INSTRUCTION MANUAL

FM BROADCAST ANTENNAS

LINEAR , CIRCULAR POLARIZATION
DIRECTIONAL
OMNIDIRECTIONAL
DIPOLE
YAGI
PANELS
LOG-PERIODIC

Antenna type...
Project Number...
Station...
Frequency..
City..
State..
Date...

GENERAL FEATURES
RECOMMENDATION

WARNING

Installation of this product **near power lines is dangerous**. For your safety, follow the installation directions.

1 – INFORMATION CONCERNING THE RISK OF ELECTROCUTION

Power lines that connect electric service to your house carry more than enough voltage required to kill a person by electrocution. Most often these electric lines run overhead along property lines with one or more lines coming off at a supporting pole and running across your property to a point on, or near the roof of your house. In some cases power lines may also be buried in the ground. Every year many careless people are killed, or seriously injured, even though they are aware of the hazard of touching or allowing something they are holding to touch electric wires. Many of these accidents involve people who are installing (or removing)) some type of antenna which is often mounted on a long metal supporting pipe that has several guy wires and cable attached to it. These assemblies are cumbersome and, therefore, difficult and unsafe for inexperienced people to handle even under the best conditions. The slightest wind, rain, too bright sunlight, too little light, a sloping roof, or other unsure footing, and other characteristics of the installation site, along with many other factors can serve to greatly increase the hazard of possible contact with power lines. For your safety get professional help with your antenna and tower installation and read observe the safety precautions outlined below.

2 – TYPES OF SUPPORT STRUCTURES

TF base station antennas and tower are designed to attach to a mast or pipe not supplied with the antenna. The types and sized are given in the assembly instruction for each model.

3 – SITE SELECTION

A- Select a site for the base of the structure that is a distance at least twice the total height away from the nearest power line.
A site which meets these safety criteria may not be practical either because of available space or because performance of the antenna may be impaired. If this situation occurs, do not attempt to install the antenna yourself. Get a professional installer to do it for you.

B - Height limitation are placed on antenna installations by the FCC, normally at 10 meter (fm service) above ground or 5 meter above building.
There may be additional restrictions or rules that are different which apply to your specific site, especially if you are near an airport.
Check the FCC rules and regulations. Also there may be local ordinance with which you must comply.

C -There are several different mounting methods used in antenna installations. Recommendations for best performance appear in some of the instructions covering specific models of Telecomunicazioni Ferrara antenna and towers. Common locations include:
1 – pole
2 – side tower
3 – top tower
4 – top of building
The characteristics of your particular site and the type of antenna involved must be considered to determine which is most suitable. Since a determination based on performance may not be compatible with the safety criteria of A above, it is recommended that a professional select the site and make the antenna and tower installation.

4 – SAFETY PRECAUTIONS

A – If you are not experienced in installing antennas or tower you are advised to seek professional assistance.

B – select the location to install your antenna with safety in mind. Again, you are urged to obtain professional help for a safe installation, as well as for best performance. More information concerning site selection is contained in a previous section.

C – Call your electric power company. Advise them of your installation plans. For your safety, ask them to provide assistance and shut-off power temporarily during the installation or removal process.

D – Plan your procedure carefully so that anyone helping knows what he is to do and when. You cannot afford confusion with a cumbersome assembly half way up or down. A few tips that may be helpful are:

1 – Install your antenna only in good weather and in daylight. Remember, a small amount of wind or rain or poor visibility greatly increases the possibility of an accident.

2 – Assemble your antenna following individual assembly instructions and attach it to the mast, if used, on the ground near the location planned for the mounting base. Attach the necessary length of coaxial feed cable.

3 – If the antenna is to be mounted on a mast of one or more section of metal tubing or pipe, the assembly should be guyed using three guy wires per level at about 10 –foot intervals starting just below the attachment point of the antenna. Estimate lengths needed and attach one end of each guy wire to the mast and lay along the mast on the ground. When all are attached, temporarily tie them in a bundle along with coaxial cable near the base of the mast to keep them from flopping about during erection.

4 – A non conductive rope can be attached near the top of the mast to be held by a person standing away from those erecting the assembly and used to used to guide it away from power lines in the event the assembly stars to fall.

5 – Before you raise the antenna or tower, install the mounting bracket and, if the antennas is to be guyed, any anchor bolts at calculated guying points.

6 – There is an extra warning label included with each antenna and tower. Attach it in a clearly visible spot on the base of any supporting structure used.

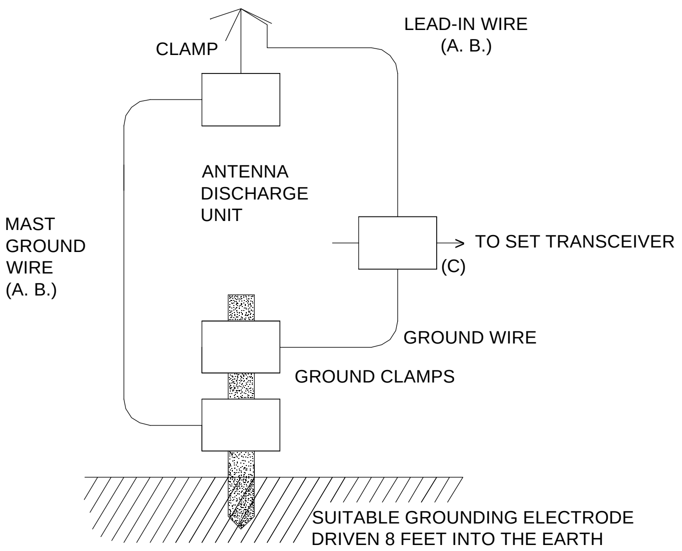
E – If the antenna start to fall and you can't control it, let go fast. Don't hang on trying to recover, let it fall. Remember should the antenna, tower, mast, cable (even though insulated for low voltage) or guy wires contact a power line the whole assembly will charged with voltage and anyone touching it can provide an electrical path to ground and be instantly electrocuted.

F – Should the assembly accidentally come in contact with power lines, don't touch it. Call the power company.

G – If someone comes in contacts with the electric power, don't touch him or you will also be electrocuted. First, remove the victim from contact with the electricity. Use a dry board, stick or rope. Call for medical help and apply artificial respiration if the victim is not breathing.

A – Use No. 8 aluminum or 10 AWG
Copper or No. 8 AWG copper-clad
steel or bronze wire, or larger
as ground wires for both
mast lead-in .
Securely clamp the wire
to the bottom of the mast.

B – Secure lead-in wire from antenna
Discharge unit and mast
Ground wire to house with stand-off
Insulators spaced from 4 feet apart.



C – Mount antenna discharge unit as possible to where the lead-in wire enters the house.

1 – Drill a hole in wall near set just large enough to permit entry of led-in.

2 – Push lead-in through hole and form a rain drip loop close to where it enters house. (Careful, there are wires in that wall).

3 – Put a small amount of caulking around lead-in where it enters house to keep out draft.

4 – Install static electricity discharge unit.

5 – Connect antenna lead-in to set.

(5) ANTENNA REMOVAL

Removal of the antenna should be exactly the reverse of the installation instructions. Please, for your own safety, follow the instructions for installing the antenna starting with the last step first. That's the only safe way to remove an antenna.

GENERAL FEATURES

RECOMMENDATION

WARNING

When energized by an RF transmitter, this antenna system will present a high intensity R.F. field. Care should be taken in order not to touch the antenna system when energized unless performing touch test under factory supervision. It is not advisable to remain in the antenna aperture for extended periods of time while the antenna system is energized. All maintenance or repairs should be done with the primary voltage to the transmitter disconnected and all transmitter remote controls disabled.

The elements and their support brackets should be installed so that the interbay transmission line is not any type of mechanical bind. If Heliax, Wallflex or other continuous air dielectric cable installed as your antenna feed line, make certain that the feed line gas barrier is usually built into the connector on the end of the feed line that comes off the shipping reel last. If the antenna is not pressurized, condensation can occur inside the antenna harness resulting in possible failure of the antenna. The proper Heliax or Wellflex transmission line end fitting attaching to the antenna will have holes in the ptfe (teflon) insulator, permitting the passage of gas to the antenna. We recommend an internal pressure of lbs. in our antenna harness for safe operation.

TEST

If your station specified a tower mounted antenna, the factory adjustments are done with the antenna mounted on a tower. Antennas specified as pole mount are factory matched on a four inch o.d. pole.

This is important in order to detect any installation errors, which might have been made during the installation. A low VSWR of less than 1.5 to 1 at the operating frequency is to be expected: Should a higher VSWR be observed, there may be a mechanical defect in the transmission line or antenna, and any defect found should be corrected before placing the antenna system in regular service.
Generally a VSWR of less than 1.2 to 1 may be expected.

COLLINEAR ANTENNA SYSTEM linear vertical polarization

1. RECOMMENDED DISTANCE BOOM TO BOOM IS 0.85*l* (see table)

2. THE FORMULA IS:

D=(300/F)*0.85
F=FREQUENCY MHZ
D=DISTANCE BOOM TO BOOM IN METERS

EXAMPLE: F=103.9MHZ
(3 00/103.9)*0.85=2.45MT.

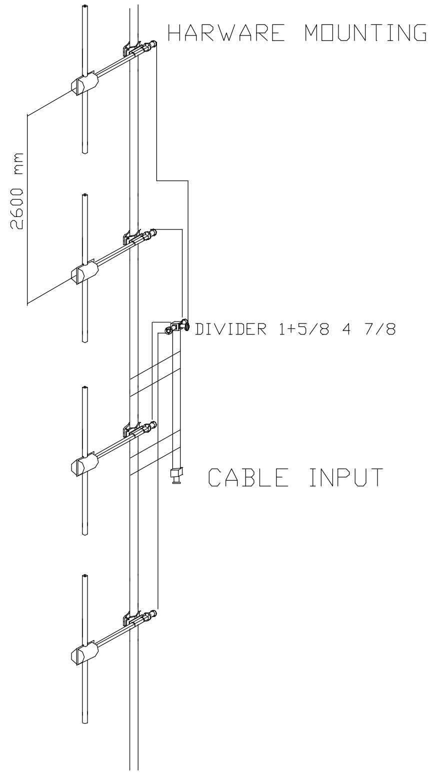


FIG.1

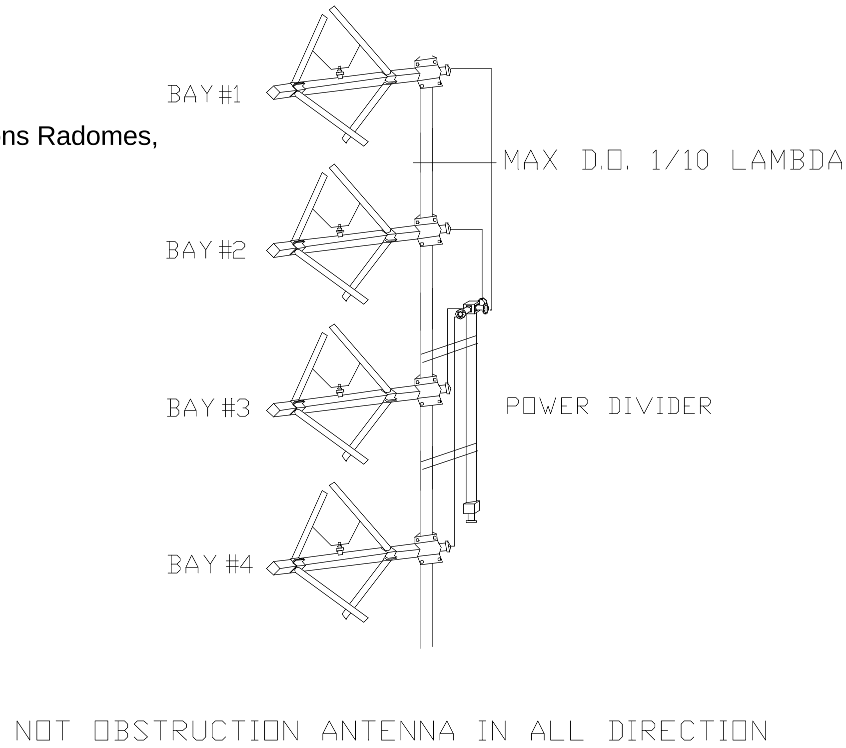
CIRCULAR POLARIZATION

CIRCULARITY
When the antenna is pole mounted at the top of a tower the
horizontally. polarized radiation pattern is omni-directional. Circularity is usually plus or minus 2-3 dB when the antenna is mounted on a 100 mm diameter steel pole. If the antenna is side mounted, the supporting structure will have a slight effect on the radiation pattern and VSWR.

