Spectrum Management System for Developing Countries (SMS4DC)

Training on SMS4DC
24-26 July, 2023
Livingstone, ZAMBIA

Ahmed BORAUD
ahmed.boraud@gmail.com

RADIO PROPAGATION

FUNDAMENTALS

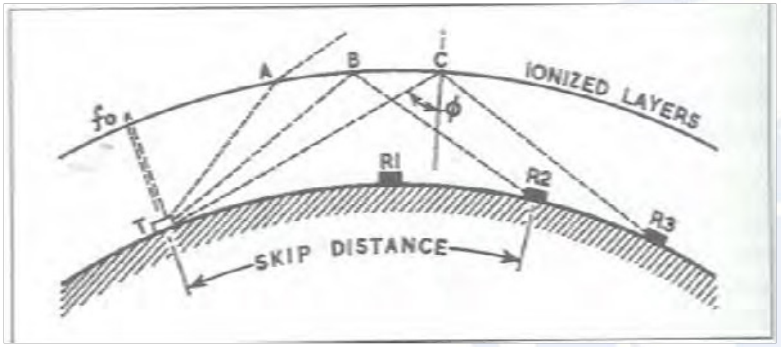
PROPAGATION IS A TERM USED TO EXPLAIN HOW RADIO WAVES BEHAVE WHEN THEY ARE TRANSMITTED, OR ARE PROPAGATED FROM ONE POINT ON THE EARTH TO ANOTHER.

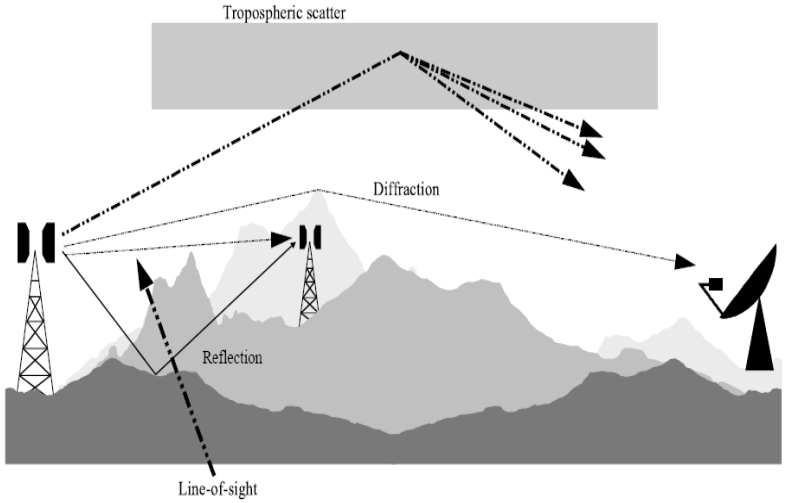
- IN FREE SPACE, ALL ELECTROMAGNETIC WAVES (RADIO, LIGHT, X-Rays, ETC.) OBEY THE INVERSE- SQUARE LAW WHICH STATES THAT THE POWER DENSITY OF AN ELECTROMAGNETIC WAVE IS PROPORTIONAL TO THE INVERSE OF THE SQUARE OF THE DISTANCE FROM A POINT SOURCE

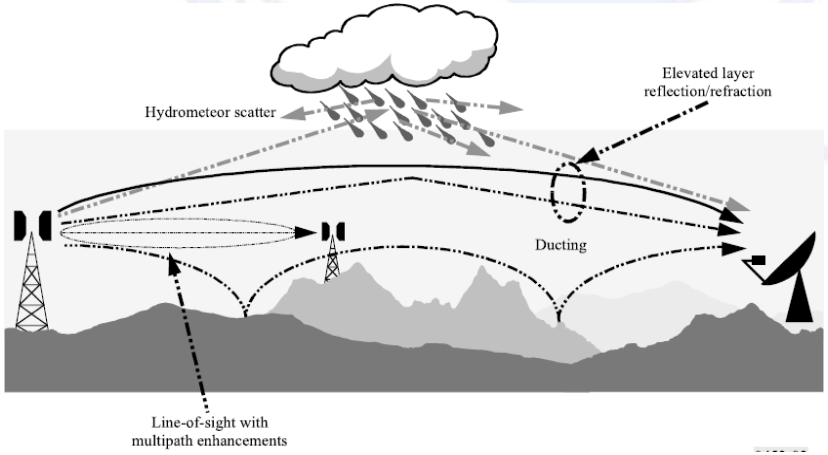
$$\rho_P \propto \frac{1}{r^2}.$$

DOUBLING THE DISTANCE FROM A TRANSMITTER MEANS THAT THE POWER DENSITY OF THE RADIATED WAVE AT THAT NEW LOCATION IS REDUCED TO ONE-QUARTER OF ITS PREVIOUS VALUE.

