The San Diego Microwave Group X-Band Repeater Update

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In November 1995 the San Diego Microwave Group installed and began testing a unique, wide-band, all-mode, non-frequency translating X-Band repeater developed for house-to-house communications. The goal of this now three and one half year old project was to provide house-to-house communication through a line-of sight repeater over a radius of 20 miles or more. Although I conceived and built this repeater, a number of the San Diego Microwave Group members have been instrumental in the installation, testing and documentation making this an exciting group project.

One unique property of this repeater is that it can retransmit any signal on its original frequency allowing common 10 GHz simplex equipment normally used for mountain-top contesting to be used between homes. Linear operation and a 10 MHz bandwidth provide the potential for many simultaneous communications of varying mode types through a single repeater including SSB, NBFM, Packet, ATV, and Spread Spectrum. Fortunately, a mountain site at approximately 2500 ft. elevation was made available to us for testing the repeater. This site was near line-of-sight from many of our local microwavers home locations.

The equipment necessary for communicating through this repeater typically involves a 12" or larger parabolic dish antenna and .1-1 watt output power. This type of power & dish size are now readily available in the form of 18" DSS dishes available from MCM for about $13 and transverters and components available from several sources including some members of the San Diego Microwave Group. An important aspect of convenient house-to-house communications is frequency stability. The systems primarily in use by the San Diego Microwave Group members are referenced to precision 10 MHz oscillators providing excellent stability at 10 GHz

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Repeater Technical Description of Phase 1

This repeater is very simple in concept. It was found through experimentation that two of the slotted wave guide type omni-directional antennas at 10 GHz have an isolation of about 90 dB when vertically separated by about ten feet. A series of amplifiers and filters are placed between the two antennas with the gain set at some level (say 10 dB) below the point of oscillation. This repeater then receives , amplifies, and retransmitts any signals within the bandpass of the filters regardless of modulation type. This means that with a 10 MHz bandpass, the repeater can pass a large number of simultaneous users at slightly different frequencies or a few users if the signals are very wide band such as fast scan ATV or very high speed packet.

Tower Mounted Unit

The antennas consist of about 12" long sections of WR-90 waveguide with 12 slots in each of the broad sides as depicted in the block diagram. On this experimental unit one side of each antenna (the side which faces the tower on which it's mounted) has been covered with aluminum tape to prevent reflections off the tower from lowering the maximum gain available before oscillation. The antennas have matching screws installed to adjust for best SWR.

The receive antenna signal is fed into a three stage GaAs FET low noise amplifier with about a 1 dB noise figure and 30 dB gain. The signal then passes through a 5 element interdigital filter. Two more similar stages of amplifiers and filters are then used to amplify/bandpass the received signal. The signal then passes through a voltage controlled variable attenuator which has a dynamic range of about 40 dB. The signal is then amplified by the power amplifier unit which has about 30 dB gain and 1 watt maximum output, filtered and transmitted through the second waveguide antenna. A diode power detector and dc amplifier provide an indication of power output level.

The power supply assembly provides a regulated +10 volts and -5 Volts to all amplifiers and the attenuator. The power amplifier and power supply units have extensive heat sinking to allow operation in n essentially sealed environment. The entire outdoor unit is enclosed within two surplus fiberglass tubes about 3" in diameter with 3/16 thick walls and is sealed against the elements. All wiring within this unit uses shielded cables and feed through capacitors to prevent improper operation in a high RF environment. Every module is shielded and SMA connectors with .141 or .085 hardline are used for all RF interconnects.

Rack Mounted Control Unit

The control unit is mounted indoors in a 3" tall standard 19" rack mounted enclosure. It is connected to the tower mounted unit through 100' of multiconductor shielded cable with detachable circular, locking connectors at both ends. The unit contains a linear power supply to provide 13.5 VDC to the Tower mounted unit and both 13.5 and 5 VDC to the control unit. The dc power to the repeater is controlled by a 440 MHz FM receiver with tone decoder and is used to remotely turn the repeater on and off. A front panel mounted 3 1/2 digit voltmeter along with the meter switch allows the display of the +13.5 VDC, +5 VDC, Attenuator control voltage, and repeater RF output power. The attenuator level is manually controlled by a ten turn pot with turns counter and lock.

