Abstract

- Propagation tests for land-mobile radio service
  - VHF (200MHz) and UHF (453, 922, 1310, 1430, 1920MHz)
  - Various situations of irregular terrain/environmental clutter
- The results analyzed statistically are described
  - Distance
  - Frequency dependences of median field strength
  - Location variabilities
  - Antenna height gain factors - the base and the vehicular station
  - In urban, suburban, and open areas over quasi-smooth terrain
- A method is presented for predicting the field strength and service area
- Comparison of predicted field strength with measured data

Outline of Propagation Tests Performed

- First series of tests
  - In 1962
  - Simple & flat areas, Quasi–smooth terrains
    contained as many built-up cities, distance up to 100 km
  - Two or more mobile courses for each base station
  - 453, 922, 1310, 1920 MHz

- Second series of tests
  - In 1965
  - Using lower base station antennas
  - Concerning hilly, mountainous, irregular terrain
  - 453, 922, 1317, 1430 MHz

Parameters of Measurement

- Vertically polarized wave was in use for all frequencies

Frequency MHz	Transmitter Power	Transmitting Antenna Gain Type	Receiving Antenna Gain Type
453	150 W	11.3 dB 5-element Yagi	1.5 dB Omni-directional unipole antenna
922	60 W	11.3 dB 90 ° Corner	1.5 dB ″
1317	150 kW Pulse	11.3 dB 1.2 m in diam. Parabola	1.5 dB ″
1430	30 W	11.3 dB 1.5 m parabola	1.5 dB ″
1920	60 W	11.3 dB Horn	1.5 dB ″

Mobile Field Strength Measurements

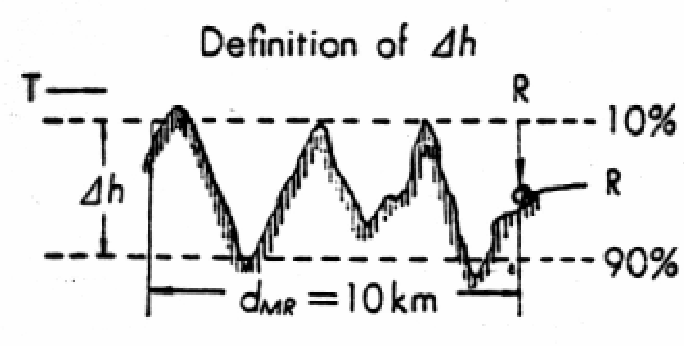
- Receiving Antennas
  - 3 m high above ground installed at both sides on top of the mobile radio van / 1.5 m high antennas
- Data recording
  - Input signals from the antennas → field strength meters

    → recorded parallel and continuously, by a 4-pen recorder

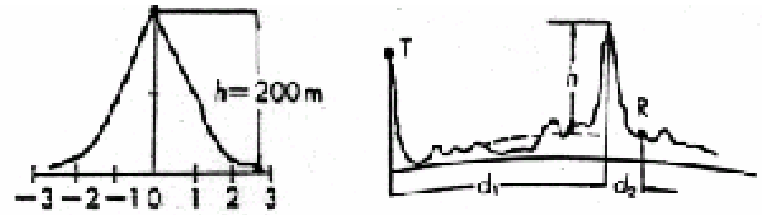
    & magnetic tape recorder
  - Minimum input level recordable : -125 dBm (-12 dBμ)
  - Recorder scope : almost linearly 50 dB
- Obtaining Data
  - Excluded regions – the corrected ratio of ant. directional characteristics became indistinct
  - Within 10 km – horizontal omni-directional Tx antenna were used for transmission as occasion demanded.

Classification and Definition of Terrain Features

- Quasi-smooth terrain ; terrain undulation height < 20 m
- Average Ground level ; 3 ~ 15 km
- Terrain Undulation Height
  - ☞ The distance between 10 % ~ 90 % within a distance of 10 km from the Rx point to the Tx point



- Single mountain
  - ☞ nothing else to interfere with the received signal except the obstacles