SIMPLIFIED DESCRIPTION OF PROPAGATION MODES





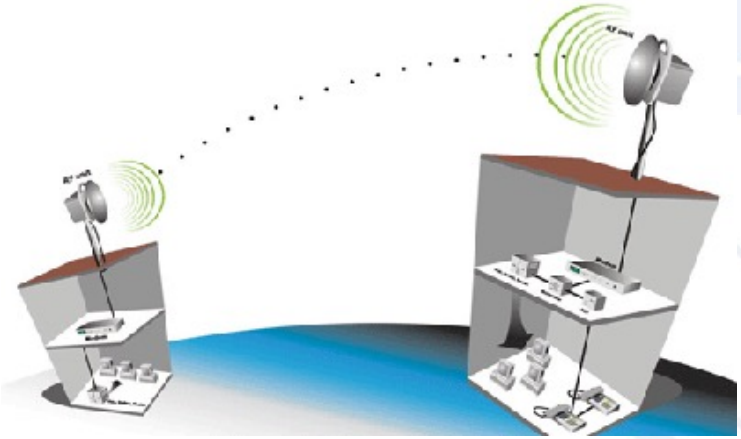


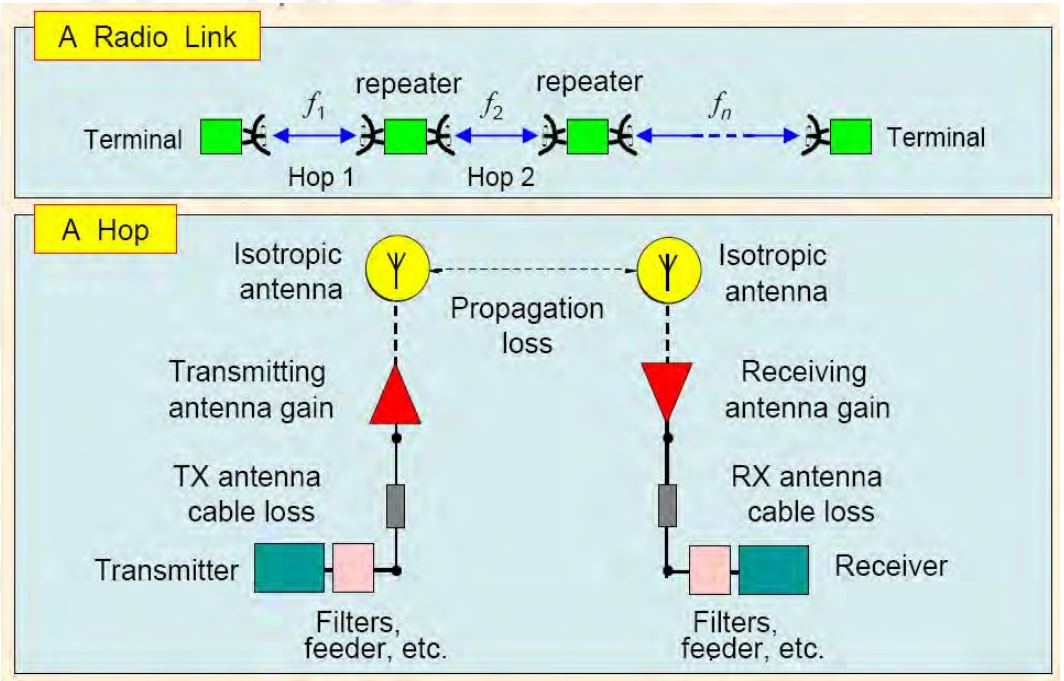
Radio frequencies and their primary mode of propagation

Band		Frequency	Wavelength	Propagation via
VLF	Very Low Frequency	3–30 kHz	100–10 km	Guided between the earth and the ionosphere.
LF	Low Frequency	30–300 kHz	10–1 km	Guided between the earth and the D layer of the ionosphere. Surface waves.
MF	Medium Frequency	300–3000 kHz	1000–100 m	Surface waves. E, F layer ionospheric refraction at night, when D layer absorption weakens.
HF	High Frequency (Short Wave)	3–30 MHz	100–10 m	E layer ionospheric refraction. F1, F2 layer ionospheric refraction.
VHF	Very High Frequency	30–300 MHz	10–1 m	Infrequent E ionospheric refraction. Extremely rare F1, F2 layer ionospheric refraction during high sunspot activity up to 30 MHz. Generally direct wave. Sometimes tropospheric ducting.
UHF	Ultra High Frequency	300–3000 MHz	100–10 cm	Direct wave. Sometimes tropospheric ducting.
SHF	Super High Frequency	3–30 GHz	10–1 cm	Direct wave.
EHF	Extremely High Frequency	30–300 GHz	10–1 mm	Direct wave limited by absorption.

