overview

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Dark-Fiber Charakterisierung für entanglement polarisierter QKD

Übersicht und Aufbereitung von Messverfahren und Messdaten

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1 Einleitung: Kenngrößen, Messgerät und Datengrundlage

1.1 Ressourcen und Literatur

- Messdaten
- Messgerät
- Abbildung: Poincaré-Kugel

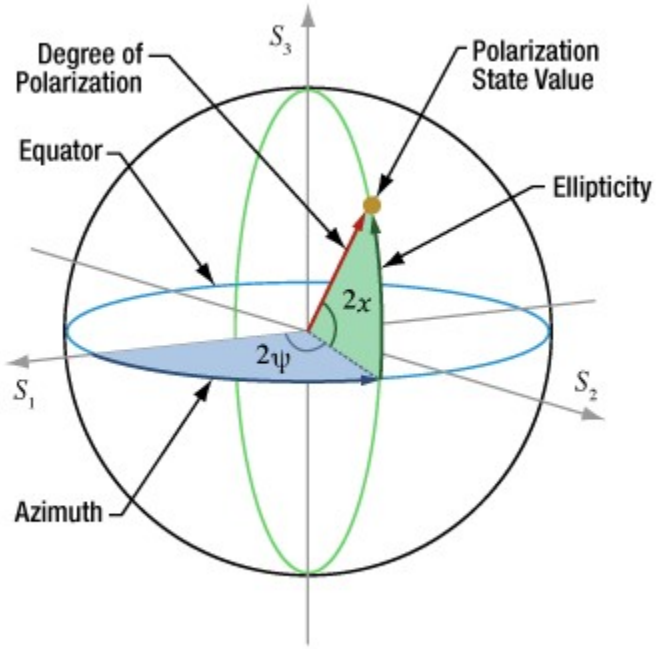
1.2 Kenngrößen: Bedeutung und Einheiten

Kenngöße	Einheit	Bedeutung
Time	date hh:mm:ss	absoluter Messzeitpunkt
Elapsed Time	hh:mm:ss:ms	relativer Messzeitpunkt
Normalized s1, s2, s3	-	Normierte Stokes-Komponenten
S0	mW	Gesamtleistung
S1, S2, S3	mW	Stokes-Komponenten
Azimuth	°	Winkel in der Poincaré-Kugel (horizontaler Winkel)
Ellipticity	°	Maß für elliptische Polarisation (vertikaler Winkel)
DOP	%	Degree of Polarization
DOCP	%	Degree of Circular Polarization (Zirkularitätsmaß)

Kenngöße	Einheit	Bedeutung
DOLP	%	Degree of Linear Polarization (Linearitätsmaß)
Power	mW / dBm	Gesamtleistung
Pol Power	mW / dBm	Polarisierter Anteil (= DOP × Gesamtleistung)
Unipol Power	mW / dBm	Unpolarisierter Anteil (= (1–DOP) × Gesamtleistung)
Phase Difference	°	Phasenunterschied zw. Polarisationsmoden
Power-Split-Ratio	-	Leistungsverhältnis zweier Polarisationsrichtungen
Warning	-	Hinweis für fehlerhafte Messung

[1]:
```
from IPython.display import Image
Image(filename="./poincare.jpg")
```

[1]:



1.3 Messgerät und Messverfahren

Kenngöße	Info
Device	PAX1000IR2/M
Serial Number	M00773008
Firmware Version	1.2.1
Software Version	1.4.2002.183
Wavelength [nm]	1560
Basic Sample Rate [Hz]	100
Operating Mode	revolutions for one measurement, 2048 points for FFT

2 Aufbereitung der Messdaten

2.1 Verwendete Libraries / Softwaretools

[3]:
```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import io
import datetime
import requests

from prettytable import PrettyTable
```

2.2 Eigene Hilfsfunktionen

[4]:
```
def fast_parse_elapsed(s):
    try:
        d, h, m, s, ms = s.replace('.', ':').split(':')
        return pd.Timedelta(days=int(d), hours=int(h), minutes=int(m),␣
↪seconds=int(s), milliseconds=int(ms))
    except:
        return pd.NaT
```

2.3 Datenaufbereitungsschritte

[5]:
```
filename ='29.11.2024_10d.csv'
skip = 8
sep = ";"
```

[6]:
```

```

```
columns = ['Time[date hh:mm:ss] ', ' Elapsed Time [hh:mm:ss:ms]', ' Normalized␣
 ↪s 1 ', ' Normalized s 2 ', ' Normalized s 3 ', ' S 0 [mW]', ' S 1 [mW]', ' S␣
 ↪2 [mW]', ' S 3 [mW]', ' Azimuth[°] ', ' Ellipticity[°] ', ' DOP[%] ', '␣
 ↪DOCP[%] ', ' DOLP[%] ', ' Power[mW] ', ' Pol Power[mW] ', ' Unpol Power[mW]␣
 ↪', ' Power[dBm] ', ' Pol Power[dBm] ', ' Unpol Power[dBm] ', '␣
 ↪Power-Split-Ratio ', ' Phase Difference[°] ', ' Warning']
for c in range(len(columns)):
    print(c, ': ', columns[c])
```

```
0 :  Time[date hh:mm:ss]
1 :   Elapsed Time [hh:mm:ss:ms]
2 :   Normalized s 1
3 :   Normalized s 2
4 :   Normalized s 3
5 :   S 0 [mW]
6 :   S 1 [mW]
7 :   S 2 [mW]
8 :   S 3 [mW]
9 :   Azimuth[°]
10 :   Ellipticity[°]
11 :   DOP[%]
12 :   DOCP[%]
13 :   DOLP[%]
14 :   Power[mW]
15 :   Pol Power[mW]
16 :   Unpol Power[mW]
17 :   Power[dBm]
18 :   Pol Power[dBm]
19 :   Unpol Power[dBm]
20 :   Power-Split-Ratio
21 :   Phase Difference[°]
22 :   Warning
```

3 Analyse der Messdaten

3.1 Fehler (Warning)

[7]:
```
warning = pd.read_csv(filename,skiprows=skip, usecols=[columns[22]], sep=sep)
```

[8]:
```
warning.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 7092298 entries, 0 to 7092297
Data columns (total 1 columns):
 #   Column    Dtype
---  ------    -----
 0    Warning  float64
dtypes: float64(1)
```

```
memory usage: 54.1 MB
```

[9]:
```
warning.isnull().sum()
```

[9]:
```
Warning    7092298
dtype: int64
```

3.2 Zeitwerte (Time, Elapsed Time)

[10]:
```
time = pd.read_csv(filename,skiprows=skip, usecols=[columns[0], columns[1]],␣
 ↪sep=sep)
```

[11]:
```
time.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 7092298 entries, 0 to 7092297
Data columns (total 2 columns):
 #   Column                        Dtype
---  ------                        -----
 0   Time[date hh:mm:ss]           object
 1    Elapsed Time [hh:mm:ss:ms]   object
dtypes: object(2)
memory usage: 108.2+ MB
```

[12]:
```
time.isnull().sum()
```

[12]:
```
Time[date hh:mm:ss]            0
 Elapsed Time [hh:mm:ss:ms]    0
dtype: int64
```

[13]:
```
time[columns[0]] = pd.to_datetime(time[columns[0]])
time['time_difference'] = time[columns[0]].diff()
time['time_frequency'] =  1 / time['time_difference'].dt.total_seconds()
time['time_difference']
```

[13]:
```
0                          NaT
1          0 days 00:00:00.060000
2          0 days 00:00:00.050000
3          0 days 00:00:00.050000
4          0 days 00:00:00.050000
                    …
7092293    0 days 00:00:05.160000
7092294    0 days 00:00:00.040000
7092295    0 days 00:00:00.050000
7092296    0 days 00:00:02.590000
7092297    0 days 00:00:00.470000
Name: time_difference, Length: 7092298, dtype: timedelta64[ns]
```

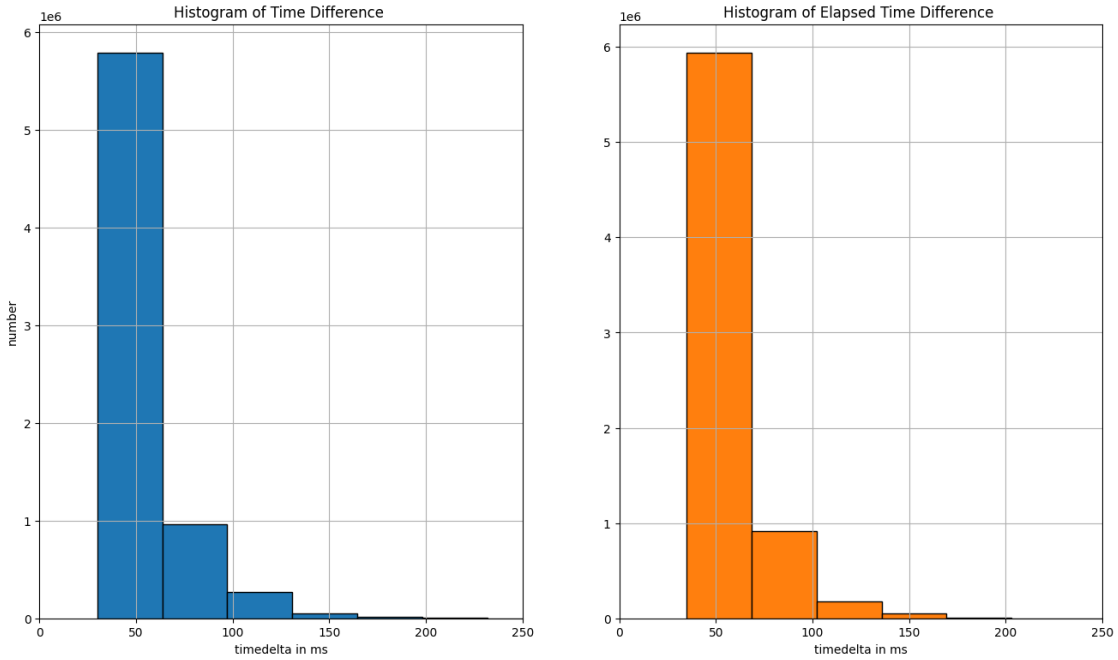
[14]:
```
time[columns[1]] = time[columns[1]].apply(fast_parse_elapsed)
time['elapsed_time_difference'] = time[columns[1]].diff()
time['elapsed_time_frequency'] =  1 / time['elapsed_time_difference'].dt.
 ↪total_seconds()
time['elapsed_time_difference']
```

[14]:
```
0                           NaT
1         0 days 00:00:00.060000
2         0 days 00:00:00.048000
3         0 days 00:00:00.056000
4         0 days 00:00:00.052000
                    …
7092293   0 days 00:00:05.155000
7092294   0 days 00:00:00.047000
7092295   0 days 00:00:00.048000
7092296   0 days 00:00:02.585000
7092297   0 days 00:00:00.477000
Name: elapsed_time_difference, Length: 7092298, dtype: timedelta64[ns]
```

[15]:
```
t = PrettyTable([' ', 'Time', 'Elapsed Time'])
t.add_row(['Max', time['time_difference'].max(),␣
 ↪time['elapsed_time_difference'].max()])
t.add_row(['Min', time['time_difference'].min(), ␣
 ↪time['elapsed_time_difference'].min()])
t.add_row(['Mean', time['time_difference'].mean(), ␣
 ↪time['elapsed_time_difference'].mean()])
t.add_row(['Std', time['time_difference'].std(), ␣
 ↪time['elapsed_time_difference'].std()])
t.add_row(['Most', time['time_difference'].value_counts(dropna=True).idxmax(),␣
 ↪time['elapsed_time_difference'].value_counts(dropna=True).idxmax()])
t.add_row(['Mean Frequency', time['time_frequency'].mean(), ␣
 ↪time['elapsed_time_frequency'].mean()])

t
```

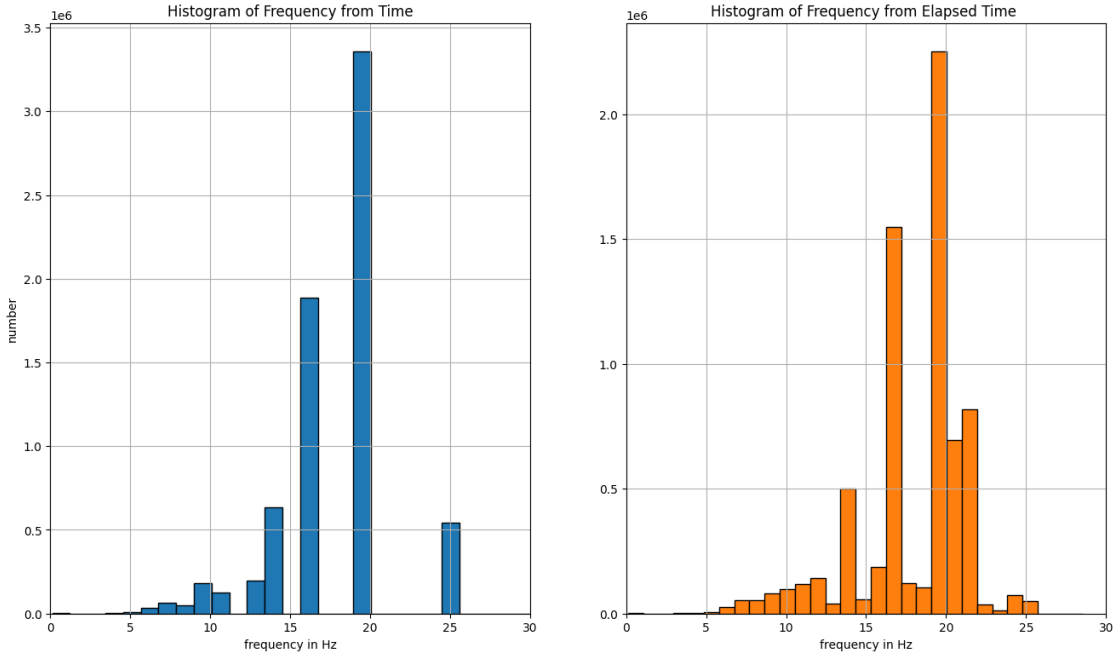
[15]:
```
+----------------+---------------------------+---------------------------+
|                |            Time           |        Elapsed Time       |
+----------------+---------------------------+---------------------------+
|      Max       |   0 days 00:00:08.440000  |   0 days 00:00:08.433000  |
|      Min       |   0 days 00:00:00.030000  |   0 days 00:00:00.035000  |
|      Mean      | 0 days 00:00:00.059365613 | 0 days 00:00:00.059365613 |
|      Std       | 0 days 00:00:00.043810670 | 0 days 00:00:00.043698223 |
|      Most      |   0 days 00:00:00.050000  |   0 days 00:00:00.051000  |
| Mean Frequency |      18.0609712139089     |     17.991727639966633    |
+----------------+---------------------------+---------------------------+
```

[16]:
```
time_difference = time['time_difference'].dt.total_seconds() * 1000
elapsed_time_difference = time['elapsed_time_difference'].dt.total_seconds() *␣
 ↪1000

plt.figure(figsize = (16,9))
plt.subplot(1, 2, 1)
plt.hist(time_difference, bins=250, color='tab:blue', edgecolor='black')
plt.xlim([0, 250])
plt.grid()
plt.xlabel('timedelta in ms')
plt.ylabel('number')
plt.title('Histogram of Time Difference ')

plt.subplot(1, 2, 2)
plt.hist(elapsed_time_difference, bins=250, color='tab:orange',␣
 ↪edgecolor='black')
plt.xlim([0, 250])
plt.grid()
plt.xlabel('timedelta in ms')
plt.title('Histogram of Elapsed Time Difference ')

plt.show()
```



