

RECOMMENDATION ITU-R P.528-2^{*,**}**PROPAGATION CURVES FOR AERONAUTICAL MOBILE AND
RADIONAVIGATION SERVICES USING THE VHF, UHF AND SHF BANDS**

(Question ITU-R 203/3)

(1978-1982-1986)

The ITU Radiocommunication Assembly,

considering

- a) that there is a need to give guidance to engineers in the planning of radio services in the VHF, UHF, and SHF bands;
- b) that the propagation model used to generate the curves given in Annex II is based on a considerable amount of experimental data (see Annex I);
- c) that the aeronautical service often provides a safety of life function and therefore requires a higher standard of availability than many other services;
- d) that a time availability of 0.95 should be used to obtain more reliable service,

recommends

that the curves given in Annex II be adopted to determine the basic transmission losses for 5%, 50% and 95% of the time for antenna heights (for both the ground station and aircraft) likely to be encountered in the aeronautical services.

Note. – It must be emphasized that these curves are based on data obtained mainly for a continental temperate climate. The curves should be used with caution for other climates.

ANNEX I

DEVELOPMENT AND APPLICATION OF THE CURVES

Transmission loss prediction methods have been extended and incorporated into the IF-77 propagation model that determine basic transmission losses for 5%, 50% and 95% of the time for antenna heights applicable to the aeronautical services. These methods are based on a considerable amount of experimental data, and extensive comparisons of predictions with data have been made. In performing these calculations, a smooth (terrain parameter $\Delta h = 0$) Earth with an effective Earth radius factor k of 4/3 (surface refractivity $N_s = 301$) was used along with compensation for the excessive ray bending associated with the $k = 4/3$ model at high altitudes. Constants for average ground horizontal polarization, isotropic antennas, and long-term power fading statistics for a continental temperate climate were also used. Although these parameters may be considered either reasonable or worst-case for many applications, the curves should be used with caution if conditions differ drastically from those assumed.

With the exception of a region “near” the radio horizon, values of median basic transmission loss for “within-the-horizon” paths were obtained by adding the attenuation due to atmospheric absorption (in decibels) to the transmission loss corresponding to free-space conditions. Within the region “near” the radio horizon, values of the transmission loss were calculated using geometric optics, to account for interference between the direct ray and a ray reflected from the surface of the Earth. Segments of curves resulting from these two methods were joined to form a curve that shows median basic transmission loss as increasing monotonically with distance.

The two-ray interference model was not used exclusively for within-the-horizon calculations, because the lobing structure obtained from it for short paths is highly dependent on surface characteristics (roughness as well as electrical constants), atmospheric conditions (the effective Earth radius is variable in time), and antenna characteristics

* This Recommendation is brought to the attention of Study Group 8.

** Radiocommunication Study Group 3 made editorial amendments to this Recommendation in 2000 in accordance with Resolution ITU-R 44.

(polarization, orientation and gain pattern). Such curves would often be more misleading than useful, i.e., the detailed structure of the lobing is highly dependent on parameters that are difficult to determine with sufficient precision. However, the lobing structure is given statistical consideration in the calculation of variability.

For time availabilities other than 0.50, the basic transmission loss, L_b , curves do not always increase monotonically with distance. This occurs because variability changes with distance can sometimes overcome the median level changes. Variability includes contributions from both hourly-median or long-term power fading and within-the-hour or short-term phase interference fading. Both surface reflection and tropospheric multipath are included in the short-term fading.

The curves provided in Annex II are selected curves from a much larger set of computer-generated smoothed curves.

The basic transmission loss, $L_b(0.05)$ curves may be used to estimate L_b values for an unwanted interfering signal that is exceeded during 95% (100% – 5%) of the time. Median (50%) propagation conditions may be estimated with the $L_b(0.50)$ curves. The $L_b(0.95)$ curves may be used to estimate the service range for a wanted signal at which service would be available for 95% of the time in the absence of interference.

