24 GHz Modules

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Recent, low cost, GaAs devices have proven to be usable at 24GHz for the construction of LNA (low noise amplifiers), power amplifiers and frequency multipliers. This article presents a low cost solution to build 24GHz modules using a common design for the mechanics, enabling, this way, the experimentation of several devices and configurations without the cost and time associated with the manufacturing of a milled case for each design. Also presented here, three basic modules for 24GHz, an amplifier, a frequency doubler, and a fundamental mixer.

Introduction

Packaged GaAs Fets, used in the TVRO industry, prove to be usable at 24GHz. although they are usually specified up to 18 (and sometimes to 20GHz) they can be put to work at 24GHz with careful tuning. Low noise amplifiers where developed /1,2/ and also frequency multipliers operating at 24GHz /3,4/, and even some attempts at 47GHz have been done by the author, by DB6NT, JA1AAH /5,6/ and certainly by others.

One major limitation on the experimentation at these frequencies is the fact that each circuit needs to be properly mechanically installed in a shielded box (usually a aluminum milled box) and provided with the necessary coaxial or wave-guide input and output. Every time a new circuit is to be experimented one must build a new box to accommodate the PCB. Therefore (excepting a few audacious people) only certified or quasi certified designs worth the effort and money.

These designs

To make the experimentation easier I decided to attack the problem the other way around. Only one mechanical design is necessary (or two if you want, I explain later) and the several modules will fit inside. This requires that all circuits must have the connections placed at the same position, which is not a restriction for the kind of modules we envisaged.

The maximum number of FET is likely to be 3, as in the DB6NT amplifier /1/, all the other circuits are expected to be smaller than a 3 FET amplifier. I used this assumption to define the maximum room that I need for a module, resulting in 45 x 16 mm internal dimensions. All power supply components will be external to save on the amount of PCB needed and also to have the smallest overall size possible.

A configuration where a wave-guide input and coaxial output (or vice versa) (fig.1) gives the maximum possibilities for interconnection. So a low noise amplifier will have WG input and coax output, while a power amplifier will have coaxial input and wave-guide output and a frequency doubler would be coaxial input (at 12GHz) and WG

output (at 24GHz). As input and output are at the same relative position, any of the modules can be placed inside the box either way.
If you want to have the same modules but only SMA connectors and no WG port a second milled case can be built (fig 2).
The WG input (or output) transition central pin is made of semirigid UT085 cable, using only the teflon inner conductor, that fits inside a hole with the same diameter as the cable's shield.
The transition from the stripline to the wave-guide is done in the same plane as the WG flange (that is, parallel to the bottom of the box, see drawing and photos for clarification).
This arrangement resulted in little return loss and proved to be better than the 90deg solution commonly used on 10GHz and 24GHz.

Low Noise Amplifier

The LNA consists of three HEMT stages connected via 1/4 wl couplers on 50Ohm lines somehow similar to DB6NT's /1/ but rearranged to fit inside the box and without negative bias voltage generation. The first stage connects directly to the waveguide for the lowest possible loss, while the output is DC isolated with a 1/4wl coupler. The prototype PCB uses only straight 50Ohm lines and requires tuning on each FET (at gate and drain) by placing small stubs along the lines while monitoring the relevant characteristics (be noise figure or gain). This way some different types of transistors could be tested and their possible use on 24GHz evaluated. The sets FHX13, FHX13, FHX14 and NE32463, NE32463, NE32563 were the ones that produced the best results. A gain better than 24dB, with noise figures below 2.0 dB, should be always possible to obtain.
The best I could get was from the NEC transistor set and was 26dB gain and 1.4dB (+/- 0.2dB) noise figure. Noise figure measurements where done with Hot/Cold method using load at different temperature and also the sky of several clear days, as suggested by DK8CI in /7/, for the people without a good noise source and no liquid nitrogen at hand.
To operate, the amplifier requires +5Volt and -5Volt from a external supply. The FET's polarization should be adjusted for maximum gain or lowest noise figure on the first FET (also on the second if desired).
Mitsubishi HEMT transistors were not available at my stock, therefore I could not test them, but should work as well.

