Approved per ECO C00433

Littlefeet Inc. **ENGINEERING REQUIREMENTS SPECIFICATION**	**Doc Number:** 740066	
	Revision: A	**Date:** 13 July 01
	Page: 1	**of: 19**
	Original Issue: 13 July 2001	
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Title: R1.5 SPICE RF Radiation Exposure Analysis (FCC)		
Approval:	**Title:**	

Content:

This document analyses and presents the expected R1.5 (Las Vegas) SPICE system RF radiation exposure levels and compares them with the Maximum Permissible Exposure (MPE) limits specified by the FCC.

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Sales: VP, Sales

Document Revision History

Document No.	740066
Subject	R1.5 (Las Vegas) SPICE RF Radiation Exposure Analysis
Department	Systems Engineering

Rev	Description of Changes	Change Date	Authored By
0.1	Draft for general review	13 July 2001	G. White
A	Initial Release	25 July 2001	G. White

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1 Introduction

1.1 Scope

This document presents predicted data for the electromagnetic radiation exposure levels in close proximity to the SPICE system RF emitting devices. The predicted RF radiation exposure levels will be compared with the Maximum Permissible Exposure (MPE) limits specified by the FCC. This analysis will be restricted to the SPICE PCS product line.

1.2 Overview

Concerns have been raised worldwide about the possibility of adverse health effects arising from exposure to RF radiation. RF radiation, as well as near ultraviolet radiation, visible light, infrared radiation and power frequency fields, are types of non-ionizing radiation. These, together with ionizing electromagnetic radiation (X-rays, gamma rays and higher frequency ultraviolet rays), make up the electromagnetic spectrum.

Ionizing radiation is of most concern, since it has the potential to destroy or alter human tissue and damage DNA. Non-ionizing radiation does not interact with human tissue in the same way as ionizing radiation. Non-ionizing radiation causes resonance interactions and research has shown that these interactions cause the molecules in biological material to vibrate and thereby generate heat. Efforts to determine whether RF radiation affects biological cells, other than through heat, are inconclusive.

It is obviously preferable to minimize the duration and magnitude of any RF radiation exposure for members of the general population, especially as there is still significant research being conducted throughout the world on other possible health risks associated with RF radiation exposure. The SPICE system is a low power infrastructure solution for the wireless industry. The Base SPICE (bSPICE) and Coverage SPICE (cSPICE) are both low output power devices. The analysis performed in this document will examine the expected RF radiation exposure levels, as a function of distance, for both the bSPICE and cSPICE devices. These exposure levels will be compared to the RF radiation exposure limits, specified by the FCC, for both Occupational (Controlled) and General Population (Uncontrolled) exposure.

PCS frequencies (1.9 to 2 GHz) produce non-ionizing RF radiation. The FCC has adopted limits for Maximum Permissible Exposure (MPE) that are generally based on exposure levels recommended by the National Council on Radiation Protection and Measurements (NCRP) and the American National Standards Institute (ANSI). The FCC MPE limits are shown in Table 1-1. These exposure levels, based upon research to date, will not produce any adverse health effects.

Table 1-1 FCC Maximum Permissible Exposure (MPE) Limits

	Power Density (mW/cm^2)	Power Density (W/m^2)
Occupational (Controlled)	5.0	50
General Population (Uncontrolled)	1.0	10

Occupational (controlled) limits apply in those situations where persons are exposed as a consequence of their employment, provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. The limits for occupational (controlled) exposure also apply in situations when an individual is transient through a location where occupational (controlled) limits apply provided he or she is made aware of the potential for exposure. General population (uncontrolled) limits apply in those situations where members of the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

The SPICE system is categorically excluded from routine evaluation or preparation of an Environmental Assessment (EA) for RF emissions per the "Summary of RF Exposure Guidelines" in Appendix A of "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", FCC OET Bulletin 65.

