

## Antenna measurements on Krypton A0 board



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## 1 Introduction

The following document describes the results of the tests obtained on a Krypton (ListenTALK) modified Rev A0 board assembled in the case supplied with Rev A1 boards. The measurements taken are for the DUT standalone and in different carrying conditions, like hand-held or attached to the belt.

Standalone tests show slightly reduced antenna performance relative to previous tests (Reference 1). Belt-worn and hand-held tests show a fairly significant loss of performance relative to standalone, which may nevertheless be tolerable in practice.

## 2 Referenced documents

Document reference	Subject	Version and/or date	Issued by
<b>Reference 1.</b> P2447-WM-023	Antenna tuning results on Krypton RevX1.2 prototype, fully populated and ABS case	Version 1.0 dated 27/01/2016	CC
<b>Reference 2.</b> P2447-WM-026	Antenna tuning on Krypton A0 board in final plastic case	Version 1.1 dated 13/10/2016	CC

Table 1 - referenced documents

## 3 Antennas Under Test

The DUT contains two antennas under test (AUT).

After the testing reported in Reference 1, antenna dimensions recommendation "A.7" was adopted for PCB revisions A0 and A1. Further modification to antenna dimensions was later recommended in Reference 2 to compensate for detuning caused by the case and the NFC board. Also for revision A1, a screening can has been added.

The DUT is an A0 board (P2447-GR-023), fitted with an A1 screening can, and with both antennas manually shortened as recommended in Reference 2, and is described as "modified Rev A0" in this report. The DUT is the same as pictured in Reference 2, with test cables leading out of the centre of the unit.

For this product variant the antennas need to cover the frequency band 1880-1930MHz, allowing it to be used in EU and US mainly.

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## 4 Test Set Up

Each antenna in turn was connected to the Satimo SG64S coaxial cable used for passive measurements. X is in the plane of the Satimo Antenna arch

Y is to the rear of the Satimo Chamber and

Z is towards the ceiling of the Satimo chamber (i.e. the top of the Satimo Antenna arch)

See also Figure 1.

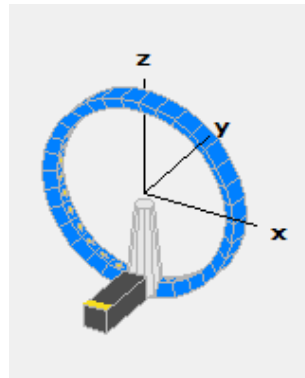


Figure 1

## 5 Test Method

As a standalone test, the DUT was initially placed in the Satimo SG64S Chamber on top of the rotating support column, with the front surface of the DUT pointing in the Z direction towards the roof of the chamber (section 0). In later tests (sections 6.2.3, 6.2.4), the DUT was worn by a volunteer, with front surface oriented in the XY plane.

In each test, the DUT was rotated through  $180^\circ$  in  $5^\circ$  steps. At each  $5^\circ$  step the frequency of the signal generator feeding the DUT was swept over the test range. The Satimo SatEnv program was used to convert the recorded Near-field information into Far-Field data. This data was processed using the Efficace program to produce total terminal efficiency plots and polar radiation patterns for each AUT.

## 6 Results

### 6.1 AUT Efficiency Results

The Total Terminal Efficiency of the AUT is a number that indicates how much of the RF energy fed into the AUT is actually radiated. In reception we can say that efficiency is the number that indicates how much of the incident RF energy into the structure is coming out of the connector. Since antennas are passive and therefore reciprocal structures, efficiency and all other parameters are identical in receive and transmit.

The Total Terminal Efficiency of an Antenna can be defined from its Radiation Resistance ( $R_{rad}$ ) and Loss Resistance ( $R_{loss}$ ) thus,

$$Total\ Terminal\ Efficiency\ (\%) = \frac{R_{rad}}{R_{rad} + R_{loss}} \times 100$$

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### 6.1.1 Antenna 1 (BOTTOM)

Comparison with previous 'A7' results in Reference 1 – standalone

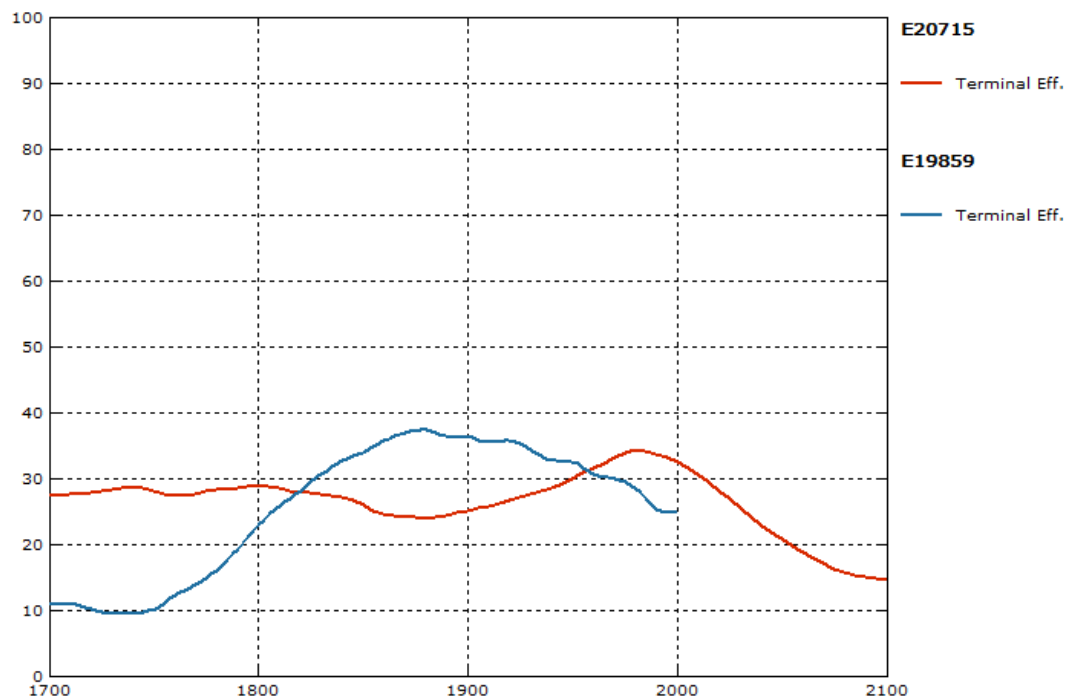


Figure 2 –Bottom antenna efficiency. E19859 results from Proto2-RevA7 measurement, E20715 current measurements (modified Rev A0)

Comparison between standalone and worn AUT

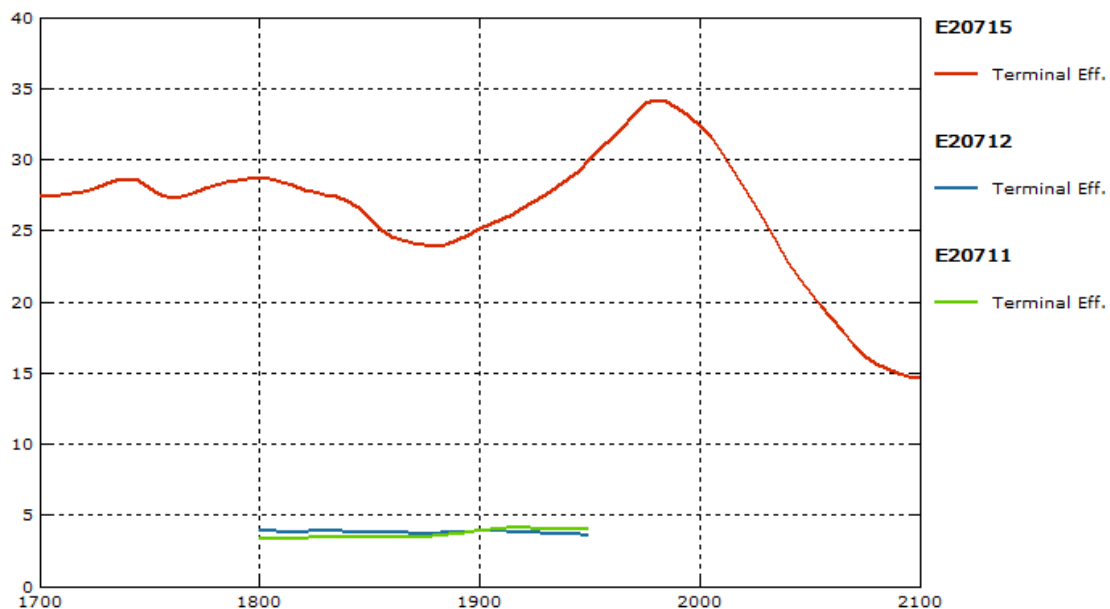


Figure 3 – Bottom antenna efficiency. E20715 (standalone), E20712 (worn on belt), E20711 (handheld)

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## 6.1.2 Antenna 2 (SIDE)

Comparison with previous 'A7' results in Reference 1 – **standalone**

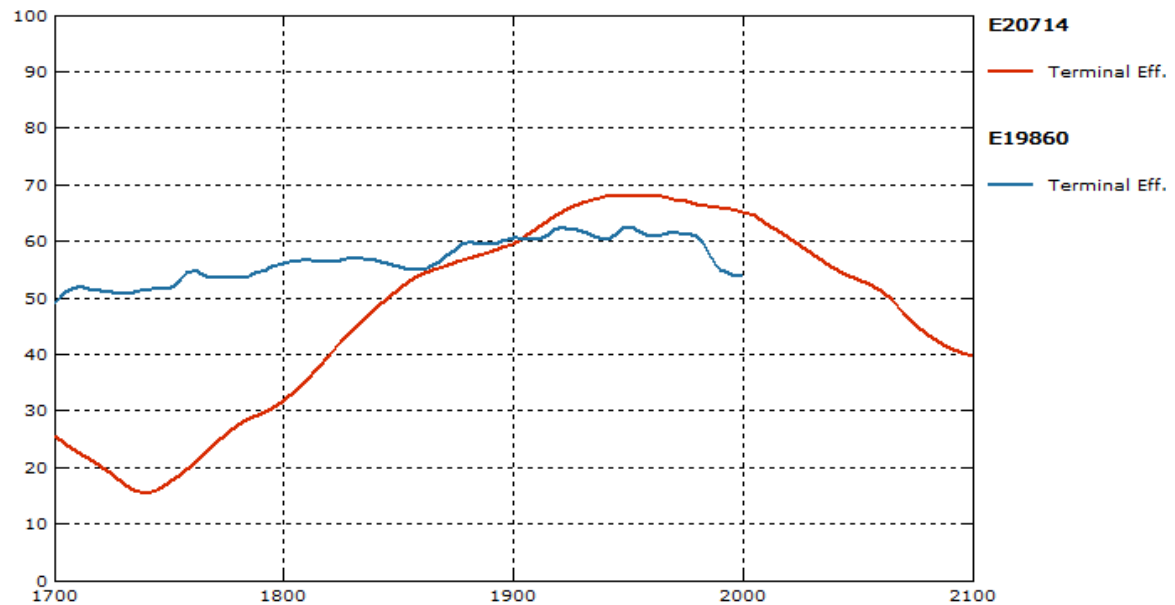


Figure 4 –side antenna efficiency. E19860 results from Proto2-RevA7 measurement, E20714 current measurements (modified Rev A0)

Comparison between standalone and worn AUT

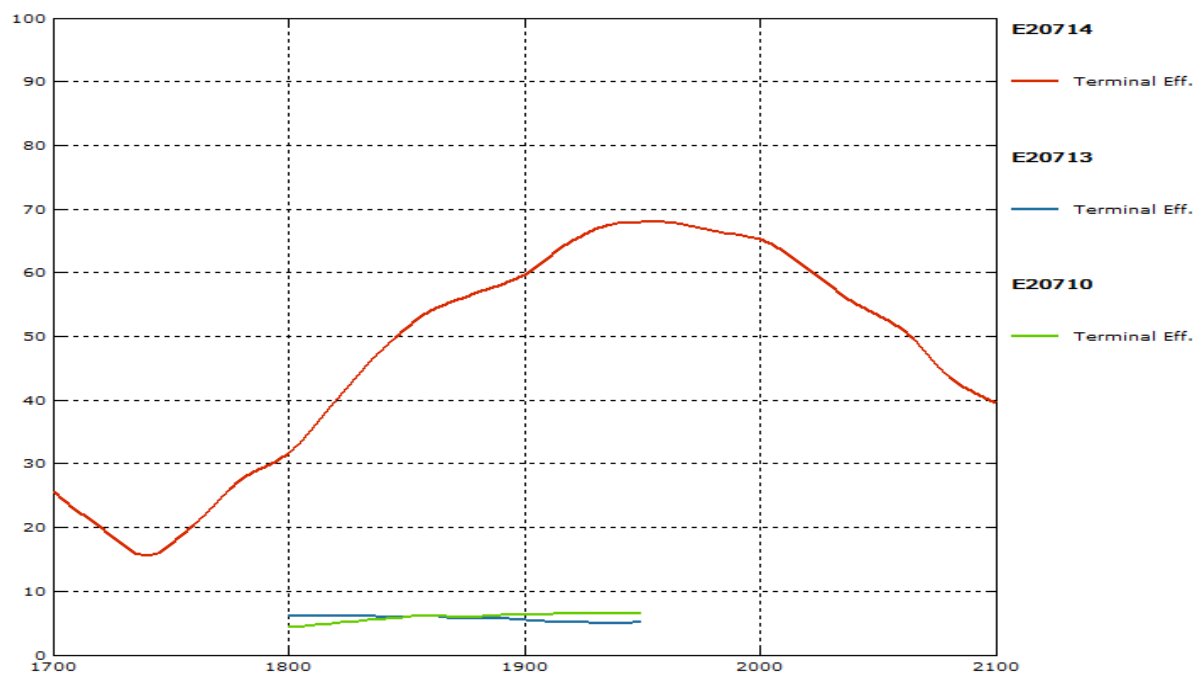
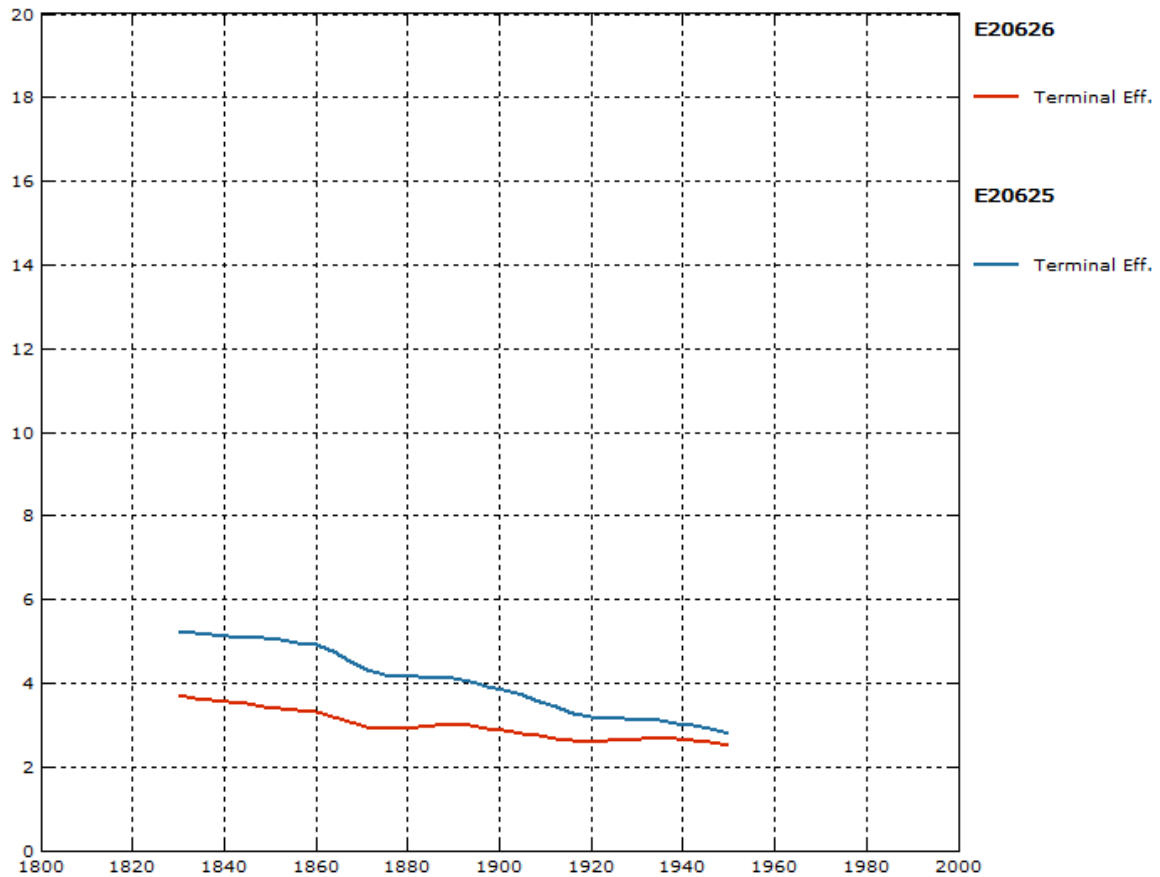


Figure 5 – side antenna efficiency. E20714 (standalone), E20710 (worn on belt), E20713 (handheld)

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### 6.1.3 Efficiency results with and without headset

The following graph describes the difference in efficiency when device is worn on the belt with (BLUE) and without (RED) using the headset. The result highlights how at the frequency of interest there is little difference between the two measurements. The headset though provides a little improvement on the overall performance.





