Measured electromagnetic radiation exposure levels around Spark mobile base stations – Historical summary

Introduction:

Spark formerly known as Telecom, routinely undergoes a field monitoring program to measure the total electromagnetic radiation field strength around its mobile base stations. The measurements are summarised in yearly reports produced “EMF Services NZ” which can be found on the Te Whatu Ora Health New Zealand web-sight (*Independent Cellsite Monitoring – Te Whatu Ora - Health New Zealand*, n.d.). The full list of references can be found in the bibliography.

The purpose of this document to analyse the available measurements to assess:

1) Power density statistics – quantify key statistics such as the average and range of the electromagnetic radiation emitted by the mobile base stations.
2) Power density distribution – quantify the distribution of the measurements by year.
3) Power density changes over time – track how the overall measurements have changed over time.
4) Power density changes by location – quantify the changes in power density for a location that had repeated measurements taken.

Method:

The compliance monitoring was performed in accordance with New Zealand Standard 2772.1:1999. For each cell site a measurement was taken where the highest exposure level for that cell site (which was accessible by the public) was identified. The measurement was taken over a six minute interval, and the average power density for that interval was calculated and recorded as the maximum exposure for that site. Because of this averaging the true peak maximum is unknown and expected to be higher than the recorded maximum. The data of the Spark compliance measurements were extracted from the available reports between the years 2014 and 2022 and compiled into a spread-sheet. The power density data was given as a percentage of the public exposure limit prescribed by NZS 2772.1:1999 along with the name of the site and the date of measurement. The native units of percent were converted to mW/m^2.

Section 1) Gives an overview of the general statistics for each year for the maximum measured power density at each site.
Section 2) Shows how the distribution of the measurements has changed over time.
Section 3) Analysed the general change for all sights over time. This was done by graphing the raw data over time. The raw data was filtered to exclude outliers and over-layed onto the raw data to show the general trend over time.
Section 4) Examined the changes at a location measured at different points in time. These were plotted by location to indicate the change for each site. The change in power density vs the change in measurement time was also assessed.

More specific data analysis detail is given in the relevant sections.

Results:

Section 1) Power density statistics

The statistics for the measured power density for each year is detailed in Table 1. The rows at the bottom show the statistics for specific data ranges, with the final row containing the statistics for the entire data set from 2014 to 2022.

Year	Average	Standard Deviation	Minimum	Maximum	Number of Points	Number of Outliers <90%	Average Excluding Outliers
2014	21.5	14.6	3.15	72	30	3	18.0
2015	39.8	94.8	4.5	585	44	2	20.7
2016	22.5	19.6	0.45	112.5	55	5	18.0
2017	40.5	53.3	1.35	270	45	4	26.0
2018	27.8	22.8	1.35	130.5	48	4	22.7
2019	36.7	24.9	6.75	139.5	49	5	30.0
2020	38.8	32.7	6.3	175.5	33	3	30.8
2021	33.7	30.0	6.75	193.5	46	2	28.9
2022	49.4	29.4	9.9	121.5	17	2	40.7
2014 ~ 2018	30.6	51.1	0.45	585	222	8	23.0
2019 ~ 2022	37.7	29.0	6.3	193.5	145	13	30.7
2014 ~ 2022	**33.4**	**43.8**	**0.45**	**585**	**367**	**15**	**26.9**

Table 1: Power density statistics

The entire data set from 2014 to 2022 ranges between a minimum of 0.45 mW/m^2 and a maximum of 585 mW/m^2. The average is 33 mW/m^2 with a standard deviation of 44 mW/m^2.

The high standard deviation of each data set indicates that the spread of the data varies significantly. Comparing the maximum column with the average, it is clear the data contains high value outliers. The number of outliers is quantified by counting how many data points are above the mean by 1.28 standard deviations which indicates that data point is above the 90^{th} percentile of the data range. The final column shows the average excluding these outliers.

The average excluding the outliers between the years 2014 and 2018 ranges from 18 mW/m^2 to 26 mW/m^2 with a typical average of 23 mW/m^2, while in the years 2019 to 2022 the average excluding outliers is greater ranging from 30 mW/m^2 to 41 mW/m^2 with and an overall average of 31 mW/m^2. Similarly in the years 2014 to 2018, the minimum value measured ranges from 0.5 mW/m^2 to 3.2 mW/m^2, while the minimum between the years 2019 and 2022 ranges from 6.3 mW/m^2 to 9.9 mW/m^2.