1.3 References

http://www.fcc.gov

"Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", FCC OET Bulletin 65

1.4 Abbreviations and Acronyms

ANSI	American National Standards Institute
BTS	Base Transceiver Station
bSPICE	Base SPICE
cSPICE	Coverage SPICE
DL	Downlink
DNA	Deoxy Ribonucleic Acid
EA	Environmental Assessment
EiRP	Effective Isotropic Radiated Power
FCC	Federal Communications Commission
GSM	Global System for Mobile Communications
MPE	Maximum Permissible Exposure
NCRP	National Council on Radiation Protection and Measurements
PCS	Personal Communication System
RF	Radio Frequency
SPICE	Small Profile Intelligent Coverage Element
UL	Uplink

2 SPICE Network Architecture

The SPICE network is based upon a distributed coverage architecture, where the SPICE network provides the RF distribution functionality, but relies upon the underlying GSM system to provide the core functionality of a GSM system. This approach dictates that the SPICE network must be essentially transparent to the underlying GSM system. The basic SPICE deployment consists of a single BTS hosting a bSPICE that in turn serves a cluster of cSPICE units. This is shown in Figure 2-1.

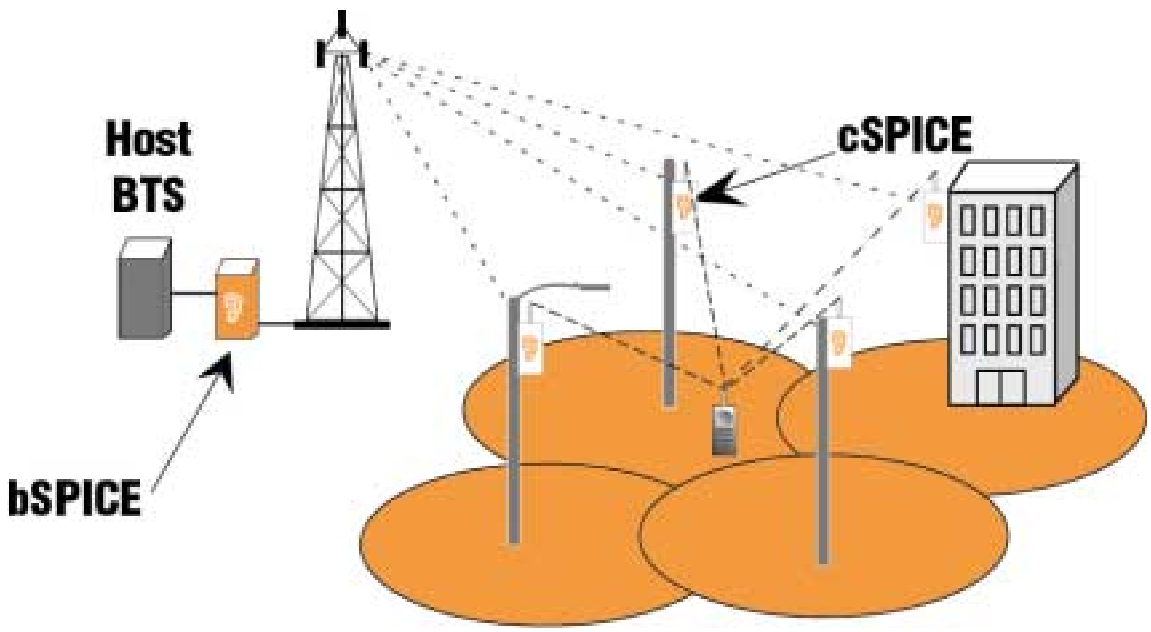


Figure 2-1 SPICE Network Architecture

The bSPICE unit is typically cabled to a standard GSM BTS on one side and to a standard sector antenna on the other. The GSM BTS does not normally radiate directly to air. The bSPICE supports up to two GSM RF carriers and its downlink output power is +23dBm per carrier. The bSPICE performs a bi-directional frequency translation between its inputs and outputs and is the interface between the GSM BTS and the cSPICE units.

The cSPICE units are located in the target service area. The cSPICE supports up to two GSM RF carriers. The maximum cSPICE downlink output power is +29dBm per carrier for the 2:2 antenna configuration (where each downlink channel uses a separate antenna), while the maximum downlink output power is +26dBm per carrier for the 2:1 antenna configuration (where the downlink channels are combined onto a single antenna). The maximum cSPICE uplink output power is +26dBm per carrier (the uplink channels are always combined onto a single antenna). The cSPICE is typically supplied with integrated coverage (cSPICE to MS) and link (cSPICE to bSPICE) antennas. The cSPICE performs a bi-directional frequency translation between its inputs and outputs and is the interface between the bSPICE and MS.

The bSPICE and cSPICE both include wireless modems for establishing communication links over which management functions are performed. The cSPICE wireless modem is cabled to an integrated low gain antenna, while the bSPICE wireless modem is cabled to a separate low gain antenna. The maximum output power for the modems is +30dBm.