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### 6.1.4 Conclusions from AUT Efficiency Results

Results obtained through the measurements show a little degradation in overall performance at the wanted frequency, compared with the previous Proto2-RevA7 measurements, when the device is standalone.

The small standalone loss in efficiency could be related to various factors:

- Screening can affecting the radiation pattern of the antenna, and coupling part of the radiated field.
- Connections between the NFC daughter board allowing the board to partially screen the field produced by the antennas.
- Lossy plastics material in the case.

When the device is hand-held or worn at the belt, efficiency of both antennas is significantly lower than standalone, but is very comparable to the previous Proto2-RevA7 results.

### 6.2 AUT Radiation Pattern Results

#### 6.2.1 AUT Radiation Pattern summary and estimated link budget

The radiation pattern of the device when standalone (not worn or hand-held) is seamless and uniform across the whole band across the whole sphere of integration. This is evidence of good matching and good integration of the antennas with the device although the measurements previously taken show that a better efficiency was achievable.

The results obtained when the device was worn on the belt or hand-held seem similarly uniform. The achieved efficiency is not great but is in line with typical worn devices of this size. The peak gain towards directions where the body is not obstructing the radiation, indicates a good behaviour of the antenna.

Plots show that in the directions where the antenna is effective when worn (primarily on the horizontal plane and towards the floor), the average gain is in the order of -15dBi, with some peaks (usually down-tilted towards the floor) of -5dBi. With a transmit power of +20dBm and a receiver sensitivity of -90dBm, and assuming similar antenna gain at both ends of the link, the available link budget would then be  $(+20 + 2 \times (-15) - (-90) = )$  80dB.

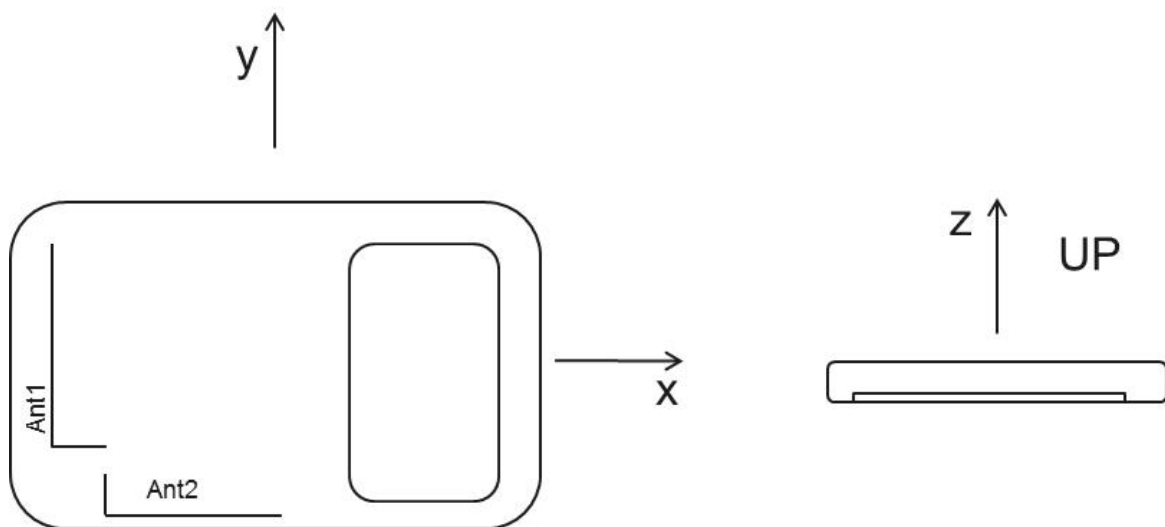
Below are some indications of range achievable with 80dB attenuation, in the absence of interference:

- Free space (no fading) = 130m
- Free space (17dB link margin) = 18m
- Indoor model with moderate walling (99% reliability) = 6m

These would be the average performance when the person wearing the device is not directly facing the master device. When the devices are facing each other, the link budget could be 10-15dB higher, leading to a range potentially 3 times greater than indicated in the above examples.

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## 6.2.2 AUT standalone (not worn or carried)



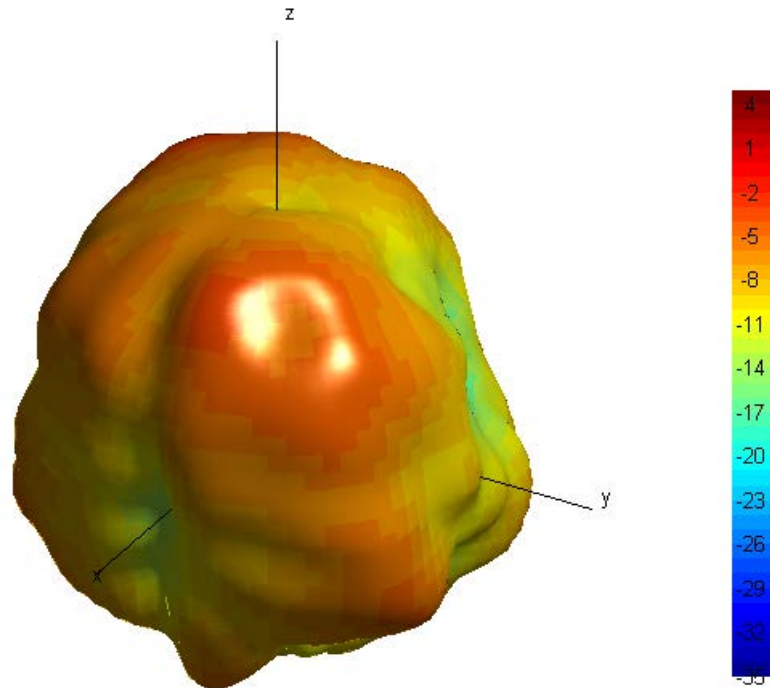
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## 6.2.2.1 Antenna 1 (BOTTOM), standalone

### 6.2.2.1.1 Three dimensional radiation pattern plots

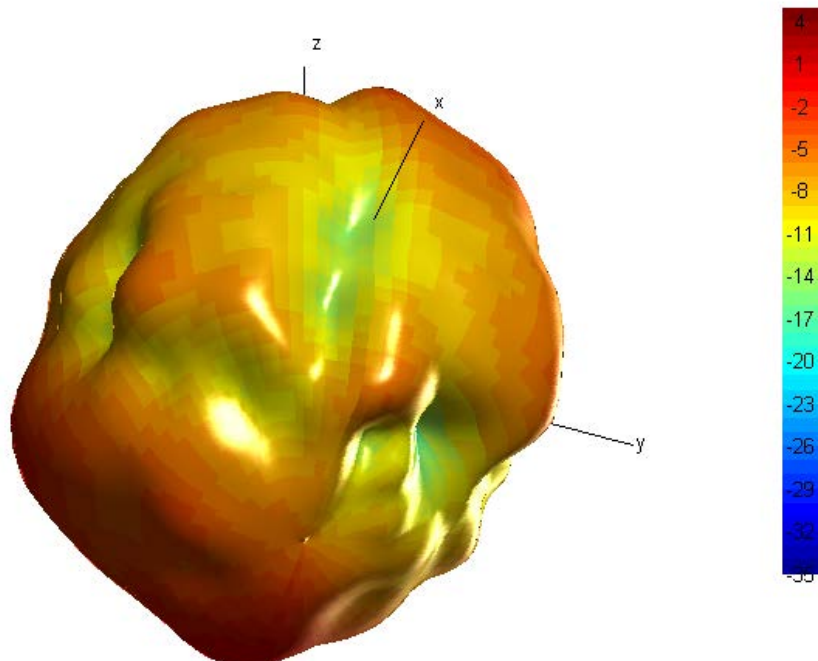
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E20715 - Total polarization, 1900 MHz



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E20715 - Total polarization, 1900 MHz



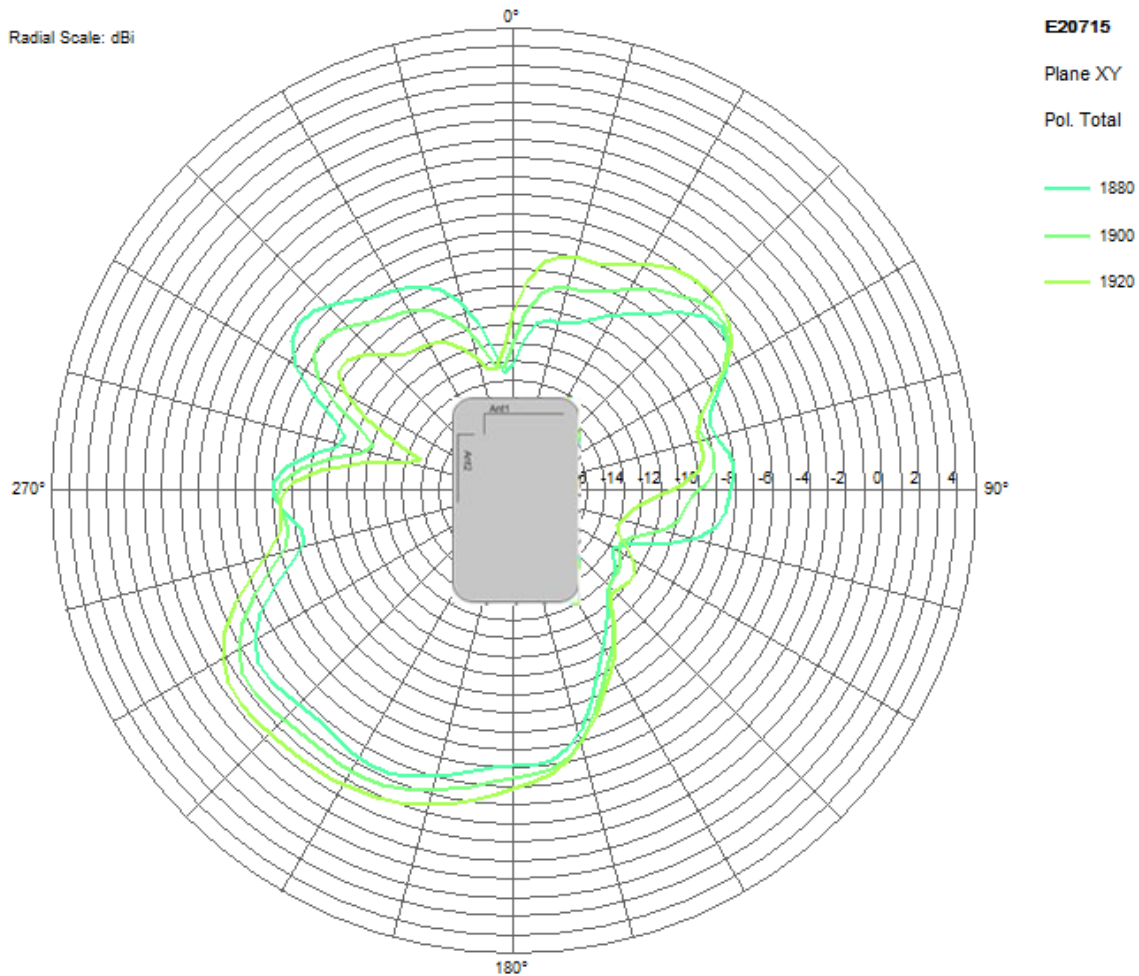
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## XY Plane Radiation Patterns

The XY radiation plot is for a cut in the XY plane with  $Z = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20715: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_BOTTOM (standalone)			
> Plane: XY - Polarization: Total			
1880	-3.3	-7.1	-7.2
1900	-2.3	-6.8	-7.0
1920	-1.3	-6.4	-6.7
Mean:	-2.2	-6.7	-6.9

