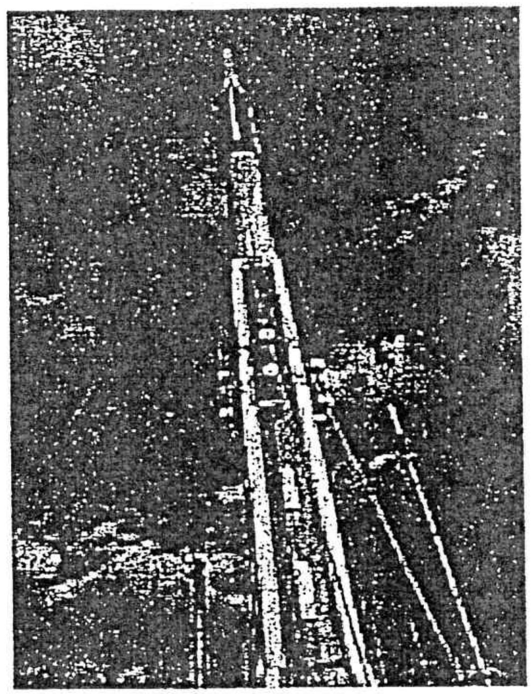
APPENDIX A-9

Richard Tell Associates, Inc., May 12, 2000,
"An Investigation of RF Safety Considerations on the WTC Antenna Mast Relevant to Work to Install a New Digital Television Antenna."

RICHARD TELL ASSOCIATES, INC.

An Investigation of RF Safety Considerations on the World Trade Center Antenna Mast Relevant to Work to Install a New Digital Television Antenna



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An Investigation of RF Safety Considerations on the World Trade Center Antenna Mast Relevant to Work to Install a New Digital Television Antenna

Table of Contents

An Investigation of RF Safety Considerations on the World Trade Center Antenna Mast Relevant to Work to Install a New Digital Television Antenna

Introduction

New York City television (TV) broadcasters at the World Trade Center (WTC) are preparing to augment their present services with high definition, or digital, TV (DTV) transmissions. This new capability will require the installation of a new master antenna that will be used by those stations electing to add DTV service to be located within a presently unused area on the existing antenna mast at the WTC north tower. A UHF antennas, formerly used by channel 41, located just above the auxiliary antenna for channels four and five, is proposed to be disassembled and removed to provide space for a new UHF master TV antenna. The process of disassembly and removal of the old channel 41 antenna and installation of the new antenna will require considerable effort and workers will necessarily have to be located in areas with potentially intense RF fields. The purpose of the work documented in this report was to characterize the RF field environment in the region of the mast to be occupied by mast workers and to use the measurements to develop a suitable set of procedures to ensure that RF exposure of all workers will comply with regulations set by the Federal Communications Commission (FCC). This report describes the process by which RF field measurements were taken in the designated work region and provides insights and recommendations that will assist in complying with the FCC rules.

The FCC RF Maximum Permissible Exposure Limits

During the antenna change out project, individuals working at the WTC rooftop site will be subject to RF fields due to a combination of both broadcast transmissions and a proliferation of wireless telecommunications antennas mounted on the roof. The roof of the north tower of the WTC is a controlled environment, as defined in the WTC RF Safety Program documentation[1]. This means that the applicable maximum permissible exposure (MPE) limit is that designated by the FCC for occupational/controlled exposure. Appendix A contains details on the FCC MPE limits. Controls are in place to restrict access to the rooftop to personnel who have been trained in RF safety matters or who are escorted by someone who has been so trained. In addition, special procedures are in place for tower maintenance activities to prevent exposure to RF fields that would exceed the occupational/controlled MPE limit.

[1] World Trade Center North Tower Roof RF Safety Program prepared by Richard Tell Associates, Inc. for the Port Authority of New York and New Jersey, World Trade Center, February 1, 1999.

Recent RF Safety Related Work at the World Trade Center

A number of relatively recent activities have taken place at the WTC in the past that have been related to RF safety. These include:

1. In 1998, a comprehensive RF safety program was documented and serves as the guidance document for matters related to RF safety considerations the WTC.
2. In 1997, a comprehensive study of roof-level RF fields was undertaken on the roof of the WTC north tower[2]. This study provided details on the distribution and magnitude of the composite RF fields produced by the combined effect of all broadcast stations and the roof-mounted wireless communications antennas. An output of this exercise was the generation of colorized roof field maps showing those areas with more intense fields and those with weaker fields. These maps could be used by personnel working on the roof to identify areas to avoid due to RF fields that might exceed the FCC exposure limits.
3. In 1999, an update of the 1997 study was prepared that took into account changes in the many wireless communications transmitters at the WTC. That project resulted in updated, colorized roof field maps as described in 2 above.
4. In addition, in 1999, a study of ambient RF fields on the public walkway located on the WTC south tower building was completed. The purpose of that study was to examine the magnitude of RF fields produced by the operations on the north tower with an emphasis on whether such fields might exceed the more stringent, general public MPE limit (see Appendix A for details on the differences between the occupational/controlled and general public/uncontrolled MPE limits). That study determined that RF fields on the walkway comply with the general public MPE limit.

Technical Approach to Evaluation of RF fields.

Attempting to perform meaningful RF field measurements at awkward points substantially elevated above the roof of the WTC north tower is problematic. After examining the proposed work activities that would be accomplished during the DTV antenna project, it was concluded that the most useful assessment of potential exposure of workers would be accomplished through a series of RF field measurements made parallel to the antenna mast. If a field measurement probe could be positioned adjacent to the mast, but close to it, the magnitude of the measured RF fields would most likely approximate the RF field exposure environment that workers could access. Proper positioning of a field probe, however, would be challenging considering the overall height of the defined work area throughout which measurements would be necessary to properly characterize the fields and the almost ever-present and disagreeable winds aloft at the top of the WTC.

The measurement approach ultimately selected consisted of rigging the antenna mast with nylon ropes to permit the raising and lowering of an electric field strength

[2] An Evaluation of the Radiofrequency Environment at the World Trade Center North Tower prepared by Richard Tell Associates, Inc. for Motorola Network Services Division, September 25, 1997.

probe from nominally roof level to the height of an ice shield located at the top of the channel 47 antenna aperture. This would allow field probing of the primary work area which would extend from the bottom of the channel 41 antenna aperture to the top of the channel 47 aperture. While workers would not occupy the region directly in front of the master FM antenna while it was active, nonetheless, any field measurement data that could be collected in this region as well was deemed as potentially useful to provide perspective on the relative magnitude of RF fields to which workers could be exposed if appropriate procedures were not followed. The principal work area during the antenna project, where personnel will be located, will be nominally between 101 feet and 175 feet above the roof. The main work area is the nominal 74 feet of vertical aperture extending from the bottom of the channel 41 to the top of the channel 47 apertures.