The expected protection ratio or wanted-to-unwanted signal ratio exceeded at the receiver for at least 95% of the time, $R(0.95)$, can be estimated using the Annex II curves as follows:

$$R(0,95) = R(0.50) + Y_R(0.95) \quad (1)$$

$$R(0.50) = [P_t + G_t + G_r - L_b(0.50)]_{Wanted} - [P_t + G_t + G_r - L_b(0.50)]_{Unwanted} \quad (2)$$

and

$$Y_R = - \sqrt{[L_b(0.95) - L_b(0.50)]_{Wanted}^2 + [L_b(0.05) - L_b(0.50)]_{Unwanted}^2} \quad (3)$$

In equation (2), P_t is the transmitted power, and G_t and G_r are the isotropic gains of the transmitting and receiving antennas expressed in dB.

Additional variabilities could easily be included in equation (3) for such things as antenna gain when variabilities for them can be determined. Continuous (100%) or simultaneous channel utilization is implicit in the $R(0.95)$ formulation provided above so that the impact of intermittent transmitter operation must be considered separately.

ANNEX II

DESCRIPTION OF THE CURVES

The aeronautical curves are contained in Figs. 1 to 6. The following points are to be noted:

1. Figures 1 to 6 show median values of the basic transmission loss, L_b , for the frequencies 125, 300, 1200, 5100, 9400 and 15 500 MHz.
2. Each figure consists of three curve sets where the upper, middle and lower sets provide $L_b(0.05)$, $L_b(0.50)$, and $L_b(0.95)$, respectively. These correspond to time availabilities of 5, 50 and 95%. For example, $L_b(0.95) = 200$ dB means that the basic transmission loss would be 200 dB or less during 95% of the time.

Code for antenna heights

Code	H_1 (m)	H_2 (m)
A	15	1000
B	1000	1000
C	15	10000
D	1000	10000
E	15	20000
F	1000	20000
G	10000	10000
H	10000	20000
I	20000	20000

