RECOMMENDATION ITU-R M.1085-1*

TECHNICAL AND OPERATIONAL CHARACTERISTICS OF WIND PROFILER RADARS FOR BANDS IN THE VICINITY OF 400 MHz

(Question ITU-R 102/8)

(1994-1997)

Summary

This Recommendation provides technical and operational characteristics of operational wind profiler radars in the bands near 400 MHz. The Recommendation includes representative power to the antenna line, necessary bandwidth, occupied bandwidth, representative antenna sidelobe suppressions and guidance for wind profiler radars sharing considerations. It contains in Annex 1 representative values and minimum requirements on system performance for wind profiler radars in bands near 400 MHz. Information about practical implementation of wind profiler radars in bands near 400 MHz is contained in the Appendices.

The ITU Radiocommunication Assembly,

considering

a) Recommendation No. 621 of the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992);

b) that wind profiler radars (WPRs) are important meteorological systems used to measure wind direction and speed as a function of altitude;

c) that many administrations plan to deploy WPRs operational networks in order to improve meteorological predictions and warnings, and support studies of the climate and increase the safety of navigation;

d) the need for frequency bands in the vicinity of 50, 400, and 1 000 MHz to permit the full performance capability of WPR operations, as requested by the World Meteorological Organization (WMO);

e) that once designed and built, WPRs could operate on centre frequencies over a range of ± 1%;

f) that WPRs may have to share spectrum with other systems both current and future;

g) that it would be desirable to have a limited number of frequencies authorized worldwide in order to minimize research and development investment in the design of components;

h) that technical standards would enhance compatibility with other systems within the same band by minimizing the adverse impact of spurious and out-of-band emissions;

j) that typical antennas are in the range 100-150 m^2;

k) that the effect of antenna side lobes may be further reduced by the selection of wind profiler locations to take advantage of terrain and other siting factors and additional enhancements (e.g. fences, berms) and antenna orientation may improve compatibility,

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* This Recommendation should be brought to the attention of Radiocommunication Study Groups 7, 9 and 11.

recommends

1 that the minimum performance standards in Annex 1 be adopted by administrations desiring to construct or operate wind profiler radars in the bands in the vicinity of 400 MHz;

2 that the transmitter power should be limited to that necessary to obtain data at the maximum altitude for which the profiler was designed;

3 that the occupied bandwidth (see Note 1) should be as close to the necessary bandwidth (see Note 2) as is technically and economically feasible to provide the required range resolution, noting that reduced values of resolution are generally acceptable at higher altitudes. Values are given in Annex 1;

NOTE 1 – Occupied bandwidth: the width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to 0.5% of the total mean power of the given emission.

NOTE 2 – Necessary bandwidth: for a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specific conditions.

4 that the unwanted emissions from wind profiler radars should be reduced as much as technically and economically feasible. Values are given in Annex 1;

5 that the antenna radiation pattern should minimize the levels of the side lobes, especially those at or near the horizon. Side lobe gain values as well as field strength values are given in Annex 1;

6 that Administrations should develop appropriate sharing criteria, such as frequency-distance (FD) separations in accordance with Recommendation ITU-R SM.337, for specific WPR designs sharing with other systems;

7 that the selection of WPR locations should take advantage of terrain and siting configuration to minimize the possibility of interaction with other systems; additional enhancements (e.g. fences, berms) and antenna orientation may improve compatibility;

8 that time-sharing should not be considered as a technically adequate means of protecting sensitive safety-of-life systems such as the COSPAS-SARSAT;

9 that frequency bands in the range 300-500 MHz should be chosen, where compatibility is possible, taking into account the necessary protection.

ANNEX 1

Representative values and minimum requirements on system performance for wind profiler radars operating in the vicinity of 400 MHz

1 Introduction

The values given below are based on current knowledge and field measurements on pulse modulated systems.