TYPES OF COMMUNICATIONS

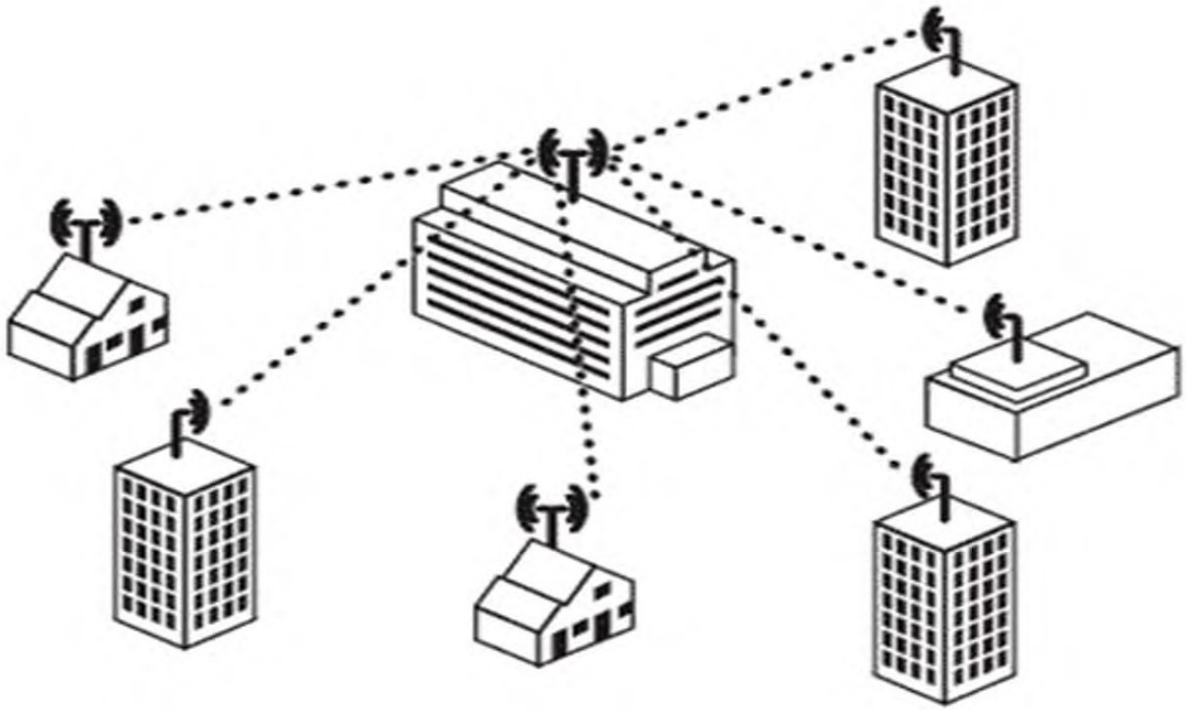
POINT TO POINT COMMUNICATION: COMMUNICATION PROVIDED BY A LINK, FOR EXAMPLE, RADIO-RELAY LINK BETWEEN TWO STATIONS LOCATED AT SPECIFIED FIXED POINTS





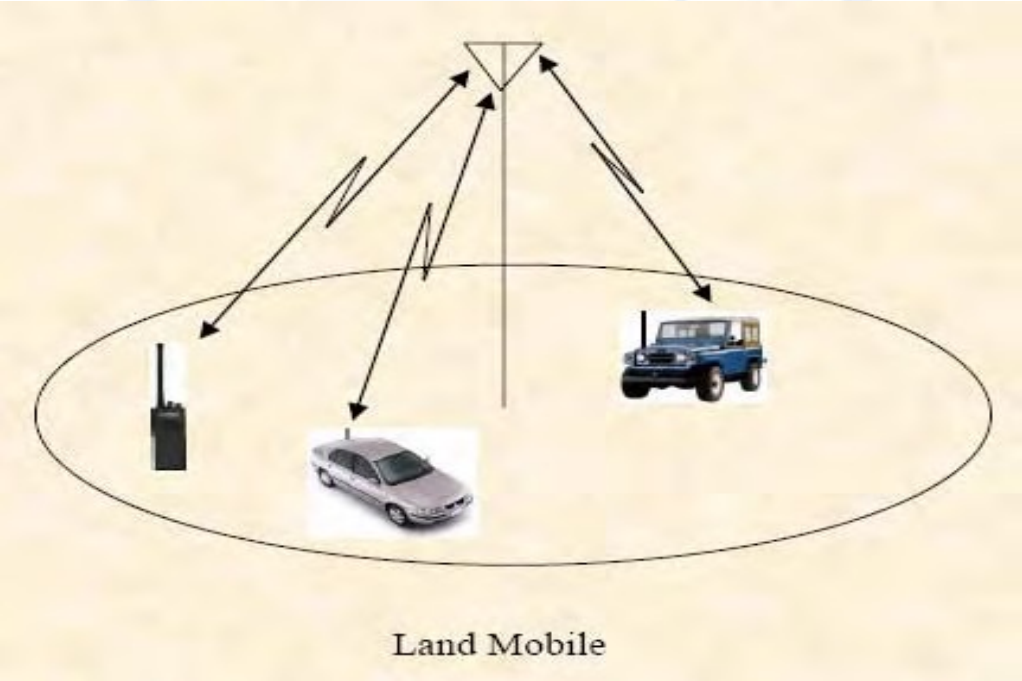
POINT TO MULTIPOINT COMMUNICATION

COMMUNICATION PROVIDED BY LINKS, FOR EXAMPLE, RADIO- RELAY LINKS **BETWEEN SINGLE STATION LOCATED** AT SPECIFIED FIXED POINT **AND A NUMBER OF STATIONS LOCATED AT SPECIFIED FIXED POINTS**



POINT TO AREA COMMUNICATION

COMMUNICATION PROVIDED BY LINKS **BETWEEN** A **STATION** LOCATED AT A SPECIFIED FIXED POINT AND **ANY NUMBER OF STATIONS LOCATED AT NON-SPECIFIED POINTS** IN A GIVEN AREA WHICH IS THE COVERAGE AREA OF THE STATION LOCATED AT THE FIXED POINT.



PROPAGATION MODELS IN SMS4DC

P.370	VHF and UHF propagation curves for the frequency range 30 - 1000 MHz
P.452	Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz
P.525	Calculation of free space attenuation
P.526	Propagation by diffraction
P.529	Prediction methods for the terrestrial land mobile service in the VHF and UHF bands
P.530	Propagation data and prediction methods required for the design of terrestrial line-of-sight systems
P.618	Propagation data and prediction methods required for the design of Earth-space telecommunication systems
P.1546	Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz

AVAILABLE SUB-ITEMS OF PROPAGATION MODELS IN THE MENU

Propagation Models \ Sub-items	Line	Polyline	Area	Link	Contour	Network processor		Earth-space
						Max. Field Strength	Best Server	
Free Space	Y	Y	Y	N	N	Y	Y	N
Line of Sight	Y	Y	Y	N	N	N	N	N
ITU-R P.370	Y	Y	Y	Y	Y	Y	Y	N
ITU-R P.1546	Y	Y	Y	Y	Y	Y	Y	N
Okumura-Hata	N	N	Y	N	N	Y	Y	N
ITU-R P.526 (by diffraction)	N	N	N	Y	N	N	N	N
ITU-R P.526 (Smooth Earth)	N	N	N	Y	N	N	N	N
ITU-R P.452	N	N	N	Y	N	N	N	N
ITU-R P.530	N	N	N	Y	N	N	N	N
ITU-R P.618	N	N	N	N	N	N	N	Y

'Y' and 'N' stand for "Yes" and "No" respectively.

