Global Journals LaTeX JournalKaleidoscope™
Artificial Intelligence formulated this projection for compatibility purposes from the original article published at Global Journals. However, this technology is currently in beta. *Therefore, kindly ignore odd layouts, missed formulae, text, tables, or figures.*

Receiving Antenna Factor Calibration Improvement

Valentino Trainotti

Received: 8 June 2021 Accepted: 2 July 2021 Published: 15 July 2021

Abstract

In a radio link two different or identical antennas are used each one performing a different role. For electromagnetic compatibility activities the receiving antenna factor is of paramount importance in order to measure the incoming spurious power density or electric field of any electrical or electronic device. Calculations as well measurements are performed to achieve this task using traditional equations and antenna software to get quick and simple results. Power transmission loss (Friis Equation) is only valid in free space as a general belief but in this paper it is proven that this principle is valid also for radio links over perfect ground [16], [17]. This statement permits the exclusion of any artificial factor to achieve the radio link power budget and power reciprocity principle [12], [21]. This fact takes into account the lack of losses in the natural space between both antennas as well in the perfect ground plane. At the same time, over perfect ground the total EM energy is travelling in a straight line connecting the transmitting (Tx) antenna radiation center and the center of the receiving (Rx) antenna, exactly like a radio link in free space, [16]. In order to improve the antenna factor calculation and calibration the procedure analizes all the parameters at any height of the Rx antenna for a fixed height of the Tx antenna at not only the maximum radiation over perfect flat ground plane. Result is achieved by a metallic ground plane where the conductivity is higher than 107S/m, so the reflexion coefficient module is exactly one.

Index terms— antenna factor, antenna gain, effective area, effective length, perfect ground plane, free space, half-wave dipole antenna.

1 Introduction

Author: e-mail: vtrainotti@fi.uba.ar II.

2 Calculation

This condition is obtained when the wave impedance Z w achieves the value of Z w = Z oo = 120 ? ? = 377 (?). The wave impedance is the relation between the electric and magnetic fields. Also, over perfect ground it depends, on the transmitting antenna radiation pattern elevation angle ? L and distance r over ground between both antennas. This condition is not achieved at a fixed distance r but at a different distance depending by the corresponding radiation at any angle ? L . This condition is achieved at a shorter distance r when the maximum radiation is obtained by the transmitting antenna. r is the distance along a straight line of an elevation angle ? L departing from the ground plane shown in Figure 1. This point is the radiation phase center of the transmitting antenna. This distance r is not obtained by a simple task but nowaday it can be determined by an antenna software [13]. This way the far field condition can be obtained and verifying it if at standard distances r the task is fulfilled [17]. At the same time, it is important to know that the wave power density flows in space travelling along the r straight line between the radio link antennas [16]. In the radio link in free space the distance r' is exactly equal to the distance r if both antennas are identical. The transmitting antenna works over perfect ground with its image under ground and constitutes an array of two elements **??**2]. Its radiation pattern depends on the separation S between them, exactly like a two element array works in free space. For this reason for horizontal polarization the maximum radiation has an elevation angle ? L according to this separation S or its height over ground H T and a null of power density on the perfect ground. Over ground this separacion is S = 2 H T . Figure 1 shows a sketch of a transmitting antenna over perfect ground. Rx antenna receives the EM waves from the actual antenna and its image and it delivers the received power on only its load resistance R L and no EM waves are received on its image. This statement is very important. This way the Rx antenna in its receiving role is working like in free space even if it is working over perfect ground **??**2], [3], [17].

The transmitting antenna (half-wave dipole) has a radiation pattern over perfect ground permitting to calculate its gain G T (dBi) for horizontal polarization. The original Dr. Kraus electric field gain equation over perfect ground is being updated to provide the power gain in dBi as a function of antenna height H T for various elevation angles ? L of the radiating element, to be [2]:

In a radio link over perfect ground traditionally two antennas are used for calibration of antenna factors. Independent of distance parameters of a receiving antenna are the effective length L eR or effective height H eR as well the antenna factor AF (dB/m). These specific parameters depend only on the current distribution along the antenna physical structure. Other parameters like effective area A e and gain g are strongly dependent of the antenna location and precisely in the free space far field over ground.

Abstract-In a radio link two different or identical antennas areG T = 10 log[F (2(sin(? H T sin? L))) 2] + 2.15 [dBi] (1)

Where:

2.15dBi is the half wave dipole antenna gain over an isotropic source in dB.

F is a factor taking into account the radiation resistance in free space and over perfect ground, or:F = R a(F F) R a(OG) (2) R a(OG) = R a(F F) ± R m [?]**(3)**

R a(F F) Tx antenna radiation resistance in free space. R a(OG) Tx antenna radiation resistance over perfect ground. R m is the mutual resistance between Tx antenna and its image.? is the space phase constant [Rad/m] or [? /m].

H T is the transmitting antenna height over perfect ground **??**m]. ? L is the elevation angle over ground from the array center phase located in the ground plane. r is the distance between the array phase center and the receiving antenna center over ground. 0.9 ? F ? 1.1f orH T ? ? You may use this simple equation to calculate the gain radiation pattern of a very thin half wave dipole antenna at any height H T and obtain the far field gain. However, for more data result for this antenna at any frequency the aid of a software program will help reduce the tediousness of individual calculation to generate the radio link geometry for the specific antenna parameters [13]. These paramenters are: the input antenna impedance, the current distribution on the antenna structure, the electric and magnetic fields, the power density on the location of the Rx antenna in space over ground, as well the gain radiation pattern in dBi in the far field. From the electric and magnetic field relation the wave impedance Z w is determined at a specific location in space. Also from the radiation pattern the antenna gain in the far field for any elevation angle is obtained [13]. This procedure is performed easily at any frequency in the wanted spectrum.

Here an example at the frequency of f = 30 [MHz] is shown.

A radio link has two horizontally polarized half-wave dipole antennas as recommended by the Standard ANSI-IEEE C 63-5-2017 [18]. Tx antenna is resonant with a radiation resistance: Using the equation [7] of Standard C 63-5-2004, [18]. the result is found to be:AF 50 = 10logf M Hz ? 24.46 + 1/2[E iM + A w]. AF 50 = 14.77?24.46+1/2[?4.11+18.70] = ?2.40 [dB/m].

The result is exactly the same as obtained by the Rx antenna factor AF R50 so it cannot be used for the Tx antenna factor AF T 50 because it has a different value. In this case two identical antennas has been used and this equation [7] cannot solve the problem. The Federal Communication Commission (F.C.C.) are giving an equation to calculate the transmitting or receiving antenna factor if the far field distance is fulfilled (Z w = Z oo = 120?) and for R L = 50?. In EMC activities this task is generally not achieved because the distance r or the antenna height H R over ground is not large enough. At the frequency of f = 30M Hz this distance it is not really achieved to fulfill the intrinsic impedance but quite close to it (Z w = 350.7(?)). However, this equation is calculated by the radio link obtained results, thus:AF 50F CC = 20log f M Hz ? 29.78 ? 10log g R [dB/m] AF R50F CC = 29.54 ? 29.78 ? 1.85 = -2.09 [dB/m] AF T 50F CC = 29.54 ? 29.78 ? 2.08 = -2.32 [dB/m]

The small difference in the Tx and Rx antenna factors are due to the Z w ? = Z oo . In order to check the performed procedure, the power budget obtained by the Friis Equation [1], valid also over perfect ground, is checked. The results are presented for the frequency of f= 30 MHz. They also are fulfilling the Friis Equation at any frequency in the spectrum of 30 to 1000 MHz as were checked accordingly. Verification of the radio link behaviour is performed by the power budget of the Friis Equation [1] and the Power Reciprocity Principle by Schelkunoff and Friis [3], [17], thus: Friis Equation for f= 30 MHz calculation Power Reciprocity Principle for f= 30 MHz according to Schelkunoff and Friis is also perfectly well fulfilled, or:G T + G R = A w ? A F S [dB]. G T + G R = 2.A eT g T = 12.81 1.61 = 7.96**(4)**A eR g R = 12.17 1.53 = 7.96**(5)**

Using the same procedure for all the frequencies in the spectrum from 30 MHz to 1000 MHz the results are presented in table I and table II. Only some frequencies are presented in these tables.

Calculation of several frequencies for the radio link of H T = 2[m] and r = 10[m] along the spectrum from 30 to 1000 MHz are presented in Figure **??**, Figure **??** and Figure 4.

The transmission loss or site attenuation A w results are located on a straight line as plotted for the logaritmic of frequency. A deviation is shown in the lower part of the spectrum where the transmitting antenna (Tx) height (H T) do not permit to get its maximum radiation between antennas in the radio link. This effect can be avoided increasing the Tx antenna height. At the same time, the perfect far field is really not achieved and for this reason the Rx antenna gain is not exactly 2.15 dBi. However, the conditions of far field are quite close if the maximum radiation is fulfilled. The wave impedance are presented in the table II permitting to know its value. Perfect far field corresponds when the wave impedance is exactly the space intrinsic impedance orZ w = Z oo = 120? ? = 377[?].

The plot of the antenna factors have a difference close to 6 dB when the Tx antenna can develop the maximum radiation. The normalized site attenuation (NSA) is also located on a straight line as plotted for the logaritmic of frequency. This is very important to take it into account.

If the radio link distance r between antennas is increased it is important to determine its results because as distance is increased the Tx antenna elevation angle decreases and the far field conditions are obtained at a larger distance.

Here a calculation can be seen for the Tx antenna height At the same time, all the results for several frequencies in the radio link of H T = 4[m] and r = 30[m] along the spectrum from 30 to 1000 MHz are presented in Figure **??**, Figure **??** and Figure 7. Here, also, the site attenuation must be on a straight line but at lower frequencies it has a deviation if the Tx antenna height is not at the proper height H T . This effect is avoided if the Tx antenna is at larger heights as shown here in Figure **??**.