In concept, the antenna mast was to be rigged with ropes similar to that illustrated in Figure 1, with pulleys being installed at the ice shield on all four sides of the mast to accommodate a succession of four separate sets of RF field measurements along each of the four sides of the mast. Figure 2 is a telephoto shot showing attachment of the nylon ropes at the ice shield. A fourth pulley, on the opposite side of the mast, cannot be seen in Figure 2. These ropes were temporarily anchored near the edge of the roof until the actual measurement process at which time the ropes were brought into near the base of the mast, passed through a second pulley and tied together. Using heavy nylon straps, the bottom pulley was then securely anchored to the bottom level of the surrounding "grand stand" and tightened such that the ropes were parallel and exhibited the least practical degree of bow due to the wind loading on the ropes. Figure 3 is a photograph showing the tower as it was rigged and identifies important points on the mast relative to the field measurement project. A field crew of tower riggers was present to handle the ropes during the measurements.

Field measurements were conducted on two occasions at the WTC, during the early morning hours of April 6 and May 1, 2000. The first set of measurements resulted in the eventual collection of field data on all four sides of the antenna mast, despite the issue of high winds that made the process rather difficult. For example, with the strong winds, the field probe that was attached to the ropes had relatively substantial movement about the axis of the unperturbed rope in the absence of wind gusts. This oscillation of the probe's lateral distance from the unperturbed rope axis was potentially most significant while the probe transited the region of the FM master antenna as, in this area, the probe was blown back and forth such that it came close to the FM elements at moments and this could lead to momentary pulse-like appearing excursions of electric field strength. At the time of the second set of measurements, the winds atop the WTC were even stronger than on the first occasion and, effectively, limited measurement options to only the south side of the mast, this being on the leeward side of the mast. During the second set of measurements, though, on this one measured side of the mast, the probe appeared to be notably more stable than in the previous measurements except at the height corresponding approximately to the height of the master FM antenna.

During the field measurement process, the auxiliary antennas located beneath the bottom of the channel 41 aperture were locked out so that they could not be used. This was done to keep roof level RF fields near the base of the mast less than the MPE limit for occupational/controlled exposures. During the first set of measurements on April 6, all stations operated in their normal mode except for channel 47, which ceased operation for the entirety of the night of measurements, which began just after 1:00 a.m. Because of channel 47's normal high power operation, 4,570 kW peak visual effective radiated power (ERP), is likely to cause excessively intense RF fields in the region immediately below it where workers will need access. Hence, during actual work on the DTV antenna project, channel 47 would operate at substantially reduced power from a temporary antenna mounted on a mast some 48.5 feet from the center of the mast at a height of about 37 feet above the roof.[3]

During the second set of measurements, field measurements were performed with all four FM stations that normally operate from the FM master antenna turned off as well as several other scenarios. Channel 47, again, ceased operation for the duration of the mast measurements.

The field measurement process involved measurement of the electric field strength as a function of height parallel to the WTC antenna mast. Typically, the measurements consisted of monitoring and recording the electric field strength in two runs, one while raising the probe and another while lowering the probe. A difference between the two measurement sessions is that during the first one, the probe was raised approximately 3-4 feet at a time and allowed to dwell at that height for approximately 10-12 seconds, during which time the field probe sampled the field at a rate of two readings per second. This approach allowed for a better indication of the average field value at each height due to the wind-induced motion of the probe relative to the mast. During the second set of measurements, an alternative rigging arrangement was used wherein the rope at the bottom of the mast was separated several feet with a third pulley and this helped prevent rotation of the ropes due to the wind. This also permitted the use of a slow and continual raising of the probe in both the upward and downward directions, providing a more continuous and smooth measurement data set. Electric field strength was measured at the rate of two readings per second at all times. Field readings were correlated with various heights on the mast by one observer watching the probe from near the edge of the roof as it was moved up or down by the mast and communicating to a person operating the computer data acquisition when the probe was adjacent to or passing by specific key points on the mast. The computer operator noted these moments by recording the time from the computer's real time clock. These recorded times then allowed for analysis of the saved data within specific regions along the mast by referencing to the correlated times. Figure 4 shows the probe as it passed by one of the FM master antenna elements.

Electric field strength readings were in terms of the resultant field obtained from an isotropic field probe with three separate, orthogonal sensors. In the first set of measurements, the resultant electric field strength was directly plotted vs. time as the

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[3] Tell, R. A. (2000). Analysis of Radiofrequency Fields from the Proposed Use of a Standby Antenna by WNJU TV (Channel 47) at the World Trade Center. Prepared for WNJU TV New York Telemundo Station Group by Richard Tell Associates, Inc., February 17.

indicator of fields parallel to the mast. In the second set of measurements, the resultant electric field strength readings were used to compute the plane wave equivalent power densities and these values were plotted vs. time for comparison with the MPE limits. Plane wave equivalent power density (S) was calculated from the following relationship:

$$S = \frac{E^2}{3770}(mW/cm^2)$$

where, E is the electric field strength in volts per meter and the factor 3,770 accounts for the impedance of free space and converts to units of milliwatts per square centimeter.

Instrumentation

The availability of a new broadband, isotropic electric field probe manufactured by Holaday Industries, Inc.[4] presented the possibility of measuring the RF field parallel to the antenna mast and observing, in real time, the value of the RF field at a convenient location on the roof. This capability is provided through a fiber optic cable that connects with the probe and a computer equipped with a fiber optic to RS-232 modem and running Holaday Industries' ProbeView™ software. The probe, shown in Figure 5, consists of three mutually orthogonal sensors mounted to the exterior of an approximate one-inch cube housing and transmits field strength data via a fiber optic cable pair to either a digital meter or directly into a computer. An internal miniature battery gives the probe a continuous operating time of 10 hours before needing to be recharged. For these measurements, the direct computer data acquisition method was used as it allows higher reading rates. Specifications for the HI-6005 probe are given in Appendix B. Different units were used on the two measurement dates and calibration data for the specific probes used are given in Figure 6. Of significance is the observation that the error associated with field readings, determined at the factory, was no more than 2%. Figure 7 illustrates the representative linearity data for the probe used during the first set of measurements and shows that over the electric field strength range of 0.5 V/m to 900 V/m, it deviates no more than 1%. These are relatively remarkable specifications for these types of measurements and help minimize the uncertainty in the final results due to instrumentation characteristics.

