

MONITORING RF SAFETY AT A MULTI-USER BROADCAST/COMMUNICATIONS SITE

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ABSTRACT

Radiofrequency (RF) safety and compliance with applicable Federal Communications Commission (FCC) regulations is commonly more complex and problematic at multi-user transmitter sites. This paper describes how the issue of RF safety is addressed at a relatively new but major broadcast and telecommunications site located at 4 Times Square in New York City. The multifaceted RF safety program at the building is described. Numerous elements of the program including initial site design and planning, RF safety awareness training and information, on-site RF measurements and analysis, use of personal RF monitors, posting of RF safety signage, and a comprehensive transmitter monitoring system interconnected with special warning lights and a custom RF safety door enunciator system are explained. These elements together with an annual audit and annual RF safety retraining of personnel form the heart of the 4 Times Square RF safety program and conform to the guidance of the new IEEE C95.7-2006 Recommended Practice on RF Safety Programs.

INTRODUCTION

The Conde Nast Building at 4 Times Square (4TS) was completed in 1999 and is a 48 story building comprising 1.6 million square feet of space located at Broadway and 42nd Street in Manhattan (see Figure 1). The height to the top of the antenna mast is 1118 feet (356 meters) above sea level. In keeping with the environmentally responsible design of the building, the rooftop construction of a main antenna tower with various broadcast antennas and their operation has been accomplished with great care to insure safety and compliance with applicable regulations of the FCC. Prior to the Federal Telecommunications Act of 1996, New York City had in place City-specific limits on RF fields but after 1996 these local limits were preempted by FCC regulations specifying maximum permissible exposures (MPEs) for members of the general public and occupationally exposed workers.



Figure 1. The 4 Times Square building showing the antenna mast with master antennas for FM radio and VHF and UHF TV broadcasting.

The antenna tower is situated in the center of the building roof starting at 733'9" feet in height, and provides master antenna facilities for FM radio broadcasting (994 feet) and VHF (1039 feet) and UHF television broadcasting (lower UHF at 1076 feet and upper UHF at 1105 feet). Figure 2 illustrates the overall physical layout of the master antenna systems at 4TS. The 4TS site has become a major primary/backup facility for broadcasters with their main/backup facilities located elsewhere, such as the Empire State Building and the site continues to expand its operations to include more stations. Currently, the site is used by

ten FM radio stations, one VHF TV station, and four UHF TV stations as summarized in Tables 1 and 2.

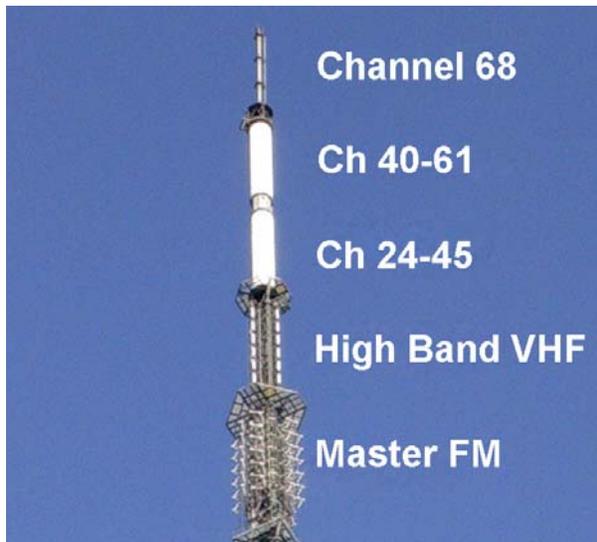


Figure 2. Photo of the antenna mast at 4TS showing the different master antennas for FM radio and VHF and UHF TV broadcasting.

Table 1. Summary of FM radio stations operating from the 4TS facility.