[17]:
```
plt.figure(figsize = (16,9))
plt.subplot(1, 2, 1)
```

```
plt.hist(time['time_frequency'], bins=30, color='tab:blue', edgecolor='black')
plt.xlim([0, 30])
plt.grid()
plt.xlabel('frequency in Hz')
plt.ylabel('number')
plt.title('Histogram of Frequency from Time')

plt.subplot(1, 2, 2)
plt.hist(time['elapsed_time_frequency'], bins=30, color='tab:orange',␣
↪edgecolor='black')
plt.xlim([0, 30])
plt.grid()
plt.xlabel('frequency in Hz')
plt.title('Histogram of Frequency from Elapsed Time ')

plt.show()
```



3.3 Polarisationsgrade (DOP, DOCP, DOLP)

[18]:
```
degree = pd.read_csv(filename,skiprows=skip, usecols=[columns[0], columns[11],␣
↪columns[12], columns[13]], sep=sep)
```

[19]:
```
degree[columns[0]] = pd.to_datetime(degree[columns[0]])
degree.set_index(columns[0], inplace=True)
```

[20]:
```
degree.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 7092298 entries, 2024-11-29 00:26:44.470000 to 2024-12-03
21:24:03.030000
Data columns (total 3 columns):
 #   Column     Dtype
---  ------     -----
 0    DOP[%]    float64
 1    DOCP[%]   float64
 2    DOLP[%]   float64
dtypes: float64(3)
memory usage: 216.4 MB
```

[21]:
```
degree.isnull().sum()
```

[21]:
```
DOP[%]      0
DOCP[%]     0
DOLP[%]     0
dtype: int64
```

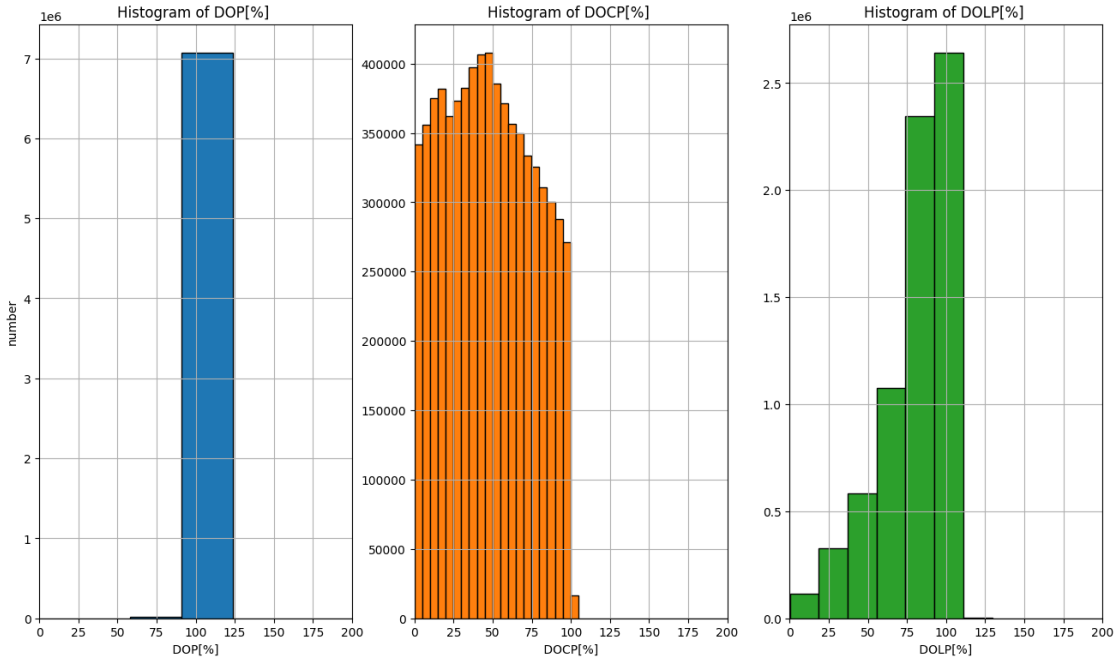
[22]:
```
degree.describe()
```

[22]:

	DOP[%]	DOCP[%]	DOLP[%]
count	7.092298e+06	7.092298e+06	7.092298e+06
mean	9.968967e+01	4.793726e+01	8.010235e+01
std	4.684479e+00	2.783318e+01	2.170073e+01
min	-3.703300e+03	0.000000e+00	5.000000e-02
25%	9.737000e+01	2.435000e+01	6.955000e+01
50%	9.950000e+01	4.698000e+01	8.768000e+01
75%	1.021500e+02	7.092000e+01	9.591000e+01
max	2.895590e+03	9.977200e+02	3.700080e+03

[23]:
```
plt.figure(figsize = (16,9))
plt.subplot(1, 3, 1)
plt.hist(degree[columns[11]], bins=200, color='tab:blue', edgecolor='black')
plt.xlim([0, 200])
plt.grid()
plt.xlabel(columns[11])
plt.ylabel('number')
plt.title('Histogram of DOP[%] ')

plt.subplot(1, 3, 2)
plt.hist(degree[columns[12]], bins=200, color='tab:orange', edgecolor='black')
plt.xlim([0, 200])
plt.grid()
plt.xlabel(columns[12])
plt.title('Histogram of DOCP[%] ')
```

```
plt.subplot(1, 3, 3)
plt.hist(degree[columns[13]], bins=200, color='tab:green', edgecolor='black')
plt.xlim([0, 200])
plt.grid()
plt.xlabel(columns[13])
plt.title('Histogram of DOLP[%] ')

plt.show()
```



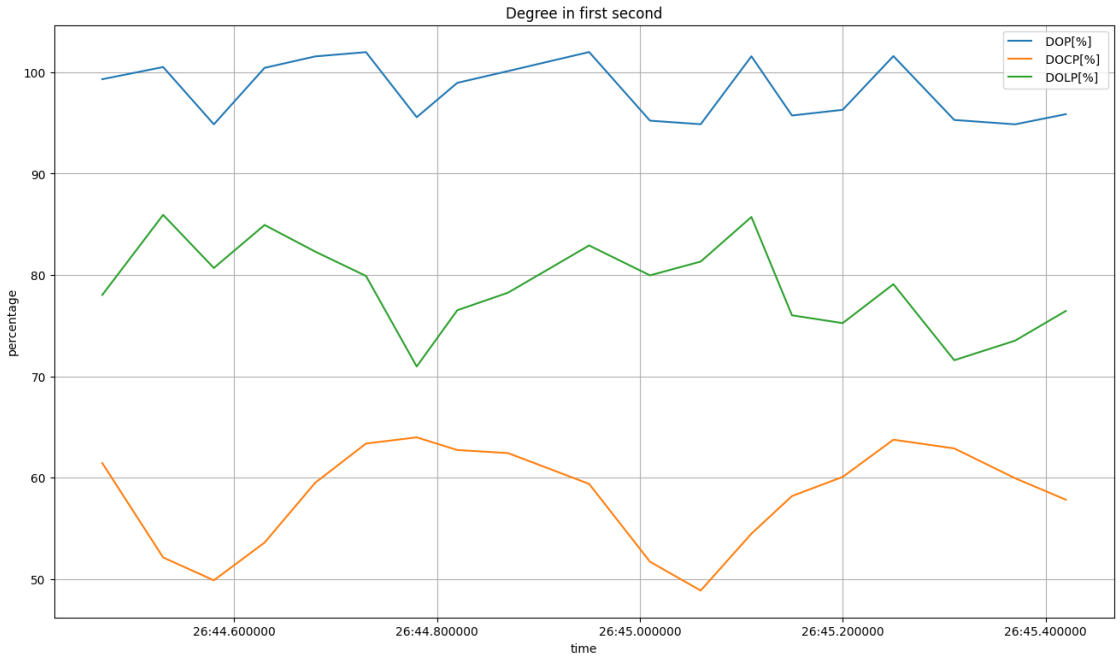
[24]:
```
one_second = datetime.timedelta(seconds=1)
one_minute = datetime.timedelta(minutes=1)
one_hour = datetime.timedelta(hours=1)
one_day = datetime.timedelta(days=1)

start_time = datetime.datetime.strptime(str(degree.index[0]), '%Y-%m-%d %H:%M:
↪%S.%f')
end_time_second = start_time + one_second
end_time_minute = start_time + one_minute
end_time_hour = start_time + one_hour
end_time_day = start_time + one_day
```

[25]:
```
first_second = degree.loc[(degree.index >= start_time) & (degree.index <␣
↪end_time_second)]
first_second
```

[25]:

Time[date hh:mm:ss]	DOP[%]	DOCP[%]	DOLP[%]
2024-11-29 00:26:44.470	99.31	61.44	78.03
2024-11-29 00:26:44.530	100.51	52.13	85.93
2024-11-29 00:26:44.580	94.86	49.88	80.69
2024-11-29 00:26:44.630	100.43	53.60	84.93
2024-11-29 00:26:44.680	101.56	59.51	82.30
2024-11-29 00:26:44.730	101.98	63.37	79.90
2024-11-29 00:26:44.780	95.56	63.98	70.97
2024-11-29 00:26:44.820	98.95	62.73	76.52
2024-11-29 00:26:44.870	100.11	62.43	78.25
2024-11-29 00:26:44.950	101.99	59.39	82.91
2024-11-29 00:26:45.010	95.22	51.71	79.96
2024-11-29 00:26:45.060	94.87	48.87	81.32
2024-11-29 00:26:45.110	101.57	54.48	85.72
2024-11-29 00:26:45.150	95.73	58.19	76.02
2024-11-29 00:26:45.200	96.29	60.08	75.25
2024-11-29 00:26:45.250	101.59	63.75	79.09
2024-11-29 00:26:45.310	95.29	62.89	71.59
2024-11-29 00:26:45.370	94.86	59.95	73.52
2024-11-29 00:26:45.420	95.86	57.83	76.45

[26]:
```
plt.figure(figsize = (16,9))
plt.plot(first_second.index, first_second[columns[11]], label = columns[11])
plt.plot(first_second.index, first_second[columns[12]], label = columns[12])
plt.plot(first_second.index, first_second[columns[13]], label = columns[13])
plt.grid()
plt.legend(loc = 'best')
plt.title('Degree in first second')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



[27]:
```
first_minute = degree.loc[(degree.index >= start_time) & (degree.index <␣
↪end_time_minute)]
first_minute
```

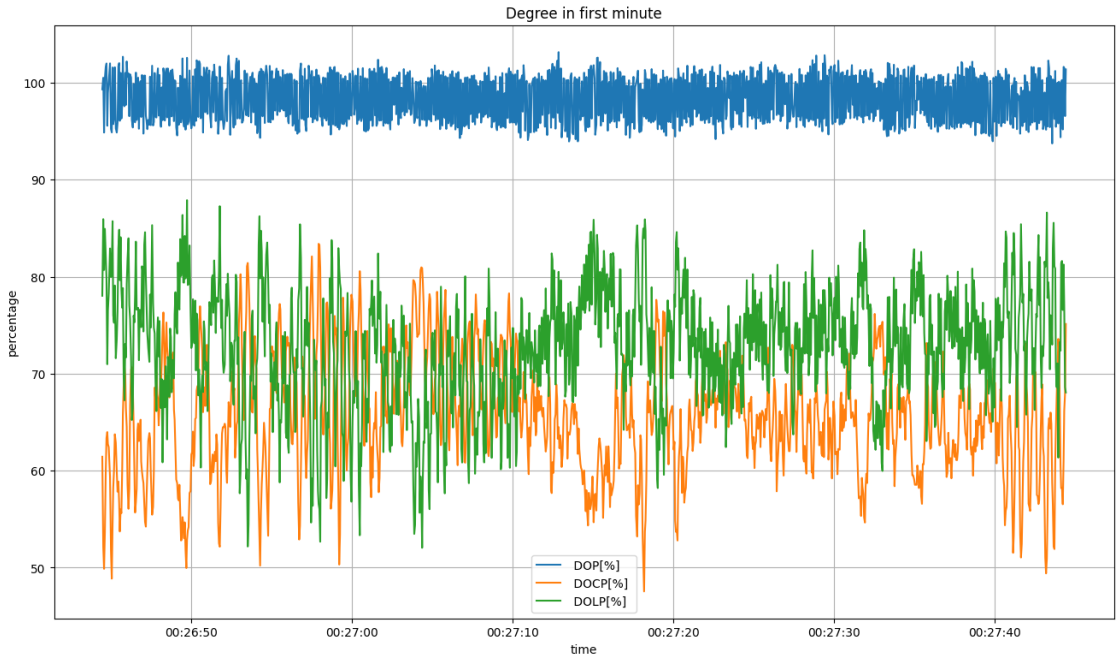
[27]:

Time[date hh:mm:ss]	DOP[%]	DOCP[%]	DOLP[%]
2024-11-29 00:26:44.470	99.31	61.44	78.03
2024-11-29 00:26:44.530	100.51	52.13	85.93
2024-11-29 00:26:44.580	94.86	49.88	80.69
2024-11-29 00:26:44.630	100.43	53.60	84.93
2024-11-29 00:26:44.680	101.56	59.51	82.30
…	…	…	…
2024-11-29 00:27:44.230	95.18	56.54	76.57
2024-11-29 00:27:44.280	101.63	61.04	81.25
2024-11-29 00:27:44.320	101.53	66.18	77.00
2024-11-29 00:27:44.370	96.55	67.93	68.61
2024-11-29 00:27:44.420	101.37	75.12	68.06

[1242 rows x 3 columns]

[28]:
```
plt.figure(figsize = (16,9))
plt.plot(first_minute.index, first_minute[columns[11]], label = columns[11])
plt.plot(first_minute.index, first_minute[columns[12]], label = columns[12])
plt.plot(first_minute.index, first_minute[columns[13]], label = columns[13])
plt.grid()
```

```
plt.legend(loc = 'best')
plt.title('Degree in first minute')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



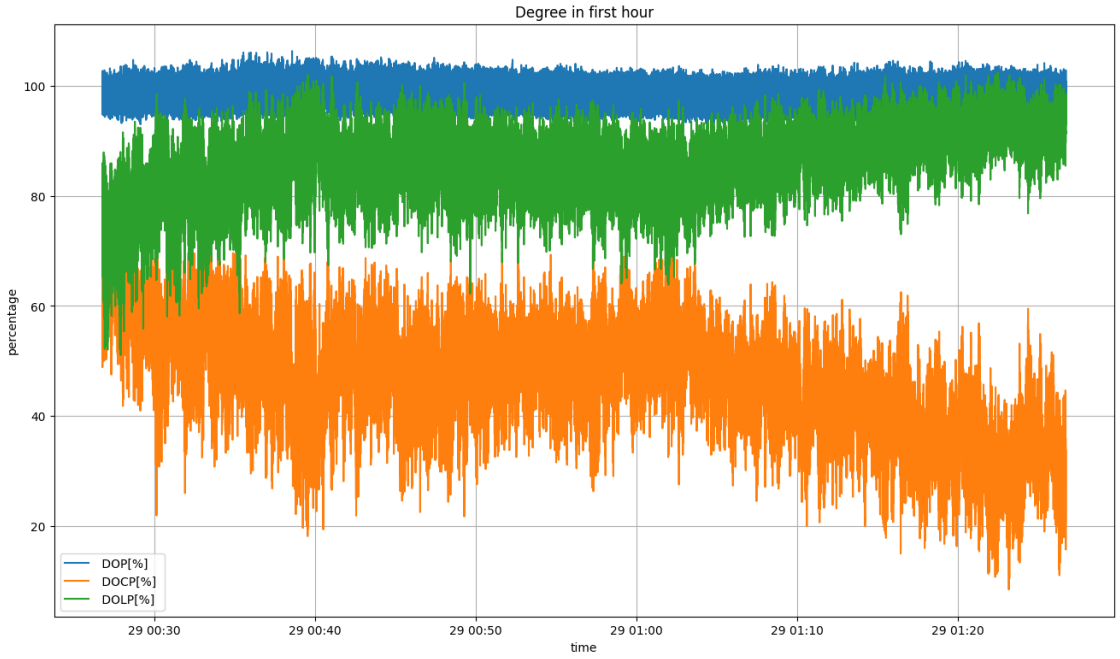
[29]:
```
first_hour = degree.loc[(degree.index >= start_time) & (degree.index <␣
↪end_time_hour)]
first_hour
```

