A PCMCIA WEATHER SATELLITE RECEIVER

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Abstract - **There are several radios on the market capable of receiving weather satellite signals, however none are available in the PCMCIA form factor. Common off the shelf components have been investigated in order to realize a subminiature receiver which will fit onto a PCMCIA laptop computer accessory card. A full size prototype has been constructed and proven successful in the reception of weather satellite signals. The conclusion is that with the proper selection of surface mount components, a PCMCIA Type II sized weather satellite receiver is a practical concept. Detailed schematics along with performance data are included in the paper.**

INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) is currently responsible for operating weather satellites which are in polar orbit around the earth. These satellites located 800 kilometers above the earth orbit every 101 minutes, moving westward 28.8 degrees on each succeeding orbit. Each satellite has an array of sensors which constantly monitor the earth and send this data back to earth via radio link.

The satellite radio signals are in the VHF band from 137 to 138 MHz with a transmitter effective radiated power of 37 dBm (EIRP), using a right hand circular polarized antenna. Since the average free space path loss at 2000 kilometers is -141.3 dBm, the received signals here on earth are relatively weak. The modulation format is Frequency Modulation (FM) with the demodulated baseband audio being an amplitude modulated carrier of 2400 Hz which contains the sensor data. The baseband audio is then processed through a modem and the resulting video image of the earth is displayed on a computer monitor.

It is not a difficult task to design a receiver which is capable of receiving these signals. The big problem arises in the form factor requested. A PCMCIA Type II card, designed to plug into the new generation of laptop computers, is about the size of a credit card and less than 1/4 inch thick. Therefore the circuit must be the simplest possible while still being able to successfully receive the satellite signals.

Specifications

The following are the target specifications:

- Input Impedance 50 ohms
- Frequency range 137 - 138 MHz
- Sensitivity < 0.3 microvolts
- IF Bandwidth 50 kHz
- Image rejection >60 dB
- Powered by 5 volts DC

The first design goal of the receiver was a front end with a noise figure of 1.5 dB, this being the galactic noise level at 137 MHz. This should prove to be an adequate noise figure for reception of satellites within 2000 kilometers of the receiver site.

The next problem addressed is image rejection. In order to achieve image rejection of 60 dB, high Q circuits are needed. It would be very difficult to design high Q coils in such a small space as the PCMCIA card, and surface acoustic wave (SAW) filters are not yet available in this frequency range. Therefore, the image rejection is supplied by circuits located at the base of the receiver antenna.

Since the NOAA satellites commonly use only two frequencies, the receiver is designed with a four channel crystal oscillator to supply local oscillator injection to the receiver mixer. The design is such that in the future, the crystal oscillator circuit can be easily removed and replaced with a frequency synthesizer.

SYSTEM ARCHITECTURE

Using the above constraints, the following system architecture was investigated. Please refer to Fig. 1.