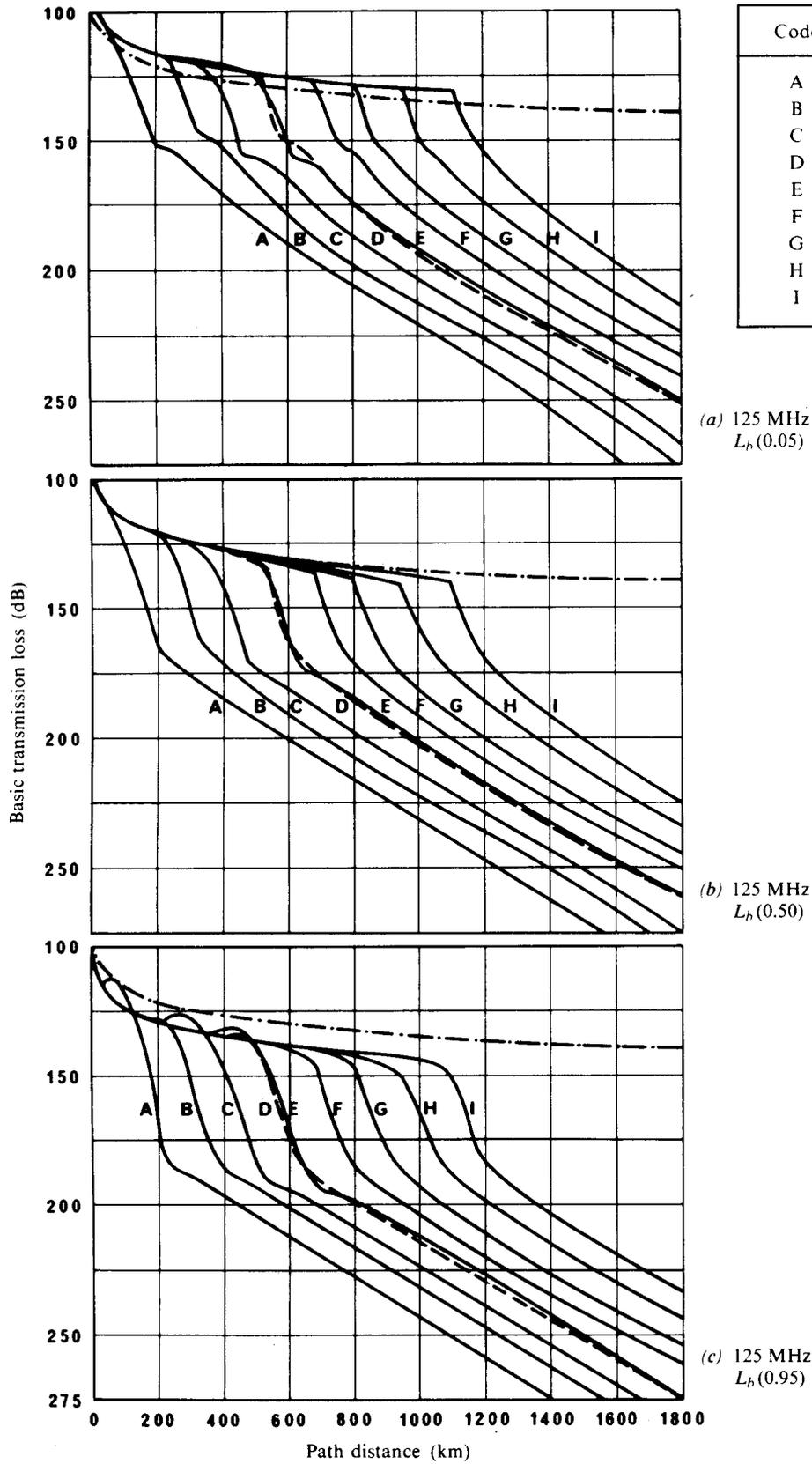


FIGURE 1 — Basic transmission loss at 125 MHz for 5%, 50% and 95% of the time

The dotted-line curve is that for free space

Code for antenna heights

Code	H_1 (m)	H_2 (m)
A	15	1000
B	1000	1000
C	15	10000
D	1000	10000
E	15	20000
F	1000	20000
G	10000	10000
H	10000	20000
I	20000	20000