[29]:

Time[date hh:mm:ss]	DOP[%]	DOCP[%]	DOLP[%]
2024-11-29 00:26:44.470	99.31	61.44	78.03
2024-11-29 00:26:44.530	100.51	52.13	85.93
2024-11-29 00:26:44.580	94.86	49.88	80.69
2024-11-29 00:26:44.630	100.43	53.60	84.93
2024-11-29 00:26:44.680	101.56	59.51	82.30
…	…	…	…
2024-11-29 01:26:44.270	97.02	16.86	95.54
2024-11-29 01:26:44.320	100.73	21.51	98.41
2024-11-29 01:26:44.370	94.44	24.55	91.19
2024-11-29 01:26:44.410	102.79	33.64	97.13
2024-11-29 01:26:44.460	98.43	35.79	91.69

[74525 rows x 3 columns]

[30]:
```
plt.figure(figsize = (16,9))
plt.plot(first_hour.index, first_hour[columns[11]], label = columns[11])
plt.plot(first_hour.index, first_hour[columns[12]], label = columns[12])
plt.plot(first_hour.index, first_hour[columns[13]], label = columns[13])
plt.grid()
plt.legend(loc = 'best')
plt.title('Degree in first hour')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



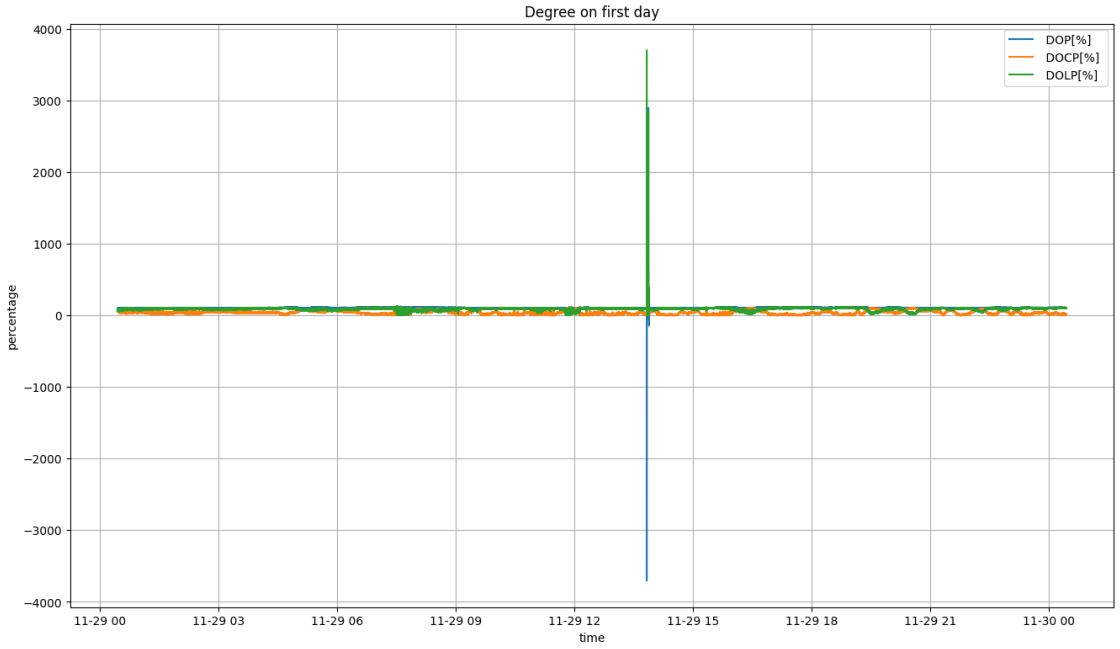
[31]:
```
first_day = degree.loc[(degree.index >= start_time) & (degree.index <␣
 ↪end_time_day)]
first_day
```

[31]:

Time[date hh:mm:ss]	DOP[%]	DOCP[%]	DOLP[%]
2024-11-29 00:26:44.470	99.31	61.44	78.03
2024-11-29 00:26:44.530	100.51	52.13	85.93
2024-11-29 00:26:44.580	94.86	49.88	80.69
2024-11-29 00:26:44.630	100.43	53.60	84.93
2024-11-29 00:26:44.680	101.56	59.51	82.30
…	…	…	…
2024-11-30 00:26:44.160	98.01	8.74	97.61
2024-11-30 00:26:44.240	105.00	20.62	102.95

```
2024-11-30 00:26:44.310   105.94     11.68    105.29
2024-11-30 00:26:44.370   104.75     14.71    103.71
2024-11-30 00:26:44.420   105.19     11.84    104.52

[1703970 rows x 3 columns]
```

[32]:
```
plt.figure(figsize = (16,9))
plt.plot(first_day.index, first_day[columns[11]], label = columns[11])
plt.plot(first_day.index, first_day[columns[12]], label = columns[12])
plt.plot(first_day.index, first_day[columns[13]], label = columns[13])
plt.grid()
plt.legend(loc = 'best')
plt.title('Degree on first day')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```

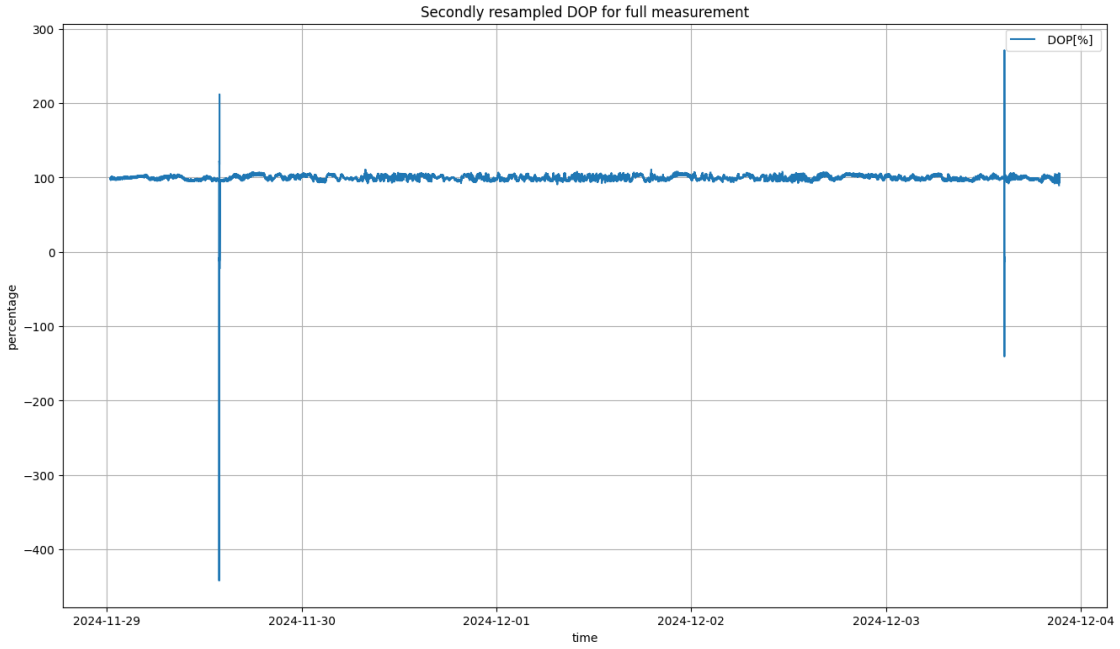


[33]:
```
degree_seconds_resample = degree.resample('s').mean()
degree_seconds_resample.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 421040 entries, 2024-11-29 00:26:44 to 2024-12-03 21:24:03
Freq: s
Data columns (total 3 columns):
 #   Column     Non-Null Count   Dtype
---  ------     --------------   -----
```

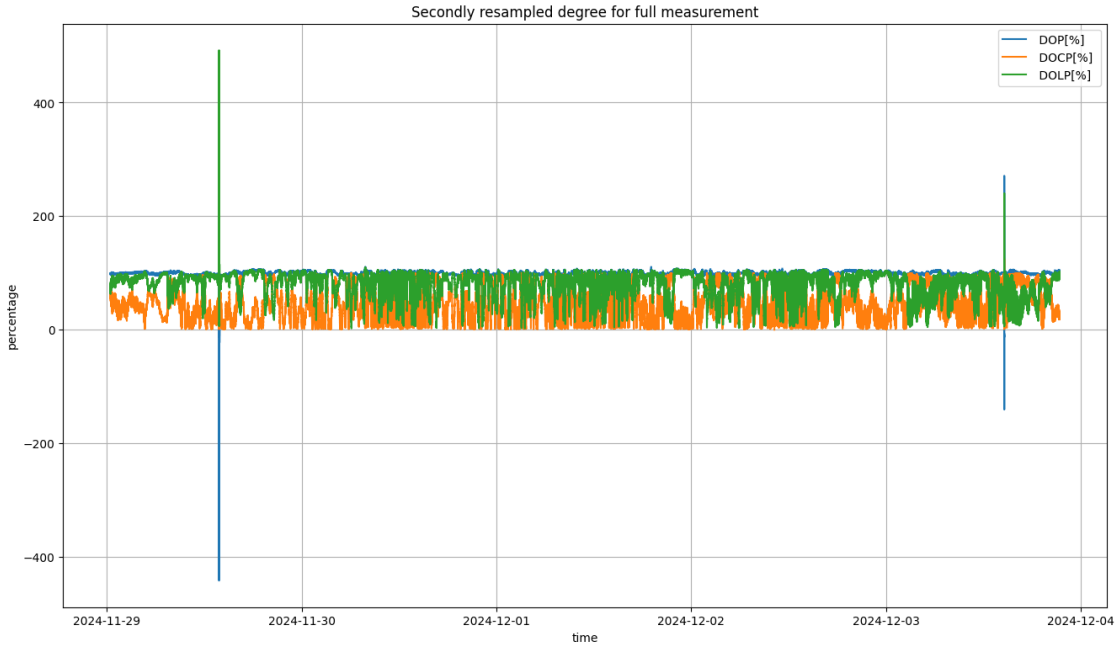
```
 0    DOP[%]    418526 non-null  float64
 1    DOCP[%]   418526 non-null  float64
 2    DOLP[%]   418526 non-null  float64
dtypes: float64(3)
memory usage: 12.8 MB
```

[34]:
```
plt.figure(figsize = (16,9))
plt.plot(degree_seconds_resample.index, degree_seconds_resample[columns[11]],␣
 ↪label = columns[11])
plt.grid()
plt.legend(loc = 'best')
plt.title('Secondly resampled DOP for full measurement')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



[35]:
```
plt.figure(figsize = (16,9))
plt.plot(degree_seconds_resample.index, degree_seconds_resample[columns[11]],␣
 ↪label = columns[11])
plt.plot(degree_seconds_resample.index, degree_seconds_resample[columns[12]],␣
 ↪label = columns[12])
plt.plot(degree_seconds_resample.index, degree_seconds_resample[columns[13]],␣
 ↪label = columns[13])
plt.grid()
plt.legend(loc = 'best')
plt.title('Secondly resampled degree for full measurement')
```

```
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



3.4 Energie (Power, Pol Power, Unipol Power [mW/dBm])

[36]:
```
power_mw = pd.read_csv(filename,skiprows=skip, usecols=[columns[0],␣
↪columns[14], columns[15], columns[16]], sep=sep)
```

[37]:
```
power_mw[columns[0]] = pd.to_datetime(power_mw[columns[0]])
power_mw.set_index(columns[0], inplace=True)
```

[38]:
```
power_mw.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 7092298 entries, 2024-11-29 00:26:44.470000 to 2024-12-03
21:24:03.030000
Data columns (total 3 columns):
 #   Column             Dtype
---  ------             -----
 0    Power[mW]         float64
 1    Pol Power[mW]     float64
 2    Unpol Power[mW]   float64
dtypes: float64(3)
memory usage: 216.4 MB
```

[39]:
```
power_mw.isnull().sum()
```

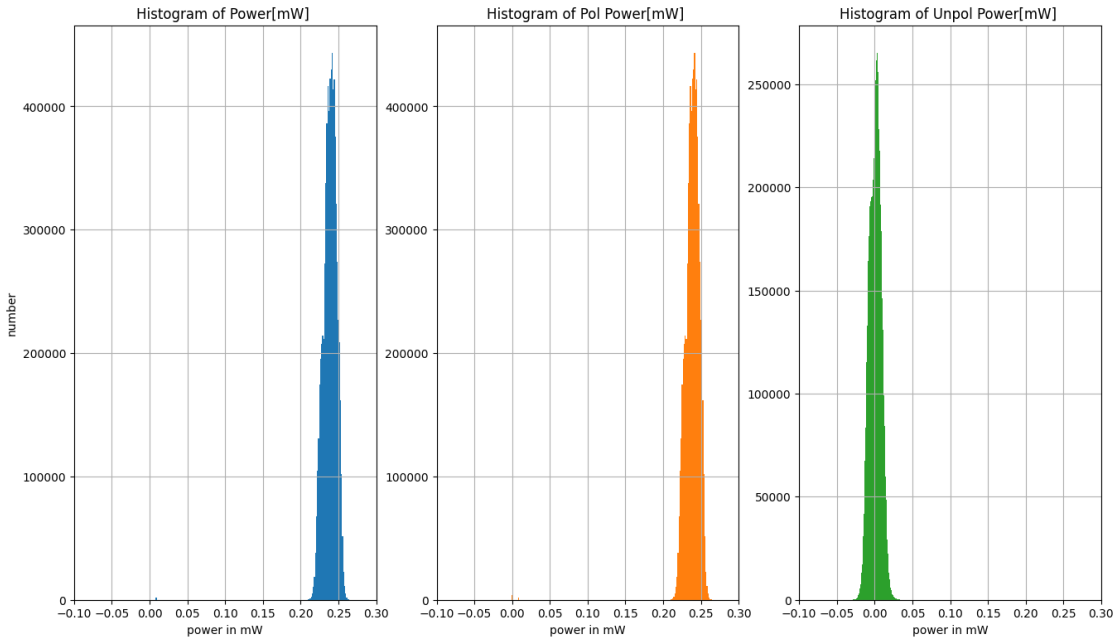
[39]:
```
Power[mW]           0
Pol Power[mW]       0
Unpol Power[mW]     0
dtype: int64
```

