

SCTE • ISBE[®]

S T A N D A R D S

Network Operations Subcommittee

SCTE OPERATIONAL PRACTICE

SCTE 222 2020

Useful Signal Leakage Formulas

NOTICE

The Society of Cable Telecommunications Engineers (SCTE) / International Society of Broadband Experts (ISBE) Standards and Operational Practices (hereafter called “documents”) are intended to serve the public interest by providing specifications, test methods and procedures that promote uniformity of product, interchangeability, best practices and ultimately the long-term reliability of broadband communications facilities. These documents shall not in any way preclude any member or non-member of SCTE•ISBE from manufacturing or selling products not conforming to such documents, nor shall the existence of such standards preclude their voluntary use by those other than SCTE•ISBE members.

SCTE•ISBE assumes no obligations or liability whatsoever to any party who may adopt the documents. Such adopting party assumes all risks associated with adoption of these documents, and accepts full responsibility for any damage and/or claims arising from the adoption of such documents.

Attention is called to the possibility that implementation of this document may require the use of subject matter covered by patent rights. By publication of this document, no position is taken with respect to the existence or validity of any patent rights in connection therewith. SCTE•ISBE shall not be responsible for identifying patents for which a license may be required or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Patent holders who believe that they hold patents which are essential to the implementation of this document have been requested to provide information about those patents and any related licensing terms and conditions. Any such declarations made before or after publication of this document are available on the SCTE•ISBE web site at <http://www.scte.org>.

All Rights Reserved

© Society of Cable Telecommunications Engineers, Inc. 2020
140 Philips Road
Exton, PA 19341

Table of Contents

Title	Page Number
NOTICE.....	2
Table of Contents.....	3
1. Introduction.....	5
1.1. Executive Summary.....	5
1.2. Scope.....	5
1.3. Benefits.....	5
1.4. Intended Audience.....	5
2. Normative References.....	5
2.1. SCTE References.....	5
2.2. Standards from Other Organizations.....	5
2.3. Published Materials.....	5
3. Informative References.....	6
3.1. SCTE References.....	6
3.2. Standards from Other Organizations.....	6
3.3. Published Materials.....	6
4. Compliance Notation.....	6
5. Abbreviations and Definitions.....	7
5.1. Abbreviations.....	7
5.2. Definitions.....	7
6. Useful Signal Leakage Formulas.....	10
6.1. Calculate wavelength (λ).....	10
6.2. Calculate the radiating near-field, far-field boundary.....	11
6.3. Calculate free space path loss.....	12
6.4. Convert microvolt (μV) to microvolt per meter ($\mu\text{V}/\text{m}$).....	13
6.5. Convert microvolt per meter ($\mu\text{V}/\text{m}$) to microvolt (μV).....	14
6.6. Convert microvolt per meter ($\mu\text{V}/\text{m}$) to decibel millivolt (dBmV).....	14
6.7. Convert decibel millivolt (dBmV) to microvolt per meter ($\mu\text{V}/\text{m}$).....	15
6.8. Convert decibel millivolt (dBmV) to microvolt (μV).....	16
6.9. Convert microvolt (μV) to decibel millivolt (dBmV).....	16
6.10. Convert decibel millivolt (dBmV) to decibel microvolt (dB μV).....	17
6.11. Convert decibel microvolt (dB μV) to decibel millivolt (dBmV).....	17
6.12. Convert decibel millivolt (dBmV) to decibel milliwatt (dBm) – 75 ohm impedance.....	18
6.13. Convert decibel milliwatt (dBm) to decibel millivolt (dBmV) – 75 ohm impedance.....	19
6.14. Calculate received signal power at a resonant half-wave dipole antenna's terminals.....	19
6.15. Convert microvolt per meter ($\mu\text{V}/\text{m}$) to decibel microvolt per meter (dB $\mu\text{V}/\text{m}$).....	20
6.16. Convert decibel microvolt per meter (dB $\mu\text{V}/\text{m}$) to microvolt per meter ($\mu\text{V}/\text{m}$).....	20
6.17. Convert leakage field strength at 30 meters measurement distance to an equivalent field strength at 3 meters measurement distance.....	21
6.18. Convert leakage field strength at 3 meters measurement distance to an equivalent field strength at 30 meters measurement distance.....	21
6.19. Calculate leakage field strength difference in decibels at new measurement distance versus reference measurement distance.....	22
6.20. Calculate leakage field strength difference in decibels between two values of the same signal measured at different distances from the source.....	23
6.21. Convert the FCC's 25 kHz and 30 kHz bandwidths to a wider equivalent bandwidth.....	23

List of Figures

Title	Page Number
Figure 1 - Approximate distance from dipole to near-field/far-field boundary	12

List of Tables

Title	Page Number
Table 1. Power conversion.....	24

1. Introduction

1.1. Executive Summary

Cable operators in North America and some other regions of the world have for many years been required by government regulations to monitor, measure, and repair signal leakage from their networks. Mathematical calculations and conversions often are a necessary part of effectively managing signal leakage. This Operational Practice includes a variety of formulas related to radio frequency (RF) signal leakage, accompanied by examples of how to use each formula.

