

Success Story

JCU Professor Successfully Identifies Filters That Lower BER of Wideband Mobile Communications

Company Profile

James Cook University (JCU) is a public teaching and research institution and is the second oldest university in Queensland, Australia. It has been graduating engineering students since its inception. The College of Science and Engineering is the home of JCU's expertise in the physical sciences, chemistry, earth sciences, and engineering, forming a strong grouping uniquely placed to tackle the grand challenges facing the tropical world.

The Design Challenge

Most mobile communications base stations use Chebychev or Cauev-Chebychev filters, which give the best protection from out-of-band signals entering the receiver. However, their poor group delay can cause degradation of the waveforms and result in higher bit error rate (BER) and lower performance of the radio. Also, for a given insertion loss and bandwidth, Chebychev filters require a higher Q value of the individual resonators used in the filter. To compare Bessel, Butterworth, and Chebychev filters for use as single-channel filters in code division multiple access (CDMA) wideband radio systems to discover which filter type gives the lowest BER when using a given resonator Q.

The Solution

For this filter study, JCU's Dr. C. J. Keith Kikkert wanted to determine which filter type results in the lowest BER for an RF filter. He used Visual System Simulator™ (VSS) system design software to simulate, investigate, and compare the behavior of Bessel, Butterworth, and Chebychev filter types when used as RF filters protecting the mobile radio base station front end from interference. The basic block diagram of a code division multiple access (CDMA) modulator used in mobile radio applications is shown in Figure 1.

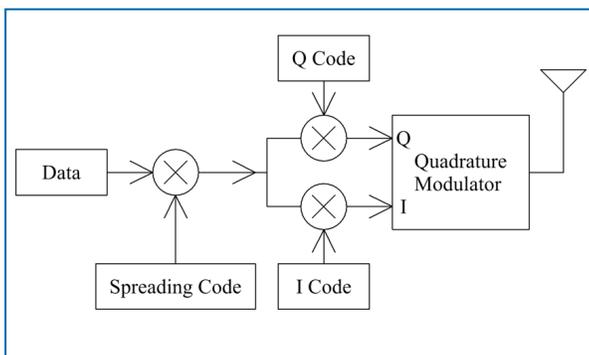


Figure 1: Basic modulation block diagram.

The data being transmitted is turned into a spread-spectrum signal by multiplying it with a spreading sequence that has a higher chip rate than the data rate. This spread-spectrum signal is then changed into quadrature signals by multiplying it by an I code and a Q code, both operating at the chip rate. The modulator includes filters to ensure that no signals outside the channel bandwidth are generated. The resulting signal can be simulated using a quadrature phase-shift keying (QPSK) signal, modulated by random data.



Application:
Wireless/Cellular
Radio Components
Filters

Software:
NI AWR Design Environment
Visual System Simulator



“The availability of NI AWR software to universities at substantial discounted rates is a great advantage. Without VSS, the computer simulations in this application would not have been possible.”

– Dr. C. J. Keith Kikkert
Professor
James Cook University
jcu.edu.au

The reverse of this process is applied during demodulation to produce I and Q data streams. There is a nonlinear relationship between the BER of the I and Q data streams, making this a good performance indicator. To provide accurate waveform information, a sampling rate of eight times the data rate was used throughout the VSS simulations. In the simulation, a root raised cosine (RRC) filter with $\alpha=0.35$ was used in the data generator to provide a transmitted waveform as close as possible to that used by a typical mobile radio system. The RRC filter was positioned in the receiver after the amplifier, as shown in Figure 2.

