NRSC GUIDELINE

NATIONAL RADIO SYSTEMS COMMITTEE

NRSC-G101
AM Modulation-Dependent Carrier Level (MDCL) Usage Guideline
April 2013

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Published by

CONSUMER ELECTRONICS ASSOCIATION
Technology & Standards Department
1919 S. Eads St.
Arlington, VA 22202

NATIONAL ASSOCIATION OF BROADCASTERS
Technology Department
1771 N Street, NW
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FOREWORD

Modulation-dependent carrier level (MDCL) technology offers a way for AM broadcasters to reduce their electrical power consumption with a minimum of impact on the quality of the audio signal received by listeners. In September, 2011 the Federal Communications Commission (FCC) greatly simplified the procedures for broadcasters in the U.S. to take advantage of this technology and as a result, U.S. broadcasters are more likely to embrace MDCL techniques. The purpose of this NRSC Guideline is to provide useful information to broadcasters that will assist them in the use of MDCL technology.

The information contained in this NRSC Guideline was compiled and reviewed by the MDCL Working Group, chaired by Tim Hardy, Nautel, a sub-group of the AFAB Subcommittee of the NRSC, co-chaired by Stan Salek, Hammett & Edison, Inc., and Gary Kline, Cumulus Broadcasting. The NRSC chairman at the time of adoption of NRSC-G101 was Milford Smith, Greater Media, Inc.

The NRSC is jointly sponsored by the Consumer Electronics Association and the National Association of Broadcasters. It serves as an industry-wide standards-setting body for technical aspects of terrestrial over-the-air radio broadcasting systems in the United States.

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AM MODULATION-DEPENDENT CARRIER LEVEL (MDCL) USAGE GUIDELINE

1 SCOPE

This is an informative Guideline document which provides information on modulation-dependent carrier level (MDCL) technologies available for use by AM broadcasters as a means to reduce electrical power consumption of their facilities and, when used carefully, will have little or no impact on the audio quality of their AM transmission.

2 REFERENCES

2.1 Normative References

This is an informative specification. There are no normative references.

2.2 Informative References

The following references contain information that may be useful to those implementing this Guideline document. At the time of publication the edition(s) or version(s) indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

[1] *MDCL Operation is a Winner for High-Power AM*, W.C. Alexander, Radio World, April 18, 2012

[2] *Implementation of Amplitude Modulation Companding in the BBC MF National Networks*, C.P. Bell and W. F. Williams, IEEE Transactions on Broadcasting, Vol. 35, No. 2, June 1989

[3] *Amplitude Modulation Radio Broadcasting: Application of companding techniques to the radiated signal*, W. I. Manson, BBC Research Department, BBC RD 1985/13, November 1985

[4] *Implementation of Amplitude Modulation Companding in the BBC MF National Networks*, C. P. Bell et. al., BBC Engineering Division Report, BBC RD 1988/15, December 1988

[5] *An Introduction to Variable Carrier Power Systems and a Comparison of Benefits*, J. Fred Riley, Continental Electronics Corporation, May 16, 2011

[6] *Millions Saved with MDCL*, Daniel Maxwell, Radio World Engineering Extra, April 18, 2012, pp. 1-10

[7] *Engineering Statement – Request for Special Temporary Authority or Experimental Operation, Kotzebue Broadcasting, Inc., KOTZ (AM), Kotzebue, Alaska*, Hatfield & Dawson, May 25, 2010

[8] *Media Bureau to Permit Use of Energy-saving Transmitter Technology by AM Stations*, FCC Public Notice, DA 11-1535, September 13, 2011 (available online at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-11-1535A1.pdf)

[9] *Application of Modulation Dependent Carrier Level ("MDCL") Control Technologies to Amplitude Modulation Transmission Systems*, Terry L. Cockerill, 2012 NAB BEC Proceedings

[10] *Energy Savings with MDCL,* Daniel Maxwell, 2012 NAB BEC Proceedings

[11] *Saving Power with AM IBOC Using Modulation-Dependent Carrier Level Control,* Brian W. Walker, 2012 NAB Proceedings

[12] *Riley Criticizes Use of AMC,* Radio World, February 3, 2012

[13] *FCC Public Notice: Media Bureau to Permit Use of Energy-Saving Transmitter Technology by AM Stations*, Federal Communications Commission, September 13, 2011

[14] *ACC+ Adaptive Carrier Control Technical Manual,* Harris, August 2009

[15] *Die Technik der Amplituden-Modulatoren*, Prof. Dr.—Ing. Dietmar Rudolph, December 15, 2009

