

Digital Block Down-Converter & COFDM

Single, Dual or Tri-Band – 2, 7 and 13 GHz

Central Receive antenna systems employ block down converters to convert the higher frequency bands such as 7 and 13 GHz down to the 2 GHz range for transmission over the coaxial cable run to the central receiver which is normally located some distance from the antenna.

Nucomm's high-performance Digital Block Down Converter DBDC Series is designed specifically for the television Digital/Analog ENG/OB operation to meet the transition to digital operations at 7 and 13 GHz. The DBDC Series is housed in a weather-proof box with all inputs and outputs protected from lightning or other high voltage transients. Band Pass or Channel Filters are recommended to reduce interference from both in and out of band signals. The DBDC Series is compatible with Nucomm's Digital/Analog Central Receiver, Newscaster CR, the Analog CR4, as well as other manufactures receivers.

Frequency Stability:

Digital operation requires much more stringent requirements of frequency stability, accuracy, phase-noise and dynamic range. With analog operation, frequency accuracy and stability of a MHz or so was quite adequate. Most digital modems, such as COFDM, QAM and 8VSB have capture ranges of +/-100 to +/-200 kHz. This requires that the overall frequency accuracy, stability and aging of the entire system (transmitter, receiver and block converter) be less than +/- 100 kHz to cover all modem possibilities. If the +/-100 kHz is divided evenly, each must maintain an accuracy and stability of better than +/- 33 kHz over a long period of time. This translates to a total stability of +/-16.5 ppm at 2 GHz, +/-4.7 ppm at 7 GHz and +/-2.5 ppm at 13 GHz for the transmitter, receiver and the Block Down-Converter. Since the Block Down-Converter generally operates where it is exposed to extreme temperature environments, its frequency stability and performance must be maintained over a wide temperature range as well as over time (aging). The transmitter and receiver in general are located in a more environmentally controlled environment. A tighter frequency accuracy and stability accuracy should therefore be allocated to the transmitter and receiver than the block converter. Typical stability specification should be as follows.

TABLE 1

Frequency Band	Transmitter	Block Converter	Receiver	Over All
2 GHz	+/-25.0 ppm	Not Applicable	+/-25.0 ppm	+/-50 ppm
7GHz	+/-3.0 ppm	+/- 8.3 ppm	+/-3.0 ppm	+/-14.3 ppm
13 GHz	+/-1.5 ppm	+/- 4.7 ppm	+/-1.5 ppm	+/-7.7 ppm

In analog systems, typical local oscillators' frequency accuracy and stability is +/-50 ppm (.005 %) per transmitter, receiver and block converter. In reality an analog system will operate without any significant degradation with a frequency error of +/-2 MHz. This translates to +/-0.1% at 2 GHz, +/-0.029% at 7 GHz and +/-0.015% at 13 GHz. With these very loose stability requirements for acceptable operation, frequency aging of the various oscillators are insignificant and never need to be readjusted. This means that ENG and STL systems will operate indefinite without oscillator retuning.

In digital microwave systems, sporadic operational problems may develop after several years of operation if preventive maintenance does not include frequency accuracy adjustments of the frequency determining reference oscillators. Digital system aging of the various frequency determining elements must be seriously considered as part of both system design and preventive maintenance scheduling by the end user. Typical frequency determining elements used in ENG and STL system have typical stability's of +/-1.0 ppm over temperature of -10 to +70 degrees Centigrade and aging of +/-1.0 ppm per year. After one year the aging in most cases is reduced to less than 1.0 ppm. The stability numbers given in the above table refer to each transmitter and receiver unit. It must be recognized that in many TX or RX units multiple reference oscillators are used. That is a digital transmitter and receiver in a digital ENG system will have two oscillators to perform dual supper-heterodyne conversion. If each conversion uses a separate reference oscillator (typically 10 MHz) then the stability of each oscillator must be better than the above table indicates. For this reason a common reference oscillator should be used.

In the case of 2 GHz operation, minimum maintenance is not required. Maintenance being required once every 20 to 25 years. However in the case of 7 and 13 GHz operation, maintenance would be required every three years for 7 GHz equipment and once every 1.5 years for 13 GHz equipment.