Section 2) Power density distribution

The distribution of the measurements can be assessed by calculating the percentage of data points above or below a power density threshold as seen in Table 2. The threshold is indicated in the first row. The table cells are colour-coded with red representing 100% and green representing 0%.

As an example, the interpretation for the year 2016 is: 91% of measurements were above 5 mW/m^2; 69% were above 10 mW/m^2; 53% were above 15 mW/m^2; and 2% were above 100 mW/m^2. The percentage of data below a threshold can be calculated by subtracting the percentage 'above' from 100 (if 91% are above 5 mW/m^2, then 9% are below 5 mW/m^2).

Year	Units	Measurements Above Threshold											
	mW/m²	5	10	15	20	25	30	35	40	45	50	75	100
2014	%	93	83	53	47	37	20	13	10	3	3	0	0
2015	%	98	73	59	45	34	25	23	16	14	5	5	5
2016	%	91	69	53	42	33	24	20	16	9	5	2	2
2017	%	93	78	71	51	44	38	36	33	22	20	9	9
2018	%	96	85	67	56	46	40	27	19	13	10	4	2
2019	%	100	96	88	78	61	49	39	33	22	18	10	2
2020	%	100	94	82	73	67	52	33	30	27	18	12	3
2021	%	100	93	70	65	57	46	41	28	15	13	4	2
2022	%	100	94	94	82	82	82	71	53	47	35	12	12

Table 2: Percentage of measurements above a power density threshold

There is a noticeable change in the data between the years 2014~2018 and 2019~2022. The distribution of measurements for these data ranges are shown in Table 3.

Year	Units	Measurements Above Threshold											
	mW/m²	5	10	15	20	25	30	35	40	45	50	75	100
2014 ~ 2018	%	94	77	61	48	39	30	24	19	13	9	4	4
2019 ~ 2022	%	100	94	81	73	63	52	42	33	24	19	9	3

Year	Units	Measurements Below Threshold											
	mW/m²	5	10	15	20	25	30	35	40	45	50	75	100
2014 ~ 2018	%	6	23	39	52	61	70	76	81	86	91	96	96
2019 ~ 2022	%	0	6	19	27	37	48	58	67	74	81	91	97

Table 3: Percentage of measurements above and below a threshold for a data range

From 2014 to 2018, a quarter (23%) of the measurements are below 10 mW/m^2, the majority (52%) are below 20 mW/m^2 and quarter (24%) are above 35 mW/m^2.

In contrast, from 2019 to 2022 only 6% of measurement are below 10 mW/m^2, the majority (52%) are above 30, and quarter (24%) are above 45 mW/m^2.

Section 3) Power density changes over time

The data set contains some high value outliers which can skew the assessment of the historical trends. This was addressed by filtering the data to exclude outliers and smooth the result. The filtering was done in four stages, two stages to exclude the outliers, and two stages of moving average filters.

The first stage of filtering compared each raw data point to a threshold which was set as the mean plus two standard deviations for its data range. The data ranges used were: 2014~2018 and 2019~2022 as identified in the previous section. If the data point was greater than this threshold, then the filtered data point was taken as the average of its neighbouring two values plus the original data point scaled by a factor of 0.25. If the data point was below the threshold, then the raw data value was retained.

The second filter stage is identical to the first, but using the filtered data as an input with the new filtered mean and standard deviations used for setting the threshold. The raw data is represented by the green crosses, while the 'Filtered' data without outliers is shown with a blue line in Figure 1. Note power density is represented on a logarithmic scale.

The third and fourth filter stage used a 41 point moving average window, displayed as the red 'Moving Average' line in Figure 1.