[16] *Electric State Profiles Map DOE/EIA-0348(01)/2,* U.S. Energy Information Administration, 2009

[17] *Dynamic Carrier Control PWB, NAPX05E/02: Installation and Operating Instructions,* January 3, 2007

[18] *Dynamic Carrier Control Unit, NAX154/NAPX05,* May 15, 2003

[19] *Comparison of CCM Techniques*, J.Fred Riley, Continental Electronics Corporation, IEEE Broadcast Symposium, September 22-23, 1994

[20] *Dynamic Carrier Control, DCC, a Valuable Method to Save Input Power of Medium Wave Transmitters*, Dr. Wolfram Schminke and Hans-Ulrich Boksberger, IEEE Transactions on Broadcasting, Vol. 35, No. 2, June 1989

[21] *Implementation of Amplitude Modulation Companding in the BBC MF National Networks*, C. P. Bell et. al., BBC Engineering Division Report, BBC RD 1988/15, December 1988

[22] *Energy Saving for AM Transmitters*, James Wood, *International Broadcasting*, October 1987

[23] *Radio Engineers' Handbook,* Frederick Emmons Terman, McGraw-Hill Book Company: New York, 1943

[24] *Phone Transmission with Voice-Controlled Carrier Power,* G.W. Fyler, QST January 1935

[25] *Megawatt Misers,* James Wood, International Broadcasting magazine (date unknown)

[26] *Adaptive Carrier Control for DX Transmitters*, Harris

2.3 Symbols and Abbreviations

In this Guideline the following abbreviations are used.

AM	Amplitude Modulation
ACC	Adaptive Carrier Control
AGC	Automatic Gain Control
AMC	Amplitude Modulation Companding
DAM	Dynamic Amplitude Modulation
DCC	Dynamic Carrier Control
DCS	Dynamic Carrier Systems
DSB	Double-sideband
MDCL	Modulation-dependent Carrier Level
MDCLWG	Modulation Dependent Carrier Level Working Group (of the NRSC AFAB Subcommittee)
NRSC	National Radio Systems Committee
FCC	Federal Communications Commission (U.S.)
IBOC	In-Band/On-Channel

N/A Not Applicable
RF Radio Frequency
TBD To Be Determined

2.4 Definitions

In this Guideline the following definitions are used:

Amplitude Modulation Companding (AMC)
An MDCL system which operates with full carrier for no or low modulation and reduces both carrier and sidebands with increasing modulation. Typically the maximum carrier and sideband compression is adjustable between 0 and 6 dB.

Adaptive Carrier Control (ACC)
An MDCL system which operates with reduced carrier for no or low modulation and increases it with modulation. The exact characteristic may be widely adjustable.

Dynamic Amplitude Modulation (DAM)
An MDCL system similar to ACC. DAM originated in Germany in the 1980s.

Dynamic Carrier Control (DCC)
An MDCL system similar to ACC. DCC originated in Switzerland in the 1980s.

Dynamic Carrier Systems (DCS)
A general category of MDCL system characterized by operation with reduced carrier for no or low modulation and increasing carrier with modulation. Dynamic Carrier Systems include Adaptive Carrier Control, Dynamic Amplitude Modulation and Dynamic Carrier Control.

HD Radio™
Trademark (of iBiquity Digital Corporation) for the digital AM and digital FM transmission technology authorized by the FCC. Note that the use of the term in NRSC documents shall be interpreted as the generic term "IBOC" and shall not be construed as a requirement to adhere to undisclosed private specifications that are required to license the HD Radio name from its owner.

Modulation-Dependent Carrier Level (MDCL)
A system for reducing the electrical energy consumption of AM transmitters whereby either the carrier or carrier and sidebands are dynamically reduced as a function of the modulation index.

3 BACKGROUND

3.1 The Purpose of MDCL Systems

The current method of transmitting analog audio information in the medium wave broadcast band in the U.S., as well as the rest of ITU Region 2, is double-sideband amplitude modulation (DSB-AM). For this modulation technique, as the amplitude of the radio frequency (RF) signal is varied in accordance with the modulating signal, the RF carrier level remains constant while the sidebands vary in amplitude and frequency. The total power of the signal at 100 % positive and negative modulation is 50 % greater than that of the carrier. This scheme has been useful for many years because the presence of the constant-amplitude carrier allows for the use of relatively simple and inexpensive, generally diode-based, detectors in the receiver. Since modern receivers work fine with no carrier present, the carrier itself is not as critical a component of the signal as it once was, and consequently it makes sense to reduce the carrier component since a substantial portion of the energy of the transmission is contained in the carrier.

