRAPH MODEL
FOR SATURN/URANUS
MONOGRAPH
MODEL FOR
JUPITER
JUPITER,
RECENT MODEL
10^4
10^5
10^6
ELECTRON DENSITY, cm^{-3}

FIGURE 7-5

An important factor to note is that the integral over the altitude of this electron density is what really determines the attenuation. Thus, if we use the most extreme model, the one for the Saturn-Uranus ionosphere, to determine attenuation, we will have a conservative estimate. Figure 7-6 shows the attenuation versus frequency for this extreme model and predicts the attenuation of the ionosphere to be less than a 10th of a db at 400 megaHertz. Please note, however, that the NASA monograph allows the peak electron density for the Saturn-Uranus ionosphere to be as much as an order of magnitude higher than this, even though thus far there is no firm scientific rationale for that. So I feel that the attenuation versus frequency profile of Figure 7-6 is realistically conservative, but not an absolute worst case.

Our first speaker, Reavis Compton, is doing telecommunications work for advanced programs at Martin-Marietta and has been involved with advanced prograns for the past four years or so. He will talk about mirowave propagation in the atmospheres of the outer planets.

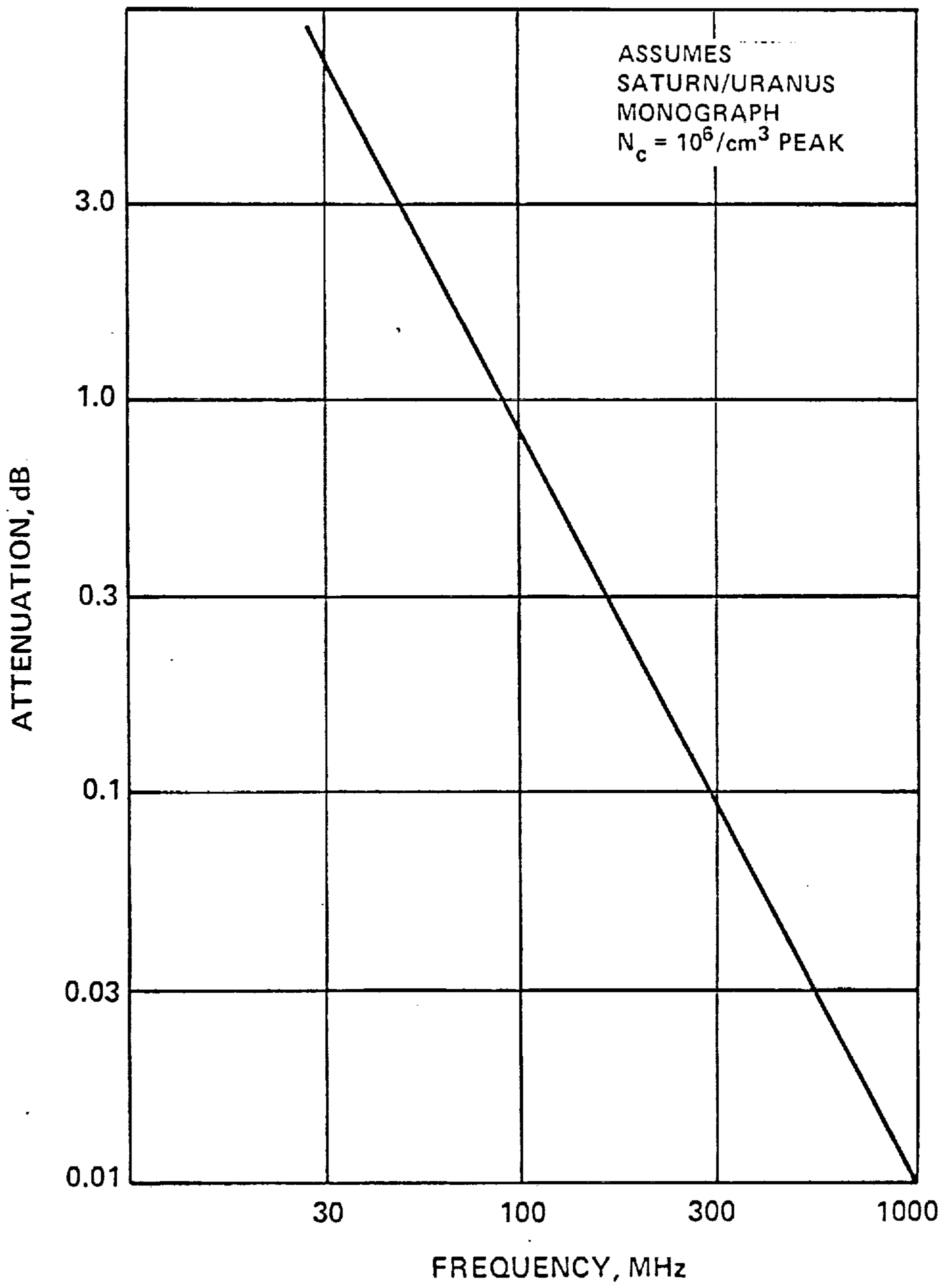
ASSUMES
SATURN/URANUS
MONOGRAPH
$N_c = 10^6/cm^3$ PEAK
3.0
1.0
0.3
0.1
0.03
0.01
ATTENUATION, dB
30
100
300
1000
FREQUENCY, MHz

FIGURE 7-6