ACTIVE INTERFERENCE CANCELLATION

Technologies Comparisons

Abstract

A performance survey of the active interference cancellation technique based on different technologies.

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Introduction

In the method of active interference cancellation, also known as signal nulling, an inverted copy of a signal is added to the original signal, and the signals cancel each other out. In other words, cancellation of a given signal can be achieved by combining a signal with an inverted copy of itself. For the signal to be perfectly canceled, this inverted copy must be an exact replica of the original signal (except for the relative inversion). The operating principle is illustrated with a simple sine wave, as shown in Figure 1. In practice, when the signal has a certain bandwidth and is dynamically changing, it is non-trivial to provide a consistent and high level of cancellation. The theoretical calculation of the cancellation versus precision requirements in attenuation and phase shift, shown in Figure 2, indicates that to achieve more than 60 dB of cancellation, the amplitude must be matched within 0.01 dB and the phase shift within less than 0.1 degree. To achieve uniform broadband operation, such precision in both variables have to be maintain for all the frequencies within the bandwidth. Below, we compare the different technologies at various development stages that provide signal nulling for a self/co-site interference scenario, where there is the advantage that the transmit signal is known and readily available.

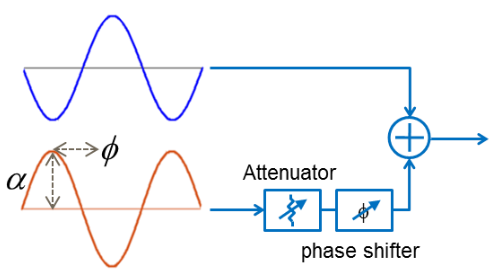

Figure 1: Operating principle of active interference cancellation.

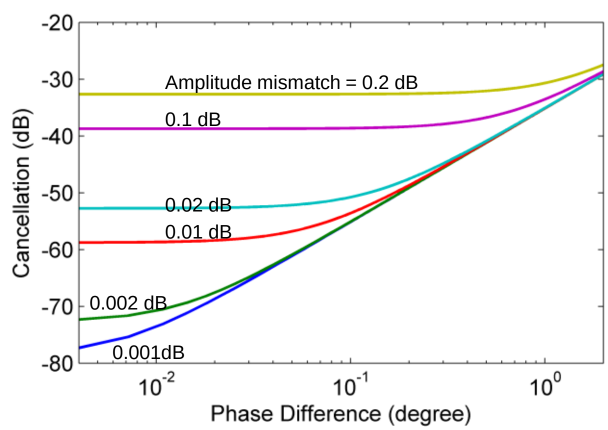

Figure 2: Theoretical cancellation vs. precision in amplitude and phase matching.

Signal Nulling Technologies

Digital nulling: Digital signal processing correlates the received signal with the transmitted signal to estimate the channel, and then subtracts the transmitted signal from the received signal, at which point sophisticated algorithms are used to estimate the channel [1,2]. One such algorithm is called successive interference cancellation, where the strongest signal is detected and then demodulated and removed from the rest of the signal [1]. This process requires prior knowledge of a signal so that it can be accurately demodulated. Although developed and demonstrated algorithms can provide fast and adaptive estimation of the channel, the digital cancellation approach is ultimately limited by the analog-to-digital converter, which is constrained by its bandwidth, sampling error, and dynamic range. The best reported cancellation is 30 dB over 10 MHz [3].

Electronic nulling: Integrated circuits can provide highly adaptive, variable gain control and phase shifting. One of the major challenges in a cancellation system is the estimation of the channel, which can be achieved using finite impulse response (FIR) filters. With a sufficient number of taps, the FIR filter can accurately estimate the channel; however, this approach suffers the same drawbacks in bandwidth and dynamic range that digital cancellation suffers from. The best cancellation that can be achieved using this technique is 20-30 dB over 30 MHz [4,5].

This electronic based signal cancellation technique is commercially available. One example of such product is the QHx220 device from Intersil [6]. The QHx220 separates the interfering signal into in-phase and quadrature-phase components with variable gains that modify the signal with arbitrary amplitude and phase shift. This technique can be implemented in small form factor; however, the simulated phase shift does not provide true-time delay, and therefore, is frequency-dependent and bandwidth limited. Furthermore, the device provides only 20-25 dB of interference cancellation for 10MHz bandwidth and suffers from large nonlinearity and distortion.