RADIOWAVE PROPAGATION MODES

Free-space waves	Unaffected by any consideration other than distance
Ionospheric waves	Influenced by the action of free electrons in the upper levels of the Earths atmosphere.
Tropospheric waves	Subject to deflection in the lower levels by variations in the refractive index structure of the air through which they pass.
Ground waves	Modified by the nature of the terrain over which they travel.

PROPAGATION TERMS USED IN SMS4DC

Free-space propagation	Propagation of an electromagnetic wave in a homogeneous ideal dielectric medium which may be considered of infinite extent in all directions.
Line of sight propagation	Propagation between two points for which the direct ray is sufficiently clear of obstacles for diffraction to be of negligible effect.
Radio horizon	The locus of points at which direct rays from a point source of radio waves are tangential to the surface of the Earth.
Troposphere	The lower part of the Earth's atmosphere extending upwards from the Earth's surface, in which temperature decreases with height except in local layers of temperature inversion. This part of the atmosphere extends to an altitude of about 9 km at the Earth's poles and 17 km at the equator.

PROPAGATION TERMS USED IN SMS4DC(1)

Effective Earth-radius factor, k	Ratio of the effective radius of the Earth to the actual Earth radius. For the standard atmosphere, the effective Earth radius is 4/3 that of the actual Earth radius.
Effective antenna height	The effective height of the transmitting antenna is defined as its height over the average level of the ground between distances of 3 and 15 km from the transmitter in the direction of the receiver.
% Time	The applicable time percentage values or range of values of the ITU Recommendation; %time is the percentage of time that the predicted signal is exceeded during an average year.
% Location	The applicable percent location range of the ITU Recommendation; % location is the percentage of locations within, say, a square with 100 to 200 m sides that the predicted signal is exceeded.
Delta h	defines the degree of terrain irregularity
Terrain clearance angle	See diagram in next slides

THE PARAMETER DELTA H (Δh)

P.370 (Cont.)

Δh : the parameter Δh is used to define the degree of terrain irregularity; for broadcasting services it is applied in the range 10 km to 50 km from the transmitter.

FIGURE 6

Application of the parameter Δh for broadcasting services

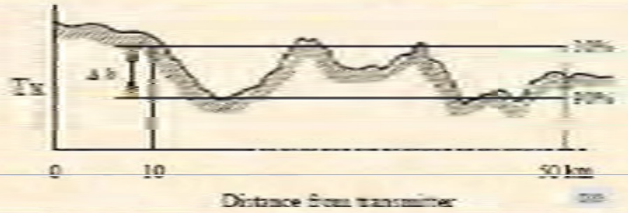


FIGURE 1

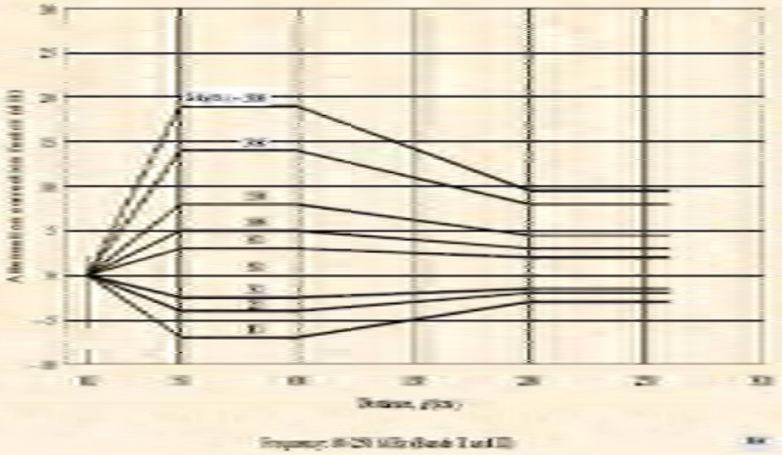
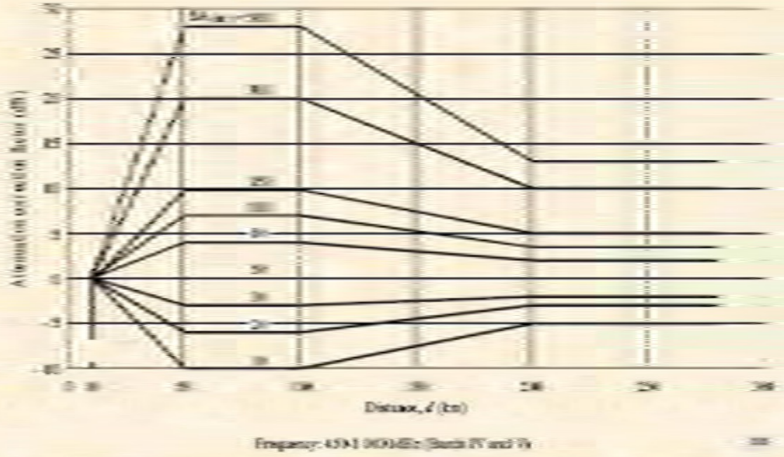


FIGURE 1



TERRAIN CLEARANCE ANGLE

P.1546 (Cont.)

