An Example of Gear for the 241GHz Amateur Band

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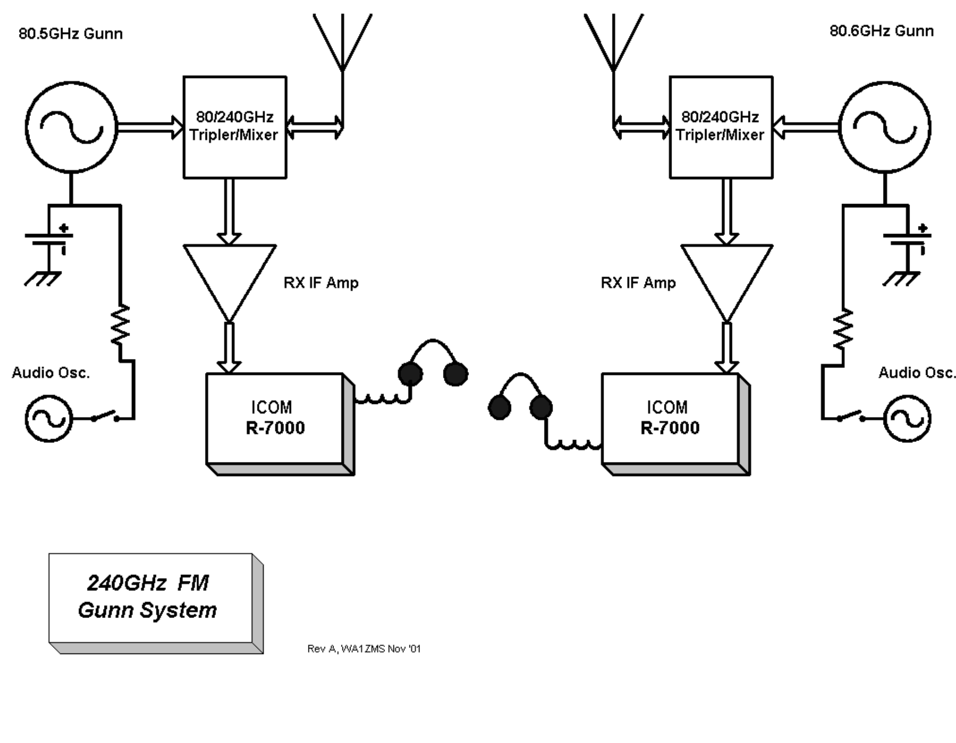
I. INTRODUCTION

This paper will explore just one of many possible design architectures resulting in gear that is truly functional for working DX on the 241GHz Amateur band. The design was driven by parts availability, proven PLL architecture, and the quest to explore what is currently the last amateur allocation below 300GHz. As a plus, this design was also able to explore the 322GHz frequency 'band' by utilizing additional harmonic outputs.

II. SYSTEM DESIGN

The basic 241GHz communications system evolved around a pair of power triplers that were originally designed for use as LO power multipliers for radio astronomy applications. (1) Each tripler use Schottky diodes as the non-linear power generating element and produces 750 uWatts at 241GHz when driven with 40 mWatts of 80GHz signal. The original tripler design was modified slightly to allow for the addition of a low-frequency IF port. This low-frequency port is the point where the receive IF signal will be picked off when the tripler is used as a harmonic mixer. The mixer conversion loss was measured to be around 35dB when used in receive mode.



The triplers are each driven by an 80GHz Gunn oscillator. The frequencies of the Gunns are offset from each other resulting in a Gunnplexer like frequency scheme. The Gunn drive signal can be thought of as being 1/3 of the final transmit frequency, and as 1/3 of the receive local oscillator frequency.

Initial use of the stations involved letting the Gunn oscillators free-run and employed power supply pushing to FM modulate the RF signal. One negative result of letting the Gunns free-run, was the high value of wide band phase noise that was contained in the transmit signal. Any FM noise generated in the Gunn source itself will be increased by a factor of three in the tripling process. The mixed-down receive IF signal not only contained the phase noise of the transmitted signal, but also contained the phase noise of the receiver LO. The end result of all this phase noise was a receiver IF signal that was over 500KHz wide with out any useable modulation added yet. Since the widest receiver IF on hand was only 200KHz (intended for broadcast FM), most of the received signal power was falling outside the receiver passband. Despite this limitation, QSOs were made that claimed North American DX records. (see section IV below).