2 Representative values for operational WPR in the bands near 400 MHz

TABLE 1

System parameter	Range of representative values(1)
Pulse peak power (kW)	5-50
Average transmitted power (kW)	0.2-2.0
Main beam antenna gain (dBi)	26-34
Beamwidth (degrees)	3-8
Tilt angle (degrees)	12-18
Antenna size (m^2)	30-150
Height range(2) (km)	0.5-16
Height resolution (m)	150-1 200

(1) Users of this table should exercise caution in using combinations of these values to represent a “typical” or “worst case” profiler. For example, a profiler operating with a peak power of 50 kW while using pulses to yield a height resolution of 150 m would be an unusual system.

(2) The maximum operating height depends upon the product: (average power) × (antenna effective area).

3 Minimum requirements on system performance

3.1 Emission bandwidth

TABLE 2

Pulse width (μs)	Necessary bandwidth (MHz)	Occupied/necessary bandwidth ratio
1-8	2.2-0.3	≤ 2.5(1)

(1) Values down to 1.2 can be obtained at the expense of higher cost and somewhat inferior performance resulting from pulse shaping. The limit applies to the power and pulse width combination producing the highest power density in the signal sidebands.

3.2 Spurious emission levels

Spurious emission levels should be measured at the antenna input using the bandwidth values given below:

IF bandwidth: ≤ $1/T$ for fixed-frequency, non-phase-coded pulsed radars, where T = pulse length. (E.g. if radar pulse length is 1 μs, then the measurement IF bandwidth should be ≤ 1/1 μs = 1 MHz)

≤ $1/t$ for fixed-frequency, phase-coded pulsed radars, where t = (phase-chip length). (E.g. if radar transmits 26 μs pulses, each pulse consisting of 13 phase coded chips that are 2 μs in length, then the measurement IF bandwidth should be ≤ 1/2 μs = 500 kHz)

Video bandwidth: ≥ Measurement system IF bandwidth

Suppression of spurious emissions: > 60 dB.

3.3 Antenna characteristics

3.3.1 Antenna side-lobes suppression

TABLE 3

Antenna side-lobe suppression for specified angles above the horizon

Angle above the horizon (degrees)	Antenna side-lobe suppression (dB)	
	Median	Minimum
0-5	40	33
5-45	25	23
> 45	20	13

3.3.2 Antenna beam swinging

The centre of the antenna main beam generated at any time should be limited within a vertical cone of 40° included angle, i. e. of half-angles that are 20° from the zenith.

3.4 Transmitter frequency tolerance

The transmitters in WPRs should maintain a frequency tolerance of 10 parts/million or better. The frequency of WPR to be operated in TV bands should either be synchronized with the nearest TV transmitter in the same channel, or the frequency stability should be 0.1×10^{-6} or better.

3.5 **Receiver characteristics** (see Note 1)

The -3 dB receiver bandwidth should be commensurate with the authorized emission bandwidth plus twice the frequency tolerance of the transmitter as specified in § 3.4. The –60 dB receiver bandwidth should be commensurate with the −60 dB emission bandwidth. Receivers should be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver IF image frequency rejection, when applicable, should be at least 50 dB. Rejection of other spurious responses should be at least 60 dB. The receivers of a wind profiler radar should not exhibit any local oscillator radiation greater than –70 dBW at the antenna input terminals. Frequency stability of receivers should be commensurate with, or better than, that of the associated transmitters.

NOTE 1 – In general, the term “commensurate” is approximately equivalent to the term “equal” and it is used several times in this section. Furthermore, in the sentence “the –60 dB receiver bandwidth shall be commensurate with the −60 dB emission bandwidth”, it is intended for the receiver to be sufficiently broadband to pass all of the desired signal, but not so wide as to render the receiver vulnerable to adjacent channel interference.

3.6 Interference rejection

Non-coherent pulsed interference of duty cycle less than 1.5 %, such that peak interfering signal levels 30 dB greater than the WPR receiver noise level at the IF output, should not degrade the performance of WPrs.

3.7 Transmitter output power

The peak effective isotropically radiated power (e.i.r.p.) should not exceed 80 dBW.