[40]:
```
power_mw.describe()
```

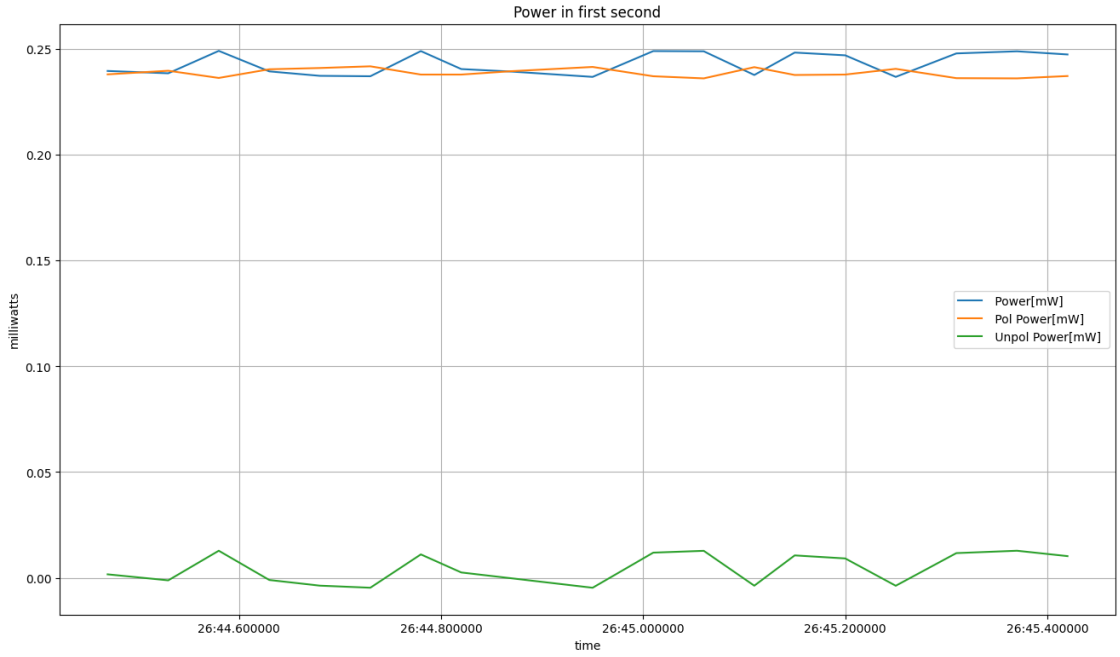
[40]:

	Power[mW]	Pol Power[mW]	Unpol Power[mW]
count	7.092298e+06	7.092298e+06	7.092298e+06
mean	2.386558e-01	2.378043e-01	8.514209e-04
std	1.068249e-02	7.764705e-03	7.812574e-03
min	-2.843000e-04	1.245000e-06	-7.365000e-02
25%	2.331000e-01	2.350000e-01	-5.019000e-03
50%	2.393000e-01	2.382000e-01	1.185000e-03
75%	2.450000e-01	2.410000e-01	6.408000e-03
max	2.754000e-01	2.882000e-01	7.396000e-02

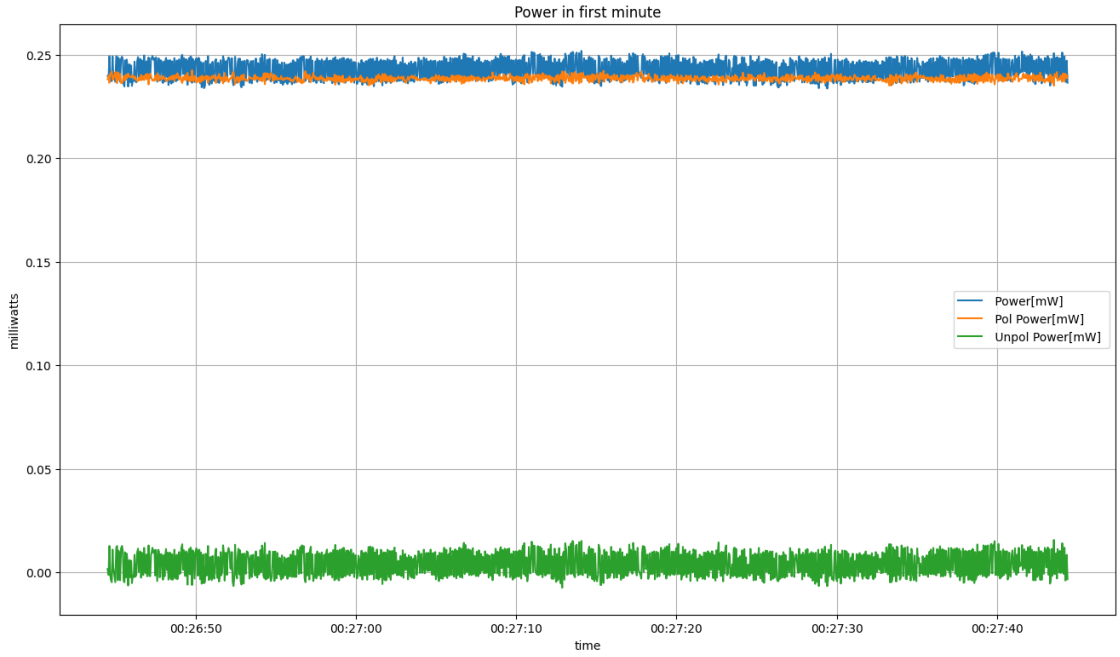
[41]:
```
plt.figure(figsize = (16,9))
plt.subplot(1, 3, 1)
plt.hist(power_mw[columns[14]], bins=200, color='tab:blue')
plt.xlim([-0.1, 0.3])
plt.grid()
plt.xlabel('power in mW')
plt.ylabel('number')
plt.title('Histogram of Power[mW] ')

plt.subplot(1, 3, 2)
plt.hist(power_mw[columns[14]], bins=200, color='tab:orange')
plt.xlim([-0.1, 0.3])
plt.grid()
plt.xlabel('power in mW')
plt.title('Histogram of Pol Power[mW] ')

plt.subplot(1, 3, 3)
plt.hist(power_mw[' Unpol Power[mW] '], bins=200, color='tab:green')
plt.xlim([-0.1, 0.3])
plt.grid()
plt.xlabel('power in mW')
plt.title('Histogram of Unpol Power[mW] ')

plt.show()
```



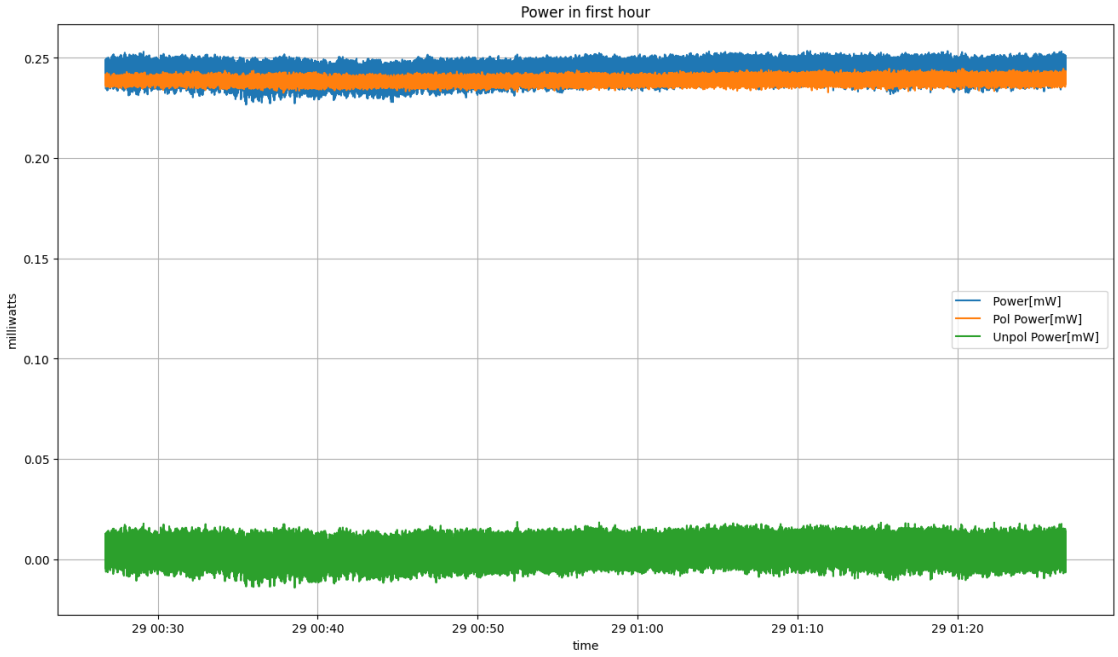
[42]:
```
first_second = power_mw.loc[(power_mw.index >= start_time) & (power_mw.index <␣
↪end_time_second)]

plt.figure(figsize = (16,9))
plt.plot(first_second.index, first_second[columns[14]], label = columns[14])
plt.plot(first_second.index, first_second[columns[15]], label = columns[15])
plt.plot(first_second.index, first_second[columns[16]], label = columns[16])
plt.grid()
plt.legend(loc = 'best')
plt.title('Power in first second')
plt.xlabel('time')
plt.ylabel('milliwatts')
plt.show()
```



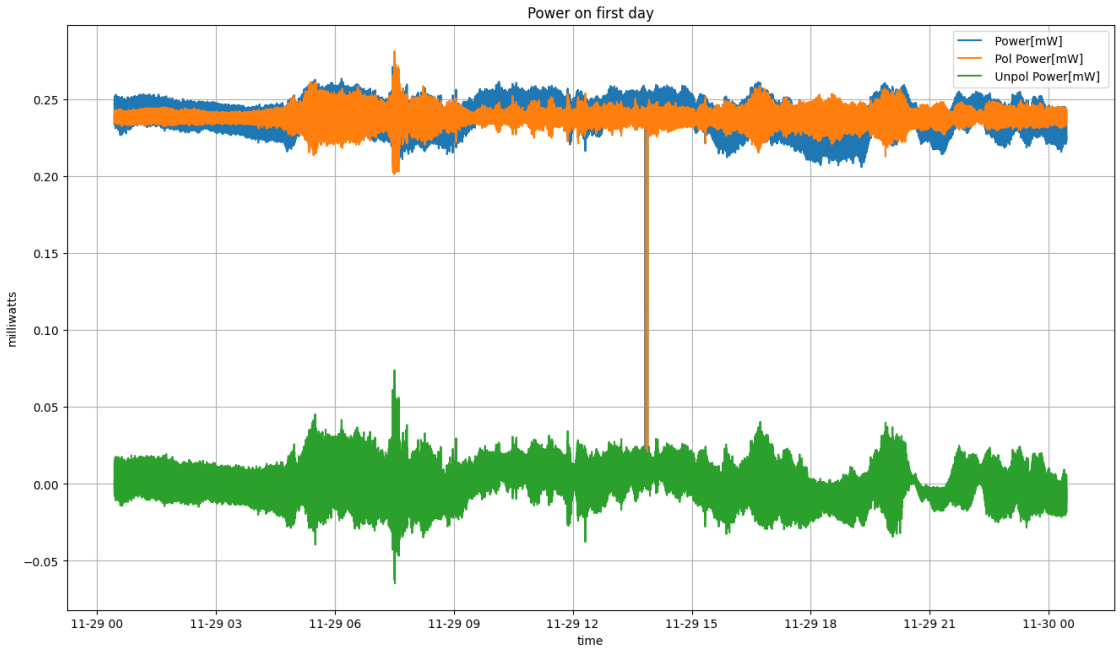
[43]:
```
first_minute = power_mw.loc[(power_mw.index >= start_time) & (power_mw.index <␣
↪end_time_minute)]

plt.figure(figsize = (16,9))
plt.plot(first_minute.index, first_minute[columns[14]], label = columns[14])
plt.plot(first_minute.index, first_minute[columns[15]], label = columns[15])
plt.plot(first_minute.index, first_minute[columns[16]], label = columns[16])
plt.grid()
plt.legend(loc = 'best')
plt.title('Power in first minute')
plt.xlabel('time')
plt.ylabel('milliwatts')
plt.show()
```



[44]:
```
first_hour = power_mw.loc[(power_mw.index >= start_time) & (power_mw.index <␣
 ↪end_time_hour)]

plt.figure(figsize = (16,9))
plt.plot(first_hour.index, first_hour[columns[14]], label = columns[14])
plt.plot(first_hour.index, first_hour[columns[15]], label = columns[15])
plt.plot(first_hour.index, first_hour[columns[16]], label = columns[16])
plt.grid()
plt.legend(loc = 'best')
plt.title('Power in first hour')
plt.xlabel('time')
plt.ylabel('milliwatts')
plt.show()
```



[45]:
```
first_day = power_mw.loc[(power_mw.index >= start_time) & (power_mw.index <␣
 ↪end_time_day)]

plt.figure(figsize = (16,9))
plt.plot(first_day.index, first_day[columns[14]], label = columns[14])
plt.plot(first_day.index, first_day[columns[15]], label = columns[15])
plt.plot(first_day.index, first_day[columns[16]], label = columns[16])
plt.grid()
plt.legend(loc = 'best')
plt.title('Power on first day')
plt.xlabel('time')
plt.ylabel('milliwatts')
plt.show()
```

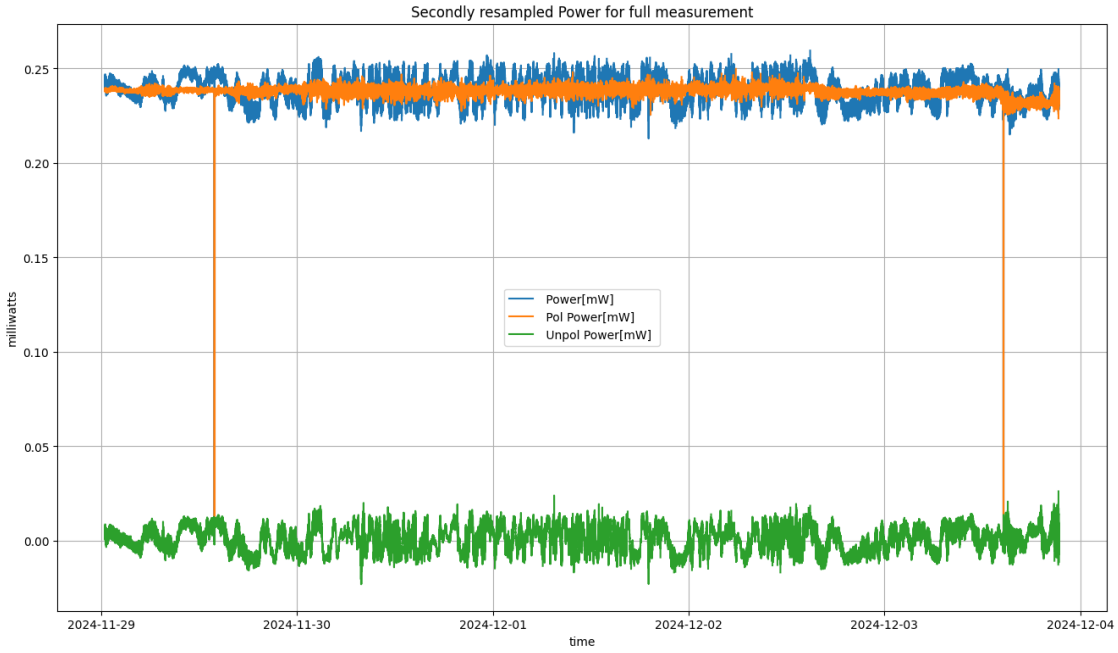


[46]:
```
power_mw_seconds_resample = power_mw.resample('s').mean()
power_mw_seconds_resample.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 421040 entries, 2024-11-29 00:26:44 to 2024-12-03 21:24:03
Freq: s
Data columns (total 3 columns):
 #   Column             Non-Null Count   Dtype
---  ------             --------------   -----
 0    Power[mW]         418526 non-null  float64
 1    Pol Power[mW]     418526 non-null  float64
 2    Unpol Power[mW]   418526 non-null  float64
dtypes: float64(3)
memory usage: 12.8 MB
```