FIGURE 26a

Terrain clearance angle: the general case

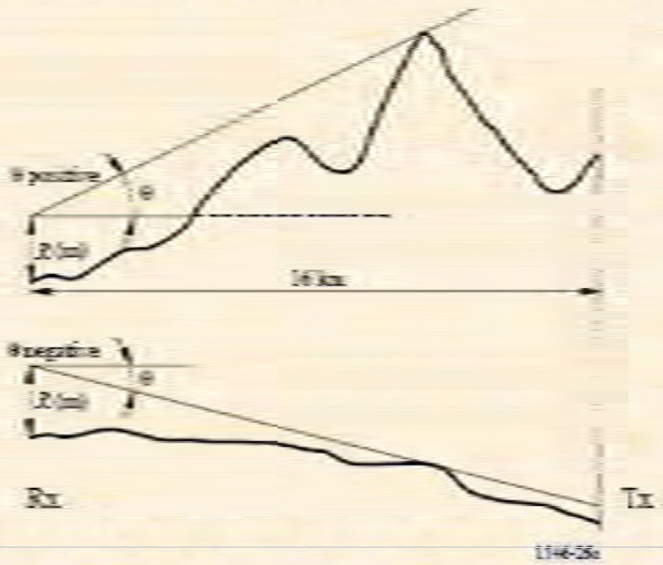
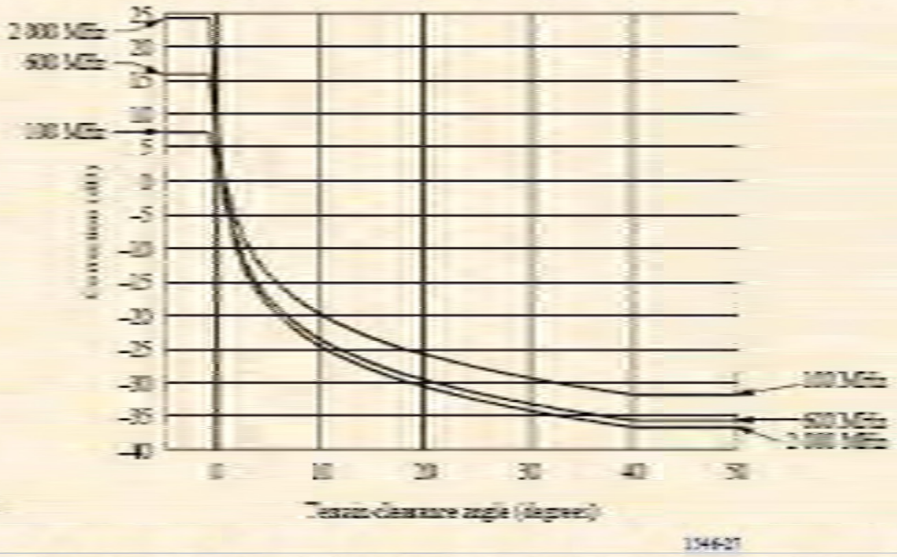


FIGURE 27

Terrain clearance angle correction



This angle, **θ**, is measured relative to the line from the receiving/mobile antenna which just clears all terrain obstructions in the direction of the transmitter/base antenna over a distance of up to 16 km but not going beyond the transmitting/base antenna.

SOME USEFUL CONCEPTS FOR PROPAGATION MODELS

- **FADING** :FLUCTUATION OF SIGNAL LEVEL WITH RESPECT TO STABLE CONDITION FOR NUMBER OFREASONS.
- **PATH PROFILE**: A VERTICAL CUT OF TERRAIN ALONG PROPAGATION PATH BETWEEN TRANSMITTER AND RECEIVER
- **NFD**: NET FILTER DISCRIMINATION (NFD) EXPRESSES THE REDUCTION (IN DB) OF THE INTERFERENCE POWER IF THE TRANSMITTER AND RECEIVER FREQUENCIES ARE DIFFERENT
- **POLARIZATION:** THE LOCUS OF ELECTRIC FIELD VECTOR FLUCTUATION

PROPAGATION EFFECTS

- **DIFFRACTION** FADING DUE TO OBSTRUCTION OF THE PATH;
- **ATTENUATION** DUE TO ATMOSPHERIC GASES;
- **FADING** DUE TO ATMOSPHERIC MULTIPATH OR BEAM SPREADING (COMMONLY REFERRED TO AS DEFOCUSING) ASSOCIATED WITH ABNORMAL REFRACTIVE LAYERS;
- **FADING** DUE TO MULTIPATH ARISING FROM SURFACE REFLECTION;
- **ATTENUATION** DUE TO PRECIPITATION OR SOLID PARTICLES IN THE ATMOSPHERE;
- **VARIATION OF THE ANGLE-OF-ARRIVAL** AT THE RECEIVER TERMINAL AND ANGLE- OF-LAUNCH AT THE TRANSMITTER TERMINAL DUE TO REFRACTION;
- **REDUCTION IN CROSS-POLARIZATION DISCRIMINATION** (XPD) IN MULTIPATH OR PRECIPITATION CONDITIONS;
- **SIGNAL DISTORTION** DUE TO FREQUENCY SELECTIVE FADING AND DELAY DURING MULTIPATH PROPAGATION..
- **ATTENUATION** DUE TO SAND AND DUST STORMS
- **MULTIPATH FADING**
- **CROSS-POLARIZATION DISCRIMINATION**

