

Childhood Cancer in the vicinity of the Sutro Tower, San Francisco.

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Abstract:

The Sutro Tower is a prominent structure on an elevated site in San Francisco. Since 1973 it has provided radio and TV signals for the San Francisco Bay region. There have been long-standing concerns about the health effects of this high-powered transmitter located in the centre of a large urban population. The *a priori* hypothesis is that RF/MW radiation is a Ubiquitous Universal Genotoxic Carcinogen. This is based on a number of occupational studies and previous studies that have shown elevated cancer rates in residential populations living in the vicinity of radar and RF/MW broadcast towers. It is supported by many laboratory studies showing that ELF and RF/MW signals damage DNA. Thus it is predicted that at residential levels of RF/MW exposure cancer rates will increase in the vicinity of the Sutro Tower. This is tested by using the childhood cancer data-set from 1973-1988 with residential locations analysed to see if there is elevation of cancer and possible dose-response relationships. All of the analyses support and together confirm the hypothesis, and the radial patterns eliminate potential confounding factors.

Key Words: Childhood cancer, Genotoxicity, Radiofrequency and microwave radiation, exposure assessment.

Introduction:

The objective of this study is to test the *a priori* hypothesis by analysing the spatial distribution of childhood cancer to determine its relationships to the emissions of RF/MW radiation from the Sutro Tower. The Sutro Tower is 977ft high, on a hill that is 921ft high and the top of the tower is at 1898ft (577m) above sea level. The majority of the antennas are within 220ft (67m) of the top of the tower. With the land within 6 km of the tower varying from near the sea level to over 100m, the relative heights of the antennas above the ground vary from about 400 to 570m (1).

The Sutro Tower, built in the early 1970's, initially had VHF FM stations and VHF TV antennas (30 to 300 MHz). The TV channels 2, 4, 5 and 7 with frequencies below 180MHz had a total Effective Radiated Power (ERP) of 616kW. Broadcasting commenced on 4 July 1973. Later channels 9, 20, 32, 38, 44 and 66 were added. Channels above 13 are in the UHF range (0.3 to 3 GHz). The total UHF ERP was 18.3MW. FM radio stations <105MHz, totalled 54.7kW. The 997kW VHF ERP has provided chronic high exposure levels close to the tower site and an undulating declining signal strength with distance. Measurements recorded in 1988 showed that the nearest residential street to the east of the tower had RF/MW field intensities in the range 6 to 33 μ W/cm², and to the west they were 1 to 7 μ W/cm². The UHF signals are more focussed towards the horizon with near equal peak heights at several separated radial distances.

The radiofrequency/microwave (RF/MW) emissions from the Sutro Tower, in the heart of San Francisco, have been a long-standing public health concern. The Department of Public Health of the City/County of San Francisco carried out a survey of childhood cancer in 1988 (2). This showed that in the Noe/Eureka Valley, the suburb to the east of the Sutro Tower, the number of childhood cancer cases from 1973-85 were 21 when 11.8 was expected (OR=1.78, 95%CI: 1.1-1.53). The suburb to the west of the Tower, East Sunset, had a lower rate (OR = 1.47, 95%CI: 0.83-2.39). It is likely that the signals to the west of the tower are weaker than those to the east. Broadcast engineers usually design horizontal antenna patterns to send the signal towards the largest population regions so this may account for some of the variations in regional cancer rates.

Several other studies have found elevated adult and childhood cancer in residential populations living in the vicinity of broadcast RF/MW transmitters, (3-7). Other studies (8-10) report significant increases in residential cancer rates in association with chronic radar exposure. Therefore there is considerable scientific epidemiological evidence supporting the public's concern. Szmigielski and Richter et al. (11, 12) reported that higher occupational exposures produced higher risks of cancer, notably haemopoietic/lymphatic cancer and brain tumors.

Selvin, Schulman and Merrill (13) used a White Childhood Cancer data-set from the San Francisco area for the period 1973-1988, derived from the Surveillance, Epidemiology and End Results (SEER) cancer registry. They chose four cancer types: Brain Cancer, Leukaemia, Hodgkin's Lymphoma and Non-Hodgkin's Lymphoma. Together they amount to around 50% of all Childhood Cancers. Selvin et al was not an epidemiological study but a study to evaluate three statistical methods for clustering. The centre point for their study was the Sutro Tower. They used the childhood cancer data-set as a working example. Their method included significantly transforming the spatial data distribution according to population density. They then analysed their sample clustering methods assuming a linear radial RF/MW exposure pattern.

There are four problems with this work relative to an epidemiologic approach:

- (a) the spatial population density method distorts the spatial position of the cancer cases and therefore significantly alters their distance and their RF/MW exposure relationship from the tower;
- (b) the radial RF/MW exposure pattern is not linear but follows a complex undulating pattern that varies according to the mix of VHF and UHF antennas on the mast;
- (c) They also misplaced the position of the Sutro Tower to 1.2km further west; and
- (d) They failed to compare the San Francisco cancer rates with the mean SEER cancer rates for the period. Hence there are four large sources of error in the original paper when it is used to relate the childhood cancer incidence to the RF/MW radiation exposure from the Sutro Tower.

Table 1 shows that all cancer rates are elevated with RR between 1.62 and 2.6. The overall San Francisco childhood cancer rates are highly significantly doubled, compared with the mean SEER data for the period. The high cancer rate poses the

question as to why the childhood cancer rates in San Francisco are twice the average. Selvin et al. (13) used the Sutro Tower as the center-point of their clustering study. Thus it is relevant to use their data in a corrected and more appropriate epidemiological fashion to determine whether there is any evidence that the RF/MW radiation from the Sutro Tower contributed to the increase in childhood cancer. If it does, then it is highly probable that it also causes increases in adult cancer and many other human health effects that are shown in occupation studies of RF/MW exposures.

Table 1: San Francisco White Childhood Cancer numbers and rates 1973-88, Selvin et al. (10), compared with age-specific, time adjusted SEER means. Using the total childhood population of 50686. Rates are per 100,000 p-yrs.

Cancer Type	Case Number	Rate	SEER Rate	Rate Ratio	95%CI	p-value
Leukaemia	51	6.29	2.41	2.61	1.61-4.2	0.000048
Brain Cancer	35	4.32	2.66	1.62	0.98-2.72	0.059
Hodgkin's Lymphoma	26	3.21	1.35	2.39	1.28-4.45	0.0048
Non-Hodgkin's Lymphoma	11	1.36	0.83	1.64	0.64-4.24	0.3
Total Cancer	123	15.18	7.25	2.09	1.53-2.81	0.000002

Selvin et al. provided spatial maps of the four childhood cancer types they chose for children residing on the San Francisco Peninsula. These are used here to evaluate the possible contribution of the Sutro Tower RF/MW emissions to the elevated cancer rates.