3 Prediction Method

The following formula provides a conservative prediction of the far field power density of an electromagnetic energy source:

$S = EiRP / (4\pi d^2)$,

where S is power density, EiRP is the equivalent (or effective) isotropic radiated power and d is the distance to the center of radiation. Power density is the effective power per unit area and decreases according to the "inverse square" law with distance. To be even more conservative a 100% ground reflection can be added. This results in a doubling of the predicted field strength and a fourfold increase in power density. The revised formula is as follows:

$S = EiRP / (\pi d^2)$

This formula is generally applicable in the far field of the antenna, but it can be used to estimate a worst-case upper limit for far field equivalent power density in the near field of the antenna. This formula will be used in the following analysis.

The analysis approach used for the bSPICE will be similar to the approach that is adopted for conventional cellular radio base station infrastructure. That is, the total power density at any point in space is simply the composition of the individual power densities from each radiating source (bSPICE antenna and wireless modem antenna). If the radiating sources are very close together, then it can be assumed that they represent a single source, where the EiRP for that single source is just the composition of the EiRP's from the individual sources. In this analysis it will be assumed that the wireless modem antenna is co-located with the bSPICE antenna (this is worst-case from a radiation perspective, but it is not a normal configuration, as the wireless modem antenna will normally be located next to the bSPICE, while the bSPICE antenna will be located on top of a tower).

The bSPICE will normally use a standard directional antenna. To simplify the prediction process, while at the same time maintaining a very conservative approach, it is assumed the antenna gain is constant, at its maximum value, irrespective of the angle or distance between the test point and antenna. The bSPICE supports up to two bi-directional GSM RF channels. The downlink path of the first channel is always active at full power. The downlink path of the second channel is only active intermittently, as dictated by traffic needs. To once again maintain a conservative approach, it is assumed that both channels are active at all times. Note that the bSPICE uplink paths of both channels do not radiate to air. The wireless modem, which rarely carries an active call, only occupies one of eight possible timeslots when a call is active. To continue with the conservative approach, it is assumed that the modem occupies all eight timeslots when a call is active.

The analysis approach for the cSPICE is similar to the bSPICE. The cSPICE enclosure and its associated antennas are shown in Figure 3-1. The link antenna has the highest gain and is directional. The coverage antennas are lower in gain and are omni-directional. The modem antenna has the lowest gain and is also omni-directional. In the cSPICE analysis it is assumed that these antennas are close enough together that they can be represented by a single source, where the EiRP for that single source is just the composition of the EiRP's from the individual sources.