OPTIONAL ACCESSORIES

Mounting brackets for special tower configurations Radomes,
fiber glass
Fine-matcher

FIG.2



BEAM-TILT OF THE PATTERN.

The beam tilt of the pattern is necessary not only in order to reduce the radiated power over the horizontal pattern, but also in order to direct the maximum power towards the earth surface. Actually, in reason of the land curve, the maximum radiation of an antenna will not reach the earth surface if the pattern is not beam tilted.

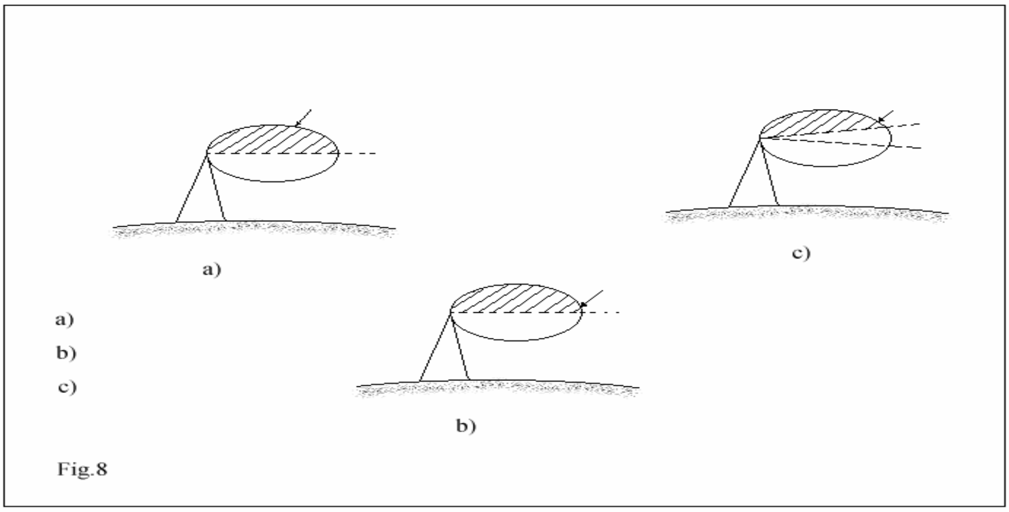


Fig.8

The pattern of an antenna situated at 300 meters from the earth will have to be beam tilted of an angle superior to 0.5 degrees in order to enable the maximum radiation to reach the earth surface.
Small angles of beam tilt (from 1 to 3 degrees) can be easily obtained thanks to a mechanical beam tilt of plan of the radiating elements. Bigger angles of mechanical beam tilt are not used for mechanical and environmental difficulties.
A beam tilt of the pattern can be obtained thanks to the control of the current phase that feed the different elements of the curtain (= series of antennas). This control can be realized by supplying the down half of the "curtain" with currents which have a fix phase delay in respect of the currents that feed the upper half of the curtain, otherwise by introducing a proper and progressive phase deviation in the current of each adjacent radiating element.
Important angles of beam tilt are normally reached thanks to an adequate combination of mechanical and electrical beam tilts. The introduction of a different phase distribution in respect of the progressive distribution, in the radiating elements will provoke a loss equivalent to a “compensation”.

A simple formula can enable to calculate the beam tilt angle of a place, in respect of the transmitting point, considering the earth curve with K=1 .33.

$$\theta = D.3.28 \cdot 10^{-6} + \arctan\left(\frac{H_{tx}-H_{rx}}{D}\right)$$

θ = beam tilt angle in degrees
D = distance in meters between the transmission point and the reception point.
H_{tx} =height S.L.M. of the transmitting point in meters
H_{rx} = height S.L.M. of the receiving point in meters

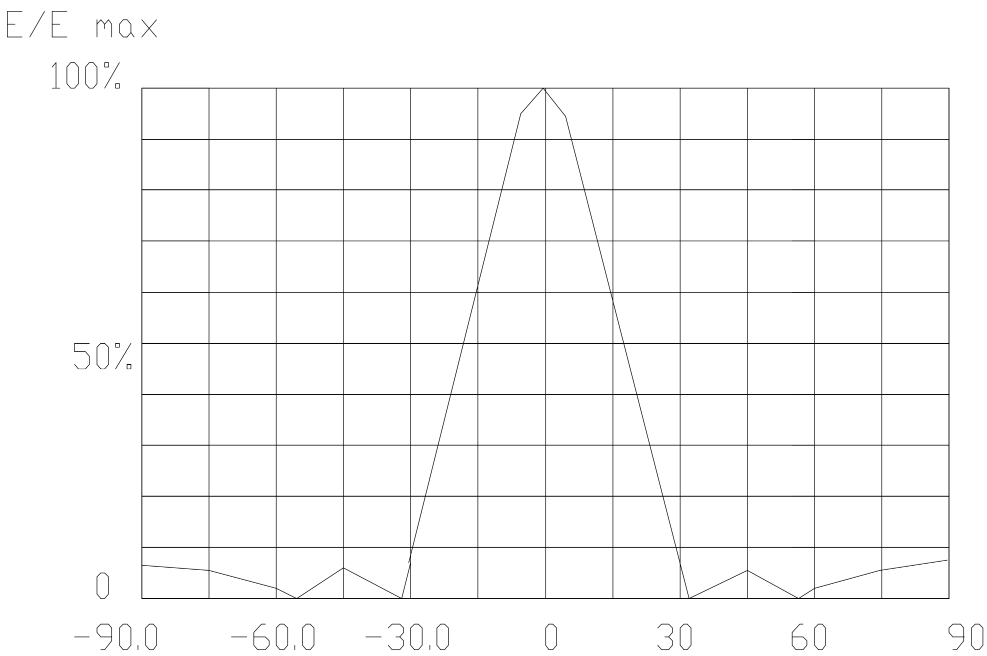
Even though with bi-nominal distribution of stone the nulls and the secondary lobes are eliminated, there is an increase of the opening and a consequent diminution of the directivity of the pattern and of the gain. Moreover, the variability field of the currents being very wide, realization difficu1ties can occur, as we11 as problems related to the stability of the currents itself.

Another distribution technique of the power that demonstrates the indicated drawbacks is the “dolph-tschebycheff’ technique.
When this technique is applied it is necessary to specify the maximum width that the secondary lobes should have in respect of the main lobes.

In the figure n°7 you can see the vertical pattern of the curtain of Figure 5, when a dolph-tschebycheff distribution of 1, 2.05, 2.57, 2.05, 1 is applied, corresponding to a suppression of the secondary lobes of 27db.

Beam tilt angle

Fig. 7 vertical pattern of the Fig.5 curtain when a “dolph-tschebycheff’ distribution is applied.



The optimum spacing between the elements in this type of distribution is 0,5 2 λ .even if in real practise bigger spacings are used.

It is important to note that, no matter the compensation technique of the nulls you are using, a reduction of the gain in respect of the uniform distribution of the power will occur. This reduction of the gain is called “loss of distribution”.

These losses can be minimized thanks to and accurate method of synthesization of the patterns in which the power for the compensation of the nulls is taken from the portion of pattern situated above the horizon, or from the compensation of the ondulations of the main lobe.

Other more complicated methods of compensation of the nulls combine an accurate phase distribution with the width distribution.

In this more general case, the gain losses in respect of a uniformal distribution of the power and of a phase supply are normally called “compensation losses”.

SHAPE OF THE VERTICAL PATTERNS

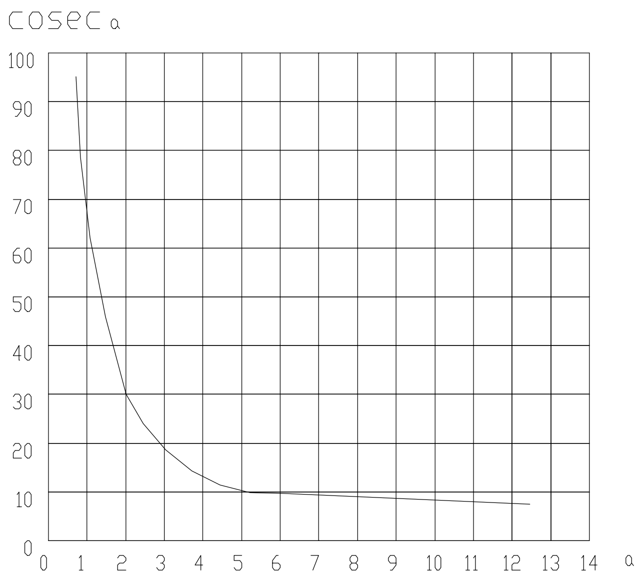
The vertical pattern of a curtain of antennas to placed on top (collinear System) must have a shape that guarantees a constant electromagnetical field in all the areas to serve. In the case of a plain terrain, we can see that such a shape follows the trigonometric function of the cosecant, which is as fo1lows:

$$A = \text{COSECANT } \alpha = \frac{1}{\text{SEN } \alpha}$$

A= width of the pattern
α = vertical beam tilt angle

When you know the vertical angle that your antenna must cover, you can choose the part of diagram that must be used, with the help the diagram showing the cosecant that you can see below.

