RECEIVER/COMBINER FOR SHIPBOARD TELEMETRY APPLICATIONS

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ABSTRACT

Improvements in the performance and electronic sophistication of Navy missiles require concurrent improvements in telemetry reception. The Microdyne 2800 Receiver/Combiner, developed for the Naval Surface Warfare Center (NSWC), provides an improved shipboard receiving capability to meet this requirement. The Microdyne 2800, or “2800”, is a dual channel diversity combining telemetry receiver, which, though designed to meet the unique Navy shipboard environment, provides a capability previously available only with large shore based receiving systems.

INTRODUCTION

Navy missile firings are supported by both land and ship based telemetry receiving systems. A significant quantity of firings, however, rely totally upon portable shipboard receiving installations. The shipboard environment, along with a portability requirement, limit the maximum size of the receiving antenna to approximately one meter diameter, restricting antenna gain. Relatively poor radiation characteristics of missile telemeter antennas and signal degradation caused by multipath phenomena further limit range and data quality.

Tests performed indicate a 3 to 5 dB dynamic signal improvement as a result of polarization combining at the receiving site (compared to using a single receiver). Even greater improvement is attained by the physical separation of a pair of identical receiving antennas such that multipath nulls do not occur simultaneously in the two antennas. Computer application software has been developed at NSWC to predict multipath effects to aid effective multipath management.

Implementation of diversity techniques in a portable shipboard system required the design and development of a compact receiving/combining system. The Microdyne 2800 is a result of that effort, offering, in 5.25 inches of rack space, a dual channel receiver and combiner. The small physical size permits optional employment of a second 2800 to provide simultaneous combining of two diversity modes (e.g., polarization and space diversity).

DESIGN AND DEVELOPMENT

Design requirements for the 2800 were based on the Navy’s need for a compact (5.25 inch maximum panel height), low power consumption, rugged, high performance dual channel receiver combiner capable of data recovery equal to that of a multipath receiver combiner system of far greater size and weight.

The constraints required the design team to reevaluate the current concept of dual channel receiver combiner systems. The 2800 (simplified block diagram shown in Figure 1) is the outcome of these efforts.

FUNCTIONAL DESCRIPTION

The 2800 incorporates a front panel plug-in tuner module permitting operation on multiple frequency bands. In addition, each channel (CH1 and CH2) has its own Independent synthesizer allowing the 2800 to tune to two different frequencies within the plug-in tuner range (frequency diversity). Tuning resolution is 100 kHz.

Each tuner channel outputs a 160 MHz 1st IF signal to its 1st IF filter module for amplification and filtering. This module also provides a wideband 160 MHz rear panel output for use with an external spectrum analyzer.

Each 1st IF filter 160 MHz output is then fed to a 2nd mixer module where it is converted to the 70 MHz 2nd IF. The local oscillator (LO) signal for each 2nd Mixer is derived from either the 230 MHz crystal LO or from the 230 MHz VCO module. The selection is determined by operating conditions and logic commands from the microprocessor unit such that the VCO is employed in the channel that is in, or has been in, the search mode.

The 2nd mixer 70 MHz output is further amplified and filtered in the 70 MHz 2nd IF filter module. IF filtering allows a wide range of bandwidths between 1.0 MHz and 36 MHz. Standard bandwidths shown are 1.2, 3.3, 10, and 22 MHz. Each channel may include up to four IF bandwidths selected at either the front panel or remotely via IEEE-488 or RS-232 busses.

The amplified and filtered 70 MHz signals are next processed by the IF distribution/AM detector module and distributed to the Pre-D combiner, other modules, and to the rear panel. The AM signal is recovered in the IF distribution/AM detector module and sent to the rear panel and post detection combiner module, where the CH1 and CH2 AM tracking Signals are combined together to provide a combined enhanced AM tracking signal output at J22.

The Pre-D combiner module is a unique design capable of combining narrow band as well as extra wide band RF signals at or near theoretical performance. The unit employs very wide band phase shifters that allow for a single conversion combining system, thereby saving space and power. This module also contains the sweep acquisition and loop filter components.