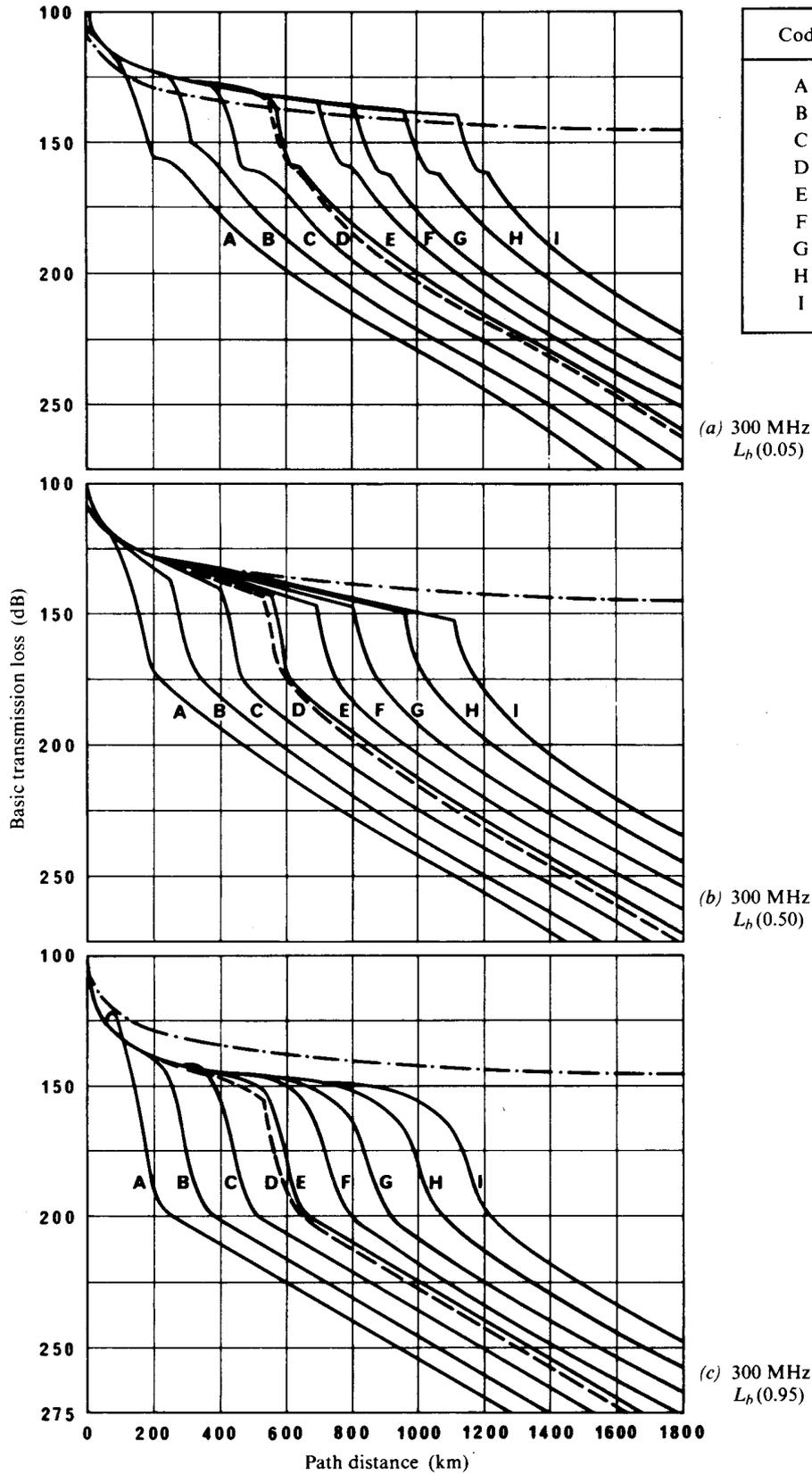


FIGURE 2 — Basic transmission loss at 300 MHz for 5%, 50% and 95% of the time

The dotted-line curve is that for free space

Code for antenna heights

Code	H_1 (m)	H_2 (m)
A	15	1000
B	1000	1000
C	15	10000
D	1000	10000
E	15	20000
F	1000	20000
G	10000	10000
H	10000	20000
I	20000	20000