The Hypothesis:

Several previous published studies have found higher cancer rates, especially leukaemia, in the close vicinity of radars and broadcast towers (2-12). Since far-field RF/MW exposure includes whole-body RF/MW exposure, it could be a Universal Genotoxic Carcinogen. Elwood (14) reviewed six occupational studies. Elwood's Table 3 supports the hypothesis, showing elevated cancer across many body organs in multiple independent studies. Since the whole world is exposed to short-wave radio and satellite RF/MW signals, then RF/MW is also a Ubiquitous substance. This is especially true for urban populations who are exposed to many radio, TV and mobile phone transmitters. Many previous studies provide a basis for the hypothesis. The hypothesis being tested by this spatial childhood cancer data around the Sutro Tower is that RF/MW is a Ubiquitous Universal Genotoxic Carcinogen.

Discussion:

The residential exposures are extremely low compared with international standards. The standards are based on avoiding heat and electric shocks during acute exposures. Residential exposures are quite small and do not involve RF/MW induced heat and shocks. Therefore there needs to be a plausible cellular carcinogenic mechanism that works at extremely low chronic exposure levels. A common plausible mechanism for such situations is a genotoxic carcinogen. A genotoxic carcinogen has no safe threshold because it damages DNA cell-by-cell, producing mistakes in the DNA repair, leading to enhanced cell death and cellular neoplastic transformation. Elevated cancer

rates are biologically plausible if the disease agent is genotoxic. RF/MW radiation significantly enhances chromosome aberrations in many studies (15-36) and direct DNA strand breakage (37-44).

The assessment of health effects is guided by Hill (45). Sir Austin Bradford Hill sets out his "viewpoints" for assessing the level of evidence for to move from association to causation. Primarily the factors are temporality, strength of association and dose-response relationship. A plausible biological mechanism is not necessary but can add support to the assessment.

Dolk et al. (5, 6) investigated cancer rates around a high-powered regional broadcast tower at Sutton Coldfield, Birmingham, followed up with a 20-site study. Their discussion of results recognizes the complexities of radiation patterns but specific patterns were not used to interpret their results, Cherry (46). Cherry identifies two general radiation and radial cancer patterns. Pattern A is low near the tower, rises to a broad, relatively flat multiple peak and then declines with further distance from the tower. Pattern B is high near the tower and declines with distance in an undulating fashion. Radiation Pattern A is produced by UHF signals and Pattern B by powerful VHF signals being present. For cancer rates to follow Pattern B, by being high near the tower, there needs to be a large human population a Pattern B radiation signal and an RF sensitive cancer type, e.g. leukaemia or brain cancer. Of the 21 sites studied, only one, Sutton Coldfield, has a high population living near a powerful tower with VHF signals. This produces a Pattern B for adult leukaemia, based on 6 leukaemia cases inside 1km. All other cancers at Sutton Coldfield follow a Pattern A, including All Cancer, Skin Melanoma and Bladder Cancer. Within 2 km of the Sutton Coldfield tower there were elevated rates of adult malignant and benign brain cancer, Skin Melanoma, Male and Female Breast Cancer, Colorectal, Prostate and Bladder Cancer. All other UK sites show Pattern A for Leukaemia, consistent with the combination of population and radiation patterns.

Accordingly, Cherry, based on logical RF/MW and cancer rate pattern matching, concluded that Dolk et al. showed an indicative causal effect as the cancer followed the population and exposure patterns. This study is based on these principles.

A follow-up Sutton Coldfield study, Cooper, Hemmings and Saunders (47) used the leukaemia rates for the period 1987-1994. They show only the 0-2km and 0-10km cancer rates. The results for All Leukaemia are summarised in Table 2.

Table 2: Summary of all Leukaemia results from the follow-up Sutton Coldfield radio and TV tower, (47).

Exposed Group	0-2km			0-10km		
	Cases	O/E	95%CI	Cases	O/E	95%CI
Adult Females	8	1.23	0.53-2.42	159	1.26	1.07-1.46
Adult Males	12	1.40	0.72-2.44	174	1.09	0.93-1.25
All Adults	20	1.32	0.59-2.92	114	1.19	0.97-1.40
Child Females	0			11	1.13	0.57-2.03
Child Males	1	2.34	0.07-13.03	15	1.04	0.59-1.73
All Children	1	1.13	0.03-6.27	26	1.08	0.71-1.59

Despite the relatively small numbers the All Adult and All Children cancer data shows a gross dose-response with higher rates in the 0-2km group than the 0-10km group.

The Sutro Tower has high-powered VHF and UHF transmitters and a dense population living near the tower. Using the above principles it is predicted that there should be Pattern B cancer patterns, especially for Leukaemia/ Lymphoma, Brain Cancer and All Cancer. The small data-set may limit the numbers in the near-tower area.

Methods:

The spatial childhood cancer data was obtained and the childhood residential population distribution was estimated using a detailed survey, to produce a radial cancer rate table within 0.5km radial rings. The first analysis involves the cancer rates very close to the tower, <0.5km and <1.0km. The second analysis uses broad rings, mainly 1km, from 0.1 to 5km and compares the cancer rates in the rings to the mean rate >5km. The third analysis uses a radial cumulative cancer RR rate from the tower moving out towards 5km in steps of 0.5km. The fourth analysis considers the radial RF/MW patterns derived from measurements and theoretical methods, and compares the cancer rates to the probable mean direct household exposure regime. Radial exposure patterns are non-linear, making log-linear trend analysis possibly more appropriate.

The 2x2 statistical analyses were carried out using EPI INFO 6 software package provided by the U.S. Center of Disease Control. Trend analysis uses linear and log-linear Least Squares Fit (LSF) with 2-tailed t-test significance. When the case sample size is 5 or more then Mantel-Haenszel statistics are used. If the case sample is smaller than 5 then the Yates Corrected Chi Squared and the Fisher Exact p-value are used.

Exposure-cancer rate comparisons were made using the Pattern A and B analysis of Cherry (46).

Personal Mean versus Direct Exposures:

Buildings, including residential homes, provide RF/MW signal blocking inside and in their "shadow". The extent of blocking varies with the type and thickness of the building materials. The actual internal exposure levels are much lower than the direct exposures used in this analysis. McKenzie, Yin and Morrell (48) took RF exposure measurements around TV masts in Sydney, Australia. At a residential site the direct signal strength measured at the roof level was $3\mu\text{W}/\text{cm}^2$. At the outdoor ground level it was $0.066\mu\text{W}/\text{cm}^2$ and inside the house it was $0.017\mu\text{W}/\text{cm}^2$. The shadow effects of trees and buildings between the tower and the site reduce the signal by a factor of 45. The building material also reduces the radiative signal strength by a factor of 175 times lower than the direct roof level signal. Since the indoor field strength is less than 0.6% and the ground level outdoor field strength is near 2 % of the direct exposure signal, a conservative estimate of the actual personal chronic childhood mean exposure is about 2-3% of the direct outside exposure. The estimate also allows for time away from home.

