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Radio TechCheck

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New Method for High Level IBOC Combining Described at NAB Show

As noted in the April 23, 2012 edition of *Radio TechCheck*, a new high efficiency FM analog/IBOC diplexer was described in a presentation at the NAB Broadcast Engineering Conference at the 2012 NAB Show. A companion technical paper entitled "High Level IBOC Combining Methods for Single Input Antenna Systems" authored by Nicholas A. Paulin and Thomas B. Silliman, P.E., Electronics Research, Inc., excerpted below, is included in the *2012 NAB Broadcast Engineering Conference Proceedings*.

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. 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.

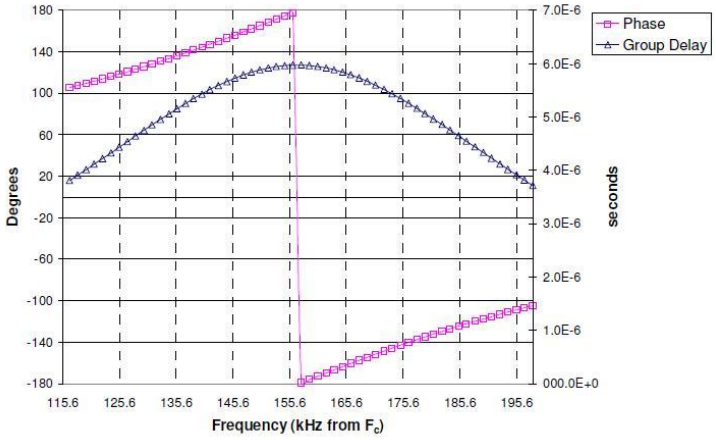

FIG 1 NOTCH FILTER GROUP DELAY AND PHASE RESPONSE

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 ½ 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.

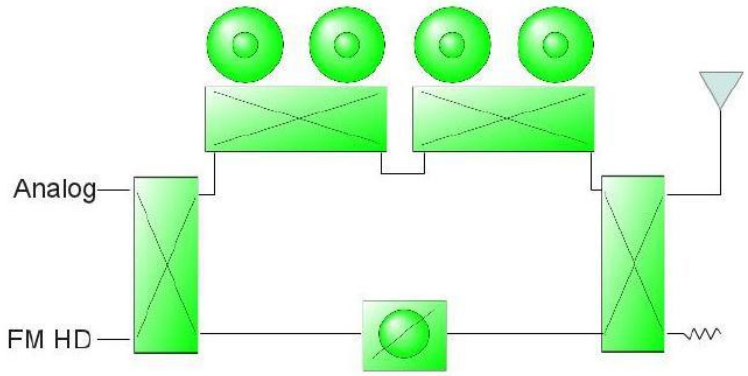

FIG 2 OVERVIEW SCHEMATIC OF ALL PASS

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)	33,046	4,094	34,050	3,777	33,344	30,000
Integrated Loss	-0.42	-1.35	-0.55	-1	-0.46	-10
Efficiency	90.8%	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)	500 ns	900 ns	1.26 µs	9.87 µs	0 ns	0 ns

The complete paper is included in its entirety in the 500+ page *2012 NAB Broadcast Engineering Conference Proceedings*, available online from the NAB Store (www.NABStore.com) as a book+CD-ROM combination or CD-ROM-only version.