1.2. Scope

This Operational Practice provides useful formulas and usage examples related to cable system RF signal leakage.

1.3. Benefits

Optimum cable network performance and compliance with government regulations require that RF signal leakage be routinely monitored, measured, and repaired. The formulas and examples in this Operational Practice will help cable operators maintain the integrity of their networks as well as compliance with applicable regulations.

1.4. Intended Audience

This document is intended for cable system technical personnel such as installers, service and maintenance technicians, and others who have to monitor, measure, and repair RF signal leakage levels as part of their daily jobs, or are interested in the treatment of such signals.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

- No normative references are applicable.

2.2. Standards from Other Organizations

- No normative references are applicable.

2.3. Published Materials

- No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

- SCTE 209 2015. Technical Report UHF Leakage, Ingress, Direct Pickup

3.2. Standards from Other Organizations

- No informative references are applicable.

3.3. Published Materials

- *The ARRL Handbook for Radio Amateurs* (any recent edition), American Radio Relay League, Newington, CT; www.arrl.org
- Johnson, R., Jasik, H. (1984). *Antenna Engineering Handbook, Second Edition*. New York: McGraw-Hill
- Kraus, J. (1988). *Antennas, Second Edition*. New York: McGraw-Hill
- Multiple contributors (1975). *Reference Data for Radio Engineers*. Indianapolis, IN: Howard W. Sams & Co., Inc.
- Multiple contributors (1989). *Reference Data for Engineers: Radio, Electronics, Computer, and Communications, Seventh Edition*. Indianapolis, IN: Howard W. Sams & Co., Inc.

4. Compliance Notation

<i>shall</i>	This word or the adjective “ required ” means that the item is an absolute requirement of this document.
<i>shall not</i>	This phrase means that the item is an absolute prohibition of this document.
<i>forbidden</i>	This word means the value specified shall never be used.
<i>should</i>	This word or the adjective “ recommended ” means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
<i>should not</i>	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
<i>may</i>	This word or the adjective “ optional ” means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
<i>deprecated</i>	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

A_e	effective aperture
dB	decibel
dB _i	decibel isotropic
dB _m	decibel milliwatt
dB _{mV}	decibel millivolt
dB _{μV}	decibel microvolt
dB _{μV/m}	decibel microvolt per meter
e.g.	for example (<i>exempli gratia</i>)
$E_{\mu V/m}$	field strength in microvolts per meter
f	frequency
FCC	Federal Communications Commission
i.e.	that is (<i>id est</i>)
ISBE	International Society of Broadband Experts
km	kilometer
log	logarithm (base 10 unless otherwise stated)
MHz	megahertz
mV	millivolt
mW	milliwatt
ref	reference
RF	radio frequency
SCTE	Society of Cable Telecommunications Engineers
μV	microvolt
μV/m	microvolt per meter
λ	wavelength

5.2. Definitions

attenuation	see loss
decibel (dB)	A logarithmic-based expression of the ratio between two values of a physical quantity, typically power or intensity. The decibel provides an efficient way to express ratios which span one or more powers of the logarithmic base, most commonly 10. Mathematically, the ratio of two power levels P_1 and P_2 in decibels is $dB = 10\log(P_1/P_2)$. ¹
decibel microvolt (dB _{μV})	Unit of RF power expressed in terms of voltage, defined as decibels relative to 1 microvolt, where 1 microvolt equals 13.33 femtowatts in a

¹ The decibel, while technically a ratio of two power levels, also can be used to represent the ratio of two voltage levels, assuming the two voltages are across the same impedance. Here is how that relationship is derived: The unit of electrical power, the watt, equals 1 volt multiplied by 1 ampere. Equation-wise $P = EI$, where P is power in watts, E is voltage in volts, and I is current in amperes. Substituting the Ohm's Law equivalent for E and I gives additional formulas for power: $P = E^2/R$ and $P = I^2R$. If the right hand side of the power equation $P = E^2/R$ is substituted for both P_1 and P_2 in the formula $dB = 10\log(P_1/P_2)$, the equation becomes $dB = 10\log[(E^2/R)/(E^2/R)]$ which is the same as $dB = 10\log[(E_1^2/R_1)/(E_2^2/R_2)]$. In this example, R represents the 75 ohm impedance of a cable network. Since R_1 and R_2 are both equal to 75 ohms, those equation terms cancel, leaving the equation $dB = 10\log(E_1^2/E_2^2)$. This can be simplified somewhat and written as $dB = 10\log(E_1/E_2)^2$ which is the same as $dB = 2 * 10\log(E_1/E_2)$ or $dB = 20\log(E_1/E_2)$.

