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S T A N D A R D S

Network Operations Subcommittee

SCTE OPERATIONAL PRACTICE

SCTE 222 2020

Useful Signal Leakage Formulas

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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.

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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.