A major technical improvement was made by phase locking the Gunn oscillators to crystal references. The specific style of offset-loop PLL design had been used by the author in previous millimeter wave projects and had been copied several times with excellent success and was selected for use in this project as well. (2)

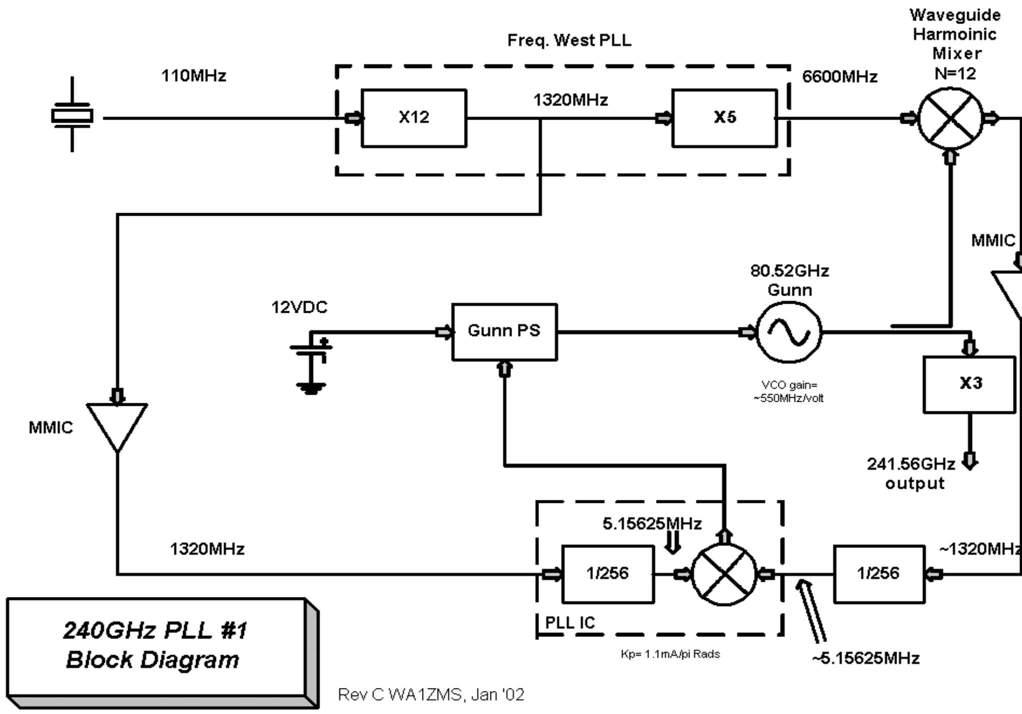
Circuit Description

The 80GHz Gunn oscillators are built around a pair of 2*Fo mode cavities that were purchased from Harmonix Corp. The diodes used are 40GHz devices obtained from a surplus house in the UK.(3) Each Gunn delivers around 50mW at 80.6GHz in the fix-tuned cavity. Electronic tuning for phase locking is accomplished through power supply pushing of the Gunn's DC supply.

The triplers are based on a design by Virginia Diodes, Inc. and were intended for use as full waveguide-band power multipliers in radio astronomy receiver LO chains. The tripler design was modified to allow for the inclusion of a low-frequency IF port. This IF port enables the power tripler to function as a harmonic mixer for use as a receiver mixer.

Phase locking of each station involved the addition of a voltage-pushed low noise power supply, PLL IC, and homebrew ovenized crystal oscillators. The oscillators are based on the classic two transistor Butler circuit and use 5th overtone series resonant 60º C crystals from International Crystal.

The basic "offset-loop" PLL design used is the same design that has been presented in similar gear for the 145GHz band. (2)

