A Small Antenna for a Temporary Short Range LORAN System

John R. Pinks
Nautel

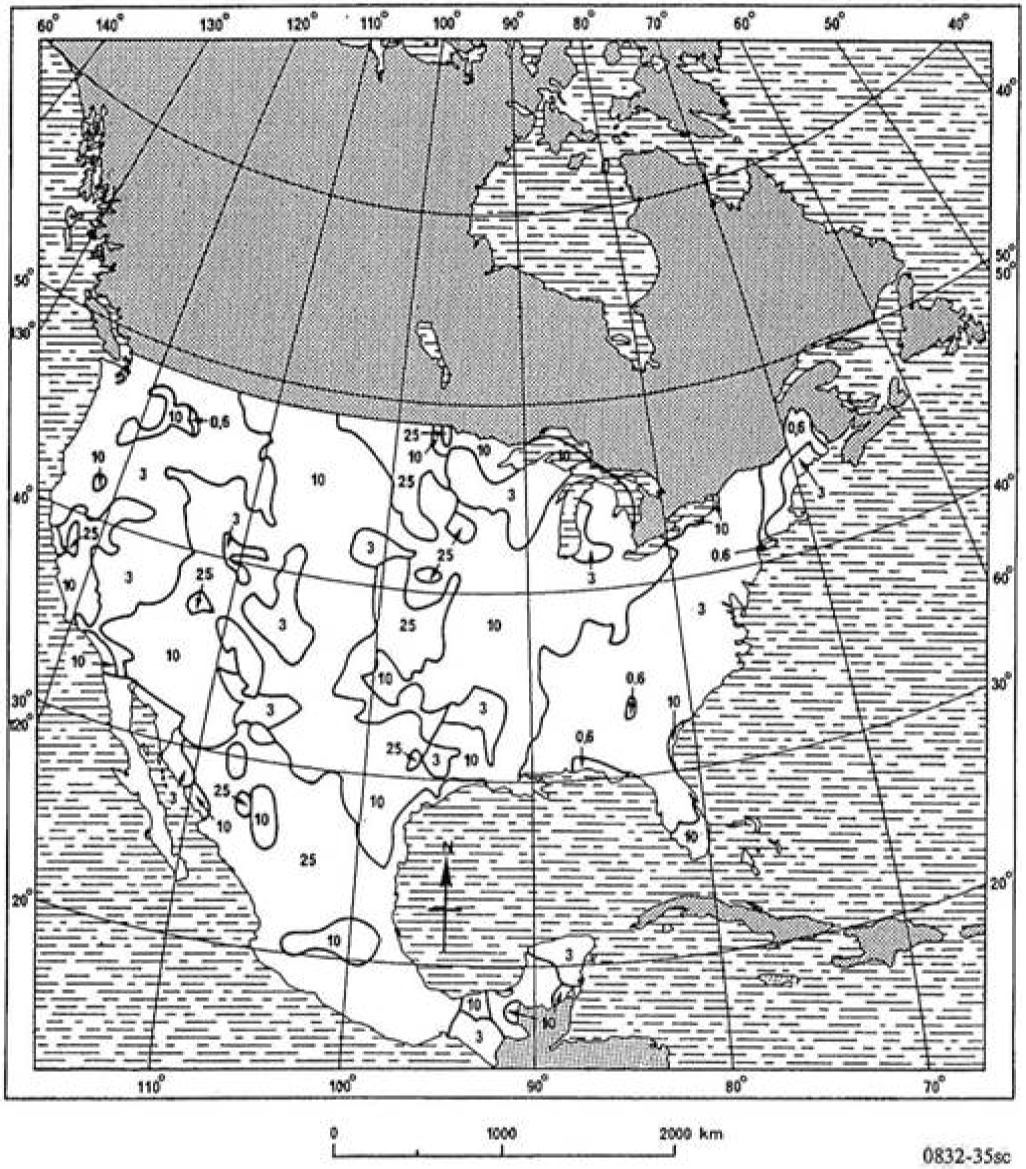
Required Level of Radiated Power

A field strength of +55dBuv/m is required at a range of 25 nautical miles

Ground-wave propagation is affected by ground conductivity.

ITU maps show conductivity throughout the World.

3 mS/m
in East USA



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ITU Propagation Curves show
Field Strength vs Range for Various Soil Conductivities.

Curves for 3mS/m Soil show a field strength at 100kHz of +76dBuv/m at 46 km for a radiated Power of 1 KW