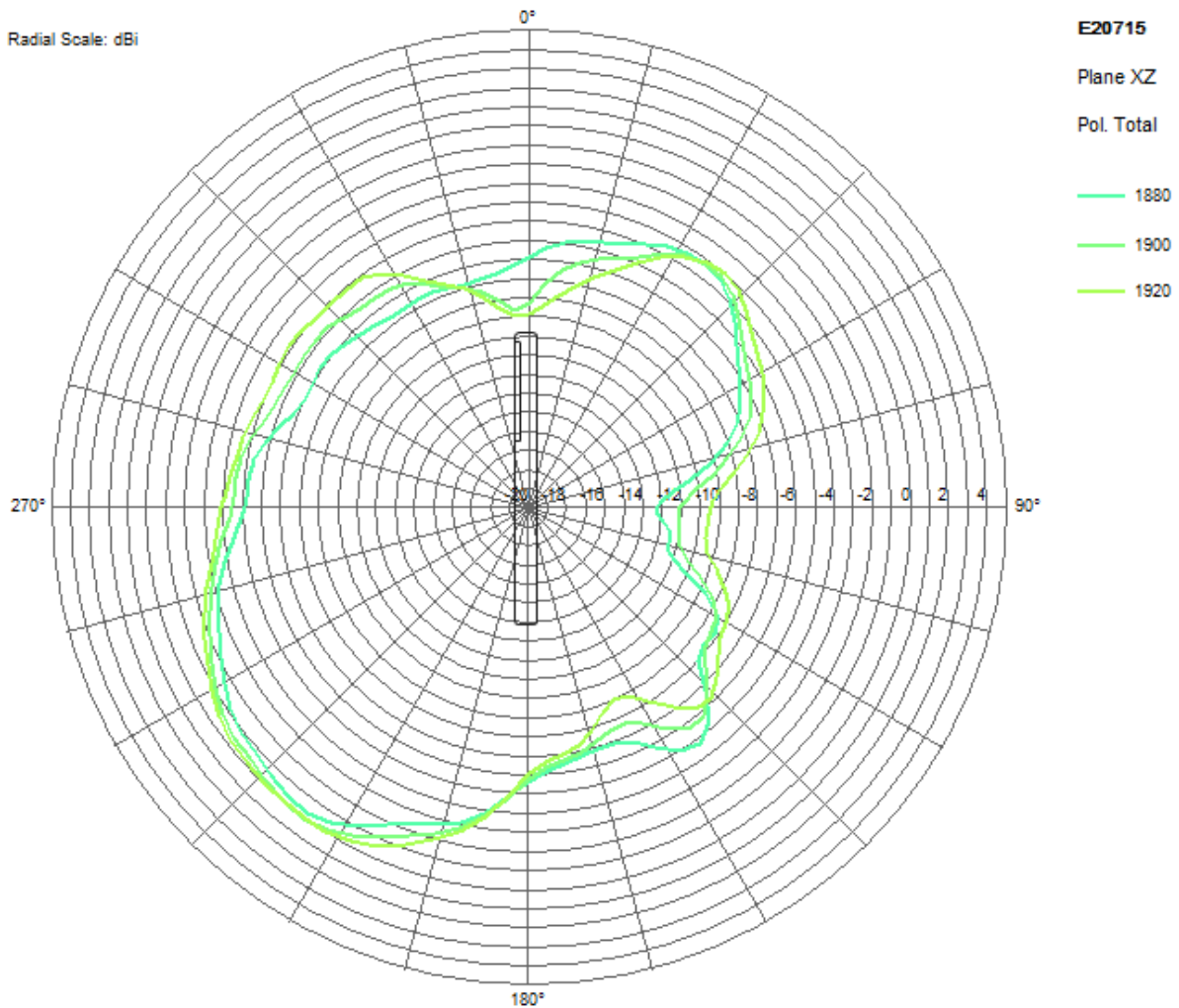
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### 6.2.2.1.2 XZ Plane Radiation Patterns

The XZ radiation plot is for a cut in the XZ plane with  $Y = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20715: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_BOTTOM (standalone)			
> Plane: XZ - Polarization: Total			
1880	-0.2	-5.2	-5.3
1900	0.1	-4.9	-4.8
1920	0.1	-4.7	-4.5
Mean:	-0.0	-4.9	-4.8

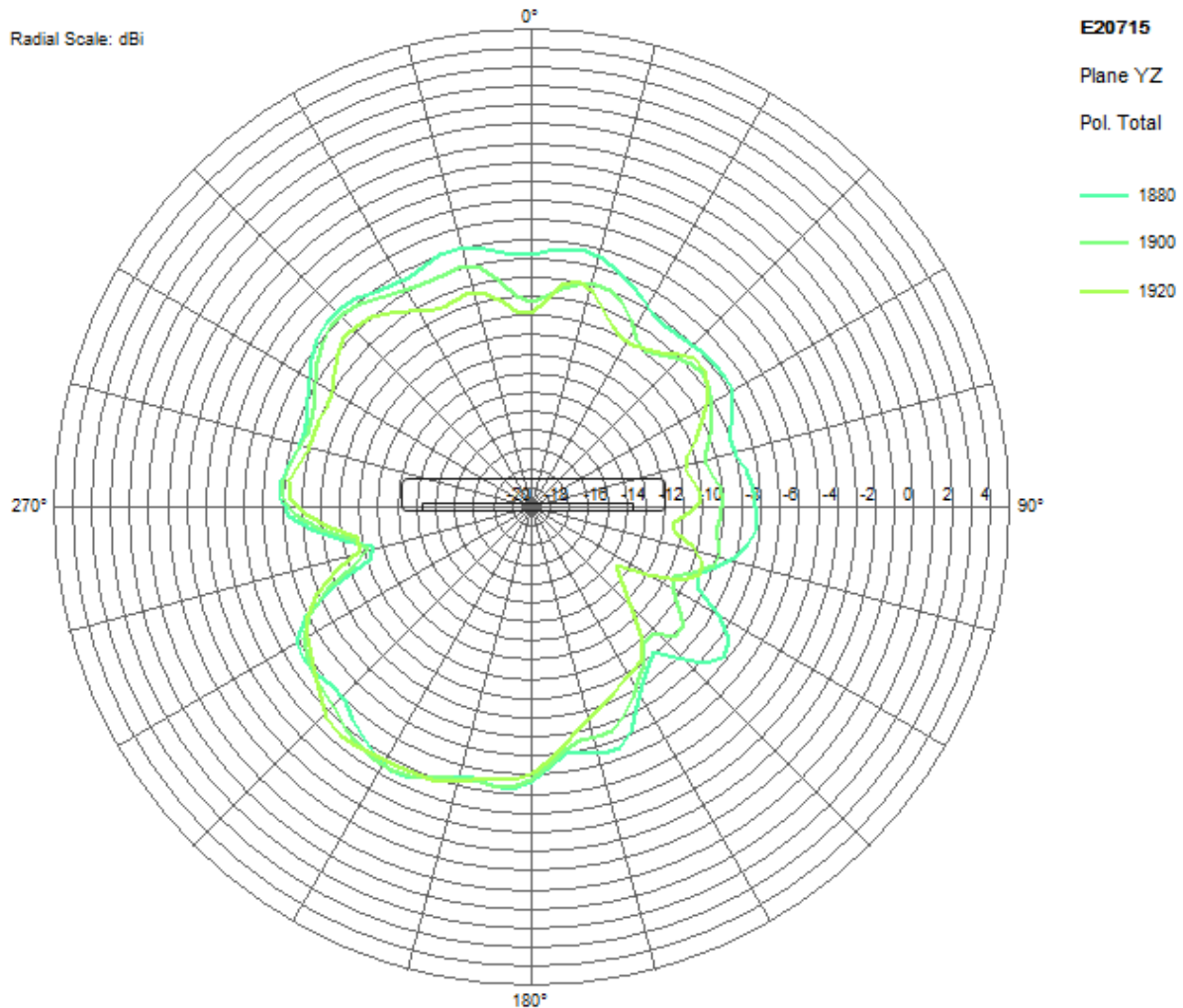
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### 6.2.2.1.3 YZ Plane Radiation Patterns

The YZ radiation plot is for a cut in the YZ plane with  $X = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20715: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_BOTTOM (standalone)			
> Plane: YZ - Polarization: Total			
1880	-4.4	-7.0	-7.4
1900	-4.4	-7.7	-8.0
1920	-4.4	-8.2	-8.5
Mean:	-4.4	-7.6	-7.9

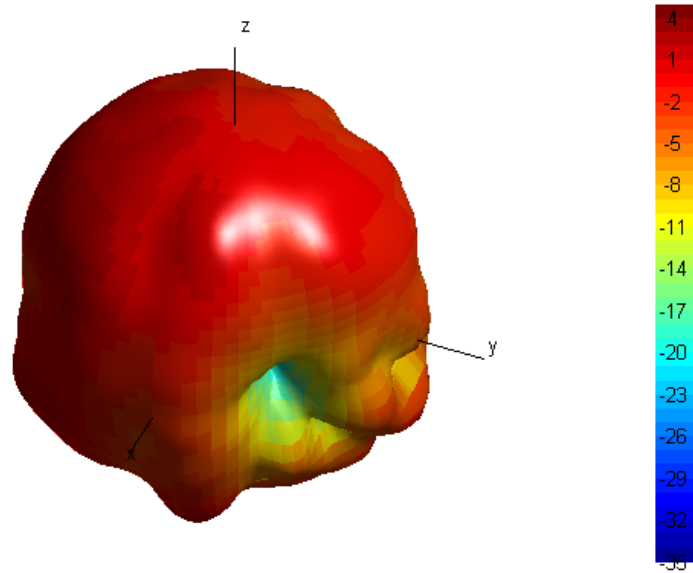
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## 6.2.2.2 Antenna 2 (SIDE) , standalone

### 6.2.2.2.1 Three dimensional radiation pattern plots

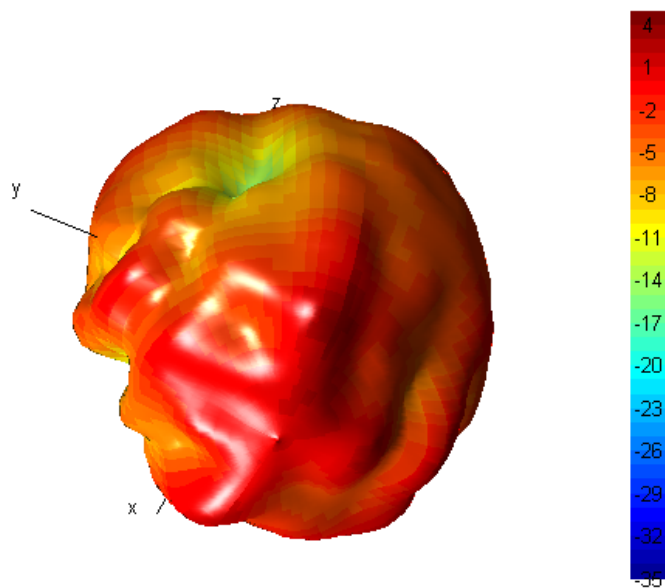
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E20714 - Total polarization, 1900 MHz



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E20714 - Total polarization, 1900 MHz

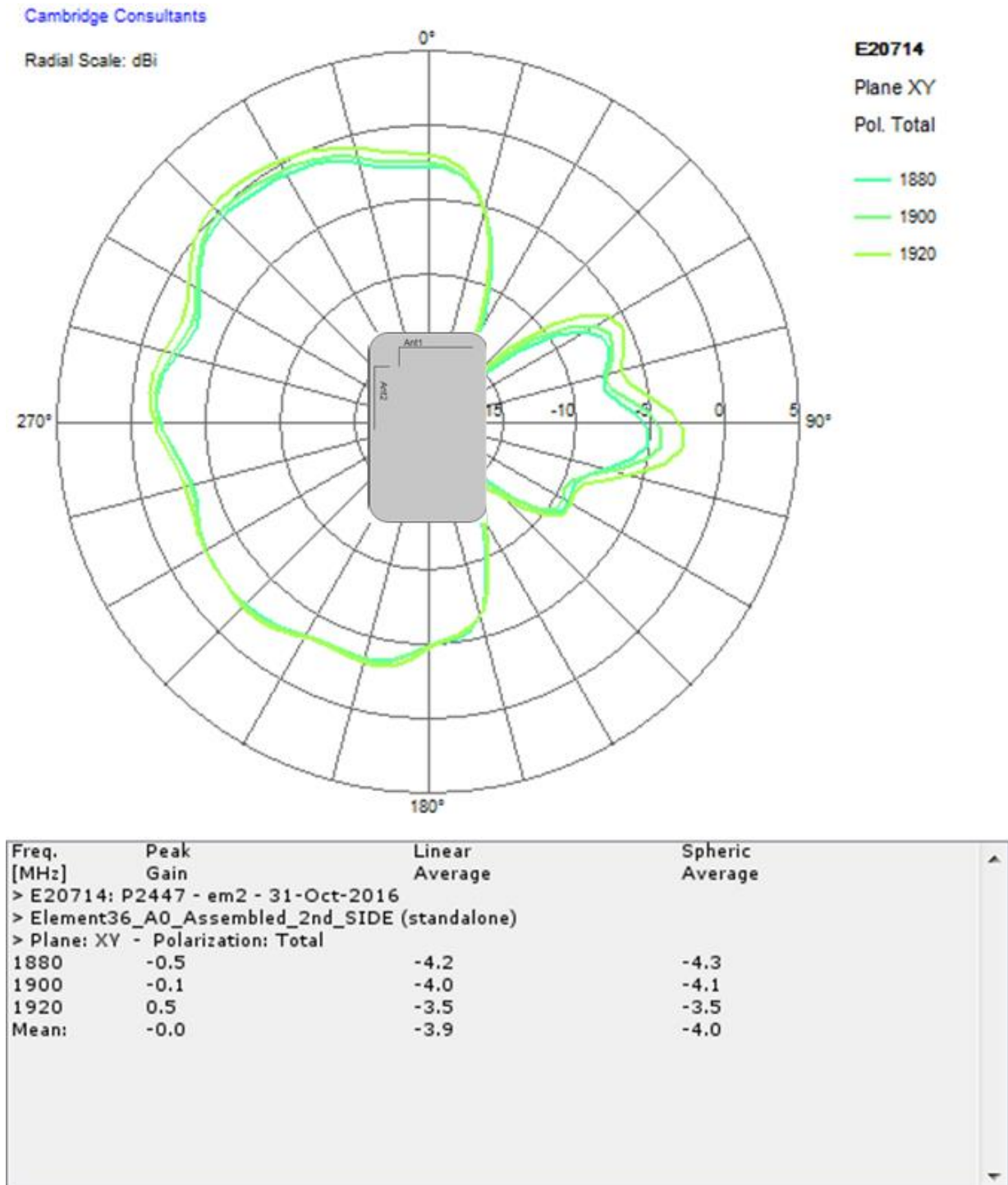




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#### 6.2.2.2.2 XY Plane Radiation Patterns

The XY radiation plot is for a cut in the XY plane with  $Z = 0$ .