	75 ohm impedance. Mathematically, $\text{dB}\mu\text{V} = 20\log(\text{value in } \mu\text{V}/1 \mu\text{V})$.
decibel microvolt per meter ($\text{dB}\mu\text{V}/\text{m}$)	An RF signal's power density expressed in terms of voltage, defined as decibels relative to 1 microvolt per meter, where 1 microvolt per meter equals 1 microvolt delivered to a receiving antenna's terminals recovered from an imaginary 1 meter x 1 meter square in free-space or air. Mathematically, $\text{dB}\mu\text{V}/\text{m} = 20\log(\mu\text{V}/\text{m})$.
decibel millivolt (dBmV)	Unit of RF power expressed in terms of voltage, defined as decibels relative to 1 millivolt, where 1 millivolt equals 13.33 nanowatts in a 75 ohm impedance. Mathematically, $\text{dBmV} = 20\log(\text{value in mV}/1 \text{mV})$.
decibel milliwatt (dBm)	Unit of power, defined as decibels relative to 1 milliwatt, where 0 dBm equals 1 milliwatt. Mathematically, $\text{dBm} = 10\log(\text{value in mW}/1 \text{mW})$.
effective aperture (A_e)	The geometric area over which an antenna receives power from an incident RF signal and delivers that power to a connected load. Mathematically, $A_e = \lambda^2 G/4\pi$, where λ is the wavelength of the RF signal, G is the receiving antenna's numerical power gain (e.g., 1.64 for a half-wave dipole), and $\pi = 3.14$. If the antenna is considered lossless, effective aperture is called maximum effective aperture (A_{em}). For a half-wave dipole antenna, A_{em} can be approximated by a rectangle that has dimensions of 0.5λ by 0.25λ , or an ellipse whose area is $0.13\lambda^2$.
far-field	The region of an antenna's radiation pattern in which the angular distribution of radiated energy is largely independent of distance from the antenna, and in which the power varies inversely with the square of distance. The approximate distance from the antenna to the beginning of the far-field is generally accepted to be $R = 2D^2/\lambda$, where R is distance from the antenna, D is the largest linear dimension of the antenna effective aperture, and λ is wavelength. Signal leakage field strength measurements are made in the far-field. See also <i>near-field</i> .
field strength	An RF signal's power density within an imaginary 1 meter x 1 meter square (that is, watts per square meter) in free space or in the air. Usually expressed as a voltage; for example, microvolts per meter.
free space path loss	The attenuation, typically in decibels, of an electromagnetic signal traveling over an unobstructed line-of-sight path between two points. Mathematically, $Loss_{dB} = 20\log(f_{MHz}) + 20\log(d_{km}) + 32.45$, or $Loss_{dB} = 20\log(f_{MHz}) + 20\log(d_{feet}) - 37.892$, where f_{MHz} is the frequency in megahertz, d_{km} is the path length in kilometers, and d_{feet} is the path length in feet ² .
gain	An increase in the power of a signal or signals, usually measured in decibels. Expressed mathematically, $G_{dB} = 10\log(P_{out}/P_{in})$, where G_{dB} is gain in decibels, P_{out} is output power in watts, P_{in} is input power in watts, and $P_{out} > P_{in}$. When signal power is stated in dBmV , $G_{dB} = P_{out}(\text{dBmV}) - P_{in}(\text{dBmV})$.
hertz (Hz)	A unit of frequency equivalent to one cycle per second.

² Real-world path loss seldom equals the calculated free space path loss, because of the constructive and/or destructive effects of signal reflection(s), refraction, and diffraction. In addition to free space path loss modeling, other models used to calculate path loss include, but are not limited to, Lee, Longley-Rice, Okumura-Hata, Walfish-Ikegami, and Young. This Operational Practice document uses free space path loss modeling in its examples.

impedance	The combined opposition to current in a component, circuit, device, or transmission line that contains both resistance and reactance. Represented by the symbol Z and expressed in ohms.
loss	A decrease in the power of a signal or signals, usually measured in decibels. Expressed mathematically, $L_{dB} = 10\log(P_{in}/P_{out})$, where L_{dB} is loss in decibels, P_{in} is input power in watts, P_{out} is output power in watts, and $P_{out} < P_{in}$. When signal power is stated in dBmV, $L_{dB} = P_{in(dBmV)} - P_{out(dBmV)}$.
megahertz (MHz)	One million (10^6) hertz. See also <i>hertz</i> .
microvolt (μ V)	One millionth (10^{-6}) of a volt.
microvolt per meter (μ V/m)	A measure of the field strength of an RF signal, calculated by dividing the received intensity in microvolts by the receiving antenna maximum effective aperture.
millivolt (mV)	One thousandth (10^{-3}) of a volt.
near-field	The space around an antenna comprises a reactive region and a radiating region. The radiating region is further subdivided into a near-field region and a far-field region. The radiating near-field is the propagation region where angular contributions from individual antenna elements vary significantly with distance from the antenna. See also <i>far-field</i> .
radio frequency (RF)	That portion of the electromagnetic spectrum from a few kilohertz to just below the frequency of infrared light.
signal leakage	Unwanted emission of RF signals from a cable TV network into the surrounding over-the-air environment, typically caused by degraded shielding effectiveness of coaxial cable, connectors, and other network components, or by poorly shielded subscriber terminal equipment connected to the cable network.