Hence required Radiated Power for +55dBuv/m is 21 dB below 1 KW or 7.94 Watts

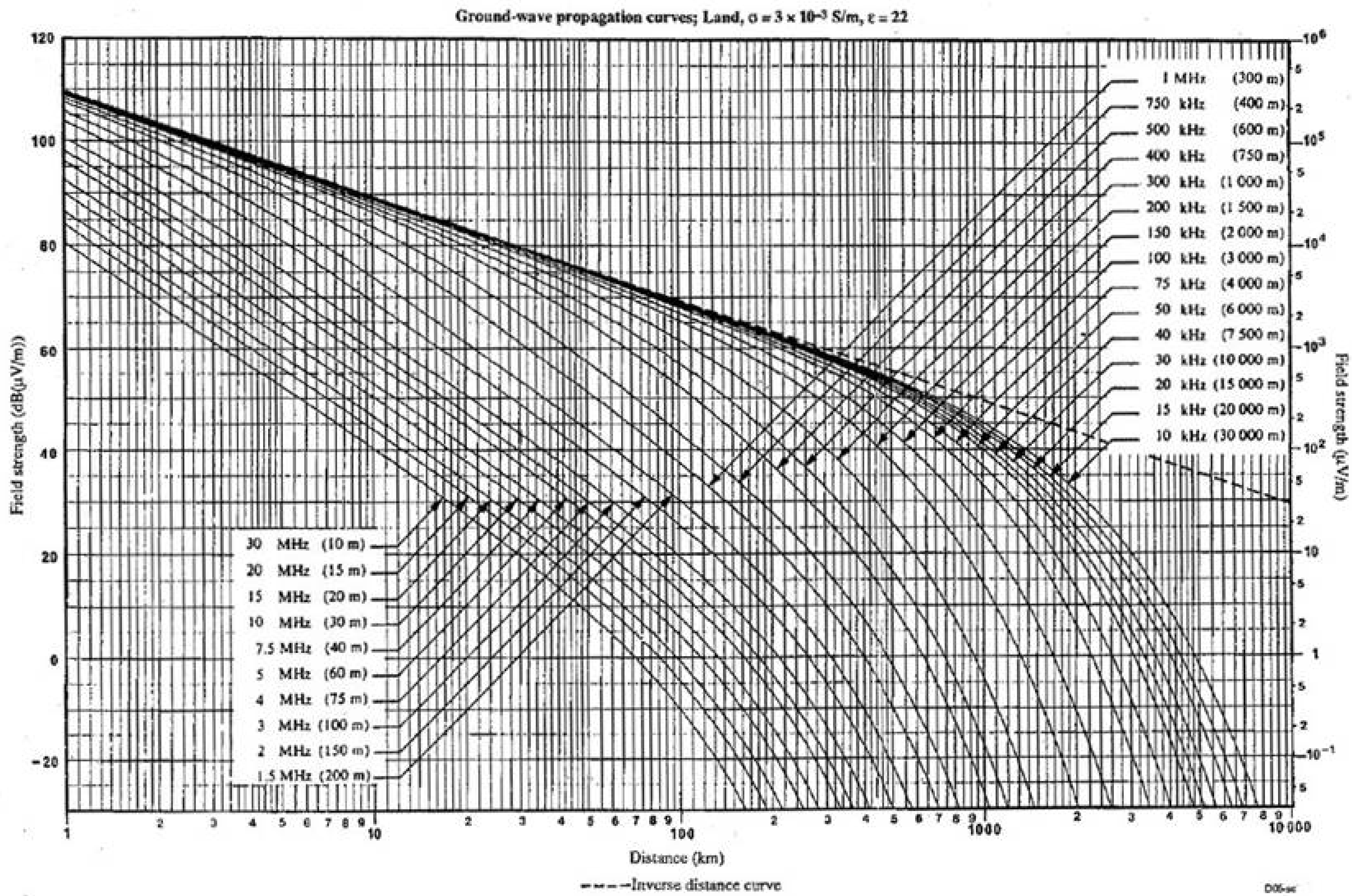
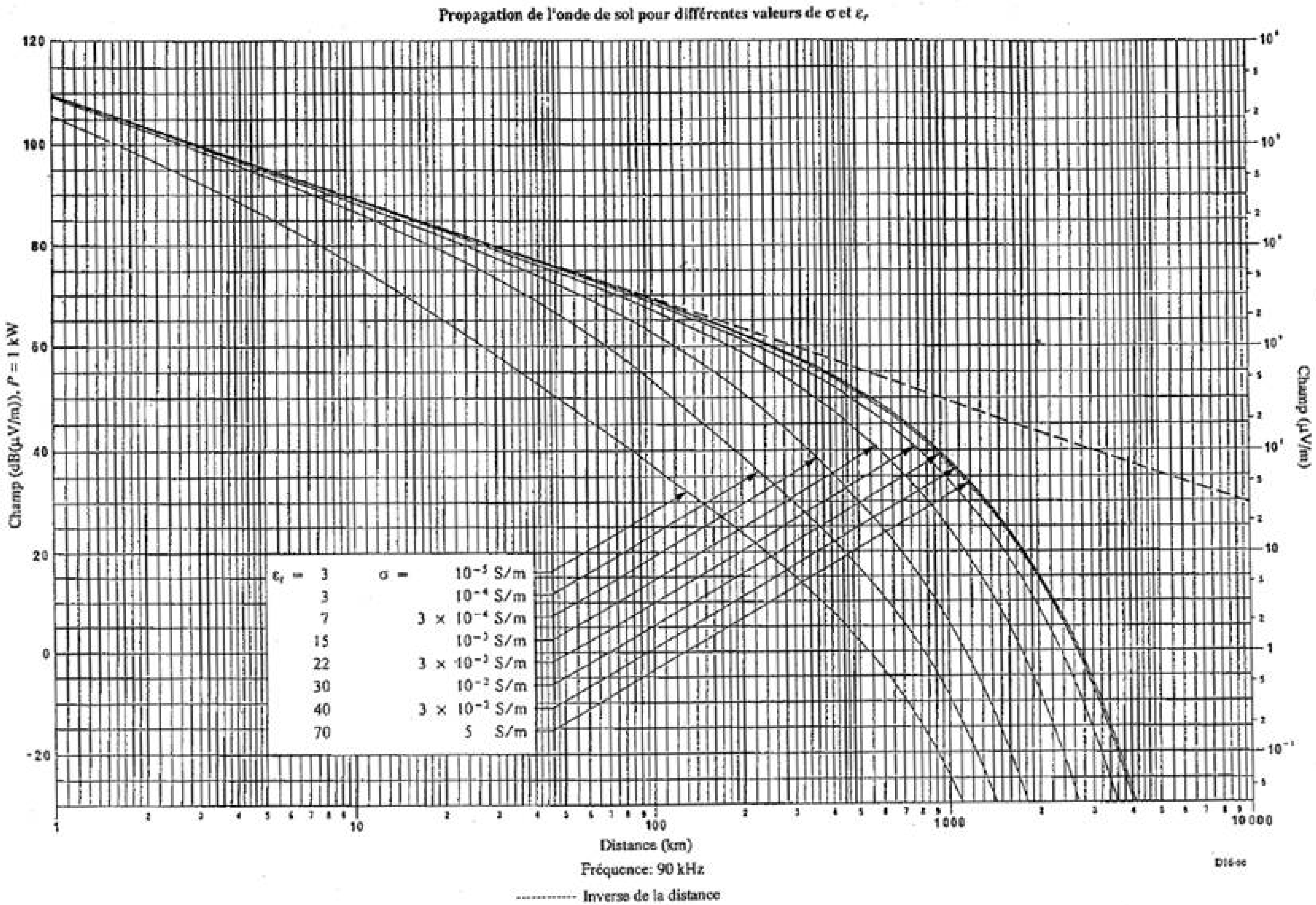

Ground-wave propagation curves; Land, σ = 3 × 10⁻³ S/m, ε = 22
Field strength (dB(μV/m))
Field strength (μV/m)
Distance (km)
Inverse distance curve
1 MHz (300 m)
750 kHz (400 m)
500 kHz (600 m)
400 kHz (750 m)
300 kHz (1 000 m)
200 kHz (1 500 m)
150 kHz (2 000 m)
100 kHz (3 000 m)
75 kHz (4 000 m)
50 kHz (6 000 m)
40 kHz (7 500 m)
30 kHz (10 000 m)
20 kHz (15 000 m)
15 kHz (20 000 m)
10 kHz (30 000 m)
30 MHz (10 m)
20 MHz (15 m)
15 MHz (20 m)
10 MHz (30 m)
7.5 MHz (40 m)
5 MHz (60 m)
4 MHz (75 m)
3 MHz (100 m)
2 MHz (150 m)
1.5 MHz (200 m)

Figure 2

At this short range of 46.3km, ground conductivity does not have a significant effect
Less than 1dB change in field strength occurs for a soil conductivity change of 5 S/m to 1mS/m (5000:1)

Soil conductivity will however affect the antenna ground loss resistance.



Propagation de l'onde de sol pour différentes valeurs de σ et εr
Champ (dB(µV/m)), P = 1 kW
Champ (µV/m)
Distance (km)
Fréquence: 90 kHz
Inverse de la distance
εr = 3 σ = 10⁻⁵ S/m
3 10⁻⁴ S/m
7 3 × 10⁻⁴ S/m
15 10⁻³ S/m
22 3 × 10⁻³ S/m
30 10⁻² S/m
40 3 × 10⁻² S/m
70 5 S/m