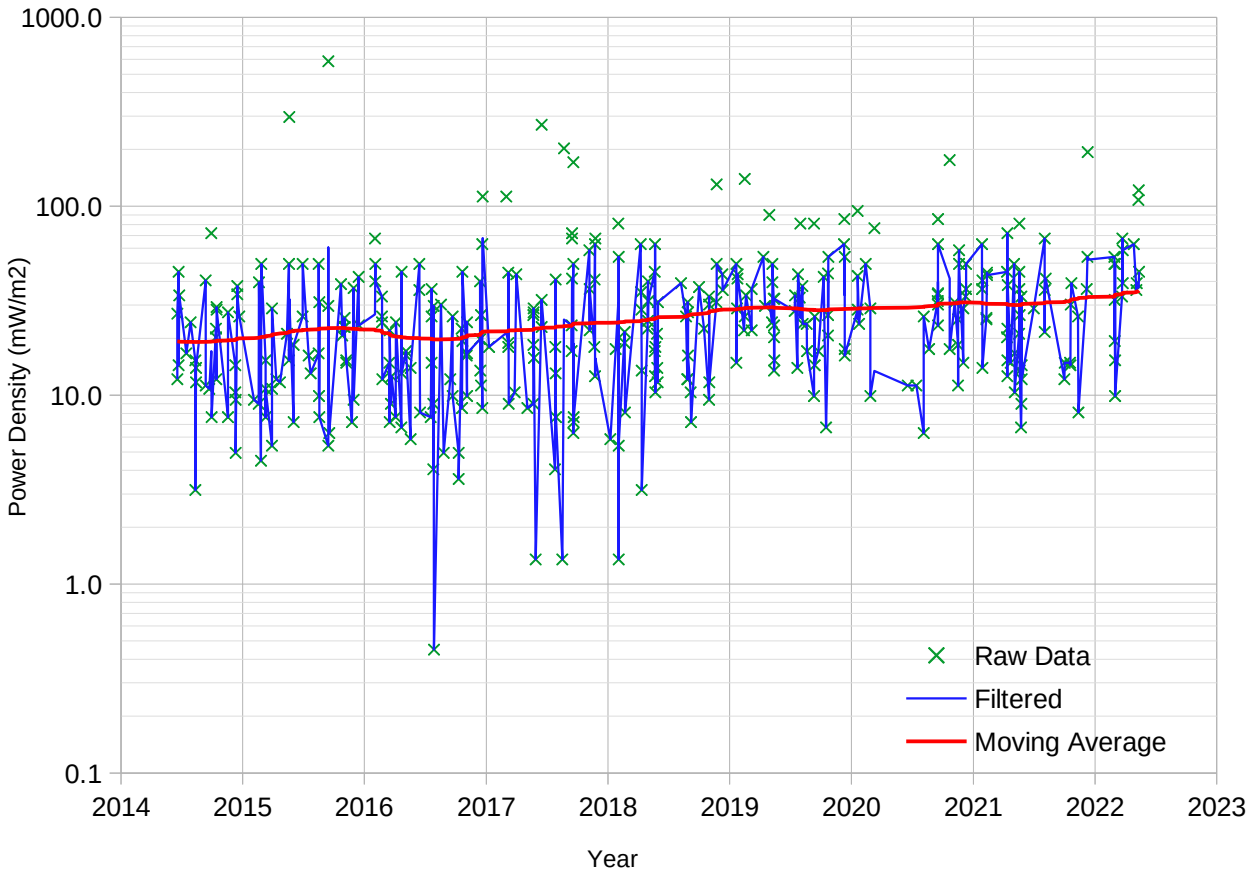

Figure 1: Historical trends with raw data

Figure 2 shows the ‘Moving Average’ on its own with a linear scale for the power density so the trend is more clearly visible. From the years 2014 to 2021 the average measurements increase from 20 mW/m^2 to 30 mW/m^2. The trend continues into 2022 reaching 35 mW/m^2, however more data is needed beyond 2022 to verify the continuation of this trend.

Overall there is a 1.5 times increase in the average power density. Between the years 2014 and 2016 the average is approximately 20 mW/m^2, while in the years 2019 to 2022 the average increases to over 30 mW/m^2.