Phase lock loop parameters were selected from previous successful bandwidths employed in the proven Microdyne 3200-PC combiner design. The loop bandwidth permits high phase fade rate tracking while still allowing the unit to phase lock two channels at levels down to -7 dBm carrier-to-noise (C/N) in each channel, thereby providing for minimum loop unlock for any given mission. The design allows manual as well as automatic acquisition. Sweep voltage and loop stress is displayed on the front panel bar graph indicator.

Output of the Pre-D combiner is fed to the FM demodulator. Four selectable demodulator bandwidths are available utilizing proven threshold extension designs. Bandwidths range from narrow to extra wide, addressing narrow and medium bandwidth FM applications as well as TV video and other wide band signals with deviations in excess of 5 MHz. A front panel video polarity switch is provided as well as internally switched de-emphasis networks for wideband or TV video applications. The demodulator is extremely linear and provides excellent noise power ratio (NPR) performance.

The output of the FM demodulator is fed to the video filter attentuator module where it is filtered by one of five selectable video filters with bandwidths between 400 kHz and 13 MHz. A bypass mode is available which provides a video response in excess of 15 MHz. This module is also equipped with a programmable video attenuator that provides attenuator increments from 0 to 53 dB in 1 dB steps. The module’s video amplifier has a bandwidth in excess of 4.0 VPP into a 75 Ohm load at J16 on the rear panel.

The 2800 also incorporates a three channel down converter module. This module takes the 70 MHz IF output from CH1, CH2, and the Pre-D combined module, and down converts these signals to any one of seven selectable record carrier frequencies. The standard frequencies employed are 300 kHz, 450 kHz, 600 kHz, 900 kHz, 1.20 MHz, 1.80 MHz, and 2.40 MHz. The design allows for optional record carrier frequencies up to center frequencies of 5.0 MHz. Each channel is independent such that all three channels can be recorded then reproduced individually for single channel analysis.

The microprocessor (MPU) board incorporates an 80C85 microprocessor using proven software and hardware design from the Microdyne 1400-MR series receiver. The MPU board processes all local as well as IEEE-488 and RS-232 remote commands, displays status on the front panel LED readout, and sends the unit's status out via a unique status repeat program on the RS-232 buss. This status repeat program was required by the Navy to aid post mission data analysis, and will provide the Navy with accurate accounting of the 2800's performance during any mission requirement.

AM and AGC control voltages are provided by the AM and AGC logic circuit PC boards. Here the AM output of each AM detector is processed through a logarithmic amplifier and summed with the AGC voltage to develop a combiner control voltage equivalent to the fade pattern at the RF input of each channel.

The Post-D combiner serves two functions in this application. When a single 2800 is used, the Post-D combiner permits CH1 and CH2 AM signals to be combined. Thus, the AM tracking signal is enhanced for improved overall antenna tracking operation. However, a unique wiring and switching arrangement in the 2800 permits an additional function. For example, when one 2800 (of a pair of 2800s) has its rear panel switch set to the master mode, the predetected combined video outputs of the two 2800s can be Post-D combined, providing the capability of implementing two diversity modes simultaneously. Since one 2800 remains in the AM/slave mode, AM tracking signals can also be combined at the same time for improved antenna tracking performance. This Post-D combiner circuitry was developed from similar technology developed for the field proven Microdyne 3200-PCA Diversity Combiner.

CONTROLS AND INDICATORS

The front panel, shown in Figure 2, was designed to simplify user operation. The exclusive use of high visibility LEDs provides the operator with a wide viewing angle as well as high visibility under any light condition.

Controls and indicators are positioned for maximum operator efficiency. Integration of the two receivers and a combiner into a single package greatly reduces the number of controls as compared to using three discrete units.

Receiver controls and indicators are largely confined to the bezel area, whereas combiner controls and indicators are located on the opposite side of the front panel. This minimizes confusion during setup and operation.

The keyboard and programming render local operation extremely user friendly. For example, function keys, such as scan, Pre-D, and AGC TC, once selected, cycle through each of the available selections for that function with each subsequent depression of the function key. Depressing the Freq key causes the display to indicate which channel is being changed, and prompts the operator for input data.

Both analog and digital LED display indicators are utilized. CH 1 and CH 2 carrier levels are displayed on analog bar graph devices providing good relative indicators. These levels can also be displayed in digital form using the front panel Level DVM with its unique slide switch arrangement. This allows the DVM to serve as CH 1 and CH 2 level indicators as well as monitor the video output level.