[47]:
```
plt.figure(figsize = (16,9))
plt.plot(power_mw_seconds_resample.index,␣
  ↪power_mw_seconds_resample[columns[14]], label = columns[14])
plt.plot(power_mw_seconds_resample.index,␣
  ↪power_mw_seconds_resample[columns[15]], label = columns[15])
plt.plot(power_mw_seconds_resample.index,␣
  ↪power_mw_seconds_resample[columns[16]], label = columns[16])
plt.grid()
plt.legend(loc = 'best')
plt.title('Secondly resampled Power for full measurement')
plt.xlabel('time')
```

```
plt.ylabel('milliwatts')
plt.show()
```



[48]:
```
power_dbm = pd.read_csv(filename,skiprows=skip, usecols=[columns[0],␣
↪columns[17], columns[18], columns[19]], sep=sep)
```

[49]:
```
power_dbm[columns[0]] = pd.to_datetime(power_dbm[columns[0]])
power_dbm.set_index(columns[0], inplace=True)
```

[50]:
```
power_dbm.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 7092298 entries, 2024-11-29 00:26:44.470000 to 2024-12-03
21:24:03.030000
Data columns (total 3 columns):
 #   Column              Dtype
---  ------              -----
 0    Power[dBm]         float64
 1    Pol Power[dBm]     float64
 2    Unpol Power[dBm]   float64
dtypes: float64(3)
memory usage: 216.4 MB
```

[51]:
```
power_dbm.isnull().sum()
```

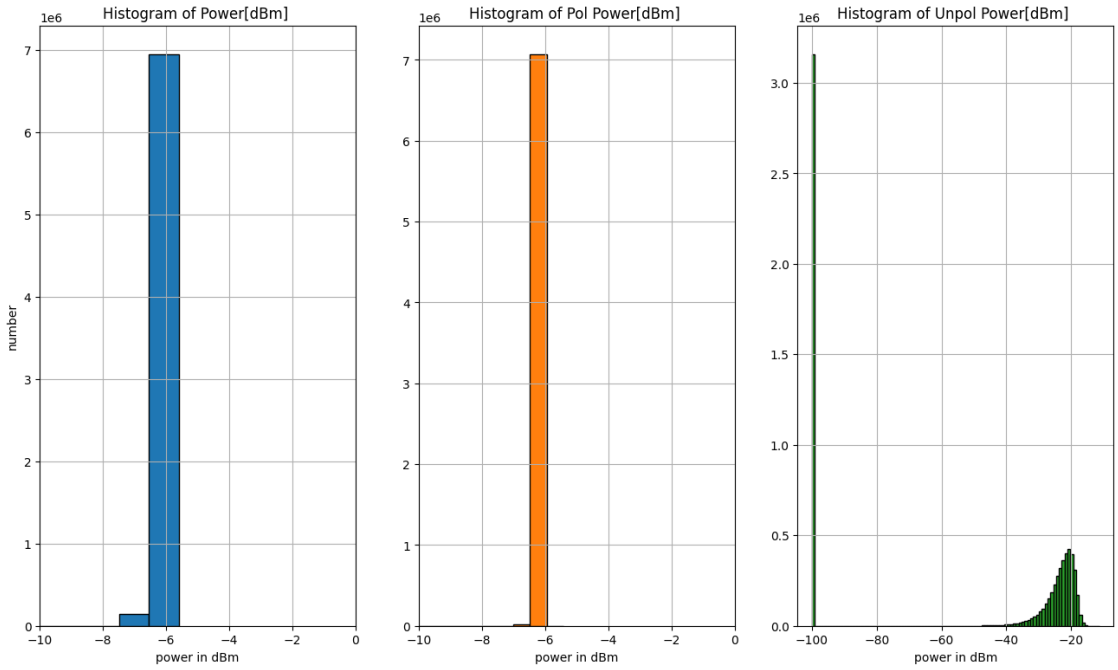
[51]:
```
Power[dBm]           0
Pol Power[dBm]       0
Unpol Power[dBm]     0
dtype: int64
```

[52]:
```
power_dbm.describe()
```

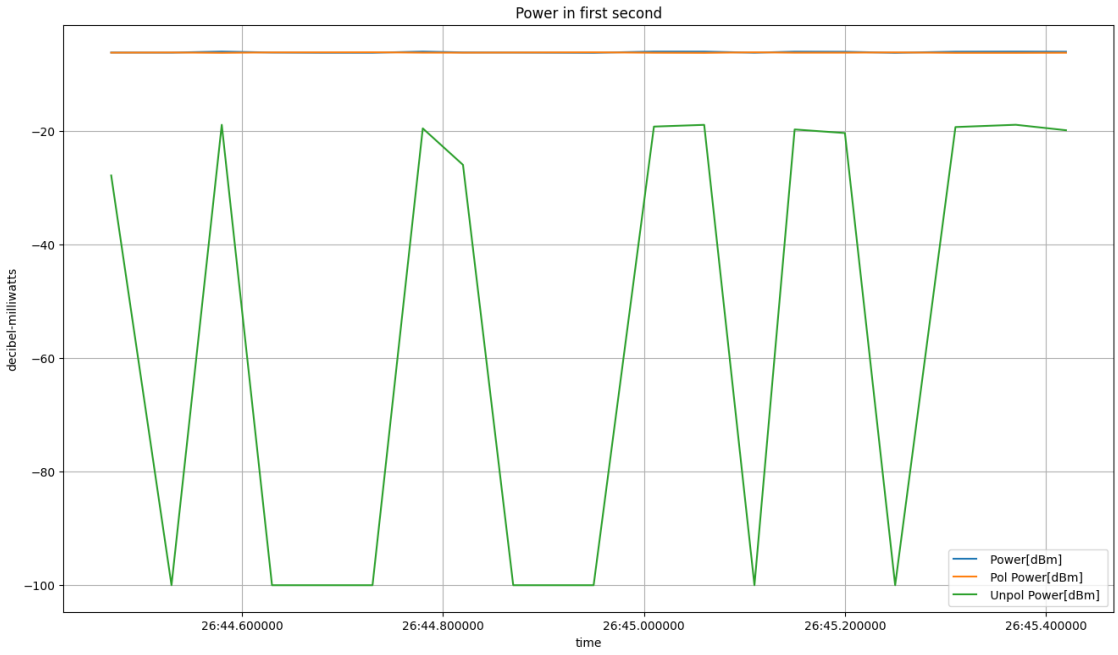
[52]:

	Power[dBm]	Pol Power[dBm]	Unpol Power[dBm]
count	7.092298e+06	7.092298e+06	7.092298e+06
mean	-6.275016e+00	-6.260080e+00	-5.751649e+01
std	2.178382e+00	9.656586e-01	3.821717e+01
min	-9.999000e+01	-5.904900e+01	-9.999000e+01
25%	-6.324000e+00	-6.289000e+00	-9.999000e+01
50%	-6.210000e+00	-6.230000e+00	-2.926400e+01
75%	-6.108000e+00	-6.181000e+00	-2.193300e+01
max	-5.601000e+00	-5.403000e+00	-1.131000e+01

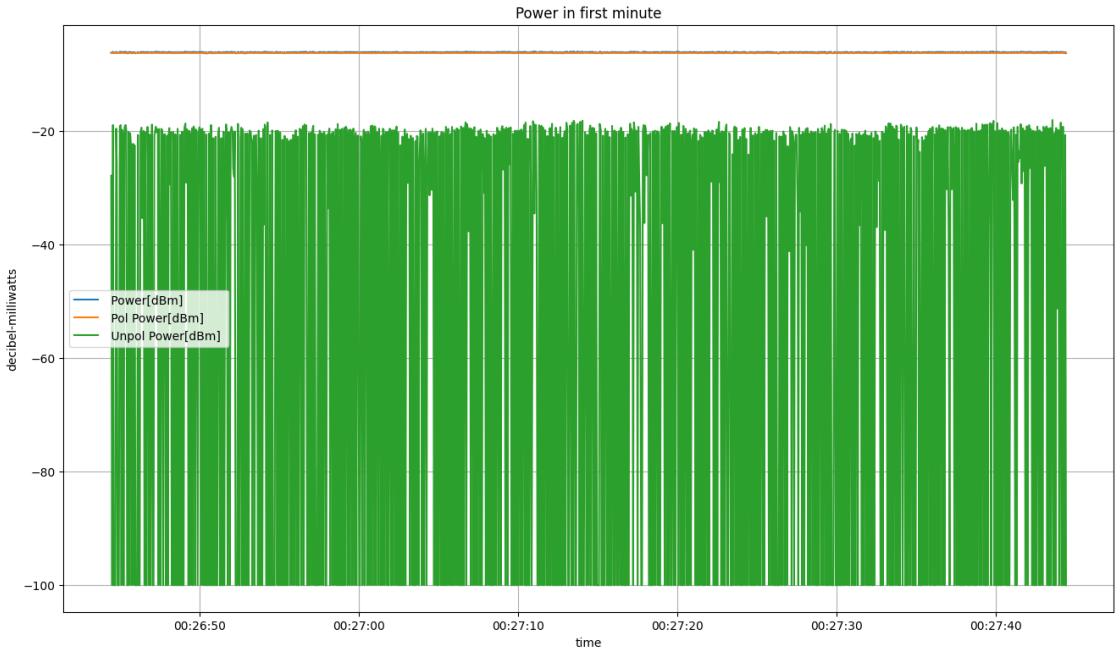
[53]:
```
plt.figure(figsize = (16,9))
plt.subplot(1, 3, 1)
plt.hist(power_dbm[columns[17]], bins=100, color='tab:blue', edgecolor='black')
plt.xlim([-10, 0])
plt.grid()
plt.xlabel('power in dBm')
plt.ylabel('number')
plt.title('Histogram of Power[dBm] ')

plt.subplot(1, 3, 2)
plt.hist(power_dbm[columns[18]], bins=100, color='tab:orange',␣
 ↪edgecolor='black')
plt.xlim([-10, 0])
plt.grid()
plt.xlabel('power in dBm')
plt.title('Histogram of Pol Power[dBm] ')

plt.subplot(1, 3, 3)
plt.hist(power_dbm[columns[19]], bins=100, color='tab:green', edgecolor='black')
plt.grid()
plt.xlabel('power in dBm')
plt.title('Histogram of Unpol Power[dBm] ')

plt.show()
```



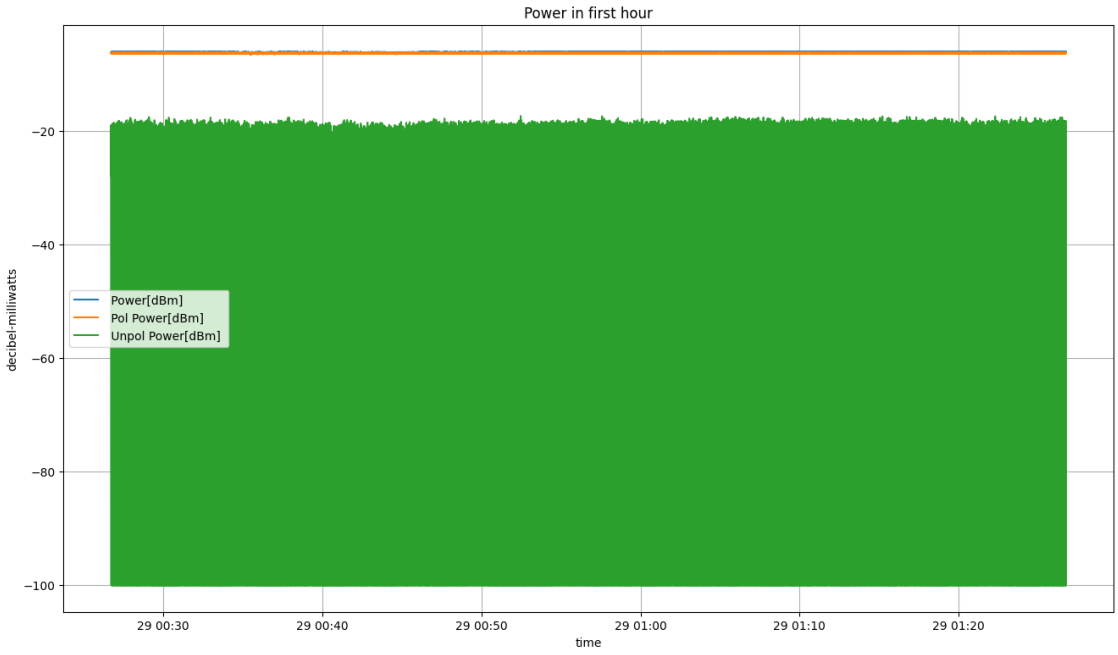
[54]:
```
first_second = power_dbm.loc[(power_dbm.index >= start_time) & (power_dbm.index
 ↪< end_time_second)]

plt.figure(figsize = (16,9))
plt.plot(first_second.index, first_second[columns[17]], label = columns[17])
plt.plot(first_second.index, first_second[columns[18]], label = columns[18])
plt.plot(first_second.index, first_second[columns[19]], label = columns[19])
plt.grid()
plt.legend(loc = 'best')
plt.title('Power in first second')
plt.xlabel('time')
plt.ylabel('decibel-milliwatts')
plt.show()
```



[55]:
```
first_minute = power_dbm.loc[(power_dbm.index >= start_time) & (power_dbm.index␣
 ↪< end_time_minute)]

plt.figure(figsize = (16,9))
plt.plot(first_minute.index, first_minute[columns[17]], label = columns[17])
plt.plot(first_minute.index, first_minute[columns[18]], label = columns[18])
plt.plot(first_minute.index, first_minute[columns[19]], label = columns[19])
plt.grid()
plt.legend(loc = 'best')
plt.title('Power in first minute')
plt.xlabel('time')
plt.ylabel('decibel-milliwatts')
plt.show()
```



[56]:
```
first_hour = power_dbm.loc[(power_dbm.index >= start_time) & (power_dbm.index <␣
↪end_time_hour)]

plt.figure(figsize = (16,9))
plt.plot(first_hour.index, first_hour[columns[17]], label = columns[17])
plt.plot(first_hour.index, first_hour[columns[18]], label = columns[18])
plt.plot(first_hour.index, first_hour[columns[19]], label = columns[19])
plt.grid()
plt.legend(loc = 'best')
plt.title('Power in first hour')
plt.xlabel('time')
plt.ylabel('decibel-milliwatts')
plt.show()
```