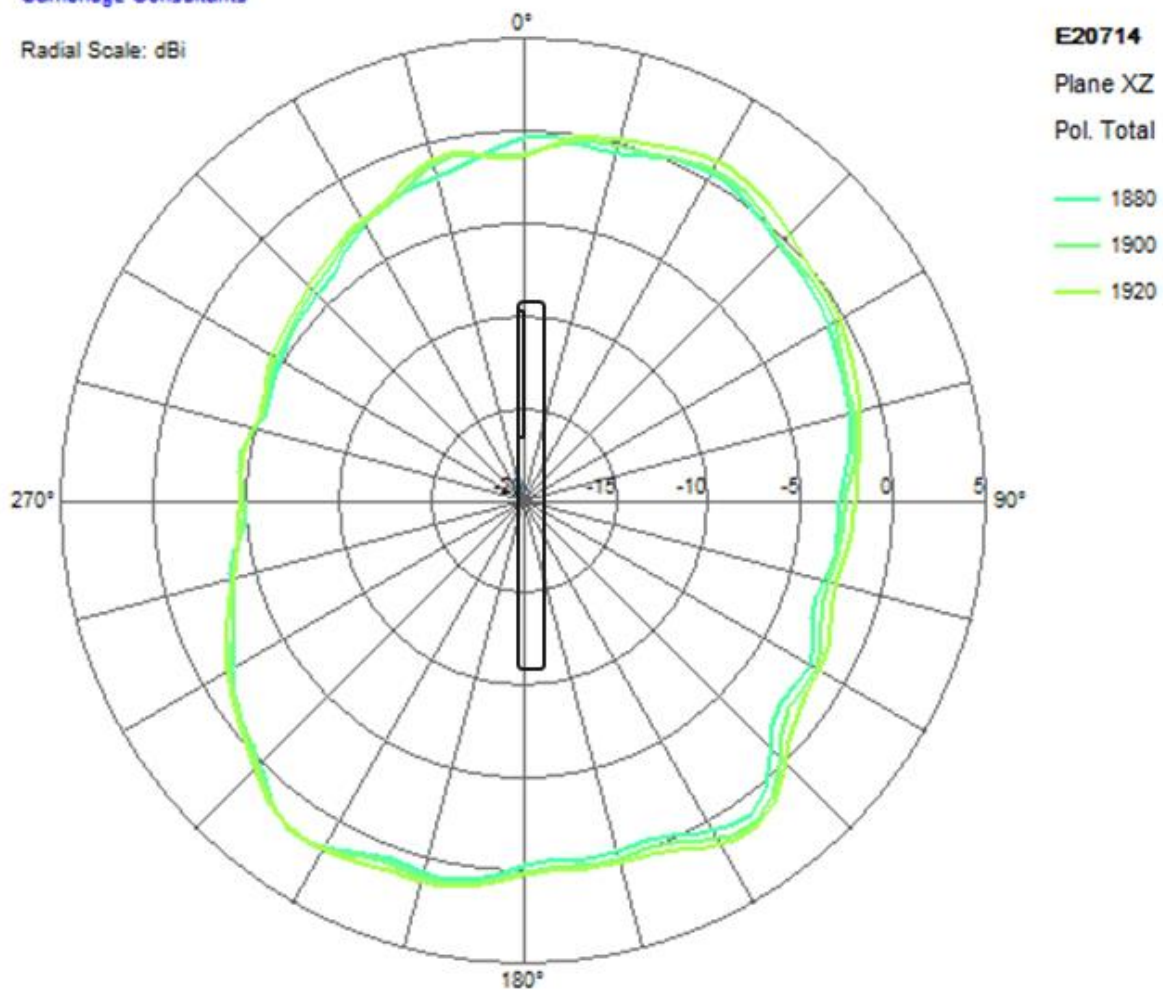
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### 6.2.2.2.3 XZ Plane Radiation Patterns

The XZ radiation plot is for a cut in the XZ plane with  $Y = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20714: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_SIDE (standalone)			
> Plane: XZ - Polarization: Total			
1880	1.8	-1.3	-1.8
1900	1.8	-1.1	-1.6
1920	1.8	-0.8	-1.3
Mean:	1.8	-1.1	-1.6

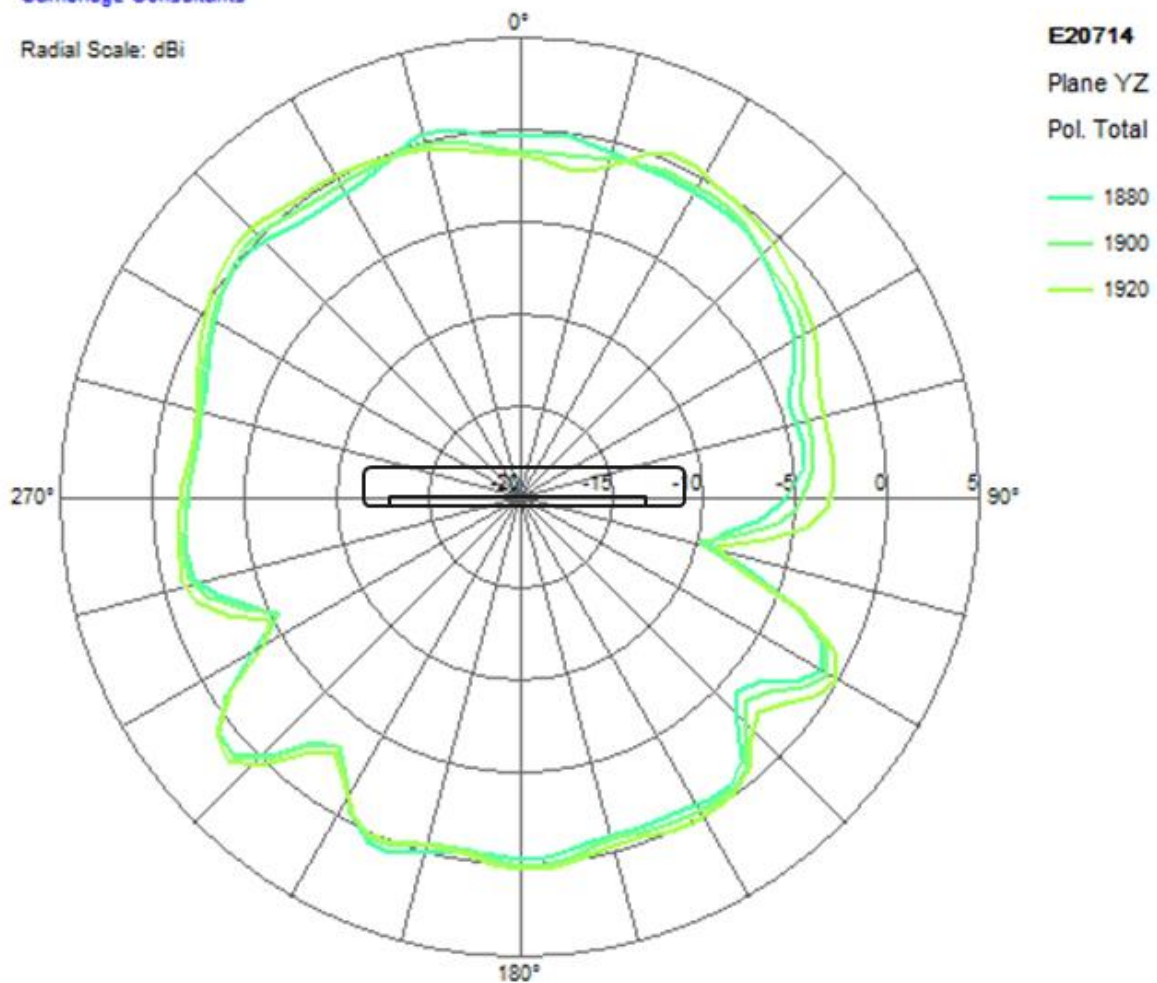
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#### 6.2.2.2.4 YZ Plane Radiation Patterns

The YZ radiation plot is for a cut in the YZ plane with  $X = 0$ .

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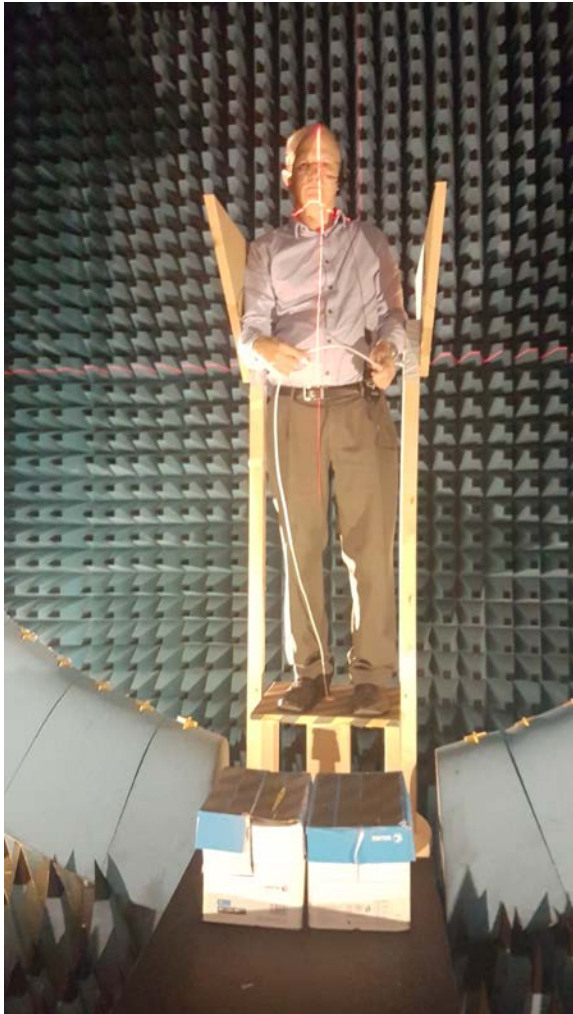
Radial Scale: dBi



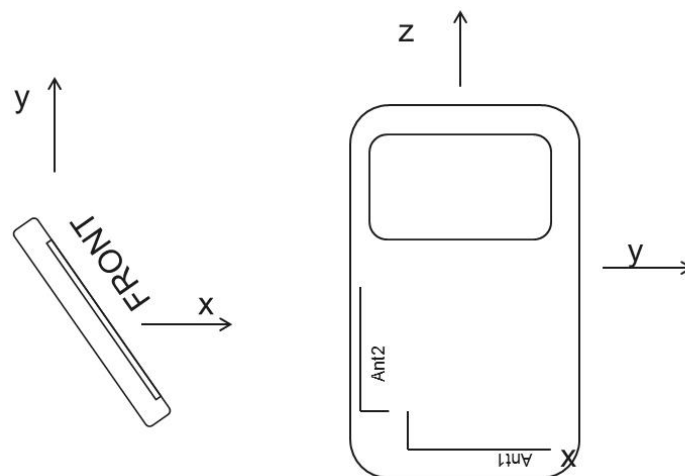
Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20714: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_SIDE (standalone)			
> Plane: YZ - Polarization: Total			
1880	0.9	-1.5	-2.0
1900	1.0	-1.4	-1.8
1920	1.3	-1.0	-1.3
Mean:	1.1	-1.3	-1.7

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### 6.2.3 DUT worn on the belt



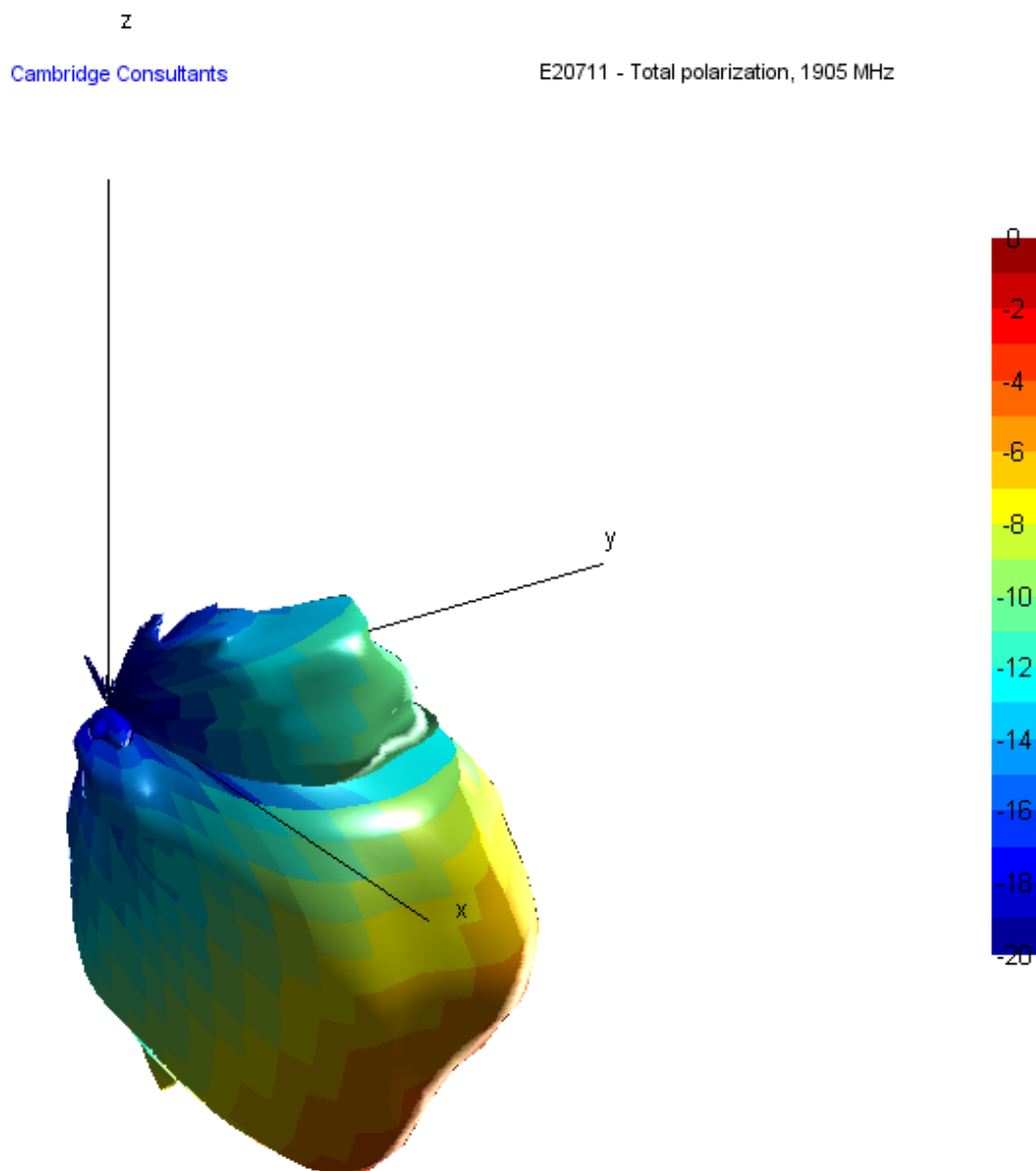
The device was clipped to the trouser belt. The Satimo centre of reference is slightly higher than the AUT position, therefore all the plots need to be considered down-tilted of some degree.