The Demodulator DVM also has a slide switch allowing it to serve the dual purpose of deviation indicator and demodulator zero indicator for precise demodulator zero control.

The combiner section of the front panel employs a DVM with interlocking switchable inputs. Each combiner adjustment control is located directly below its associated switch function for efficient and precise combiner setup.

Other controls and indicators such as demodulator and IF controls are also well defined and user friendly.

LABORATORY PERFORMANCE

Laboratory and Acceptance Test Procedures were performed on the 2800 to verify that its performance met the Navy's procurement specifications. The unit met specifications and performed at or near theoretical in all aspects including combiner system performance tests.

AGC vs Signal Level

Figure 3 plots AGC voltage versus input level. A high performance AGC controlled optimal ratio combiner system requires a linear AGC control signal to provide optimal combining operation. Note that the CH 1 and CH 2 AGC voltages are not only linear at low input levels, but remain linear throughout the entire operating range of the system.

The combined AGC curve is also plotted in Figure 3. This is the control voltage supplied to the four channel combiner circuitry when two 2800s are configured as a four channel combiner system. Note that this combiner voltage is 150 MV higher than CH 1 and CH 2 AGC voltages indicating a 3 dB improvement in AGC voltage required for proper operation of a four channel combining system. Note also that the combined AGC voltage tracks the individual AGC voltages over the entire operating range.

Demodulator Performance

The FM demodulator is comprised of four selectable demodulator bandwidths utilizing proven threshold extension designs. Performance for the unit was exceptional, especially in the area of Noise Power Ratio (NPR) tests. NPR performance is highly dependent on the linearity of the FM demodulator.

FM demodulator linearity for the medium bandwidth position is shown in Figure 4. Note the unit is essentially linear over the 1 MHz bandwidth, contributing to NPR performance in the 45 dB range.

FM demodulator linearity for the extra (EX) wide BW position is shown in Figure 5. Note that linearity is over a 10 MHz bandwidth. Linear performance over this range will yield excellent data quality for both wideband and video applications.

S/N vs C/N Performance

Signal-to-noise ratio as a function of input carrier-to-noise ratio for two widely different system configurations is shown in Figures 6 and 7.

Figure 6 plots the output signal-to-noise ratio for CH 1, CH 2 and combined outputs versus the carrier-to-noise ratio at the 2800 input channels. Note the excellent FM demodulator threshold performance for both CH 1 and CH 2 occurring in the 7-8 dB C/N range. The combiner plot indicates almost the maximum theoretical 3 dB improvement over the entire range. It is important to note that the threshold for the 2800, using the Pre-D combiner, is pushed down an additional 3 dB to the 3-4 dB C/N range.

Figure 7 shows a wideband application using EX wide FM demodulator range. Threshold performance is excellent and typical of the proven performance of this demodulator design in other video applications. The combiner curve indicates the theoretical improvement of 3 dB over the entire range and lowers the threshold by another 1-2 dB.

Combiner AM/AGC Performance

Pre-D combiner performance under dynamic conditions is shown in Figure 8. In this test each RF channel is amplitude modulated such that the RF signal has a fade depth of 20 dB, and the fade pattern of one channel is set 180 degrees out of phase with the other. RF input to each channel is set such that CH 1 and CH 2 outputs produce a bit error rate (BER) of

10,000 errors per million bits (EPMB). The 2800's combiner circuits then combine these two signals and improve the BER to less than 1 EPMB. Figure 8 shows this improvement to occur for fade rates from 100 Hz to over 100 kHz.

Figure 9 shows the same data as Figure 8 except that each channel BER is increased to 30,000 EPMB to test the limits of the combined improvement of the system. Note that the BER is still less than 1 EPMB until the fade rate exceeds 35 kHz.