The probe was placed inside a small canvas bag, which was, in turn, attached to the rope for elevation along the mast on the first measurement date. For the second set of measurements, the probe was placed inside a protective Styrofoam shell as shown in Figure 8. The two hemispherical Styrofoam shells were fastened together with Velcro strips and the entire assembly was then taped to one of the ropes rigged to the mast. Data was read out through the ProbeView™ software as viewed on the screen of a laptop computer used on-site during the measurement process. Figure 9 provides a view of the appearance of the laptop screen and shows that each individual polarization component magnitude as well as the resultant field magnitude is displayed in real time. A time series

[4] Holaday Industries, Inc., 14825 Martin Drive, Eden Prairie, MN 55344 (telephone: 612-934-4920 X115) <www.holadayinc.com>. Model HI-6005 electric field probe.

chart is also displayed to permit visualization of the acquired data as the probe was moved up or down the mast. Upon each run of the probe, a data file was saved to the hard drive of the computer representing the measured values for each polarization component and the resultant magnitude. These files were then analyzed with a spread sheet program following the data collection and the data were used to prepare graphical plots of the measured field strengths expressed in volts per meter (V/m) or derived plane wave equivalent power densities expressed in milliwatts per square centimeter (mW/cm^2).

An important issue relative to this evaluation is that while the applicable exposure limits are frequency dependent, the measurement probe used has a flat response over the entire range of importance at the WTC. This difference can be addressed as follows. First, all fields measured were referenced to the MPE limit applicable in the VHF portion of the spectrum where the limit is most stringent, i.e., where the MPE limit is equivalent to a power density of 1 mW/cm^2, even though there may be RF energy present above the 30-300 MHz frequency range and at which the MPE limit is less stringent. This approach would be conservative in that any field contributions above 300 MHz would be evaluated as though they were actually in the 30-300 MHz band. Secondly, it would not be anticipated that the RF fields in the regions measured would be significantly affected by UHF energy due to the fact that the probe measurement path never placed the probe in front of any UHF TV antennas and the elevation plane directivity of the channel 31 antenna is such as to significantly reduce downward directed energy into the measurement path. Based on these observations, it was deemed that use of the flat responding Holaday Industries field probe would not lead to any significant uncertainty in the field readings relative to a conservative assessment of compliance with the MPE limits. It is relevant to point out that the Model HI-6005 probe does make use of diode sensors and that the measurement system is designed to correct probe sensor outputs for their possible deviation from true square law response, for example, when the fields are intense enough to drive the diode out of its square law performance region of operation. While this method provides highly accurate results for singular frequency RF field measurements, the square law correction method used can, for very strong and approximately equal strength RF fields on different frequencies, result in over-indication of the resultant RF field strength. This phenomenon is the result of multiple frequency RF fields adding together in phase and leading to a given diode output voltage that will be corrected for square law response as though the diode sensor output is due to a single frequency field. This process can result in an overstatement of the actual field. In summary, use of the HI-6005 probe was believed to represent the overall best instrumentation for the task resulting in data with the least overall uncertainty, considering the inherent problems of correlating measured fields with specific heights on the mast. At the same time, any error resulting from use of this probe, if any, would generally lead to conservative determinations of field levels from a safety perspective, indicating somewhat stronger fields relative to MPE limits than might actually exist at a point.

Measurement Results

April 6, 2000 - Processed electric field strength data are presented for the four sides (North through West) of the antenna mast in Figures 10-17. For each side of the mast, data are provided for both the up and down movement of the probe. Figure 10 illustrates measured fields on the north side of the mast for the upward path of the probe. As the probe passes through the aperture region of the FM master antenna, very strong fields were found. Figure 10 plots the data, however, only for the work region extending from the bottom of the channel 41 aperture to the top of the channel 47 aperture. RF fields exceeding the electric field strength limit of 61 V/m (equivalent to a power density of 1 mW/cm^2) are indicated throughout a large portion of the channel 41 aperture. These peak electric field strengths correspond to a maximum plane wave equivalent power density of 2.8 mW/cm^2. The upper half of the channel 41 aperture and throughout the channel 47 aperture, the RF fields are substantially reduced. Similar plots of the electric field strengths are found in the remaining figures 11-17 and demonstrate a similar character with RF fields being greatest near the bottom of the channel 41 aperture. Figure 12 is a plot of measured fields that included the FM master antenna region and clearly shows the extremely elevated fields near the FM antenna. These fields decrease very quickly both below and above the master FM antenna. Nonetheless, RF fields exceeding 1 mW/cm^2 are commonly found near the bottom of the work area. The remaining figures illustrate similar results and can summarized by the observation that RF fields above the FM master antenna, but within the work area, have the potential of exceeding the FCC MPE limits somewhat. An anomaly in Figure 13 is represented by a spike in the plotted values of electric field strength near the bottom of the channel 41 aperture. It is not clear just what may have led to this reported value. One hypothesis is that the elevated fields near the bottom of the channel 41 area may be caused by reradiation by the auxiliary antennas for channels 4 and 5 of fields produced by the master FM antenna. Clearly, the relatively strong fields produced by the master FM antenna have the potential for illuminating the adjacently mounted auxiliary antennas and, hence, the presence of reradiated and scattered fields in that vicinity.

The various measurements obtained for the work area on April 6, are summarized in the chart below.

Summary of RF field measurement data obtained April 6, 2000 in WTC antenna mast work area.		
Side of mast	Power density up (mW/cm^2)	Power density down (mW/cm^2)
North	3.0	2.8
East	77	1.1
South	0.42	1.3
West	0.56	1.3

The single very high value of 77 mW/cm^2 recorded on the east side of the mast while the probe was moving upwards is considered most likely to be an artifact associated with the field probe.

May 1, 2000 - After evaluating the measurement data obtained during the earlier session on April 6, it was decided that a supplemental set of measurements should be obtained to help confirm tentative conclusions. Measurement data from the May 1, 2000, session are presented in Figures 18-31. During this session, several different scenarios were used to better understand the RF fields within the working area and what was responsible for those fields. Based on the earlier set of data, the elevated fields within the lower half of the channel 41 aperture were hypothesized to be the result of direct upward radiation from the FM master antenna as well as reradiation and scattering of the FM fields from the auxiliary antennas for channels 4 and 5. The first scenario presented is that with all stations operating normally, including all FM stations. The second scenario presented is when all FM stations ceased operation from the master antenna. Other scenarios included removing one and, then, two FM stations from operating from the master antenna to observe for any measurable differences.

Examination of Figures 18-31 reveals that operation of the FM stations has a very significant effect on the presence of elevated fields within the lower half of the channel 41 aperture as had been hypothesized. Interestingly, however, operation with fewer FM stations from the master antenna did not appear to substantially reduce the maximum field magnitude within the working area but, instead, tended to change the number of points within that region exhibiting peak fields greater than the MPE limit.

For each of the scenarios examined, the following chart summarizes the findings relative to maximum field levels, expressed in terms of power density, within the working area beginning at the bottom of the channel 41 aperture.