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### 6.2.3.1 Antenna 1 (BOTTOM), belt worn

#### 6.2.3.1.1 Three dimensional radiation pattern plots



Peak gain = -3.7dBi

Avg gain from efficiency = -14dBi

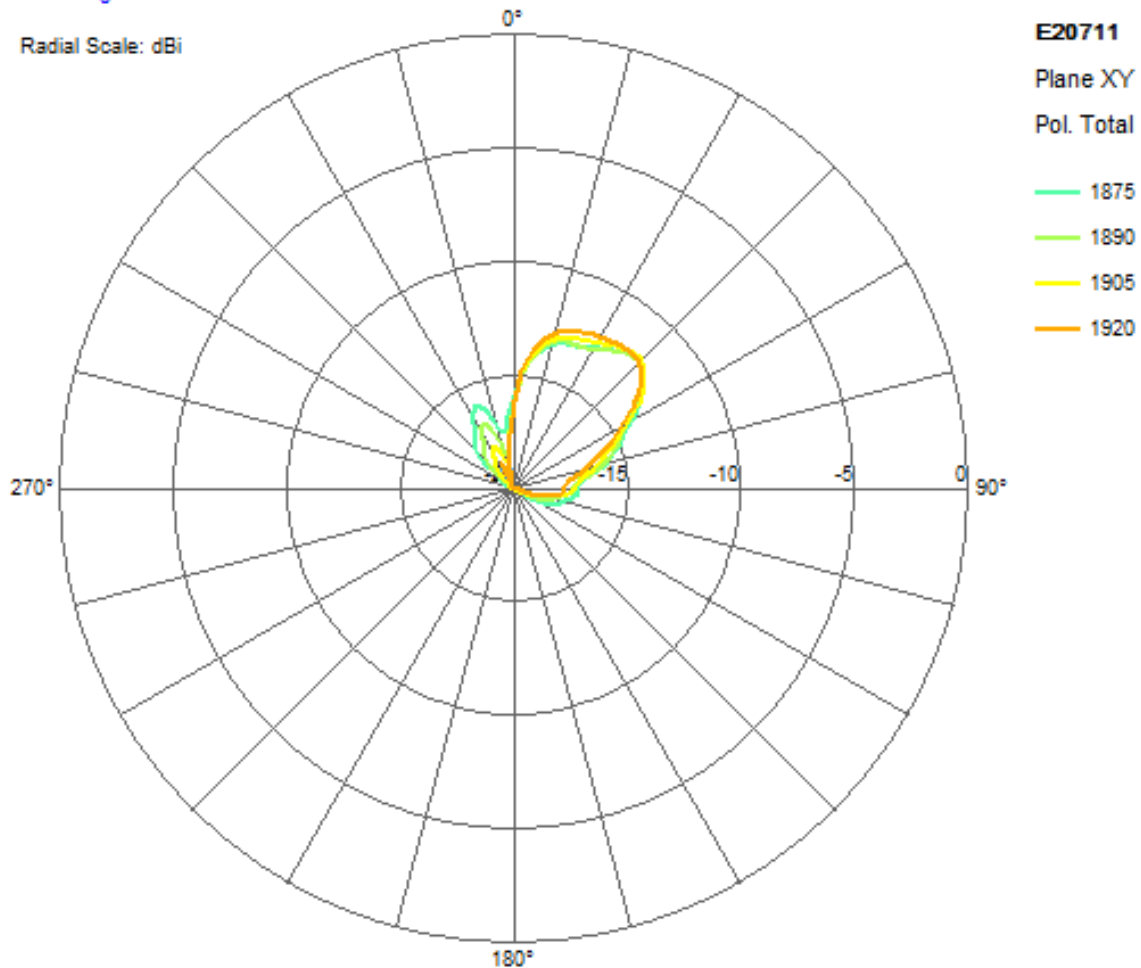
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### 6.2.3.1.2 XY Plane Radiation Patterns

The XY radiation plot is for a cut in the XY plane with  $Z = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20711: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_BOTTOM_onBELT			
> Plane: XY - Polarization: Total			
1875	-12.1	-17.8	-18.0
1890	-12.2	-18.1	-18.3
1905	-12.0	-18.3	-18.4
1920	-12.1	-18.5	-18.8
Mean:	-12.1	-18.2	-18.3

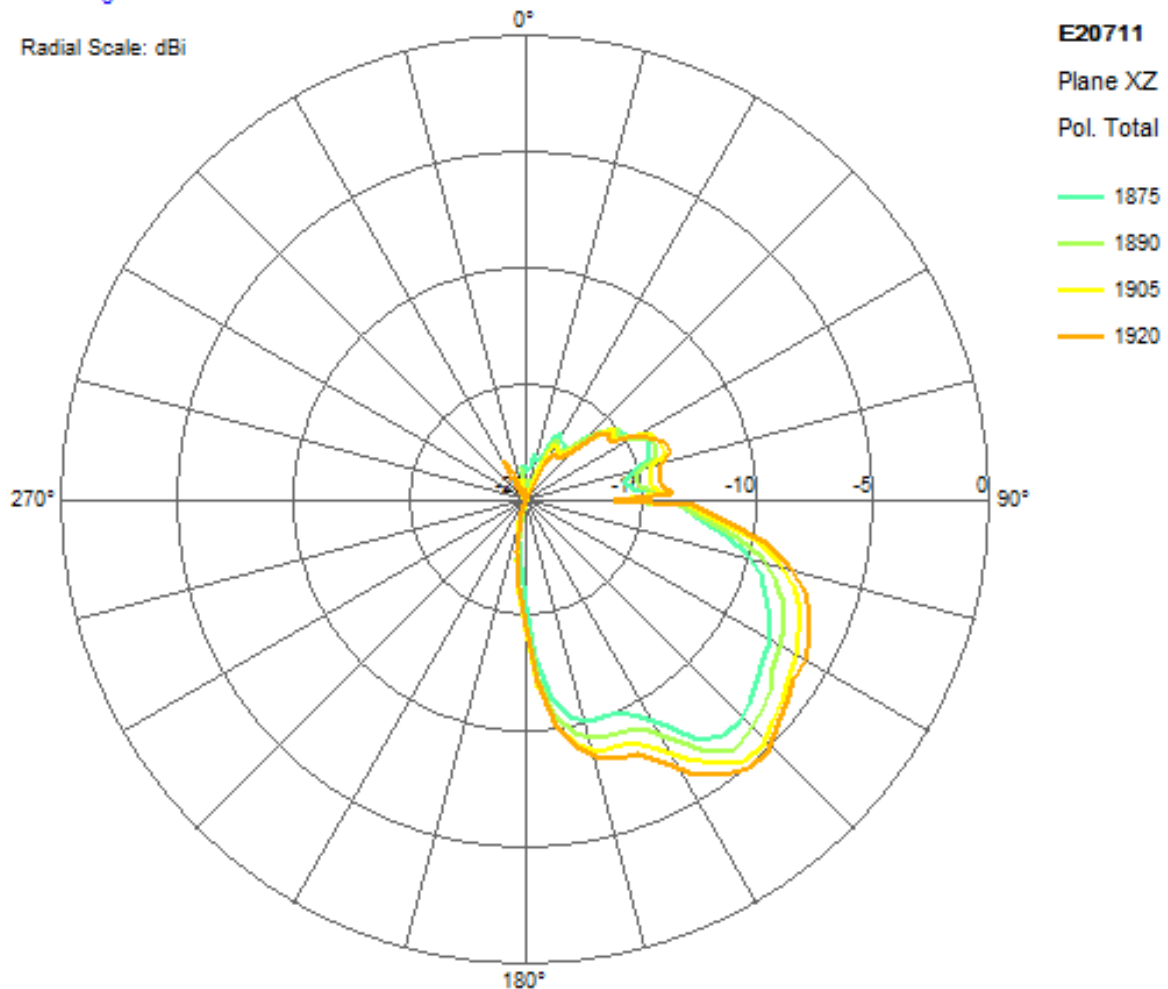
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### 6.2.3.1.3 XZ Plane Radiation Patterns

The XZ radiation plot is for a cut in the XZ plane with  $Y = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20711: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_BOTTOM_onBELT			
> Plane: XZ - Polarization: Total			
1875	-6.7	-14.1	-13.8
1890	-5.9	-13.6	-13.3
1905	-5.3	-13.0	-12.7
1920	-4.9	-12.7	-12.3
Mean:	-5.6	-13.3	-13.0

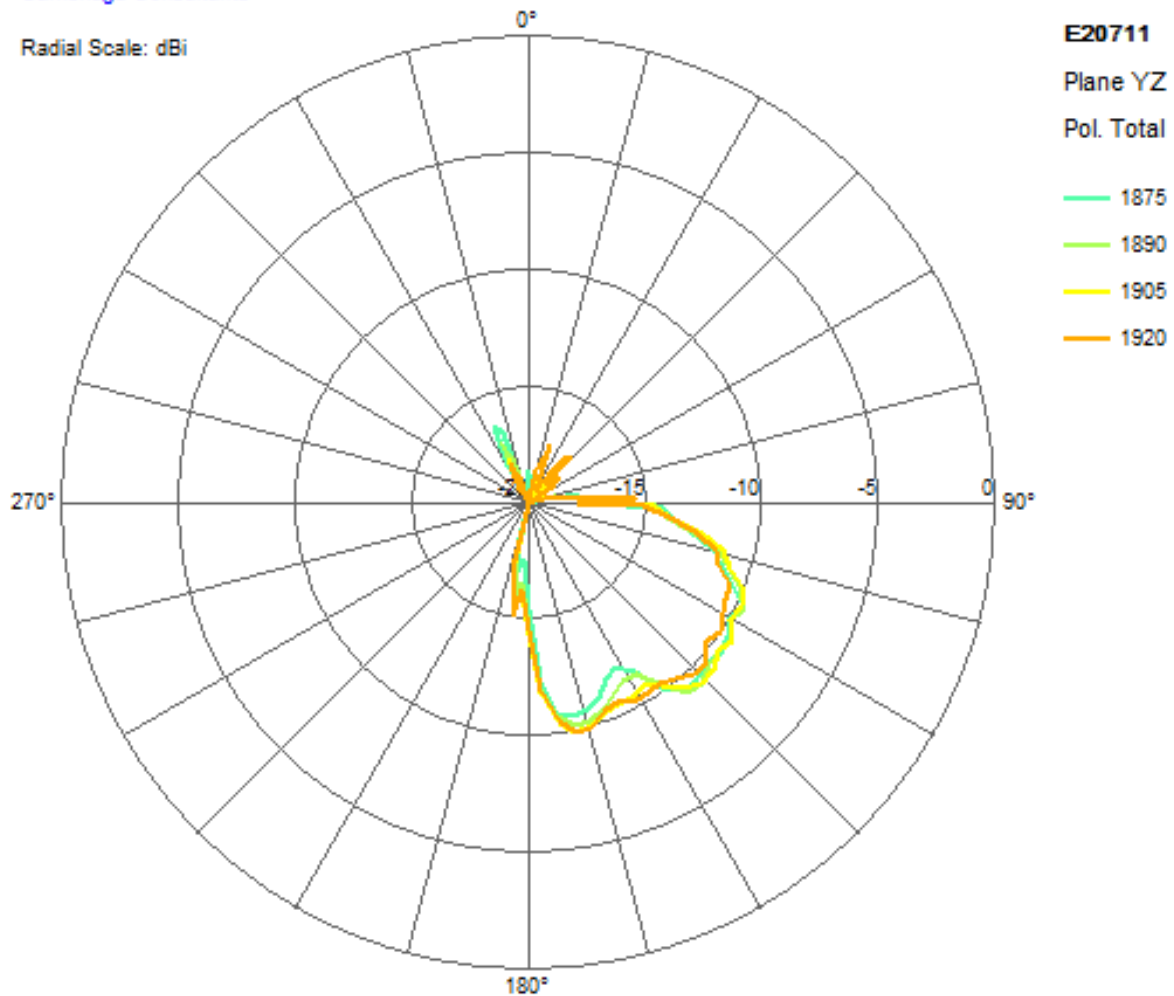
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#### 6.2.3.1.4 YZ Plane Radiation Patterns

The YZ radiation plot is for a cut in the YZ plane with  $X = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20711: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_BOTTOM_onBELT			
> Plane: YZ - Polarization: Total			
1875	-9.5	-16.0	-16.1
1890	-9.3	-15.9	-16.0
1905	-9.3	-15.7	-15.9
1920	-9.7	-15.8	-16.1
Mean:	-9.4	-15.9	-16.0

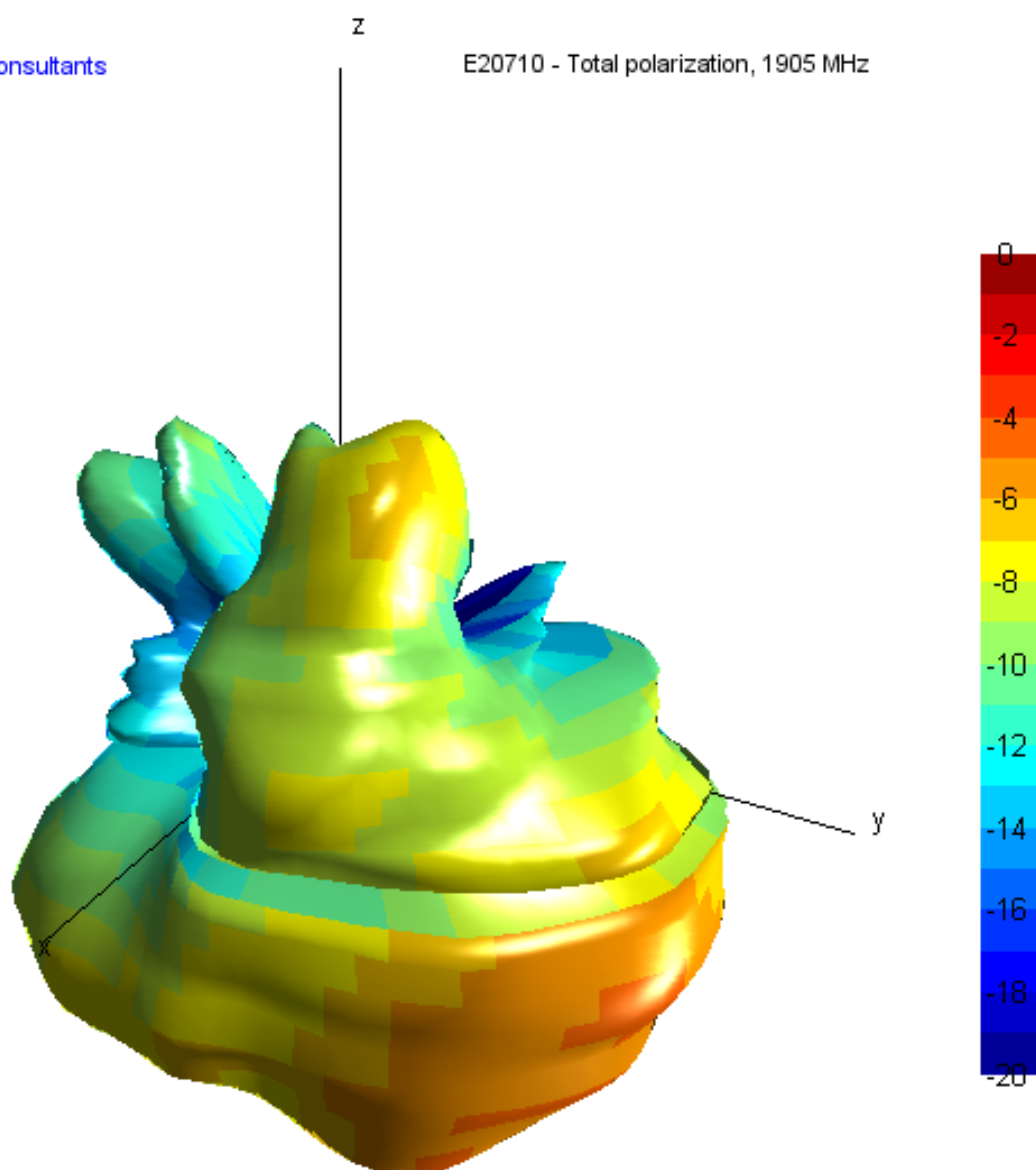


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## 6.2.3.2 Antenna 2 (SIDE) , belt worn