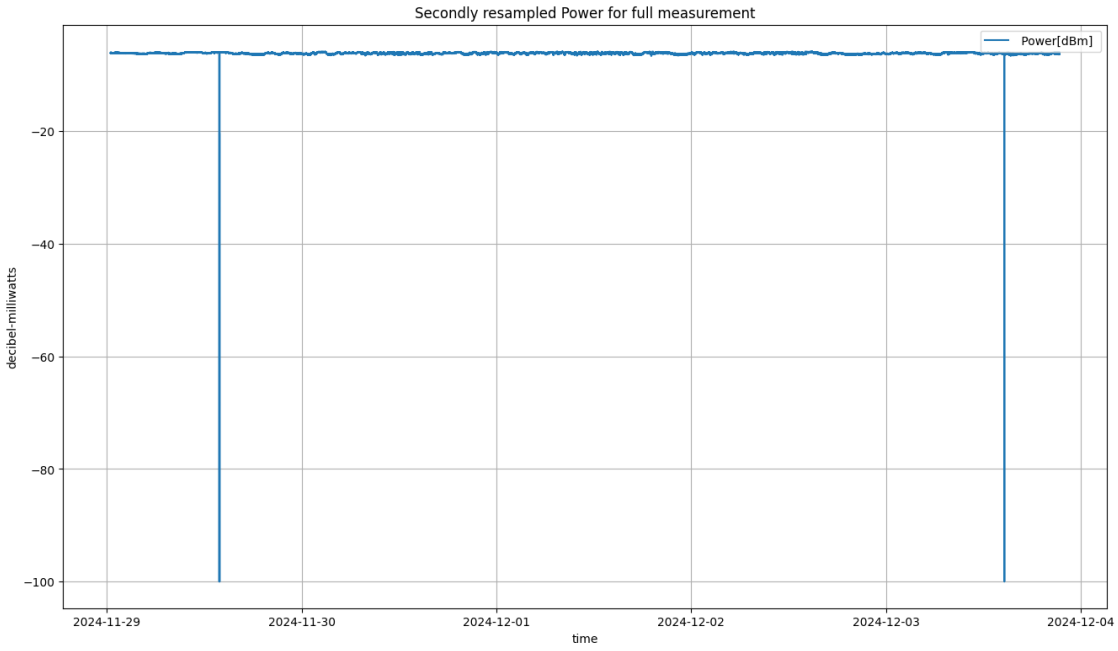


[57]:
```
first_day = power_dbm.loc[(power_dbm.index >= start_time) & (power_dbm.index <␣
↪end_time_day)]

plt.figure(figsize = (16,9))
plt.plot(first_day.index, first_day[columns[17]], label = columns[17])
plt.plot(first_day.index, first_day[columns[18]], label = columns[18])
plt.plot(first_day.index, first_day[columns[19]], label = columns[19])
plt.grid()
plt.legend(loc = 'best')
plt.title('Power on first day')
plt.xlabel('time')
plt.ylabel('decibel-milliwatts')
plt.show()
```

[58]:
```
power_dbm_seconds_resample = power_dbm.resample('s').mean()
power_dbm_seconds_resample.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 421040 entries, 2024-11-29 00:26:44 to 2024-12-03 21:24:03
Freq: s
Data columns (total 3 columns):
 #   Column              Non-Null Count   Dtype
---  ------              --------------   -----
 0    Power[dBm]         418526 non-null  float64
 1    Pol Power[dBm]     418526 non-null  float64
 2    Unpol Power[dBm]   418526 non-null  float64
dtypes: float64(3)
memory usage: 12.8 MB
```

[59]:
```
plt.figure(figsize = (16,9))
plt.plot(power_dbm_seconds_resample.index,␣
 ↪power_dbm_seconds_resample[columns[17]], label = columns[17])
plt.grid()
plt.legend(loc = 'best')
plt.title('Secondly resampled Power for full measurement')
plt.xlabel('time')
plt.ylabel('decibel-milliwatts')
plt.show()
```



[60]:
```
plt.figure(figsize = (16,9))
plt.plot(power_dbm_seconds_resample.index,␣
 ↪power_dbm_seconds_resample[columns[17]], label = columns[17])
plt.plot(power_dbm_seconds_resample.index,␣
 ↪power_dbm_seconds_resample[columns[18]], label = columns[18])
plt.plot(power_dbm_seconds_resample.index,␣
 ↪power_dbm_seconds_resample[columns[19]], label = columns[19])
plt.grid()
plt.legend(loc = 'best')
plt.title('Secondly resampled Power for full measurement')
plt.xlabel('time')
plt.ylabel('decibel-milliwatts')
plt.show()
```

3.5 Winkel (Azimuth, Ellipticity)

[61]:
```
angle = pd.read_csv(filename,skiprows=skip, usecols=[columns[0], columns[9],␣
↪columns[10]], sep=sep)
```

[62]:
```
angle[columns[0]] = pd.to_datetime(angle[columns[0]])
angle.set_index(columns[0], inplace=True)
```

[63]:
```
angle.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 7092298 entries, 2024-11-29 00:26:44.470000 to 2024-12-03
21:24:03.030000
Data columns (total 2 columns):
 #   Column            Dtype
---  ------            -----
 0    Azimuth[°]       float64
 1    Ellipticity[°]   float64
dtypes: float64(2)
memory usage: 162.3 MB
```

[64]:
```
angle.isnull().sum()
```

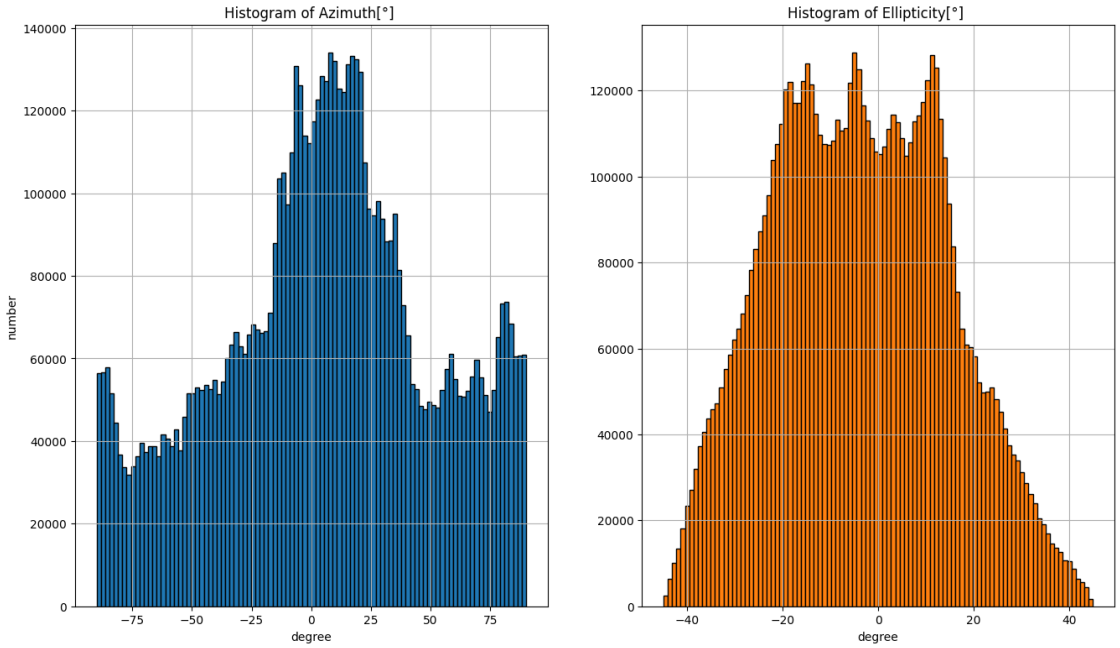
[64]:
```
Azimuth[°]         0
Ellipticity[°]     0
dtype: int64
```

[65]:
```
angle.describe()
```

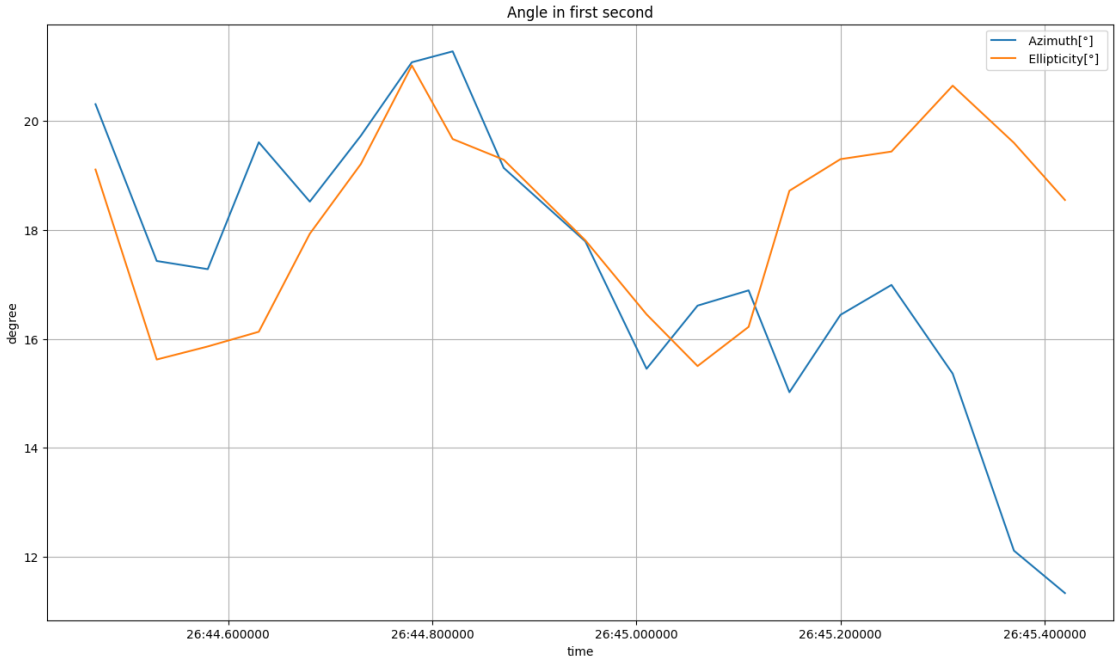
[65]:

	Azimuth[°]	Ellipticity[°]
count	7.092298e+06	7.092298e+06
mean	5.349416e+00	-3.838762e+00
std	4.483804e+01	1.833112e+01
min	-9.000000e+01	-4.498000e+01
25%	-2.413000e+01	-1.805000e+01
50%	7.080000e+00	-4.300000e+00
75%	3.522000e+01	1.001000e+01
max	9.000000e+01	4.498000e+01

[66]:
```
plt.figure(figsize = (16,9))
plt.subplot(1, 2, 1)
plt.hist(angle[columns[9]], bins=100, color='tab:blue', edgecolor='black')
plt.grid()
plt.xlabel('degree')
plt.ylabel('number')
plt.title('Histogram of Azimuth[°] ')

plt.subplot(1, 2, 2)
plt.hist(angle[columns[10]], bins=100, color='tab:orange', edgecolor='black')
plt.grid()
plt.xlabel('degree')
plt.title('Histogram of Ellipticity[°] ')

plt.show()
```

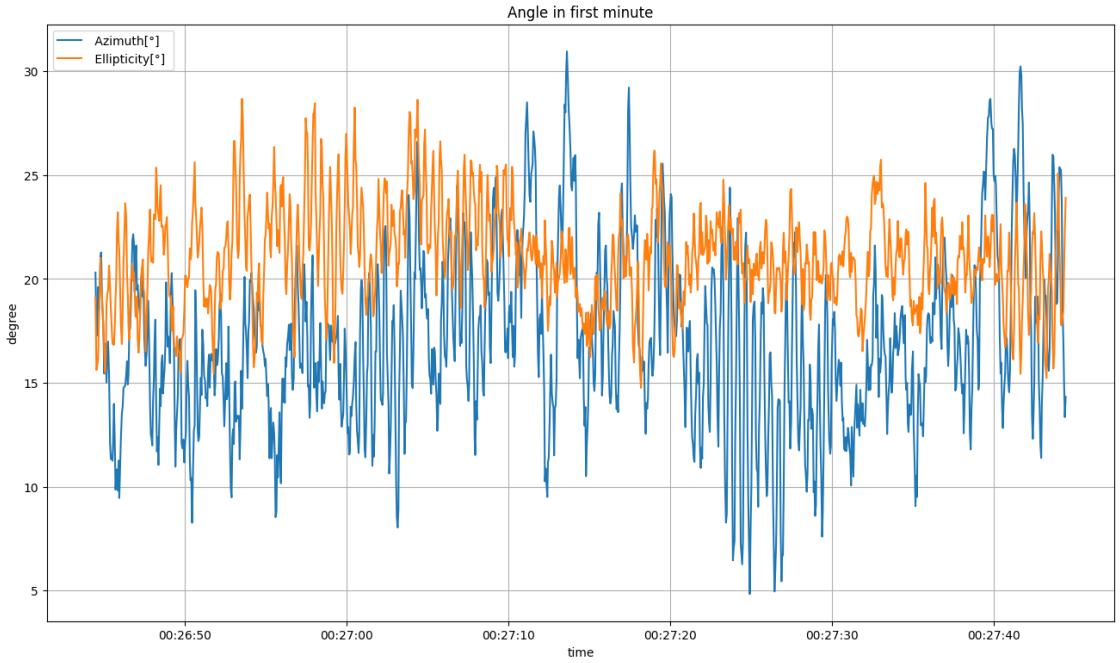


[67]:
```
first_second = angle.loc[(angle.index >= start_time) & (angle.index <␣
 ↪end_time_second)]

plt.figure(figsize = (16,9))
plt.plot(first_second.index, first_second[columns[9]], label = columns[9])
plt.plot(first_second.index, first_second[columns[10]], label = columns[10])
plt.grid()
plt.legend(loc = 'best')
plt.title('Angle in first second')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```

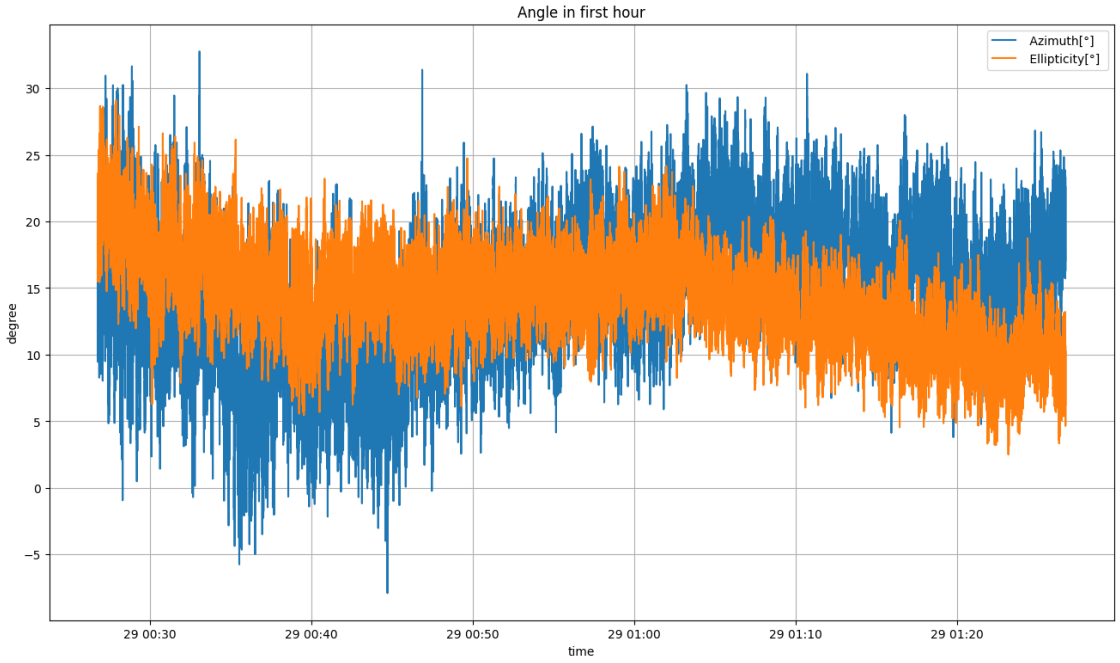


[68]:
```
first_minute = angle.loc[(angle.index >= start_time) & (angle.index <␣
 ↪end_time_minute)]

