

# High Level IBOC Combining Methods for Single Input Antenna Systems

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**Abstract** - Combining separate analog and HD Radio FM transmitters into a single antenna allows broadcasters to use existing equipment including transmitters, transmission line, and antennas; however, the options for accomplishing this are limited. A new method of high level analog/FM HD combining is discussed and compared to the other traditional methods.

## INTRODUCTION

Combining two frequencies in close proximity is a difficult engineering challenge, especially when trying to maintain high efficiency, flat group delay, low input VSWR, and high transmitter to transmitter isolation. A typical two frequency FM multiplexer can combine two stations 800 kHz apart. This would use two 4-pole filters with a cross coupling from the one-to-four cavities. The worst case scenario would be 0.75% bandwidth separation combining 107.1 MHz and 107.9 MHz. The IBOC combiner attempts to implement a much narrower bandwidth separation of 0.04%. This can be accomplished either with a 10 dB hybrid coupler or with a filter solution using one of two methods. The first method is by using bandpass filters as described in [3] and [4]. The second approach is by using all pass filters, a method not previously introduced. The all pass filter approach is capable of operating with the HD transmitter at -10 dB of the analog carrier.

## THEORY OF OPERATION

The heart of this approach lies with the notch filter cavity. The resonant frequency of the cavity will provide a phase shift of 180 degrees, and a tapering phase shift on the adjacent frequencies. Fig 1 shows a typical response for S11 group delay and S11 phase. A shallow notch, typically -1 dB, is used to gain a broader phase response.

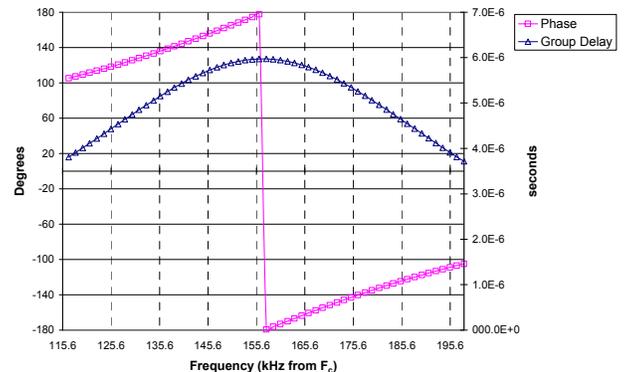


FIG 1 NOTCH FILTER GROUP DELAY AND PHASE RESPONSE

When a module composed of two identically tuned notch filters and a 90 degree hybrid coupler is constructed, it is normally known as a group delay module. That is, the device is typically used to correct for high levels of group delay in a filter system by creating the opposite group delay response. This module is typically inserted just before a filter or just after an exciter to provide extra correction at high power levels. For this new device, a different tuning method is used on this existing technology. Instead of stagger tuning the notch filters to create a response to correct for group delay, the notch filters are tuned identically to provide the same group delay and same notch depth. This insures that the short circuit seen by the hybrid is the same. When this approach is taken, the 90 degree hybrid coupler is capable of maintaining an excellent input VSWR while passing a high percentage of the power to the output port. Since there are two sidebands for HD, two of these modules are required to accomplish the performance required.

A constant impedance effect is typically used on band pass filters. This is done by carefully tuning two filters so they match as closely as possible for return loss and insertion phase. The filters are then connected together by two 90 degree hybrids. The hybrids allow several things to occur. First, the power is split so each filter only sees 50% of the power. Second, all of the power enters one port and exits an opposite port on the second hybrid. The remaining two ports are isolated and see very little power.

This concept has been adapted to the all-pass circuit. By connecting the two group delay modules and placing them in the same leg of a constant impedance circuit, we

can insure that the group delay modules only see half of the input power. As stated earlier, a shallow notch is used to produce the desired response. As a system, the losses will only be half that of the tuned notches because only 1/2 the applied power incurs losses in the group delay modules. This is important since group delay modules typically produce heat. The second leg of the constant impedance circuit can be connected by using a critical length of transmission line. This line can be phased so that the analog and digital insertion loss is minimized.

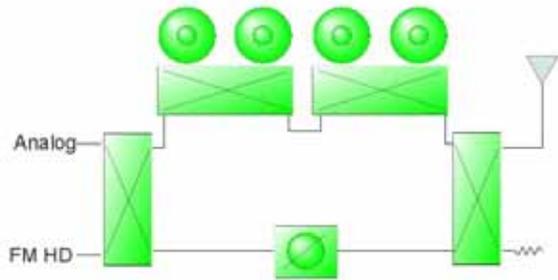


FIG 2 OVERVIEW SCHEMATIC OF ALL PASS

**DATA COMPARISON**

So how does all of this compare to what has been available? There have been two types of solutions in the past this design competes with. The 10dB High-level Injector and the HD Mask Filter are both in use today. These approaches have been written about at length in the past, and are not the topic of this article. See [1]-[4] for further information on these approaches. See Table 1 for efficiencies of these other approaches. Also note the total power generated from each approach, in order to reach the correct ERP. The all pass filter has a slight efficiency advantage overall. The integrated loss is defined as the average insertion loss across the frequency spectrum that is used for an application.

Table 2 shows the group delay comparisons between the different methods of combining. The all pass filter shows a significant improvement over the mask filter.