Phase-Noise and Microphonics:

Phase-noise and microphonics in analog block converter local oscillators are generally not critical. In Digital Block Down-Converters phase-noise and microphonics are extremely important requiring improvements of better than 3 orders of magnitude over analog.

The Nucomm DBDC Series Digital Block Down Converter is specifically designed to pass COFDM and meet the stringent requirements of frequency stability, phase-noise, microphonics and temperature with models at both 7 and 13 GHz. The DBDC Series uses Nucomm's time tested low-noise amplifier-mixer designs of the analog converters in combination with its time tested ultra-low noise DRO crystal stabilized phase locked signal sources that have been a part of Nucomm's Digital radio product line since 1995. Not only does this combination give state-of-the-art noise and microphonic performance but provides stabilities of better than 1 ppm over extreme temperature ranges thus insuring reliable operation to both 7 and 13 GHz.

The DBDC series is a direct replacement for existing analog block converters in the field. At 7 GHz, the internal local oscillator frequency is 9,125 MHz. At 13 GHz it is 10.678 MHz. These are the same LO frequencies used by most manufactures in US for analog Block Converters. Other LO frequencies are available on request for international applications. Consult the factory. Power to the block converter is provided by either through the coax center conductor or by connectors

Relative Signal Receive Level Between 2, 7 and 13 GHz

COFDM operation at 7 GHz is relatively new to ENG operations. Nucomm has designed, installed and commissioned over six 7 GHz systems over the past year with over 18 ENG trucks operational. Nucomm has found that COFDM modulation at 7 GHz works as well if not better than at 2 GHz. However, there are several factors at 7 GHz (as well as 13 GHz) that do not exist at 2 GHz that must be carefully addressed in order to realize this performance. First, refer to Table 2. This shows that for the same antenna size at each frequency, there is an 18 dB increase in antenna gain at 7 GHz over 2 GHz. At 13 GHz the increase is a 28 dB increase over 2 GHz. Taking into account the difference in free space loss (128.6 dB at 2 GHz versus 139.5 dB at 7 GHz) at a distance of 20 miles, the receive signal level at 7 GHz is -45.5 dBm versus -51.6 dBm at 2 GHz. This is a 6.1 dB improvement over 2 GHz.

Table 2

Relative Signal Receive Level Between 2, 7 and 13 GHz For a Typical ENG System							
Operating Frequency	Free Space Loss (dB) 20 Miles	ENG Truck TX Antenna Gain (dB)	Central Receiver RX Antenna Gain (dB)	Typical TX Power (dBm) Digital operation	Receiver Receive Level	Receiver Threshold (dBm)	Fade Margin
2 GHz	128.6	20	20	37	-51.6	-95	-43.4
7 GHz	139.5	29	29	36	-45.5	-94	-48.5
13 GHz	144.9	34	34	31	-45.9	-93	-47.1

Dynamic Range:

The second and most important factor in realizing successful operation at 7 GHz, is the design of the 7 to 2GHz (or 13 to 2 GHz) block down converter. Experience gained from these operations point out a number of factors that must be considered when designing the block down converter and 2 GHz Central Receiver. The most important factor is "Dynamic Range" or "Inter-Modulation" performance.

A number of occurrences during transmissions suggest that if the ENG or airborne transmitter is too close to the Central Receive site, saturation of one or more stages in the receiver chain can cause the modem to loose lock or fail to re-lock. This saturation causes excessive inter-modulation or side-band re-growth to an extent that the modem can no longer decode the received signal. This exact condition has been observed at receive site using a spectrum analyzer connected to the Central Receiver 70 MHz output. The situation is easily correct by turning the transmitter or receiver antenna several degrees off center to reduce the received signal level. The problem for a Master Control operator is how is he or she to recognize this condition as compared to adjacent or other interference. If the Master Control operator had a spectrum analyzer view of the Central Receivers 70 MHz output. The cause of the problem and corrective action could be taken.

Short of having a spectrum analyzer display, the operator should recognize the presence of a strong signal without video and adjust the receive antenna as required until modem lock and picture restoration has occurred.