Call	Freq (MHz)	ERP (kW)	TPO (kW)
WKCR	89.9	0.65	0.394
WPAT	93.1	7.50	4.250
WNYC	93.9	10.80	6.223
WSKQ	97.9	12.40	6.806
WHTZ	100.3	13.50	7.338
WKTU	103.5	13.50	7.203
WAXQ	104.3	13.50	6.844
WWPR	105.1	13.50	6.942
WCAA	105.9	1.00	0.715
WLTW	106.7	13.50	6.669

Table 2. Summary of VHF and UHF TV stations operating from the 4TS facility.

Call	Channel	Freq (MHz)	ERP (kW)
WABC	7	174-180	205
WABC-DT	45	656-662	225 (STA)
WXTV	41	632-638	1,400
WFUT-DT	53	704-710	150
WFUT	68	794-800	3,000

The building, when opened in 1999, had a 132' broadcast tower that accommodated the original Shively master FM Antenna, designed for operation of

12 FM stations. The original design also had rights for an additional 68' of structure to accommodate a master DTV antenna, although it was never constructed. 9/11 changed everything. In the summer of 2002, it was decided that the original tower, Shown in Figure 3, would be demolished and replaced with a new tower to accommodate all the TV & FM stations formerly at the World Trade Center. In the spring of 2003, the



Figure 3. Original FM master antenna from Shively Laboratories.

tower was demolished and work started on the present tower, which was completed on October 2, 2003. Before the demolition could begin, however, a temporary construction antenna was needed to give the FM stations (now numbering eight, five from before 9/11 and three after) a place to broadcast from as a primary or backup site as needed. The antenna was a specially designed, single bay, FM antenna known as a Lindenblad design from Shively Laboratories. This antenna, shown in Figures 4 and 5,



Figure 4. The FM backup antenna mounted near the southeast corner of the 4TS building. The Empire State Building is seen in the distance.

is located on the southeast corner of the roof and is attached to the east facing sign mount. FM stations operating at 4TS operated from this antenna until construction of the new Shively Model 6016-3/4-SPL master FM antenna (shown in Figure 2) could be completed.



Figure 5. Closeup photograph of the Lindenblad FM backup antenna at the 4TS facility mounted to the steelwork of the eastern facing 4TS sign.

A challenge associated with development of the 4TS site was providing transmitting facilities for new tenants while, at the same time, insuring that all operations would be safe from an RF perspective and, importantly, comply with FCC rules on human exposure. From the beginning, RF safety was incorporated into the overall building operation plans and this effort required cooperation and support from building management. These efforts resulted in an evolution of RF safety protocols and work practices that, ultimately, formed a comprehensive and multifaceted program that conforms to a recently published IEEE Recommended Practice on RF Safety Programs known as C95.7-2006 (IEEE, 2006). This new recommended practice outlines the application of numerous elements that can comprise an effective RF safety program and this paper summarizes a number of these elements as used in the RF safety program at 4TS.

GENERAL SITE DESIGN CRITERIA AND RF SAFETY OFFICER

It is important to note that the collection of these elements as a whole form the 4TS RF safety program and are administrated by an in-house RF Safety Officer who has the responsibility and authority from building owner/management to insure that all aspects of the program are observed on a continuing basis and that the program is changed when it becomes necessary to accommodate changes in broadcasting and telecommunications operations at the site. Attempts to implement an RF safety program without clear-cut administrative responsibilities and solid backing by management usually fall short of the goal of keeping the public and personnel safe. The RF Safety Officer is the site point of contact for any and all questions regarding RF safety and it is imperative that all personnel who work at the facility are made aware of how to contact this person.

As the 4TS site continued to develop, the RF Safety Officer directly participated in all discussions and planning pertaining to the design of the building and transmitter support facilities. Outside experts were brought in, from time to time, to assist in providing guidance on various aspects of how to best achieve an overall effective safety program related to RF exposure.