Figure 3

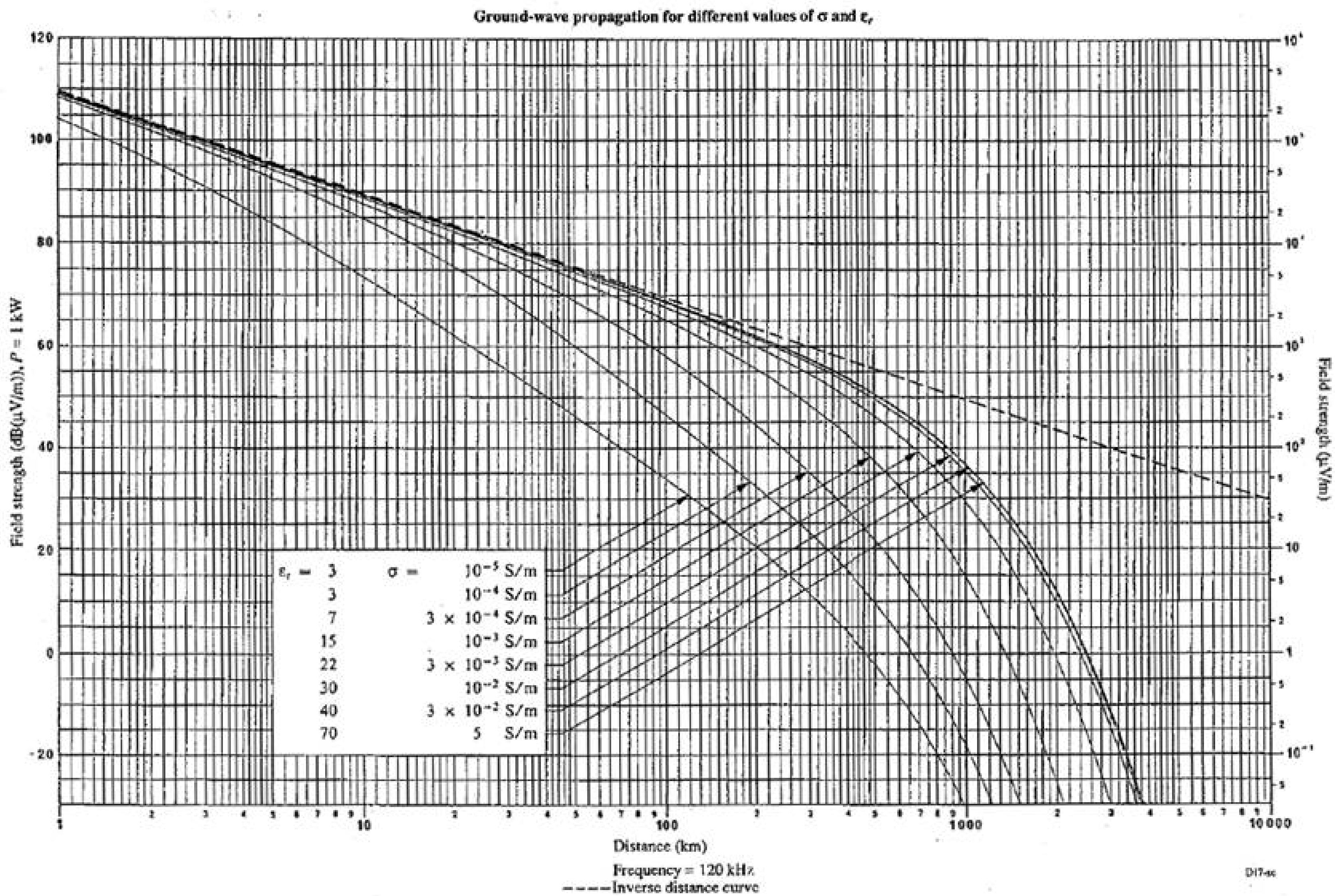

Ground-wave propagation for different values of σ and ε_r
Field strength (dB(μV/m)), P = 1 kW
Field strength (μV/m)
ε_r = 3 σ = 10^{-5} S/m
3 10^{-4} S/m
7 3×10^{-4} S/m
15 10^{-3} S/m
22 3×10^{-3} S/m
30 10^{-2} S/m
40 3×10^{-2} S/m
70 5 S/m
Distance (km)
Frequency = 120 kHz
----Inverse distance curve

Figure 4

Search for a suitable antenna

Designers of low frequency antennas have sought the optimum configuration for an electrically short antenna since the dawn of radio communications.
The trick is to get as much capacitance as possible as high as possible but wires compete with each other for capacitance to space.

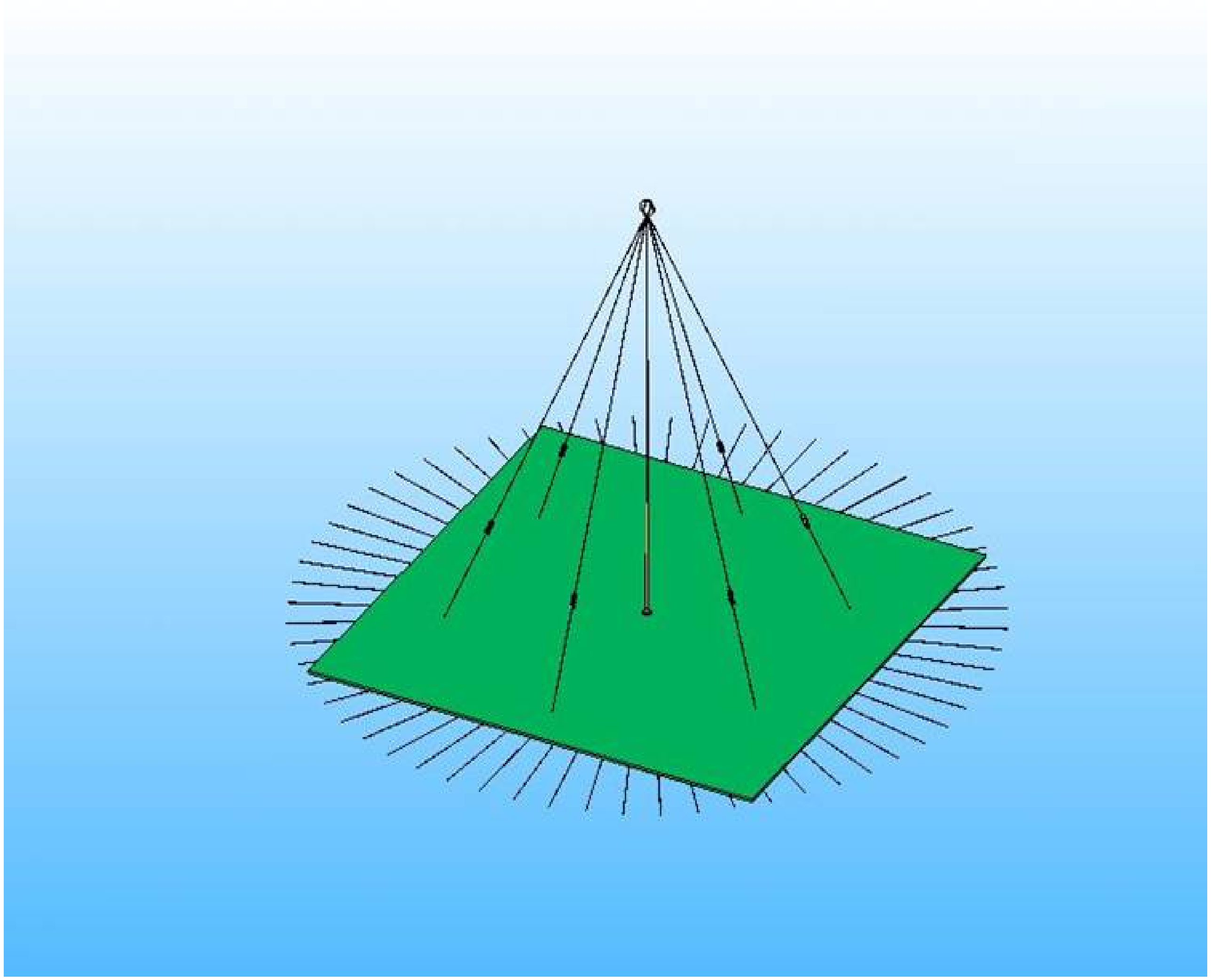
The effectiveness of a short antenna depends on :