An additional calculation is performed for a radio link with a distance r = 10 Far field do only depends on distance r like in free space. Over a ground plane a radio link has a far field strongly dependent of the radiating elevation angle ? L from the Tx antenna. For this reason in Figure 11, Figure 12 and Figure 13 Measurement value minimum as shown in Figure 14. This effect is also visible on the Rx antenna gain G R in Figure 15. However, no effect in the Rx antenna factor AF R50 is shown in Figure 16. In this case the Rx antenna factor is independent of the distance r like the effective length L eR . This constant antenna factor do not occur for the Tx antenna because it is strongly dependent on the Tx antenna gain (G T) according to the Rx antenna height (H R). In the Tx antenna radiation pattern the minimum between lobes in the far field distance r' is obtained at more than 100 wavelengths. For this reason far field Rx antenna gain (G R) and effective area (A eR) values are practically very difficult to be achieved. These parameters are shown here to be really dependent Measurement needs an antenna range in order to verify the antenna parameters. To determine antenna gains the antenna range needs a proper site to fulfill the far field distance. This task is difficult to achieve at the lower frequencies between 30 and 100 MHz because the wave impedance must achieve a value very close or exactly Z w = Z oo = 120? ? = 377?. It was determined here that this value depends not only of the distance r but also by the elevation angle ? L of the Tx radiation pattern. Year 2021 ersion I of the far field condition or when the wave impedance isZ w = Z oo = 120? (?).

This task was practically achieved very closely with an anechoic chamber of INTI, Buenos Aires, Argentina. This chamber was used in order to verify the antenna factor of a Rohde und Schwarz precision half-wave dipole antennas model HZ-12 [19]. The useful range of these antennas is between 30 and 300 MHz and recommended for horizontal polarization [18]. I R = W R R L 1/2 = 5.36E ? 3 [A]**(6)**

Rx antenna load voltage V R results in:V R = (W R R L) 1/2 = 3.91E ? 1 [A]**(7)**

Induced Voltage on the Rx antenna V i results in:V i = 2 V R = 7.82E ? 1 [V]

Rx antenna effective length:L eR = ? ? = 6.37 m]**(8)**

Incoming electric field E i results in:E i = V i L eR = 1.23 [V /m]**(9)**

Incoming power density P i results in:P i = E 2 i Z oo = 4.002E ? 3 [W/m 2] (**10**)

Rx antenna effective area A eR results in:A eR = W R P i = 5.23E ? 1 [m 2] (**11**)

Rx antenna numerical gain g R :g R = 4? A eR ? 2 = 1.64**(12)**

Rx antenna gain G R = 2. **??**6 [dBi] Friis equation permits to know the true Tx antenna gain G T , thus:G T = K ? G R = 9.47 ? 2.16 = 7.31 [dBi]**(13)**

Tx antenna numerical gain g T = 5.38.

Checking the Tx antenna gain at the distance r :g T = 4 ? (r') 2 P i = 5.38**(14)**

Tx antenna gain G T = 7.31 [dBi] was calculated correctly.

Rx antenna factor aF R73 results in: It can be seen here that the Friis Power Budget is perfectly fulfilled. Tx antenna effective area A eT :aF R73 = E i V R = 3.14 [1/m]**(15**A eT = g T ? 2 4 ? = 1.71 [m 2] (**25**)

Applying the Schelkunoff and Friis Power Reciprocity Principle:A eT g T = 3.18E ? 1 (26) A eR g R = 3.18E ? 1 (27)

The Power Reciprocity Principle is also fulfilled. For this measurement it was supposed that the wave impedance Z w = Z oo = 120? or at the real far field. Calculation with the same radio link geometry are giving a wave impedance Z w = 382 [?]. This value is very close to the real far field for the radiation maximum of the Tx antenna at the elevation angle ? L = 15[?], and its result error is negligible. Other possible difference could be using the radiation resistance of both antenna as 73 ?. In this case if the mismatch is lower than 1.5 in VSWR the mismatching losses could produce an error lower than 0.2 dB. In order to make the task more complete measurements were performed at several Rx antenna heights and simulated at the same Rx heights. These results are compared in table VII, table VIII and table IX. Results are also presented in Figure 17

3 Conclusions

In conclusion it was found to be correct the power gain and antenna factor from Rohde und Schwarz model HZ-12 antenna manual [19]. Rx antenna factor as well its effective length are parameters not depending on the far field of the electromagnetic waves. It was determined that the effective length depends from the current distribution on its physical structure but if the current distribution is unknown it can be determined by the relation between the induced voltage V i at open circuit on the Rx antenna and the incoming field E i [14]. Simulation and measurements are confirming this statement. This relation is valid in near and far field and it produces always the same results. Rx antenna factor is also independent of its height over ground and distance because it operates practically like in free space. For this reason a half-wave dipole antenna can be adopted as a natural standard sensor useful to calibrate any other antenna at any frequency between 30 and 1000 MHz [11]. On the contrary, the Tx antenna factor is not constant and depends on its gain over perfect ground considering it is an array of two elements [2], [3], [6], the actual antenna and its image. Of course its factor is different as well the gain from that of the Rx antenna as was shown in this paper results [8]. Rx antenna gain G R and effective area A eR are far field parameters and they acquire the proper value when the wave impedance is Z w = Z oo = 120?. In this paper it was clearly obtained the Rx antenna factor AF R50 with exactly the same value in any radio link for several distance r and for any Tx antenna height H T using the relation E i /V R . Main Friis equation is useful and valid over perfect ground [1], as was perfectly demostated and it gives a perfect power budget between losses (A w , A F S) and gains (G R , G T). No additional factors are needed, as was published [12], [21], but only the true gains (G R , G T) as was determined here. Also with these results, the reciprocity power principle (A eT /g T = A eR /g R) is fulfilled according to Schelkunoff and Friis [3]. The transmitting antenna is a simple devise and it only needs to radiate the EM energy in the surrounding space. Receiving antenna is a more complex device because it needs to operate in two roles, the receiving role and the retransmitting or scattering role. For this reason, in a radio link with two identical half wave dipole antennas in horizontal polarization, the theoretical transmitting antenna gain is G T = 8.15[dBi], the receiving antenna gain is G R = 2.15[dBi] and the scattering gain is G s = 5.15 **??**dBi]. The effective receiving area A eR is the relation between the power received W R and the incoming power density P i . The scattering effective area A es , according to Friis, is the product between the isotropic source area and the scattering numerical gain g s . The gain difference between the transmitting antenna gain G T and the receiving antenna gain G R is really 6 dB, according to calculations and measurements. [1]

---

[1] ( ) F © 2021 Global Journals

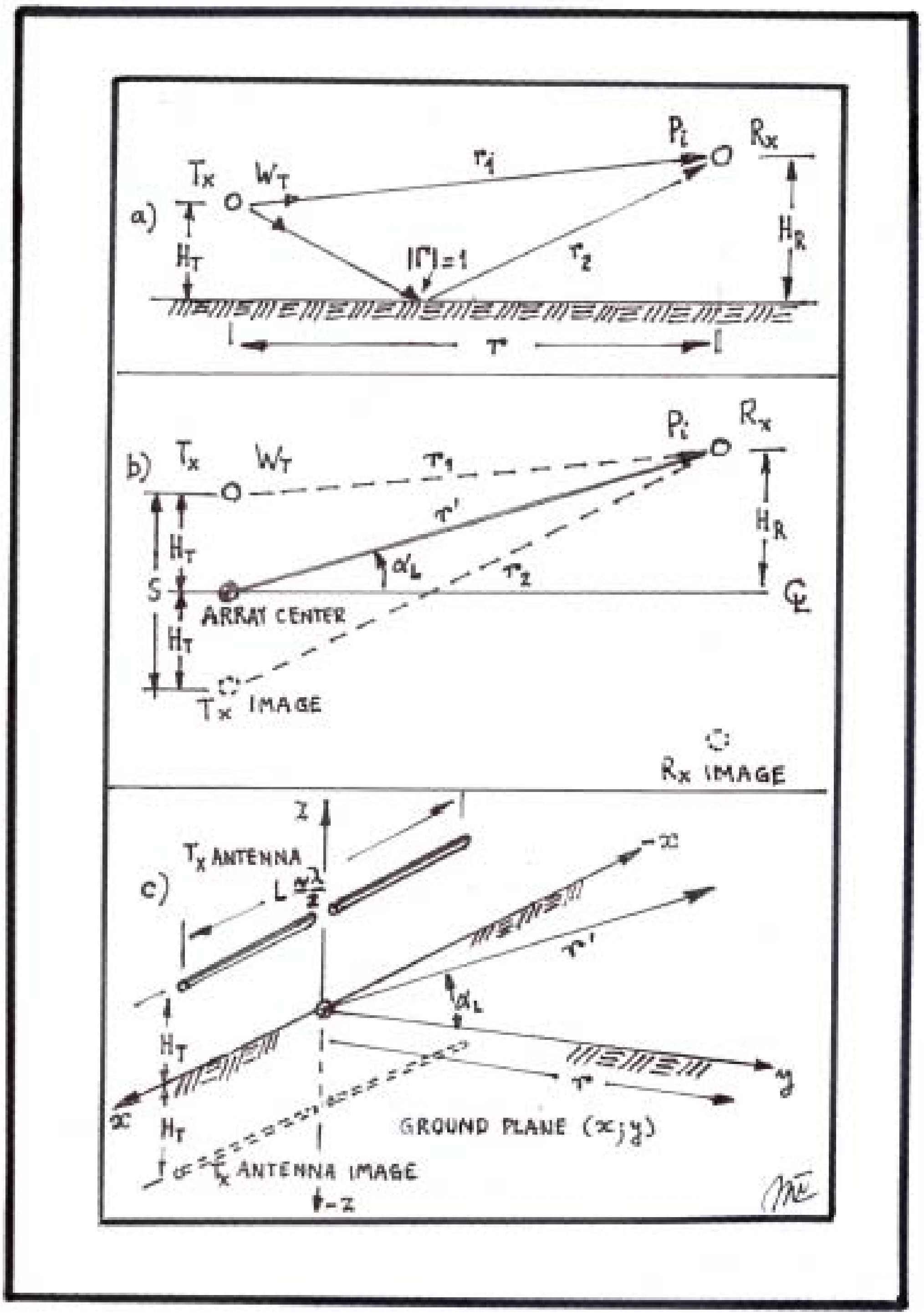
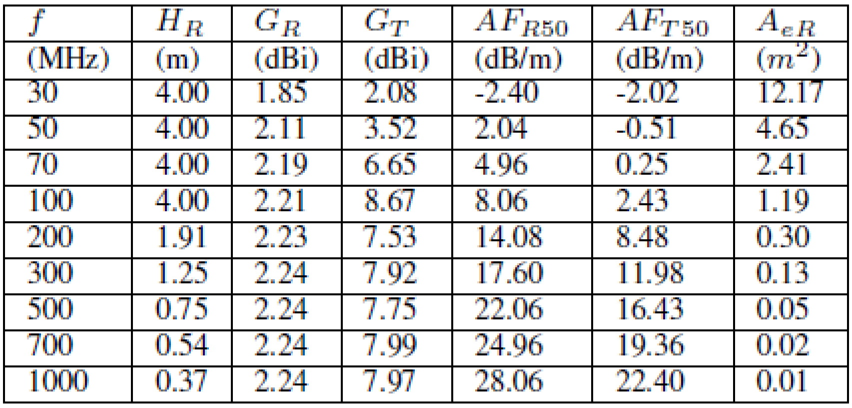