RF SAFETY AWARENESS TRAINING AND INFORMATION

A crucial aspect of the 4TS program has been the development and presentation of an RF safety awareness training session that is presented annually. This session explains:

- the technical basis for concerns over RF exposure,
- how federal standards have been promulgated to control exposure to safe levels,
- the concept of Maximum Permissible Exposure (MPEs) and how these relate to potentially hazardous exposure,
- who, where, and when RF personal monitors should be used and what to do if a monitor alarms,
- what RF safety signage looks like and what it means,
- what is known about restricted access areas at the site and areas to avoid,
- how the warning light system works,
- how the door enunciator system provides additional guidance on RF safety
- why the RECON™ monitoring system is in place, what it does, and how it helps personnel stay safe.

RF safety awareness training is given each year to accommodate new workers at the 4TS site as well as a refresher course to those who have previously attended the training. All relevant building personnel and subcontractors who provide services to the building are required to attend. This includes employees from the building security and engineering departments, personnel management, and others designated by the RF Safety Officer.

Beyond the more formal RF safety awareness classes, personnel who have need to access the roof of 4TS are provided a succinct RF safety information sheet to read.¹ This information sheet is a one-page description of the hazard associated with over-exposure to RF fields with descriptions of how signage, personal monitors, and avoidance of restricted access areas on the roof and tower can control personnel exposures. The sheet has a place for the reader to sign acknowledging that they have read and understand the message on the sheet. The sheet affords the worker one way to become aware of the critical RF safety issues relevant to the 4TS site.

ON-SITE RF FIELD MEASUREMENTS AND ANALYSIS

As a part of the 4TS RF safety program, RF field surveys are performed from time to time, based on changes that are made in the transmitting environment. For example, when a new station initiates operation at the site, measurements are conducted to verify that the RF fields on the roof do not exceed the applicable MPEs set by the FCC. Keeping an updated survey of ambient RF field levels is helpful when considering the potential need for changes to RF safety protocols at the site. Figure 6 shows a commonly used broadband RF field probe and meter useful for documenting RF field levels. In some cases, more detailed field measurements may be performed using a portable spectrum analyzer (Figure 7) equipped with an isotropic type of antenna.

In some cases, detailed analysis may be performed in concert with measurements to identify potential restricted areas for certain operational scenarios. When the FM backup antenna is used, a region near the southeast corner of the roof can exhibit RF fields above the lower tier of the FCC MPEs and this region can be mapped to assist workers in understanding which areas must be avoided during backup operation. Figure 8 is a representative illustration of an RF field map resulting from analysis of the FM backup antenna when simultaneously driven with eight FM stations.



Figure 6. RF field measurements are routinely performed with broadband RF field probes and meters, as above, whenever changes in the operational environment occur.

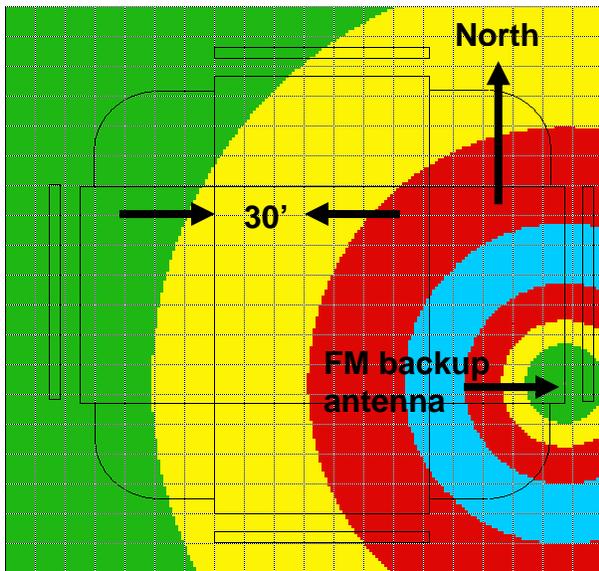


Figure 7. Using the Narda SRM-3000 portable spectrum analyzer and isotropic antenna to document RF field level in a building adjacent to the 4TS site.