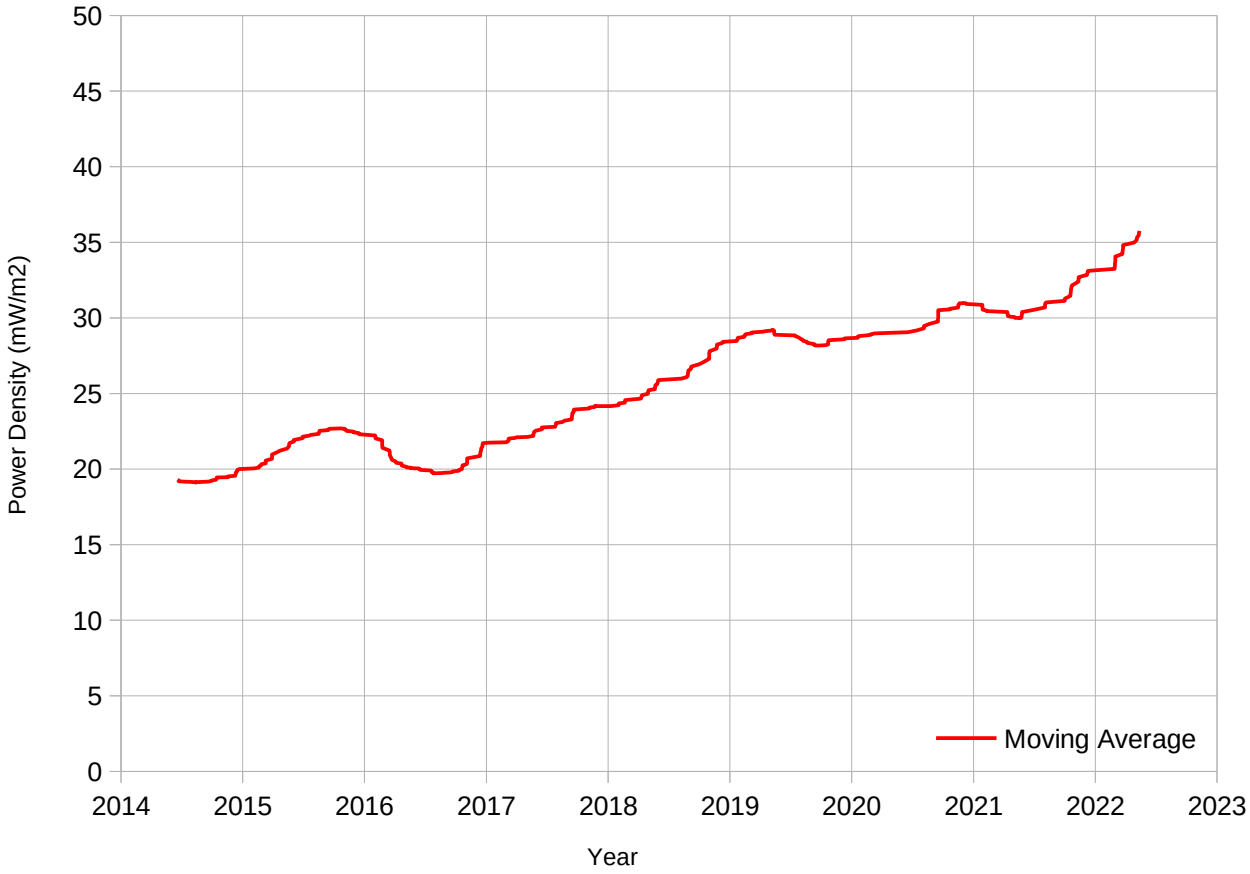

Figure 2: Historical trends moving average on linear scale

Section 4) Power density changes by location

The full data set contains some duplicate locations, measured at different times. The changes to these locations are graphed in Figure 3.