Fig.2 COSECANT DIAGRAM



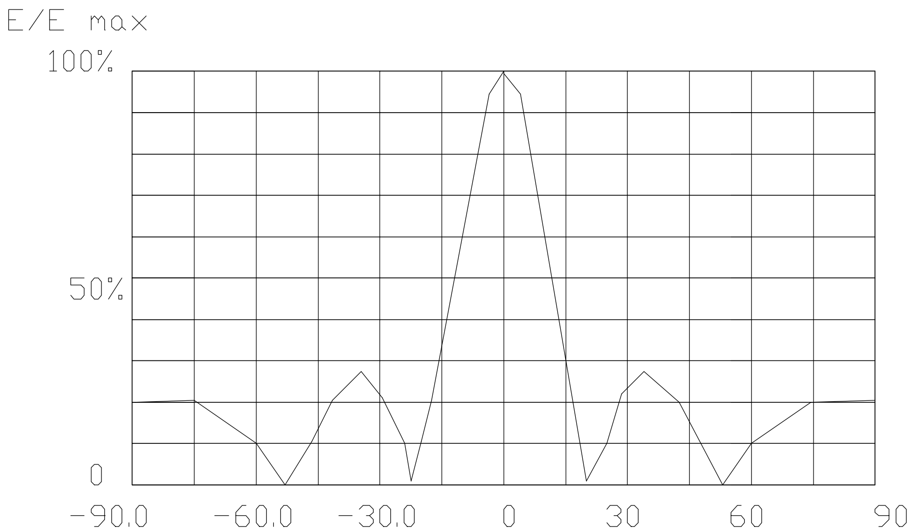
NULL FILL

In the angle sector which corresponds to the required service area, the vertical pattern must not contain any null, the presence of nulls would provoke theoretically at zero fields in the areas where the nulls themselves would occur. What will happen is that the width of the received signal will be significantly inferior in respect of what is required and there will be reflections provoked by the signal radiated from the other areas of the vertical pattern.

Atypical vertical pattern of an antenna composed of a series of superposed elements. with a regular space between each other and feeder with a current having the same width, is indicated in figure 5.
You can note that the nulls occupy a significant portion of the pattern. which could correspond to some parts of the service area required.

Beam tilt angle

FIG.5



Vertical radiation pattern of a curtain composed of elements with a space of 0.5λ. between each other and feeder with the same current and phase.

The angles in which there are nulls can be calculated thanks to the following formula:

$$0=\text{ARCSIN}+\frac{-K}{n.d.}$$

K = number of the null (1 for the first, 2 for the second, and so on...)
n = number of superposed elements
d = space between the elements in wave length.

Some methods for the "compensation of the nulls" have been developed in order to obtain vertical patterns that reach the ideal shape that was described formerly.

The most simple and largely used method consists in feeding the different elements
of the curtain with currents of different widths, for instance with an appropriate power distribution.

A very famous method of distribution of the power, developed by J.S. Stone, is called “binominal distribution”. In this method the width of the currents that feed the antennas is proportional to the coefficients of a bi-nominal series of the following form:

$$(a+b)^{n-1} = a^{n-1} + (n-1)^{n-2} .\, a \;.\; b \; \frac{(n-1)\,(n-2)}{2} \;.\; a^{n-3} .\, b^{2} + \ldots\ldots\ldots\ldots\ldots$$

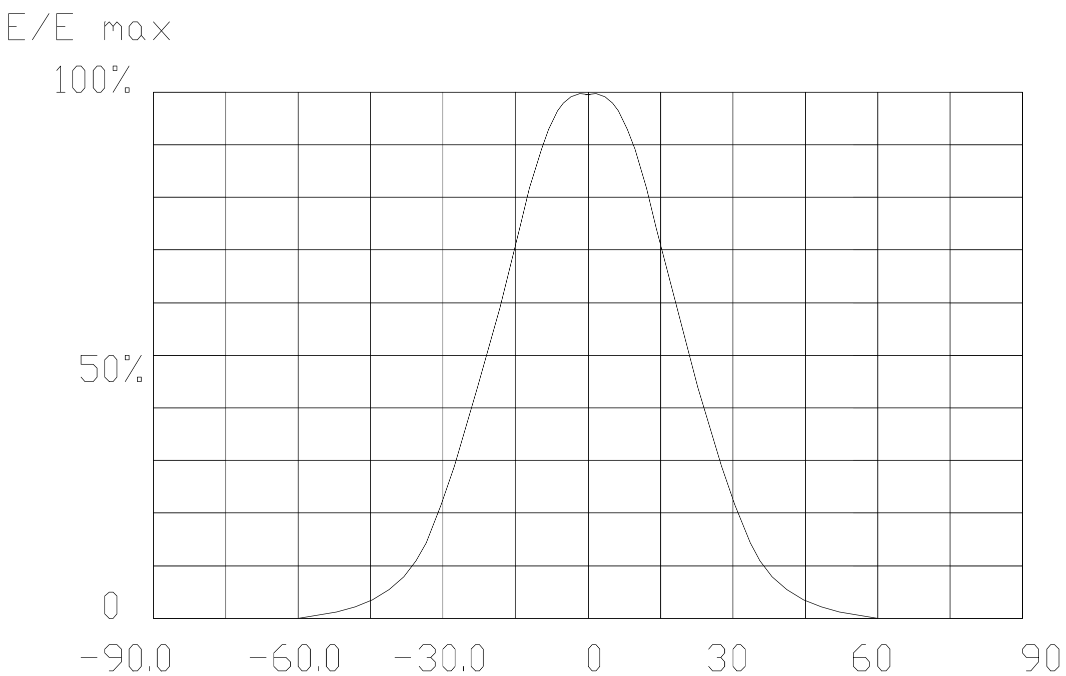
Where “n” represents the number of radiating elements

For curtains having from 3 to 6 elements, the relative width of the feeding currents is obtained by:

n	**Relative amplitude**
3	1,2,1
4	1,3,3,1
5	1,4,6,4,1
6	1,5,10,10,5,1

In the Figure n°6, you can see the vertical pattern of the curtain of the Figure n°5 when it is applied to a current distribution of the “bi-nominal” type.

Fig.6 Vertical pattern of the curtain of Figure 5 with a "bi-nominal" type power distribution.



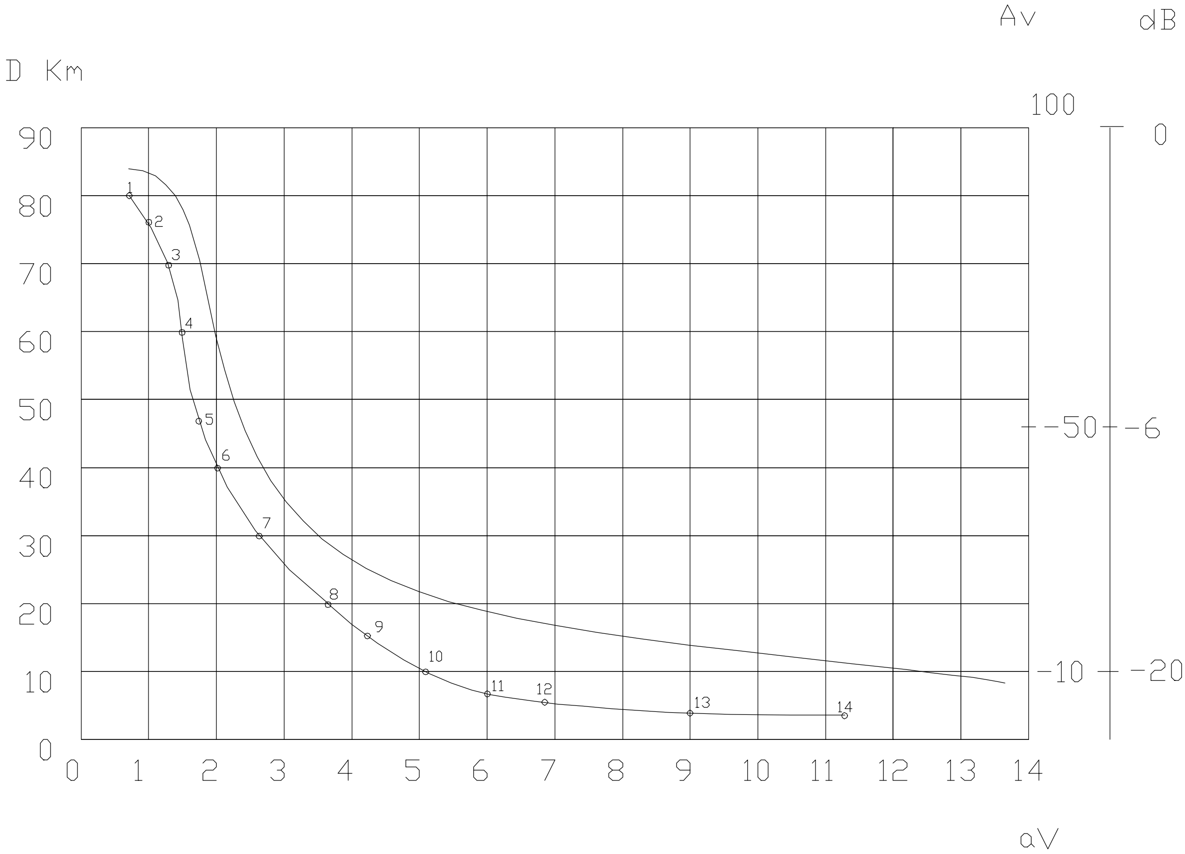
On a second diagram, set the distance in function of the vertical angle of the points indicated before (Fig.4). By linking these new points, you obtain the shape that the vertical pattern should have. In practice, in order to avoid that the areas situated under higher vertical angles, it is possible to have reflections caused by the power which is radiated on the maximum.

It is important to avoid that the radiated power corresponding to such angles reaches a level inferior to 20db (1/10 of tension) in respect of the power radiated on the maximum it self.

In our case, the diagram which is represented by a continuous line in the Fig. 4 respects the mentioned criteria.

D Km

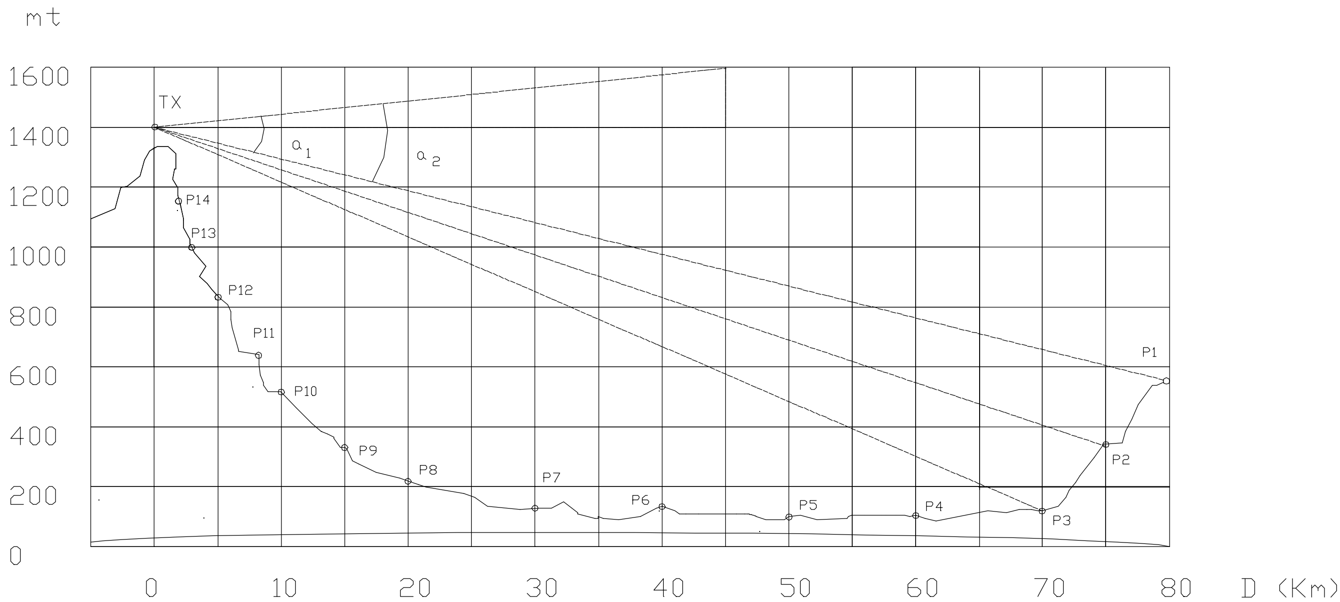
Fig. 4 Distance in function of the vertical angle.