APPENDIX 1

TO ANNEX 1

Example of a 400 MHz wind profiler radar standard

1 Introduction

This Appendix presents an example of an operational standard applied to a 449 MHz WPR. This standard is contained in the National Telecommunications and Information Administration (NTIA), Manual of Regulations and Procedures for Federal Radio-Frequency Management.

2 Symbols and terms defined

B: emission bandwidth (MHz)

B_c: bandwidth of the frequency deviation (MHz) (The total frequency shift during the pulse duration.)

B_d: bandwidth of the frequency deviation (peak difference between instantaneous frequency of the modulated wave and the carrier frequency) – (FM/CW radar systems)

B_s: maximum range over which the carrier frequency will be shifted (MHz) (frequency hopping radar systems)

d: pulse compression ratio (emitted pulse duration/compressed pulsed duration, at 50% amplitude points)

F_0: operating frequency (MHz). For non-FM pulse radars, the peak of the power spectrum; for FM pulse radars, the average of the lowest and highest carrier frequencies during the pulse

N: total number of chips (sub-pulses) contained in the pulse. ($N = 1$ for non-FM and FM pulse radars)

PG: processing gain (dB). For a non-FM pulsed radar $PG = 10 \log N$

P_p: peak power (dBm)

PRR: pulse repetition rate (pulses/s)

P_t: maximum spectral power density (dB(mW/kHz))

t: emitted pulse duration (μs) at 50% amplitude (voltage) points. For coded pulses, the pulse duration is the interval between 50% amplitude points of one chip (sub-pulse). The 100% amplitude is the nominal flat top level of the pulse (see Fig. 1)

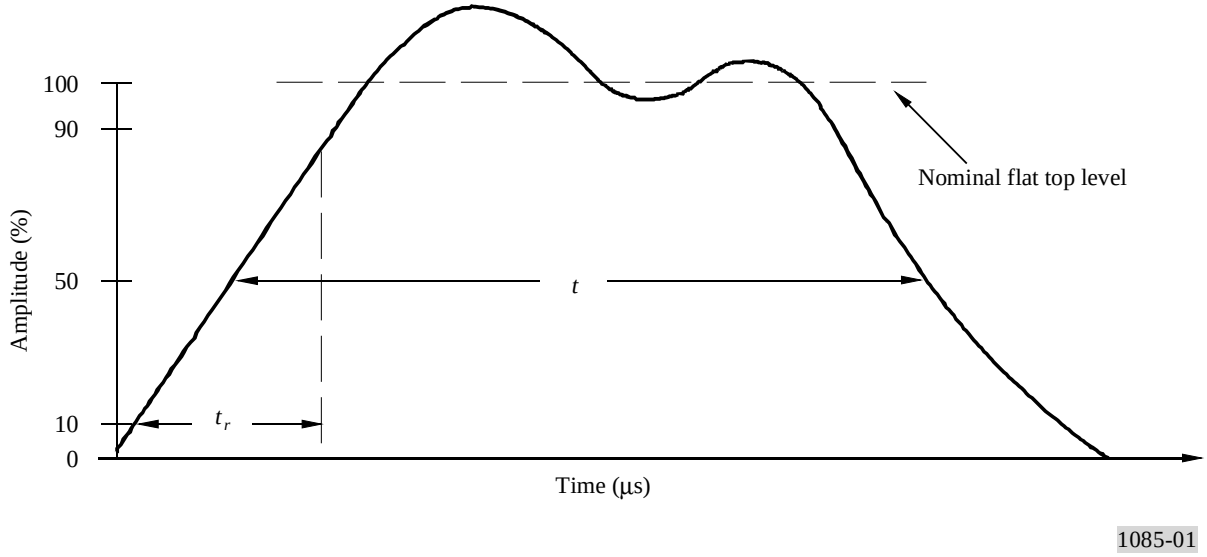
t_r: emitted pulse rise time (μs) from the 10% to 90% amplitude points on the leading edge (see Fig. 1). For coded pulses it is the rise time of a sub-pulse; if the sub-pulse rise time is not discernible, assume that it is 40% of the time to switch from one phase or sub-pulse to the next

t_f: emitted pulse fall time (μs) from the 90% to 10% amplitude points on the trailing edge (see Fig. 1). If t_f is less than t_r, t_f is to be used in place of t_r when performing the emission bandwidth calculations

S: roll-off slope (dB/decade). (Defines the slopes of the emission at and beyond the 40 dB point; it is the upper limit of the permissible energy level beyond that point.)

