Low Phase Noise 38GHz 20 dBm Source for PCN Radio Links

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ABSTRACT:

This paper describes the first Low Cost, Low Phase Noise Source using Silicon Bipolar Transistor, GaAs PHEMT frequency multipliers and a GaAs PHEMT MMIC amplifier to achieve 20 dBm at 36 to 40 GHz. This source includes a Si MMIC prescaler to achieve an L-Band output for easy phase locking of the RF source. Phase noise of better than -85 dBc/Hz at 100 KHz offset has been achieved at 40 GHz to help meet the system requirements of the PCN digital radio link.

INTRODUCTION:

The wireless revolution has created a number of new opportunities for microwave technology. Point to point radios are now being used to connect cellular and PCN cell sites with the central switching station as well as for private data links. With the saturation at 2,4,6,10,11,18 & 23 GHz radio bands, a need for a virgin frequency band was obvious. 38 ± 2 GHz has emerged as an internationally accepted band for the emerging wireless applications. Europe has taken a lead in exploiting this band and is rapidly deploying these radio systems. These radios however need to be cost competitive to leasing equivalent wireline capacity from the local telephone or cable TV company. In the US the FCC recently has licensed 36 to 40 GHz band to cover a rectangular area.

In order to produce radios for this huge need, low cost, user friendly and high performance components are a basic necessity. The Tx source is typically the most expensive RF component in the system. A number of different approaches have been used in the transmitter design of radios above 18 GHz. The most common approach has been the use of fundamental Gunn Oscillators.

Till recently the three terminal device technology, though available for years have not been cost competitive with the Gunn solution. Gunn oscillators have inherent problems of microphonics, cold start, consistency, mechanical tolerance requirement, DC power, space and weight requirement. Multiple Gunn oscillators are required to cover the full band. On the other hand Gunns have excellent phase noise and can generate the required 17 to 20 dBm power using a single device. GaAs MMIC prices at mmw frequencies have now come down to be an attractive alternative. A recent approach used a fundamental GaAs MMIC VCO with dual varactors[1], but has inadequate phase noise and linearity for easy application in the high level FSK modulation scheme. Fundamental oscillators have an additional disadvantage of requiring complex harmonic sampler based phase locking techniques.

DESIGN APPROACH:

In this paper a unique approach optimizing the use of silicon and GaAs technologies for a high performance and cost competitive solution for the Tx source at 38 GHz is presented. An optimum use of Silicon and GaAs technology particularly MMICs, has helped develop a low cost and high performance solution for this new application.

Figure 1 shows a block diagram of the proposed configuration. This source simultaneously provides an L-Band signal in addition to the final frequency. A low phase noise C-Band Si Bipolar VCO is followed by two GaAs frequency multipliers to achieve a multiplication factor of 8. A times two followed by a times four GaAs transistor active multiplier is used. Using times four first would have required an expensive K band buffer between the two multipliers. An auxiliary output of the VCO feeds a silicon divide by four MMIC Prescaler to generate L-Band signal to be used for phase locking. A high gain 20 dBm power MMIC represents the final stage. A diode detector in the output provides a power monitor feature. A unique feature of this source is the optimum utilization of Silicon & GaAs technologies. The main features of this 36 to 40 GHz source are:

1) Availability of L-Band signal for phase locking the source to the reference frequency.
2) High isolation of the oscillator frequency from load due to freq. converters & MMIC.
3) Freedom from microphonics & thermal issues compared to the Gunn cavity oscillators.
4) Low phase noise of silicon bipolar VCO and optimized use of frequency converters.
5) High linearity single diode tuning characteristics for efficient data transmission.
6) Single source to cover the full bandwidth of 36 to 40 GHz.