plt.figure(figsize = (16,9))
plt.plot(first_minute.index, first_minute[columns[9]], label = columns[9])
plt.plot(first_minute.index, first_minute[columns[10]], label = columns[10])
plt.grid()
plt.legend(loc = 'best')
plt.title('Angle in first minute')
plt.xlabel('time')
```

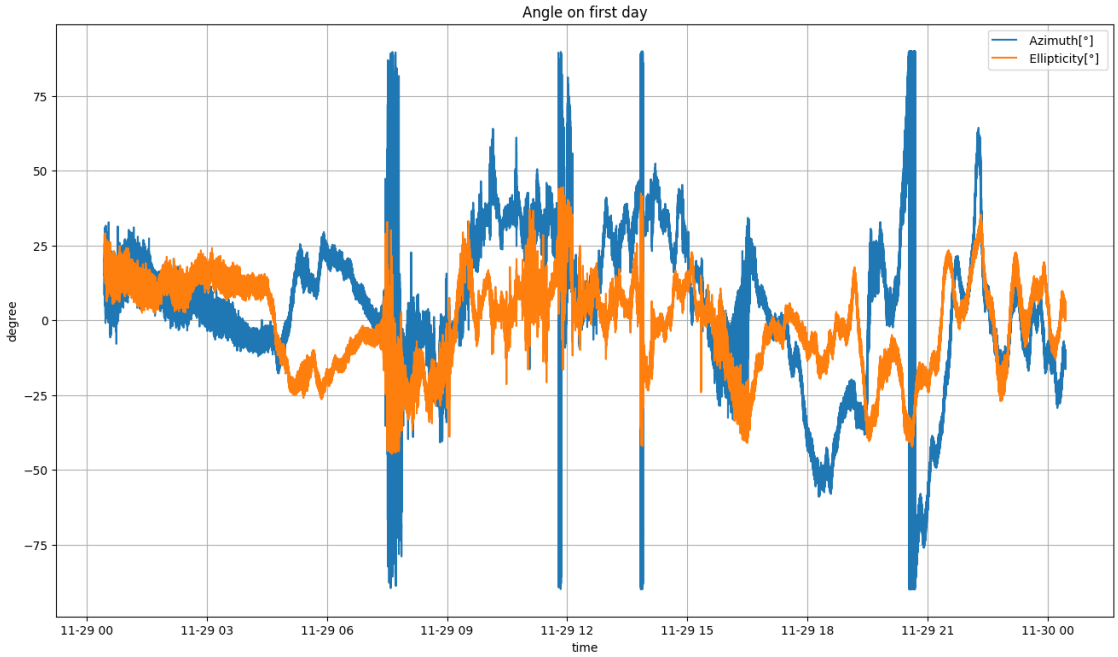
```
plt.ylabel('degree')
plt.show()
```



[69]:
```
first_hour = angle.loc[(angle.index >= start_time) & (angle.index <␣
 ↪end_time_hour)]

plt.figure(figsize = (16,9))
plt.plot(first_hour.index, first_hour[columns[9]], label = columns[9])
plt.plot(first_hour.index, first_hour[columns[10]], label = columns[10])
plt.grid()
plt.legend(loc = 'best')
plt.title('Angle in first hour')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```



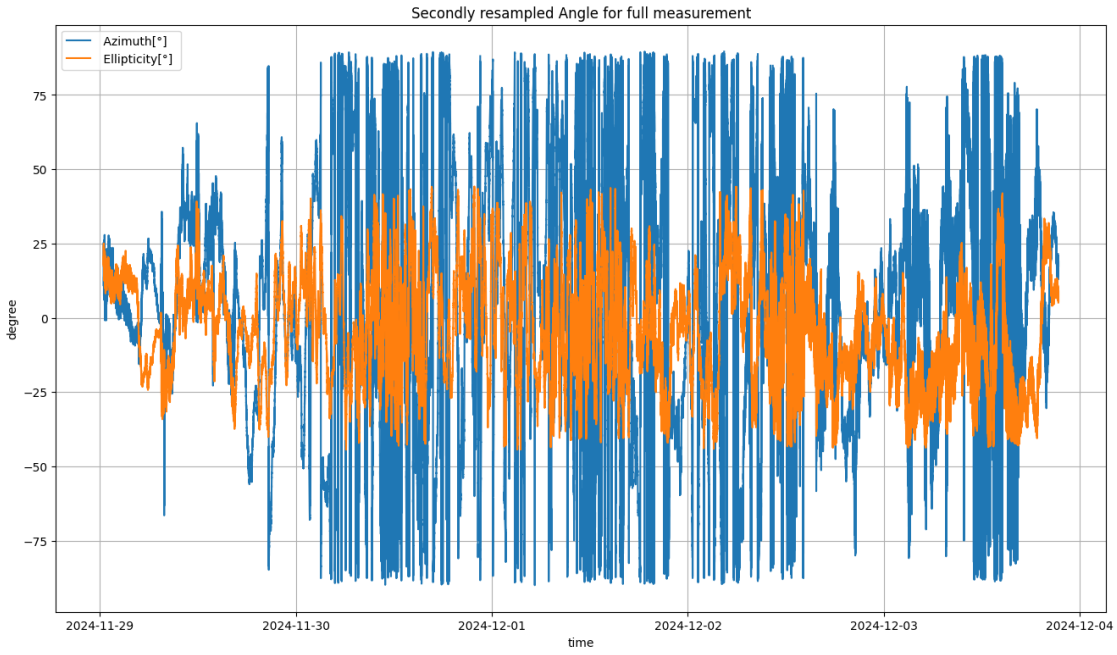
[70]:
```
first_day = angle.loc[(angle.index >= start_time) & (angle.index <␣
 ↪end_time_day)]

plt.figure(figsize = (16,9))
plt.plot(first_day.index, first_day[columns[9]], label = columns[9])
plt.plot(first_day.index, first_day[columns[10]], label = columns[10])
plt.grid()
plt.legend(loc = 'best')
plt.title('Angle on first day')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```



[71]:
```
angle_seconds_resample = angle.resample('s').mean()
angle_seconds_resample.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 421040 entries, 2024-11-29 00:26:44 to 2024-12-03 21:24:03
Freq: s
Data columns (total 2 columns):
 #   Column            Non-Null Count   Dtype
---  ------            --------------   -----
 0    Azimuth[°]       418526 non-null  float64
 1    Ellipticity[°]   418526 non-null  float64
dtypes: float64(2)
memory usage: 9.6 MB
```

[72]:
```
plt.figure(figsize = (16,9))
plt.plot(angle_seconds_resample.index, angle_seconds_resample[columns[9]],␣
 ↪label = columns[9])
plt.plot(angle_seconds_resample.index, angle_seconds_resample[columns[10]],␣
 ↪label = columns[10])
plt.grid()
plt.legend(loc = 'best')
plt.title('Secondly resampled Angle for full measurement')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```



3.6 Stokes-Parameter (S0, S1, S2, S3 / Normalized S1, S2, S3)

[73]:
```
stokes = pd.read_csv(filename,skiprows=skip, usecols=[columns[0], columns[5],␣
↪columns[6], columns[7], columns[8]], sep=sep)
```

[74]:
```
stokes[columns[0]] = pd.to_datetime(stokes[columns[0]])
stokes.set_index(columns[0], inplace=True)
```

[75]:
```
stokes.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 7092298 entries, 2024-11-29 00:26:44.470000 to 2024-12-03
21:24:03.030000
Data columns (total 4 columns):
 #   Column     Dtype
---  ------     -----
 0    S 0 [mW]  float64
 1    S 1 [mW]  float64
 2    S 2 [mW]  float64
 3    S 3 [mW]  float64
dtypes: float64(4)
memory usage: 270.5 MB
```

[76]:
```
stokes.isnull().sum()
```

[76]:
```
S 0 [mW]    0
S 1 [mW]    0
S 2 [mW]    0
S 3 [mW]    0
dtype: int64
```

[77]:
```
stokes.describe()
```

[77]:

	S 0 [mW]	S 1 [mW]	S 2 [mW]	S 3 [mW]
count	7.092298e+06	7.092298e+06	7.092298e+06	7.092298e+06
mean	2.386558e-01	4.826444e-02	1.702841e-02	-2.669778e-02
std	1.068249e-02	1.413223e-01	1.286800e-01	1.294159e-01
min	-2.843000e-04	-2.557000e-01	-2.594000e-01	-2.460000e-01
25%	2.331000e-01	-6.597000e-02	-8.226000e-02	-1.400000e-01
50%	2.393000e-01	8.051000e-02	2.759000e-02	-3.555000e-02
75%	2.450000e-01	1.711000e-01	1.209000e-01	8.157000e-02
max	2.754000e-01	2.572000e-01	2.684000e-01	2.430000e-01

[78]:
```
normalized_stokes = pd.read_csv(filename,skiprows=skip, usecols=[columns[0],␣
↪columns[2], columns[3], columns[4]], sep=sep)
```

[79]:
```
normalized_stokes[columns[0]] = pd.to_datetime(normalized_stokes[columns[0]])
normalized_stokes.set_index(columns[0], inplace=True)
```

[80]:
```
normalized_stokes.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 7092298 entries, 2024-11-29 00:26:44.470000 to 2024-12-03
21:24:03.030000
Data columns (total 3 columns):
 #   Column            Dtype
---  ------            -----
 0    Normalized s 1   float64
 1    Normalized s 2   float64
 2    Normalized s 3   float64
dtypes: float64(3)
memory usage: 216.4 MB
```

[81]:
```
normalized_stokes.isnull().sum()
```

[81]:
```
Normalized s 1    0
Normalized s 2    0
Normalized s 3    0
dtype: int64
```

[82]:
```
normalized_stokes.describe()
```

[82]:
	Normalized s 1	Normalized s 2	Normalized s 3
count	7.092298e+06	7.092298e+06	7.092298e+06
mean	2.034914e-01	7.109757e-02	-1.129362e-01
std	5.928214e-01	5.405157e-01	5.451928e-01
min	-1.000000e+00	-1.000000e+00	-1.000000e+00
25%	-2.800000e-01	-3.500000e-01	-5.900000e-01
50%	3.400000e-01	1.200000e-01	-1.500000e-01
75%	7.200000e-01	5.100000e-01	3.400000e-01
max	1.000000e+00	1.000000e+00	1.000000e+00

3.7 Power-Split-Ratio & Phase Difference

[83]:
```
modality = pd.read_csv(filename,skiprows=skip, usecols=[columns[0],␣
↪columns[20], columns[21]], sep=sep)
```

[84]:
```
modality[columns[0]] = pd.to_datetime(modality[columns[0]])
modality.set_index(columns[0], inplace=True)
```

[85]:
```
modality.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 7092298 entries, 2024-11-29 00:26:44.470000 to 2024-12-03
21:24:03.030000
Data columns (total 2 columns):
 #   Column                 Dtype
---  ------                 -----
 0    Power-Split-Ratio     float64
 1    Phase Difference[°]   float64
dtypes: float64(2)
memory usage: 162.3 MB
```

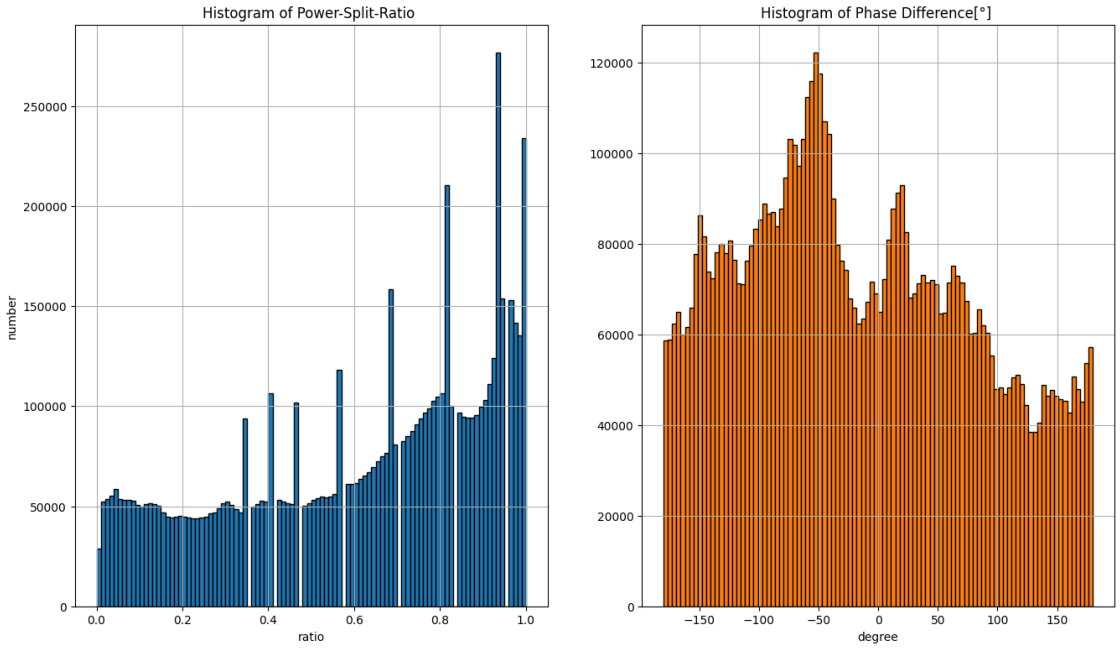
[86]:
```
modality.isnull().sum()
```

[86]:
```
Power-Split-Ratio       0
Phase Difference[°]     0
dtype: int64
```

[87]:
```
modality.describe()
```

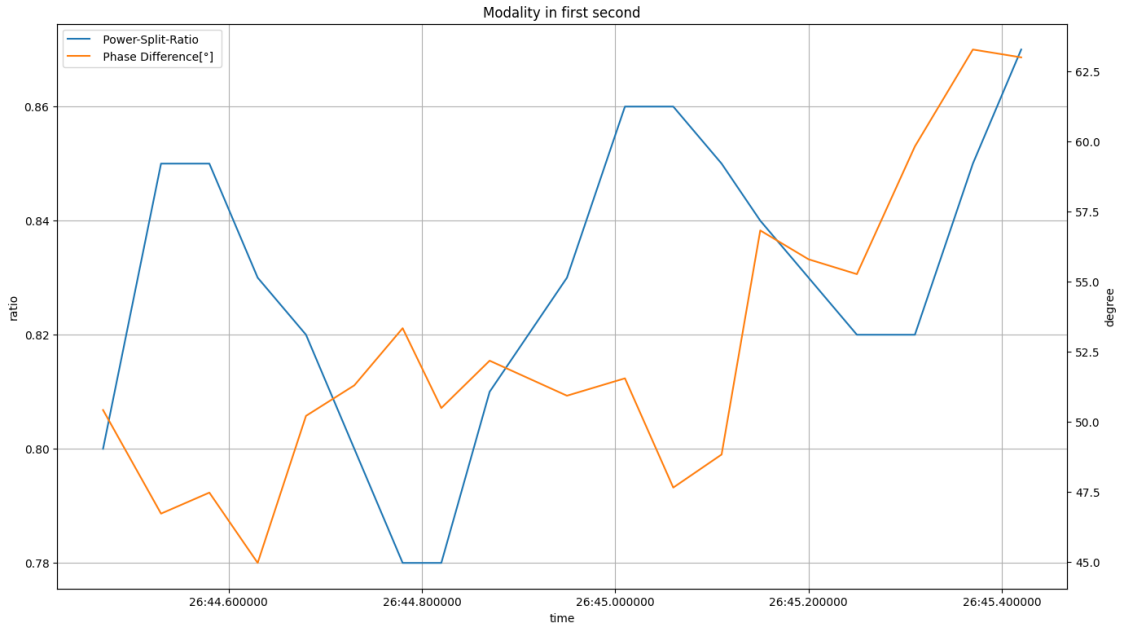
[87]:
	Power-Split-Ratio	Phase Difference[°]
count	7.092298e+06	7.092298e+06
mean	6.017494e-01	-1.623205e+01
std	2.964305e-01	9.624108e+01
min	0.000000e+00	-1.800000e+02
25%	3.600000e-01	-9.366000e+01
50%	6.700000e-01	-2.880000e+01
75%	8.600000e-01	5.927000e+01
max	1.000000e+00	1.800000e+02