FIGURE 1

Determination of t and t_r



3 Criteria

3.1 Emission bandwidth

The emission bandwidth for WPRs at the antenna input shall not exceed the following limits:

3.1.1 For non-FM pulse radars (including coded pulse radars):

$$B(-40\ \text{dB}) = 6.2 / (t_r\, t)^{½} \text{ or } 64 / t, \text{ whichever is less.}$$

3.1.2 For FM pulse radars (intentional FM):

$$B(-40\ \text{dB}) = 6.2 / (t_r\, t)^{½} + 2(B_c + 0.105 / t_r)$$

3.1.3 For WPRs, an operational justification shall be provided if the pulse rise time, t_r, is less than 0.01 μs.

NOTE 1 – The –20 dB bandwidth for WPRs operating at 449 MHz shall not exceed 2 MHz.

3.1.4 For CW radars:

$$B(-40\ \text{dB}) = 0.0003\ F_0$$

3.1.5 For FM/CW radars:

$$B(-40\ \text{dB}) = 0.0003\ F_0 + 2\ B_d$$

3.2 Emission levels

Wind profiler radar emission levels at the antenna input shall be no greater than the values obtainable from the curve in Fig. 2. At the frequencies ± B(–40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. At and beyond the frequencies ± B(–X dB)/2 from F_0, the level shall be at least the dB value below the maximum spectral power density given by:

X (dB) = 60 dB, or

X (dB) = P_t + 30, whichever is greater attenuation.

Between the –40 dB and –X dB frequencies, the level shall be below the 40 dB per decade (S = 40) roll-off lines in Fig. 2. All harmonic frequencies shall be at a level that is at least 60 dB below the maximum spectral power density.

NOTE 1 – P_t may be measured or may for the purpose of these criteria be calculated from the following:

$$P_t = P_p + 20 \log (Nt) + 10 \log (PRR) - PG - 90$$

NOTE 2 – The roll-off slope, *S*, from the –40 dB to –*X* dB points is at 40 dB per decade. The –20 dB bandwidth is limited to 2 MHz for wind profiler radars operating at 449 MHz. The maximum emission spectrum level between the −40 dB and –*X* dB points for *S* dB per decade slope is described by the formula:

$$\text{Suppression (dB)} = -S \cdot \log \left| \frac{F - F_0}{½\, B(-40\ \text{dB})} \right| - 40$$

where:

$$½\, B(-40\ \text{dB}) \leq |F - F_0| \leq ½\, B(-X\ \text{dB})$$

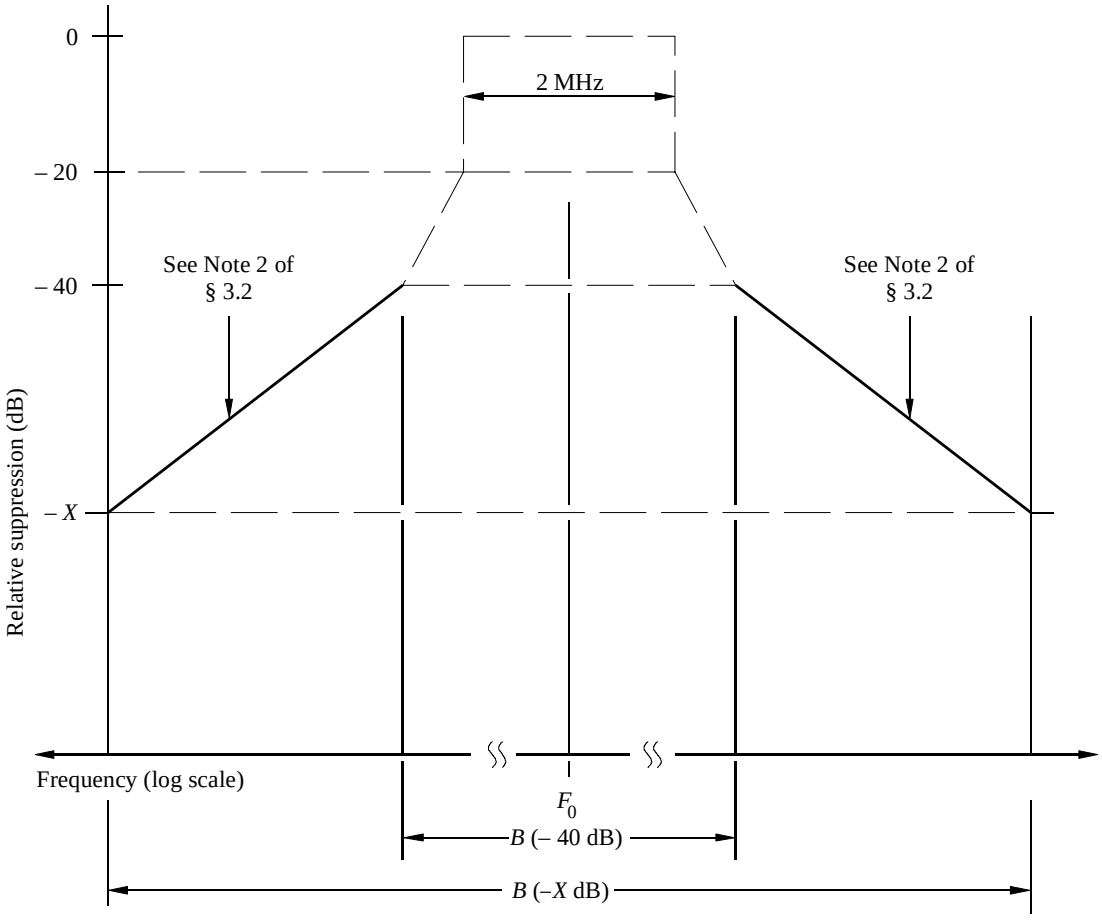
and:

$$B(-X\ \text{dB}) = (10^a)\ B(-40\ \text{dB})$$

$$a = \frac{X - 40}{S}$$

FIGURE 2

Radar emission bandwidth and emission levels for wind profiler radars operating at 449 MHz



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3.3 Antenna gain characteristics

The centre of the antenna main beam generated at any time shall be limited within a cone of half-angles that are 20° from the zenith. The side-lobe levels (excluding the main beam) in all azimuths shall not exceed the following values:

Elevation angle (degrees)	Side-lobe levels (dBi)	
	Median	Maximum
≥ 45	0	12
For 5 to 45	–5	7
≤ 5	–20	–8

3.4 Transmitter frequency tolerance

Wind profiler radar transmitters shall meet a frequency tolerance no greater than 10 parts/million.

3.5 Receiver characteristics

The –3 dB receiver bandwidth should be commensurate with the authorized emission bandwidth plus twice the frequency tolerance of the transmitter as specified in § 3.4. The –60 dB receiver bandwidth shall be commensurate with the –60 dB emission bandwidth. Receivers shall be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver IF image frequency rejection shall be at least 50 dB. Rejection of other spurious responses shall be at least 60 dB. Wind profiler radar receivers shall not exhibit any local oscillator radiation greater than –40 dBm at the antenna input terminals. Frequency stability of receivers shall be commensurate with, or better than, that of the associated transmitters.

3.6 EMC provision

Wind profiler radars should have the capacity to tolerate incoherent pulsed interference of duty cycle less than 1.5% such that peak interfering signal levels 30 dB greater than the WPR receiver noise level at the IF output will not degrade WPR performance.