USE OF RF PERSONAL MONITORS

The policy at 4TS is to always wear a personal RF monitor when working near active antennas. Generally, this means when work at any point on the tower is required. Personal monitors, similar to that shown in Figure 9, provide a ready means for the individual worker to monitor his/her own exposure and, if need be, take corrective actions to reduce exposure. Personal monitors used at 4TS include the Nardalert™ which possesses a frequency shaped response wherein field intensities on different frequencies are weighted in accordance with the FCC MPE so that the unit can be set to alarm when the aggregate RF field exceeds a user specified threshold

¹ A copy of the RF safety information sheet is provided in Appendix A.



RF fields expressed in relation to the FCC worker MPE



Figure 8. Calculated RF field at main roof level at 4TS for a total of 8 FM radio stations operating simultaneously from the Lindenblad backup antenna. The total effective radiated power in vertical and horizontal polarization planes in this example is 64 kW.



Figure 9. The NardAlert™ personal monitor detects RF emissions and weights the field intensities in accordance with the FCC MPE. The alarm threshold may be set at user selected values as a percentage of the MPE. The device also indicates the greatest field to which it has been exposed and a history of the monitor field readings can be downloaded to a personal computer for further analysis. The unit detects RF fields across the frequency range of 100 kHz to 100 GHz.

expressed as a percentage of the MPE. The RF monitor unit allows for downloading of a historical picture of RF field levels over a long period of time, such as an

entire workday. This feature provides a way to document personnel exposure when workers may have need to access areas with suspected high fields.

POSTING OF RF SAFETY SIGNAGE

The 4TS broadcast site is posted with RF safety signs at appropriate locations to alert personnel to the fact that active antennas exist at the site and caution should be used when working near these antennas. Three different kinds of locations, relative to signage, exist at the site: points of main roof access from inside the building where RF Notice signs are used; the southeast corner of the main roof level in the vicinity of the FM backup antenna where RF Caution signs are posted; at the base of the antenna tower where Tower Caution signs are installed to remind tower workers of the fact that intense RF fields exist near the master antennas if the 4TS stations are active. These signs are illustrated in Figures 10, 11, and 14.



Figure 10. Signs posted at the 4TS broadcast site.



Figure 11. RF Tower Caution sign installed on tower access hatch.

TRANSMITTER MONITORING SYSTEM

An important component of the overall 4TS RF safety program is a system designed to monitor the status of each of the transmitters operating into the various antennas. This system, the RECON™ system, is based on signals obtained from power sensors connected to each of the transmission lines leading to/from the various FM diplexers and the inputs to the VHF and UHF combiners.² The system monitoring screen, illustrated in Figure 12, has the capacity to indicate the forward and reflected power levels of each transmitter. Based on user selected power thresholds, the monitor system continuously measures and compares transmitter power levels against the various thresholds and permits the switching of other devices, such as the RF safety lighting system described below.



Figure 12. CRT display of the Harris RECON™ system used for continuous monitoring of the status of each transmitter at the 4TS facility. Trip points may be set to cause activation of alarms based on transmitter power levels.

A unique and highly useful aspect of the RECON™ system is the ability to log into the system remotely from any computer connected to the Internet and observe transmitter status. This is particularly helpful during times when transmitters may be active at the 4TS site and coordination is necessary to effect certain kinds of tower work. By observing the operational status and power level of various transmitters, the system provides an assurance of the likelihood of high RF field levels at the site and, thereby, assists in determining the level of control necessary to insure compliance with the MPE rules. Being able to remotely interrogate the system means that transmitter operation may be verified from another location such as the Empire State Building where many stations have their main operations.

RF SAFETY LIGHTING SYSTEM

Monitor system outputs are used at 4TS to control the status of a series of RF safety alerting lights that are installed at each of the three main roof access doors, at two points in the southeastern corner of the main roof near the location of the FM backup antenna, and at the hatch and door access points to the base of the antenna tower. These lights include a green, amber, and red lamp assembly at the main roof doors and at the southeast corner of the main roof and a green, amber, red, white, and blue lamp assembly located at the tower base. The chart below summarizes many, but not all, of the meanings of the various lamp conditions based on its present configuration.

Location	Color	Meaning relative to RF fields
Main roof access doors	Green	Main roof less than public MPE
	Amber	FM backup antenna energized, use caution in that area
	Red	An emergency condition exists on the roof, use caution and observe all posted signs and verbal announcements.
Southeast corner of roof	Green	FM backup antenna not energized
	Amber	FM backup antenna is operating at low power. Fields on roof and eastside cooling towers and 4TS signs may exceed public MPE.
	Red	FM backup antenna energized at full power, fields may exceed worker MPE on the

² The RECON™ system is a product of Harris Corporation.

		eastside AC cooling towers and the 4TS signs.
Tower base access hatch and door	Green	FM master antenna is operating at very low power but is safe to climb.
	Amber	FM master antenna is operating at medium power, do not enter FM aperture.
	Red	FM master antenna is operating at high power, do not enter aperture.
	White	VHF antenna is on. Use caution when working near the VHF antenna.
	Blue	UHF antenna is on. Use caution when working near the UHF antenna.

RF SAFETY DOOR ENUNCIATOR SYSTEM

Coupled with the RF safety lamps is an RF safety door enunciator system.³ This system provides customized verbal announcements at the main roof access doors, at the southeast corner of the roof near the FM backup antenna, and at the tower base hatch and access door, based on the status of the various RF safety lamps. The TowerSwitch™ devices become operative when a door or hatch is opened or a button on the unit is pressed to obtain RF safety related information. Figure 14 shows one of the units installed at one of the main roof access doors. A total of 16 different RF safety messages are contained in digital memories of the various units. The particular message that is played depends on the specific lamp status of the associated RF safety lighting system. An example message developed for the RF safety enunciator units installed near the FM backup antenna when the red lamp is on, is:

Your attention please! The FM backup antenna is ON and operating at high power. Enter this area of the roof with special caution and always use a personal RF monitor. Also, be aware that RF fields may exceed the occupational exposure limit for safe exposure on the east side A/C cooling towers and on the 4 Times Square sign supports. Do not climb on the east side cooling towers or sign supports. Remain out of this area of the roof if you have not received RF safety awareness training.

³ TowerSwitch™, Deerfield Beach, FL.
<www.towerswitch.com>

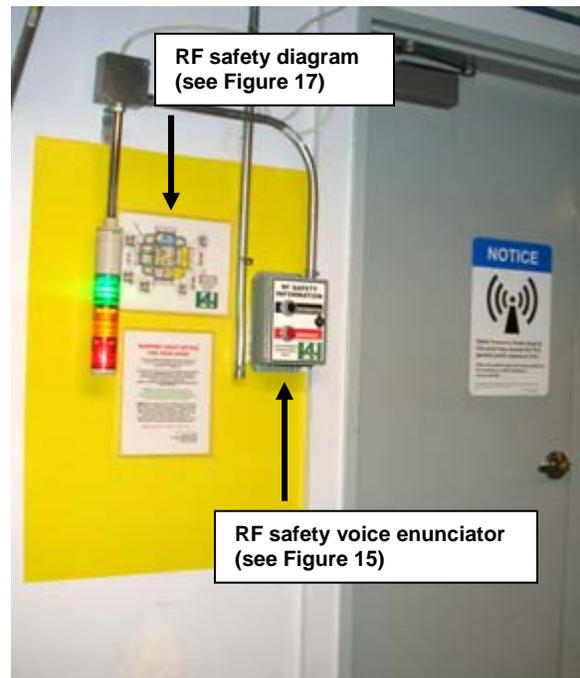


Figure 14. Alerting light system is installed at each roof access and tower access point at the 4TS facility. The lamp status, controlled by the monitor system, controls, in turn, the message that is played by the voice enunciator system located adjacent to the alerting light.



Figure 15. Close-up photograph of the TowerSwitch™ RF safety door enunciator unit that is mounted at main roof access doors, outside on the main roof, and at the hatch and door access points for the antenna tower.

This message plays when the RF safety info button is pressed (see Figure 15). Other messages, customized for each of the different transmitter conditions that can exist at the 4TS facility, are played by the various units. The combination of signal lights with verbal messages enhances the RF safety program by providing reinforcement of the do's and don'ts of working in RF fields at the 4TS broadcast site. In addition to the warning lights and enunciators, access to the tower base through the tower access hatch is controlled by an access card reader and logger. Only those licensees who have attended an RF Safety Seminar and are on record with the building will have their access cards coded for this portal. All others must be escorted by the RF Safety Officer or other designated 'certified' building official.

LOCKOUT/TAGOUT PROCEDURE

As a part of the 4TS RF safety program, lock-out/tag-out procedures are used when FM transmissions are switched from the main master antenna to the FM backup antenna. In this scenario, the main combiner output feed is locked out/tagged out before the manual patch is moved to the backup antenna. This is a manual switchover to protect workers who may be already



Figure 16. A manual patch is used to isolate the main combiner feed from either the main or backup antenna. The lockout/tagout switch preceding the patch assures that there is no RF energy present, before the patch can be pulled and moved.

within the restricted area of the main roof. This procedure insures that all safety concerns are addressed and that all areas are cleared before the backup antenna is energized. Figure 16 shows the manual patch and the lockout/tagout switch. Similar lockout/tagout switches are in use in the VHF and UHF transmission paths, between the combiner outputs and antenna feed systems.

MEDICAL DEVICE CONSIDERATIONS

There are no federal regulations that prescribe field strength limits for avoiding adverse interference with implanted medical devices such as cardiac pacemakers or defibrillators. Nonetheless, the issue of potential interference with medical devices is included in the RF safety awareness training sessions described above. Persons who may rely on such devices are directed to consult with their physician prior to entering work areas on the roof. (See also RF Safety Information Sheet in Appendix A).

ANNUAL PROGRAM AUDIT AND RETRAINING

An effective RF safety program must include some way of auditing its performance. This is accomplished at 4TS through a continual appraisal of how well the procedures seem to work and maintaining a record of any over-exposure incidents that may occur. This facet of the program can provide important feedback on aspects of the program that may need to be changed or strengthened, or suggest features of the program that may, ultimately, prove unnecessary. Besides a written record of the program's activities during a year, personnel are provided with retraining each year to freshen workers' memory of the established protocol for maintaining RF safety at 4TS and strengthen each person's awareness of and appreciation for RF safety. Each person present at the RF safety awareness training is provided with a certificate and record is made of their participation for retention by the RF Safety Officer.

DEVELOPMENT OF AN RF SAFETY PROTOCOL

A so-called 4TS RF safety protocol lays out the basics of staying safe at the facility and is similar to the RF safety information sheet discussed earlier but with more detail. This protocol includes, for example, guidance such as:

- All personnel should be trained for RF safety awareness or escorted by a person who is trained
- Obey all posted signs
- Obey light beacons for roof access
- Listen to and obey verbal instructions
- Always assume antennas are active
- Use personal RF monitors when working near active antennae
- Follow procedures established by RF Safety Officer
- Remain out of restricted access areas designated by the RF Safety Officer

This protocol is made available to all personnel who need access to the roof and tower areas. In addition to the guidance provided within the protocol, descriptive drawings of the 4TS roof are posted at each of the main roof access doors and the entry points to the antenna tower. These drawings, such as that for the main roof level shown in Figure 17, identify the location of telephones and alerting light beacons. The protocol is changed as warranted by changes in usage of the 4TS facility but in all cases, the intent of the RF safety program at 4TS is to maintain a main roof level that is, except for certain limited conditions, free of exposures that would exceed the FCC's public MPE (also called the Action Level in the most current version of the IEEE standard for human exposure, C95.1-2006 (IEEE, 2006b)).

CONCLUSIONS AND RECOMMENDATIONS

Implementation of a robust and effective RF safety program is best accomplished through design from the very beginning of development of high-power facilities. The RF safety program at the 4TS building continues to evolve as the number of broadcasting and non-broadcasting licensees increases and new technology provides enhanced ways of insuring safety. The various elements discussed here may prove effective for managers and operators at other multi-use facilities elsewhere. While the technical and procedural details of an RF safety program are important, real success at complex sites is crucially dependent on a strong commitment to supporting the RF safety program by facility management and the day-to-day oversight provided by an on-site RF Safety Officer. Engineering personnel charged with the development of RF safety programs at other multi-use broadcast sites are encouraged to work carefully with their building and/or site managers in the overall design and support of their programs.

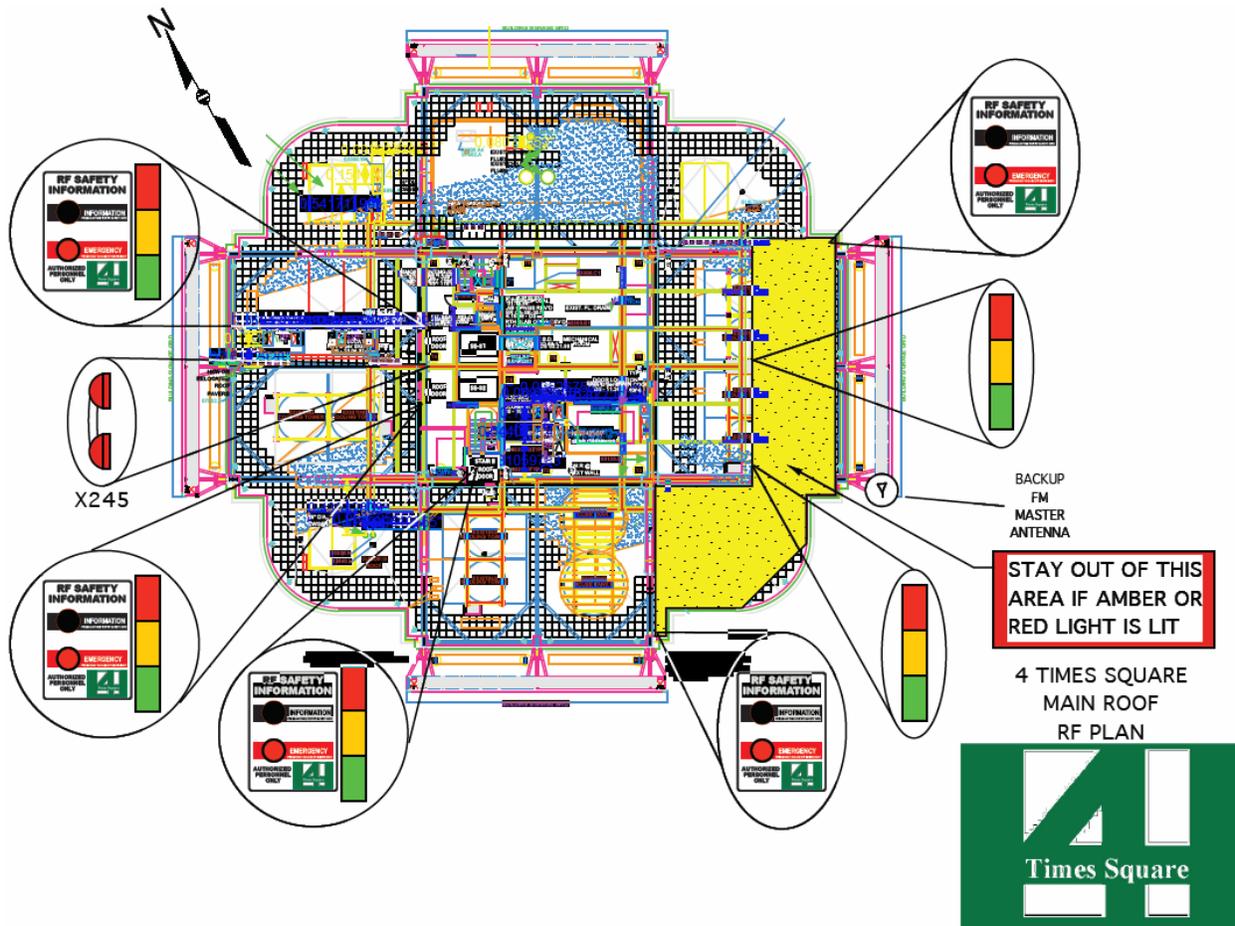


Figure 17. Illustrative drawing of the main roof level showing locations of RF safety signage, RF alerting beacons, and RF safety enunciators and the telephone. A similar drawing for the tower access level is provided at the tower access hatch and door.

REFERENCES

FCC (1997). Federal Communications Commission. "Radiofrequency radiation exposure limits," 47 CFR 1.1310 *et seq.* (Federal Communications Commission, Washington, DC).

IEEE (2006a). *IEEE Recommended Practice on RF Safety Programs, C95.7-2006*. Institute of Electrical and Electronics Engineers. Institute of Electrical and Electronics Engineers, Inc., New York, NY.

IEEE (2006b). *Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, C95.1-2006*. Institute of Electrical and Electronics Engineers, Inc., New York, NY.

APPENDIX A

RF SAFETY INFORMATION SHEET

(This sheet must be provided by the building security department, the main building office, or the RF Safety Officer to all persons accessing the roof of 4 Times Square— either the main roof or the tower and each person reading the sheet must acknowledge their understanding of the information by signing and dating a log book.)

The roof of this building is used as an antenna site by FM radio and television broadcasting stations and wireless communications systems such as two-way radio transmitters, and paging systems. Transmitting antennas create strong radiofrequency (RF) fields near them. Accessing areas near these antennas may result in exposures that could exceed federally established safety guidelines. The main hazard of exposure that exceeds the safety guidelines is undesirable heating of the body. Complying with the exposure guidelines ensures that your exposure will not be hazardous.