In reality, on the one hand because the terrain is never flat and on the other hand in reason of the observations that will be made later on, the procedure is the following:

Taking the maximum direction of the considered curtain radiation, trace an altimetric profile section of the ground between the transmitting point and the farther receiving point.
Locate some significant points in this profile corresponding to the areas that will be covered. Then you obtain for each point, the distance and the vertical beam tilt angle in respect of the transmitting point.
For distances that exceed 30Km, it is convenient to take the ground curve in consideration (K =1.33). A formula that enables to calculate the beam tilt angle taking in respect of the ground curve is indicated further.
In the above diagram a practice case is indicated:

Fig.3 An example of altimetric profile section



LIGHTNINGS - ORIGINS AND PROTECTION CRITERIA

The violent and timely atmospherical perturbations, in which electrical phenomena are involved, such a lighting strokes, have an important influence on the choice of the site in which the transmitting station will be created.
In the low part of the clouds, there is an important quantity of negative loads, while in the upper part there is the same quantity of positive loads.
When the ionization of the surrounding air reaches some critical values. in the low part of the cloud, a discharge towards the earth is developed, and determines an elevating counter-discharge that will intercept the downdraft discharge. The ground draining of the electrical loads enable the passage of a current pulse that goes from a value of a few KA to several thousands of KA with an intense electrical field that reaches 300.000 Volt/m: such a passage represents the visible part of the lightning stroke, which can be one Km long if the discharge happens between the cloud and the earth.
On very high structures, especially if they are situated in dominating positions such as radio and television transmitting installations, during the storm perturbations. some over-tensions that create real elevating discharges can be observed. One must keep in mind that during the discharge phenomenon, there can be some clouds which are electrically loaded and which have not already found their discharge channel ; these positions consist of materials that are good electric conductors, and that because of its nature the lightning stroke chooses the way that presents the lowest electrical resistance. One realizes the importance and delicateness of the problem and the resolution of the lightnings themselves. <u>The lightnings phenomenon depends much on probability, and as a consequence, one can never have the absolute and guaranteed certainty to be protected.</u>
One should not protect all the positions without any discrimination, but protect the positions that could be touched more easily in reason of the geographical and keraunographical characteristics of the terra in.
The most important and preferred criteria that must be followed for the protection of the radioelectrical stations are normally the fo1lowing:

1) Creation of a valid grounding system for the whole site, this system must have a bow resistance value of discharge dispersion.
2) Screening of all the electrical and radioelectrical circuits after the supply transformation.
3) Superposition of opportune voltage limiters in the connection points between the screened and non-screened circuits including the isolation of such circuits.

The antenna tower, the equipment room, but also the transformation box must be connected to the same grounding system. Such system must be designed and built in such way that it guarantees the major and uniform equipotentiality between the different parts which are connected to it. Moreover, the resistance value of discharge dispersion must be low enough. As far as material is concerned, one can use both copper or zinc-plated steel under the form of cords or plaits. Copper is more resistant
to corrosion. However, it is not sufficient to protect the active connection parts of the systems by connecting the grounds between each other. it is necessary to install another conductor in the space reserved to the first ones: The latter takes the function of a lightning arrester.
One must pay particular attention to the dispersor, which is directly connected to the antenna tower which is encharged of dispersing almost all the lightning current to the ground. The dispersor can be either vertical (pales) or horizontal (rings or nets), depending on the resistivity of the terrain. For a major guarantee of safety of the staff, it is necessary and opportune to install a metallic net with steady meshes in the flooring, which should not be crossed by the current of the lightning. Finally, it will be necessary to link the metallic fence to the general grounding system, while the distance between such fence and the dispersors of the system shall not exceed 5 meters. As for the screening of all the electrical and radioelectrical circuits, one can obtain a more valid result by connecting between each and in several points. hut also to the grounding system the screens, the ground metallic sheaths of all the cables, the equipment and the box of the machines and of the supply transformer. One should remember that in order to have a more efficient screening, the screens of the cables and the metallic sheaths must be grounded at both ends. All the

grounding connections must have a short and rectilinear path, and have multiple interconnections. As indicated before, the discharges can come from the systems that supply electrical energy which can discharge themselves directly to the equipment and provoke very serious damages. In order to avoid such risk, one can install some transformers separately in the supply network, or some surge gap limiters in air or in gas. It is preferable to use cables having a thermo-plastic isolation which are better than those made in impregnated paper.

To conclude, the lightning stroke generally touches the antenna tower that carries the radiating antennas. In order to avoid serious damages it is necessary that the antennas are situated with large margin, within the protection cone of the tower.

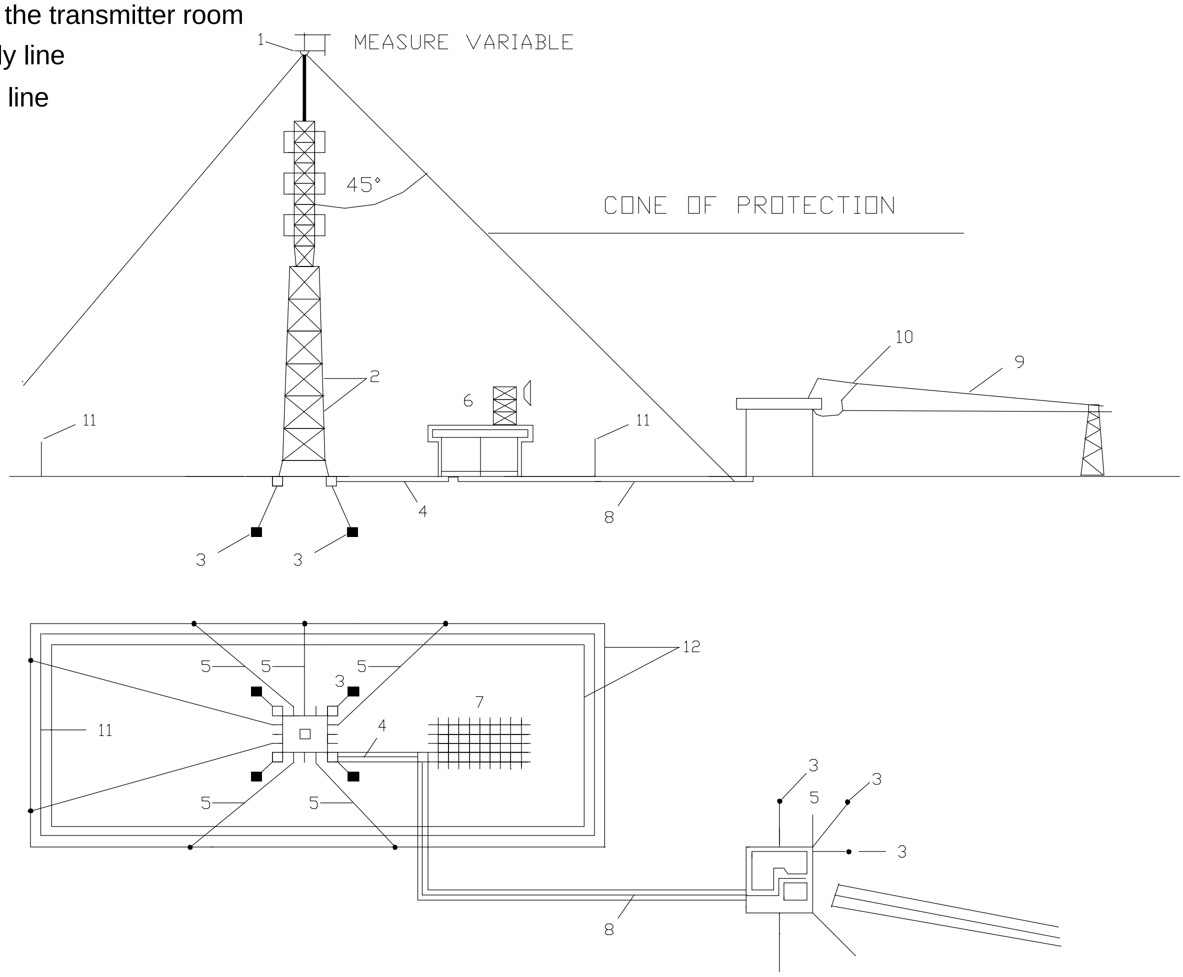
Otherwise it is indispensable to install metallic rods that pick-up the discharges to the top of the tower, connected to it with a good electrical contact. It is not necessary to use a radioactive lightning arrester, since it is not more efficient than the normal one and costs more. In presence of small diameter coaxial cables situated along the vertical stay of the supporting tower, like the energy conductor itself, that provides the necessary illumination to the tower. it is necessary to install a download copper plait on the same stay where the cables are situated.

EXAMPLE OF A SITE PROTECTED AGAINST LIGHTNINGS AND NETWORKS OVERTENSIONS.

Variable measure

Protection cone

1- metallic rods for the picking-up of discharges
2- download vertical stay
3- dispersion pales
4- illumination supply line
5- plaits for the connections of the dispersor
6- protection of the transmitter room
7- metallic net for the transmitter room
8- protected supply line
9- external supply line
10- protection
11- protection
12- protection ring



Propagation curves on earth surface as per C.C.J.R. tables

Minimum electromagnetic field strength levels as recommended by C.C.I.R.