3.7 Measurement capability

In order to coordinate radar operations in the field, an accurate measurement of the operating frequency is necessary. An accuracy of 1.0 part per million is adequate. Of comparable importance is the capability to measure pulse rise time and spectrum occupancy. Accordingly, the instrumentation necessary to make a frequency measurement shall have at least 1.0 part per million and suitable oscilloscopes and spectrum analysers to measure time and frequency parameters necessary to determine conformance with these criteria. Measurement instruments shall have resolution bandwidths of at least 10 kHz to measure close in bandwidth limits, and otherwise 100 kHz bandwidth below 1 GHz and 1 MHz bandwidth at and above 1 GHz should be used.

3.8 Transmitter output power

The peak effective isotropically radiated power (e.i.r.p.) of any WPR operating at 449 MHz should not exceed 110 dBm.

APPENDIX 2
TO ANNEX 1

Field strength measurements around an operational WPR at 482 MHz

4.1 System parameters of the WPR:

Pulse peak power (kW)	16
Pulse width (μs)	1.7
Pulse repetition period (μs)	100
Antenna type	Coaxial co-linear
Antenna size (m^2)	169
Antenna gain (dBi)	32
Antenna tilt angle (degrees)	15
Beam positions	5

4.2 Measurement parameters:

Antenna height	10 m above ground
Polarization	Vertical and horizontal

4.3 Measurements results

Figure 3 gives 50% location, 50% time values of field strength for six different antenna directions (dB(μV/m)) measured in the horizontal plane as a function of distance. Twelve median field strength values (indicated as 12 dashed lines in a vertical order at the test points MP 1 to MP 7) were calculated on the basis of the recorded measurement data.

The trend of the decrease in the field strength was calculated on the basis of the results obtained for the seven test points and is illustrated in the figure as a continuous line. This curve shows a measured decrease in the field strength of 42 dB per decade of distance. The diagram therefore shows that this measured decrease in field strength of 42 dB per decade corresponds to the decrease in field strength of 40 dB per decade calculated in the case of the mobile service using the Hata propagation model.

Figure 3 can be used in order to assess the radio compatibility between a wind profiler assigned to the radiolocation service and a TV broadcasting reception area by reading off the distance at which the permissible WPR interfering field strength is adhered to.

4.4 Example of TV service interfered by WPR

– minimum TV field strength: 52 dB(μV/m) Report ITU-R BT.409 (Düsseldorf, 1990)