Every effort must be taken to design the block converter and the Central Receiver with a high enough dynamic range so overload or saturation of the receiver chain amplifiers will not saturate. Dynamic range of the block converter and Central Receiver defines the input signal level range over which the system will operate and still meet its specified operational specifications. Specified input level includes both the lower and upper receive levels. The minimum input signal level for an analog receive system is typically -83 to -87 dBm (defined as the input level at which the video signal to noise is equal to -37 dBm). These input receive levels depend on the frequency of operation as well as the system noise figure.

The maximum input signal level for an analog receive system is typically -10 to -20 dBm. Although at these maximum input signal levels, the LNA amplifiers in the block converter or Central Receiver may saturate, the FM analog signal can still be demodulated with little or no degradation when various stages saturate. The dynamic range of an analog Block Down Converter and Central Receiver is relatively large and its upper input signal level is relatively unimportant.

In a digital system the dynamic range is determined by entirely different parameters. The lower receive level is defined as that level at which pixelation occurs, total loss of the picture occurs or the “Before FEC BER” reaches a defined level (typically 10^{-3}). The difference between these three occurrences is only about one dB. Typical minimum receive levels for COFDM signals using QPSK are of the order of -92 to -95 dBm. For non-COFDM QPSK modulation the minimum receive levels are of the order of -90 dBm.

The maximum receive level for digital systems can also be defined as that level at which the receiver modem will lock to the received signal without pixelation. Although COFDM operates extremely well in the presence of multi-path, minimum and maximum levels will also be affected, to a minor degree, by the amount of multi-path.

The principle mechanism in a digital receive system, that determines the maximum receive level, is that signal level that produces a given third-order two-tone inter-modulation level. This inter-modulation level is different for different modulation formats. Typical inter-modulation levels for COFDM_QPSK are -25 to -30 dBc as shown in Figure 1. That is with two equal amplitude input signals spaced by about 2 MHz, (spacing must be significantly less than the operational bandwidth) the inter-modulation spurious or side-band signals at the input to the modem (typically 70 MHz) must be grader than 20 to 25 dB below the two signal levels. A well designed block converter and Central Receiver will pass high receive levels without producing inter-modulation greater than the COFDM demodulator can handle. This receive level can be maximized in both the block converter and or the Central Receiver by a combination of design techniques such as using high dynamic range front end amplifiers, AGC applied to the LNA and methods to switch out amplifier stages either manually or automatically when the receive level reaches certain levels. Caution must be observed when switching amplifier stages in and out. First, adequate hysteresis must be incorporated so the system does not switch back and forth due to small fluctuation in signal level. Second, the switching transient must not cause the modem to lose lock or create pixelation.

