Notes on IBOC Power Increase

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Purpose

Many questions are being asked by customers regarding the widely reported efforts to increase the current standard one percent FM IBOC injection levels to 10% of carrier power.

This document is intended as basic guidance for station engineers to assist in planning and designing transmitter installations for today's one percent IBOC injection levels, while protecting their investment when and if a power increase is authorized.

Transmitter De-Rating with increased IBOC levels

The first difficulty encountered in increasing the IBOC carriers is the fact that the transmitter's available output must be de-rated to accommodate them. The more the IBOC carriers are increased, the more the transmitter must be de-rated. Due to the high power, bandwidth and a 5-6 dB effective peak to average AM component of the IBOC carriers, HD Radio™ transmitters must be de-rated from their saturated FM (CW) only maximum transmitter power output (TPO) when operating FM+HD or HD only.

For example, Harris currently rates the Z-16HD up to 8 kW of common amplification power at -20 dB (one percent) injection level. By increasing the IBOC injection ratio from -20 dBc to -10 dBc (10 percent), we must de-rate the maximum power output of the Z16 must be de-rated by 53 percent to 4.3 kW.

For HD-only operation, the power, bandwidth and AM modulation depth is increased even further, but without the constant envelope analog signal present, the maximum available TPO is reduced even further. The Z16 is rated at 3.5 kW of HD-only at -20 dBc.

At -10 dBc injection, the inter-modulation products need to be suppressed an additional 10 dB (100x) from that needed at -20 dBc to maintain mask compliance. If one applies a 2:1 ratio of third order levels to fundamental level, that would call for a drop of 5 dB in the fundamental to get the additional 10 dB IMD headroom. Due to the occasional clipping mode of operation, an additional 3 dB of back off (50 percent) is needed to maintain the same IMD and NRSC mask compliance when the sidebands are raised to the -10 dBc levels.

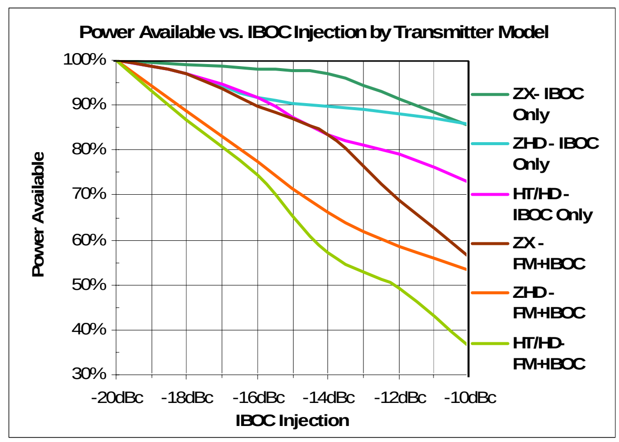

Figure 2 - Transmitter De-Rating Graph

The chart in Figure and the graph in Figure 2 may be used to calculate the expected TPO for each of the Harris FM HD Radio™ transmitters at injection levels of -20 dBc to -10 dBc. These figures assume a minimum of 3 dB of headroom below RF mask limit of 74.4 dBc.

Additional Headroom for Extended Hybrid Modes

All tests and measurements were performed in HD Radio™ MP1 mode. As the HD mode is changed

Harris Transmitter	FM+HD Common Amplification TPO						HD-Only Separate Amplification TPO					
	-20dBc	-18dBc	-16dBc	-14dBc	-12dBc	-10dBc	-20dBc	-18dBc	-16dBc	-14dBc	-12dBc	-10dBc
ZX500	400	388	359	333	276	225	200	174	160	140	120	100
ZX1000	850	825	763	708	586	478	400	396	392	388	366	342
ZX2000	1650	1601	1481	1374	1138	928	775	674	622	543	465	388
ZX3500	2800	2718	2513	2332	1930	1575	1350	1175	1083	945	810	675
Z4HD+	1650	1394	1271	1093	982	817	775	753	711	695	682	664
Z6HD+	2800	2663	2325	1988	1751	1598	1350	1275	1204	1178	1155	1125
Z8HD+	4000	3380	3080	2650	2380	1980	1750	1650	1580	1560	1410	1250
Z12HD+	6000	5325	4650	3975	3503	3195	2600	2550	2408	2355	2310	2250
Z16HD+	8000	7100	6200	5300	4670	4260	3500	3400	3210	3140	3080	3000
ZD24HD+	12000	10650	9300	7950	7005	6390	5200	5100	4815	4710	4620	4500
ZD32HD+	16000	14200	12400	10600	9340	8520	7000	6800	6420	6280	6160	6000
HT/HD+	25000	21700	18600	14300	12300	9100	9600	9300	8800	8000	7600	7000