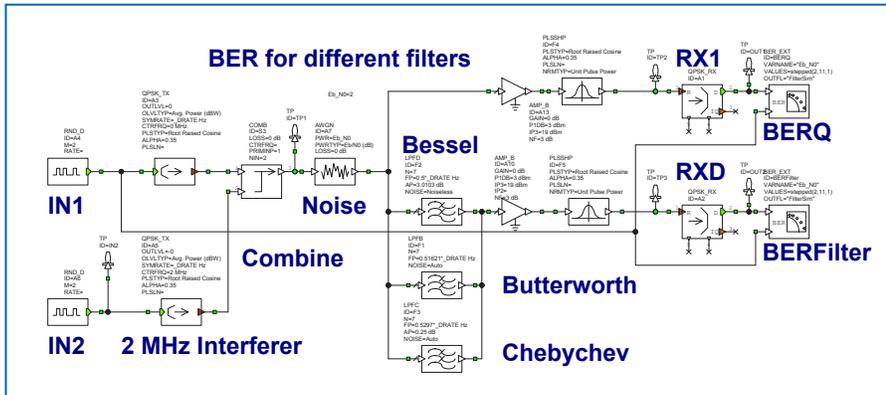


Figure 2: Block diagram of the simulation using VSS.

In the block diagram of Figure 2, input and interferer are two random binary data generators, which generate data at a variable data rate. A data rate of 4 Mbps was used, resulting in a channel bandwidth of ± 1 MHz for an ideal system using QPSK. The ± 1 MHz bandwidth was chosen to simplify the scaling to higher data rates. Most wideband mobile radio systems have data rates higher than the 4 Mbps and thus require wider bandwidth filters.

Figure 3 shows the passband response of the three different filters when a 3-dB cutoff frequency of 1 MHz is used. Figure 4 shows the resulting BER at an E_b/N_0 ratio of 11 dB, the Chebychev filter has 300 times more errors than the Bessel filter. It can be seen in both figures that the Bessel filter performed significantly better than the Butterworth filter and the Chebychev filter performed the worst.

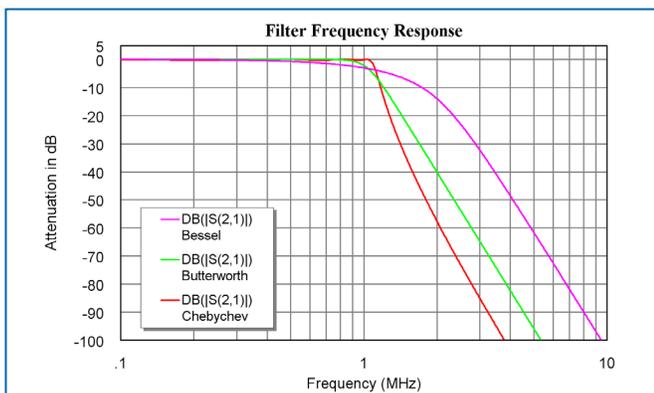


Figure 3: Filter responses with 3 dB attenuation at 1 MHz.

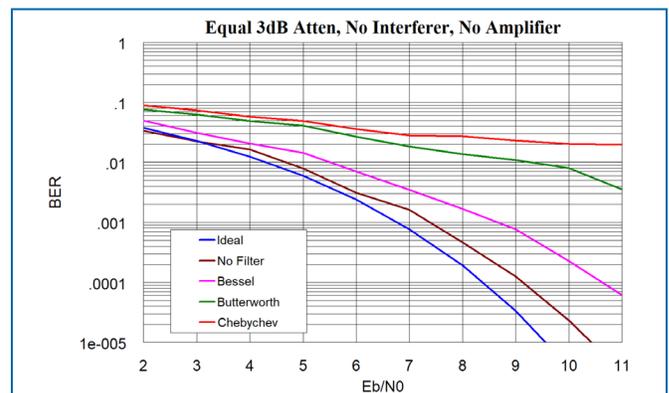


Figure 4: BER of Bessel, Butterworth, and Chebychev filters.

Why NI AWR Design Environment

Dr. Kikkert's research and simulations showed that a Bessel filter provides a significantly lower BER and insertion loss than the Chebychev filter currently used in mobile radio base stations. He concluded that a combination of Bessel RF filters and linear input amplifiers will result in the best base station performance. Dr. Kikkert commented that without the use of NI AWR Design Environment the simulations for this filter study would not have been possible.

For more information about this application, the original paper that is the inspiration for this success story can be accessed by IEEE members at ieeexplore.ieee.org/document/4449608.