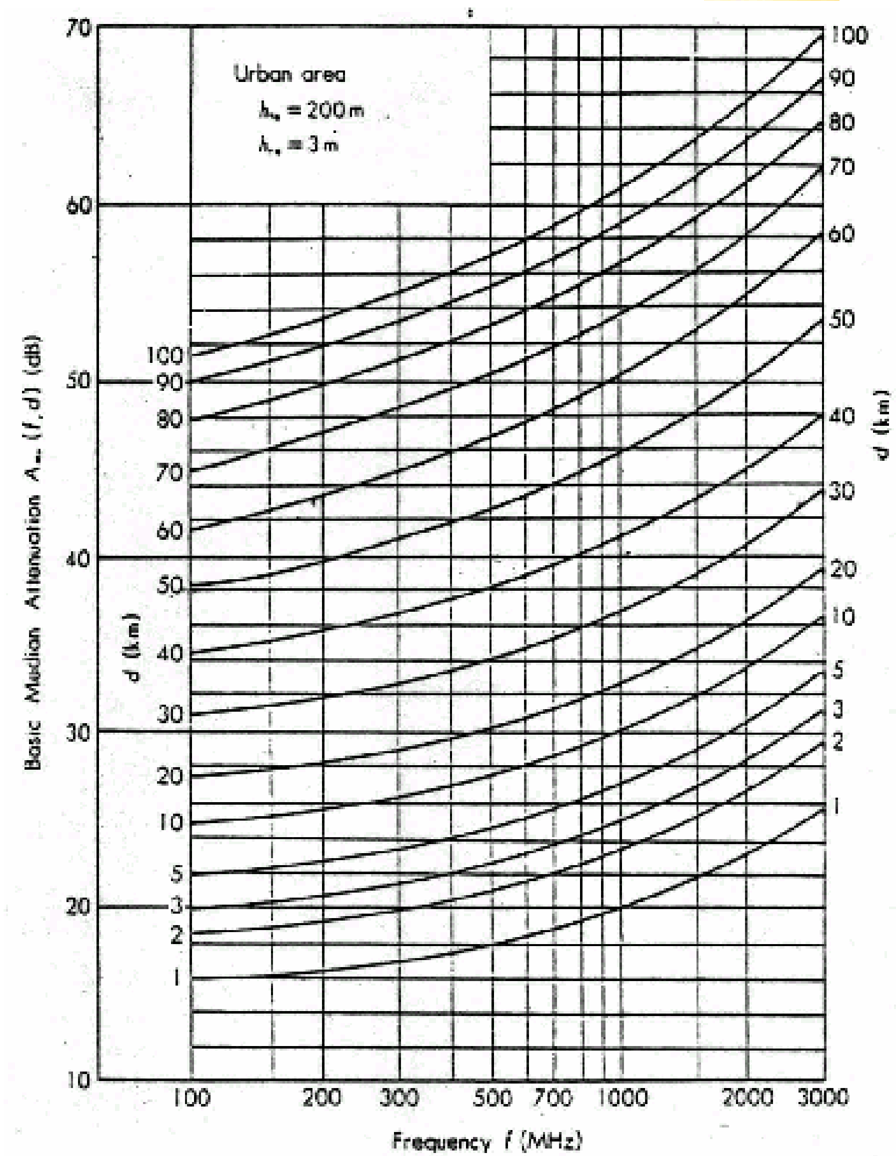


- General slope – slope over a distance of at least 5 ~ 10 km
- Distance Parameter for Mixed Land-Sea Path

Treatment of Data ; Method of Expression

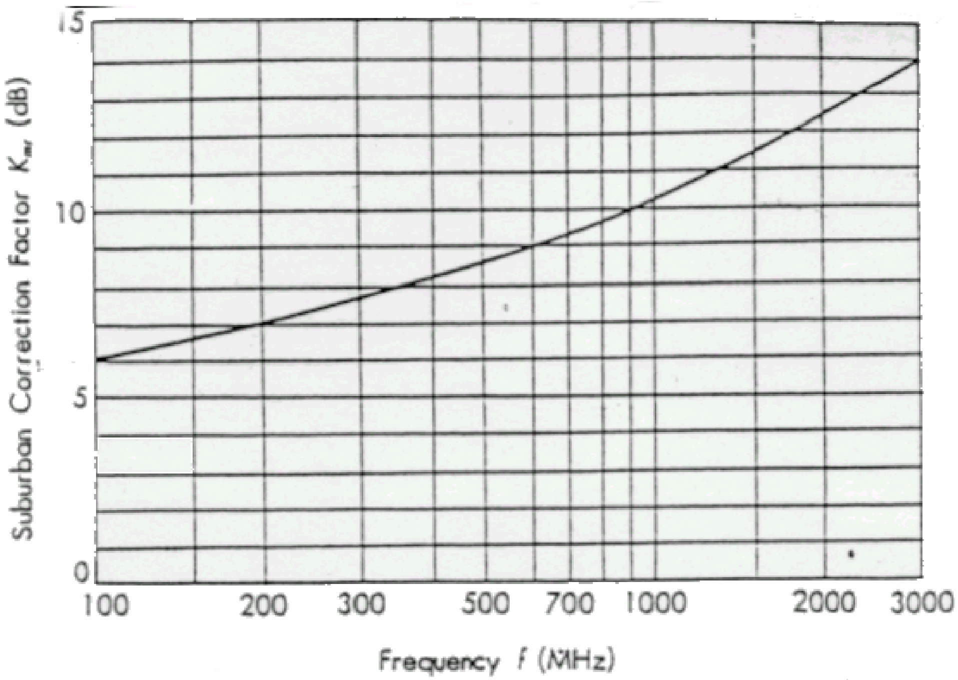
- Field strength data
  - treated statistically
- Entire distance
  - divided into "sampling interval" 1 ~ 1.5 km
- Readings
  - taken "small-sector medians" at intervals of about 20 m
- Att. due to terrain irregularities & environment clutters
  - Median value of the distribution curve
- Location variability
  - Variation range of the distribution
- Correction factor

Freq/Distance Dependence of Median Field Strength

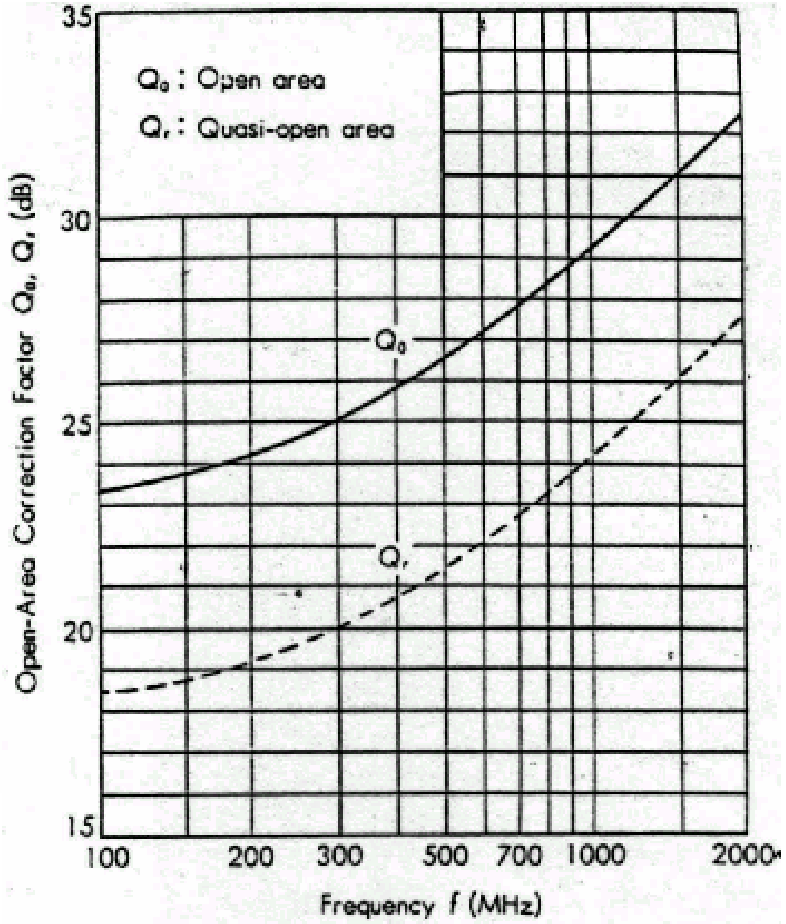


- The prediction curves for basic median attenuation relative to free space in urban area over quasi-smooth terrain, referred to h_{te} = 200 m, h_{re} = 3 m