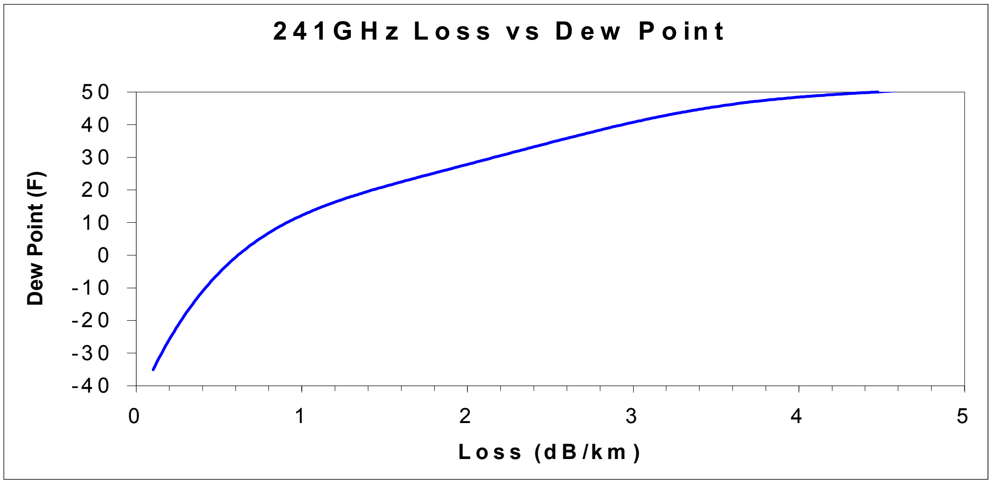


III. ATMOSPHERIC CHARACTERISTICS

By far, one of the most interesting aspects of operating on the 241GHz band has to be that of radio wave propagation through the atmosphere. A majority of the commercial and military applications at these frequencies involves space-based satellite linking and limited earth to space links with high angles of elevation. Very little actual low-angle terrestrial linking takes place this high in frequency, primarily due to the relatively high value of atmospheric losses. This gives the amateur community an excellent opportunity to explore yet to be discovered propagation modes and methods. The majority of the commercial industry has written off practical use of these high frequencies for long haul terrestrial paths due to this high loss.

Both water vapor and oxygen are the primary gaseous absorbers of radio signal in this band. For the standard ITU atmosphere (7.5g/m^3, 1013mb, 15degs C), the loss due to oxygen is around .028dB/km. However at the same time, the loss due to water vapor is 2.72dB/km or some 97 times that of oxygen alone.

Below, is a graph based on equations from Leibe showing the expected total atmospheric loss from both water vapor and oxygen as a function of dew point, with dew point being a direct indicator of water vapor content in a given air mass. (4)



IV. CONTACTS MADE

Once the initial free-running Gunn stations were constructed, some simple short range QSOs were planned. Based on receive margin tests done over a 50 meter path (along with sighting-in the rife scopes used for pointing) it was determined that the 'official' minimum distance of 1km could be traversed on 241GHz.

On Dec 15th, 2001 a 1 km 241GHz WBFM QSO was made between the two stations using the callsigns W2SZ/4 and WA4RTS. Also on that same day, a QSO on 322GHz was made using the same gear by tuning the IF receivers to what would be the corresponding IF frequency while the triplers were operating as quadruplers and as times-four harmonic mixers. At that time, the best distance that could be made was 50 meters. Both of these QSOs were noted as being North American firsts for their respective bands.

Later in the winter of 2002, each station was modified to include the necessary phase locking components. This resulted in a dramatic reduction of the transmitted phase noise (and RX LO phase noise as well). This allowed for the use of much narrower receiver IF bandwidths and gave a calculated 23dB improvement in signal to noise ratio.

Various QSOs were then made, each one setting a new DX record as progress went on. By the summer of 2002, our best DX for 241GHz stands at 11.4km during an FSK-CW QSO between W4WWQ and WA1ZMS/4 on March 11th, 2001 at 02:25z. While on 322GHz, our best DX ends up being 0.5km during an FSK-CW QSO on March 1st, 2001 between W4WWQ and WA1ZMS/4. These QSOs now stand as both World and North American DX records.

Future plans include the use of very narrow band modulation techniques along with a possible reduction in the conversion loss of the receive harmonic mixers. Larger dish antennas are also planned.

V. CONCLUSION

Photos of the equipment and audio files of some of the QSOs can be found by going to: http://www.mgef.org

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VI. REFERENCES

1 – Virginia Diodes Inc, web site: http://www.virginiadiodes.com/

2 – B. Justin, WA1ZMS, "An Example of Gear for the 145GHz Amateur Band", Microwave Update Proceedings, ARRL, 2001.

3 – P. Day, G3PHO, "Microwave Newsletter", RSGB, Feb 2001.

4 – G. Brussaard & P. A. Watson, "Atmospheric Modelling and Millimetre Wave Propagation", Chapman & Hall, 1995.