Repeater Identification/Beacon

An existing 10.36832 MHz beacon is collocated with the repeater at the same sight. The beacon is an ovenized crystal-referenced unit which provides a CW identification at least once each minute by keying a carrier on and off with the Morse message "DE WB6IGP/B" at about 8 wpm . This beacon is amplified and transmitted by the repeater unit.

Repeater Setup

The initial setup/adjustment of the repeater gain is the only adjustment required. The attenuator control is turned fully CCW to insert maximum attenuation and then the AC power switch is turned on. The REMOTE/OFF/ON dc power control switch is placed into the ON position. The meter switch is set to display power output. With the beacon turned off, the attenuator is decreased (CW) until a rise in output power is noted. A chart of the approximate attenuator value versus control voltage is then consulted to determine what voltage setting for the attenuator will increase the attenuation approximately 10 dB and the attenuator control is set to that value. The beacon is then turned on and the repeater output power level should increase and fluctuate according to the beacon’s modulation patttern.

Operating Through the Repeater

Operation through the repeater is very straightforward. Normally a high gain, highly directional parabolic dish antenna is required at the users station to operate through the antenna. A typical station might transmit 0.1-1 watt with a 1'-4' dish antenna. This requires proper pointing of the dish antenna at the repeater, as the typical beam widths may vary from 2-8 degrees. To align the dish, the beacon is first tuned in and the antenna peaked for maximum received signal. A frequency different than that of the beacon is then selected and communications is established through the repeater.

Test results of Phase 1

Two stations running SSB with 30" dish antennas and .3 watts and 8 watts at distances of 20 miles and 10 miles lined up their antennas on the beacon and began communicating. Both stations received each other "S9" when the repeater was operating, and barely copyable when the repeater was turned off. The station at 20 miles also noted that the beacon level increased about 8 dB when the repeater was turned on. 7 different stations have worked through the repeater. Tests have indicated that the overall apparent gain of the repeater is about 10 dB lower than expected. The measured system gain based on data from two sites located 8 miles from the repeater is equivalent to having two 13 dB antennas with 70 dB of amplifier gain.

While in operation from about Nov 1995 to June 1996, the repeater successfully supported transmissions of CW/SSB, NBFM, ATV (AM), Full Duplex WBFM (30 MHz Offset centered around 10368 MHz), and 1200 Baud Packet. At the end of this document are a block diagram, a printout of the MathCad signal strength calculations and a chart showing the calculated received signal for two repeater users with varying distances from the repeater.

Phase II

The repeater was taken down in June 1996 with the intent of increasing the gain through greater separation of the antennas. During Phase I testing it was also realized that an oversight of the placement of the variable attenuator directly ahead of the PA did not allow full power output to be achieved. The attenuation required to prevent oscillation reduced the maximum power output of the previous stage below that needed to drive the PA to 1 watt output. The maximum power available from the repeater was about 0.1 watt with this configuration.

Modifications

The original receive antenna and first two LNAs with filters were removed from the repeater housing and built into a separate PVC pipe enclosure with its own power supply board. The original repeater enclosure was left in tact with the two LNAs removed. Also the remaining LNA which drives the PA was connected directly to the PA through a filter and the variable attenuator placed ahead of that LNA. This raised the maximum PA output power to 1 watt and eliminated the dependence upon the attenuator setting. While performing garage and backyard testing with this configuration, it was realized that the maximum amount of gain at the point of oscillation was not limited by antenna separation but by leakage around the SMA cables and connectors of the input LNAs. The realization came when the slots of the antenna were covered with adhesive backed aluminum tape and the maximum gain at oscillation change only slightly.

The problem was investigated by connecting the output of the receive antenna/LNA assembly to a spectrum analyzer and a source consisting of a GUNN oscillator and flexible coax cable with a female SMA connector on the unconnected end. The localized field from the end of the coax worked well to determine where leakage was occurring by slowly moving the end of the coax along the entire antenna/LNA chain placing it in close proximity to all connections and housings. Two types of shielding problems became apparent. All of the SMA flange mounted connectors on the receive antenna, LNA input and LNA output were bolted and not soldered to the housing. The leakage around those connectors was amazing even though they appeared to not have any visible gaps between the connectors and the housings. The connector on the WR-90 waveguide to SMA transition was very bad & this was a commercial unit! The other main source of leakage was the LNA housings themselves. All leads pass through feed through type capacitors and they were doing the job. Here is the approach taken to most easily solve the problem with the current hardware. The LNA housings were wrapped with 2" wide aluminum tape taking care to overlap all joints. The connector problem was reduced to a manageable level by cutting a hole in the tape just large enough to slide over the threads of the female chassis mount connectors but small enough to cover the connector screws and flange.