Attenuation in Suburban Area and Open Area

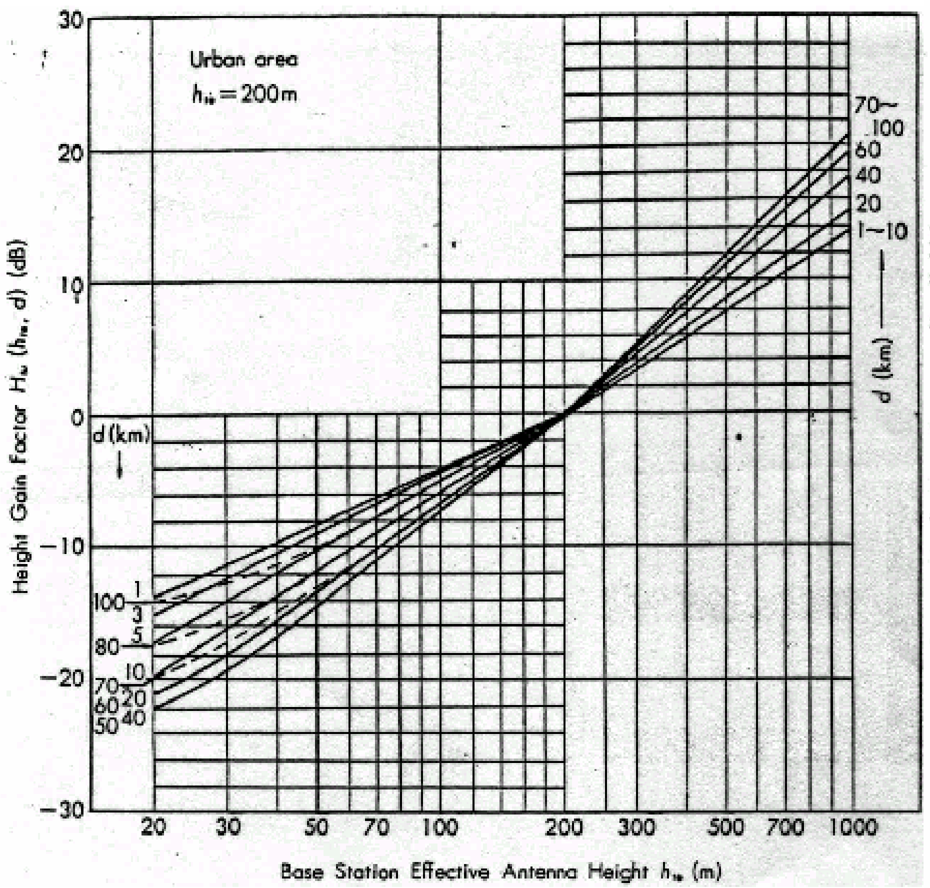


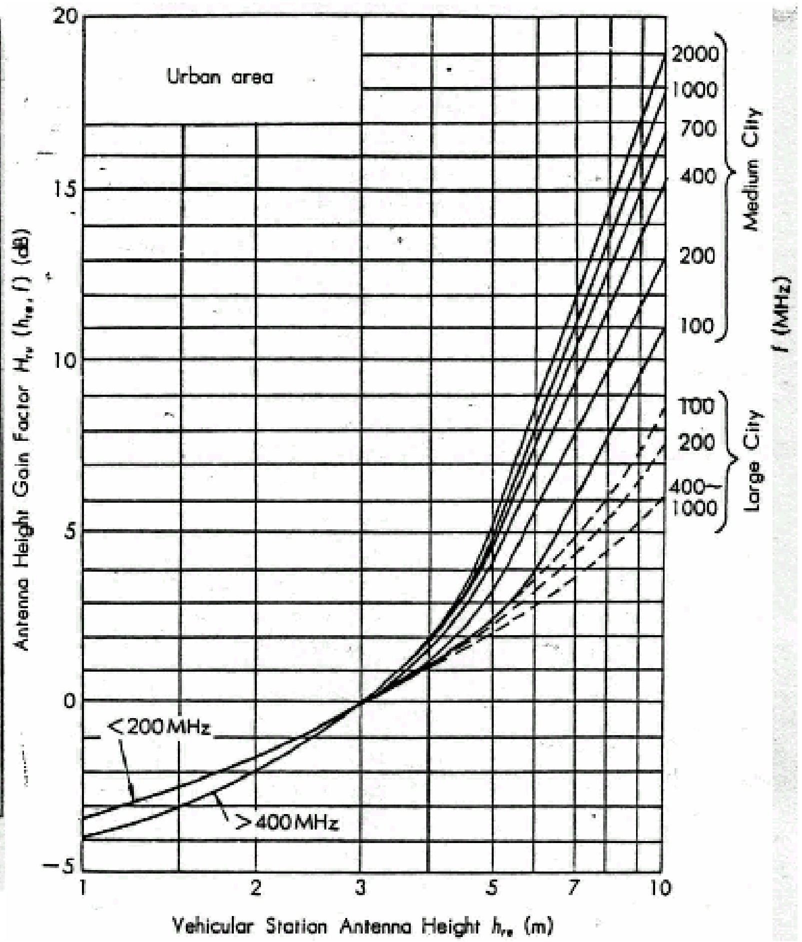
➢ Prediction curves for 'suburban correction factor' as a function of the frequency



➢ Prediction curves for 'Open-Area Correction Factor'

Antenna Height Gain Factor





- The prediction curves for base station ant. height gain factor referred to h_{te} = 200 m
- The prediction curves for vehicular station ant. height gain factor

Sampling Interval Correction Median on Rolling Hilly Terrain

- Deciding Terrain Parameters
  - To obtain the terrain undulation height Δh
  - To apply this Δh to undulations of more than a few in number
    - ✓ Average angle of general slope θ_m
  - To resort to a measure of fine correction
    - ✓ The correction for the rolling hilly terrain