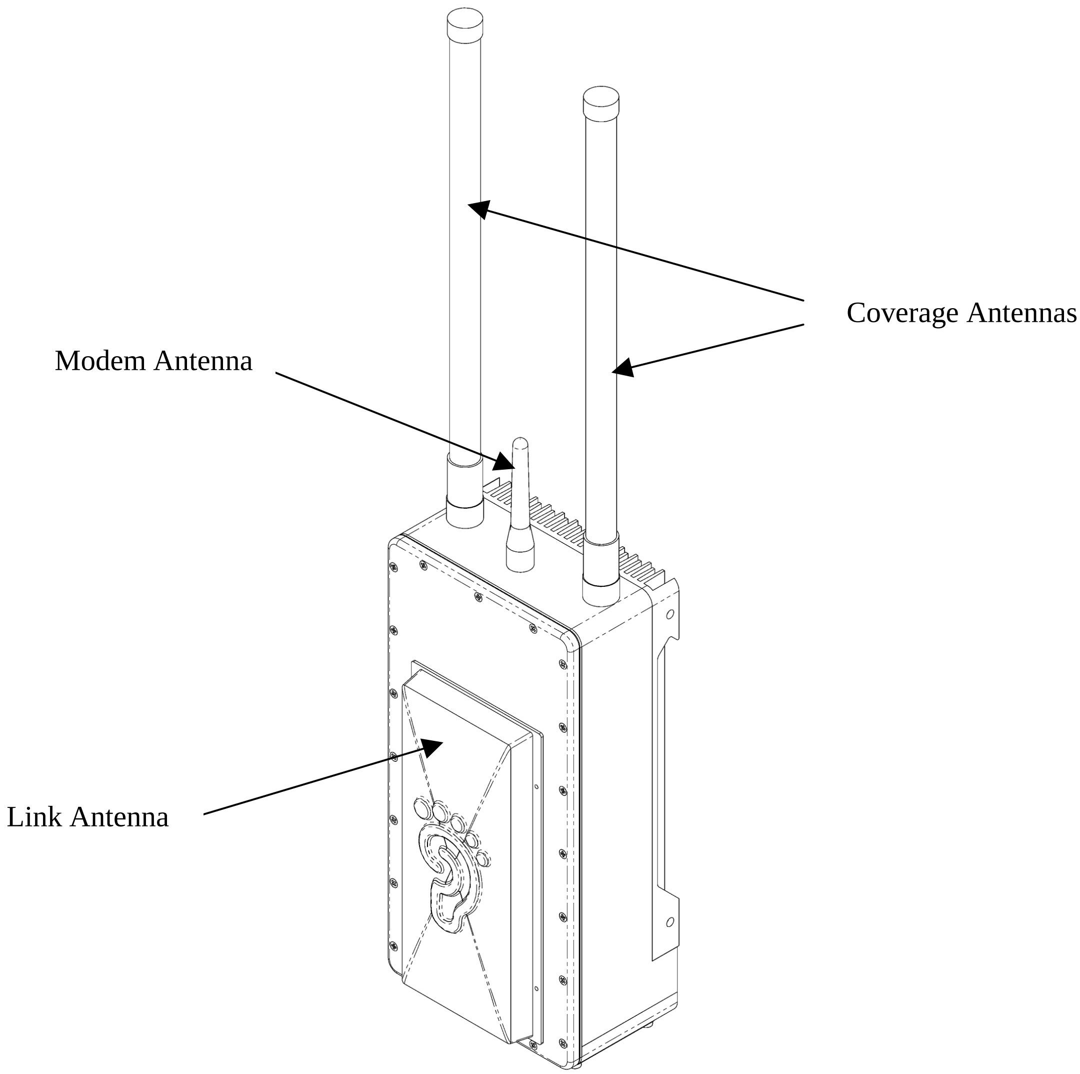


Figure 3-1 cSPICE Enclosure

To simplify the prediction process for the cSPICE, while at the same time maintaining a very conservative approach, it is assumed the link antenna gain is constant, at its maximum value, irrespective of the angle or distance between the test point and the link antenna. It is also assumed that the 2:2 coverage antenna configuration is implemented (which yields the maximum output power per carrier). The cSPICE supports up to two bi-directional GSM RF channels (same as the bSPICE). The downlink path of the first channel is always active at full power. The downlink path of the second channel, as well as the uplink paths of both channels, is only active intermittently, as dictated by traffic needs. To once again maintain a conservative approach, it is assumed that both paths of both channels are active at all times. The wireless modem, which rarely carries an active call, only occupies one of eight possible timeslots when a call is active. To continue with the conservative approach, it is assumed that the modem occupies all eight timeslots when a call is active. The cSPICE downlink and uplink outputs, for both channels, operate over a range of powers (downlink output power is set by the user; uplink output power is set by the cSPICE). In both cases, it is assumed that these outputs are operating at their maximum rated powers.

4 Prediction Input Parameters

Table 4-1 presents the prediction input parameters for the bSPICE (Base SPICE) and cSPICE (Coverage SPICE) sites. The composite EiRP for any of the sites is simply the sum of the composite EiRP's for each of the radiating elements at each site. For example, at the cSPICE site, the contributing elements are the downlink RF channels, the uplink RF channels and the wireless modem. The EiRP for each of these elements is based upon maximum output power per carrier, number of carriers, cable loss and antenna gains. The composite EiRP is then the sum of the EiRP's from these three radiating elements.

Table 4-1 Prediction Input Parameters

	Base SPICE		**Coverage SPICE**		
	DL RF Channels	Wireless Modem	DL RF Channels	UL RF Channels	Wireless Modem
Output Power per Carrier (dBm)	23.00	30.00	29.00	26.00	30.00
Cable Loss (dB)	0.000	0.000	0.000	0.000	0.000
Antenna Gain (dBi)	17.00	2.000	8.000	14.00	2.000
EiRP per Carrier (dBm)	40.00	32.00	37.00	40.00	32.00
EiRP per Carrier (W)	10.00	1.580	5.010	10.00	1.580
Number of Carriers (#)	2.000	1.000	2.000	2.000	1.000
Composite EiRP [element] (W)	20.00	1.580	10.02	20.00	1.580
Composite EiRP [site] (W)	**21.58**		**31.61**		

5 Power Density Predictions

Table 5-1 presents predicted power densities as a function of distance for the bSPICE and cSPICE sites. The range of distances in these predictions has been chosen to show the points at which the predicted power densities pass through the FCC MPE limits (50W/m^2 for Occupational and 10W/m^2 for General Population).