6. Useful Signal Leakage Formulas

The following formulas are used to calculate various signal leakage-related parameters and to convert between various signal leakage-related units. When dealing with leakage measurements and distance(s) from a leakage source, it is assumed that all field strength measurements are in the far-field.

6.1. Calculate wavelength (λ)

$$\text{wavelength}_{\text{meters}} = \frac{299.792458}{f_{\text{MHz}}}, \text{ and}$$

$$\text{wavelength}_{\text{feet}} = \frac{983.571056}{f_{\text{MHz}}}$$

Example:

What is the approximate length of a half-wave dipole tuned to receive 139.25 MHz?

Solution in meters:

$$\text{wavelength}_{\text{meters}} = \frac{299.792458}{f_{\text{MHz}}}$$

$$\text{wavelength}_{\text{meters}} = \frac{299.792458}{139.25}$$

$$\text{wavelength}_{\text{meters}} = 2.15$$

Answer: Divide the free-space wavelength by 2 to get the free-space half wavelength: $2.15/2 = 1.08$ meters. A half-wave dipole's physical length is approximately 95% of the free-space half wavelength value, or 1.02 meters in this example.³

Solution in feet:

$$\text{wavelength}_{\text{feet}} = \frac{983.571056}{f_{\text{MHz}}}$$

$$\text{wavelength}_{\text{feet}} = \frac{983.571056}{139.25}$$

$$\text{wavelength}_{\text{feet}} = 7.06$$

Answer: Divide the free-space wavelength by 2 to get the free-space half wavelength: $7.06/2 = 3.53$ feet. A half-wave dipole's physical length is approximately 95% of the free-space half wavelength value, or 3.35 feet in this example.

³ A dipole antenna's physical length is almost always less than its calculated free-space value because of the elements' length-to-diameter ratio, and capacitive end effect. Additional details about this can be found in *The ARRL Handbook for Radio Amateurs*, listed in section 3.3.

6.2. Calculate the radiating near-field, far-field boundary

$$R = \frac{2D^2}{\lambda}$$

where

R = distance from the antenna elements

D = largest dimension of the antenna aperture (for a resonant half-wave dipole, D is equal to approximately 0.5λ to 0.6λ ⁴)

λ = wavelength

Note: All variables must be in the same units (feet, meters, etc.)

Example:

What is the approximate distance defining the radiating near-field and radiating far-field boundary for a half-wave dipole tuned for resonance at 139.25 MHz? Assume the free-space wavelength is 7.06 feet, 0.5λ is 3.53 feet, and 0.6λ is 4.24 feet.

Solution:

$$R = \frac{2D^2}{\lambda}$$

$$R = \frac{2(3.53^2)}{7.06}$$

$$R = \frac{2(12.46)}{7.06}$$

$$R = \frac{24.92}{7.06}$$

$$R = 3.53$$

to

$$R = \frac{2D^2}{\lambda}$$

$$R = \frac{2(4.24^2)}{7.06}$$

⁴ In *Antennas, Second Edition* (Kraus), the maximum effective aperture of a dipole "...is approximately represented by a rectangle $\frac{1}{2}$ by $\frac{1}{4}\lambda$ on a side." Using this definition, a half wavelength is the largest dimension of a dipole antenna's aperture, so D is 0.5λ . Kraus also says maximum effective aperture can be "...represented by elliptical area of $0.13\lambda^2$." Here the largest dimension of the aperture (width of the ellipse) is approximately 0.6λ .