a)
Tx
W_T
r_1
P_L
Rx
H_T
H_R
|Γ|=1
r_2
r
b)
Tx
W_T
r_1
P_L
R_x
H_T
H_R
S
r'
α_L
r_2
ARRAY CENTER
℄
H_T
Tx IMAGE
Rx IMAGE
c)
z
Tx ANTENNA
L ≈λ/2
x
r'
α_L
H_T
x
H_T
r
y
GROUND PLANE (x;y)
Tx ANTENNA IMAGE
-z

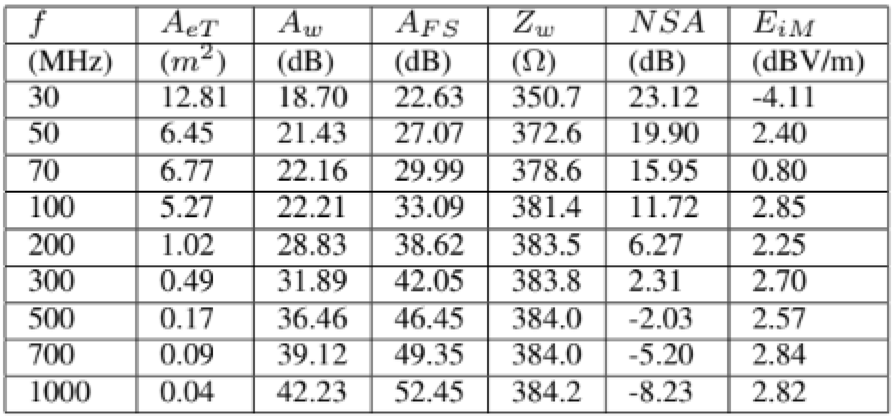
Figure 1:



f	H_R	G_R	G_T	AF_{R50}	AF_{T50}	A_{eR}
(MHz)	(m)	(dBi)	(dBi)	(dB/m)	(dB/m)	(m^2)
30	4.00	1.85	2.08	-2.40	-2.02	12.17
50	4.00	2.11	3.52	2.04	-0.51	4.65
70	4.00	2.19	6.65	4.96	0.25	2.41
100	4.00	2.21	8.67	8.06	2.43	1.19
200	1.91	2.23	7.53	14.08	8.48	0.30
300	1.25	2.24	7.92	17.60	11.98	0.13
500	0.75	2.24	7.75	22.06	16.43	0.05
700	0.54	2.24	7.99	24.96	19.36	0.02
1000	0.37	2.24	7.97	28.06	22.40	0.01

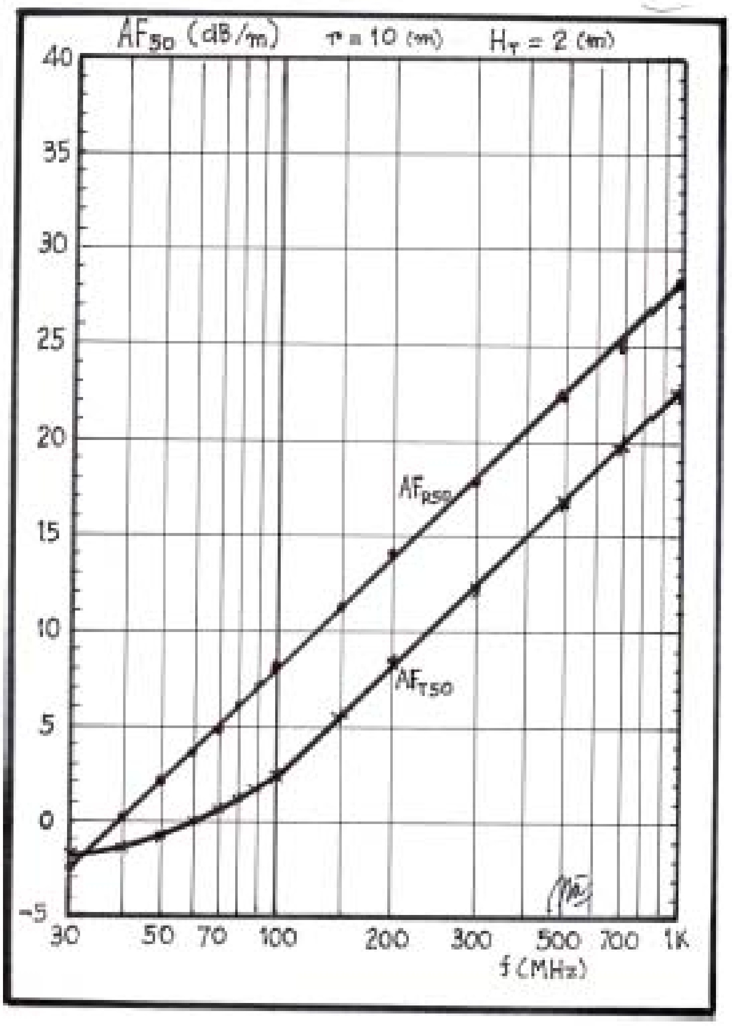
1

Figure 2: Figure 1 :



f	A_{eT}	A_w	A_{FS}	Z_w	NSA	E_{iM}
(MHz)	(m^2)	(dB)	(dB)	(Ω)	(dB)	(dBV/m)
30	12.81	18.70	22.63	350.7	23.12	-4.11
50	6.45	21.43	27.07	372.6	19.90	2.40
70	6.77	22.16	29.99	378.6	15.95	0.80
100	5.27	22.21	33.09	381.4	11.72	2.85
200	1.02	28.83	38.62	383.5	6.27	2.25
300	0.49	31.89	42.05	383.8	2.31	2.70
500	0.17	36.46	46.45	384.0	-2.03	2.57
700	0.09	39.12	49.35	384.0	-5.20	2.84
1000	0.04	42.23	52.45	384.2	-8.23	2.82

Figure 3:



1

Figure 4: Table 1 :

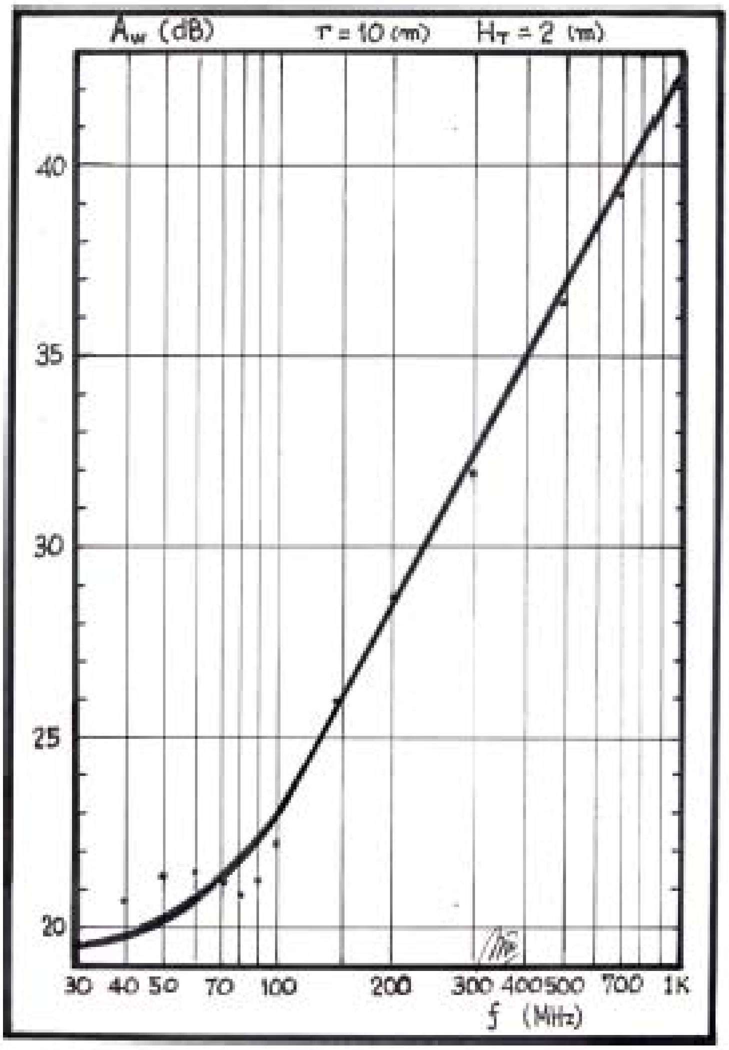

A_w (dB)
r = 10 (m)
H_T = 2 (m)
40
35
30
25
20
30
40
50
70
100
200
300
400
500
700
1K
f (MHz)