Table 5-1 bSPICE / cSPICE Site Power Densities

Distance (m)	Base SPICE (W/m²)	Coverage SPICE (W/m²)
0.2	171.77	251.53
0.3	76.34	111.79
0.4	42.94	62.88
0.5	27.48	40.25
0.6	19.09	27.95
0.7	14.02	20.53
0.8	10.74	15.72
0.9	8.48	12.42
1.0	6.87	10.06
1.1	5.68	8.32
1.2	4.77	6.99
1.3	4.07	5.95
1.4	3.51	5.13
1.5	3.05	4.47
1.6	2.68	3.93

Figure 5-1 is a graphical representation of the bSPICE power densities shown in Table 5-1 and compares these power densities to the FCC MPE limits. The Occupational MPE limit occurs at 0.37m and the General Population MPE limit occurs at 0.83m.

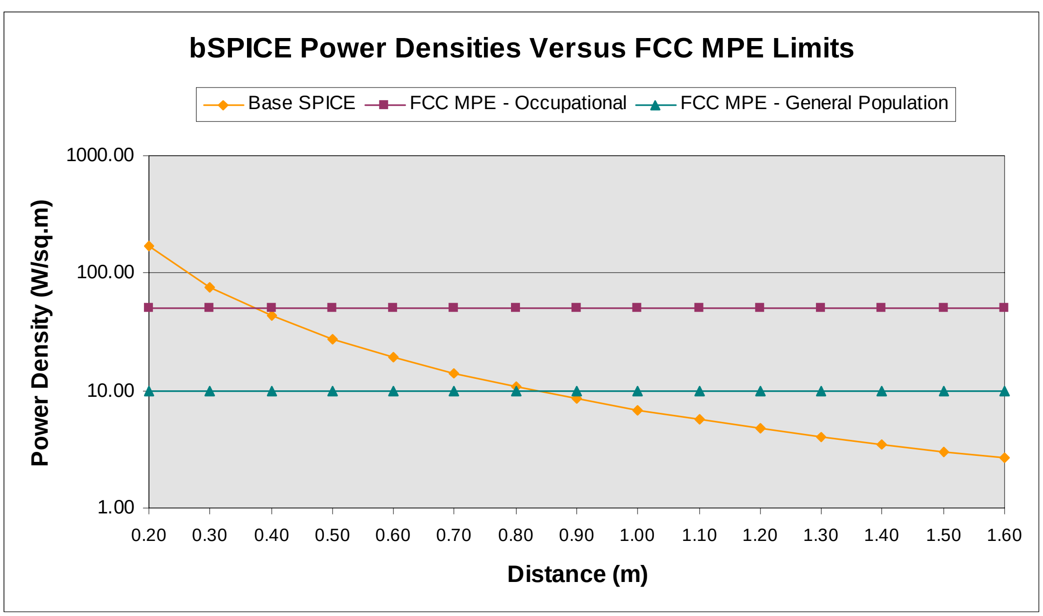


Figure 5-1 bSPICE Power Densities Versus FCC MPE Limits

Figure 5-2 is a graphical representation of the bSPICE power densities shown in Table 5-1 and compares these power densities to the FCC MPE limits. The Occupational MPE limit occurs at 0.45m and the General Population MPE limit occurs at 1.00m.