Television

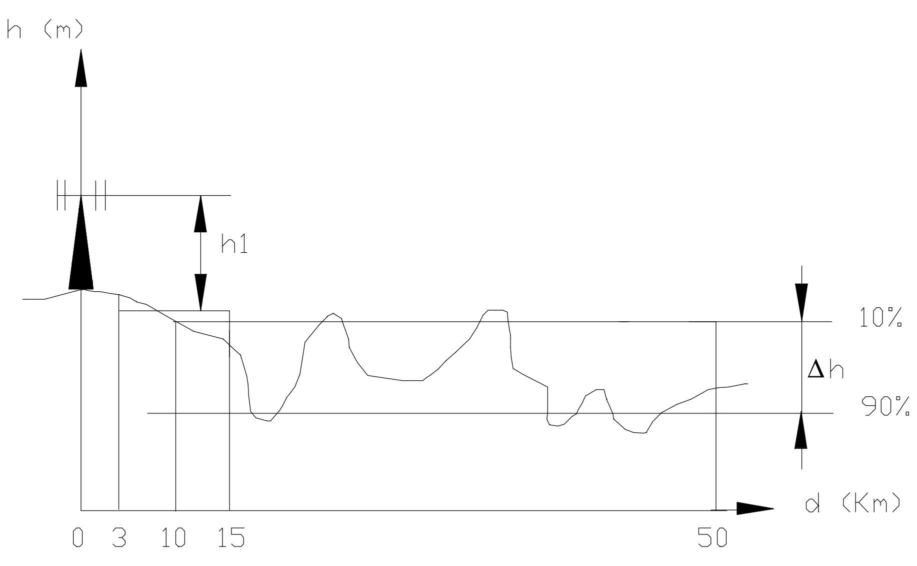
Band I	48db µV	Voltage on a half-wave dipole (R=73 ohm) within an electromagnetic field
Band III	55db µV	$V = \frac{\lambda E}{2\pi}$
Band IV	65db µV	
Band V	70db µV	V = Volts
		E = Mv/m
		λ = wave length in meters

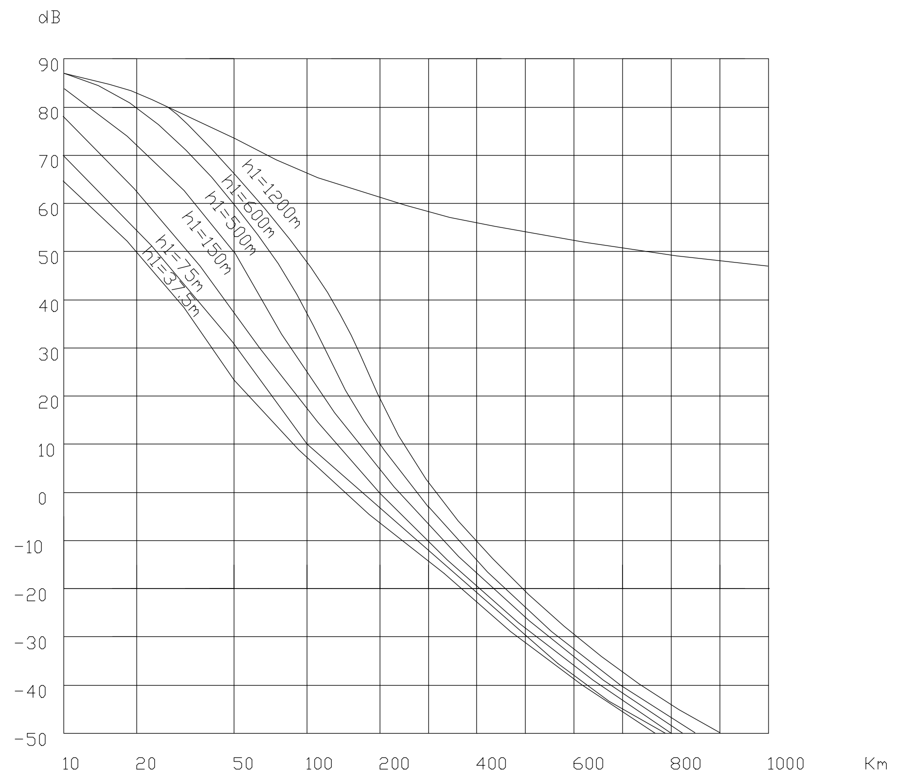
FM Broadcasting

Band II	rural areas	48db µV
	urban areas	60db µV
	big industrial cities	70db µV

h1 - equivalent height of the transmitting antenna (raising of the antenna above the average level of the earth, about 3Km to 15Km from the transmitter)

h2 - Average irregularity factor of the propagation terrain (difference between heights superior of 10% and 90% in the propagation path situated between 10 to 50 Km from the transmitter).





Linear scale Logarithmic scale

Field strength for 1 kw E.r.p.
(dB rel. 1 μ V/m.)

Frequency: 40 ÷ 250 MHz; land; 50% of the time;
50% of the location; h_1 = 10 m; Δh = 50 m.

Voltage and power ratios in DB

Ratio Down (-) Voltage	Power	dB	Ratio Up (1) Voltage	Power
1.0	1.0	0	1.0	1.0
.989	.977	1	1.012	1.023
.977	.955	2	1.023	1.047
.966	.933	3	1.035	1.072
.955	.912	4	1.047	1.096
.944	.891	5	1.059	1.122
.933	.871	6	1.072	1.148
.923	.851	7	1.084	1.175
.912	.832	8	1.096	1.202
.902	.813	9	1.109	1.23
.891	.794	1	1.122	1.259
.891	.794	1	1.122	1.259
.871	.750	1.2	1.148	1.318
.851	.724	1.4	1.175	1.38
.832	.692	1.6	1.202	1.445
.813	.661	1.8	1.23	1.514
.794	.631	2	1.259	1.585
.776	.603	2.2	1.288	1.66
.759	.575	2.4	1.318	1.738
.741	.55	2.6	1.349	1.82
.724	.525	2.8	1.38	1.905
.708	.501	3	1.413	1.995
.668	.447	3.5	1.496	2.239
.631	.398	4	1.585	2.512
.596	.355	4.5	1.679	2.818
.562	.316	5	1.778	3.162
.531	.282	5.5	1.884	3.548
.501	.251	6	1.995	3.981
.447	.2	7	2.230	5.012
.398	.158	8	2.512	6.31
.355	.126	9	2.818	7.943
.316	.1	10	3.162	10
.282	.079	11	3.548	12.580
.251	.063	12	3.981	15.849
.224	.05	13	4.467	19.953
.2	.04	14	5.012	25.119
.178	.032	15	5.623	31.623
.158	.025	16	6.31	39.811
.141	.02	17	7.079	50.119
.126	.016	18	7.943	63.096
.112	.013	19	8.913	79.433
.1	.01	20	10	100
.0562	.003	25	17.8	320
.0316	.001	30	31.6	1000
.0178	0	35	56.2	3200
.01	0	40	100	10000
.0056	0	45	178	32000
.0032	0	50	316	100000
.001	0	60	1000	1000000
.0003	0	70	3160	10000000
.0001	0	80	10000	100000000
0	0	90	31600	1000000000
0	0	100	100000	100000000

Conversion table DBm, Watt, Volt/50 ohm

dBm	pW	µV
-90	1	7.071
-89	1.259	7.934
-88	1.585	8.902
-87	1.995	9.988
-86	2.512	11.207
-85	3.162	12.574
-84	3.981	14.109
-83	5.012	15.83
-82	6.31	17.762
-81	7.943	19.929
-80	10	22.361
-79	12.589	25.089
-78	15.849	28.15
-77	19.953	31.585
-76	25.119	35.439
-75	31.623	39.764
-74	39.811	44.615
-73	50.119	50.059
-72	63.096	56.167
-71	79.433	63.021
-70	100	70.711
-69	125.893	79.339
-68	158.489	89.019
-67	199.526	99.881
-66	251.189	112.069
-65	316.228	125.743
-64	398.107	141.086
-63	501.187	158.301
-62	630.957	177.617
-61	794.328	199.29

dBm	µW	mV
-30	1	7.071
-29	1.259	7.934
-28	1.585	8.902
-27	1.995	9.988
-26	2.512	11.207
-25	3.162	12.574
-24	3.981	14.109
-23	5.012	15.83
-22	6.31	17.762
-21	7.943	19.929
-20	10	22.361
-19	12.589	25.089
-18	15.849	28.15
-17	19.953	31.585
-16	25.119	35.439
-15	31.623	39.764
-14	39.811	44.615
-13	50.119	50.059
-12	63.096	56.167
-11	79.433	63.021
-10	100	70.711
-9	125.893	79.339
-8	158.489	89.019
-7	199.526	99.881
-6	251.189	112.069
-5	316.228	125.743
-4	398.107	141.086
-3	501.187	158.301
-2	630.957	177.617
-1	764.328	199.29

dBm	W	V
30	1	7.071
31	1.259	7.934
32	1.585	8.902
33	1.995	9.988
34	2.512	11.207
35	3.162	12.574
36	3.981	14.109
37	5.012	15.83
38	6.31	17.762
39	7.943	19.929
40	10	22.361
41	12.589	25.089
42	15.849	28.15
43	19.953	31.585
44	25.119	35.439
45	31.623	39.764
46	39.811	44.615
47	50.119	50.059
48	63.096	56.167
49	79.433	63.021
50	100	70.711
51	125.893	79.339
52	158.489	89.019
53	199.526	99.881
54	251.189	112.069
55	316.228	125.743
56	398.107	141.086
57	501.187	158.301
58	630.957	177.617
59	764.328	199.29

Bm	nW	µV
-60	1	223.607
-59	1.259	250.891
-58	1.585	281.504
-57	1.995	315.853
-56	2.512	354.393
-55	3.162	397.635
-54	3.981	446.154
-53	5.012	500.593
-52	6.31	561.675
-51	7.943	630.21
-50	10	707.107
-49	12.589	793.387
-48	15.849	890.195
-47	19.953	998.815
-46	25.119	1120.689
-45	31.623	1257.433
-44	39.811	1410.864
-43	50.119	1583.015
-42	63.096	1776.172
-41	79.433	1992.898
-40	100	2236.068
-39	125.893	2508.91
-38	158.489	2815.043
-37	199.526	3158.53
-36	251.189	3543.929
-35	316.228	3976.354
-34	398.107	4461.542
-33	501.187	5005.933
-32	630.957	5616.749
-31	794.328	6302.096

dBm	mV	V
0	1	..224
1	1.259	.251
2	1.585	.282
3	1.995	.316.
4	2.512	354
5	3.162	.398
6	3.981	.446
7	5.012	.501
8	6.31	.562
9	7.943	.63
10	10	.707
11	12.589	.793
12	15.849	.89
13	19.953	.999
14	25.119	1.121
15	31.623	1.257
16	39.811	1.411
17	50.119	1.583
18	63.096	1.776
19	79.433	1.993
20	100	2.236
21	125.893	2.509
22	158.489	2.815
23	199.526	3.159
24	251.189	3.544
25	316.228	3.976
26	398.107	4.462
27	501.187	5.006
28	630.957	5.617
29	764.328	6.302

dBm	KW	V
60	1	223.607
61	1.259	250.891
62	1.585	281.504
63	1.995	315.853
64	2.512	354.393
65	3.162	397.635
66	3.981	446.154
67	5.012	500.593
68	6.31	561.675
69	7.943	630.21
70	10	707.107
71	12.589	793.387
72	15.849	890.195
73	19.953	998.815
74	25.119	1120.689
75	31.623	1257.433
76	39.811	1410.864
77	50.119	1583.015
78	63.096	1776.172
79	79.433	1992.898
80	100	2236.068
81	125.893	2508.91
82	158.489	2815.043
83	199.526	3158.53
84	251.189	3543.929
85	316.228	3976.354
86	398.107	4461.542
87	501.187	5005.933
88	630.957	5616.749
89	764.328	6302.096
90	1000	7071.068