Figure 5:

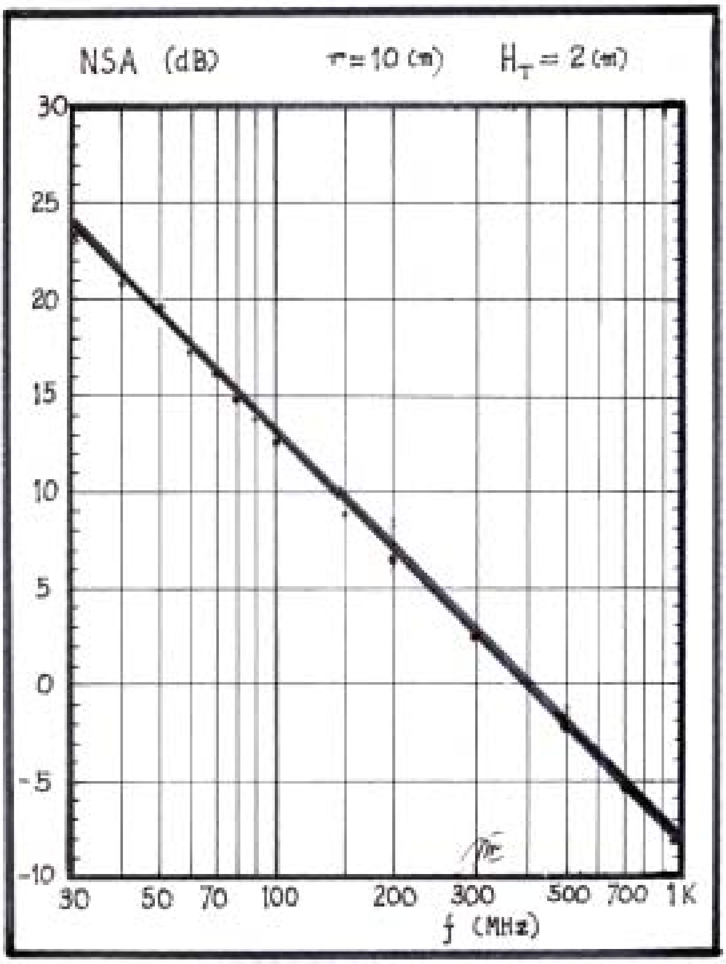
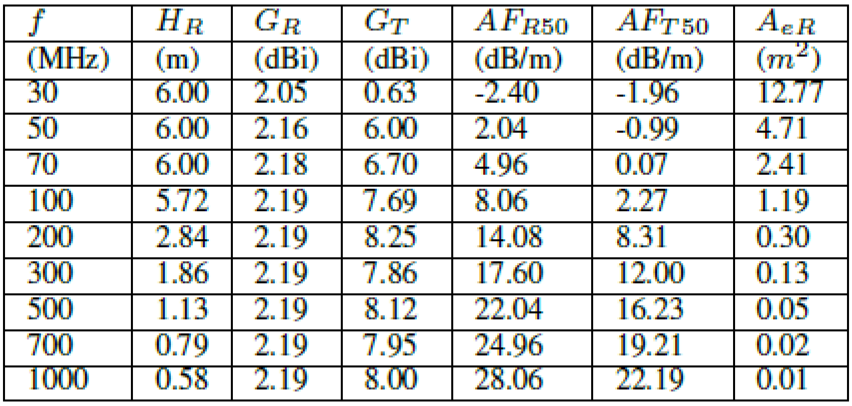


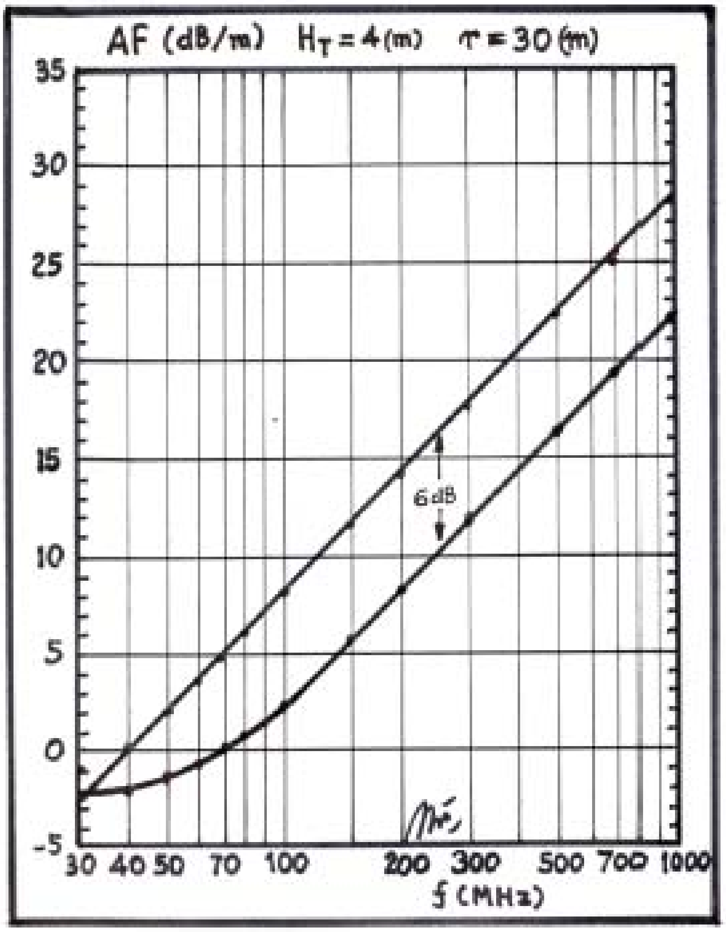
Figure 6:

23



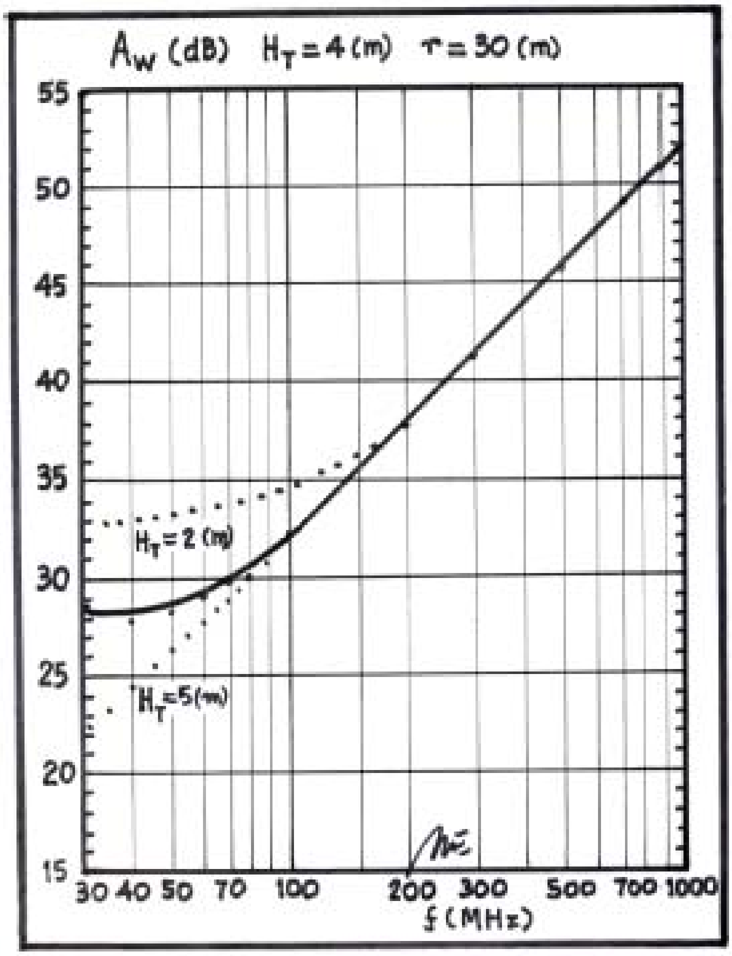
f	H_R	G_R	G_T	AF_{R50}	AF_{T50}	A_{eR}
(MHz)	(m)	(dBi)	(dBi)	(dB/m)	(dB/m)	(m^2)
30	6.00	2.05	0.63	-2.40	-1.96	12.77
50	6.00	2.16	6.00	2.04	-0.99	4.71
70	6.00	2.18	6.70	4.96	0.07	2.41
100	5.72	2.19	7.69	8.06	2.27	1.19
200	2.84	2.19	8.25	14.08	8.31	0.30
300	1.86	2.19	7.86	17.60	12.00	0.13
500	1.13	2.19	8.12	22.04	16.23	0.05
700	0.79	2.19	7.95	24.96	19.21	0.02
1000	0.58	2.19	8.00	28.06	22.19	0.01

Figure 7: Figure 2 :Figure 3 :