$$R = \frac{2(17.98)}{7.06}$$

$$R = \frac{35.96}{7.06}$$

$$R = 5.09$$

The answer is approximately 3.5 to 5.1 feet

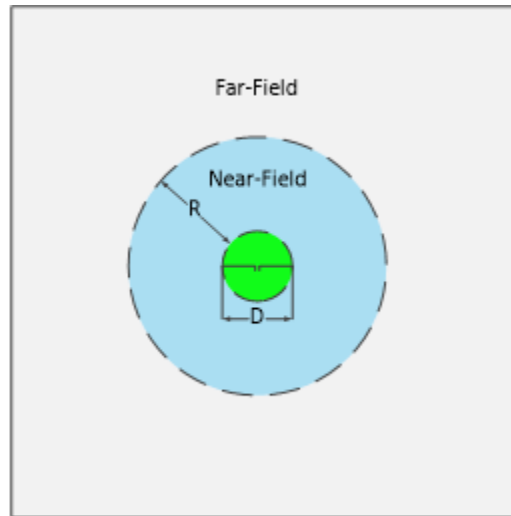


Figure 1 - Approximate distance from dipole to near-field/far-field boundary

6.3. Calculate free space path loss

$$Loss_{dB} = 20 \log(f_{MHz}) + 20 \log(d_{km}) + 32.45$$

where

$Loss_{dB}$ is free space path loss in decibels

f is frequency in megahertz

d_{km} is path length in kilometers (1 meter = 0.001 km)

Example 1:

What is the free-space path loss at 139.25 MHz between a leakage source and an antenna 3 meters away from the leak? (Note: 3 meters is equal to 0.003 kilometers)

Solution 1:

$$Loss_{dB} = 20 \log(f) + 20 \log(d_{km}) + 32.45$$

$$Loss_{dB} = 20 \log(139.25) + 20 \log(0.003) + 32.45$$

$$Loss_{dB} = (20 * [\log(139.25)]) + (20 * [\log(0.003)]) + 32.45$$

$$\begin{aligned} Loss_{dB} &= (20 * [2.14]) + (20 * [-2.52]) + 32.45 \\ Loss_{dB} &= (42.88) + (-50.46) + 32.45 \\ Loss_{dB} &= (42.88) + (-50.46) + 32.45 \\ Loss_{dB} &= 24.87 \end{aligned}$$

The answer is approximately 25 dB

Where the distance is in feet:

$$Loss_{dB} = 20 \log(f_{MHz}) + 20 \log(d_{feet}) - 37.89$$

where

$Loss_{dB}$ is free space path loss in decibels

f is frequency in megahertz

d_{feet} is path length in feet

Example 2:

What is the free-space loss at 139.25 MHz between a leakage source and an antenna 9.84 feet away from the leak?

Solution 2:

$$\begin{aligned} Loss_{dB} &= 20 \log(f_{MHz}) + 20 \log(d_{feet}) - 37.89 \\ Loss_{dB} &= 20 \log(139.25) + 20 \log(9.84) - 37.89 \\ Loss_{dB} &= (20 * [\log(139.25)]) + (20 * [\log(9.84)]) - 37.89 \\ Loss_{dB} &= (20 * [2.14]) + (20 * [0.99]) - 37.89 \\ Loss_{dB} &= (42.88) + (19.86) - 37.89 \\ Loss_{dB} &= 24.85 \end{aligned}$$

The answer is approximately 25 dB

6.4. Convert microvolt (μV) to microvolt per meter (μV/m)

$$E_{\mu V/m} = \mu V * 0.021 * f$$

where

$E_{\mu V/m}$ is field strength in microvolt per meter

μV is RF signal level in microvolt at the terminals of a resonant half-wave dipole

f is frequency in megahertz

Example:

What is the μV/m equivalent of 4 μV at 139.25 MHz?

Solution:

$$E_{\mu V/m} = \mu V * 0.021 * f$$

$$E_{\mu V/m} = \mu V * 0.021 * 139.25$$

$$E_{\mu V/m} = 4 * 2.92$$

$$E_{\mu V/m} = 11.7$$

The answer is approximately 12 $\mu V/m$

6.5. Convert microvolt per meter ($\mu V/m$) to microvolt (μV)

$$\mu V = \frac{E_{\mu V/m}}{0.021 * f}$$

where

μV is RF signal level in microvolt at the terminals of a resonant half-wave dipole

$E_{\mu V/m}$ is field strength in microvolt per meter

f is frequency in megahertz

Example:

What is the voltage equivalent of 11.7 $\mu V/m$ at 139.25 MHz?

Solution:

$$\mu V = \frac{E_{\mu V/m}}{0.021 * f}$$

$$\mu V = \frac{11.7}{0.021 * 139.25}$$

$$\mu V = \frac{11.7}{2.92}$$

$$\mu V = 4$$

The answer is 4 μV

6.6. Convert microvolt per meter ($\mu V/m$) to decibel millivolt (dBmV)

$$dBmV = 20 \log \left[\frac{\left(\frac{E_{\mu V/m}}{0.021 * f} \right)}{1000} \right]$$

where

$dBmV$ is RF signal level in decibel millivolt at the terminals of a resonant half-wave dipole antenna

$E_{\mu V/m}$ is field strength in microvolt per meter

f is frequency in megahertz

Example:

What is the power, in dBmV, delivered to the terminals of a resonant half-wave dipole antenna by a 139.25 MHz leak whose field strength is 20 $\mu\text{V/m}$ at the point of measurement?