If the carrier amplitude as well as sideband amplitude are varied in accordance with the modulating signal, it is possible to provide approximately equivalent transmission service while reducing the total energy of the transmitting process. Such systems are considered "Modulation Dependent Carrier Level" systems, or MDCL systems.[1]

There are two basic types of MDCL operation. The first reduces the carrier and sidebands to an arbitrary percentage of the nominal power level, and increases the carrier and sidebands with increased modulating signal level up to the nominal power level. The second only modifies the carrier level, using full carrier transmission at low modulation indices, while reducing carrier with increasing modulation level to the point where the total signal amplitude is the same as that of "full carrier."

Each of these two methods provides benefits, in particular reduced power consumption, and are detailed below. Each has some drawbacks, which are also described below, as well as in some detail in the references listed in Section 2.2.[2]

3.2 The History of MDCL Systems

During the same period when high-quality, relatively efficient amplitude modulated transmission systems were developed, early recognition of the benefits of some control of carrier by modulating signal amplitude took place.[3] The first known published description of such a system was in 1934, in the German journal Physik, by Pungs and Gerth. It is not known if tests of the proposal, named HAPUG, were conducted.

The first reported tests were undertaken by the General Electric Co. at their 50 kW medium wave broadcast station, WGY, Schenectady, New York. These were reported without detail in an article in QST in January, 1935. The QST article's purpose was to describe a prototype method for obtaining controlled carrier with class B plate modulation. This was also reported briefly in Terman's classic Radio Engineer's Handbook.

The introduction of modern switched-carrier techniques for generating an AM modulated signal, together with the introduction of solid state high power amplification techniques in the early 1980s, led to reexamination of the possibility of use of modulation-controlled carrier methods. By 1985, modulation-controlled carrier systems were in use in several MF broadcasting stations in continental Europe and the

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[1] The term MDCL was first suggested as a non-proprietary general description of the various methods by J.F. Riley of Continental Electronics at an IEEE BTS Symposium in 1994.
[2] In particular, [19] and [22] discuss the pros and cons of various MDCL systems.
[3] The transformer coupled high level plate modulated class C amplifier, the Doherty load-pulling amplifier, and the Chireix phase-to-amplitude system were all developed in the middle 1930's, and first provided high quality high fidelity high power AM transmission capabilities.

U.K. By the end of the decade, a flurry of publications reported the success of these systems in substantially reducing electrical power consumption costs. The applications tried in continental Europe used various versions of a system called “DAM” (see Section 4.2), operating with reduced carrier for no or low modulation and increasing carrier with increasing modulation depth. The U.K. implementations used a different system, “AMC” (see Section 4.1), in which full carrier is employed with no or low modulation and carrier is reduced with increasing modulation depth. This system was used by BBC on conventional Doherty linear amplifier transmitters as well as those employing switched modulation methods.[4]

Over the past two decades, the use of these systems by HF broadcasters has been widespread. Use of these systems by MF broadcasters has also taken place, particularly at high power installations in Europe and the Middle East where the power savings proved very attractive. By the late 1990s, MDCL techniques were essentially standard operating practice at many if not most HF transmitting stations. Within the past 10 years or so, most if not all major transmitter manufacturers have made the equipment necessary for MDCL operation available as an option and, in some cases, standard equipment with high power transmitters.

3.3 MDCL Systems Commonly in Use

Most manufacturers of modern solid state AM transmitters include optional or standard features that support MDCL operation. Additionally, upgrades for installed transmitters are also available. Harris supports both AMC and ACC for DX, 3DX and DAX series transmitters. Nautel NX series transmitters support MDCL as a standard feature including AMC and Dynamic Carrier Systems. Nautel also manufactures an external Dynamic Carrier Control unit for installation with earlier models. European manufacturers including Transradio and Ampegon offer support for a range of modes including AMC, DAM and DCC. Many transmitters not designed with a “built-in” MDCL capability but capable of being DC-coupled on the analog audio input would likely be able to support MDCL operation, by using an external MDCL adapter (made by various manufacturers).