This site is posted with RF safety signs to remind you of the presence of strong RF fields. During operation of the FM backup antenna, some areas on the main roof level may exceed the exposure limits set by the Federal Communications Commission (FCC) for uninformed members of the general public. These areas are indicated on a drawing mounted near the main roof access doors and are also identified by the installation of two RF safety enunciators near the

southeast corner of the roof. Some areas on the tower can exceed the exposure limits set for workers that have read this RF Safety Information Sheet. **Do not climb above the marked area on the tower and do not touch any antenna.** If your work requires access inside the restricted area near the FM backup antenna when it is active or requires that you climb the main antenna tower, you must first contact the 4 Times Square RF Safety Officer to get additional information on what to do to avoid over exposure. Generally, this will require that various broadcasters will have to be contacted for further information and possible transmitter shutdown. Staying outside the marked area on the main roof, staying below the marked area on the tower, and avoiding touching any antenna will ensure your safety from RF exposure.

Your exposure to RF fields is directly related to how close you are to the antenna. Moving away from an antenna will result in reducing your exposure. When possible, you should avoid spending prolonged periods very close to antennas unless you have information indicating that the area does not exceed the FCC exposure limits.

Personal RF monitors can be used to determine whether your exposure exceeds the safety guidelines and can be used to determine if a transmitter is turned off. Always wear a personal monitor if you are working near active antennas.

Strong RF fields can affect the operation of certain electronic medical devices. If you make use of such a device, you should consult with your doctor for guidance before working on this rooftop.

The most recent information on hazard areas on the main roof level and on the tower is indicated on a diagram contained in an RF Safety Folder located near the main roof access doors and the tower access hatch and door. You should look at this diagram to better understand the areas on the main roof and the area of the tower that you must avoid. If you have any questions regarding your work on the roof, please call John Lyons at 212-997-5508, 4 Times Square RF Safety Officer.

Acknowledgement

Date _____ Name _____

Signature _____