The adjustment factor would only alter the slope of the trend, increasing the RR gradient 30 to 50 times higher and not changing the intercept if it is close to zero.

Spatial Childhood cancer data-sets:

The cancer data-set provided by Selvin et al. (13) involves spatial distributions of four White Childhood (aged <21 years) Cancer incidence cases in San Francisco for the 16-year period 1973-1988. This data contained a total of 123 cases of childhood cancer from a population of 50,686 White Children. This provided Selvin et al. with sufficient cases to carry out their cluster analysis but it is a small data-set but adequate for a preliminary spatial epidemiological study. The data included 51 cases of leukaemia, 35 cases of Brain Cancer, 26 cases of Hodgkins Lymphoma and 11 cases of Non-Hodgkins Lymphoma cancer. Selvin et al. estimated that these categories of cancer cover close to 50 % of All Childhood Cancers.

The residential locations of the four types of cancer are provided on separate maps. Each map was enlarged. The cancer case locations for each type of cancer were determined using a computer linked digitizing pad. This formed the database of 123 cases with x and y co-ordinates, radial distance from the Tower and the cancer type, Figure 1 and Table 3.

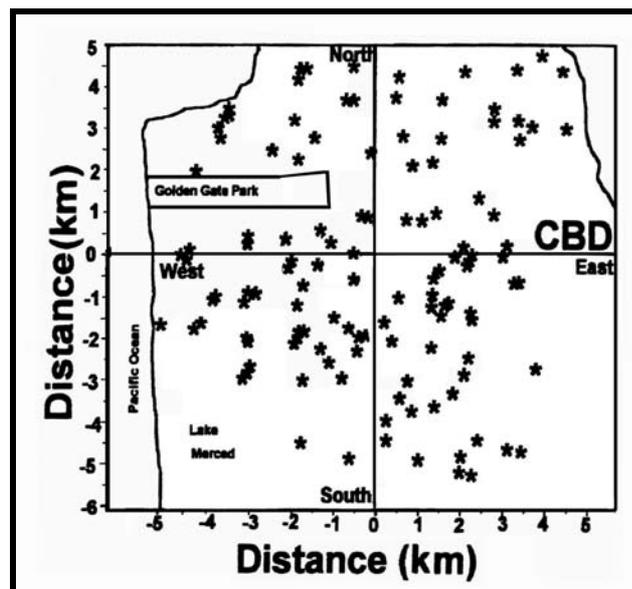


Figure 1: Spatial map of White Childhood (<21 years) Cancer for San Francisco, 1973-88, constructed from Figure 2(a) Selvin et al. (13). The Sutro Tower is at the intersection of the north-south and east-west lines.

All cancer incidence residential sites were placed on a detailed street map of San Francisco to confirm that they corresponded to residential locations. The spatial uncertainty, based on the ability to locate the centre of the mapped points and normal measurement uncertainty, is estimated as less than $\pm 100\text{m}$. However the original positions are based on the centre of the census tracts rather than actual residences. This adds about 100m to the position uncertainty of the actual residential location.

Table 3: Data analyzed into 0.5 km radial rings, centered on the Sutro Tower, including the estimated residential and the white, 0-<21, Childhood Cancer cases, 1973-1988. Total Cancer is the sum of the four cancers cited, amounting to about 50% of all Childhood Cancers (13).

Ring Range Km	RDF	Population Est.	Cancer cases			Total Cancer
			Brain Cancer	Leukaemia	Lymphoma	
0.1-<0.5	0.26	144	2	-	-	2
0.5-<1.0	0.44	750	1	2	2	5
1.0-<1.5	0.57	1625	4	6	0	10
1.5-<2.0	0.61	2430	3	8	2	13
2.0-<2.5	0.71	3610	3	6	6	15
2.5-<3.0	0.75	4700	3	6	7	16
3.0-<3.5	0.75	5515	3	3	4	10
3.5-<4.0	0.70	5980	5	6	7	18
4.0-<4.5	0.62	6000	4	2	3	9
4.5-<5.0	0.56	6060	4	6	4	14
>5.0	0.40	13872	3	6	2	11
Total		50686	35	51	37	123

For a public environmental health study, a total sample size of 123 cancer cases is considered quite small for a spatial analysis, especially when cancer sub-types are separately analysed. This small number means that unless the evidence in support of the hypothesis is extremely strong then it will be unlikely to produce significantly elevated cancer rates or significant dose-response relationships.

Childhood population spatial patterns.

The population and cancer data were analysed in a pattern of circular radial in rings with incremental diameters of 500m, giving 10 rings out to 5 km. The population and cases outside 5 km is used as the reference group. A detailed street map of San Francisco was used to identify the mean residential area densities in each ring, giving a Residential Density Factor (RDF) for each ring. In the radii of >5 km, the ocean becomes more and more dominant. Areas where few children are likely to live were identified and adjusted for, including the central business district (CBD), the port area, parks and reserves such as the Lincoln Park, Golden Gate Park and Harding Park/Lake Merced, and unpopulated areas, such as the San Miguel Hills, and low population areas such as the Presidio Reserve. Close to the tower, to the east is Twin Peaks Reserve and to the northwest is Mt Sutro. General residential density assessments were made in several site visits. The nearest highly-exposed residential property was at least 100m from the base of the tower.

The RDF for most of the rings is given in Table 3. The RDF varied from 26% very near the tower to a maximum of 75% in the 2.5 to 3.5km rings. Outside this the RDF drops off with the inclusion of the CBD, ocean, port area, reserves, etc, to decline to a mean of 56% in the 5km ring. Apart from the <0.5km and >5km rings the population estimates are rounded to the nearest 5. The area >5 km is the reference group area. It contains the ocean, the CBD and several reserves but it also contains several dense population

areas, including the area north of the CBD from China Town to Telegraph Hill (4 cancer cases). Along the southern border there is the Bayview District and Ingelside (6 cancer cases).

A possible confounding or bias factor could be the large antenna farm at the northwest end of the ridge of the San Bruno Mountains. This is about 2-3 km from the cluster of cancers in the reference group along the southern boundary of the San Francisco City/County, Figure 1. The group includes 4 Brain Cancers, 4 Leukaemias and 2 Hodgkin Lymphomas. Since multiple studies show that RF/MW exposure elevates the cancer rate it is likely that the cancer rate in the reference group is elevated because of this situation.

Beyond 5km the area is primarily ocean except for the band across the south that includes Harding Park and John McLean Park and a segment is outside San Francisco. It also includes the Central Business District (CBD). The >5km area was analyzed as three 0.5 km bands, giving a mean RDF = 0.4 and a population of 13872. Table 3 shows the 0.5km circular rings around the Sutro Tower, with estimated population and reported childhood cancer types data from Selvin et al.