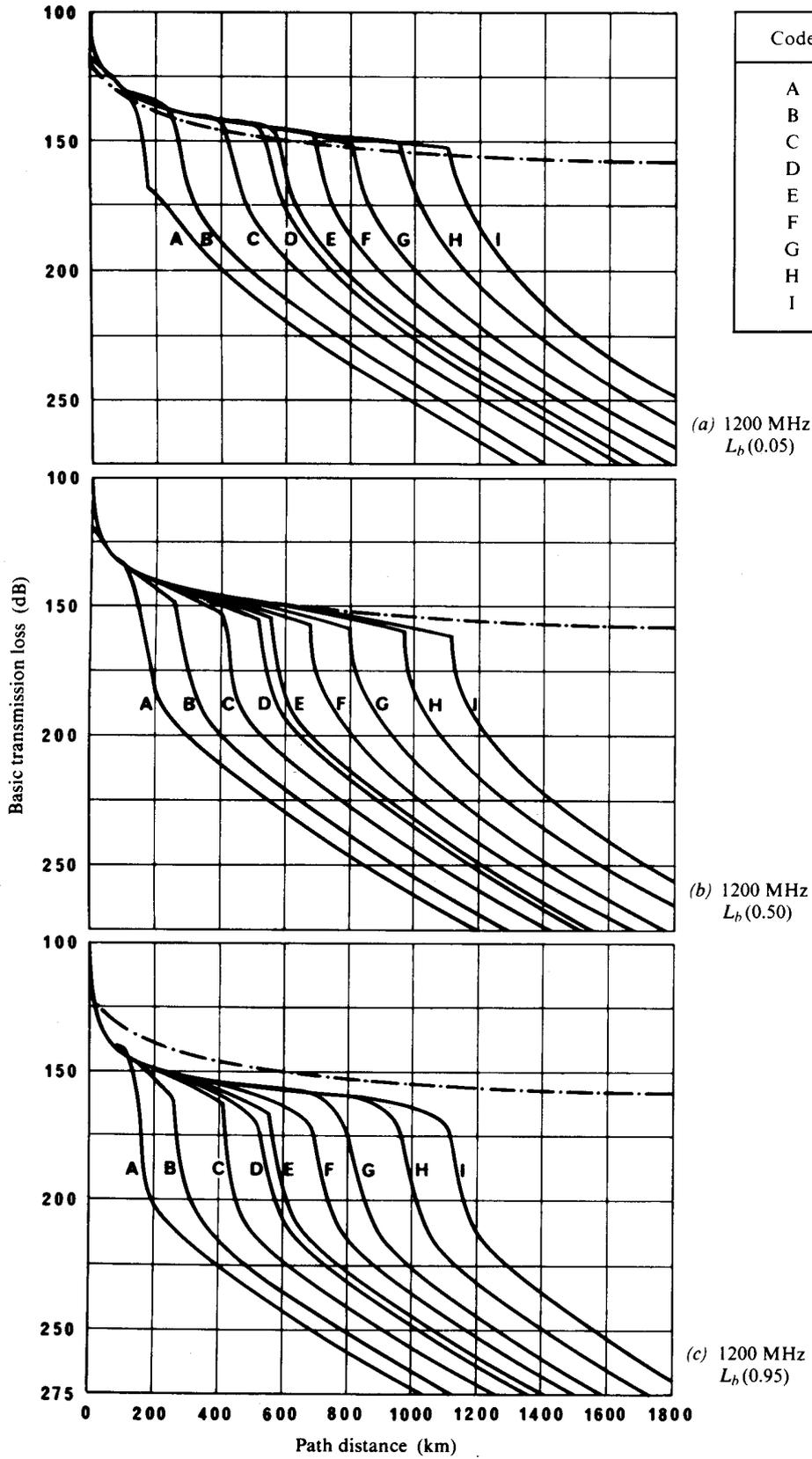


FIGURE 3 — Basic transmission loss at 1200 MHz for 5%, 50% and 95% of the time

The dotted-line curve is that for free space

Code for antenna heights

Code	H_1 (m)	H_2 (m)
A	15	1000
B	1000	1000
C	15	10000
D	1000	10000
E	15	20000
F	1000	20000
G	10000	10000
H	10000	20000
I	20000	20000