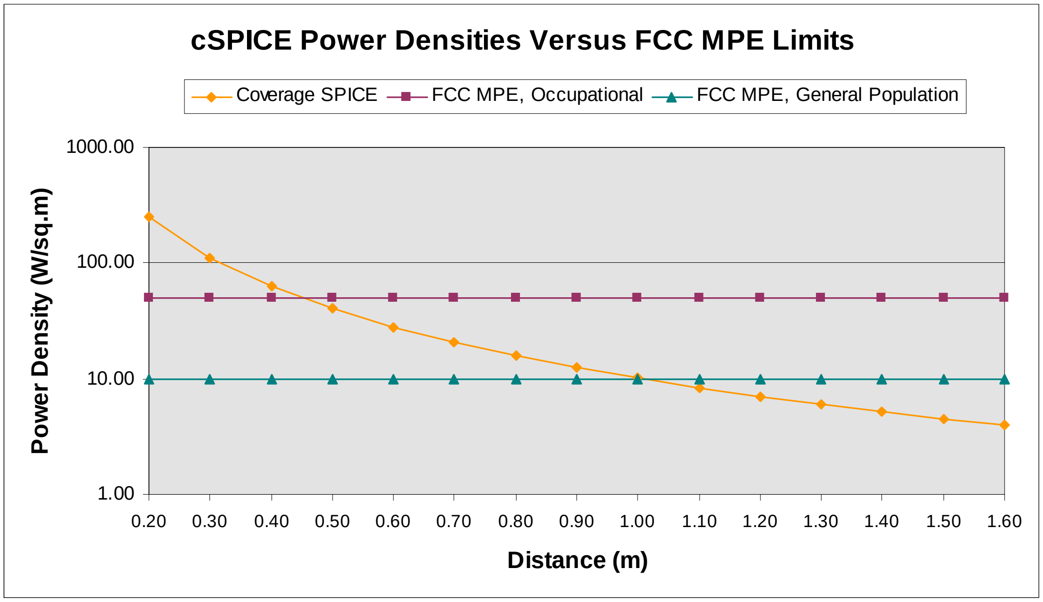


Figure 5-2 cSPICE Power Densities Versus FCC MPE Limits

6 Ratio of FCC MPE Limits to Power Density

Table 6-1 presents the predicted ratio of the power density to the FCC Occupational MPE limit as a function of distance for the bSPICE and cSPICE sites. The range of distances in these predictions has been chosen to show predicted ratios at what would be the typical minimum distances between the radiating elements and the ground. Table 6-2 presents the same information, but against the FCC General Population MPE limit.

Table 6-1 Ratio of Power Density to FCC Occupational MPE Limit

Distance (m)	Base SPICE (W/m^2)	Coverage SPICE (W/m^2)
2.0	3.44E-02	5.03E-02
4.0	8.59E-03	1.26E-02
6.0	3.82E-03	5.59E-03
8.0	2.15E-03	3.14E-03
10.0	1.37E-03	2.01E-03
12.0	9.54E-04	1.40E-03
14.0	7.01E-04	1.03E-03
16.0	5.37E-04	7.86E-04
18.0	4.24E-04	6.21E-04
20.0	3.44E-04	5.03E-04
22.0	2.84E-04	4.16E-04
24.0	2.39E-04	3.49E-04
26.0	2.03E-04	2.98E-04
28.0	1.75E-04	2.57E-04
30.00	1.53E-04	2.24E-04

Table 6-2 Ratio of Power Density to FCC General Population MPE Limit

Distance (m)	Base SPICE (W/m^2)	Coverage SPICE (W/m^2)
2.0	1.72E-01	2.52E-01
4.0	4.29E-02	6.29E-02
6.0	1.91E-02	2.79E-02
8.0	1.07E-02	1.57E-02
10.0	6.87E-03	1.01E-02

12.0	4.77E-03	6.99E-03
14.0	3.51E-03	5.13E-03
16.0	2.68E-03	3.93E-03
18.0	2.12E-03	3.11E-03
20.0	1.72E-03	2.52E-03
22.0	1.42E-03	2.08E-03
24.0	1.19E-03	1.75E-03
26.0	1.02E-03	1.49E-03
28.0	8.76E-04	1.28E-03
30.00	7.63E-04	1.12E-03

Figure 6-1 is a graphical representation of the predicted ratio of the power density to the FCC Occupational MPE limit for the bSPICE and cSPICE sites. The bSPICE and cSPICE site ratios, at the typical mounting heights of 30m and 7m, are 1.53E-04 and 4.11E-03 respectively.