3.4 Recent Developments in the United States

The U.S. government’s international broadcasting agency, the Broadcast Board of Governors, which operates several high power HF and MF transmitting stations, began using various versions of MDCL systems when they became generally available in the 1980s and 1990s. By 2010 the agency had conducted studies of the relative merits of the systems, and had determined that the BBC type, AMC, provided the most benefits. The system was implemented at 19 of their transmitters, and resulted in very significant reductions in power use. [6]

At approximately the same time, Alaska Public Broadcasting, which provides technical services to public broadcasting stations throughout Alaska, became aware that costs of electrical power, supplied by diesel generators in many cases, were escalating rapidly, particularly in the remote areas of the state. FCC staff, when questioned, indicated that experimental or special temporary authority for MDCL operation would be obtainable. The Alaska agency decided to pursue the possibility of using MDCL methods to reduce these costs, and budget for the necessary tests became available in early 2010. The initial request, for KOTZ in very remote Kotzebue, was filed June 18, 2010, and granted by FCC on June 24th. [7] These tests, and subsequent tests by KDLG, Dillingham later that year, were so successful that a general request for experimental authority for all Alaska public broadcasting AM stations was filed with the FCC in March, 2011.

[4] The two publications which provide the most succinct descriptions of these two systems are both contained in Vol. 35, No. 2, the June ,1989 IEEE Transactions on Broadcasting. They are: Bell & Williams, “Implementation of Amplitude Modulation Companding in the BBC MF National Networks,” and Schminke & Boksberger, “Dynamic Carrier Control, DCC, A Valuable Method to Save Input Power of MF Transmitters.”

3.5 The FCC Experimental Authorization and Waiver Process

Although historically the FCC has required AM stations to operate with 5 % or less (at 100 % modulation) “carrier shift,” *i.e.*, reduction (or increase) in carrier amplitude, this rule was eliminated sometime in the 1980s.[5] Subsequently, the principal FCC rule requiring waiver in order to operate with any of the MDCL methods was 47 CFR §73.1560(a), the rule requiring AM broadcasting stations to maintain operating power within +5/-10 % of authorized power.

Following the successful test conducted by Alaska public broadcasting stations and the March 2011 general Alaska waiver request, the Commission staff determined that a general waiver for any AM station desiring to implement MDCL was desirable. The official announcement of this policy was made on September 13, 2011. [8] The Public Notice contains a succinct explanation of the MDCL methods, refers to recent transmitter manufacturer technical data, points out that the National Radio Systems Committee (NRSC) has undertaken to study compatibility of MDCL with hybrid AM in-band/on-channel (IBOC) digital radio, and contains a caveat requiring operation with full carrier when field intensity measurements are being conducted.

The FCC also requires that the transmitter achieve full licensed power at some audio input level, or when the MDCL is temporarily disabled. This requirement will permit stations to use energy-saving MDCL technologies, which preserve licensed coverage areas, while distinguishing between such operations and simple reductions in transmitter power, which do not preserve the licensed coverage area. The FCC will permit AM stations broadcasting in hybrid AM IBOC mode to implement energy-saving MDCL technology provided the hybrid signal continues to comply with spectral emissions mask requirements in Section 73.44, and also provided that the relative level of the analog signal to the digital signal remains constant. It also provides specific instructions for submitting an MDCL waiver request.

Subsequent to the issuance of the Public Notice, a modest number of AM broadcasting stations have implemented MDCL operation. To date, all public reports from these users of MDCL have been favorable, and have noted significant electrical power savings.

3.6 Receiver Topics Overview

When the FCC initially announced that it would permit AM stations to use MDCL technologies, the initial Public Notice [8] expressed some concern about the following possible issues:

- Audio distortion
- Reduced receiver SNR
- Reduced coverage area

However, the Public Notice indicates that these effects are ”generally imperceptible.“ Various MDCL technologies have been in use in Europe for years, and as a result there is some experience base for receiver compatibility. This experience shows that MDCL generally is acceptable or unnoticeable to the consumer. Note, however, that the European experience base generally applies only to analog AM transmission, not hybrid AM IBOC transmission. Compatibility of MDCL with hybrid AM IBOC transmissions has not yet be rigorously tested. Despite this, some points can be made about MDCL, AM analog reception and hybrid AM IBOC reception:

- In all AM systems, any change in carrier power is tracked by the receiver’s AGC. If the MDCL system’s rate of carrier power change is significantly slower than the AM modulation, the MDCL variations will not fall in-band to the audio AM modulation;

[5] Within the jurisdictions of other administrations (outside of the U.S.), carrier shift rules may still be in effect.