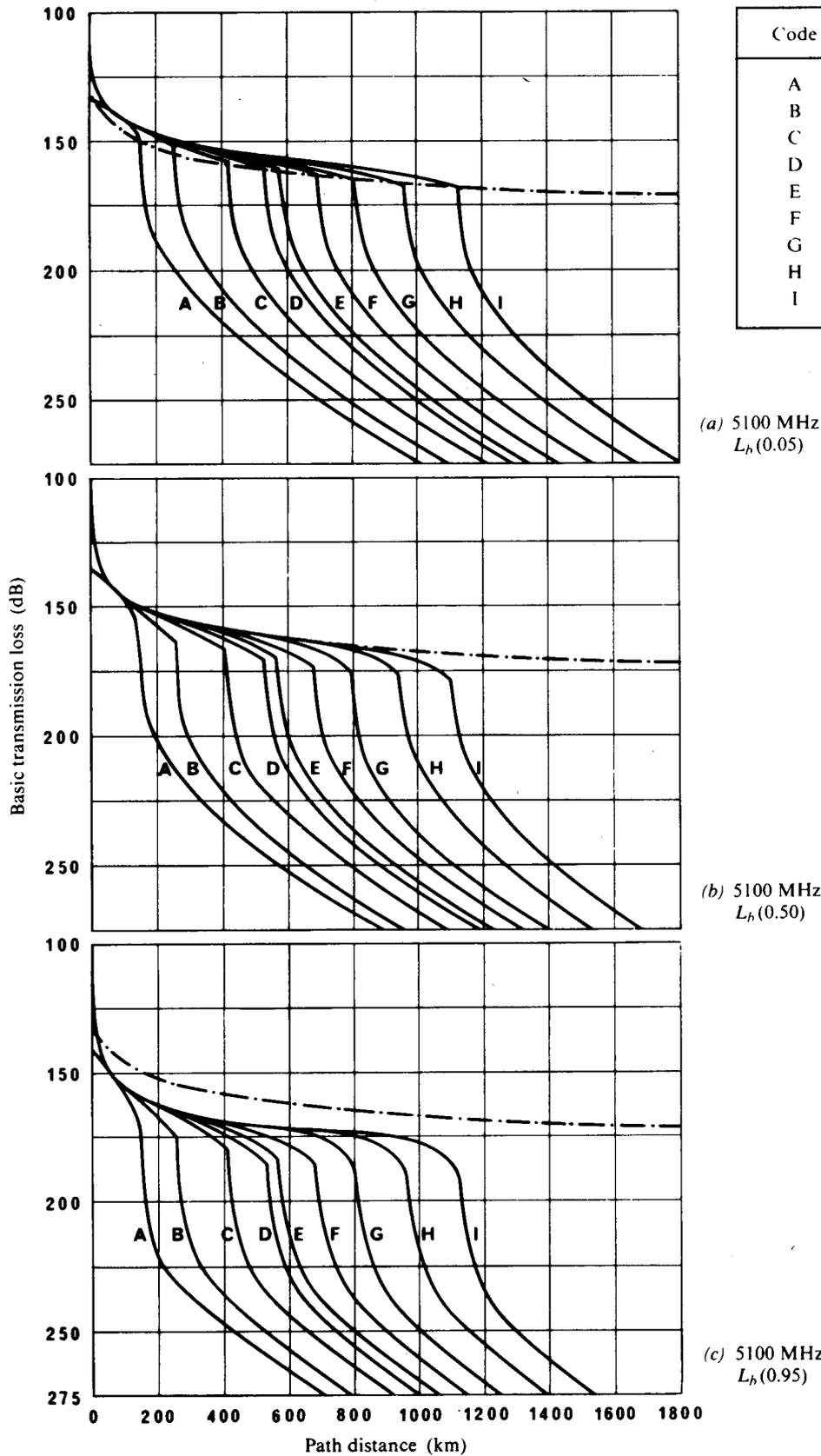


FIGURE 4 — Basic transmission loss at 5100 MHz for 5%, 50% and 95% of the time

The dotted-line curve is that for free space

Code for antenna heights

Code	H_1 (m)	H_2 (m)
A	15	1000
B	1000	1000
C	15	10000
D	1000	10000
E	15	20000
F	1000	20000
G	10000	10000
H	10000	20000
I	20000	20000

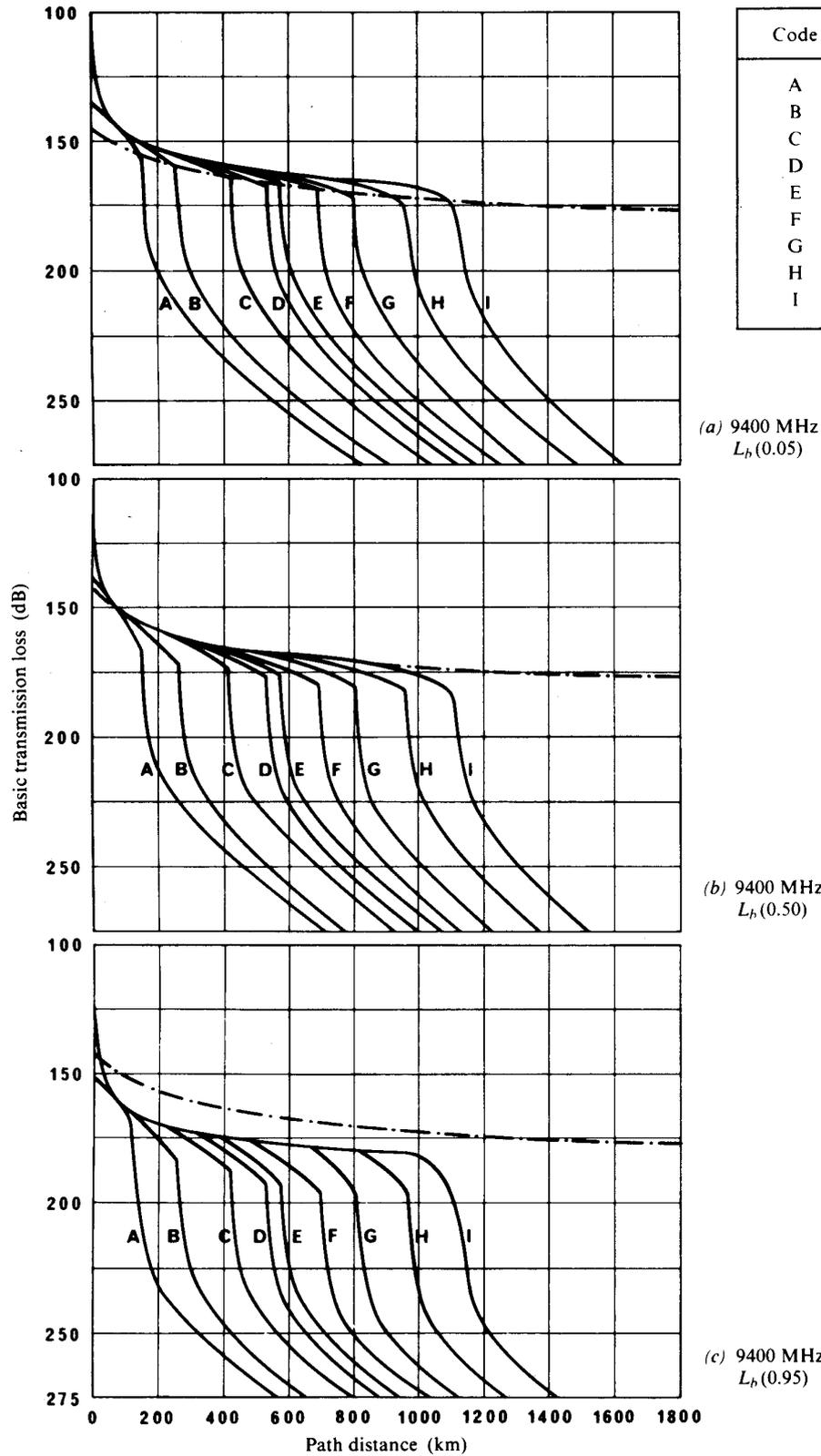


FIGURE 5 — Basic transmission loss at 9400 MHz for 5%, 50% and 95% of the time

The dotted-line curve is that for free space

Code for antenna heights

Code	H_1 (m)	H_2 (m)
A	15	1000
B	1000	1000
C	15	10000
D	1000	10000
E	15	20000
F	1000	20000
G	10000	10000
H	10000	20000
I	20000	20000

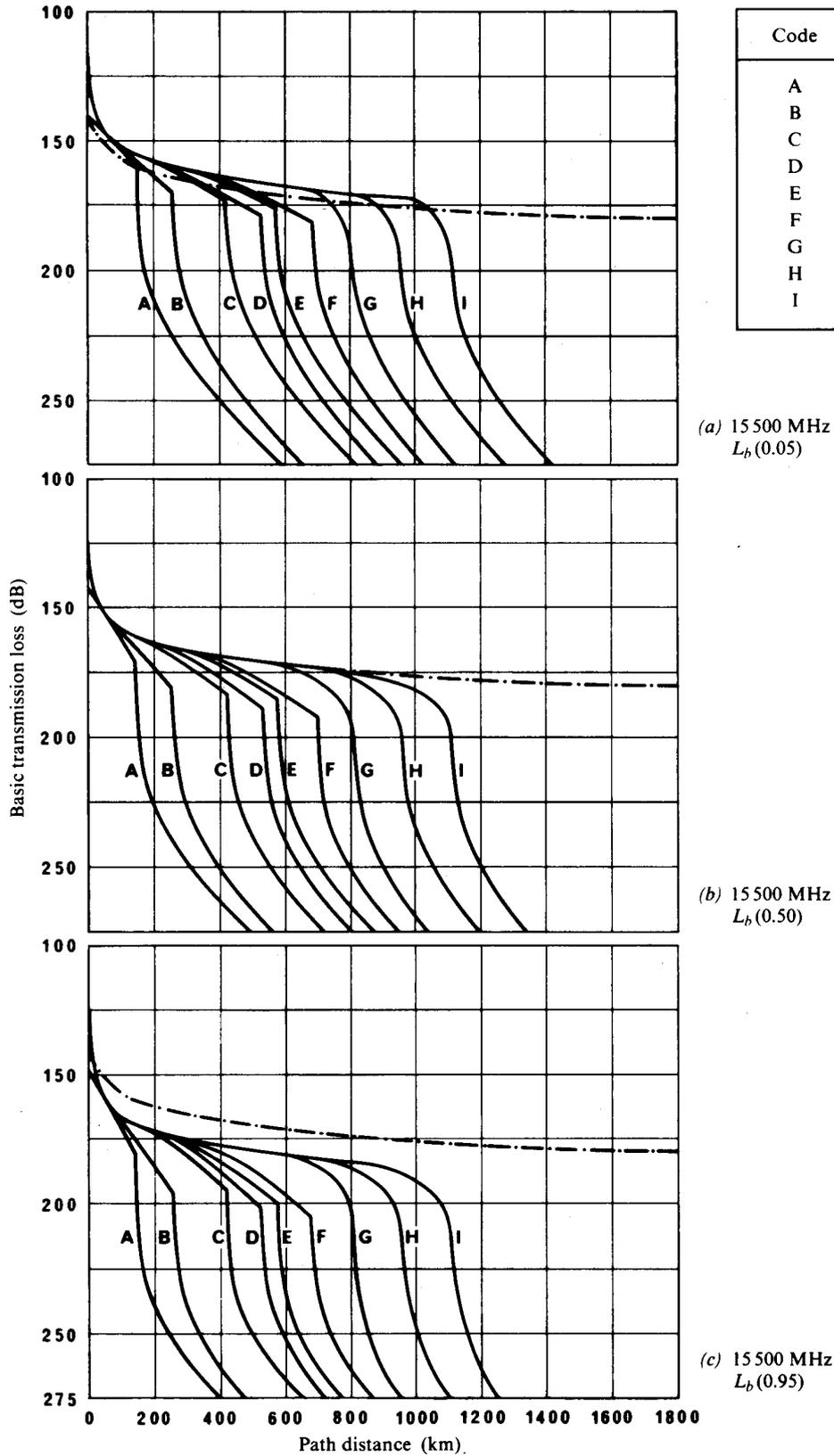


FIGURE 6 – Basic transmission loss at 15500 MHz for 5%, 50% and 95% of the time

The dotted-line curve is that for free space

3. The antenna heights shown vary from 15 m to 20 000 m covering both ground station and aircraft heights.
4. The development and application of these curves are discussed in Annex I.
5. At zero distance $L_b(0.50)$ is simply the free-space value corresponding to a path length equal to the difference in antenna heights. The free-space curves shown were calculated for a 19 985 m height difference.

ANNEX III

EXPERIMENTAL RESULTS

Propagation tests at 930 MHz were conducted on air-to-ground paths in Japan in November 1982 and April and June 1983. According to the test results, propagation losses within line-of-sight agreed well with free space values. The line-of-sight distance as calculated from the measured data at an altitude of 10 000 m was shorter than the distance implied by the curves in Annex II.