Summary of RF field measurement data obtained May 1, 2000 in WTC antenna mast work area.		
Operating conditions	Probe movement	Maximum power density (mW/cm^2)
All FMs on	Up	1.63
	Down	1.81
All FMs off	Up	0.51 (single spike)
	Down	0.92 (single spike)
All FMs on but WKTU operating from uptown	Up	1.78
	Down	1.39
All FMs on but WKTU operating from uptown and WNYC off & channel 31 off	Up	1.65
	Down	1.04

These data convincingly show that when the FM stations ceased operation from the master antenna, the field profile within the working area became very substantially weaker. Typical power densities were less than 0.1 mW/cm^2 throughout most of the working area with the FM stations off. During the measurements, it was noted, as shown in Figure 22, that near the top of the channel 47 aperture, a narrow spike in the power density profile was observed. It is not apparent why this was observed but, in any event, the magnitude of the spike was less than 1 mW/cm^2, the MPE limit in the FM broadcast band. The most likely source of this narrow peak in field would be the channel 31 antenna that operates at 2,820 kW of ERP at 572 MHz where the MPE limit is 1.9 mW/cm^2. Thus, this value, while not clear what the source was, is less than the MPE for either the FM band or the UHF spectrum.

The data in the above chart also support that contention that RF fields within the working area, while observed to exceed the FCC limit for occupational/controlled exposures, do not substantially do so, typically being less than twice the MPE limit and, in addition, are not uniform in value along the mast. This finding is helpful in that it suggests that a wider range of options for controlling exposure of workers may be available. For example, the use of RF protective clothing would be feasible in these fields.

In all of these measurements, the Holaday Industies Model HI-6005 fiber optic isolated electric field probe proved to be invaluable for characterizing the RF field environment of the WTC antenna mast by allowing real-time observation of the local field strengths from the convenience of roof level. This made the entire measurement process highly efficient as local field conditions aloft could be ascertained immediately, thereby eliminating wasted time in downloading data from a meter that had to be transported to roof level each on each run and only then learning that a particular measurement may need to be repeated.

Discussion of Results and Implications for RF Safety

The RF field measurements reported here lead to a number of observations and insights pertinent to RF safety during the upcoming DTV antenna project work. These observations and insights are summarized as follows:

1. The RF field environment determined from the first set of measurements, within the proposed work area, is qualitatively similar for all four sides of the antenna mast without substantial differences between the four sides.

2. The magnitude of RF fields found during both measurement session are generally consistent and the results found during the second session on the south side of the mast should be applicable to the other three sides.

3. RF fields near the FM master antenna are very intense and may reach levels some 75 times the maximum permissible exposure (MPE) limit. Workers should not occupy the area below the bottom of the channel 41 aperture without very special precautions.

4. The field strengths within the FM master antenna aperture are sufficiently intense to preclude the use of time averaging as a method for mitigating exposure. This conclusion is based on the finding of plane wave equivalent power densities as great as 75 mW/cm^2 (at the lateral distance used in these measurements) and finding that, based on six-minute time averaging of whole-body exposures, this would imply a maximum exposure time of only 4.8 seconds during any six minute period. Ensuring that personnel would not be subject to these intense fields for longer than 4.8 seconds would is not practical and is subject to error.

5. RF fields at greater distances from the FM master antenna elements could prove to be more manageable such that compliance with the time-averaging aspects of the MPE limits would be practical. However, this would have to be evaluated with additional, on-site field measurements for the actual points where personnel might be located aloft near the FM master antenna.

6. RF fields within the channel 41/47 apertures, <u>with channel 47 not operating from its main antenna</u>, are very significantly less intense than near the FM master antenna and are readily amenable to mitigation. Maximum expected RF field levels within the channel 41/47 apertures should not exceed approximately 3 mW/cm^2.

7. In every instance, the strongest measured fields within the channel 41 aperture were within the bottom half, closest to the TV auxiliary antennas for channels 4 and 5 and the master FM antenna. These stronger field values are not representative of fields throughout the aperture but represent usually only a few points within the lower half of the aperture.

8. These higher peak fields in the lower half of the channel 41 aperture are due to two possible reasons: (a) direct radiation by the FM master antenna, and (b) reradiation of FM energy and scattering by the TV auxiliary antennas for channels 4 and 5. This conclusion is strongly supported by the observation that during measurements with none of the FM stations operating from the master FM antenna, only very weak fields were found, typically no more than 0.1 mW/cm^2.

9. Reduction of the magnitude of RF fields in the lower half of the channel 41 aperture would at first appear to be controllable by reducing the overall power transmitted from the FM master antenna and that this could be effected by turning off one or some of the FM stations. However, data collected during the second measurement session suggest that, at best, reduction of the number of FM stations operating from the master antenna only reduces the extent of the region within which the peak RF fields exceed the MPE limit, not the peak field magnitudes. This is apparently the result of the different frequencies associated with different stations producing slightly different field patterns by the master antenna. Based on this finding, it has to be concluded that actual power levels of each station operating from the master antenna would need to be reduced to accomplish the desired field strength reduction near the bottom of the work area. A power reduction to approximately 30% of normal operating power would likely result in fields not exceeding the MPE limit at any point

within the working area, however, this alternative approach was not evaluated during these measurements.

10. All of the field measurements reported here were conducted with channel 47 off the air. During the actual DTV antenna project work, channel 47 would operate at substantially lower power from a proposed temporary antenna located away from the main antenna mast. A reevaluation of the calculated results obtained in an earlier study of the RF fields that would be produced by operation of the channel 47 temporary antenna, within the working area parallel to the mast, indicated a maximum field of no more than about 0.017 mW/cm^2 on the mast[5].

11. The maximum field level on the mast from the channel 47 temporary antenna was projected to be about 2.6 mW/cm^2 at a height of 36 feet above the base of the mast and would exceed the MPE limit only within a region of about 2.5 vertical feet along the mast at that point.

12. During the DTV antenna project work, when men are aloft, channel 47 must never operate from its main antenna on the mast and all auxiliary antennas must be locked to prevent their activation.

13. At anytime workers must access the very top of the channel 47 aperture and bottom of the channel 31/2 aperture, channel 31 should cease operation and channel 2 should operate from its auxiliary location at the Empire State Building.

14. High intensity RF fields in front of the FM master antenna could produce significant interaction with steel being raised or lowered through the master antenna aperture during the DTV work and could lead to significant voltages between various metal components and possible arcing. This could also influence matching between the FM transmitters and the antenna, causing high VSWR at times. Consideration should be given to an evaluation of the VSWR on the master antenna while raising steel to assess the magnitude of possible reflected fields back to the master antenna. Caution should be exercised to avoid any transport of flammable liquids through the FM master antenna aperture while FM stations operate normally.