Reflection coefficient table

$ROS\ (VSWR) = \frac{1 + r}{1 - r}$

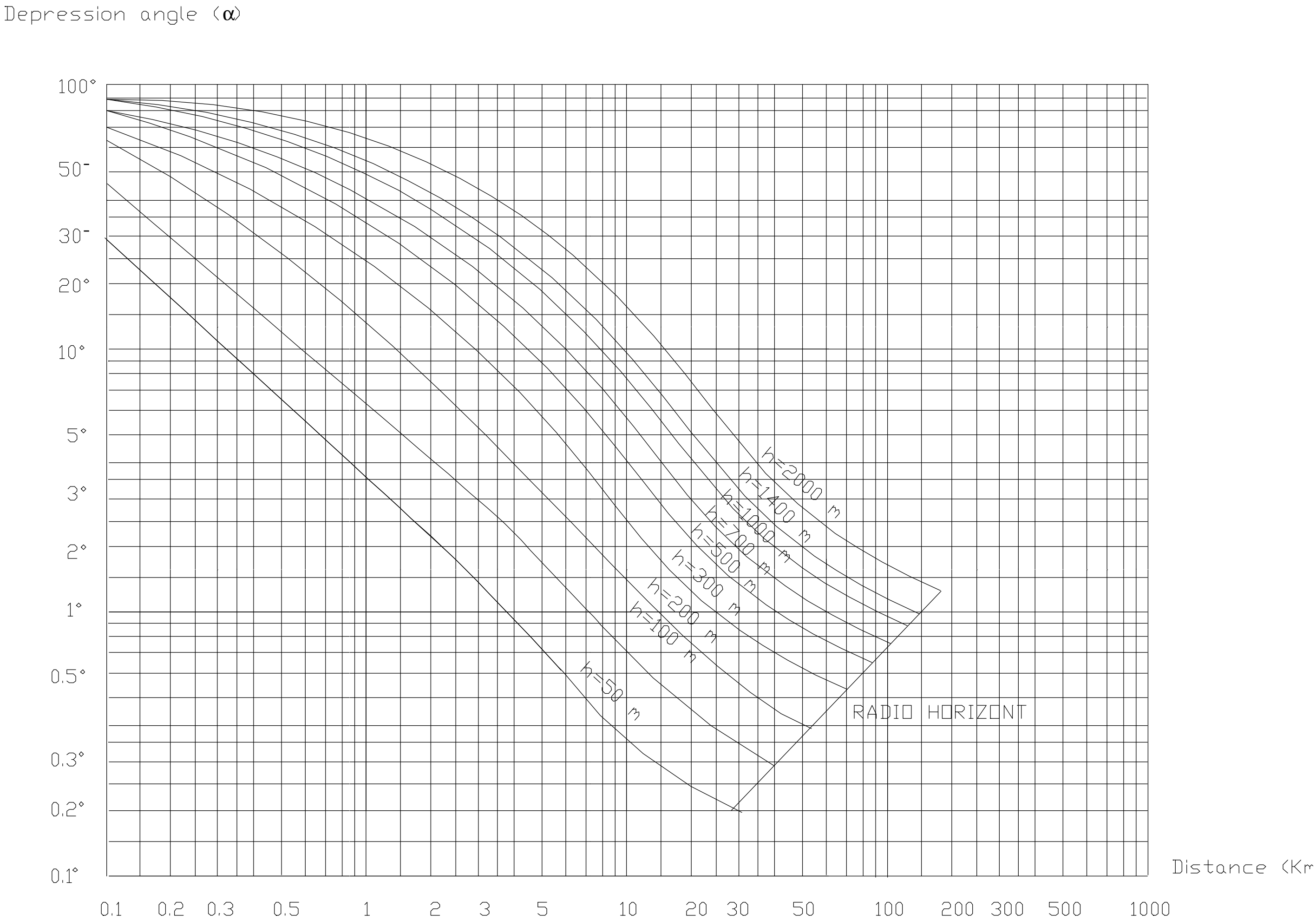
r = Absolute value of reflection coefficient

r^2 = Reflected to incident power ratio

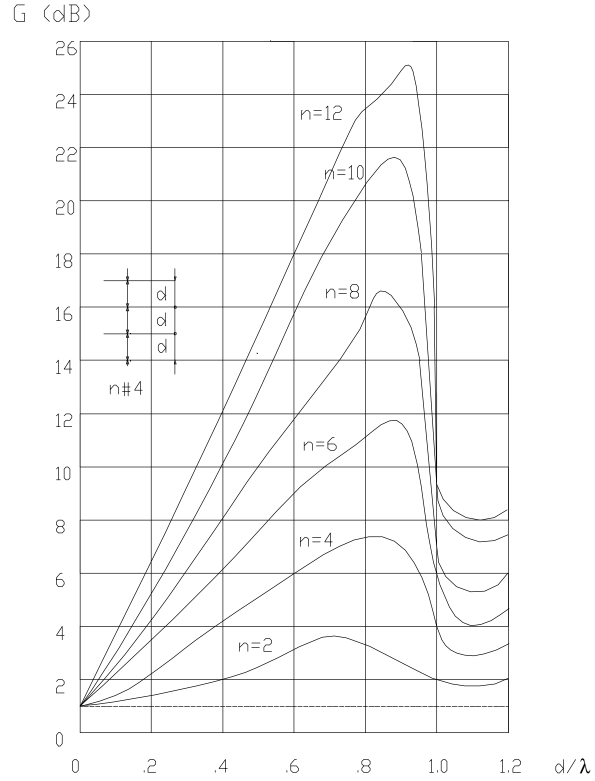
$-20LOG\ r = -10LOG\ r^2 =$ Return loss

ROS VSWR	-20LOG r -10LOG r^2	r	r^2
00	0	1.0000	1.0000
17.391	1	.8913	.7943
8.724	2	.7943	.631
5.848	3	.7079	.5012
4.419	4	.631	.3981
3.57	5	.5623	.3162
3.01	6	.5012	.2512
2.615	7	.4467	.1995
2.323	8	.3981	.1585
2.1	9	.3548	.1259
1.925	10	.3162	.1
1.785	11	.2818	.0794
1.671	12	.2512	.0631
1.577	13	.2239	.0501
1.499	14	.1995	.0398
1.433	15	.1778	.0316
1.377	16	.1585	.0251
1.329	17	.1413	.02
1.288	18	.1259	.0158
1.253	19	.1122	.0126
1.222	20	.1	.01
1.196	21	.0891	.0079
1.173	22	.0794	.0063
1.152	23	.0708	.005
1.135	24	.0631	.004
1.119	25	.0562	.0032
1.106	26	.0501	.0025
1.094	27	.0447	.002
1.083	28	.0398	.0016
1.074	29	.0355	.0013
1.065	30	.0316	.001
1.058	31	.0282	.0008
1.052	32	.0251	.0006
1.046	33	.0224	.0005
1.041	34	.02	.0004
1.036	35	.0178	.0003
1.032	36	.0158	.0003
1.029	37	.0141	.0002
1.025	38	.0126	.0002
1.023	39	.0112	.0001
1.02	40	.01	.0001
1.018	41	.0089	.0001
1.016	42	.0079	.0001
1.014	43	.0071	.0001
1.013	44	.0063	0
1.011	45	.0056	0
1.01	46	.005	0
1.009	47	.0045	0
1.008	48	.004	0
1.007	49	.0035	0
1.006	50	.0032	0
1.006	51	.0028	0
1.005	52	.0025	0
1.004	53	.0022	0
1.004	54	.002	0
1.004	55	.0018	0
1.003	56	.0016	0
1.003	57	.0014	0
1.003	58	.0013	0
1.002	59	.0011	0
1.002	60	.001	0

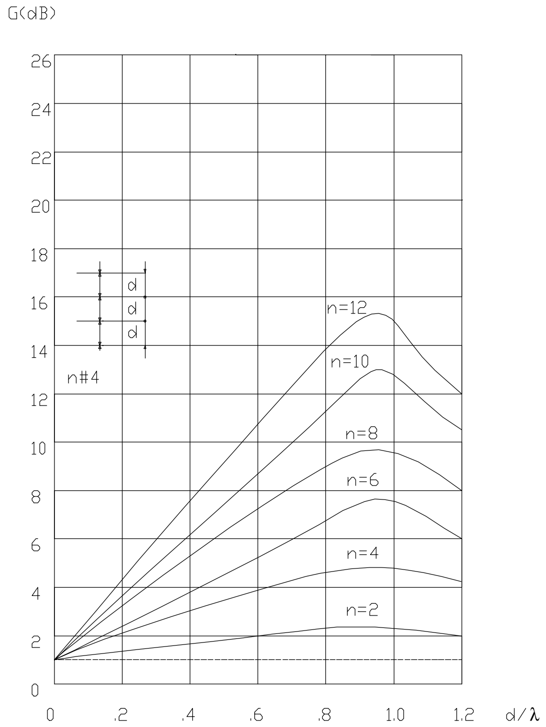
Depression angle (α) versus distance (Km)
For towers of different heights (h) above sea level

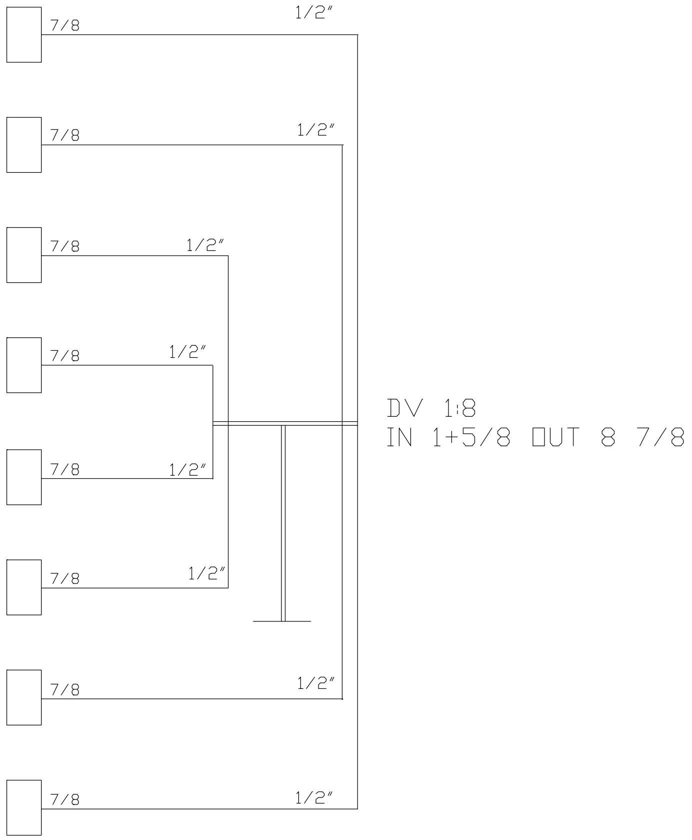


Gains diagram of horizontal dipole
Array with "n" dipoles versus relative
D/λ distance between them