RF analog nulling: It is possible to use a RF analog component, balanced/unbalanced transformer (Balun), to obtain a copy of the invert signal, and a RF delay line/phase shifter and attenuator can be added to achieve signal nulling. However, there is not a good tradeoff between the size of the RF delay and attenuator, and the precision required for a high level of cancellation. Such a system provides 45 dB of cancellation over 40 MHz bandwidth [3].

Antenna nulling: With multiple antenna configurations, two transmitting antennas can be positioned such that one has an additional ½ of wavelength distance from the receiving antenna. This creates a nulling point for the receiving antenna, thus mitigating cosite interference from the transmitting signal. This approach has been demonstrated in a lab environment with 20 dB of interference mitigation [7].

Optical analog nulling: Optical components offer one inherent benefit: their bandwidth is many orders of magnitude wider than that of RF electronic components. Unlike RF or digital cancellation systems that are

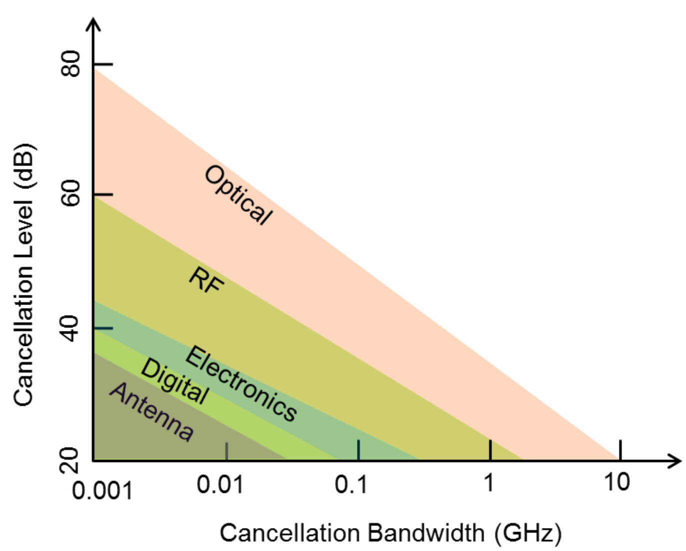

Figure 3: Comparing the cancellation level over bandwidth among various technologies.

restricted in their operational bandwidths, optical signal nulling is potentially applicable over the entire RF and microwave frequency bands (10 kHz - 100 GHz). RF signals “ride” an optical carrier wave within an optical fiber that experiences fewer amplitude and phase fluctuations than an electrically conductive medium would experience. The same is true of optical attenuators and optical delay lines in comparison with their electronic counterparts. These devices are capable of providing precise attenuation (down to thousandths of decibels) and precise time delay (on the order of femto-seconds) of real-time analog signals over a bandwidth of 100 GHz. The optical signal nulling approach was proposed as early as the 1990s [8,9], and is demonstrated to be capable of 45 dB of cancellation over 2GHz. Gheorma proposed using the independently modulated dual port Mach-Zehnder modulator to achieve 45dB of cancellation over 1 GHz and 30 dB over 2 GHz bandwidth [8]. The demonstrated system used the counter-phase modulation function of the Mach-Zehnder modulation to obtain a perfect copy of the inverted broadband signal for such a high level of cancellation. The most recently demonstrated results were 30 dB over 5 GHz of instantaneous bandwidth [10].

The performance of all the different technologies are summarized in the table below. Of course, it is possible to combine multiple technologies to achieve as high as 100 dB of cancellation.

Table 1. Summary of the performance comparisons among various cancellation technologies.

Methods\ Parameters	Bandwidth	Dynamic Range	Complexity	Adaptability	SWaP
Digital					
Electronic					
RF					
Antenna					
Optical					

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The amount of data sent wirelessly has increased tenfold over the last five years. The result is a dramatic increase in demand for wireless bandwidth, which is growing exponentially with no foreseeable slowdown. The finite resource of available radio frequency spectrum, however, is plagued by unreliable coverage and signal interference, which means that today’s solutions simply will not meet tomorrow’s growing demand. Bascom Hunter’s mission is to enable customers to get the most out of the RF technology revolution. We provide the leading solutions in wireless communication and security at competitive prices. Contact us to learn how our products can help you to address coverage problems and take full advantage of new wireless technologies.

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