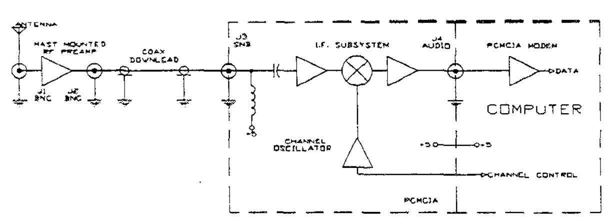

Fig. 1. System Architecture

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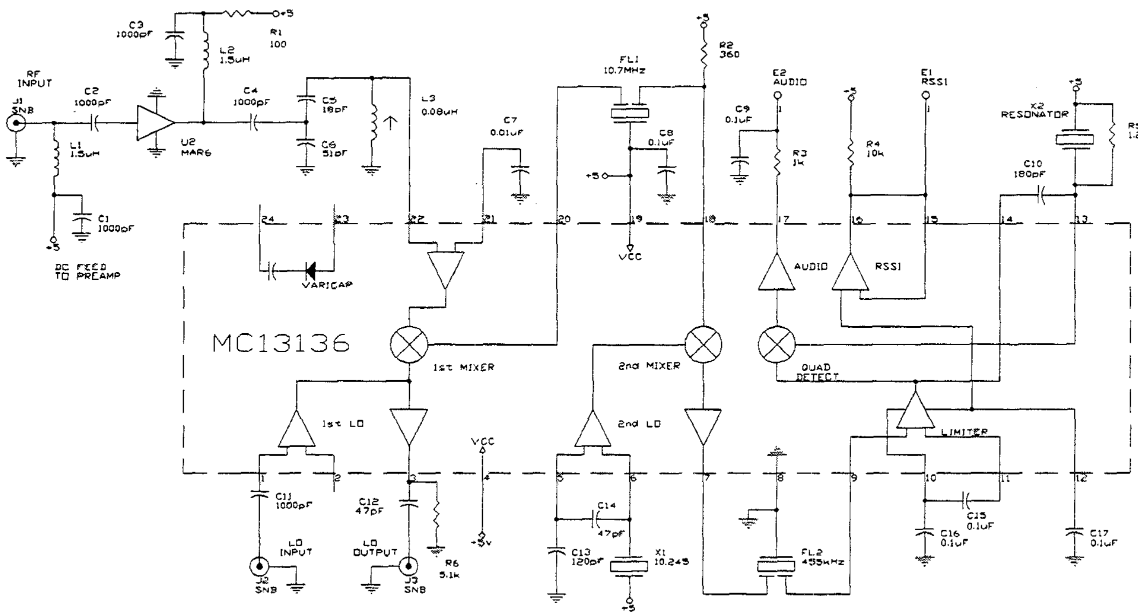

Fig. 2. Receiver Intermediate Frequency Subsystem

Intermediate Frequency (IF) Subsystem

The IF subsystem could be considered the heart of the receiver. Since it is called upon to handle the bulk of the signal processing tasks, this IF subsystem must possess the following characteristics:

- 100 dB of gain
- Selectivity (50 kHz bandwidth)
- Mixing of 137 MHz signal
- Image rejection of mixing process
- Limiter to remove AM components
- FM detector (+/- 15 kHz deviation)
- Powered by 5 volts DC
- Received Signal Strength Indicator

A search of the available literature indicated a variety of single Integrated Circuit (IC) chips which provide most of the functions necessary for the IF section of the receiver [1],[2]. These chips are mainly used in cellular telephones, cordless telephones and Global Positioning System (GPS) receivers, guaranteeing low price and good availability.

A single conversion receiver was built using the Philips NE605 chip on an evaluation board. The receiver was capable of receiving FM signals with quite low audio distortion, (less than 1%). On strong signals, the single conversion receiver sounded quite nice, both in the FM broadcast band (88-108 MHz) and the 2 meter amateur band (144-148 MHz). However, the single conversion design suffered from feedback on the circuit board. This is due to the fact that over 100 dB of gain at 10.7 MHz is developed on a physically small circuit board. This problem is inherent in high gain, high frequency single conversion designs and is not associated with any particular chip or manufacturer. The oscillation was quite obvious from the outset since "motor boating" could be heard in the background noise and the receiver didn't produce the steady rushing sound of white noise. Different shielding schemes were tried in order to isolate the input from the output but nothing proved totally successful. This underlying oscillation masked the reception of low level signals.

A dual conversion receiver was built using the Motorola MC13136 chip on an evaluation board. See Fig. 2. There was no sign of oscillation as present in the single conversion design. This is due to the fact that the gain is divided between two intermediate frequencies, namely 10.7 MHz and 455 kHz. After adjusting the values of the ceramic discriminator capacitor and resistor, the chip was capable of demodulating +/- 15 kHz deviation signals at a distortion level of about 5%. This distortion level is adequate for clear reception of satellite signals. Extensive on the air reception of satellite signals proves the reliability of this circuit.