Gains diagram of horizontal dipole
Array with "n" dipoles versus relative
D/λ distance between them




7/8
1/2″
7/8
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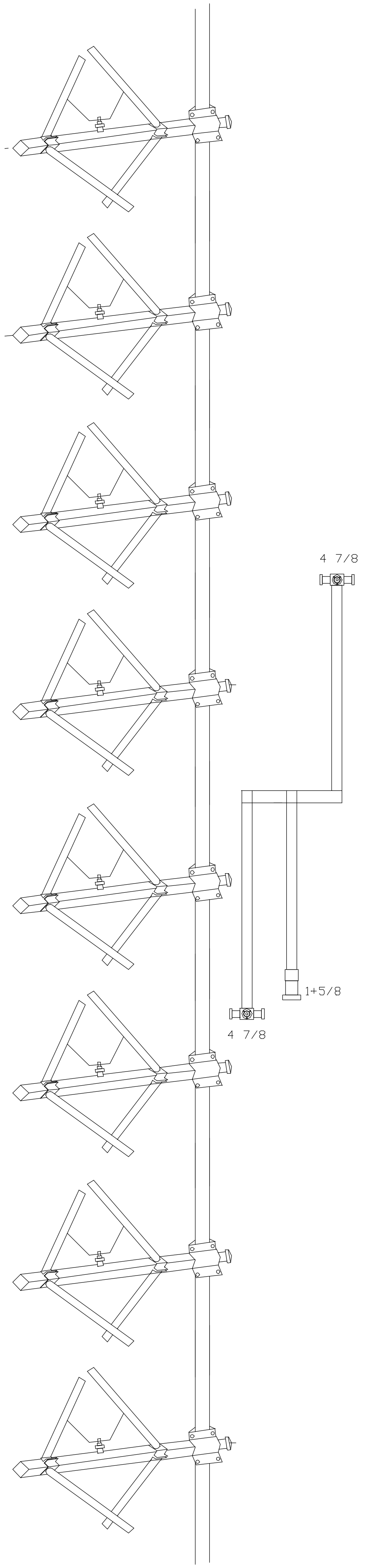
7/8
1/2″
DV 1:8
IN 1+5/8 OUT 8 7/8


4 7/8
1+5/8
4 7/8

- Military – all microwave frequencies – range not specified
- USSR – 300 Mhz to 30 Ghz
- Czech – 300 Mhz to 300 Ghz

Definition of Power Density:
Power Densities referred to in standards is that average density measured in accessible regions (USASI, or military) or at actual exposure sites (USSR and Czech) in the absence of subject.

Averaging time:
USAS C95.1 – 0.1 hour or 6 minutes
AF and ARMY – 0.001 hour or 36 seconds
Navy – 3 seconds
USSR – not specified
Czech – not specified, but the standard implies that an average density is calculated from an integrated dose. For example, for occupational situations the maximum permissible exposure is given by:

$$\int_0^8 PdT < 200 \text{ microwatts/ cm}^2 \text{ – hours}$$

averaged over 8 hours where P is power density and T is time in hour. The total exposure dose over five consecutive working days is summed and divided by 5 obtain an average exposure dose for 8 hours.

Dependence on Area Of Exposure:
No distinction are generally made between partial and whole body exposure.

Modification for Pulse or Other Modulation:
None except for reduction of exposure level by a factor of 2.5 in Czech standards.

Restriction on Peak Power:
None.

Allowance for Environment:
None except for proposal by Mumford to reduce the radiation exposure guide from 10 mw/cm^2 according to the formula Po(mw/cm^2) = 10 – (THI – 70) for values of the temperature-humidity index (THI) in the range of 70 to 79 with P0 = 1 mw/cm^2 for THI above 79.

Instrumentation:
Generally not well specified but far-field type probes such as small horns or open waveguides are specified with effective apertures $A_e = \lambda^2/4\pi G$ where G is the power gain. Response times are not well specified but are implied to be much greater than pulse durations and much smaller than duration of exposure, generally of the order of seconds. Some use of true dosimetry, integrated absorbed energy is made in USSR and Czechoslovakia. Under USSR standard exposure near 1 mW/cm^2 is permitted only with use of protective goggles for the eyes.

CABLE TIPE	IMPEDANCE Ω	DIELETRIC	VELOCITY FACTOR	FREQUENCY (Mhz) Maximum power (Kw) / Attenuation (dB/100 m)			
				50		100	
				Kw	dB	Kw	dB
RG 58	50	Compact Polythen	0,67	0,42	10,8	0,3	16,1
RG 59	75	Compact Polythen	0,66	0,75	8	0,5	11,2
RG 213	50	Compact Polythen	0,66	2,7	4,27	1,7	6,23
RG 8	52	Compact Polythen	0,66	2,7	4,27	1,7	6,23
RG 11	75	Compact Polythen	0,66	1,7	4,8	1,03	7
1/4 Inch	50	Expanded Polythene (FOAM)	0,84	0,985	4,17	0,69	5,94
1/2 Inch	50	Expanded Polythene (FOAM)	0,81	2,91	2,4	2,03	3,44
7/8 Inch	50	Expanded Polythene (FOAM)	0,89	7,74	0,843	5,38	1,21
1+5/8 inch	50	Expanded Polythene (FOAM)	0,88	19,3	0,512	13,4	0,738
1/2 Inch	50	Air Dielectric	0,914	2,97	1,9	2,1	2,72
5/8 Inch	50	Air Dielectric	0,92	6	1,12	4,21	1,6
7/8 Inch	50	Air Dielectric	0,9	9,2	0,853	6,4	1,21
1+5/8 Inch	50	Air Dielectric	0,921	20,7	0,476	14,4	0,679
3 Inch	50	Air Dielectric	0,933	54	0,322	29,1	0,448
4 Inch	50	Air Dielectric	0,92	82	0,256	56	0,371
5 Inch	50	Air Dielectric	0,931	107	0,177	73	0,259

FREQUENCY (Mhz) Maximum power (Kw) / Attenuation (dB/100 m)													
200		500		800		1000		2000		3000		8000	
Kw	dB	Kw	dB	Kw	dB	Kw	dB	Kw	dB	Kw	dB	Kw	dB
0,2	24,3	0,18	39,6	0,14	39,8	0,125	55	0,08	75	0,62	111,5	-	-
0,35	16,1	0,23	27	0,17	37	0,15	43	0,09	68	0,007	85	-	-
1,1	8,86	0,65	17	0,48	23	0,4	26	0,3	43	0,19	57	-	-
1,1	8,86	0,65	17	0,48	23	0,4	26	0,3	43	0,19	57	-	-
0,81	10,03	0,48	17	0,36	25	0,3	29	0,19	46	0,15	60	-	-
0,482	8,46	0,298	13,7	0,231	17,5	0,205	19,7	0,14	28,6	0,111	35,8	0,062	62,7
1,42	4,92	0,867	8,06	0,669	10,4	0,59	11,7	0,4	17,4	0,318	22,1	0,166	42
3,72	1,76	2,25	2,9	1,73	3,78	1,52	4,3	1,01	6,46	0,785	8,31	-	-
9,22	1,08	5,53	1,79	4,21	2,36	3,69	2,69	2,42	4,1	-	-	-	-
1,48	3,9	0,924	6,13	0,72	7,77	0,64	8,69	0,44	12,6	0,338	16,2	0,175	32,2
2,94	2,29	1,82	3,71	1,41	4,76	1,25	5,27	0,858	7,86	0,682	9,89		

TYPE	TE_{11}Mode Cutoff (Ghz)	MAXIMUM FREQ. RANGE (Ghz)	ATTENUATION (Db/100 M)	MAX POWER (W)	VELOCITY FACTOR
EW 127 A	7,67	10,0 - 13,25	11,83	1,24	0,78
EW 132	9,22	11,0 - 15,35	15,84	0,85	0,78

VSWR vs. Return loss (dB)

VSWR	RETURN LOSS (dB)
1.00	∞
1.05	32.3
1.10	26.4
1.15	23.1
1.20	20.8
1.22	20.1
1.25	19.1
1.30	17.1
1.40	15.6
1.50	14.0
1.70	11.7
1.92	10.0
2.00	9.5
3.00	6.0
6.00	2.9
10.00	1.7

Half wave dipole vs. isotropic dipole

Half wave dipole gain (with reference to isotropic radiator) ≅ 2.14 dB

Units:

Antenna gain (with reference to isotropic radiator): dBi
Antenna gain (with reference to half wave dipole): dBd

Generally: dBd = dBi – 2.14

-90	1 pW	17	7 µV
-80	10 pW	27	22 µV
-70	100 pW	37	70 µV
-60	1 nW	47	220 µV
-50	10 nW	57	700 µV
-47	20 nW	60	1 mV
-40	100 nW	67	2.2 mV
-30	1 µV	77	7 mV
-20	10 µV	87	22 mV
-10	100 µV	97	70 mV
0	1 mW	107	220 mV
10	10 mW	117	700 mV
20	100 mW	127	2.2 V
30	1 W	137	7 V
40	10 W	147	22 V
50	100 W	157	70 V
60	1 kW	167	220 V
70	10 kW	177	700 V
80	100 kW	187	2.2 kV
90	1 MK	197	7kV

These values refers to 50 Ω Impedance. (For 75 Ω voltage values must be increased by 20%).

Nominal cross section area	Placed in free air				
	1-pole cable	2-pole cable	3-pole cable	N° of conductors	Diameter (mm)
mm^2	*Amperes*	*Amperes*	*Amperes*		
0.5	3	3	3	1	0.8
0.75	5	5	5	1	1
1	7	7	7	1	1.15
1.5	10	10	10	1	1.4
2.5	16	16	16	1	1.8
4	22	22	22	1	2.25
6	31	30	30	1	2.8
10	47	45	40	7	1.35
16	66	61	51	7	1.7
25	88	83	68	7	2.15
35	108	95	84	7	2.5
50	135	128	105	19	1.8
75	176	167	135	19	2.25
100	213	202	165	19	2.6
120	240	227	186	37	2
150	280	263	217	37	2.25
180	325	300	245	37	2.5
200	375	320	260	37	2.6

Units	Meter	Mils	Inch	Feet	Yard	Terr. Mile (1)	Naut. Mile (2)
Meter	1	3937	39.37	3.281	1.094	0.000621	0.00054
Mils	2.540E-5	1	0.001	8.333E-5	2.778E-5	-	-
Inch	0.02540	1000	1	0.083	0.0278	-	-
Feet	0.3048	12000	12	1	0.333	-	-
Yard	0.914	35997	36	3	1	-	-
Terr. Mile (1)	1609	-	-	5279	1760	1	0.868
Naut. Mile (2)	1853	-	-	6080	2027	1.151	1

(1)Terr. Mile = Terrestrial Mile; (2)Naut. Mile = Nautical Mile;
1 micron = 1e-3 millimetres;
1 angstrom = 1E-7 millimetres