ITU-R P.370

- Intended for prediction of field strength for the broadcasting service for the frequency range 30 to 1 000 MHz and for the distance range up to 1000 km Replaced by P.1546 but still used in some bilateral agreements

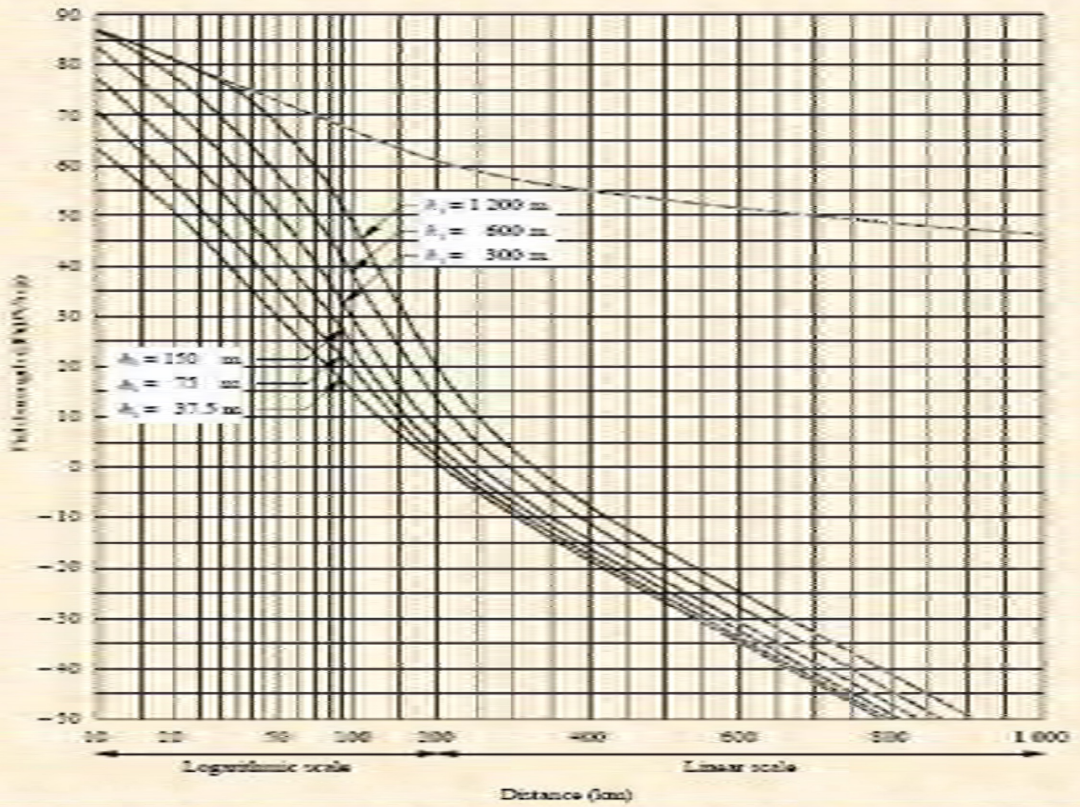
- Input parameters:
  - % Time (range 1 – 50 %): typical 1% for interference contour, 50 % for coverage contour
  - % Locations (range 1-99 %): typical coverage contour 99 %, interference contour 50 %
  - Δh defines the degree of terrain irregularity; for broadcasting services it is applied in the range 10 km to 50 km from the transmitter. Typical value = 50 m.
  - Contour value: appropriate to service type e.g. VHF land mobile fsmin =12dBμV/m
  - Land/Sea discrimination: if checked will apply correction for % sea/land path