Exposure Modelling and Assessment:

Cherry (46) outlined the relationship between radial cancer rates and radial exposure patterns around broadcast towers in relation to Dolk et al. (5,6). Both the population density and the RF/MW exposure patterns need to be considered in epidemiological studies. As mentioned above, there are two general patterns. Pattern A is low, rises to a broad undulating peak and then declines. Pattern B is high near the tower and declines, undulating, with distance. Pattern B is associated with VHF signals that produce a peak inside 1km. The shorter the wavelength (and higher the frequency) makes it easier to focus the UHF signal towards the horizon. AM and FM radio stations use frequencies from 500 kHz to about 300 MHz (Medium (MF), High (HF) and Very High Frequency (VHF) radiation). High-powered TV stations usually use 300-800 MHz, in the Ultra High Frequency (UHF) range.

Figure 2 shows two examples of VHF ground levels radial exposure patterns. The first is from 1933 around the Empire State Building in New York (49,50). Both graphs show logarithmic variation and undulating signal strength. In contrast to the VHF signals in Figure 2 the UHF antenna patterns are more focussed towards the horizon, Figures 3 and 4.

In Figure 3 the Relative Field peaks at 0.5, 3.5, 5.7, 7.9, 10.1 and 12.3°. With the assumption of the height of the antennae at 460m, these peak angles correspond to ground level positions at 52.7, 7.5, 4.6, 3.3, 2.6 and 2.1km from the tower. The actual exposure intensity is a function of the square of the Relative Field and the inverse square of the distance along a beam. This results in the ground level peaks being closer to the Tower, especially for the most remote peaks. These adjustments are taken into account by the radial UHF pattern in Figure 4. Figure 4 shows the main beam peaks at 12.5km and the major side-lobe peaks at 6, 4.5, 3.2, 2.2 and 1.1km.

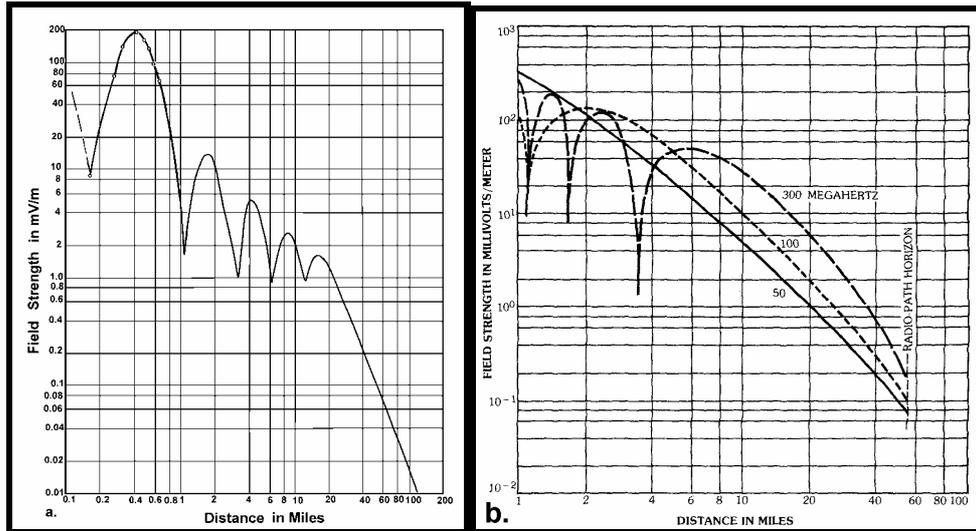


Figure 2: Ground level radiation pattern for (a) the 44 MHz (VHF) signal from the Empire State Building in New York City, Jones (12) by merging his figures 6 and 8, and (b) a theoretical set of 1 kW antenna at a height of 1000ft and a receiver at a height 30ft, Jordon (13). Field strength of 100mV/m=2.7nW/cm², 10mV/m=26.5pW/cm² and 1mV/m=0.27pW/cm².

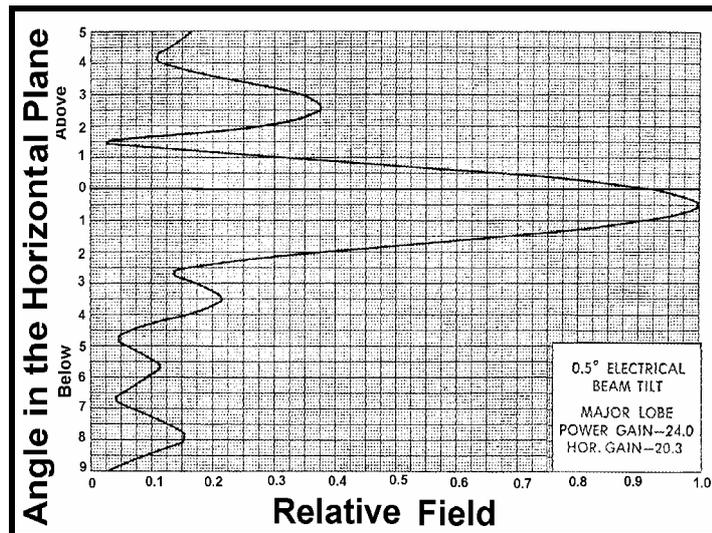


Figure 3: A typical Relative Field for a UHF RF/MW broadcast antenna from Hammett and Edison (1). The signal intensity is a function of the square of the Relative Field.

Because of the presence of powerful VHF signals, the Sutro Tower emissions follow a Pattern B radial shape. Hence the childhood cancer radial patterns are expected to also follow Pattern B if they are related to the RF/MW exposures from the Sutro Tower.

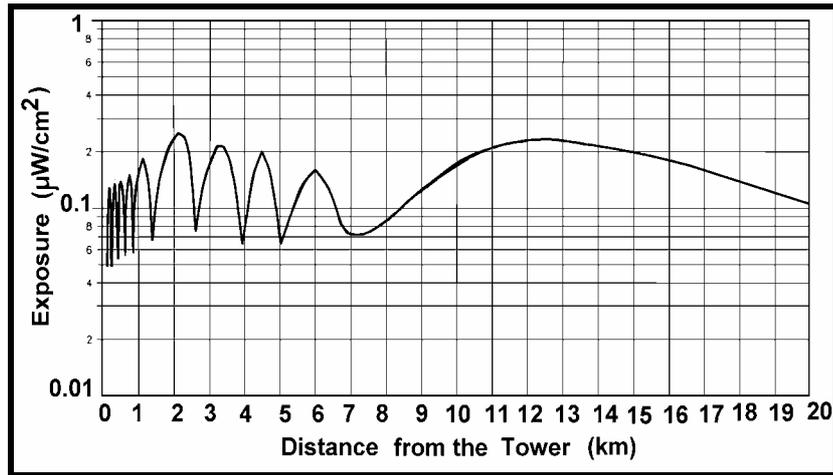


Figure 4: Ground level exposure for a typical UHF TV broadcast signal, from an antenna pattern (1), for an 18 MW EIRP transmitter at 460m AGL, for a flat horizontal surface.