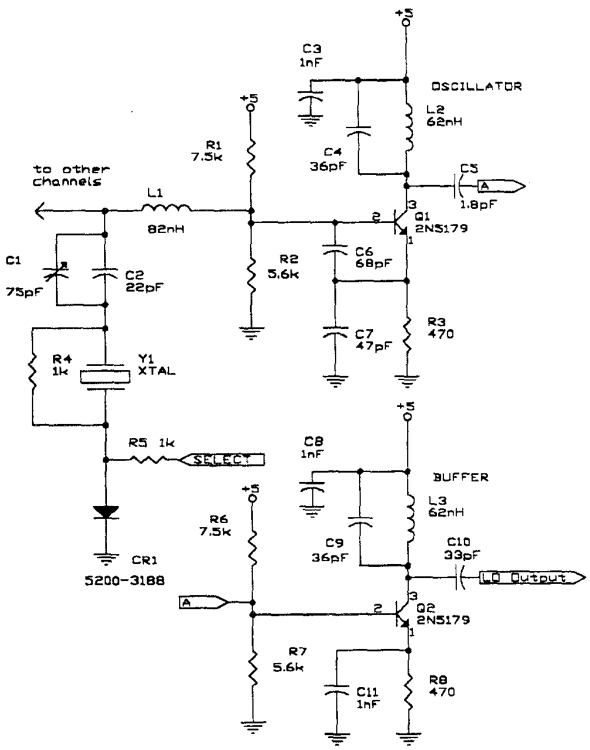

Fig. 3. Third Overtone Third Harmonic Oscillator

Injection Oscillator

Since the current NOAA satellites use only two channels, a crystal oscillator is chosen for its simplicity. The oscillator provides the necessary injection into the receiver mixer in order to produce the desired intermediate frequency (IF). Since the IF chosen for the receiver is 10.7 MHz and the received signals are in the 137 MHz range, the crystal oscillator operates in the 126 MHz range.

Fundamental mode crystals are now just becoming available for this high a frequency. However, they are expensive and difficult to work with. Therefore, overtone crystals are used. An overtone crystal oscillates on an odd overtone of the fundamental crystal frequency. These overtones are almost but not quite an exact integral multiple of the fundamental frequency. Three oscillators were investigated, a fifth overtone Butler, a fifth overtone Colpitts and a third overtone third harmonic Colpitts [3],[4].

The Butler oscillator is similar to a Colpitts except that a crystal is placed in series with the emitter of the transistor and the tapped capacitor network tied to the base. Despite the popularity of the Butler, reliable operation with this circuit was not achieved. It was found that the values of the feedback capacitors were very critical and the tolerances of 5% expected in surface mount component values could cause start up problems. The crystal used in this circuit was a fifth overtone, which is more expensive than a third overtone.

The next oscillator investigated was the classic overtone Colpitts. This oscillator proved more reliable than the Butler but it also exhibited sensitivity to the values of the feedback capacitors. Again, this circuit uses a fifth overtone crystal.

The final circuit tested was a third overtone, third harmonic Colpitts oscillator. See Fig. 3. In this circuit, the oscillator uses a third overtone crystal in the 42 MHz range, but the tank circuit of the oscillator is tuned to the third harmonic, or 126 MHz range. This signal is then passed to another amplifier which is also tuned to 126 MHz, thus further amplifying the desired signal while rejecting the unwanted products. This oscillator design proved extremely reliable both in oscillator startup and frequency stability. Also, the third overtone crystal is much less expensive than the fifth overtone crystal.

Preamplifier

The preamplifer, as seen in Fig. 4, has three main goals [5]. It establishes the noise figure for the receiver, provides 20 dB of gain and provides over 60 dB of image rejection. Since the target noise figure for the receiver is less than 1.5 dB, a Gallium Arsenide Field Effect Transistor (GaAs FET) is chosen for the active device. After a review of the available devices, a Mitsubishi MGF1302 was chosen as the ideal device. This transistor is capable of achieving noise figures below 1 dB at the design frequency of 137 MHz while developing in excess of 20 dB of gain. The normal drain to source bias voltage is 3.9 volts which makes the device easy to bias from a 5 volt power supply. And since the device is a depletion mode FET, a simple source resistor supplies the necessary self bias. The preamplifier is designed with a high Q, low loss network at the input of the GaAs FET followed by the lossier image rejection filter.