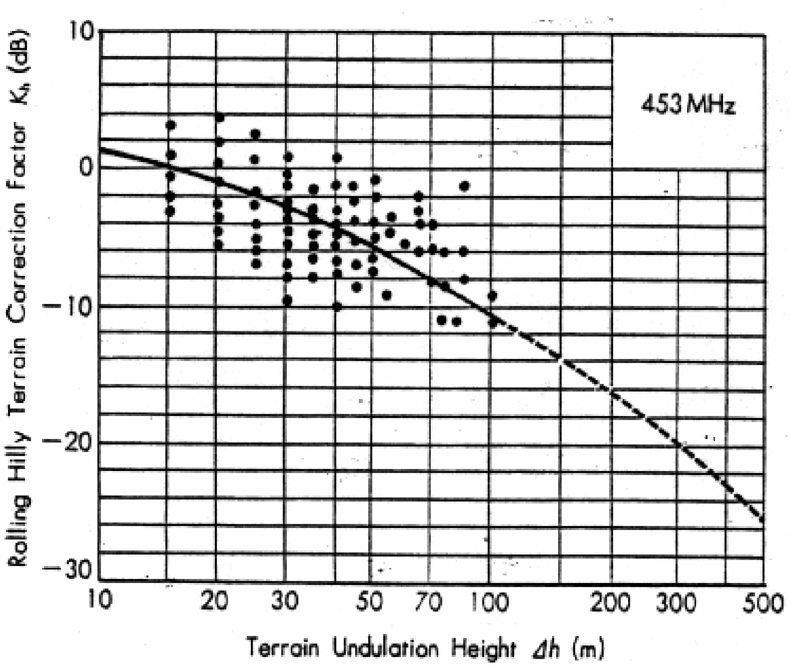


Fig. 28(a) 453 MHz

- The correction factor relative to Δh
  - Fluctuating for all frequency and becoming larger as Δh increases

Sampling Interval Correction Median on Rolling Hilly Terrain (Graphs)

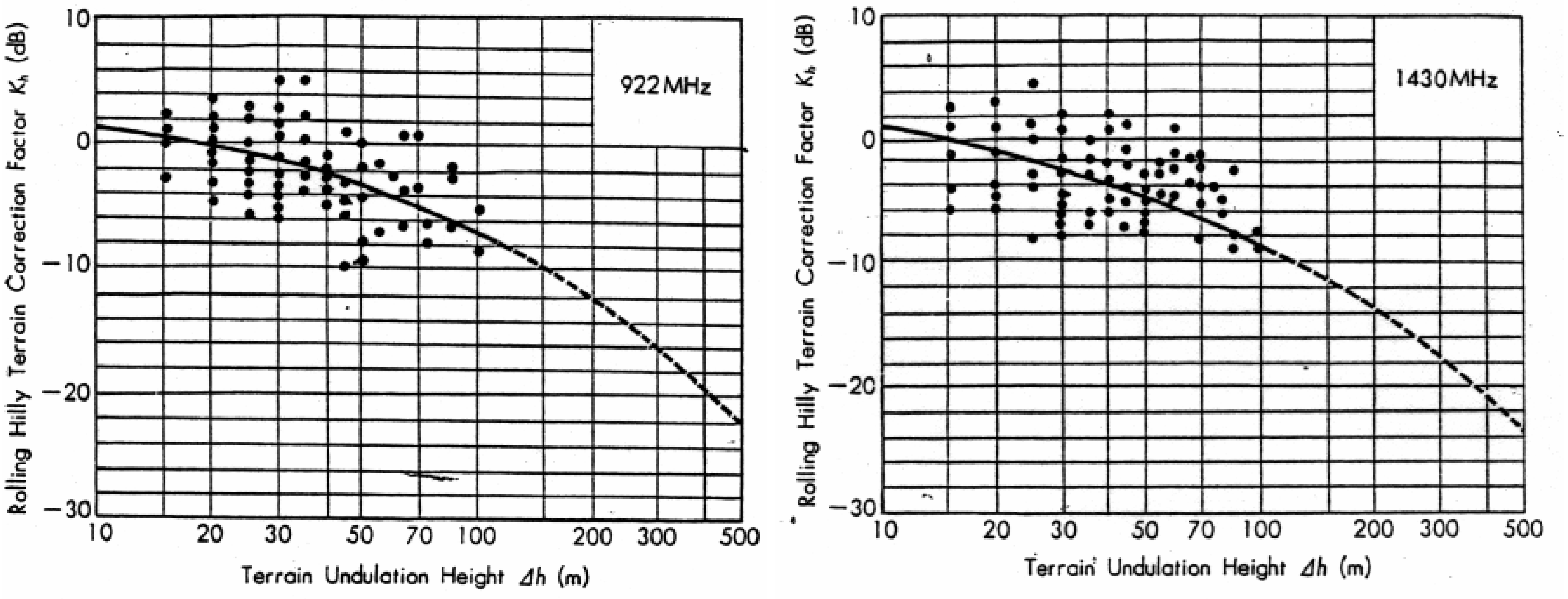


Fig. 28(b) 922 MHz

(c) 1430 MHz

- Measured values and prediction curve for "rolling hilly terrain correction factor."