- Carrier power modulation is not necessarily symmetric on the attack and decay. In this context, ”attack“ refers to the rise of carrier power; ”decay“ refers to the drop in carrier power as part of the MDCL algorithm;

- At least one MDCL algorithm has a fast attack time (goes high quickly) and a relatively slow decay time (goes low more slowly);

- For IBOC reception, different algorithms have different behavior, depending on whether the IBOC subcarriers are power-modulated along with the analog carrier.

4 DESCRIPTION OF ALGORITHMS

MDCL algorithms can be classified into two categories. The first category consists of a single system, Amplitude Modulation Companding (AMC), for which both the carrier level and the sideband level are dynamically reduced together. For the second category, Dynamic Carrier Systems (DCS), only the carrier is dynamically reduced and the sideband power remains constant at the normal AM level. A number of systems fall into this category.

The performance of MDCL algorithms depends strongly on the audio source material and the audio processing. In some cases where the audio has been processed to increase the loudness levels significantly, high positive peak modulation levels may occur very regularly, *i.e.*, many times per second. Under these conditions the MDCL algorithm may saturate (due to the fast attach - slow decay modulation detector) and the carrier power will reach a relatively static state near the 100% modulation point on the carrier compression function. For the AMC mode this behavior may be very similar to AM with reduced carrier power and for DCS modes, this behavior may be very similar to AM at full carrier power.

4.1 Amplitude Modulation Companding (AMC)

The AMC system reduce the level of the carrier and sideband together as the instantaneous audio level is increased. The degree of signal compression can vary typically from 6 dB to 1 dB with 3 dB used commonly. The exact compression functions are shown in Figure 1 for 1, 3 and 6 dB compression levels.

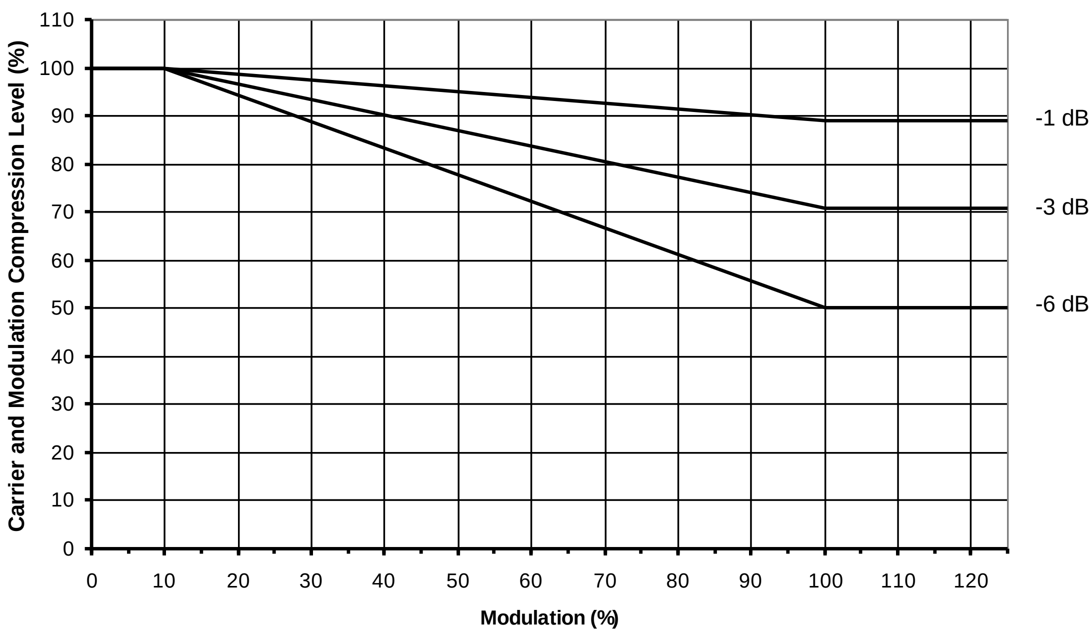

Figure 1. Amplitude Modulation Companding (AMC) compression function.

The compression characteristic is defined as follows: from 0 to 10 % modulation there is no compression (0 dB); from 10 % to 100 % modulation the compression increases linearly to full compression at 100 % modulation; from 100 % modulation to maximum peak modulation, the compression is maintained at the full level. It is important to note that the compression levels shown in Figure 1 are in voltage units and the values should be squared to determine power levels. For example, the -3 dB AMC characteristic reduces the signal to 71 % (voltage or current) at 100 % modulation and above, which is equivalent to a 50 % power reduction.