Solution:

$$dBmV = 20 \log \left[\frac{\left(\frac{E_{\mu V/m}}{(0.021 * f)} \right)}{1000} \right]$$

$$dBmV = 20 \log \left[\frac{\left(\frac{20}{(0.021 * 139.25)} \right)}{1000} \right]$$

$$dBmV = 20 \log \left[\frac{\left(\frac{20}{2.92} \right)}{1000} \right]$$

$$dBmV = 20 \log \left[\frac{(6.84)}{1000} \right]$$

$$dBmV = 20 \log [0.006839]$$

$$dBmV = 20 * (\log[0.006839])$$

$$dBmV = 20 * (-2.16)$$

$$dBmV = -43.30$$

The answer is approximately -43 dBmV

6.7. Convert decibel millivolt (dBmV) to microvolt per meter ($\mu\text{V/m}$)

$$E_{\mu V/m} = 21 * f * 10^{\frac{dBmV}{20}}$$

where

$E_{\mu V/m}$ is field strength in microvolt per meter

f is frequency in megahertz

$dBmV$ is RF signal level in decibel millivolt at the terminals of a resonant half-wave dipole antenna

Example:

What is the field strength in microvolts per meter when the power delivered to the terminals of a resonant half-wave dipole is -48 dBmV at 139.25 MHz?

Solution:

$$E_{\mu V/m} = 21 * f * 10^{\frac{dBmV}{20}}$$

$$E_{\mu V/m} = 21 * 139.25 * 10^{\frac{dBmV}{20}}$$

$$E_{\mu V/m} = 21 * 139.25 * 10^{\frac{-48}{20}}$$

$$E_{\mu V/m} = 21 * 139.25 * 0.004$$

$$E_{\mu V/m} = 11.7$$

The answer is approximately 12 $\mu V/m$

6.8. Convert decibel millivolt (dBmV) to microvolt (μV)

$$\mu V = 1000 * 10^{\frac{dBmV}{20}}$$

where

μV is RF signal level in microvolt

$dBmV$ is RF signal level in decibel millivolt

Example:

What is the voltage equivalent of -48 dBmV (assume 75 ohms impedance)?

Solution:

$$\mu V = 1000 * 10^{\frac{dBmV}{20}}$$

$$\mu V = 1000 * 10^{\frac{-48}{20}}$$

$$\mu V = 1000 * 0.004$$

$$\mu V = 4$$

The answer is 4 μV

6.9. Convert microvolt (μV) to decibel millivolt (dBmV)

$$dBmV = 20 \log \left(\frac{\mu V}{1000} \right)$$

where

$dBmV$ is RF signal level in decibel millivolt

μV is RF signal level in microvolt

Example:

What is the dBmV equivalent of 4 μV (assume 75 ohms impedance)?

Solution:

$$dBmV = 20 \log \left(\frac{\mu V}{1000} \right)$$

$$dBmV = 20 * \log \left(\frac{4}{1000} \right)$$

$$dBmV = 20 * -2.4$$

$$dBmV = -48$$

The answer is -48 dBmV

6.10. Convert decibel millivolt (dBmV) to decibel microvolt (dBμV)

$$dB\mu V = dBmV + 60$$

where

$dB\mu V$ is RF signal level in decibel microvolt

$dBmV$ is RF signal level in decibel millivolt

Example:

What is the dBμV equivalent of -48 dBmV?

Solution:

$$dB\mu V = dBmV + 60$$

$$dB\mu V = -48 + 60$$

$$dB\mu V = 12$$

The answer is 12 dBμV

6.11. Convert decibel microvolt (dBμV) to decibel millivolt (dBmV)

$$dBmV = dB\mu V - 60$$

where

$dBmV$ is RF signal level in decibel millivolt

$dB\mu V$ is RF signal level in decibel microvolt

Example:

What is the dBmV equivalent of 12 dBμV?

Solution:

$$dBmV = dB\mu V - 60$$

$$dBmV = 12 - 60$$

$$dBmV = -48$$

The answer is -48 dBmV

6.12. Convert decibel millivolt (dBmV) to decibel milliwatt (dBm) – 75 ohm impedance

$$dBm = dBmV - 48.75$$

where

dBm is RF signal level in decibel milliwatt

$dBmV$ is RF signal level in decibel millivolt

Example:

What is the 75 ohm power equivalent of -48 dBmV?

Solution:

$$dBm = dBmV - 48.75$$

$$dBm = -48 - 48.75$$

$$dBm = -96.75$$

The answer is approximately -97 dBm

6.13. Convert decibel milliwatt (dBm) to decibel millivolt (dBmV) – 75 ohm impedance

$$dBmV = dBm + 48.75$$

where

$dBmV$ is RF signal level in decibel millivolt

dBm is RF signal level in decibel milliwatt

Example:

What is the dBmV equivalent of -96.75 dBm (assume 75 ohms impedance)?