APPLICATIONS

The 2800 was designed to meet the Navy's immediate and long term specifications. The unit has the designed-in versatility to function in a wide variety of applications including:

- Dual channel polarization diversity combiner applications
- Dual channel frequency diversity combiner applications
- Dual channel space diversity combiner applications
- Four channel polarization or frequency diversity combiner applications using two 2800s
- Four channel space diversity combiner applications using two 2800s
- Portable applications as well as fixed ground, seaborne, or airborne support
- Enhanced video recovery for commercial or military applications

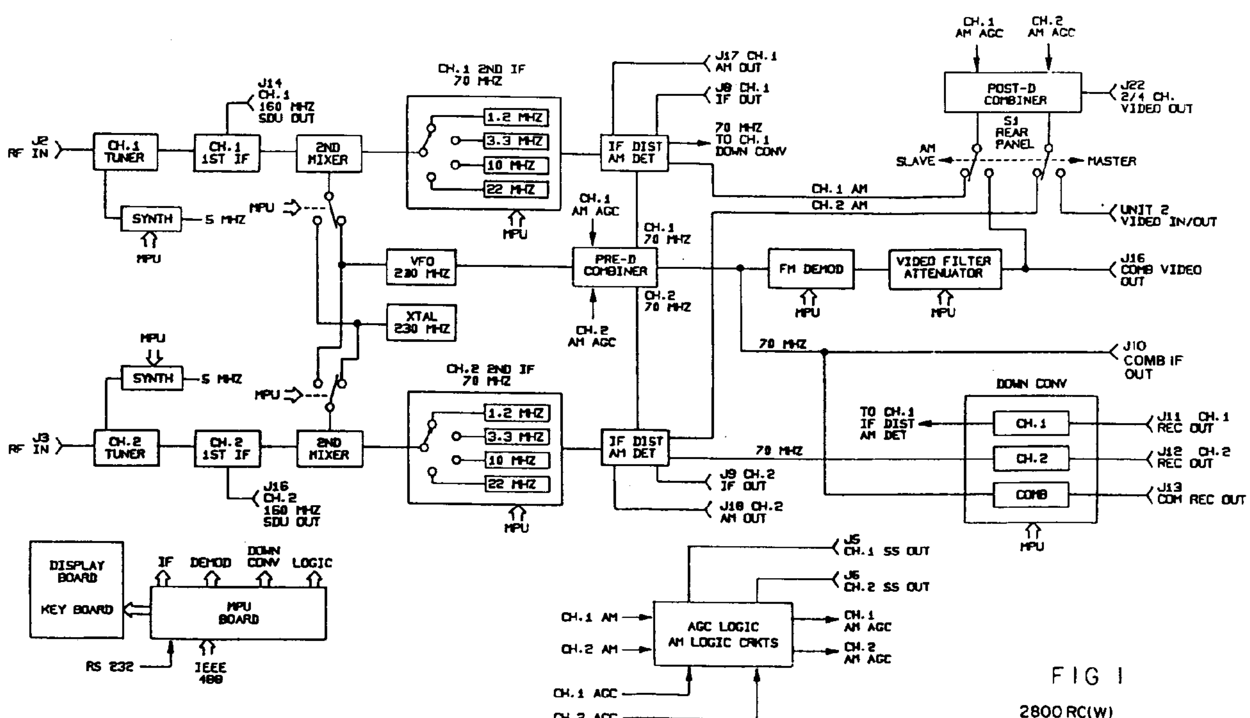