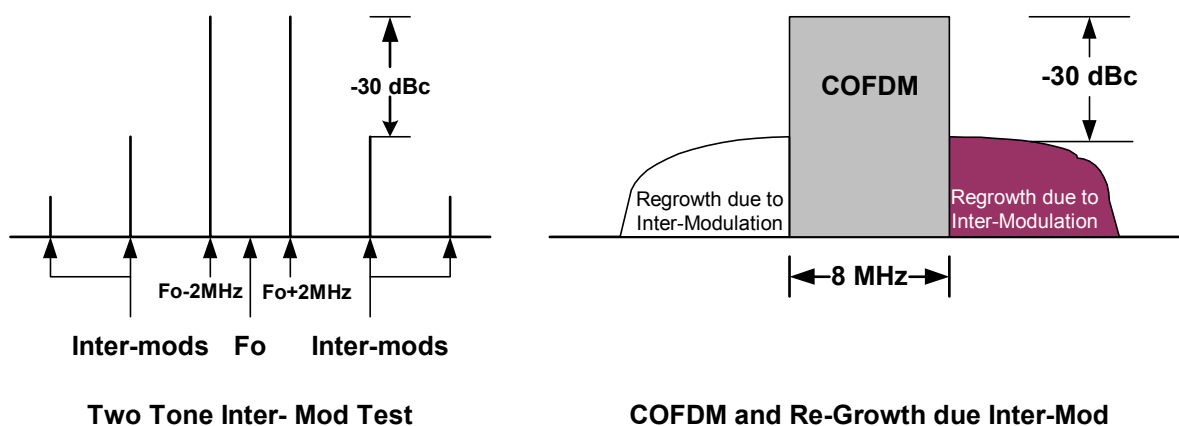


Figure 1

To better understand the effect that received signal levels can have on a typical block converter and Central Receiver see Figure 2 and Table 3. Figure 2 shows an ENG van operating in the 6/7 GHz band with an antenna gain of 29 dB and a transmit power of 4 Watts (36 dBm). The Central Receive site consists of an antenna with a gain of 29 dB, a block converter and a Central Receiver. The block converter has a 7 GHz low noise amplifier with a gain of 15 dB, a mixer with a conversion loss of 8 dB and a 2GHz booster amplifier with a gain of 15 dB. The power, P_{lna} , at the input to the low noise amplifier is

$$P_{\text{lna}} = 36 + 29 + 29 - \text{free space loss between antennas.}$$

$$P_{\text{lna}} = 94 - \text{free space loss.}$$

Column C of Table 3 give the power received at the input to the LNA as a function of distance between the ENG van and the Central Receive antenna. Column D gives the output level from the 15 dB gain LNA into the mixer. Column E is the mixer output level. Column F is the output level from the 15 dB booster amplifier. Columns G, H and I gives the signal level for different cable losses from the block converter to the Central Receiver.

A typical Central Receiver has an maximum linear input dynamic range of about -25 dBm. That is for signal levels above this level intermodulation products or sideband regrowth will cause COFDM demodulator problems. From Table 3 column G, if there is a 10 dB loss between the block converter and the Central receiver, the Central Receiver is overloaded for Van distances of less than 10 to 15 miles. The higher the cable loss (longer cable runs) the closer the Van can operate to the Central Receive site.

A well designed block converter should have provisions to by-pass the 2 GHz booster amplifier. Table 4 shows the signal level at the Central Receiver with the booster amplifier by-passed. For cable losses of 10 dB the distance between Van and central receiver only need be slightly greater than 1 mile. For cable losses greater than 10 dB the distance could be less than a mile.

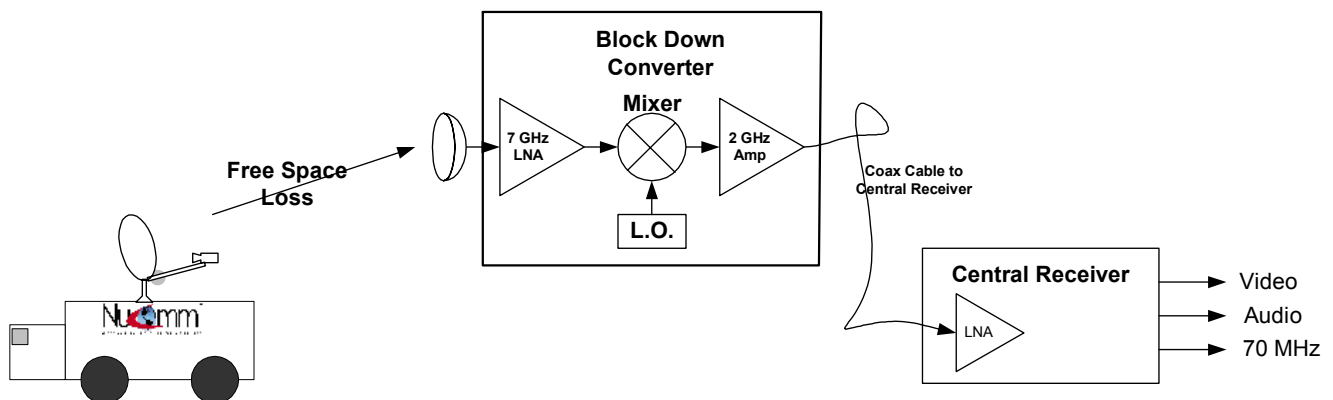


Figure 2
Block Diagram of 7 GHz ENG System