Other general characteristics of AMC include the following:[6]

- Time domain behavior: the implementation requires that different time constants are used for the attack and decay of the detected audio/modulation level;
- Attack time: the detected modulation level is increased with a fast attack time of approximately 1 ms. The filter used to implement the fast attack time is normally a simple exponential filter; however, it may be beneficial to use a finite impulse response filter that will settle more quickly for the decay implementation. A low overshoot implementation such as a Gaussian filter is recommended;
- Decay time: the detected modulation level is decreased with a slow attack time of approximately 250 ms;
- A key performance aspect of AMC systems is that there is no change in the perceived loudness of the signal. This is a consequence of the carrier and sideband levels tracking, unlike the systems which fall into the second category (DCS) where only the carrier level is being modified.

4.2 Dynamic Carrier Systems (DCS)

Generally, all systems other than AMC including Adaptive Carrier Control (ACC), Dynamic Amplitude Modulation (DAM), and Dynamic Carrier Control (DCC) fall into the DCS category. These systems reduce the carrier power dynamically but leave the transmitted sideband power unaffected, and they reduce the carrier power at low modulation levels and return the carrier to full power as modulation is increased. In general, the carrier level should never be reduced to the point where there is insufficient carrier to support negative modulation without clipping and distortion. These systems save more energy in quiet periods, as opposed to AMC which saves more energy during loud periods.

A characteristic that all systems in the DCS category share is the effect on received signal intensity which will likely impact loudness perception. In the receiver, the AGC will keep the carrier level constant. When the carrier is reduced at the transmitter, the gain at the receiver is increased causing a corresponding increase in loudness. AMC systems do not exhibit this behavior because the sidebands and carrier are always reduced together.

For DCS, time domain behavior typically has a fast attack time of 1 ms and a slow decay time of approximately 250 ms. While there are several different system names employed by manufacturers, the operation of these systems are very similar to one another with the primary differences being in the carrier compression functions. Two example systems are shown in Sections 4.2.1 and 4.2.2 below.

4.2.1 <u>Dynamic Carrier System Example 1</u>

In this example, the maximum carrier compression is 4 dB, between 0 and 60 % modulation (see Figure 2). Above 60 %, the carrier voltage is increased linearly to 100 % at 95 % modulation. The carrier compression between 60 % and 95 % is very close to the maximum possible compression. For example, at 70 % modulation, the carrier is compressed to approximately to 74 % with 70 % being the limit. The actual modulation depth realized at this point on the curve will be very close to 100 % (the modulation depth is increased as the carrier is reduced). Below 60 % modulation, the carrier compression of 4 dB is relatively large. Overall, this example system has relatively aggressive compression characteristic resulting in relatively greater power savings.

[6] Note that there may be some differences between implementations currently in use.