Antenna current x Effective height in which it flows

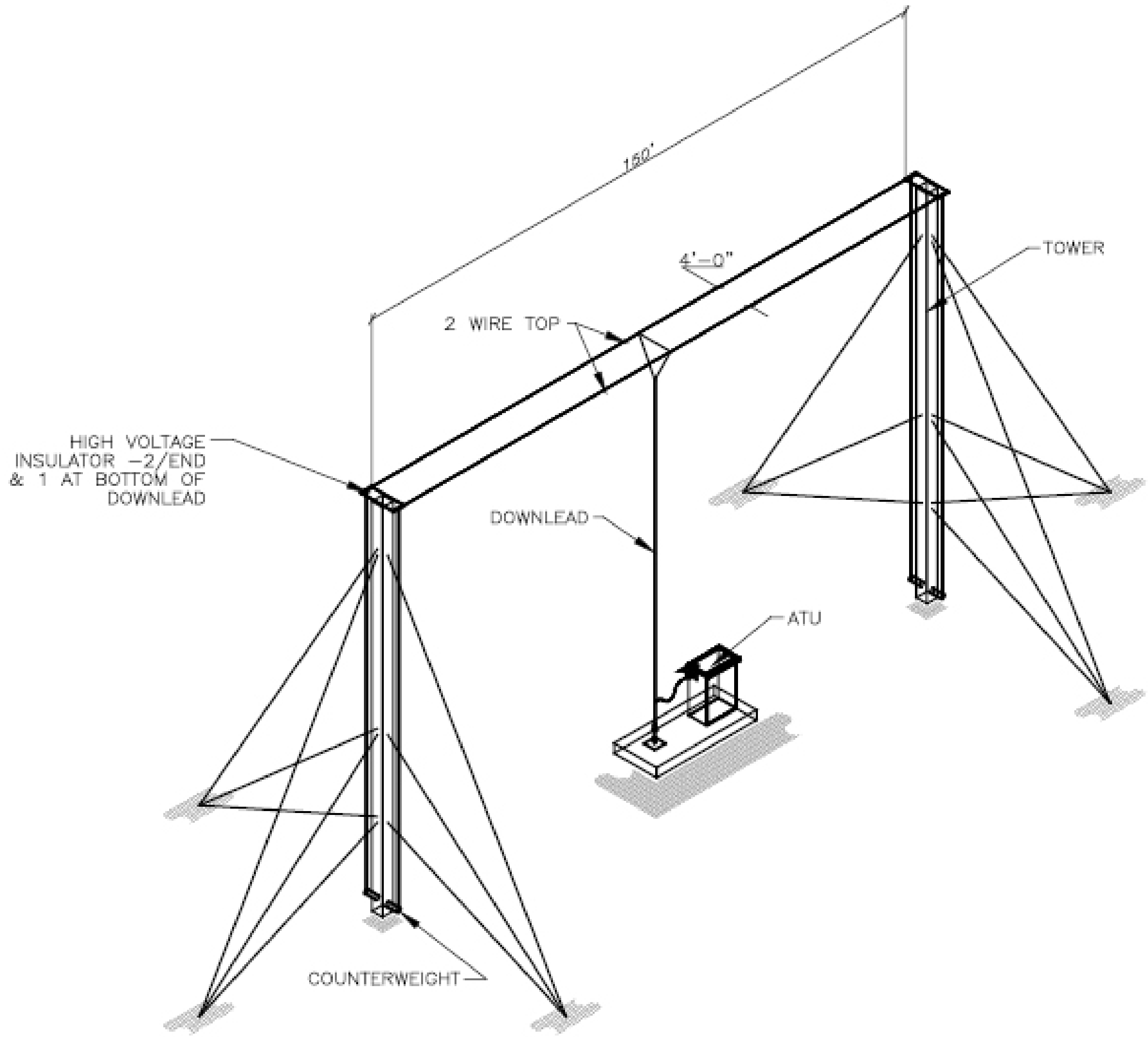
For this application base insulated towers were rejected due to excessive weight and difficulty of construction.

We sought a lightweight structure that could be erected by untrained personnel without heavy machines or the need for concrete foundations.

Two commonly used structures are compared to a new configuration of wire radiators supported by four supporting masts



75 ft fiberglass whip with 6-70 ft TLE’s
with 60 x 60 ft ground radials



60 x 150ft T Antenna with 26 x 90 ft and 18 x 135 ft ground radials

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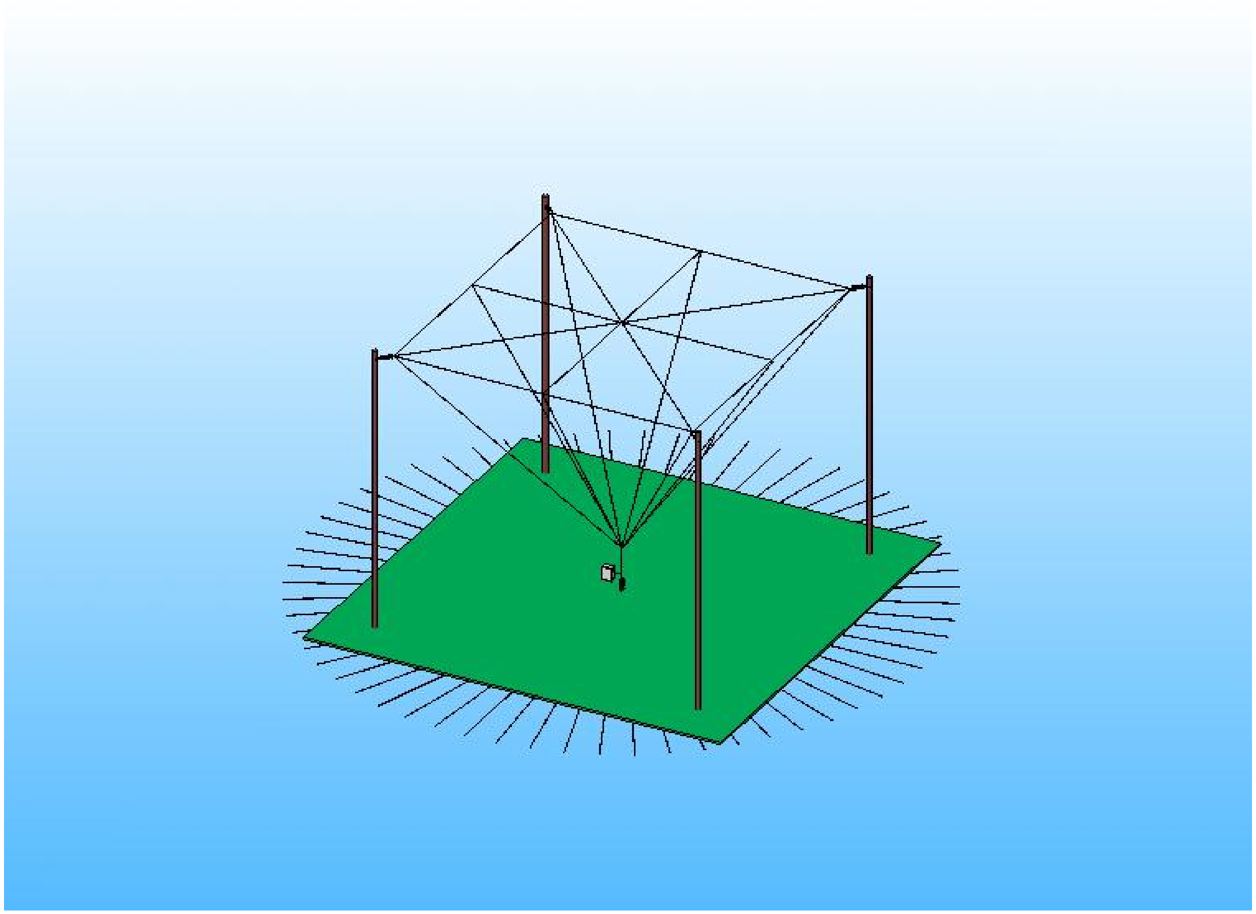
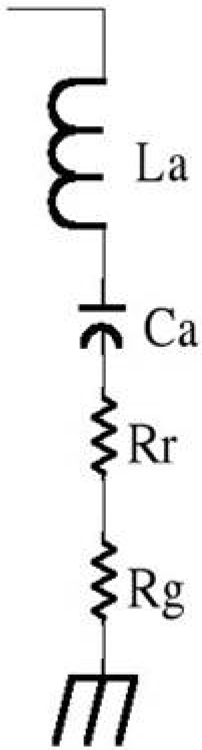