15. Mitigation of worker RF exposures within the lower portion of the channel 41 aperture could be achieved via the use of RF protective clothing, reduction of FM station operating power levels or ceasing operation of the FM stations all together during the mast work. Since WKTU has the option of now operating from an alternative uptown transmitter location, this would leave only two other higher power FM stations and one low power station at the WTC site. If the two higher power stations could operate at about 30% of their normal power level, the working area on

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[5] A Reevaluation of Radiofrequency Fields on the World Trade Center North Tower: A Supplemental Report prepared by Richard Tell Associates, Inc. for Motorola Land Mobile Products Sector, September 5, 1999, Revised March 21, 2000.

the mast should comply at all locations with the MPE limit. This was not, however, confirmed during these measurements.

16. Because of the potential for personnel to be exposed to strong RF fields when working on the WTC antenna mast, unless special precautions are taken, as described within this report, it is suggested that the work region be cleared prior to each work session by having an individual transit the region with a personal monitor set to alarm at 0.5 mW/cm^2 or 50% of the MPE limit to ensure that no areas exhibit fields above the alarm threshold. In the event that the monitor alarms, the person should immediately remove themselves from the region causing the alarm and an investigation made as to the cause so that it may be corrected before the work for the night is begun. Once the region has been cleared, this fact should be documented and retained.

17. At all times, personnel that are aloft at the site should be equipped with personal monitors set to alarm at 0.5 mW/cm^2 or 50% of the MPE limit. At any time that a worker's monitor alarms, they should immediately remove themselves from the area and the cause of the elevated RF field be determined and further investigated to ensure that exposure above the MPE will not occur.

18. All personnel involved in the DTV antenna project should participate in a RF safety awareness briefing prior to their work aloft at the WTC.

19. The latest version of the colorized RF field map for the roof of the WTC north tower should be consulted to identify those areas that should be avoided for long term exposure. This map has been reproduced as Appendix C.

20. An RF safety log book should be maintained throughout the duration of the DTV antenna project and archived for future reference. This log book should contain dated entries for each work session at the WTC and should include for each session: (1) date; (2) names of all personnel working aloft at any time during the work session; (3) time of initial clearing of work area (as described in 16 above) and whether excessive RF fields were determined and what was done to correct the issue ; (4) name of person confirming that channel 47 has either ceased operation or has transferred operation to their temporary antenna and time transfer occurred; (5) name of person confirming that all auxiliary antennas have been locked out and time this was accomplished; (6) name of person confirming that channel 31 and channel 2 have ceased operation from WTC mast, if this is necessary, during the work session due to personnel having to access the top of the channel 47 aperture and time that operation was ceased and reestablished; (7) notation of any high-field incidents noted during the work session, when they occurred, who noted them and what was done to correct the issue(s); (8) time that last man aloft returns to roof at end of work session; name and phone number of person confirming that each broadcast station has returned to normal operating conditions and time this occurs. An example log book sheet is provided in Appendix D that could be used for this purpose.

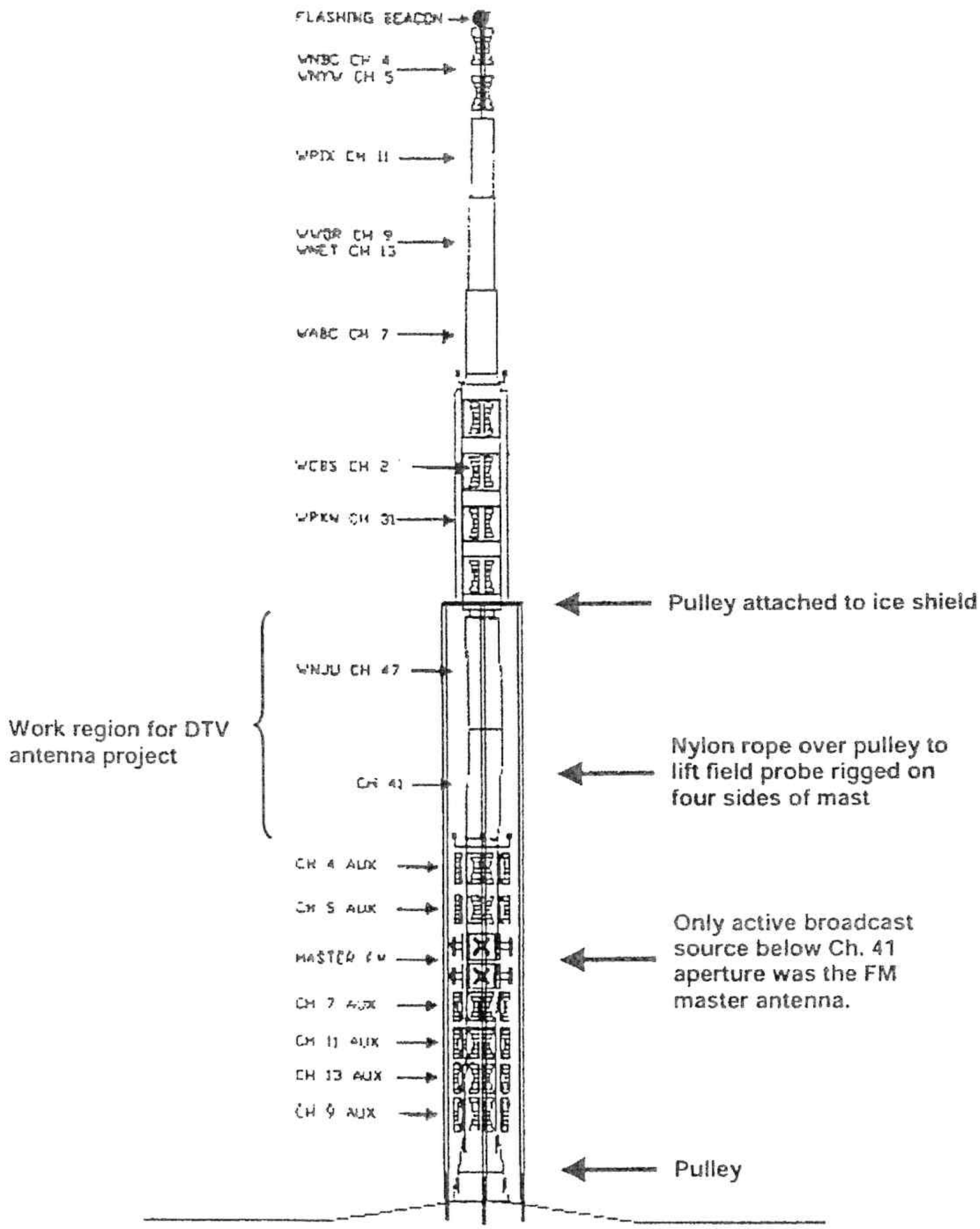

Figure 1. Simplified illustration of rigging arrangement of antenna mast. Adapted from drawing by D. W. Sargent Broadcast Services, Inc.