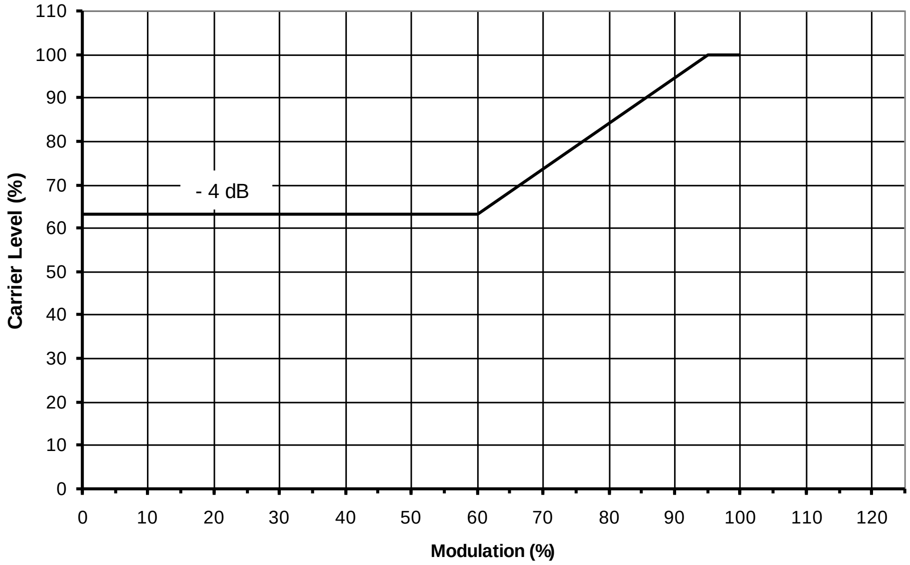

Figure 2. DCS example 1 – carrier compression function

4.2.2 Dynamic Carrier Example 2

The carrier compression characteristic of the second example system is shown in Figure 3. This system has a maximum compression of 4.44 dB between 20 % and 40 % modulation. Below 20 % modulation, the carrier compression is reduced, with the carrier level at 80 % of its normal value during silent periods with no modulation. The reason for this increase in carrier level during quiet periods is that background noise is most perceptible when the program audio is quiet. To mitigate the increase in noise, the carrier is increased slightly. Between 40 % and 80 % modulation, the carrier is linearly increased to 100 % of its nominal value. Above 80 % modulation, the carrier remains at 100 %.

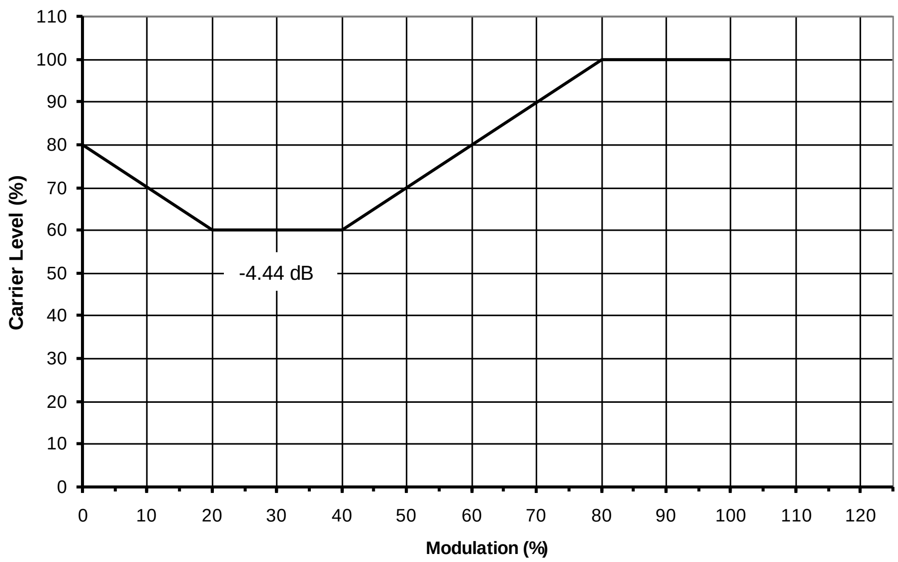

Figure 3. DCS example 2 – carrier compression function

4.2.3 **Power Savings Comparison**

Energy savings will vary between MDCL systems and will also be affected by the audio program material and audio processing. Table 1 shows energy savings predictions for several different audio samples. The performance of 3 dB AMC and the two examples of Dynamic Carrier Systems were compared to standard AM. Note that these examples all use talk format audio material and that the results for music format audio material would be different.

Table 1. Energy savings performance

Sample 1 - VOA Greenville English		Sample 3 - VOA Greenville Spanish	
MDCL Version	Average Signal Power	MDCL Version	Average Signal Power
AM	100%	AM	100%
AMC 3dB	63.5%	AMC 3dB	60.1%
DCS Example 1	84.2%	DCS Example 1	91.0%
DCS Example 2	76.7%	DCS Example 2	79.7%

Sample 2 - VOA Greenville Portuguese		Sample 4 - Clear Channel WSYR Talk Format	
MDCL Version	Average Signal Power	MDCL Version	Average Signal Power
AM	100%	AM	100%
AMC 3dB	60.1%	AMC 3dB	58.6%
DCS Example 1	88.7%	DCS Example 1	89.2%
DCS Example 2	81.5%	DCS Example 2	81.2%

A computer simulation was used to estimate the system performance indicators shown in Table 1. Audio source files, recorded after audio processing, were processed using a computer model of each algorithm and the average power levels of the modified signals were measured. The average signal power shown in Table 1 is referenced to normal AM operation as 100%. If the Average Signal Power in Table 1 is 60%, a 40% reduction in electrical power consumption should be expected. While the performance of individual transmitters may vary from these estimates, it is expected that the results shown in the table are a good indication of the expected electrical energy savings of modern transmitters assuming the compression levels simulated. Note that more aggressive use of MDCL (*i.e.*, higher levels of compression) may not result in commensurate power savings due to efficiency limitations of the transmitter.