Results Of The Modifications

It was found following the above modifications, that even with the original antenna spacing of 10' oscillation was not now the limiting factor. As stated earlier, the slots of one side of both antennas have been covered with aluminum tape. This has allowed backyard testing of the repeater by placing the repeater horizontal on a tripod and aiming the active side of the antennas straight up. With this setup it was possible to increase the gain of the amplifier chain by an additional 20 dB without oscillation. The limiting factor now appears to be the overall noise of the amplifier system. It is anticipated that the gain will be set for some broadband noise output power level that is considered acceptable. At this point an initial level of about 10 milliwatts will be tested to see if it will provide a reasonable compromise between dynamic range, gain and background noise level. This level should provide about a 20 dB increase in gain over the Phase I configuration and provide a 20 dB dynamic range. The noise level is not expected to be a problem as this power level will be reduced by 30-40 dB for narrow band reception.

Testing and Future Modifications

By the time the 1996 Microwave Update convention is held, we hope to have installed the modified repeater. The tests to be performed will include transmitting through the repeater using a station with known ERP and measuring the received power at another location to determine the effective overall gain of the repeater. The noise power increase observed by close in stations will also be measured to help determine the best repeater gain setting. A potential future modification might be to try using the repeater output power indicator to control the variable attenuator as a form of AGC . One additional test that should prove interesting will be to see if the additional repeater gain will allow the 10,368.000 MHz Palos Verdes Beacon, some 90 miles away, to be heard and repeated into the San Diego area. This could provide an excellent frequency check and propagation indicator. Approximately 20 dB should be able to be added to the MathCad calculations and Signal strength chart over those used for Phase 1.

Acknowledgments

A number of Hams have contributed to the success of this project. Jerry, WA6VLF, provided the site and installation. Chuck, WB6IGP, contributed components and has documented this effort through photos. Ed, W6OYJ, worked with the ARRL to obtain an opinion on the legality of this repeater type. Pete, W6DXJ, modified LNAs for the project. All of these Hams have been intimately involved in the support of the repeater testing. Phil Karn, KA9Q, Paul Williamson, KB5MU, and Dewayne Hendricks, WA8DZP have contributed the equipment and software support for future 56 Kb experiments. Additional members of our local group have also contributed by using the repeater system & providing feedback.

X-Band Repeater Calculations

$H1ant := 28$ Home 1 Ant Gain db
$H12repdist := 8$ Home 1 to Rep Dist Miles
$H1xpwr := 30$ Home 1 Xmit Pwr dBm

$Home2ant := 28$ Home 2 Ant Gain db
$H22repdist := 8$ Home 2 to Rep Dist Miles
$H2xpwr := 30$ Home 2 Xmit Pwr dBm

$Repant := 13$ Repeater Ant Gain dB
$Repgain := 70$ Repeater Amp Gain dB

$Freq := 10368$ Operating Frequency in MHz

$k := 36.57$ Distance units = Miles

K for variuos units

Meters=-27.56

Yards=-28.34
Feet=-37.88
Km=32.44
Miles=36.57
Naut Miles=37.79

$PathlossH12rep := k + 20\cdot\log(H12repdist) + 20\cdot\log(Freq)$ $PathlossH12rep = 134.946$ dB

$Reprxpwr := H1ant + H1xpwr - PathlossH12rep + Repant$ $Reprxpwr = -63.946$ dbm

$Repxmtpwr := Reprxpwr + Repgain$ $Repxmtpwr = 6.054$ dBm

$PathlossH22rep := k + 20\cdot\log(H22repdist) + 20\cdot\log(Freq)$ $PathlossH22rep = 134.946$ dB