Inverted square cone of wire radiators with 36 ground radials equals in length to the mast height. Both 60ft and 70 ft versions are investigated.

Equivalent circuit of antennas that are very short compared to the operating wavelength

Values of Equivalent Circuit



WHERE:

La = ANTENNA INDUCTANCE

Ca = ANTENNA CAPACITANCE

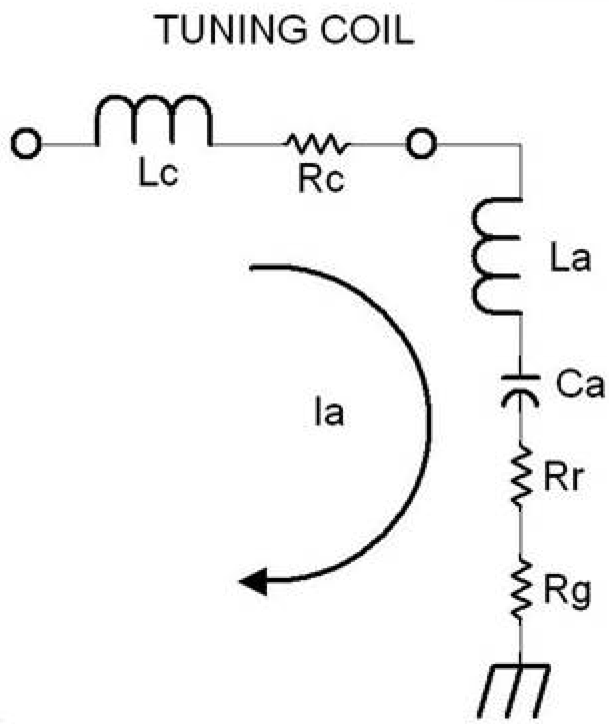
Rr = RADIATION RESISTANCE

Rg = GROUND LOSS RESISTANCE

Fig 9

Tuning the antenna with a series connected loading coil

Values of Equivalent Circuit
Required Tuning Coil
Peak Antenna Current
Peak Antenna Voltage



WHERE:

Lc = TUNING COIL INDUCTANCE

Rc = TUNING COIL LOSS RESISTANCE

La = ANTENNA INDUCTANCE

Ca = ANTENNA CAPACITANCE

Rr = RADIATION RESISTANCE

Rg = GROUND LOSS RESISTANCE

Ia = PEAK ANTENNA CURRENT

Figure 10

Comparing the four antenna configurations
The powerful NEC-4 antenna analysis was used to investigate the four configurations with a soil conductivity of 1 mS/m.

Each model was tuned with a high Q loading coil then driven with an input signal sufficient to produce a field strength of +55dBuv/m at 46.3 km

The following values were measured

- Field strength at 10km = (e)
- Antenna Reactance (Xa)
- RMS Antenna Current (Ia)

The following parameters were calculated

- Radiated Power (Pr) = $(1.33\text{pi}.\ e^2\ 10^4)$ /377 ohms
- Radiation resistance = Pr / Ia^2
- Peak Voltage at antenna input terminal = 2. Ia. Xa

Antenna Parameters for a Radiated Power level of 7.94watts

Antenna	Loading Coil Inductance µH	Antenna Reactance Xl ohms	Antenna Current Ia amps	Radiation Resistance Rr ohms	Peak Antenna Voltage (kV) Vp
75' Top loaded whip	3741.8	2351	16.63	0.0287	76.66
60' x 150' T antenna	4464	2805	14.09	0.04	79.1
60' Inverted cone	2957	1858	15.82	0.0317	58.7
70' Inverted cone	2488	1563	13.37	0.0431	41.8

Table 1

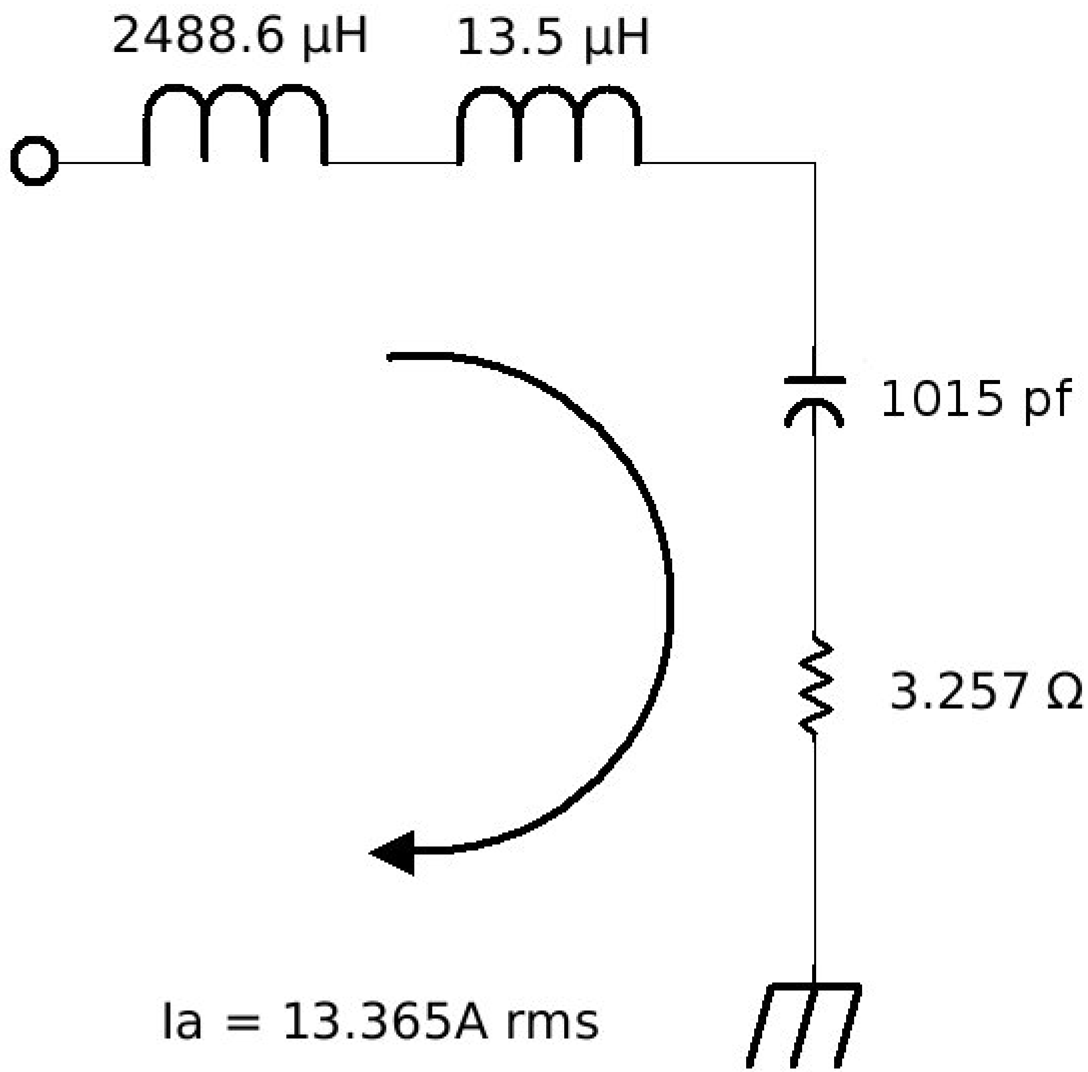
The 70 ft Inverted Cone was chosen as the only antenna that had a peak antenna input voltage less than 50 KV. The ground conductivity was changed to 3 mS/m