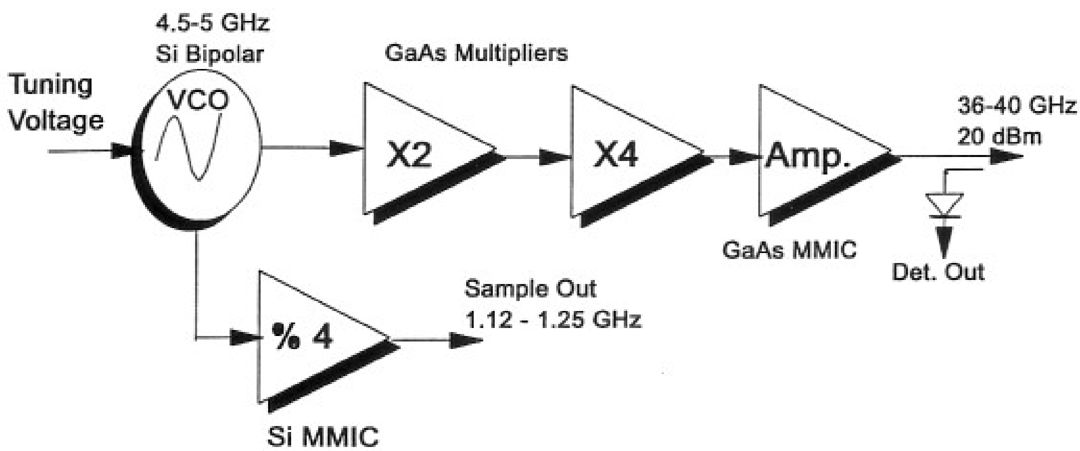

Figure 1 Block Diagram

OSCILLATOR & FREQUENCY DIVIDER:
The 4.5 to 5 GHz VCO is the main element of this unique source module. The challenge is to provide a low phase noise and high linearity VCO. An Avantek AT42000 low phase noise silicon bipolar device in conjunction with a high Q hyperabrupt varactor has been used. The varactor diode is used in the emitter terminal of the transistor and RF output is taken from the collector (Fig. 2). A series feedback inductor is used in the base to generate necessary negative resistance in the desired frequency range. Matching circuit at the collector is optimized for phase noise and power output. An adjustable attenuator in the output is used to provide the necessary isolation from the frequency multiplier. Power output of greater than 10 dBm has been obtained over 4.5 to 5 GHz. Phase noise at 100 KHz was measured to be better than -100dBc/Hz. An HPIFD 53000 silicon static Frequency Divider by four is used on the second RF output port, lightly coupled to the VCO. This prescaler requires only -10 dBm and provides -5 dBm power output at one fourth of frequency.