### 6.2.3.2.1 Three dimensional radiation pattern plots

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Peak gain = -4.7dBi

Avg gain from efficiency = -14dBi



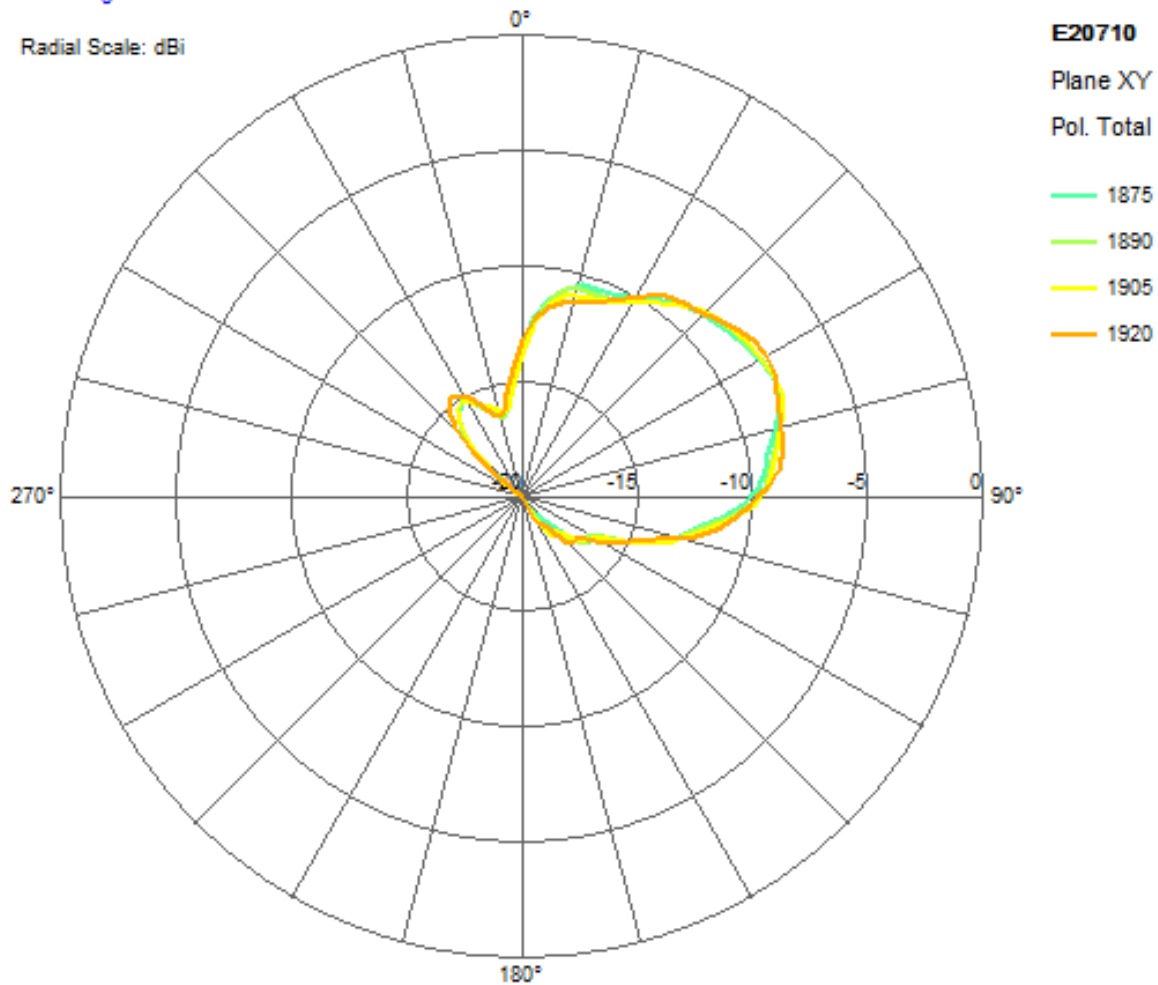
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### 6.2.3.2.2 XY Plane Radiation Patterns

The XY radiation plot is for a cut in the XY plane with  $Z = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20710: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_SIDE_(BELT)			
> Plane: XY - Polarization: Total			
1875	-7.9	-14.0	-13.6
1890	-7.9	-13.9	-13.5
1905	-7.9	-13.9	-13.4
1920	-7.8	-13.8	-13.3
Mean:	-7.9	-13.9	-13.5

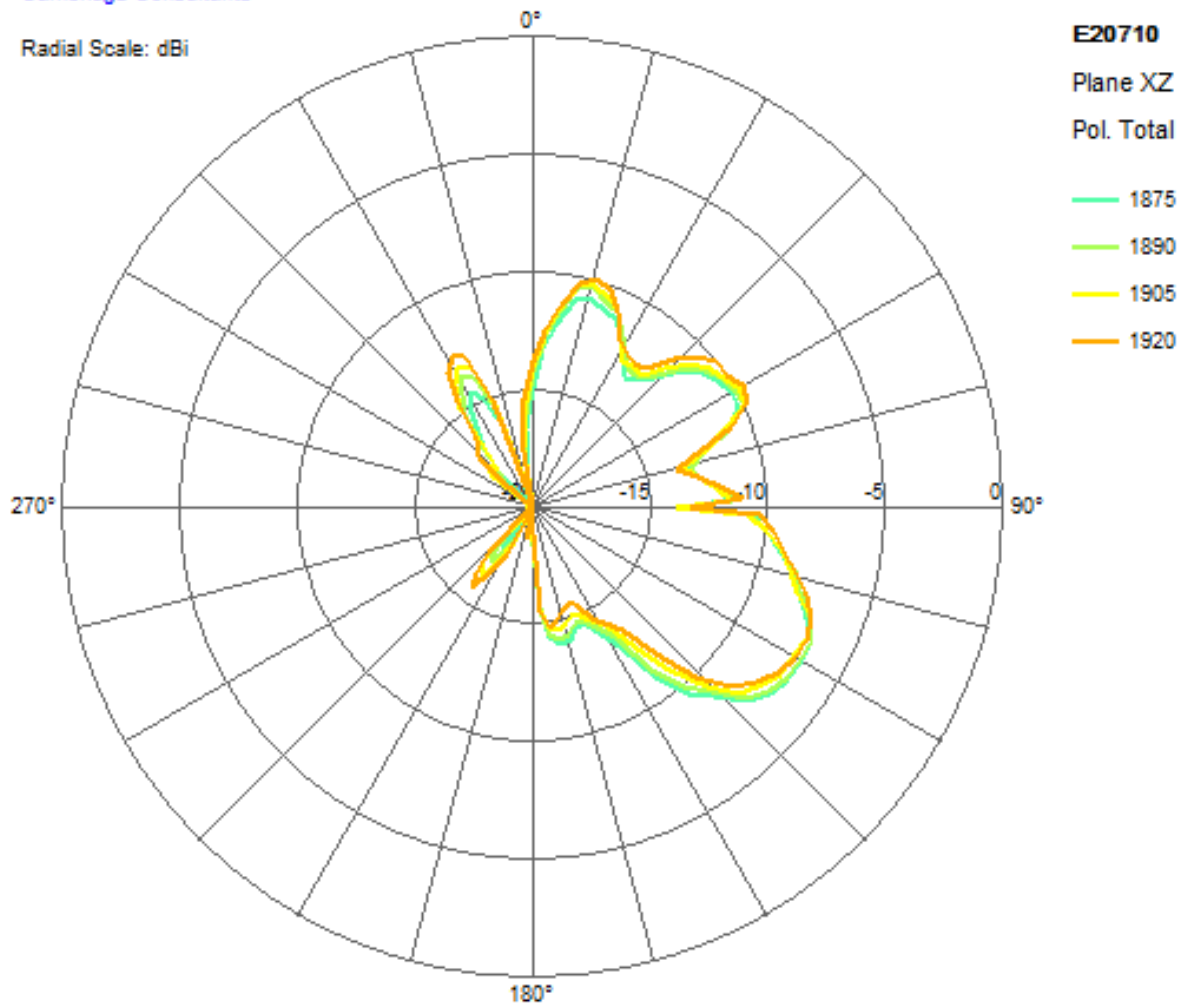
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### 6.2.3.2.3 XZ Plane Radiation Patterns

The XZ radiation plot is for a cut in the XZ plane with  $Y = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20710; P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_SIDE_(BELT)			
> Plane: XZ - Polarization: Total			
1875	-6.8	-13.2	-12.6
1890	-6.8	-13.0	-12.6
1905	-7.0	-13.1	-12.7
1920	-7.0	-13.0	-12.6
Mean:	-6.9	-13.1	-12.6

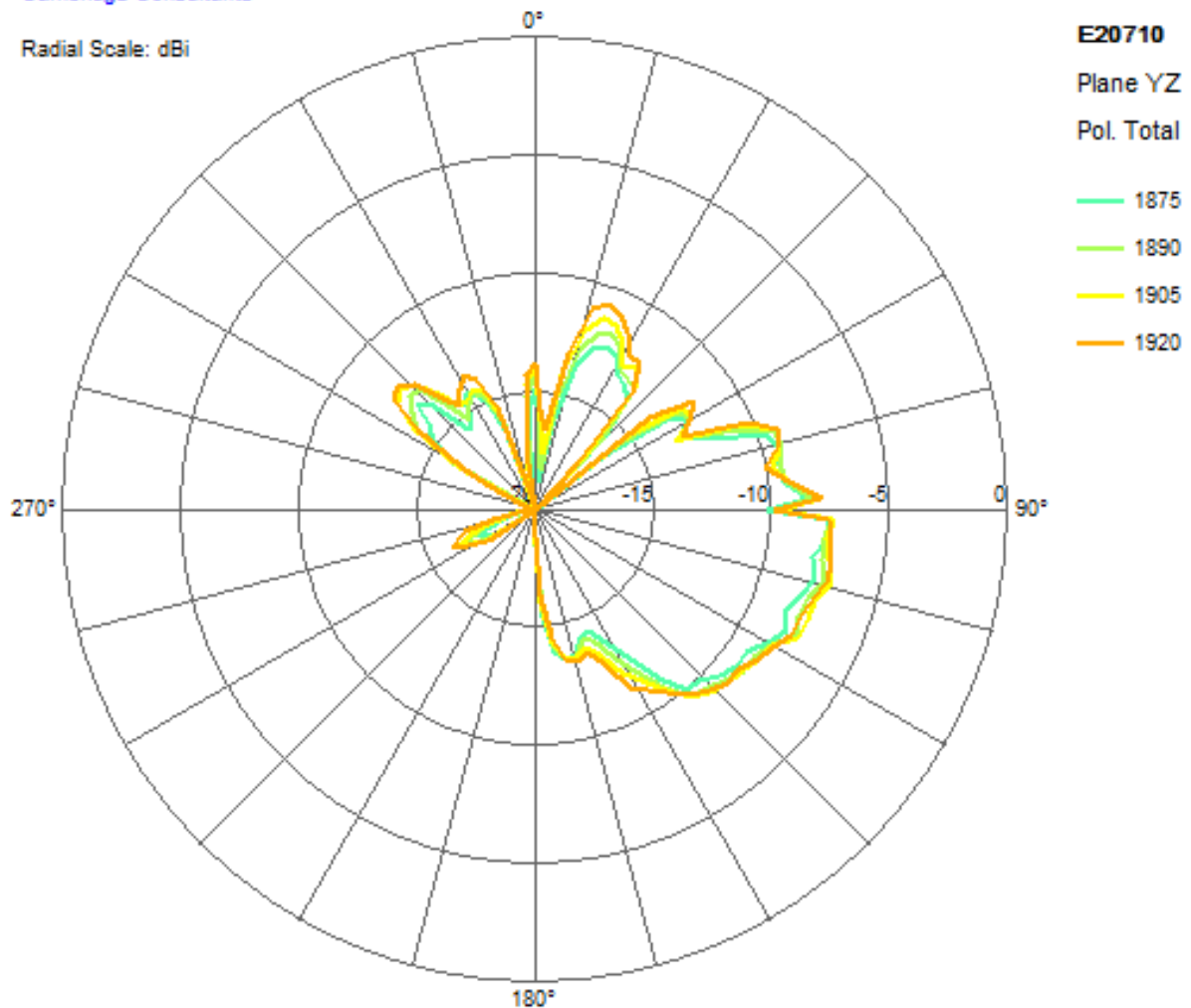
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#### 6.2.3.2.4 YZ Plane Radiation Patterns

The YZ radiation plot is for a cut in the YZ plane with  $X = 0$ .

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Radial Scale: dBi



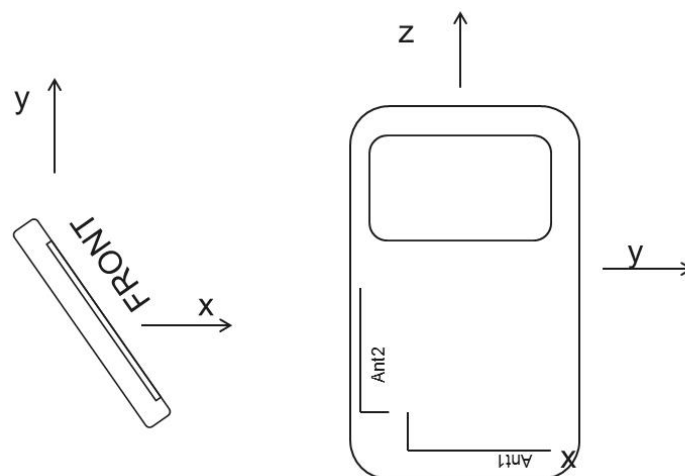
Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20710: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_SIDE_(BELT)			
> Plane: YZ - Polarization: Total			
1875	-7.6	-13.4	-12.6
1890	-7.4	-13.0	-12.3
1905	-7.1	-12.8	-12.1
1920	-7.2	-12.7	-12.0
Mean:	-7.3	-13.0	-12.3

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## 6.2.4 AUT hand-held



The DUT was hand-held at shoulder height (near the centre of the chamber reference), with the base of the thumb close to Ant2. The results should show the combined effect of detuning (due to the closeness of the hand to the antenna) and absorption due to the hand itself and the body in proximity.