Measured Values

Reactance slope = 15.75 ohms/ kHz
Antenna Current = 13.37 amps rms
Antenna Total Resistance = 3.257 ohms
Input voltage (Vin) = 43.52 volts rms

Calculated Values:

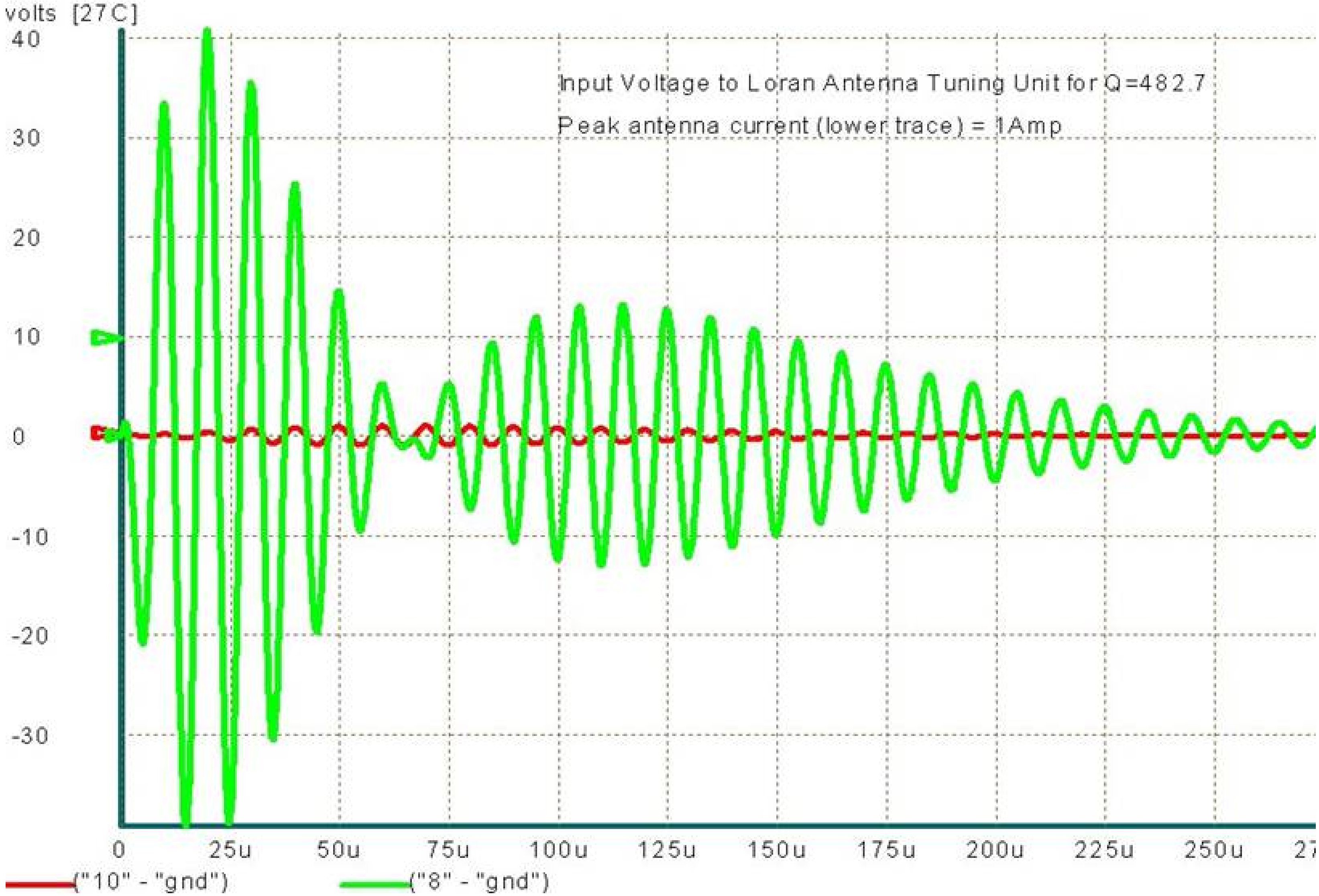
Antenna inductance (Xa) = 13.5 uH
Antenna capacitance (Ca) = 1015 pf
Circuit Q value = Xa / Rt = 482
Bandwidth = 100 kHz / 482 = 207 Hz



Equivalent Circuit

This Q value is 482
This is much higher than that of typical LORAN antennas.

Fig 12 shows that an input voltage required to achieve the required pulse rise time is given by 41 x Vin = 1784 volts rms
= 2523 volts peak



volts [27C]
40
30
20
10
0
-10
-20
-30
Input Voltage to Loran Antenna Tuning Unit for Q=482.7
Peak antenna current (lower trace) = 1Amp
0
25u
50u
75u
100u
125u
150u
175u
200u
225u
250u
("10" - "gnd")
("8" - "gnd")

Figure 12

RF Radiation Hazard

IEEE Standard C95.1-2005 recommends maximum levels of exposure of the general public to electromagnetic fields.