Figure 1 - Maximum TPO for IBOC Injection Levels

from MP1 to MP2, MP3 or MP11, we must further de-rate the transmitter due to the increasing spectral bandwidth density and average power of the IBOC sidebands. If the mode is switched from MP1 to lsMP11, while maintaining an overall injection level of -20 dBc, the Z-16HD would be capable of 7.5 kW of common amplification power, or a six percent

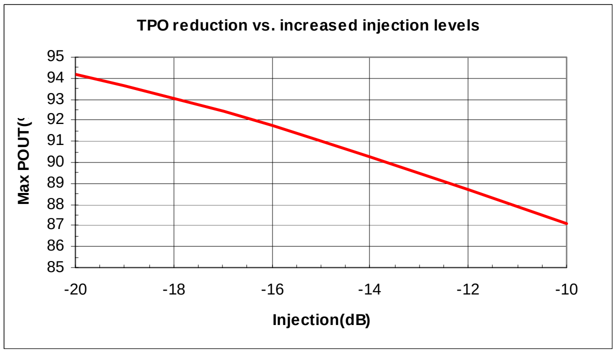

Figure 3 - TPO Reduction vs. Increased Injection Levels

reduction. At -10 dBc, the back off would be 13 percent or about 7.1 kW. The chart in Figure above includes 3 dB of RF mask headroom which should accommodate all present and future IBOC service modes. The graph in **Error! Reference source not found.** illustrates the de-rating necessary for MP11 versus increased IBOC sideband injection.

Analog/IBOC Combining Techniques Applied to Increased IBOC Sideband Power

Common Amplification

Common amplification uses a single linearized (Class AB) amplifier for both the analog FM and the IBOC signal. Common amplification has been a popular choice for stations with TPO requirements below 8 kW using the ZD16. Many stations are on the air using this method for more than 10 kW using the ZD24, 15 kW using the ZD32 and up 25 and 50 kW with single and dual HT/HD+ systems.

As the IBOC injection is increased from -20 to -10 dBc, more of the available power is needed for the increasing peak-average IBOC AM component. Also, greater headroom is required to maintain NRSC mask compliance due to the non-linearity of the class AB amplifier. The amplifier must be de-rated by about 42 percent of that available at -20 dBc. Adding a second matching transmitter using a 3 dB combiner coupler will in many cases achieve the required 10 dBc power increase.

Example 1 Licensed TPO of 7.5 kW, -20 dBc Common Amp configuration running a Z16HD+ capable of 8,000 watts max TPO

When the station decides to increase IBOC injection to -10 dBc, the same common amp configuration can be used efficiently by adding a second Z16HD+ and a 3 dB combiner delivering about 8,300 watts maximum

Example 2 – With a licensed TPO of 23.5 kW in a -20 dBc common amp configuration with an HT/HD+ running 23,500 watts licensed TPO, adding a second HT/HD+ through a 3 dB combiner would not enable the station to achieve -10 dBc as this would only deliver about 17.8 kW. At -14 dBc however, this configuration would be capable of about 24 kW.

Due to the steeper de-rating curve of a tube transmitter, the HT/HD+ power output is limited to around 9 kW or lower per cabinet at -10 dBc, but the power per cabinet quickly increases at lower injection levels.