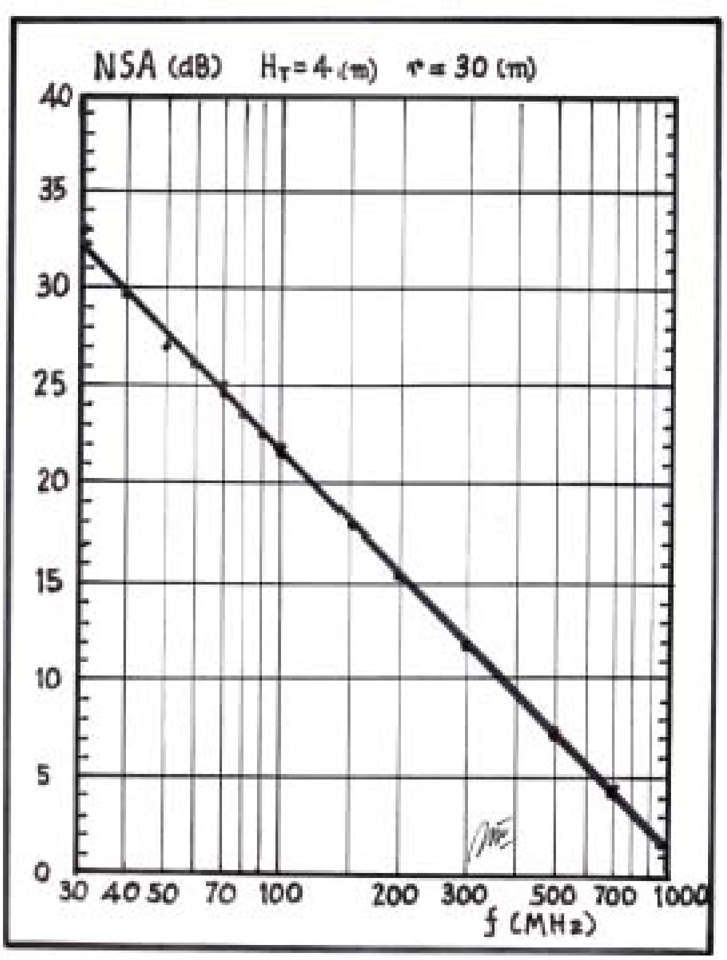
4

Figure 8: Figure 4 :



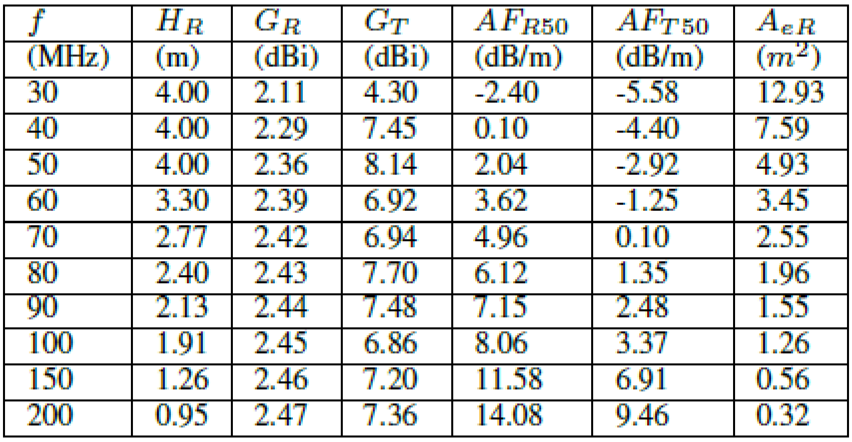
4

Figure 9: Table 4 :



56

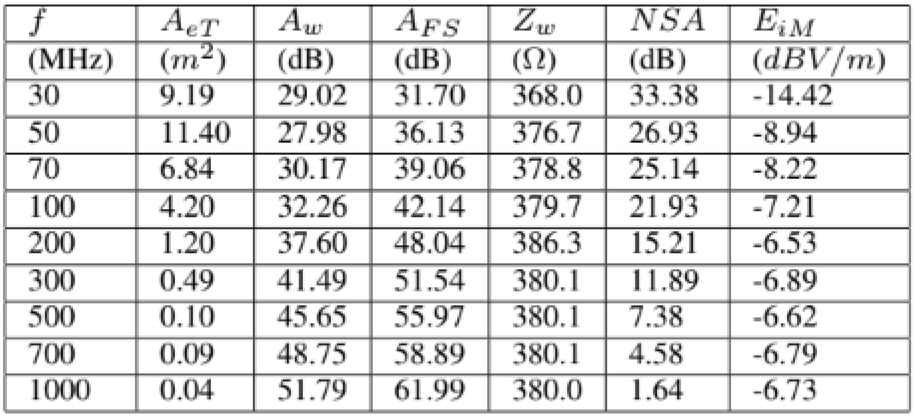
Figure 10: Figure 5 :Figure 6 :



f (MHz)	H_R (m)	G_R (dBi)	G_T (dBi)	AF_{R50} (dB/m)	AF_{T50} (dB/m)	A_{eR} (m^2)
30	4.00	2.11	4.30	-2.40	-5.58	12.93
40	4.00	2.29	7.45	0.10	-4.40	7.59
50	4.00	2.36	8.14	2.04	-2.92	4.93
60	3.30	2.39	6.92	3.62	-1.25	3.45
70	2.77	2.42	6.94	4.96	0.10	2.55
80	2.40	2.43	7.70	6.12	1.35	1.96
90	2.13	2.44	7.48	7.15	2.48	1.55
100	1.91	2.45	6.86	8.06	3.37	1.26
150	1.26	2.46	7.20	11.58	6.91	0.56
200	0.95	2.47	7.36	14.08	9.46	0.32

7

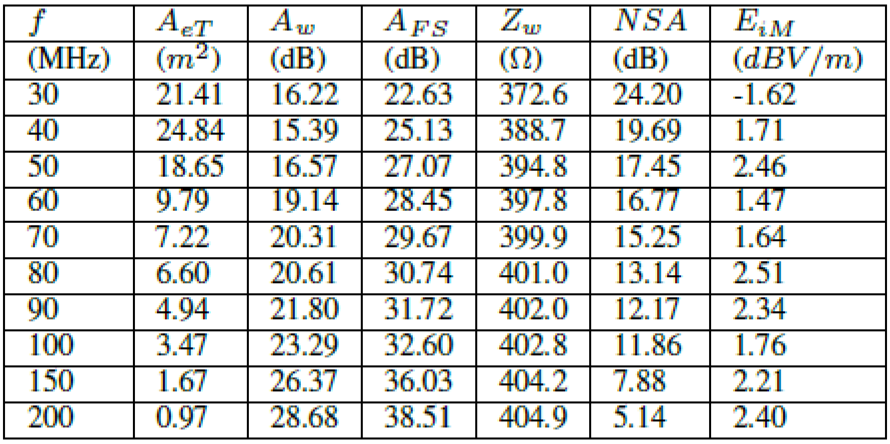
Figure 11: Figure 7 :



f	A_{eT}	A_w	A_{FS}	Z_w	NSA	E_{iM}
(MHz)	(m^2)	(dB)	(dB)	(Ω)	(dB)	(dBV/m)
30	9.19	29.02	31.70	368.0	33.38	-14.42
50	11.40	27.98	36.13	376.7	26.93	-8.94
70	6.84	30.17	39.06	378.8	25.14	-8.22
100	4.20	32.26	42.14	379.7	21.93	-7.21
200	1.20	37.60	48.04	386.3	15.21	-6.53
300	0.49	41.49	51.54	380.1	11.89	-6.89
500	0.10	45.65	55.97	380.1	7.38	-6.62
700	0.09	48.75	58.89	380.1	4.58	-6.79
1000	0.04	51.79	61.99	380.0	1.64	-6.73

589

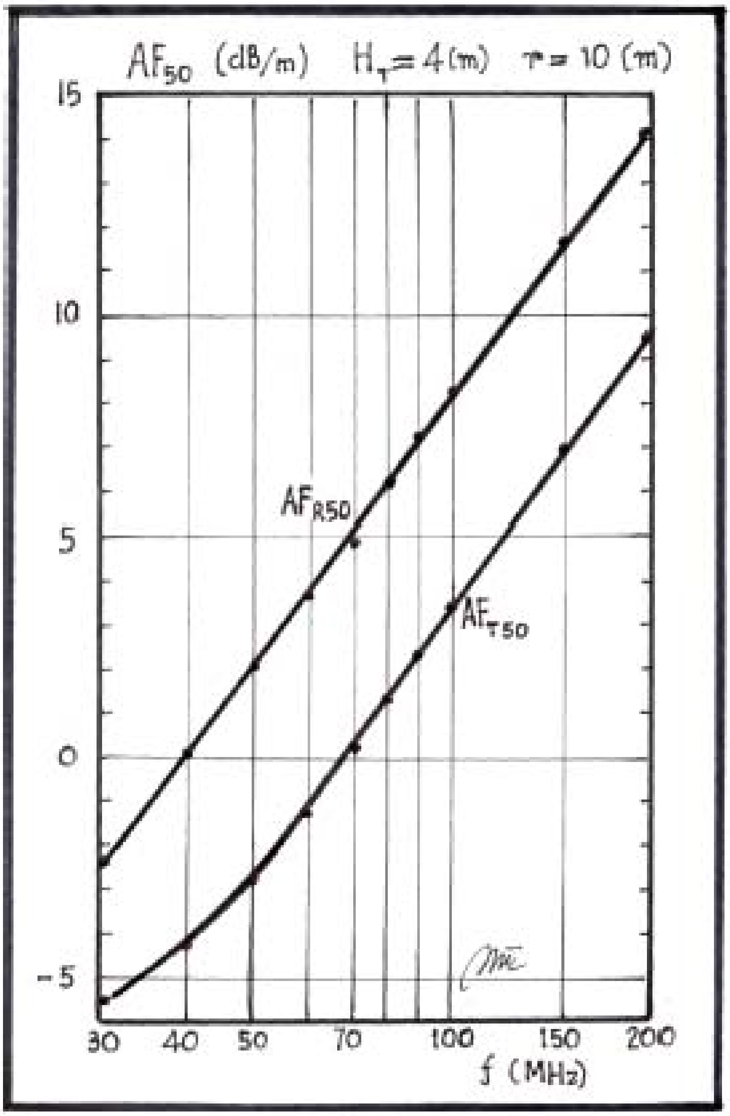
Figure 12: Table 5 :Figure 8 :Figure 9 :



f	A_{eT}	A_w	A_{FS}	Z_w	NSA	E_{iM}
(MHz)	(m^2)	(dB)	(dB)	(Ω)	(dB)	(dBV/m)
30	21.41	16.22	22.63	372.6	24.20	-1.62
40	24.84	15.39	25.13	388.7	19.69	1.71
50	18.65	16.57	27.07	394.8	17.45	2.46
60	9.79	19.14	28.45	397.8	16.77	1.47
70	7.22	20.31	29.67	399.9	15.25	1.64
80	6.60	20.61	30.74	401.0	13.14	2.51
90	4.94	21.80	31.72	402.0	12.17	2.34
100	3.47	23.29	32.60	402.8	11.86	1.76
150	1.67	26.37	36.03	404.2	7.88	2.21
200	0.97	28.68	38.51	404.9	5.14	2.40