ITU-R P.370

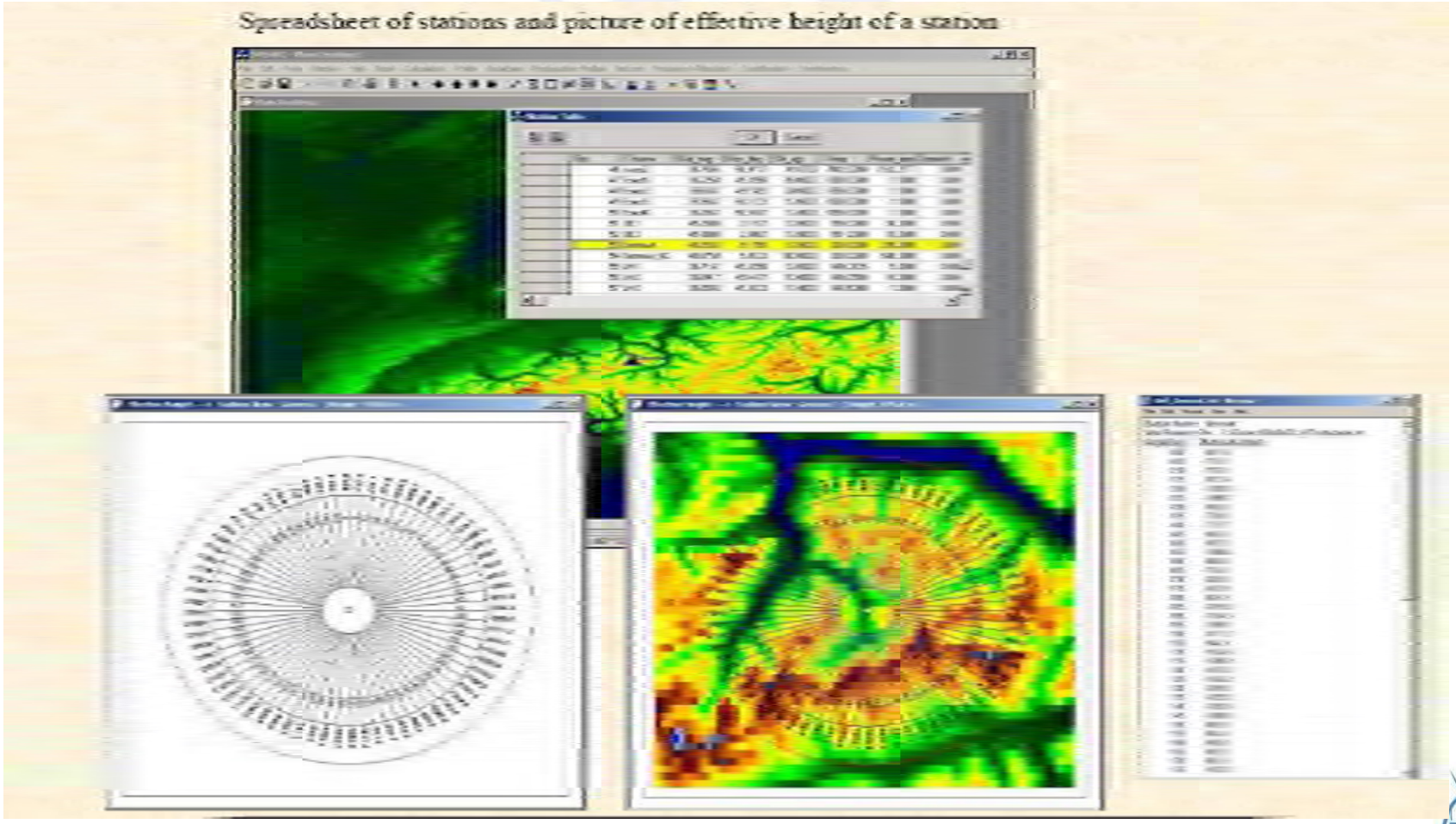
P.370

hl : the effective height of the transmitting antenna is defined as its height over the average level of the ground between distances of 3 and 15 km from the transmitter in the direction of the receiver

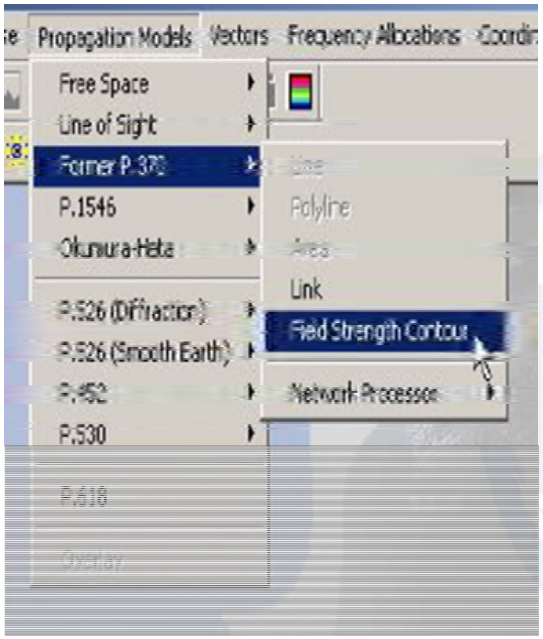
FIGURE 1a

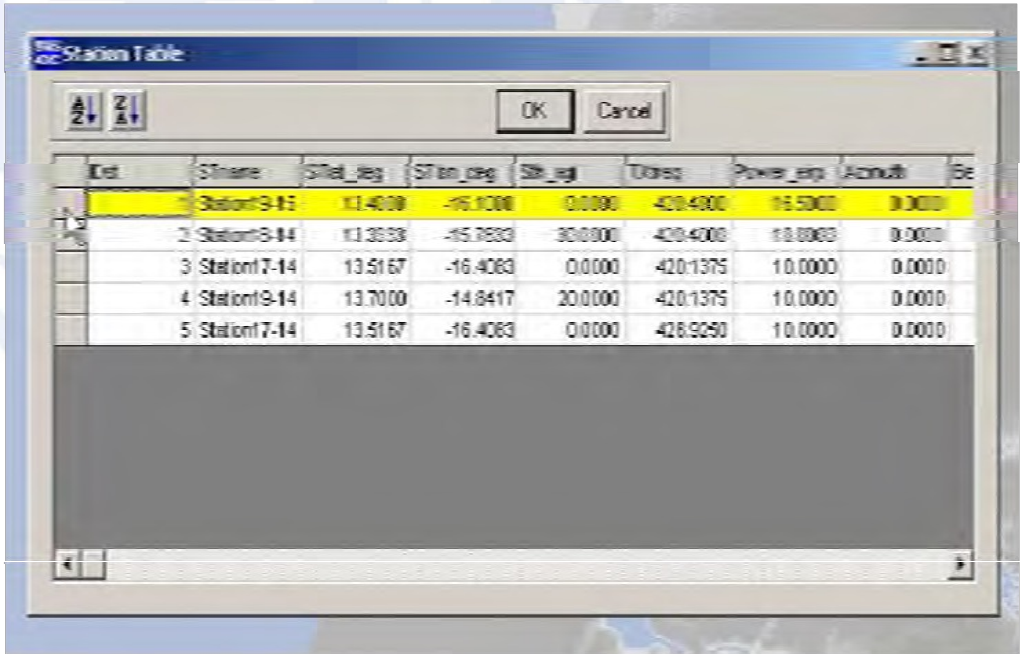


EFFECTIVE ANTENNA HEIGHT CALCULATION (SMS4DC TOOL)