Table 9 on page 25 specifies these limits for a frequency of 0.1 MHz when averaged over a period of 6 minutes as:

E field = 614 V/m H field = 163 A/m

The measured values for this antenna are shown in Figure 12.
Loran transmissions have a duty cycle of less than 10%.
Hence these values can be reduced by a factor of 10.
Accordingly the peak E and H values at a distance of 2m are

E field = 385 V/m H field = 59.6 A/m

*** NEAR ELECTRIC FIELDS
****

Frequency = 0.10, File: C:\GNEC16\EXAMPLES\NEC4\Inverted Cone 70ft 1/8 wire.nec

-LOCATION-			- EX -		- EY -		- EZ -		- PEAK FLD -
X	Y	Z	MAG	PHASE	MAG	PHASE	MAG	PHASE	MAG
M	M	M	VOLTS/M	DEG	VOLTS/M	DEG	VOLTS/M	DEG	VOLTS/M
2	0	2	2.0E+03	-89.84	7.3E-03	21.34	3.24E+03	90.18	3.8543E+03
4	0	2	8.2E+02	-89.90	2.9E-03	-11.33	1.9E+03	90.22	2.1480E+03
6	0	2	4.4E+02	-89.98	1.8E-04	-164.13	1.4E+03	90.26	1.4829E+03
8	0	2	2.7E+02	-90.10	3.5E-04	171.98	1.0E+03	90.30	1.1183E+03
10	0	2	1.8E+02	-90.27	1.5E-04	167.95	8.6E+02	90.35	8.8410E+02
12	0	2	1.3E+02	-90.52	5.9E-05	14.61	7.1E+02	90.41	7.1868E+02
14	0	2	1.0E+02	-90.90	2.3E-04	-0.82	5.8E+02	90.49	5.9428E+02

*** NEAR MAGNETIC FIELDS
****

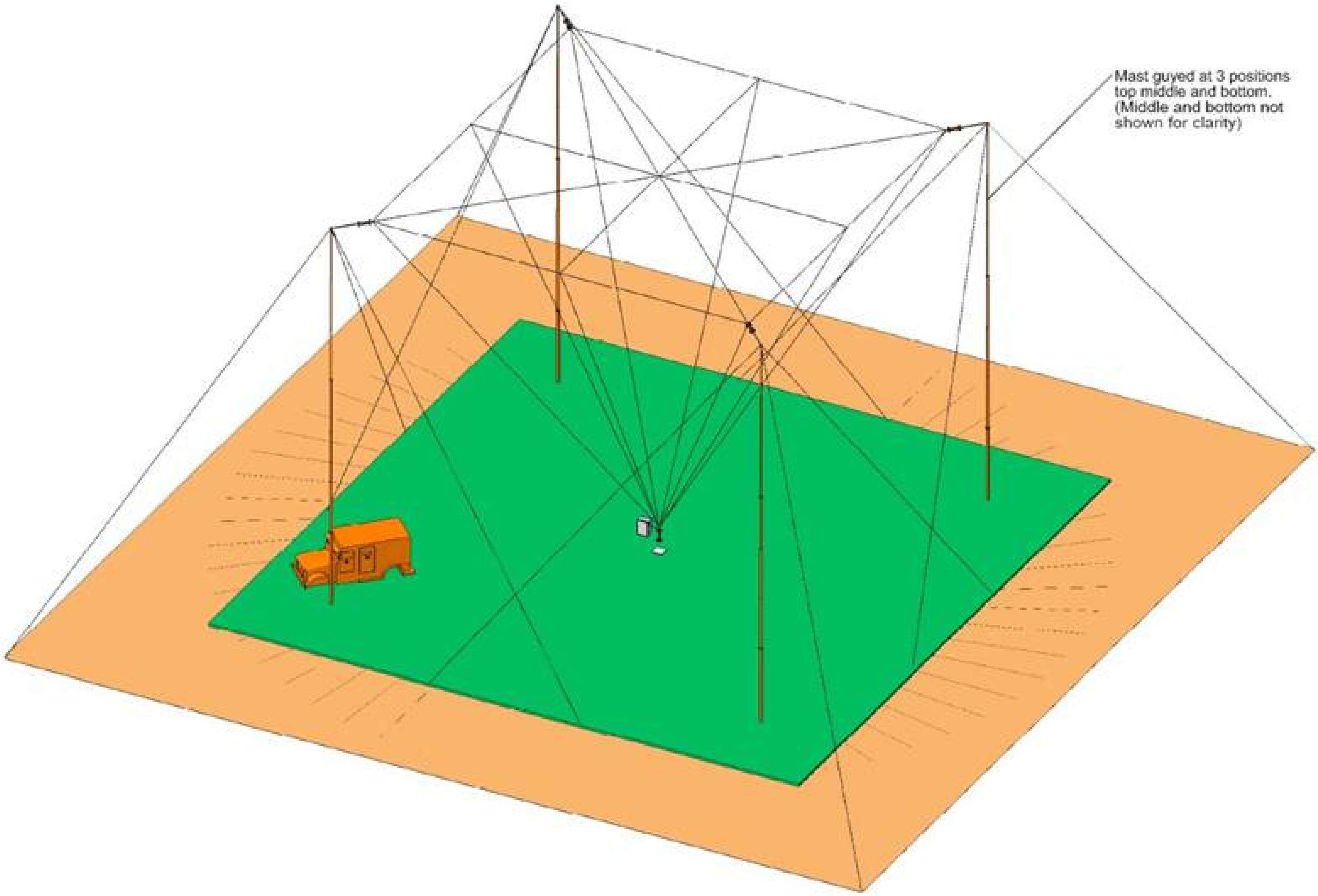
Frequency = 0.10, File: C:\GNEC16\EXAMPLES\NEC4\Inverted Cone 70ft 1/8 wire.nec

-LOCATION-			- HX -		- HY -		- HZ -		- PEAK FLD -
X	Y	Z	MAG	PHASE	MAG	PHASE	MAG	PHASE	MAG
M	M	M	AMPS/M	DEG	AMPS/M	DEG	AMPS/M	DEG	AMPS/M
2	0	2	1.3E-02	84.85	5.9E+02	0.12	2.5E-03	-106.65	5.96E+02
4	0	2	7.9E-04	85.80	4.4E+02	-179.90	3.5E-03	74.49	4.43E+02
6	0	2	3.9E-05	102.34	1.1E+02	-179.88	2.0E-03	-96.26	1.14E+02
8	0	2	3.0E-05	-105.77	5.36E+01	-179.88	3.2E-04	-101.28	5.37E+01
10	0	2	3.2E-05	-101.62	3.1E+01	-179.92	1.1E-05	118.13	3.12E+01
12	0	2	2.9E-05	-99.06	2.0E+01	180.00	6.0E-05	86.51	2.03E+01
14	0	2	2.8E-05	-98.22	1.48E+01	179.90	6.7E-05	85.40	1.44E+01

Figure 13

A typical temporary installation might utilize a vehicle mounted transmitter feeding the antenna tuning unit via a coaxial cable. The site could be deployed and placed into service within a few hours.

The following pictures show a typical deployment using a seven section telescopic aluminum mast that is extended using a small 12 volt compressor. The entire deployment was completed within less than 4 hours by 10 personnel with no previous experience in antenna construction.