FIG 1

2800 RC(W)
SIMPLIFIED BLOCK DIAG

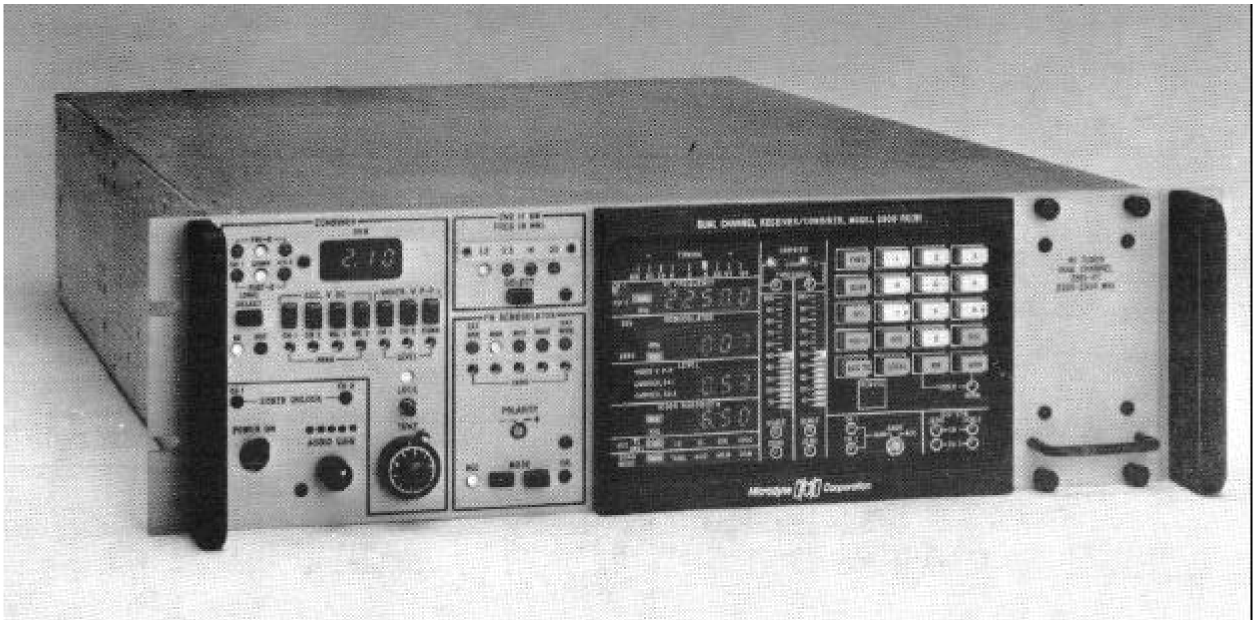

FIG 2
2800 RC(W) FRONT PANEL

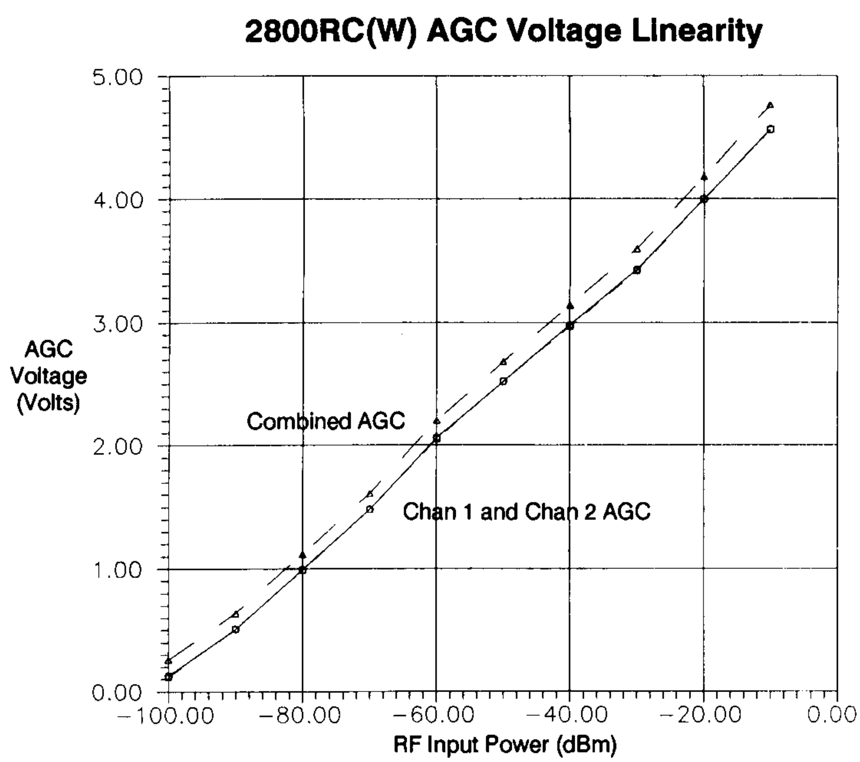

Figure 3

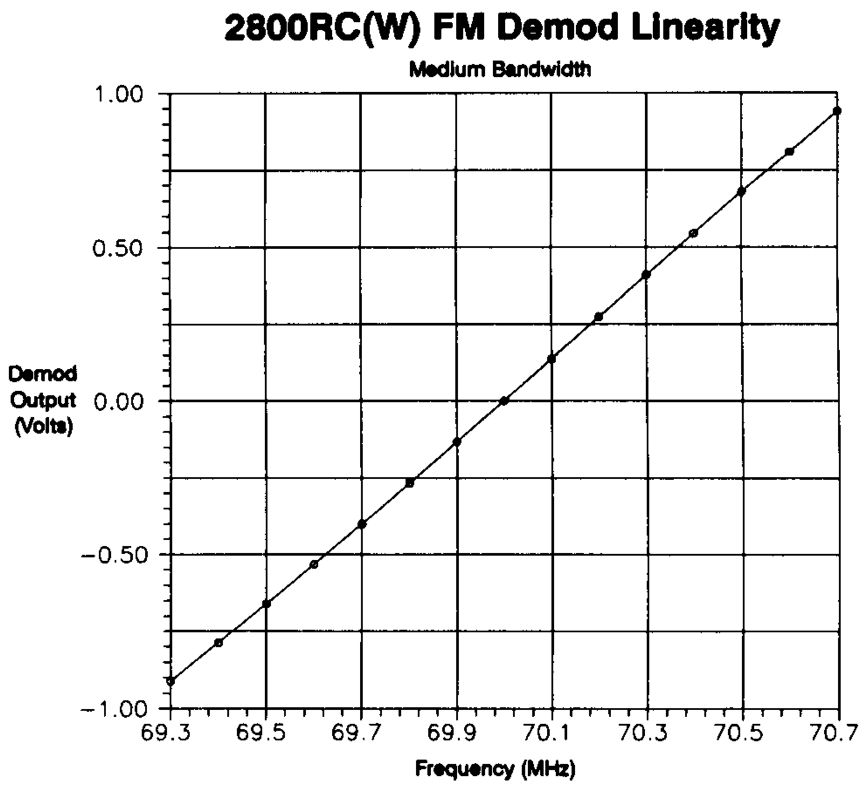

Figure 4