Epidemiological Analysis Methods:

The highest exposures, due to the VHF signals are experienced in residences within 100m to 1km of the tower. Hence cancer rates inside 500m and in the 0.5 to 1km ring are possible indications of the high RF/MW exposure. The data allows for a simple five 1km ring analysis for very high, high, middle, low and very low exposure, using the 2x2 analysis method to determine whether this reveals significant elevations and a dose-response. A radial cumulative analysis was used to determine if the radial distance from the Sutro Tower provides log-linear or linear correlation trends with cancer rates. A detailed radial ring analysis (0.5km ring bands) of cancer rates was compared with measured and theoretical radial RF/MW radiation patterns, to investigate the possible exposure-based dose-response characteristics.

The Sutro Tower broadcast facility was established in 1973 and the data in this study covers the period from 1973-88, following the producing of the public exposure to RF/MW from the Tower. The latency for childhood cancer is as short as 1 year. In the data-set involved 123 children, 21 of the children were diagnosed with cancer in the 0-2yr age range.

Results:

Close to Tower Childhood Cancer Rates:

The spatial cancer map, Figure 1, shows some circular patterns of high and low cancer rates and a high cancer rate in the immediate vicinity to the tower, <1 km. Within 500m of the tower there are 2 Brain Cancer cases, Table 3. Compared with the Brain Cancer rate in the very low exposure group (>5 km), this results in:

$$RR = 64.2, 95\%CI: 10.8-382, p=0.00103$$

The first 0.5km ring with at least one case of each cancer type is 0.5-1km. The cancer rates in the <1.0km ring are in Table 4.

Table 4: The Near Sutro Tower (<1km) Childhood Cancer rates compared with the remote >5km rates. (* Fisher Exact p-value for n<5).

Cancer Type	Cases	RR	95%CI	p-value
Brain Cancer	3	15.5	3.14-76.8	0.004*
Leukaemia	2	5.2	1.05-25.6	0.08*
Lymphoma	2	15.5	2.19-110	0.02*
Leukaemia/Lymphoma	4	7.8	2.34-25.7	0.0045*
All Cancer	7	9.9	3.84-25.4	<0.0000001

All cancer types are significantly elevated, except the lowest, Leukaemia, RR = 5.2, 95%CI: 1.05-25.6, n=2. For All Cancer the RR = 9.9, 95%CI 3.84-25.4, p<0.0000001. Brain Cancer (RR = 15.5) and Lymphoma (RR=15.5) are highly significantly elevated. The strength of the relationship of the All Cancer is classically causal, Hill (45). This occurs despite the very small sample size but the strength of the relationship is supported by several previous studies showing elevated cancer rates around broadcast towers.

Broad Ring (1km) Analysis:

The data set out in Table 3 was grouped into 1km rings out to 5km, with the cancer rates compared to the rates in the >5km remote ring, Table 5.

Table 5: The broad ring trend analysis with distance from the Sutro Tower, with Childhood Cancer rates relative to the remote >5km ring. The brackets show p-value adjusted for the single low data outlier.

Ring km	Brain Cancer		Leukaemia		Lymphoma		All Cancer	
	RR	95%CI	RR	95%CI	RR	95%CI	RR	95%CI
0.1-1	15.5	3.14-76.8	5.2	1.05-25.6	15.5	3.19-110	9.9	3.84-25.4
1-2	7.8	2.1-30.9	7.2	3.07-20.8	3.4	0.48-24.3	7.2	3.45-14.7
2-3	3.3	0.84-13.4	3.3	1.25-8.9	11.0	2.48-48.6	4.7	2.37-9.35
3-4	3.2	0.85-12.1	1.8	0.64-5.1	6.6	1.47-29.9	3.1	1.53-6.17
4-5	3.07	0.81-11.6	1.5	0.53-4.4	4.0	0.84-19.4	2.41	1.17-4.93
>5	1.00		1.00		1.00		1.00	
Trend p-value		0.03		0.02 (<0.005)		0.08 (<0.001)		<0.001
Log/Lin Trend		p<0.001		0.05 (<0.03)		0.07 (<0.02)		<0.0001

Table 5 shows significantly elevated childhood cancer rates in all 1km rings for All Cancer. For Brain Cancer all rates are significantly elevated for <2km and with a consistently declining with a significant linear trend, p=0.03, and highly significant log-linear trend, p=<0.001. Leukaemia and Lymphoma rates show quite variable patterns, especially for the small samples in ring <1km for Leukaemia and out to 2km for Lymphoma. They both show significant linear and log-linear trends, especially when the small sample outliers are removed. When all the data is combined to form the All Cancer trend, it is significantly elevated in all 1km rings and consistently declines with

distance. There is also a highly significant linear trend, $p=0.001$, and a log-linear trend, $p=0.0001$, Figure 5.

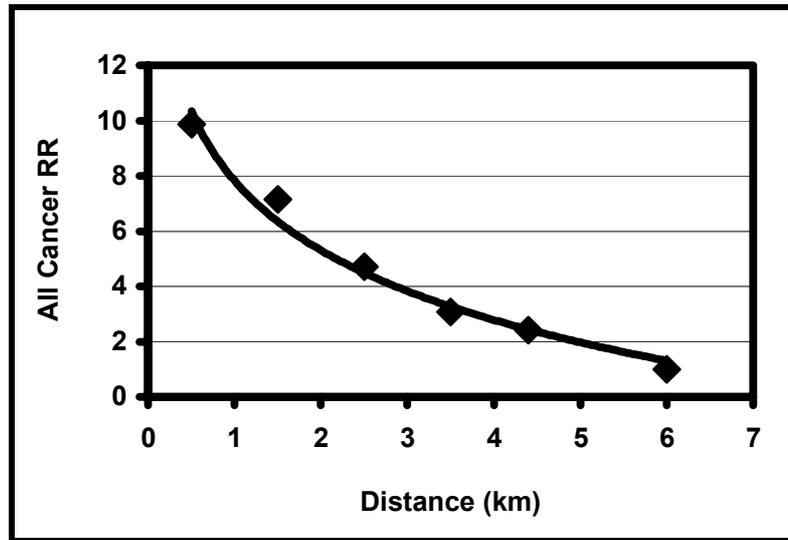


Figure 5: All Cancer around the Sutro Tower in a 1 km radial ring pattern, Log-Linear Trend $p<0.0001$.

These observations, through their strength of association, the level of significance and the dose-response relationships, especially for All Cancer, give considerable support to the hypothesis of an association between RF/MW exposure and risk.

Radial Cumulative Childhood cancer trends:

All methods used the group living further than 5km from the tower as the reference group. The cumulative incidence rate and Relative Risk was calculated from the 0.5km or 1km rings, in 0.5km increments out to 5km. This method is independent of the actual exposure assumptions since a uniform radial increment is used. The trend analysis results are summarized in Table 6.