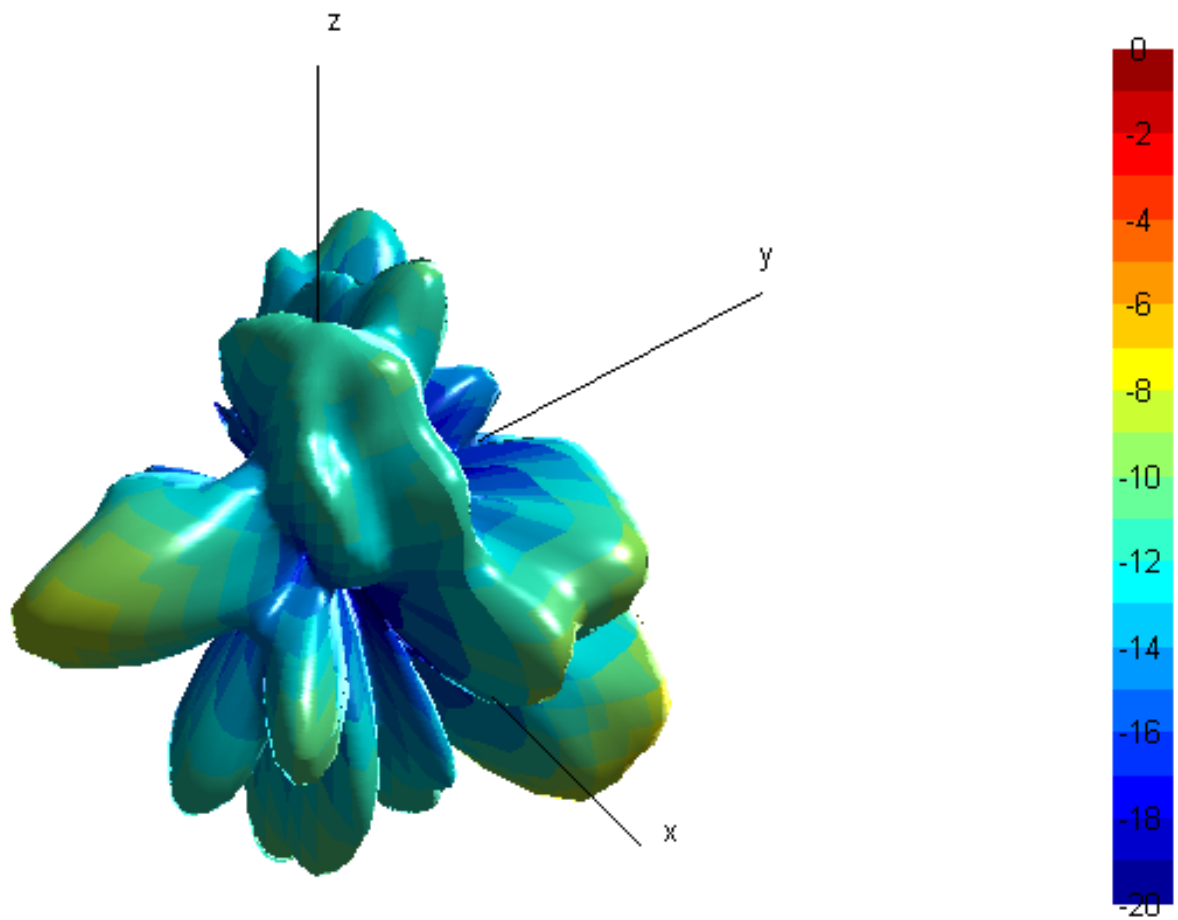
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### 6.2.4.1 Antenna 1 (BOTTOM), hand-held

#### 6.2.4.1.1 Three dimensional radiation pattern plots

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E20712 - Total polarization, 1905 MHz



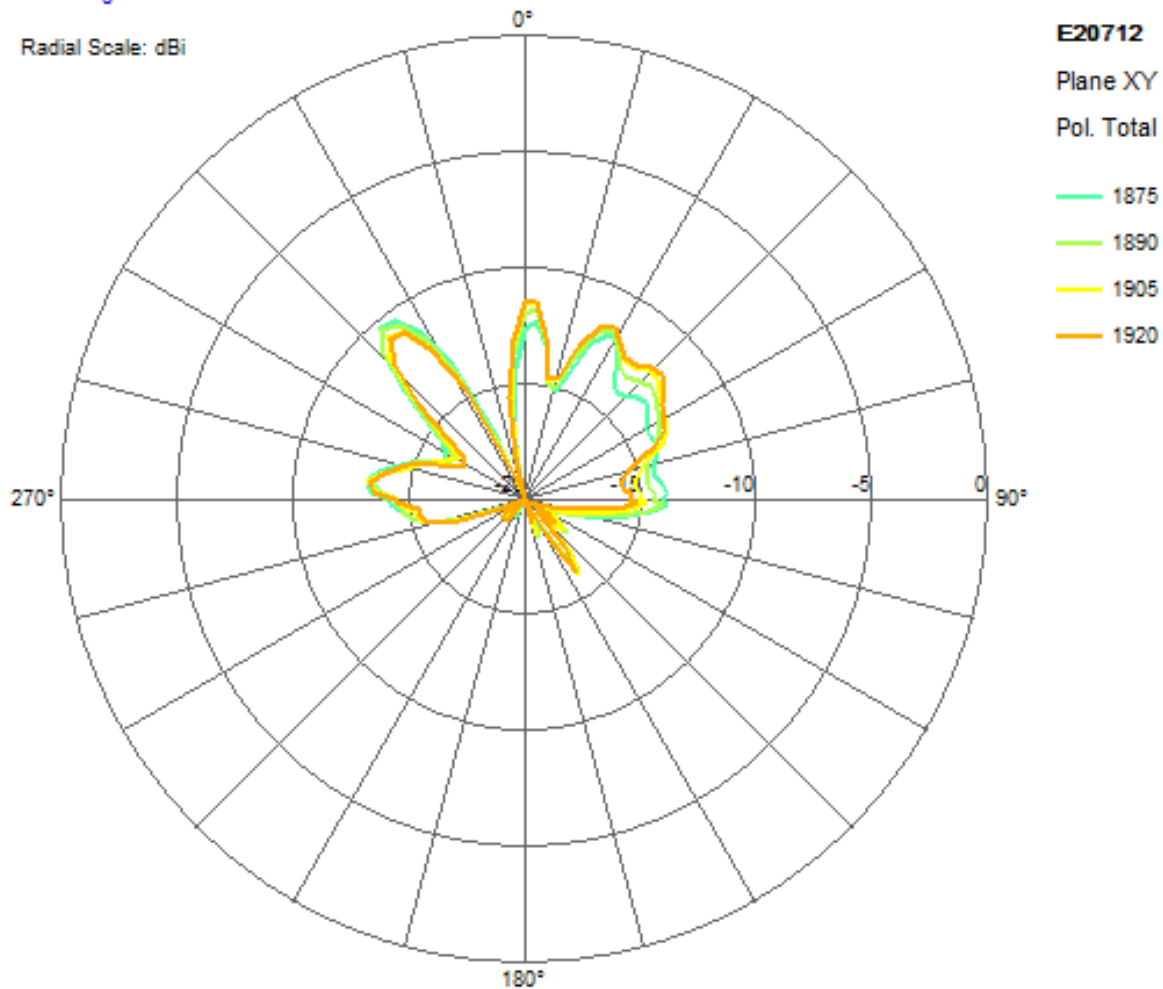
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#### 6.2.4.1.2 XY Plane Radiation Patterns

The XY radiation plot is for a cut in the XY plane with  $Z = 0$ .

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Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20712: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_BOTTOM( hand held)			
> Plane: XY - Polarization: Total			
1875	-10.5	-15.4	-15.2
1890	-10.5	-15.3	-15.2
1905	-10.9	-15.3	-15.3
1920	-11.1	-15.4	-15.4
Mean:	-10.7	-15.4	-15.3

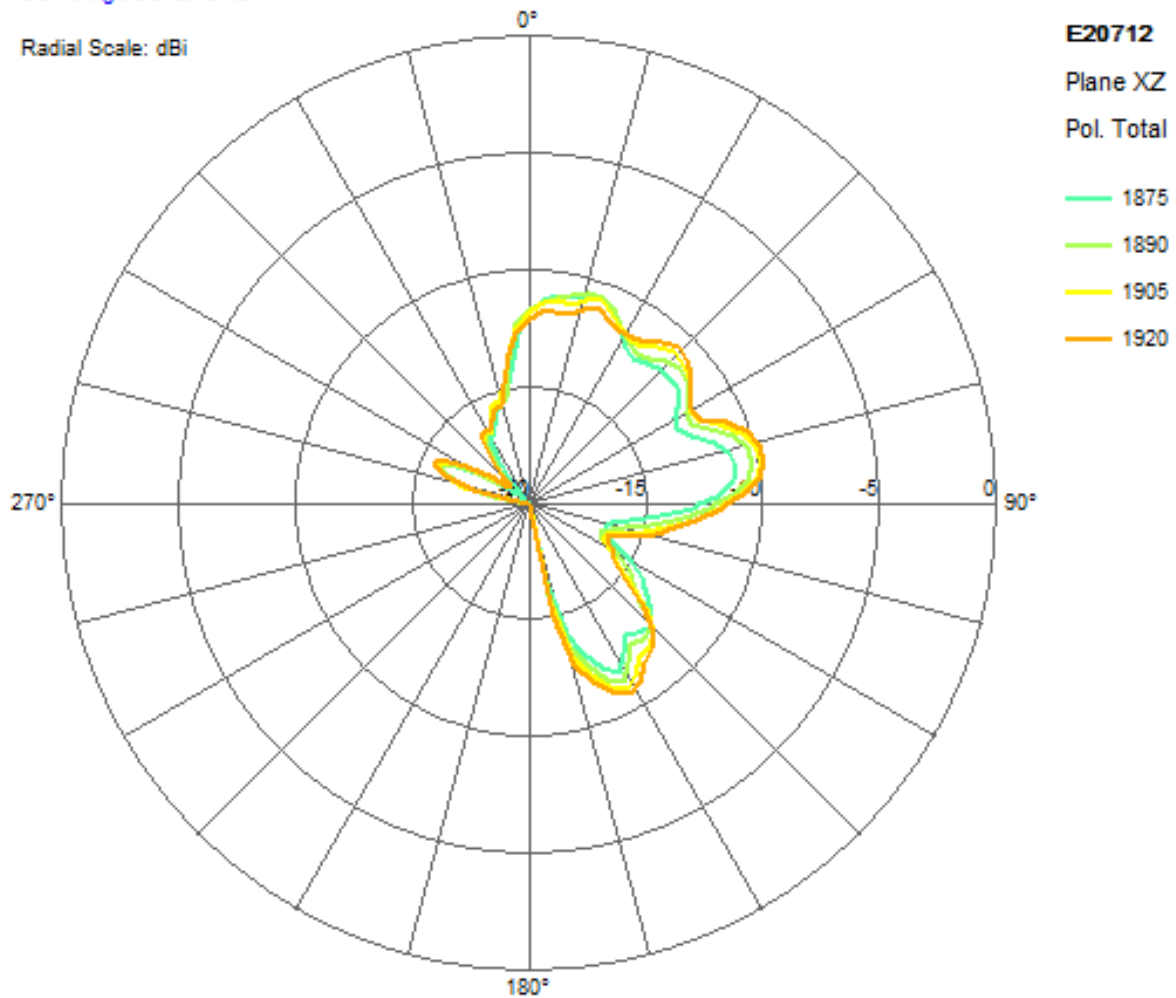
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### 6.2.4.1.3 XZ Plane Radiation Patterns

The XZ radiation plot is for a cut in the XZ plane with  $Y = 0$ .

Cambridge Consultants

Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20712: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_BOTTOM( hand held)			
> Plane: XZ - Polarization: Total			
1875	-10.7	-14.8	-15.0
1890	-10.3	-14.5	-14.7
1905	-9.9	-14.3	-14.4
1920	-9.8	-14.3	-14.3
Mean:	-10.1	-14.5	-14.6

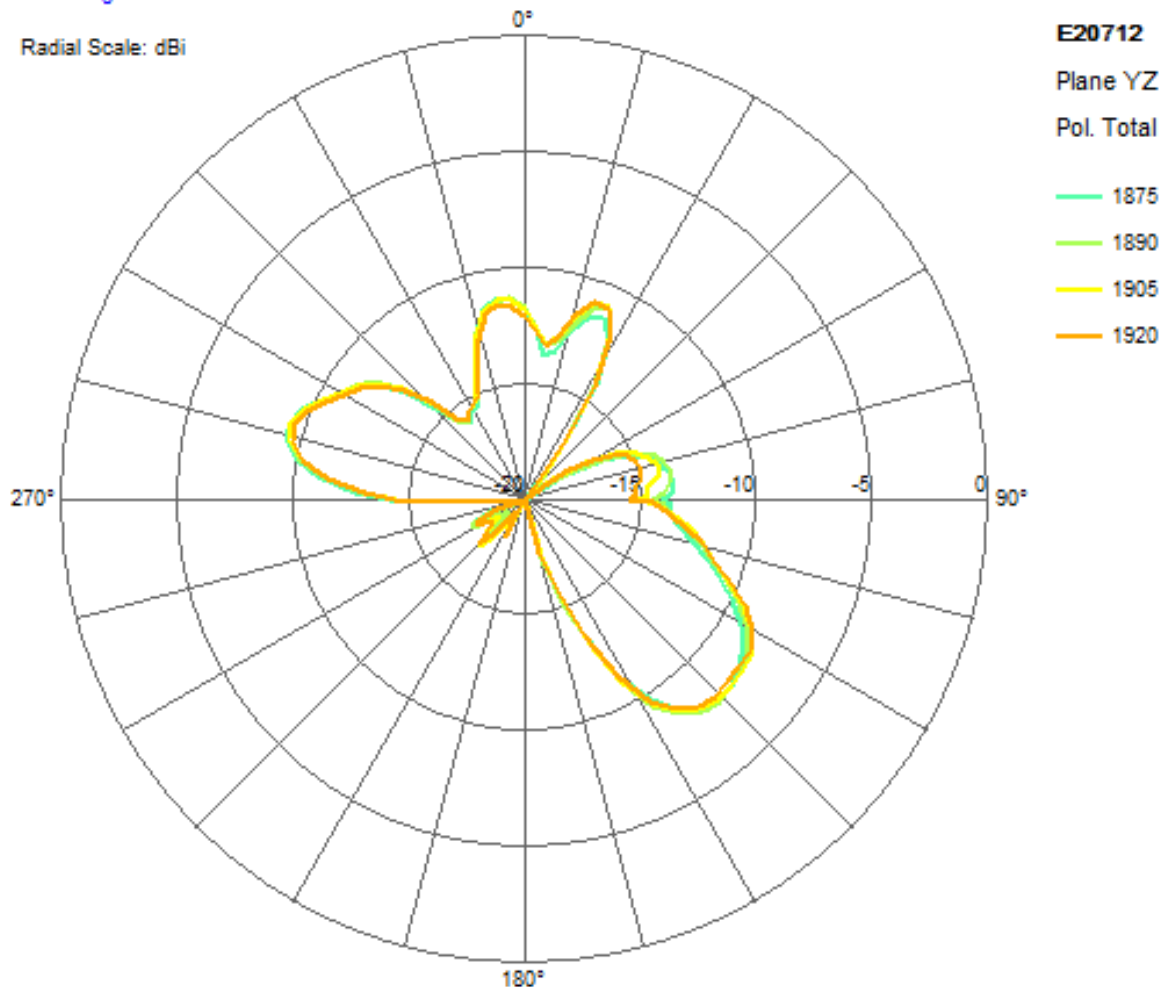
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#### 6.2.4.1.4 YZ Plane Radiation Patterns

The YZ radiation plot is for a cut in the YZ plane with  $X = 0$ .