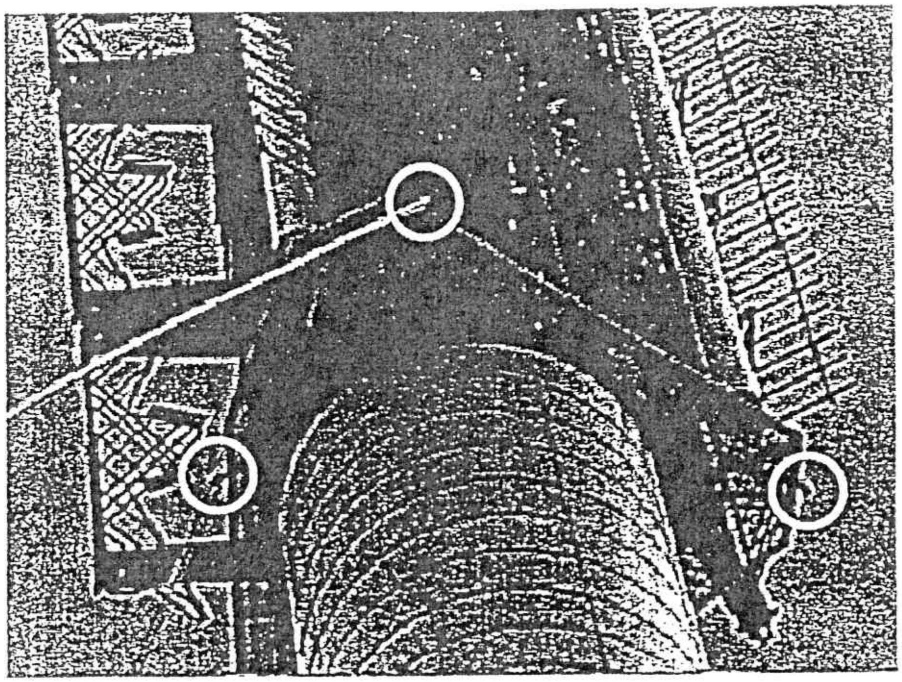

Figure 2. Close up photo showing attachment of nylon ropes at ice shield at top of the channel 47 antenna aperture. Pulleys allow the ropes to be pulled to elevate the electric field probe. A fourth pulley, on the opposite side of the mast, cannot be seen in this view.

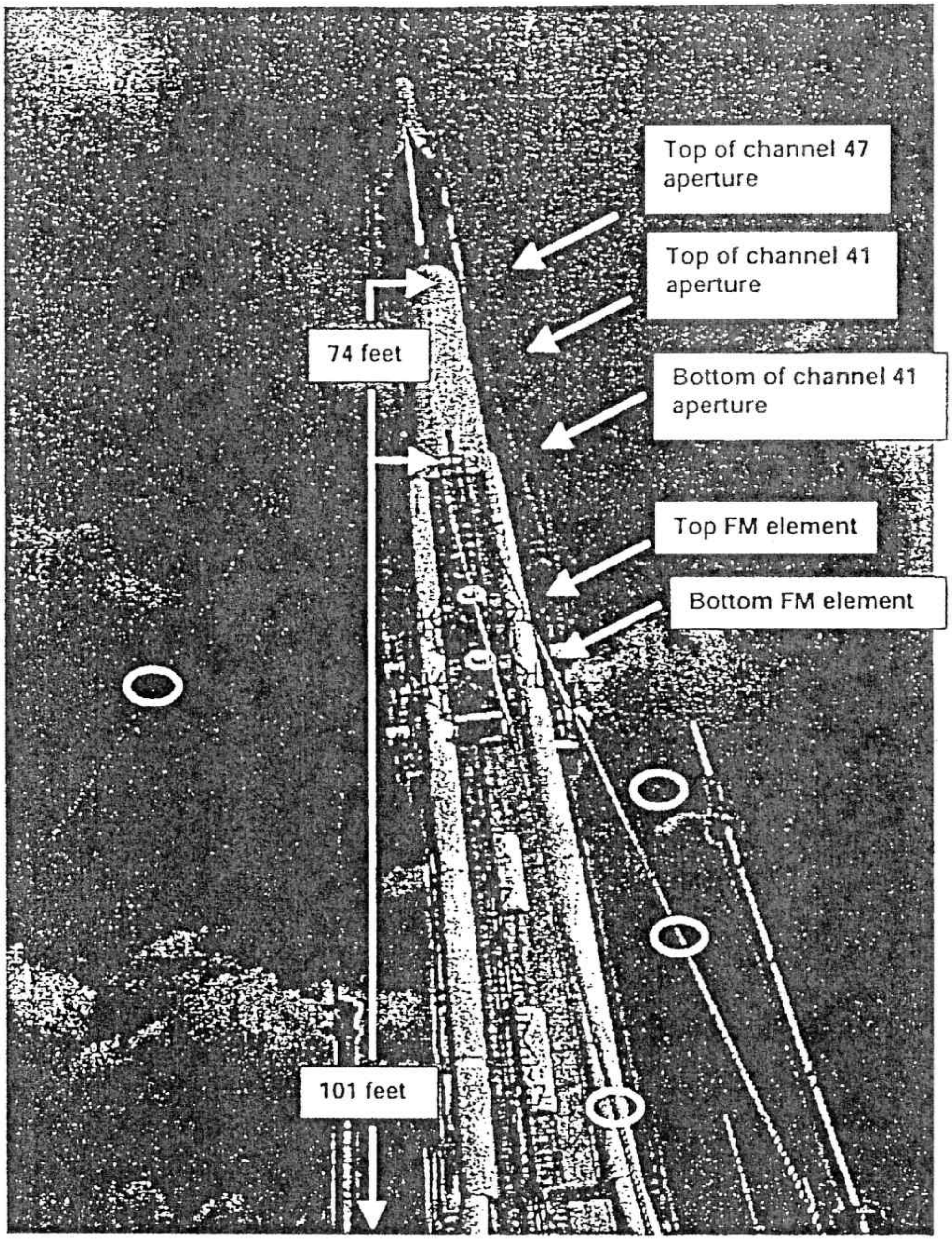

Figure 3. View of the antenna mast on the World Trade Center north tower showing ropes rigged to ice shield at top of the channel 47 antenna aperture. During measurements, the bottom ends of the ropes were brought from their temporary anchor points near the edge of the roof to the base of the mast and rigged over pulleys to facilitate up and down movement of the electric field strength probe. The principal working area that will be used during the antenna work is shown. The lower dimension is relative to the TV mast interface on the roof. Ropes are highlighted with ovals around them.