$Home2rxpwr := Repxmtpwr + Repant + Home2ant - PathlossH22rep$

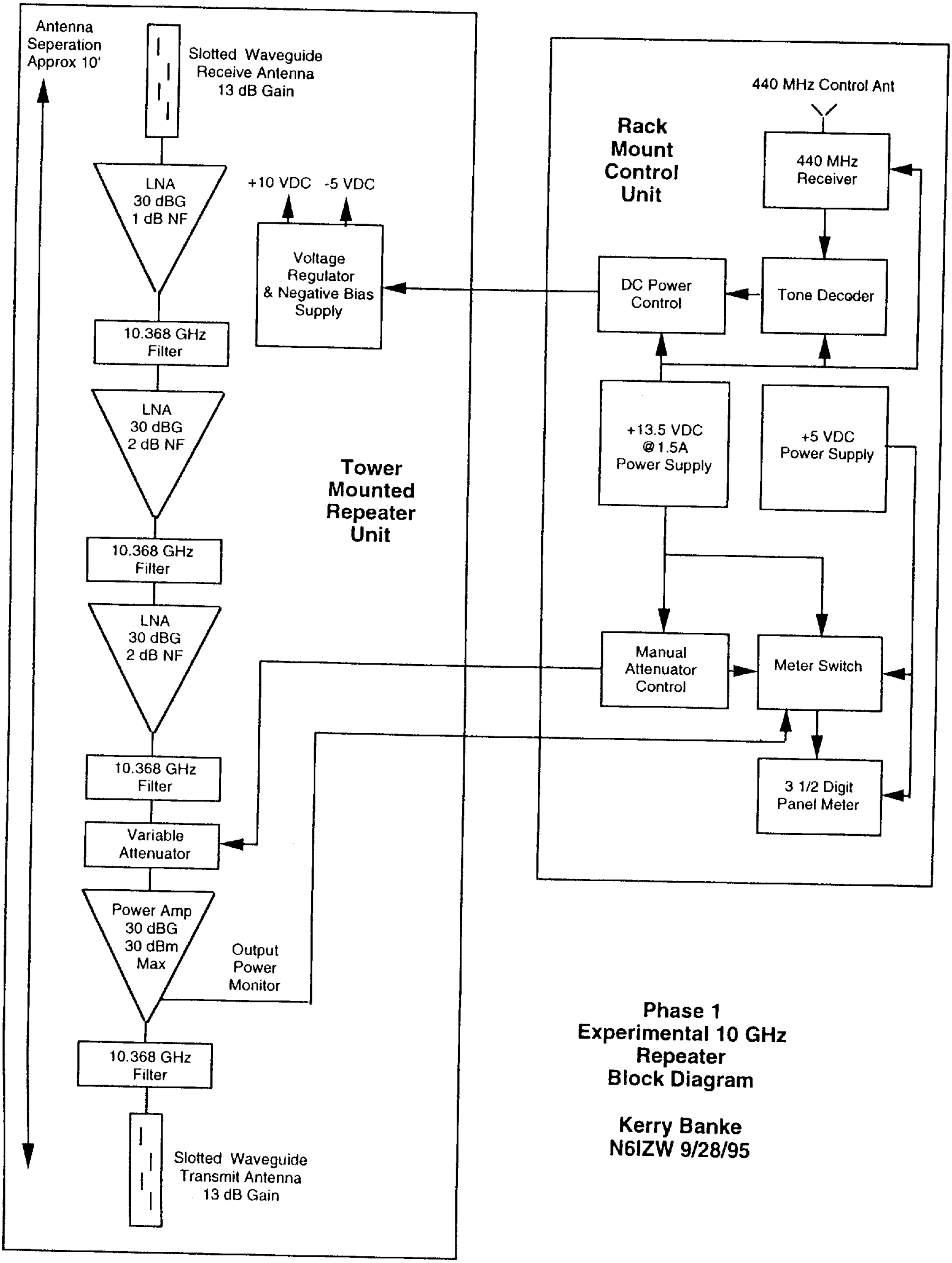
$Home2rxpwr = -87.891$ dBm

$PDBM := Home2rxpwr$ $PMW := 10^{\frac{PDBM}{10}}$ $PMW = 1.625\cdot 10^{-9}$

$V := \sqrt{PMW\cdot 50\cdot 10^{-3}}$ $V = 9.0139\cdot 10^{-6}$

Received Signal strength Calculations 1Watt, 12" Dish Antenna

	Distance Station 1 to Repeater Miles	Distance Station 2 to Repeater Miles	Receive Power dBm	Receive Voltage Microvolts		
	8	8	-87	9		
	30	8	-99	2.4		
	30	30	-110	0.64		
	8	70	-107	1		
	15	15	-99	2.6		



Phase 1
Experimental 10 GHz
Repeater
Block Diagram

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