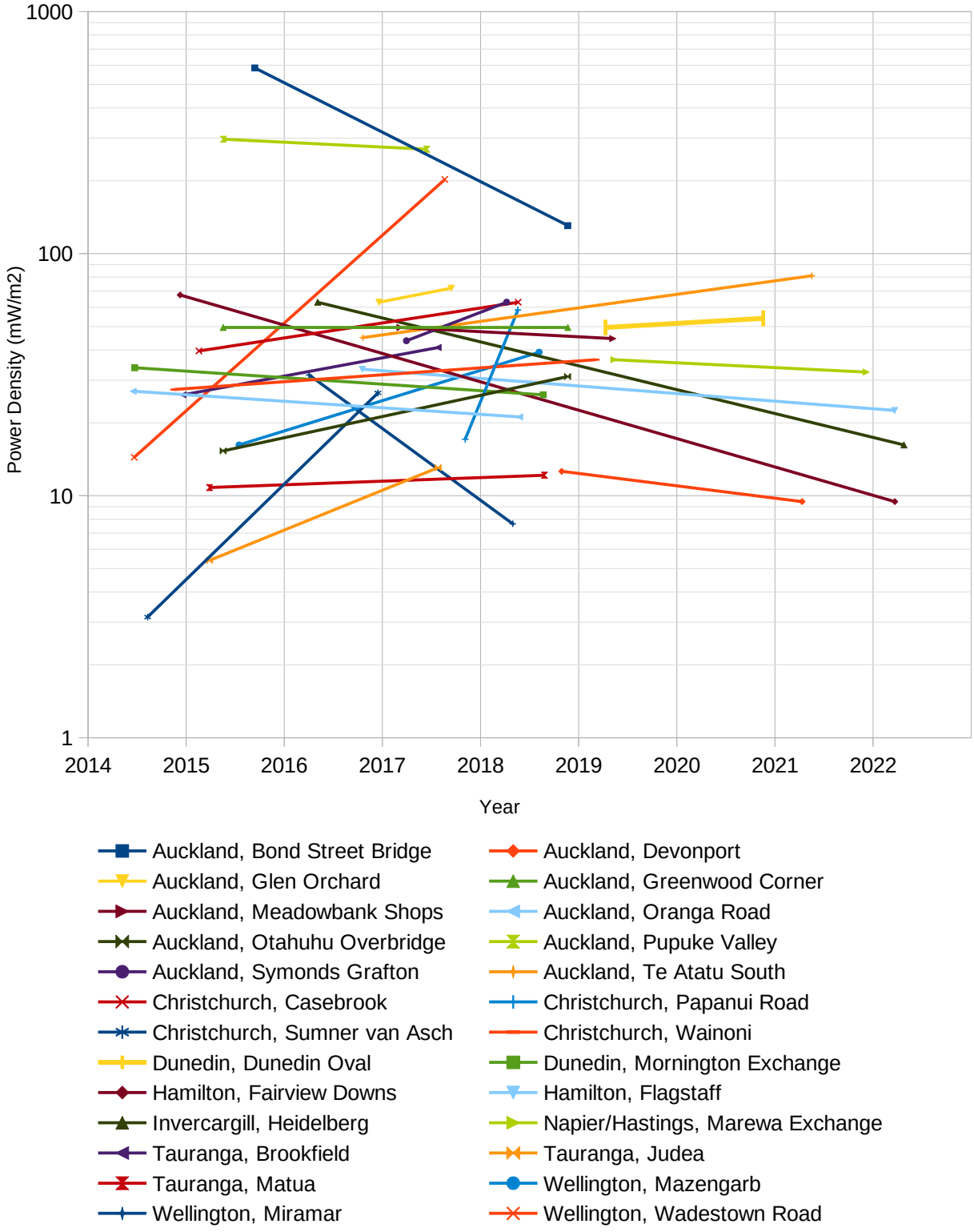

Figure 3: Duplicate locations raw data

There are a total of 25 duplicate locations, excluding the outlier at “Auckland, Bond Street Bridge”. Of these locations: 9 show a decrease in power density (negative slope); 3 show no significant change in power density (very small slope); and 13 show an increase (positive slope). The slope change was determined by calculating if the change of power density is greater than 10% of the average power density between two points.

The cell sites that show a reduction had an average starting power density of 40 mW/m^2, with an average decrease in power density of 18 mW/m^2. The cell sites that have an increase had an average starting power density of 25 mW/m^2 and increased by 32 mW/m^2 on average.

The changes in power density is better visualised by plotting the change in power density by the change in time, graphed in Figure 4.