Solution:

$$dBmV = dBm + 48.75$$

$$dBmV = -96.75 + 48.75$$

$$dBmV = -48$$

The answer is -48 dBmV

6.14. Calculate received signal power at a resonant half-wave dipole antenna's terminals

$$P_{receive} = \text{transmit power (dBm)} - \text{transmit feedline loss (dB)} + \text{transmit antenna gain (dBi)} - \text{free space path loss (dB)} + \text{receive antenna gain (dBi)}$$

where

$P_{receive}$ is the RF power in decibel milliwatt (dBm) at the terminals of a receive antenna

transmit power (dBm) is the transmitter's output power in decibel milliwatt

transmit feedline loss (dB) is the attenuation in decibels of the feedline between the transmitter and its antenna (if a filter is used between the transmitter and antenna, its loss in decibels *should* be added to the feedline loss)

transmit antenna gain (dBi) is the transmitter's antenna gain in decibel isotropic

free space path loss (dB) is the free space path loss in decibels between the transmit antenna and receive antenna

receive antenna gain (dBi) is the receiver's antenna gain in decibel isotropic (2.15 dBi for a resonant half-wave dipole)

Example:

What is the received power at the terminals of a resonant half-wave dipole given the following:

- Transmit power = 46 dBm @ 752 MHz
- Transmit feedline loss = 2 dB
- Transmit antenna gain = 18 dBi
- Free-space path loss = 108 dB
- Receive antenna gain = 2.15 dBi

Solution:

$P_{receive} = \text{transmit power (dBm)} - \text{transmit feedline loss (dB)} + \text{transmit antenna gain (dBi)} - \text{free space path loss (dB)} + \text{receive antenna gain (dBi)}$

$$P_{receive} = 46 - 2 + 18 - 108 + 2.15$$

$$P_{receive} = -43.85$$

The answer is approximately -44 dBm

6.15. Convert microvolt per meter ($\mu\text{V}/\text{m}$) to decibel microvolt per meter ($\text{dB}\mu\text{V}/\text{m}$)

$$\text{dB}\mu\text{V}/\text{m} = 20\log(E_{\mu\text{V}/\text{m}})$$

where

$\text{dB}\mu\text{V}/\text{m}$ is field strength in decibel microvolt per meter

$E_{\mu\text{V}/\text{m}}$ is field strength in microvolt per meter

Example:

What is the $\text{dB}\mu\text{V}/\text{m}$ equivalent of $50 \mu\text{V}/\text{m}$?

Solution:

$$\text{dB}\mu\text{V}/\text{m} = 20\log(E_{\mu\text{V}/\text{m}})$$

$$\text{dB}\mu\text{V}/\text{m} = 20 * \log(50)$$

$$\text{dB}\mu\text{V}/\text{m} = 20 * 1.70 \text{ dB}\mu\text{V}/\text{m} = 34$$

The answer is 34 $\text{dB}\mu\text{V}/\text{m}$

6.16. Convert decibel microvolt per meter ($\text{dB}\mu\text{V}/\text{m}$) to microvolt per meter ($\mu\text{V}/\text{m}$)

$$E_{\mu\text{V}/\text{m}} = 10^{\frac{\text{dB}\mu\text{V}/\text{m}}{20}}$$

where

$E_{\mu\text{V}/\text{m}}$ is field strength in microvolt per meter

$\text{dB}\mu\text{V}/\text{m}$ is field strength in decibel microvolt per meter

Example:

What is the $\mu\text{V}/\text{m}$ equivalent of 34 $\text{dB}\mu\text{V}/\text{m}$?

Solution:

$$E_{\mu\text{V}/\text{m}} = 10^{\frac{\text{dB}\mu\text{V}/\text{m}}{20}}$$

$$E_{\mu V/m} = 10^{\frac{34}{20}}$$

$$E_{\mu V/m} = 10^{1.70}$$

$$E_{\mu V/m} = 50.12$$

The answer is approximately 50 $\mu V/m$

6.17. Convert leakage field strength at 30 meters measurement distance to an equivalent field strength at 3 meters measurement distance

$$E_{\mu V/m} \text{ at 3 meters} = E_{\mu V/m} \text{ at 30 meters} * \left(\frac{30}{3}\right)$$

where

$E_{\mu V/m}$ at 3 meters is field strength in microvolt per meter at a 3 meter measurement distance

$E_{\mu V/m}$ at 30 meters is field strength in microvolt per meter at a 30 meter measurement distance

Example:

What would be the equivalent field strength at 3 meters given a measured value of 15 $\mu V/m$ at 30 meters?