– protection ratio (half-line offset): 39 dB

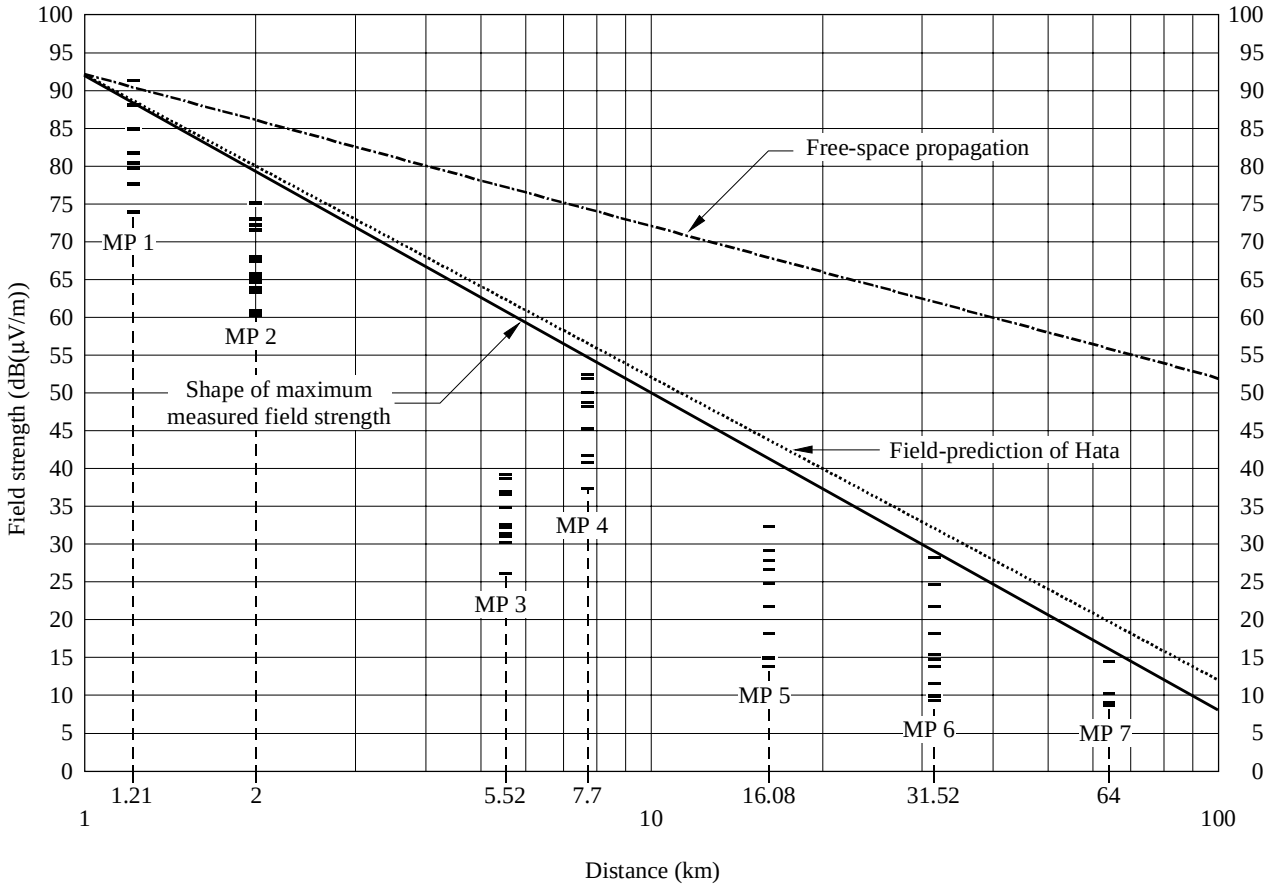
– maximum wind profiler field strength at receiving point: 52 – 39 = 13 dB(μV/m)

– minimum distance to wind profiler radar (Fig. 3): 70 km

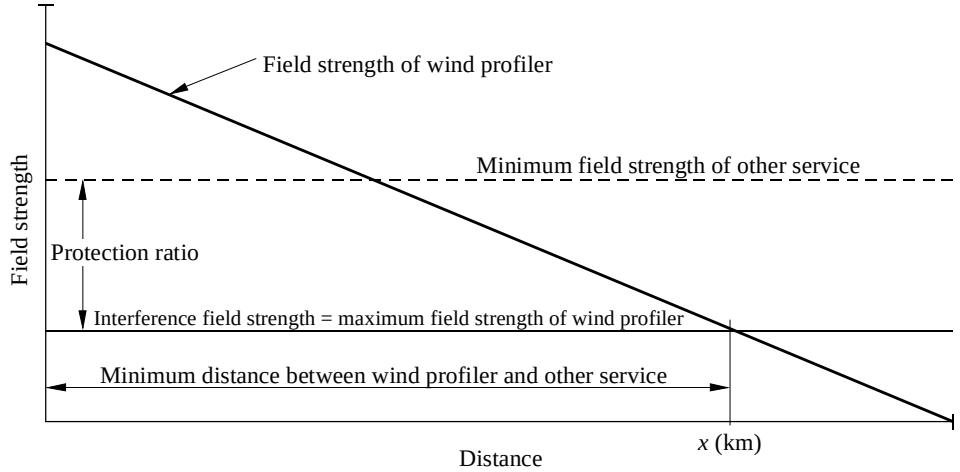
NOTE 1 – This example deals only with the case of protection of TV for 50% of the time.

FIGURE 3

Measured field-strength values at 482 MHz



Note 1 – Explanations for the use of Fig. 3.



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