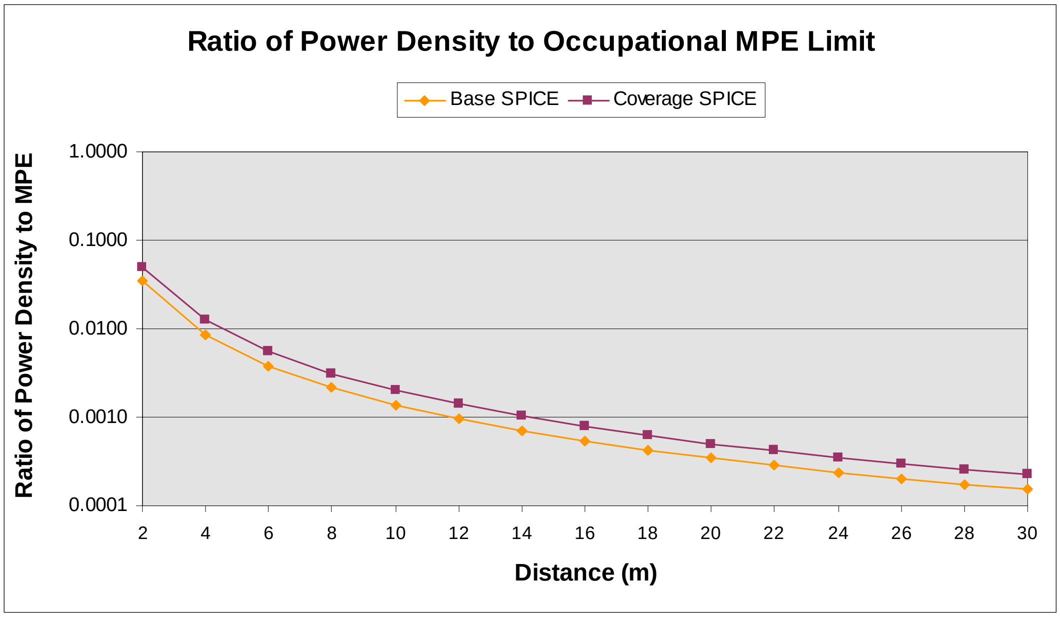


Figure 6-1 Ratio of Power Density to Occupational MPE Limit

Figure 6-2 is a graphical representation of the predicted ratio of the power density to the FCC General Population MPE limit for the bSPICE and cSPICE sites. The bSPICE and cSPICE site ratios, at the typical mounting heights of 30m and 7m, are 7.63E-04 and 2.05E-02 respectively.

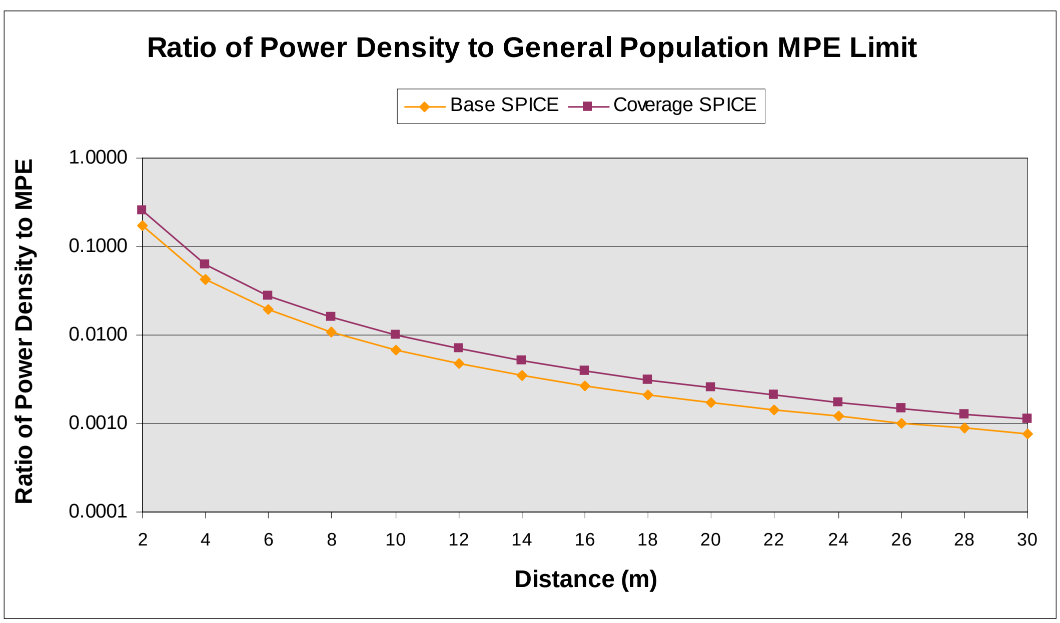


Figure 6-2 Ratio of Power Density to General Population MPE Limit

7 Conclusion

The power density predictions presented in this document show the MPE limits for Occupational and General Population, stipulated by the FCC, are only exceeded in very close proximity to the radiating elements of the SPICE system. The actual power densities are expected to be far lower than the predicted power densities. This is due to the highly conservative approach that has been taken in the analysis presented in this document.