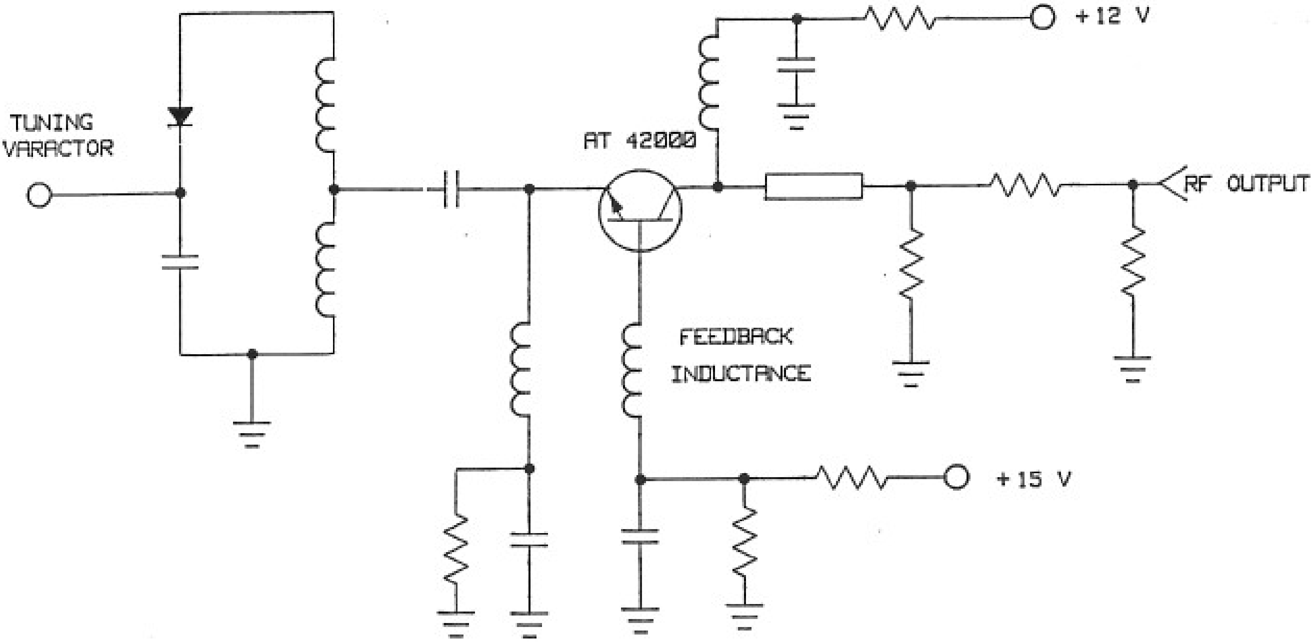

Figure 2 : VCO Schematic

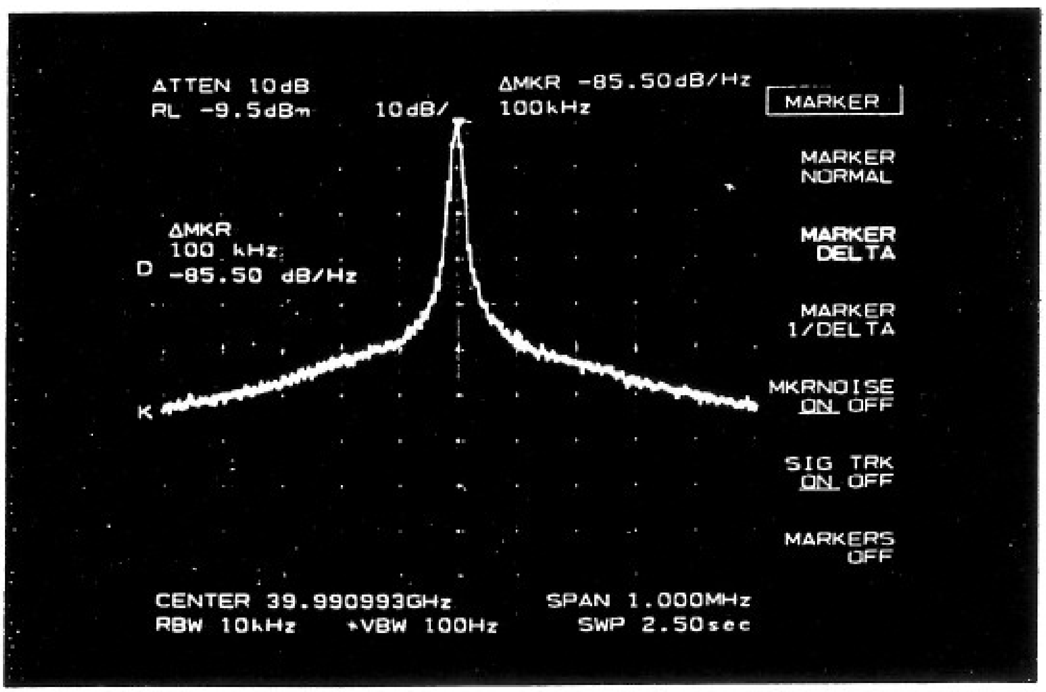

Figure 3: Frequency Spectrum at 40 GHz using HP 8565 E Spectrum Analyzer

FREQUENCY MULTIPLIERS:

The first multiplier (times 2) is an HP GaAs FET with 0.25μm gate length and 250μm gate width, fabricated on MBE material. An open stub of electrical length of 90° at 4.75 GHz was connected to the drain for blocking the fundamental frequency mode while simultaneously presenting the necessary drain reactance for maximum multiplication gain. HP MDS program was used to optimize the input/output match as well as the bias. A highly selective band pass filter was used in the output to eliminate the undesired harmonics. A conversion gain of 2 dB was obtained over 9 to 10 GHz output.