Solution:

$$E_{\mu V/m} \text{ at 3 meters} = E_{\mu V/m} \text{ at 30 meters} * \left(\frac{30}{3}\right)$$

$$E_{\mu V/m} \text{ at 3 meters} = 15 * \left(\frac{30}{3}\right)$$

$$E_{\mu V/m} \text{ at 3 meters} = 150$$

The answer is 150 $\mu V/m$

6.18. Convert leakage field strength at 3 meters measurement distance to an equivalent field strength at 30 meters measurement distance

$$E_{\mu V/m} \text{ at 30 meters} = E_{\mu V/m} \text{ at 3 meters} * \left(\frac{3}{30}\right)$$

where

$E_{\mu V/m}$ at 30 meters is field strength in microvolt per meter at a 30 meter measurement distance

$E_{\mu V/m}$ at 3 meters is field strength in microvolt per meter at a 3 meter measurement distance

Example:

What would be the equivalent field strength at 30 meters given a measured value of 150 $\mu\text{V}/\text{m}$ at 3 meters?

Solution:

$$E_{\mu\text{V}/\text{m}} \text{ at 30 meters} = E_{\mu\text{V}/\text{m}} \text{ at 3 meters} * \left(\frac{3}{30}\right)$$

$$E_{\mu\text{V}/\text{m}} \text{ at 30 meters} = 150 * \left(\frac{3}{30}\right)$$

$$E_{\mu\text{V}/\text{m}} \text{ at 30 meters} = 15$$

The answer is 15 $\mu\text{V}/\text{m}$

6.19. Calculate leakage field strength difference in decibels at new measurement distance versus reference measurement distance

$$C_{dB} = 20 \log \left(\frac{d_{new}}{d_{ref}} \right)$$

where

C_{dB} is the correction factor in decibels

d_{new} is the new measurement distance

d_{ref} is the reference measurement distance (e.g., 3 meters)

Example:

What is the difference in decibels between a field strength of 15 $\mu\text{V}/\text{m}$ measured at 30 meters and a field strength of 150 $\mu\text{V}/\text{m}$ measured at 3 meters?

Solution:

$$C_{dB} = 20 \log \left(\frac{d_{new}}{d_{ref}} \right)$$

$$C_{dB} = 20 * \log \left(\frac{30}{3} \right)$$

$$C_{dB} = 20$$

The answer is 20 dB

6.20. Calculate leakage field strength difference in decibels between two values of the same signal measured at different distances from the source

$$C_{dB} = 20 \log \left(\frac{\mu V/m_{new}}{\mu V/m_{ref}} \right)$$

where

C_{dB} is the correction factor in decibels

$\mu V/m_{new}$ is the new measured value

$\mu V/m_{ref}$ is the measured reference value

Example:

What is the difference in decibels between a field strength of 150 $\mu V/m$ measured at 3 meters and field strength of 15 $\mu V/m$ measured at 30 meters?

Solution:

$$C_{dB} = 20 \log \left(\frac{\mu V/m_{new}}{\mu V/m_{ref}} \right)$$

$$C_{dB} = 20 * \log \left(\frac{150}{15} \right)$$

$$C_{dB} = 20$$

The answer is 20 dB

6.21. Convert the FCC's 25 kHz and 30 kHz bandwidths to a wider equivalent bandwidth

$$\Delta dB = 10 \log \left(\frac{BW_{new}}{BW_{FCC}} \right)$$

where

ΔdB is the correction factor in decibels to add to the FCC's power threshold

BW_{new} is the new bandwidth (e.g., 6 MHz), expressed in Hz

BW_{FCC} is the bandwidth used in Part 76 of the FCC Rules (i.e., 25 kHz or 30 kHz), expressed in Hz

The values in the following table assume 75 ohms impedance:

Table 1. Power conversion

Power (exp.)	Power (μW)	Power (dBmV)
10^{-4} watt	100	38.750613
–	75.85	37.550168
10^{-5} watt	10	28.750613

Example 1:

What is the FCC's 100 microwatts (μW) power threshold across a 25 kHz bandwidth [ref. §76.610] in a 6 MHz equivalent bandwidth?

Solution 1:

$$\Delta dB = 10 \log \left(\frac{BW_{new}}{BW_{FCC}} \right)$$

$$\Delta dB = 10 * \log \left(\frac{6000000}{25000} \right)$$

$$\Delta dB = 23.80$$

From the table, 100 μW is 38.75 dBmV. Add 23.80 dB to 38.75 dBmV. The answer is 62.55 dBmV.

Example 2:

What is the FCC's 10^{-5} watt power threshold across a 30 kHz bandwidth [ref. §76.616(b)] in a 6 MHz equivalent bandwidth?

Solution 2:

$$\Delta dB = 10 \log \left(\frac{BW_{new}}{BW_{FCC}} \right)$$

$$\Delta dB = 10 * \log \left(\frac{6000000}{30000} \right)$$

$$\Delta dB = 23.01$$

From the table, 10^{-5} watt is 28.75 dBmV. Add 23.01 dB to 28.75 dBmV. The answer is 51.76 dBmV.