PRESSURE

Units	Atm.(1)	MmH_2O	mmHg	Pa.(2)	Bar	Kg/cm_2
Atm.(1)	1	10332	760	101325	1.01327	1.03333
MmH_2O	9.68E-5	1	0.07355	9.81	9.81E-5	1.0003E-4
mmHg	1.316E-3	13.597	1	133.34	1.333E-3	1.359E-3
Pa.(2)	9.87E-6	0.102	7.5E-3	1	1.0001E-5	1.02E-5
Bar	0.6869	10196.69	750.04	99998.02	1	1.02
Kg/cm_2	0.9677	9998.74	735.486	98059.61	0.980	1

(1)Am. = Atmosphere; (2)Pa. = Pascal

MASS

Units	Kilogram	Pound	Ounce	Dynes
Kilogram	1	2.205	35.27	980665
Pound	0.4535	1	16	444746
Ounce	0.02835	0.0625	1	27804.5
Dynes	1.02E-6	2.248E-6	36E-6	1

°F(2)	(9*°C/5)+32	-	(9*°K/5)-459.67	°R-459.67
K(3)	°C+273.15	(5*F/9)+255.37	-	(5*°R)/9
°R(4)	(9*°C/5)+491.67	°F+459.67	(9*°R)/5	-

ENERGY

Units	Btu	Calorie,gram	Joule	Erg
Btu	1	252	1054.8	1.055E10
Calorie,gram	3.9685E-3	1	4.1857	41865079.36
Joule	9.48E-4	02389	1	1E7
Erg	9.48E-11	0.2389E-7	1E-7	1

POWER

Units	Watt	Btu/hr	Hp	Kg-cal/min
Watt	1	3.412	1.341E-3	0.01433
Btu/hr	0.2931	1	3.93E-4	4.2E-3
Hp	745.712	2544.22	1	10.68
Kg-cal/min	69.78	238.1	0.0936	1

- DC power (KW): $\frac{volt \times ampere}{1000}$

- AC power (single phase) (KW): $\frac{volt \times ampere}{1000} \times \cos(\varphi)$

- AC power (Three-phase) (KW): $1.73 \times \frac{volt \times ampere}{1000} \times \cos(\varphi)$,

where:

Volt: linked voltage
Ampere: single phase current or balanced mean of the 3 cables current

All with balanced load
φ = power factor

General information

Medium radius of earth = 6371.03 Km
Equatorial radius of earth = 6376.8 Km
Polar radius of earth = 6355.41
Resistivity for some common metals:
Silver 0.0164 Ω*mm^2/m
Copper 0.0178 Ω*mm^2/m
Gold 0.0223 Ω*mm^2/m
Brass 0.077 Ω*mm^2/m

- Reflection coefficient vs. impedance: $\Gamma = \frac{Z-Zo}{Z+Zo}$

Z= Load impedance (Ω)
Zo = Characteristic impedance of the line (Ω)

- Voltage standing wave ratio: VSWR= $\frac{1+|\Gamma|}{1-|\Gamma|}$

where $|\Gamma|$ = magnitude of reflection coefficient

- Reflection coefficient:

$$K = \frac{VSWR-1}{VSWR+1}$$

- Return loss (dB): -K (dB) = -20*LOG (k)
  VSWR (Db) = 20* log (VSWR)

- Ratio of power transmitter: $1-K^2$

- Loss due to VSWR: $-(1-K^2)$ (dB) = 10* LOG$(1-K^2)$

Use of isotropic antennas at either end of the path

[A]: Frequency – Frequency for calculation expressed in Mhz

[B]: Distance – Distance between transmitting and receiving antennas, in Km

$$\text{Free Space attenuation (path loss) [dB]} = 20 \times \mathit{Log}\ (A) + 20 \times \mathit{Log}\ (B) + 32.5$$

<u>Signal ⇒ Field Strength</u>

Signal Field Strength at the location of receiving antenna, given the received signal level measured at the output connector of this antenna, across 50 Ohms.

[A]: Frequency – the frequency of the calculation, expressed in Mhz
[B]: Rx antenna gain – the gain of the complete receiving antenna, expressed in dBd (which is the gain in dB referred to a half wavelength dipole) in the actual direction (horizontally and vertically) in which the transmitting antenna is situated.

[C]: Received signal (dBuV) – the received signal voltage expressed in dB relative to 1 uV (microvolt) measured at the output connector of the receiving antenna across a resistive impedance of 50 Ohms.

$$\text{Field strength [dBuV/m]} = 20 \times \mathit{Log}\left[10^{(C-B/20)} \times \frac{2 \times \pi \times A}{300} \right]$$

<u>Parabolic Antenna Gain</u>

Calculating of parabolic antenna gain, with the prime focus feed, with respect to an isotropic radiator (dBi).

[A]: Diameter – the diameter of the antenna, measured rim-to-rim directly across the parabolic reflector, expressed in metres
[B]: Frequency – the frequency for the calculation, expressed in Ghz
[C]: Efficiency factor – efficiency factor for the illumination of the antenna.
This takes into account the fact that the radiation from the feed does not illuminate the reflector uniformly. If the efficiency is not known, 0.55 may be assumed.

$$\left(\left[\left(\frac{A}{2} \right)^2 \right] \right)$$

reflection from obstructions.

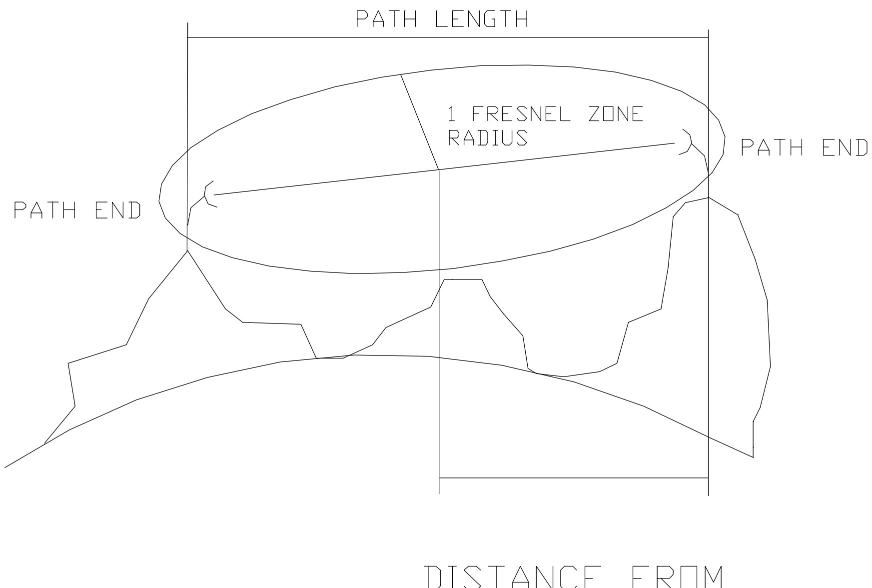
[A]: Path length – the direct distance between the transmitting and receiving antennas, measured in a straight line, expressed in Km

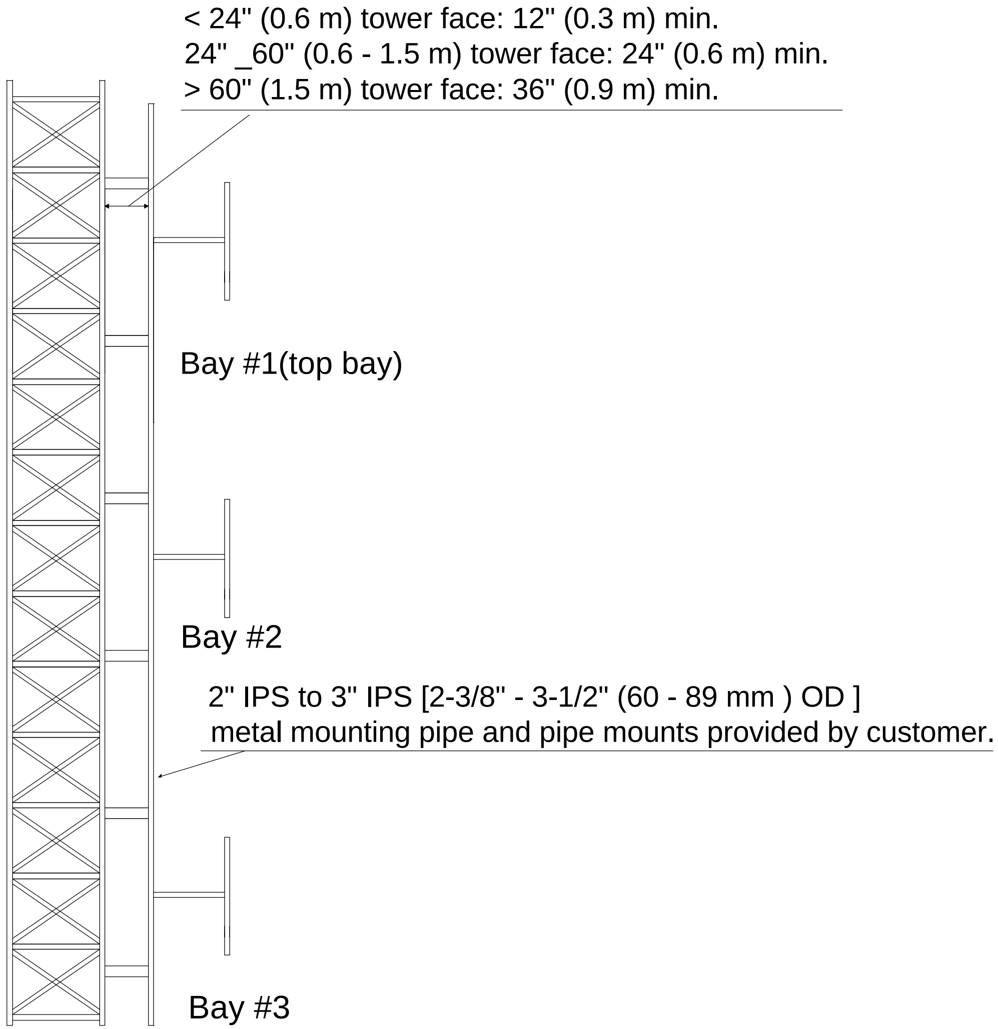
[B]: Distance from calculation point to path end – it is the distance from calculation point to the path end, measured horizontally in a straight line, expressed in Km.

[C]: Frequency – the frequency for the calculation, expressed in Ghz

1st Fresnel zone radius over obstacle:

$$[m] = \frac{\sqrt{\left(\frac{0.3}{C}\right) \times B \times 100 \times (A-B) \times 100 \times \left(\frac{1}{A \times 100}\right)}}{2}$$




< 24" (0.6 m) tower face: 12" (0.3 m) min.
24" _60" (0.6 - 1.5 m) tower face: 24" (0.6 m) min.
> 60" (1.5 m) tower face: 36" (0.9 m) min.
Bay #1(top bay)
Bay #2
2" IPS to 3" IPS [2-3/8" - 3-1/2" (60 - 89 mm) OD]
metal mounting pipe and pipe mounts provided by customer.
Bay #3