Table 6: Trend p-values for the radial cumulative Childhood Cancers Relative Risk as a function of distance from the Sutro Tower, using 0.5 km increments, with linear, log-linear and inner ring outlier removed trends.

	Linear Original	Log-Linear Original	Linear Outlier Adj	Log-Linear Outlier Adj
Brain Cancer	<0.05	<0.005	<0.001	<0.0001
Leukaemia	<0.01	<0.02	<0.0001	<0.0001
Lymphoma	0.30	0.12	<0.005	<0.0001
Leukaemia/Lymphoma	<0.00001	<0.001	<0.00001	<0.001
All Cancer	<0.001	<0.0001	<0.0001	<0.00001

Table 6 shows a significant linear ($p<0.05$) and log-linear ($p<0.005$) cumulative trend for Brain Cancer, Figure 6.

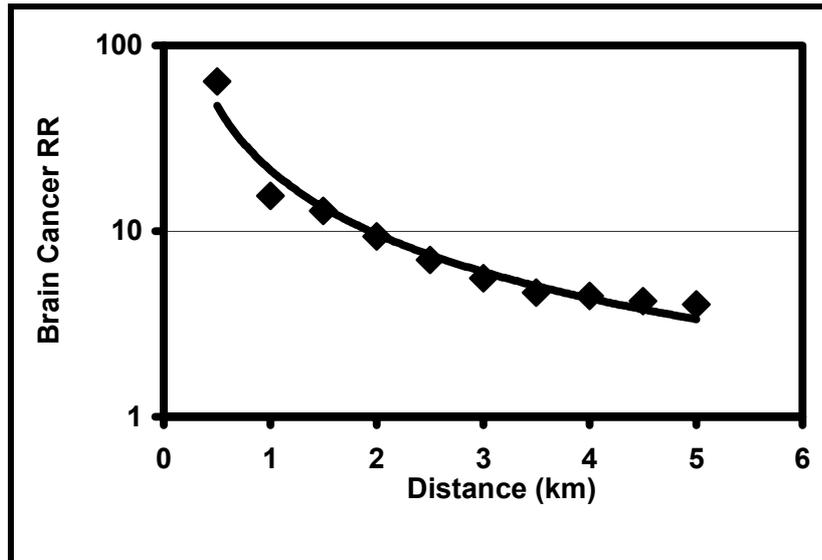


Figure 6: Radial cumulative Brain Cancer for childhood cancer in 0.5km radial segments around the Sutro Tower. Trends: linear $p = <0.05$, log-linear $p = <0.005$. The shown fitted line is a power law curve, $p < 0.00001$.

Inside 1.5km there were only 5 Leukaemia cases and 2 Lymphoma cases. Therefore Leukaemia and Lymphoma were combined for the radial analysis, Figure 7.

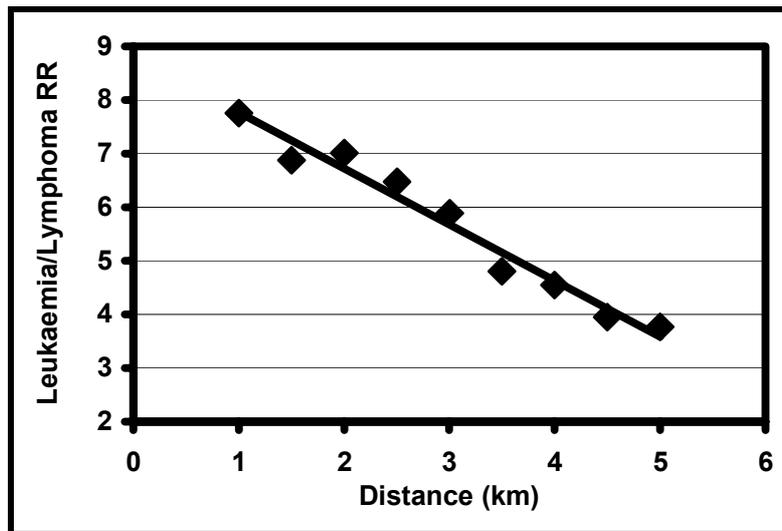


Figure 7: Radial cumulative Childhood Leukaemia/Lymphoma in 0.5km radial segments $>1\text{km}$, around the Sutro Tower. Trends: linear $p = <0.00001$ (shown curve), log-linear $p = <0.001$.

Removing the inner ring low sample outliers gives a highly significant trend, $p < 0.0001$. When all the data is combined to form the All Cancer set, both the linear and log-linear radial cumulative trends are highly significant, $p = 0.001$ and $p = 0.0001$, respectively, Figure 8.

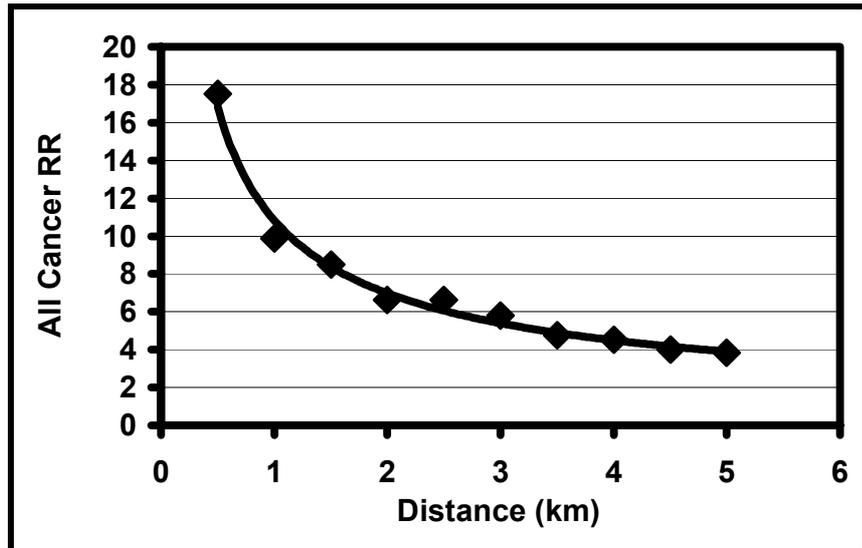


Figure 8: Radial Cumulative All Cancer for Childhood Cancer in 0.5 km radial segments >0.5km, around the Sutro Tower. Trends: linear $p = <0.001$, log-linear $p = <0.0001$ (shown curve).

Discussion of distance results:

The low sample size of cancer cases near the Tower produces lower RR rates inside 2km for Lymphoma and significant cumulative trends outside 2km. When all small sample outliers are removed the trends are all highly significant. The radial cumulative trend analysis shows that Brain Cancer, Leukaemia, Leukaemia/Lymphoma and All Cancer show totally significant radial cumulative trends that point towards the Sutro Tower as the primary cause of the elevated rates of Childhood Cancers in San Francisco.