[88]:
```
plt.figure(figsize = (16,9))
plt.subplot(1, 2, 1)
plt.hist(modality[columns[20]], bins=100, color='tab:blue', edgecolor='black')
plt.grid()
plt.xlabel('ratio')
plt.ylabel('number')
plt.title('Histogram of Power-Split-Ratio ')

plt.subplot(1, 2, 2)
plt.hist(modality[columns[21]], bins=100, color='tab:orange', edgecolor='black')
plt.grid()
plt.xlabel('degree')
plt.title('Histogram of Phase Difference[°] ')

plt.show()
```



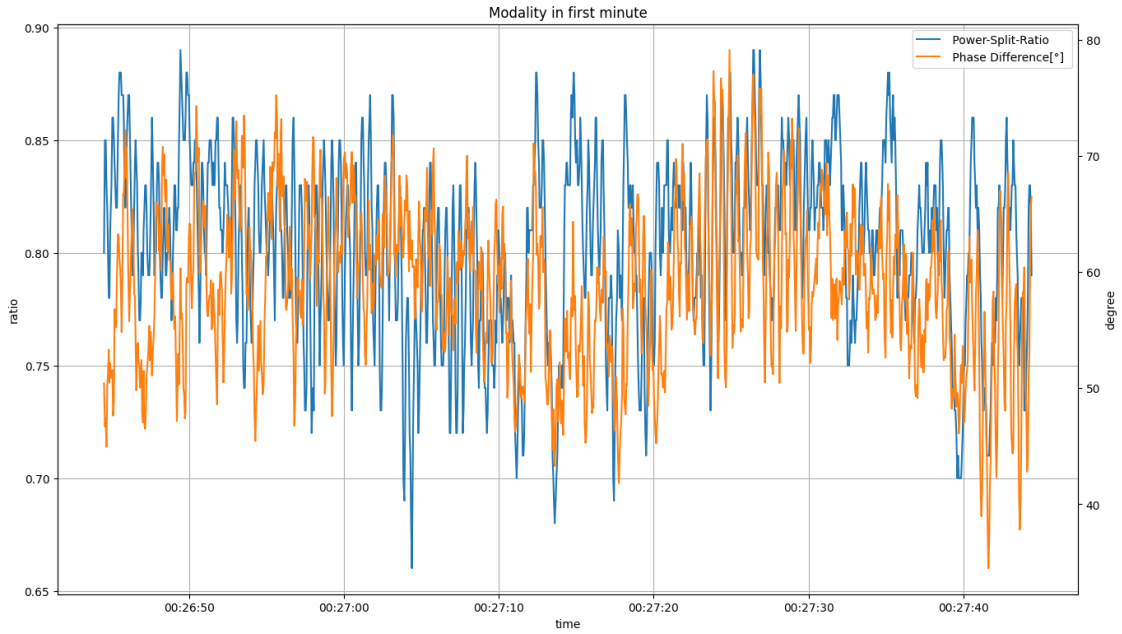
[89]:
```
first_second = modality.loc[(modality.index >= start_time) & (modality.index <␣
↪end_time_second)]

fig, ax1 = plt.subplots(figsize=(16, 9))

ax1.plot(first_second.index, first_second[columns[20]], color='tab:blue',␣
↪label=columns[20])
ax1.set_xlabel('time')
ax1.set_ylabel('ratio')
```

```
ax1.grid()

ax2 = ax1.twinx()
ax2.plot(first_second.index, first_second[columns[21]], color='tab:orange',␣
 ↪label=columns[21])
ax2.set_ylabel('degree')

plt.title('Modality in first second')

lines_1, labels_1 = ax1.get_legend_handles_labels()
lines_2, labels_2 = ax2.get_legend_handles_labels()
plt.legend(lines_1 + lines_2, labels_1 + labels_2, loc='best')

plt.show()
```



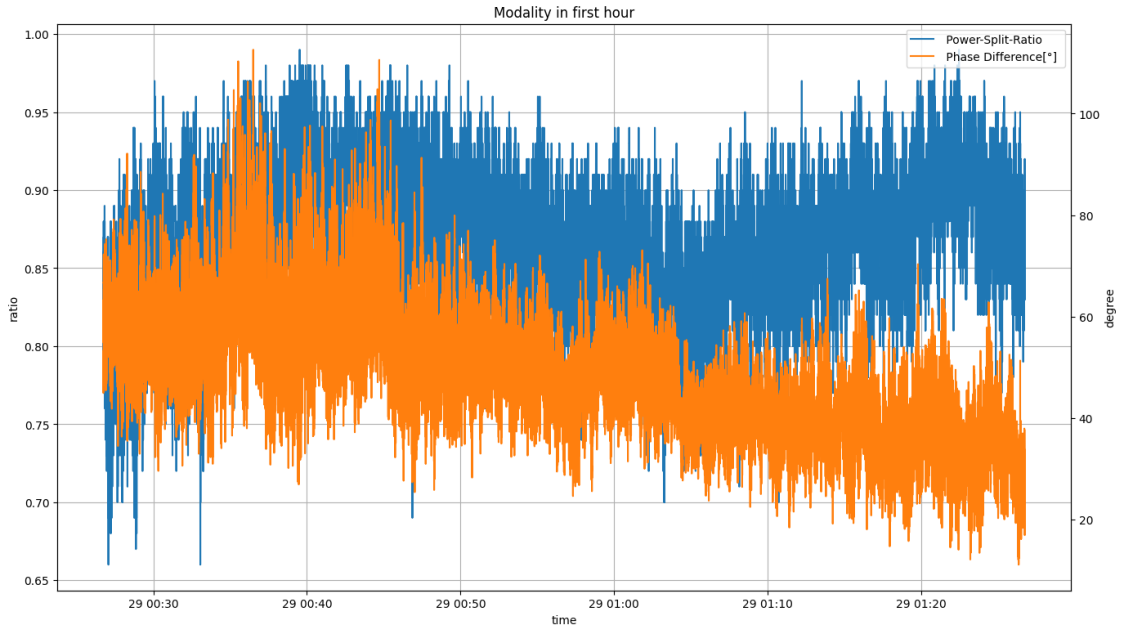
[90]:
```
first_minute = modality.loc[(modality.index >= start_time) & (modality.index <␣
 ↪end_time_minute)]

fig, ax1 = plt.subplots(figsize=(16, 9))

ax1.plot(first_minute.index, first_minute[columns[20]], color='tab:blue',␣
 ↪label=columns[20])
ax1.set_xlabel('time')
ax1.set_ylabel('ratio')
ax1.grid()
```

```
ax2 = ax1.twinx()
ax2.plot(first_minute.index, first_minute[columns[21]], color='tab:orange',␣
 ↪label=columns[21])
ax2.set_ylabel('degree')

plt.title('Modality in first minute')

lines_1, labels_1 = ax1.get_legend_handles_labels()
lines_2, labels_2 = ax2.get_legend_handles_labels()
plt.legend(lines_1 + lines_2, labels_1 + labels_2, loc='best')

plt.show()
```



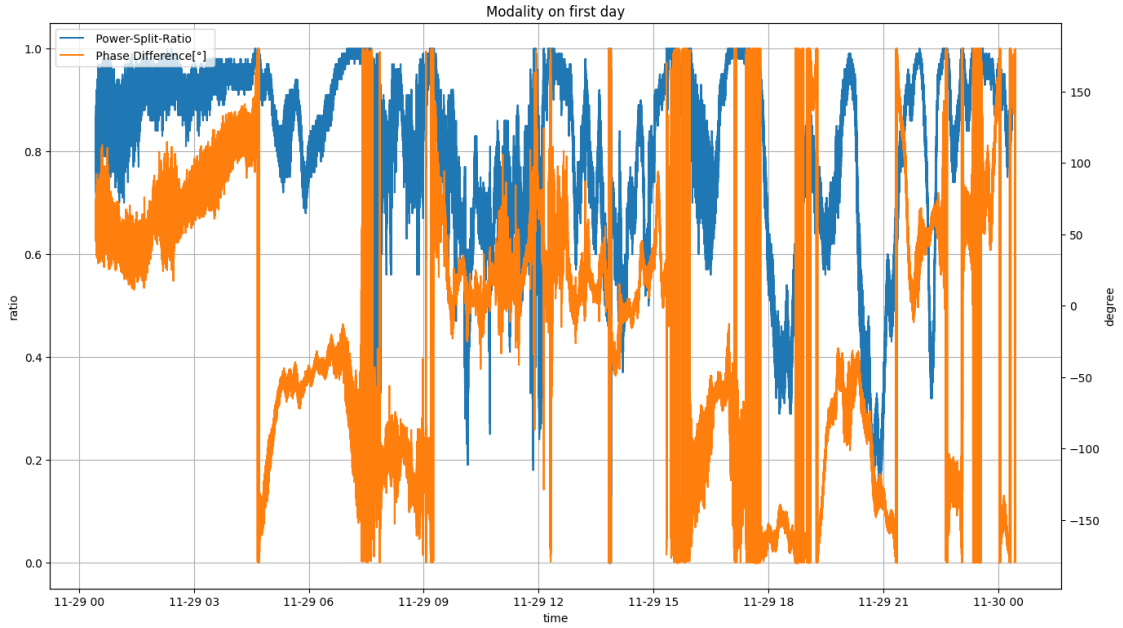
[91]:
```
first_hour = modality.loc[(modality.index >= start_time) & (modality.index <␣
 ↪end_time_hour)]

fig, ax1 = plt.subplots(figsize=(16, 9))

ax1.plot(first_hour.index, first_hour[columns[20]], color='tab:blue',␣
 ↪label=columns[20])
ax1.set_xlabel('time')
ax1.set_ylabel('ratio')
ax1.grid()

ax2 = ax1.twinx()
```

```
ax2.plot(first_hour.index, first_hour[columns[21]], color='tab:orange',␣
 ↪label=columns[21])
ax2.set_ylabel('degree')

plt.title('Modality in first hour')

lines_1, labels_1 = ax1.get_legend_handles_labels()
lines_2, labels_2 = ax2.get_legend_handles_labels()
plt.legend(lines_1 + lines_2, labels_1 + labels_2, loc='best')

plt.show()
```



[92]:
```
first_day = modality.loc[(modality.index >= start_time) & (modality.index <␣
 ↪end_time_day)]

fig, ax1 = plt.subplots(figsize=(16, 9))

ax1.plot(first_day.index, first_day[columns[20]], color='tab:blue',␣
 ↪label=columns[20])
ax1.set_xlabel('time')
ax1.set_ylabel('ratio')
ax1.grid()

ax2 = ax1.twinx()
ax2.plot(first_day.index, first_day[columns[21]], color='tab:orange',␣
 ↪label=columns[21])
```

```
ax2.set_ylabel('degree')

plt.title('Modality on first day')

lines_1, labels_1 = ax1.get_legend_handles_labels()
lines_2, labels_2 = ax2.get_legend_handles_labels()
plt.legend(lines_1 + lines_2, labels_1 + labels_2, loc='best')

plt.show()
```

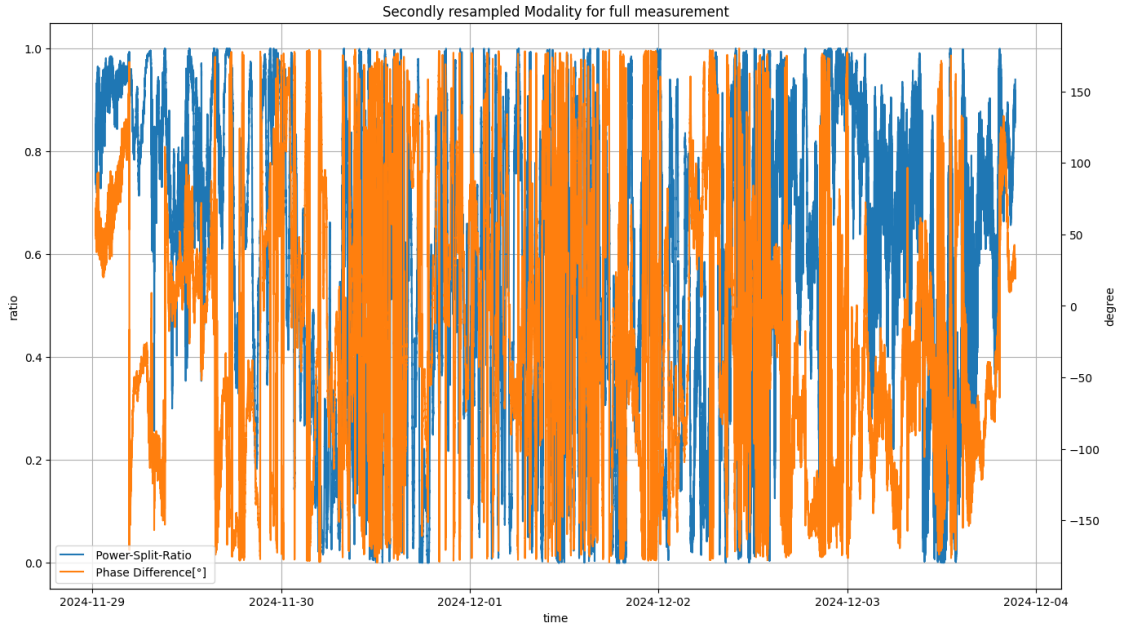


[93]:
```
modality_seconds_resample = modality.resample('s').mean()
modality_seconds_resample.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 421040 entries, 2024-11-29 00:26:44 to 2024-12-03 21:24:03
Freq: s
Data columns (total 2 columns):
 #   Column                Non-Null Count   Dtype
---  ------                --------------   -----
 0    Power-Split-Ratio     418526 non-null  float64
 1    Phase Difference[°]   418526 non-null  float64
dtypes: float64(2)
memory usage: 9.6 MB
```

[94]:
```
fig, ax1 = plt.subplots(figsize=(16, 9))
```

```
ax1.plot(modality_seconds_resample.index,␣
 ↪modality_seconds_resample[columns[20]], color='tab:blue', label=columns[20])
ax1.set_xlabel('time')
ax1.set_ylabel('ratio')
ax1.grid()

ax2 = ax1.twinx()
ax2.plot(modality_seconds_resample.index,␣
 ↪modality_seconds_resample[columns[21]], color='tab:orange',␣
 ↪label=columns[21])
ax2.set_ylabel('degree')

plt.title('Secondly resampled Modality for full measurement')

lines_1, labels_1 = ax1.get_legend_handles_labels()
lines_2, labels_2 = ax2.get_legend_handles_labels()
plt.legend(lines_1 + lines_2, labels_1 + labels_2, loc='best')

plt.show()
```



[ ]: