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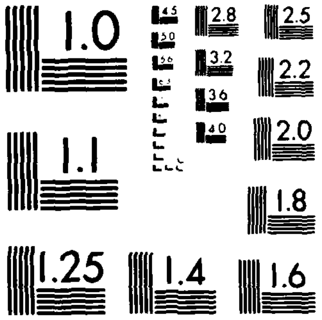

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USAF OEHL REPORT
85-028CV111ARA

FOR HEALTH & ENVIRONMENT

RADIO FREQUENCY RADIATION (RFR) MEASUREMENTS IN OPERATIONAL SETTINGS

USAF Occupational and Environmental Health Laboratory
Aerospace Medical Division (AFSC)
Brooks Air Force Base,Texas 78235

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JOHN J. COUGHLIN, Colonel, USAF, BSC
Commander

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This report ~~was prepared as a~~ paper for presentation at the AGARD ~~Aerospace Medical~~ Lecture Series, Number 138 in Portugal, France and Italy in April of 1985. It is an overview and summary of how the USAF carries out the field measurement aspects of the RFR protection program and offers some broad guidelines as to how other agencies might accomplish the same mission.

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USAF OCCUPATIONAL AND ENVIRONMENTAL

HEALTH LABORATORY

Brooks AFB, Texas 78235

RADIO FREQUENCY RADIATION (RFR) MEASUREMENTS IN OPERATIONAL SETTINGS

Prepared by:

R.B.GRAHAM, Colonel, USAF, BSC
Vice Commander

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I. SUMMARY

This is a detailed discussion of the principles, procedures, and instrumentation required to carry out routine RFR measurements under field or operational conditions. The information herein contained comes largely from several years of experience gathered by the USAF Occupational and Environmental Health Laboratory (USAF OEHL) and its predecessor the USAF Radiological Health Laboratory (USAFRHL). There are few literature references available in this area and much of the information is based on a previously published report (1) and first-hand experiences.

II. PRELIMINARY CONSIDERATIONS

The technology to make routine meaningful, reliable, and repeatable radio frequency radiation (RFR) power density measurements in the field is now readily available. Over the last 12 years there have been significant advances in power density instrumentation technology that now provide us with lightweight portable devices that exhibit acceptable accuracy. The development and evolution of that instrumentation was largely driven by requirements that the U.S. Air Force first defined in the early 1970s.

Prior to 1972, field power density instruments were essentially limited to RAMCO 1200 and Empire Devices NF-157 instruments that employed horn-type antennae which manifested serious deficiencies including a total inability to accurately capture RFR travelling in a circularly polarized mode. The most glaring deficiency, however, was the fact that standard gain horns, or similar antennae, are incapable of accurately dealing with Fresnel or near field wave fronts. Experience over the years has shown that a large percentage of all personnel hazards from RFR emitters lie in the near field. Therefore, instruments that utilize horn-type antennae have serious limitations.

In the spring of 1972, the Narda Microwave Corporation introduced to the market the first "user friendly" isotropic broadband power density devices that were to revolutionize the making of field measurements. Those early instruments were only capable of measuring average power densities up to 20 mW/cm² with a 60 Watt/cm² peak power burnout rating. First attempts to use these early instruments (Model 8300), in the investigation of an alleged overexposure, were disastrous. The emitter in question was an FPN-16 Precision Approach Radar with an average power output of approximately 40 watts in the X-band. The duty factor (DF), however, was very short; e.g., 0.000339. That short DF was capable of causing peak powers considerably in excess of the 60 Watt limit. It was because of this peculiarity that the first two 8300 probes were burned out within a matter of seconds, even though the average power density encountered never exceeded 6 mW/cm². This phenomenon was not adequately explained for several weeks and determination of the cause led directly to Narda developing a series of increasingly hardened probes. Today, state-of-the-art probes exist that are capable of withstanding several Watts/cm² average power density, and several hundreds of Watts/cm² peak power density.

Even the early isotropic probes exhibited essentially flat responses; i.e., ± 0.5 dB, over a frequency range of 300 MHz to 18 GHz and measured E-field equivalent average power density. These devices utilized orthogonal dipoles that rendered them at least theoretically isotropic, which provided an accuracy capability in the near field not previously possible. Many improvements have since been made so that reliable E- and H-field measurements are now possible from 300 KHz to more than 34 GHz.

Over the last 12 years the USAF OEHL and its predecessor organization have evaluated and field tested a wide variety of RFR power density instrumentation designed, developed and manufactured by a number of firms and agencies. Each of these instruments has some outstanding characteristics and some equally poor features. At the present time the USAF OEHL inventory of power density instrumentation is made up primarily of Narda Microwave devices.

Making reliable RFR field measurements is often very difficult. Modern isotropic equipment has overcome many of the earlier problems such as temperature sensitivities, static interferences, and voltage fluctuations. The physical and organizational problems in conducting RFR field surveys shall no doubt always be present.

It is our opinion, based on a number of years of experience, that only about 15% of the RFR emitters will account for about 95% of the measurement problems. There are a number of classes of emitters that may be easily and promptly dismissed from consideration as a potential hazard to personnel. For instance, hand-held transceivers, commonly known as "bricks", which operate from 136 to 174 MHz and in the 510 MHz regions of the spectrum are considered to be nonhazardous to personnel if they emit less than 7 watts, as virtually all do. As another example, many large very high-powered emitters have main beams that are not normally accessible to personnel. Whatever levels such emitters may generate are largely of academic interest only, because personnel simply cannot get to the hazard during the normal course of day-to-day activities. In general, emitters that utilize very thin horizontal or vertical antennae with essentially omni-directional patterns have personnel hazards that are very easily managed by applying the results of many previous measurements that have been used to validate the data depicted in Table 1, and observing the caveats that are noted. Finally, many of the older and very common emitters have been measured over and over again. Such data are summarized for the Air Force at USAF OEHL and are readily available to the field. The U.S. Army and Navy have somewhat similar counterpart organizations where this kind of data for their respective emitters are maintained for reference. By contacting one or more of these sources, <u>at least some</u> information regarding virtually every emitter operated by the U.S. military should be available.

Table I

Personnel Hazard Predictions for Thin Vertical and Horizontal Omni-Directional Antennae (2)

Transmitter	Vertical						Horizontal			
Power In	10 mW/cm^2		1 mW/cm^2		0.1 mW/cm^2		10 mW/cm^2		1 mW/cm^2	
Watts	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
10	0.7	0.20	2.1	0.64	5.2	1.59	0.4	0.13	1.4	0.43
20	0.8	0.25	2.6	0.79	7.1	2.17	0.6	0.18	1.9	0.58
30	1.0	0.30	3.1	9.46	8.9	2.71	0.7	0.22	2.3	0.70
40	1.2	0.36	3.7	1.13	10.6	3.23	0.8	0.25	2.6	0.79
50	1.3	0.40	4.2	1.28	14.7	4.48	0.9	0.28	2.9	0.88
75	1.6	0.50	5.2	1.59	16.4	5.00	1.1	0.35	3.6	1.10
100	1.8	0.56	5.8	1.77	18.6	5.67	1.3	0.40	4.2	1.28
120	2.0	0.62	6.4	1.95	20.1	6.13	1.4	0.44	4.6	1.40
150	2.3	0.70	7.3	2.23	22.8	6.95	1.6	0.49	5.1	1.56
200	2.6	0.80	8.3	2.53	—	—	1.8	0.56	5.8	1.77
250	3.0	0.90	9.3	2.84	—	—	2.0	0.63	6.5	1.98
400	3.9	1.20	12.5	3.81	—	—	2.6	0.80	8.3	2.53
500	4.1	1.26	13.1	4.00	—	—	2.9	0.89	9.2	2.81
750	4.9	1.50	15.6	4.76	—	—	3.6	1.10	11.4	3.48
1000	5.8	1.78	18.5	5.64	—	—	4.1	1.26	13.1	4.00
1500	7.2	2.20	22.8	6.95	—	—	5.0	1.55	16.1	4.91
2000	8.2	2.50	25.9	7.90	—	—	5.8	1.78	18.5	5.64

Notes:

1. Predictions may be applied to omni-directional antennae with gains of 6 dB or less.
2. Table may be applied to frequencies between 3 and 600 MHz.
3. Although these data do not represent a linear relationship, interpolation is possible, but will cause the distances to be even more conservative.

Prior to making measurements, all available information on the RFR emitter should be gathered and studied. It is an essential first that the nominal operating characteristics of the emitter in question be known. This is often much more difficult than you might expect. As a minimum, the following emitter information must be obtained before proceeding with any survey:

1. Operating Frequency
2. Peak Power
3. Pulse Width (PW), if any
4. Pulse Repetition Frequency (PRF), if any
5. Antenna Gain in dB
6. Antenna Dimensions
7. Beam Width (BW)
8. Scan or Rotation Rate, if any

You will often find that some of this information is difficult to obtain. It is unfortunate, but true, that operators of RFR emitting equipment often do not know all and sometimes none of the parameters of their emitter and, they frequently don't know where to find the data. Many times you will spend hours and hours getting ready to do a survey that will require only minutes and much of that time will often be consumed getting the nominal characteristics properly identified. There is, unfortunately, no simple and foolproof solution to *this particular problem*, and it frequently challenges the most ingenious of surveyors. If the emitter operators cannot provide the information, the first place to look should be the applicable Technical Order (T.O.), which in many cases still may not contain everything. Even if the operators do supply you with the data, you must never assume that it is totally accurate. Therefore, an alternate data source for confirmation is most helpful. Those alternate sources might even include the emitter manufacturer.

By whatever means possible, you will eventually obtain the necessary information and the next step is to estimate the hazard distance in order to give you a starting place for making measurements. If this is not done, it is quite easy to expose oneself to unnecessarily high levels of RFR at the outset of your survey. There are three possible and practical ways to estimate the hazard:

1. Previous survey results
2. Computer modeling
3. Far field calculations (Inverse Square Law)

The first is, of course, the best and usually the easiest, if previous surveys have been done on the emitter in question. The second method can yield very accurate results, but there are only a few agencies that have the capability. The parameters needed for a computer model are the same as those already noted. Not all emitters can be acceptably handled, the limitation being what sort of illumination is employed. The third method may be thought of as a "quick and dirty" one that is useful and yields very conservative results. It assumes that plane-wave, far-field conditions exist in close to the antenna though that is hardly ever the case. The only data needed are the peak power, PW, PRF, antenna gain in absolute terms, and the hazard level you are interested in. By multiplying the PW by the PRF the duty factor (DF) is obtained and when the peak power is multiplied by that DF one obtains the average power (Pav). Since antenna gains are specified in dB, which is a logrithmic expression, it is necessary to convert them to a "multiplication factor" by use of the following equation:

G abs = anti/log (G db/10)

Table II is much easier to use however, and once the necessary conversions have been made and the average power obtained, the following equation can then be employed to calculate the distance.

$$D = \sqrt{\frac{(\text{Power})\ (\text{Gain})}{4\ \pi W}}$$

Where: D = distance in meters
W = power density of interest in Watts/cm²

For 10 mW/cm², the equation then is:

$$D\ (10\ \text{mW/cm}^2) = \sqrt{\frac{(\text{Pav})\ (\text{G abs})}{4\pi\ (100)}}$$

D will be in meters
Pav must be in Watts

This equation will provide you with a very conservative estimate of the hazard distance, which you will find useful as a starting point for your measurements. The factor of conservatism will vary from as little as one, to as great as 5.0, depending on how far from the antenna the far field really begins. There are some small aperture antennae operating in the J- and X-bands that have short near fields where this equation will yield very accurate predictions. The important point to remember is that <u>any</u> method other than actual measurements is only an estimate and/or prediction, and all are markedly influenced by a variety of factors, most of which are unknown or poorly understood. Actual measurements are always preferable, but estimates are useful as tentative numbers and for a starting place for any survey.

Table II

Antenna Power Gain—Conversion Between Absolute and Decibel Units

Gain in dB	Absolute Gain	Gain in dB	Absolute Gain	Gain in dB	Absolute Gain
1.0	1.26	20.0	100.00	40.0	10000.00
1.5	1.41	20.5	112.20	40.5	11220.18
2.0	1.58	21.0	125.89	41.0	12589.25
2.5	1.78	21.5	141.25	41.5	14125.38
3.0	2.00	22.0	158.49	42.0	15848.93
3.5	2.24	22.5	177.83	42.5	17782.79
4.0	2.51	23.0	199.53	43.0	19952.62
4.5	2.82	23.5	223.87	43.5	22387.21
5.0	3.16	24.0	251.19	44.0	25118.86
5.5	3.55	24.5	281.84	44.5	28183.83
6.0	3.98	25.0	316.23	45.0	31622.78
6.5	4.47	25.5	354.81	45.5	35481.34
7.0	5.01	26.0	398.11	46.0	39810.72
7.5	5.62	26.5	446.68	46.5	44668.34
8.0	6.31	27.0	501.19	47.0	50118.72
8.5	7.08	27.5	562.34	47.5	56234.13
9.0	7.94	28.0	630.96	48.0	63095.73
9.5	8.91	28.5	707.95	48.5	70794.58
10.0	10.00	29.0	794.33	49.0	79432.82
10.5	11.22	29.5	891.25	49.5	89125.09
11.0	12.59	30.0	1000.00	50.0	100000.00
11.5	14.13	30.5	1122.02	50.5	112201.85
12.0	15.85	31.0	1258.93	51.0	125892.54
12.5	17.78	31.5	1412.54	51.5	141253.75
13.0	19.96	32.0	1584.89	52.0	158489.32
13.5	22.39	32.5	1778.28	52.5	177827.94
14.0	25.12	33.0	1996.26	53.0	199526.23
14.5	28.18	33.5	2238.72	53.5	223872.11
15.0	31.62	34.0	2511.89	54.0	251188.64
15.5	22.39	34.5	2818.38	54.5	281838.29
16.0	39.81	35.0	3162.28	55.0	316227.77
16.5	44.67	35.5	3548.13	55.5	354813.39
17.0	50.12	36.0	3981.07	56.0	398107.17
17.5	56.23	36.5	4466.84	56.5	446683.59
18.0	63.10	37.0	5011.87	57.0	501187.23
18.5	70.79	37.5	5623.41	57.5	562341.33
19.0	79.43	38.0	6309.57	58.0	630957.34
19.5	89.13	38.5	7079.46	58.5	707945.78
		39.0	7943.28	59.0	794328.23
		39.5	8912.51	59.5	891250.38
				60.0	1000000.00

III. INSTRUMENTATION

At this point you have established, by whatever means, a starting place to make your measurements and are now just about ready to take the instruments out of the case. It is assumed for purposes of this report that the measurements will be made using Narda 8600 Equipment and that the power density level of interest is 10 mW/cm². Further, in order to describe the worst of all possible situations, the emitter to be evaluated is of a pulsed, i.e., radar, variety.

Narda 8600 E-field probes are available in two power handling types. The 8621 is white in color and will handle up to 60 mW/cm² average power density and 60 Watts/cm² peak power density. The 8623 probe is yellow and will handle up to 300 mW/cm² average and 300 Watts/cm² peak power. Both probes are normally calibrated at several points over the 300 MHz to 26 GHz frequency range. The larger 8616 meter accomplishes the coverage of the 30 dB dynamic power density range through the use of a 3 position (range) switch. A smaller and much more portable 8601 meter is available, but lacks many of the more sophisticated features of the larger and heavier 8616.

For field measurements, these 8620 series probes may be considered to be isotropic and, if used properly, are quite capable of yielding accurate, reliable, repeatable and very useful power density data. As an aside, Narda also makes several other probe series for measurements to as low as 300 KHz.

All Narda probes are susceptible to burnout when exposed to high power densities. Be aware that these probes can be burned out even though they are not connected to a meter. Probe burnout is generally not a problem when making measurements of continuous wave (CW) emissions, because the burnout threshold is much higher than the maximum meter reading. Under CW conditions, as long as the surveyor does not allow the meter to exceed full scale deflection (20 mW/cm² for white and 100 mW/cm² for yellow probes), the risk of burnout is negligible. However, when measurements of pulsed emissions are undertaken, the risk of burnout becomes much greater and is inversely proportional to the length of the DF; e.g., the shorter the DF the greater the risk. If when the DF is short enough, the average power emanating from an emitter may be quite low while the peak power can be quite high, and the peak power absorbed by the probe may easily exceed the peak overload value. The probe will then fail even though the average power indicated by the meter is something less than a full scale reading. The following equation can be used to avoid a rather costly accident:

$$PD\ max = DF \times BR/CF$$

Where: PD max = Maximum meter reading before probe burnout will occur.

DF = Duty factor of emitter being evaluated.

BR = Probe burnout rating (e.g., 3 x 10^5 mW/cm² for yellow probes, 6 x 10^4 mW/cm² for white probes).

CF = Probe correction factor at the frequency being measured.

If PD max exceeds 100 mW/cm² for yellow probes or 20 mW/cm² for white, there is no cause for any special concern on the part of the surveyor regarding probe failure, as long as the meter is never allowed to go off scale at high end. On the other hand, if PD max turns out to be <u>less</u> than the maximum power density ratings of the probes being used, the surveyor must be very very careful not to allow the meter to exceed the PD max. Even brief excursions will almost certainly burn the probe out. The following examples should help clarify this matter:

Example 1:
PW = 2 μsec
PRF = 360 Hz
DF = 0.00072 (PW x PRF)
CF = 1.2 for a 8623 (yellow) probe

PD max = 0.00072 x 300000/1.2
= 180 mW/cm² which is greater than a full scale meter reading.

Conclusion: Low risk of probe failure if meter needle is kept on scale

Example 2:
PW = 0.25 μsec
PRF = 800 Hz
DF = 0.0002
CF = 0.95 for a 8623 (yellow) probe

PD max = 0.0002 x 300000/0.95
= 63 mW/cm² which is nearly 37% less than a full scale meter reading

Conclusion: Very high risk of probe failure. Be very careful and never allow the meter reading to exceed approximately 60 mW/cm²

IV. FINAL PRESURVEY CONSIDERATIONS

In preparation for field measurements you have now completed nearly all of the preliminaries and are almost ready to begin the measurement phases. There will be instances where you will not have and cannot get the necessary instrumentation to make measurements, usually because of the frequency of the emitter. These cases will almost always involve emitters operating at frequencies <u>below</u> 30 MHz, sometimes much below. Such instances lie outside the scope of this report.

The next-to-last step before making measurements is to check out the equipment. The burnout threshold problem has already been discussed and all that remains is to make certain the meter battery voltage is within tolerance and the probe(s) are within the manufactures calibration interval(s).

The final preliminary step is to consider the safety aspects of what you are about to do. The only <u>successful</u> survey is a <u>safe</u> survey which produces the necessary data and results in the understanding and satisfaction of all those involved. This is usually not as easy to accomplish as it may seem. Consider the following matters before you begin:

1. Completely brief all involved personnel on exactly what you are going to do, how it will be done, and what you specifically wish to accomplish. You must inspire confidence.

2. Establish an absolutely positive and fail-safe communications link between yourself and the operator of the emitter. A most important part of this is the assumption that you, the surveyor, have absolute control over the emitter during the survey.

3. Always begin your measurements at a distance greater than where the hazard is expected to be.

4. Remember that surveyors must not subject themselves to an overexposure.

5. Anticipate unexpected problems and be flexible in your approach.

For those of you who appreciate the value of a checklist and are more comfortable with one, the following has been developed over the years.

RADIO FREQUENCY RADIATION SURVEY CHECKLIST

I. Pre-survey Phase

  A. Contact person(s) in charge; obtain and record:

    1. Exact location of emitter
    2. Description of emitter environment
    3. Names, office symbols, and extensions of persons who are knowledgeable and/or responsible
    4. Emitter operating parameters

  B. Coordinate arrangements for the survey:

    1. Date and time when emitter will be available
    2. Personnel to operate the system
    3. Mobile lifting equipment, climbing gear, etc., as required
    4. Miscellaneous support items

  C. Perform calculations:

    1. Estimated hazard distance
    2. Probe burnout level
    3. Probe correction factor

D. Check equipment:

1. Battery levels
2. Probe and meter function
3. Calibration due date

II. Survey Phase

A. Contact person in charge; inbrief as necessary

B. Arrange for emitter set-up in "worst-case" mode

C. Using correct technique, locate and record (if practical):

1. PEL hazard radius and height above ground
2. All areas in which the PEL could be exceeded
3. Levels at work stations and "normally accessible" areas
4. Any "hot-spots"

D. Observe and note:

1. Adequacy of warning signs and access-limiting devices
2. Adequacy of any standard procedures used to reduce or avoid exposure to radiation
3. Degree of caution exercised by workers
4. Knowledge of workers about handling a suspected overexposure

E. Outbrief as necessary

III. Post-Survey Phase

1. Analyze results; formulate conclusions and recommendations.

2. Prepare letter/report for concerned offices.

3. File data, photographs, drawings, correspondence, etc., in shop folder.

V. RFR EMITTER IDENTIFICATION AND NOMENCLATURE

In the United States, most emitters have standard nomenclatures assigned to them according, more or less, to a logical scheme. The so called "AN" nomenclatures consist of three letters, a dash and one, two or three numbers. The letters have meaning and generally describe what the emitter's primary function is according to Table III.

The three numbers that follow the letter have little or no meaning to measurement personnel in that they are indicators of chronological developmental or generational sequence only.

While most emitters have "AN" designations, some do not and it is quite easy to overlook a potentially hazardous emitter because its designation does not conform to the "AN" scheme.

Table III

"AN" Nomenclature Scheme (3)

First Letter
How Installed

A - Piloted Aircraft
B - Underwater mobile, submarine
C - Air transportable (inactivated, do not use)
D - Pilotless carrier
F - Fixed Ground
G - General ground use
K - Amphibious
M - Ground, mobile
P - Portable
S - Water Surface
T - Ground, transportable
U - General utility
V - Ground, vehicular
W - Water surface and underwater combination
Z - Piloted and pilotless airborne vehicle combination

Second Letter
Type of Equipment

A - Invisible Light, heat radiation
B - Pigeon (do not use)
C - Carrier
D - Radiac
E - Nupac
F - Photographic (not used in U.S.)
G - Telegraph or teletype
I - Interphone and public Address
J - Electromechanical or Inertial wire covered
K - Telemetering
L - Countermeasures
M - meteorological
N - Sound in air
P - Radar
Q - Sonar and underwater sound
R - Radio
S - Special types, magnetic, etc., or combinations of types
T - Telephone (wire)
V - Visual and visible light
W - Armament (peculiar armament, not otherwise, covered
X - Facsimile or television
Y - Data processing

Third Letter
General/Primary Purpose

A - Auxiliary assemblies (not complete operating sets used with or part of two or more sets series)
B - Bombing
C - Communications (receiving and transmitting)
D - Direction finder, reconnaissance, and/or surveillance
E - Ejection and/or release
G - Fire-control, or searchlight directing
H - Recording and/or reproducing (graphic meteorological and sound)
K - Computing
L - Searchlight control (inactivated, use G)
M - Maintenance and/or test assemblies (including tools)
N - Navigational aids (including altimeters, beacons, compasses, racons, depth, sounding approach, and landing)
P - Reproducing (inactivated, use H)
Q - Special, or combination of purposes
R - Receiving, passive detecting
S - Detecting and/or range and bearing, search
T - Transmitting
W - Automatic flight or remote control
X - Identification and recognition

VI. SURVEY OF GROUND-BASED RF EMITTERS

Ground-based RF emitters generally bear "AN" nomenclatures beginning with the letter F, M, G, or T, denoting the following:

1. Fixed

FPN-47	RAPCON (Radar Approach Control)
FPS-90	Height finder
FRT-49	Ground to Air Communications

2. Mobile

MPN-14	Area Surveillance and GCA (Ground Control Approach)
MRC-113	High powered tropospheric scatter communications unit
MPS-9	Area Surveillance and Guidance

3. Ground

GPN-12	State-of-the art RAPCON
GRN-20	TACAN (Tactical Air Control and Navigation)
GRC-75	Flight Facilities

4. Transportable

TPS-43	Tactical Air Control Radar
TRC-97	Medium powered tropospheric communications unit
TPB-1	Threat simulator

Various modifications of a given emitter may have a letter (A, B, C, etc.) following the numbers.

Ground mounted radar systems are sometimes capable of operating in more than one mode. It is, therefore, vital that during the presurvey, careful consideration be given to all of the possible modes to insure that measurements will be made with the system operating in the mode which will create the "worst case" (highest peak power, highest duty factor, and narrowest beam configuration).

A visual inspection of the site should be made to determine if the main radiated beam is normally accessible to personnel. If not, then there is no hazard, but it must be recognized that there may be future modifications of either the emitter itself or the environment that may make the beam accessible.

If the main beam is normally accessible to personnel, antenna rotation (if applicable) must be stopped and access to the main beam gained at a distance from the antenna determined during presurvey. The beam size, shape, and character should be determined, then the actual limit of the appropriate personnel hazard distance located. In order to assure that meter readings are accurate, care must be taken to keep the probe handle parallel to the beam axis, or perpendicular to the emitter surface as appropriate. In addition, try to avoid beam reflections from nearby objects.

Regardless of whether or not the main beam is normally accessible, the area surrounding the antenna itself should be carefully probed for possible hazardous levels of energy, as well as a determination made as to what might be required for personnel to access hazardous levels in the immediate vicinity of the antenna proper.

> WARNING: When surveying aperture type systems, the area between the feedhorn and the reflector is normally very dangerous, both to personnel and to the RF power density probes, and should be very carefully avoided by both.

Operating personnel should be asked to accurately determine the actual power input value at the time measurements were made. Many ground systems have integral directional couplers and power meters available for this purpose.

An inspection should be conducted to determine if the system under evaluation has adequate interlock mechanisms, and to ascertain if they can be or are, in fact, regularly bypassed for routine maintenance or other purposes.

A visual inspection should be made to determine if there are appropriate RF warning signs in sufficient numbers, and at proper locations.

Operating and maintenance personnel should be interviewed relative to their acquaintance with the potential health hazards associated with radio frequency emissions. It is often possible to gain further insight into this area by observing the activities of these personnel as they go about their normal activities. Technical Orders for each emitter being evaluated should be reviewed for the presence and adequacy of warnings to personnel regarding these hazards. It should also be determined if there are, in fact, adequate, up-to-date written operating and accident reporting Standard Operating Procedures (SOPs) that provide acceptable personnel protection.

VII. SURVEY OF AIRBORNE RF EMITTERS

Airborne RF systems usually bear "AN" nomenclatures beginning with the letter A. Some examples include:

1. APQ-100, 109, and 120: All fire control systems on the various Air Force versions of the F-4
2. APN-59: A navigational and weather radar common to many aircraft including the C-141, most models of the C-130 and the KC/KB-135
3. APQ-128: Terrain Following Radar (TFR) aboard all models of the F/FB-111
4. ASG-21: Search/tracker aboard the B-52 G & H.

As with ground systems, it is usual to suffix the nomenclature with a letter to designate various modifications or technical updates.

There are several airborne systems with atypical or "non-AN" nomenclatures, such as:

1. MD-9: Search/tracker aboard the B-52 D
2. R-14C: Navigational/weather radar aboard some models of the C-140 and T-39
3. Multimode: the dual band navigational/weather radar aboard the C-5A

When airborne systems are fired live on the ground, the main beam is almost always normally accessible to personnel, and the possible hazards must be recognized by both operating and survey personnel prior to actual measurements.

Airborne antennae, in general, and RADAR antennae, in particular, are often at or very near eye level above the ground, and it must be recognized that, in the normal course of operation, the main beam is often directed downward.