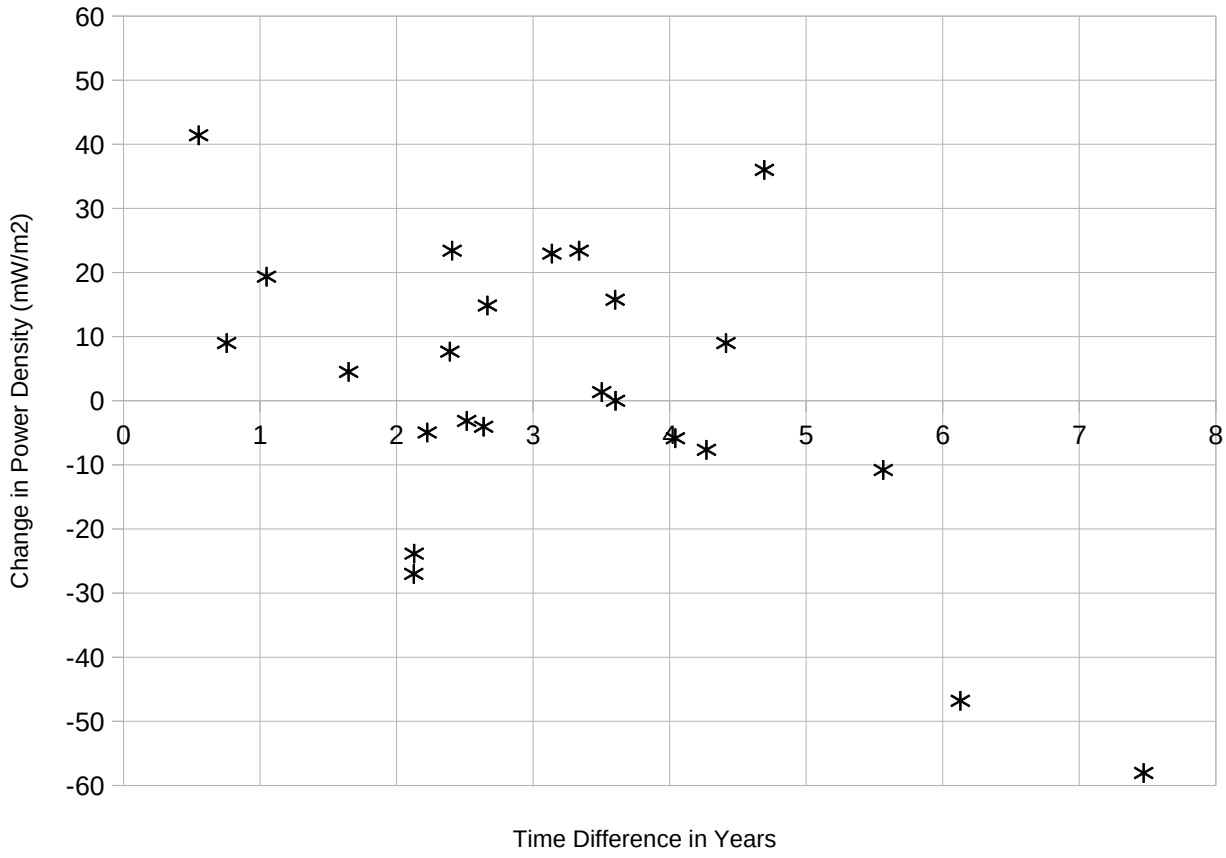

Figure 4: Change in power density over change in time by location

The majority of the data points are above the x-axis indicating an increase in power density. Points that lie very close to the x-axis suggest a small change while points that are significantly below the x-axis indicate a decrease in power density. Note, the original starting power density is not shown here, only the change in power density can be seen.

The overall average increase in power density is 9 mW/m^2 for all the duplicate locations excluding the outlier. The increase in power density is in agreement with the general increase observed with the full data set.

Conclusions:

The spread of measurements varies substantially between mobile base stations with a range between 0.45 mW/m^2 to 585 mW/m^2.

The typical average excluding the outliers between the years 2014 and 2018 is 23 mW/m^2, while in the years 2019 to 2022 the typical average is 31 mW/m^2.

The distribution of the data changes significantly with time. From the years 2014 to 2018 a quarter (23%) of the measurements are below 10 mW/m^2, the majority (52%) are below 20 mW/m^2 and quarter (24%) are above 35 mW/m^2. While from 2019 to 2022 only 6% of measurement are below 10 mW/m^2, the majority (52%) are above 30 mW/m^2, and quarter (24%) are above 45 mW/m^2.

The overall power density has increased by a factor of 1.5 from 2014 to 2022.

The 26 locations where measurements were repeated shows an overall increase of 9 mW/m^2. Nine locations had an average decrease of 18 mW/m^2 and had an average starting level of 40 mW/m^2. Thirteen locations had an average increase of 32 mW/m^2 and had an average starting level of 25 mW/m^2.

Overall there is an increase in power density as the years progress.

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