Fine Correction Factor on Rolling Hilly Terrain

- Near an undulation
  - The attenuation rises far above the correction factor
- Close to the top of the undulation
  - The field strength ascending in the meantime
- The fine correction factor
  - The mobile van is traveling on a road lying at bottom or on top of an undulation
- In the position at the bottom
  - Correction factor : $-K_{hf} - K_h$
- On the top of the undulation
  - Correction factor : $K_{hf} - K_h$

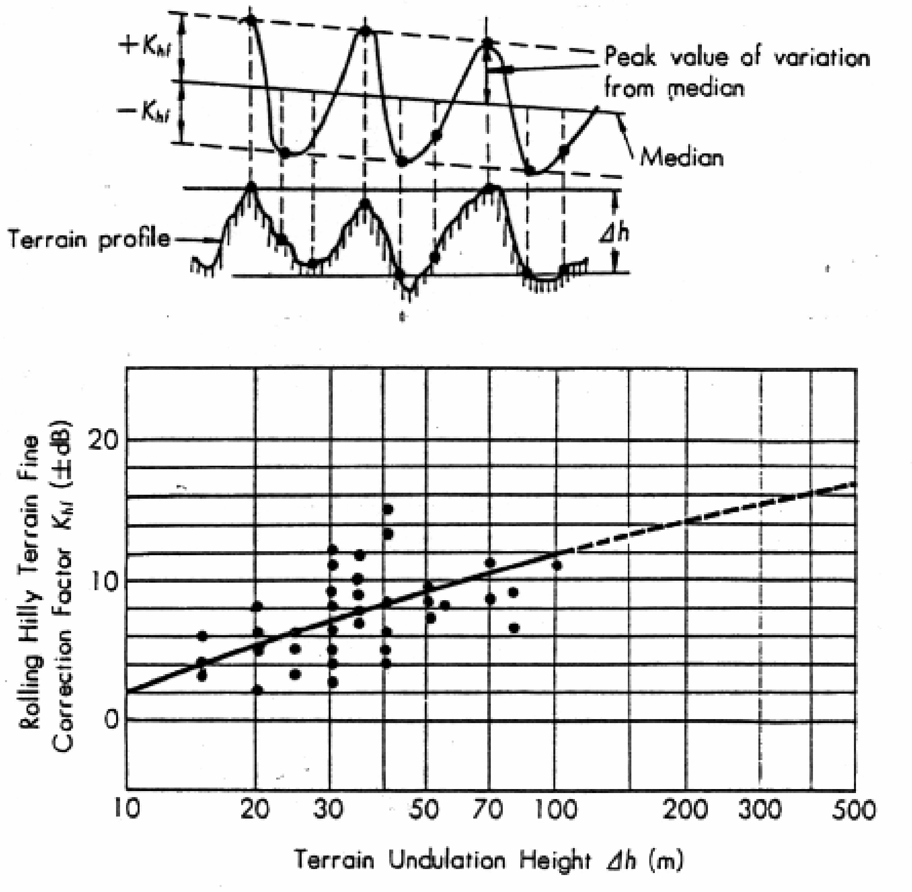


Fig. 29—Measured values and prediction curve for "rolling hilly terrain fine correction factor."

Vehicular Station Antenna Height Gain Factor on Rolling Hilly Terrain

- The differences of the medians in one and the same sampling interval measured, with the antenna height 3m and 1.5m
- There seems to be no distinct variation with respect to the distance
- The gain factor
  - 2.8 dB at 453 MHz
  - 3.3 dB at 922 MHz
  - 3.3 dB at 1430 MHz
- The estimation of antenna height gain factor for heights below 3m on a rolling hilly terrain 3 dB/oct