11

Figure 13: Figure 11 :



10

Figure 14: Figure 10 :

12

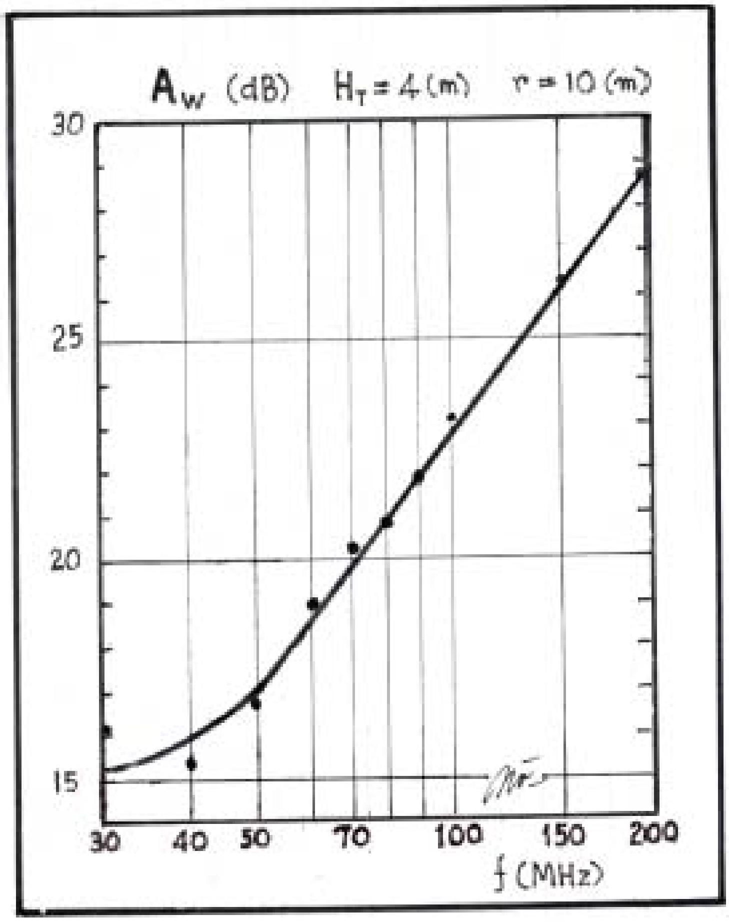
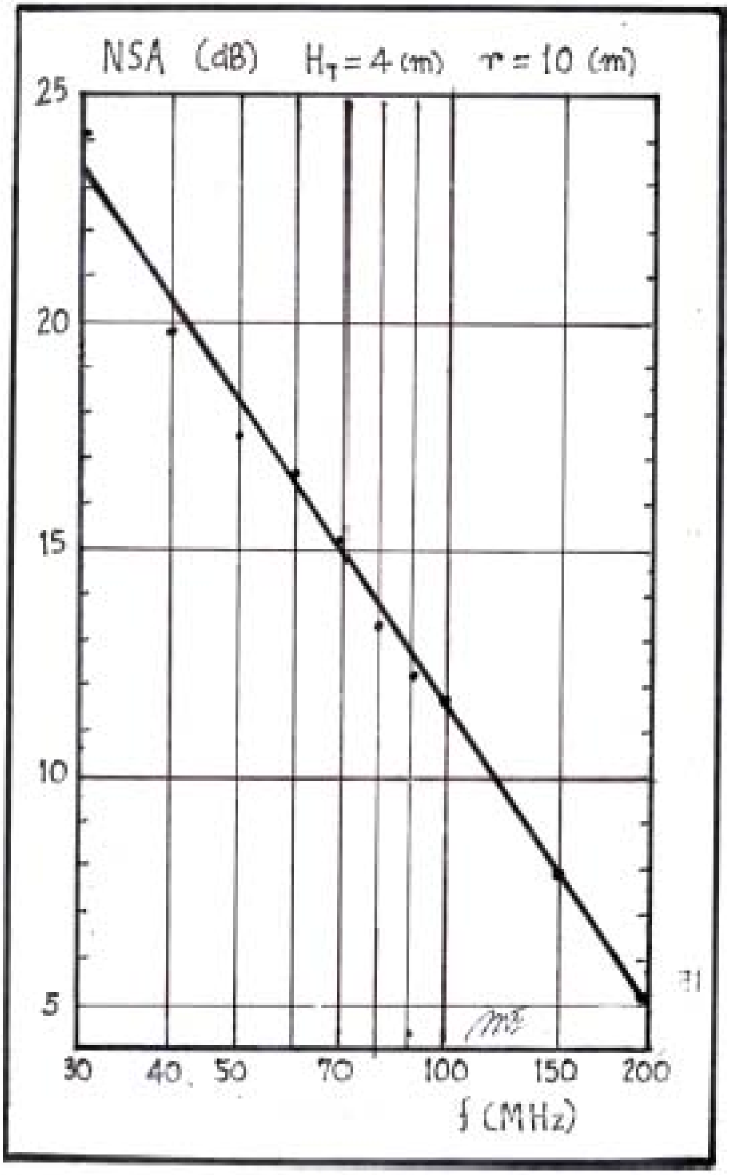
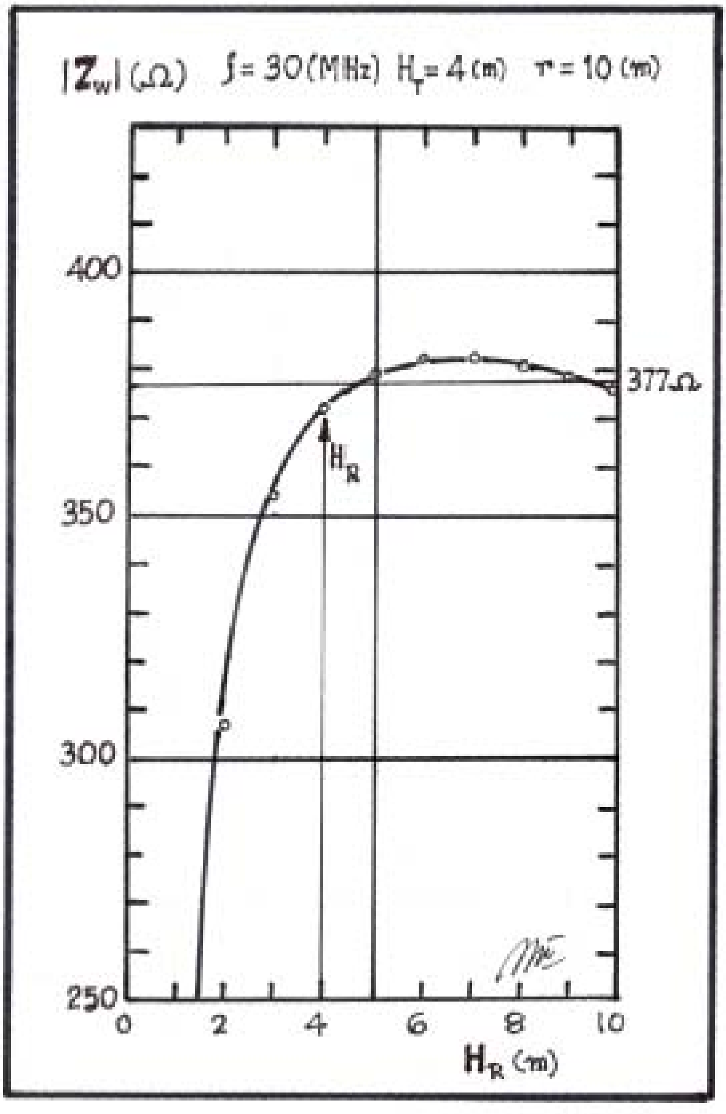


Figure 15: Figure 12 :