All transmitters will have a reduction in AC to RF power efficiency as output power is reduced. For older transmitters, such as those using tube amplifiers, the low power reduction in efficiency will be more substantial than modern transmitters. For transmitters where low power efficiency is reduced more substantially, the AC power savings performance will deviate to a larger extent from the predictions in Table 1.

5 IBOC COMPATIBILITY

5.1 Definition of how IBOC and MDCL are used together

There are two ways in which an MDCL system may be implemented for hybrid AM IBOC. In the first way, the MDCL compression has no effect on the IBOC subcarriers. In the second way, the IBOC subcarriers are reduced in power together with the AM carrier. The relative advantages or disadvantages of having the IBOC carrier insertion level track the analog carrier level need to be further investigated, but it assumed that:

- If the IBOC carriers are reduced with the AM carrier, then a small additional power savings may be realized at the expense of a small reduction in IBOC coverage;
- If the IBOC carriers are not reduced with the AM carrier, then a small amount of additional digital IBOC interference into the analog host modulation may be expected.

Different commercially-available implementations of hybrid AM IBOC / MDCL may or may not support one or the other of these approaches. The FCC's September 2011 Public Notice [8] will permit AM stations broadcasting in hybrid AM IBOC mode to implement energy-saving MDCL technology provided the hybrid signal continues to comply with spectral emissions mask requirements in Section 73.44, and also provided that the relative level of the analog signal to the digital signal remains constant.

5.2 Transmitter linearity

Modern AM solid state transmitters use two or more different methods to produce amplitude modulation. In all cases, the approach requires that the desired RF signal be separated into an audio frequency (<100 kHz) envelope and an RF frequency carrier with phase information. These two separate signals are amplified using different processes before being recombined in the RF amplifier to produce the desired RF signal. This method of amplification, Envelope Elimination and Restoration (EER), is used to improve transmitter efficiency. As a result of using the EER method, modern AM transmitter efficiencies are generally on the order of 80–90 %.

However, EER has tradeoffs which include non-linear effects that generally cause some increase in out-of-band emissions. These non-linear effects are typically made worse when antenna systems deviate significantly from ideal impedance levels. Depending on the individual transmitter and antenna system, some broadcasters may have challenges meeting the regulated emissions mask.

A key element of MDCL is that the carrier level is reduced and for the Dynamic Carrier Systems (DAM, DCC, and ACC), the modulation depth can be significantly increased. For modern AM transmitters using EER, the changes in modulation depth and reduction in carrier levels can have negative effects:

- Reducing absolute signal level will force the transmitter to spend more time operating at low levels;
- Because AM/AM and AM/PM transmitter nonlinearities generally increase as power decreases, the intermodulation levels and out of band emissions will generally increase;
- When the AM component of the signal is decreased, the bandwidth of the RF phase and envelope signals is generally increased;
- Because the amplification processes for RF phase and envelope have bandwidth limits, increasing signal bandwidths may result in an increase in intermodulation and out of band emissions.

Considering the effect that MDCL has on the signal, as well as the practical limitations of transmitter technology, caution is advised when implementing hybrid AM IBOC with MDCL. In particular, some increase in out-of-band emissions should be expected. For the same reasons outlined above, some reduction of IBOC signal quality may also be expected.

6 FUTURE WORK

The NRSC is interested in expanding this Guideline in the future to include information on the following topics:

- Field test results and case studies of MDCL deployment;
- Interaction of MDCL technologies with the Arbitron Portable People Meter (PPM) audience measurement system;
- Recommended use – recommendations regarding the setup and operation of specific implementations of MDCL systems;
- Compatibility with AM IBOC.

Readers who are interested in contributing to these future sections can contact the NRSC at nrsc@nrsc.org.

NRSC Document Improvement Proposal

If in the review or use of this document a potential change appears needed for safety, health or technical reasons, please fill in the appropriate information below and email, mail or fax to:

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URGENCY OF CHANGE: _____ Immediate	_____ At next revision
PROBLEM AREA (ATTACH ADDITIONAL SHEETS IF NECESSARY): a. Clause Number and/or Drawing: b. Recommended Changes: c. Reason/Rationale for Recommendation:	
ADDITIONAL REMARKS:	
SIGNATURE:	DATE:

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Date forwarded to NAB Tech: ______________________________

Responsible Committee: ______________________________

Co-chairmen: ______________________________

Date forwarded to co-chairmen: ______________________________

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