The Sutro Tower radiation is ubiquitous over the whole study area and beyond. The only other genotoxic ubiquitous substance identified is the toxic air pollution from transport vehicle emissions. However, because the Sutro Tower is in a highly elevated site, surrounded by open land and suburban streets, the area has a small emission rate from vehicles and it is more well ventilated by wind. In contrast, the area outside 4 to 5 km contains many high vehicle volumes on busy roads and highways. Thus the transport spatial pattern is the reverse pattern of the radial cancer rates shown. Hence vehicle air pollution emissions are not a confounder of these results. There are no known sources of ionizing radiation or toxic water pollution specifically associated with living near the Sutro Tower.

This gives comprehensive, independent and direct support for the hypothesis and that the RF/MW radiation from the Sutro Tower is highly probably the source of elevated cancer rates in children living in San Francisco.

Actual and probable exposure patterns:

Figures 9 and 10 show the 0.5km Risk Ratios for Brain Cancer and All Cancer, respectively. They show high rates inside 1 km as shown in Dolk et al. (5) for Adult

Leukaemia, showing a Pattern B form, appropriate with having a high population density living close to tower and powerful VHF signals from the antenna.

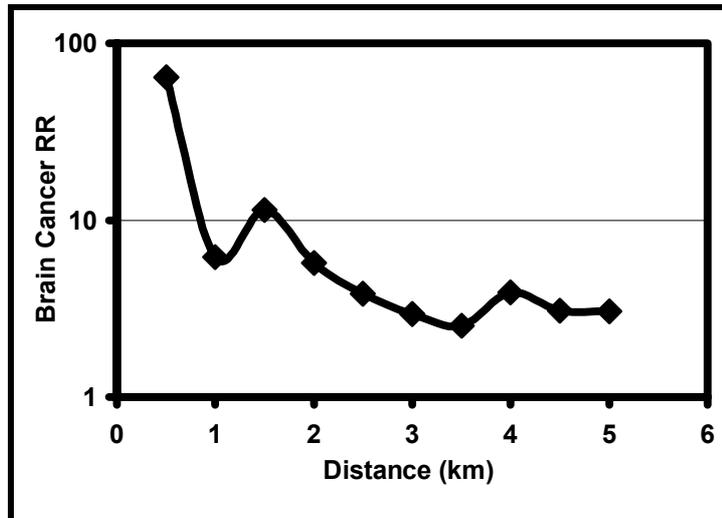


Figure 9: The Childhood Brain Cancer Radial RR 0.5 km pattern around the Sutro Tower, showing a Pattern B consistent with the radiation Pattern B.

The All Cancer data only has brain cancer in the <0.5km ring, hence the RR is exceptionally low when it is included in the All Cancer data, Figure 10. Therefore the first point in the All Cancer data is reasonably treated as an outlier point.

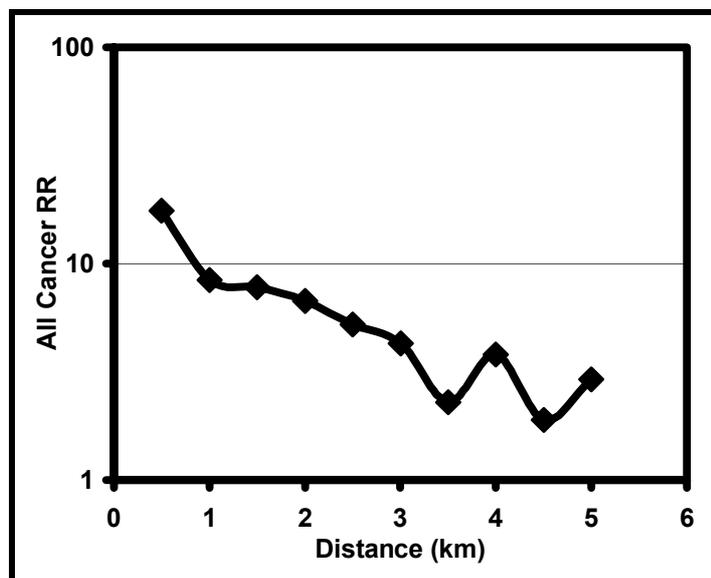


Figure 10: The All Cancer RR for Childhood Cancer in 0.5 km radial segments around the Sutro Tower, showing a Pattern B consistent with the radiation Pattern B.

Figure 11 sets out the 10 measured exposures in the 2 km radius, pointing to three peak and two minimum levels. The estimated exposure levels >2km are based on the UHF antenna pattern, Figure 4. The mixed VHF/UHF set of powerful antenna signals produce a Pattern B shape. Alternative exposure peaks are higher and lower because of the antenna vertical patterns, Figure 4. Because of the non-linear radial variation of exposure the patterns are presented with logarithmic exposures and RR levels. The

radial cancer rates are very similar to the broad shape of the exposure patterns. Both are Pattern B shapes. Hence the cancer radial patterns are close to the RF/MW probable radial pattern. Both Figure 9 and Figure 10 show a lower RR rate near 1km. This is associated with a lower intensity side-lobe, Figure 11.

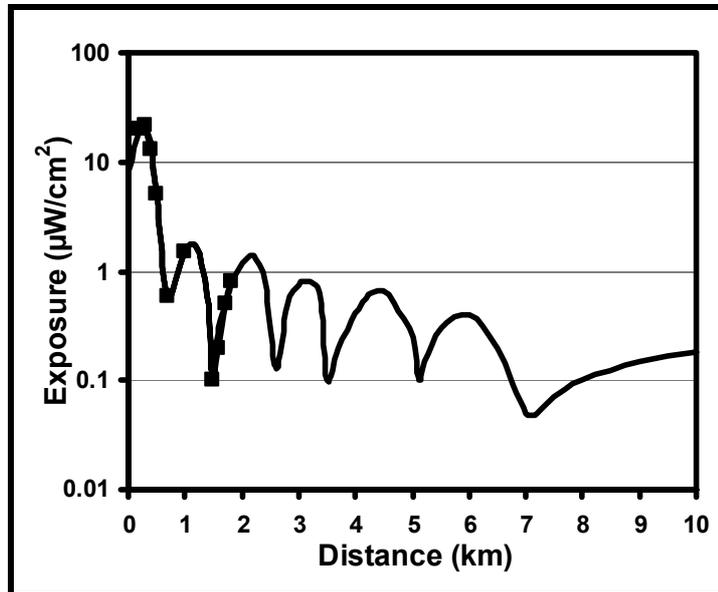


Figure 11: The probable radial RF/MW exposure pattern around the Sutro Tower estimated from 1988 measurements (circles) and the calculated radial exposure patterns from VHF and UHF antennas, Figures 2 and 4.