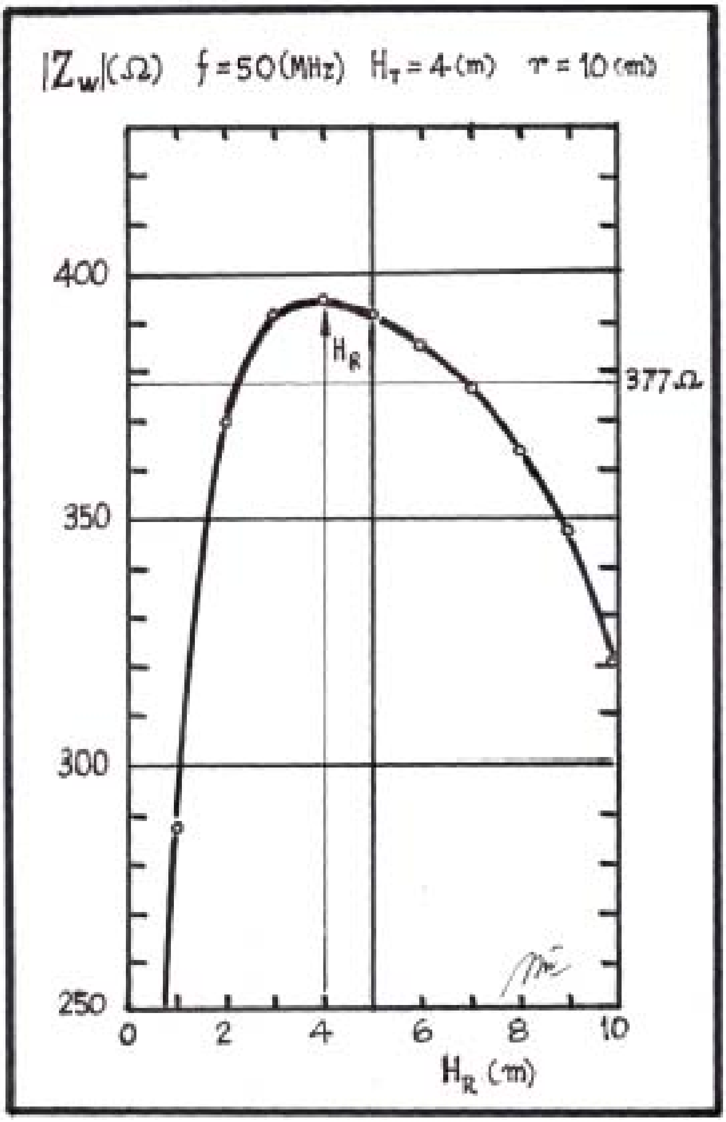
13

Figure 16: Figure 13 :



15

Figure 17: Figure 15 :



14

Figure 18: Figure 14 :

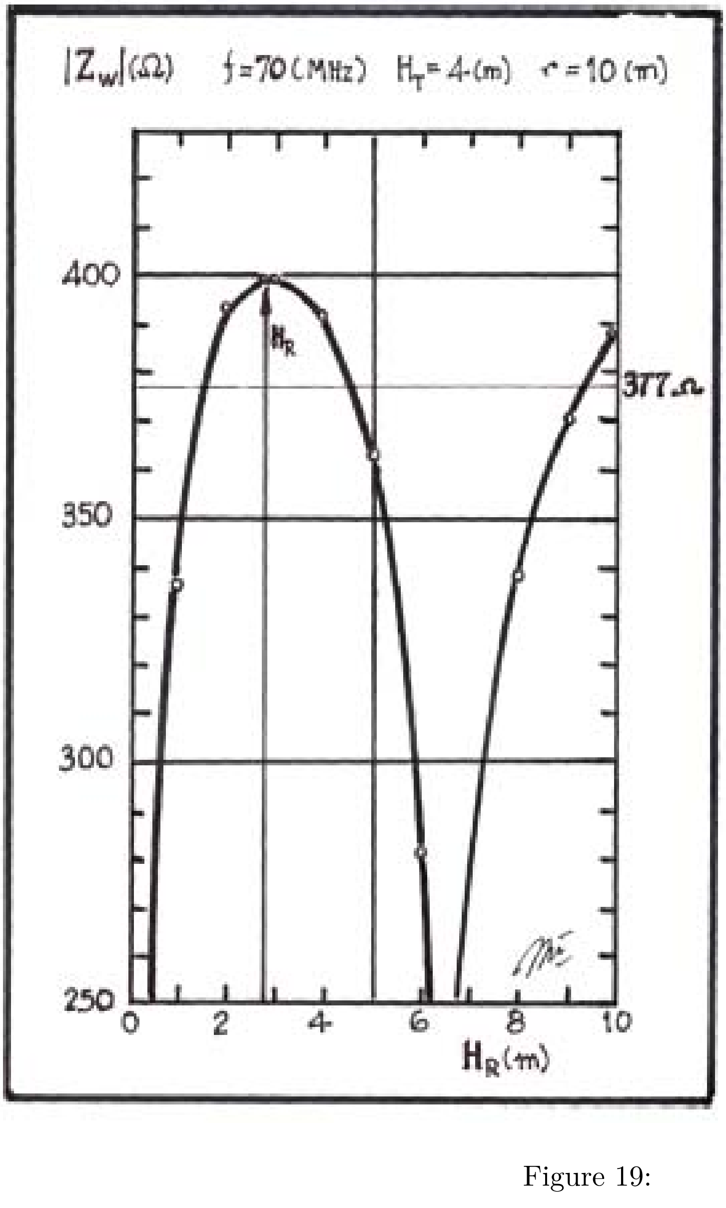


Figure 19:

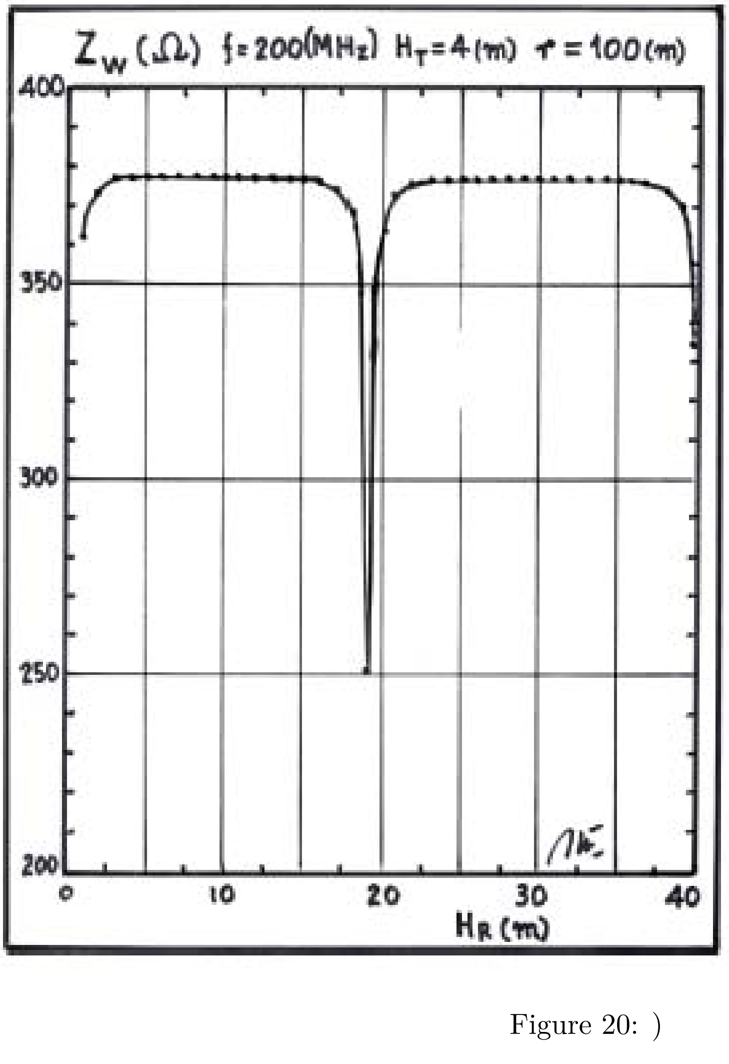
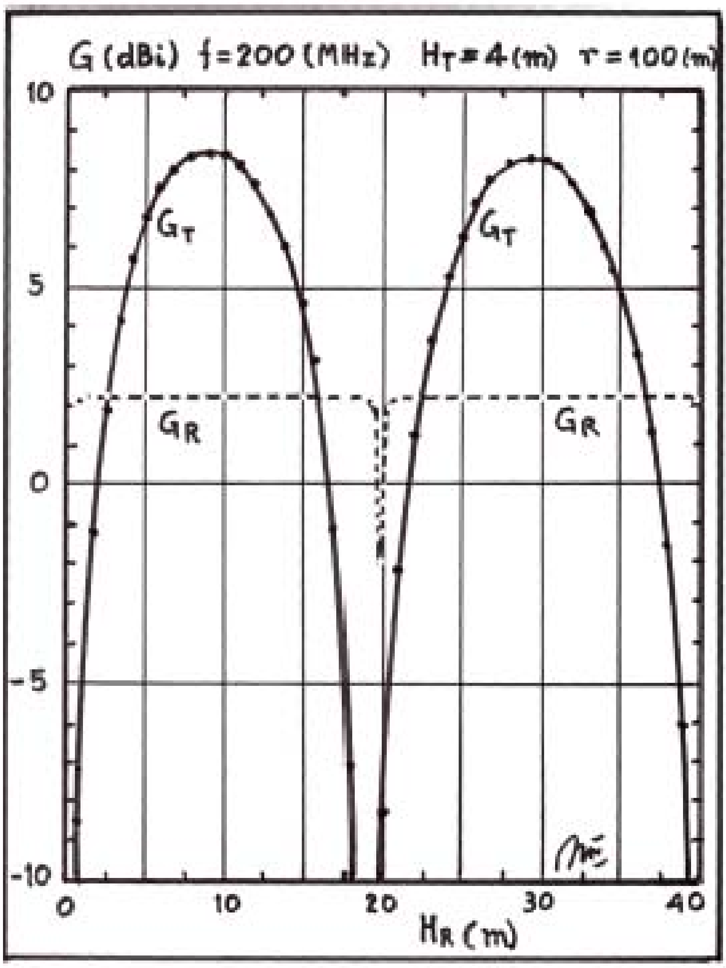
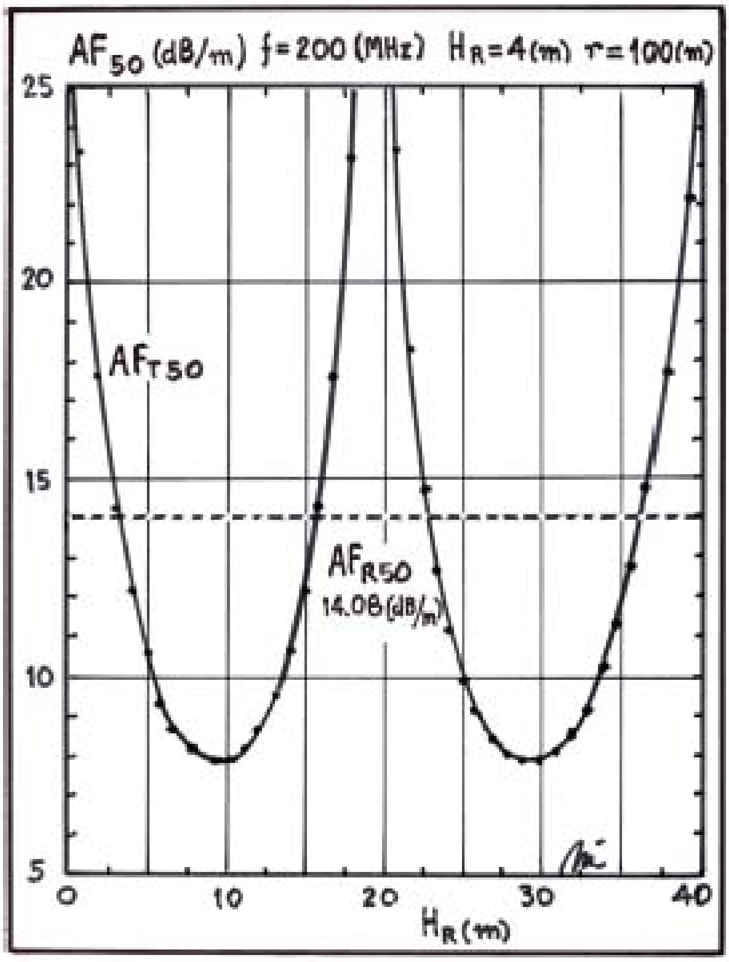