Cambridge Consultants

Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20712: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_BOTTOM( hand held)			
> Plane: YZ - Polarization: Total			
1875	-7.8	-13.2	-12.9
1890	-7.8	-13.1	-12.8
1905	-8.0	-13.1	-12.8
1920	-8.1	-13.3	-12.9
Mean:	-7.9	-13.2	-12.9



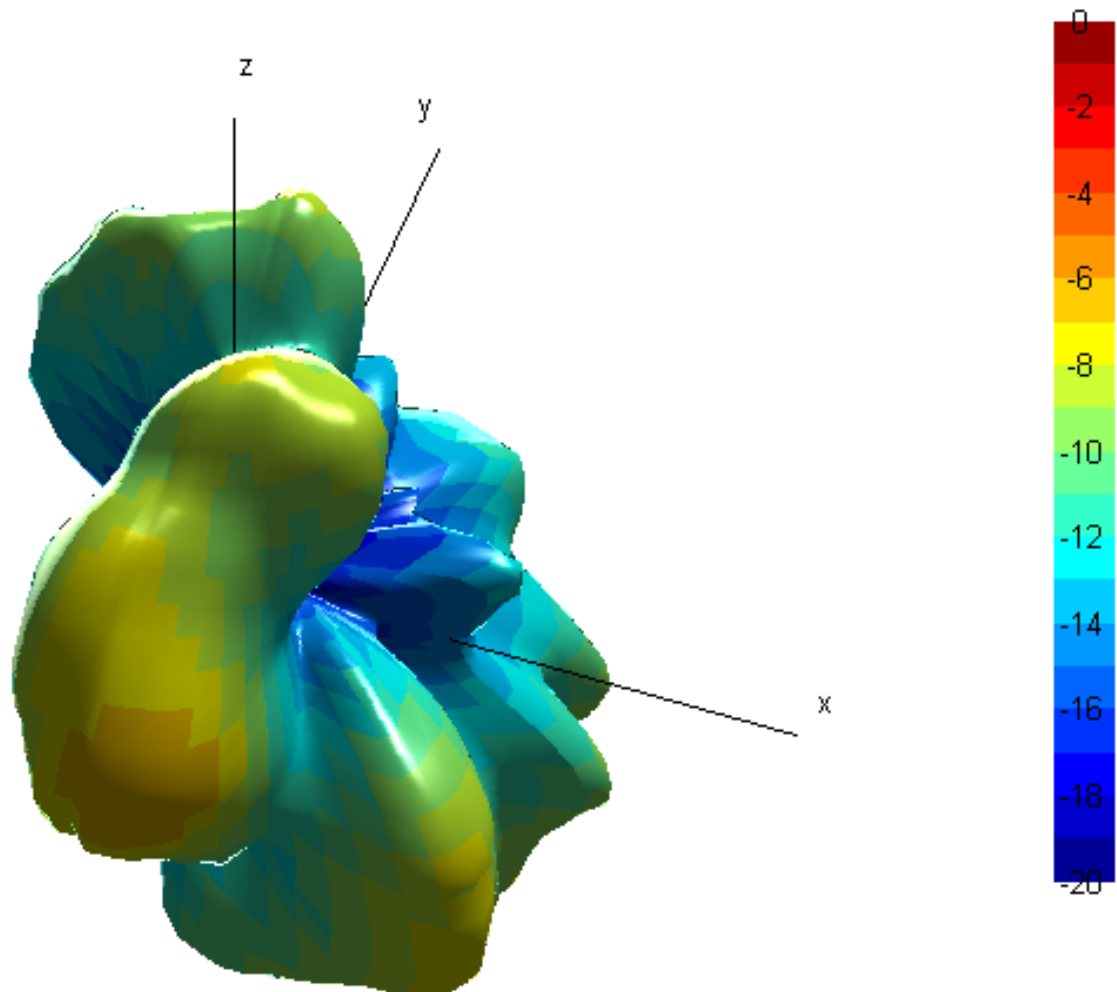
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## 6.2.4.2 Antenna 2 (SIDE) , hand-held

### 6.2.4.2.1 Three dimensional radiation pattern plots

Cambridge Consultants

E20713 - Total polarization, 1905 MHz



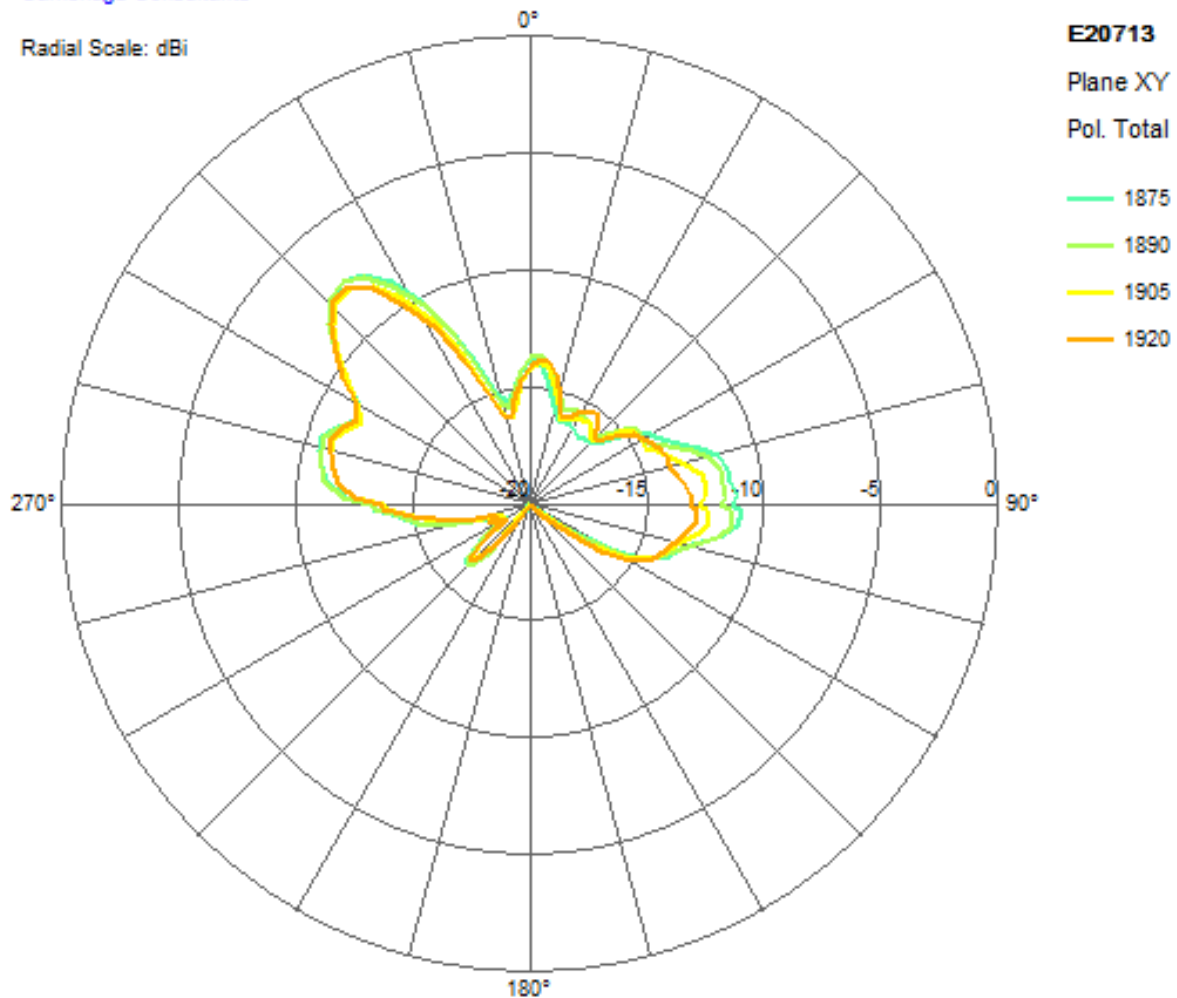
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#### 6.2.4.2.2 XY Plane Radiation Patterns

The XY radiation plot is for a cut in the XY plane with  $Z = 0$ .

Cambridge Consultants

Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20713: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_SIDE( hand held)			
> Plane: XY - Polarization: Total			
1875	-7.6	-13.9	-13.3
1890	-7.6	-13.9	-13.3
1905	-8.0	-14.3	-13.8
1920	-8.0	-14.4	-13.8
Mean:	-7.8	-14.1	-13.5

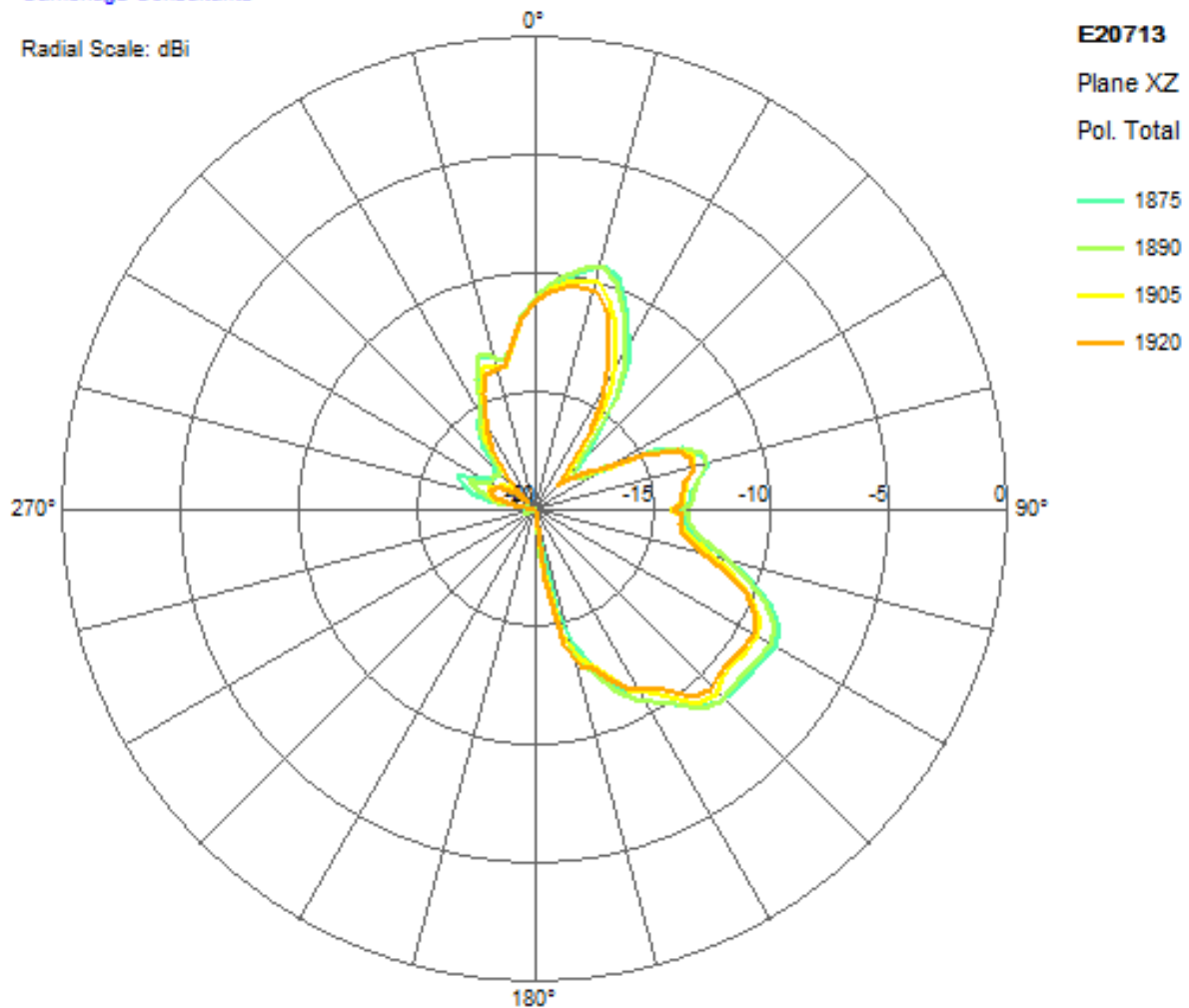
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### 6.2.4.2.3 XZ Plane Radiation Patterns

The XZ radiation plot is for a cut in the XZ plane with  $Y = 0$ .

Cambridge Consultants

Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20713: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_SIDE( hand held)			
> Plane: XZ - Polarization: Total			
1875	-8.3	-13.7	-13.8
1890	-8.5	-13.7	-13.9
1905	-9.0	-14.2	-14.4
1920	-9.3	-14.4	-14.6
Mean:	-8.8	-14.0	-14.2

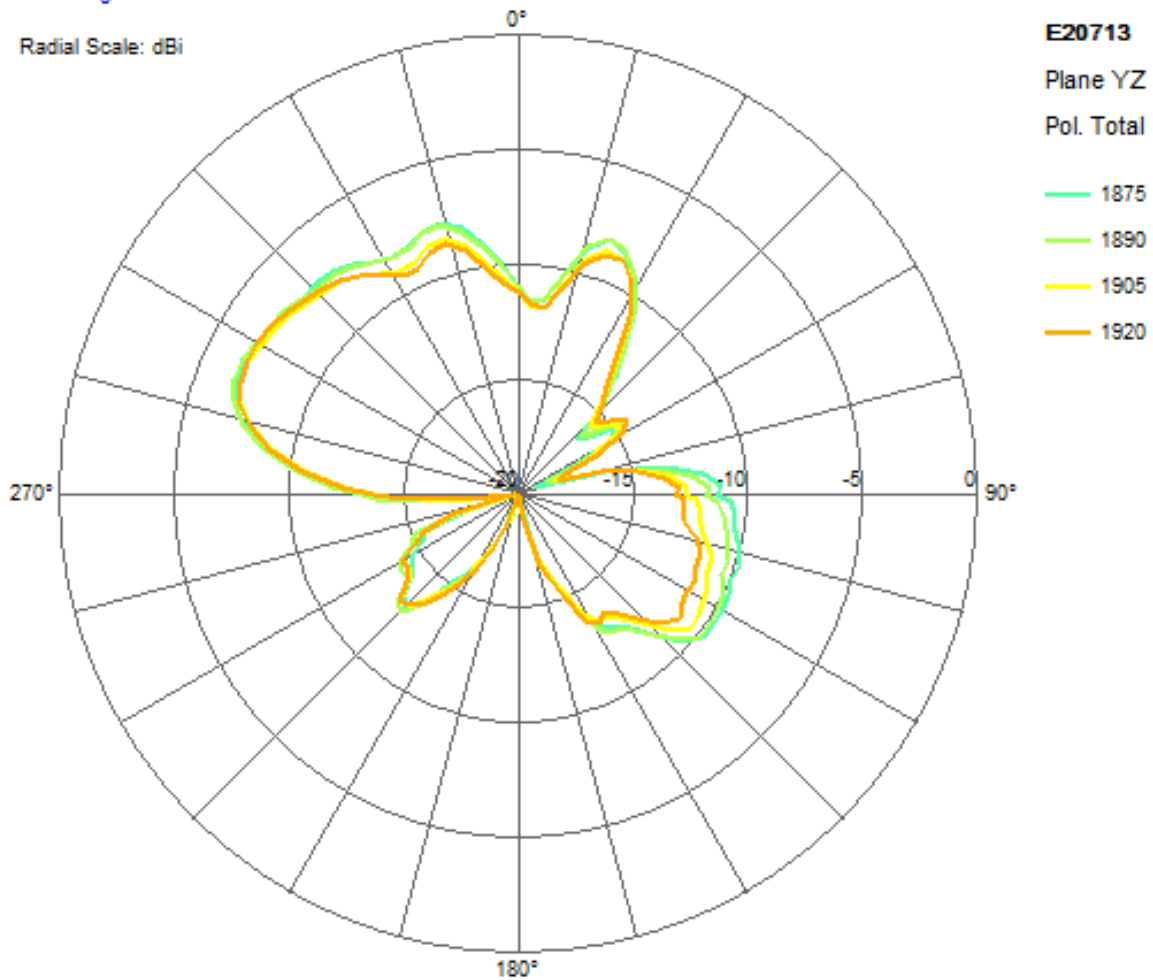
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#### 6.2.4.2.4 YZ Plane Radiation Patterns

The YZ radiation plot is for a cut in the YZ plane with  $X = 0$ .

Cambridge Consultants

Radial Scale: dBi



Freq. [MHz]	Peak Gain	Linear Average	Spheric Average
> E20713: P2447 - em2 - 31-Oct-2016			
> Element36_A0_Assembled_2nd_SIDE( hand held)			
> Plane: YZ - Polarization: Total			
1875	-6.7	-11.1	-10.9
1890	-6.6	-11.2	-11.0
1905	-6.9	-11.6	-11.4
1920	-6.9	-11.7	-11.5
Mean:	-6.8	-11.4	-11.2