A second frequency multiplier (times four) uses an HP GaAs PHEMT with a sub 0.2μm gate length and 448μm gate width, fabricated on MBE material. The device has an f_t of 70 GHz and f_{max} of 120 GHz and the device is capable of delivering 21 dBm of linear power with 9dB of gain at 20 GHz. The device has a high non-linear transconductance that is adequate for generation of high order harmonics once the bias and matching circuits are optimized[2]. A highly selective band pass filter was used in the output to eliminate the undesired harmonics. A conversion loss of 8 dB was achieved for times four multiplying of the 9 to 10 GHz signal

POWER MMIC:

PCN38 a 20-40 GHz MMIC 4-stage amplifier, designed on a sub 0.25μm-gate PHEMT production IC process. This chip has exceptional gain of greater than 20 dB and saturated power of greater than 20 dBm over the entire 20 to 40 GHz[3].

A traveling-wave-input/power-combined-output scheme used in the first stage using two 120μm FETs has resulted in an area efficient broadband amplifier design. The second, third & fourth stages are 240μm, 360μm and 450μm FETs respectively. A reactive output match provides optimum load for max. power across the band. Important typical parameters of the chip are shown below in table 1:

PCN38 MMIC Power Amplifier

Frequency Bandwidth	20 - 40 GHz
Gain	22 dB
In/Out Return Loss	> 8 dB
P_o (-1 dB)	18 dBm
P_o Sat	21 dBm
Bias	5V; 300 mA; -0.4V
Size	1.72 X 0.76 mm^2

Table 1

EXPERIMENTAL RESULTS:

The oscillator with first multiplier and frequency divider are constructed on a 0.25 mm thick alumina substrate with thin film hybrid circuitry. A second substrate contains the second multiplier, microstrip bandpass filter, GaAs MMIC power amp and detector for power monitoring. Adjustable small value thin film attenuators were used before the first and second frequency multiplier for better level control, matching and isolation between the stages. DC circuit was incorporated on a PCB. All the three substrates are assembled in an environmentally sealed package of 3" X 3" X 1".

Microstrip to waveguide transition is incorporated in the package and final output is made available on WR42 waveguide output. The results of the complete source are as follows:

Frequency : 36 to 40 GHz
Power Out: 21 ± 1 dBm
Sample Out: 1.125 to 1.25 GHz
Phase Noise: -85 dBc at 100 KHz
Modulation Bandwidth: >20 MHz
Tuning Voltage: 2 to 13 Volts
Tuning Sensitivity variation: < 1.1 : 1 over 300 MHz,
< 1.5 : 1 over full band
Spurious: -50 dBc
RF Power detector: 0.5 to 1.5V at full power

Figure 3 shows the frequency spectrum of the free running source at 39.9 GHz and Fig. 4 represents the phase noise plot.
Figure 5 shows the predicted and measured frequency and tuning sensitivity with tuning voltage.

CONCLUSION:
A Low Cost, Low Phase Noise Source using Silicon Bipolar Transistor, PHEMT frequency multipliers and an MMIC to achieve 20 dBm at 38 GHz has been described. This source includes a prescaler to achieve L-Band output for easy phase locking option of the RF source. Phase noise of -85 dBc/Hz at 100 Khz offset has been achieved over the radio bandwidth.