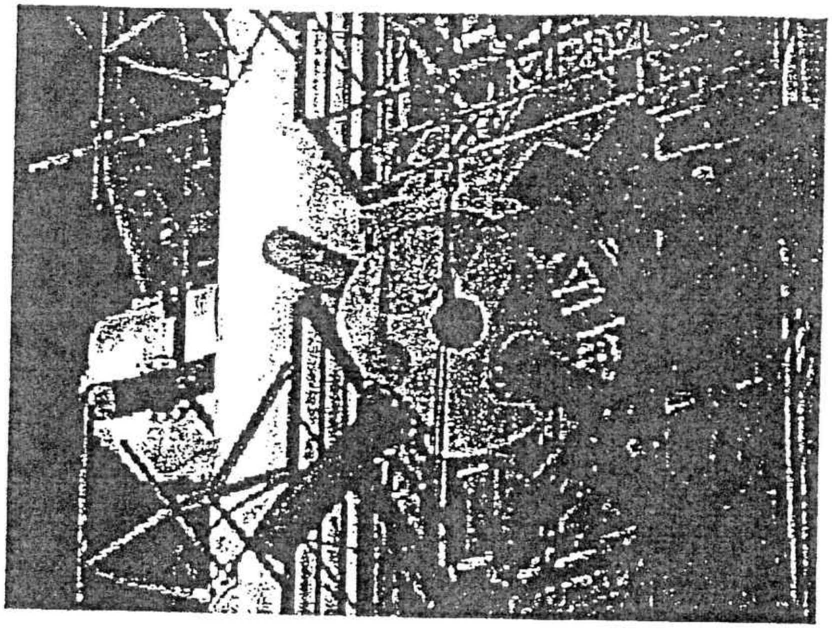

Figure 4. Telephoto shot of the Holaday Industries Model HI-6500 probe being elevated near one of the FM master antenna elements as it was raised to the ice shield above the channel 47 antenna aperture. High winds were problematic during the measurements on both occasions but particularly so during the second set performed on May 1, 2000. Despite keeping the ropes as taught as possible, there was probe movement during the raising process. Hence, especially when the probe passed near the FM master antenna elements and auxiliary antennas above the FM antenna, the probe would move in and out relative to the vertical rope axis leading to an observed effect of stronger and weaker fields just due to the effect of the wind.

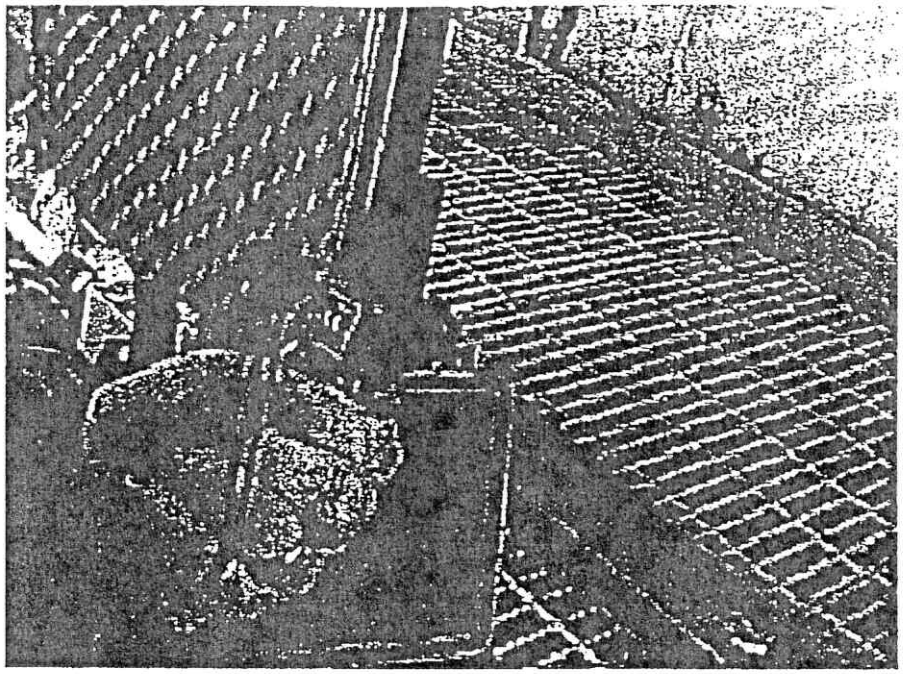

Figure 5. The Holaday Industries Model HI-6005 isotropic field probe. The probe has two fiber optic cables emerging from the small cube containing electronics and self-contained battery. The three elements are arranged to provide for isotropic response to all electric field polarization components. Using a special, 100 meter long fiber optic cable, electric field strengths were able to be observed in real time as the probe was elevated to different locations parallel to the antenna mast permitting immediate indication of the RF field strength.

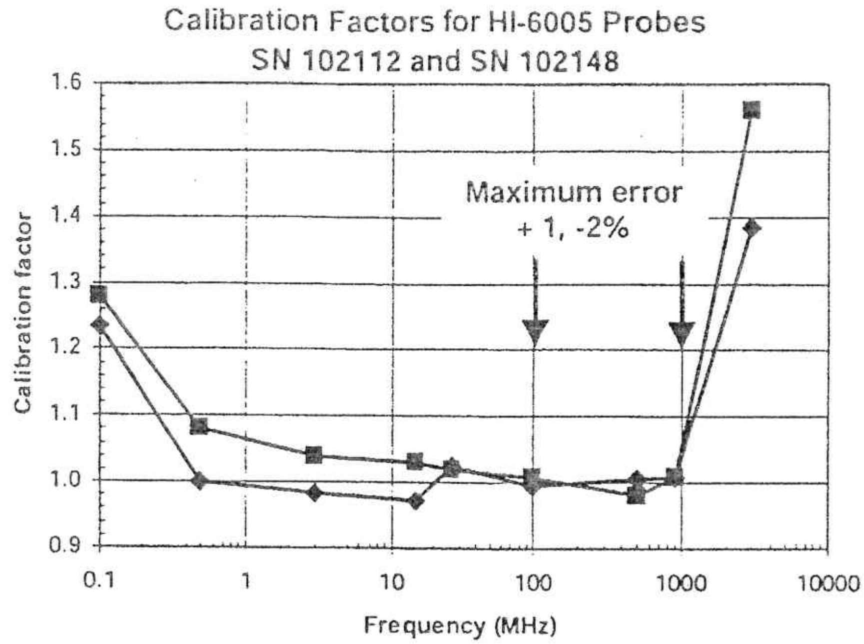

Figure 6. Calibration factors for the Holaday Industries Model HI-6005 isotropic field probe (SN 102112). In the frequency range applicable to the predominate RF fields near the antenna mast, the maximum error was measured to be no greater than ± 1%.