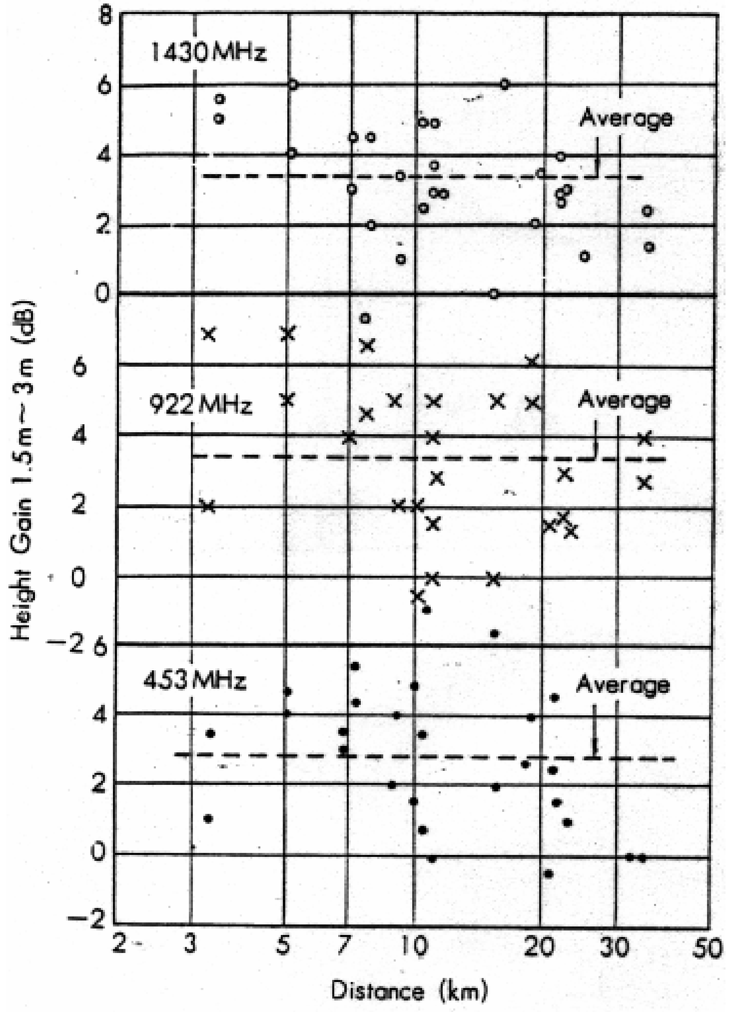
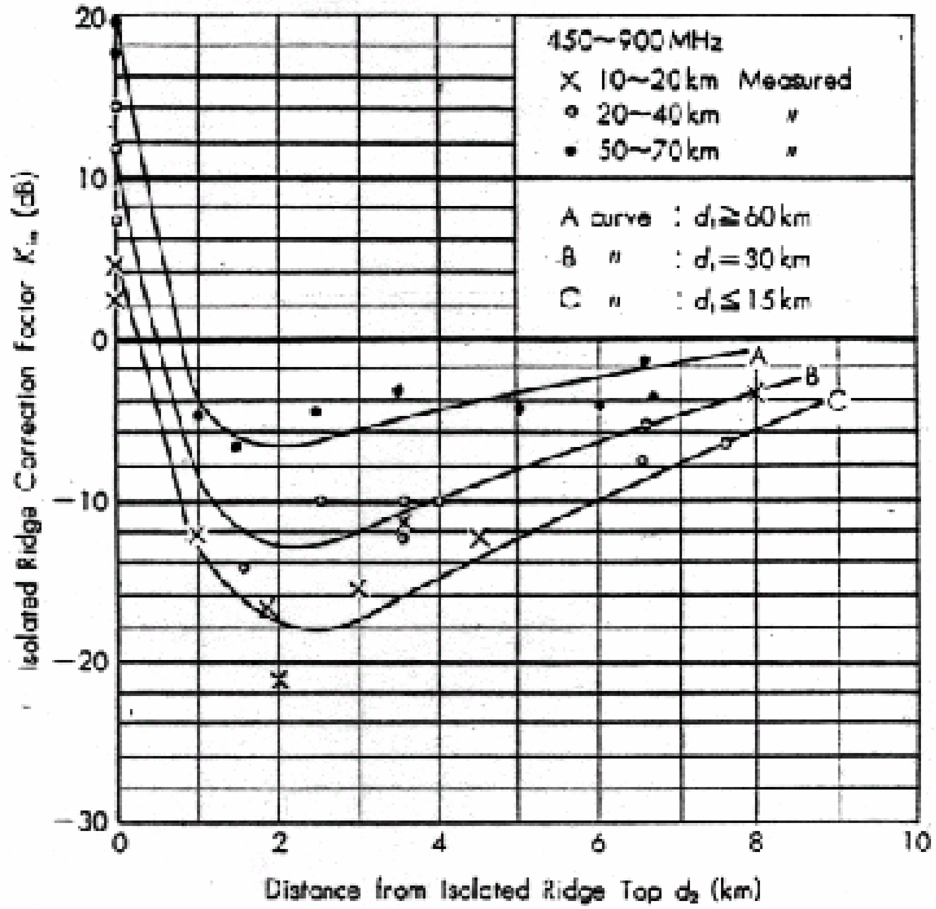
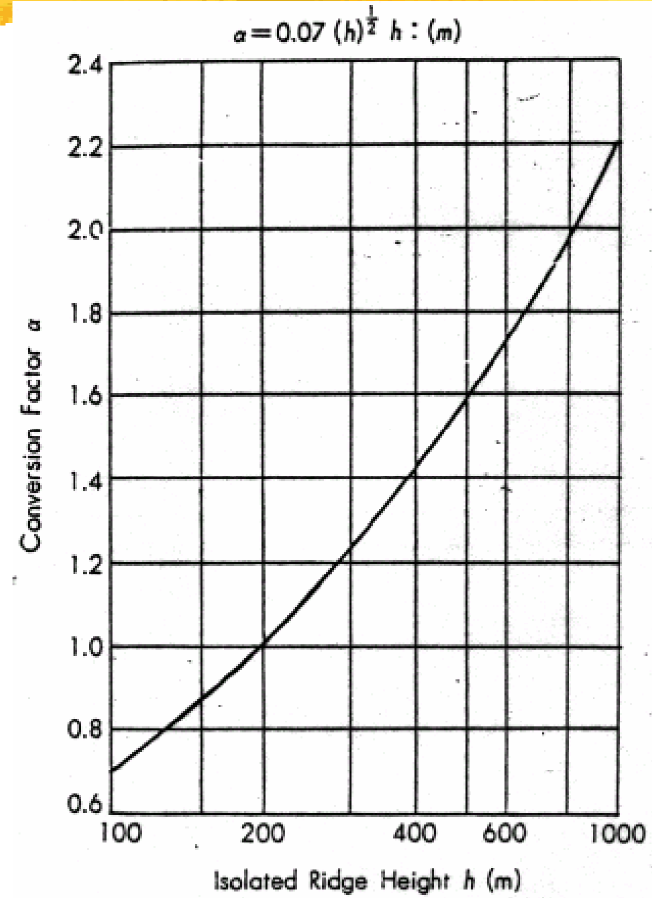


Fig. 30—Measuured values of 1.5 m to 3 m height-gain of vehicular station in rolling hilly terrain.

Correction Factor for Isolated Mountain

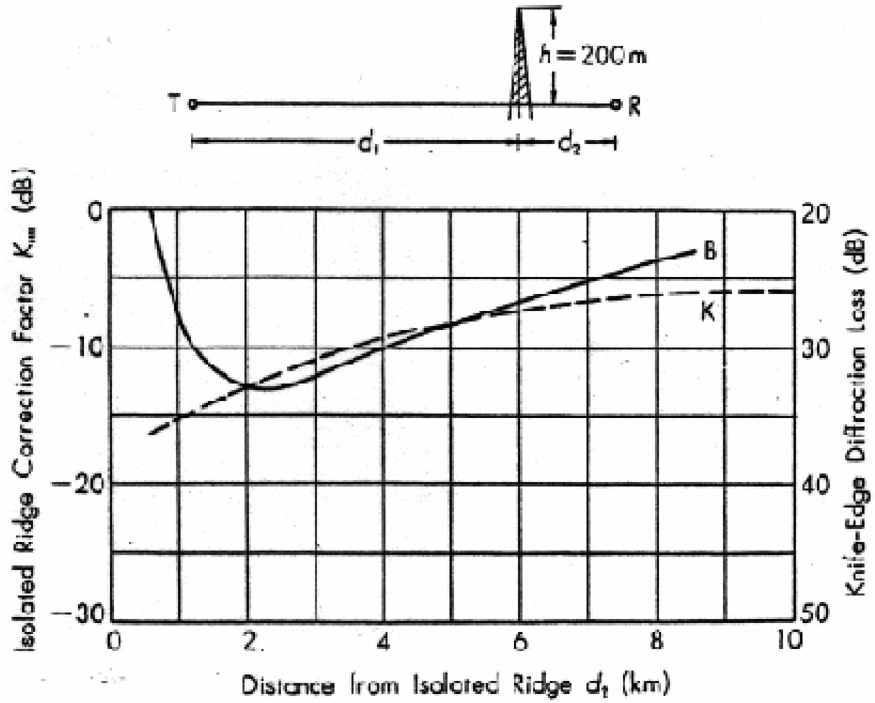




- There is an isolated mountain ridge like a knife edge
- Ridge height correction factor normalized at h = 200m
- Conversion factor to be multiplied to the value of ridge height correction factor when ridge height h ≠ 200 m