An exposure-based dose-response relationship is necessary for determining safety exposure standards, (51). Mean exposures for each 0.5km ring were taken from Figure 11. For the rings very close to the tower there are larger populations living in the outer half of the ring. Noting the logarithmic scale and the observation that within 500m of the tower the homes are generally in the range 300-500m, with more homes at the larger radius, giving a mean exposure estimate of $9\mu\text{W}/\text{cm}^2$. The 0.5km-ring mean direct exposure and the All Cancer rate was plotted in a dose-response graph, Figure 12, trend $p < 0.0001$.

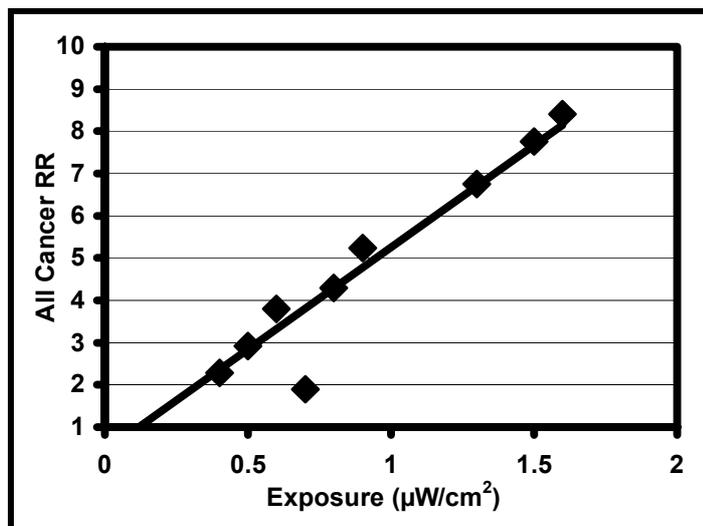


Figure 12: All Childhood Cancer as a function of measured and estimated RF/MW exposure in 0.5 km radial rings, ignoring the 9 $\mu\text{W}/\text{cm}^2$ outlier that only contained Brain Cancer. Trend $p < 0.0001$.

The trend line was fitted to ignore the outlier. The low exposure outlier near $0.7 \mu\text{W}/\text{cm}^2$ contains a very small population of Leukaemia/ Lymphoma cases. When it is removed then the trend has $p < 0.00001$. The Brain Cancer RF/MW exposure trend is extremely significant, $p < 0.00001$, Figure 13.

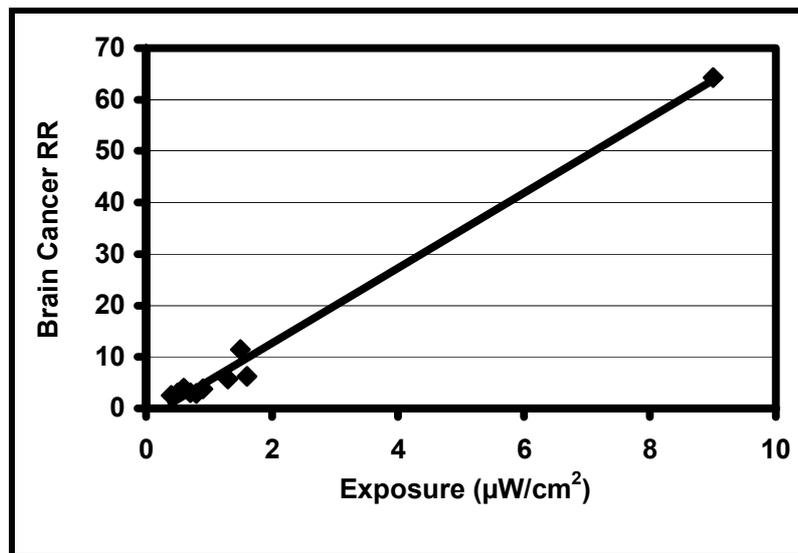


Figure 13: Childhood Brain Cancer as a function of measured and estimated RF/MW exposure in 0.5 km radial rings. Trend $p < 0.00001$.

The exposures used are the measured and estimated direct exposures. The actual chronic mean personal exposures are highly probably less than 2-3% of the direct exposure because of the shadow effects and household protection effects. All of the dose-response relationships are extremely significant and support the hypothesis that RF/MW is a Universal Genotoxic Carcinogen increasing the incidence of multiple cancer types with no safe threshold level.

This analysis shows that a fairly realistic approach accepts that the radial RF/MW radiation and cancer patterns vary in a logarithmic fashion with distance from the tower. This produces a linear exposure-based dose-response trend for cancer rates.

Recommendations for further research:

To further examine the hypothesis, this study should be extended to include all childhood cancers and all adult cancers. One data set could include the annual cancer age and site rates from 1960 to 2000 to evaluate the time series effects, including the introduction of the Sutro Tower exposure and in the later years the massive increase in other RF/MW sources throughout the city.

Spatial data for all cancer cases from 1970 to 2000 can be used to produce a time series of the spatial radial cancer rates. A detailed RF/MW spectrum exposure survey would assist the assessment of the spatial RF/MW exposures over time by considering

the introduction of each frequency from the Sutro Tower and any changes in the power output. It would also identify the range of frequencies and mean intensities of the over 2000 antennas now operating in San Francisco. The larger cancer and exposures datasets would provide a basis to carry out a geographic analysis of the effects of hills, valleys and built-up areas.

Summary and Conclusions:

There are several previous studies showing elevated adult and childhood cancer around high-powered broadcast towers. Four previous studies also showed cancer associated RF/MW dose-response relationships (5-8). The previous epidemiological studies and the direct evidence of RF/MW genotoxicity was the basis of the hypothesis that RF/MW is a Ubiquitous Universal Genotoxic Carcinogen.

Close to the Sutro Tower there are very high and extremely significantly elevated childhood cancer rates where the mean exposure is relatively high but still a very small fraction of the Federal Communication Commission (FCC) standard. The five 1km-ring distance analysis shows dose-response relationships for each cancer type, and a highly significant linear or log-linear trends for the All Cancer, Leukaemia, combined Leukaemia/Lymphoma and Brain Cancer rates. The radial distance cumulative RR trends show cumulative show many significant trends that are extremely significant when small sample outliers are removed. The measured and theoretical radial exposure patterns are close to the 0.5km ring cancer radial rates in type B Pattern. The close similarity of the radial cancer and exposure patterns provides a basis to exclude confounder factors. These relationships result in highly significant exposure-based linear dose-response gradients, all pointing to the absence of a threshold for detectable risk.

Cherry (52) shows that the naturally occurring Schumann Resonance signal, with a mean field intensity of $0.1\text{pW}/\text{cm}^2$, is correlated with enhanced Human Cancer rates. Therefore every separate analysis in this study, the combined results taken together and with many previous studies, strongly support and confirm the hypothesis that RF/MW is a Ubiquitous Universal Genotoxic Carcinogen.

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