This method of combining will likely remain a viable option for lower power installations with TPOs of 8 kW or less, or at something less than -10 dBc (10 percent) injection levels. See Figure for references to other power levels and injection ratio combinations

Separate Amplification and High Level Combining

High level combining becomes exponentially more difficult to implement as the IBOC to analog ratio increases. Due to the higher peak-average power of the IBOC only signal, the digital only transmitter TPO must be de-rated by approximately 1/3 of the FM only rating..

Typically, high-level combining is accomplished using separate analog and digital amplification and a 10 dB hybrid combiner, in which 10 percent of the analog power and 90 percent of the digital power is sent to the reject load and wasted as heat.

For a 20 kW station running a high-level combined system at -20 dBc, in order to produce the necessary 200 watts of IBOC, a 2200-watt digital transmitter is required and a combined total of 4,022 watts would be sent to the reject load. Based on the chart in Figure , a Z12HD+ would be an appropraite choice.

Lic. TPO 20,000 Watts		Combiner -10 dBc
HD Injection dB	**HD Power Watts**	**Reject Watts**
-20	2,000	4,022
-18	3,170	5,075
-16	5,024	6,744
-14	7,962	9,388
-13	10,024	11,244
-12	12,619	13,579
-10	20,000	20,222

Figure 4 – TPO Wattage/Combiner Totals

For -10 dBc IBOC injection on the same station, based on the calculations above, 20,000 watts would need to be produced by the digital transmitter for 2,000 watts on air, and a total of 20,222 watts would be rejected as heat. High-level combining is not practical in terms of capital expense or operating efficency for increasd IBOC injection.

At lower injection levels, or using other combining schemes and ratios, some use may still come from this technique. Research is currently underway in these areas.

Separate Amplification and Space Combining

Separate amplification and space combining using separate antennas remains the most efficient and cost-effective method of combining the IBOC and FM analog signals.

For a 10 kW ERP station to run IBOC at -20 dBc, a 100-watt (after line losses) linearized transmitter and a 2-bay (gain of 1) antenna are all that is required, so long as the isolation between the antennas is 30 dB or greater. At -10, that same station will need to deliver 1000 watts of digital power to the antenna and isolation between the analog and digital must be 10 dB greater, or 40 dB. A circulator may be required to provide sufficient isolation between the digital and analog transmitters.

High-level combined stations currently operating at -20 dBc will be able to use their existing digital transmitter for space combining, as it is already operating at -10 dBc with 90 percent of the power being sent to the reject load.

Space combining is not without drawbacks however. The IBOC antenna must be within 70-100 percent of the HAAT and within 3 seconds Lat/Lon of the main antenna. Gain and pattern of the digital antenna must be carefully matched. Ferrite circulators may be required, which can be very expensive, particularly at high power levels.

Various antenna manufacturers have dual feed and inter-spaced antenna systems that promise to handle the increased digital power and provide adequate isolation.

Split Level Combining.

Split level combining becomes a more difficult technique to implement because as sideband levels increase, the significantly higher IBOC/Analog ratio's peak-average demands more of the transmitter's available power. The maximum digital-to-analog ratio that can be obtained with current solid-state transmitter technology, and still maintain NRSC mask compliance is about -4 dBc, which is not sufficient to provide efficient split level combining for more than a modest increase of 2-3 dB overall IBOC carrier levels. For all practical purposes, split-level combining does not appear to be a viable or practical solution for increased IBOC levels greater than -18 dBc. This is still better than high-level at lower injection levels, so the book is certainly not closed on the subject.

Conclusions

These guidelines are a "work in progress." Harris continues to evaluate existing technologies and explore new opportunities to improve the IBOC system as developments unfold. For the most part, simply adding a second IBOC transmitter will, at the very least, support injection levels of -12 to 13 dBc and in many scenarios will make -10 dBc. There will be a trade off as to what lengths one will be willing to go in order to make the full -10 dBc level. It seems obvious that current combiner technology does not easily support the demands of increased IBOC levels. As powers are increased, efficiency will become a much larger concern. The inefficiencies of any of the high-level combining schemes make them unlikely candidates for successful implementation at significantly increased levels. It is likely that antenna space combining will become a popular method of deployment and most efficient, particularly for high power installations.

Harris will continue to keep you informed of progress as all the various scenarios are explored.

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