Correction Factor for Isolated Mountain (Cont’d)

- Curve B
  - Measured correction factor at $d_1 = 30$ km
- Curve K
  - Calculated value of knife-edge diffraction loss for d_2
- The loss on Curve K in increases if $d_2 < 2$ km
  - The isolated ridge model has a thickness while the knife-edge model has none
- The relation between the two curves in their absolute value
  - differs according to the terrain factors relative to distances



- Relation between the curves of ridge height correction factor and of knife-edge diffraction loss (450 MHz)

Correction Factor for General Slope of Terrain

- The relation of the average angle θ_m of general slope on terrain to the correction factors
- The correction factor varies with the distance
- For the sloped rolling hilly terrain
  - The correction factor
    ; rolling hilly correction factor
    + general slope correction
    factor

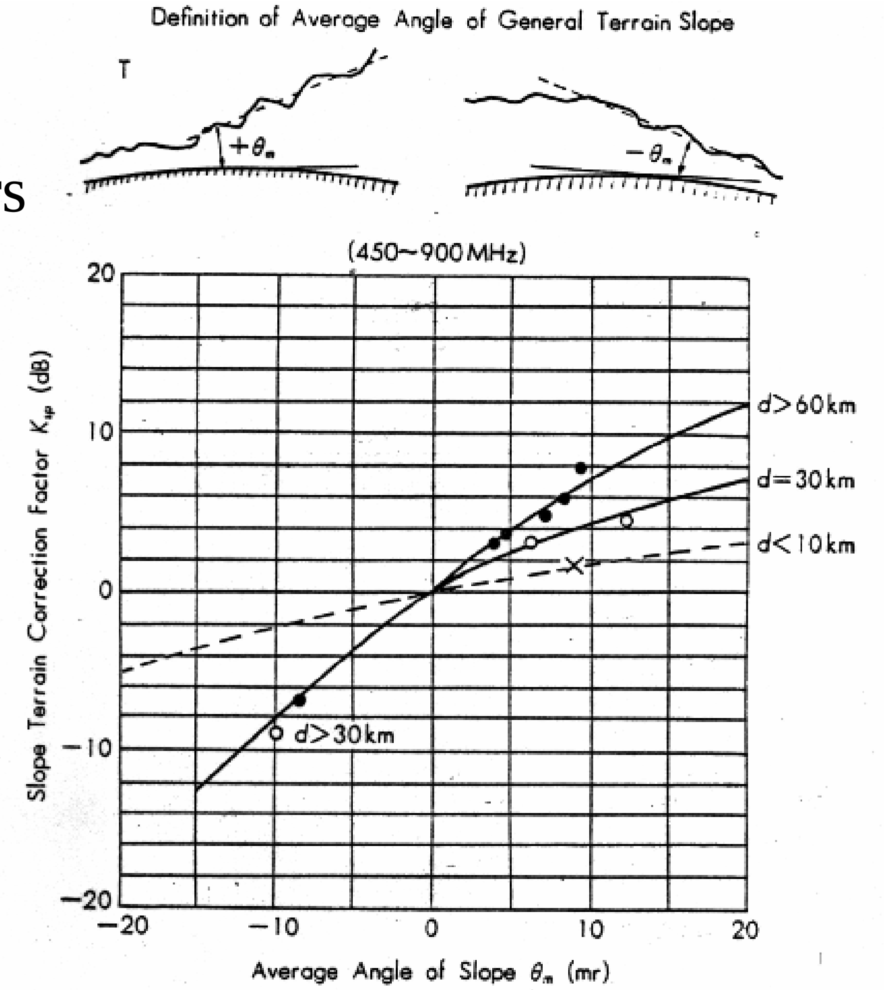


Fig. 34—Measured value and prediction curves for "slope terrain correction factor."

Correction Factor for Mixed Land-Sea Path

- Where there is an expanse of sea or lake in the propagation path, the field strength is generally higher than on land only
- Correction factor for mixed land-sea path
- The degree of field strength rise is larger if the water adjoins the vehicular station than if it adjoins the base station
- If the water is in the middle of the path, the intermediate values are chosen