Airborne RADAR are very often capable of operating in many different modes. It is, therefore, vital that an adequate presurvey analysis be accomplished to insure that measurements will be made with the system operating in the mode which will create the "worst case" (highest average power output and narrowest beam widths).

When surveying airborne systems, it is essential that the aircraft be positioned with an ample clear area in front of the antenna to preclude unnecessary radiation of other aircraft, vehicles, buildings, etc. This distance should be determined during the presurvey. The antenna should be stopped and positioned dead ahead in azimuth, and at zero degrees or slightly above in elevation. This last point is necessary in order to prevent reflections from the ground which can create unwanted, unpredictable, and possibly dangerous "hot-spots."

The antenna should be approached from a known safe distance and the main beam located. Once found, its size, shape, and other characteristics should be determined, then the antenna approached util the appropriate hazard distance is located. Care must be taken to maintain the probe handle parallel to the main beam axis.

The area immediately surrounding the antenna (to the side and behind) should be probed for hazardous side lobes and back scatter. These are not commonly seen. As with ground aperture systems, the area between the feedhorn and the reflector is very dangerous and should be avoided by both the RF probe and personnel.

It is highly desirable to evaluate a minimum of three different transmitters (three different aircraft) of a given emitter. In addition, actual power input values should be obtained from operating personnel if at all possible. Many airborne systems have integral directional couplers for this purpose.

The potential for personnel RF hazards in the repair and maintenance (avionics) shops is very great. Most systems are ordinarily fired only into dummy loads in the shops, but some require actual radiation through an antenna. In the former case, the dummy loads should be evaluated for effectiveness, and in the latter case, the evaluation should be similiar to that of the aircraft mounted system, and should include a careful evaluation for possible reflections and scattering within the shop area. An inspection should be conducted to make certain that the area immediately in front of any radiating antenna is off limits to personnel, vehicles, etc., to a distance appropriate for the emitter.

The shop area should be inspected for the presence of appropriate warning signs (if warranted) in sufficient numbers and at appropriate locations.

Both operating and maintenance personnel should be interviewed relative to their acquaintance with the potential health hazards associated with radio frequency emissions. In addition, it will be useful to observe their activities in both the shop and flight line environments in order to gain some feeling for the prevailing attitudes regarding these hazards.

Technical Orders for each emitter being evaluated should be reviewed for the presence and adequacy of warning to personnel regarding radio frequency hazards. It should also be determined if there are, in fact, adequate, up-to-date written operating and accident reporting procedures that provide acceptable personnel protection.

During flight line measurements, observations should be made to determine if there are adequate and effective procedures to protect personnel during routine ground firing of these systems.

VIII. SURVEY OF MEDICAL RF EMITTERS

The most common medical RF emitter is the diathermy machine. These units can usually be found in the physical therapy section of many hospitals and clinics. Medical diathermy machines in the U.S. are authorized to operate on a number of frequencies, but by far the most common are 13.56 and 27.12 MHz (short wave diathermy) and 2450 MHz (microwave diathermy). Most units within the Air Force Medical Service operate on the two lower frequencies. A definitive study has been accomplished on these units and copies of the report were sent to all USAF hospitals.

The prime concern in evaluating diathermy units is NOT with the patient undergoing treatment, since it is assumed the therapy is being administered by or under the supervision of competent professional personnel. There is a potentially significant hazard to the operators of this equipment, particularly the S-band units (2450 MHz). Evaluation may be necessary to be assured that the therapists operate the equipment in a manner that will not cause them to be unnecessarily exposed, particularly to the head and shoulders. (Note: The proper probe for measuring radiation from shortwave diathermy units is not available at most bases.)

IX. POST SURVEY

The data you have gathered must now be analyzed and some conclusions drawn. Those conclusions should then logically generate certain recommendations or suggested actions. Regardless of the purpose, some sort of written document must always be prepared that will preserve the data for whatever future use might be dictated.

Field measurements of RFR emitters are not difficult today, primarly because of the ready availability of reliable, portable, and acceptably accurate instrumentation. With a little forethought and adequate planning and preparation very useable data can be obtained.

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