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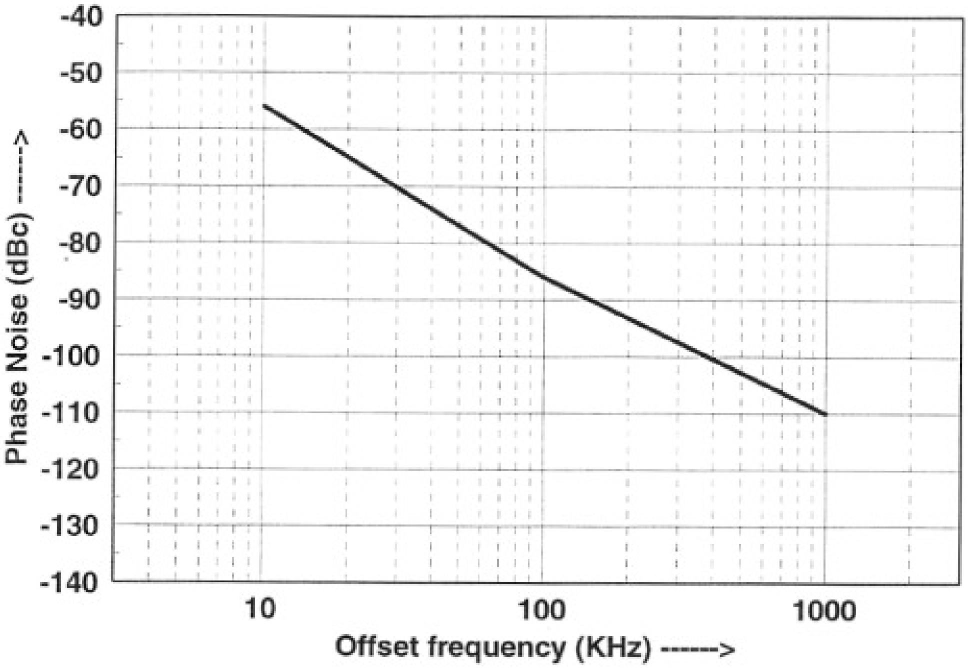

Figure 4: Phase Noise plot at 40 GHz

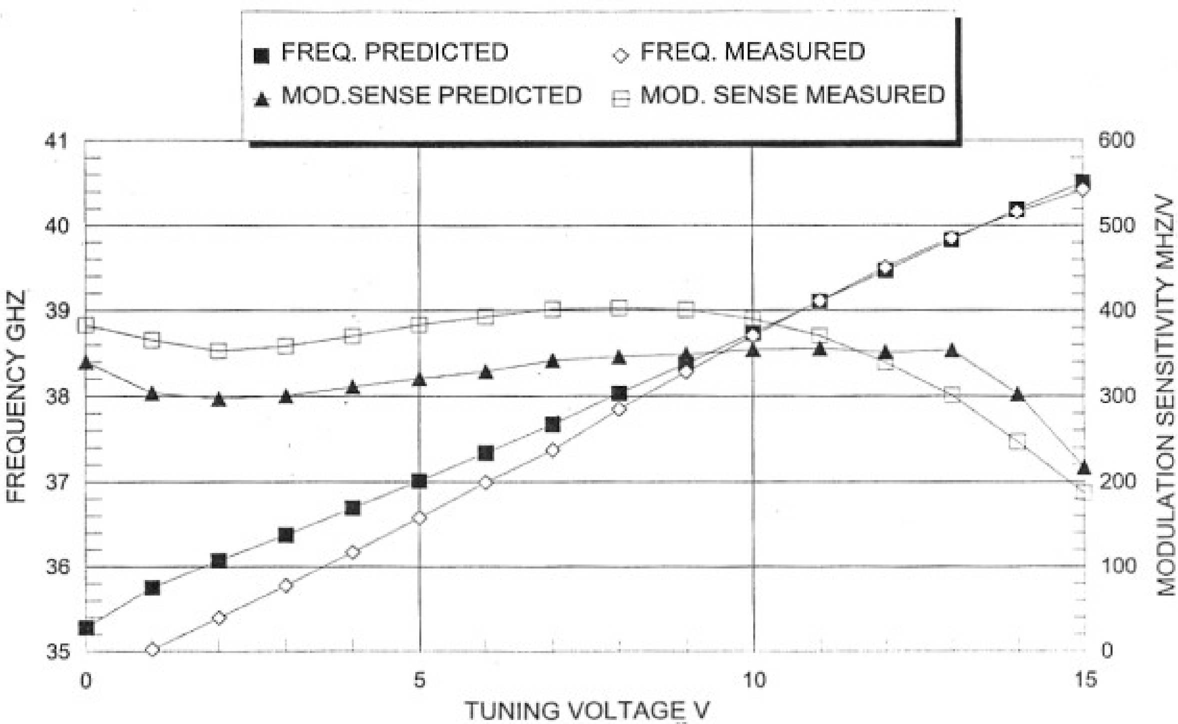

Figure 5: Frequency and Tuning Sensitivity with Tuning Voltage