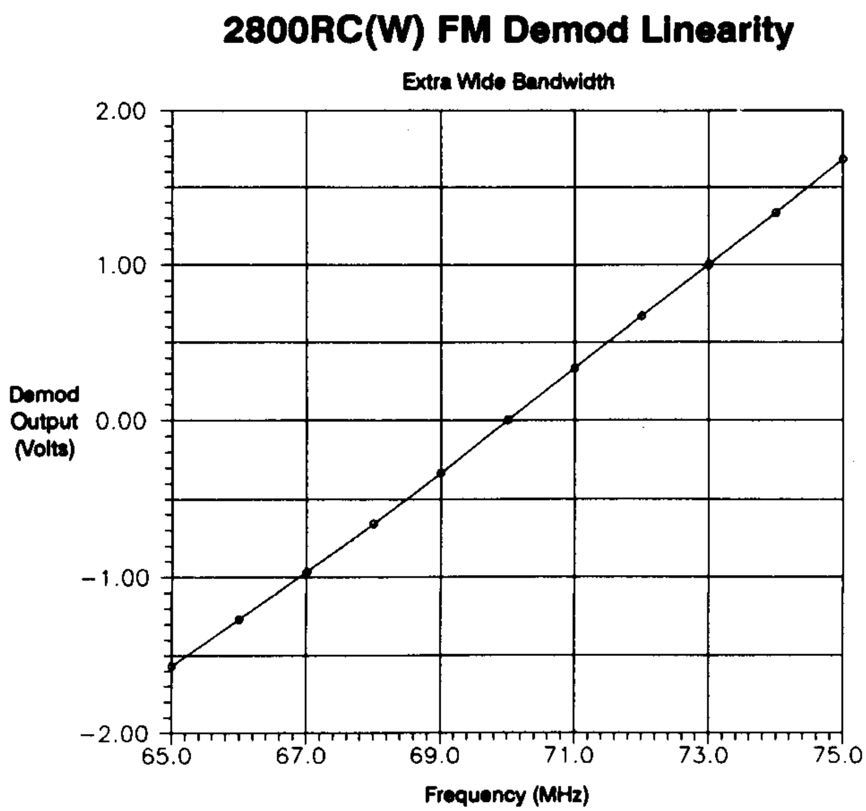

Figure 5

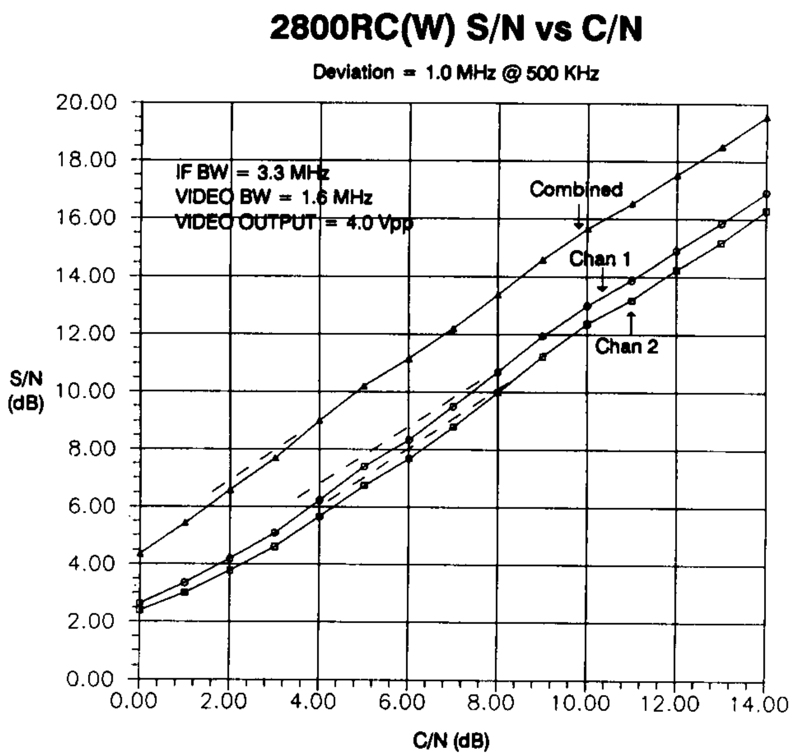

Figure 6

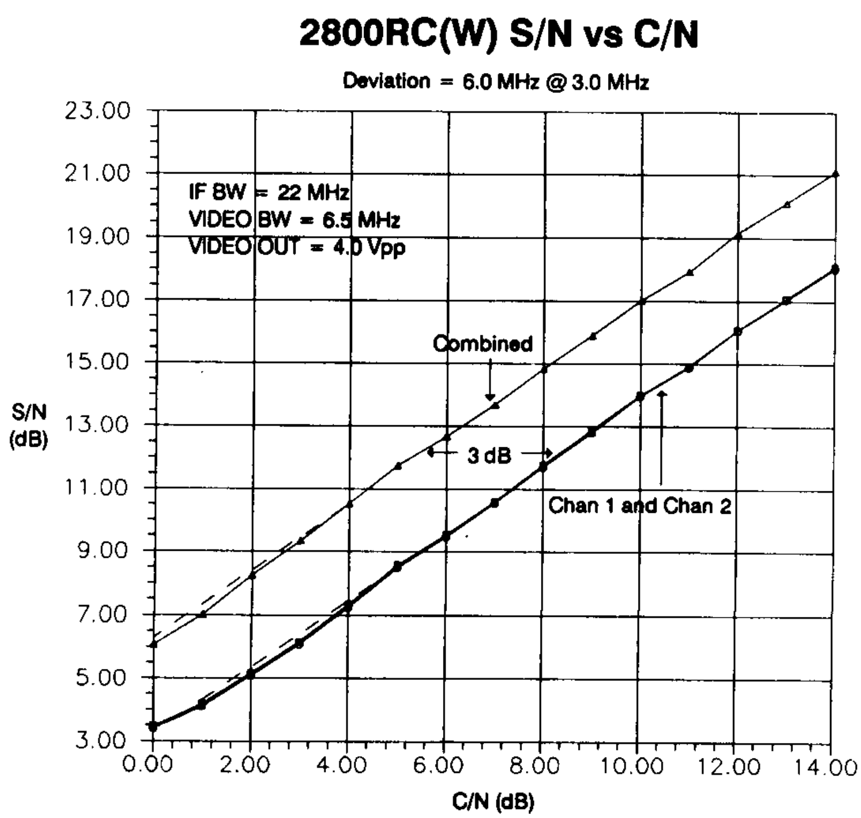

Figure 7

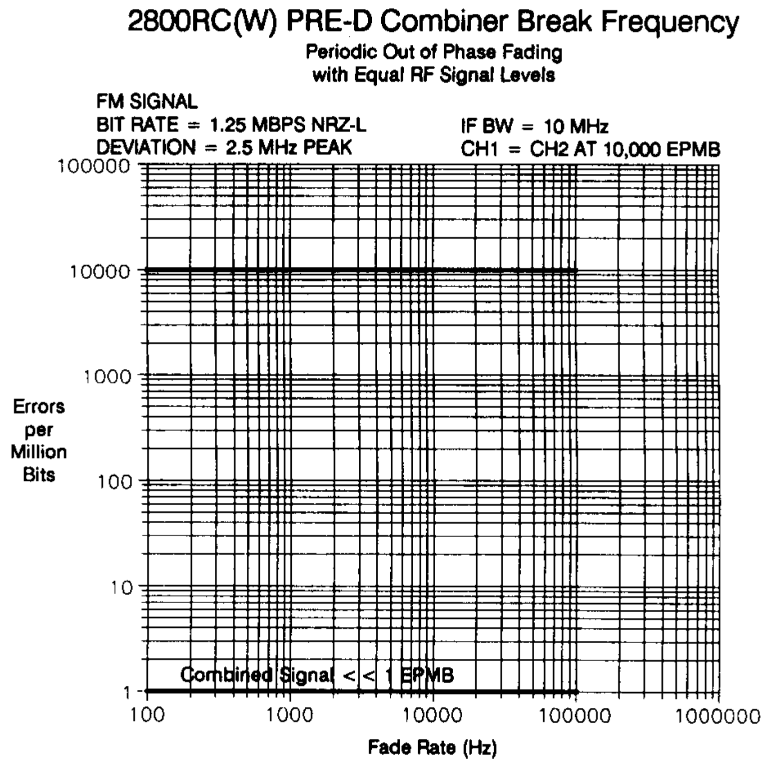

Figure 8

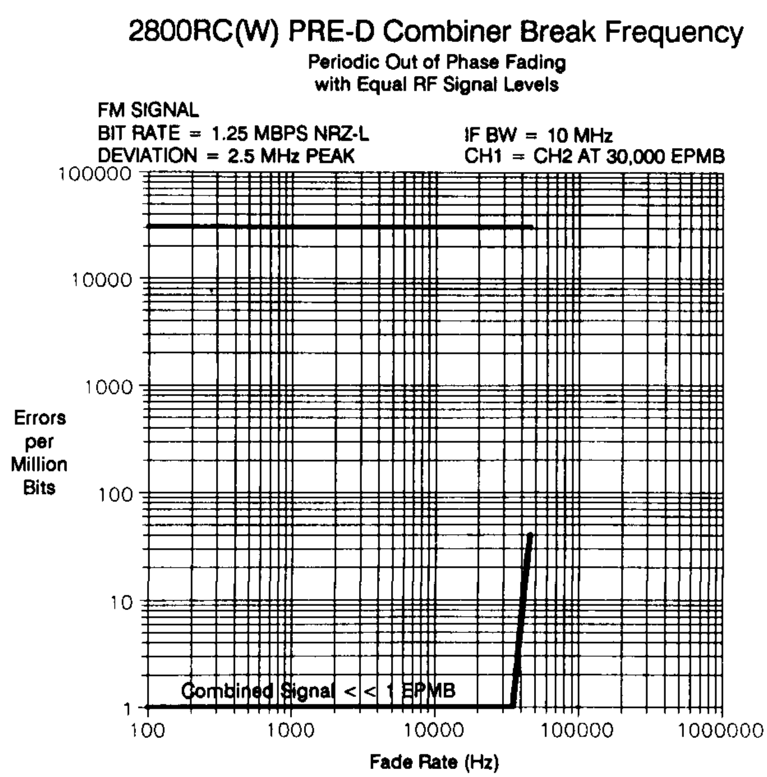

Figure 9