Power amplifier

A 10 milliwatt power amplifier can be built using the same strategy as the LNA described previously. Basically the PCB design is the same with only the 1/4wl coupler now on the input and direct stripline on the output, to the waveguide port. Also the FET biasing resistors are modified in order to make them drawn more current from the 5V, specially on the last stage (reduce the R1, R2 and R3 to 47Ohm). The HEMT transistors used here may be the ones with higher NF (lower cost) like the NE32863 or the FHX15, since in principle they have the same all other caracteristics besides noise figure. Attempts with a MGF1303 and MGF1425 where done with good results but lower gain was obtained (15dB) comparing with the HEMT devices (23dB). Output power, at 1dB compression, vary from device to device and are in the range of 8 to 12 dBm. A 10dBm output is easy to obtain.

Frequency doubler

To use fundamental mixers on 24GHz (sometimes, good WG units were found at flea markets) a good source for local oscillator is mandatory. Also for those experimenting at 47GHz a good source of 24GHz is of interest. This design uses two transistors, the first as a buffer for the 12GHz, and the second as the multiplying device. Again, to allow the test of several types of transistors, all signal lines are 50Ohm and tuning is required to match every transistor. Tests were made using a MGF1303 plus a MGF1425 and more than 10dBm were obtained after quick tuning (for 10dBm at input). Levels as high as 15dBm may be reached by increasing the current and exhaustive tuning but also the transistor may show its limits during the tests. If you don't have many transistors or don't like GaAs smoke, don't push much above 10 dBm.

24GHz Mixer

This is the last module I present here and is a fundamental one to make a transverter. Two different version are presented: one with integral microstrip band pass filter and another without filter.
For transverter designs using 144MHz as intermediate frequency the filter required is too narrow to be feasible in a microstrip design. In this case a mixer module without filter should be used and installed with the input to the WG port, allowing direct connection to the waveguide filter.
The module with integral band pass filter is suitable only for configurations having an IF greater than 1GHz since the filter has about 1.5GHz band pass at 3dB. The filter design resulted in a compromise between insertion loss and bandwidth. The present design has already 3 to 4 dB of insertion loss making the realization of narrower filters unpractical. Although the 1.5 GHz bandwidth can be tweak in such a way that it starts to cut just below the frequency of interest, making the image suppression greater than 30dB for an IF of 1296MHz.
This module requires a local oscillator in the 12GHz range and it employs a GaAs FET as the local oscillator frequency doubler to get about 7dBm to drive a rat race mixer. The diodes should be the best one can get. The BAT15 work reasonably well while the BAT30 (beam lead) should be the way to go for best performance (I already have them in stock, and in my agenda).

Construction

All PCBs are made of Rogers RT5780 10mils. After etched 1.5mm holes are opened at the grounding positions. Then solder them to a 0.8mm thick cooper sheet cut to fit inside the milled box. Some filing may be necessary for them to fit correctly. After some cleaning, to remove the solder flux they are ready to be populated. The modules can be placed in and changed as many times as necessary. Assembly of all components should be made with the modules out of the aluminum box. The ground connection of the FET's sources should be done at the exact position where the ceramic case ends (to make the connection as short as possible). Apply all general rules for GaAs FETs and SMD described in so many other articles.

Concluding remarks.

I believe that one dB or two more may be obtainable on any of the developed modules, but it is also my opinion that the tuning of such circuits becomes limited by the hand movement precision and patience (that last no longer than one hour) than by the devices themselves. There is plenty of room for your skills here. Thanks to all that helped with info and components.

/1/ - Low noise 24GHz amplifier - Michael Kunhe DB6NT - DUBUS 3/96

/2/ - 24GHz RatRace mixer - Erich Zimermann HB9MIN - DUBUS 2/93

/3/ - Rauscharmer 24GHz Vorvestärker - Erich Zimermann HB9MIN - DUBUS 1/94

/4/ - 47GHz Transverter - Michael Kunhe DB6NT - DUBUS 1/94

/5/ - 47GHz High performance components – T. Takamisava JA1AAH - MW update 96

/6/ - 47GHz Active doubler - Torishiko Takamisawa JA1AAH – DUBUS 4/94

/7/ - Hermann Hagn DK8CI - CT1WW Memorial 1997 - Oliv.Azmeis/Portugal.