Since filters capable of 60 dB image rejection at 137 MHz are physically larger than a PCMCIA card, another solution was necessary. The GaAs FET preamplifier and image rejection filter are housed in a small weather tight box and then located at the base of the receiving antenna. The DC power for the preamplifier is supplied along the coaxial cable which also carries the radio frequency signal. This configuration has the benefit of placing the lossy coax cable further along in the system, which is a better arrangement for the overall system noise figure.

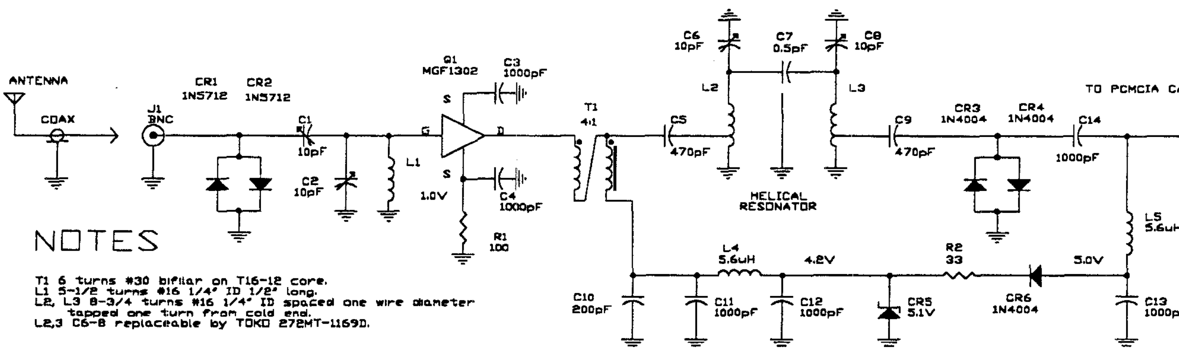

Fig. 4. GaAs FET Preamplifier

Two image filters were tested. The first was a critically coupled bandpass filter with hand wound silver plated coils. The second filter tested was a commercial subminiature helical resonator. Both filters exhibited image rejection close to the desired goal of 60 dB.

A four to one transmission line transformer was chosen as the output network for the GaAs FET. This matches the 200 ohm output impedance of the amplifier to the 50 ohm line while the ferrite core contains the magnetic field, thus greatly reducing the radiation of the output of the amplifier back into the input network. The result is an extremely stable amplifier, even with the input or output unterminated.

TEST RESULTS

The entire system consisting of a GaAs FET preamp, crystal channel oscillator and a dual conversion IC chip was assembled and tested. This system's performance was measured as follows:

Sensitivity:	0.356 microvolts for 20 dB of quieting
Selectivity:	1st IF 50 kHz 2nd IF 35 kHz
Output:	160 millivolts RMS into 600 ohms
Distortion:	5.6 % (+/- 15 kHz deviation)
Image rejection:	64 dB
Power:	5 volts at 45 milliamps maximum

Over the course of several weeks, dozens of satellite images were received using a simple crossed dipole antenna. The quality of the received images is excellent. See Fig. 5. Note that the image viewed on the computer screen is of a much higher resolution and quality than this printed example.

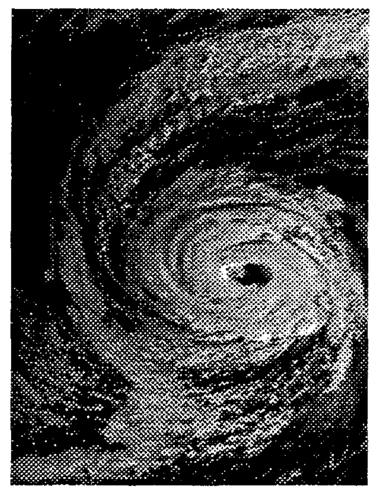

Fig. 5. Hurricane Florence on 7 November 1994

CONCLUSION

This simple design consisting of a GaAs FET, two transistors, a MMIC and one IC chip, will fit in the PCMCIA Type II form factor.

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