The conservative nature of the analysis starts with the basic prediction formula, which inherently provides a conservative prediction of the far field power density. This conservatism is extended by assuming a 100% ground wave reflection. This significantly increases the predicted power density, yet it is unlikely the ground wave reflection will be of this magnitude. The prediction model provides a worst-case upper limit for far field equivalent power density in the near field of the antenna. The analysis has shown that most of the MPE limits were exceeded in the near field for the radiating elements of the SPICE system, so these power densities will be highly conservative simply due to the limitations of the prediction model. The predictions make a number of other assumptions that extend the conservative nature of the analysis. It is assumed that directional antennas in the system maintain their peak gain through 360 degrees in the horizontal plane. It is also assumed that all antennas in the system maintain their peak gain through 360 degrees in the vertical plane. This leads to significant over estimation of power density, especially at those points below the antenna where in reality significant benefits should be derived from the antenna pattern nulls. It is also assumed that the radiating elements at each site are close enough to be considered a single source, when in reality they are not, which can lead to an over estimation of power density. The other areas of conservatism in the analysis include the assumption that there are no cable losses, the assumption that the modem occupies all eight timeslots and the assumption that all downlink and uplink channels are fully utilized in the bSPICE and cSPICE. In reality, there are cable losses; the modem only occupies one of eight timeslots; and it is rare for all downlink and uplink channels to be fully utilized.

The results presented in this document show that even with a very conservative approach, the Occupational and General Population MPE limits for the bSPICE site occur at 0.37m and 0.83m respectively. The equivalent distances for the cSPICE site are 0.45m and 1.00m. The mounting heights for typical bSPICE and cSPICE installations are 30m and 7m above ground level. Under these conditions, the predicted power densities for the bSPICE site are only a fraction of the Occupational and General Population MPE limits (1.53E-04 and 7.63E-04 times the respective limits). Similarly, the predicted power densities for the cSPICE site are also only a fraction of the Occupational and General Population MPE limits (4.11E-03 and 2.05E-2 times the respective limits).

The results of the analysis performed in this document place the SPICE system in a commanding position for the wireless industry of today and the future. There is no way of knowing what researchers may find as they continue to investigate RF radiation, but should it be shown that there are adverse health effects, the SPICE system will be the ideal infrastructure solution due to its low power characteristics.

P/N 480001

PCS VERTICAL POLARIZED OMNIDIRECTIONAL ANTENNA

RACAL PART NO. 1971-000

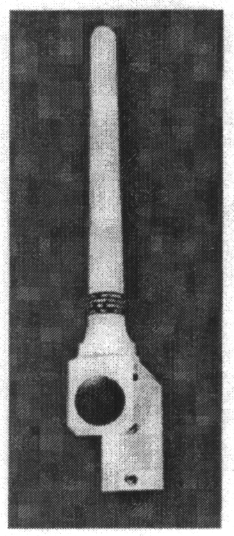
S. Mikuteit

TYPE 8100
VP/360/2

- Discrete Visual Profile
- Mechanically Robust
- Indoor/Outdoor Applications
- Simple Mounting Arrangement
- 5 Year Warranty

ELECTRICAL PERFORMANCE

Frequency Range	:	1850-1990 MHz
Gain	:	2dBi
VSWR	:	1.3:1 maximum
Polarization	:	Vertical
Horizontal Beamwidth	:	360°
Vertical Beamwidth	:	70°
Power Rating	:	100W
Impedance	:	50Ω
Connector	:	SMA or N Type



PCS
VERTICAL POLARIZED
OMNIDIRECTIONAL
ANTENNA

TYPE 8100 CONT'D

MECHANICAL PERFORMANCE

Length	:	6in (152mm)
Diameter	:	.8in (20mm)
Weight	:	4oz (.2kg)
Mounting	:	Single M/8 nut
Radome Material	:	Polypropylene

ENVIRONMENTAL SURVIVAL

Temperature	:	-40°F to +158°F (-40°C to +70°C)
Wind Survival	:	>150mph
No Degradation During or After	:	Salt mist/driving rain and any moisture ingress

Specifications subject to change without notice