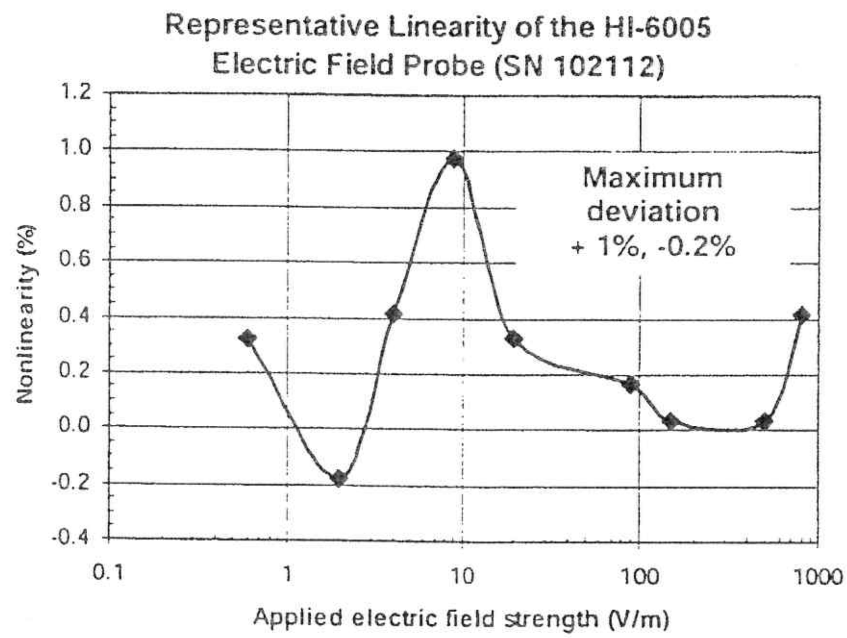

Figure 7. Measured linearity of the Holaday Industries Model HI-6005 isotropic field probe (SN 102112). The maximum deviation from perfect linearity over the electric field strength range of 0.5 V/m to 900 V/m was found to be + 1%, - 0.2%.

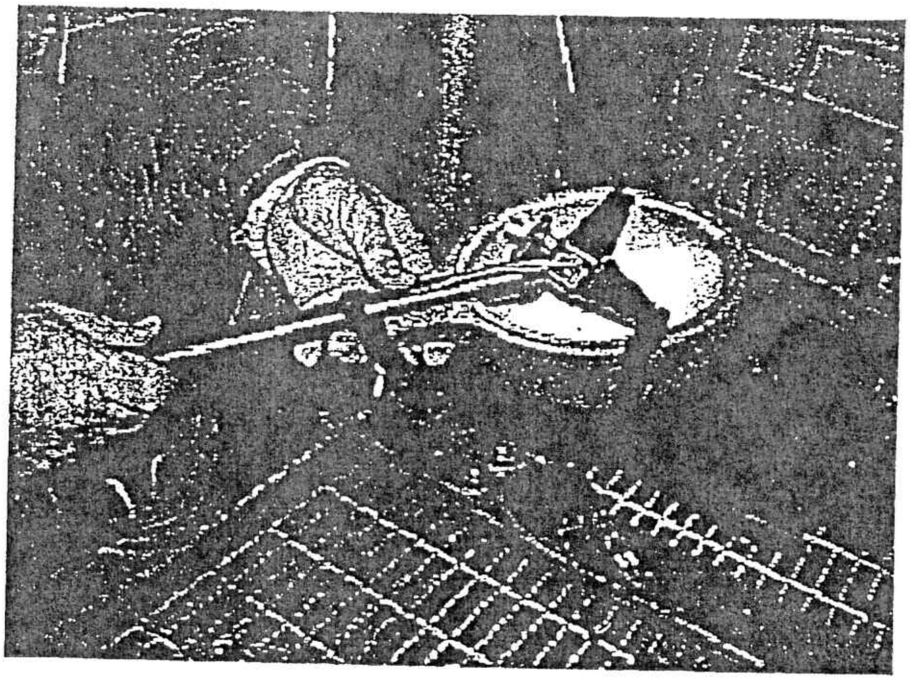

Figure 8. The isotropic field probe was placed inside a Styrofoam protective sphere during its use on the second set of measurements performed May 1, 2000. The two hemispherical Styrofoam shells were fastened with Velcro strips and the entire assembly was then taped to one of the ropes rigged to the mast. By slowing pulling on one rope, the field probe could be elevated to any height between the roof and the ice shield above the channel 47 antenna aperture.

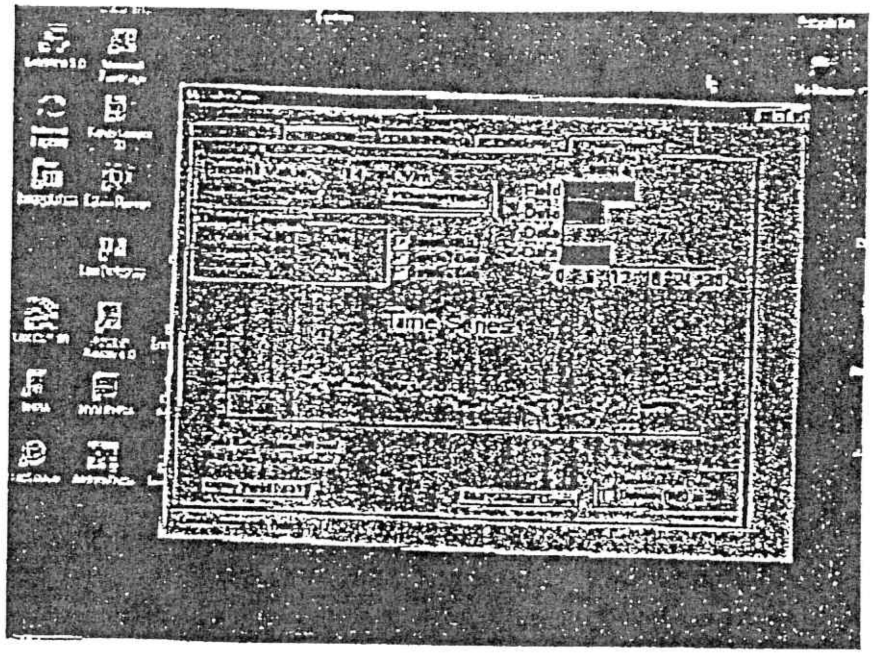

Figure 9. The Holaday Industries Model HI-6005 isotropic field probe was read by using the Holaday Industries ProbeView™ software package. This photo of a laptop computer screen, taken during the actual field measurements, illustrates the ability of the software to simultaneously display the individual x, y and z polarization components of the electric field strength as well as the resultant field magnitude. The data are saved to files allowing them to be analyzed in more detail at a later time.