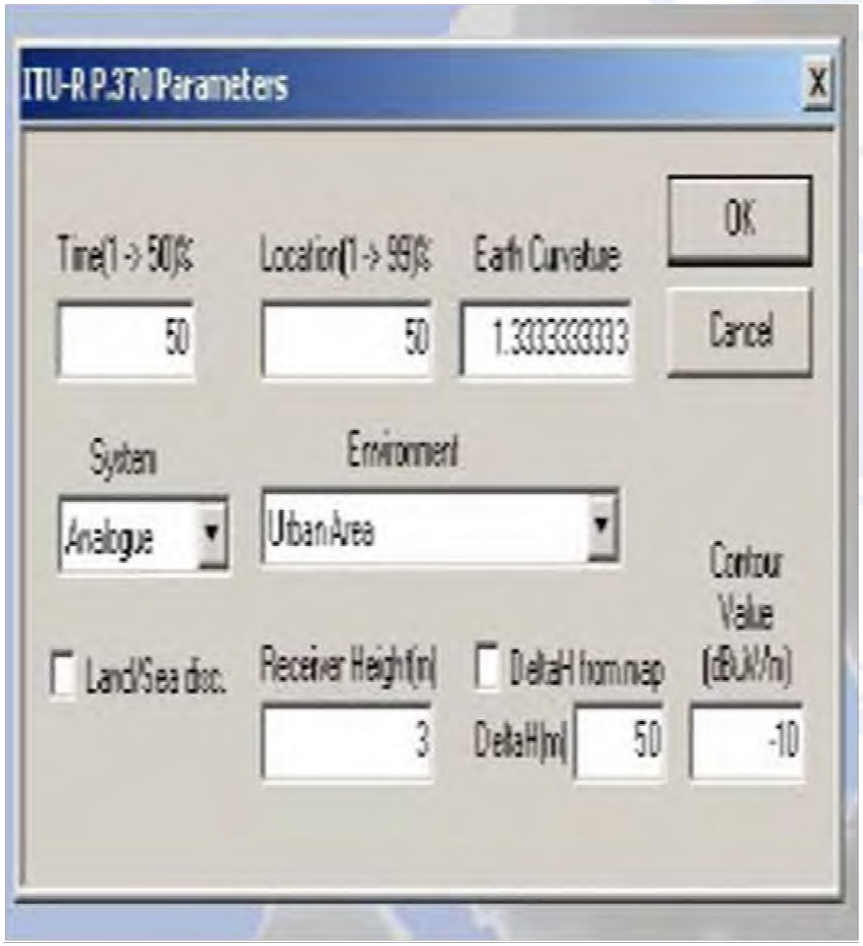


FIELD STRENGTH CONTOUR USING ITU-R P.370





ITU-R P.370 INPUT PARAMETERS



% Time: (1 – 50 %)
% Location: (1 – 99 %)
Effective radius of the Earth: (k=4/3)
System: Analogue/Digital
Environment: see inset

Land/Sea discrimination
Receiver height
Delta H Contour value

LIST OF FREQUENCY BANDS AND ADOPTED RECOMMENDATIONS

Section	Frequency Band	Frequency band	ITU-R Recommendation or Reports
5.1	800 MHz	790 – 862 MHz	ITU-R M.1036
5.2	2 GHz	2025-2110 MHz//2200-2290 MHz	ITU-R F.1098
5.3	2.6 GHz	2 500 – 2 690 MHz	ITU-R M.1036
5.4	3.5 GHz	3 400 – 3 600 MHz	ITU-R F.1488, Annex 2
5.5	4 GHz	3 600 – 4 200 MHz	ITU-R F.635, Annex 1
	5 GHz	4 400 – 5 000 MHz	ITU-R F.1099, Annex 1
5.7	Lower 6 GHz	5 925 – 6 425 MHz	ITU-R F.383
5.8	Upper 6 GHz	6 425 – 7 110 MHz	ITU-R F.384
5.9	7 GHz (L7 + U7)	7 110 – 7 750 MHz	ITU-R F385, Annex 3
5.10	Lower 8 GHz	7 725 – 8 275 MHz	ITU-R F.386, Annex 6
5.11	Upper 8 GHz	8 275 – 8 500 MHz	ITU-R F.386, Annex 1
5.12	10.5 GHz	10.15-10.3 GHz//10.5-10.65 GHz	ITU-R F.1568, Annex 1
5.13	11 GHz	10.7 – 11.7 GHz	ITU-R F.387
5.14	13 GHz	12.75 – 13.25 GHz	ITU-R F.497
5.15	15 GHz	14.5 – 15.35 GHz	ITU-R F.636
5.16	18 GHz	17.7 – 19.7 GHz	ITU-R F.595, Annex 1
5.17	23 GHz	21.2-23.6 GHz or 22.0-23.6 GHz	ITU-R F.637, Annex 1 ITU-R F.637, Annex 3
5.18	26 GHz	24.5 – 26.5 GHz	ITU-R F.748, Annex 1
5.19	28 GHz	27.5 – 29.5 GHz	ITU-R F.748, Annex 2
5.20	32 GHz	31.8 – 33.4 GHz	ITU-R F.1520, Annex 1
5.21	38 GHz	37.0 – 39.5 GHz	ITU-R F.749 Annex 1

Thank you!