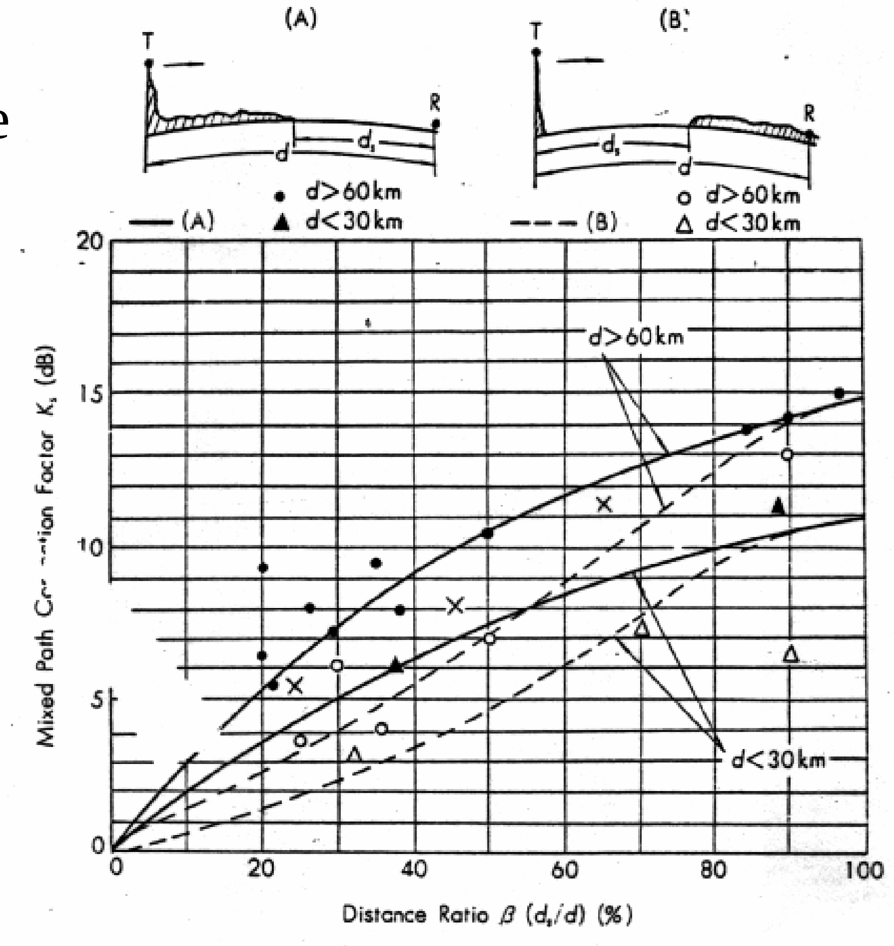


Fig. 35—Measured values and prediction curves for "mixed path correction factor."

Prediction of Basic Median Field Strength

- The basic field strength median
  - the standard of prediction procedures

$$E_{mu} = E_{fs} - A_{mu}(f,d) + H_{tu}(h_{te},d) + H_{ru}(h_{re},d)$$

E_{mu} : The median field strength (dB rel. 1μV/m) for a quasi-smooth terrain urban area under a given condition of transmission

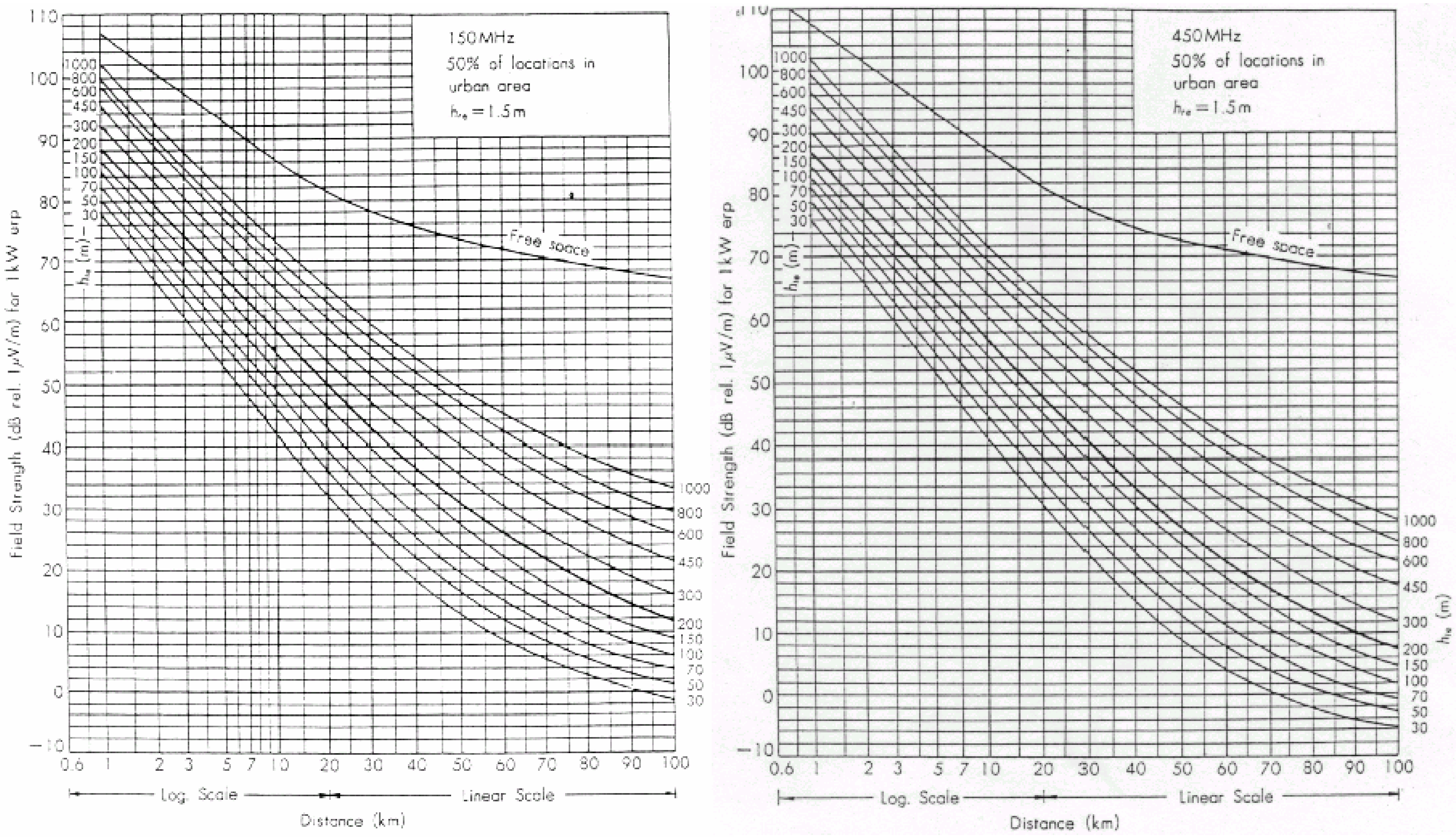
E_{fs} : The free-space field strength (dB rel. 1μV/m) for a given condition of transmission

A_{mu}(f,d) : The median attenuation relative to free space in an urban area, where h_{te} = 200m, h_{re} = 3m

H_{tu} (h_{te},d) : The base station antenna height gain factor (dB) relating to h_{te} = 200m

H_{ru} (h_{re},d) : The vehicular station antenna height gain factor (dB) relating to h_{re} = 3m

Prediction Curves of "basic median field strength" $P_{erp} = 1kW, h_{re} = 1.5m$



Prediction Curves of “basic median field strength” $P_{erp} = 1kW, h_{re} = 1.5m$