Z_W (Ω) f=200(MHz) H_T=4(m) r=100(m)
400
350
300
250
200
0
10
20
30
40
H_R (m)

Figure 20:)



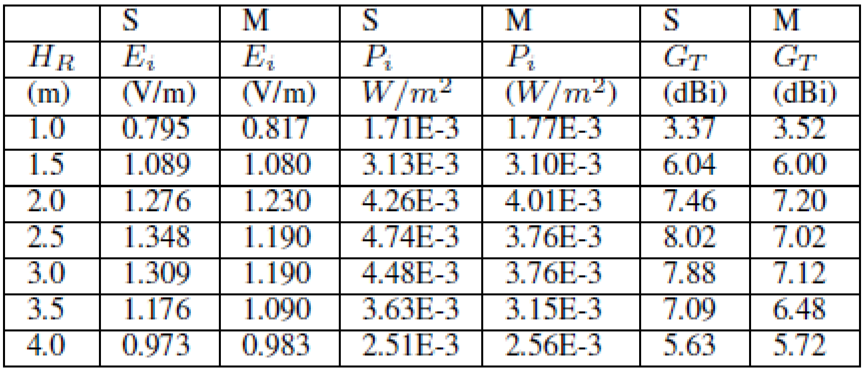
1617

Figure 21: Figure 16 : 17)



789

Figure 22: Table 7 :Table 8 :Table 9 :

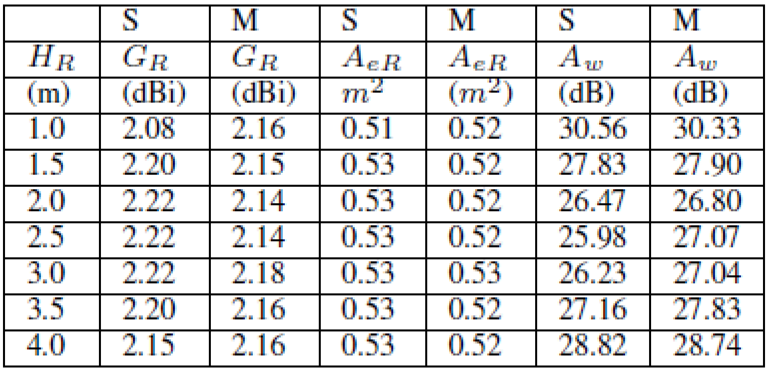


	S	M	S	M	S	M
H_R	E_i	E_i	P_i	P_i	G_T	G_T
(m)	(V/m)	(V/m)	W/m^2	(W/m^2)	(dBi)	(dBi)
1.0	0.795	0.817	1.71E-3	1.77E-3	3.37	3.52
1.5	1.089	1.080	3.13E-3	3.10E-3	6.04	6.00
2.0	1.276	1.230	4.26E-3	4.01E-3	7.46	7.20
2.5	1.348	1.190	4.74E-3	3.76E-3	8.02	7.02
3.0	1.309	1.190	4.48E-3	3.76E-3	7.88	7.12
3.5	1.176	1.090	3.63E-3	3.15E-3	7.09	6.48
4.0	0.973	0.983	2.51E-3	2.56E-3	5.63	5.72

17

Figure 23: Figure 17 :

18



	S	M	S	M	S	M
H_R	G_R	G_R	A_{eR}	A_{eR}	A_w	A_w
(m)	(dBi)	(dBi)	m^2	(m^2)	(dB)	(dB)
1.0	2.08	2.16	0.51	0.52	30.56	30.33
1.5	2.20	2.15	0.53	0.52	27.83	27.90
2.0	2.22	2.14	0.53	0.52	26.47	26.80
2.5	2.22	2.14	0.53	0.52	25.98	27.07
3.0	2.22	2.18	0.53	0.53	26.23	27.04
3.5	2.20	2.16	0.53	0.52	27.16	27.83
4.0	2.15	2.16	0.53	0.52	28.82	28.74

Figure 24: Figure 18 :

.1 Acknowledgments

I would like to express my appreciation to Ramiro Alonso, Walter Gustavo Fano and Lucas Gonzalez for the written version and computational support. Also support from INTI personnel Edmundo Gatti, Luciano Blas and Matias Fernandez is very much appreciated.

[D (1959)] , D . July-Aug. 1959. p. .

[American National Standard for Electromagnetic Compatibility Radiated Emission Measurements in Electromagnetic Interferenc *American National Standard for Electromagnetic Compatibility Radiated Emission Measurements in Electromagnetic Interference (EMI) control Calibration and Qualification of Antennas (9 kHz to 40 GHz*, 2017. p. . (revision of ANSI c 63-5-2005)

[Trainotti (2018)] ‘Antenna Characteristics Over Perfect Ground’. V Trainotti . *IEEE EMC Magazine* Dec. 2018. 7 p. .

[Scott (1986)] ‘Bennett Properly Applied Antenna Factors’. W S Scott . *IEEE Transaction on EMC* Feb. 1986. 28 p. .

[Smith et al. (1982)] ‘Calculation of Site Attenuation from Antenna Factors’. A A Smith , R F German , J B Pate . *IEEE Transaction on EMC* Aug. 1982. 24 p. .

[Trainotti (2017)] ‘Electromagnetic Compatibility (ECM) Antenna Gain and Factor’. V Trainotti . *IEEE Trans. on EMC* Aug. 2017. 59 p. .

[Trainotti (2010)] ‘Figueroa Vertically Polarized Dipole and Monopoles, Directivity, Effective Height and Antenna Factors’. V Trainotti , G . *IEEE Trans. On Broadcasting* Sep. 2010. 56 p. .

N.B.S. Tech. Note 1098
(1986)]b10 *Fitzgerrell Linear Gain-Standard Antenna Below 1000 MHz*, RG
N.B.S. Tech. Note 1098 . May 1986. CODEN: NBTNAE

[RG (1986)] ‘Fitzgerrell Site Attenuation’. RG . *IEEE Transaction on EMC* Feb. 1986. 28 p. .

[HT (1946)] ‘Friis A Note on a Simple Transmission Formaula’. HT . *Proc. I.R.E* May. 1946. 34 p. .

[Schelkunoff ()] *Friis Antennas, Theory and Practice*, S A Schelkunoff , HT . 1952. N.Y.: Wiley and Sons.

[Thiele (2019)] ‘Friis Transmission over Ground Plane’. G A Thiele . *IEEE Antennas and Propagation Magazine* Feb. 2019. 61.

[Ames and Edson (1983)] ‘Gain, Capture Area and Transmission Loss for Grounded Monopoles and Elevated Dipoles. R:F: Design, Part I’. J W Ames , W A Edson . *Part II*, Nov.-Dec. 1983. Jan.-Feb. 1984.

[KA] ‘Norton System Loss in Radio Propagation’. KA . *Jour. Nat. Bur. of STD. Radio Propagation*

[Trainotti (2019)] ‘Radio Link and the Receiving Antenna Calibration over Perfect Ground’. V Trainotti . *Power Point IEEE International Symposium on EMC, Signal and Power Integrity*, (New Orleans, USA) Jul. 2019. Ernest N. Morial Convention Center. p. .

[Trainotti (2019)] ‘Radio Link Power Density and Antenna Factor’. V Trainotti . *IEEE Trans. on EMC* Feb. 2019. 61 (1) p. .

[Logan (1997)] ‘Rockway Dipole and Monopole Antenna Gain and Effective Area for Communication Formulas. Naval Command, Control and Ocean Surveillance Center’. J C Logan , JW . *Tech. Rpt* Sep. 1997. 1756 p. .

[Kolundzija and Ognjanovic ()] *Sarkar WIPL-D Software Electromagnetic Modeling of Composite Metallic and Dielectric Structures. Artech House*, B M Kolundzija , J S Ognjanovic , TK . 1999. Boston.

[Schwarz] Rohde Schwarz . *Precision Half Wave Dipole Set HZ-12 and HZ-13. Rohde Schwarz*, (Munich, Germany, POB 801469)

[Norton (1953)] ‘Transmission Loss in Radio Propagation’. K A Norton . *Proc. I.R.E* Jan. 1953. 41 p. .

[EA ()] *Wolff Antenna Analysis*, EA . 1966. Wiley and Sons, N.Y.