Mast guyed at 3 positions
top middle and bottom.
(Middle and bottom not
shown for clarity)

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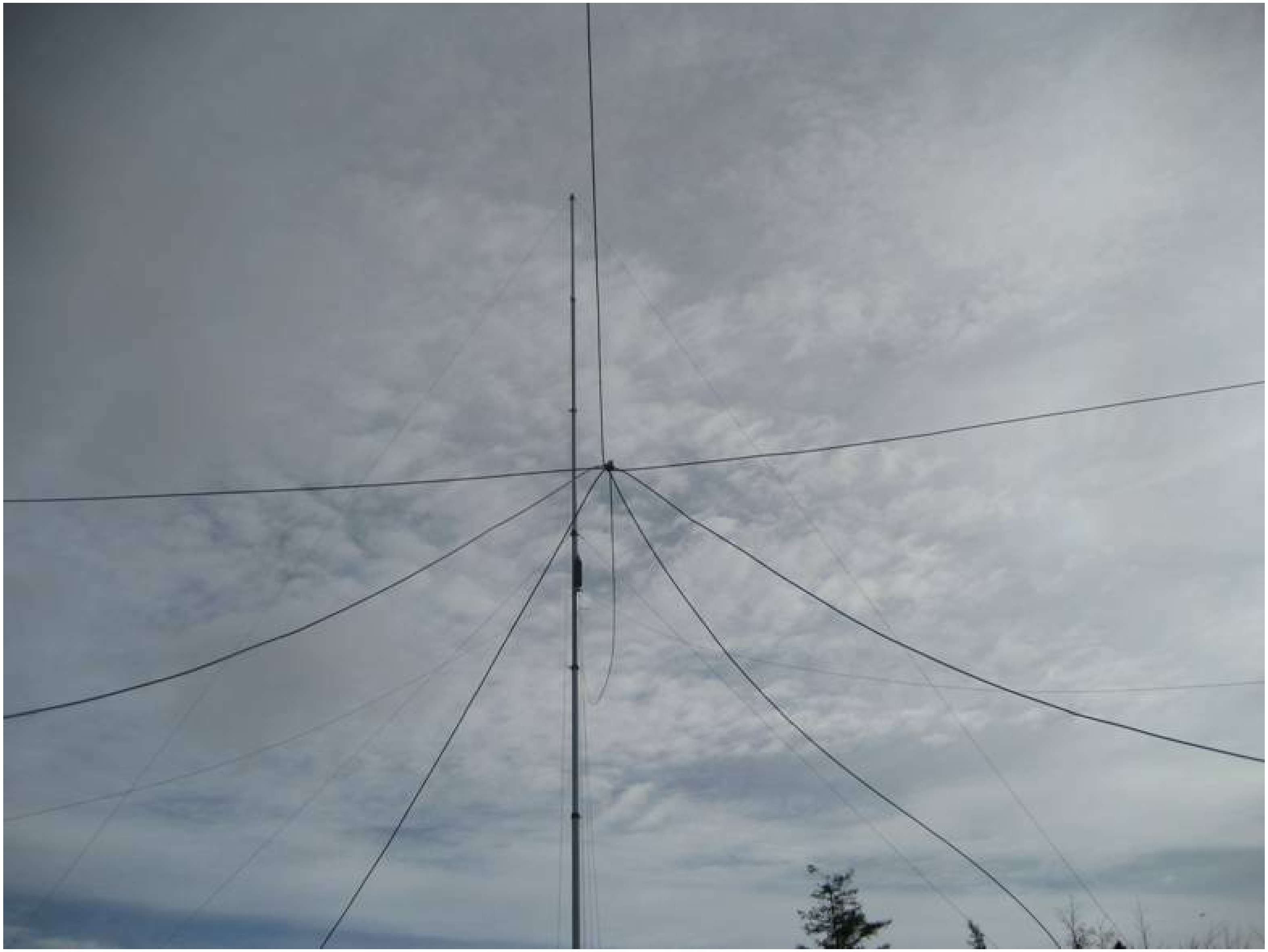

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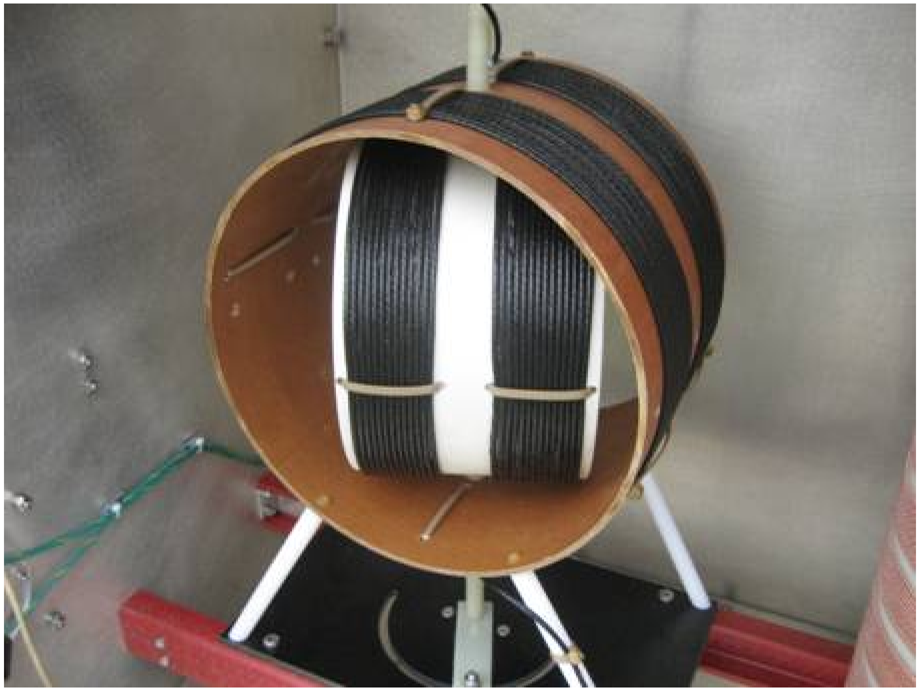

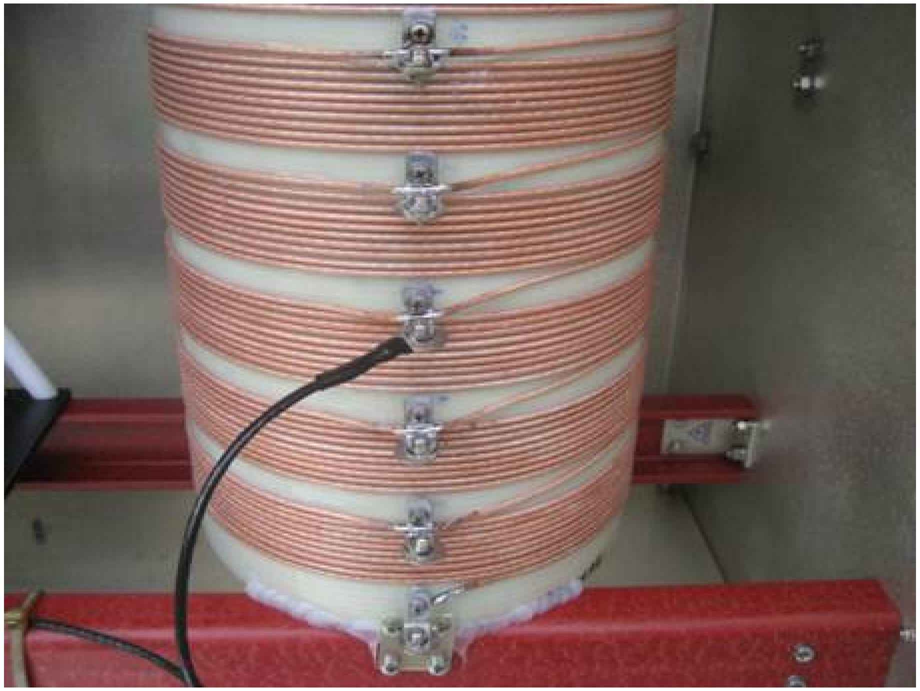

Thank You