TABLE 1 EFFICIENCIES COMPARISON

	FM Analog All Pass	FM HD All Pass	FM Analog Mask Filter	FM HD Mask Filter	FM Analog 10 dB Injector	FM HD 10 dB Injector
Input Power (dB from Analog Carrier)	0	-10	0	-10	0	-10
TPO Transmitter (Watts)	32,518	4,094	34,050	3,777	33,344	30,000
Integrated Loss	-0.35	-1.35	-0.55	-1	-0.46	-10
Efficiency	92.3%	73.3%	88.1%	79.4%	90.0%	10.0%
TPO Combiner (Watts)	30,000	3,000	30,000	3,000	30,000	3,000

TABLE 2 GROUP DELAY COMPARISON

	FM Analog All Pass	FM HD All Pass	FM Analog Mask Filter	FM HD Mask Filter	FM Analog 10 dB Injector	FM HD 10 dB Injector
Group Delay (MP3)	350 ns	600 ns	1.26 μs	9.87 μs	0 ns	0 ns

Fig 3 and Fig 4 show responses of the HD mask filter and all pass filter. Even though there are some differences, the efficiencies remain very close. The HD insertion loss response is the most variable. The mask filter gives a tapered attenuation response as the frequency approaches the analog carrier, while the all pass filter response has a maximum in the center of the digital side band. Fig 5 and Fig 6 show the corresponding group delay plots with respect to their insertion response plots.

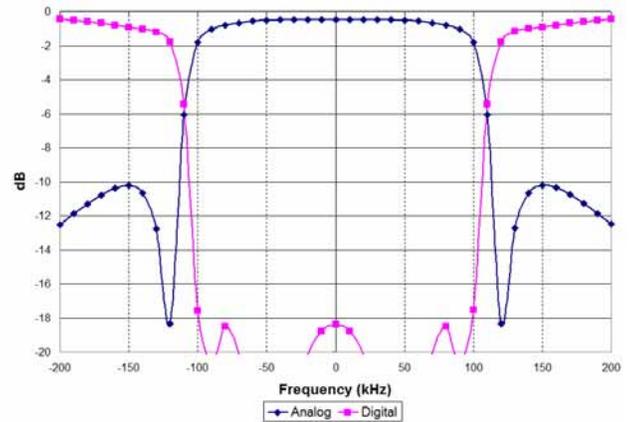


FIG 3 FM HD MASK FILTER INSERTION RESPONSE

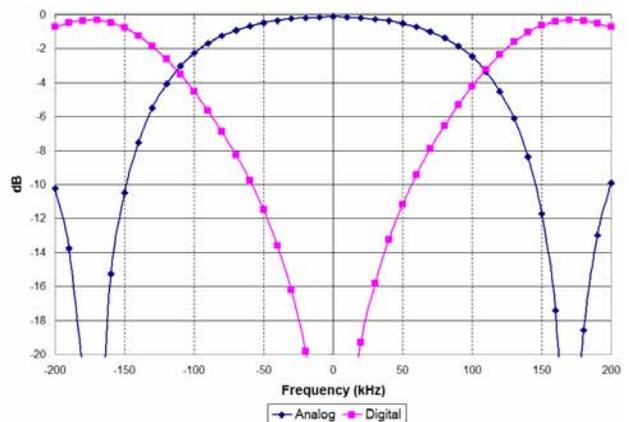


FIG 4 FM HD ALL PASS FILTER INSERTION RESPONSE

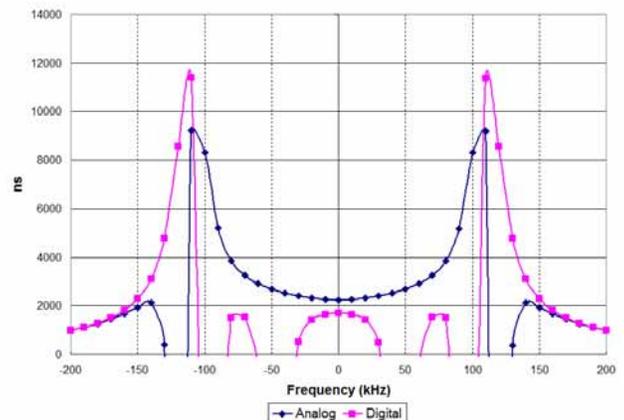


FIG 5 FM HD MASK FILTER GROUP DELAY

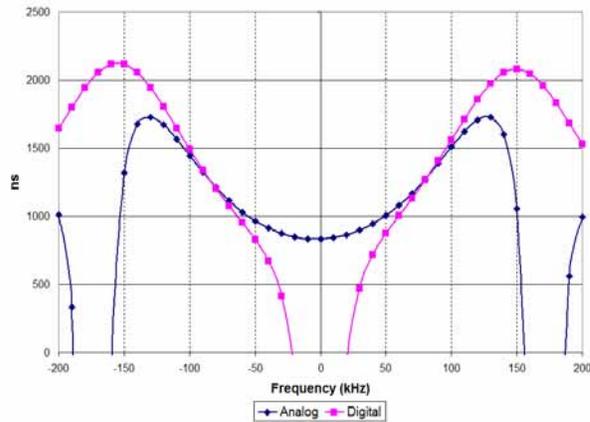


FIG 6 FM HD ALL-PASS FILTER GROUP DELAY

### CONCLUSIONS

The all pass filter combiner approach has been described and compared to the -10 dB injector and FM HD Mask filter approaches. It has higher efficiency than the -10 dB coupler and HD mask filter, and improves group delay performance for both transmitter inputs while maintaining high efficiency. This approach presents a new viable approach for combining high level analog and HD transmitters to be operated from a single antenna.

### REFERENCES

- [1] Liebe, R, F, and Surette, R, A, "Combining digital and analog signals for US IBOC FM broadcasting," *IEEE Transactions on Broadcasting*, vol. 48, no. 4, pp. 361-364, Dec. 2002.
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